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INTERIM REPORT III, PRODUCTION TEST IP-560-A:
HALF-PLANT LOW DICHROMATE - LOW pH WATER
TREATMENT AT C REACTOR

AUTHOR

R. G. Geier

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Page 1

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HW-76078 F
Page 2

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INTRODUCTION

A half-plant low dichromate-low pH test⁽¹⁾ was started at C Reactor on March 1, 1963. The test will demonstrate whether 1.0 ppm sodium dichromate provides adequate corrosion inhibition when the reactor coolant pH is 6.6. The test monitoring will consist of ex-reactor tube examinations, in-reactor wall thickness measurements, coupons, visual examination of fuel elements and fuel element weight loss measurements. Previous interim reports have discussed the results obtained from the visual examination of two twenty column discharges obtained as follows:

1. One discharge prior to the start of the test.⁽²⁾
2. One discharge such that the fuel was exposed to coolant treated at both 7.0 and 6.6 pH.

This report discusses the results from the visual examination and weight loss measurements on fuel irradiated under test conditions, the results from coupons exposed in the downstream spacer pattern, and the ex-reactor examination of two process tubes.

SUMMARY

The visual examination of 19 columns of fuel elements, 9 from the near side and 10 from the far side, showed:

1. Ledge corrosion although high on both sides of the reactor was higher on the low dichromate side.
2. Groove corrosion although low on both sides of the reactor was higher on the low dichromate side.

The weight loss data from the first 15 elements of the 19 columns showed that the low dichromate side fuel had lost an average of 25 per cent less weight than the high dichromate side fuel.

The ex-reactor examination of two tubes, one from each side, indicated that the low dichromate side tube had corroded relatively more than the high dichromate side tube.

Coupons located in the downstream spacer pattern on each side of the reactor showed no difference in the corrosion of X-8001 aluminum between the two sides, but indicated a higher corrosion rate of 1100 aluminum on the low dichromate side.

Thus, with the exception of total weight loss from fuel, the data reported herein indicate an aluminum corrosion penalty associated with reducing the sodium dichromate from 1.8 to 1.0 ppm. However, when investigating a phenomenon as subtle and poorly understood as dichromate inhibition, lengthy testing is required and anomalies in the data are to be expected. Neither firm conclusions nor quantitative estimates should be made at this time.

DISCUSSION

A. Water Treatment

Prior to March 1, 1963, C Reactor had been operating under a production test which specified the following water treatment conditions:

	<u>Control Side</u> <u>(Near)</u>	<u>Test Side</u> <u>(Far)</u>
pH	7.0	7.0
Dichromate, ppm	1.8	1.0
Alum, ppm	18.0	18.0

On March 1, 1963, water treatment conditions were changed to conform to those specified in Production Test IP-560-A:

	<u>Control Side</u> <u>(Near)</u>	<u>Test Side</u> <u>(Far)</u>
pH	6.6	6.6
Dichromate, ppm	1.8	1.0
Alum, ppm	18.0	18.0

The above conditions have been maintained since.

B. Irradiation Conditions

Nineteen columns of fuel elements, 9 from the near side and 10 from the far side of C Reactor, which had been charged on May 7, 1963 were discharged on August 2, 1963. The fuel elements had been numbered, charged in numerical order and pre-irradiation weights had been obtained on the downstream 15 elements of each column. The average irradiation conditions are given in Table I. The conditions were very similar on the two sides of the reactor.

C. Weight Loss Measurements

The individual weight loss measurements in grams for each of the 15 downstream fuel elements in the 19 columns are given in Table II. There is some variation among the tubes and among the individual fuel elements, but no more than would normally be expected. In every case, the pattern of weight loss appears to be normal.

The weight loss from the near and far side fuel elements have been averaged and are shown in Table III. The data show that the weight loss from the far

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side fuel (low dichromate) is about 25 per cent less than from the near side fuel. Inasmuch as all of the weight losses are quite low, the significance of the difference is not known. However, in any event it does not appear that 1.0 ppm sodium dichromate is less effective than 1.8 ppm sodium dichromate as far as total aluminum loss from fuel jackets is concerned.

D. Visual Fuel Element Examination

1. Definitions

Visual fuel element examination identifies the serious type of corrosion attack as well as recognizing the presence of secondary effects. A fuel element may exhibit pitting, uniform, ledge or groove corrosion. However, only primary and secondary are reported according to the following definitions:

Primary - Type of corrosion considered most detrimental to fuel survival.

