CRITICAL EXPERIMENTS SUPPORTING CLOSE PROXIMITY WATER STORAGE OF POWER REACTOR FUEL

TECHNICAL PROGRESS REPORT
FOR THE PERIOD
OCTOBER 1, 1978-DECEMBER 31, 1978

M. N. Baldwin
G. S. Hoovler
R. L. Eng
F. G. Welfare

MASTER

March 1979

Work Performed Under Contract EY-77-C-09-1001
Form 189 Number 210.2

THE BABCOCK & WILCOX COMPANY
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LYNCHBURG, VIRGINIA 24505

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THE BABCOCK & WILCOX COMPANY
RESEARCH AND DEVELOPMENT DIVISION
LYNCHBURG RESEARCH CENTER
LYNCHBURG, VIRGINIA

Critical Experiments Supporting Close Proximity
Water Storage of Power Reactor Fuel
Technical Progress Report

By: M. N. Baldwin, G. S. Hoovler
R. L. Eng, F. G. Welfare

ABSTRACT

Experimental measurements are being taken on critical configurations of clusters of fuel rods mocking up LWR-type fuel elements in close proximity water storage. The results will serve to benchmark the computer codes used in designing nuclear power reactor fuel storage racks.

Lynchburg Research Center Report BAW-1484-5
March 1979
Critical Experiment, Power Reactor Fuel
Storage, Benchmark Experiments

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1. INTRODUCTION

In July 1977, the Babcock & Wilcox Company (B&W) was awarded a contract by the U. S. Department of Energy (DOE) to conduct critical experiments supporting close proximity water storage of nuclear power reactor fuel. The need for this program resulted from delays in the nuclear fuel reprocessing capability in the United States. These delays have greatly increased the amount of fuel requiring storage and have placed a premium on the optimum use of storage capacity.

Experimental measurements are being taken on critical configurations of fuel rod clusters, mocking up LWR-type fuel elements in close proximity water storage. The square clusters with 14 rods on each side are arranged in 3 by 3 arrays. Both the spacing between the fuel clusters and the intervening materials are being varied to provide a variety of benchmark loadings.

The KENO IV and PDQ07 (in selected cases) codes are being used to analyze each benchmark loading to determine the calculated k_{eff} of each configuration.

In the first part of the program, the clusters were separated by water only or by water and B_4C -filled pins. Large top and bottom grid plates held the fuel rods and B_4C pins in place. These measurements established nine benchmark cores. Although these measurements were completed during a previous quarter, some of the calculational analysis is reported here.

In the second part of the experimental program, the nine clusters are being separated by water only, by water and stainless steel sheets, and by water and borated aluminum sheets. These measurements are in progress.

Quarterly reports are being issued during the experimental measurement portion of the contract. This report is the fifth in the quarterly series. Work performed during the previous quarters is reported in references 1 through 4.

2. DESCRIPTION OF CRITICAL FACILITY

2.1. Facility

The facility, located at B&W's Lynchburg Research Center, is a critical assembly within a core tank 152.4-cm in diameter by 198-cm high having aluminum walls 1.27-cm thick. The facility is further described in reference 1.

2.2. Fuel Rods

The fuel rods are 1.206-cm in outside diameter (OD) and 154.4-cm long. The type 6061 cladding is 0.081-cm thick and the UO_2 fuel is enriched to 2.46 wt % ^{235}U . The fuel is further described in reference 1.

2.3. B_4C Pins

The B_4C pins are aluminum tubes, 1.113-cm in OD by 0.089-cm thick, filled with natural B_4C powder ranging from 30 to 50 mesh. The pins are further described in reference 2.

2.4. Unit Assemblies

The unit assemblies are 14 by 14 rod assemblies that can be moved as units; each has its own top, center, and bottom grid plates. Fuel rods occupy 192 of the rod positions and threaded aluminum rods occupy the corner positions. The lower ends of the threaded rods have fittings which fit into a large bottom grid for alignment. The unit assemblies are further described in references 3 and 4.

2.5. Stainless Steel Sheets

Four identical type 304 stainless steel sheets were fabricated to isolate the nine unit assemblies from one another. These sheets assemble in "egg-crate" fashion and are further described in reference 4.

2.6. Borated Aluminum Sheets

Twenty lightly borated aluminum sheets were custom-made for these critical experiments by Kawecki Berylco Industries Incorporated (KBI). The alloy is

similar to KBI's 4 wt % boron nuclear grade product, except that the boron content was reduced for our application. Five sets of the boron aluminum alloy sheets were fabricated. Each set consists of four sheets and each set has a different boron loading.

Each sheet is 91.6-cm wide by 156-cm high and is approximately 0.64-cm thick. Two slots, 0.711 ± 0.013 cm wide and extending 78 cm up each sheet, are centered 12.18 cm on each side of the vertical centerline so that the four sheets may be assembled in "egg-crate" fashion.

The nominal boron content of each set is given in Table 1. These values are not final, however, and may be refined.

