UNCLASSIFIED

X-821

OAK RIDGE NATIONAL LABORATORY
Operated By
UNION CARBIDE NUCLEAR COMPANY

POST OFFICE BOX P
OAK RIDGE, TENNESSEE

External Transmittal
Authorized

ORNL
CENTRAL FILES NUMBER

57-11-30

COPY NO. 63

DATE: November 28, 1957
SUBJECT: POWER CALIBRATION FOR BSR LOADING 33
FROM: E. B. Johnson

NOTICE

This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and, therefore, does not represent a final report.

UNCLASSIFIED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

UNCLASSIFIED

POWER CALIBRATION FOR BSR LOADING 33

E. B. Johnson

BSR Loading 33 consists of an essentially 5 by 6 fuel element array completely reflected by water. It was controlled by means of two boron carbide shim-safety rods and a type 347 stainless steel regulating rod with an 87-mil wall, located as shown in Fig. 1. The critical mass was about 3.4 kg of U^{235} , with an excess reactivity for the clean cold loading of about 0.6%. The total mass in the initial loading was 3.6 kg of U^{235} .

Loading 33 was initially assembled in November, 1954, from clean cold fuel elements. The power calibration was made during the first series of runs at power levels appreciably above 1 watt.

Cobalt foils were used as the detector material for the thermal neutron flux determination in the lattice. The foils were exposed at 6-in. intervals in vertical traverses in the water passage between the last two plates on the outside of the fuel elements. Measurements were also made along the vertical axis of the element in lattice position 25, which was approximately at the center of the configuration. Cadmium ratios were determined at centerline and at 6-in. intervals below centerline. Symmetrical flux distribution was assumed around the north-south centerline of the core and cadmium ratios were assumed to be symmetrical around the reactor horizontal centerline. The treatment of the data has been described in detail in ORNL-1027¹ and ORNL-1682.²

UNCLASSIFIED

- 2 -

Table 1 shows the actual neutron flux measurements at a nominal reactor power of 20 kw. Table 2 is a summary of the same data, where the average fluxes at 6- and 12-in. distances above and below the horizontal reactor centerline were determined. The numbers in parentheses were based on cadmium ratios estimated from values measured elsewhere in the lattice. In the nomenclature in the first column of this table, the first number refers to the position of the fuel element in the reactor grid plate and the second to the distance from the horizontal reactor centerline. For example, the notation 05-0 would refer to a flux determination on the east side of the fuel element in lattice position 5 at a distance 0 in. from centerline.

Table 3 shows the result of the averaging of the thermal neutron fluxes in each fuel element in the core (as described in Ref. 1), the total amount of U^{235} in each element, and the average power generation per element. It was found as a result of this determination that the nominal power of 20 kw corresponded to an actual power of 27.3 kw. Therefore all data taken with the initial loading was normalized to the actual operating power of 1.37 watts per nominal watt by a factor of 0.73.

It should be noted that this power determination was made using the results of the energy released per fission experiment reported in ORNL-1537³ and discussed in ORNL-CF-53-5-21.⁴

A number of neutron flux determinations were made in water along the reactor north-south centerline. Indium foils were used as the detector material at distances greater than 40 cm from the reactor face for the

UNCLASSIFIED

UNCLASSIFIED

- 3 -

purpose of normalizing fission-chamber data. Small gold foils were used in the water near the reactor face (from 0 to 15.5 cm) in order to determine the shape of the attenuation curve in this region. This data is presented in Table 4.

UNCLASSIFIED

Fig. 1. Bulk Shielding Reactor Loading 33.

UNCLASSIFIED

-5-

Table 1. Neutron Flux Measurements for BSR Loading 33

20-kw Nominal Power

Lattice Position	Side	Vertical Position	ϕ , "True" Neutron Flux ^a (neuts·cm ⁻² ·sec ⁻¹ x 10 ⁻¹¹)			Cadmium Ratio
			Total	Epicadmium	Thermal	
5	East	£	2.25	0.25	2.00	9.0
		6" above £	1.65			
		6" below £	1.85	0.21	1.64	8.8
		12" above £	1.35			
		12" below £	1.47	0.07	1.40	21
6	East	£	1.92	0.23	1.69	8.3
		6" above £	1.50			
		6" below £	1.45	0.19	1.26	7.6
		12" above £	1.00			
		12" below £	1.15	0.07	1.08	16
7	East	£	1.66	0.11	1.55	15
		6" above £	1.26			
		6" below £	1.36	0.09	1.27	15
		12" above £	0.679			
		12" below £	0.874	0.031	0.843	28
15	East	£	2.53	0.36	2.17	7.0
		6" above £	1.83			
		6" below £	2.14	0.30	1.84	7.1
		12" above £	1.26			
		12" below £	1.53	0.10	1.43	15

UNCLASSIFIED

UNCLASSIFIED

-6-

Table 1 (Cont.)

