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FINAL REPORT - PT IP-754
PHYSICS TESTING OF H REACTOR

A. D. Vaughn
G. C. Masche

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FINAL REPORT - PT IP-754 - PHYSICS TESTING OF REACTOR and Changed To

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By:

A. D. Vaughn
G. C. Masche

By Authority of DS Lewis
CG-NMP-1, 5-2-94
By DK Hanson, 5-19-94
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FINAL REPORT - PT IP-754 - PHYSICS TESTING OF H REACTORINTRODUCTION

Significant changes in fuel design, operating levels, loading geometry, and moderator condition have taken place since the Hanford reactors started operation. Changes which affect nuclear safety parameters require continuing analysis of the possible effects on safety system strengths and maximum potential reactivities. For this reason the shutdown of a Hanford reactor offered an excellent opportunity to measure many of the above factors without a significant production loss.

Therefore a test program¹ was proposed and carried out at H Reactor starting April 22, 1965 and ending May 5, 1965. All of the tests were designed to provide information concerning parameters which affect nuclear safety and control calculation limits.

This document is a summary of the deactivation test results without application and recommendations to specific nuclear safety questions. Rather, it is intended that the results listed herein will serve as a basis for further study and application to nuclear safety technology.

SUMMARY

Because of the numerous tests performed and the voluminous data received it would be difficult to adequately summarize the results of the complete test program. In general, the test was successful and provided very meaningful data. Specifically, every nuclear safety control parameter which was measured proved that a factor of conservatism existed between the measured value of the parameter and the previously estimated value of the parameter.

DISCUSSION

The purpose of the deactivation testing program was to perform measurements which would provide an up-to-date basis for normalizing calculational methods and results, thus allowing a determination of the degree of conservatism in certain safety practices and associated improvements in production efficiency. Therefore the following testing program was devised which would be within the intent of the Reactor Operating Limits, and as such, would pose no "unreviewed" nuclear safety problems.

1. Description of Tests

The complete test program consisted of 11 individual parts, not all of which were to provide test data. Some of the early programs were necessary to provide adequate instrumentation and calibration of the nuclear safety system and power level limit devices, but in general the tests were designed to measure the reactivity effects of controls, various fuel types, and various control and fuel geometries.

Specifically the test programs and associated data analysis are listed below in Table I. The status of the reactor before and during the tests is shown in Figure 1.

¹RL-REA-606, Production Test IP-754, Physics Testing at H Reactor Deactivation
GC Masche, AD Vaughn, February 1, 1965

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Figure 1
Loading and Measurement Configurations

Note: Spike enrichment location shown on page 40.

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Table I

Outline of Tests Performed

<u>Test No.</u>	<u>Description</u>	<u>Est. Time Requirement</u>	<u>Actual Time Requirement</u>
Test A	Installation and modification of instruments	30 Hrs.	30 Hrs.
Test B	Calibration and operability check of nuclear power level trip protection	2 Hrs.	4 Hrs.
Test C	Vertical safety rod calibration	44 Hrs.	42 Hrs.
Test D	Comparison test of spline and vertical safety rod local control effects	4 Hrs.	4.75 Hrs.
Test E	Measurement of the number of full splines necessary to compensate one vertical safety rod	2 Hrs.	2 Hrs.
Test F	Measurement of the reactivity effect of the top and bottom enrichment pattern	16 Hrs.	4.25 Hrs.
Test G	Discharge to minimum critical slab	72 Hrs.	88.5 Hrs.
Test H	Measurement of cold long-term gains reactivity effect in 5x5 lattice supercell	24 Hrs.	26.5 Hrs.
Test I	Supercell test of various fuel and target ratios	144 Hrs.	138 Hrs.
Test J	Measurement of reactivity effect of fringe poison discharge	16 Hrs.	8 Hrs.
Test K	Flux traverses (time included in above tests)	—	—
	Total Time	354 Hrs.	348 Hrs.

The raw data for the above tests have been compiled into two reference documents:

RL-REA-2311, Vol. I and Volume II, "Raw Data - H Reactor Deactivation," G. C. Masche, A. D. Vaughn, 7-14-65

The ending test period and final criticality of H Reactor were completed at 1330 on May 5, 1965 when the vertical rods were inserted for the last time.

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2. Instrumentation

R. R. Cone and M. L. Peterson of Instrument Development Unit set up and maintained the additional instruments necessary for the test. This required installation of two special types of equipment, additional safety instruments, and specific test apparatus for data compilation. The location of the special instrumentation is depicted in Figure 1 and also described below:

- a. Beckman chambers were installed into three far-side test holes and their cables were coupled to the neutron flux monitor (Beckman) amplifiers in the #1 safety circuit.
- b. Two subcritical monitor chambers were installed in VSR channel #17.
- c. VSR #20 was removed and set up for flux traverses during the test.
- d. An E-fold measuring device plus a typewriter and timer circuit were set up in the control room to measure periods and to generate count rate data.

The E-fold instrument was the primary instrument for obtaining test data. The subcritical monitor charts and period meters were also available and used throughout the test to control periods and to obtain quick data.

The Beckman chambers normally under the reactor, plus the side test hole chambers were used alternately throughout the test. As the pile was discharged away from the bottom chambers the side test hole chambers, which had been previously tested and calibrated, were connected to the amplifiers.

INDIVIDUAL TEST DISCUSSIONS

The reports and analysis of individual tests are presented in the following sections. The index for these reports is as follows:

	<u>Page No.</u>
A. VSR Calibration	7
B. Spline Tests	34
C. Discharge of Top E-ring	38
D. Discharge of Pile to Minimum Critical Size	41
E. Natural Uranium Supercell Test	53
F. Special Loading Ratios Supercell Test	55
G. Enriched Uranium Supercell Test	82
H. Fringe Poison Discharge Test	99

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A. TEST C - CALIBRATION OF VERTICAL SAFETY RODS

INTRODUCTION

This section describes the calibration of vertical safety rods during the deactivation test program¹ at H Reactor. The reactivity compensating effects of various safety rod patterns were measured between 1 and 24 mk using rising period data obtained with specific rods inserted during the xenon decay transient immediately following shutdown from equilibrium operation for a minimum outage. No specific applications nor analysis have been included except the analysis of the raw data; rather, it is intended that this document will serve as a reference basis for further development of control studies and/or nuclear safety parameters.

SUMMARY (Vertical Safety Rod Calibration)

The observed control strengths of the vertical safety rods at H Reactor were greater than anticipated. At present it is not definite whether the added effectiveness is due to the decrease in pile size from the fringe poison or overconservatism in calculational analysis.

The current restrictions in total control safety application to controls out of service are consistent with the results of measurements involving specific geometries during the VSR calibration.

DISCUSSION

Some control worths measurements were made during startup testing programs; however, this data is limited to a few controls in homogenized unirradiated fuel lattice. The H Reactor deactivation testing program offered an excellent opportunity to measure numerous control geometries in a reactor which contained irradiated fuel and an operating enrichment pattern.

1. Test Description

The vertical safety rod test was composed of calibrations for approximately 125 different patterns of the vertical safety rod system. The test patterns were intended to approximate all conceivable configurations, both balanced across the pile or severely unbalanced. Differences in individual rod worths were also measured. Due to the fact that each vertical control element is worth at least a mk of reactivity, minute reactivity and control adjustments, necessary to achieve measurable periods, were made by using two horizontal control rods. Horizontal control rods, No's. 5 and 11, were also calibrated during the test so that more exact vertical safety rod worths could be obtained from the data.

In practice, controls were inserted to various specified patterns, and a pile rising period was obtained at each pattern. Periodically, a rod configuration previously measured was repeated; this repetition provided

¹GC Masche, et al, op. cit.

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base points so that the pile reactivity as a function of time could be determined. Any given rod configuration was evaluated by subtracting the value of the rising period measured with the rods in that configuration from the pile reactivity derived by the summation of the reactivity increases at the tie points.

2. Instrumentation

A neutron-sensitive chamber was inserted into VSR channel #17 prior to the test and connected to an E-fold measuring device to provide an improved means of obtaining fundamental test data. The subcritical monitors were also used as a check against the E-fold instrumentation and to measure the rising period data. The auxiliary instrumentation was provided and installed under the direction of IPD Instrument Development Operation. The special test readout instruments were operated by the physics crews.

3. Test Procedure

The first four hours following minimum critical were used to calibrate, set, and test safety instrument trip points so that pile power could never exceed 1 MW. Some xenon tie points were obtained during this interval; however, actual VSR calibration began after the potential pile excess reactivity was approximately four mk. Approximately 125 different control configurations were calibrated through a range of 24 mk. The reactivity transient and strength of the rod configurations used during the test are shown in Figure 1-A.

4. Results and Data

a. Vertical Safety Rods

The test data and procedures are listed in Appendix A in the order of the test procedure. The delays involved in setting and calibrating instruments, plus the time necessary to change control configurations prevented the measuring of all the configurations previously scheduled.

Likewise, the maximum potential reactivity of the reactor with coolant limited the number of vertical safety rods which could be measured during a single test; however, the data was adequate for future theoretical extrapolation to the full system strength.

The specific control strengths derived from each measurement are listed with the procedures and raw data in Appendix A. For illustration purposes, additional figures are included herein which depict the various control patterns and the specific reactivity compensating effect respective to each.

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b. Horizontal Control Rods

As mentioned previously, the reactivity of individual vertical safety rods is greater than 1 mk; therefore minute adjustments in the control strengths being measured were made using horizontal control rods 5&11. Figure 2-A shows the measured worth of 5&11 rods with respect to the vertical safety rod configurations. In other words, the corrected reactivity compensating effect of the vertical safety rods was derived from the test data by subtracting the worth of the horizontal control rods respective to their position during the test measurement from the total configuration strength (i.e. VSR pattern plus horizontal rods).

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FIGURE 1-A
Vertical Safety Rod Calibration Data
H Reactor Deactivation Test

FIGURE 1-A
Vertical Safety Rod Calibration Data
H Reactor Deactivation Test

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Figure 2-A

Reactivity Compensating Effect
of 5&11 Rods
(Fully Loaded Reactor)

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Figure 3-A

Reactivity Compensating Effect
of Individual Vertical Safety Rods
H Reactor Deactivation Test

Vertical Safety System Plane
H Reactor

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Figure 4-A

Reactivity Compensating Effect of Specific
Rod Pairs - H Reactor Deactivation Test

Vertical Safety System Plane
(H Reactor)

Figure 5-A

Reactivity Compensating Effect of
Patterns Containing Three Rods

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Figure 6-A
Reactivity Compensating Effect
of Pattern C-23

Figure 7-A

Reactivity Compensating Effect
of Rod Pattern C-27

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Figure 8-A

Reactivity Compensating Effect of
Rod Pattern C-24 and Variations

* with 38 rod out (8.14 mk)
 ** with 55 rod inserted (11.57 mk)
 *** with 42 rod inserted (12.19 mk)

Figure 9-A
Reactivity Compensating Effect of
Rod Pattern C-46

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Figure 10-A

Reactivity Compensating Effect of
Rod Pattern C-54

Figure 11-A

Reactivity Compensating Effect
Rod Pattern C-28 with Variations

With 36 and 40 VSR's inserted and 37, 38, and 39 VSR's removed - 16.36 mk.
 With 36 and 40 VSR's inserted and 37, 39 VSR's removed - 16.87 mk.
 With 36 and 40 VSR's inserted and 38 VSR removed - 17.50 mk.

Figure 12-A

Reactivity Compensating Effect of
Rod Pattern C-28 with Variations

Figure 13-A

Reactivity Compensating Effect of
Rod Pattern C-51 with Variations

1. With VSR #50 out - 18.05 mk	4. With VSR #36 out - no data
2. With VSR #51 out - 18.68 mk	5. With VSR #38 out - 17.94 mk
3. With VSR #43 out - 18.87 mk	6. With VSR #40 out - 18.90 mk
7. With VSR #25 out - 18.02 mk	

Figure 14-A

Reactivity Compensating Effect
Rod Pattern C-61 with Variations

1. With VSR #42 out - 19.00 mk	3. With VSR #44 out - 19.20 mk
2. With VSR #43 out - 19.20 mk	4. With VSR #31 out - 17.52 mk
5. With VSR #33 out - 18.77 mk	

Figure 15-A

Reactivity Compensating Effect of
Rod Pattern C-69

Figure 16-A

Reactivity Compensating Effect of
Rod Pattern C-76

Figure 17-A

Reactivity Compensating Effect of
Rod Pattern C-74

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Figure 18-A
Reactivity Compensating Effect
Rod Pattern C-75

20.09 mk (total worth)

VSR inserted

Figure 19-A

Reactivity Compensating Effect of
Rod Pattern C-78

* With #18 VSR inserted - 21.71 mk

Appendix A

Vertical Safety Rod Calibration Test
(Raw Data)

