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FINAL REPORT

PRODUCTION TEST IP-728

HALF-PLANT SODIUM SILICATE TEST

7

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FINAL REPORTPRODUCTION TEST IP-728HALF-PLANT SODIUM SILICATE TEST

by

R. G. Geier

July 28, 1966

DOUGLAS UNITED NUCLEAR, INC.

RICHLAND, WASHINGTON

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FINAL REPORT
PRODUCTION TEST IP-728
HALF-PLANT SODIUM SILICATE TEST

INTRODUCTION

The radionuclides in reactor effluent are produced almost entirely from the irradiation of parent elements which are adsorbed on the film which forms on the in-reactor surfaces. After irradiation the radionuclides are desorbed into the coolant and leave the reactor with the effluent water. One of the areas of study in the research and development program directed toward reducing the amount of radioactivity released to the Columbia River has been to find some means of minimizing the adsorption of parent materials and/or the desorption of radionuclides. In the course of the investigations, it was shown in laboratory coupon tests that sodium silicate added to process water reduced the adsorption of arsenic by a factor of five.¹ A single tube in-reactor test using a sodium silicate addition equivalent to 20 ppm SiO₂ was carried out to determine the effect of flux and other reactor variables on the behavior of the silicate. The results from the test showed that the concentration of Plutonium-32, Arsenic-76, and Neptunium-239 in the effluent were reduced by a factor of two to three. Lesser reductions were obtained for other isotopes and the Na-24 concentration increased by a factor of about two.²

The cost of feeding silicate at 20 ppm SiO₂ to the coolant for the five production reactors operated by Douglas United Nuclear, Inc., is estimated to be \$2,000,000 per year (sodium silicate cost of \$0.01 per pound of 28 percent SiO₂ material). Such a cost is believed to be prohibitively high unless very significant reductions are obtained for a broad spectrum of radionuclides. However, it was considered desirable to confirm the effluent activity reductions on a large scale as well as to determine the effect of silicate on corrosion and filming. A half-reactor test was initiated at D Reactor to accomplish the above.³

This report summarizes the data obtained and the observations made during the test.

SUMMARY

A. Effluent Activity

The results of routine effluent monitoring analyses indicated that reductions in radioactivity releases by factors of 2, 6, 4.5, and 5.5 would be obtained for P-32, As-76, Np-239, and Cr-51, respectively.

The concentration of Na-24 in the effluent increased by 50 percent, and there was no change in the concentration of Zn-65.

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B. Filming

Filming occurred in the fringe tubes during the cold inlet water periods of the test causing Panellit pressures to increase. Some relief was obtained during the warm inlet water periods, but by the end of the test Panellit pressures on the bottom fringe tubes had increased 50 psig. Although not a safety problem, the phenomenon adds to the complexity of reactor operation and the interpretation of data. No filming occurred in the central zone tubes under normal operating conditions.

C. Rear-Face Exposure

Throughout the test the radiation exposure from the rear face on the test side has been higher than on the control side by a factor of at least two. If sodium silicate were to be used at all five reactors, it has been estimated that the cost associated with 50 to 100 additional personnel would accrue.

D. Corrosion

Corrosion information obtained from fuel and coupons indicated that uniform corrosion was reduced but nonuniform corrosion was accelerated.

CONCLUSION

The sodium silicate addition to the coolant reduced the effluent concentrations of certain radionuclides. Nothing was observed during the course of the test to indicate that sodium silicate could not be used at all plants. However, the reductions obtained in effluent activity are not believed commensurate with the cost of silicate usage.

DISCUSSION

A. General

1. Water Treatment

The following water treatment parameters were established to be used during the test.

	Control Side (Near)	Test Side (Far)
Alum feed rate, ppm	18	18
Dichromate feed rate, ppm	1.0	1.0
pH	6.6	6.6
SiO ₂ , ppm	4-6*	20

* There are approximately 4-6 ppm SiO₂ present in normal coolant.

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2. Startup

The half-reactor test was initiated at D Reactor on January 15, 1965. The silicate concentration was increased gradually and test conditions of 20 ppm SiO_2 were established on January 25, 1965. The sodium silicate was added as a dilute solution to the lines entering the far side 190 tanks. Additional sulfuric acid was added to the far side 190 tanks to compensate for the basicity of the sodium silicate. During shutdowns the silicate additions were continued, but the concentration was reduced to between 5 and 10 ppm SiO_2 .

The sodium silicate used was "N" grade and contained a SiO_2 to Na_2O weight ratio of 3.20. The material was obtained from the Philadelphia Quartz Company.

3. Termination

The test was terminated on March 11, 1966. During the 13 months (327 operating days) of the test, silicate receipts indicated an average addition rate of 15.5 ppm SiO_2 .⁵ This was verified by spot analyses comparing the silica content of the near- and far-side coolant.

4. Reactor Operation

At the start of the test, the reactor contained a natural uranium core loading and a fringe thoria plus supporting 94 metal loading in accordance with PITA-31.⁵ during the test the following major charge-discharges took place.

<u>Outage Date</u>	<u>Event</u>
2/19/65	Block discharge of natural uranium. Core thoria plus 94 metal charged. ⁶
4/2/65	Discharged core thoria. Charged core thoria.
5/18/65	Discharged core thoria and 94 metal. Charged natural uranium.
7/16/65	Discharged fringe thoria. Charged fringe thoria.
8/5/65	Block discharge of natural uranium. Charged natural uranium.
11/14/65	Block discharge of natural uranium. Charged natural uranium.
1/15/66	Block discharge of natural uranium. Charged natural uranium. Discharged fringe thoria. Charged fringe thoria.
3/19/66	Block discharge of natural uranium. Charged natural uranium.

