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THE AURORA BREMSSTRAHLUNG ENVIRONMENT.(U)
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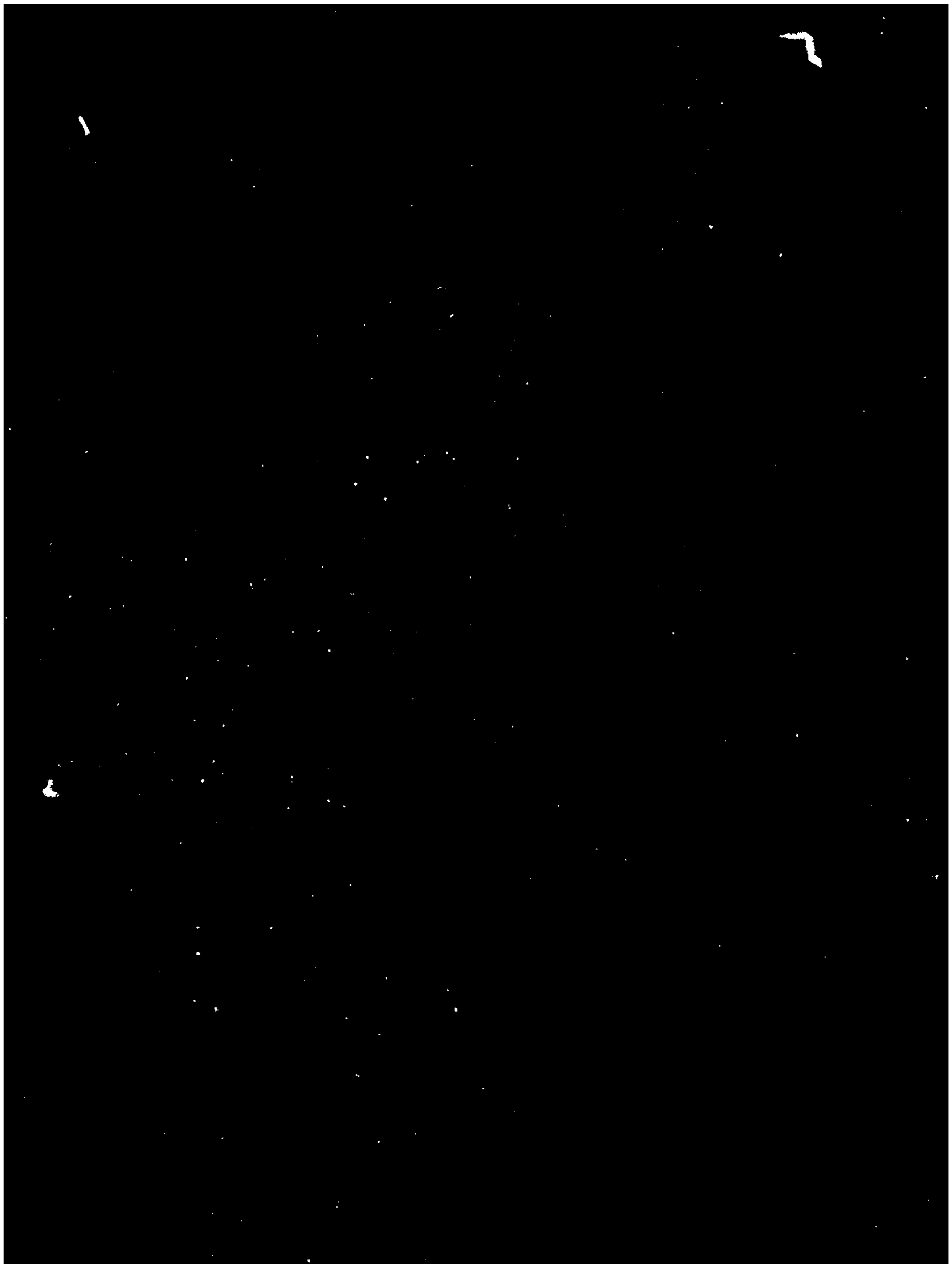

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report compiles all measurements and calculations characterizing the bremsstrahlung output of AURORA. The first part gives measurements of the dose distribution throughout the test cell and on the anode faceplates. All dose maps are given in normalized form so that the dose and the dose rate may easily be found for any Marx charging voltage. The second part describes the measured time history of the bremsstrahlung pulse from early times to very late times over four decades of amplitude. The third part discusses the bremsstrahlung energy spectrum and presents calculations of the energy and the angular distribution of photons. It is hoped that this report will be useful to prospective experimenters planning tests at the AURORA Facility.

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FIGURES

1. DOSE DISTRIBUTION

1.1 Test Cell Coordinate System

The coordinate system used to describe the dose distribution in the Harry Diamond Laboratories AURORA test cell is illustrated in figure 1. It is a right-handed cartesian coordinate system with the z-axis along the machine center line and the origin in the plane of the forward test cell wall. Coordinates are always specified in meters. The machine center line is 1.8 m (approximately 70 in.) above the test cell floor. Since the pyramid shaped "dimple panel" that covers the four anodes is recessed into the forward test cell wall, it is possible to have negative values of z.