Test Number	Pattern* Number	Time	HCR (5&11)	VSR Pattern (Inserted)	Period		Control Worth (mk)
					sec	c-mk	
1	A-1	0800	Out	Out	116	54.5	-
2	B-1	Set Safety Trips				-	-
3	C-1	1130	145"	35	70.0	80.5	3.30
4	C-3	1200	150"	36	75.7	76.0	3.79
5	C-5	1225	150"	37	106.6	58.4	4.37
6	C-7	1238	150"	25	22.2	166.2	3.43
7	C-10	1252	175"	35,36	24.5	160.0	3.79
8	C-17	1318	160"	35,36,37	181.0	37.6	5.42
9	C-13	1335	175"	35,38	63.0	87.0	5.23
10	C-14	1349	175"	24,51	40.2	118.5	5.12
11	C-15	1405	175"	37,39	71.7	79.6	5.77
12	C-17a	1419	160"	Repeat C-17	36.4	126.3	5.42
13	C-16	1440	175"	22,35,48,38	61.8	88.2	6.22
14	C-19	1453	125"	35,38,41	43.8	111.9	6.23
15	C-20	1514	200"	25,38,51	145.0	145.0	6.20
16	C-18	1534	200"	37,38,39	69.1	69.1	7.31
17	C-20	1540	200"	--	Data in Error		-
18	C-21	1623	140"	35,36,37,38	270	26.5	8.49
19	C-18	1637	200"	Same as C-18	22.8	167.8	7.31
20	C-22	1650	Out	36,37,38,39,40	115.7	54.6	8.65
21	C-21	1658	140"	35,36,37,38	7.15	79.3	-
22	C-23	1724	210"	31,32,38,44,45	75.5	76.1	8.94
23	C-22	1739	Out	36,37,38,39,40	33.6	54.6	8.62
24	C-27	1808	250"	18,19,25,31,32,38,44,45, 51,57,58	92.6	79.3	9.75
25	C-23a	1815	210"	31,32,38,44,45	26.2	76.1	9.00
26	C-24x	1835	170"	35,36,37,39,40,41	59.6	132.9	9.89
27	C-27a	1845	250"	Repeat C-27	32.8	65.1	9.75
28	C-24	1918	Out	35,36,37,38,39,40,41	156.3	155.0	11.02
29	C-24x	1932	170"	Same as C-24x	21.8	172.1	9.88
30	C-25	2019	280"	35,36,37,38,39,40,41,55	134.3	48.2	11.82

*Raw data reference test No. in RL-REA-2311

NOT RECORDED

Appendix A
(Cont'd)

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Test Number	Pattern Number	Time	HCR (5&11)	VSR Pattern (Inserted)	Period sec	c-mk	Control Worth (mk)
31	C-24a	2030	Out	Repeat C-24	29.3	144.7	11.02
32	C-25-1	2054	Out	35,36,37,38,39,40,41,55	37.8	123.3	11.62
33	C-25-2	2055	300"	35,36,37,38,39,40,41,55	41.4	116.2	11.69
34	C-25-3	2101	260"	35,36,37,38,39,40,41,55	62.8	87.2	12.08
35	C-25-4	2120	240"	35,36,37,38,39,40,41,55	59.0	91.2	12.29
36	C-25-5	2125	220"	35,36,37,38,39,40,41,55	89.3	67.0	12.63
37	C-25a	2127	280"	Repeat C-25	30.4	141.5	11.82
38	C-26	2151	240"	35,36,37,38,39,40,41,42	75.9	75.9	12.89
39	C-25-6	2158	180"	35,36,37,38,39,40,41,55	117.5	53.9	13.21
40	C-25-7	2209	160"	35,36,37,38,39,40,41,55	191.3	35.9	13.54
41	C-25-8	2237	220"	35,36,37,38,39,40,41,55	25.0	159.0	12.63
42	C-25-9	2244	140"	35,36,37,38,39,40,41,55	123.5	51.8	13.83
43	C-26a	2253	240"	Repeat C-26	26.8	152.7	12.89
44	C-25-10	2315	120"	35,36,37,38,39,40,41,55	82.0	71.5	13.24
45	C-25-11	2323	100"	35,36,37,38,39,40,41,55	128.9	50.0	14.40
46	C-25-12	2330	80"	35,36,37,38,39,40,41,55	150.6	44.0	14.51
47	C-28x	2351	315"	30,31,32,33,37,38,39,43, 44,45,46	35.6	128.1	13.92
48	C-28x-1	2358	300"	30,31,32,33,37,38,39,43, 44,45,46	64.8	85.2	14.35
49	C-25-12a	0017	80"	Repeat C-25-12	54.1	96.9	-
50	C-25-13	0032	60"	35,36,37,38,39,40,41,55	51.3	100.6	14.59
51	C-25-14	0042	30"	35,36,37,38,39,40,41,55	52.1	99.5	14.69
52	C-25-15	0053	In	35,36,37,38,39,40,41,55	48.8	104.8	14.75
53	C-28x-1a	0106	300"	Repeat C-28x-1a	25.6	156.8	14.35
54	C-28x-2	0200	Out	30,31,32,33,36,40,43,44, 45,46	420.0	14.0	16.36
55	C-45	0239	250"	24,25,26,30,31,32,33 43,44,45,46,50,51,52	117.6	53.9	16.31
56	C-46	0315	225"	18,19,24,25,26,31,32,37,38 38,39,44,45,50,51,52,57,58	51.9	99.7	16.20
57	C-28x-2a	0331	Out	Repeat C-28x-2	57.0	93.4	16.36
58	C-28x-3	0339	Out	43,44,45,46 36,38,40 30,31,32,33			

REF ASSIGNED

Appendix A

(Cont'd)

<u>Test Number</u>	<u>Pattern Number</u>	<u>Time</u>	<u>HCR (5&11)</u>	<u>VSR Pattern (Inserted)</u>	<u>Period sec</u>	<u>c-mk</u>	<u>Control Worth (mk)</u>
59	C-47	0434	Out	16,18,19,22,23,24,25,29, 30,31,32,25,26,37,38,42, 43,44,48,49,50,51,55,56, 57	240	29.4	17.60
60	C-28x-3a	0447	Out	Repeat C-25	44.5	110.8	
61	C-28x-4	0456	Out	30,31,32,33,36,37,39,40, 43,44,45,46	122.6	52.1	17.48
62	C-28x-5	0512	Out	30,31,32,33,36,37,38,39, 43,44,45,46	141.1	46.4	17.69
63	C-28x-6	0523	260"	30,31,32,33,37,38,39,40, 43,44,45,46	21.8	172.1	16.53
64	C-28x-5a	0539	Out	Repeat C-28x-5	87.6	68.0	17.69
65	C-28x-4a	0552	Out	Repeat C-28x-4	56.1	94.5	17.48
66	C-28	0603	Out	30,31,32,33,36,37,38,39,40, 43,44,45,46			
67	C-28a	0747	Out	30,31,32,33,36,37,38,39,40, 43,44,45,46	27.8	14.94	17.75
68	C-48	0753	Out	25,30,31,34,33,36,37,38,39, 40,43,44,45,46	82.0	71.5	18.59
69	C-49	0817	Out	18,30,31,32,33,36,37,38,39, 40,43,44,45,46	180.0	37.8	1902
70	C-50	0841	Out	18,30,31,32,33,36,37,39,40, 43,44,45,46	90.0	66.6	18.83
71	C-51	0902	Out	36,43,50,51,52,46,40,33,26, 25,24,30,38	105	59.0	18.96
72	C-52	0911	Out	Repeat C-51	50.2	102.1	18.68
73	C-53	0918	Out	Same as C-51 except VSR #38 out	17.9	181.1	17.94
74	C-54	0920	Out	Same as C-51 except VSR #25 out	21.8	172.9	18.02
75	C-55	0931	Out	Same as C-51 except VSR #36 out	Scram	No Data	
76	C-56	0942	Out	Same as C-51 except VSR #40 out	55.8	94.8	18.90
77	C-57	0959	250"	Same as C-51 except VSR #43 out	120.0	53.0	19.42
78	C-58	1010	Out	Same as C-51 except VSR #50 out	17.3	147.8	18.52
79	C-51(a)	1018	Out	Repeat C-51	49.2	195.5	18.05
80	C-60	1020	275"	Same as C-51 except VSR #38 out	95.0	103.5	-

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Appendix A
(Cont'd)

Test Number	Pattern Number	Time	HCR (5&11)	VSR Pattern (Inserted)	Period		Control Worth (mk)
					sec	c-mk	
81	C-60-1	1029	300"	Same as C-51 except VSR #38 out	22.9	63.9	19.41
82	C-61	1039	Out	42,43,44,45,46,47, 29,30,31,32,33,34	Subcrit	-	-
83	C-62	1040	200"	Same as C-61 except VSR #31 out	33.4	133.4	18.82
84	C-63	1053	Out	Same as C-61 except VSR #44 out	51.9	99.7	19.20
85	C-64	1058	Out	Same as C-61 except VSR #33 out	27.8	148.4	18.77
86	C-65	1104	250"	Same as C-61 except VSR #42 out	78.1	74.3	19.55
87	C-65-1	1107	275"	Same as C-61 except VSR #42 out	35.7	127.9	19.12
88	C-67	1120	250"	Same as C-61 except VSR #43 out	100.0	61.3	19.74
89	C-67-1	1123	275"	Same as C-61 except VSR #43 out	53.5	97.6	19.47
90	C-67-2	1125	300"	Same as C-61 except VSR #43 out	30.9	140.1	19.05
91	C-67-3	1132	Out	Same as C-61 except VSR #43 out	23.0	166.9	18.83
92	C-68	1140	Out	Same as C-61 except VSR #47 out	No period	-	-
93	C-69	1210	Out	55,56,57,58,48,49,50,51, 42,43,44,45,35,36,37,38, 29,30,31,32,22,23,24,25, 16,17,18,19	28.5	147.2	19.11
94	C-70	1210-1335		Flux traverse	-	-	-
95	C-51a	1346	310"	Repeat C-51	19.8	181.6	
96	C-71	1352-1425		Flux traverse	-	-	-
97	C-72	1432	310"	Same as C-51 except VSR #57 In	18.5	188.5	
98	C-61a	1544	Out	Repeat C-61	98.2	62.2	20.68
99	C-67a	1552	250"	Repeat C-67	25.1	158.6	19.74
100	C-74	1605	Out	Pattern No. 29 24,26,30,31,32,33,36,38, 40,43,44,45,46,50,52	20.1	180.1	19.60
101	C-75	1809	250"	16,18,21,26,30,32,34,35, 38,44,46,54,55,57,59	75.4	76.2	20.64
102	C-75-1	1905	250"	Same as C-75 except tube 2668 discharged	82.9	71.0	21.14

REF ASSIGNED

Appendix A
(Cont'd)

Test Number	Pattern Number	Time	HCR (5&11)	VSR Pattern (Inserted)	Period		Control Worth (mk)
					sec	c-mk	
103	C-76	2311	180" 2&14 @ 310"	56,57,58,59,60,50,51,52,53, 54,43,44,45,46,47,37,38,39, 40,41,30,31,32,33,34,24,25, 26,27,28,18,19,20,21	60.2	89.9	21.20
104	C-75-1a	2337	250"	Repeat C-75-1	29.0	145.6	-
105	C-78	0025	250"	24,25,26,35,36,37,38,39,40, 41,50,51,52	37.9	123.2	20.37
106	C-78-1	0218	220"	24,25,26,35,36,37,38,39,40, 41,50,51,52	85.1	69.5	21.48
107	C-78-2	0236	240"	24,25,26,35,36,37,38,39,40, 41,50,51,52	37.0	125.0	21.01
108	C-78-3	0245	260"	24,25,26,35,36,37,38,39,40, 41,50,51,52	20.9	176.2	20.54
109	C-78-4	0259	210"	24,25,26,35,36,37,38,39,40, 41,50,51,52	110.9	56.8	21.80
110	C-79	0312	260"	18,24,25,26,35,36,37,38,39, 40,41,50,51,52	94.6	64.1	21.80
111	C-80	0333	300"	18,24,25,26,35,36,37,38,39, 40,41,50,51,52,57	22.7	168.2	20.86
112	C-80-1	0340	280"	18,24,25,26,35,36,37,38,39, 40,41,50,51,52,57			
113	C-81	0348	300"	18,19,24,25,26,35,36,37,38, 39,40,41,50,51,52,57,58	28.2	148.1	21.14
114	C-82	0355	300"	24,25,26,31,35,36,37,38,39, 40,41,44,50,51,52	33.4	133.4	21.32
115	C-83	0407	300"	18,24,25,26,31,35,36,37,38, 39,40,41,44,50,51,52,57	204.9	33.8	22.37
116	C-83-1	0414	Out	18,24,25,26,31,35,36,37,38, 39,40,41,44,50,51,52,57	83.9	70.2	22.05
117	C-84	0429	175"	24,25,26,35,36,37,38,39,40, 50,51,52	105.8	58.7	22.23
118	C-85	0438	175"	24,25,26,35,36,37,38,40,41, 50,51,52	41.4	116.0	22.46
119	C-85-1	0449	150"	Repeat C-85	57.4	93.0	21.99
120	C-85-2	0458	100"	Repeat C-85	119.5	53.2	22.44
121	C-86	0500	100"	24,25,26,35,36,37,39,40,41, 50,51,52	80.00	72.9	22.25
122	C-86-1	0515	210"	24,25,26,35,36,37,39,40,41, 50,51,52	51.4	-	-
123	C-78-4a	0529	210"	Repeat C-84	43.9	111.8	22.00
124	C-84a	0540	210"	Same as C-78	66.9	83.3	22.35

NOT ASSIGNED

B. TESTS D AND E - COMPENSATING EFFECT OF POISON SPLINES

INTRODUCTION

This test was designed to determine the exact number, length, and location of poison splines necessary to compensate a vertical safety rod should it be withdrawn during an outage.

SUMMARY

The test data demonstrated that at least eight splines fully inserted are necessary to compensate the control effect of a single vertical safety rod. If the spline insertion distance is limited so as to cover only the control zone of the compensated vertical safety rod, reactivity compensation by a reasonable number of splines will be inadequate. The effects of the compensating splines, with adjacent VSR's inserted, were negligible until the splines were fully inserted.

DISCUSSION

A specific pattern of vertical safety rods was calibrated during the vertical safety rod tests (Test C, Section A of this document) which would provide adequate control tests which were to follow and also serve as a base configuration for normalization of other test data. This specific pattern will be referred to as the base configuration and is depicted in Figure 1-B.

1. Description of Test

The reactivity compensating effect of poison splines with respect to the control effect of specific vertical safety rods was measured by three distinct methods, each one described below.

- a. Method 1 consisted of an attempt to compensate a single vertical safety rod by strategically charging elements of poisonous spline across the local control zone normally covered by the respective vertical rod. Therefore the Type I splines were standard half-splines cut such that 5' 2-13/16" of poison remained. These were inserted 24' 7-1/4" so as to cover the control region of VSR #38. The control area and safety system plane are shown in Figure 2-B.

