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FENDL NEUTRONICS BENCHMARK:

NEUTRON MULTIPLICATION MEASUREMENTS IN BERYLLIUM, BERYLLIUM OXIDE AND LEAD WITH 14-MEV NEUTRONS

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Abstract

Following the recommendations of an IAEA Consultant's Meeting on "Preparation of Fusion Benchmarks in Electronic Format for Nuclear Data Validation Studies", the present report on benchmark experiments with 14-MeV neutrons on beryllium, beryllium oxide and lead was prepared. It complements the experimental data available on-line from the IAEA Nuclear Data Section so as to enable any user to perform transport calculations for this experiment in order to validate nuclear data libraries, such as the Fusion Evaluated Nuclear Data Library (FENDL).

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Introduction

(written by U. von Möllendorff, Kernforschungszentrum Karlsruhe, Germany,
and S. Ganesan, IAEA Nuclear Data Section, Vienna, Austria)

The IAEA Nuclear Data Section has implemented a computerized collection of data from those integral neutronic experiments that are suitable to test libraries of evaluated fusion relevant nuclear data ("benchmark experiments"). In particular, the Fusion Evaluated Nuclear Data Library (FENDL), the reference library for the International Thermonuclear Experimental Reactor (ITER) project, should be validated using these experimental data. An IAEA Consultant's Meeting on "Preparation of Fusion Benchmarks in Electronic Format for Nuclear Data Validation Studies has given detailed recommendations for submissions of experimental data and parameters for this collection (see summary report INDC(NDS)-298, March 1994). It was pointed out that, in addition to numerical data, explanatory hard-copy material in the form of text and figures is indispensable to enable calculations to be made.

The present report which follows is such material. It complements the following file that is available by ftp command on-line from the IAEA:

ftp 161.5.2.2
user FENDL
cd FENDL/BENCHMARKS/BOMBAY
The file "REPORT.DOC" corresponds to this document.

IAEA Benchmark Experiment for Fusion Blanket Multiplier

NEUTRON MULTIPLICATION MEASUREMENTS IN BERYLLIUM, BERYLLIUM OXIDE AND LEAD WITH 14-MEV NEUTRONS

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I. Measured Quantities

The apparent leakage multiplication for 14-MeV neutrons in 8, 12 and 20 cm thick beryllium metal, 20 cm thick beryllium oxide and 10 cm thick lead, all in rectangular geometry. This multiplication is defined per source neutron and not per neutron entering the multiplier.

II. Method

The leakage neutron multiplication due to 14 MeV neutron in a multiplier is defined as the total neutron production minus the absorptions in the multiplier. This can be measured by using an infinite 1/v moderating and absorbing medium surrounding the multiplier. Similarly the source term can be measured without the multiplier in place, and the ratio of the two measurements would give the leakage multiplication. However, in practice a finite medium is used and absorption measurements are made with a 1/v detector. In this case, the ratio of absorption with and without the multiplier gives the apparent multiplication. In these experiments, polyethylene/polypropylene was used as a 1/v absorber and BF-3 detector was used to measure the absorptions.

III. Geometry and Experimental Details

III.1. Beryllium metal assembly

This experiment was performed at the IRE, KFA, Juelich in Germany along with V.R. Nargundkar, P. Cloth, D. Filges and S. Taczanowski /1/. Beryllium metal rods of 1.85 g/cc density having a 2- X 2- cm cross section and 65- cm length were used for making the assembly. A 125- X 120- X 120- cm rectangular polyethylene assembly was built with a 125- X 14- X 14- cm central through channel to introduce the neutron generator tube.

The shape of the source channel was conical at the ends on either side so that the source neutrons which do not contribute to multiplication, leak out from the assembly. A central cavity was provided to accomodate beryllium. For 12 cm thick beryllium, the size of the central cavity was 65- X 38- X 38- cm and for 8 cm and 20 cm thick beryllium, the size was 65- X 54- X 54- cm. Thus in all the three assemblies, the outer dimensions of polyethylene were kept unchanged.

12 cm beryllium assembly had 41 cm thick polyethylene in the y- and z- directions and 30 cm thick polyethylene in the x-direction. The 20 cm beryllium assembly had 33 cm thick polyethylene in the y- and z- directions and 30 cm thick polyethylene in the x-direction. Since the beryllium stock was limited, the 20- cm thick assembly was arranged in four configurations, details of which are given in Ref./1/. The 8 cm beryllium assembly was also surrounded by 33 cm thick polyethylene in the y- and z- directions and 30 cm in the x-direction but the inner channel dimension was 65- X 38- X 38- cm whereas for 12 and 20 cm beryllium assembly, the inner channel dimension was 65- X 14- X 14- cm. Details of the dimensions are given in Ref./2/.

