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A COMPUTERIZED METHOD OF PREDICTING ELECTRON BEAM BREMSSTRAHLUNG RADIATION WITH SPECIFIC APPLICATION TO HIGH VOLTAGE FLASH X-RAY MACHINES

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ABSTRACT

Many interesting phenomena occurring in the radiation output of large flash X-ray machines can be utilized only by understanding the action of the incident electron stream on the target. The detailed calculations required to understand these effects are best performed with a computer. This report explains the computer program utilized and tabulates the outputs obtained. The report also draws conclusions for future research, analysis, and machine design. Interrelationships were developed between the switch rise time, the radiation pulse length, the dose expected at 1 meter, and the dose distribution.

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INTERRELATIONSHIPS BETWEEN RADIATION DOSES AT ONE METER AND MAIN SWITCH GAP RISE TIME IN LARGE FLASH X-RAY MACHINES

Introduction

Many interesting phenomena occurring in the radiation output of large flash X-ray machines can be utilized only by understanding the action of the incident electron stream on the target. This involves detailed computations which can be performed only on a computer.

In November 1967, the dependence of the dose output at 1 meter on the angular distribution of electrons incident on the flash X-ray machine target was recognized to be a pertinent and somewhat neglected factor in the design of flash X-ray machines. A computer program to analyze flash X-ray machine outputs was written at Sandia Laboratories for use in the Hermes Program. The first results became available approximately February 1968. To date a general trend has been established for these calculations, and an insight into this problem has been developed which can be of value in future generator research and in the establishment of dose levels of experiments to be conducted on flash X-ray facilities.

Computer Program

The computer program was written to operate on a RAX terminal for the IBM 360 computer. Figures 1 and 2 show the system analyzed. The target (A) was divided into 36 pie-shaped segments. One of these pie-shaped segments was then subdivided into six parts. A hemispherical dome, (B), was then placed above the target and divided into 10-degree segments. Eighteen planes, (C), were then defined along the Z axis which intersected the hemisphere's surface at 5-degree increments. The 10-degree segments on the sphere and the 5-degree increments are defined by the planes, so that the space above the target is divided into 648 points. Solutions for the radiation at these 648 points associated with each of the six target segments are obtained. After the radiation levels at the 648 points are defined, points are summed up by rotating one point into the other around the Z axis

