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INTERIM REPORT I, PRODUCTION TEST IP-442-A
HALF-PLANT REDUCTION IN PROCESS WATER pH, 105-D

By

R. G. Geier
Process and Reactor Development Subsection
Research and Engineering Section

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INTRODUCTION

A half-plant low pH test[1] began at D Reactor on March 19, 1963. The purpose of the test was to provide quantitative data on the reduction in aluminum corrosion obtained by lowering reactor coolant pH from 7.0 to 6.6. The benefits of lower pH will be monitored by ex-reactor tube examinations, in-reactor wall thickness measurements, coupons, and visual examination plus weight loss measurements of fuel elements. This report presents the results of the visual examination and weight loss measurements on 18 columns of fuel elements irradiated during the test.

SUMMARY

The fuel element weight loss measurements and visual fuel element examination data from 18 columns of D Reactor elements irradiated during the half-plant low pH test gave the following results:

1. Weight loss measurements on fuel exposed to 800 Mwd/t indicated that the anticipated factor of two reduction in aluminum corrosion with a 0.4 unit reduction in coolant pH is substantially correct.

2. The frequency of occurrence of both ledge and groove corrosion was high on both sides of the reactor.

3. Other things being equal, neither the 0.3 unit reduction in pH (test conditions) nor the use of a water mixer when considered as single variables is capable of reducing ledge or groove corrosion.

4. Combining the pH reduction with the use of a water mixer results in some reduction in the frequency of occurrence of ledge and groove corrosion. However, even with the combination a major reduction was not achieved.

DISCUSSION

A. Water Treatment

In order to determine quantitatively the reduction in aluminum corrosion which results from lowering reactor coolant pH, the following half-plant test conditions were established at D Reactor on March 19.

	Control Side (Near)	Test Side (Far)
pH	7.0	6.6
Dichromate, ppm	1.8	1.8
Alum, ppm	18	18

(1) VanWormer, F. W. Production Test IP-442-A, Half-Plant Reduction in Process Water pH, 105-D, HW-71141. May 8, 1962.

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The actual pH achieved on each side of the reactor is shown in Figure 1. Although the pH appears to fluctuate, the scale of the graph is large and actually good control, particularly on the test side, was maintained throughout. The average pH during the fuel exposure periods to be discussed was as follows:

Date	Control Side (Near)	Test Side (Far)
3/19-4/30	6.99	6.61
3/19-6/14	6.94	6.61
3/19-7/12	6.93	6.62

B. Fuel Element Irradiation Conditions

Eighteen columns of fuel elements, nine on each side of the reactor, were charged into D Reactor on March 19, 1963. The fuel elements had been numbered, charged in numerical order, and pre-irradiation weights had been obtained on the downstream 15 elements in each column. The fuel was discharged on the following dates:

Four columns	4/30/63
Twelve columns	6/14/63
Two columns	7/12/63

The irradiation conditions for each column are given in Table I.

Inasmuch as the fuel can be grouped into three exposure categories, 375, 800, and 890, some with mixers and some without mixers, a variety of correlations can be made.

C. Weight Loss Measurements

The individual weight loss measurements in grams for each of the 15 downstream fuel elements in the 18 columns are given in Table II. With the exception of tubes 2278 and 2284, the weight loss data from the individual tubes appears to fall in the general pattern expected for fuel element corrosion.

1. Fuel Exposure - 375 Mwd/t

The fuel from four columns, two from the near side and two from the far side, was discharged after receiving an exposure of 375 Mwd/t. One of each pair of fuel columns contained a water mixer and one did not. The weight loss measurements on the near side fuel as shown in Table II indicate that the mixer did not have a significant effect on either the total metal loss or the distribution of the metal loss. The average values of the fuel element weight loss are shown in Table III.

The weight loss measurements for the far side fuel are also shown in Table II. Tube 2278 contained four elements which showed a weight gain as well as several fuel pieces which showed a weight loss of almost twice that of the corresponding piece on the near side. On the other hand, the fuel from tube 2284 showed inordinately low weight losses which do not have much meaning considering the accuracy of the data. It was concluded that it would not be possible from the available data to develop a near to far side comparison at low exposure.