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B. Effluent Activity Results

Samples of reactor effluent were taken each week day during reactor operation from each side of the reactor. Normally the samples are combined and one analysis is made. However, throughout the course of the test separate analyses were made for P-32 and As-76. Beginning in August separate analyses were also obtained from Np-239 and Cr-51. From late December to the termination of the test, separate analyses were obtained on weekly composites for Zn-65.

The effluent radioactivity data were correlated on the basis of operating periods. Each central zone thorium irradiation and one-half of each subsequent natural uranium irradiation were considered to be operating periods. Each operating period contained from 24 to 40 days. Therefore, the effluent data for the period are the averages of from 11 to 24 individual analyses. The data for P-32, As-76, Np-239, and Cr-51 are shown in Table I.

It is apparent that in the case of P-32 a lengthy equilibration period (four to five months) is required before much reduction in the concentration occurs. In the case of As-76, a more rapid and greater response to the silicate can be noted. The average factors of reduction in concentration (ratio conc. control/conc. test) for the last seven months of the test were 2, 6, 4.5, and 5.5 for P-32, As-76, Np-239, and Cr-51, respectively.

The weekly Zn-65 results are shown in Table II. No reduction attributable to the sodium silicate can be observed. Spot samples indicated similar behavior for Mn-56 and Cu-64. The addition of sodium ion increased the concentration of Na-24 by about 50 percent.

Graphical comparisons of the control side concentration and the test side concentration as a function of operating days are shown in Figures 1-4, inclusive, for P-32, As-76, Np-239, and Cr-51, respectively. In the case of P-32, the control side exhibited what might be considered a normal seasonal pattern. That is, a minimum concentration occurs during the July-September period. Initially the silicate addition actually increased the test side P-32 concentration at the start. After about a month, the concentrations from the two sides had become about equal. From that point on the test side concentration curve closely paralleled the control side concentration curve. After four months, the ratio of control side concentration to test side concentration had reached a value of two and remained at about that value for the remainder of the test.

A different situation can be seen in Figures 2, 3, and 4 for As-76, Np-239, and Cr-51. In each case the control side concentration curve followed a pattern dictated by river conditions and water treatment efficiency. After a short equilibrium period, the concentration of As-76 in the test side effluent reached 25 pCi/ml and remained at about that value for the duration of the test. Similarly the Np-239 and Cr-51 in the test side effluent remained at 25 and 90 pCi/ml, respectively. It may be that the difference between the behavior of the P-32 and the As-76, Np-239 and Cr-51 is due to the fact that the P-32 is formed by both the following reactions:

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P³¹ ~~IX~~ P³²

S³² ~~N₂P~~ P³²

and thus has two parent isotopes. The As-76, Np-239, and Cr-51 have only one parent isotope. It is possible that perhaps the P-31 is being strongly affected by the silicate while the S-32 is not. The essentially constant test side concentrations of As-76, Np-239, and Cr-51 also suggest that possibly the concentration of parent isotope in the influent does not affect the concentration of radioisotope in the effluent. A subsequent test⁷ was carried out to determine the effect of increased parent material in the influent, and the results will be the subject of a later report.

The effect of operating time on the effluent activity reduction produced by sodium silicate (expressed as the ratio of control side concentration to test side concentration) is shown in Figure 5 for P-32 and As-76. It is of interest to note that with only one exception the results from the second operating period of a metal cycle have improved over the first operating period results. It is believed that this is due to the effect of the fresh fuel and the time required for a silicate film to be formed.

During the course of the test it was observed that the film on the spacers and Van Stone inserts from the silicate treated side was different from the film on similar pieces from the control side. There were differences in color, texture, adherence, and amount. It was also noted that the film from the test side had a negative zeta potential as compared to the zero zeta potential of film from the control side. This may be at least a partial explanation of the fact that the isotopes which are being effected are those which exist in the anionic state.

Additional film information as well as effluent radioactivity data can be found in a document⁸ in publication at the present time.

Data obtained by the Environmental Studies and Evaluation Section, BNW, showed that persons eating one meal a week of whitefish caught between Ringold and Richland would have received 30 percent of maximum permissible rate of intake for bone in 1964⁹ primarily from P-32. Also, an individual drinking Richland sanitary water would be expected to receive 50 mrem per year exposure to the gastro-intestinal tract which is equivalent to about 10 percent of the ICRP limit for populations at large. If silicate were used at all five reactors, the P-32 would be reduced by a factor of two. Thus, if other things, in particular those influencing the dietary habits of the fish, were equal, the dose to bone from eating whitefish would also decrease by a factor of two. It can be calculated that the gastro-intestinal tract exposure would be reduced from 10 to 6 percent of the limit by using silicate. Because of the already low level of potential exposure to people, the additional reductions attributable to the silicate treatment do not appear commensurate with the cost.

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C. Reactor Filming

The fringe tubes of the reactor were loaded with thoria target elements throughout the test. Comparative Panellit gauge readings between the control and the test side of the reactor showed that a filming condition began at the initiation of the test and continued for the test duration.¹⁰ The filming was most severe on the bottom row of tubes on the test side. The increase in Panellit pressure for those tubes is shown in Figure 6 as a function of operating days and is compared with the change in Panellit pressure for the bottom row of control side tubes. It is apparent that the test side Panellit pressure rose rapidly during the first 50 days of operation, peaked and then began to decrease slowly. After 200 days of operation (October, 1965), the Panellit pressure began to increase sharply again. In February, 1966, it peaked and began to decrease. The control side bottom tubes exhibited a normal pattern, staying within ± 5 psig of zero. The side fringe tubes on the test side showed a pattern similar to the bottom except about 10 psig lower, and the top fringe tubes also had a similar pattern about 5 psig lower than the side fringe tubes. Heat producing central zone tubes showed no filming. When thoria tubes were present in the central zone, they also exhibited some filming but it was less than half as severe as in the bottom tubes. It is of interest to note that the Panellit pressure did not respond for more than a few days to the discharge of the thoria targets.

