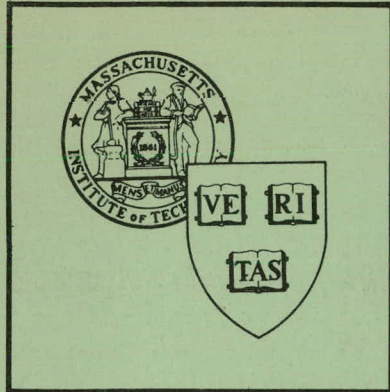


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CEAL- 1007

EFFECTIVENESS OF ILMENITE-LOADED CONCRETE
IN ATTENUATING NEUTRON RADIATION
PRODUCED BY A 5-BEV PHOTON BEAM

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by

Samuel Kao
Gustav-Adolf Voss

20 December 1963

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Samuel Kao
Gustav-Adolf Voss
20 December 1963

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Abstract

The neutron radiation was produced by directing a 5-Bev bremsstrahlung beam at a heavy copper quantameter serving as target. The transverse (90°) neutron flux was attenuated by a variable-thickness wall of ilmenite-loaded concrete having a density of 4.0g/cm^3 , and the biological dose, in rems, behind the wall was determined with the aid of a Texas Nuclear Corporation Model 9120 neutron dosimeter. The half-value thickness of the ilmenite-loaded concrete was found to be 3.2 inches when the wall thickness was 1 to 2 ft. and 6.4 inches when the thickness was 2 to 3 ft.

I. Introduction

Most of the experiments performed at the Cambridge Electron Accelerator Laboratory are performed with the aid of bremsstrahlung beams (photon beams) from thin tungsten targets mounted inside the vacuum ring of the synchrotron. A typical photon beam emerges from the synchrotron via a 0.002-inch stainless steel window, travels via an evacuated beam pipe to the Experimental Hall where it encounters the experimenter's thin hydrogen target and then strikes a Wilson-type quantameter that serves both as beam monitor and beam-catcher. The quantameter is almost totally enclosed in a shielding hut made of ilmenite-loaded concrete blocks having a density of 4.0g/cm^3 .

The present tests were designed to show the effectiveness of this loaded concrete in reducing the biological dose due to neutrons. Previous tests showed that neutrons, rather than photons, constituted the major part of the radiation escaping from such a hut.

II. The Photon Beam

The electron synchrotron was operated at an energy of 5 Bev and an intensity of about 4×10^{11} electrons/second. By means of the rf-turn-off method the electrons were made to strike an (internal) machine target consisting of a 0.01"-thick tungsten ribbon. The spill time was about 400 μ s, representing a duty cycle of 2.5%.

The photon beam emerging through the 0.002" stainless steel window was collimated by a thick Hevimet diaphragm that had a 0.33"-square aperture and was situated about 30 ft. downstream from the machine target. Traveling within an evacuated pipe 3 to 6" in diameter, the photon beam passed through a clearing magnet, through a beam pipe in the main shielding wall, and into the Experimental Hall. Here, at a location 165 ft. from the machine target, it struck the quantameter. Typically, the beam incident on the quantameter contained 2.0×10^{10} equivalent quanta/second, corresponding to about 16 watts (or about 5% of the power in the electron beam).

III. Radiation Detectors

Main reliance was placed on a Texas Nuclear Corporation Model 9120 dosimeter which provides readings proportional to the biological dose, in rems, due to incident 0 to 15 Mev neutrons. The sensing element, a cylindrical LiI(Eu) crystal 4mm long and 4mm in diameter, is situated at the center of a 12 inch diameter polyethylene sphere which is said to have a moderating effect that results in an output proportional to biological dose (within perhaps 20 or 30% in typical situations) provided the neutron energy is less than 15 Mev. The crystal is optically coupled to a photomultiplier by a light pipe. Neutrons, after being moderated by the sphere, are detected by the $\text{Li}^6 (n, \alpha)\text{H}^3$ reaction, which has such a large Q-value (about 4.8 Mev) that a generously large bias may be used to eliminate practically all response to photons. The device was calibrated by the manufacturer with a Po-Be source of 3 to 5 Mev neutrons, and the calibration was confirmed by us with a Pu-Be source of 1 to 4 Mev neutrons. Using a Co^{60} source of 1 Mev photons we confirmed the lack of response to photons.

