~~SECRET COVER SHEET~~

UNCLASSIFIED

OAK RIDGE NATIONAL LABORATORY

Operated By

UNION CARBIDE NUCLEAR COMPANY

UCC

POST OFFICE BOX P
OAK RIDGE, TENNESSEEORNL
CENTRAL FILES NUMBER

56-4-128

DATE: April 12, 1956

SUBJECT: THREE-REGION REFLECTOR-MODERATED CRITICAL
ASSEMBLY WITH END DUCTS. EXPERIMENTAL RESULTS
WITH CA-21-2. REDUCED CONCENTRATION."C-84, Aircraft Reactors"

This document consists of 22 pages.

Copy 27 of 29 copies. Series A

"External Transmittal Authorized"

TO: Listed Distribution

FROM: Dunlap Scott, J. J. Lynn, E. V. Sandin* and Stuart Snyder*.

DISTRIBUTION

1. E. P. Blizard	11. W. E. Kinney
2. H. W. Bertini	12. M. LaVerne
3. A. D. Callihan	13. A. J. Miller
4. R. A. Charpie	14. A. M. Perry
5. S. Comer	15. H. W. Savage
6. E. P. Epler	16. A. W. Savolainen
7. W. K. Ergen	17. Dunlap Scott
8. A. P. Fraas	18. A. Simon
9. B. L. Greenstreet	19. J. A. Swartout
10. W. H. Jordan	20. A. M. Weinberg
21. W. G. Kennedy - P and W, Fox Project	
22. Pratt and Whitney Aircraft (Fox Project)	
23. C. B. Mills, c/o AFPR, Woodridge	
24. ORNL - RC	
25-26. Laboratory Records	
27-29. TIS, AEC	

* Pratt and Whitney

Classification cancelled (or changed to)

down + list from declassification
by authority of Branch, dtd 10-23-63

J. E. Ridenour TISOR, date 6-17-64

UNCLASSIFIED

UNCLASSIFIED

NOTICE

RESTRICTED DATA

This document contains Restricted Data as defined in the Atomic Energy Act of 1954. Its transmittal or the disclosure of its contents in any manner to an unauthorized person is prohibited.

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.

~~SECRET COVER SHEET~~

1

3337

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.

UNCLASSIFIED

-2-

~~SECRET~~

Pilot

Table of Contents

	Pg No.
I. Critical Mass	3
II. ART Fission Chamber Sensitivity	3
III. Radial Importance of Uranium in the Fuel Zone	7
IV. Sodium Activation	7
V. Power Distribution	9
VI. Neutron Flux Measurement	11
VII. Summary	21

~~SECRET~~

UNCLASSIFIED

UNCLASSIFIED

-3-

~~SECRET~~

THREE-REGION REFLECTOR-MODERATED CRITICAL
ASSEMBLY WITH END DUCTS. EXPERIMENTAL
RESULTS WITH CA-21-2. REDUCED
CONCENTRATION

The three-region reflector-moderated reactor with end ducts has been reassembled with a reduced uranium concentration and was critical with a mass of 20.07 kg of U-235 and a k-excess of 0.14%. The experimental results with this modified assembly, identified as CA-21-2, are given below.

I. Critical Mass

The original assembly of this reactor was with a higher uranium concentration and contained 24.24 kg of U-235 with approximately 3% k-excess, however, the estimation of the critical mass was complicated by the large excess reactivity available. It was the purpose of this reduced concentration assembly to obtain a value for the critical mass. A summary of the materials loaded is given in Table 1.

Table 1. Core Materials of the Three-Region Reflector-Moderated Critical Assembly with End Ducts - Reduced Concentration

Uranium (93.17% U-235), kg	21.55
U-235, kg	20.07
U-235 density, g/cc	
Average for core	0.345
Central region	0.342
End ducts	0.352
Distance between fuel sheets, in.	0.173
Uranium coating material, kg	0.21
Scotch tape, kg	0.15
Teflon, kg	108.2
Inconel shells (1/8 in. thick), kg	53.02
Outer shell, kg	33.19
Inner shell, kg	19.83
Excess reactivity as loaded, %	0.14
Critical mass, estimated U-235, kg	19.9

II. (ART) Fission Chamber Sensitivity

A fission chamber of the type to be used in the (ART) was placed in a mockup of the core shell - water shield during the approach to critical for this assembly with the purpose of determining the source strength requirements for the (ART) and the sensitivity of the chamber.