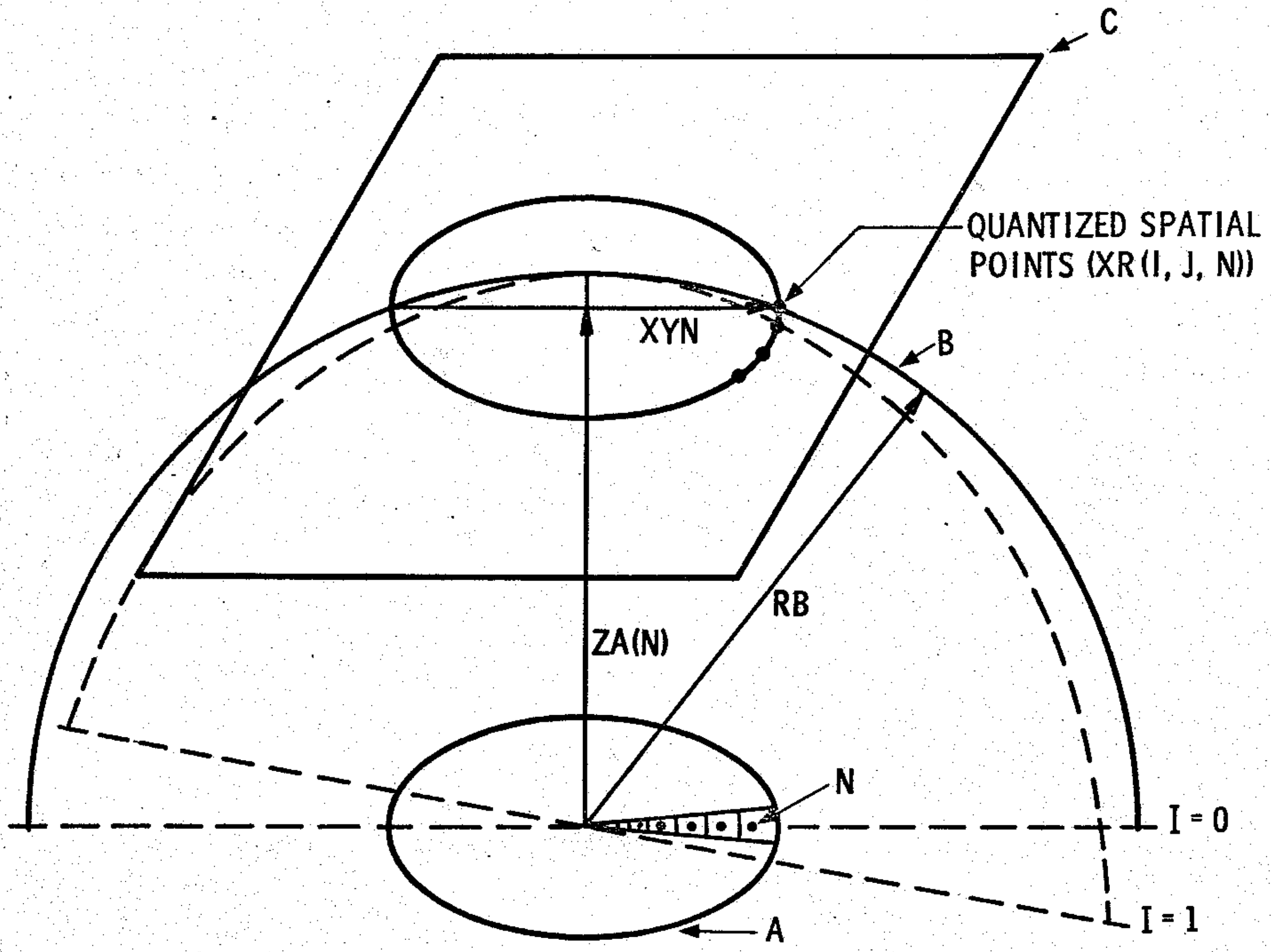


Figure 1. Geometry of Computer Solution

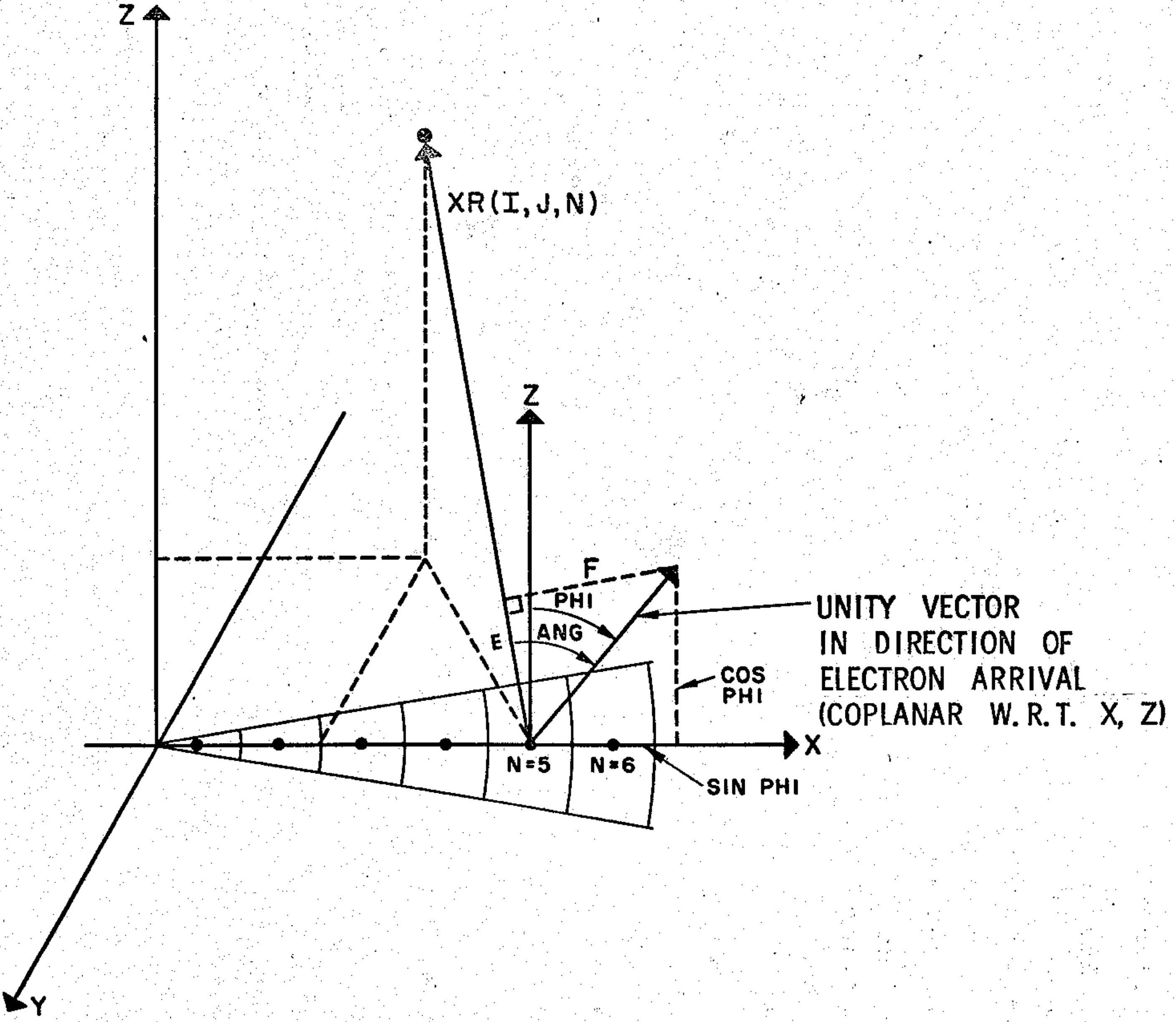


Figure 2. Vector Diagram of Electron Arrival Geometry

of the sphere. Thus, after 360-degree rotation, the six target segments are made to appear as the entire target. The radiation from the six target segments can be defined both in electron numbers and angle. The actual geometry used is shown in Figure 2.

Major Assumptions

Electron Beam Diameter -- It was assumed for this analysis that the spot size diameter was approximately equal to the number of megavolts between the anode and cathode multiplied times 1 inch per megavolt. Thus a 5-megavolt machine would have a 5-inch target diameter, and a 10-megavolt machine would have a 10-inch target diameter. This assumption is obviously open to question, but it has been valid for many of the machines at AWRE and for the machines at Sandia Laboratories. The spot size diameter will, in general, vary linearly with voltage in that the energy deposited on the target approximates a V^2 relationship and the target area must increase as V^2 or sustain damage. This assumption, if it isn't valid, can be easily modified in the program as better information becomes available.

Angular Distribution -- The normalized angular distribution of the radiation produced by electrons incident on a target was assumed to be a formula which is an average of the information available in the literature (References 1 and 2). This function was determined to be

$$F = e^{-\theta V/0.667\pi},$$

where F is the intensity, θ the angle in radians, and V in megavolts.

Divergence Angle -- It was assumed that divergence angle of the electron stream was a reasonably smooth function varying from approximately zero at a target radius of zero and then gradually increasing to achieve the average divergence angle which is used for the calculations in this paper. Results from Dr. Boers' computer program (Ref. 3) of Sandia Laboratories tend to indicate that this is not an accurate assumption in that the electrons closer to the center of the target may actually have a larger divergence angle than those on the periphery. However, this fact does not seriously affect the overall use of the computer output. This data can be modified to utilize trajectories available in the future.

Bremsstrahlung Production Efficiency Curve -- The curve used was the one proposed by Sandia. The Roentgens per coulomb equation is

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

where V is in megavolts (Reference 4).

The actual computer program in FORTRAN language is included in Figure 3.

In order to obtain a uniform, slowly varying electron distribution on the target as a first approximation, straight lines were drawn from the anode to the cathode, and these lines were assumed to be the electron trajectories. The computer runs were then made by subdividing these angles so that the average angular distribution of the electrons could be programmed at 0, 5, 10, 15, and 20 degrees. Computations were also made where the angular distribution was constant across the target. For a constant electron beam arrival angle, the maximum intensity did not occur on axis but at the angle at which the electrons were distributed. Consequently, a constant angle of distribution was deemed as not representing any experimental bremsstrahlung distributions achieved to date. Computations were performed at 3, 4, 6, 8, 10, 12, and 15 and 20 MeV at 0, 5, 10, 15, and 20-degree average angles. The computer output consists of bremsstrahlung radiation intensity directly in front of the target on axis and at 5-degree increments from zero to 90 degrees. The program also normalizes the dose distribution to the dose on axis at zero degrees.