Also, a portable device of rather similar type (but employing a sphere only 10" in diameter was employed. It was made at CEA, following the principles described by Hankins^{1/}. It too was calibrated at CEA with Pu-Be source.

1) D.E. Hankins, Los Alamos Scientific Laboratory, TID-4500, LA-2717, March, 1962

IV. Experimental Procedure

Fig. 1 indicates the experimental arrangement. The Wilson-type quantameter was mounted squarely in the path of Photon Beam #10, at a location 165 ft. from the machine target. One side of the hut enclosing the quantameter was of adjustable thickness (of ilmenite-loaded concrete) and the other side wall, the back wall, and the top had fixed thicknesses of 6 to 7 ft. of this same material. The neutron dosimeter was placed at a location (Position I) 12 ft. from the quantameter and in direction at 90° to the photon beam.

The quantameter consisted essentially of 18 copper disks each 1 cm. thick and 10 inches in diameter. Each was separated from its neighbors by (gas-filled) gaps 1 to 2 mm thick. Since the photon beam struck the central 2 inch diameter region of the quantameter, much of the neutron flux emerging at 90° traveled through about 5 inches of copper.

As the thickness of the wall was increased in increments of 1 ft, the readings of the dosimeter were noted and recorded.

In later series of measurements, the detector was placed at Position II, 22 ft. from the quantameter. Still later, measurements were made with the detector in Positions III and IV as indicated in Fig. 1.

V. Results

Fig. 2 shows the measured values of biological dose as a function of thickness of shielding wall. Analysis of the curves pertinent to 90° neutron flux at Position I shows that the half-value thickness of the ilmenite-loaded concrete is 3.2" when the wall thickness is 1 to 2 ft. and 6.4" when the thickness is 2 to 3 ft. Comparing the data pertinent to dosimeter positions (I, II) 12 ft. and 22 ft. from the quantameter, one finds that an inverse square law is closely obeyed only when the wall thickness is small ($t \sim 1$ foot). When the wall thickness is 2 ft. or more the dose decreases more slowly with distance.

The attenuation found when the dosimeter was placed at location IV, which is at a forward angle of 50° from the photon beam, was nearly the same as that applicable to the 90° geometry, despite the fact that the path length in the wall was about 30% greater. Presumably the explanation is that neutrons having a more nearly forward direction have a greater energy. The neutron background from sources other than the quantameter was not measured and is difficult to estimate. Accurate measurements of attenuation of forward-traveling (0°) neutrons have not yet been made, but rough measurements have indicated that a 7 ft. wall is as effective for such radiation as a 5 ft. wall is for transverse radiation.

Acknowledgment

We wish to thank T.L. Collins for initiating this project and L. Law for help in preparing the detection equipment. W. Shurcliff has been most helpful in the editing of the manuscript.

