MEASUREMENT OF NEUTRON ENERGY SPECTRA EMERGING FROM A LAMINATED SHIELD DUE D-T SOURCE AND COMPARISON WITH CALCULATIONS

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ABSTRACT

An experimental facility was built to conduct shielding benchmark experiments. In this paper an experiment conducted in this facility is described. The experiment consists on a measurement of neutron energy spectrum emerging from a laminated shield of stainless steel, polyethylene and lead due a source of ~14 MeV deuterium-tritium neutrons from a Van de Graaff accelerator (400 KeV). The neutron energy spectrum was measured using an organic liquid scintillator (NE-213) and pulse shape discrimination technique to reject gamma-ray counts. The measured proton-recoil pulse height spectra was unfolded by the FANTI unfolding code to obtain the neutron energy spectrum. The experimental results were compared with calculated by a network of codes. The source term was obtained by a program based in the kinematics of DT reaction; the cross section were processed with AMPX-II system using VITAMIN-C library with basic data from ENDF-B-IV, and the transport through the shield was calculated by DOT 3.5. The comparison between measured and calculated neutron spectra was made in the range of 2.4 and 16 MeV and showed good agreement.

INTRODUCTION

Experimental data are needed to validate shielding calculational methods. Since the early days in shielding, experimental facilities have been used to provide data, check calculational methods, and support physical models, such as the "Lid Shielding Tank Facility".

Since then, several others experiments had been made using nuclear reactors as radiation source, as well as radiation produced by accelerators, as the work of Santoro et alli (1). This paper describes an experiment conducted in a facility which uses a Van de Graaff accelerator (400 KeV) to produce DT neutrons which are incident in a laminated shield. The neutron energy spectrum emerging from this shield is measured by a NE-213 spectrometer, and compared with a calculated by a network of codes, in order to verify a calculational method.

The experimental facility, and experimental techniques are described in section II, the calculational method is described in section III, and the comparison between calculated and experimental results are presented and discussed in section IV.

DESCRIPTION OF THE EXPERIMENT

The experimental facility used to conduct shielding benchmark experiments is shown schematically in figure 1. In this facility, a Van de Graaff accelerator is used to accelerate deuterium with a voltage up to 170 KV to produce 14 MeV neutron in a TiT_N target due a $^3H(d,n)^4He$ reaction. The accelerator tube and target are located inside a water tank, used to have a well defined model for computational purposes. Inside the water tank is located a test section, (60x60x60cm), in which a laminated shield under study can be inserted.

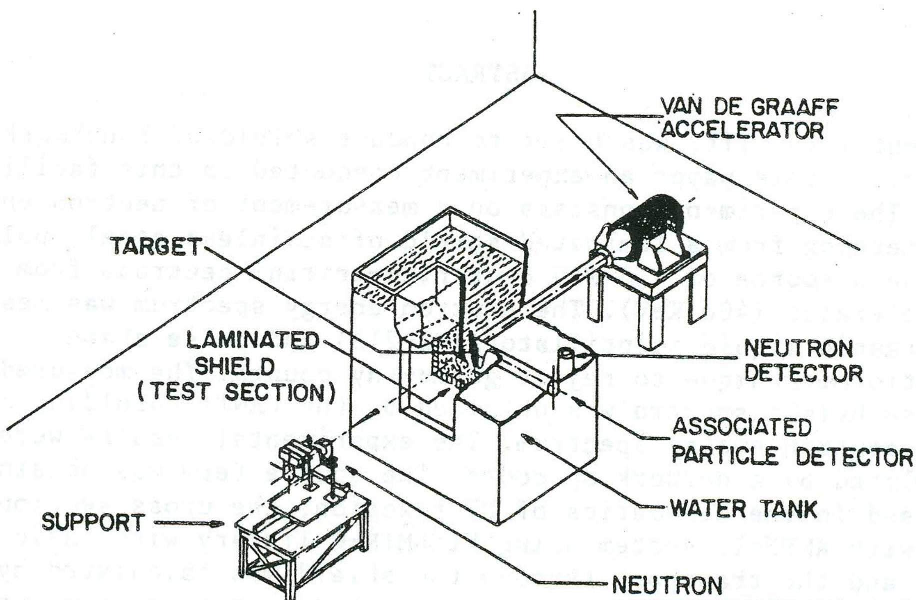

Figure 1. Experimental Facility. (Schematic View)