Table 1. Nominal Boron Concentration
of Borated Aluminum Sheets

<u>Set number</u>	<u>Boron content (wt % of natural boron)</u>
1	0.11
2	0.25
3	0.44
4	1.26
5	1.55

3. DESCRIPTION OF LYNCHBURG POOL REACTOR

A neutron beam extracted from the LPR is being used to evaluate the uniformity of the boron throughout the borated aluminum sheets. Figure 1 is a vertical view of the Lynchburg Pool Reactor (LPR).

The pool is 13 feet long, 7 feet wide, and 18 feet deep. The poured concrete walls range from 6 to 8 feet thick at the basement (core) level and are 6 feet thick at the first floor level. The water level is about 13 feet above the top of the core. A storage pit at one end of the pool is 2.5 feet wide and extends 5.5 feet below the bottom level of the pool.

In its present application the core, consisting of 16 MTR type fuel elements, is loaded on grid No. 2. A 4-inch ID void aluminum pipe extends from about mid-core height to a work surface above the surface of the water. A 2-inch diameter BF_3 proportional detector is positioned above the work surface in line with the neutron beam emanating from the aluminum pipe.

Figure 1. Lynchburg Pool Reactor

4. MEASUREMENTS

During the quarter, neutron transmission measurements were made on four of the five sets of borated aluminum sheets. These measurements were made using the LPR as a source of neutrons as shown in Figure 1. With the core operating at 5 kW and a borated sheet in place on the work surface, neutron counts were taken at 15 uniformly spaced locations on each borated sheet. This data is being used to evaluate the uniformity of the boron loading throughout each sheet.

Also during the quarter, two benchmark cores were established. Both are represented by Figure 2, since only the concentration of the boron in the isolation sheets was different. A summary of the benchmark cores studied during the quarter is given in Table 2. Since the moderator samples have not yet been analyzed for boron content, the moderator boron concentrations listed are preliminary.

Table 2. Core Loadings Established During Quarter

<u>Core.</u>	<u>Run</u>	<u>Spacing betw ass'ys pin pitches</u>	<u>Boron content of metal separating unit assemblies wt %</u>	<u>Moder temp, C</u>	<u>Preliminary moderator boron conc, ppm</u>	<u>Critical moder ht, cm (± 0.2)</u>	<u>Super- critical moder ht, cm (± 0.2)</u>	<u>Doubling time, s</u>
XIII	2378	1	1.55	20	19	150.27	155.54	59.5
XIV	2384	1	1.26	18	92	149.12	153.40	72.0

Figure 2. Loading Diagram for Cores XIII and XIV

- Fuel Rod Position
- Threaded Aluminum Rod
- Isolation Sheet

5. ANALYSIS

The results of the KENO calculations of cores VII through IX are tabulated in Table 3, together with those of cores I through VI reported previously. As a group, the KENO calculated values very closely reproduce the experimental values. The difference between the two mean values is 0.0005. The average absolute difference is 0.0059 which is approximately equal to one standard deviation in the KENO results. The differences for the nine cores are evenly distributed between zero and plus and minus two sigma. Statistically, the KENO model seems to accurately calculate criticality for this type of fuel arrangement.

A PDQ calculation of core IX also yielded a value close to experimental, 1.0103 versus 1.0028. The PDQ model used homogenized cross sections generated by NULIF.⁵ Sensitivity studies showed the PDQ model to be insensitive to a reflected water layer greater than 11 cm. Hence, the fuel assemblies were surrounded by only 11 cm of water (in the PDQ model). The optimum interval sizes were found to be 0.818 cm for the water, and 3.274 cm for the fuel composition. In the vertical direction, material above the water level was ignored. Material below the fuel was mostly aluminum. A single homogenized material (0.8244 Al + 0.1756 H₂O) was substituted for the actual material below the fuel. A copy of the PDQ run is provided in the appendix.

Table 3. Comparison of KENO-Calculated k_{eff} Values

<u>Cores</u>	<u>Calculated</u>	<u>Experimental</u>	<u>Difference</u>
I	1.006	1.0002	0.0058
II	1.006	1.0001	0.0059
III	1.000	1.0000	0.0
IV	1.010	0.9999	0.0101
V	1.003	1.0000	0.003
VI	1.006	1.0098	-0.0032
VII	0.988	0.9998	-0.0118
VIII	1.003	1.0078	-0.0048
IX	0.994	1.0028	-0.0088
Mean values	1.0018	1.0023	0.0059

Difference in means -0.0005.