~~SECRET~~

UNCLASSIFIED

Fission Chamber Sensitivity Core Shell-Water Shield Mockup

Fig. 1

UNCLASSIFIED

et

MLL-IR-DWG-13302

UNCLASSIFIED

SECRET

With a source of 5.4×10^6 neutrons/sec located on the axis of the reactor at the midplane and with the fission chamber in the shield mockup as shown in Fig. 1, the background counting rate obtainable was 6.2 c/sec under the following optimum conditions:

Fission chamber - Westinghouse WL-6376
 Cable - Approximately 8 ft RG 62/U
 Preamplifier - A I A
 Amplifier - A 1
 Settings - 2 mc Bandwidth gain 64
 Pulse height selector set at 2 volts above alpha count.

An extrapolation of the data back to a loading which was 80% of the clean critical loading indicates a counting rate of 74 c/sec. It must be recognized that these were optimum conditions and that operation in the ART might require a reduced sensitivity. The counting rate observed at two subcritical uranium loadings is given in Table 2 and Fig. 2.

Table 2. Counting Rate with a Subcritical Uranium Loading

Clean Critical Mass (%)	Counting Rate c/sec
88.3	137
94.6	299

Electronic difficulties discovered at the end of the critical loading invalidated the data taken earlier. The system was unloaded to obtain a point at the 89% condition. It was not, however, deemed necessary to further unload the reactor since the region of interest is an 80% loading.

An approximation of the effectiveness of the plastic surrounding the chamber in attenuating the side leakage and back scattering was made by adding an additional 2-in. layer of Plexiglas around the mockup. Essentially no change was detected with this addition. Removal of the 3/8 in. of Boral from the mockup increased the counting rate a factor of 2.9 and as detected by a change in the critical positions of the control rods, there was an increase in reactivity of approximately $1/2\%$.

The fission chamber, associated electronic components, and assistance in operation were supplied by J. C. Gundlach of the Instrumentation and Controls Division.

Variation of Counting Rate with
Uranium Loading

Fig. 2

SECRET

III. Radial Importance of Uranium in the Fuel Zone

The relative radial importance of adding uranium to several radial positions in the fuel annulus was measured by adding two sheets 7-3/16 in. long by 2-7/8 in. wide containing 22.5 g of U-235 each to a reduced loading of 20 sheets. The eighth and fifteenth sheets were removed from positions 19-1/2 and 39-1/2 Teflon sheets from the island to establish the base and gave a loss in reactivity of 3.2¢. The test section was at the top of the core region in the assembly and was centered 3/4 in. from the midplane, the same section from which the midplane power distribution was measured. Table 3 and Fig. 3 give the results.

Table 3. Radial Importance of Uranium in Fuel Annulus

Distance Between Island and Added Uranium (in.)	Number of Sheets Between Island and Added Uranium		Change in Reactivity from Reduced 20-Sheet Loading (cents)
	Uranium (4 mils thick)	Teflon (71 mils thick)	
.037	0	1	+ 6.7
.36	2	5	+ 5.2
2.09	10	29-1/2	+ 3.7
3.70	18	52	+ 3.7
4.02	20	55	+ 4.2

IV. Sodium Activation

A rough measurement of the relative leakage of sodium resonance (3 kev) neutrons from the surface of the beryllium reflector was obtained by placing cadmium-covered cans of sodium at three positions around the reactor and measuring the resulting activation. The cans are 2-7/8 x 2-7/8 x 1 in. thick with an effective thickness of 905 mg/cm² Na. The container was made of 304 stainless steel, 10 mils thick. The sketch below gives the location of the cans and the activity relative to the value at the midplane. The cadmium cover was 20 mils thick and completely surrounded the can.

EUGENE DIETZGEN CO.
PRINTED IN U. S. A.

