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FINAL REPORT
(PRODUCTION TEST 105-526-E)
ELIMINATION OF LIME AS A PROCESS
WATER ADDITIVE

BY

N. R. MILLER

PILE TECHNOLOGY SECTION
ENGINEERING DEPARTMENT

JUNE 20, 1955

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FINAL REPORT
(PRODUCTION TEST 105-526-E)
ELIMINATION OF LIME AS A PROCESS WATER ADDITIVE

By

N. R. Miller

Recirculation Technology Unit
Pile Materials Sub-Section

June 20, 1955

HANFORD ATOMIC PRODUCTS OPERATION
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FINAL REPORT
(PRODUCTION TEST 105-526-E)
ELIMINATION OF LIME AS A PROCESS WATER ADDITIVE

INTRODUCTION

Interest in using low pH water (pH 6.5 - 7.3) for cooling Hanford reactors dates back to early laboratory investigation. Work has consistently shown that the use of this low pH water should reduce overall corrosion rates of the aluminum components. Work done by Draley at the Clinton Laboratories with simulated Columbia River water showed that aluminum corrosion rates at 80 C were minimized at pH 6.5. ⁽¹⁾ These results were later substantiated by work at Hanford by the CMX Project. ⁽²⁾ In spite of these results, the original specifications called for the process water pH to be maintained in the range 7.5 - 7.8. This step was taken because it was decided to add dichromate to the water to inhibit pitting attack and it was feared that at lower pH's the Cr^{+6} would be reduced to Cr^{+3} by the pile fluxes. The trivalent chromium was known to be a virulent film former. ⁽²⁾

In early 1952, when it was thought that dichromate addition was unnecessary, new interest was taken in the possibility of reducing the pH of process water. Results obtained with the equipment in the 105-D Flow Laboratory with water treated with two different coagulants showed that overall corrosion rates were lowered by reducing the pH to the range 6.2 - 7.3. Unfortunately, however, the incidence and severity of pitting increased with decreasing pH and thoughts of using dichromate-free low pH water were abandoned. ^(3, 4) It was later found that even at

-
- (1) Draley, J. E., "The Corrosion of Aluminum in Dilute Solutions," CT-3027, June 19, 1945.
(2) Kidder, C. P., "CMX Final Report," 7-4444, July 31, 1946.
(3) Atwood, J. M., "Process Water pH Effects," HW-24007, May 15, 1952.
(4) Miller, N. R., "Interim Report No. 1, PT-105-509-E, The Effects of Low pH Alum Water on Pile Operation," HW-30574, February 18, 1954.

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higher pH's, pitting attacks on the aluminum components became severe in the absence of dichromate addition.^(5,6) The addition of dichromate was therefore reinstituted early in 1953.

When the necessity of dichromate addition became apparent, studies were made with the in-pile facilities of the 105-D Flow Laboratory to determine if film formation would actually become a severe problem if the pH of process water containing dichromate were lowered. The results of these tests showed that no such problems would occur at pH's at least as low as 7.2.⁽⁴⁾ When this was learned, a two tube in-pile test was initiated utilizing water obtained in the process at a point before a base was added for pH control. The pH of this water varies with the amount of the (acidic) coagulant, aluminum sulfate, required. The pH actually ranged between 7.2 and 7.7. The results from this test on base elimination were encouraging but insufficient to be conclusive.⁽⁷⁾ Therefore, it was decided to eliminate base addition from the water cooling half of a Hanford reactor, 100-F. This was done in late 1953 under the terms of this production test.⁽⁸⁾

The next step taken in testing was to add sufficient acid to the water cooling three tubes in 100-D Pile to obtain a fixed pH of 7.3.⁽⁹⁾ Preliminary results of that test were found to be favorable⁽¹⁰⁾ so a

(4) Miller, N. R., HW-30574.

(5) Wilson, C. D., "Flow Laboratory Investigations of 'F-Type' Pitting," HW-28027, June 1, 1953.

(6) Lutton, J. M., "Sodium Dichromate as a Process Water Additive: An Evaluation," HW-27158, March 19, 1953.

(7) Miller, N. R., "Final Report, PT-105-509-E, The Effects of Low pH Alum Water on Pile Operation," HW-32603, July 30, 1954.

(8) Atwood, J. M., "PT-105-526-E, Elimination of Lime as a Process Water Additive," HW-28934, August 10, 1953.

(9) Miller, N. R., "PT-105-525-E, The Effects of Water Quality on Pile Operation," HW-29406, September 21, 1953.

(10) Miller, N. R., "An Evaluation of the Use of Sulfuric Acid as a Process Water Additive," HW-30487, January 12, 1954.

supplement to the 100-F test was issued. (11) This supplement authorized the addition of sufficient sulfuric acid to maintain the pH of water cooling half of 100-F Pile between 7.2 - 7.4. Also, the supplement authorized the resumption of the addition of limited amounts of base. This later step was taken because it had been determined that the post filtration addition of a base helped combat film formation. (7)

This document reports the data obtained from the 100-F test.

SUMMARY

A half-plant test has been carried out at 100-F Area to determine the effects of adding sufficient sulfuric acid to plant process water to obtain a pH of 7.3. Also, the effects of eliminating or minimizing lime dosages to the water have been studied. These tests were based on the results of multiple tube testing carried out with the in-pile facilities of the 105-D Flow Laboratory.

The results of the half-plant test show that reduction of the process water pH will reduce overall slug jacket and process tube corrosion rates about 30 per cent. This overall rate reduction will be accomplished without an increase in pitting attack.

Studies carried out on carbon steel corrosion show that lowering process water pH to 7.3 will not be harmful to the cold part of the carbon steel water system nor to the carbon steel effluent lines.

Reduction of the process water pH and minimizing lime dosages is expected to cause an increase in the filming tendencies of the process water. Experience has shown, however, that this increased tendency towards film formation can be handled by standard plant practices such as purging, or bettering the quality of filter effluent water. ●

(7) Miller, N. R., HW-32603.

(11) Miller, N. R., "PT-105-526-E, Supplement A, Elimination of Lime as a Process Water Additive," HW-30487, January 12, 1954.

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Operating experience obtained from the test has shown that production of pH 7.3 water will be more costly than the production of pH 7.7 water. Savings on lime costs are more than balanced by the increased acid costs and coagulation at pH 7.3 does not allow reductions in alum dosages. However, the increased water treatment costs are small when compared to the gains obtained from lowering slug and tube corrosion rates. The above holds true for current flows. At the higher flows which will be obtained after water flow rates are increased, coagulation at lower pH's may permit reduction in alum dosages under the dosages required at the higher pH's.