Fifteen Type I splines were charged with practically no measurable compensating effect of VSR #38 when removed.

- b. Method 2 consisted of extending the poison half-spline length to 10' 5-5/8". The Type II splines were inserted 24' 7-1/4" so that the poison spline section would affect the same control area as two vertical safety rods, specifically rod #25 and rod #38.

Ten of the Type II splines showed no measurable compensating effect.

- c. The third part of the spline compensation test program called for the use of full length, regular poison splines to be strategically charged across VSR #38 until the reactivity increase due to the withdrawal of this control was completely compensated. Full compensation was achieved with eight regular full length splines for both #38 rod which was directly compensated and then for #41 rod (with #38 reinserted) which covers a control area somewhat removed from the splines.

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Figure 1-B

(Test D)

Base VSR Configuration

Data

The test data resulting from the spline test is listed in Appendix B. Although all measurements were assigned a test number which carries the prefix D, the data from both tests D and E as outlined in the original test document are included.

Figure 2-B

Safety Control Plane
H Reactor

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Appendix B

<u>Time</u>	<u>Test #</u>	<u>HCRs (Inches Out)</u>	<u>VSRs</u>	<u>τ (sec)</u>	<u>No. of Splines & Type</u>
0540	C-78	5&11 @ 210"	Base VSRs Inserted (See Fig. 1)	66.9	All splines out
0630	D-1	5&11 In.	Base VSR 38 out	~90.0	5 - Type I splines
-	D-1	5&11 In	Base VSR 38 out	~90.0	9 - Type I splines
-	D-1	5&11 In	Base VSR 38 out	~90.0	15 - Type I splines
0854	D-3	5&11 @ 250"	Base	17.5	All splines out
0910	D-4	5&11 @ 280"	Base plus VSRs 18 & 57 In	23.4	All splines out
1006	D-5	5&11 @ 280"	Base plus VSRs 18 & 57 In	26.5	10 Type II splines
1012	D-6	5&11 @ 250"	Base minus VSR 38 18 & 57 In	28.2	10 Type II splines
1120	D-7	5&11 @ 280"	Base plus VSRs 18 & 57 In	52.6	5 Regular splines
1132	D-7	5&11 @ 250"	Base minus VSR 38 18 & 57 In	35.4	5 Regular splines
1144	D-8	5&11 @ 270"	Base minus VSR 38 18 & 57 In	20.3	6 Regular splines
1156	D-9	5&11 @ 280"	Base minus VSR 38 18 & 57 In	16.7	7 Regular splines
1205	D-10	5&11 @ 280"	Base minus VSR 41 18 & 57 In	45.9	7 Regular splines

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C. TEST F - REACTIVITY WORTH OF TOP AND BOTTOM ENRICHMENTINTRODUCTION AND SUMMARY

The enriched fuel charged in the top portion of the reactor for flux distribution was displaced with natural uranium, and pile reactivities were measured before and after the change. The measured reactivity effect of the enrichment with respect to effective safety system strength was practically negligible (0.53 mk).

DISCUSSION

The reactivity worth of the enriched fuel in the top and bottom of the reactor is assumed to increase the potential pile reactivity in proportion to the number of enriched fuel columns. Therefore a correction is added to nuclear safety calculations in order that adequate controls will be available to compensate the added effect due to the top and bottom enriched fuel.

Because the vertical control systems are designed to pass through the top and bottom E-rings, it seemed that the added reactivity effect should be negligible; therefore an actual measurement of this reactivity effect was made during the H Reactor deactivation test.

1. Test Description

Eighty columns of 0.947% enriched uranium fuel, strategically located in the top E-ring of H pile, were discharged and replaced with natural uranium fuel elements. By taking a rising period measurement with the same controls inserted before and after the replacement of the enriched fuel, the reactivity contribution of the enrichment with respect to the controls was obtained.

2. Instrumentation

A neutron-sensitive chamber was inserted into VSR channel #17 prior to the test and connected to an E-fold measuring device which provided the means of obtaining the fundamental test data. The subcritical monitors were also monitored using a stop watch and best by-eye measurement of the neutron density.

3. Results and Data

Before any tubes were discharged and following the VSR calibration test (i.e. Test C) VSRs 18, 24, 25, 26, 35, 36, 37, 38, 39, 40, 41, 50, 51, 52, and 57 were inserted and HCRs 5 and 11 withdrawn to 280" out. A rising period equivalent to 174 c-mk was measured on the E-fold period measuring instrument.

After 80 columns of enriched fuel in the top enrichment ring were replaced with natural uranium fuel the controls were withdrawn to the same positions as in the earlier measurement and another period measurement was taken. This time the E-fold instrument calibrated the rising period to be equivalent to 121 c-mk excess reactivity. Therefore, there was a 53 c-mk pile

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reactivity loss after replacing the enriched fuel in the top E-ring and with the safety system inserted so that the reactor was barely critical.

PERTINENT FINDINGS

It is concluded that the corrections presently made in total control calculations for the top and bottom enriched fuel effect, could conservatively be reduced. The reactivity effect of an enrichment pattern equivalent to the one discharged in this test is currently calculated to be worth 9.0 mk effective pile reactivity, a value considerably higher than the 0.53 mk measured in the deactivation test.

Although this reduction will not necessarily result in a savings in the use of splines, because the maximum number of splines is usually dictated by operating control requirements following startup, there will be some saving in outage time by lengthening the period between shutdown and initial supplementary control requirements.

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Figure 1-C

Top Enrichment Pattern
H Reactor Deactivation Test ☐ Spike enrichment

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D. TEST G - DISCHARGE TO MINIMUM CRITICAL SLAB

INTRODUCTION

Physics parameter measurements were coordinated with the deactivation process, namely discharge of fuel out of the pile. Reactivity measurements were taken at various intervals in the discharge process in order to measure the effective neutron migration area in a lattice with irradiated fuel. It is standard practice during initial startup testing programs to obtain a neutron migration area measurement in the "pure" lattice containing unirradiated fuel.

SUMMARY

H Reactor was discharged to a vertical lattice dimension of 18 lattice units plus 13 fuel columns remaining in the 19th lattice row before subcriticality was attained. The migration area measurements which were taken during this discharge varied widely, from about 900 Cm² maximum to around 600 Cm² minimum.

DISCUSSION

Although the large variations in migration measurements during the discharge have not been satisfactorily explained at this time, further analysis may develop their usefulness. The data and results are described below.

1. Test Description

The full pile tests were completed after the enriched fuel in the top of the reactor was replaced with natural uranium, and the respective reactivity loss was measured (Test F, Section C of this document). The following test procedures entailed the discharge of fuel from the reactor until a minimum critical size pile was attained. This specific test involved the series of reactivity measurements which were taken during the fuel discharge.

The fuel was discharged in specific increments, row-by-row, which were interrupted by reactivity measurements at various intervals. The discharge sequence was as follows:

Horizontal Row Discharge Pattern

1. 1-5 and 42-46	11. 12
2. 41	12. 13
3. 6	13. 14
4. 40	14. 15
5. 7	15. 16
6. 39	16. 17
7. 8	17. 38
8. 9	18. 37
9. 10	19. 36
10. 11	

After discharge of row 36 several fuel columns were recharged with green natural uranium fuel in order to increase the potential pile reactivity such that an adequate data could be obtained during the small block test.

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The basic control pattern which was inserted at the start of the discharge test and also those which were used as the pile reactivity decreased are shown in Figures 1-D, 2-D, and 3-D. All of the test data was obtained by adjusting one or two controls in these basic control patterns.

2. Instrumentation

Two subcritical monitor chambers were installed in VSR channel #17 prior to the test so that adequate sensitivity could be maintained should the reactor be discharged below the regular chambers (i.e. between horizontal rows 35 and 36). Such was not the case because the reactor was not discharged below horizontal row 36.

Three of the Beckman safety instruments were operated from chambers inserted in the near side test holes. The sensitivity of the Beckmans would have been affected as the fuel was discharged away from the bottom of the reactor where the chambers are usually located.

As in the previous test, the E-fold measuring instruments were used to obtain the raw test data.

3. Test Data

The raw test data is listed in Appendix C and may be evaluated according to the following principles:

$$k_{\text{eff}} = \frac{k_{\infty} e^{-B^2 \tau}}{1 + L^2 B^2} \approx \frac{k_{\infty} (1 - B^2 \tau)}{1 + L^2 B^2} \approx \frac{k_{\infty}}{1 + M^2 B^2}$$

where

B = buckling

k = multiplication factor

L^2 = diffusion length

τ = neutron age

differentiating with respect to B^2 :

$$\frac{dk}{dB^2} = \frac{-M^2 k_{\infty}}{(1 + M^2 B^2)^2} = -\frac{k_{\text{eff}} M^2}{1 + M^2 B^2}$$

$$\text{for } k_{\text{eff}} \approx 1 \quad \frac{dk}{dB^2} \approx -M^2$$

The change in bucklings are derived by the following equations:

$$\text{By definition } B^2 = \frac{\pi^2}{L^2} \therefore B_{\text{Pile}}^2 = \frac{\pi^2}{X^2} + \frac{\pi^2}{Y^2} + \frac{\pi^2}{Z^2}$$

where X, Y, and Z are the dimensions of the reactor. It was the intent of this test to merely change the geometric buckling in one-dimension so that

$$\Delta B_Y = \left(\frac{\pi}{Y_1} \right)^2 - \left(\frac{\pi}{Y_2} \right)^2$$

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where Y_1 and Y_2 represent the vertical pile size before and after the fuel discharge. Therefore extrapolation distances must be included.

$$Y_1 = n_1 \times L + 2D_1 \text{ (cm)}$$

$$Y_2 = n_2 \times L + 2D_2 \text{ (cm)}$$

where n_1 = number of fuel rows charged before the alteration

n_2 = number of fuel rows charged after the alteration

L = lattice dimension

D_1 and D_2 are reflector extrapolation distances.

4. Test Results

At the time of this report writing there was inadequate time to derive the proper neutron extrapolation distances in the area of the discharged fuel columns. A rough interpretation of the data is listed in Table I-D using a constant extrapolation distance of 60 Cm per side. These results indicate reasonable data can be further derived from this test which will provide a measured value of the neutron migration area in irradiated fuel with various spike enrichment and controls inserted.

Table I-D

Migration Area Measurement Results

Row Discharged	Δ Reactivity (c-mk)	Δ Buckling (μ b)	M^2 (Cm ²)
1-5 and 42-46	pile went subcritical - no data		
41 empty	58.5	.627	933
6 empty	61.0	.674	905
40 empty	72.0	.728	989
7 empty	66.0	.782	844
39 empty	69.0	.856	806
8 empty	69.0	.925	746
9 empty	83.0	1.006	825
10 empty	86.0	1.096	785
11 empty	88.0	1.200	733
12 empty	no data	1.313	-
13 empty	98.0	1.445	678
14 empty	94.0	1.594	590
15 empty	104.0	1.764	590
16 empty	127.0	1.958	649
17 empty	136.0	2.184	623
38 empty	~196.0	2.443	802
37 empty	215.5	2.748	784
36 empty	307.0	3.103	989

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Figure 1-D

(Test G)

Base VSR Configuration

Figure 2-D
(Test G)
New Base Configuration

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Figure 3-D
(Test G)
New Base Configuration

NEW BASE

Appendix C

Discharge to Minimum Critical Size Data

Test #	Horizontal Rows with Fuel	Controls		Period		Δ Reactivity mk
		VSRs (out)	HCRs	sec.	c-mk	
F-2	Full Pile (Base Case)	None Base Config. (Fig. 1)	5&11 @ 304"	20.2	191	
G-1	36 Row 1-5 empty Row 42-46 empty	None	5&11 out	-	-	~ -191
G-2	36	57	5&11 out	360	21.5	
G-3	36	57,18	5&11 out	72.5	82.7	
G-4	36	57,18,51,25	5&11 @ 280"	22.2	180.0	
G-5	36 (8 splines charged - no measurable period)					
G-6	36 (8 splines charged)	57,18,24,40,51,25	5&11 @ 140"	78.2	78	
G-7	36	57,18,24,36,51,25	5&11 In	23.0	176	
G-8	35 Row 41 empty	18,25,51,57	5&11 out	no period		
G-9	35	57,18,24,40,51,25	5&11 @ 140"	395	19.5	-58.5
G-10	35	18,24,29,51,52,57	5&11 @ 225"	21.0	186	
G-11	34 Row 6 empty	18,24,25,51,52,57	5&11 @ 225"	40	125	-0.610
G-12	33 Row 40 empty	18,24,25,51,52,57	5&11 @ 225"	128	55	-0.720
G-13	33	18,25,25,51,52,57	5&11 @ 310"	no data		
G-13A	33	18,24,25,50,51,52,57	5&11 @ 175"	24	172	
G-14	33	New Base (see Fig. 2) None out	5&11 @ 210"	249	169	
G-15	32 Row 7 empty	New Base - None	5&11 @ 210"	53.5	103	-0.66
G-16	32	New Base - None	5&11 @ 240"	19.6	194	
G-17	31 Row 39 empty	New Base - None		160	44	-0.69
G-18	30 Row 8 empty	None	5&11 @ 240"	160	44	-0.69
G-19	30	None	5&11 @ 275"	27	160	
G-20	29 Row 9 empty	None	5&11 @ 240"	no data		-0.83
G-20A	29	None	5&11 @ 275"	79.5	77	

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Appendix C
(Cont'd)