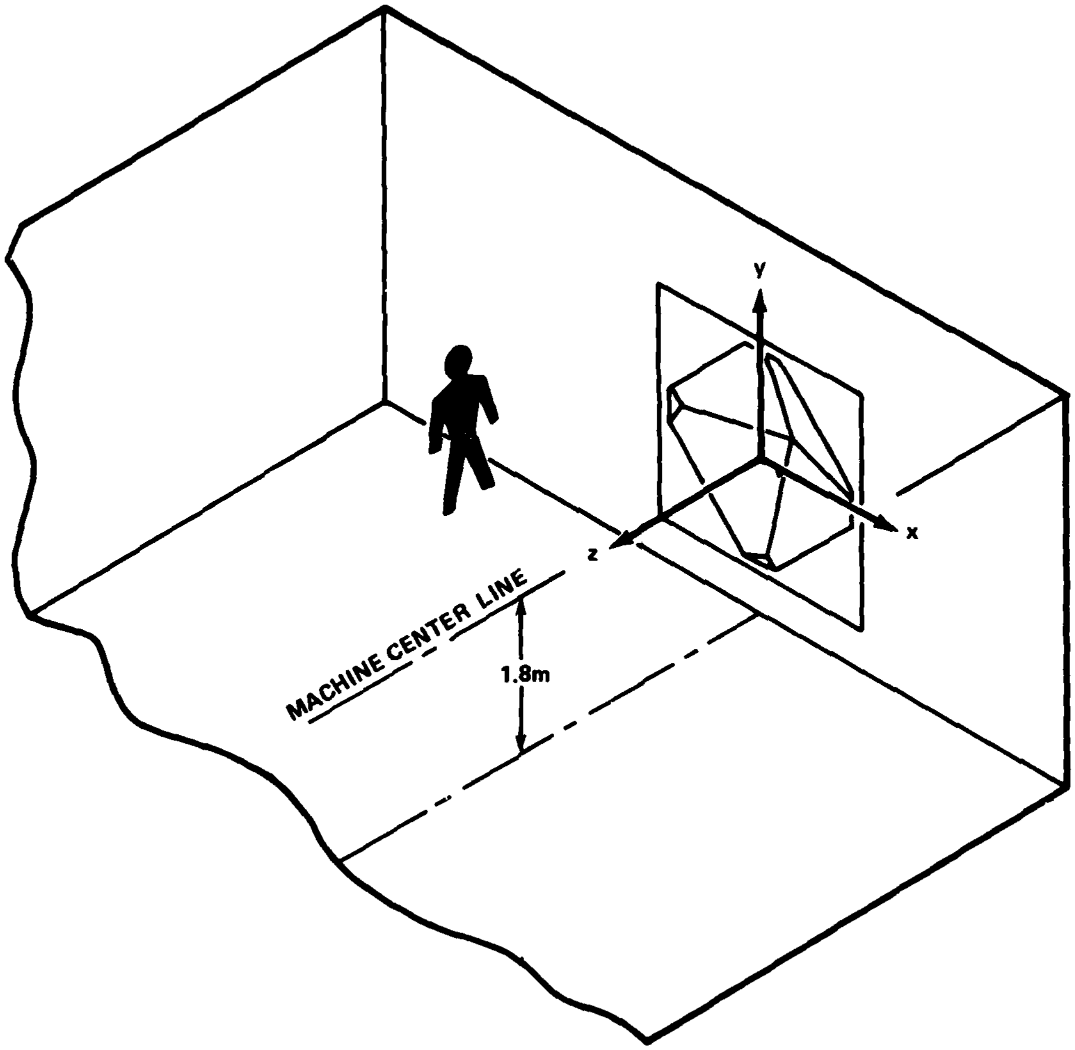

Figure 1. AURORA test cell coordinate system.

1.2 *Normalization of Dose Maps*

To make the dose maps usable for any machine operating parameter, we present them in normalized form, with 1 krad (Si) in the "hot spot" (that is, the region of maximum dose in the test cell) and 1 rad (Si) near the rear of the test cell. To find the actual dose or dose rate for a given Marx generator charging voltage, the normalized dose values must be multiplied by the appropriate constant (K_D for dose, K_R for dose rate) found in figure 2; thus,

$$D = K_D D_N \,, \tag{1}$$

$$\dot{D} = K_R D_N \,, \tag{2}$$

where

D = silicon equilibrium dose in rad (Si),

$\dot{D}$ = silicon equilibrium dose rate in rad (Si)/s,

D_N = normalized dose (from fig. 3 to 11),

K_D = dose multiplier (from fig. 2),

K_R = dose rate multiplier (from fig. 2).

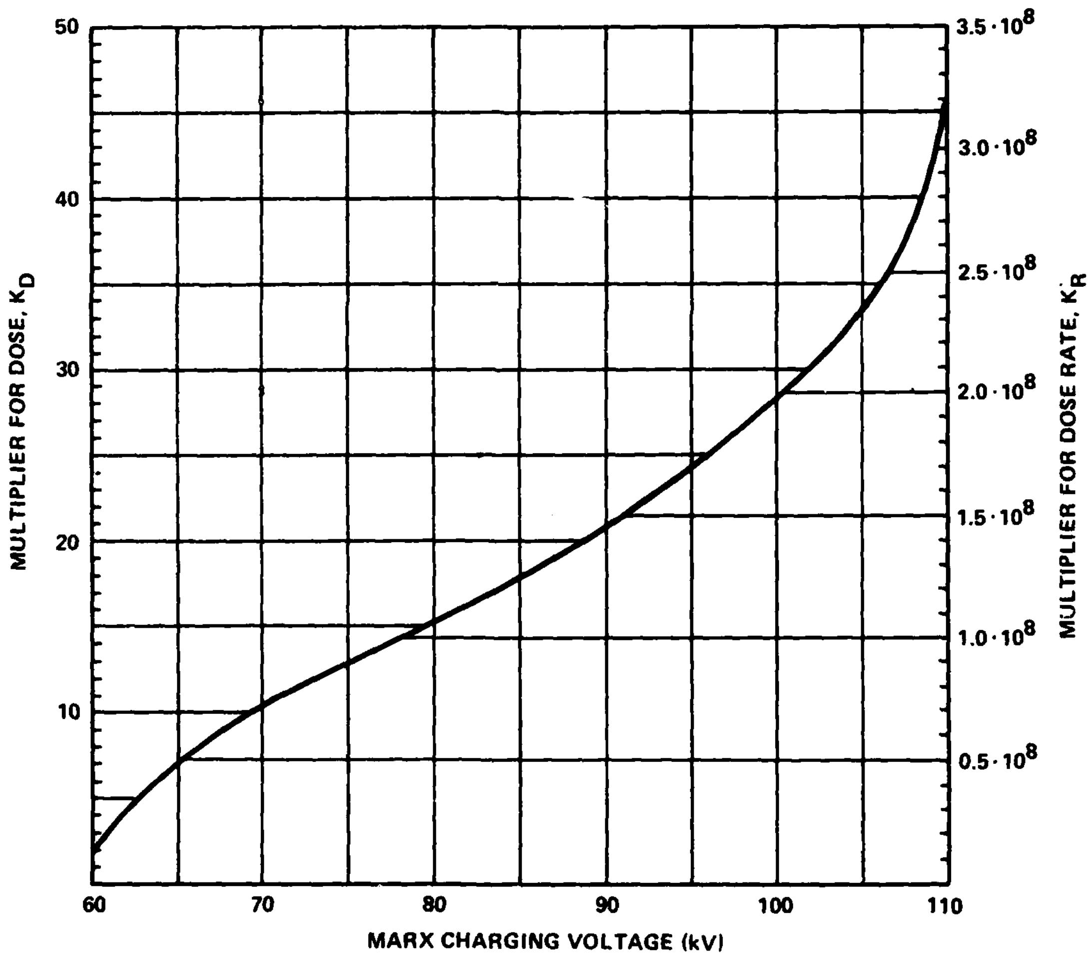

Figure 2. Dose and dose rate multipliers.

1.3 Normalized Center Line Dose

The normalized dose along the machine center line (that is, on the z-axis) is shown in figure 3 as a function of z. The hot spot at $z \cong 0.15$ m is the highest dose achievable anywhere in the AURORA test cell, except on the anode plates. Also, from $z = 1$ m to about $z = 10$ m, the dose falls off as z^{-2}.

1.4 Normalized Test Cell Isodose Contours: Plan

Figure 4 shows isodose contours in the test cell in a horizontal plane 1.8 m above the floor (that is, in the x-z plane). Since the dose distribution in the test cell is approximately rotationally symmetrical about the machine center line, figure 4 may be used also to find the dose for points where $y \neq 0$. In that case, the x-coordinate of figure 4 may be reinterpreted as an r-coordinate, where $r = (x^2 + y^2)^{1/2}$.

1.5 Normalized Test Cell Isodose Contours: Elevations

Figures 5 to 7 show gross isodose contours in the test cell in the vertical x-y planes at $z = 1$, $z = 3$, and $z = 5$ m.

1.6 Normalized Test Cell Isodose Contours: Detail

The volume in the immediate vicinity of the hot spot has been mapped in considerably more detail than the rest of the test cell because it is the most frequently used area for irradiations and also because the dose gradients are higher there than elsewhere in the test cell. A cylindrical volume 1 m long and 1 m in diameter surrounding the hot spot is generally called the "test volume." Figure 8 shows two longitudinal sections through this test volume, one horizontal in the x-z plane, the other in a plane that is at 45 deg to the horizontal. (The horizontal section is equally valid for the vertical, or y-z, plane.) The important thing to note here is that for $z < 0.5$ m, the dose distribution is no longer even approximately rotationally symmetric about the z-axis, but takes on a distinct fourfold symmetry. This loss of symmetry is dramatically evident in figure 9, which shows two vertical sections through the test volume, one at $z = 0.15$ m (right through the hot spot) and one at $z = -0.1$ m, in which the effect of the four individual anodes is more pronounced.

