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THE R-UNIT AT 320 AND 160 MEV

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PHYSICS

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The r-unit is used today in at least two different ways: as a measure of radiation dosage, and as a measure of x-ray intensity. The meaning of the former is fairly well defined in terms of energy absorbed per gram of tissue, and the standard thimble chambers are calibrated to read in these terms. The meaning of the latter is much less clear. As originally defined, the r-unit referred to the ionization in air due to secondary electrons in equilibrium with the primary beam of x-rays. With low-energy x-rays equilibrium is easily attained since the range of the secondaries is small compared with the absorption distance of the primaries in air, but with high-energy x-rays this is no longer true. Since a clearly defined equilibrium no longer exists, the old definition must be abandoned and the question remains: what should the r-unit mean in connection with the intensity of a beam of high-energy x-rays?

It would seem that the definition must be arbitrary, that is, it must apply to some specified setup of the ionization chamber and its surroundings. Because of their convenience in use and universal availability, the Victoreen thimble chambers have been most widely used as measuring devices. Some workers have used these bare; some, in a block of plastic; some, inside a lead cylinder; and some, behind a lead sheet. Because of this ambiguity the r-unit has lost much of its value for x-ray measurements in the range of many Mev, and we believe that it should be replaced by absolute measurements in terms of energy flux or "effective number of quanta" (energy flux divided by upper limit quantum energy). However, it would be convenient to retain the r-unit, with a suitable arbitrary definition, for rough measurements and for intercomparison of various x-ray sources.

Therefore we would like to suggest that a standard setup should be adopted, consisting of a Victoreen thimble chamber inside a lead cylinder with 1/8-inch wall thickness, 5/8-inch inside diameter, and 2-inch length. This arrangement was chosen because it is easily reproducible and because there is already considerable precedent for its use. It should be placed with its axis transverse to the beam direction and at a sufficient distance from the x-ray source that the intensity is reasonably uniform over a region at least an inch wide. The r-unit so specified can be calibrated in terms of absolute x-ray energy per unit area. To do this, a beam is defined by an aperture in a thick lead wall; the total energy flux in this beam is measured, and the Victoreen thimble reading in the center of the same beam is determined. The flux divided by the area of the beam at the Victoreen thimble gives the average intensity of the beam at this distance; this is multiplied by a factor, computed from the measured angular distribution in the beam, to get the central intensity.

Calibrations of this sort have been carried out for two energies, using the method of Blocker, Kenney, and Panofsky[1] for the flux measurements. The apertures are holes in a 9.57-inch thick lead wall placed 56.5 inches from the target; they are tapered to follow rays of the beam, and hole diameters of 1/2, 1, and 1-1/2 inches (at the small end) were used, with good internal consistency. Victoreen thimbles of 250 r, 100 r, and 25 r ratings (also with good agreement) were placed 337 inches from the target. A thin-walled integrating monitor chamber permanently mounted between the target and the aperture was useful in making the intercomparisons.

The results are given in the following table. The x-ray energies are

[1] W. Blocker, R. W. Kenney, and W. K. H. Panofsky, Phys. Rev. 79, 419 (1950)

accurate to about 2 percent, the calibrations to about 10 percent.

x-ray energy	ergs/cm^2 r	Mev/cm^2 r	"effective quanta"/cm^2 r
320 Mev	5.3×10^3	3.3×10^9	1.04×10^7
160 Mev	3.5×10^3	2.2×10^9	1.38×10^7

We find that our Victoreen setup gives 1.5 times the reading of that used by Kerst (thimble behind 1/8-inch lead sheet), and if allowance is made for this our result for 320 Mev is in good agreement with the absolute calorimetric measurement of Kerst and Price.[2] The r-unit mentioned in ref. 1 was defined in terms of Zeus meter readings, and was included only to show the order of magnitude of intensities used; it is in very poor agreement with thimble chamber readings and should not be used again.

The thimble chamber readings obtained in the course of the calibration, reduced to a standard distance by the inverse square law, indicate that the output of the Berkeley synchrotron is 1000 r per minute at one meter under best operating conditions. This is at full energy and with a pulse rate of six per second. Operation at this level has been maintained for periods of many hours.

The work described was performed under the auspices of the Atomic Energy Commission.

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[2] D. W. Kerst and G. A. Price, Phys. Rev. 79, 725 (1950)

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