The absolute yield of neutrons can be measured by an alpha particle associated counting technique, using a surface barrier detector located outside the water tank in the exit of a tube perpendicular to the accelerator tube. Since the surface barrier detector can be damaged by radiation it cannot be used during all data acquisition, so a BF_3 neutron detector was calibrated with a surface barrier detector and used during the measurements to obtain the neutron production. The laminated shield in study in this experiment is composed by 60cm square plates with thickness of 2.2cm of stainless steel (2 plates), 2.5cm of polyethylene (6 plates), and 10cm lead, as shown in figure 2. The neutrons emerging from the shield were measured by a fast neutron spectrometer consisting of a NE-213 proton recoil liquid scintillator, encapsulated in a standard type VH-1 aluminium

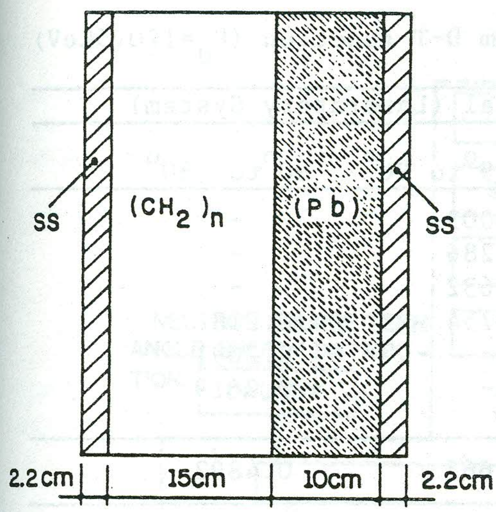

Figure 2. Laminated Shield.

can (5,08x3,81cm), connected to a photo-multiplier RCA 8850 through a light guide. The electronic system used in the experiment is shown in figure 3. This system has been used for pulse shape, and discrimination technique to reject gamma ray counts.

The measured proton recoil pulse height spectra was unfolded using FANTI code (2) which applies the matrix inversion method to obtain the neutron energy spectrum. The neutron spectrometer linearity and its energy calibration were made with gamma ray sources, and the performance of the spectrometer was evaluated by measuring spectra from standard neutron sources of Am-Be and ^{252}Cf (3).

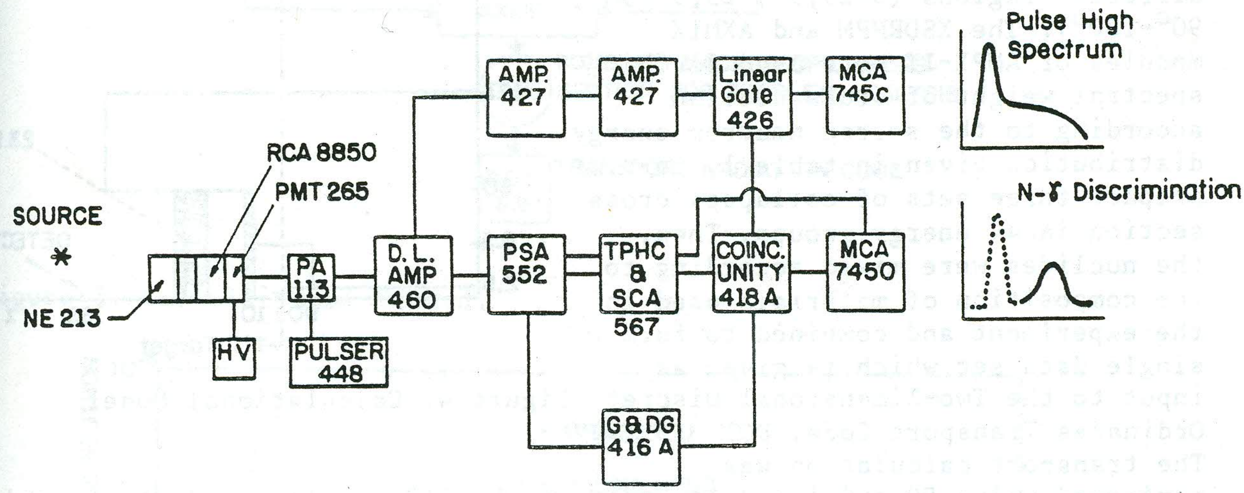

Figure 3. Fast Neutron Spectrometer with an associated electronics.

CALCULATIONAL METHODS

The energy-angle neutron distribution from a DT reaction needed as source term in the calculational method was obtained from a computer program, CALCDT(4). This calculation was based in the kinematics of DT reaction, to obtain the neutron emission probability between the zenith angles θ_1 and θ_2, in the lab system with energies in the interval E_1 to E_2, due to an incident deuteron with energy E_d in a thick target of TiT_N (N=1,4)(4). Table 1 gives the results of CALCDT program for E_d=170 KeV, and angle-energy intervals used in this paper.