It would appear from the shape and timing of Figure 6 that the degree of filming may be related to inlet water temperature. Perhaps solution viscosity or the precipitation of a different species of SiO_2 polymer may be involved.

Panellit pressures are a fundamental part of the reactor safety system as well as providing indications of ruptures of fuel and target element swelling. The rate of film formation observed in the test is not great enough to abrogate the early detection of an abnormal tube. However, complications such as those introduced by the film formation make rapid and accurate interpretations of operating data more difficult.

D. Rear Face Radiation Levels

Throughout the test radiation levels on the test side rear face of the reactor have been higher than on the control side. In order to permit some estimates on the increased exposure to personnel resulting from the use of silicate, a series of radiation readings was taken during the reactor outage of May 20, 1966. The readings were taken on tube rows 29 and 16 at tube numbers 63 and 83. Ratios of the dose rates as a function of time after shutdown were:

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<u>Time After Shutdown</u>	<u>Ratio of Dose Rates Test/Control</u>
3 hours	4.8
8 hours	4.0
1 day	2.0
2 days	1.7
5 days	1.3

It is clear that outages of short duration give rise to the most serious problems. The values above have been imposed upon an assumed work schedule consistent with present exposures to process operators, radiation monitors, and millwrights plus pipefitters.¹¹ The results indicate that if sodium silicate at 20 ppm SiO_2 were used at all five reactors, an additional 35 to 75 process operators and an additional 15 to 25 radiation monitors would be required. Very few, if any, additional maintenance personnel would be needed. Thus, in addition to the out-of-pocket material cost for the silicate, the costs associated with an additional 50 to 100 people would be needed.

It was reported previously¹² that the increased rear face exposure on the test side appeared to be due to a significantly higher amount of lanthanum-140 plus other rare earth. Other than to determine that lanthanum is present in the sodium silicate in very low concentrations, no further work has been done on means of alleviating the exposure problem.

E. Corrosion

1. Fuel

During the course of the test, two groups of weighed and numbered fuel elements were charged to the central zones of reactor to provide weight loss and visual examination data. The first group of 20 columns was charged on February 18, 1965, and discharged on May 19, 1965. The columns consisted of 43 pieces of 94 metal without a water mixer. Only the first 34 pieces were numbered and weighed. The second group of 13 columns was charged on November 4, 1965, and discharged on January 15, 1966. The columns contained 32 bumpered pieces of natural uranium with water mixer in the seventh position. All of the pieces except the water mixer were numbered and weighed.

a. May 19, 1965, Discharge

(1) Operating Conditions

The operating conditions of the 20 columns discharged on May 19, 1965, are given in Table III. Although there is some variation within each group of ten columns the averages for each side are nearly identical as far as exposure, tube power, outlet temperature, and flow are concerned.

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(2) Weight Loss Measurements

Weight loss measurements were obtained on the downstream 25 fuel elements on the control side and from the downstream 34 elements on the test side. The weight loss from each individual element is shown in Table IV. The average control and test side value for each fuel position is shown in Table V and has been plotted in Figure 7.

The weight loss from the control side fuel pieces exhibit a normal pattern. That is, a small weight loss is seen on the farthest downstream fuel element followed by a rapid increase to a maximum at pieces 8 to 10 from the downstream end. The weight loss then decreases until pieces 15 to 20 from the downstream end are reached. At this point weight losses less than 1.0 gram are observed for the remainder of the pieces in the column. It should be pointed out that the maximum weight loss obtained, 2 to 3 grams per fuel element, is very low although representative of weight losses expected at a coolant pH of 6.6. If the weight loss represented the removal of aluminum uniformly distributed over the surface of the element, on the order of 1 mil would have been removed. This gives an indication of the almost inconsequential significance of uniform fuel element corrosion at present operating conditions.

The weight loss from the test side fuel elements shows quite a different pattern. The weight losses in the normally high corrosion region although increasing slowly are low, 1 gm or less, which is a factor of two lower than seen on the control side elements. Beginning at piece 14 from the downstream end, the rate of weight loss increase becomes greater and a maximum is reached at piece 18 to 20. The weight loss at the maximum point is 1.5 to 2.0 gm which is lower than the maximum reached on the control side. From the maximum a gradual decline begins and weight losses in the range of 0.6 to 0.8 gm are reached by piece 31.

In summary, the maximum weight loss from the test side is moved upstream about seven feet from where it occurs on the control side. The weight loss is greater on the control side pieces for the downstream 33 percent of the column, greater on the test side pieces for the middle third of the column and about the same on the upstream third of the column. This suggests that the test side corrosion is possibly more flux dependent than is usually the case.

(3) Visual Fuel Examination

(a) Definitions

Visual fuel element examination identifies the serious

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type of corrosion attack as well as recognizing the presence of secondary effects. While a fuel element may exhibit several types of corrosion (pitting, uniform, ledge, or groove), only primary and secondary were reported.

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 AlSi.

Also identified by the visual examination is the presence of hot spots and hot areas.

(b) Results

The number of fuel elements from each of the 20 columns exhibiting ledge and groove corrosion, the severity of the corrosion, and the number of heat-affected zones is shown in Table VI. A summary of the data is given in Table VII. It is apparent that the test side exhibits somewhat more primary ledge and primary groove corrosion. Although the frequency of occurrence of ledge corrosion is high, on both sides, the incidence of groove corrosion is modest and no corrosion judged to be 10 mils deep was found. Thus, throughout the fuel exposure the localized corrosion environment was mild.

b. January 15, 1966, Discharge

(1) Operating Conditions

The operating conditions for the 13 columns of fuel discharged on January 15, 1966, are given in Table VIII. As in the previous discharge, the averages for the tube operating parameters, exposure, tube power, outlet temperature, and tube flow are essentially the same on the two sides of the reactor.