1.7 Normalized Anode Faceplate Isodose Contours

As mentioned in section 1.3, certain small areas of the anode faceplates exhibit a dose (or dose rate) about 20 percent higher than that in the hot spot. The anode hot spots can be seen in figures 10 and 11, which are the normalized anode faceplate maps for 80-kV and 110-kV Marx generator charging voltage, respectively. The four quadrants in these figures represent the four faces of the dimple panel, which is in the shape of a shallow concave pyramid. The influence of the four anodes, which are located behind the faces of the pyramid, is clearly visible. Letters A through D are the conventional identification of the four anodes. (See pages 8 through 14 for figures 3 through 11.)

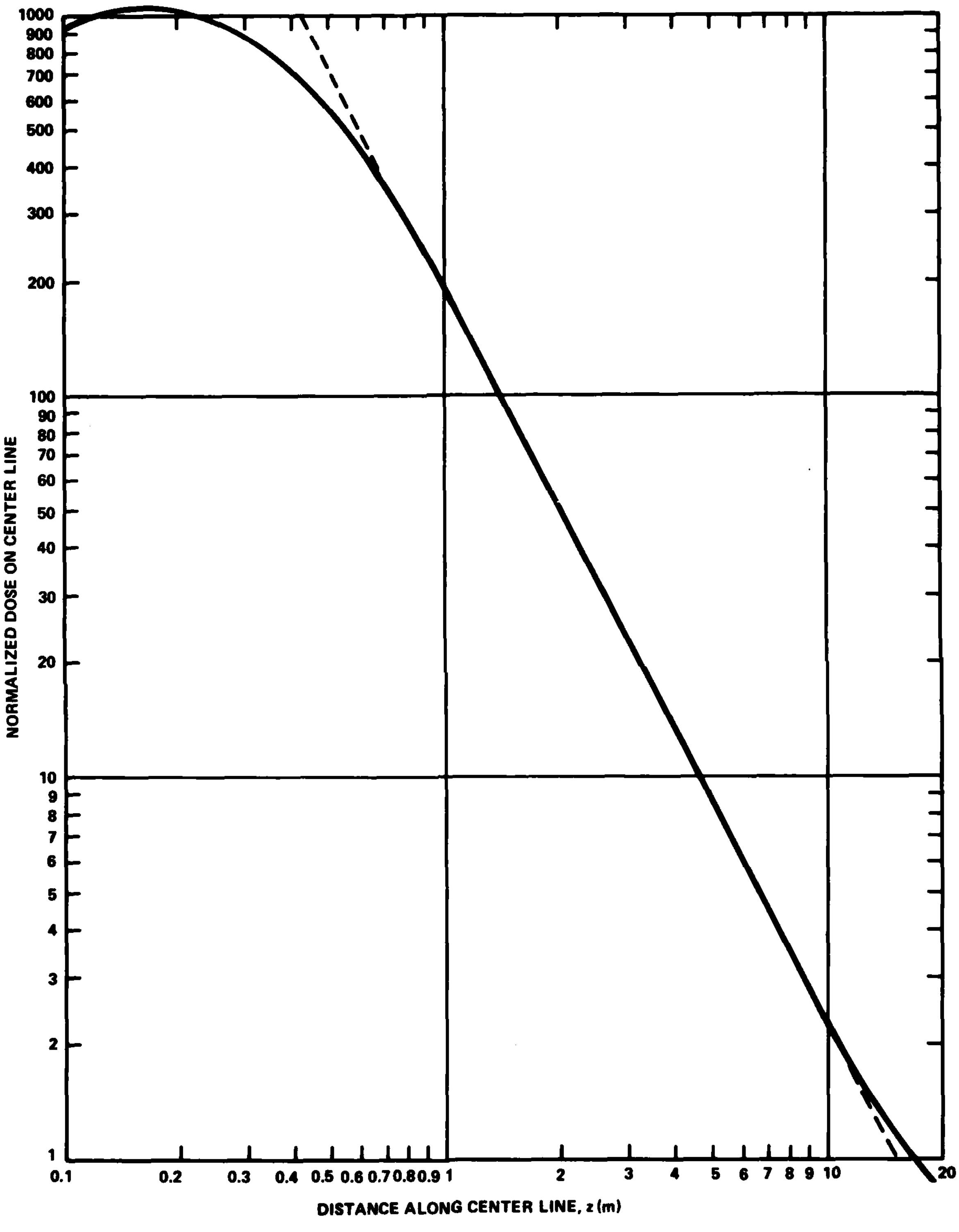

Figure 3. Normalized center line dose (must be multiplied by appropriate constant for dose or dose rate—see sect. 1.2 and fig. 2).