All the calculated results were obtained using two-dimensional radiation transport methods, in R-Z geometry with cylindrical symetry about the deuteron beam axis. Figure 4 shows the model used to simulated the experimental configuration. The generation of multigroup cross section in 44 neutron energy groups have been made by AMPX-II system (5) using the

TABLE 1

Energy-Angle Neutron Distribution from D-T reaction (E_d=170,5KeV)

Energy Interval (KeV)	angle interval (Laboratory System)		
	0^o to 23.9^o	23.9^o to 90^o	90^o to 180^o
14920 to 15680	0.0063	0.0003	-
14550 to 14920	0.0358	0.1286	-
14190 to 14550	0.0028	0.2632	-
13800 to 14190	-	0.0754	0.2182
13500 to 13800	-	-	0.2091
12840 to 13500	-	-	0.0619
total	0.0449	0.4665	0.4892

VITAMIN-C Nuclear Data Library (6) with basic data from ENDF-B-IV. One dimensional calculations were adopted for cross section collapsing in three different regions (0-23,9°; 23,9°-90°; 90°-180°). The XSDRNPM and AXMIX modules of AMPX-II were used for spectral weight of cross section according to the source neutron energy distribution given in table 1, to prepare three sets of collapsed cross section in 44 energy groups. Then, the nuclides were mixed according to the composition of materials used in the experiment and combined to form a single data set which is given as input to the Two-Dimensional Discret Ordinates Transport Code, DOT 3.5 (7). The transport calculation was performed using 99 axial and 64 radial mesh, S12 angular quadrature, and P_3 Legendre expansion of the cross sections. Figure 5 shows the sequence of the calculational method.

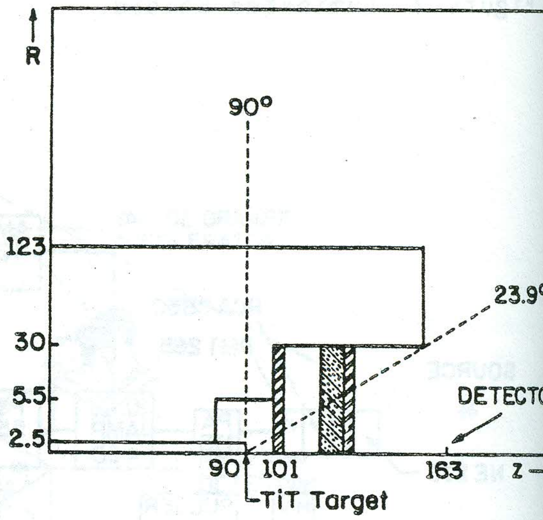

Figure 4. Calculational Model.

RESULTS AND DISCUSSION

The results obtained, and here published, are the first of a sequence of measurements that the authours are conducting in the experimental shielding facility. Figure 6, shows the measured and calculated differential neutron energy spectrum in the spatial detector position R=0cm, Z=163cm. Although we still have some statistical flutuation in the experimental results due mainly low neutron production obtained in the target (~10n/s), our results can be considered good, having obtained ~12% difference between an integrated neutron energy spectra measured and calculated. To improve our results we will try to increase the neutron production by the accelerator and in the calculational methods, will use FALSTF for transport calculation outside the laminated shield, and the first collision source as suggested by Santoro (1).