Analysis of the computer data is difficult since no one chart or graph can represent all of the information. One of the more complex factors that becomes evident is the changing spot size at voltages above 10 MV which causes apparent inconsistencies in almost all of the analyses. However, it is felt that this spot size is an important factor which should be taken into account. Since the prime information which is needed for flash X-ray machine analysis is the actual rads per coulomb plotted versus voltage, or the modified bremsstrahlung production efficiency, this important information was plotted. The plot for the actual bremsstrahlung production efficiency curve for various divergence angles is included as Figure 4. The important information is listed as follows:

1. With zero-degree divergence at a zero spot size, the modified bremsstrahlung production efficiency duplicates the bremsstrahlung production efficiency programmed on the computer.
2. The effect of large spot size drastically reduces the bremsstrahlung production at 1 meter.
3. The beam divergence angle causes extreme degradation of the modified efficiency curve. These efficiency curves can be used directly as a first approximation of bremsstrahlung output in designing new machines.

DC - diameter of cathode target spot in meters

RN[N] - radial distance to center spots of the 6 target sections

PA - angles in radians to divide sphere into 18 sections in elevation

ZA(N) - the intersection point on the Z-axis corresponding to planes intersecting the sphere at 5-degree increments

RB - radius of sphere and/or distance from target at which computation is desired

XYN - radius of circle formed by intersection of plane with the sphere

XA[N, I] - X coordinate of plane N intersecting with longitude I.

YA[N, I] - Y coordinate of plane N intersecting with longitude I

XR[I, J, N] - distance from target segment n to XA[N, I] YA[N, I]. See Figure 2.

PHI(N) - angle of electron arrival at target segment N in radians

C(N) - equals sin (PHJ(N)). See Figure 2.

D(N) - equals cos (PHI(N)). See Figure 2.

E - See Figure 2

F - See Figure 2

ANG - determined by E, F above--angle between electron stream and XR(I, J, N) the observation point. Read in for six target points

G - product of ANG(I, J, N) and megavolts

FE - degradation due to angle represented by an equation using G as the input. Obtained by experiment.

RABN - the inverse square distance degradation factor

RQ - the rads at 1 meter per coulomb curve which also uses volts as an input

XCOL - defined by input data

RELI(N) - relative current density at target position N. Read in dist-card for six positions

SCOL - an operational unit

COL(N) - the coulombs deposited on target section N

ARADS - the radiation level at 1 meter from target section N

BRADS - the radiation at point IJ on the sphere from all six target sections

RADS(I) - the radiation at the 5-degree angles from all 216 target sections

TIME - the pulse duration in seconds

V - voltage in volts

Figure 3. List of Parameters and Program Used on Computer

```
/DISPLAY SV841
M.0073 ACTION IN PROGRESS.
L.0001  /JOB GO,TIME>10
L.0002  /FTC NAME>RAD
L.0003          DIMENSION RN[6], ZA[20],             XA[20,20], YA[20,20],
L.0004         1   C[6],          PHI[6], ANG[20,20,6], COL[6], FE[20,20,6],
L.0005         1 PHE[6], RELI[6],    RADN[20],
L.0006         1RABN[20,20,6],  BRADS[20,20], RADS[20], ARADS[6], XR[20,20,6]
L.0007         1 ,D[6]
L.0008  C       RADS 1 METER FROM N2
L.0009       10 READ [9,2] V,AMPS, RB,       TIME
L.0010          READ [9,3] [PHE[N], N>1,6],[RELI[N], N>1,6]
L.0011     2    FORMAT  [2E9.2/[E9.2]]
L.0012      3   FORMAT [6E10.2]
L.0013          PI>3.14159265
L.0014          DC>V*1.0E-6/39.37
L.0015          DO 101 N>1,6
L.0016    101   RN[N]>DC/12.0*[FLOAT[N]-0.5]
L.0017          DO 102 N>1,19
L.0018          PA>PI/36.0*[N-1]
L.0019    102   ZA[N]>RB*COS[PA]
L.0020          DO 104 N>1,19
L.0021          XYN>SQRT[RB**2-ZA[N]**2]
L.0022          DO 104 I>1,19
L.0023          XA[N,I]>XYN*COS[PI/18.0*[I-1]]
L.0024    104   YA[N,I]>XYN*SIN[PI/18.0*[I-1]]
L.0025          DO 105  N>1,6
L.0026          DO 105 I>1,19
L.0027          DO 105 J>1,19
L.0028    105    XR[I,J,N]>SQRT[[XA[I,J]-RN[M]]**2<YA[I,J ]**2<ZA[I]**2]
L.0029          DO 106 N>1,6
L.0030          PHI[N]>PHE[N]/180.0*PI
L.0031          C[N]>SIN[PHI[N]]
L.0032    106   D[N]>COS[PHI[N]]
L.0033          DO 107 N>1,6
L.0034          DO 107 I>1,19
L.0035          DO 107 J>1,19
L.0036          E>[C[N]*[XA[I,J]-RN[N]]<D[N]*ZA[I]]/XR[I,J,N]
L.0037          F>SQRT[1.0-E**2]
L.0038          IF [E] 109, 207,108
L.0039    108   ANG[I,J,N]>ATAN[F/E]
L.0040          GO TO 107
L.0041     207 ANG[I,J,N]>PI/2.0
L.0042          GO TO 107
L.0043    109   ANG[I,J,N]>PI-ATAN[ABS[F/E]]
L.0044    107    CONTINUE
L.0045          DO 110 N>1,6
L.0046          DO 110 I>1,19
L.0047          DO 110 J>1,19
L.0048          G>ABS[ANG[I,J,N]*V*1.0E-6]
L.0049    110   FE[I,J,N]>                          1.0*EXP[-G/[0.667*PI]]
L.0050          DO 111 N>1,6
L.0051          DO 111 I>1,19
L.0052          DO 111 J>1,19
L.0053    111   RABN[I,J,N]>1.0/XR[I,J,N]**2
L.0054          RO>1.1E3*[V*1.0E-6]**2.8
L.0055          XCOL>AMPS*TIME
L.0056          TT>0.0
L.0057          DO 112 N>I,6
L.0058    112   TT>[2*N-1]*RELI[N]<TT
L.0059          DO 116 N>I,6
L.0060          SCOL>XCOL/[36.0*TT]
L.0061    116   COL[N]>SCOL*[2*N-1]*RELI[N]
L.0062          DO 117 N>1,6
L.0063     117 ARADS[N]>RQ*COL[N]
L.0064          DO 118 J>1,20
L.0065          DO 118 I>1,20
L.0066     118 BRADS [I,J]>0.0
L.0067          DO 111 N>1,6
M.0065 TRANSMISSION ERROR.
M.0065 TRANSMISSION ERROR.
L.0068          DO 113 I>1,19
L.0069          DO 113 J>1,19
L.0070    113   BRADS[I,J]>[ARADS[N]]*RABN[I,J,N]*FE[I,J,N]<BRADS[I,J]
L.0071          DO 114 I>1,19
L.0072    114    RADS[I]>0.0
L.0073          DO 115 J>2,18
L.0074          DO 115 I>1,19
L.0075    115   RADS[I]>[BRADS[I,J]<RADS[I]]
L.0076          DO 216 I>1,19
L.0077     216     RADS[I]>2.0*RADS[I]<BRADS[I,1]<BRADS[I,19]
L.0078          WRITE [6,35] [RADS[I],I>1,19]
L.0079          DO 217 I>1,19
L.0080    217   RADN[I]>RADS[I]/RADS[1]
L.0081          WRITE [6,36] [RADN[I],I>1,19]
L.0082     36   FORMAT  [8E15.5]
L.0083          GO TO 10
L.0084     35   FORMAT  [8E15.5]
L.0085          END
```

