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DETERMINATION OF BREMSSTRAHLUNG PRODUCTION EFFICIENCIES FROM DATA OBTAINED ON PHERMEX AT 27 MeV

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ABSTRACT

Recent experiments conducted at Los Alamos Scientific Laboratory on the PHERMEX installation and analyzed with a Sandia Laboratories computer program indicate that the generally accepted bremsstrahlung production efficiency versus voltage curve needs corrections at voltages above approximately 13 MeV.

Analysis of the data shows that electron beam divergence angles must be taken into account and subsequently indicates that a 2-degree average beam divergence angle exists on PHERMEX. When the beam divergence is eliminated the bremsstrahlung production efficiency curve can be represented by the relatively simple equation

$$D/Q = 1.1 \times 10^{3} V^{2.8},$$

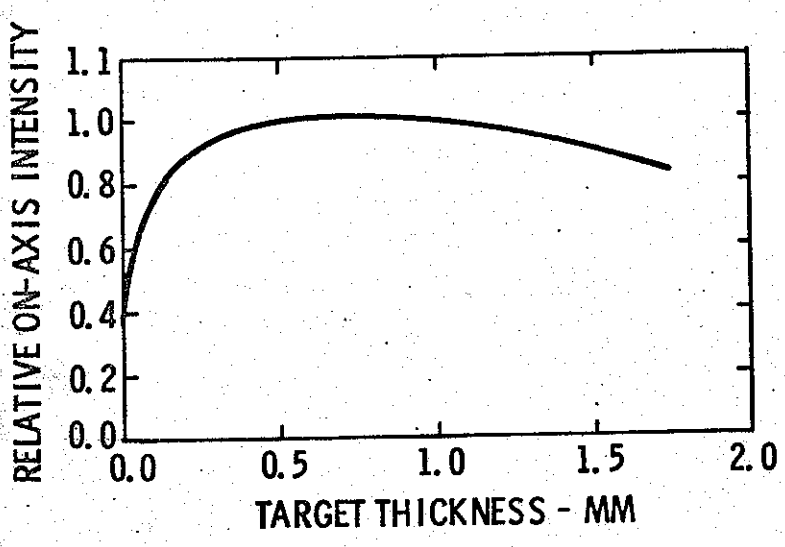
for at least $1 \leq V \geq 27$ where V is given in megavolts, D in roentgens, and Q in coulombs.

DETERMINATION OF BREMSSTRAHLUNG PRODUCTION EFFICIENCIES FROM DATA OBTAINED ON PHERMEX AT 27 MeV

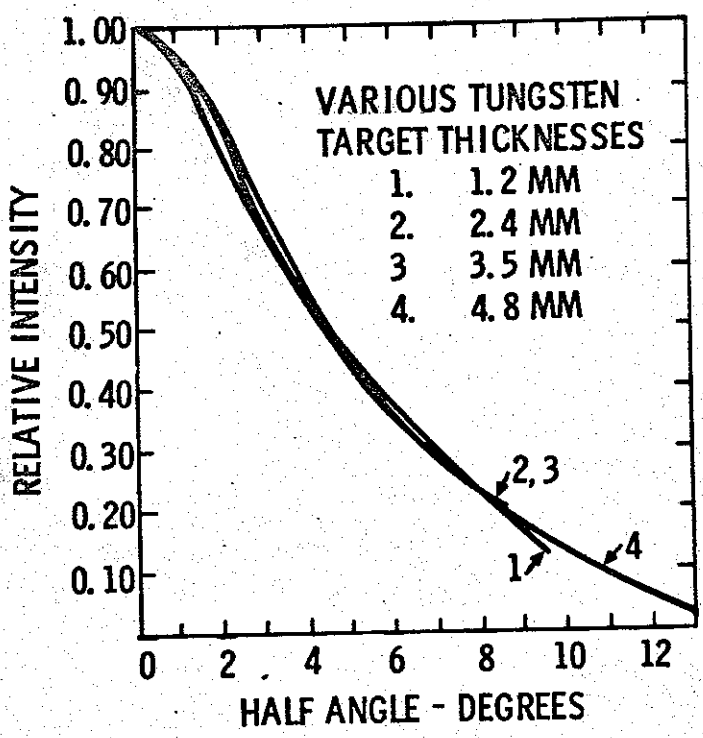
Most of the proposed bremsstrahlung production efficiency versus voltage curves utilized for flash X-ray machine design are very dependent, at voltages above 10 MeV, upon data from the PHERMEX (pulsed high-energy radiographic machine emitting X-rays) installation at LASL. Computer calculations made at Sandia Laboratories on the angular distribution of radiation expected from flash X-ray machines showed that small average angles of electron arrival at the target at voltages above 13 MeV could have serious effects on the dose output measured at 1 meter.