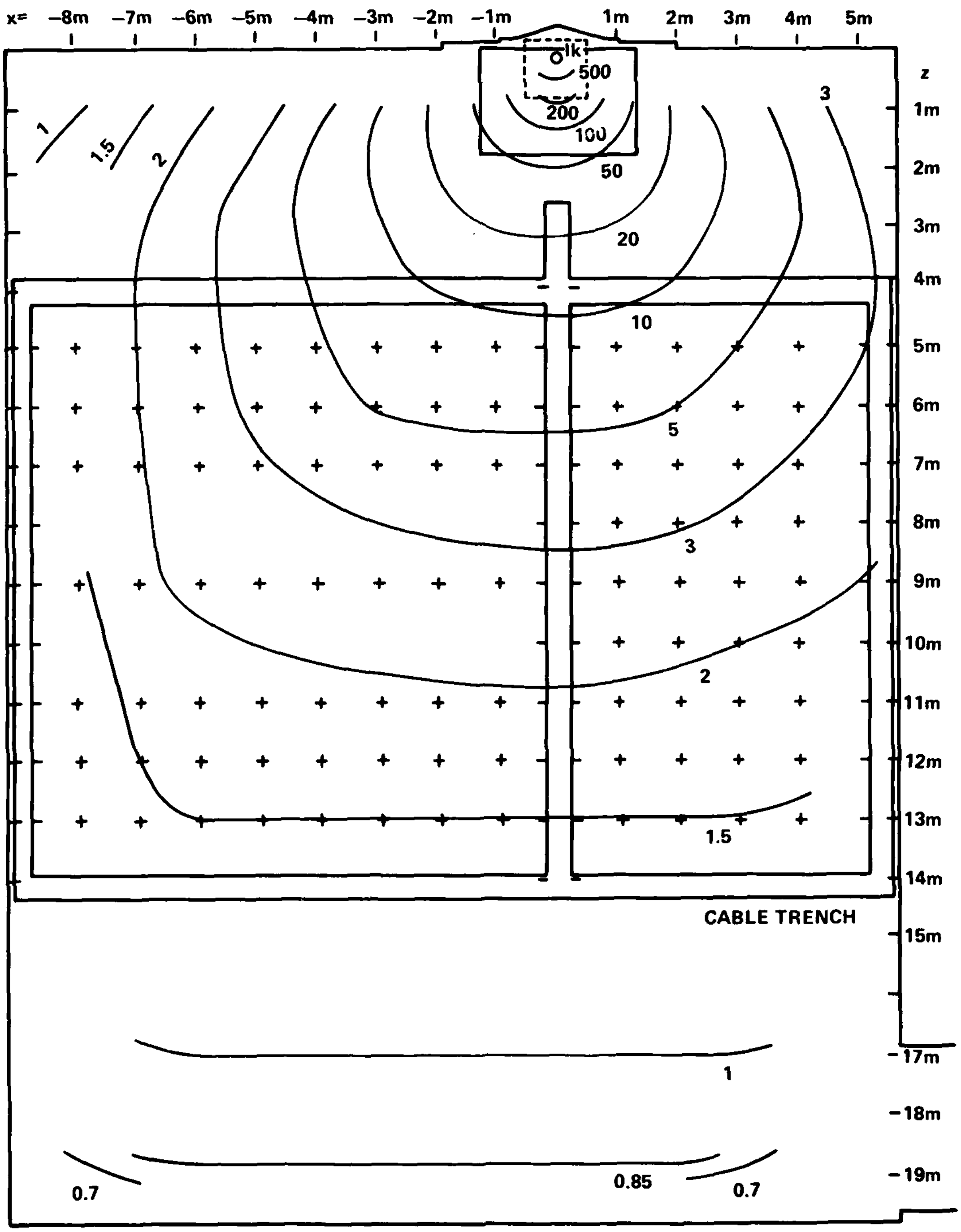

Figure 4. Normalized test cell isodose contours, plan (all contour values must be multiplied by appropriate constant for dose or dose rate—see sect. 1.2 and fig. 2).

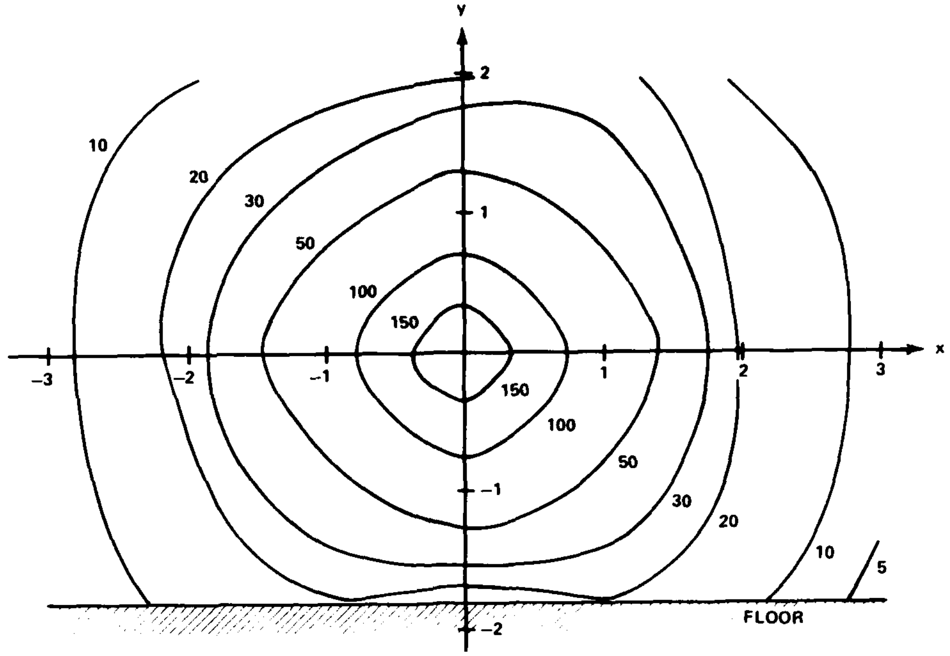

Figure 5. Normalized test cell isodose contours, z = l m (all contour values must be multiplied by appropriate constant for dose or dose rate--see sect. 1.2 and fig. 2).

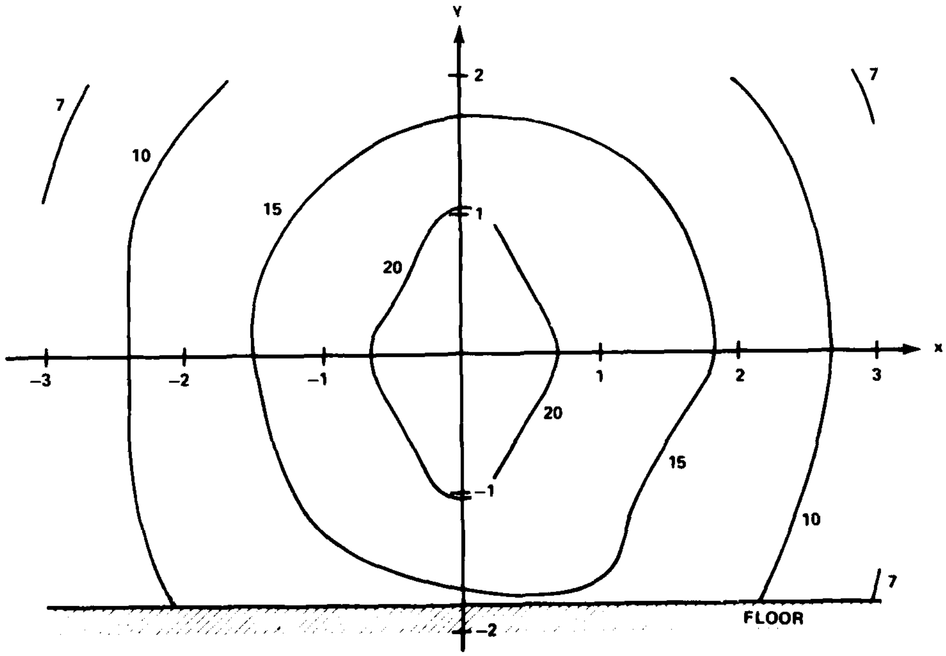

Figure 6. Normalized test cell isodose contours, z = 3 m (all contour values must be multiplied by appropriate constant for dose or dose rate—see sect. 1.2 and fig. 2).

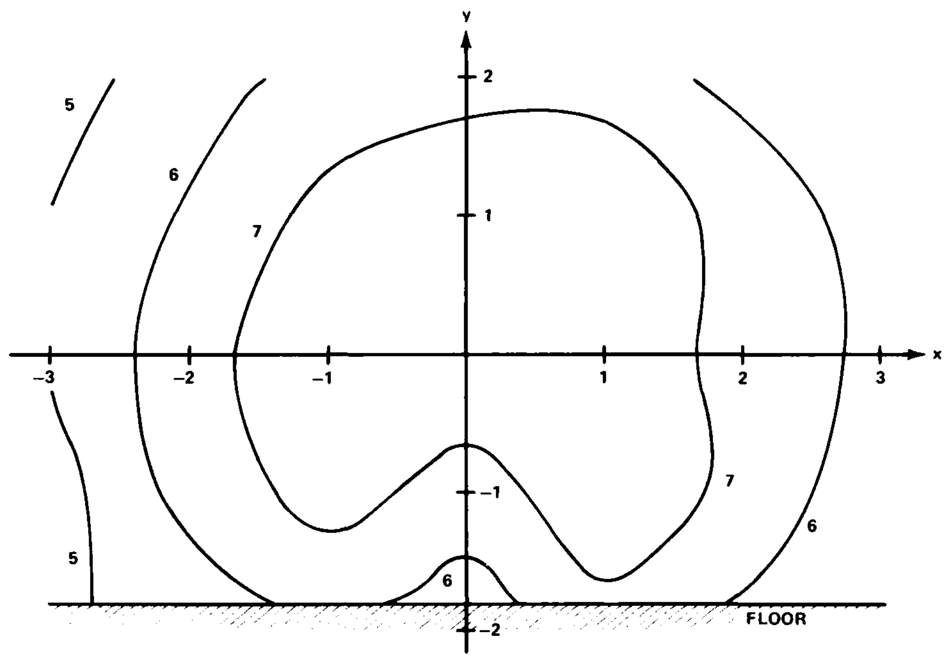

Figure 7. Normalized test cell isodose contours, z = 5 m (all contour values must be multiplied by appropriate constant for dose or dose rate—see sect. 1.2 and fig. 2).