REFERENCES

- ¹ M. N. Baldwin and G. S. Hoovler, Critical Experiments Supporting Close Proximity Storage of Power Reactor Fuel — Technical Progress Report For Period October 1-December 31, 1977, BAW-1484-1, Babcock & Wilcox, Lynchburg, Virginia, March 1978.
- ² M. N. Baldwin and G. S. Hoovler, Critical Experiments Supporting Close Proximity Storage of Power Reactor Fuel — Technical Progress Report For Period January 1-March 31, 1978, BAW-1484-2, Babcock & Wilcox, Lynchburg, Virginia.
- ³ M. N. Baldwin, G. S. Hoovler, R. L. Eng, and F. G. Welfare, Critical Experiments Supporting Close Proximity Storage of Power Reactor Fuel — Technical Progress Report For Period April 1-June 30, 1978, BAW-1484-3, Babcock & Wilcox, Lynchburg, Virginia, September 1978.
- ⁴ M. N. Baldwin, G. S. Hoovler, R. L. Eng, and F. G. Welfare, Critical Experiments Supporting Close Proximity Storage of Power Reactor Fuel — Technical Progress Report For Period July 1-September 30, 1978, BAW-1484-4, Babcock & Wilcox, Lynchburg, Virginia, November 1978.
- ⁵ W. A. Wittkopf, et al., Fuel Utilization and Performance Analysis Code (FUPAC) System, BAW-426, Babcock & Wilcox, Lynchburg, Virginia, August 1976.

APPENDIX
PDQ Input and Output
for Core IX

LISTING OF INPUT DATA FOR CASE 1	
1	GENERAL 010001.2.0.2.1.2.1.05.05.04.2.33.33.14.0.0.0.0
2	015001.0.-2
3	015011.2.-14
4	060001.2.14
5	010024.2
6	070001.46036+1.2.12075-2.14
7	BOUNDARY 010002.1.0.1.0.0.0
8	EIGENVAL 010003.1+1.1-2
9	010004.1+1.0+0
10	010029.TESICAS
11	010021.NRCRITICAL
12	010022.0.0
13	030001.01.1.05
14	030021.01.3.02.03.1.03.04.4.04.05.2.05
15	012001.05.0.1.-5
16	013001.01.-05.0.1
17	014001.05.0.5
18	110001.1.1.2.2.3.3.4.4
19	010009.0.1
20	MESH XY 050101.3272+1.3.1636+1.4
21	MESH XY 050201.1636+1.1.3272+1.7.1636+1.8
22	MESH XY 050301.818+0.8
23	MESH XY 050401.812+0.13
24	GRID 801000.33.33.01.03.02.04.0.01.03.02.04
25	BASEPLAT 801001.01.0.33.0.33
26	802000.4.4.01.0.01
27	802001.04.0.4.0.4
28	803000.4.4.02.0.02
29	803001.04.0.4.0.8
30	804000.4.4.01.0.02
31	804001.04.0.4.0.8
32	170001.01.010.0.0.0.0
33	170002.02.020.0.0.0.0
34	170003.03.030.12.12.0.0
35	170004.04.040.0.12.0.0
36	170005.05.040.20.0.1.0
37	401000.1
38	401001.ALUMINUM (.4244 V/O)
39	401100.19746+1.42238-3.10789-1
40	401200.80901+0.12233-1.0.0
41	402000.2
42	402001.HOMOGENIZED FUEL -EXTERIOR FUEL
43	402100.12556+1.93566-2.28089-1.65362-2.81273-13
44	402200.26344+0.96477-1.0+0.15075+0.20007-11
45	403000.3
46	403001.WATER
47	403100.12961+1.43037-3.50919-1
48	404200.15402+0.18747-1.0+0
49	404000.4
50	404001.HOMOGENIZED FUEL -INTERIOR FUEL
51	404100.12454+1.89400-2.25926-1.62514-2.78127-13
52	404200.31919+0.81952-1.0+0.12753+0.16925-11

=PDQ7 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL, 4 PIN PITCH SPACEPDQ7 VER7 PDQTHF 10/24/78 09.00.50

PROBLEM TYPE - EIGENVALUE

ADJOINT - NO

TOTAL GROUPS - 2

THERMAL GROUPS - 1

DEPLETION - BLOCK

GEOMETRY - RECTANGULAR

LARGEST FINAL FIGURE - 5

LARGEST PLANAR REGION - 5

LARGEST COMPOSITION - 4

COMPOSITION CORRESPONDENCE - REGION

COLUMN BOUNDARY - 33

ROW BOUNDARY - 33

PLANE BOUNDARY - 14

MESH INTERVALS - CENTIMETERS

COLUMN 0 BOUNDARY CONDITION - ZERO CURRENT

COLUMN 33 BOUNDARY CONDITION - ZERO FLUX

ROW 0 BOUNDARY CONDITION - ZERO CURRENT

ROW 33 BOUNDARY CONDITION - ZERO FLUX

PLANE 0 BOUNDARY CONDITION - ZERO FLUX

PLANE 14 BOUNDARY CONDITION - ZERO FLUX

INPUT EIGENVALUE - 100000+01

CONVERGENCE PARAMETER - 100000-02

JOB LABEL - TESTCAS

CHI VALUES - 100000+01 0

=PDQ7 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL, 4 PIN PITCH SPACE PDQ7 VER7 PDQTHF 10/24/78 09.00.50