NO. 340. H DIETZGEN GRAPH PAPER
MILLIMETER

Radial Importance of Fuel Fig. 3

SECRET

V. Power Distribution

The relative power distribution across the fuel annulus was measured at four longitudinal positions; 0 in., 12-1/4., 15-1/8 in., and 19 in. from the midplane. The aluminum catcher foil technique was used to obtain the bare and cadmium covered activity of this measurement. The results are given in Table 4 and are plotted in Fig. 4 as a function of the layers of uranium sheets between the datum point and the island.

Table 4. Power Distribution Across Fuel Annulus

Foil Position			Activity	
Distance from Reactor Midplane (in.)	Distance from Axis of Reactor (in.)	Fuel Sheets from Island	Bare Catcher Foil	Cadmium- Covered Catcher Foil
0.00	5.259	0	85,710	26,889
	5.263	1	62,338	-
	5.440	2	46,741	23,663
	5.794	4	33,580	-
	7.033	11	20,341	18,137
	8.445	18	35,655	-
	8.799	20	51,855	19,140
	8.976	21	68,717	-
	8.980	22	84,624	21,144
10.72	3.751	0	82,298	22,797
	3.755	1	65,977	-
	4.282	4	46,489	18,767
	4.809	6	63,880	-
	4.813	7	74,860	20,370
13.59	3.751	0	60,585	16,207
	3.755	1	47,585	-
	4.282	4	34,652	13,265
	4.809	6	45,679	-
	4.813	7	55,931	14,422
19.34	3.751	0	14,009	4,104
	4.282	4	8,387	3,274
	4.813	7	13,658	3,819

The fission rate in the uranium contained in the fuel-to-NaK heat exchanger is a source of high energy neutrons which must be attenuated in the shield surrounding the reactor. A measure of this fission rate was

SECRET

Power Distribution
across Fuel Annulus
Fig. 4

SECRET

obtained from catcher foils placed in a mockup of a section of the heat exchanger. This configuration consisted of a layer of boron (300 mg/cm^2) adjacent to the reflector beryllium, followed by a 1.3-in.-thick fuel zone, containing uranium metal and Teflon, and a layer of stainless steel 1-7/16 in. thick. It was located approximately at the midplane and was $8\text{-}5/8 \times 8$ in. in the plane perpendicular to the flux gradient. The arrangement and the results are shown in Fig. 5 together with the fission rate distribution across the core midplane for comparison.

Other measurements of neutrons leaking from the beryllium reflector have shown¹ that a layer of boron having a thickness of about 300 mg/cm^2 reduces the relative value of the flux from 1000 to 3; further increasing the boron thickness by 50% only reduces the flux to a relative value of 2.

VI. Neutron Flux Measurement

Two radial traverses were made with gold foils 0.3125-in.-dia. and weighing 450 mg. One traverse was at the midplane and extended radially from the axis to 20.59 in. The other was 10-11/16 in. from the midplane and extended from 0.31 in. to 14.31 in. These traverses were made with bare and cadmium covered foils. The cadmium covers were 0.020-in.-thick. The result of these traverses are tabulated in Tables 5 and 6 and plotted in Figs. 6 and 7. Nine cadmium covered foils from the radial traverse in the end duct, 10-11/16 in. from the midplane, were mislaid prior to counting and as a result were not included in the data.

One radial and one axial traverse were made with both bare and cadmium covered indium-aluminum alloy foils. The foils were 0.3125-in.-dia. and contained 5.4 mg/cm^2 of indium. The covers were 0.020-in.-thick. The radial run was at the midplane and extended from the axis to 20.41 in. The axial traverse extended from -19.69 to +18.47 in. relative to the midplane. The results of these traverses are tabulated in Tables 7 and 8 and plotted in Figs. 8 and 9. An activity of 1000 taken from the table represents approximately 13,700 total counts for the gold foils and 670 total counts for the indium foils.

1. Dunlap Scott, J. J. Lynn, E. V. Sandin and S. Snyder, "Three-Region Reflector-Moderated Critical Assembly with End Ducts - Experimental Results with CA-23, Enlarged Island Modification," ORNL-CF-56-1-97, (January 30, 1956).