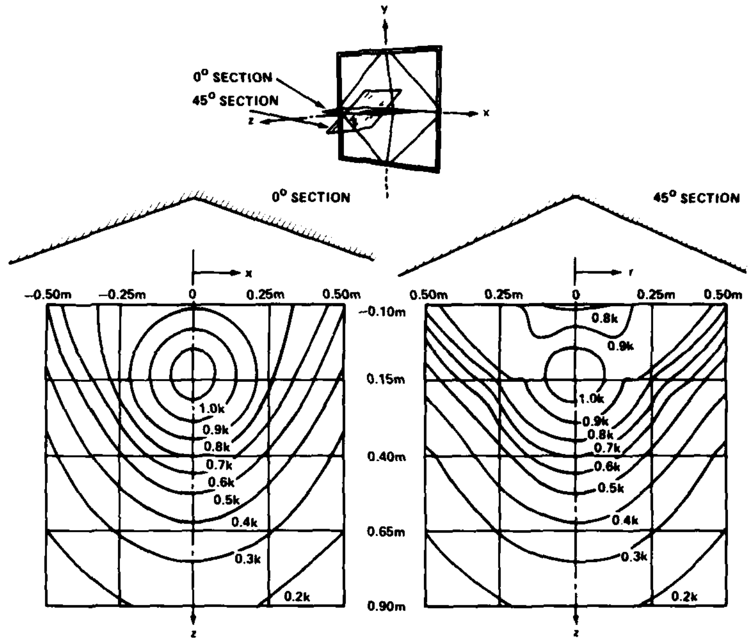

Figure 8. Normalized test volume isodose contours, longitudinal sections (all contour values must be multiplied by appropriate constant for dose or dose rate—see sect. 1.2 and fig. 2).

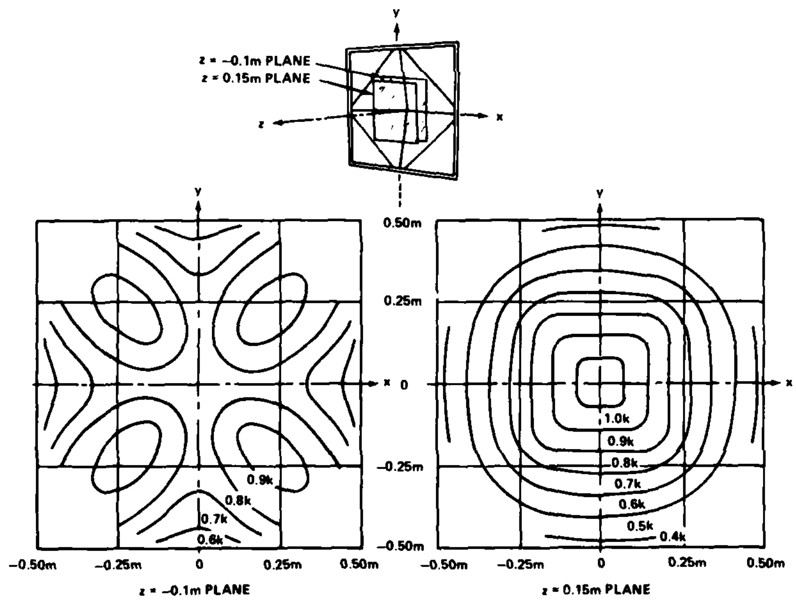

Figure 9. Normalized test volume isodose contours, vertical sections (all contour values must be multiplied by appropriate constant for dose or dose rate—see sect. 1.2 and fig. 2).

