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EXPERIMENTAL SHIELDING STUDY OF THE ARGONNE 12.5 MeV TANDEM VAN DE GRAAFF INSTALLATION

by

N. C. Dyer and R. L. Mundis

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Industrial Hygiene and Safety Division

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EXPERIMENTAL SHIELDING STUDY OF THE ARGONNE 12.5 MeV TANDEM VAN DE GRAAFF INSTALLATION

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ABSTRACT

The radiation hazards associated with operation of the 12.5 MeV Tandem Van de Graaff Accelerator at Argonne National Laboratory were determined experimentally. The operating conditions of the accelerator during this study were such as would produce the greatest possible radiation hazards. The levels of penetrating radiation, both gamma and neutron, were measured outside the shield walls. With few exceptions, the radiation levels outside the shielding were far below 2.5 mRem/hr, which is the average level that would result in an exposure equal to the RPG (radiation protection guide) of 5 Rem/year. In areas adjacent to the accelerator that normally are occupied by personnel, such as the control room and data rooms, the radiation levels never exceeded 0.02 mRem/hr. A brief description of the Tandem Van de Graaff installation is given.

INTRODUCTION

Possible radiation hazards around the Tandem Van de Graaff Accelerator in Argonne National Laboratory's Building 203 were investigated during the summer of 1962. The object of the investigation was to determine experimentally the effectiveness of the shielding with the accelerator operating in a manner that would produce maximum radiation hazards.

The accelerator is located in the building's vault room. The particle beam can be brought into either of two target areas by energizing the appropriate 90° analyzer magnet. This arrangement allows an experiment to be in progress in one target area while equipment for the next experiment is assembled in the other target area (see Figs. 1, 2, and 3). Personnel are excluded from the vault and target area in use by means of the interlocked shielding doors located at E-1, V-3, and W-1 in Fig. 1 and the gates located at points A and B, also in Fig. 1.

Biological shielding is provided by a wall of ordinary concrete approximately $5\frac{1}{2}$ ft thick between the vault and target areas and the occupied areas, i.e., the control room, data rooms, and assembly area. In

Fig. 1. Plan View of Experimental Level, Tandem Van de Graaff Accelerator

109-3446 Rev. 1

Fig. 2. Cross Section through Target Areas

109-3985

Fig. 3. Cutaway View of Tandem Van de Graaff Accelerator

addition, a wall of ordinary concrete approximately 4 ft thick is located between the vault and each target area. The exterior walls of the vault and target areas are shielded with concrete approximately 2 ft thick, plus an earth embankment that extends up to roof level (Figs. 2 and 3). The bottom of the earth embankment is shown by the dotted line in Fig. 1.

For this investigation, the Tandem Van de Graaff Accelerator was operated with deuterons accelerated to approximately 12 MeV with the beam current at maximum intensity. An infinitely thick (1/8-in.) target of Be^9 was used, which resulted in the reaction $\text{Be}^9(\text{d},\text{n})\text{B}^{10}$. The target was located successively on the south 30° beam line in the east target area, on the same beam line in the west target area, and then in the vault just beyond the south 90° analyzer magnet. Previous experience indicated that these operating conditions would produce maximum radiation hazards to personnel hypothetically present in the vicinity of the accelerator during operation.

INSTRUMENTATION

The primary instruments used for neutron measurements were unshielded versions of the Hanson and McKibben Long Counter.¹ Both the fast (epicadmium) neutron flux and the thermal neutron flux were measured. Because the Long Counter is not easily portable, battery-operated, small, moderator-type neutron detectors were used for the roof areas to indicate and measure any neutron radiation present. The gamma measurements were made with portable instruments of the scintillation and Geiger-Mueller types.

To calculate fast-neutron dose rates from the measured fast fluxes, the effective neutron energy was assumed to be 6.5 MeV, (Ref. 2) with a corresponding flux-to-Rem dose-conversion factor of 0.143 mRem/hr per neutron/cm²-sec (Ref. 3). It was realized that this flux-to-dose conversion factor would give an overestimate of the fast-neutron dose, mainly because the assumed neutron energy was not adjusted for degradation due to the shielding.