Test #	Horizontal Rows with Fuel	Controls		Period		Reactivity mk
		VSRs (out)	HCRs	sec.	c-mk	
G-20B	29	None	5&11 @ 300"	39	128	
G-20C	29	None	5&11 out	30.2	144	
G-21	29	51 out	5&11 @ 275"	16.9	210	
G-22	28 Row 10 empty	51 out	5&11 @ 275"	40.5	125	-0.86
G-22A	28	51 out	5&11 @ 300"	24.3	171	
G-22B	28	51 out	5&11 out	20.0	191	
G-23	27 Row 11 empty	51 out	5&11 out	54.8	101.5	-0.88
G-24	27	51,25 out	5&11 out	159.2	44.1	
G-24A	27	New Base (Fig. 3)	5&11 @ 170"	19.3	194	
G-25	26 Row 12 empty	New Base	5&11 @ 170"	44.6	118	-0.76
G-26	25 Row 13 empty	New Base	5&11 @ 170"	420	20	-0.98
G-27	25	New Base	5&11 @ 210"	48	111	
G-28	25	New Base	5&11 @ 240"	29.5	151	
G-29	24 Row 14 empty	New Base	5&11 @ 240"	115.5	57.4	-0.94
G-30	24	New Base	5&11 out	48	111	
G-31	24	35,37,39,41 In	5&11 @ 170"	32.5	143	
G-32	24	35,37,39,41 In	5&11 @ 140"	238	31.0	
G-33	24 Pulled 2 splines	35,37,33,41 In	5&11 @ 140"	66.0	88.6	
G-34	23 Row 15 empty	35,37,39,41 In	5&11 @ 170"	191	37.8	-1.05
G-34A	23	35,37,39,41 In	5&11 @ 200"	57	99	
G-35	23	35,37,39,41 In	5&11 @ 245"	19.6	194	
G-36	22 Row 16 empty	35,37,39,41 In	5&11 @ 245"	96	67	-127
G-37	22	35,37,39,41 In	5&11 out	52.6	105	
G-38	22	37,38,39 In	5&11 out	31	148	

REF ASSIFIED

Appendix C
(Cont'd)

Test #	Horizontal Rows with Fuel	Controls		Period		Reactivity mk
		VSR (out)	HCRs	sec.	c-mk	
G-39	22	25,38,41 In	5&11 @ 245"	82	75.4	
G-40	22	25,51 In	5&11 In	no period		
G-40A	22	25,51 In	5&11 @ 175"	20	191	
G-41	21 Row 17 empty	25,51 In	5&11 @ 175"	124	55	- 136
G-42	21	25,51 In	5&11 @ 230"	no data		
G-43	21 Pulled spline out of tube 3074	25,51 In	5&11 @ 100"	no data		
G-44	21 HCR Calibration	25,38,41 In	11&12 In 8 @ 90" 10 @ 170"	224.4		
G-44A	21 HCR Calibration	25,38,51 In	11&12 @ 100" 8 @ 90" 10 @ 170"	160	44	
G-44B	21 HCR Calibration	25,38,41 In	11&12 @ 170" 8 @ 90" 10 @ 170"	138	50	
G-44C	21 HCR Calibration	25,38,51 In	11&12 @ 225" 8 @ 90" 10 @ 225"	~140	49	
G-44D	21	HCR Calibration	25,38,51 In 8 @ 90" 10 out	78	78	
G-45	21	18,25,51,58 In	5&11 @ 270" 8 @ 90"	41	124	
G-46	21	25,38,51 In	10,11,12 In	42	121	
G-46A	21 Flux traverse	25,38,51 In	5&8 @ 200"			
G-47	21 Flux traverse	25,38,51,58 In	8 @ 170" 5 @ 310"			
G-48	21 Flux traverse	25,38,51 In	11&12 @ 260" 5 @ 285"			
G-49	21	25,38,51 In	5 @ 260"	19	196	
G-50	20 Row 38 empty	25,38,51 In	5 @ 260"	no period		>-196

REF ASSIFIED

Appendix C
(Cont'd)

Test #	Horizontal Rows with Fuel	Controls		Period		Δ Reactivity mk
		VSR (out)	HCRs	sec.	c-mk	
G-51	20	25,51 In	5 @ 210"	20	191	
G-52	20 + discharged tubes 3752-3757 & 3790-3795	25,51 In	5 @ 210"	34	139	-52
G-53	20 + discharged tubes 3752-3757 & 3790-3795	25 In	5 @ 139"	18	202	
G-54	20 + discharged tubes 3752-3757 & 3790-3795	All out	5&6 @ 125"	19	196	
G-55	20 + discharged tubes 3752-3757 3790-3795 plus tubes 3759, 3761, 3765, 3767, 3769, 3771, 3774, 3776, 3778, 3780, 3782, 3784, 3786, 3788	All out	5&6 @ 125"	81	81.5	-57.5
G-56	20 + Same as G-55	All out	5 @ 120"	20	191	
G-57	20 + Same as G-55	All out	5 @ 140" 10 @ 125" 11&12 In	20	191	
G-58	20 + Same as G-55 Pulled spline 2163	All out	5&6 @ 125"	67	88	+ 6.5
G-59	20 + Same as G-55	Flux Traverse				
G-60	20 + Same as G-55	Reactivity change after Turco operation		62	93	+ 5.0
G-60A	20 + Same as G-55	All out	5 @ 125" 6 @ 160"	no data		
G-61	20 + Same as G-55	All out	5 @ 125" 6 @ 190"	24	174	
G-62	19 Row 37 empty	All out	5 @ 125" 6 @ 190"	95	68	-106
G-63	19	All out	5 @ 125" 6 out	42	122	

NOT RECORDED

Appendix C
(Cont'd)

Test #	Horizontal Rows with Fuel	Controls		Period		Reactivity mk
		VSR (out)	HCRs	sec.	c-mk	
G-64	19	All out	5 @ 135" 6 out	26	165	
G-65	19 + discharged tubes 3651, 3652 3653, 3654 3655, 3656 3666, 3670 3675, 3691 3692, 3693 3694, 3695 3696	All out	5 @ 135" 6 out	58	97	-68
G-66	19 + Same as G-65	All out	5 @ 160" 6 out	20	191	
G-67	19 + Same as G-65	All out	5 @ 180" 10 @ 125" 11&12 In	26	163	
G-67A	19 + Same as G-65	All out	5 @ 160" 10 @ 125" 11&12 In	56	99	
G-68	19 + discharged tubes 3657, 3658 3660, 3662 3664, 3668 3672, 3673 3677, 3679 3681, 3683 3685, 3687 3689, 3690	All out	5 @ 160"	91	70	-121
G-68A	19 + Same as G-68	All out	5 @ 180"	36	135	
G-69	19 + Same as G-68	All out	5 @ 190"	26	162	
G-70	19 + Same as G-68	All out	5 @ 290"	16	214	
G-71	19 + Same as G-68	All out	5 @ 260" 10 @ 125" 11&12 In	20	191	
G-72	18 Row 36 empty	All out	5 @ 260" 10 @ 125" 11&12 In	86	73	-118

REF ASSIGNED

Appendix C
(Cont'd)

Test #	Horizontal Rows with Fuel	Controls		Period		Δ Reactivity mk
		VSR (out)	HCRs	sec.	c-mk	
G-72	18	All out	5 out 10 @ 125" 11&12 In	40	125	
G-73	18	All out	5 out 10 @ 170" 11&12 In	36	135	
G-74	18	All out	10 @ 170" 11&12 @ 150"	25	169	
G-75	18	All out	2 @ 170" 10 @ 170" 11&12 @ 150"	34	140	
G-76	18	All out	2&10 @ 170" 1-3-11-12 In	245	30	
G-77	18	All out	2&10 out 1-3-11-12 In	99	65	
G-78	18	All out	1&3 In 11&12 @ 150"	52	106	
G-79	18	All out	1&3 In 11&12 out	30	150	
G-80	18	All out	1&3 @ 150" 11&12 out	20	179	
G-81	18	VSR 51 In	1&3 @ 150"	no period		
G-82	18	VSR 51 In	All out	182	39	
G-83	18	VSR 51 out	All out	150	47	
G-80A	18	All out	1&3 @ 150"	21	187	

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E. TEST H - LONG-TERM GAINS MEASUREMENT IN NATURAL URANIUM SUPERCCELL

INTRODUCTION

The fuel in H Reactor prior to the deactivation test had been irradiated to goal exposure (i.e. ~ 700 MWD/T) and therefore data was obtained which applies to reactor conditions somewhat different from the "pure lattice" conditions during startup tests. In other words the reactivity change due to long-term gains could be measured by replacing irradiated fuel with green natural uranium.

SUMMARY

Because five enriched fuel columns were in the 25-tube supercell prior to the Deactivation Test Program it was difficult to differentiate between the reactivity losses due to replacing the enriched fuel to natural uranium and replacing irradiated natural uranium with green natural uranium. The total measured reactivity change was 101 c-mk loss after the 25 tubes in the supercell were recharged. Allowing 10 c-mk for each enriched fuel charge the reactivity increase due to the exposure difference would be ~ 50 c-mk.

DISCUSSION

The 25 tubes in the supercell, containing irradiated fuel were recharged with green natural uranium fuel in increments of five tubes between each reactivity measurement. The data and charge-discharge list are listed in Table I-E.

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Table I-E

<u>Test #</u>	<u>Tube #</u>	<u>Reactor Change</u>		<u>Reactivity Change</u>
		<u>Discharged</u>	<u>Charged</u>	
H-1	2372	Enriched Uranium	Green Natural Uranium	-50 c-mk
	2672	Natural Uranium	"	
	2575	Enriched Uranium	"	
	2275	Natural Uranium	"	
	2476	Natural Uranium	"	
H-2	2272	Natural Uranium	Green Natural Uranium	-19 c-mk
	2572	Natural Uranium	"	
	2674	Natural Uranium	"	
	2374	Enriched Uranium	"	
	2376	Natural Uranium	"	
H-3 & H-4	Flux Traverse			
H-5	2472	Natural Uranium	Green Natural Uranium	-21 c-mk
	2673	Enriched Uranium	"	
	2274	Natural Uranium	"	
	2475	Natural Uranium	"	
	2676	Natural Uranium	"	
H-6	2573	Natural Uranium	Green Natural Uranium	- 8 c-mk
	2273	Natural Uranium	"	
	2474	Natural Uranium	"	
	2576	Natural Uranium	"	
	2276	Enriched Uranium	"	
H-7	2675	Natural Uranium	Green Natural Uranium	- 3 c-mk
	2574	Natural Uranium	"	
	2473	Natural Uranium	"	
	2373	Natural Uranium	"	
	2375	Natural Uranium	"	
Total Reactivity Change				-101 c-mk

Expected reactivity change due to fuel
change of 5 enriched fuel columns ~50 c-mk.

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F. TEST I - SPECIAL LOADING SUPERCELL TESTS (Fuel and Target Configurations)INTRODUCTION

The reactivity parameters of six different special fuel loadings were measured during the H Deactivation Physics Test. These small 25 lattice unit supercell or test blocks, having isolated target material in a number of tubes with supporting enrichment in the remaining tubes, were tested with and without coolant. The target materials were thorium, bismuth, and depleted uranium supported by 0.947 W/o U-235 enriched uranium and 1.25 W/o U-235 enriched uranium as driving material.

The 25-tube test block was loaded with 0.947 W/o enriched fuel following the testing of fuel and target ratios. The enriched fuel was added in one or two tube increments, and reactivity measurements were alternately taken with the test cells wet and dry.

SUMMARY

The results of the small block tests are summarized in Table I-F. This data is presented in the Discussion Section in greater detail. It should be noted that more than one special arrangement was changed without altering the fuel-to-target ratios. Each time significant reactivity changes were noted. Therefore, the summarized data may be misleading without reference to the specific fuel and target configurations..

Likewise, due to the increase in the reactivity importance factor of the test cells with respect to the amount of enrichment, quantitative results should not be inferred prior to mathematical analysis.

One useful conclusion already available from these tests is the compensating reactivity effect of empty fuel channels in the dry pile which heretofore had been conservatively estimated to possibly cause a positive reactivity change and which showed negative reactivity changes in this test.

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Table I-F

Summarized Supercell Data

Reactivities (c-mk)

Ratio Fuel/Target	Type 0.947% E	Base Wet	VSR #51 Worth	Spline Worth (Fuel)	Spline Worth (Target)	Base Dry	VSR #51 Worth	Spline Worth (Fuel)	Spline Worth (Target)	Δ Wet to Dry
All	Nat. U	179	160	60	-	331	187	71	-	152
19/6	E-D	193	163	74	60	364	195	95	47	171
20/5	E-Q	287	166	75						
21/4	E-Q	120	165	38	34	293	178	114	48	173
22/3	E-Q	346	186							
12/13	E-B	38								
13/12	E-B	49								
14/11	E-B	144								
15/10	E-B	242	177	40	98	637	293	76	155	395
	1.25% E									
15/10	E-D	85	-							
16/9	E-D	205	172	65	53	433	234	89	92	228
17/8	E-D	401	~197			709	293	126		108
18/7	E-Q	156		67	42	358	187	98	69	206
19/6	E-Q					481	246			
17/8	E-Q	69	~140							
18/7	E-Q	119	-			324	206			
18/7	E-Q	130	-			325	175			
9/16	E-B	23	183							
10/15	E-B	124	199			584	180	129		
All	Nat. U	147	-			329				
24	"	0	(1 tube load cadmium in supercell)							
24	"	80	(1 tube water in supercell)							
24	"	93	(1 tube solid Al. in supercell)							
24	"	430	(1 tube 1.25% Enr. fuel in supercell)							

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Table I-F

(Cont'd)

Ratio Fuel/Target	Type 0.947% E	Base Wet	VSR #51 Worth	Spline Worth (Fuel)	Spline Worth (Target)	Base Dry	VSR #51 Worth	Spline Worth (Fuel)	Spline Worth (Target)	Δ Wet to Dry
24	Nat. U	188	(1 tube 0.947% Enr. fuel in supercell)							
24	"	64	(1 tube D metal in supercell)							
24	"	120	(1 tube Bismuth in supercell)							
24	"	39	(1 tube Thoria in supercell)							
24	"		(1 tube empty in supercell)				272			
23	"		(2 tubes empty in supercell)				220			
22	"		(3 tubes empty in supercell)				190			
21	"		(4 tubes empty in supercell)				168			
22	"		(5 tubes empty in supercell)				145			

Small Block 0.947% E²

E/Natural Ratio	Base Wet	VSR #51 Worth	Base Dry	VSR #51 Worth
0/25	141	subcrit	314	
2/23	215	204	385	201
3/22	248	203	423	-
5/20	321	203	524	288
7/18	378	245	643	314
9/16	477	274	763	320
13/12	701	286	1022	355
15/10	824	326	1162	377
17/8	977	~332	1329	~400
19/6	1088	363	1488	483
21/4	1238	405	1572	520
25E	1526		~2000	

DISCUSSION1. Test Description

The specific tubes used for the supercell tests are shown in Figure 1-F with respect to VSR #51. Prior to the supercell test measurements the reactor had been discharged to a minimum critical slab as shown in Figure 2-F. During the preceding test (H), the irradiated metal in the 25-tube test cell was replaced with green natural uranium. With the green natural Uranium fuel in the supercell the following data was taken to be used as a basis for comparison with the special loading data.