(2) Weight Loss Measurements

Weight loss measurements were obtained on the downstream 20 fuel elements from both the test and control side columns. The

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weight loss from each individual fuel element is given in Table IX. The average control and test side value for each fuel element position is shown in Table X and plotted in Figure 8.

Again the control side pieces exhibit a normal pattern. Maximum weight loss occurs at piece 9 from the downstream end. By the time piece 17 from the downstream end is reached, the weight loss is low enough to indicate that only a small amount of corrosion has taken place. Again the maximum weight loss is less than 3 grams.

The test side weight losses are low in the region the control side losses are high. A peak of about 1 gram weight loss is reached at pieces 12 to 14 from the downstream end. From that point the weight losses decreased to a range of 0.6 to 0.7 at piece 20 from the downstream end.

Considering the differences between the May discharge and the January discharge, the consistency of the results is considered remarkable. Not only are the weight loss patterns nearly identical, the test side shows a lower maximum weight loss in both cases. It would appear that the silicate is acting as an inhibitor to the corrosion of aluminum in the downstream section of the fuel charge.

(3) Visual Examination

The number of fuel elements from each of the 13 columns exhibiting ledge and groove corrosion, the severity of corrosion, and the number of heat-affected zones is shown in Table XI. A summary of the results is shown in Table XII. On both the test and control sides the incidence of ledge corrosion is insignificant. However, while there is essentially no groove corrosion in the control side, the 33 percent incidence on the test side is high. As in the previous fuel discharge, the severity of the groove corrosion is low.

Of even more significance is the location of the groove corrosion on the two sides of the reactor. Table XIII shows the percentage of pieces exhibiting ledge or groove corrosion in the downstream portion of the fuel column and in the upstream portion of the column. In the May 19, 1965, discharge 91 percent of the control side pieces which exhibited ledge or groove corrosion were downstream in the column. In the test side 69 percent of the ledge and groove corrosion was in the upstream portion of the column. Similarly, in the January, 1966, discharge 94 percent of the test side ledge and groove corrosion was located upstream in the column. The control side ledge and groove corrosion locations were not correlated because of the very low incidence.

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Figure 7 shows the percentage of test and control side fuel elements from the May, 1965, discharge as a function of fuel element position. The figure simply amplifies the fact that the silicate has shifted the position of the ledge and groove corrosion.

Considering both the weight loss data and the localized corrosion information, it would appear that the silicate reduces uniform corrosion but enhances the tendency toward nonuniform corrosion. This is borne out by the coupon and corrosion probe data discussed below. Perhaps more important, however, to the eventual understanding of ledge and groove corrosion is the shift in location of the corrosion from the normally most severe zones to about the middle of the fuel column.

2. Coupons and Corrosometer Probes

Coupon samples were exposed in the downstream ends of two process tubes, one on the test side and one on the control side of the reactor. The corrosion penetrations found after a 30-day exposure are shown in the following table:

Penetration at 30 Days, Mils

<u>Alloy</u>	<u>Test Side</u>	<u>Control Side</u>
X-8001 Al	0.91	1.1
6063 Al	0.47	0.69
1100 Al	0.59	0.94
A-212 C/S	0.16	0.12

The differences in corrosion measured for aluminum alloys X-8001 and 6063 are not significant and may be due to small temperature differences between the two tubes. The 1100 aluminum appears to be protected by the silicate addition. Carbon steel corrosion was as great on the silicate treated sides as in normal process water. In addition, there was noticeable nonuniform (pitting) corrosion on some of the carbon steel samples.

Measurements from carbon steel corrosion probes (AISI 1010) in both sides of the 105-D inlet water system indicated corrosion rates of 0.3 to 0.6 mils per year on both sides of the reactor during a six-month period. Later measurements indicate that significant pitting was occurring on the test side probe.

Other measurements from probes exposed to reactor effluent water indicate that the corrosion of X-8001 aluminum and 1020 carbon steel was about the same on both sides of the reactor. These probes also indicated that pitting may be occurring on the test side.

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3. Process Tubes

The wall thickness of process tubes is monitored by in-reactor measurement with an eddy current wall thickness gauge. There are several ways of converting the measurements to corrosion rate, all of which have inherent weaknesses. This is due to the type of measurement obtained, the accuracy of the measurement, the low corrosion rates at a coolant pH of 6.6, and the fact that process tube corrosion changes from the top of the tube to the bottom during the life of the tube. During the recent test, the method of using double wall thickness gauge measurements indicated that the corrosion rate was reduced by a factor of two by the silicate.¹⁴ The method of using the difference between calculated wall thickness and actual wall thickness would indicate some reduction in corrosion rate on the test side. On the other hand, plotting the actual wall thickness against time in reactor shows no difference in corrosion rates.¹⁰ It can be inferred from the fuel corrosion data that some reduction in uniform corrosion rate is probably provided by the silicate. However, the magnitude of the reduction, based on all the data, is surely not large and in fact may be negated by an increase in nonuniform corrosion.

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FIGURE 1
THE EFFECT OF SODIUM SILICATE
ON THE CONCENTRATION OF
PHOSPHORUS-32 IN REACTOR EFFLUENT

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FIGURE 2

THE EFFECT OF SODIUM SILICATE
ON THE CONCENTRATION OF
ARSENIC-76 IN REACTOR EFFLUENT

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FIGURE 3

THE EFFECT OF SODIUM SILICATE
ON THE NEPTUNIUM-239 CONCENTRATION
IN REACTOR EFFLUENT

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FIGURE 4
THE EFFECT OF SODIUM SILICATE
ON THE CONCENTRATION OF CHROMIUM-51
IN REACTOR EFFLUENT

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FIGURE 5

THE EFFECT OF OPERATING TIME
ON THE EFFLUENT ACTIVITY REDUCTION
PRODUCED BY SODIUM SILICATE

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FIGURE 6

THE EFFECT OF SODIUM SILICATE
ON FRINGE TUBE FILMING

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FIGURE 7

WEIGHT LOSS DATA FROM
SODIUM SILICATE TEST FUEL ELEMENTS

Forty-three enriched uranium fuel elements per column.
Discharge date- May 19, 1965.