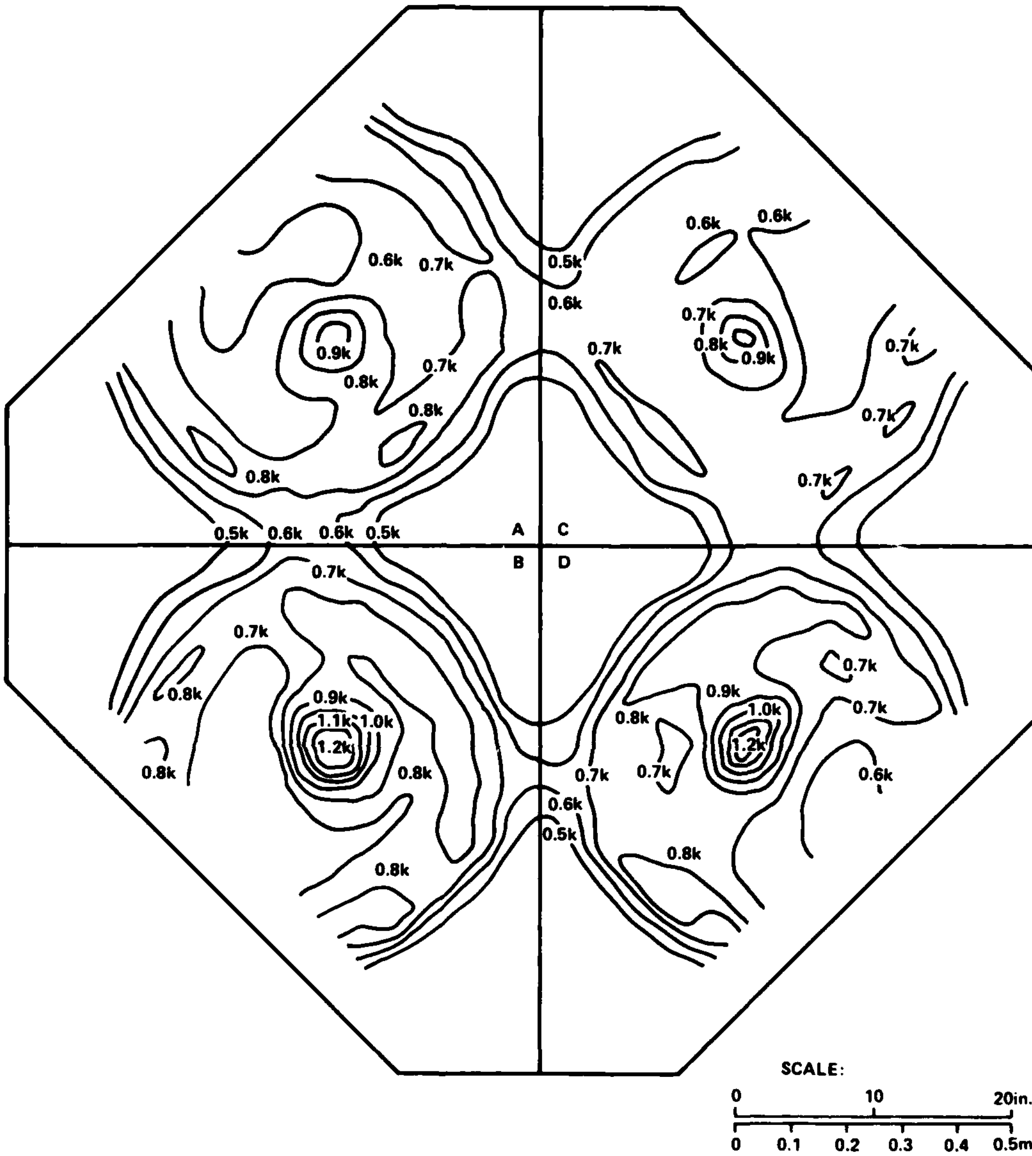

Figure 10. Normalized anode faceplate map, 80-kV Marx charge (all contour values must be multiplied by appropriate constant for dose or dose rate—see sect. 1.2 and fig. 2).

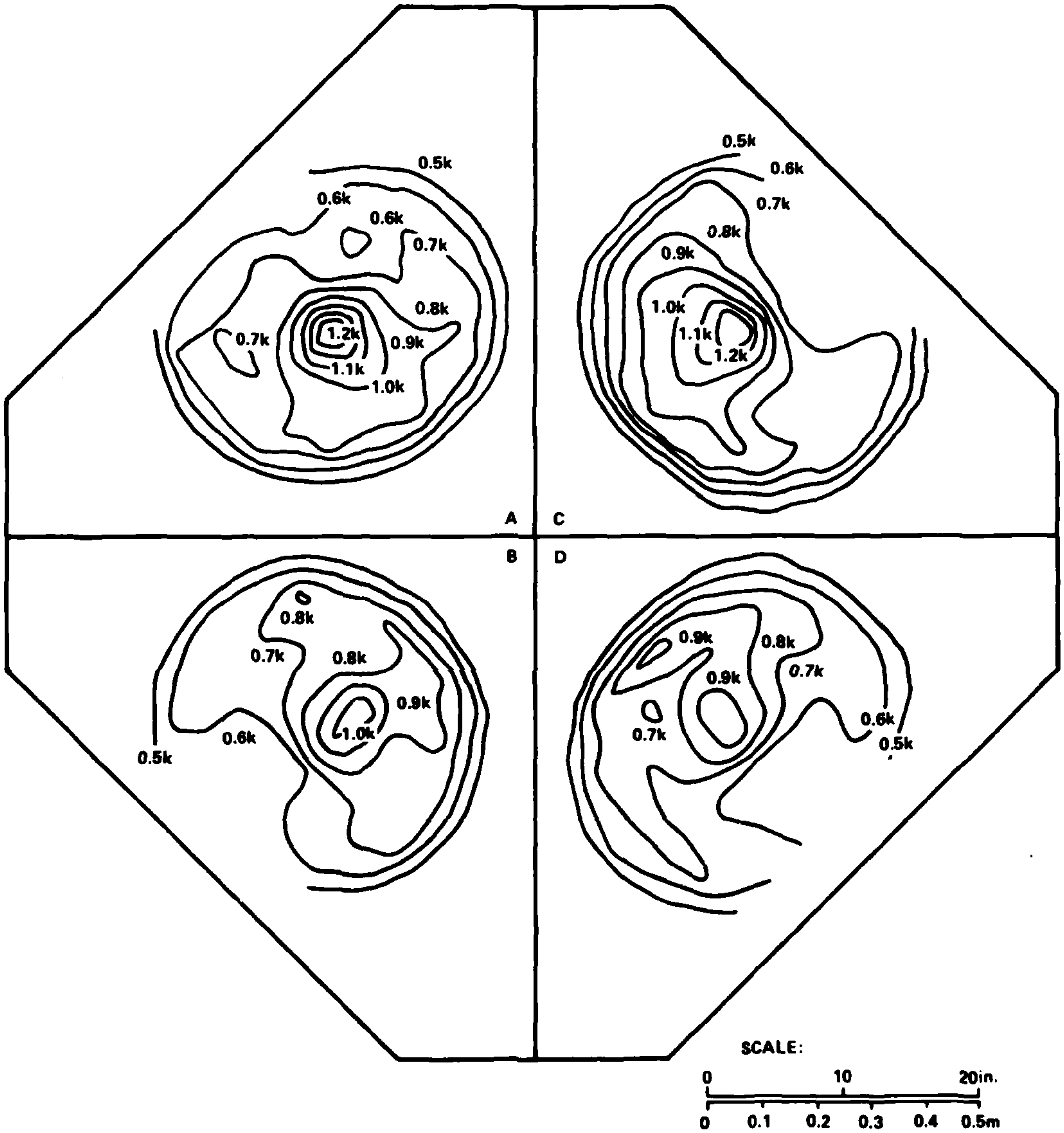

Figure 11. Normalized anode faceplate map, 110-kV Marx charge (all contour values must be multiplied by appropriate constant for dose or dose rate—*see sect. 1.2 and fig. 2*).

2. PULSE SHAPE

The shape of the AURORA bremsstrahlung pulse is shown in figure 12, which is an oscilloscope trace showing the dose rate as a function of time as measured by a Pilot-B scintillator and vacuum photodiode.[1] The dose rate at very early and very late times, relative to the dose rate at the peak, is shown in figure 13. Figure 13 is a composite plot of a number of measurements taken on a number of AURORA pulses from 1973 to 1979 and may be regarded as typical for a good AURORA pulse at either a 90- or a 110-kV Marx charge, measured in the hot spot. At $z = 4$ m, the pulse tends to be a little wider, averaging about 135 ns full width at half maximum (FWHM).

The dose rate at the peak of the pulse is not calculated correctly by dividing the dose by the FWHM; that is,

$$\dot{D}_{peak} \neq D/\mathrm{FWHM}\,. \tag{3}$$

The correct equation is

$$\dot{D}_{peak} = D/\mathrm{eff\ width}\,, \tag{4}$$

where the effective width is defined by

$$\mathrm{eff\ width} = \mathrm{area}/\mathrm{peak\ height}\,. \tag{5}$$

The dose rate is therefore calculated most accurately by measuring the peak height and the area of the bremsstrahlung pulse (fig. 12) and using equations (4) and (5). When this accuracy is not required and it is inconvenient to measure the area under the pulse, it is useful to know the following relationship (true for a typical good AURORA pulse):

$$\mathrm{eff\ width}/\mathrm{FWHM} = 1.08 \pm 0.05\,. \tag{6}$$

The dose rate can therefore be approximated pretty well by

$$\dot{D}_{peak} \cong D/(1.08\ \mathrm{FWHM})\,. \tag{7}$$

[1]*Klaus G. Kerris, The AURORA Dosimetry System, Harry Diamond Laboratories HDL-TR-1754 (March 1976).*