Secondary - Type of corrosion, although less important than primary, which may be a potential cause of future corrosion problems.

The severity of corrosion is categorized as follows:

Code 2 - Corrosion judged to be 10 mils deep.

Code 3 - Penetration to the Al-Si.

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2. Results

The number of fuel elements from each of the 19 columns which exhibited ledge and groove corrosion and the severity of corrosion is shown in Table IV. A summary of the incidence of ledge and groove corrosion is shown below:

	<u>Localized Corrosion Frequency</u> <u>Per Cent of Pieces</u>		
	<u>Near</u>	<u>Far</u>	<u>Over-all</u>
Primary Ledge	15.5	23.4	19.7
Secondary Ledge	0.0	1.3	0.7
Primary Groove	0.7	2.7	1.8
Secondary Groove	7.4	20.3	14.3
Severity - Code 2	3.0	5.3	4.2

The results obtained from previous fuel discharges made under the production test are as follows:

	<u>Localized Corrosion Frequency</u> <u>Per Cent of Pieces</u>	
	<u>Pre-Test</u> <u>Over-all</u>	<u>First Test</u> <u>Over-all</u>
Primary Ledge	25.6	4.1
Secondary Ledge	2.5	0.2
Primary Groove	3.5	0.2
Secondary Groove	3.8	0.0

It is apparent that the incidence of primary ledge corrosion on the present fuel is much higher than found in the last fuel discharge and approximately that found on the pre-test fuel. The incidence of primary groove corrosion has also increased somewhat but is still low, and the small number of pieces involved make the increase of doubtful significance. On the other hand, the large increase in secondary groove corrosion may portend a large increase in primary groove in the next few months.

It is also evident that the incidence of ledge and groove corrosion is higher on the far side (low dichromate) of the reactor than on the near side. With the exception of the secondary groove the differences are not large, however, they do occur in every category. Thus, dichromate may be a factor of perhaps second order importance in protecting against ledge and groove corrosion.

As in previous fuel examination data, over 90 per cent of the hot spots and hot areas occur on the top of the fuel element while over 90 per cent of the ledge corrosion occurs on the bottom. The location of the hot spots and ledge corrosion with respect to position in the column is:

<u>Fuel</u> <u>Element</u> <u>Position*</u>	<u>Per Cent of Pieces Exhibiting</u>	
	<u>Hot Spots</u> <u>and Hot Areas</u>	<u>Ledge</u> <u>Corrosion</u>
1 - 8	9.0	80.6
10 - 12	30.7	15.9
16 - 24	60.3	3.5

*Numbered from downstream end.

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It is quite obvious that the majority of the ledging occurs downstream of the water mixer located at the 9th position while the majority of the hot spots occur upstream of the mixer located in the 15th position.

E. Coupon Samples(5)

Coupon samples of aluminum alloys 1100, X-8001, and 6061 and carbon steel were exposed in the downstream spacer pattern of one channel on each side of the reactor. Operating conditions were the same on both sides. Equilibrium corrosion rates, calculated from the weight of metal removed, are compared below:

<u>Alloy</u>	<u>Corrosion Rate Low Dichromate</u>	
	<u>Corrosion Rate High Dichromate</u>	
X-8001		1.1
1100		2.3
6061		1.0
A-212 C/S		1.3

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The ratios for X-8001, 6061, and carbon steel indicate that corrosion is about the same in both dichromate concentrations. The data do indicate that 1.8 ppm provides more protection for alloy 1100 than does 1.0 ppm.

F. Tube Examination

Tubes 2960C and 2889C, which had been installed during the outage of March 25, 1963, were removed during the outage of September 21, 1963. Both tubes had operated for a total of 148 days without water mixer pieces. The average inlet water temperature was 14.5 C, and the average outlet temperature was 104 C for 2960 and 102 C for 2889. Ex-reactor examination⁽⁶⁾ of the tubes showed the following corrosion.