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FIGURE 8

AVERAGE WEIGHT LOSS DATA FROM
D REACTOR SODIUM SILICATE TEST FUEL ELEMENTS

Thirty-two natural uranium fuel elements per column.
Discharge date - January 15, 1966

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FIGURE 9

DISTRIBUTION OF LEDGE AND GROOVE CORROSION
DURING SODIUM SILICATE TEST

Forty-three enriched uranium fuel elements per column.
Discharge date - May 19, 1965

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TABLE I

ENTRATIONS OF P-32, As-76, Np-239, and Cr-51
EFFLUENT DURING HALF-PLANT SODIUM SILICATE TEST

As-76			Np-239			Cr-51		
Control	Test	Ratio	Control	Test	Ratio	Control	Test	Ratio
pCi/ml		$\frac{C}{T}$	pCi/ml		$\frac{C}{T}$	pCi/ml		$\frac{C}{T}$
53	37	1.4						
52	28	1.8						
110	32	3.5						
74	28	2.6						
90	25	3.6						
67	19	3.5	84	26	3.2	435	89	4.9
111	19	5.8	98	25	3.9	415	90	4.6
139	22	6.3	106	23	4.6	425	99	4.3
155	19	8.2	120	24	5.0	555	100	5.6
127	23	5.5	122	21	5.8	445	60	7.4
228	30	7.6	160	27	5.9	535	81	6.6

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TABLE IITHE CONCENTRATION OF Zn-65 IN D-REACTOR
EFFLUENT DURING HALF-PLANT SODIUM SILICATE TEST

<u>Week Beginning</u>	<u>Zn-65</u>	
	<u>Control</u>	<u>Test</u>
12/28/65	10.4	6.2
1/4/66	10.7	7.3
1/11/66	35.1	23.9
1/25/66	9.5	10.4
2/1/66	8.4	9.8
2/8/66	11.4	8.1
2/15/66	10.0	9.0
2/22/66	15.9	11.5
3/1/66	12.2	17.8
3/8/66	12.6	13.8
Average	13.6	11.8

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TABLE IIIIRRADIATION CONDITIONS OF D REACTOR
SODIUM SILICATE TEST FUEL ELEMENTS

Charge Date: February 18, 1965

Discharge Date: May 19, 1965

Fuel Charge: 43 OIIIE Elements

Inlet Water Temperature: 8 C

<u>Tube No.</u>	<u>Exposure MWD/T</u>	<u>Tube Power, kw</u>	<u>Outlet Temp., °C</u>	<u>Flow, gpm</u>
3061	788	1283	110	47.8
3062	815	1327	114	47.3
3063	846	1377	113	49.5
3064	843	1372	113	49.4
3065	840	1366	116	48.0
3066	853	1403	120	47.4
3067	854	1384	116	48.7
3068	837	1357	115	48.0
3069	826	1341	111	49.7
3070	799	1300	110	48.3
Average	830	1350	114	48.4
3076	817	1322	112	48.4
3077	823	1335	112	48.7
3078	827	1345	114	47.8
3079	826	1350	113	48.9
3080	830	1351	118	46.8
3081	845	1372	115	48.5
3082	815	1323	114	47.4
3083	815	1322	111	48.4
3084	815	1321	111	49.1
3085	818	1325	109	49.6
Average	823	1337	113	48.4

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TABLE IV
WEIGHT LOSS DATA FROM
D REACTOR SODIUM SILICATE TEST
FUEL ELEMENTS

Forty-three piece, enriched uranium fuel elements per column.
Discharge date - May 19, 1965.

Pieces numbered from downstream end of tube.
Weight loss in grams.

Tube No.		3061	3062	3063	3064	3065	3066	3067	3068	3069	3070
Piece No.	1	0.32	0.60	0.84	0.83	---	1.69	1.28	0.92	0.98	0.96
	2	0.35	1.28	0.29	1.83	1.28	1.65	2.09	1.44	0.92	1.08
	3	0.48	1.26	1.80	2.16	1.88	1.85	2.61	2.65	1.16	1.61
	4	0.38	0.95	2.56	---	1.95	3.37	2.18	3.20	0.32	1.45
	5	0.81	1.54	3.11	---	---	2.78	2.40	3.41	1.39	1.59
	6	0.87	1.37	3.52	2.24	2.87	---	4.77	3.44	1.86	1.84
	7	0.74	1.57	---	1.37	2.93	3.26	3.57	3.39	2.12	2.28
	8	1.32	1.32	2.12	---	2.98	3.98	3.26	3.39	2.15	2.62
	9	1.33	1.62	1.48	3.07	3.19	3.51	2.99	3.35	2.16	1.80
	10	1.24	1.28	2.22	1.78	2.38	3.55	3.77	3.03	1.81	1.71
	11	1.02	1.76	1.55	0.45	3.19	2.77	2.71	2.63	1.60	1.67
	12	1.23	2.49	1.93	1.78	1.66	---	2.93	2.74	0.97	1.40
	13	1.16	2.00	1.30	2.14	1.82	2.64	2.11	3.13	2.09	1.95
	14	1.66	1.92	1.67	2.11	1.86	3.45	2.12	2.49	1.14	1.10
	15	0.38	2.12	1.89	1.66	2.53	2.42	1.91	1.68	2.10	1.01
	16	2.13	---	---	2.28	---	2.64	2.04	2.16	1.29	1.59
	17	1.33	1.46	1.67	1.96	1.73	2.18	---	1.69	1.09	1.25
	18	1.17	1.50	1.39	1.52	---	---	0.56	1.31	---	1.01
	19	---	1.14	1.35	1.12	---	---	0.97	1.03	0.59	0.81
	20	0.92	1.10	0.86	---	---	1.05	0.76	---	0.24	0.61
	21	0.82	0.98	0.94	0.89	0.97	---	0.51	0.53	0.45	0.42
	22	0.52	0.81	0.52	0.68	0.65	---	---	0.51	0.47	0.50
	23	0.46	0.50	0.45	---	---	0.73	---	---	0.25	---
	24	0.44	0.53	0.45	---	---	0.53	---	0.43	0.42	0.56
	25	0.54	0.61	0.55	0.55	0.43	0.54	0.59	---	0.37	0.46