Consequently, any information on bremsstrahlung production efficiency above 12 MeV should be used very cautiously if the angular distribution of the bremsstrahlung is not available. For instance at 20 MeV, according to the Sandia program, a 2-degree average electron beam divergence can result in a decrease of 20 to 30 percent in the dose measured at 1 meter. The 20-MeV angular distribution of radiation from PHERMEX, published by Douglas Venable,[1] is included as Figure 1. Figure 1 shows that the angular distribution varies little with the target thicknesses. Consequently, the target thickness can be neglected.

PHERMEX is being constantly improved and the voltage level that has been achieved to date is 27 MeV. R. E. Stapleton of Los Alamos Scientific Laboratory has conducted an experiment to define dose output and angular distribution from PHERMEX at 27 MeV. This data is included as Figure 2.

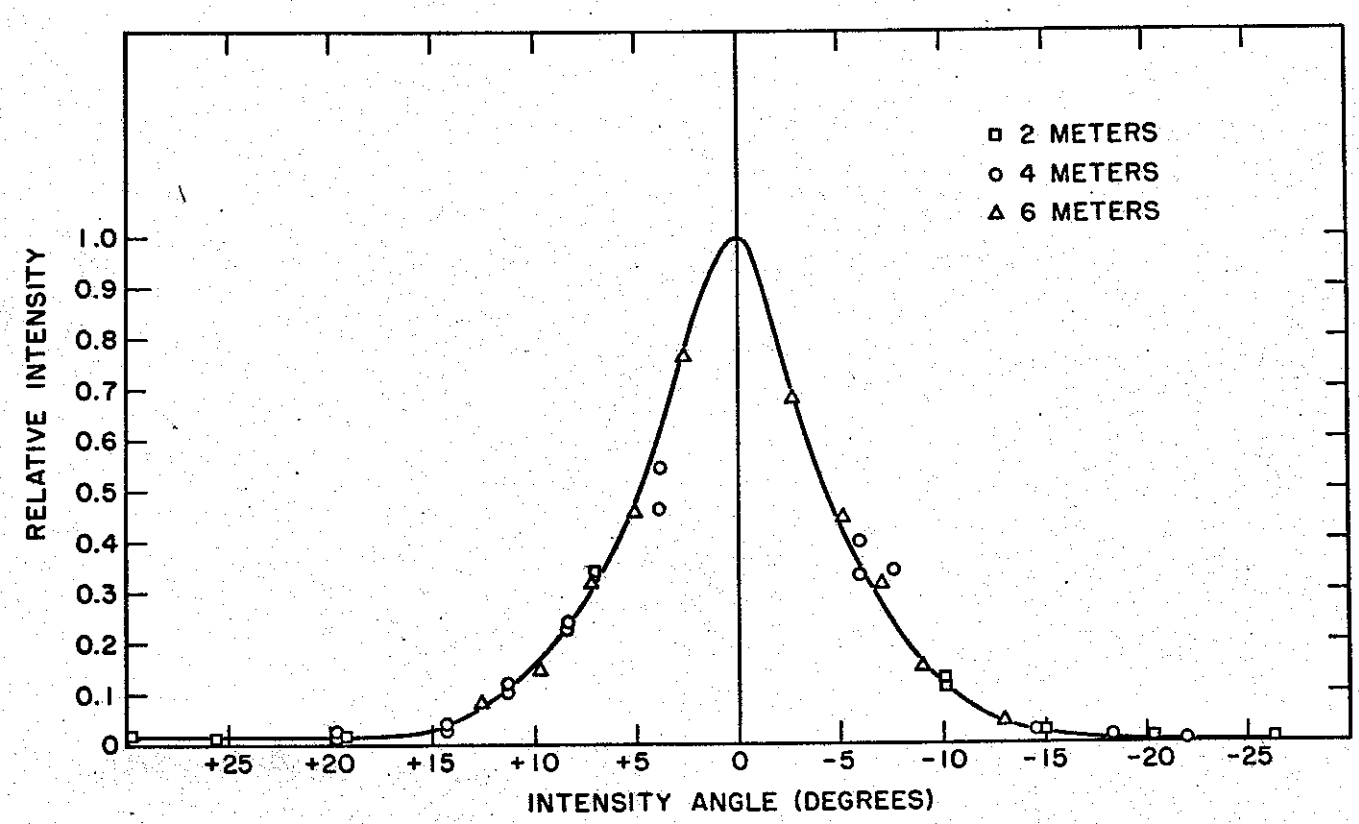


RELATIVE ON-AXIS RADIATION INTENSITY VS TARGET THICKNESS FOR 20 MeV BREMSSTRAHLUNG



EXPERIMENTALLY DETERMINED INTENSITY-ANGLE DISTRIBUTION FOR 20 MeV BREMSSTRAHLUNG WITH NO ABSORBER

Figure 1. Curves from LASL Report No. LA-3241



NOTES:

V = 27 MeV

Q = 6×10^{-6} coulomb