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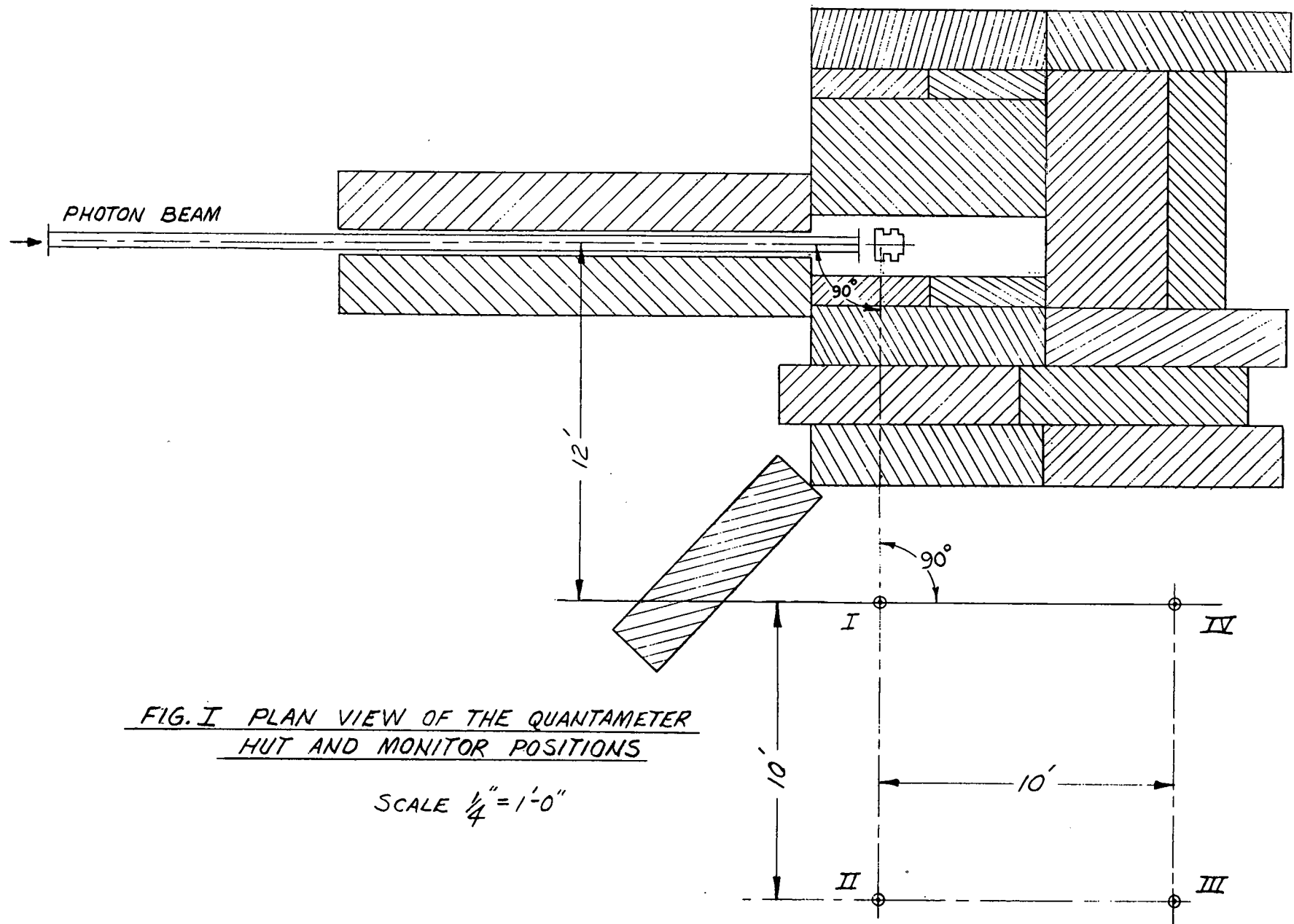