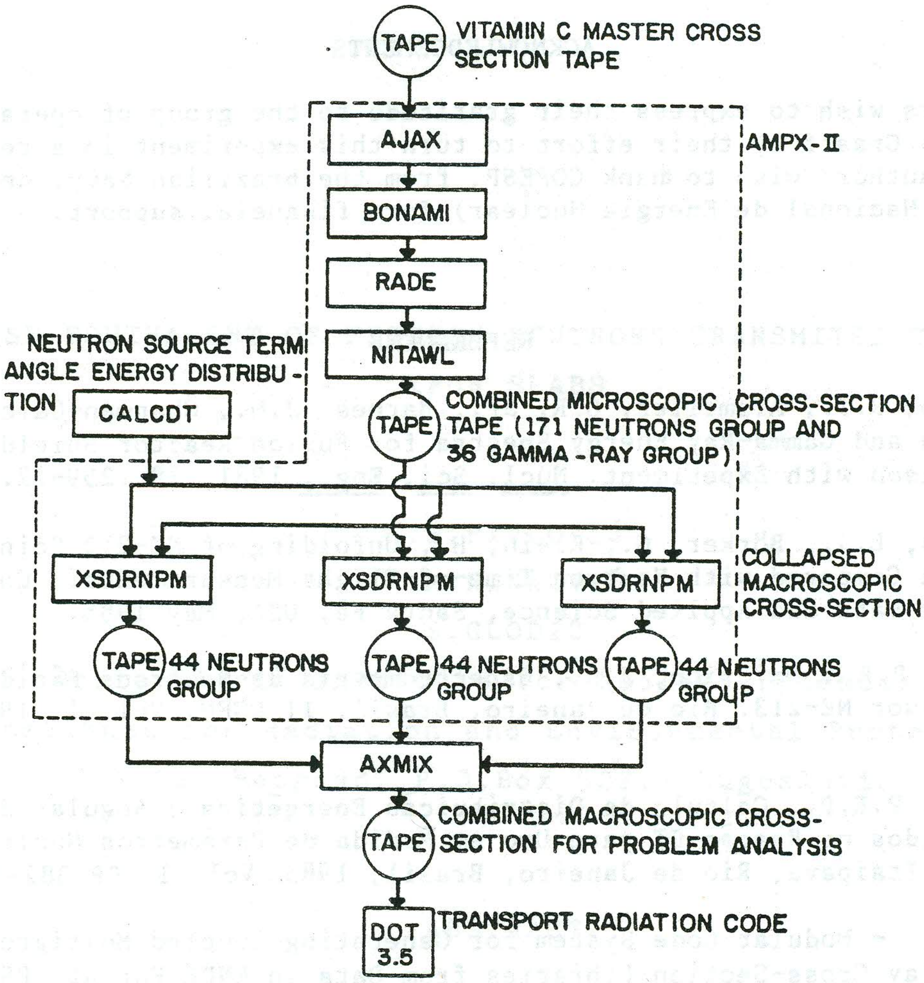

Figure 5. Calculational Method.

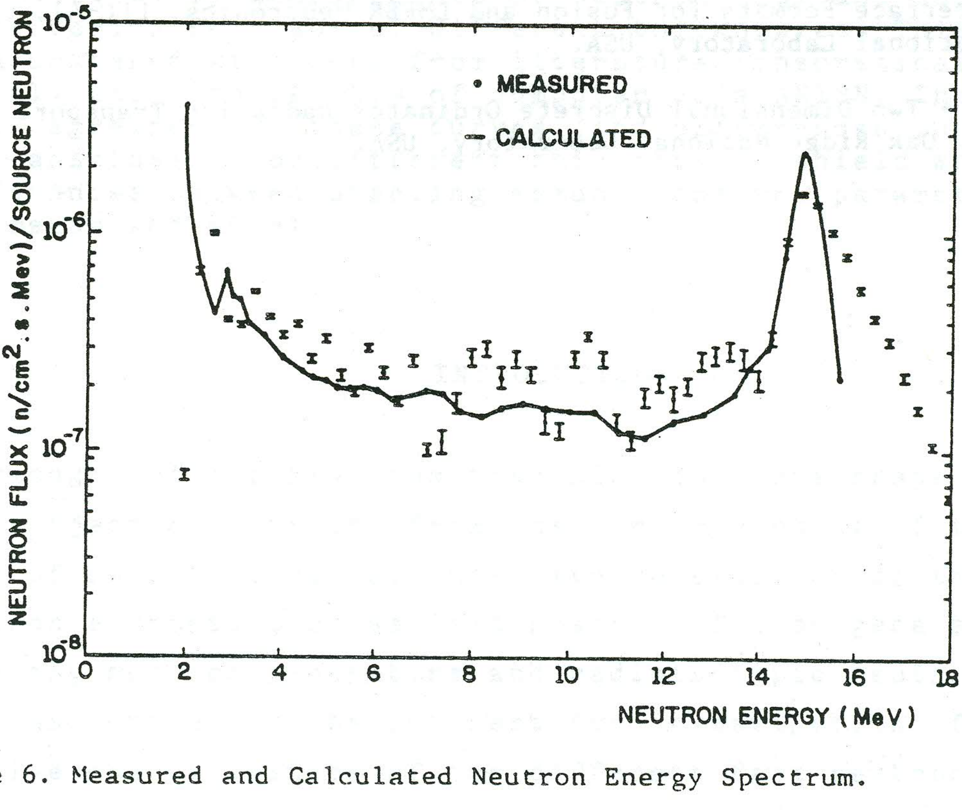

Figure 6. Measured and Calculated Neutron Energy Spectrum.

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