			<u>Test #</u>
Wet	Base Block Reactivity	179 c-mk	H-14
	VSR #51 worth	160 c-mk	H-26
	1 Spline worth	60 c-mk	H-27
	2 Spline worth	101 c-mk	H-28
	Base Block Reactivity	331 c-mk	H-30
Dry	VSR #51	187 c-mk	H-32
	1 Spline worth	71 c-mk	H-35
	2 Spline worth	131 c-mk	H-36

2. Test Cell Loading Patterns

The specific loading patterns and corresponding test numbers are shown on the following pages. The analyzed data corresponding to each test measurement follows the section.

Figure 1-F

H Reactor Process Tubes Used for Supercell Test Channels

VSR #51

2672	2673	2674	2675	2676
2572	2573	2574	2575	2576
2472	2473	2474	2475	2476
2372	2373	2374	2375	2376
2272	2273	2274	2275	2276

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Figure 2-F
Final Slab Reactor

- ① Rod Bank, HCR's 1, 2 & 3 ② Rod Bank, HCR's 10, 11 & 12 ③ Supercell
 ○ Fringe Poison ⊗ Enriched ⊞ Discharged

DCPI 1001077

			D	
	D			
			D	
D				D
		D		

This block was in place from Test I-1 through Text I-7x.

The block consisted of .947% w/o U-235 enriched uranium - depleted uranium with a ratio of 19/6.

The target columns are marked; the blank columns contain the fuel.

			D	
	D			
			D	
D				
		D		

This block was in place from Test I-7x* through Test I-20.

The block consisted of .947% w/o U-235 enriched uranium - depleted uranium with a ratio of 20/5.

The target columns are marked; the blank columns contain the fuel.

			Q	
	Q			
			Q	
Q				
		Q		

This block was in place from Test I-21 through Test I-22.

The block consisted of .947% w/o U-235 enriched uranium - thoria with a ratio of 20/5.

The target columns are marked; the blank columns contain the fuel.

REF ASSIFIED

			Q	
	Q			
			Q	
Q				

This block was in place from Test I-23 through Test I-36.

The block consisted of .947% w/o U-235 enriched uranium - thoria with a ratio of 21/4.

The target columns are marked; the blank columns contain fuel.

			Q	
			Q	
Q				

This block was in place from Test I-37 through Test I-38.

The block consisted of .947% w/o U-235 enriched uranium - thoria with a ratio of 22/3.

The target columns are marked; the blank columns contain fuel.

			Q	
Q				
			Q	
Q				

This block was in place from Test I-39 through Test I-42.

The block consisted of .947% w/o U-235 enriched uranium - thoria with a ratio of 21/4.

The target columns are marked; the blank columns contain fuel.

REF ASSIGNED

		Q		
	Q			
		Q		
	Q			

This block was in place from Test I-43 through Test I-46.

The block consisted of .947% w/o U-235 enriched uranium - thoria with a ratio of 21/4.

The target columns are marked; the blank columns contain fuel.

			Q	
			Q	
Q				

This block was in place from Test I-47 through Test I-47A.

The block consisted of .947% w/o U-235 enriched uranium - thoria with a ratio of 22/3.

The target columns are marked; the blank columns contain fuel.

	B	B		B
B			B	
B	B		B	
B		B		B
		B		B

The block was in place for Test I-49 only.

The block consisted of .947% w/o U-235 enriched uranium - bismuth with a ratio of 12/13.

The target columns are marked; the blank columns contain fuel.

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	B	B		B
B			B	
B	B		B	
B		B		B
			B	

This block was in place for Test I-50 only.

The block consisted of .947% w/o U-235 enriched uranium - bismuth with a ratio of 13/12.

The target columns are marked; the blank columns contain fuel.

	B			B
B			B	
B	B		B	
B		B		B
		B		

This block was in place for Test I-51 only.

The block consisted of .947% w/o U-235 enriched uranium - bismuth with a ratio of 14/11.

The target columns are marked; the blank columns contain fuel.

	B			B
B			B	
	B		B	
B		B		B
		B		

This block was in place from Test I-52 through Test I-69.

The block consisted of .947% w/o U-235 enriched uranium - bismuth with a ratio of 15/10.

The target columns are marked; the blank columns contain fuel.

	D	D		D
D			D	
D	D		D	
D		D		D
		D		

This block was in place for Test I-70 only.

The block consisted of 1.25% w/o U-235 enriched uranium - depleted uranium with a ratio of 13/12.

The target columns are marked; the blank columns contain fuel.

	D	D		D
D			D	
	D		D	
D		D		D
		D		

This block was in place for Test I-71 only.

The block consisted of 1.25% w/o U-235 enriched uranium - depleted uranium with a ratio of 14/11.

The target columns are marked; the blank columns contain fuel.

	D	D		D
D			D	
	D		D	
D				D
		D		

This block was in place for Test I-72 and Test I-72A.

The block consisted of 1.25% w/o U-235 enriched uranium - depleted uranium with a ratio of 15/10.

The target columns are marked; the blank columns contain fuel.

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	D			D
D			D	
	D		D	
D				D
		D		

This block was in place from Test I-73 through Test I-89.

The block consisted of 1.25% w/o U-235 enriched uranium - depleted uranium with a ratio of 16/9.

The target columns are marked; the blank columns contain fuel.

	D			D
D			D	
	D			
D				D
		D		

This block was in place from Test I-90 through Test I-95.

The block consisted of 1.25% w/o U-235 enriched uranium - depleted uranium with a ratio of 17/8.

The target columns are marked; the blank columns contain fuel.

	D			D
D			D	
	D		D	
D				D
		D		

This block was in place from Test I-96 through Test I-101.

The block consisted of 1.25% w/o U-235 enriched uranium - depleted uranium with a ratio of 16/9.

The target columns are marked; the blank columns contain fuel.

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	Q			Q
	Q		Q	
Q				Q
		Q		

This block was in place for Test I-102 only.

The block consisted of 1.25% w/o U-235 enriched uranium - thoria with a ratio of 18/7.

The target columns are marked the blank columns contain fuel.

	Q			
	Q		Q	
Q				Q
		Q		

This block was in place from Test I-103 through Test I-104A.

The block consisted of 1.25% w/o U-235 enriched uranium - thoria with a ratio of 19/6.

The target columns are marked; the blank columns contain fuel.

	Q			Q
	Q		Q	
Q				Q
		Q		

This block was in place from Test I-105 through Test I-118.

The block consisted of 1.25% w/o U-235 enriched uranium - thoria with a ratio of 18/7.

The target columns are marked; the blank columns contain fuel.

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	Q			
			Q	
	Q			
Q				Q
		Q		

This block was in place from Test I-119 through Test I-121A.

The block consisted of 1.25% w/o U-235 enriched uranium - thoria with a ratio of 19/6.

The target columns are marked; the blank columns contain fuel.

	Q			Q
			Q	
	Q			
Q				Q
		Q		

This block was in place from Test I-122 through Test I-123.

The block consisted of 1.25% w/o U-235 enriched uranium - thoria with a ratio of 18/7.

The target columns are marked; the blank columns contain fuel.

	Q			Q
Q			Q	
	Q			
Q				Q
		Q		

This block was in place from Test I-124 through Test I-125A.

The block consisted of 1.25% w/o U-235 enriched uranium - thoria with a ratio of 17/8.

The target columns are marked; the blank columns contain fuel.

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Q			Q	
Q				
			Q	
Q				Q
			Q	

This block was in place from Test I-126 through Test I-129.

The block consisted of 1.25% w/o U-235 enriched uranium - thoria with a ratio of 18/7.

The target columns are marked; the blank columns contain fuel.

	Q	Q		
	Q			
		Q		
	Q			Q
		Q		

This block was in place from Test I-130 through Test I-133.

The block consisted of 1.25% w/o U-235 enriched uranium - thoria with a ratio of 18/7.

The target columns are marked; the blank columns contain fuel.

Q			Q	
	Q			
			Q	
Q				Q
		Q		

This block was in place from Test I-134 through Test I-136A.

The block consisted of 1.25% w/o U-235 enriched uranium - thoria with a ratio of 18/7.

The target columns are marked; the blank columns contain fuel.

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	B	B		B
B		B	B	
B		B		B
	B	B	B	
B	B		B	B

This block was in place for Test I-137 and Test I-138.

The block consisted of 1.25% w/o U-235 enriched uranium - bismuth with a ratio of 9/16.

	B	B		B
B		B	B	
B		B		B
	B		B	
B	B		B	B

This block was in place from Test I-139 through Test I-152.

The block consisted of 1.25% w/o U-235 enriched uranium - bismuth with a ratio of 10/15.

The target columns are marked; the blank columns contain fuel.

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3. Test Procedure

The small block tests followed this general procedure:

1. Charge a fuel and target ratio which is conservatively estimated to match the reactivity of natural uranium fuel.
2. Measure the reactivity effect of this target-to-fuel pattern.
3. Add or subtract one fuel column as is necessary to approach basic natural uranium reactivity and remeasure the reactivity.

Once the basic wet reactivity of the target and fuel matched natural uranium fuel the following tests were performed with and without coolant in the test block:

1. Basic reactivity measurement of the pattern without inserted controls.
2. Reactivity measurement with VSR #51 inserted.
3. Reactivity measurement with spline in target column.
4. Reactivity measurement with spline in fuel column.
5. For several target fuel ratios, two splines were charged into the test block so that the shadowing effect of the splines could be determined.

An especial manifold valving system was constructed and attached to the 25 fuel channels in the test block so that coolant or air could be easily inserted into the tubes. The air was used to blow the tubes dry for the dry block reactivity measurements.

Insertion difficulties developed when splines were charged into the target and fuel tubes; therefore some of the tests with splines were dropped from the program. Also several tests using thorium target fuel were left unfinished because of the condition of the target charges after several charging operations.

All raw test data has been interpreted using period reactivity tables calculated for H Reactor² fuel at 600 MWD/T exposure and an average enrichment inventory of 20 per cent (i.e., 20 per cent of the pile containing 0.947 W/o enriched fuel).

4. Data

This series of tests comprises raw data numbers I-1 through I-152. The original data sheets have been documented under RL-REA-2311, Vol. II.

²HW-46100, Vol. 1, Pile Physics Manual of Standard Practices
Period Reactivity Tables by A.D. Vaughn, Pg D-1.38

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The base reactivity values listed on the following data sheets are based on observed whole pile excess reactivity with the block of interest in place. The observed base change during the test program was probably due to water leakage into the pile during a tube replacement required because of a stuck thoria charge.

a. Horizontal Control Rod Calibration

Due to the significant reactivity contributions during these tests it was necessary to "shim" with horizontal control rods; their effect in turn must be included in the interpretation of the test data. Utilization of rods 1, 2, 3, 10, 11 and 12 enable the test measurements to be taken with minimum perturbation from the rods since these controls are all located near the reflector of the minimum critical size pile and did not enter near the actual small test block.

Since the reactivity effect of the horizontal control rods is important to the interpretation of the test data, the specific controls in use were calibrated throughout the small block test program. It was possible to observe the same reactivity compensating effects due to the control rods time after time as they were rechecked during the test. The horizontal rod calibration worths are listed in Table II-F and may be used to interpret the other data for the small test blocks.

b. Period Data and Results

The results from the small block tests are analyzed in the following section. An E-fold period measuring instrument was used to obtain the raw data. If the E-fold data seemed to be in error, the subcritical monitor chart data was used. Typewritten count rate data was also taken during these tests, and the period rates were calculated from the typewritten data using the digital computer code KORCOUNT.³ These calculated results were redundant to the original E-fold data so that the latter was used almost exclusively.

5. Flux Pattern Across Supercell

Following the small block tests, the fuel channels in the test cell were recharged with natural uranium and the flux pattern across the cell was measured by using the relative worth of poison splines in the cell. These results are shown in Figure 3-F.

³KORCOUNT, a digital computer code which is designed to correct count rate data and derive the period time. The code was written by P.D. Gross for the IBM-7090.