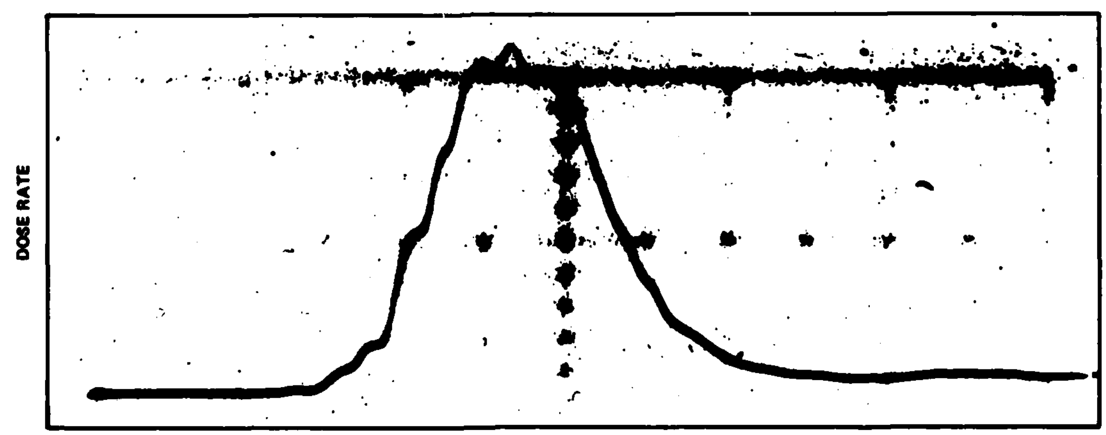

Figure 12. AURORA bremsstrahlung pulse.

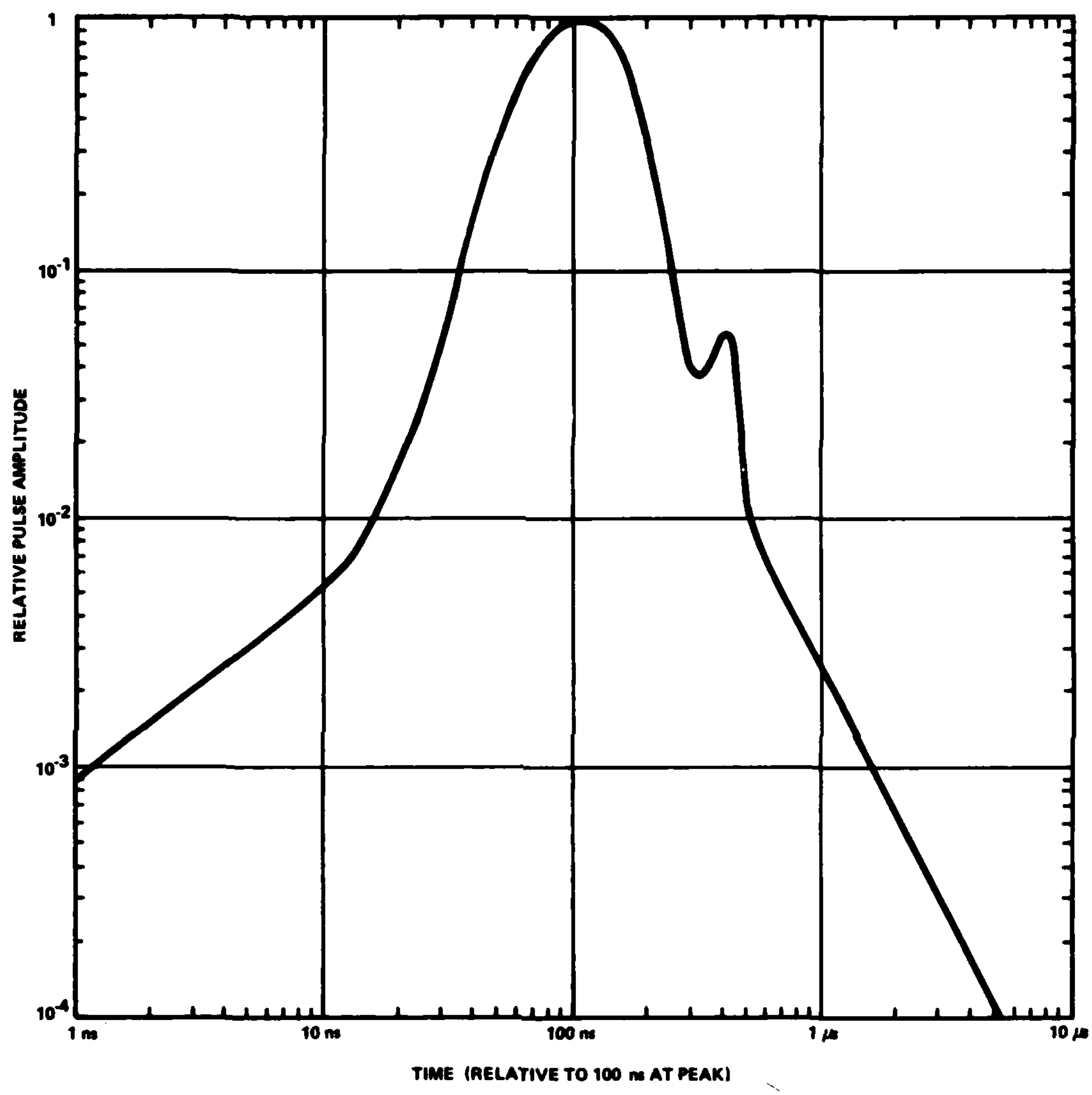

Figure 13. AURORA bremsstrahlung pulse at early and late times.

3. BREMSSTRAHLUNG SPECTRUM

The AURORA bremsstrahlung spectrum is difficult to measure directly because of the peculiar source geometry of the four large anodes. That the hot spot is almost surrounded by four large bremsstrahlung sources makes any kind of collimated measurement almost impossible. Calculation of the bremsstrahlung spectrum from a known target is quite feasible, provided that the energy spectrum and the angular distribution of the incident electrons are known. The electron energy spectrum can be calculated, given good time-resolved voltage and current diagnostics; however, the angular distribution of the incident electrons is not well known at all. Some reasonable assumptions can be made, though.

For the following spectra, we calculated the electron energy spectrum from the voltage and current pulses using the computer code EBSPEC. All electrons were assumed to be incident on the AURORA target at an angle of 20 deg from the normal. (This angle was deduced from the fact that the dose distribution from a single anode is symmetrical about an axis that is inclined at 20 deg with respect to the normal to the anode plane.) The transmitted bremsstrahlung spectrum and angular distribution were then calculated by using the electron-photon transport code TIGER. Figure 14 shows the energy spectrum, and figure 15 shows the angular distribution of photon intensity, for a single anode, for a 110-kV Marx charge. Figure 16 shows the energy spectrum for a 90-kV Marx charge.

All Monte Carlo transport calculations were run for 5000 histories of incident primary electrons. The statistical error is less than 10 percent from 0.2 to 4.0 MeV for the 110-kV spectrum and less than 16 percent from 0.15 to 3.0 MeV for the 90-kV spectrum.