BASIC FIGURE 1

INTERVAL	COL	INTERVAL	COL	INTERVAL	COL	INTERVAL	COL	INTERVAL	COL	INTERVAL	COL
3272000+01	3	1636000+01	4	8180000+00	12	1636000+01	13	3272000+01	19	1636000+01	20
8180000+00	33										
INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW
3272000+01	3	1636000+01	4	8180000+00	12	1636000+01	13	3272000+01	19	1636000+01	20
8180000+00	33										

BASIC FIGURE 2

INTERVAL	COL	INTERVAL	COL
3272000+01	3	1636000+01	4
INTERVAL	ROW	INTERVAL	ROW
3272000+01	3	1636000+01	4

BASIC FIGURE 3

INTERVAL	COL	INTERVAL	COL	INTERVAL	COL
1636000+01	1	3272000+01	7	1636000+01	8
INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW
1636000+01	1	3272000+01	7	1636000+01	8

BASIC FIGURE 4

INTERVAL	COL	INTERVAL	COL		
3272000+01	3	1636000+01	4		
INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW
1636000+01	1	3272000+01	7	1636000+01	8

=PDQ7 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL, 4 PIN PITCH SPACEPDQ7 VER7 PDQTHF 10/24/78 09.00.50

FINAL FIG	INITIAL FIG	COL	ROW	ANGLE	REFLECTED
1	10	0	0	0	NO
2	20	0	0	0	NO
3	30	12	12	0	NO
4	40	0	12	0	NO
5	40	20	0	90	NO

MESH INTERVALS FOR ENTIRE PROBLEM

INTERVAL	COL	INTERVAL	COL	INTERVAL	COL	INTERVAL	COL	INTERVAL	COL	INTERVAL	COL
3272000+01	3	1636000+01	4	8180000+00	12	1636000+01	13	3272000+01	19	1636000+01	20
8180000+00	33										

INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW
3272000+01	3	1636000+01	4	8180000+00	12	1636000+01	13	3272000+01	19	1636000+01	20
8180000+00	33										

ACCUMULATED MESH INTERVALS

DISTANCE	COL	DISTANCE	COL	DISTANCE	COL	DISTANCE	COL	DISTANCE	COL	DISTANCE	COL
3272000+01	1	6544000+01	2	9816000+01	3	1145200+02	4	1227000+02	5	1308800+02	6
1390600+02	7	1472400+02	8	1554200+02	9	1636000+02	10	1717800+02	11	1799600+02	12
1963200+02	13	2290400+02	14	2617600+02	15	2944800+02	16	3272000+02	17	3599200+02	18
3926400+02	19	4090000+02	20	4171800+02	21	4253600+02	22	4335400+02	23	4417200+02	24
4499000+02	25	4580800+02	26	4662600+02	27	4744400+02	28	4826200+02	29	4908000+02	30
4989800+02	31	5071600+02	32	5153400+02	33						

DISTANCE	ROW	DISTANCE	ROW	DISTANCE	ROW	DISTANCE	ROW	DISTANCE	ROW	DISTANCE	ROW
3272000+01	1	6544000+01	2	9816000+01	3	1145200+02	4	1227000+02	5	1308800+02	6
1390600+02	7	1472400+02	8	1554200+02	9	1636000+02	10	1717800+02	11	1799600+02	12
1963200+02	13	2290400+02	14	2617600+02	15	2944800+02	16	3272000+02	17	3599200+02	18
3926400+02	19	4090000+02	20	4171800+02	21	4253600+02	22	4335400+02	23	4417200+02	24
4499000+02	25	4580800+02	26	4662600+02	27	4744400+02	28	4826200+02	29	4908000+02	30
4989800+02	31	5071600+02	32	5153400+02	33						

INTERVAL	PLANE	INTERVAL	PLANE
4603600+01	2	1207500+02	14

=PDQ7 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL, 4 PIN PITCH SPACE PDQ7 VER7 PDQTHF 10/24/78 09.00.50

ACCUMULATED MESH INTERVALS

DISTANCE	PLANE	DISTANCE	PLANE	DISTANCE	PLANE	DISTANCE	PLANE	DISTANCE	PLANE	DISTANCE	PLANE
4603600+01	1	9207200+01	2	2128220+02	3	3335720+02	4	4543220+02	5	5750720+02	6
6958220+02	7	8165720+02	8	9373220+02	9	1058072+03	10	1178822+03	11	1299572+03	12
1420322+03	13	1541072+03	14								

AREA OF PLANAR REGIONS 1 - 5

1475418+04	0	0	1180335+04	0
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FINAL FIGURE OVERLAY

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026	*			*				*				*				

FINAL FIGURE OVERLAY

030	032
000	*****
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002	001 001 001*
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004	001 001 001*
	*
	001 001 001*
	*
006	001 001 001*
	*
	001 001 001*
	*
008	001 001 001*
	*
	001 001 001*
	*
010	001 001 001*
	*
	001 001 001*
	*
012	001 001 001*
	*
	001 001 001*
	*
014	001 001 001*
	*
	001 001 001*
	*
016	001 001 001*
	*
	001 001 001*
	*
018	001 001 001*
	*
	001 001 001*
	*
020	001 001 001*
	*
	001 001 001*
	*
022	001 001 001*
	*
	001 001 001*
	*
024	001 001 001*
	*
	001 001 001*
	*
026	001 001 001*
	*