On the basis of the results of this test, the process specification has been changed to require that the process water pH be maintained at pH 7.2 - 7.4. Also, further testing at lower pH's has been carried out.

DISCUSSION

The discussion of the test will be made from the following aspects:

1. Description of Test
2. Slug Corrosion Data
3. Tube Corrosion Data
4. Carbon Steel Corrosion
5. Film Formation
6. Water Plant Operation

1. Description of the Test

The pH of untreated Columbia River water generally ranges between 7.9 and 8.3. In the water treatment process, this pH is reduced slightly by the addition of chlorine and significantly by the addition of the coagulant, aluminum sulfate. The post coagulation pH of the water varies with the chemical dosages in the range 7.2 - 7.7. Until May 1955, specifications required that the pH of process water supplied to the pile be in the range

7.5 - 7.8. To meet this specification during much of the year it was necessary to add a base to the water after coagulation and filtration. Lime was the base used at all areas except at 100-KW and 100-KE where caustic soda was employed.

In accordance with the terms of this production test, lime addition to the water produced by the west half of the water plant at 100-F was stopped on 9-21-53 and the water produced by this half of the plant was allowed to "float" at the coagulation pH. ⁽¹²⁾

In accordance with the supplement to the test, on April 11, 1954, limited lime addition to the process water was resumed. Also, sufficient sulfuric acid addition was made to keep the pH of the water supplied to the reactor in the range 7.2 - 7.4. ⁽¹³⁾ The sulfuric acid initially was added with the coagulant. Later the process was modified to add the acid to the raw water at a point before the coagulant addition.

The physical characteristics of the water plant at 100-F are such that there is very little mixing of the water produced at the two halves of the plant until the time it leaves the pile. This means that it is known which tubes in the pile are cooled with water produced in a given half of the water plant. At 100-F, the tubes on the far side of the pile (columns XX74 through XX96) are cooled with water produced in the west half of the filter plant. This feature of the water plant makes it possible to determine differential effects in corrosion or film formation in the pile caused by changes in the water treatment at one half of the water plant.

To obtain data on the corrosion rates of the aluminum slug jackets, weighed, numbered slugs were charged into tubes on both sides of the pile. After irradiation the slugs were cleaned with chromic-phosphoric acid to remove the iron oxide deposition film, dried, and

(12) Atwood, J. M., HW-28934.

(13) Miller, N. R., HW-30487.

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weighed with the underwater weighing facility by personnel in the Fuel Technology Sub-Section. From a knowledge of the operating data, it was possible to calculate the corrosion rates the slugs would have experienced had they been cooled with pH 7.7 process water. This calculation was made using the correlation derived by de Halas from data collected on 540 slugs exposed to regular pH 7.7 process water. (14) From a knowledge of slug weight losses and operating times it was also possible to determine the corrosion rates actually experienced by the slugs.

Tube corrosion data were obtained by inspection of the cold front sections of the tubes during pile outages, by inspecting tubes removed from the pile, and by exposing sections of tubing under out-of pile conditions.

2. Slug Corrosion Data

At the beginning of the test, three tubes on the "far" side of the pile were charged with numbered and weighed metal slugs. These slugs were discharged after 142 days of operation at temperature. Operating conditions are tabulated below:

TABLE I
OPERATING CONDITIONS OF SLUGS EXPOSED
TO FLOATING pH WATER

<u>Tube No.</u>	<u>Time of Operation Days</u>	<u>Avg Coolant Flow Rate GPM</u>	<u>Avg Tube Power KW</u>	<u>Avg Tube Outlet Temp. °C</u>	<u>Exposure Concentrations MWD/T</u>
1680-F	142	26	440	74	500
2177-F	142	26	450	75	510
1779-F	142	27	450	73	510

Data on the individual slugs are summarized in Appendix I.

(14) de Halas, D. R., "The Corrosion of Hanford Fuel Elements - Method for Treatment and Analyses of In-Pile Corrosion Data," HW-34196, December 21, 1954.

The pH of the water varied between 7.3 and 7.7 and averaged 7.55 during the period the slugs were in the pile.

Figure 1 is a plot of "expected" corrosion losses versus actual corrosion losses. "Expected" corrosion losses mean losses one would have expected the slugs to have experienced if they had been cooled with pH 7.7 water. ●

The "expected" rates were determined from graphs developed by de Halas⁽¹⁵⁾ based on his slug corrosion rate correlation.⁽¹⁶⁾ From the graph, it appears that cooling the slugs in the floating pH water did significantly reduce corrosion losses. The results of a statistical study of the data are presented later in this section of the document.

When acid addition to the water was started at 100-F, additional tubes were charged with weighed slugs to obtain additional data. The operating conditions of these charges are tabulated below:

TABLE II
OPERATING CONDITIONS OF SLUGS EXPOSED
TO pH 7.3 WATER AT 100-F

<u>Tube No.</u>	<u>Time of Operation Days</u>	<u>Avg Coolant Flow Rate GPM</u>	<u>Avg Tube Power KW</u>	<u>Avg Tube Outlet Temp. ° C</u>	<u>Exposure Concentration MWD/T</u>
1592-F	198	21	410	88	650
3786-F	193	26	480	87	740
2590-F	177	27	480	83	680
1779-F	239	31	550	82	1050
2090-F	114	28	500	85	460
2177-F	239	30	560	86	1070

Dichromate concentration: 2 ppm

(15) de Halas, D. R., "Supplement to HW-34196, Slug Corrosion Rates in pH 7.6 Water," HW-36337-RD, April 22, 1953.

(16) de Halas, D. R., HW-34196.

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FIGURE 1
EFFECT OF FLOATING pH WATER ON SLUG JACKET CORROSION RATES

More detailed operating and corrosion data will be found in Appendix I.