--- No data

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TABLE IV (Cont.)

WEIGHT LOSS DATA FROM
D REACTOR SODIUM SILICATE TEST
FUEL ELEMENTS

Forty-three piece enriched uranium fuel elements per column.
 Discharge date - May 19, 1965.

Pieces numbered from downstream end of tube.
 Weight loss in grams.

Tube No.		3076	3077	3078	3079	3080	3081	3082	3083	3084	3085
Piece No.	1	0.42	---	0.71	0.72	0.65	0.82	0.87	0.65	0.59	0.69
	2	0.68	0.71	0.59	0.50	0.28	0.62	0.81	0.94	0.82	0.60
	3	0.73	0.99	0.86	---	0.81	---	0.44	0.65	0.45	0.56
	4	0.33	0.86	0.83	0.74	1.03	1.38	0.77	0.68	0.06	0.71
	5	0.89	1.05	0.87	0.78	0.56	0.63	1.02	0.79	0.70	0.78
	6	0.72	0.58	0.85	1.37	0.92	0.77	0.77	0.85	0.69	0.84
	7	1.03	0.79	0.79	0.78	---	0.52	0.73	0.67	0.69	0.70
	8	0.97	0.33	0.77	0.96	0.82	0.57	0.77	1.05	1.11	0.73
	9	---	0.99	0.96	0.70	0.91	1.07	0.77	1.00	1.15	1.13
	10	0.96	1.11	0.78	2.35	0.97	0.71	0.76	0.84	0.78	0.78
	11	1.01	0.93	1.07	0.81	0.87	1.07	0.78	1.21	1.00	1.14
	12	1.12	1.13	1.07	1.05	0.98	0.86	1.08	0.94	0.84	0.90
	13	0.98	1.07	0.84	0.97	1.58	0.97	0.87	0.81	1.10	1.05
	14	0.95	1.07	1.44	1.04	1.10	0.87	0.80	0.96	1.35	0.96
	15	0.95	1.14	1.13	1.02	1.23	1.56	0.94	1.15	1.14	1.38
	16	1.67	1.11	1.28	1.11	0.96	1.24	1.14	1.56	1.14	1.73
	17	1.20	0.94	1.51	1.14	1.25	1.38	1.24	1.76	1.53	1.77
	18	1.04	1.90	2.22	1.23	1.44	2.23	1.15	2.52	2.07	2.76
	19	1.10	1.20	2.32	0.85	2.39	2.00	2.02	2.57	1.85	2.85
	20	1.31	1.17	1.36	2.02	1.83	2.19	1.31	2.12	1.72	2.31
	21	0.94	0.93	1.08	1.04	1.17	1.41	1.02	1.25	1.38	1.70
	22	0.73	0.90	1.32	1.59	1.23	1.36	1.45	1.13	1.35	1.67
	23	0.67	1.26	1.28	1.31	1.09	1.74	1.53	1.62	1.14	1.53
	24	1.97	1.32	1.49	1.33	1.39	1.61	1.85	1.46	1.33	1.48
	25	1.12	1.09	1.38	1.88	1.59	1.42	1.78	1.36	1.55	1.34
	26	1.40	1.20	1.16	1.52	0.94	1.71	1.42	1.39	1.12	1.27
	27	1.57	1.27	1.56	1.55	1.29	1.49	1.42	1.12	0.96	1.05

--- No data

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TABLE IV (Cont.)

Tube No.	3076	3077	3078	3079	3080	3081	3082	3083	3084	3085
Piece No. 28	1.01	1.01	1.07	0.96	1.48	1.17	0.96	1.00	1.04	1.05
29	1.50	0.18	0.99	1.27	1.20	1.50	1.17	1.01	1.00	0.83
30	0.99	0.82	1.02	1.17	0.72	1.14	0.70	0.72	0.70	0.91
31	0.64	0.64	0.96	0.84	1.20	---	0.89	0.64	0.69	0.61
32	0.55	0.47	0.78	1.83	0.93	0.61	0.73	0.69	0.65	0.45
33	0.32	0.64	0.58	0.84	1.06	0.78	---	0.50	0.66	0.66
34	0.78	0.72	0.43	0.43	0.78	0.50	0.57	0.58	0.54	0.49

--- No data

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TABLE VAVERAGE WEIGHT LOSS DATA FROM D REACTOR
SODIUM SILICATE TEST FUEL ELEMENTS

Forty-three enriched uranium fuel elements per column.

Discharge date - May 19, 1965

Fuel elements numbered from downstream end of tube.

Weight loss in grams.