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Table II-F

Rod Calibration

All rods out	0 c-mk
1&3 at 150"	44 c-mk
1&3 in	97 c-mk
1&3 in - 11&12 at 150"	138 c-mk
1,3,11,12 in	160 c-mk
1,3,11,12 in - 2&10 at 170"	204 c-mk
1,3,11,12 in - 2&10 at 170" - 5 at 225"	281 c-mk
1,3,11,12 in - 2&10 at 170" - 5 at 200"	323 c-mk
1,3,11,12 in - 2&10 at 170" - 5 at 170"	398 c-mk
1,3,11,12 in - 2&10 at 170" - 5 at 125"	553 c-mk
1,3,11,12 in - 2&10 at 170" - 4,5,6,7,8,9 at 285"	265 c-mk
1,3,11,12 in - 2&10 at 170" - 4,5,6,7,8,9 at 250"	344 c-mk
1,3,11,12 in - 2&10 at 170" - 4,5,6,7,8,9 at 220"	434 c-mk
1,3,11,12 in - 2&10 at 170" - 4,5,6,7,8,9 at 200"	528 c-mk
1,3,11,12 in - 2&10 at 170" - 4,6,7,8,9, at 200" - 5 at 170"	582 c-mk
1,3,11,12 in - 2&10 at 170" - 4,6,7,8,9, at 200" - 5 at 140"	680 c-mk
1,3,11,12 in - 2&10 at 170" - 4,6,7,8,9, at 200" - 5 at 98"	854 c-mk
1,3,11,12 in - 2&10 at 170" - 4,6,7,8,9, at 200" - 5 at 75"	924 c-mk
1,3,5,11,12 in - 2,6,10 at 170" - 4,7,8,9, at 200"	1056 c-mk
1,3,5,11,12 in - 2,4,10 at 170" - 7,8,9, at 200" - 6 at 75"	1219 c-mk
1,3,5,6,11,12 in - 2,4,10 at 170" - 7,8,9, at 180"	1333 c-mk
1,3,5,6,11,12 in - 2,4,8,10 at 170" - 7,9, at 160"	1573 c-mk

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The following data was taken with the 19-6 E-D supercell in the reactor.

Test #	HCR Worth	VSR #51	Spline Status	Wet or Dry	Period		Remarks
					Sec.	C-mk	
I-1	All out	Out	Out	Wet	16.5	193	Good match to natural
I-2	All out	In	Out	Wet	230	30	VSR #51 worth 163 c-mk
I-3	All out	Out	2672	Wet	37.8	119	Fuel spline worth 74 c-mk
I-4	All out	Out	2672, 2375	Wet	66.6	80	Two fuel splines worth 113 c-mk
I-5	All out	Out	2573	Wet	32	133	Target spline worth 60 c-mk
I-6	All out	Out	2573, 2376	Wet	47.6	102	2 target splines worth 91 c-mk
I-7	160 c-mk	Out	Out	Wet	210	32	HCR's 1,3,11,12 full-in = 160 c-mk
I-8 through I-14	The downstream poles were not secure to ensure that the metal was in the proper front-to-rear location. This data is not presented. The trouble was corrected and the tests rerun.						
I-8x	204 c-mk	Out	Out	Dry	23.2	160	Δ reactivity wet to dry = +171 c-mk
I-9x	44 c-mk	In	Out	Dry	35	125	Dry VSR #51 worth 195 c-mk
I-10x	160 c-mk	Out	2672	Dry	43.1	109	Fuel spline worth 95 c-mk
I-11x	160 c-mk	Out	2672, 2375	Dry	104	58	2 fuel splines worth 146 c-mk
I-12x	No meaningful data.						
I-13x	204 c-mk	Out	2376	Dry	41.3	113	1 target spline worth 47 c-mk
I-13x*	204	Out	2376	E dry-D wet	70.8	77	Water on 6 - Dep worth 36 c-mk
I-13x**	204	Out	Out	"	37.7	119	Wet dep target spline worth 42 c-mk
I-14x	160	Out	Out	"	21.6	167	Rod calibration
I-7x	160	Out	Out	Wet	212	32	Base recheck
The following tests have E-D ratio of 20-5. #2376 was charged enriched.							
I-7x*	160	Out	Out	Wet	34.1	127	Worth of 1 col. of D→E is +95 c-mk
I-15	~138	Out	Out	Wet	23.7	159	HCR Calib.
I-16	~125	Out	Out	Wet	20.6	172	HCR Calib.
I-17	~116	Out	Out	Wet	18.7	181	HCR Calib.
I-18	~116	In	Out	Wet	Long	5	VSR #51 worth ~175 c-mk here
I-19	~116	Out	2672	Wet	52.3	96	Fuel spline worth 75 c-mk
I-20	~116	Out	2672, 2375	Wet	146	44	2 fuel splines worth 137 c-mk

RECEIVED

Test #	HCR Worth	VSR #51	Spline Status	Wet or Dry	Period		Remarks
					Sec.	C-mk	
At this point an E-Q block with 20-5 ratio was charged.							
I-21	Out	Out	Out	Wet	No period		
I-22	Nothing						
At this point one tube was charged E for a 21-4 E-Q block.							
I-23	Out	Out	Out	Wet	37.5	120	Base reactivity for a 21-4 E-Q
I-24	Out	In	Out	Wet	(-224)(-45 c-mk)		VSR #51 worth 165 c-mk
I-25	138	Out	Out	Wet	No period		
I-25	97	Out	Out	Wet	325	21	
I-26	Out	Out	2275	Wet	65	82	1 fuel spline worth 38 c-mk
I-27	Out	Out	2372	Wet	61.4	86	1 target spline worth 34 c-mk
I-28	97	Out	2372	Dry	23.9	158	Base reactivity dry = 293 c-mk
I-29	160	Out	2372	Dry	62.1	85	HCR calib, target spline worth 48 c-mk
I-30	97	Out	2275	Dry	65	82	1 fuel spline worth 114 c-mk
I-31	97	In	Out	Dry	360	18	VSR #51 worth 178 c-mk
I-32	160	Out	Out	Dry	32	133	Base for following tests
I-33	160	Out	Out	E-Dry Q-Wet	43	110	Water on target worth 23 c-mk
I-34	92	Out	Out	E-Dry Q-Wet	19	180	HCR Calib.
I-35	Out	Out	Out	Wet	37.2	121	Wet base recheck
I-36	97	Out	Out	Wet	290	24	Base for following tests
At this point the E-Q block was changed to a 22-3 ratio.							
I-37	160	Out	Out	Wet	17.8	186	1 Q column worth 225 c-mk
I-38	97	In	Out	Wet	93.2	63	VSR #51 worth 186 c-mk
At this point a 21-4 E-Q block was charged.							
I-39	Out	Out	Out	Wet	40.2	115	Base for this configuration
I-40	Out	In	Out	Wet	(-155)(-68)		VSR #51 worth 183 c-mk

Test #	HCR Worth	VSR #51	Spline Status	Wet or Dry	Period		Remarks
					Sec.	C-mk	
I-41	160	Out	Out	Dry	34.9	125	Wet to dry worth 170 c-mk
I-42	Out	In	Out	Dry	52.6	96	VSR #51 worth 181 c-mk
At this point the arrangement was changed - same ratio.							
I-43	160	Out	Out	Dry	29.5	139	Base for this configuration
I-44	Out	In	Out	Dry	35.7	124	VSR #51 worth 175 c-mk
I-45	Out	Out	Out	Wet	31.2	135	Dry to wet worth 164 c-mk
I-46	97	In	Out	Wet	(-100)	(-160)	VSR #51 worth 198 c-mk
At this point the 22/3 E-Q block was recharged.							
I-47	204	Out	Out	Wet	39.5	116	Base block reactivity 320 c-mk
I-48	Out	In	Out	Wet	29.6	139	VSR #51 worth 181 c-mk
I-47A	204	Out	Out	Wet	39.6	116	Recheck I-47
At this point an E-B block - ratio 12/13 was charged.							
I-49	Out	Out	Out	Wet	175	38	Base reactivity is 141 c-mk below Nat
At this point the E-B block was changed to a 13/12 ratio.							
I-50	Out	Out	Out	Wet	126.1	49	Base reactivity is 130 c-mk below Nat
At this point the E-B block was changed to a ratio of 14/11							
I-51	Out	Out	Out	Wet	27.9	144	Base reactivity is 35 c-mk below Nat
At this point the E-B ratio was changed to 15/10.							
I-52	44	Out	Out	Wet	15.9	198	Base reactivity is 63-cm over Nat
I-53	Out	In	Out	Wet	89	65	VSR #51 worth 177 c-mk
I-54	44	Out	2275	Wet	23.7	158	Fuel spline worth 40 c-mk
I-55	44	Out	2275, 2573	Wet	61	86	Two fuel splines worth 112 c-mk
I-56	44	Out	2676	Wet	49.6	100	Target spline worth 98 c-mk
I-57	44	Out	2676, 2372	Wet	174	38	Two target splines worth 160 c-mk
I-57A	44	Out	2275	Wet	24.3	156	Recheck I-54
I-58	482	Out	Out	Dry	24.6	155	Wet to dry worth 395 c-mk

Test #	HCR Worth	VSR #51	Spline Status	Wet or Dry	Period		Remarks
					Sec.	C-mk	
I-59	204	In	Out	Dry	29.3	140	VSR #51 worth 293 c-mk
I-59A	278	In	Out	Dry	87.9	66	HCR calibration
I-60	482	Out	2275	Dry	68.7	79	Fuel spline worth 76 c-mk
I-61	Not sure	Out	Out	Dry	15.7	200	Base for next measurement
I-62	Same	Out	2275, 2573	Dry	77.3	72	2 Fuel splines worth 128 c-mk
I-63	482	Out	2676	Dry	∞		1 target spline worth 155 c-mk
I-64	Not sure	Out	2676	Dry	19.8	176	Base for next measurement
I-65	Same	Out	2676, 2372	Dry	96.9	61	Two target splines worth 270 c-mk
I-66	482	Out	Out	E-Dry B-Wet	∞	0	Wet target worth 155 c-mk
I-67	295	Out	Out	E-Dry B-Wet	17.6	187	Base for next measurement
I-68	295	Out	Out	Wet	∞	0	Bad data point
I-69	97	Out	Out	Wet	28.4	142	Recheck wet base - good check
At this point a 1.25 E-D block with a 13/12 ratio was charged.							
I-70	Out	Out	Out	Wet	subcritical		
At this point a 1.25 E-D block with a 14/11 ratio was charged.							
I-71	Out	Out	Out	Wet	subcritical		
At this point a 1.25 E-D block with a 15/10 ratio was charged.							
I-72	Out	Out	Out	Wet	62.4	85	Block reactivity 94 c-mk below Nat.
I-72A	Out	In	Out	Wet	(-147)(-74)		Date of questionable value
At this point a 1.25 E-D block with a 16/9 ratio was charged.							
I-73	44	Out	Out	Wet	23.2	161	Block reactivity 26 c-mk above Nat.
I-74	Out	In	Out	Wet	206	33	VSR #51 worth 172 c-mk
I-75	Out	Out	2574	Wet	29.3	140	Fuel spline worth 65 c-mk
I-76	Out	Out	2574, 2373	Wet	56	92	2 fuel splines worth 113 c-mk
I-77	Out	Out	2575	Wet	25.4	152	Target spline worth 53 c-mk
I-78	Out	Out	2575, 2473	Wet	49	100	2 target splines worth 105 c-mk
I-79	63	Out	2575, 2473	Dry	213	32	HCR Calibration
I-80	160	Out	2575, 2473	Dry	45.1	106	

Test #	HCR Worth	VSR #51	Spline Status	Wet or Dry	Period		Remarks
					Sec.	C-mk	
I-81	204	Out	2575, 2473	Dry	91.3	64	HCR Calibration
I-82	204	Out	2575	Dry	30.2	137	2 target splines worth 165 c-mk
I-83	323	Out	2575	Dry	400	18	Base for next measurement
I-84	323	Out	Out	Dry	43	110	Target spline worth 92 c-mk
I-85	160	in	Out	Dry	167	39	VSR #51 worth 232 c-mk
I-86	398	Out	Out	Dry	188	35	HCR Calibration
I-87	204	Out	2373	Dry	39.1	140	Fuel spline worth 89 c-mk
I-88	204	Out	2373, 2574	Dry	119	52	Two fuel splines worth 177 c-mk
I-89	204	Out	2574	Dry	37.8	119	Fuel spline worth 110 c-mk
At this point a 1.25 E-D block with a 17/8 ratio was charged.							
I-90	398	Out	2574	Dry	18	185	Δ reactivity is 260 c-mk for 1 depleted
I-91	553	Out	2574	Dry	227	30	HCR Calib.
I-92	553	Out	Out	Dry	24.5	156	Fuel spline worth 126 c-mk
I-93	398	In	Out	Dry	374	19	VSR #51 worth 293 c-mk
I-94	204	Out	Out	Wet	16.1	197	Wet block reactivity is 222 above Nat.
I-95	204	In	Out	Wet	∞	0	VSR #51 worth ~ 197 c-mk
At this point the 16/9 1.25 E-D block was recharged.							
I-96	44	Out	Out	Wet	23.3	160	Recheck wet 16/9 base (I-73)
I-97	Out	In	Out	Wet	211.6	32	Recheck I-74
I-98	281	Out	Out	Dry-E Wet-D	88.3	65	Dry fuel worth 142 c-mk
I-99							Worthless data
I-100	44	Out	2276	Wet	35.6	124	Spline worth 36 c-mk
I-101	44	Out	2272	Wet	38.4	118	Spline worth 42 c-mk
At this point a 1.25 E-Q block with a 18/7 ratio was charged.							
I-102	Out	Out	Out	Wet	24.5	156	Block reactivity 23 c-mk below Nat.
At this point a 1.25 E-Q block with a 19/6 ratio was charged.							