Film packets containing a beta-gamma film (DuPont-508) and a neutron film (Kodak NTA) were placed on the walls of the vault and target areas. The packets were partially wrapped in a cadmium shield. The film was placed on the walls at the same height as the beam lines and target (69.5 in.) because the highest flux at the walls would be in the horizontal plane of the beam.

PROCEDURE

Three series of measurements were taken, the target being placed at a different location for each series. The three target locations are shown

in Fig. 1. At each location, a beam of approximately 12-MeV deuterons with a current of 3 μ Amp was directed at the beryllium target. Therefore, approximately 2×10^{13} deuterons/sec were striking the target, resulting in the production of approximately 10^{11} neutrons/sec (Ref. 4). Film packets were attached to the walls of the inaccessible areas at intervals approximately every 10 ft. Film packets also were placed at certain locations on the accessible sides of the shield walls to give an indication of the attenuation afforded by the walls.

Gamma, fast-neutron, and thermal-neutron measurements were made in all areas outside the shielding walls of the target area and vault. The measurements were made at approximately waist height of an average person. To detect shielding voids, the walls were scanned with both gamma and neutron portable detecting instruments. Suspected hot spots, such as door cracks, cable ducts, hood ducts, etc., were investigated.

RESULTS

The locations noted in Fig. 1 are points external to the vault- and target-area shielding where the dose rates from penetrating radiation were 2.5 mRem/hr or greater during the experimental measurements. Table I shows the total dose rates and the contributions to them from the gamma, fast-neutron, and thermal-neutron components at the given locations. The location numbers are prefixed with the letters, W, V, and E, which refer to the target being in the west target area, vault, or east target area, respectively. All areas that had dose rates greater than 2.5 mRem/hr are not normally occupied by personnel during operation of

TABLE I. Experimental Floor Dose Rates above 2.5 mRem/hr

Location (from Fig. 1)	Gamma Dose Rate, mRem/hr	Thermal-neutron Dose Rate, mRem/hr	Fast-neutron Dose Rate, mRem/hr	Total Dose Rate, mRem/hr
W1	1.30	0.45	16.8	18.55
W2	0.38	0.19	7.5	8.07
V1	0.17	0.05	2.58	2.80
V2	1.70	0.37	16.8	18.9
V3	0.40	0.16	7.72	8.28
V4	0.17	0.08	3.03	3.28
V5	0.23	0.15	12.0	12.4
V6	1.25	0.56	46.0	47.8
V7	0.40	0.12	18.4	18.9
V8	0.33	-	4.75	5.08
V9	0.13	-	3.69	3.82
E1	0.75	0.19	9.45	10.4
E2	0.29	0.15	5.36	5.80
E3	0.38	0.21	20.8	21.4
E4	0.16	0.03	4.39	4.58

the accelerator. For example, areas not continuously occupied are: locations behind the interlocked gates, such as W1 and E1; in cable ducts, such as V1 and V5; cracks under the shield doors, such as V3 and V4; and on the access road, such as E4 and V7.

In only two other areas that are accessible to personnel did the penetrating radiation dose rate exceed 2.5 mRem/hr. These were points A and A' in Fig. 2. At these locations, the earth embankment had settled so that the shielding was not adequate. The maximum total dose rate measured at these locations was 6.3 mRem/hr, of which about 80% was due to fast neutrons. It was recommended that more earth be added to the top of the embankment to correct this weakness in shielding.

The films exposed inside the target areas and vault during the measurements showed integrated doses up to 22.6 Rem. Films exposed for a corresponding period outside the shield walls gave results less than the minimum detectable dose of 25 mRem.

CONCLUSIONS

In general, the results of this study indicated the shielding for the Tandem Van de Graaff to be adequate even when the accelerator was operated so as to produce the greatest radiation hazards possible. Normal machine-operating conditions have presented lower radiation levels than those detected during this study. In addition, any error introduced in the dose-rate calculations by neglect of neutron-energy degradation in the shielding caused an overestimate of the hazard rather than an underestimate.

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