2. Fuel Exposure - 800 Mwd/t

The fuel from 12 columns, five from the near side and seven from the far side, was discharged at an exposure of 800 Mwd/t. Three of the columns from each side did not contain water mixers. The individual weight loss measurements shown in Table II have been averaged in Table III on the following basis:

a. Total near side and total far side tubes.

b. Near side tubes with water mixers and far side tubes with water mixers.

c. Near side tubes without water mixers and far side tubes without water mixers.

A comparison of the total weight loss for the downstream 15 fuel element positions in the tubes without water mixers indicates that the ratio of near side (pH 6.9) to far side (pH 6.6) metal loss is 1.6. A similar comparison for the tubes containing water mixers shows a near to far side metal loss ratio of 2.0.

It can be concluded, therefore, that the anticipated factor of two reduction in aluminum corrosion obtained by lowering pH from 7.0 to 6.6 is substantially correct. It is also of interest to note that the use of water mixers, while enhancing the total metal loss benefit somewhat, also appears to rather substantially influence the weight loss distribution at pH 6.6. The data from Table III show that the weight loss from the downstream six elements in water mixer tubes is nearly a factor of two lower than from the downstream six elements in nonmixer tubes at low pH. At a pH of 7.0 the weight loss distribution is about the same regardless of whether water mixers are used.

3. Fuel Exposure - 890 Mwd/t

The fuel from two near side columns containing water mixers was discharged at 890 Mwd/t. The average weight loss from the 15 downstream pieces is shown in Table III. The 143 gram loss for the 15 elements is higher as expected than the 120 gram loss for similar fuel elements exposed to 800 Mwd/t. In fact, if the near side weight loss data from the three exposure periods is plotted against exposure, a linear correlation results.

D. Visual Fuel Examination

1. Definitions

Visual fuel element examination identifies the serious type of corrosion attack as well as recognizing the presence of secondary effects. While

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a fuel element may exhibit several types of corrosion (pitting, uniform, ledge or groove), 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.

2. Results

The number of fuel elements from each of the 18 columns exhibiting ledge and groove corrosion and the severity of corrosion is shown in Table IV.

a. Low Exposure Fuel

An examination of the frequency of ledge and groove corrosion on the fuel elements discharged at 375 Mwd/t shows one near side (pH 6.9) tube and one far side (pH 6.6) tube to be free of both ledge and groove corrosion.

The other far side tube contained one fuel element exhibiting groove corrosion while the other near side tube showed a high incidence of ledge and groove corrosion. Since only four tubes are involved, these data should not be construed to illustrate a beneficial effect of low pH. If the experiment was repeated, it is possible that the high frequency of ledge and groove corrosion might have occurred in a far side tube.

b. High Exposure Fuel

Previous studies of ledge and groove corrosion have shown that small differences in fuel exposure do not significantly influence the frequency of occurrence of either ledge or groove corrosion. For this reason, the fuel discharged at 800 Mwd/t and 890 Mwd/t has been combined for the purposes of analysis. The frequency of occurrence of ledge and groove corrosion on the fuel from the 14 high exposure columns is shown in Table V. Since four of the tubes from each side contained mixers and three did not, the frequency of occurrence is given for the over-all seven tubes, for the four mixer tubes, and for the three nonmixer tubes.

The immediate general conclusion from the data is that the frequency of occurrence of ledge and groove corrosion is high on both sides of

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the reactor. As a comparison, the examination of over 600 fuel elements charged into F Reactor on March 29, and discharged June 19, 1963, showed 11 per cent ledge corrosion and less than one per cent groove corrosion.