Test #	HCR Worth	VSR #51	Spline Status	Wet or Dry	Period		Remarks
					Sec.	C-mk	
I-103	281	Out	Out	Wet	15.6	200	Block reactivity 302 c-mk above Nat.
I-104	281	In	Out	Wet	subcritical		
I-104A	204	In	Out	Wet	113	54	VSR #51 worth 223 c-mk
At this point the 18/7 1.25 E-Q block was recharged.							
I-105	Out	Out	Out	Wet	24.6	156	Base recheck
I-106	52	Out	Out	Wet	47	103	HCR Calibration
106A	100	Out	Out	Wet	107.5	56	HCR Calibration
I-107	Out	In	Oct	Wet	subcritical		
I-108	Out	Out	2574	Wet	58.6	89	Fuel spline worth 67 c-mk
I-109	Out	Oute 2574, 2374		Wet	122	51	2 fuel splines worth 105 c-mk
I-110	Out	Out	2473	Wet	42.3	111	Target spline worth 45 c-mk
I-111	Out	Out	2473, 2673	Wet	106.2	56	2 target splines worth 100 c-mk Oops
I-112	97	Out	Out	E-Wet Q-dry	72.8	76	Δ reactivity for dry targets is 17 c-mk
I-113	138	Out	Out	E-Wet Q-dry	216.4	31	HCR Calibration
I-114	204	Out	Out	Dry	24.9	154	Δ Reactivity for dry block is 206 c-mk
I-115	97	In	Out	Dry	74.6	74	VSR #51 worth 187 c-mk
I-116	204	Out	2574	Dry	108.2	56	Fuel spline worth 98 c-mk
I-117	204	Out	2473	Dry	62.3	85	Target spline worth 69 c-mk
I-118	331	Out	Out	Dry	254	27	HCR Calibration
At this point the E-Q block with the 19/6 ratio was recharged.							
I-119	535	Out	Out	Dry	21.3	169	Wet to dry worth 223 c-mk
I-120	398	In	Out	Dry	99.6	60	VSR #51 worth 246 c-mk
I-121	281	Out	Out	Wet	33.3	129	Recheck I-103
I-121A	323	Out	Out	Wet	56	92	HCR Calibration

Note: The loading sheet shows that the initial arrangement of the 19/6 1.25 E-Q block is different than the one charged prior to test I-119. The initial block was charged in error. The initial block was 71 c-mk more reactive than the block in place at this time even though they had the same fuel to target ratio. The same comment also holds true for the 18/7 ratio 1.25 E-Q block which is charged in the next step. The initial block was 36 c-mk more reactive.

RECEIVED

Test #	HCR Worth	VSR #51	Spline Status	Wet or Dry	Period		Remarks
					Sec.	C-mk	
At this point the 18/7 ratio 1.25 E-Q block was recharged.							
I-122	Out	Out	Out	Wet	37.6	120	Recheck I-105
I-123	Out	In	Out	Wet	(-214)	(-47)	Data in doubt
At this point a 1.25 E-Q block with a 17/8 ratio was charged.							
I-124	Out	Out	Out	Wet	subcritical		
I-125	Out	Out	Out	Dry	82.7	69	Dry block base of 69 c-mk
I-125A	Out	In	Out	Dry	(-105)	(-140)	Data in doubt
At this point a 1.25 E-Q block with an 18/7 ratio was charged.							
I-126	204	Out	Out	Dry	37.7	120	Dry base for this arrangement
I-127	Out	In	Out	Dry	38.3	118	VSR #51 worth 206 c-mk
I-128	Out	Out	Out	Wet	37.4	119	Wet base
I-129	97	In	Out	Wet	(-87)	(-328)	VSR #51 worth is doubted from this
At this point the 1.25 E-Q block with the 18/7 ratio was rearranged.							
I-130	Out	Out	Out	Wet	32.8	130	Wet Base
I-131	97	In	Out	Wet	(-100)	(-160)	Doubtful data
I-132	204	Out	Out	Dry	87.2	121	Dry base
I-133	Out	In	Out	Dry	26.1	150	VSR #51 worth 175 c-mk
At this point a ThO ₂ slug was damaged in process tube 2672. The rest of the data shows a reactivity loss. <u>Probably</u> some water was leaked into the stack during retubing operations.							
At this point the 18/7 1.25 E-Q block was rearranged.							
I-134	204	Out	Out	Dry	71.4	77	Base reactivity 281 c-mk
I-135	Out	In	Out	Dry	56	92	VSR #51 189 c-mk
I-136	Out	Out	Out	Wet	85.4	67	Base reactivity is 67 c-mk
136A	Out	In	Out	Wet	(-110)	(-125)	VSR #51 worth 192 c-mk
At this point a 1.25 E-B block was charged with a ratio of 9/16.							
I-137	Out	Out	Out	Wet	319	23	Wet base
I-138	Out	In	Out	Wet	(-100)	(-160)	VSR #51 worth 183 c-mk
At this point a 1.25 E-B block with a 10/15 ratio was charged.							

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Test #	HCR Worth	VSR #51	Spline Status	Wet or Dry	Period		Remarks
					Sec.	C-mk	
I-139	Out	Out	Out	Wet	35.5	124	Base wet reactivity questionable data
I-140	97	In	Out	Wet	(-90)	(-253)	Questionable data
I-141	160	Out	Out	E-dry B-wet	35.8	123	Dry fuel worth 161 c-mk
I-142	Out	In	Out	E-dry B-wet	63.1	84	VSR #51 worth 199 c-mk
I-143	273	Out	Out	E-dry B-wet	slow	10	HCR Calibration
I-144	273	Out	Out	E-dry ^{5B dry} _{10B wet}	99.4	60	
I-145	312	Out	Out	"	328	21	HCR Calibration
I-146	312	Out	2672	Dry	28.1	143	
I-147	411	Out	2672	Dry	144.3	44	HCR Calibration
I-148	411	Out	Out	Dry	30.4	173	Fuel spline worth 129 c-mk, Wet to Dry is 460 c-mk
I-149							Cannot determine poison worth
I-150							
I-151	Out	Out	Out	Wet	31	135	Recheck wet base - Inaccurate somewhere
I-152	Out	In	Out	Wet	(-217)	(-45)	Best value VSR #51 at 180 c-mk

Figure 3-F

Flux Pattern Across Supercell with Natural Uranium Fuel

26	.685		.694		.730
25					
24			.811		
23					
22	.964		.982		1.00
	72	73	74	75	76

Note: The flux is definitely depressed in the upper portion of the supercell adjacent to the probable water source (2672). Spline worth also depends on spike enrichment location outside the supercell. This can be found on the pile loading map in an earlier section.

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G. TEST I - SPECIAL LOADING SUPERCELL TESTS (Enriched Uranium Supercell Test
and Empty Channel Test)

The 25-tube test block was charged with 0.947 W/o U-235 enriched fuel, in one- and two-tube incremental steps, following the fuel and target ratio tests. The specific test results are shown in Figures 3-G and 4-G.

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Figure 3-G

Base Whole Pile Excess Reactivity with the
Listed Block in the Supercell

x dry
o wet

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Figure 4-G

VSR #51 Worth With the Listed Block
in Place in the Supercell

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1. Test Procedure

The following diagrams show the charging sequence for the enriched supercell test and the respective test numbers given to the raw data. Reactivity measurements with and without coolant in the test cells were taken for each fuel pattern shown. Likewise, as in the previous tests, VSR #51 was inserted and the reactivity loss measured.

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		E ²	E ²	

This block was in place from Test I-178 through test I-189.

The marked columns contained .947% w/o U-235 enriched uranium. The remaining columns contained natural uranium.

	E ²	E ²	E ²	

This block was in place from Test I-190 through test I-194.

The marked columns contained .947% w/o U-235 enriched uranium. The remaining columns contained natural uranium.

		E ²		
	E ²	E ²	E ²	
		E ²		

This block was in place from Test I-195 through Test I-198.

The marked columns contained .947% w/o U-235 enriched uranium. The remaining columns contained natural uranium.

DECLASSIFIED

		E ²	E ²	
	E ²	E ²	E ²	
	E ²	E ²		

This block was in place from Test I-199 through Test I-207.

The marked columns contained .947% w/o U-235 enriched uranium. The remaining columns contained natural uranium.

	E ²	E ²	E ²	
	E ²	E ²	E ²	
	E ²	E ²	E ²	

This block was in place from Test I-208 through Test I-210A.

The marked columns contained .947% w/o U-235 enriched uranium. The remaining columns contained natural uranium.

		E ²		
	E ²	E ²	E ²	
E ²	E ²	E ²	E ²	E ²
	E ²	E ²	E ²	
		E ²		

This block was in place from Test 211 through Test I-216.

The marked columns contained .947% w/o U-235 enriched uranium. The remaining columns contained natural uranium.

DECLASSIFIED

		E ²		
E ²	E ²	E ²	E ²	
E ²	E ²	E ²	E ²	E ²
	E ²	E ²	E ²	E ²
		E ²		

This block was in place from Test I-217 through Test I-221.

The marked columns contained .947% w/o U-235 enriched uranium. The remaining columns contained natural uranium.

		E ²		
E ²	E ²	E ²	E ²	E ²
E ²	E ²	E ²	E ²	E ²
E ²	E ²	E ²	E ²	E ²
		E ²		

This block was in place from Test I-222 through Test I-226.

The marked columns contained .947% w/o U-235 enriched uranium. The remaining columns contained natural uranium.

	E ²	E ²		
E ²	E ²	E ²	E ²	E ²
E ²	E ²	E ²	E ²	E ²
E ²	E ²	E ²	E ²	E ²
		E ²	E ²	

This block was in place from Test I-227 through Test I-231.

The marked columns contained .947% w/o U-235 enriched uranium. The remaining columns contained natural uranium.

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	E ²	E ²	E ²	
E ²	E ²	E ²	E ²	E ²
E ²	E ²	E ²	E ²	E ²
E ²	E ²	E ²	E ²	E ²
	E ²	E ²	E ²	

This block was in place from Test I-232 through Test I-237.

The marked columns contained .947% w/o U-235 enriched uranium. The remaining columns contained natural uranium.

E ²	E ²	E ²	E ²	E ²
E ²	E ²	E ²	E ²	E ²
E ²	E ²	E ²	E ²	E ²
E ²	E ²	E ²	E ²	E ²
E ²	E ²	E ²	E ²	E ²

This block was in place from Test I-238 through Test I-239.

The marked columns contained .947% w/o U-235 enriched uranium. The remaining columns contained natural uranium.

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2. Test Data

The period data and analyzed results for the enriched supercell test are listed in the following pages. As in the previous test, this data has been derived from the E-fold instrument readings.

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2 of 2

Test #	HCR Worth	VSR #51	Spline Status	Wet or Dry	Period		Remarks
					Sec.	C-mk	
I-153	Out	Out	Out	Wet	28.8	142	p loss since H-29 of 37 c-mk
I-154	Out	In	Out	Wet	subcritical		VSR #51 worth > 142 c-mk

Note: Because of reactivity defect noted in I-153, splines were inserted in various locations around the the supercell block to test local flux depressions. This was done in tests I-155 - I-162. The data was normalized to 1.0 and presented graphically in Figure 3-F, Section F.

I-155	Out	Out	2272	Wet	44.8	107	
I-156	Out	Out	2274	Wet	43.5	109	
I-157	Out	Out	2276	Wet	42.2	111	
I-158	Out	Out	2474	Wet	57.2	90	
I-159	Out	Out	2672	Wet	73	76	
I-160	Out	Out	2674	Wet	70.7	77	
I-161	Out	Out	2676	Wet	66.7	81	
I-162	Out	Out	Out	Wet	28.7	142	I-153 recheck

Note: Tests I-163 thru I-170 involve comparing reactivity worth of various materials in center tube of supercell (surrounded by natural uranium).

I-163	Out	Out	45 pcs Pd-Cd on 2474	Wet	Very slow	~ 5	1 column Pb-Cd worth - 137 c-mk
I-164	Out	Out	H ₂ O in 2474	Wet	76.4	73	1 column H ₂ O worth - 69 c-mk
I-165	Out	Out	SA in 2474	Wet	60.7	86	1 column SA worth - 56 c-mk
I-166	44 c-mk	Out	52 pcs of 1.25 E ² in 2474	Wet	25.0	154	1 column 1.25 E ² worth +36 c-mk
I-167	Out	Out	43 pcs of 0.947 E ² in 2474	Wet	20.6	172	1 column 0.947 E ² worth + 30 c-mk
I-168	Out	Out	Depleted in 2474	Wet	101	59	1 column depleted worth - 83 c-mk
I-169	Out	Out	B-Metal in 2474	Wet	43.3	109	1 column B-metal worth 33 c-mk
I-170	Out	Out	Thoria in 2474	Wet	183	36	1 column Thoria worth 106 c-mk
I-171	Out	Out	Supercell all Nat.	Wet	28.6	142	Base recheck
I-172	160 c-mk	Out	Out	Dry	29.1	140	Dry base = 300 c-mk

Notice that there appears to be very little change in Δ reactivity, wet to dry, even though both the wet and dry bases are lower than the values prior to the retubing on tube #2672.

Test #	HCR Worth	VSR #51	Spline Status	Wet or Dry	Period		Remarks
					Sec.	C-mk	
Tests I-173 through I-177 checked poison worth of air channels in the dry natural uranium block.							
I-173	160	Out	2474 MT	Dry	36.5	122	1 air channel worth - 18 c-mk
I-174	160	Out	2474, 2672, MT	Dry	74	75	2 air channels worth - 65 c-mk
I-174A	90	Out	Same	Dry	27.6	145	HCR Calibration
I-175	90	Out	2474, 2672, 2675 MT	Dry	38.9	117	3 air channels worth - 93 c-mk
I-176	90	Out	2474, 2672, 2675, 2275 MT	Dry	51.7	97	4 air channels worth - 113 c-mk
I-177	90	Out	2474, 2672, 2675, 2275, 2475 MT	Dry	92.1	63	5 air channels worth - 147 c-mk

Note: All of the rest of the supercell tests (I-178 through I-239) deal with taking the supercell up to a fully enriched dry block by steps. The loading patterns are shown on the earlier diagrams.