<u>Piece No.</u>	<u>Control Side (Near)</u>	<u>Test Side (Far)</u>
1	0.94	0.68
2	1.22	0.66
3	1.75	0.69
4	1.82	0.74
5	2.14	0.81
6	2.54	0.84
7	2.35	0.74
8	2.57	0.81
9	2.45	0.96
10	2.28	1.00
11	1.95	0.99
12	1.95	1.00
13	2.03	1.02
14	1.95	1.05
15	1.77	1.16
16	2.02	1.29
17	1.60	1.37
18	1.21	1.86
19	1.00	1.92
20	0.79	1.73
21	0.73	1.19
22	0.58	1.27
23	0.48	1.32
24	0.48	1.52
25	0.51	1.45
26		1.31
27		1.33
28		1.08
29		1.07
30		0.89
31		0.79
32		0.79
33		0.65
34		0.58

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TABLE VI

VISUAL FUEL ELEMENT EXAMINATION DATA
FROM D REACTOR SODIUM SILICATE TEST

Forty-three enriched uranium fuel elements per column.
 Discharge date - May 19, 1965.

Data obtained from thirty-four downstream pieces only.

Tube No.	3061	3062	3063	3064	3065	3066	3067	3068	3069	3070
No. of Pieces	34	34	32	28	24	30	33	34	33	33
Primary Ledge	9	9	9	11	9	12	11	12	9	9
Secondary Ledge	0	5	3	4	2	3	3	4	1	2
Primary Groove	0	4	3	2	1	3	3	4	0	0
Secondary Groove	1	3	2	3	1	4	4	7	0	0
Severity 2*	0	0	0	0	0	0	0	0	0	0
Severity 3**	0	0	0	0	0	0	0	0	0	0
Hot Areas	5	6	5	9	5	11	8	11	0	0

Tube No.	3076	3077	3078	3079	3080	3081	3082	3083	3084	3085
No. of Pieces	32	34	34	34	34	33	34	34	34	34
Primary Ledge	14	16	16	8	19	16	15	15	19	17
Secondary Ledge	4	4	5	6	4	4	2	2	3	2
Primary Groove	4	5	6	6	5	2	2	1	1	1
Secondary Groove	0	1	0	2	5	3	0	0	2	2
Severity 2*	0	0	0	0	0	0	0	0	0	0
Severity 3**	0	0	0	0	0	0	0	0	0	0
Hot Areas	0	0	2	0	0	0	2	0	0	1

* Corrosion 10 mils deep.

** Corrosion to the AlSi layer.

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TABLE VIISUMMARY OF VISUAL FUEL ELEMENT EXAMINATION DATA
FROM D REACTOR SODIUM SILICATE TEST

Forty-three enriched uranium fuel elements per column.
Discharge date - May 19, 1965.

Data obtained from thirty-four downstream elements only. The nine upstream elements were assumed to be free of ledge, groove, or severe corrosion.

Percent of Pieces

	<u>Control</u> <u>Side</u> <u>(Near)</u>	<u>Test</u> <u>Side</u> <u>(Far)</u>	<u>Over-all</u>
Primary Ledge	24.7	36.3	30.6
Secondary Ledge	6.7	8.4	7.6
Primary Groove	4.9	7.7	6.4
Secondary Groove	6.2	3.5	4.8
Severity 2*	0.0	0.0	0.0
Severity 3**	0.0	0.0	0.0

* Corrosion 10 mils deep.

** Corrosion to the AlSi layer.

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TABLE VIIIIRRADIATION CONDITIONS OF D REACTOR
SODIUM SILICATE TEST FUEL ELEMENTS

Charge Date: November 4, 1965
Discharge Date: January 15, 1966
Fuel Charge: 31 OIIN elements plus
1 water mixer in the seventh position.
Inlet Water Temperature: 10 C

<u>Tube No.</u>	<u>Exposure, MWD/T</u>	<u>Tube Power kw</u>	<u>Outlet Temp., °C</u>	<u>Flow, gpm</u>
1663	548	1318	108	50.8
1664	555	1336	112	49.8
1665	548	1317	112	49.0
1666	557	1334	111	49.9
1667	546	1306	109	49.8
1668	545	1301	107	50.7
1669	547	1303	109	50.2
Average	549	1316	110	50.0
1675	560	1340	109	51.2
1676	556	1335	110	50.7
1677	562	1350	112	50.2
1678	560	1347	108	51.9
1679	561	1352	112	50.4
1680	560	1345	109	51.5
Average	559	1344	110	50.9

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TABLE IX

WEIGHT LOSS DATA FROM
D REACTOR SODIUM SILICATE TEST
FUEL ELEMENTS

Thirty two natural uranium fuel elements per column.
Discharge date - January 15, 1966.

Pieces numbered from downstream end of tube.
Weight loss in grams.

Tube No.		1675	1676	1677	1678	1679	1680
Piece No.	1	0.23	0.94	0.49	0.22	0.23	0.46
	2	0.67	0.64	0.28	0.91	0.15	---
	3	0.62	0.46	0.80	0.51	---	0.25
	4	0.47	0.89	0.23	0.92	0.54	0.19
	5	0.50	0.41	0.80	0.97	0.42	0.23
	6	0.43	0.90	0.40	0.58	0.69	0.44
	7	(a)	(a)	(a)	(a)	(a)	(a)
	8	0.40	1.09	0.32	0.52	0.64	---
	9	0.83	0.66	1.08	1.18	0.74	0.25
	10	0.96	0.91	0.39	1.14	0.74	0.96
	11	0.32	0.98	0.67	1.13	0.85	---
	12	0.61	1.14	0.99	0.74	0.59	---
	13	0.94	---	0.79	1.03	1.06	0.83
	14	0.95	0.68	0.96	0.83	0.94	0.84
	15	0.92	0.74	0.87	0.66	0.98	0.76
	16	0.66	0.78	0.87	0.57	0.77	0.79
	17	0.68	0.68	0.83	0.67	---	---
	18	0.74	1.17	0.73	0.63	0.82	---
	19	0.74	0.40	0.61	0.74	---	0.50
	20	0.66	0.48	0.65	0.60	0.66	---

(a) Water mixer

--- No data

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TABLE IX (Cont.)