FIG. I PLAN VIEW OF THE QUANTAMETER HUT AND MONITOR POSITIONS

SCALE $\frac{1}{4}'' = 1'-0''$

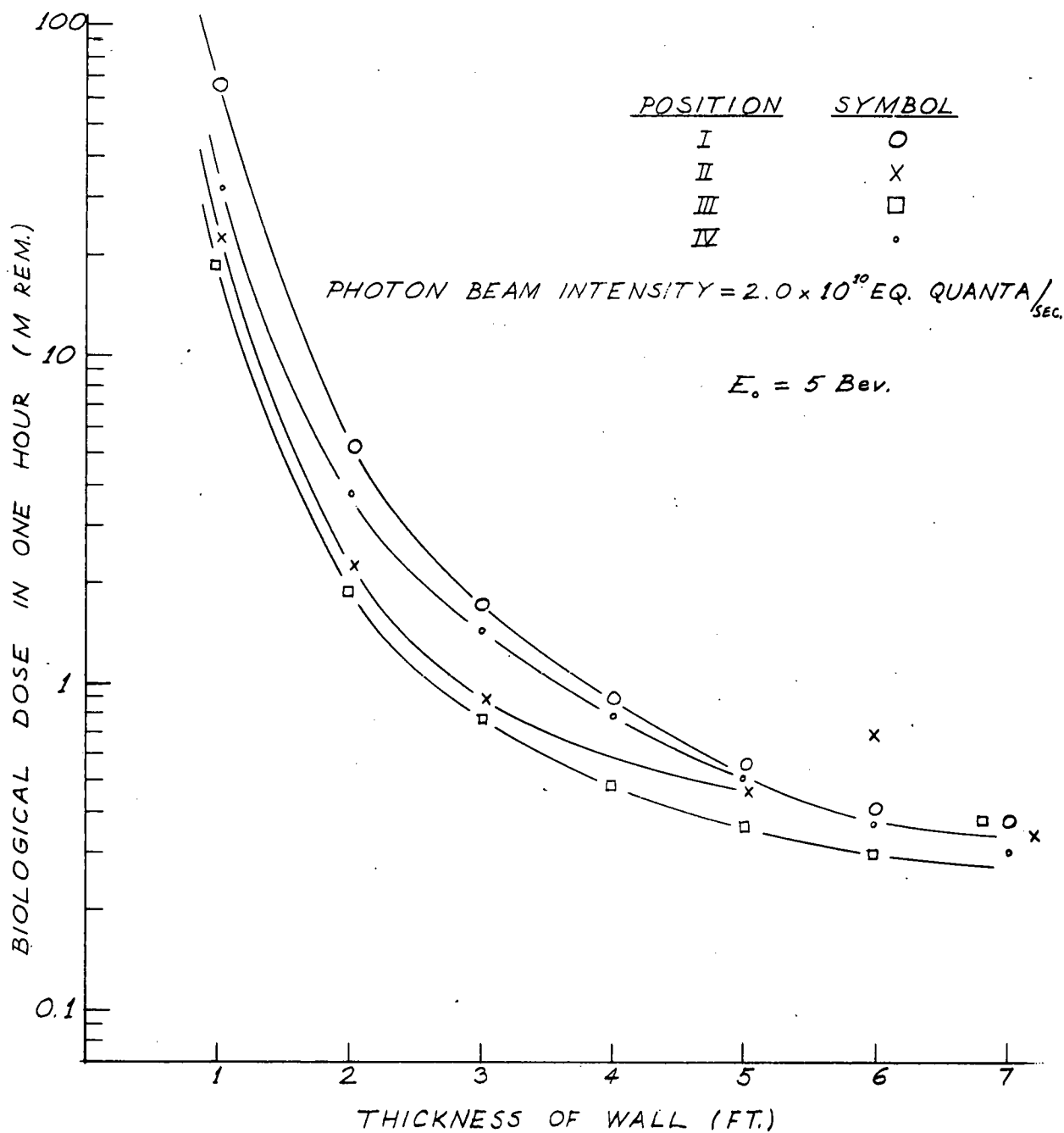


FIG. 2. BIOLOGICAL DOSE AT POSITIONS I, II, III & IV AS A FUNCTION OF THE THICKNESS OF THE ILMENITE-LOADED CONCRETE WALL. (THE CEASBUILT DOSIMETER GAVE ESSENTIALLY SIMILAR RESULTS.)
 (NOTE: CURVES NOT CORRECTED FOR BACKGROUND. SEE TEXT.)