D = 48.1 R at 1 meter
11.66 R at 2 meters

Dia. Spot = 2 mm

Pulse Length = 0.2 μsec in 10 subpulses

Half Angle, Predicted = 3^{o}

Half Angle, Actual = 4.5^{o}

Figure 2. Normalized Dose Distribution from PHERMEX (27 MeV)

Recently, more experiments were performed with PHERMEX operating at 27 MeV where the target was repositioned after every pulse. These experiments show that a definite convergence angle exists; the data is presented in Figure 3. A convergent or a divergent electron stream will exhibit the same bremsstrahlung radiation characteristics at 1 meter for small spot sizes provided both streams have the same electron angle of arrival at the target.

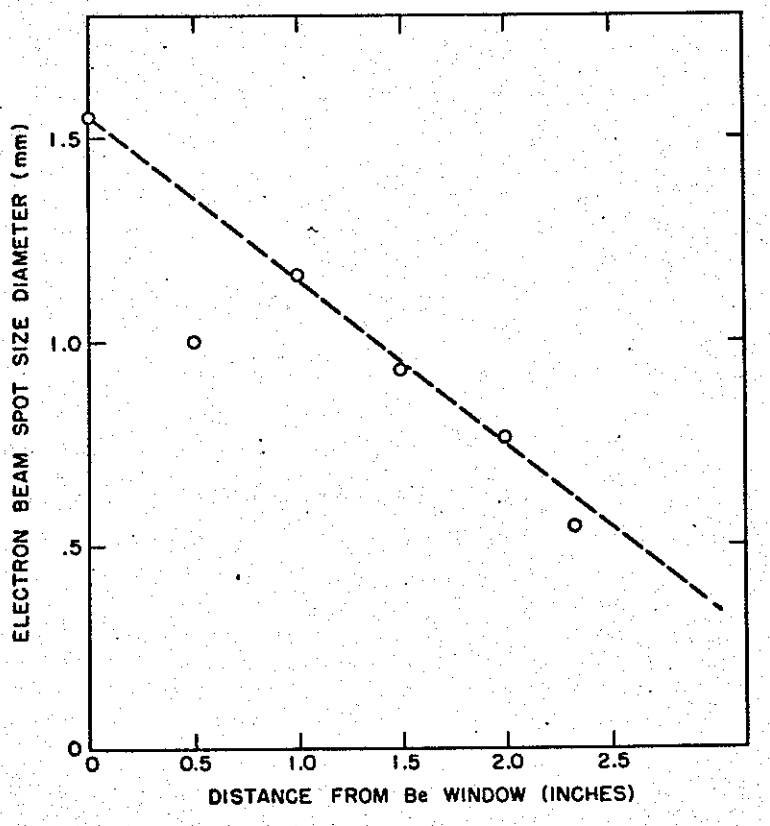


Figure 3. Spot Size Versus Target Location on PHERMEX Operating at 27 MeV

Several solutions were computed with the Sandia-developed program[2] in an attempt to match the actual PHERMEX angular distribution curve; a reasonable match was found to be a uniformly varying electron beam arrival angle. Computer curves for 0, 2, 3, and 5-degree average electron divergence angles are given in Figure 4. The 2-degree beam average electron divergence angle almost coincides with the experimentally obtained PHERMEX curve (see Figure 5).