In addition to these tubes, control corrosion data were obtained from slugs charged into tubes in the side of the pile cooled with pH 7.7 water. These slugs were irradiated during the same period as the pH 7.3 slugs. Any differences in corrosion rates, therefore, should be attributable to the pH change. The operating conditions of the tubes cooled with pH 7.7 water are tabulated below:

TABLE III
OPERATING CONDITIONS OF SLUGS EXPOSED
TO pH 7.7 WATER AT 100-F

<u>Tube No.</u>	<u>Time of Operation Days</u>	<u>Avg Coolant Flow Rate GPM</u>	<u>Avg Tube Power KW</u>	<u>Avg Tube Outlet Temp. C</u>	<u>Exposure Concentration MWD/T</u>
3561-F	171	30	470	74	640
2160-F	114	● 31	460	73	420
2762-F	279	28	460 ●	76	1030
1559-F	198	27	430	74	680

Dichromate Concentration: 2ppm.

Data on the individual slugs are included in Appendix I.

Corrosion losses obtained from the slugs cooled with pH 7.3 and 7.65 water are shown in Figure 2. The data are plotted in the same manner as are the data in Figure 1. It can be seen that the slugs exposed to pH 7.3 water tended to corrode less than one would expect from de Halas' correlation and the slugs exposed to pH 7.65 water tended to corrode slightly more than one would predict. The results of a statistical study of the data are presented later in this section.

In addition to the data obtained from slugs exposed to pH 7.3 water at 100-F Pile, a considerable amount of slug corrosion data on pH 7.3 water was obtained with the in-pile facilities of the 105-D Flow Laboratory. The operating conditions of the 100-D Area tubes are listed below:

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FIGURE 2
CORROSION OF SLUGS COOLED WITH pH 7.3 AND 7.65 WATER AT 100-F AREA

TABLE IV
OPERATING CONDITIONS OF SLUGS EXPOSED
TO pH 7.3 WATER AT 100-D

<u>Tube No.</u>	<u>Time of Operation Days</u>	<u>Avg Coolant Flow Rate GPM</u>	<u>Avg Tube Power KW</u>	<u>Avg Tube Outlet Temp. °C</u>	<u>Exposure Concentration MWD/T</u>	<u>Dichromate Concentration ppm</u>
2570-D-1	57	25	480	82	250	2.0
3472-D-1	109	26	540	88	530	2.0
3571-D-1	135	26	560	88	690	2.0
3472-D-2	188	25	490	88	840	0.2
2570-D-2	203	27	490	83	920	0.2

Data on the individual slugs are tabulated in Appendix I.

It will be noticed that two tubes were cooled with water with a dichromate concentration of 0.2 ppm. Available information show that this should not affect aluminum corrosion rates. (17, 18) The slugs exposed in charge 2570-D-1 do not fit in de Halas' correlation because of the low exposure time at relatively low temperatures and powers.

Inasmuch as slug corrosion data from 100-D Area were used in arriving at de Halas' correlation, the data from this 100-D test are compared directly with the correlation and no other control comparisons are made.

In Figure 3 expected weight losses are plotted against actual losses. From the figure it is seen that the use of pH 7.3 water to cool the 100-D tubes appreciably reduced corrosion rates.

(17) de Halas, D. R. Miller, N. R., "Slug and Tube Corrosion with Reduced Dichromate Concentrations," HW-30952, April 9, 1954.

(18) Miller, N. R., "Final Report, PT-105-509-E, The Effects of Low pH Alum Water on Pile Operation," HW-32603, July 30, 1954.

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The foregoing statements on the data have been qualitative in nature. In order to obtain a more quantitative estimate on the effects of reducing the pH of process water to 7.3 on corrosion rates, the data were submitted to the Statistics Unit for mathematical evaluation. From this study, certain conclusions were obtained.⁽¹⁹⁾ These are: [⊙]

- a. Corrosion rates experienced with pH 7.3 water were significantly lower than rates experienced with pH 7.65 water.
- b. There were no significant differences found between corrosion rates obtained with pH 7.3 water containing 2.0 ppm of dichromate at 100-D and 100-F.
- c. There were no significant differences between corrosion rates obtained with pH 7.3 water containing 2 ppm and 0.2 ppm dichromate.
- d. No significant differences were found between corrosion rates obtained with pH 7.3 water and floating pH water at 100-F.

In the treatment of the data, the corrosion rates actually obtained [⊙] were compared with rates expected from de Halas' correlation, thusly:

$$K = \frac{CR}{CR_0}$$

where: CR = actual corrosion rates experienced by an individual slug

CR₀ = corrosion rate predicted for the slug by de Halas' correlation.

The different values of K are tabulated in Table V. [⊙]

(19) Jaech, J. L., Private Communication, "Water Quality and Aluminum Corrosion," May 2, 1955.

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TABLE V
SUMMARY OF STATISTICAL STUDY OF
CORROSION RATE DATA

pH of Water	Dichromate Concentration ppm	Area	$-\ln_e K^*$	Standard Deviation of $\ln_e K$	K	95% confidence range of K $\dagger$
7.3	2	100-F	-0.39	0.085	0.67	0.57 - 0.81
7.3	2	100-D	-0.43	0.029	0.65	0.61 - 0.69
7.3	2	Com- bined 100-D and F	-0.42	0.035	0.66	0.61 - 0.71
7.3	0.2	100-D	-0.76	0.14	0.47	0.35 - 0.62
Floating	2	100-F	-0.39	0.091	0.68	0.57 - 0.81
7.7	2	100-F	-0.56	0.19	1.75	1.12 - 2.56

* K = ratio of actual corrosion rate to rate predicted by de Halas for pH 7.7 water.

$\dagger$ = Actually, 95% confidence intervals were found for values of $\ln K$ and the corresponding values of K determined.

As can be seen from the table, the probable corrosion rate reduction obtained by reducing the pH to 7.3 would be 35 per cent with a high probability that the reduction will lie in the range 20-40 per cent. The fact that the control slugs irradiated at 100-F experienced rates higher than predicted by de Halas' correlation tends to make this conclusion conservative.

The preceding discussion has covered the effects of lowering process water pH to 7.3 on overall slug jacket corrosion rates. Of at least equal importance is the effect of such a change on localized attacks. In the following paragraphs this feature will be discussed.

Determination of the extent and severity of localized attacks on slug jackets is made by inspecting the slugs with an underwater viewer after irradiation. Unfortunately, this type of inspection gives only a semi-quantitative indication of the localized attacks. Pit depths are estimated,

but this estimation can be only a refined guess. Further, the slugs receive a considerable degree of mechanical damage as they are discharged from the tube, fall in air for 10-40 feet, through water an additional 20 feet, then land on a concrete floor. Further mechanical damage is incurred when the slugs are picked up with steel tongs and loaded into buckets. It is not always possible to distinguish this mechanical damage from localized corrosion attack.

