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FINAL REPORT
PRODUCTION TEST IP-750
RAW WATER AS A REACTOR COOLANT

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FINAL REPORT

PRODUCTION TEST IP-750

RAW WATER AS A REACTOR COOLANT

by

J. W. Frymier
R. G. Geier

August 10, 1966

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FINAL REPORT
PRODUCTION TEST IP-750
RAW WATER AS A REACTOR COOLANT

INTRODUCTION

Approximately ten years ago single-tube tests demonstrated the feasibility of using unfiltered river water as a reactor coolant from the standpoint of aluminum corrosion and film formation.¹ However, some effluent activity penalty was indicated. Inasmuch as both current water plant operation and the characteristics of Columbia River water have changed, it was deemed appropriate to reinvestigate the use of partially treated water as a reactor coolant. This report summarizes the results of a half-reactor test carried out at F Reactor.²

SUMMARY

Approximately two months of experience (March 8, 1965, through May 3, 1965) was accumulated using unflocculated-filtered water containing 1.0 ppm sodium dichromate and having a pH of 6.6 as reactor coolant in a half-plant test at F Reactor. The data obtained indicated the following:

1. There was no filming problem.
2. Corrosion of aluminum may be somewhat less in the test water and surely is no greater.
3. The concentration of phosphorus-32 in the reactor effluent increased by a factor of 4.
4. The concentration of arsenic-76 in the reactor effluent increased by a factor of 2.

In view of the emphasis to reduce the amount of radionuclides in the reactor effluent, the type of coolant treatment used in this test is not satisfactory.

DISCUSSIONA. Pretest Activity

Several years ago at F Reactor, a short period, informal test was run in which uncoagulated-filtered water was supplied to half the reactor. Rapid

¹Miller, N.R. The Effects of Water Quality on Pile Operation, Final Report, Production Test No. 105-255E. HW-34544. September 23, 1955.

²Pitman, R.W. Production Test IP-750, Raw Water as a Reactor Coolant. RL-REA-532. January 22, 1965.

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film buildup in the process tubes was indicated and the test was terminated. Based upon this experience, it was believed a means for bypassing the filters would be required to provide a particulate size in the coolant which would prevent a recurrence.

The initial concept was to insert 12-inch-diameter pipe sections through the filter media. The pipes would extend down into the heavy gravel strata and thereby reduce bed resistance and retain large debris-type suspended material (Figure 1). In the event of unsatisfactory test results, such as excessive reactor tube film, buildup or screen plugging, pipe caps were provided to restore the filter to its original condition (Figure 2).

Half-filter tests were made in the No. 6 filter at F Reactor using the piping configuration shown in Figure 3 during the period January 21 to January 25, 1965. Both during backwash and normal flow cycles, the open pipes filled with filter media to its normal depth. The condition continued to occur when the pipe was lowered to within one inch of the underdrain system. In view of this, the concept was abandoned.

A 42-inch steel line with a 36-inch valve and transition piece was installed between the far side basin outlet flume and the far side clearwell at F Reactor to bypass the filters.

In order to minimize the effect of adverse results, it was decided to start the test prior to a scheduled outage. Consequently, on March 5, 1965, at 11 a.m., the alum and chlorine feeds to the far side were stopped and the filter bypass line was opened.

Uncoagulated-unfiltered water averaging 12.5 ppm turbidity, 1.0 ppm dichromate, and 6.6 pH was passed through the far side until 6 p.m. on March 7, 1965. At this time, two far side filters were returned to operation. Subsequently, at both 8 p.m. and 10 p.m. two additional filters were returned to operation, and the filter bypass was closed. The reactor now operating on uncoagulated-filtered water ran until scheduled shutdown at 4:30 a.m., March 8, 1965.

Some observations made during this pretest period include:

1. The monitoring of ten Panellit gauges on each side of the reactor showed that the near side average was +0.1 psi from base and the far side average was -1.0 psi from base.
2. The reactor effluent gamma monitor remained stable on the near side but increased somewhat on the far side.
3. An examination of the process water header screens in the 105 Building valve pit revealed some deposition of tumbleweed particles and small pieces of wood and roofing paper. Screen plugging did not appear imminent.