Figure 3 (cont)

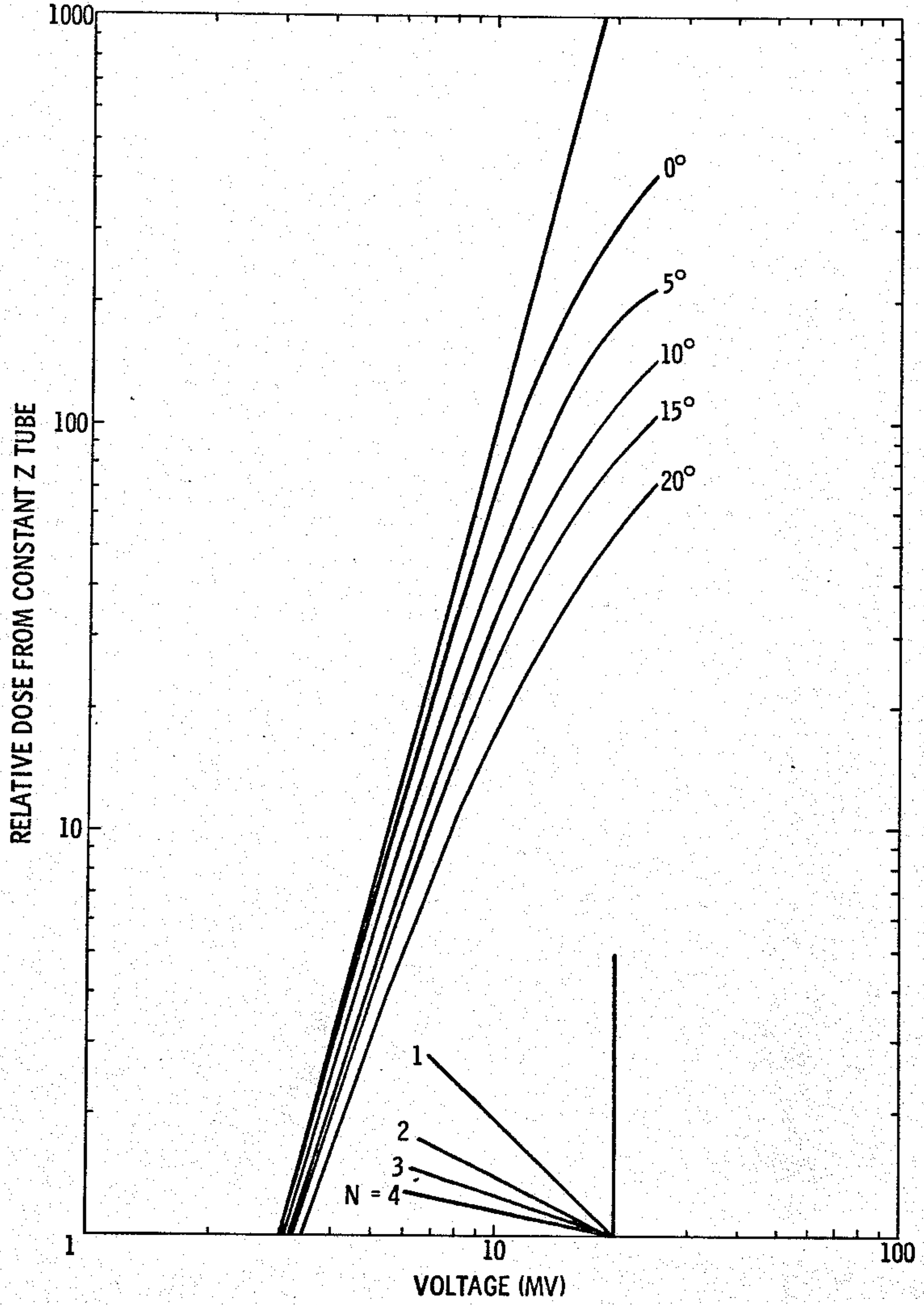
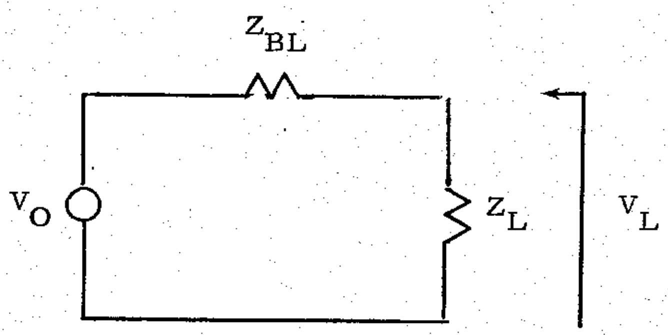


Figure 4. Summary of Computer Results

Optimum Tube Impedance Derivation

The optimum way to design a flash X-ray machine would be to determine the bremsstrahlung production efficiency at a given voltage and then make the tube impedance n - 1 times the impedance of the Blumleins. This derivation is shown below:



Assume that there is bremsstrahlung radiation emanating which is given as

$$\text{Output} = KV_L^{n-1} I,$$

where n - 1 is the bremsstrahlung efficiency Roentgens per coulomb exponent:

$$I = \frac{V_L}{Z_L}$$

$$V_L = \frac{V_o \; Z_L}{Z_{BL} + Z_L}$$

$$\text{Output} = K \, V_o^n \, Z_L^{n-1} \, (Z_{BL} + Z_L)^{-n}$$

$$\frac{d(\text{Output})}{d\,Z_L} = KV_o^n \left[(n-1)Z_L^{n-2} \, (Z_{BL} + Z_L)^{-n} - n \, Z_L^{n-1} \, (Z_{BL} + Z_L)^{-n-1} \right].$$

Maximizing by equating to zero

$$0 = (n - 1)(Z_{BL} + Z_L) - n Z_L$$

$$= (n - 1)Z_B - Z_L$$

and

$$Z_L = (n - 1)Z_B$$

This means that if the bremsstrahlung production efficiency goes as V^4 for a constant impedance tube then the X-ray tube impedance for maximum bremsstrahlung production at 1 meter should be three times the Blumlein impedance. This fact becomes more important in the machines operating between 10 and 20 MeV. If one looks at the newly generated efficiency curves, the conclusion can be reached that the bremsstrahlung production efficiency exponent rapidly decreases for large spot size and large angular distributions. Thus, for optimum bremsstrahlung production, the tube impedance can actually approach the matched condition or less, and a mismatched system is of value only when small distribution angles and small spot sizes are utilized.