Power Distribution
Central Region and Heat Exchanger Mockup
Fig. 5

SECRET

Table 5. Gold Foil Radial Traverse at Midplane

Radial Distance from Axis (in.)	Relative Activity of Foil		Cadmium Fraction
	Bare	Cadmium Covered	
0.045	5388	2065	0.6167
1.59	5156	2008	0.6106
3.16	4074	1796	0.5592
4.13	2914	1446	0.5038
4.22		1414	
5.03	1637	922	0.4368
5.03-5.09	Position of 1/16-in.thick Inconel Shell		
5.09	1245	-	
5.09-5.15	Position of 1/16-in.-thick Inconel Shell		
5.15	913	783	0.1424
6.47	536	459	0.1437
7.69	470	416	0.1149
8.94		523	
9.22	1105	544	0.3275
9.22-9.28	Position of 1/16-in.-thick Inconel Shell		
9.28	1440	-	
9.28-9.34	Position of 1/16-in.-thick Inconel Shell		
9.35	1225	636	0.4808
9.59	1359	734	0.4599
9.84	1764	763	0.5675
10.88	2487	878	0.6170
11.38	2453	896	0.6347
11.94	2790	828	0.7032
12.69	2764	696	0.7482
13.72	2592	531	0.7951
16.25	1741	217	0.8754
18.03	1137	96	0.9156
20.59	310	15	0.9339

SECRET

SECRET

Table 6. Gold Foil Radial Traverse 10-11/16 in. From Midplane

Radial Distance From Axis (in.)	Relative Activity of Foil		Cadmium Fraction
	Bare	Cadmium Covered	
0.31	3010	1473	0.5106
1.31		1267	
3.38	2522	912	0.6384
3.59-3.72	Position of 1/8-in.-thick Inconel Shell		
3.72	928	684	0.2629
3.75	855		
4.21	791	616	0.1687
4.87	812		
4.9	879	708	0.1945
5.03	1095		
5.03-5.15	Position of 1/8-in.-thick Inconel Shell		
5.81	1663		
7.09	2169		
8.63	2301		
9.63	2180		
11.81	1815		
14.31	937		

SECRET

EUGENE DIETZEN CO.
MADE IN U.S.A.

NO. 3400-20 DIETZEN GRAPH PAPER
20 X 20 PER INCH

SECRET

Table 7. Indium Foil Radial Traverse at Midplane

Radial Distance From Axis (in.)	Relative Activity of Foil		Cadmium Fraction
	Bare	Cadmium Covered	
0.0	97,102	55,546	0.4280
2.81		42,930	
3.0	70,750		
4.53	42,500		
4.69		30,063	
5.03	30,165	21,928	0.2731
5.03-5.09	Position of 1/16-in.-thick Inconel Shell		
5.09	26,156		
5.09-5.15	Position of 1/16-in.-thick Inconel Shell		
5.15	20,708	18,092	0.1263
5.63	17,114	15,718	0.0816
7.09	12,270	11,322	0.0773
8.63	14,291	12,971	0.09236
9.22	17,952	13,641	0.2401
9.22-9.28	Position of 1/16-in.-thick Inconel Shell		
9.28	20,285		
9.28-9.34	Position of 1/16-in.-thick Inconel Shell		
9.35	21,890	14,830	0.3225
9.84	32,071	18,491	0.4234
10.88	42,459	22,268	0.4755
11.84	44,915	20,734	0.5384
12.88	45,706	18,027	0.6056
15.88	29,071	7,292	0.7492
17.88	16,871	3,205	0.8101
20.41	3,831	542	0.8585

SECRET

SECRET

Table 8. Indium Foil Axial Traverse

Distance From Midplane (in.)	Relative Activity of Foil		Cadmium Fraction
	Bare	Cadmium Covered	
-19.69	9,334	5,612	0.3988
-15.75	31,006	18,751	0.3952
- 9.72	61,473	37,164	0.3954
- 4.69	81,802	47,855	0.4150
- 2.78	87,409	50,210	0.4256
- 1.50	92,236	52,244	0.4336
- 0.75	91,127		
0.0	93,033		
+ 0.75	90,910	53,764	0.3978
1.78	89,661		
2.78	87,185	50,278	0.4233
9.78	66,125	39,049	0.4095
14.75	33,979	20,994	0.3821
18.47	13,739	8,819	0.3581

SECRET

EUGENE DIETZGEN CO.
MADE IN U.S.A.