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4. During the last 10 hours of the test when uncoagulated water was being passed through the filters, the head loss increase was observed to be negligible. Filtered water turbidity was about 15 percent below the raw water turbidity.

B. Test Conditions

Based on the operating experience during the period in which uncoagulated water was passed through the filters, it was decided to run the test in this manner. The test was initiated on March 11, 1965, with the water plant operating as follows:

	<u>Test</u> <u>(Far)</u>	<u>Control</u> <u>(Near)</u>
pH	6.6	6.6
Alum, ppm	0	18
Dichromate, ppm	1.0	1.0
Chlorine, ppm	0	Normal

These conditions were maintained until test termination on May 3, 1965.

C. Results

1. Filter Performance

Minimum test side filter head losses were experienced throughout the test. Although not required, the test side filters were washed on a 24-hour cycle. The expelled filter residue was light brown in color and appeared to be silt particles.

Daily average turbidity measurements taken on raw water, basin outlet water, and 190 Building process water are shown in Table I. Average values for the test period were:

	<u>Turbidity, ppm</u>
Raw Water	21.6
Basin Outlet Water	21.2
190 Process Water	17.6

The values indicate very little (2 percent) of the incoming turbidity settling out in the sedimentation basin. The filters removed 19 percent of the turbidity in the untreated water.

2. Microorganisms

Algae colonies were in evidence in the sedimentation basins, filters, and 190 tank outlet sample containers. The concentration did not appear to be much greater than that experienced during hot summer periods when chlorine was being added.

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A cursory microscopic examination of a water sample obtained from the 190 Building on March 12, 1965, revealed a high micro-organism content. The residue retained on a 0.45 micron filter was primarily diatoms of the Asterionella, Melosira and Synedra species.

3. Filming

During the test, ten Panellit gauges on each side of the reactor were monitored daily. The gauges were located as shown in Table II. Pressure deviation from the base pressures was computed daily, and the values are shown in Table III. The test side of the reactor averaged a 0.5 psi below base while the control side averaged 0.3 psi below base. It would appear that the use of unflocculated-filtered water as the coolant did not cause filming to occur.

4. Effluent Radioactivity

The Columbia River normally contains between 30 and 100 ppb of phosphate. In the water treatment process this is reduced routinely to 5 ppb or less. The use of unflocculated-filtered coolant would contain substantially higher quantities of phosphate as well as other parent isotopes. It was felt that the presence of the turbidity in the coolant might serve as a continuous purge and compensate for the additional parent material.

Samples of effluent were obtained daily from each riser and were analyzed for phosphorus-32 and arsenic-76. The results obtained are given in Table IV. Phosphorus-32 was higher in the test side effluent by a factor of 4, and As-76 was higher on the test side by a factor of 2. Clearly, any purging action obtained did not completely compensate for the increased amounts of parent material.

5. Gamma Monitors

No difference was observed between test and control side effluent gamma monitor readings during the test.

6. Corrosion

a. Fuel

Seventeen columns of numbered and weighed fuel were charged into F Reactor on March 8, 1965, and irradiated until the termination of the test on May 3, 1965. Of the 17, ten columns were on the test side and seven columns were on the control side. The columns each consisted of 32 pieces of OIIN fuel with a water mixer in the seventh position from the downstream end.

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(1) Operating Conditions

The operating conditions of the 17 columns are shown in Table V. There is some variation within the group of tubes on each side of the reactor, but the averages for exposure, tube power, outlet temperature, and flow are nearly identical.

(2) Weight Loss Measurements

Weight loss measurements were obtained on the downstream 15 fuel elements. The weight loss from each individual element is shown in Table VI. The average control and test side value for each position is shown in Table VII. The values from both sides of the reactor are low. It appears that the values from the test side are in general lower than on the control side. Thus, it can be concluded that as far as weight loss is concerned, there is no penalty if uncoagulated-filtered coolant is used.

(3) Visual Examination

The visual examination of the 17 columns showed only two pieces with primary ledge corrosion and two pieces with secondary ledge corrosion. No groove corrosion was observed. A total of 13 hot areas were evident. Thus, the nonuniform corrosion environment was very mild. Under these conditions the use of unflocculated-filtered coolant did not produce ledge or groove corrosion.

b. Coupons

Coupons were located in the downstream end of a process tube on each side of the reactor for a seven-week period. The following information was obtained.