Despite the above limitations, it is possible to obtain certain trends from a large number of examinations. Tabulated below are inspection data on slugs exposed to pH 7.3 water at 100-F and 100-D and on the control slugs exposed to pH 7.7 water at 100-F.

TABLE VI
SUMMARY OF INSPECTION DATA ON
SLUGS COOLED WITH pH 7.3 WATER AT 100-F

<u>Surface Temperature C</u>	<u>No. of Pitted Slugs</u>	<u>No. of Pit-Free Slugs</u>	<u>Frequency of Pitting</u>
10-59	20	58	0.26
60-69	22	7	0.76
70-79	24	5	0.83
80-89	43	10	0.81

TABLE VII
SUMMARY OF INSPECTION DATA ON
CONTROL SLUGS COOLED WITH pH 7.7 WATER AT 100-F

<u>Surface Temperature C</u>	<u>No. of Pitted Slugs</u>	<u>No. of Pit-Free Slugs</u>	<u>Frequency of Pitting</u>
10-59	4	30	0.12
60-69	12	1	0.92
70-79	15	2	0.88

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TABLE VIII
SUMMARY OF INSPECTION DATA ON
SLUGS COOLED WITH pH 7.3 WATER AT 100-D

<u>Surface Temperature C</u>	<u>No. of Pitted Slugs</u>	<u>No. of Pit-Free Slugs</u>	<u>Frequency of Pitting</u>
10-59	40	35	0.53
60-69	13	13	0.50
70-79	24	6	0.80
80-89	41	10	0.80
90-99	18	3	0.86

Some of the slugs from 100-D were cooled with water containing 0.2 ppm of dichromate instead of 2.0 ppm. However, the difference in dichromate concentration in that range apparently does not have an effect on localized corrosion. At any rate the inclusion of the data on the slugs cooled with water with 0.2 ppm dichromate should make conclusions based on the data conservative.

In Figure 4, frequency of slug pitting is plotted against surface temperatures. The line in the graph describes data obtained by de Halas on observations of a great many slugs cooled with pH 7.7 process water. (20)

A statistical study of the pitting data was made by members of the Statistics Unit. This study showed: (21)

- a. No difference in the pitting of slugs cooled with pH 7.3 water and pH 7.7 water when slug surface temperatures were 60 C and higher. This statement applies to the slugs cooled with pH 7.3 water at both 100-D and 100-F.
- b. Of slugs operating at surface temperatures of less than 60 C, the ones cooled with pH 7.3 water at 100-F showed no difference in pitting from the ones cooled with pH 7.7 water.

(20) de Halas, D. R., "Summary of Slug Pitting Data," HW-34430, January 12, 1955.

(21) Jaech, J. L., "Private Communication," May 2, 1955.

FIGURE 4
PITTING OF SLUGS

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- c. The slugs exposed to pH 7.3 water at 100-D and operating at surface temperatures less than 60 C did exhibit higher pitting frequencies than slugs cooled with pH 7.7 water.

While the apparent higher pitting frequency exhibited by the colder slugs at 100-D tends to be unfavorable, the effect is not believed to be important for the following reasons:

- a. The effect did not occur with the slugs exposed to pH 7.3 water at 100-F. The 100-F test, being a scale-up of the 100-D test, is believed to be more reliable.
- b. While the incidence of pitting of the low temperature slugs at 100-D was higher than expected, it is still lower than the incidence of pitting experienced at high temperatures. At the low temperatures, where the overall corrosion weight losses are low, a higher incidence of pitting is acceptable provided that the severity (or depth of penetration) of the attack is not increased.
- c. The inspection reports did not indicate that the attack on the low temperature 100-D Area slugs was particularly severe.

3. Tube Corrosion Data

One of the main benefits possible from lowering the process water pH is the reduction of the process tube corrosion rates. This corrosion rate reduction might allow increased production by increasing the permissible tube outlet water temperatures or lower operating costs by decreasing the frequency of tube replacements.

A considerable amount of data has been amassed on process tube corrosion in pH 7.7 water by members of the Pile Coolant Studies Unit. Overall corrosion rates as determined by in-pile and out-of-pile testing are shown in Figure 5. ⁽²²⁾ Though there is a considerable scatter in the data, there are no apparent differences in the corrosion rates experienced under-in-pile and laboratory conditions. Thus, comparisons

(22) Houck, W. C., Unpublished Tube Corrosion Data.

FIGURE 5
PROCESS TUBE CORROSION IN pH 7.65 PROCESS WATER

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of laboratory tube corrosion data should be of some significance.

In Figure 6 are plotted tube corrosion rates as a function of pH at 120 C. These rates were determined by laboratory testing in support of another production test and will be completely presented elsewhere. ⁽²³⁾ The data in the figure show that the water pH has an important effect on tube corrosion rates and suggests that lowering the process water pH from 7.7 to 7.3 may reduce corrosion rates about 30 per cent. This reduction agrees rather closely with that obtained on slug jackets as discussed in the previous section.

In addition to the out-of-pile data on tube corrosion rates, some in-pile data are also available. Tube 2683-F was replaced in May 1954, shortly after acid addition was initiated. This replacement tube was removed from the pile in April 1955, after 10 months of operation at an average outlet temperature of 90 C. Measurements of the 72-S cladding indicated that 2 mils of the 72-S cladding had been removed from the hot rear sections of the tube due to corrosion. ⁽²⁴⁾ This actual rate of 0.20 mils/month is quite low when compared to the expected rate of 0.46 mils/month at 90 C as determined for tubes supplied with pH 7.7 water.

It should be noted that the in-pile data are not statistically significant because of the scatter in data from pH 7.7 water. Measurements of 72-S cladding on many more in-pile tubes cooled with pH 7.3 water will be required before a significant statement may be made based on in-pile results.

In addition to overall corrosion attacks, pitting corrosion of process tubing is important. The front tube sections of the in-pile tubes were inspected during pile outages for signs of pitting attack. This

(23) Miller, N. R., "Final Report, Production Test 105-525-E, The Effect of Water Quality on Pile Operation," (To be published).

(24) Houck, W. C., Private Communication, June 9, 1955.