A 150-kV Philips portable neutron generator tube capable of giving a neutron yield of 10**9 n/s was used in the experiment. The neutron generator tube was introduced at the centre of the polyethylene assembly. The polyethylene assembly consisted of two parts: the outer block surrounding the multiplier radially and the end blocks surrounding it axially. The neutron absorption measurements were confined to a representative slab of the outer block by symmetry considerations. The representative slab itself was further divided into two parts: lower and upper. This slab had the flexibility for creating a measuring channel along its length (x-direction) at any height (z) and width (y). Except the representative slab where measurements were made, rest of the polyethylene was fixed together by means of polyethylene screws.

A 1-cm diam, 5-cm active length BF-3 detector was used for the measurement. A 2- X 2- cm axial channel was created in the block to insert the detector. The measurements were made at seven values of z. For each value of z, five channels were formed in the y-direction, corresponding to 1, 6, 11, 21, and 31 cm. For each channel, seven measurements were made in the x-direction. Thus about 250 points were scanned in the representative block. The relative variation of the neutron source intensity during individual runs was monitored by two large BF-3 detectors suitably located in the polyethylene assembly. The monitor counts were normalised with regard to absolute neutron yield, which was determined by the (n,2n) reaction in fluorine having a threshold energy of 11.2 MeV. For this purpose, four 10-mm diam, 2-mm thick Teflon discs placed at 90 deg. apart on the target holder were irradiated for 2 h.

The integration of the individual BF-3 counts for the lower and upper blocks of the representative slab was done using Simpson's method. The exact geometry of the outer block of the polyethylene assembly can be constructed by using 16 times the lower block plus 8 times the upper block. Therefore, the lower block integral counts were given a weight of 16 and the upper block integral counts a weight of 8. Then they were added together to obtain the net integral counts in the outer block which is proportional to the net neutrons in the polyethylene assembly. The measurement was done with and without multiplier and the ratio of the neutron absorptions (integral counts) in two cases give the apparent leakage multiplication.

III.2. Beryllium oxide assembly

In the case of beryllium metal, the neutron absorption measurement in polyethylene was restricted to the outer block and not in the end blocks. To see the effect of this, BeO (density=3.01 g/cc) measurement was performed at Bhabha Atomic Research Centre,(BARC), Bombay using the indegenously built 14-MeV (d,t) neutron source. A 120- X 125- X 125- cm near cubical polypropylene asembly was built with a 120- X 15- X 15- cm axial through channel for introducing the neutron generator tube. The 20 cm thick BeO was surrounded by polypropylene of 35 cm radially and 30 cm axially /3/. The measurements in polypropylene were carried out in representative blocks of both the outer block and the end block regions. A 2- X 2- cm channel was created at a time and a 1-cm diam and 5-cm active length BF-3 detector was used to measure the neutron absorptions at nine different axial locations. In all, 600 readings were taken for the outer block and 100 readings for the end block.

III.3. Lead assembly

The leakage multiplication measurement in 10 cm thick lead assembly was also conducted at BARC., Bombay. The lead (density=11.24g/cc) assembly had 45 cm thick polypropylene in the y- and z- direction (radial) and 30 cm thick polypropylene in the x- direction (axial) surrounding it /4/. The neutron absorption measurements in polypropylene was done the similar way as in the case of BeO.

IV. Calculations

The Monte Carlo general geometry code MORSE-E /5/ was used for all calculations. The Los Alamos National Laboratory 30-group CLAW-IV /6/ cross-section set in P-3 scattering approximation and the response functions, both based on ENDF/B-IV data library were used in the calculations. The neutron source was placed at the centre of the assembly and was assigned energy corresponding to the second group (13.5-15 MeV) for isotropic source distribution. Calculations were also done for anisotropic source but its effect was not much. B-10 responses in polypropylene were calculated with and without multiplier and the ratio of these two values give the apparent calculated multiplication. Table I summarises the experimental and calculated apparent leakage multiplication for Be, BeO and Pb. The values written in brackets are errors.

Table I

Experimental and calculated apparent leakage multiplication

Geometry Description				Apparent Multiplication		
Multi-plier	Thick-ness	Outside Dimension (cm)	Inside Channel Dimension (cm)	Calc.	Expt.	Expt/Cal
Be metal	8 cm	65 X 54 X 54	65 X 38 X 38	1.64 (0.01)	1.33 (0.05)	0.81
Be metal	12 cm	65 X 38 X 38	65 X 14 X 14	2.03 (0.01)	1.70 (0.05)	0.84
Be metal	20 cm	65 X 54 X 54	65 X 14 X 14	2.07 (0.01)	1.68 (0.20)	0.81
BeO	20 cm	60 X 55 X 55	60 X 15 X 15	1.54 (0.01)	1.19 (0.05)	0.77
Pb	10 cm	60 X 35 X 35	60 X 15 X 15	1.55 (0.01)	1.53 (0.03)	0.99

V. Conclusion

For beryllium metal and beryllium oxide, the measured leakage multiplication values are nearly 20% smaller than the corresponding calculated values whereas for lead, the experimental leakage multiplication agrees fairly well with the calculated value.

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