Computer Results

The results of the computer runs are given in the appendix. Comparison of computer results with experiments conducted at voltages between 2 and 12 MeV on Sandia's Hermes flash X-ray machine have demonstrated excellent agreement in both the intensity and angular distribution. This will be detailed in a future report.

Voltage Rise Time Effects

The voltage output pulse from these machines can be reasonably described to a first approximation as two exponentials. The first starts at zero time and builds to a maximum value. After the voltage pulse time has elapsed, the other exponential will drop the voltage back towards zero. Ion Physics has generated a plot of the effect of various rise times in nondimensional form. The pulse width divided by the switch rise time is plotted (Figure 5) versus the degradation in bremsstrahlung dose (Reference 1). The higher the exponential of the modified bremsstrahlung production efficiency, the worse the degradation from the switch rise time will be. Therefore, for a machine with either a large spot size or large electron beam divergence angle, the voltage rise time is a less important consideration in the

(Reference: Ion Physics DASA Proposal Contract DA-01-67C-0001)

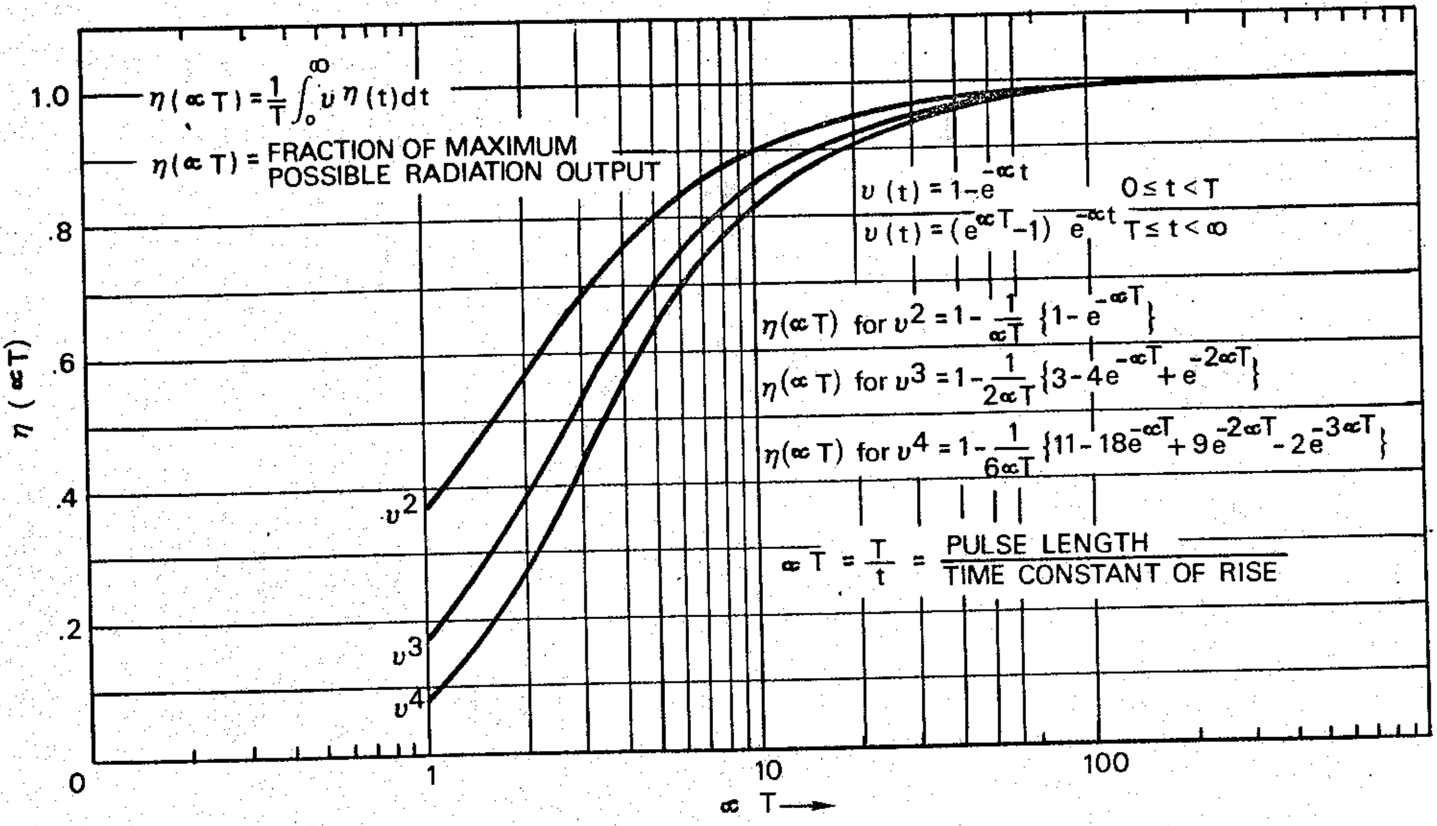


Figure 5. The Influence of Pulse Rise Time Upon System Efficiency

machine design. Simultaneous research needs to be conducted on the spot size, the beam divergence angle, and the rise time in order to obtain the maximum possible radiation dose in small volumes; the hypothesis set forth here has been verified in data obtained on large flash X-ray generators. For a 13-degree average electron beam divergence angle, the computer calculations predict that the bremsstrahlung production efficiency is proportional to the square of the voltage at 10 MeV. The radiation half intensity then occurs when the tube voltage reaches 0.707 of its peak value as predicted by the modified bremsstrahlung efficiency curve instead of 0.83 as predicted by the original efficiency curves; thus a longer radiation pulse results. This effect has been experimentally verified. This leads to the interesting conclusion that at voltages above 10 MV a good approximation to the beam divergence angle can be made by using the ratio of the bremsstrahlung production time half-width to the voltage pulse half-width.