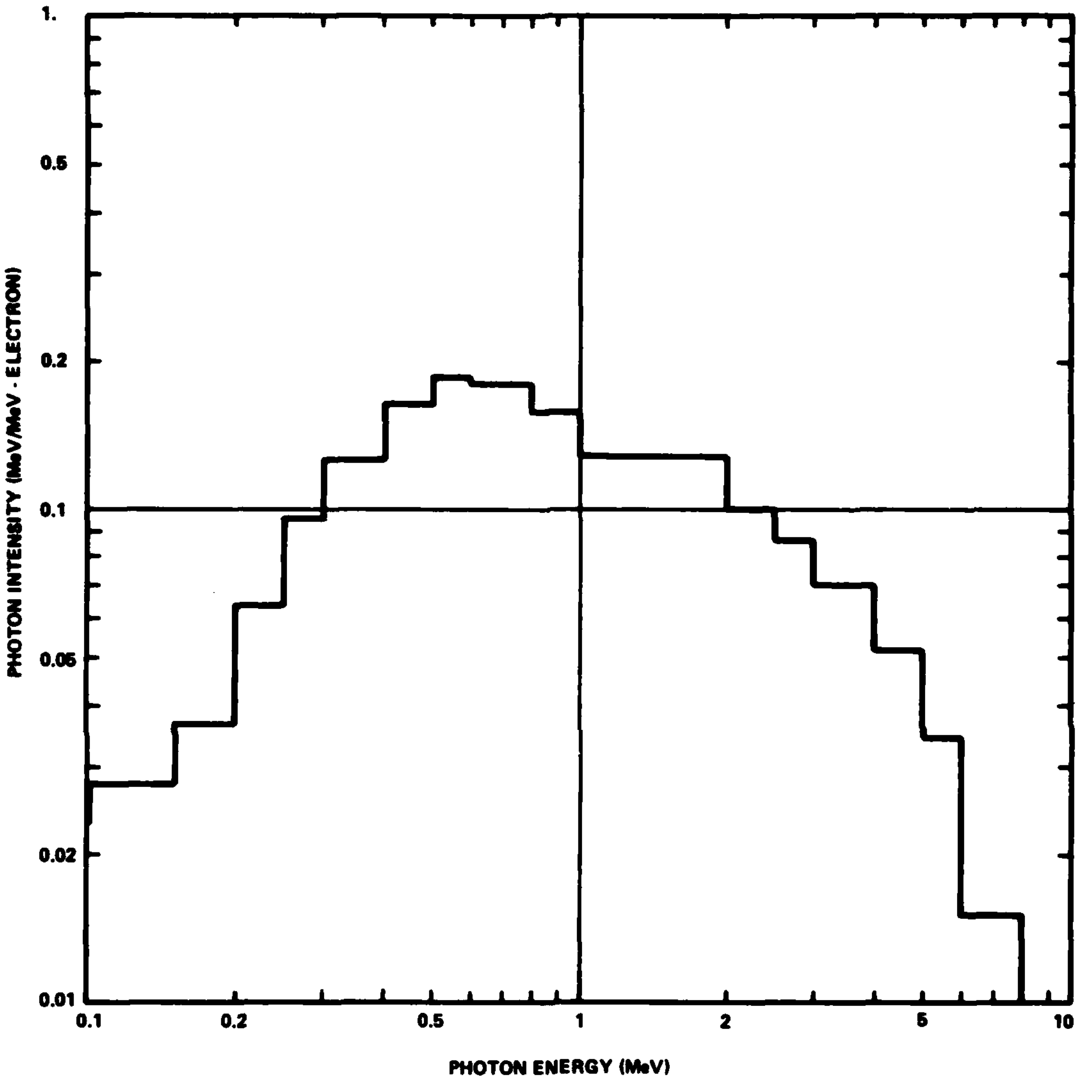

Figure 14. Bremsstrahlung spectrum, 110-kV Marx charge.

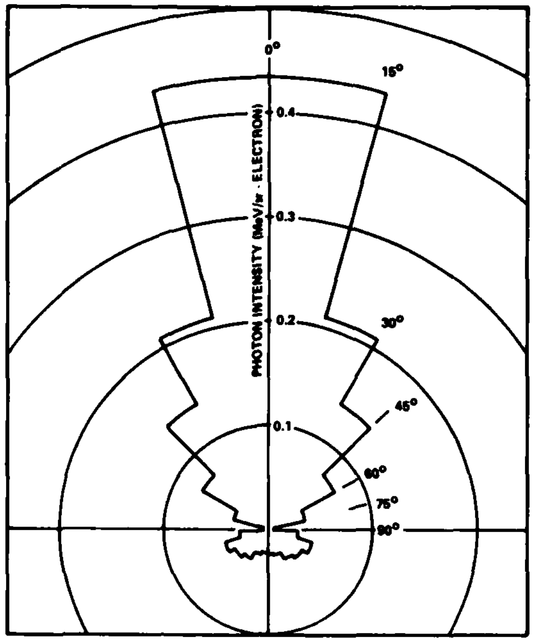

Figure 15. Bremsstrahlung angular distribution, single anode, 110-kV Marx charge.

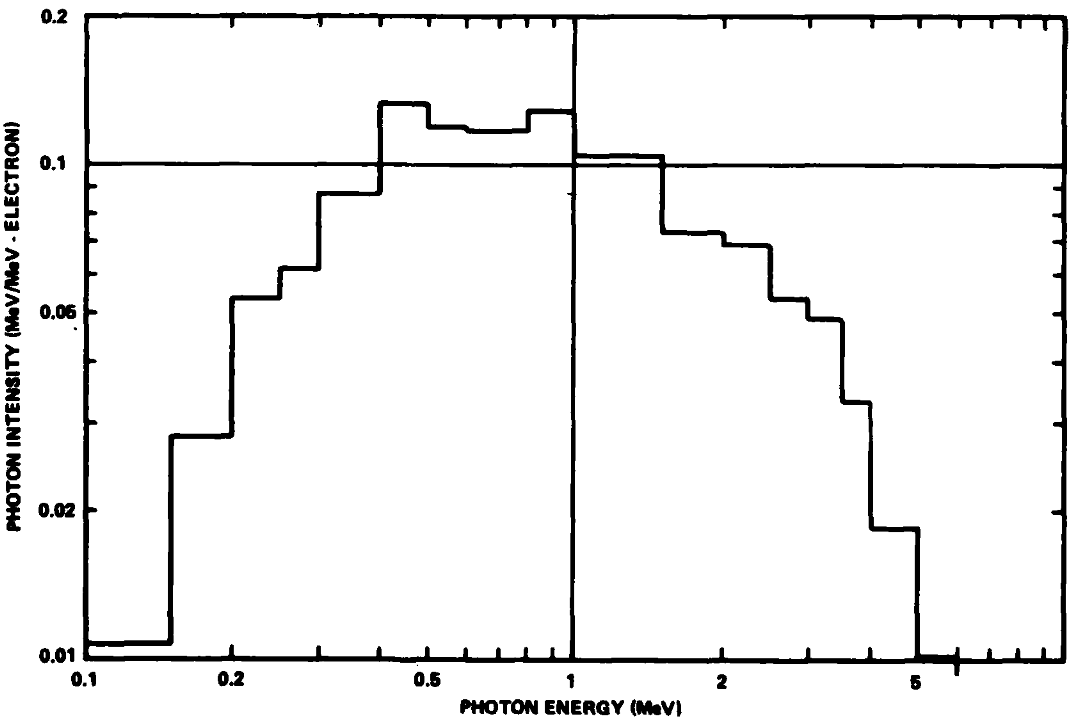

Figure 16. Bremsstrahlung spectrum, 90-kV Marx charge.

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