WEIGHT LOSS DATA FROM
D REACTOR SODIUM SILICATE TEST
FUEL ELEMENTS

Thirty two natural uranium fuel elements per column.
 Discharge date - January 15, 1966.

Pieces numbered from downstream end of tube.
 Weight loss in grams.

Tube No.		1663	1664	1665	1666	1667	1668	1669
Piece No.	1	0.80	1.18	1.41	1.06	1.26	0.93	0.86
	2	0.78	1.17	1.67	1.06	1.68	1.30	1.04
	3	1.26	---	---	1.79	1.56	1.72	1.45
	4	1.45	2.38	---	2.00	1.60	1.88	1.31
	5	1.71	2.06	2.67	1.95	0.97	1.47	1.90
	6	1.50	2.92	2.43	1.37	2.08	1.96	2.25
	7	(a)	(a)	(a)	(a)	(a)	(a)	(a)
	8	2.26	4.38	2.40	1.96	2.03	2.07	1.20
	9	2.75	3.78	3.71	3.77	2.97	2.11	0.91
	10	2.68	2.88	2.15	3.02	2.17	1.24	0.81
	11	2.59	3.28	3.38	2.12	1.84	1.79	1.19
	12	1.72	2.65	3.30	1.98	1.83	1.95	0.78
	13	1.89	2.08	2.38	2.00	1.46	1.59	0.48
	14	1.50	1.52	1.76	0.68	1.09	0.83	0.12
	15	0.93	1.18	1.53	---	0.68	0.70	1.65
	16	1.04	1.05	1.07	0.49	0.40	0.61	2.10
	17	0.69	0.69	0.15	0.55	0.46	0.61	0.54
	18	0.55	0.43	0.44	0.62	0.24	0.18	0.44
	19	0.23	0.62	0.12	---	0.34	0.39	---
	20	---	0.79	0.46	---	0.38	0.46	0.59

(a) Water mixer

--- No data

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TABLE XAVERAGE WEIGHT LOSS DATA FROM D REACTOR
SODIUM SILICATE TEST FUEL ELEMENTS

Thirty-two natural uranium fuel elements per column.
Discharge date - January 15, 1966

Fuel elements numbered from downstream end of fuel column.
Weight loss in grams.

<u>Piece Number</u>	<u>Control Side (Near)</u>	<u>Test Side (Far)</u>
1	1.07	0.43
2	1.24	0.53
3	1.56	0.53
4	1.77	0.54
5	1.81	0.55
6	2.07	0.59
7	(a)	(a)
8	2.33	0.60
9	2.87	0.79
10	2.13	0.85
11	2.31	0.79
12	2.03	0.81
13	1.70	0.93
14	1.07	0.86
15	1.11	0.82
16	0.97	0.74
17	0.53	0.72
18	0.41	0.82
19	0.34	0.60
20	0.54	0.71

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TABLE XI

VISUAL FUEL ELEMENT EXAMINATION DATA
FROM D REACTOR SODIUM SILICATE TEST

Thirty-two natural uranium fuel elements per column.
Discharge date - January 15, 1966.

Tube No.	1663	1664	1665	1666	1667	1668	1669
No. of Pieces	30	28	25	24	30	24	29
Primary Ledge	0	0	0	0	0	0	0
Secondary Ledge	0	1	0	0	0	0	0
Primary Groove	1	2	0	1	0	1	1
Secondary Groove	0	0	0	0	0	0	0
Severity 2*	0	0	0	0	0	0	0
Severity 3**	0	0	0	0	0	0	0
Hot Areas	5	9	10	6	6	0	4

Tube No.	1675	1676	1677	1678	1679	1680
No. of Pieces	31	29	29	29	22	17
Primary Ledge	1	0	0	0	0	0
Secondary Ledge	0	1	1	0	1	0
Primary Groove	8	10	11	8	8	7
Secondary Groove	0	0	0	0	0	0
Severity 2*	0	1	0	0	0	0
Severity 3**	0	0	0	0	0	0
Hot Areas	0	0	0	0	0	0

* Corrosion 10 mils deep.

** Corrosion to the AlSi layer.

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TABLE XIISUMMARY OF VISUAL FUEL ELEMENT EXAMINATION DATA
FROM D REACTOR SODIUM SILICATE TEST

Thirty-two natural uranium fuel elements per column.
Discharge Date - January 15, 1966.

	<u>Percent of Pieces</u>		
	<u>Control</u> <u>Side</u> <u>(Near)</u>	<u>Test</u> <u>Side</u> <u>(Far)</u>	<u>Over-all</u>
Primary Ledge	0.0	0.6	0.3
Secondary Ledge	0.5	1.9	1.2
Primary Groove	3.1	33.0	16.7
Secondary Ledge	0.0	0.0	0.0
Severity 2*	0.0	0.6	0.3
Severity 3**	0.0	0.0	0.0
Hot Areas	21.0	0.0	11.5

* Corrosion 10 mils deep.

** Corrosion to the AlSi layer.

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TABLE XIIIDISTRIBUTION OF LEDGE AND GROOVE CORROSION
ON D REACTOR SODIUM SILICATE TEST FUEL ELEMENTS

	<u>Percent of Pieces Exhibiting Ledge and Groove Corrosion</u>	
	<u>Control Side (Near)</u>	<u>Test Side (Far)</u>
May 19, 1965, Discharge		
Pieces 1-15*	90.8	31.4
Pieces 16-34	9.2	68.6
January 15, 1966, Discharge		
Pieces 1-12	---	5.8
Pieces 13-32	---	94.2

* Fuel elements numbered from the downstream end.

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