=PDQ7 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL , 4 PIN PITCH SPACE PDQ7 VER7 PDQTHF 10/24/78 09.00.50

FINAL FIGURE OVERLAY

030	032	*
026	001 001 001	*
	001 001 001	*
028	001 001 001	*
	001 001 001	*
030	001 001 001	*
	001 001 001	*
032	001 001 001	*
	001 001 001	*

=PDQ7 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL, 4 PIN PITCH SPACEPDQ7 VER7 PDQTHF 10/24/78 09.00.50

AXIAL BOUNDARIES

2 14

COMPOSITION NUMBERS OF REGIONS 1 - 5

PLANES 0 - 2

1 1 1 1 1

PLANES 2 - 14

3 3 1 4 2

ERROR ON CARD 010024 --- COMPOSITION PICTURE EDIT BYPASSED

EDIT SET 1 FIGURES 5

REGIONS 1 2 3 4 5

EDIT SET 2 FIGURES 1 2 3 4 5

REGIONS 1

EDIT SET 3 FIGURES 5

REGIONS 5

PLANE GROUPING 1 PLANES 0 - 2

PLANE GROUPING 2 PLANES 2 - 14

IDENTIFICATION OF TABLE SETS USED.

- 1 ALUMINUM (0.8244 V/O)
- 2 HOMOGENIZED FUEL - EXTERIOR FUEL
- 3 WATER
- 4 HOMOGENIZED FUEL - INTERIOR FUEL

COMP. TABLE SET AREA RATIO

1	1	100000000+01
2	2	100000000+01
3	3	100000000+01
4	4	100000000+01

=PDQ7 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL, 4 PIN PITCH SPACEPDQ7 VER7 PDQTHF 10/24/78 09.00.50

GROUP 1.	PASS 1.	RHO = 9415213+00.	OMEGA(6) = 1610535+01.	SIGMA = 8668180+00.	DELTA(10) = 1000000+00
GROUP 1.	PASS 2.	RHO = 9454141+00.	OMEGA(12) = 1622634+01.	SIGMA = 9459401+00.	DELTA(10) = 1000000+00
GROUP 1.	PASS 3.	RHO = 9469639+00.	OMEGA(18) = 1625626+01.	SIGMA = 9594551+00.	DELTA(10) = 1000000+00
GROUP 1.	PASS 4.	RHO = 9527446+00.	OMEGA(24) = 1642868+01.	SIGMA = 9696893+00.	DELTA(11) = 1000000+00
GROUP 2.	PASS 1.	RHO = 8891018+00.	OMEGA(6) = 1500360+01.	SIGMA = 9000000+00.	DELTA(6) = 1000000+00
GROUP 2.	PASS 2.	RHO = 9013434+00.	OMEGA(12) = 1521958+01.	SIGMA = 9995000+00.	DELTA(7) = 1000000+00
GROUP 2.	PASS 3.	RHO = 9102505+00.	OMEGA(18) = 1538956+01.	SIGMA = 9959148+00.	DELTA(7) = 1000000+00
GROUP 2.	PASS 4.	RHO = 9246986+00.	OMEGA(24) = 1569352+01.	SIGMA = 9797320+00.	DELTA(8) = 1000000+00
GROUP 1	IT. = 12	R(1) = 3634154+03	DELTA = 8983535-02	PASSES = 3	
GROUP 2	IT. = 9	R(1) = 1631564+03	DELTA = 1336472-01	PASSES = 3	
SIG/I = 0		MAX. = 2867047+01	GAMMA = 1876952+01	RATIO(0) = 1000000+01	