A more detailed comparison of the near side (pH 6.9) and the far side (pH 6.6) data indicate that without water mixers, pH has essentially no effect on the frequency of occurrence of ledge and groove corrosion. If mixers are used, reducing the coolant pH appears to reduce the occurrence of ledge and groove corrosion but the magnitude of the reduction is not large. By the same token, at a pH of 6.9, mixers have no influence on the frequency of occurrence of ledge and groove corrosion, but at a coolant pH of 6.6 the use of mixers reduces the frequency of occurrence. As with pH, however, the effect of the mixers is not large. The same phenomenon is evident as far as severity Code - 2 is concerned. However, penetration to the Al-Si (severity Code - 3) does not appear affected by either pH or the use of mixers.

The small effect of pH and/or mixers on the frequency of occurrence of ledge and groove corrosion is significant. It shows that neither pH nor mixers as a single variable in the over-all corrosion environment, to which the fuel was exposed, is capable of preventing ledge and groove corrosion. The apparent increased effect of reduced pH by mixers and vice versa is not surprising since it would be expected that as the corrosion environment moderated, the influence of a single variable would become more pronounced.

The weight loss measurements had demonstrated that the use of mixers at a coolant pH of 6.6 appeared not only to enhance the metal loss benefit of low pH but also change the metal loss distribution. Since the mixer was in the seventh position, an analysis of the frequency of occurrence of ledge and groove corrosion on the downstream six fuel elements from the high exposure tubes was made. The data are presented in Table VI. As in the case of the analysis based on the complete column of fuel elements, neither a reduction in coolant pH to 6.6 nor the use of water mixers substantially reduces the frequency of occurrence of ledge or groove corrosion.