Physical Interpretation

The following physical interpretation is presented in order to attach some reality and significance to the data obtained from the computer. At low voltage, the electrons yield bremsstrahlung radiation in almost isotropic distributions. At voltages above approximately 8 megavolts, the electron radiation sources are no longer isotropic but become highly directional. This is analogous to a flashlight bulb being utilized as the radiator for the lower voltages with a collimating reflector being moved into position behind the bulb proportional to the voltage. The higher voltage is analogous to a better collimated beam. The radiation or illumination half-angle will decrease, the on-axis intensity will increase, and the beam from the flashlight bulb will become a searchlight-type pattern where the inverse square law becomes invalid except for very large distances from the source. The reason for this is that when a point in the radiation field looks back at an extremely well-collimated source, the point can see only a small portion of the reflector or illuminator. In other words, since the radiation is so strongly collimated from other portions of the target, the point does not see these, and, consequently, no inverse square law can be obtained. This analogy also shows that dose distributions given in rads at 1 meter are meaningless for flash X-ray machine operation at about 8 MeV and above, in that a case could be hypothesized where an electron beam would be made converging and all the radiation would also converge at a point 1 meter from the target. This yields a maximum dose at that particular point only, and the intensity decreases in every direction. This converging beam, which requires better beam control and handling methods than presently available, appears possible in the future.

Conclusions

1. A computer program has been written for the IBM 360 computer which accurately predicts bremsstrahlung outputs in intensity and angle from large flash X-ray generators.
2. The long X-ray pulse width compared to the voltage pulse has been explained.
3. The interactions between voltage rise time, spot size, electron divergence angle, and bremsstrahlung dose output were derived.
4. From Figures 4 and 5, bremsstrahlung outputs from proposed flash X-ray machines can be accurately and quickly determined.

APPENDIX

COMPUTER PRINTOUT FORMAT

```
M 0077  ENTER DATA
        VOLTAGE CURRENT               VOLTS AND AMPS
M 0077 ENTER DATA
        DISTANCE FROM TARGET IN METERS RADS AT ONE METER
M 0077  ENTER DATA
        PULSE WIDTH IN SECONDS-TIME
M 0077  ENTER DATA
ANGLES IN DEGREES FOR THE SIX TARGET SEGMENTS (FROM CENTER TO OUTSIDE) -- AVERAGE ANGLE
M 0077  ENTER DATA
        RELATIVE CURRENT INTENSITIES ON THE SIX TARGET SEGMENTS (FROM CENTER TO OUTSIDE)

Dose Values     ( 0 degrees    5 degrees   10 degrees   15 degrees   20 degrees   25 degrees   30 degrees   35 degrees
in Roentgens    {40 degrees   45 degrees   50 degrees   55 degrees   60 degrees   65 degrees   70 degrees   75 degrees
                (80 degrees   85 degrees   90 degrees

Relative Dose   ( 0 degrees    5 degrees   10 degrees   15 degrees   20 degrees   25 degrees   30 degrees   35 degrees
Normalized to   {40 degrees   45 degrees   50 degrees   55 degrees   60 degrees   65 degrees   70 degrees   75 degrees
0 Degrees       (80 degrees   85 degrees   90 degrees
```

```
                 SIZE OF COMMON  00000    PROGRAM  47592
   END OF COMPILATION  RAD
   M.0077 ENTER DATA.
       3.0E6    3.0E4          VOLTS AND AMPS
   M.0077 ENTER DATA.
       1.0E0           RADS AT ONE METER

   M.0077 ENTER DATA.
       3.0E-8          TIME

   M.0077 ENTER DATA.


   M.0077 ENTER DATA.
          1.       1.       1.       1.       1.       1.

      0.20684E 02   0.18877E 02   0.16688E 02   0.14738E 02   0.13012E 02   0.11487E 02   0.10141E 02   0.89518E 01
      0.79019E 01   0.69749E 01   0.61565E 01   0.54339E 01   0.47960E 01   0.42328E 01   0.37357E 01   0.32968E 01
      0.29094E 01   0.25675E 01   0.22657E 01
      0.10000E 01   0.91265E 00   0.80679E 00   0.71251E 00   0.62908E 00 20   0.55537E 00 25   0.49027E 00 30   0.43279E 00 35
      0.38203E 00   0.33721E 00   0.29764E 00   0.26271E 00   0.23187E 00   0.20464E 00   0.18061E 00   0.15939E 00
      0.14066E 00   0.12413E 00   0.10954E 00
   M.0077 ENTER DATA.
       3.0E6    3.0E4          VOLTS AND AMPS
   M.0077 ENTER DATA.
       1.0E0           RADS AT ONE METER
   M.0077 ENTER DATA.
       3.0E-8          TIME
   M.0077 ENTER DATA.
    .573      1.85      3.12      4.4      5.67      6.95      5 DEG ANG
   M.0077 ENTER DATA.
          1.       1.       1.       1.       1.       1.
      0.18284E 02   0.17752E 02   0.16318E 02   0.14573E 02   0.12935E 02   0.11456E 02   0.10135E 02   0.89603E 01
      0.79189E 01   0.69964E 01   0.61800E 01   0.54580E 01   0.48195E 01   0.42552E 01   0.37566E 01   0.33160E 01
      0.29269E 01   0.25832E 01   0.22798E 01
      0.10000E 01   0.97001E 00   0.89250E 00   0.79703E 00   0.70745E 00   0.62655E 00   0.55430E 00   0.49007E 00
      0.43311E 00   0.38266E 00   0.33801E 00   0.29852E 00   0.26360E 00   0.23273E 00   0.20546E 00   0.18137E 00
      0.16008E 00   0.14129E 00   0.12469E 00
   M.0077 ENTER DATA.
       3.0E6    3.0E4          VOLTS AND AMPS
   M.0077 ENTER DATA.
       1.0E0           RADS AT ONE METER
   M.0077 ENTER DATA.
       3.0E-8          TIME
   M.0077 ENTER DATA.
    1.15      3.70      6.25      8.8      11.35      13.9      16 DEG ANG

   M.0077 ENTER DATA.
          1.       1.       1.       1.       1.       1.
      0.16194E 02   0.15942E 02   0.15223E 02   0.14095E 02   0.12717E 02   0.11355E 02   0.10100E 02   0.89632E 01
      0.79439E 01   0.70341E 01   0.62265E 01   0.55551E 01   0.48979E 01   0.42955E 01   0.38019E 01   0.33589E 01
      0.29609E 01   0.26243E 01   0.23133E 01
      0.10000E 01   0.98481E 00   0.90095E 00   [illegible]   0.78551E 00   0.70[illegible]E 00   0.62508E 00   0.55343E 00
      0.49054E 00   0.43437E 00   0.38438E 00   0.33938E 00   0.30050E 00   [illegible]   0.23477E 00   0.20741E 00
      0.18321E 00   0.16183E 00   0.14286E 00
```

```
    3.0E6     3.0E4             VOLTS AND AMPS
 M.0077 ENTER DATA.
    1.0E0             RADS AT ONE METER
 M.0077 ENTER DATA.
    3.0E-8            TIME
 M.0077 ENTER DATA.
 1.72      5.55      9.37      10.7      13.2      20.9      15 DEG ANG
 M.0077 ENTER DATA.
       1.        1.        1.        1.        1.        1.
    0.14895E 02   0.14730E 02   0.14251E 02   0.13419E 02   0.12347E 02   0.11198E 02   0.10036E 02   0.89505E 01
    0.79610E 01   0.70687E 01   0.62691E 01   0.55551E 01   0.49192E 01   0.43530E 01   0.38518E 01   0.34065E 01
    0.30119E 01   0.26567E 01   0.23950E 01
    0.10000E 01   0.98894E 00   0.95676E 00   0.90093E 00   0.82896E 00   0.75183E 00   0.67378E 00   0.60091E 00
    0.53448E 00   0.47458E 00   0.42089E 00   0.37295E 00   0.33020E 00   0.29230E 00   0.25860E 00   0.22871E 00
    0.20221E 00   0.17637E 00   0.15475E 00
 M.0077 ENTER DATA.
    3.0E6     3.0E4             VOLTS AND AMPS
 M.0077 ENTER DATA.
    1.0E0             RADS AT ONE METER
 M.0077 ENTER DATA.
    3.0E-8            TIME
 M.0077 ENTER DATA.
 2.29      7.40      12.5      17.6      22.7      27.8      20 DEG ANG
 M.0077 ENTER DATA.
       1.        1.        1.        1.        1.        1.
    0.12787E 02   0.12693E 02   0.12430E 02   0.12003E 02   0.11417E 02   0.10684E 02   0.98240E 01   0.88854E 01
    0.79776E 01   0.71327E 01   0.63602E 01   0.56609E 01   0.50316E 01   0.44676E 01   0.39637E 01   0.35144E 01
    0.30971E 01   0.26813E 01   0.22861E 01
    0.10000E 01   0.99259E 00   0.97207E 00   0.93868E 00   0.89286E 00   0.83548E 00   0.76826E 00   0.69486E 00
    0.62387E 00   0.55779E 00   0.49738E 00   0.44209E 00   0.39348E 00   0.34938E 00   0.30997E 00   0.27484E 00
    0.24220E 00   0.20968E 00   0.17878E 00
```