SIG/O = 0		MIN. = 3261871+00	PT/AV = 2871833+01	EPS.(1) = 2002731+01	LAMBDA = 954813231+00
GROUP 1	IT. = 12	R(1) = 4213335+02	DELTA = 1678174-01	PASSES = 3	
GROUP 2	IT. = 9	R(1) = 3016624+02	DELTA = 1343460-01	PASSES = 3	
SIG/I = 1299620+00		MAX. = 1180935+01	GAMMA = 1029531+01	RATIO(0) = 1000000+01	
SIG/O = 1999067+00		MIN. = 5152510+00	PT/AV = 4722249+01	EPS.(2) = 4758435+00	LAMBDA = 983009864+00
GROUP 1	IT. = 12	R(1) = 2586176+02	DELTA = 1497885-01	PASSES = 3	
GROUP 2	IT. = 9	R(1) = 1886034+02	DELTA = 1163159-01	PASSES = 3	
SIG/I = 6176965+00		MAX. = 1099680+01	GAMMA = 1010156+01	RATIO(0) = 1000000+01	
SIG/O = 6496868+00		MIN. = 6626148+00	PT/AV = 5172214+01	EPS.(3) = 3327096+00	LAMBDA = 992993266+00
GROUP 1	IT. = 12	R(1) = 1917518+02	DELTA = 1388606-01	PASSES = 3	
GROUP 2	IT. = 9	R(1) = 1419129+02	DELTA = 1037349-01	PASSES = 3	
SIG/I = 7452837+00		MAX. = 1076735+01	GAMMA = 1005132+01	RATIO(1) = 1000000+01	
SIG/O = 7586104+00		MIN. = 7747119+00	PT/AV = 4615950+01	EPS.(4) = 2238050+00	LAMBDA = 998089274+00
GROUP 1	IT. = 12	R(1) = 1380984+02	DELTA = 1327205-01	PASSES = 3	
GROUP 2	IT. = 9	R(1) = 1038521+02	DELTA = 9374471-02	PASSES = 3	
SIG/I = 8132676+00		MAX. = 1070361+01	GAMMA = 1004622+01	RATIO(2) = 6837726+00	
SIG/O = 8217330+00		MIN. = 8805630+00	PT/AV = 3433414+01	EPS.(5) = 1218106+00	LAMBDA = 100270284+01
GROUP 1	IT. = 12	R(1) = 9259546+01	DELTA = 1277975-01	PASSES = 3	
GROUP 2	IT. = 9	R(1) = 6952789+01	DELTA = 8830553-02	PASSES = 3	
SIG/I = 8409731+00		MAX. = 1057364+01	GAMMA = 1003930+01	RATIO(3) = 4220809+00	
SIG/O = 8453776+00		MIN. = 9465332+00	PT/AV = 2516279+01	EPS.(6) = 5962006-01	LAMBDA = 100654337+01
GROUP 1	IT. = 12	R(1) = 6598368+01	DELTA = 1318649-01	PASSES = 3	
GROUP 2	IT. = 9	R(1) = 5028905+01	DELTA = 9010881-02	PASSES = 3	
SIG/I = 8507284+00		MAX. = 1043005+01	GAMMA = 1001722+01	RATIO(1) = 3218217+00	
SIG/O = 8538391+00		MIN. = 9668367+00	PT/AV = 2432782+01	EPS.(7) = 4110520-01	LAMBDA = 100827613+01
GROUP 1	IT. = 12	R(1) = 5231928+01	DELTA = 1355346-01	PASSES = 3	
GROUP 2	IT. = 9	R(1) = 4039651+01	DELTA = 9143739-02	PASSES = 3	
SIG/I = 8730364+00		MAX. = 1034965+01	GAMMA = 1000710+01	RATIO(2) = 8320665+00	