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FIGURE 1

NEAR AND FAR SIDE pH MAINTAINED
DURING D REACTOR LOW pH TEST

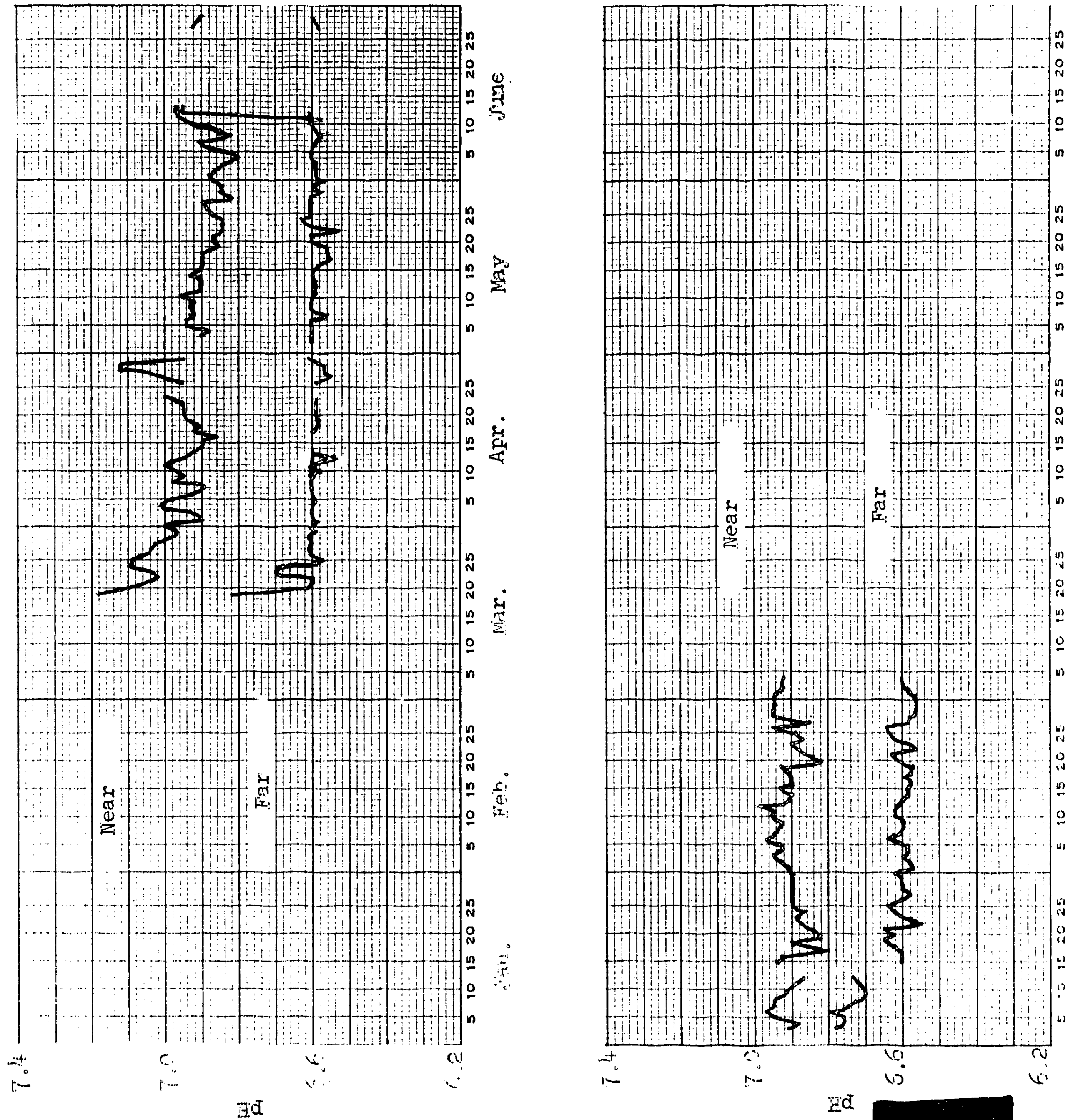

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TABLE I

IRRADIATION CONDITIONS OF D REACTOR LOW pH TEST FUEL ELEMENTS

Tube No.	Charge Date	Discharge Date	Fuel Pieces (OIIIN)	Exposure Mwd/t	Tube Power kw	Outlet Temp. °C	Inlet Temp. °C	Flow gpm
2060	3/19/63	4/30/63	31 + WM	381	1164	105	8.5	45.3
2261	3/19/63	4/30/63	32	375	1232	112	8.5	45.0
2278	3/19/63	4/30/63	32	376	1203	108	8.5	45.7
2284	3/19/63	4/30/63	31 + WM	377	1155	103	8.5	46.3
2161	3/19/63	6/14/63	32	789	1207	111	10.5	45.7
2260	3/19/63	6/14/63	32	767	1208	111	10.5	45.5
2262	3/19/63	6/14/63	32	781	1204	110	10.5	45.8
2362	3/19/63	6/14/63	31 + WM	796	1192	110	10.5	45.5
2463	3/19/63	6/14/63	31 + WM	786	1177	108	10.5	45.7
1684	3/19/63	6/14/63	31 + WM	827	1222	107	10.5	46.4
1982	3/19/63	6/14/63	31 + WM	804	1194	110	10.5	45.6
1984	3/19/63	6/14/63	31 + WM	816	1215	110	10.5	46.0
2185	3/19/63	6/14/63	31 + WM	826	1229	113	10.5	45.5
2281	3/19/63	6/14/63	32	789	1199	110	10.5	45.8
2282	3/19/63	6/14/63	32	810	1229	110	10.5	46.7
2283	3/19/63	6/14/63	32	792	1215	110	10.5	46.3
2059	3/19/63	7/12/63	31 + WM	886	1162	108	12	45.9
2360	3/19/63	7/12/63	31 + WM	896	1080	102	12	45.4

