OAK RIDGE NATIONAL LABORATORY

Operated by

UNION CARBIDE NUCLEAR COMPANY

Division of Union Carbide Corporation

Post Office Box X

Oak Ridge, Tennessee

MASTER

External Transmittal
AuthorizedORNL
CENTRAL FILES NUMBER

60-1-43

Fourth Issue

COPY NO. 9

DATE: January 15, 1960

SUBJECT: Nuclear Characteristics of BeO-Moderated
Cores vs Graphite-Moderated Cores

TO: Distribution

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Abstract

Multigroup calculations were performed to compare BeO-moderated cores with graphite-moderated cores, using various void fractions and core diameters. The core leakages and conversion ratios which were calculated are presented in a series of curves.

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NUCLEAR CHARACTERISTICS OF BeO-MODERATED CORES VS GRAPHITE-MODERATED CORES

In considering the possibility of using beryllium oxide for moderation in a gas-cooled, ceramic-fueled reactor, it is of interest to make a comparison with the characteristics of similar graphite-moderated reactors.

A series of multigroup calculations was made using the IBM-704 GNU II code. For each case a two-region reactor was specified consisting of a cylindrical core containing a homogeneous mixture of U^{233} , Th^{232} , and moderator; surrounded by a cylindrical blanket containing the same moderator mixed homogeneously with Th^{232} . The blanket thickness was 2 ft in the cases using graphite and 1.4 ft in the cases using BeO in the blanket since previous calculations with no thorium in the blanket had indicated that these thicknesses are equivalent in neutron economy. The thorium concentration in the blanket was fixed at 6.21×10^{20} atoms/cm³ and 8.28×10^{20} atoms/cm³ for the BeO and graphite cases respectively, since previous calculations had indicated that these concentrations would give equal leakage from the blanket.

The axial buckling was computed by using a core length of 10 ft plus a reflector savings due to a thick graphite reflector in the case of graphite-moderated cores or a thick BeO reflector in the case of BeO-moderated cores. The reflector savings, which were estimated from the flux shapes of similar, fully reflected cores, were 69 cm with graphite and 119 cm with BeO. Thus the values for the axial buckling were¹:

$$B_c = \frac{\pi}{H + 2\delta},$$

for graphite, $B_c = 7.09 \times 10^{-3} \text{ cm}^{-1}$,

for BeO, $B_c = 5.79 \times 10^{-3} \text{ cm}^{-1}$.

The ratio of moderator atoms to fuel atoms in the core was fixed at 4000 with BeO and 8000 with graphite. In general it has been found in other multigroup calculations that approximately equal values of ηf are obtained when the moderator to fuel atomic ratio is twice as high with graphite as

¹S. Glasstone and M. C. Edlund, The Elements of Nuclear Reactor Theory, Sec. 8.25, p 234, D. Van Nostrand Company, Inc., New York.

with the corresponding BeO-moderated case.

The cases studied included BeO-moderated cores of 3, 5, 8, and 12 ft dia and graphite-moderated cores of 5, 7, 10, and 14 ft dia. With each type, void fractions of 0.15, 0.25, and 0.40 were simulated by a fractional reduction of the density of all materials in the core.

The thorium concentrations in the core were adjusted to give an effective multiplication of 1.1. This value was chosen, rather than 1.0, in order to approximate the conditions which would prevail with the inclusion of appropriate fission-product poisons.

The quantities of particular interest in the calculations are the leakages from the core, the over-all conversion ratios, and the distributions of the conversion ratios between core and blanket.

The net leakage from the core can be seen in Fig. 1. This quantity increases, of course, with decreasing core diameter and with increasing void fraction. In comparing the graphite-moderated core with a BeO-moderated core of the same void fraction, one obtains the same core leakage when the graphite-moderated core is about twice the diameter of the BeO-moderated core. However, it should be kept in mind that the exact shape of these curves depends strongly on the composition of the blanket, and to some extent on the thickness of the blanket.

The conversion ratios are seen in Figs. 2 through 7. The total conversion ratio in each case seems to decrease with decreasing core diameter and with increasing void fraction. However, analysis of the results shows that the former effect is substantially due to an increase in radial leakage from the blanket, while the latter effect is due to an increase in axial leakage from the core. Hence, the total conversion ratio would be nearly independent of void fraction and core diameter if the core were made longer and the blanket thicker. Decreasing the core diameter also had very minor effects on total conversion ratio due to increasing the fraction of the conversion in the blanket, since the amount of "parasitic" capture is not in general the same in the core as in the blanket. This effect was not shown accurately since the fission products were not explicitly included in the calculation. Changing the core diameter did not have any perceptible effect on total conversion ratio

attributable to changes in neutron energy spectrum.

The amount of conversion which takes place in the core naturally increases with increasing core size while the amount of conversion in the blanket decreases. Again, the shape of the curves obtained with BeO moderation is similar to that obtained with graphite, and equal fractions of core conversion divided by total conversion are found with a graphite-moderated core of about twice the diameter of a BeO-moderated core. The higher total conversion ratios obtained with the BeO-moderated cores are primarily due to the fast reactions in Be, i.e., the net result of the $n,2n$ reaction and the n,α reaction.