=P007 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL, 4 PIN PITCH SPACEP007 VER7 PDQTHF 10/24/78 09.00.50

SIG/O	= 8731109+00	MIN.	= 9694174+00	PT/AV	= 2919513+01	FPS.(8)	= 3922172-01	LAMBDA	= 100899180+01
GROUP 1	IT. = 12	R(1)	= 3283914+01	DELTA	= 1462462-01	PASSES	= 3		
GROUP 2	IT. = 9	R(1)	= 2603379+01	DELTA	= 9378456-02	PASSES	= 3		
SIG/I	= 8783537+00	MAX.	= 1025545+01	GAMMA	= 1000760+01	RATIO(3)	= 7299303+00		
SIG/O	= 8783281+00	MIN.	= 9789721+00	PT/AV	= 3592891+01	EPS.(9)	= 3048922-01	LAMBDA	= 100975890+01
GROUP 1	IT. = 12	R(1)	= 2070448+01	DELTA	= 1525995-01	PASSES	= 3		
GROUP 2	IT. = 9	R(1)	= 1671223+01	DELTA	= 9515407-02	PASSES	= 3		
SIG/I	= 8820538+00	MAX.	= 1019355+01	GAMMA	= 1000312+01	RATIO(1)	= 6152375+00		
SIG/O	= 8820282+00	MIN.	= 9925631+00	PT/AV	= 3226475+01	EPS.(10)	= 1733627-01	LAMBDA	= 101007402+01
GROUP 1	IT. = 12	R(1)	= 1701205+01	DELTA	= 1536305-01	PASSES	= 3		
GROUP 2	IT. = 9	R(1)	= 1377025+01	DELTA	= 9550311-02	PASSES	= 3		
SIG/I	= 8919495+00	MAX.	= 1017291+01	GAMMA	= 1000076+01	RATIO(2)	= 9073158+00		
SIG/O	= 8920680+00	MIN.	= 9966080+00	PT/AV	= 13033707+01	EPS.(11)	= 1340623-01	LAMBDA	= 101015031+01
GROUP 1	IT. = 12	R(1)	= 1091957+01	DELTA	= 1569147-01	PASSES	= 3		
GROUP 2	IT. = 9	R(1)	= 8905948+00	DELTA	= 9618769-02	PASSES	= 3		
SIG/I	= 8941214+00	MAX.	= 1014355+01	GAMMA	= 1000089+01	RATIO(3)	= 8546107+00		
SIG/O	= 8941480+00	MIN.	= 1002347+01	PT/AV	= 2747613+01	EPS.(12)	= 7812747-02	LAMBDA	= 101024012+01
GROUP 1	IT. = 12	R(1)	= 6631913+00	DELTA	= 1594128-01	PASSES	= 3		
GROUP 2	IT. = 9	R(1)	= 5441601+00	DELTA	= 9666768-02	PASSES	= 3		
SIG/I	= 8957526+00	MAX.	= 1012359+01	GAMMA	= 1000042+01	RATIO(4)	= 7840891+00		
SIG/O	= 8957691+00	MIN.	= 1005446+01	PT/AV	= 2766763+01	EPS.(13)	= 4787922-02	LAMBDA	= 101028277+01
GROUP 1	IT. = 12	R(1)	= 4122109+00	DELTA	= 1599394-01	PASSES	= 3		
GROUP 2	IT. = 9	R(1)	= 3385396+00	DELTA	= 9681817-02	PASSES	= 3		
SIG/I	= 8970758+00	MAX.	= 1011438+01	GAMMA	= 1000017+01	RATIO(5)	= 7118440+00		
SIG/O	= 8970944+00	MIN.	= 1007091+01	PT/AV	= 2951754+01	EPS.(14)	= 3176050-02	LAMBDA	= 101029987+01
GROUP 1	IT. = 12	R(1)	= 2633718+00	DELTA	= 1596267-01	PASSES	= 3		
GROUP 2	IT. = 9	R(1)	= 2161124+00	DELTA	= 9669986-02	PASSES	= 3		
SIG/I	= 8979639+00	MAX.	= 1011122+01	GAMMA	= 1000006+01	RATIO(1)	= 6624886+00		
SIG/O	= 8979790+00	MIN.	= 1008226+01	PT/AV	= 2996072+01	EPS.(15)	= 2058896-02	LAMBDA	= 101030569+01
GROUP 1	IT. = 12	R(1)	= 2193190+00	DELTA	= 1596893-01	PASSES	= 3		
GROUP 2	IT. = 9	R(1)	= 1801309+00	DELTA	= 9669250-02	PASSES	= 3		
SIG/I	= 8996573+00	MAX.	= 1010988+01	GAMMA	= 1000002+01	RATIO(2)	= 9817906+00		
SIG/O	= 8996716+00	MIN.	= 1008575+01	PT/AV	= 2996453+01	EPS.(16)	= 1715271-02	LAMBDA	= 101030752+01
GROUP 1	IT. = 12	R(1)	= 1405836+00	DELTA	= 1597338-01	PASSES	= 3		
GROUP 2	IT. = 9	R(1)	= 1156094+00	DELTA	= 9650822-02	PASSES	= 3		
SIG/I	= 8999470+00	MAX.	= 1010745+01	GAMMA	= 1000002+01	RATIO(3)	= 9728114+00		
SIG/O	= 8999063+00	MIN.	= 1009203+01	PT/AV	= 2984700+01	EPS.(17)	= 1095424-02	LAMBDA	= 101030950+01
GROUP 1	IT. = 12	R(1)	= 8110322+01	DELTA	= 1596630-01	PASSES	= 3		
GROUP 2	IT. = 9	R(1)	= 6676176+01	DELTA	= 9617018-02	PASSES	= 3		

=PD07 TEST CASE. NRC CRITICAL. 17.5C. 3 D MODEL 4 PIN PITCH SPACE PD07 VER7 PDQTHF 10/24/78 09.00.50

SIG/I = 9002268+00	MAX. = 1010537+01	GAMMA = 1000001+01	RATIO(4) = 9574315+00	
SIG/O = 9002165+00	MIN. = 1009664+01	PT/AV = 3023639+01	EPS.(18) = 6405389-03	LAMBDA = 101031070+01

AFTER 18 OUTER ITERATIONS, EIGENVALUE = 101031070+01. REACTIVITY (PERCENTAGE) = 102054748+01

=PDQ7 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL , 4 PIN PITCH SPACEPDQ7 VER7 PDQTHF 10/24/78 09.00.50

INTEGRATION EDITS

FLUX NORMALIZATION = 655617449+12
POWER NORMALIZATION = 655617449+12

FLUX INTEGRALS FOLLOWED BY FLUX AVERAGES

PLANE GROUPING 1

EDIT SET	VOLUME	GROUP 1	2
1	241501733+04	233508355+15 966901363+11	119459988+15 494654786+11
2	135844725+05	492417523+15 362485569+11	479571353+15 353029059+11

=PDQ7 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL, 4 PIN PITCH SPACE PDQ7 VEN7 PDQTHF 10/24/78 09.00.50