FIGURE 6

CORROSION OF 72-S CLAD ALUMINUM PROCESS TUBING
IN PLANT PROCESS WATER AS A FUNCTION OF pH

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type of inspection is possible because pitting occurring in the front, cold sections of the process tubes is accompanied by the formation of corrosion product mounds or barnacles which are easily detectable. An inspection made in May 1955, of some tubes replaced June 1954 or later showed that no barnacle formations had occurred in either the side of the pile cooled with pH 7.3 or pH 7.7 water. Inspection of old tubing which contained barnacles at the beginning of the test showed no significant new activity. (25) In addition, no barnacle formation was detected in two in-pile tubes supplied with pH 7.3 water at 100-D Area.

Three tubes were also installed in the out-of-pile facilities of the 105-F Flow Laboratory. After one year of exposure two of the tubes showed essentially no barnacle formation. The third tube when inspected contained a quantity of miscellaneous debris and dirt. Apparently this foreign material was present from the beginning of the test. This tube was heavily attacked in areas adjacent to the ribs. It is believed the attack is associated with the foreign material in the tube and points out the importance of insuring that tubes are clean before installation in the pile.

Inspections of the tubes used for the in-pile tests made after removal of the tubes from the pile showed no increase in the severity or incidence of pitting of the tubing in the rear, thermally hot sections.

4. Corrosion of Carbon Steel

In evaluating a change in the water treatment process, it is necessary to evaluate the effects of the change on the carbon steel portion of the water system.

(25) Newby, F. M., Private Communication.

The general effect of pH on carbon steel corrosion is known. (26) At a given temperature in the range 5-90 C, carbon steel corrosion rates are low at water pH's in the range 9.5 - 10.0. As the pH of the water is reduced, corrosion rates increase until a critical pH is reached. Lowering the pH below this value (the numerical value of which depends on the temperature and water composition) does not change carbon steel corrosion rates until a second critical pH is obtained. At this pH hydrogen evolution begins accompanied by rapid corrosion attack. The hydrogen evolution is produced from the cathodic reaction:

Considerable information shows there need be no concern for the cold part of the carbon steel system if the process water pH is lowered in the range 6.5 - 7.3. In the temperature range 5-25 C, the pH of hydrogen evolution is about 4.5. In confirmation of this are the results of an inspection made by W. C. Houck of the 190 Tanks. This inspection was made in February 1954 after the tanks on the west half of the plant had contained floating pH water seven months and pH 7.3 water ten months. The results of the inspection showed that the corrosion attack was no deeper on the tanks containing low pH water than on the tanks containing pH 7.7 water. However, corrosion tubercles were more prevalent and larger in area on the tanks containing the low pH water. (27) This effect is not believed important.

From the above, it is concluded that corrosion of the cold parts of the carbon steel system presents no barrier to the reduction of process water pH to at least 7.3. Continued monitoring of the type described above for the 190 Tanks should be carried out to guard against any long term deleterious effects.

(26) Uhlig, H. H., "Corrosion Handbook," John Wiley and Sons, N. Y., N. Y., 1948.

(27) Houck, W. C., Private Communication, March 7, 1955.

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Conclusions based on the cold parts of the system do not necessarily apply to the carbon steel effluent line. At higher temperatures, the pH of hydrogen evolution is known to increase. Because of this, a number of corrosion tests were made with AISI-C1010 carbon steel coupons at a temperature of 90 C. These tests were performed primarily in support of another production test and the data from the tests are reported in detail elsewhere. (28) The results of the tests conducted with water containing 2 ppm of dichromate are presented in Figure 7. From the figure it appears that corrosion rates obtained at pH as low as 6.6 are not appreciably different than those obtained at pH 7.7. A statistical analysis of the raw data confirms this. (29)

Thus the tests results indicate that the carbon steel effluent system will not be damaged by reducing the process water pH from 7.7 to 7.3. It is realized that it is a considerable extrapolation from a steel coupon to an effluent line. For this reason, inspections of the lines should be made periodically.

5. Film Formation

It was realized at the initiation of the test that the partial or total elimination of lime addition and the addition of sulfuric acid for pH control might have a significant effect on the film forming properties of the process water. Previous experience had indicated that such would be the case. Multiple tube in-pile tests with dichromate-free water at 100-D had demonstrated the effects of both pH and lime addition on film formation. In the absence of lime addition, it was found that the film forming tendencies of the water were roughly inversely proportional to the pH. Further

(28) Miller, N. R., "Final Report, Production Test 105-525-E, The Effects of Water on Pile Operation," (To be published).

(29) Jacch, J. L., "Water Quality and Steel Corrosion," HW-36771-RD, May 18, 1955.

FIGURE 7
STEEL CORROSION RATES IN PROCESS WATER AT 90C

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experience showed that the addition of lime to the water effectively inhibited film formation at all pH's in the range 7.0 - 7.7. (30)

Another series of tests also carried out at 100-D were made with water obtained at a point in the process before the base is added. Two tubes in the pile were cooled with this water with no further pH correction and three tubes were cooled with this water with caustic soda added for pH control. Results showed that the base-free water exhibited considerably greater tendencies toward film formation than did the controlled pH water. However, it was found that during some periods of the test no filming occurred with either type of water; apparently, if the water quality were sufficiently high, no base addition was required. (31)

Experience at 100-F in general confirmed previous experience. Concurrently with operation of the test, W. R. Conley conducted a Process Test to determine the water quality and in-pile effects resulting from changes in water treatment chemical feed rates for various raw water conditions. Data obtained from June through November 1954 are reported. (32) Conley was able to show that, all else being equal, film formation rates were proportional to process water turbidity concentrations. Further, he showed that during the period of his test, at a given turbidity concentration, there was significantly more film formation in the low pH side of the pile than in the high pH side. He attributed the difference primarily to the differences in lime feed rates. As can be seen in Figure 8, Appendix II, lime feed rates were appreciably higher to the water from the east side of the plant than to the west side. From previous tests, it had been concluded that lime acts to prevent film formation by causing a secondary coagulation of the small particles (0.2 μ diameter or less) in the water to

(30) Miller, N. R., HW-30574.

(31) Miller, N. R., HW-32603.

(32) Conley, W. R., "Final Report, Process Test MR-105-17, Water Quality Control - 100-F Area," HW-35764, March 14, 1955.

larger particles (1.0μ diameters or higher). These larger particles will have a smaller electrical charge-to-mass ratio and hence will have less tendency to "stick" to the negatively charged slugs and tube surfaces. Conley further brings up the point that lime addition may act to prevent film or remove film already deposited by acting as a purging material. It is known that commercial lime contains a percentage of insolubles. Further, the addition of lime slurry to the process water causes carbonate precipitation by the action of local high concentration of hydroxyl ion on bicarbonate ions.