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Net Core Leakage - Fraction of Total Neutrons

FIG. 1. NET CORE LEAKAGE FROM GRAPHITE AND BeO MODERATED CORES

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FIG. 2. CONVERSION RATIOS FOR GRAPHITE MODERATED CORES
(0.15 VOID FRACTION)

FIG. 3. CONVERSION RATIOS FOR BeO MODERATED CORES
(0.15 VOID FRACTION)

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

FIG. 4. CONVERSION RATIOS FOR GRAPHITE MODERATED CORES
(0.25 VOID FRACTION)

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FIG. 5. CONVERSION RATIOS FOR BeO
MODERATED CORES
(0.25 VOID FRACTION)

0 2 4 6 8 10 12 14
Core Diameter (ft)

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FIG. 6. CONVERSION RATIOS FOR GRAPHITE MODERATED CORES
(0.40 VOID FRACTION)

FIG. 7. CONVERSION RATIOS FOR BeO MODERATED CORES
(0.40 VOID FRACTION)

494 008

Core Diameter (ft)

Appendix A

Graphite-Moderated, Graphite-Reflected Cores

Case Number	79	80	81	82	83	84	85	86	87
Core Diameter (ft)	5	7	7	10	10	10	14	14	14
Core Void Fraction	0.15	0.15	0.25	0.15	0.25	0.40	0.15	0.25	0.40
Core Nuclide Concentrations									
N_c	0.07038	0.07038	0.0621	0.07038	0.0621	0.04968	0.07038	0.0621	0.04968
N_{23}	8.798×10^{-6}	8.798×10^{-6}	7.76×10^{-6}	8.798×10^{-6}	7.763×10^{-6}	6.21×10^{-6}	8.798×10^{-6}	7.763×10^{-6}	6.21×10^{-6}
N_{th}	9.053×10^{-5}	1.701×10^{-4}	1.251×10^{-4}	2.234×10^{-4}	1.777×10^{-4}	1.1119×10^{-4}	2.437×10^{-4}	2.069×10^{-4}	1.437×10^{-4}
Blanket Thickness (ft)	2	2	2	2	2	2	2	2	2
Blanket Nuclide Concentrations									
N_c	0.0828	0.0828	0.0828	0.0828	0.0828	0.0828	0.0828	0.0828	0.0828
N_{th}	8.28×10^{-4}	8.28×10^{-4}	8.28×10^{-4}	8.28×10^{-4}	8.28×10^{-4}	8.28×10^{-4}	8.28×10^{-4}	8.28×10^{-4}	8.28×10^{-4}
Core Length (ft)	10	10	10	10	10	10	10	10	10
Axial Buckling (cm^{-1})	7.09×10^{-3}	7.09×10^{-3}	7.09×10^{-3}	7.09×10^{-3}	7.09×10^{-3}	7.09×10^{-3}	7.09×10^{-3}	7.09×10^{-3}	7.09×10^{-3}
k_{eff}	1.0935	1.0982	1.0956	1.0911	1.0989	1.0948	1.1051	1.0982	1.0987
R_c	0.8594	0.8785	0.8606	0.9079	0.8745	0.8345	0.8915	0.8864	0.8418
P_{max}/P_{avg}	1.600	1.725	1.676	1.845	1.804	1.720	1.942	1.917	1.839
Radial Core Leakage	0.3193	0.1879	0.2288	0.1030	0.1275	0.1834	0.0574	0.0710	0.1046
Radial Blanket Leakage	0.0199	0.0111	0.0136	0.0059	0.0072	0.0104	0.0032	0.0039	0.0058
Axial Leakage	0.0290	0.0280	0.0355	0.0272	0.0348	0.0534	0.0269	0.0344	0.0533

Appendix A (contd.)

BeO-Moderated, BeO-Reflected Cores

Case Number	88	89	90	91	92	93	94	95	96
Core Diameter (ft)	3	5	5	8	8	8	12	12	12
Core Void Fraction	0.15	0.15	0.25	0.15	0.25	0.40	0.15	0.25	0.40
Core Nuclide Concentrations									
N_{BeO}	0.05854	0.05854	0.05165	0.05854	0.05165	0.04132	0.05854	0.05165	0.04132
N_{23}	1.464×10^{-5}	1.464×10^{-5}	1.291×10^{-5}	1.464×10^{-5}	1.291×10^{-5}	1.033×10^{-5}	1.464×10^{-5}	1.291×10^{-5}	1.033×10^{-5}
N_{th}	2.716×10^{-4}	4.258×10^{-4}	3.453×10^{-4}	4.856×10^{-4}	4.180×10^{-4}	3.132×10^{-4}	5.091×10^{-4}	4.447×10^{-4}	3.432×10^{-4}
Blanket Thickness (ft)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Blanket Nuclide Concentrations									
N_{BeO}	0.06887	0.06887	0.06887	0.06887	0.06887	0.06887	0.06887	0.06887	0.06887
N_{th}	6.21×10^{-4}	6.21×10^{-4}	6.21×10^{-4}	6.21×10^{-4}	6.21×10^{-4}	6.21×10^{-4}	6.21×10^{-4}	6.21×10^{-4}	6.21×10^{-4}
Core Length (ft)	10	10	10	10	10	10	10	10	10
Axial Buckling (cm^{-1})	5.79×10^{-3}	5.79×10^{-3}	5.79×10^{-3}	5.79×10^{-3}	5.79×10^{-3}	5.79×10^{-3}	5.79×10^{-3}	5.79×10^{-3}	5.79×10^{-3}
k_{eff}	1.0978	1.0928	1.0999	1.0979	1.0956	1.0912	1.1019	1.0989	1.0967
R_c	0.8913	0.9641	0.9355	0.9806	0.9770	0.9658	0.9836	0.9840	0.9738
P_{max}/P_{avg}	1.449	1.636	1.588	1.794	1.769	1.674	1.898	1.898	1.829
Radial Core Leakage	0.2312	0.1064	0.1293	0.0494	0.0602	0.0867	0.0246	0.0300	0.0441
Radial Blanket Leakage	0.0294	0.0127	0.0154	0.0056	0.0068	0.0098	0.0027	0.0033	0.0049
Axial Leakage	0.0063	0.0057	0.0072	0.0054	0.0069	0.0107	0.0053	0.0068	0.0106

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