INTEGRATED POWER EDIT

PLANE GROUPING 1

POWER FRACTION		GROUP FRACTION OF EDIT-SET POWER	
EDIT	FOLLOWED BY		
SET	REL. PWR. DEN. GROUP 1	2	

=PDQ7 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL , 4 PIN PITCH SPACE PDQ7 VER7 PDQTHF 10/24/78 09.00.50

INTEGRATED ABSORPTION EDIT

PLANE GROUPING 1

GROUP FRACTION OF TOTAL ABSORPTION FOLLOWED BY GROUP FRACTION OF EDIT-SET ABSORPTION

EDIT SET	ABSORP. FRACT.	GROUP 1	2
1	128329748-03	811359197-05 632245610-01	120216156-03 936775439+00
2	499716756-03	171097727-04 342389412-01	482606984-03 965761059+00

=PDQ7 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL, 4 PIN PITCH SPACE PDQ7 VERT PDQTHF 10/24/78 09.00.50

TOTAL GROUP-INDEPENDENT BUCKLING, K INFINITY, AND K EFFECTIVE EDITS

PLANF GROUPING 1

K INFINITY FOLLOWED BY K EFFECTIVE

EDIT

SET

GP. IND. BUCK.

SUM

GROUP 1

2

=PDQ7 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL, 4 PIN PITCH SPACEPDQ7 VER7 PDQTHF 10/24/78 09.00.50

FLUX-WEIGHTED AVERAGE MACROSCOPIC DATA

PLANE GROUPING 1

GROUP 1

EDIT SET	D	SIGMA A	SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	19746000+01	42238000-03	10789000-01	0	0	-56777980-02
2	19746000+01	42238000-03	10789000-01	0	0	-56777980-02

FLUX-WEIGHTED AVERAGE MACROSCOPIC DATA

PLANE GROUPING 1

GROUP 2

EDIT SET	D	SIGMA A	SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	80901000+00	12233000-01	0	0	0	10947023-01
2	80901000+00	12233000-01	0	0	0	-14276677-02

=PDQ7 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL, 4 PIN PITCH SPACEPDQ7 VER7 PDQTHF 10/24/78 09.00.50

INTEGRATION EDITS

FLUX NORMALIZATION = 655617449+12
POWER NORMALIZATION = 655617449+12

FLUX INTEGRALS FOLLOWED BY FLUX AVERAGES.

PLANE GROUPING 2

EDIT SET	VOLUME	GROUP 1	2
1	340067785+05	531250564+17 139777847+13	224675904+17 591146929+12
2	213788129+06	932400544+17 436132983+12	144624610+18 676485689+12

=PDQ7 TEST CASE. NRC CRITICAL. 17.5C, 3 D MODEL . 4 PIN PITCH SPACEPDQ7 VER7 PDQTHF 10/24/78 09.00.50

INTEGRATED POWER EDIT

PLANE GROUPING 2

POWER FRACTION		GROUP FRACTION OF EDIT-SET POWER	
EDIT	FOLLOWED BY		
SET	REL. PWR. DEN.	GROUP 1	2

1	246604537+00	984069834-01	901593017+00
	110972042+01		

=PD07 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL, 4 PIN PITCH SPACE PD07 VER7 PDQTHF 10/24/78 09.00.50

INTEGRATED ABSORPTION EDIT

PLANE GROUPING 2

GROUP FRACTION OF TOTAL ABSORPTION FOLLOWED BY GROUP FRACTION OF EDIT-SET ABSORPTION

EDIT SET	ABSORP. FRACT.	GROUP 1	2
1	190538974+00	390700817-01 205050342+00	151468892+00 794949658+00
2	226340338+00	330104847-02 145844462-01	223039290+00 985415554+00

=PDQ7 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL, 4 PIN PITCH SPACE PDQ7 VER7 PDQTHF 10/24/76 09.00.50

TOTAL GROUP-INDEPENDENT BUCKLING, K INFINITY, AND K EFFECTIVE EDITS

PLANE GROUPING 2

K INFINITY FOLLOWED BY K EFFECTIVE

EDIT SET	GP. IND. BUCK.	SUM	GROUP 1	2
1	806040309-02	133643865+01	179297883+00	115714077+01
		101031070+01	104938531+00	905372170+00

=PD07 TEST CASE, NRC CRITICAL, 17.5C, 3 D MODEL, 4 PIN PITCH SPACE PD07-VER7 PDQTHF 10/24/78 09.00.50

FLUX-WEIGHTED AVERAGE MACROSCOPIC DATA

PLANE GROUPING 2

GROUP 1

EDIT SET	D	SIGMA A	SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	12455000+01	89400000-02	25926000-01	62514000-02	78127000-13	19836225-01
2	12961000+01	43037000-03	50919000-01	0	0	-39618370-01

FLUX-WEIGHTED AVERAGE MACROSCOPIC DATA

PLANE GROUPING 2

GROUP 2

EDIT SET	D	SIGMA A	SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	31919000+00	81952000-01	0	12753000+00	16925000-11	-64693337-01
2	15402000+00	16747000-01	0	0	0	91421111-01

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