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TABLE II

WEIGHT LOSS DATA FROM D REACTOR
LOW pH TEST FUEL ELEMENTS

Weight Loss, Grams

Tube No.	2060	2261	2059	2161	2260	2262	2360	2362	2463
Piece No. 1	2.01	1.31	3.28	3.05	3.42	3.53	5.41	(a)	3.19
2	1.99	1.57	4.98	3.66	4.09	4.26	7.50	6.55	4.51
3	3.61	3.10	11.45	4.60	4.84	5.65	9.61	10.22	5.25
4	4.40	2.46	9.40	9.76	6.14	8.93	13.80	15.57	8.33
5	3.05	3.46	15.27	10.37	8.22	10.53	17.92	11.22	(a)
6	4.28	4.20	13.50	11.75	9.65	10.51	18.76	14.83	12.13
7	(a)	3.79	(a)	13.88	12.87	12.06	(a)	(a)	(a)
8	4.45	3.88	11.50	10.47	11.00	12.25	14.67	11.27	11.15
9	5.18	(a)	(b)	12.40	11.52	9.45	11.93	8.93	8.99
10	4.68	3.62	(a)	(a)	10.63	8.48	12.15	7.57	9.00
11	4.42	3.93	9.91	10.17	10.06	9.75	9.96	10.08	9.93
12	4.43	3.98	10.55	9.97	10.52	10.13	9.66	9.56	8.38
13	3.58	3.62	8.24	8.76	10.05	7.52	9.11	8.66	8.76
14	3.39	4.63	6.17	(a)	8.00	7.24	8.27	7.32	6.29
15	2.18	1.86	5.48	4.52	6.66	4.98	4.48	5.29	(a)

Tube No.	2278	2284	1684	1982	1984	2185	2281	2282	2283
Piece No. 1	1.24	0.14	3.17	1.74	1.75	2.18	3.26	2.19	2.18
2	7.10	0.25	2.57	2.44	2.49	0.95	5.19	3.11	2.94
3	(b)	0.54	3.06	2.37	2.64	2.81	5.07	3.35	3.03
4	2.56	0.68	3.57	2.84	2.60	4.42	7.21	6.80	5.83
5	1.77	0.76	3.82	3.50	2.89	5.00	7.09	6.90	7.17
6	9.37	(b)	4.79	3.53	3.36	4.26	7.50	7.56	7.31
7	7.55	(a)	(a)	(a)	(a)	(a)	6.52	7.42	7.35
8	9.39	1.35	6.51	7.26	7.35	7.42	6.45	7.54	6.97
9	6.72	1.18	6.97	6.65	7.51	8.43	5.14	7.29	6.34
10	(b)	0.99	7.18	7.01	6.76	6.79	5.01	7.20	5.49
11	(b)	1.05	6.49	5.43	5.34	7.53	5.64	(b)	5.39
12	1.95	0.81	5.05	4.52	4.70	5.84	5.80	5.36	4.63
13	(a)	0.85	4.96	3.79	4.36	4.72	5.05	5.32	4.22
14	(b)	0.72	3.42	2.56	4.09	4.59	(b)	3.97	4.22
15	5.33	0.75	2.39	1.86	1.69	3.24	(a)	3.38	2.57

(a) No post weight
(b) Weight gain

Note: Pieces numbered from downstream end of tube.

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TABLE III

AVERAGE WEIGHT LOSS DATA FROM D REACTOR
LOW pH TEST FUEL ELEMENT

Weight Loss, Grams

Fuel Element*	375 Mwd/t Exposure Near Side	800 Mwd/t Exposure Near Side: Total	800 Mwd/t Exposure Near Side: With Mixer	800 Mwd/t Exposure Near Side: Without Mixer	890 Mwd/t Exposure Near Side
1	1.65	3.29	3.19	3.33	4.35
2	1.78	4.62	5.53	4.00	6.24
3	3.35	6.11	7.74	5.03	10.53
4	3.43	9.74	11.96	8.27	11.60
5	3.20	10.09	11.22	9.71	16.59
6	4.24	11.79	13.48	10.64	16.13
7	3.79	12.94	-----	12.94	-----
8	4.16	11.22	11.21	11.24	13.09
9	5.18	10.26	8.96	11.12	11.93
10	4.15	8.95	8.29	9.57	12.15
11	4.18	10.00	10.00	9.99	9.94
12	4.20	9.71	8.97	10.21	10.10
13	3.60	8.74	8.71	8.78	8.68
14	4.01	7.21	6.80	7.62	7.22
15	2.02	5.36	5.29	5.39	4.98
Total	52.94	130.03	121.35	127.84	143.53