<u>Tube No.</u>	<u>Corrosion, mils</u>	
	<u>Top</u>	<u>Bottom</u>
2960	13	0
2889	17	2

Based on calculated R values the expected corrosion for the operating conditions would be:⁽⁷⁾

<u>Tube No.</u>	<u>Corrosion, mils</u>	
	<u>Top</u>	<u>Bottom</u>
2960	24	1
2889	13	1

Since the near side tube corroded less than expected and the far side tube corroded more than expected, it can be presumed that the higher dichromate on the near side offered increased protection. However, due to the inherent fallibility of using calculated R values, estimates of the magnitude of the effect cannot be made without additional data.

During the examination of the tubes it was noted that film color and pattern were identical in both tubes. In addition, no evidence of ledge or groove corrosion was observed in either tube.

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HW-76078 F

Page 10

T A B L E I

IRRADIATION CONDITIONS OF C REACTOR LOW DICHROMATE TEST FUEL ELEMENTS

Charge Date: May 7, 1963

Discharge Date: August 12, 1963

Fuel Charge: 30 CIIN plus 2 Water Mixers (9th and 15th positions)

<u>Tube No.</u>	<u>Exposure, Mwd/t</u>	<u>Tube Power, kw</u>	<u>Outlet Temperature °C</u>	<u>Inlet Temperature °C</u>	<u>Flow, gpm</u>
961	884	1162	102	14.5	50.1
1559	904	1194	105	14.5	50.3
1964	884	1170	102	14.5	51.2
2066	890	1174	102	14.5	50.5
2363	895	1185	102	14.5	51.0
2259	931	1242	107	14.5	51.0
2760	945	1247	107	14.5	51.2
3358	882	1168	102	14.5	50.4
4061	905	1192	104	14.5	50.3
Avg. Near Side	900	1190	104	14.5	50.7
786	898	1200	103	14.5	51.2
1189	896	1187	103	14.5	50.6
1891	899	1188	104	14.5	50.1
2091	907	1202	104	14.5	50.9
2291	914	1214	104	14.5	51.4
2380	866	1157	98	14.5	52.2
2482	839	1120	95	14.5	52.0
2685	858	1157	98	14.5	51.9
3083	870	1156	101	14.5	50.2
3483	887	1130	101	14.5	49.3
Avg. Far Side	880	1170	101	14.5	51.0

WEIGHT LOSS DATA FROM C REACTOR LOW pH-LOW DICHROMATE TEST FUEL ELEMENTS

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HW-76078 F
Page 12

TABLE III

AVERAGE WEIGHT LOSS DATA FROM C REACTOR LOW pH-LOW DICHRIMATE FUEL ELEMENTS

<u>FUEL ELEMENT*</u>	<u>WEIGHT LOSS, GRAMS</u>	
	<u>NEAR</u>	<u>FAR</u>
1	0.62	0.54
2	0.84	0.71
3	1.28	0.96
4	1.66	1.30
5	2.18	1.47
6	2.49	1.65
7	3.19	1.97
8	3.00	1.78
10	4.15	3.24
11	3.30	2.32
12	2.61	2.12
13	2.19	1.75
14	1.67	1.55
Total	29.20	21.40

*Numbered from downstream end of tube.

T A B L E I V

VISUAL FUEL ELEMENT EXAMINATION DATA FROM C REACTOR LOW pH-LOW DICHROMATE FUEL ELEMENTS

TUBE NO.	961	1559	1964	2066	2363	2760	2759	3358	4061
Fuel Pieces	30	30	30	30	30	30	30	30	30
Primary Ledge	5	1	6	4	7	3	7	5	4
Primary Groove	0	0	0	0	1	0	1	0	0
Secondary Ledge	0	0	0	0	0	0	0	0	0
Secondary Groove	0	0	0	11	9	0	0	0	0
Severity - 2*	0	0	0	0	1	2	5	0	0
Severity - 3**	0	0	0	0	0	0	0	0	0

TUBE NO.	786	1189	1891	2091	2291	2380	2482	2685	3083	3483
Fuel Pieces	30	30	30	30	30	30	29	30	30	30
Primary Ledge	7	9	5	12	14	3	3	5	8	6
Primary Groove	0	1	0	1	2	0	0	0	3	1
Secondary Ledge	0	0	0	0	0	2	0	0	2	0
Secondary Groove	0	8	0	7	5	0	11	12	16	2
Severity - 2*	0	0	3	2	2	1	0	0	5	3
Severity - 3**	0	0	0	0	0	0	0	0	0	0

* Corrosion estimated to be 10 mils deep.

** Corrosion to the Al-Si.

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