Experience with the 100-F test proves that large quantities of the particles do pass through the reactor. At the beginning of the test, the west clearwell was inspected and the floor found to be covered with a two or three inch layer of insoluble sediment. About four months after the cessation of lime addition, the clearwell was reinspected and found to be essentially clean. Apparently the sludge is caught up in the water stream and pumped through the reactor. When lime addition is stopped and the sludge is not replenished, the floor gradually becomes clean. Certainly the sludge pumped through the reactor should have some purging action.

Still further support is given to the theory of the importance of lime in inhibiting film formation by experience at 100-F after November 1954 - the cut-off date for Conley's report.

During all of January and until March 12, 1955, except for the pile outage during most of February and part of March, the lime dosage to the east side of the water plant was stopped while the west side dose was maintained at about 0.5 ppm as is shown by Figure 10. Comparisons of film formation rates are tabulated below:

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TABLE IX
COMPARISON OF FILM FORMATION RATES IN
NEAR AND FAR SIDE OF 100-F PILE

<u>Period</u>	<u>Increase in panellit pressure of 10 near side fringe zone tubes</u>	<u>Increase in panellit pressure of 10 far side fringe zone tubes</u>
June 1954*	0.6	3.6
July 1954*	-2.7	-0.8
August 1954*	-0.9	9.6
September 1954*	-0.2	7.5
October 1954*	3.1	5.4
January 1955	7.0	4.9
March 4 through March 12, 1955	1.1	-0.5
March 13 through March 21, 1955	3.0	7.7

* Data obtained from W. R. Conley in HW-35764.

Thus it is seen that less film was formed in the far side than the near side during January and the first part of March when lime doses to water cooling the far side were higher than near side dosages. No data are reported for February because the pile was down during most of the month. When near side lime dosages were increased on March 12, 1955, the familiar pattern of heavier filming in the far side returned.

Thus it can be concluded that reducing the pH of process water and minimizing lime dosages will tend to increase film formation tendencies. However, it is not believed that this tendency will present serious difficulties if process water pH's is reduced to 7.3 for the following reasons:

- a. In the absence of base addition and at lower pH's, filming can be prevented by keeping process water quality high.
- b. Operational purges with diatomaceous earth are being perfected to the point that film formation as such is not too serious a problem.
- c. Film formation in the past has been particularly troublesome in the low-flow fringe zone tubes. After the water plant expansion program, there will be no low-flow tubes and the film problem may simply disappear.
- d. During periods of particular difficulty, lime or caustic addition rates can be increased to alleviate the problem.

6. Water Plant Operation

At the beginning of the test, no changes were made in the water plant operation except that lime addition to the west side of the plant was stopped. It soon appeared that elimination of the lime was causing film formation in the far side of the pile. To combat this, alum doses were increased to the west side of the plant in order to produce a better quality of water. Weekly average alum and lime doses are plotted in Figures 8 and 10 in Appendix II.

When the test was revised to add acid to the water produced in the west half of the plant, it was decided to make the addition at the treatment plant. Previous information indicated that alum should act more efficiently at lower coagulation pH's. It was hoped that with acid addition, alum dosages would be reduced. As the plot in Figure 10 shows, these hopes were not realized. When it was found that coagulation at pH 7.3 was not beneficial, members of the Process Sub-Section studied the effects of further lowering the coagulation pH to 7.0. This action was also unsuccessful. In the future, no doubt, more work will be done on the effects of coagulation pH with higher filter rates and, hence, shorter settling times. Under these conditions acid addition may prove to be beneficial.

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In the second part of the test, sufficient acid was added to reduce the pH of the water to the range 7.2 - 7.4. The required acid dosages, which are shown in Figure 9 depended on the alum dosage. Actual required dosages of alum and acid as shown by operating experience are shown in Figure 11, Appendix III.

In order to determine charges to be made to the Production Test, members of the Power Sub-Section calculated chemical treatment costs for producing water on both sides of the water plants. The results are shown below:⁽³³⁾

TABLE X
ADDITIONAL COSTS OF PRODUCING pH 7.3 WATER IN
THE WEST HALF OF 100-F WATER PLANT

<u>Month and Year</u>	<u>Additional Cost in \$</u>
April 1954	40
May 1954	-67
June 1954	-319
July 1954	-75
August 1954	200
September 1954	382
October 1954	897
November 1954	615
December 1954	696
January 1955	856
February 1955	230

The cost for November 1954 is clouded by the test of pH 7.0 coagulation. The average additional cost for the remaining ten months is \$256 per month. The above figures apply to one-half of the plant which produced water at a rate of about 23,000 gpm. Extrapolating these data

(33) Wells, G. W., Private Communication.

to the total combined flows of all plants after the water plant expansion program, 774,000 gpm, one calculates that the adoption of pH 7.3 water will cost an additional \$8,600 per month or roughly \$100,000 annually. At the present total combined plant flow rates, 540,000 gpm, the production of pH 7.3 water is calculated to cost an average of \$6,300 per month more than pH 7.65 water.

It should be emphasized that the above costs are only approximate. Actually, with the higher flows required by project CG-558, the addition of sulfuric acid may become necessary to obtain proper coagulation.

CONCLUSIONS

The data obtained from the test lead to the following conclusions:

1. Lowering the pH of the present process water to 7.3 will decrease overall slug jacket and tube corrosion rates about 30 per cent without increasing the severity of localized corrosion attacks.

2. The reduction of process water pH will not have a deleterious effect on the carbon steel portions of the water system.

3. The addition of sulfuric acid to the raw water for pH reduction in the range 7.0-7.3 will not significantly benefit the water treatment process at current flows. Some improvement may be evidenced after flows are increased by Project CG-558.

4. The reduction of process water pH to 7.3 will cause a net increase in chemical treatment costs.

5. Film formation may become slightly more troublesome as the process water pH is reduced to 7.3. However, all evidence indicates that this additional tendency for filming can be handled by current methods.