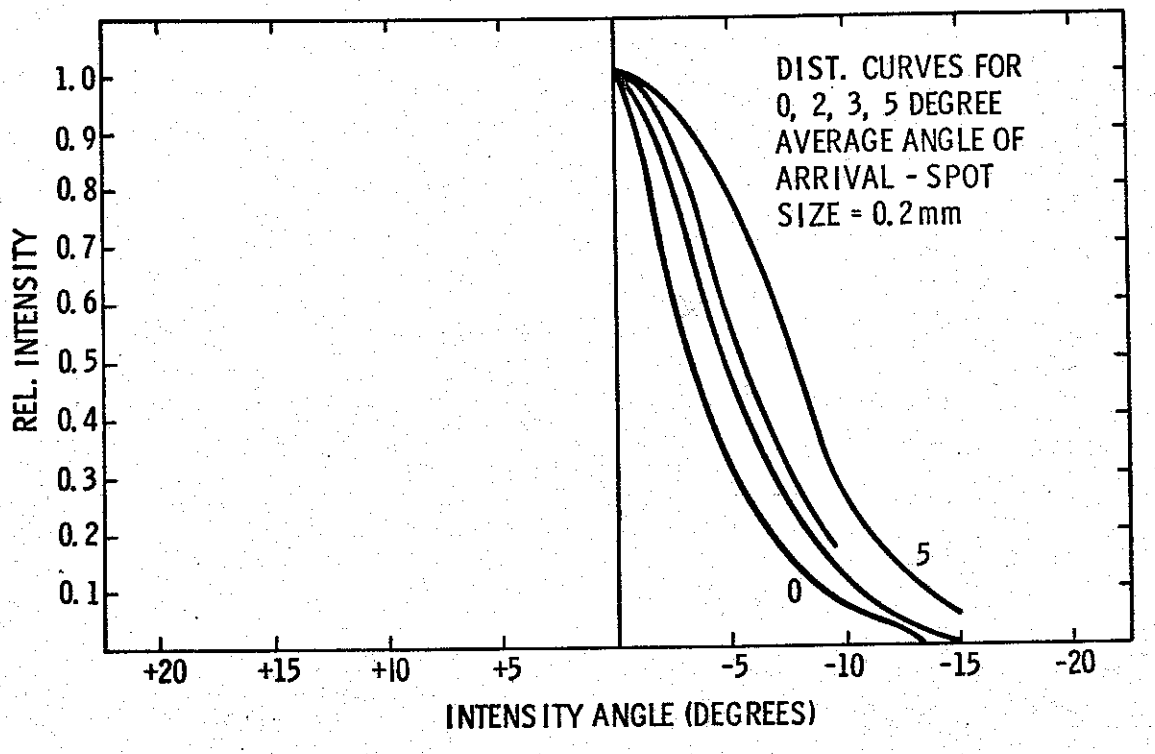


Figure 4. Computer Angular Distribution Curves for PHERMEX

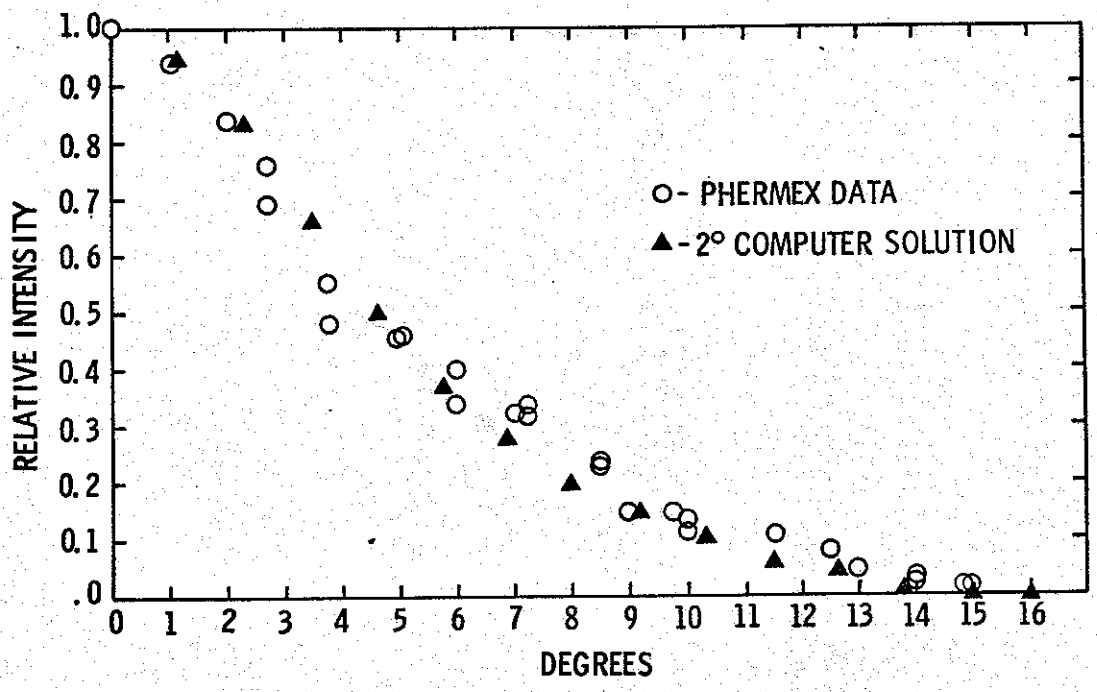


Figure 5. Comparison of PHERMEX Angular Distribution Data with 2-Degree Average Divergence Computer Solution