Lattice Position	Side	Vertical Position	ϕ , "True" Neutron Flux ^a (neuts.cm ⁻² .sec ⁻¹ x 10 ⁻¹¹)			Cadmium Ratio
			Total	Epicadmium	Thermal	
17	West	£	2.40	0.26	2.14	9.2
		6" above £	1.77			
		6" below £	2.00	0.19	1.81	10.5
		12" above £	0.86			
		12" below £	1.37	0.07	1.30	19.6
17	East	£	2.38	0.27	2.11	8.8
		6" above £	1.77			
		6" below £	1.93	0.23	1.70	8.4
		12" above £	0.90			
		12" below £	1.11	0.08	1.03	14
25	Center	£	3.74			
		6" above £	2.42			
		6" below £	2.77			
		12" above £	1.41			
		12" below £	2.16			
25	East	£	3.63	0.38	3.25	9.5
		6" above £	2.60			
		6" below £	3.05	0.31	2.74	9.8
		12" above £	1.24			
		12" below £	2.22	0.01	2.12	22

UNCLASSIFIED

UNCLASSIFIED

-7-

Table 1 (Cont.)

Lattice Position	Side	Vertical Position	ϕ , "True" Neutron Flux ^a (neuts·cm ⁻² ·sec ⁻¹ x 10 ⁻¹¹)			Cadmium Ratio
			Total	Epicadmium	Thermal	
27	West	£	3.05	0.28	2.77	11
		6" above £	2.28			
		6" below £	2.53	0.24	2.29	10.5
		12" above £	1.10			
		12" below £	1.82	0.07	1.75	26
27	East	£	2.58			
		6" above £	1.91			
		6" below £	2.12			
		12" above £	1.00			
		12" below £	1.26			
36	West	£	3.36	0.33	3.03	10
		6" above £	2.55			
		6" below £	2.85	0.27	2.58	10.5
		12" above £	1.57			
		12" below £	1.92	0.09	1.83	21
36	East	£	2.77	0.27	2.50	10
		6" above £	1.99			
		6" below £	2.37			
		12" above £	1.22			
		12" below £	1.56	0.07	1.49	22

UNCLASSIFIED

UNCLASSIFIED

-8-

Table 1 (Cont.)

Lattice Position	Side	Vertical Position	ϕ , "True" Neutron Flux ^a (neuts.cm ⁻² .sec ⁻¹ x 10 ⁻¹¹)			Cadmium Ratio
			Total	Epicadmium	Thermal	
37	East	£	2.54	0.16	2.38	16
		6" above £	1.93			
		6" below £	2.06	0.13	1.93	16
		12" above £	1.15			
		12" below £	1.30	0.04	1.26	33
45	East	£	3.29	0.26	3.03	13
		6" above £	2.52			
		6" below £	2.75	0.20	2.55	14
		12" above £	1.58			
		12" below £	1.92	0.06	1.86	32
46	East	£	2.21	0.25	1.96	9
		6" above £	1.66			
		6" below £	1.82	0.20	1.62	9.1
		12" above £	1.23			
		12" below £	1.30	0.05	1.25	26
47	East	£	1.95	0.12	1.83	16
		6" above £	1.50			
		6" below £	1.60	0.10	1.50	16
		12" above £	0.90			
		12" below £	1.10	0.03	1.07	37

UNCLASSIFIED

Table 1 (Cont.)

Lattice Position	Side	Vertical Position	ϕ , "True" Neutron Flux ^a (neuts·cm ⁻² ·sec ⁻¹ x 10 ⁻¹¹)			Cadmium Ratio
			Total	Epicadmium	Thermal	
54	West	£	2.19			
		6" above £	1.33			
		12" above £	0.70			
55	East	£	2.03			
		6" above £	1.62			
		12" above £	1.21			

- a. "True" thermal neutron flux is defined operationally as the specific activation of a 1/v foil divided by the absorption cross section of the foil material, averaged over a Maxwellian distribution with an assumed temperature of 293°K. The commonly used "2200 m/sec" flux is obtained from the true thermal flux by division by a factor of 1.13.