UTILIZATION OF TEST RESULTS

Because of the desirability of taking advantage of the benefits offered by lowering process water pH as soon as possible, certain steps based on the results of this test have already been taken. These steps

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are described below:

1. Initiation of Acid Addition Facilities Project

When early results from this test and the tests conducted at 100-D appeared favorable, an evaluation was made of the use of sulfuric acid as a water treatment chemical. This evaluation concluded that the probable gain to be obtained by adding sulfuric acid to the process water warranted the initiation of a project for constructing acid addition facilities at each 100 Area. (34)

2. Change in Process Specifications

When the data from the later stages of the test become available they were immediately evaluated and briefly summarized. On the basis of the results, it was decided to change the process specification on process water pH. The revision requires that the pH of process water be maintained on the range 7.2 - 7.4. It was found that the benefits to be obtained by this change would warrant the extra cost of adding additional alum to the water in the interim between approval of the specification change and completion of the acid addition facilities. (35)

3. Additional Testing of Low pH Water

The favorable results of this half-plant test gave added importance to plans to explore the effects of lowering process water pH further to the range 5.9 - 7.0. Tests carried out in this pH range have been completed using the in-pile and out-of-pile facilities of the 105-D Flow Laboratory. Evaluation of the available data from these tests is already underway. It is anticipated that the remainder of the data from this test will be available by July 1, 1955, and will be reported by August 1, 1955.

NRM:ms

N. R. Miller

(34) Miller, N. R., "An Evaluation of the Use of Sulfuric Acid in the Water Treatment Process," HW-33143, September 22, 1954.

(35) Hupp, L. P., "Reduction of Process Water pH," HW-33754, March 14, 1955.

APPENDIX I

In the following pages are detailed data on slugs:

Tube Number	1680-F
Time of Operation, Days	142
Average Tube Power, KW	440
Average Tube Outlet Temperature, C	74
Average Tube Inlet Temperature, C	10
Average Coolant Flow Rate, GPM	26
pH	Floating, 7.3-7.7
Dichromate Concentration, ppm	2
Exposure Concentration, MWD/l	500

Slug No. From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate Mils/Month
3	80	6	0.31
5	80	8	0.34
7	80	11	0.42
9	81	14	0.37
11	79	15	0.42
13	78	18	0.24
15	76	21	0.16
17	69	20	0.11

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Tube Number	1779-F
Time of Operation, Days	142
Average Tube Power, KW	450
Average Tube Outlet Temperature, C	73
Average Tube Inlet Temperature, C	10
Average Coolant Flow Rate, GPM	27
pH	Floating. 7.3-7.7
Dichromate Concentration, ppm	2
Exposure Concentration, MWD/T	510

Slug No. From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate Mils/Month
1	78	5	0.20
3	78	6	0.21
5	83	12	0.35
7	83	15	0.34
9	78	15	0.34
11	75	15	0.29
13	69	14	0.23

[REDACTED]

Tube Number	2177-F
Time of Operation, Days	142
Average Tube Power, KW	450
Average Tube Outlet Temperature, C	75
Average Tube Inlet Temperature, C	10
Average Coolant Flow Rate, GPM	26
pH	Floating, 7.3-7.7
Dichromate Concentration, ppm	2
Exposure Concentration, MWD/T	510

Slug No. From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate Mils/Month
1	79	3	0.16
3	84	9	0.23
5	81	9	0.45
7	85	16	0.35
9	77	12	0.16
11	72	11	0.19

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Tube Number	2090-F
Time of Operation, Days	114
Average Tube Power, KW	500
Average Tube Outlet Temperature, C	85
Average Tube Inlet Temperature, C	17
Average Coolant Flow Rate, GPM	28
pH	7.3
Dichromate Concentration, ppm	2
Exposure Concentration, MWD/T	460

Slug No. From Rear	Surface Temperature, C	Slug Power KW/6" Slug	Corrosion Rate Mils/Month
3	87	9	0.17
5	85	13	0.10
7	84	15	0.70
9	80	16	0.36
11	78	19	0.34
13	75	21	0.15
15	70	22	0.14

Tube Number 2590-F
Time of Operation, Days 177
Average Tube Power, KW 480
Average Tube Outlet Temperature, C 83
Average Tube Inlet Temperature, C 15
Average Coolant Flow Rate, GPM 27
pH 7.3
Dichromate Concentration, ppm 2
Exposure Concentration, MWD/T 680

Slug No. From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate Mils/Month
3	84	7	0.37
5	85	10	0.46
7	83	12	0.58
9	82	15	0.52
11	78	17	0.39
13	76	19	0.31

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Tube Number	3786-F
Time of Operation, Days	193
Average Tube Power, KW	480
Average Tube Outlet Temperature, C	87
Average Tube Inlet Temperature, C	16
Average Coolant Flow Rate, GPM	26
pH	7.3
Dichromate Concentration, ppm	2
Exposure Concentration, MWD/T	740

Slug No From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate Mils/Month
1	39	4	0.18
3	89	8	0.31
5	89	11	0.59
7	87	14	0.81
9	84	16	0.68
11	81	18	0.70
13	78	19	0.63
15	72	20	0.41
17	68	21	0.42

Tube Number	1592-F
Time of Operation, Days	198
Average Tube Power, KW	410
Average Tube Outlet Temperature, C	88
Average Tube Inlet Temperature, C	14
Average Coolant Flow Rate, GPM	21
pH	7.3
Dichromate Concentration, ppm	2
Exposure Concentration, MWD/T	650

Slug No. From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate, Mils/Month
1	93	11	0.17
3	90	13	0.12
5	86	14	0.15
7	81	13	0.27
9	77	14	0.35
11	73	14	0.26
13	70	16	0.26

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Tube Number	1779-F
Time of Operation, Days	239
Average Tube Power, KW	550
Average Tube Outlet Temperature, C	82
Average Tube Inlet Temperature, C	14
Average Coolant Flow Rate, GPM	31
pH	7.3
Dichromate Concentration, ppm	2
Exposure Concentration, MWD/T	1050

Slug No. From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate Mils/Month
1	84	6	0.17
3	84	9	0.44
7	82	16	0.71
9	80	19	0.44
11	77	21	0.41
13	73	23	0.36

Tube Number 2177-F
Time of Operation, Days 239
Average Tube Power, KW 560
Average Tube Outlet Temperature, C 86
Average Tube Inlet Temperature, C 14
Average Coolant Flow Rate, GPM 30
pH 7.3
Dichromate Concentration, ppm 2
Exposure Concentration, MWD/T 1070

Slug No. From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate Mils/Month
1	87	6	0.49
3	87	11	0.87
5	86	14	0.65
7	85	18	0.58
9	81	20	0.64
11	77	22	0.42
13	73	23	0.31

