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DATE April 11, 1967

TO W. E. Wilson

FROM K. L. Swinth

SUBJECT Fast Neutron Medical Research Facility Dosimetry for 2.5 MeV Neutrons

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L A Braby
C E Newton
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F L Rising
W C Roesch
W G Spear
K L Swinth (2)
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Below is a brief summary and review of the dosimetry for 2.5 MeV neutrons at the Fast Neutron Medical Research Facility in Walla Walla, Washington.

Introduction

The Fast Neutron Medical Research Facility, designed to selectively irradiate the testes of volunteers, has been previously described[1,2]. The facility consists of a massive shield of concrete and water containing a neutron generator capable of producing low dose rates of 2.5 MeV neutrons, and much higher dose rates of 14 MeV neutrons.

The facility is designed to irradiate the testes of volunteer subjects while affording protection to other areas of the body. To selectively irradiate the volume of interest it is necessary to use r^2 attenuation and irradiate with the neutron source as close as feasible to the volume of interest. In order to produce uniform doses at close distances, it is necessary to irradiate with one-half the dose delivered from the front and the other half from the rear. Figure 1 shows a schematic representation of the facility indicating the major pieces of hardware.

The volume to be irradiated is contained in a 5 by 7 by 10 cm plastic cup filled with warm water. This is done for two reasons: first, the warmth will cause descent of the testes; and second, the water will make the system approximate one tissue equivalent mass, thus making the dose distribution independent of variations from subject to subject. Recently, a control circuit was constructed for regulation of the temperature in the plastic cup. It can regulate the temperature within 0.25°F of any predetermined temperature. It is necessary to control the temperature since elevated temperatures may introduce errors by extraneously causing sperm suppression.

To give a continuous monitor of the dose delivered, a moderated BF_3 tube is located at the rear of the shield (See Figure 1). This monitor is calibrated during dosimetry experiments, but cannot be used as a primary standard due to variations caused by position changes of the subject. This is pointed out in the next section. For a primary standard, tissue equivalent ion chambers or sulfur pellets will be used.

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Dosimetry

All of the dosimetry is based on tissue-equivalent dosimetry methods although activation methods have been and will be used occasionally. Most of the measurements are made with small pulse-read tissue-equivalent ion chambers[3]. These ion chambers are air filled, but are calibrated against a large flow chamber of tissue-equivalent plastic. This is done at the facility to assure calibration for the proper neutron spectrum. To investigate the spectrum present for biological purposes, we use a spherical-tissue-equivalent-proportional counter after the method of H. H. Rossi[4].

Monitor Reliability

The first experiments were done to investigate the effect on the monitor of the position of the man and the bed on which he lies. Both the bed and a spacer block are positioned by slide bolts and an indexing rod to within 1/16 of an inch and cannot move. The volume of interest can be positioned with respect to the bed to an accuracy of 1/16 inch. The only uncontrolled variable is the position of the man's trunk which he is free to move.

For the purposes of dosimetry, an Alderson Research Remab phantom filled with a tissue-equivalent solution of water and sugar is used. The phantom is articulated and contains a skeleton and dosimeter tubes so that dosimeters can be placed at various points of interest.

When the facility is set up to irradiate the front of the testes (See Figure 1), the trunk of the subject is, effectively, between the target and the monitor. In this position, moving the phantom's torso left or right caused a maximum decrease of 8% in the dose delivered to the volume of interest per unit monitor count compared to the normal position. Removing the right arm caused a decrease in the dose of 3% per unit monitor count. Keeping the position of the volume of interest fixed with respect to the source of neutrons, it was found moving the bed and phantom 2-3/4 inches toward the generator caused an 11% increase in the dose per unit monitor count. The position of the spacer located behind the bed had no effect on the dose per unit monitor count.

When the facility is set up to irradiate the testes from the rear, it was found the position of the phantom's trunk had no effect on the dose to the volume of interest for a unit monitor count. In this position the spacer is between the neutron source and monitor and the neutron source is behind the subject.

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Removing the lower leg of the phantom, which rests in a notch in the spacer, caused a decrease of 12% in the dose per unit monitor count. If we again held the position of the volume of interest constant, but moved the spacer toward the generator one inch, this caused an increase of 5% in the dose per unit monitor count.