Based on the agreement between computed and experimental results, a 2-degree average angle of electron arrival was assumed. The bremsstrahlung production efficiency curve of the computer program was then modified at the 27-MeV point to give the experimentally observed value at 2 meters of 11.66 roentgens. The corrected bremsstrahlung production efficiency at 0-degree electron beam divergence was 11×10^6 r/coulomb at 27 MeV. This value is now consistent with those of previous investigations.[3,4] The PHERMEX data at the 20-MeV point was then recalculated; it was also consistent. The proposed bremsstrahlung production efficiency curve, shown in Figure 6, has a rather simple expression of $D/Q = 1.1 \times 10^3 \, V^{2.8}$ where V is in megavolts and the expression is valid at least from 1 to 27 MeV.

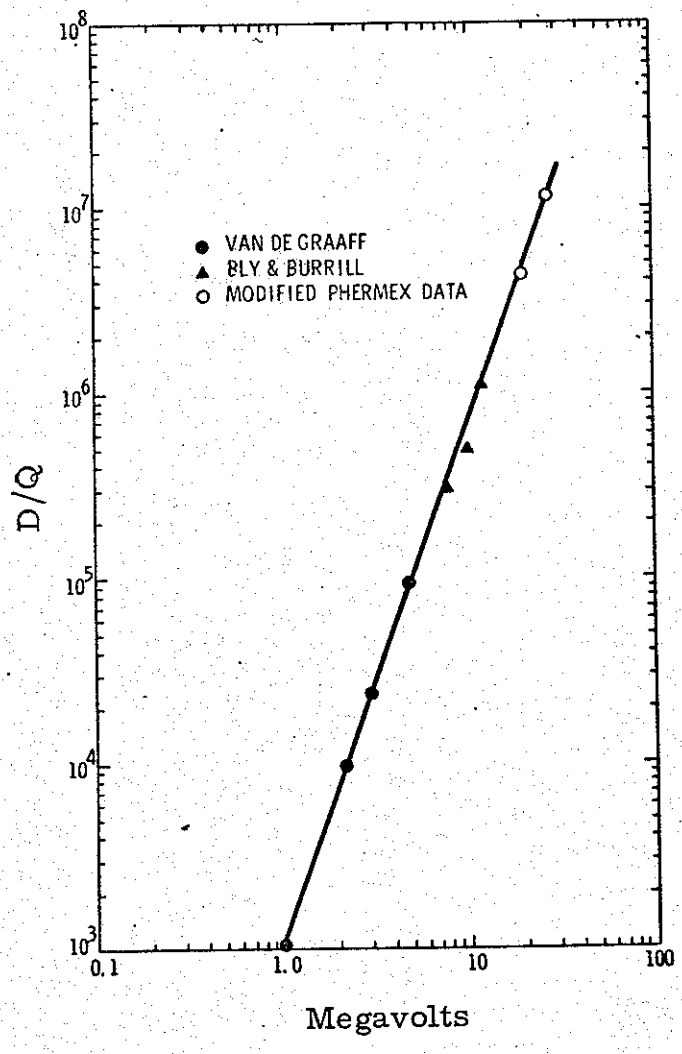


Figure 6. Proposed Bremsstrahlung Production Efficiency Curve Versus Voltage Based on Modified PHERMEX Data

LIST OF REFERENCES

1. Douglas Venable, Editor, PHERMEX: A Pulse High-Energy Radiographic Machine Emitting X-Rays, LA-3241, Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico, May 15, 1967.

2. T. H. Martin, Interrelationships Between Radiation Doses at One Meter and Main Switch Gap Rise Time in Large Flash X-Ray Machines, SC-RR-68-462, December 1968.

3. J. H. Bly and E. A. Burrill, ASTM Bulletin No. 278, 20, 1959.

4. W. W. Buechner and R. J. Van de Graaff, et al., Phys. Rev. 74, 1348, (1948).