I-178	204	Out	Out	Dry	21.6	168	Base reactivity is 372 c-mk
I-179	-	Out	Out	Dry	15.4	200	HCR Calibration
I-180	Same	In	Out	Dry	very slow	0	VSR #51 worth ~ 200 c-mk
I-180A	97	In	Out	Dry	67.4	80	VSR #51 worth check (195 c-mk)

The following tests are measurements of falling period worths in order to check the calculated period tables (i.e., HW-46100, Page No. D-1.38)

I-181	Out	Out	Out	Wet	15.7	199	Base reactivity 199 c-mk
I-182	Out	In	Out	Wet	274	25	VSR #51 worth 175 c-mk
I-183	-97	Out	Out	Wet	47.6	102	HCR Calibration
I-183A	-97	In	Out	Wet	-148	-73	Period tables $\tau = -73$ c-mk
I-184	-132	Out	Out	Wet	95.9	67	
I-184A	-132	In	Out	Wet	-100.7	-108	Period table $\tau = 157$ c-mk
I-185	-168	Out	Out	Wet	220.0	31	
I-185A	-168	In	Out	Wet	-89.9	-144	Period table $\tau = -144$ c-mk
I-186	-145	Out	Out	Wet	114.0	54	
I-186A	-145	In	Out	Wet	-82.5	-121	Period table $\tau = -9.09$ mk (9090 C-mk)
I-187	-123	Out	Out	Wet	72.6	76	
I-187A	-123	In	Out	Wet	-110.5	-99	Period table $\tau = -124$ c-mk

Test #	HCR Worth	VSR #51	Spline Status	Wet or Dry	Period		Remarks
					Sec.	C-mk	
I-188	-84	Out	Out	Wet	39.5	115	
I-188A	-84	In	Out	Wet	-170.0	-60	Period table τ = -60 c-mk
I-189	-119	Out	Out	Wet	68.0	80	
I-189A	-119	In	Out	Wet	-107.4	-95	Period table τ = -193 c-mk
At this point a 22/3 natural/enriched block was charged.							
I-190	138	Out	Out	Wet	56	92	Wet base = 230 c-mk
I-190A	138	In	Out	Wet	-112	-151	Data of doubtful value
I-191, I-192 and I-192A all are void because of improper supercell drying							
I-193	204	Out	Out	Dry	15.5	200	Dry base = 404 c-mk
I-193A	204	In	Out	Dry	-356	-	Data of doubtful value
I-194	?	Out	Out	Dry	138.4	46	New base for loading charge
At this point a 20/5 natural/enriched block was charged.							
I-195	Same	Out	Out	Dry	30.1	138	VSR #51 ~ 331 c-mk
I-196	?	Out	Out	Dry	156.3	41	Base for next dry measurement
I-197	138	Out	Out	Wet	23.8	158	VSR #51 worth 197 c-mk
I-198	Out	In	Out	Wet	50.3	99	VSR #51 worth 197 c-mk
At this point an 18/7 natural/enriched block was charged.							
I-199	204	Out	Out	Wet	23.5	160	Wet base = 364 c-mk
I-199A	204	In	Out	Wet	-160	-65	VSR #51 worth 225 c-mk
I-200	265	Out	Out	Wet	50.4	98	HCR Calibration
I-201	344	Out	Out	Wet	310	21	HCR Calibration
I-202	323	Out	Out	Wet	135.8	46	HCR Calibration
I-203	344	Out	2674	Dry	30.5	137	Dry base = 610 c-mk
I-204	434	Out	2676	Dry	134.6	46	HCR Calibration
I-205	434	Out	Out	Dry	19.9	175	Spline worth 129 c-mk
I-205A	434	In	Out	Dry	-180	-160	VSR #51 worth 335 c-mk
I-206	528	Out	Out	Dry	67	81	HCR Calibration
I-207	582	Out	Out	Dry	252	27	HCR Calibration

At this point a 16/9 natural/enriched block was charged.

Test #	HCR Worth	VSR #51	Spline Status	Wet or Dry	Period		Remarks
					Sec.	C-mk	
I-208	582	Out	Out	Dry	30.5	137	Dry base = 719 c-mk
I-208A	528	In	Out	Dry	-105	-140	VSR #51 worth 331 c-mk
I-209	680	Out	Out	Dry	165.5	39	HCR Calib.
I-210	265	Out	Out	Wet	17.1	190	Wet base = 455 c-mk
I-210A	265	In	Out	Wet	-160	-63	VSR #51 worth 255 c-mk
At this point a 12/13 natural/enriched block was charged.							
I-211	582	Out	Out	Wet	66.3	81	Wet base = 663
I-211A	528	In	Out	Wet	-94	-201	VSR #51 worth 336 c-mk
I-212	680	Out	2372	Dry	15.6	200	Base dry value = 956 c-mk
I-212A	680	In	2372	Dry	-95	-193	VSR #51 worth 394 c-mk
I-213	854	Out	2372	Dry	256	27	HCR Calib.
I-214	854	Out	Out	Dry	47.6	102	Spline worth 75 c-mk
I-215	528	In	Out	Dry	47.4	102	VSR #51 worth 326 c-mk
I-216	924	Out	Out	Dry	213.3	32	HCR Calib.
At this point a 10/15 natural/enriched block was charged.							
I-217	924	Out	Out	Dry	23.6	159	Dry base = 1083 c-mk
I-218	680	In	Out	Dry	140.6	45	VSR #51 worth 358 c-mk
I-219	1056	Out	Out	Dry	240.5	28	HCR Calib.
I-220	680	Out	Out	Wet	53.2	95	Wet Base = 775 c-mk
I-221	434	In	Out	Wet	146.9	43	VSR #51 worth 298 c-mk
At this point a 8/17 natural/enriched block was charged.							
I-222	854	Out	Out	Wet	95.2	62	Wet base = 916 c-mk
I-222A							Valueless data
I-223	528	In	Out	Wet	100	59	VSR #51 worth 329 c-mk
I-224	1056	Out	Out	Dry	18	182	Dry base = 1238
I-225	1219	Out	Out	Dry	385	20	HCR Calib.
I-226	854	In	Out	Dry	"	0	VSR #51 worth 384 c-mk
At this point a 6/19 natural/enriched block was charged.							
I-227	1219	Out	Out	Dry	22.5	164	Dry base = 1383 c-mk

Test #	HCR Worth	VSR #51	Spline Status	Wet or Dry	Period		Remarks
					Sec.	C-mk	
I-228	1333	Out	Out	Dry	125.4	49	HCR Calib.
I-229	854	In	Out	Dry	60.3	87	VSR #51 worth 442 c-mk
I-230	854	Out	Out	Wet	22.7	163	Wet base = 1017 c-mk
I-231	582	In	Out	Wet	47.4	103	VSR #51 worth 332 c-mk
At this point a 4/21 natural/enriched block was charged.							
I-232	1056	Out	Out	Wet	50.9	98	Wet base = 1154 c-mk
I-233	680	In	Out	Wet	47	103	VSR #51 worth 371 c-mk
I-234	1333	Out	Out	Dry	15.4	200	Dry base = 1533
I-235	?	Out	Out	Dry	34.8	126	HCR Calib.
I-235A	?	Out	Out	Dry	33.9	128	HCR Calib.
I-236	1573	Out	Out	Dry	slow	-40	HCR Calib.
I-237	924	In	Out	Dry	31.7	134	VSR #51 worth 475 c-mk
At this point the supercell was charged all enriched.							
I-238	1219	In	Out	Dry	240	28	Estimated dry base $\approx$ 1800
I-239	1333	Out	Out	Wet	63.2	84	Wet base = 1417 c-mk

3. Relative Worth of Various Fuel and Target Charges

Various fuel and target types were charged into tube 2474 of the test block so that their relative reactivity worths could be measured. The data is not particularly significant except it shows that the measured worths follow the generally accepted values.

Table III

Relative Fuel and Target Reactivity Worths

<u>Material</u>	<u>Nominal* Worth Normal- ized to Water</u>	<u>Observed Worth Normal- ized to Water</u>
H ₂ O	1	1
Bismuth	0.490	0.48
Solid Aluminum	0.71	0.81
Depleted Uranium	1.37	1.20
Lead-Cadmium	3.63	1.99

*Reference HW-46100 Vol. 2, "Pile Physics Manual of Standard Practices," Chapter on Effective Pile Fractions, page 2102-12-1.

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4. Reactivity Effect of Air Channels in Dry Test Block

The reactivity effect of empty channels in the dry reactor was measured during the supercell test and found to be negative. Previously it had been expected that empty channels in the dry reactor could possibly cause a reactivity increase. This test indicates some total control compensation may be possible for empty channels in the 8-3/8" lattice reactors.

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Worth of Air Channels in the
Dry Supercell Block

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H. TEST J - EFFECT OF FRINGE POISON DISCHARGEINTRODUCTION AND DISCUSSION

In order to use leakage neutrons for isotope production and to reduce shield deterioration because of the heating resulting from high neutron flux in the fringe zones, neutron absorbing material is charged in the outer-most lattice unit of the reactors. The use of such material sharply decreases the effective size and hence the reactivity; to restore adequate operating reactivity, compensating enrichment has been charged in the adjacent (second to fourth) lattice units.

Of particular consequence is the effect of the fringe poison and compensating enrichment loading on nuclear safety.⁴ Therefore the reactivity effect of a fringe poison discharge, leaving uncompensated enrichment in the fringe, was measured during the deactivation test at H Reactor.

The reactivity effect of accidentally charging enriched fuel in place of the fringe poison was also conservatively measured by replacing two of the empty fringe poison tubes with 0.947% enriched fuel following the initial measurement in which all the fringe tubes were empty (but filled with water).

1. Description of Test

The fringe poison discharge and reactivity measurement took place following the discharge of the pile to a minimum critical size. In other words the pile contained fuel as depicted in Figure 1 with approximately 18-1/2 horizontal rows with fuel and all others empty. Therefore only 18 fringe poison columns were discharged (replaced with water), one at the far end of each remaining horizontal row.

After the reactivity change was measured for fringe poison replaced with water, natural uranium fuel was charged into the 18 fringe tubes and another reactivity change was measured. Finally two columns of natural uranium previously charged into the fringe were recharged with 0.947% enriched fuel, and another reactivity measurement was taken.

2. Summary of Test Results

The test results and raw data for the fringe poison discharge are recorded below. Due to the increments of reactivity which were gained following the fuel changes in fringe column 96, it was necessary to compensate these reactivity gains with control rods. Therefore a rod calibration graph is necessary to interpret the data.

The reactivity worth of the horizontal controls in the minimum critical size pile are shown in Figure 2-H and are the results of a brief rod calibration carried out during the small block tests when small increments of enriched fuel were charged at various intervals and reactivity measurements were taken between each charge increment.

⁴HW-68250, Total Control Aspects of Fringe Poison Loadings, AD Vaughn, 1-26-61

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Figure 2-H

Horizontal Control Rod Calibration
(Minimum Critical Size Pile)

<u>Rods and Position</u>	<u>Compensating Reactivity (c-mk)</u>
1&3 @ 150"	53
1&3 In	97
1&3 In, 11&12 @ 150"	138
1,3,11,12 In	160
1,3,11,12 In, 2&10 @ 170"	204
1,3,11,12 In, 2&10 @ 170", 4,5,6,7,8,9 @ 200"	
1,3,11,12 In, 2&10 @ 170", 4,5,6,7,8,9 @ 285"	265
1,3,11,12 In, 2&10 @ 170", 4,5,6,7,8,9 @ 250"	344
1,3,11,12 In, 2&10 @ 170", 4,5,6,7,8,9 @ 220"	434
1,3,11,12 In, 2&10 @ 170", 4,5,6,7,8,9 @ 200"	528
1,3,11,12 In, 2&10 @ 170", 4,6,7,8,9 @ 200", 5 @ 170"	582
1,3,11,12 In, 2&10 @ 170", 4,6,7,8,9 @ 200", 5 @ 140"	680
1,3,11,12 In, 2&10 @ 170", 4,6,7,8,9 @ 200", 5 @ 98"	854
1,3,11,12 In, 2&10 @ 170", 4,6,7,8,9 @ 200", 5 @ 75"	924
1,3, 5,11,12 In, 2&10 @ 170", 4,7,8,9 @ 200", 6 @ 170"	1056
1,3,5,11,12 In, 2,4,10 @ 170", 7,8,9, @ 200", 6 @ 75"	1219
1,3,5,6,11,12 In, 2,4,10 @ 170", 7,8,9, @ 180"	1333

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Figure 3

Fringe Poison Discharge - Test Data and Results

Test No.	Pile Conditions	Controls Inserted	Period		Remarks or Results
			Sec.	c-mk	
J-1	Minimum critical size pile	All rods out	28.9	138	Base reactivity measurement
J-2	Vertical Row 96	HCRs 1&3 @ 150"	17.25	189	HCRs worth 53 c-mk $\Delta\rho = 53 + 51 = 104$
J-3	Vertical row 96 discharged and with coolant	HCRs 1&3, In 11&12, In 2&1- @ 150"	276.86	25	Base reactivity measurement before charging natural-U
J-4	Same as above	Flux traverses			----
J-5	Vertical row 96 charged with natural uranium	HCRs 1&3 In 11&12 In 2&10 @ 170" 4,6,7,8,9 @ 200" 5 @ 75"	22.18	166	HCRs worth 924 c-mk $\Delta\rho = 858$ c-mk
J-6	Same as J-5	Flux traverses			----
J-7	Vertical row 96 charged with natural uranium	HCRs 1,3,11,12 In 4,6,7,8,9 @ 200" 2,10 @ 170" 5 @ 30"	138.91	46	Base reactivity measurement before charging two enriched fuel columns in fringe
J-8	0.947% enriched fuel charged into tubes 2696 and 2596	Same as J-7	34.8	125	Two enriched columns in fringe worth 79 c-mk

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Flux Traverses

Several flux traverses were taken during the fringe poison discharge test to provide material for further evaluation of the test. Near to far side traverses of the flux pattern following the fringe poison discharge, with the discharged tubes containing coolant, are depicted in Figure 4-H. The flux pattern taken after natural uranium was charged into the fringe tubes is shown in Figure 5-H.

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Figure 4-H

Test J-4 - Near to Far Flux Traverse
B Test Hole
Fringe Poison Discharged (Water)

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Figure 5-H
Test J-6 - Near to Far Flux Traverse
B Test Hole
Natural Uranium in Fringe Tubes

I. FLUX TRAVERSE DATA

Flux traverses were taken throughout the testing program and this data is necessary to any further considerations of the test results. The traverses have been analyzed and plotted by a computer code; however, the results are too voluminous for this report document. Therefore the flux traverse data and results have been compiled into a separate document, RL-REA-2704.

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