These experiments indicated that the monitor can not be used as a primary calibration. In the case of 2.5 MeV neutrons, it was decided to use tissue-equivalent ion chambers as a primary standard.

Dose Distribution

Figure 2 shows the dose distribution for a typical irradiation on the facility with one-half the dose delivered from the front and one-half from the rear. These points were measured with ion chambers as mentioned previously. This distribution represents an average dose of 0.98 rads to the volume of interest. The points show a standard deviation from the average of 0.22 rads and range from 0.60 rads to 1.45 rads. This represents an exposure time of about 50 minutes.

The calibration for the monitor is about 106,000 counts per rad when the testes are irradiated from the front and 100,000 counts when the testes are irradiated from the rear.

Doses to other portions of the body were also investigated. The doses are shown in Table I.

TABLE I

Doses to the Body for a One Rad Dose to the Volume of Interest

Area of Body	Dose (mrad)
Eye	64
Base of Sternum	118
Prostatic Urethra	87
Trigone Area of Bladder	84
Anus	40
Rectum	59

In most cases the doses are less than one-tenth the dose to the volume of interest. Most of the doses are approximately as expected. In the case of the eye and the base of the sternum the doses are much higher than expected from calculations. The reason for the high readings is not known.

Shielding

For generally occupied areas around the facility measured dose rates were less than 0.5 mrem/hr for 2.5 MeV neutrons. Moving up mext to the entrance, dose rates of 2 mrem/hr were obtained.

Work has begun on similar measurements with 14 MeV neutrons. Preliminary measurements outside the controlled area indicate dose rates will be within established limits.

References

1. W. C. Roesch, K. L. Swinth, and L. L. Nichols. "Fast Neutron Medical Research Facility," Hanford Radiological Sciences Research and Development Annual Report for 1963. HW-81746. January 1964.
2. K. L. Swinth. "Fast Neutron Medical Research Facility," Hanford Radiological Sciences Research and Development Annual Report for 1964. BNWL-3611. Jan 1965.
3. L. A. Braby. "Miniature Ion Chambers with Integral Switches," Hanford Radiological Sciences Research and Development Annual Report for 1966. BNWL- January 1967.
4. H. H. Rossi, M. H. Biavati, and W. Gross. "Local Energy Density in Irradiated Tissues," Radiation Reserach, 15, p. 431 (1961).

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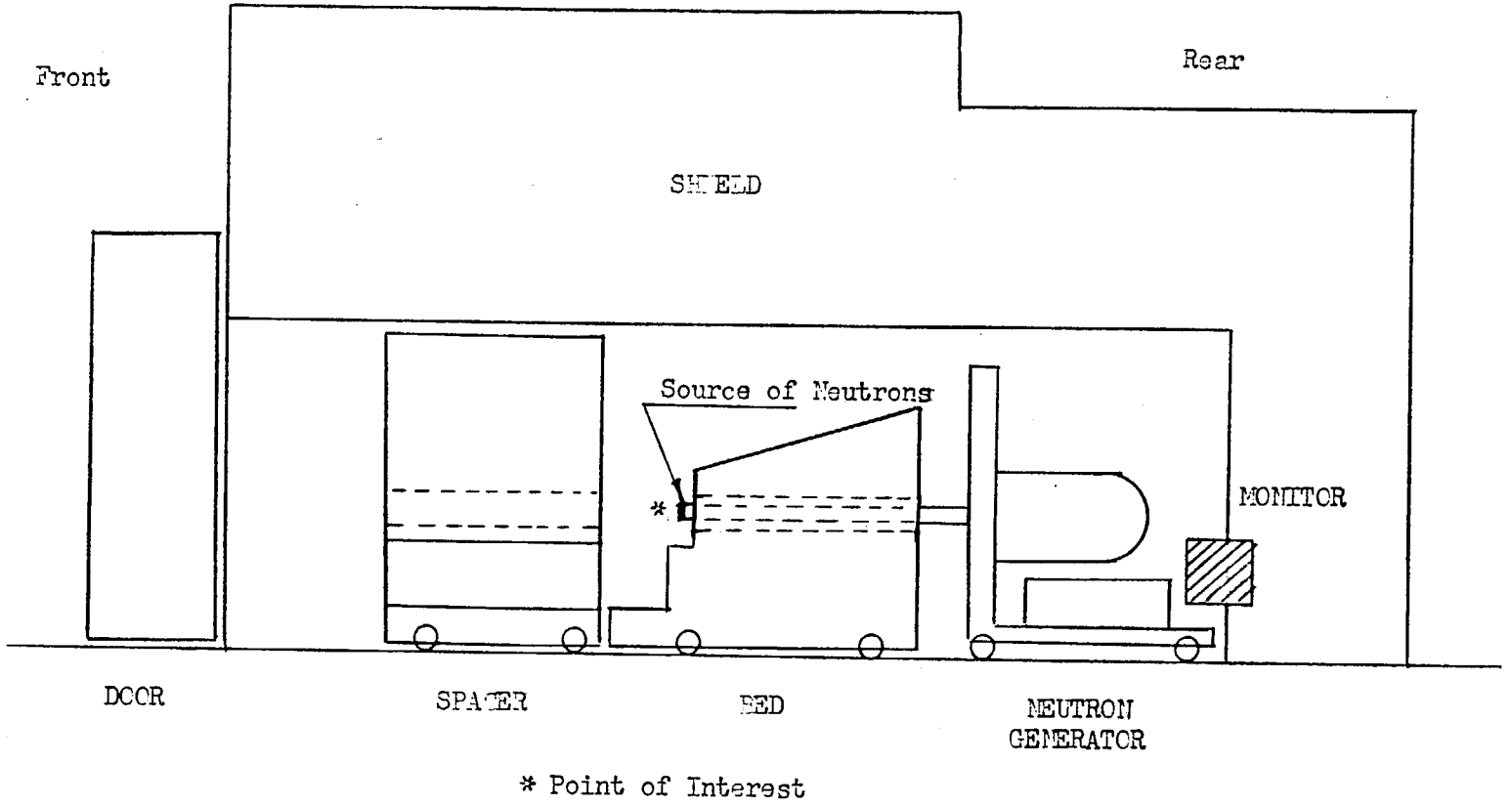