<u>Material</u>	<u>Corrosion Rate</u> <u>mils/mo</u>	
	<u>Test</u>	<u>Control</u>
X8001 Aluminum	0.18	0.42
1100 Aluminum	0.30	0.66
6063 Aluminum	0.38	0.48
Carbon Steel	<0.1	<0.1

The corrosion of aluminum was less in the test side coolant than in the control side coolant. There was no difference in the corrosion rates of carbon steel. The data tend to confirm the fuel weight loss results reported above.

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TABLE I

Daily Average Water Turbidity, ppm
During Raw Water Test
F Reactor

	<u>Raw</u>	<u>Basin Outlet</u>	<u>190 W Header</u>	<u>% Turbidity Passed 190/Raw</u>
3/11/65	17		6.5 (Diluted)	38
12	14		9.1	65
13	14	12.3	9.6	69
14	11.5	11.7	8.8	77
15	15.5	13.5	10.2	66
16	16.9	15.5	10.8	64
17	19.0	19.0	11.0	58
18	19.7	17.5	14.8	75
19	21.9	20.0	17.0	78
20	23.2	21.5	19.3	83
21	25.7	21.5	20.2	79
22	24.7	22.7	21.5	87
23	25.0	23.0	23.0	92
24	26.0	28.0	23.5	90
25	27.0	27.0	22.0	81
26	27.0	26.0	24.0	89
27	30.3	27.3	23.3	77
28	26.1	25.5	21.3	82
29	Down			
30	Down			
31	Down			
4/1/65	26.8	28.8	20.3	76
2	27.7	23.6	20.4	74
3	22.4	22.9	20.8	93
4	21.2	22.0	20.3	96
5	20.9	21.0	21.8	--
6	20.8	21.5	20.0	96
7	21.5	23.5	19.3	90
8	21.9	20.5	19.3	88
9	Down			
10	21.8	22.5	16.0	73
11	22.9	23.2	17.8	78
12	20.8	21.2	17.8	86
13	20.9	20.0	18.3	88
14	19.0	19.5	19.0	100
15	Down			
16	Down			
17	Down			

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TABLE I (Cont.)

	<u>Raw</u>	<u>Basin Outlet</u>	<u>190 W Header</u>	<u>% Turbidity Passed 190/Raw</u>
4/18/65*	20.0	20.0	22.0	--
19 *	21.9	21.7	21.6	99
20 *	19.0	18.0	--	--
21 *	20.4	20.1	23.0	
22 *	21.0	22.7	22.7	
23 *	20.1	20.8	24.0	
24 *	25.4	22.1	24.3	
25 *	20.5	22.0	25.0	
26 *	20.8	20.7	23.4	
27 *	22.5	19.2	24.0	
28 *	17.9	18.5	24.6	
29 *	15.0	15.0	23.0	
30 *	16.0	16.0	23.0	
5/1/65*	15.5	16.0	19.0	
2	19.2	15.1	15.9	83
3	Down			

* Instruments faulty - data excluded from averages.

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TABLE II

F Reactor Panellit Gauges Monitored
During Raw Water Test

Tube No.

3958

3968

3980

3991

3151

3168

3180

3196

2353

2368

2380

2394

1551

1568

1580

1596

0758

0768

0780

0791

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TABLE III

Panelit Pressure
F Reactor Raw Water Test

Base minus average for ten gauges on each side of reactor.

	<u>Control Side</u> <u>(Near)</u>	<u>Test Side</u> <u>(Far)</u>
3/12/65	- 1.4	- 0.8
13	- 1.3	- 0.6
14	- 0.8	- 0.2
15	- 0.9	0.0
16	- 0.9	- 0.1
17	- 0.8	+ 0.2
18	- 0.4	+ 0.3
19	- 0.8	+ 0.2
20	- 0.2	+ 0.5
21	- 0.2	+ 0.1
22	0.0	+ 0.3
23	+ 0.6	+ 0.5
24	0.0	+ 0.2
25	+ 0.7	+ 0.2
26	+ 0.4	+ 0.5
27	+ 0.9	+ 0.2
28	+ 0.7	+ 0.5
29	+ 0.8	+ 0.2
30	Down	
31	Down	
4/1/65	- 1.8*	- 3.2*
2	- 2.2	- 2.0
3	- 1.8	- 2.0
4	- 2.1	- 1.1
5	+ 0.4	- 0.5
6**	+ 0.2*	- 0.2*
7	+ 0.6	- 0.7
8	- 0.2	- 1.2
9	Down	
10	Down	
11	- 2.0*	- 1.2*
12	- 1.5	- 1.2
13	- 1.0	- 1.0
14	- 0.9	- 1.4