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Tube Number			
Time of Operation, Days			2160-F
Average Tube Power, KW			114
Average Tube Outlet Temperature, C			460
Average Tube Inlet Temperature, C			73
Average Coolant Flow Rate, GPM			17
pH			31
Dichromate Concentration, ppm			7.7
Exposure Concentration, MWD/T			2
			420

Slug No. From Rear	Surface Temperature, C	Slug Power K W/8" Slug	Corrosion Rate Mils/Month
3	73	10	0.30
5	73	13	0.49
7	72	15	0.52
9	69	18	0.49

[REDACTED]

Tube Number	3561-F
Time of Operation, Days	171
Average Tube Power, KW	470
Average Tube Outlet Temperature, C	74
Average Tube Inlet Temperature, C	15
Average Coolant Flow Rate, GPM	30
pH	7.7
Dichromate Concentration, ppm	2
Exposure Concentration, MWD/T	640

Slug No. From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate Mils/Month
3	77	7	0.22
5	76	12	0.28
7	75	16	0.36
9	73	18	0.37
11	69	19	0.33

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Tube Number	1559-F
Time of Operation, Days	198
Average Tube Power, KW	430
Average Tube Outlet Temperature, C	74
Average Tube Inlet Temperature, C	13
Average Coolant Flow Rate, GPM	27
pH	7.7
Dichromate Concentration, ppm	2
Exposure Concentration, MWD/ T	680

Slug No. From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate Mils/Month
3	76	9	0.17
5	76	12	0.34
7	73	14	0.51
9	71	16	0.68

Tube Number	2762-F
Time of Operation, Days	279
Average Tube Power, KW	460
Average Tube Outlet Temperature, C	75
Average Tube Inlet Temperature, C	12
Average Coolant Flow Rate, GPM	28
pH	7.7
Dichromate Concentration, ppm	2
Exposure Concentration, MWD/T	1030

Slug No. From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate Mils/Month
3	78	9	0.46
5	77	13	0.48
7	72	14	0.44
9	72	16	0.45
11	69	18	0.48

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Tube Number	3472-D-1
Time of Operation, Days	109
Average Tube Power, KW	540
Average Tube Outlet Temperature, C	88
Average Tube Inlet Temperature, C	8
Average Coolant Flow Rate, GPM	26
pH	7.3
Dichromate Concentration, ppm	2
Exposure Concentration, MWD/T	530

Slug No. From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate Mils./Month
1	92	8	0.18
3	92	9	0.24
5	92	10	0.32
7	90	11	0.42
9	89	13	0.43
11	88	14	0.57
13	87	15	0.63
15	87	17	0.64
17	85	19	0.58
19	83	20	0.52
21	82	22	0.53
23	79	23	0.41
25	78	24	0.37
27	75	25	0.28
29	72	26	0.28
31	70	27	0.23

Tube Number	3571-D-1
Time of Operation, Days	135
Average Tube Power, KW	560
Average Tube Outlet Temperature, C	88
Average Tube Inlet Temperature, C	8
Average Coolant Flow Rate, GPM	26
pH	7.3
Dichromate Concentration, ppm	2
Exposure Concentration, MWD/T	690

Slug No. From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate Mils/Month
5	92	10	0.37
7	91	12	0.48
9	91	14	0.66
11	90	16	0.85
13	89	18	0.86
15	88	20	0.70
17	86	22	0.69
19	84	23	0.70
21	82	24	0.60
23	79	25	0.50
25	77	25	0.37
27	74	26	0.46
29	71	26	0.30

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Tube Number 3472-D-2
Time of Operation, Days 188
Average Tube Power, KW 490
Average Tube Outlet Temperature, C 88
Average Tube Inlet Temperature, C 14
Average Coolant Flow Rate, GPM 25
pH 7.3
Dichromate Concentration, ppm 0.2
Exposure Concentration, MWD/T 840

Slug No. From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate Mils/Month
3	92	8	0.27
5	90	8	0.36
7	90	10	0.45
9	90	12	0.53
11	89	14	0.53
13	90	18	0.52
15	87	18	0.51
17	86	20	0.42
21	81	22	0.41
23	80	22	0.32
25	77	22	0.30
27	74	22	0.21
29	71	22	0.17

Tube Number	2570-D 2
Time of Operation, Days	203
Average Tube Power, KW	490
Average Tube Outlet Temperature, C	82
Average Tube Inlet Temperature, C	13
Average Coolant Flow Rate, GPM	27
pH	7.3
Dichromate Concentration, ppm	0.2
Exposure Concentration, MWD/T	920

Slug No. From Rear	Surface Temperature, C	Slug Power KW/8" Slug	Corrosion Rate Mils/Month
1	88	10	0.34
3	87	11	0.31
5	86	12	0.38
7	85	13	0.45
9	85	15	0.45
11	83	16	0.51
13	82	17	0.57
15	81	19	0.58
17	79	20	0.29
19	77	21	0.38
21	75	21	0.24
23	73	21	0.34
25	70	21	0.35

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APPENDIX II

Appendix II graphically shows the dosages of some of the water treatment chemical to the water during the period of this test.

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FIG. 1
WEEKLY AVERAGE LIME

URE 8

DOSAGES AT 100F AREA

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FIGURE 9

WEEKLY AVERAGE ACID DOSAGES AT 100F AREA

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WEEKLY AVERAGE

100-40-000-000

FIGURE 10
LUM DOSAGES AT 100F AREA

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APPENDIX III

Appendix III shows the combined alum-sulfuric acid dosages to the raw Columbia River water required to maintain plant process water pH in the range 7.2 - 7.4.

[REDACTED]

FIGURE 11

ALUM-SULFURIC ACID DOSAGES NECESSARY TO LOWER pH
OF RIVER WATER TO RANGE 7.2-7.4

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ABSTRACT

Plant scale testing has been carried out to determine the effects of lowering the pH of pile cooling water from 7.5 - 7.8 to 7.2 - 7.4 and minimizing lime dosages to the water.

Test results show that important reductions in aluminum fuel element jacket and process tube corrosion rates would occur if the pH were lowered. These corrosion rate reductions make the changes desirable despite the fact that film formation rates may become more severe and the chemical treatment costs will be slightly increased. Other results showed that the change will not be detrimental to the carbon steel piping in the water system.

Based on these test results, the plant specification pertaining to process water pH was changed in May 1955, to require the use of pH 7.2 - 7.4 water for pile cooling.

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