(2)

```
M.0077 ENTER DATA.
     4.E6      4.E4                VOLTS AND AMPA
M.0077 ENTER DATA.
     1.0E0                RADS AT ONE METER
M.0077 ENTER DATA.
     3.0E-8               TIME
M.0077 ENTER DATA.

M.0077 ENTER DATA.
          1.          1.          1.          1.          1.          1.
     0.59988E 02   0.53828E 02   0.45749E 02   0.38788E 02   0.32867E 02   0.27842E 02   0.23583E 02   0.19972E 02
     0.16914E 02   0.14322E 02   0.12127E 02   0.10267E 02   0.86920E 01   0.73582E 01   0.62286E 01   0.52721E 01
     0.34972E 01   0.0           0.0
     0.10000E 01   0.89732E 00   0.76263E 00   0.64660E 00   0.54789E 00   0.46413E 00   0.39312E 00   0.33294E 00
     0.28195E 00   0.23875E 00   0.20215E 00   0.17115E 00   0.14490E 00   0.12265E 00   0.10383E 00   0.87886E-01
     0.58297E-01   0.0           0.0
M.0077 ENTER DATA.
     4.E6      4.E4                VOLTS AND AMPA
M.0077 ENTER DATA.
     1.0E0                RADS AT ONE METER
M.0077 ENTER DATA.
     3.0E-8               TIME
M.0077 ENTER DATA.
 .573        1.85       3.12          4.4      5.67         6.95        5 DEG ANG
M.0077 ENTER DATA.
          1.          1.          1.          1.          1.          1.
     0.50945E 02   0.49173E 02   0.44342E 02   0.38263E 02   0.32886E 02   0.27823E 02   0.23643E 02   0.20070E 02
     0.17025E 02   0.14435E 02   0.12235E 02   0.10367E 02   0.87815E 01   0.74370E 01   0.62970E 01   0.50400E 01
     0.31006E 01   0.11226E 01   0.57378E-01
     0.10000E 01   0.96520E 00   0.87039E 00   0.75106E 00   0.64159E 00   0.54614E 00   0.46408E 00   0.39394E 00
     0.33418E 00   0.28335E 00   0.24016E 00   0.20349E 00   0.17237E 00   0.14598E 00   0.12360E 00   0.98930E-01
     0.60802E-01   0.22036E-01   0.11263E-02
M.0077 ENTER DATA.
     4.E6      4.E4                VOLTS AND AMPA
M.0077 ENTER DATA.
     1.0E0                RADS AT ONE METER
M.0077 ENTER DATA.
     3.0E-8               TIME
M.0077 ENTER DATA.
 1.15        3.70       6.25          8.8         11.35        13.9        10 DEG ANG
M.0077 ENTER DATA.
          1.          1.          1.          1.          1.          1.
     0.43423E 02   0.42611E 02   0.40296E 02   0.35643E 02   0.32115E 02   0.27072E 02   0.23036E 02   0.20223E 02
     0.17223E 02   0.14648E 02   0.12440E 02   0.10567E 02   0.89656E 01   0.75746E 01   0.61026E 01   0.45745E 01
     0.31366E 01   0.18547E 01   0.80847E 00
     0.10000E 01   0.98129E 00   0.92798E 00   0.84385E 00   0.73958E 00   0.63729E 00   0.54570E 00   0.46571E 00
     0.39664E 00   0.33734E 00   0.28662E 00   0.24334E 00   0.20647E 00   0.17444E 00   0.14054E 00   0.10535E 00
     0.72237E-01   0.42711E-01   0.16612E-01
```

```
   4.E6     4.E4              VOLTS AND AMPA
 M.0077 ENTER DATA.
   1.0E0              RADS AT ONE METER
 M.0077 ENTER DATA.
   3.0E-8          TIME
 M.0077 ENTER DATA.
 1.72      5.55       9.37       10.7       13.2       20.9       15 DEG ANG
 M.0077 ENTER DATA.
       1.         1.        1.         1.         1.         1.
    0.38947E 02    0.38437E 02    0.36960E 02    0.34359E 02    0.30925E 02    0.27384E 02    0.23651E 02    0.20331E 02
    0.17405E 02    0.14860E 02    0.12665E 02    0.10779E 02    0.90728E 01    0.75150E 01    0.60446E 01    0.45551E 01
    0.33003E 01    0.22043E 01    0.12432E 01
    0.10000E 01    0.98690E 00    0.94898E 00    0.88221E 00    0.79402E 00    0.70196E 00    0.60727E 00    0.52202E 00
    0.44688E 00    0.38155E 00    0.32518E 00    0.27676E 00    0.23235E 00    0.19297E 00    0.15520E 00    0.11096E 00
    0.84740E-01    0.56596E-01    0.31921E-01
 M.0077 ENTER DATA.
   4.E6     4.E4              VOLTS AND AMPA
 M.0077 ENTER DATA.
   1.0E0              RADS AT ONE METER
 M.0077 ENTER DATA.
   3.0E-8          TIME
 M.0077 ENTER DATA.
 2.29      7.40       12.5       17.6       22.7       27.8       20 DEG ANG
 M.0077 ENTER DATA.
       1.         1.        1.         1.         1.         1.
    0.31922E 02    0.31643E 02    0.30830E 02    0.29664E 02    0.27969E 02    0.25823E 02    0.23271E 02    0.20436E 02
    0.17735E 02    0.15291E 02    0.13118E 02    0.11075E 02    0.92120E 01    0.75573E 01    0.60982E 01    0.48186E 01
    0.37137E 01    0.27495E 01    0.19322E 01
    0.10000E 01    0.99120E 00    0.96788E 00    0.92325E 00    0.87615E 00    0.80623E 00    0.72899E 00    0.64020E 00
    0.55557E 00    0.47992E 00    0.41093E 00    0.34694E 00    0.28899E 00    0.23675E 00    0.19103E 00    0.15095E 00
    0.11633E 00    0.86131E-01    0.60528E-01
```