*Base Change

**Short diatomaceous earth purges were given on the near side (April 6, 1965) and far side (April 7, 1965) in an attempt to plug a suspected tube leak.

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[REDACTED]

[REDACTED]

TABLE III (Cont.)

	<u>Control Side</u> (Near)	<u>Test Side</u> (Far)
4/15/65		
16	Down	
17	Down	
18	Down	
19	Down	
20	0.0*	0.0*
21	+ 0.3	- 0.1
22	+ 0.2	- 0.2
23	+ 0.1	- 0.4
24	+ 0.5	- 0.4
25	+ 0.2	- 0.7
26	+ 0.4	- 0.9
27	+ 0.4	- 0.7
28	+ 0.4	- 1.1
29	+ 0.5	- 0.8
30	0.0	- 1.2
	+ 0.1	- 1.1
5/1/65		
2	+ 0.2	- 0.8
	+ 0.7	- 0.9

*Base Change

[REDACTED]

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TABLE IV

Reactor Effluent Radioactivity
F Reactor Raw Water Test

	<u>As⁷⁶, pCi/ml</u>		<u>P³², pCi/ml</u>	
	<u>Near</u> <u>(Control)</u>	<u>Far</u> <u>(Test)</u>	<u>Near</u> <u>(Control)</u>	<u>Far</u> <u>(Test)</u>
3/11/65		49		7.9
12		112		23.1
15		167		38.8
16		196		36.6
17		223		38.1
18		178		31.5
19	82	296	(39.9)	25.8
22	63	181	7.6	49.1
23	92	262	13.6	99.7
24	98	276	12.3	72.9
25	63	162	9.0	--
26	27	73	11.2	55.8
29	(73)	(58)	13.8	76.8
30	--	--	--	--
31	18	79	(35.4)	(6.3)
4/1/65	49	95	11.5	40.6
2	(6)	--	12.5	32.2
5	--	--	--	--
6	55	125	13.7	60.5
7	97	208	15.5	72.3
8	--	--	16.8	73.8
9	--	--	--	--
12	120	158	(64.4)	67.7
13	76	127	15.3	58.6
14	84	166	16.0	45.1
15	--	--	--	--
16	--	--	--	--
19	--	--	--	--
20	96	196	15.9	59.7
21	70	129	14.2	55.6
22	80	290	12.6	43.2
23	86	172	10.2	54.6
26	111	167	16.1	56.2
27	93	184	15.9	68
28	79	151	(45.8)	(26.1)
29	80	170	19.1	44.9
30	88	204	15.4	45.3
Average	78	176	13.7	57.2
Factor Increase		2.26		4.18

() Excluded from average

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TABLE V

Irradiation Conditions of F Reactor
Raw Water Test Fuel Elements

Charge Date: March 8, 1965

Discharge Date: May 3, 1965

Fuel Charge: 31 OIIN elements plus 1 water mixer in the seventh position.

Inlet Water Temperature: 9 C

<u>Tube No.</u>	<u>Exposure MWD/T</u>	<u>Tube Power KW</u>	<u>Outlet Temp. C</u>	<u>Flow gpm</u>
1259	483	1194	104	47.5
1262	487	1189	106	46.3
1862	468	1158	104	46.0
1865	465	1145	101	47.2
2259	466	1151	101	47.5
2263	483	1203	99	50.9
2266	498	1229	107	47.5
Average	478	1181	103	47.6
1280	494	1175	106	46.2
1285	495	1216	106	47.9
1288	467	1160	100	48.4
1881	483	1178	106	45.7
1885	476	1159	101	48.0
2281	496	1215	107	47.2
2288	437	1104	99	46.7
3080	497	1218	107	47.4
3085	494	1210	106	47.3
2285	489	1198	105	47.5
Average	483	1183	104	47.2

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TABLE VI

Weight Loss Data From
F Reactor Raw Water Test Fuel Elements

Thirty-two natural uranium fuel elements per column.
Discharge Date: May 3, 1965.
Elements numbered from the downstream end.
Weight loss in grams.