UNCLASSIFIED

-10-

Table 2. Summary of Neutron Flux Distributions for Loading 33

20-kw Nominal Power

East Side of Lattice Position	ϕ , "True" Neutron Flux ^a (neutrons·cm ⁻² ·sec ⁻¹ x 10 ⁻¹¹)			Cadmium Ratio
	Total	Episcadmium	Thermal	
05-0	2.25	0.25	2.00	9.0
06-0	1.92	0.23	1.69	8.3
07-0	1.66	0.11	1.55	15
05-6	1.75 ^b	0.20	1.55	8.8
06-6	1.47 ^b	0.19	1.28	7.6
07-6	1.31 ^b	0.09	1.22	15
05-12	1.41 ^b	0.07	1.34	21
06-12	1.07 ^b	0.06	1.01	16
07-12	0.776 ^b	0.028	0.75	28
15-0	2.53	0.36	2.17	7
16-0	2.40	0.26	2.14	9.2
17-0	2.38	0.27	2.11	8.8
15-6	1.99 ^b	0.28	1.71	7.1
16-6	1.88 ^b	0.18	1.70	10.5
17-6	1.85 ^b	0.22	1.63	8.4
15-12	1.39 ^b	0.09	1.30	15
16-12	1.11 ^b	0.06	1.05	19.6
17-12	1.00 ^b	0.07	0.93	14
25-0	3.63	0.38	3.25	9.5
26-0	3.05	0.28	2.77	11
27-0	2.58	(0.21)	(2.37)	(12)
25-6	2.82 ^b	0.29	2.53	9.8
26-6	2.40 ^b	0.23	2.17	10.5
27-6	2.02 ^b	(0.17)	(1.85)	(12)
25-12	1.73 ^b	0.08	1.65	22
26-12	1.46 ^b	0.06	1.40	26
27-12	1.13 ^b	(0.04)	(1.09)	(27)
35-0	3.36	0.33	3.03	10
36-0	2.77	0.27	2.50	10
37-0	2.54	0.16	2.38	16

UNCLASSIFIED

UNCLASSIFIED

-11-

Table 2 (Cont.)

East Side of Lattice Position	ϕ , "True" Neutron Flux ^a (neutrons·cm ⁻² ·sec ⁻¹ x 10 ⁻¹¹)			Cadmium Ratio
	Total	Epicadmium	Thermal	
35-6	2.70 ^b	0.26	2.44	10.5
36-6	2.18 ^b	(0.21)	(1.97)	(10.5)
37-6	1.99 ^b	0.12	1.87	16
35-12	1.74 ^b	0.08	1.66	21
36-12	1.39 ^b	0.06	1.33	22
37-12	1.22 ^b	0.04	1.18	33
45-0	3.29	0.26	3.03	13
46-0	2.21	0.25	1.96	9
47-0	1.95	0.12	1.83	16
45-6	2.65 ^b	0.19	2.46	14
46-6	1.74 ^b	0.19	1.55	9
47-6	1.55 ^b	0.10	1.45	16
45-12	1.75 ^b	0.05	1.70	32
46-12	1.26 ^b	0.05	1.21	26
47-12	1.00 ^b	0.03	0.97	37
55-0	2.03	(0.17)	(1.86)	(12)
56-0	2.19	(0.15)	(2.04)	(15)
55-6	1.62 ^b	(0.13)	(1.49)	(12)
56-6	1.33 ^b	(0.09)	(1.24)	(15)
55-12	1.21 ^b	(0.05)	(1.16)	(25)
56-12	0.70 ^b	(0.02)	(0.68)	(30)

a. "True" thermal neutron flux is defined operationally as the specific activation of a 1/v foil divided by the absorption cross section of the foil material, averaged over a Maxwellian distribution with an assumed temperature of 293°K. The commonly used "2200m/sec" flux is obtained from the true thermal flux by division by a factor of 1.13.

b. Averages of measurement reported in Table 1 above and below centerline.

UNCLASSIFIED

UNCLASSIFIED

-12-

Table 3. Power Calculation for BSR Loading 33

20-kw Nominal Power

Lattice Position	^{235}U Content (g)	$\bar{\phi}_{\text{th}}$ ($\times 10^{-11}$) (a)	Power Per Element (watts)
03	140	1.25	746
04	139	1.46	865
05	139	1.61	954
06	140	1.46	871
07	140	1.25	746
13	140	1.61	961
14	139	1.69	1002
15	139	1.72	1020
16	143	1.69	1010
17	140	1.61	961
23	140	1.96	1170
24	70	2.31	689
25	140	2.49	1486
26	70	2.31	689
27	140	1.96	1170
33	140	1.88	1122
34	140	2.17	1295
35	69	2.39	703
36	139	2.17	1286
37	140	1.88	1121
43	139	1.50	889
44	140	1.99	1188
45	69	2.41	709
46	140	1.99	1188
47	140	1.50	895
54	140	1.40	836
55	140	1.50	895
56	140	1.40	836