NO. 3400-20 DIETZGEN GRAPH PAPER
20 X 20 PER INCH

~~SECRET~~

ORNL-LP-DWG 13310

Reflector Moderated Critical Assembly with End
Ducts and Reduced Concentration
Axial Traverse
Indium Flux
FIG 9

NO. 3400-20 DIETZGEN GRAPH PAPER
20 X 20 PER INCH
EUGENE DIETZGEN CO.
MADE IN U.S.A.

Activity (Arbitrary Units), Cadmium Fraction

Distance From Midplane - Inches

UNCLASSIFIED

-21-

~~SECRET~~

VII. Summary

This assembly completes the series of reflector-moderated critical assemblies at this time. A complete listing of previous memoranda in this series is given below for reference.

CF Number	Title	CA-No.	Authors
54-4-53	Reflector Moderated Critical Assembly, Experimental Program		Dunlap Scott B. L. Greenstreet
54-7-159	The First Assembly of the Small Two Region Reflector Moderated Reactor	19	Dunlap Scott
54-8-180	The Second Assembly of the Small Two Region Reflector Moderated Reactor	19	Dunlap Scott
54-9-185	The Second Assembly of the Small Two Region Reflector Moderated Reactor (Part II)	19	Dunlap Scott R. M. Spencer
54-10-119	Reflector Moderated Critical Assembly Experimental Program - Part II		B. L. Greenstreet
54-11-33	The First Assembly of the Three Region Reflector Moderated Reactor	20	R. M. Spencer
54-11-150	The Second Assembly of the Three Region Reflector Moderated Reactor	20	R. M. Spencer B. L. Greenstreet
54-12-189	Three Region Reflector Moderated Critical Assembly (Experimental Results)	20	R. M. Spencer
55-1-123	Three Region Reflector Moderated Critical Assembly with 1/16-in. Inconel Core Shells	20	R. M. Spencer
55-2-93	Three Region Reflector Moderated Critical Assembly with 1/8-in. Inconel Core Shells	20	R. M. Spencer
55-2-16	Preliminary Evaluation of Possible Poisons For Use in the ART Control Rod		J. W. Noaks
55-4-84	Evaluation of Reactivity Characteristics of Control Rods and Materials Potentially Suitable for use in the ART. Part II		J. W. Noaks
55-4-137	Evaluation of ART Control Rod Materials, Part III. The Effects of Neutron Irradiation on Some Rare Earth Samples.		J. W. Noaks

~~SECRET~~

UNCLASSIFIED

UNCLASSIFIED

-22-

~~SECRET~~

select

55-4-178	Evaluation of ART Control Rod Materials, Part IV. The Variation of Reactivity with Control Rod Diameter.		J. W. Noaks
55-5-147	Evaluation of ART Control Rod Materials, Part V. Addendum to Parts I - IV.		J. W. Noaks
55-5-181	Reflector Moderated Critical Assembly Experimental Program - Part III.	22-23	E. V. Sandin
55-6-96	Reflector Moderated Critical Assembly with End Ducts - Experimental Program (Experimental Results).	21-1	Dunlap Scott J. J. Lynn E. V. Sandin
55-10-142	Three Region Reflector Moderated Critical Assembly with End Ducts and 1/8-in. Inconel Core Shells. CA-21-1 Neutron Flux Measurement.	21-1	S. Snyder J. J. Lynn E. V. Sandin Dunlap Scott
56-1-96	Three Region Reflector Moderated Critical Assembly with End Ducts. Experimental Results with CA-22, Enlarged End Duct Modification.	22	Dunlap Scott J. J. Lynn E. V. Sandin S. Snyder
56-1-97	Three Region Reflector Moderated Critical Assembly with End Ducts - Experimental Results with CA-23, Enlarged Island Modification.	23	Dunlap Scott J. J. Lynn E. V. Sandin S. Snyder

~~SECRET~~

UNCLASSIFIED