Piece No.	Tube Number																
	1280	1285	1288	1881	1885	2281	2285	2288	3080	3085	1259	1262	1862	1865	2259	2263	2266
1	0.42	0.65	0.58	0.62	0.58	0.79	0.54	0.61	0.87	0.67	0.51	1.01	0.68	0.58	0.54	0.55	0.49
2	0.45	0.77	0.56	--	0.50	0.85	0.52	0.56	0.73	0.65	--	2.50	0.69	0.50	0.81	0.66	1.19
3	0.44	0.87	0.41	0.53	0.60	0.64	0.67	0.67	0.68	0.68	0.48	1.35	0.74	0.59	0.66	0.67	1.35
4	0.35	0.73	0.25	0.60	0.61	0.88	0.57	0.58	0.68	0.47	--	0.80	0.86	0.54	0.57	0.79	0.59
5	0.49	0.79	1.23	0.65	0.54	0.73	0.57	0.60	0.87	0.61	0.68	--	0.88	0.60	0.66	0.64	0.80
6	0.36	0.63	0.53	0.49	0.61	--	0.37	0.24	0.64	0.00	0.54	0.92	0.90	0.57	0.68	0.71	0.99
7	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
8	0.40	0.63	0.33	0.57	0.43	0.62	0.31	0.40	0.57	0.40	0.51	1.12	0.91	0.38	0.67	0.86	1.00
9	0.45	0.58	0.21	0.65	0.13	0.71	0.44	0.35	0.36	0.22	--	1.69	0.68	0.55	0.70	0.63	0.93
10	0.45	0.00	0.16	0.34	0.21	0.32	0.20	0.40	0.62	0.89	0.53	1.05	0.81	0.59	0.55	0.64	0.91
11	0.42	0.47	0.05	0.20	0.00	0.37	0.19	0.46	0.19	0.11	0.72	2.30	1.25	0.73	--	0.79	0.96
12	1.60	0.30	0.00	--	0.10	0.12	0.13	0.32	0.29	0.05	0.69	1.53	1.20	0.81	0.46	0.78	0.95
13	0.47	0.20	0.26	0.14	0.14	0.22	0.47	0.19	0.27	0.24	0.54	1.25	1.33	0.80	0.40	--	0.88
14	0.47	0.00	0.13	0.23	0.28	0.09	--	0.44	0.22	0.24	0.71	0.67	1.16	0.99	0.43	0.81	0.70
15	2.73	0.17	0.19	0.43	0.16	0.16	0.19	0.40	--	0.11	0.52	0.68	0.84	1.17	0.53	0.81	0.67

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(a) Water Mixer.

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TABLE VII

Average Weight Loss Data From
F Reactor Raw Water Test Fuel Elements

Thirty-two natural uranium fuel elements per column.

Discharge Date: May 3, 1965

Fuel elements numbered from downstream end of fuel column.

Weight loss in grams.

<u>Piece No.</u>	<u>Control Side</u>	<u>Test Side</u>
1	0.62	0.63
2	1.06	0.62
3	0.83	0.62
4	0.69	0.57
5	0.71	0.71
6	0.76	0.45
7	(a)	(a)
8	0.78	0.47
9	0.86	0.41
10	0.73	0.36
11	1.12	0.25
12	0.92	0.32
13	0.86	0.26
14	0.78	0.23
15	0.75	0.50

(a) Water Mixer

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HALF PLANT RAW WATER TEST
183-F

Figure 1

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NOTES:

- A) END CAP TO BE FABRICATED FROM $\frac{3}{4}$ PLY.
- B) INSERT TO BE CUT FROM 2" THK. WOOD.
- C) DIAMETER TO GIVE TIGHT FIT IN PIPE.
- D) NOTCH-OUT FOR "C"-CLAMP.

HALF PLANT RAW WATER TEST
183-F

Figure 2

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HALF PLANT RAW WATER TEST
183-F

Figure 3

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RAW WATER BY PASS
183-F

Figure 4

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