FIGURE 1

Schematic representation of Medical Research Facility showing major hardward. As diagrammed the facility is set up to irradiate the testes from the front. To irradiate from the rear the positions of the spacer and bed are interchanged (rotate 180°). The man kneels over the bed with his lower legs extending into notches in the sides of the spacer.

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0.7

.71	.97	.97	.63
.98	1.33	1.22	.85
1.02	1.45	1.43	.94
.70	.94	.94	.66

1.8

.66	.86	.84	.63
.88	1.15	1.12	.71
.86	1.16	1.07	.79
.86	.90	.81	.67

2.8

.64	.49	.86	.64
1.05	1.19	1.12	.94
1.01	1.29	1.43	1.01
.72	.98	1.00	.60

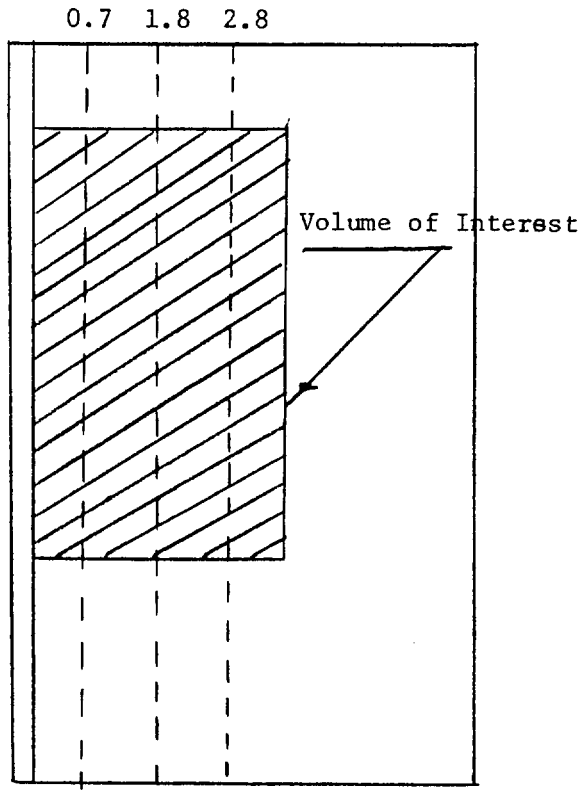

FIGURE 2

Dose distribution on three planes extending through the volume of interest as marked on the figure.

Kathy typed this for Ken. He wanted only original to you. Distribution not made on letter.

Pat

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