27.34 kw/20 kw nominal
1.365 watts/nominal watt

a. $\bar{\phi}_{\text{th}}$ = average "true" thermal neutron flux per element

UNCLASSIFIED

UNCLASSIFIED

-13-

Table 4. Thermal-Neutron Flux Measurements in Water along
Reactor North-South Centerline BSR Loading 33

Distance from North Face of Reactor (cm)	Detector Material	ϕ_{th}/watt (a)
0	Gold	1.13×10^7
1.0		1.40×10^7
2.5		1.40×10^7
3.5		1.32×10^7
4.0		1.27×10^7
5.0		1.11×10^6
6.0		9.58×10^6
7.5		7.59×10^6
8.5		6.35×10^6
9.0		5.78×10^6
10.0		4.72×10^6
11.0		3.95×10^6
40	Indium	1.27×10^4
50		2.45×10^3
60		5.41×10^2

a. ϕ_{th} = "true" thermal-neutron flux

UNCLASSIFIED

UNCLASSIFIED

-14-

REFERENCES

1. J. L. Meem and E. B. Johnson, "Determination of the Power of the Shield-Testing Reactor I. Neutron Flux Measurements in the Water-Reflected Reactor," ORNL-1027 (Dec. 1, 1954).
2. R. G. Cochran, J. L. Meem, T. E. Cole and E. B. Johnson, "Reactivity Measurements with the Bulk Shielding Reactor," ORNL-1682, Appendix A (Nov. 30, 1954).
3. J. L. Meem, L. B. Holland and G. M. McCammon, "Determination of the Power of the Bulk Shielding Reactor - Part III. Measurement of the Energy Released Per Fission," ORNL-1537 (Feb. 19, 1954).
4. J. L. Meem, E. B. Johnson and H. E. Hungerford, "Energy Per Fission and Power of the BSR," ORNL-CF-53-5-21 (May 12, 1953).

UNCLASSIFIED

Distribution

Internal

1. E. P. Blizzard	15. F. C. Maienschein
2. A. D. Callihan	16. A. J. Miller
3. R. A. Charpie	17. R. B. Murray
4. C. E. Clifford	18. R. W. Peelle
5. R. R. Coveyou	19. S. K. Penny
6. G. deSaussure	20. C. A. Preskitt (9704-1, Y-12)
7. G. M. Estabrook	21. E. G. Silver
8. K. M. Henry	22. A. Simon
9. L. B. Holland	23. D. K. Trubey
10. E. B. Johnson	24. A. M. Weinberg
11. W. H. Jordan	25. C. D. Zerby
12. F. L. Keller	26. W. Zobel
13. J. D. Kington	27-29. Laboratory Records Department
14. T. A. Love	30. Doc. Reference Section
	31-32. Central Research Library

External

- 33. Aircraft Reactors Branch, Washington (Attn: Capt. G. K. Dicker)
- 34-35. Bureau of Aeronautics (Attn: Ralph Zirkind; LCDR Russell, R551)
- 36. Convair, Ft. Worth (Attn: N. M. Schaeffer)
- 37-38. Convair, San Diego (Attn: C. E. Chapman, Dr. Donaldson)
- 39. Curtiss-Wright Corp., Research Div., Quehanna, Pa. (Attn: K. L. Rooney)
- 40-45. General Electric, Cincinnati (Attn: F. A. Aschenbrenner, J. MacDonald, W. E. Edwards, J. Carver, R. H. Clark, L. S. Byrnes)
- 46. General Electric, Idaho (J. Van Hoomissen)
- 47. Douglas Aircraft Company, Inc., Santa Monica, Calif. (Attn: J. W. McKee)
- 48. Hq., Air Research and Development Command, Baltimore, Maryland (Attn: Maj. C. L. Scoville)
- 49-50. Lockheed, Marietta, Ga. (Attn: J. C. Flack, F. N. Watson)
- 51. National Advisory Committee for Aeronautics, Cleveland, Ohio (Attn: Irving M. Karp)
- 52. Nuclear Development Corp. (Attn: H. Goldstein)
- 53-54. Pratt and Whitney Aircraft (Attn: J. B. Dee, W. E. Price)
- 55. Technical Research Group (Attn: R. Aronson)
- 56-58. The Martin Company (Attn: C. R. Fink, F. N. Greene, G. J. Rausa)
- 59. U. S. Naval Research Laboratory (Attn: A. G. Pieper)
- 60-61. Wright Air Development Center (Attn: L. L. Antes, WCRRX; E. J. Zawalick, WCLJX)
- 62. R. K. Osborn, University of Michigan, Ann Arbor, Michigan
- 63-77. TISE, AEC