Fuel Element*	800 Mwd/t Exposure Far Side: Total	800 Mwd/t Exposure Far Side: With Mixer	800 Mwd/t Exposure Far Side: Without Mixer
1	2.35	2.21	2.54
2	2.81	2.11	3.73
3	3.19	2.72	3.81
4	4.75	3.35	6.61
5	5.19	3.80	7.05
6	5.47	3.99	7.45
7	7.09	----	7.09
8	7.07	7.13	6.98
9	6.90	7.39	6.26
10	6.49	6.93	5.90
11	5.96	6.19	5.52
12	5.13	5.02	5.26
13	4.63	4.45	4.86
14	3.80	3.66	4.09
15	2.52	2.29	2.97
Total	73.35	61.24	80.12

* Numbered from downstream end of tube.

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TABLE IV

VISUAL FUEL EXAMINATION DATA FROM D REACTOR LOW pH TEST FUEL ELEMENTS

Tube No.	2060	2261	2059	2161	2260	2262	2360	2362	2463
Fuel Pieces	31	31	30	32	32	32	31	28	29
Primary Ledge	0	4	9	5	8	9	9	2	4
Primary Groove	0	6	5	7	5	6	5	5	5
Secondary Ledge	0	0	4	6	5	6	5	5	4
Secondary Groove	0	1	0	0	0	2	0	2	0
Severity - 2*	0	11	5	7	4	5	3	9	3
Severity - 3**	0	0	0	3	1	1	2	1	0

Tube No.	2278	2284	1684	1982	1984	2185	2281	2282	2283
Fuel Pieces	32	31	28	31	31	31	30	31	31
Primary Ledge	0	0	0	4	4	9	4	6	7
Primary Groove	0	1	7	3	3	2	7	6	5
Secondary Ledge	0	0	3	2	0	3	4	6	5
Secondary Groove	0	0	0	0	0	1	0	0	0
Severity - 2*	0	0	5	3	2	3	9	2	3
Severity - 3**	0	0	1	1	1	0	1	1	2

* Corrosion estimated to be 10 mils deep.
** Corrosion to the Al-Si.

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TABLE V

THE FREQUENCY OF OCCURRENCE OF LOCALIZED CORROSION ON D REACTOR LOW pH TEST FUEL

	Per Cent of Pieces					
	Control Side (Near)			Test Side (Far)		
	Over-all	With Mixers	Without Mixers	Over-all	With Mixers	Without Mixers
Primary Ledge	21.5	20.4	22.9	16.0	14.0	18.5
Primary Groove	17.7	17.0	18.8	15.5	12.4	19.6
Total Occurrence Ledge and Groove*	57.2	54.4	61.5	42.8	33.8	54.3
Severity - 2	16.8	17.0	16.7	12.7	10.7	15.2
Severity - 3	3.7	2.5	5.2	3.3	2.5	4.3

* Includes both primary and secondary classifications.

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TABLE VI

THE FREQUENCY OF OCCURRENCE OF LEDGE AND GROOVE CORROSION ON THE DOWNSTREAM SIX ELEMENTS OF THE D REACTOR LOW pH FUEL

Number of Fuel Pieces

Near Side

	Mixer				No Mixer		
Tube No.	2059	2360	2362	2463	2161	2260	2262
Primary Ledge	1	1	1	0	0	1	2
Primary Groove	5	5	3	5	5	5	4
Secondary Ledge	4	5	3	4	5	5	4
Secondary Groove	0	0	1	0	0	0	2
Severity - 2	4	3	3	2	3	3	5
Severity - 3	0	2	2	0	2	1	1

Far Side

	Mixer				No Mixer		
Tube No.	1684	1982	1984	2185	2281	2282	2283
Primary Ledge	0	2	1	3	0	1	0
Primary Groove	4	3	3	2	6	4	4
Secondary Ledge	2	2	0	1	5	3	4
Secondary Groove	0	0	0	1	0	0	0
Severity - 2	4	1	1	1	3	2	1
Severity - 3	0	0	0	0	1	1	0

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