5

```
      6.E6     6.E4                VOLTS AND AMPA
 M.0077 ENTER DATA.
      1.0E0                RADS AT ONE METER
 M.0077 ENTER DATA.
      3.0E-8               TIME
 M.0077 ENTER DATA.

 M.0077 ENTER DATA.
          1.         1.         1.         1.         1.         1.
    0.25835E 03    0.22802E 03    0.18010E 03    0.14099E 03    0.11014E 03    0.85901E 02    0.67053E 02    0.52284E 02
    0.40755E 02    0.31759E 02    0.24724E 02    0.81765E 01    0.0            0.0            0.0            0.0
    0.0            0.0            0.0
    0.10000E 01    0.88260E 00    0.69714E 00    0.54576E 00    0.42833E 00    0.33273E 00    0.25955E 00    0.20238E 00
    0.15775E 00    0.12293E 00    0.95701E-01    0.31643E-01    0.0            0.0            0.0            0.0
    0.0            0.0            0.0
 M.0077 ENTER DATA.
      6.E6     6.E4                VOLTS AND AMPA
 M.0077 ENTER DATA.
      1.0E0                RADS AT ONE METER
 M.0077 ENTER DATA.
      3.0E-8               TIME
 M.0077 ENTER DATA.
 .573      1.85      3.12      4.4       5.67      6.95      5 DEG ANG
 M.0077 ENTER DATA.
          1.         1.         1.         1.         1.         1.
    0.20304E 03    0.19456E 03    0.17093E 03    0.13904E 03    0.11034E 03    0.86893E 02    0.68176E 02    0.53373E 02
    0.41722E 02    0.32036E 02    0.21298E 02    0.11322E 02    0.35304E 01    0.79440E-02    0.0            0.0
    0.0            0.0            0.0
    0.10000E 01    0.95827E 00    0.84135E 00    0.68473E 00    0.54343E 00    0.42797E 00    0.33578E 00    0.25287E 00
    0.20549E 00    0.15778E 00    0.10489E 00    0.55765E-01    0.17388E-01    0.30130E-04    0.0            0.0
    0.0            0.0            0.0
 M.0077 ENTER DATA.
      6.E6     6.E4                VOLTS AND AMPA
 M.0077 ENTER DATA.
      1.0E0                RADS AT ONE METER
 M.0077 ENTER DATA.
      3.0E-8               TIME
 M.0077 ENTER DATA.
 1.15      3.70      6.25      8.8       11.35     13.9      10 DEG ANG
 M.0077 ENTER DATA.
          1.         1.         1.         1.         1.         1.
    0.16093E 03    0.15732E 03    0.14099E 03    0.13054E 03    0.10920E 03    0.87370E 02    0.69965E 02    0.55271E 02
    0.42309E 02    0.30907E 02    0.21359E 02    0.13584E 02    0.74424E 01    0.28775E 01    0.29932E 00    0.0
    0.0            0.0            0.0
    0.10000E 01    0.97761E 00    0.91342E 00    0.81119E 00    0.67856E 00    0.54371E 00    0.43477E 00    0.34346E 00
    0.26291E 00    0.19206E 00    0.13273E 00    0.84614E-01    0.40240E-01    0.18532E-02    0.10600E-02    0.0
    0.0            0.0            0.0
```

```
      6.E6      6.E4               VOLTS AND AMPA
 M.0077 ENTER DATA.
      1.0E0            RADS AT ONE METER
 M.0077 ENTER DATA.
     3.0E-8            TIME
 M.0077 ENTER DATA.
  1.72      5.55      9.37      10.7      13.2      20.8      15 DEG AND
 M.0077 ENTER DATA.
         1.        1.        1.        1.        1.        1.
     0.13786E 03    0.13577E 03    0.12982E 03    0.11889E 03    0.10342E 03    0.87522E 02    0.70922E 02    0.55786E 02
     0.45167E 02    0.31798E 02    0.22620E 02    0.15304E 02    0.96437E 01    0.43891E 01    0.10629E 01    0.64951E 00
     0.0            0.0            0.0
     0.10000E 01    0.98480E 00    0.94167E 00    0.86235E 00    0.75010E 00    0.63485E 00    0.51445E 00    0.40451E 00
     0.31312E 00    0.23000E 00    0.16412E 00    0.11164E 00    0.69945E-01    0.38126E-01    0.14238E-01    0.47113E-02
     0.0            0.0            0.0
 M.0077 ENTER DATA.
      6.E6      6.E4               VOLTS AND AMPA
 M.0077 ENTER DATA.
      1.0E0            RADS AT ONE METER
 M.0077 ENTER DATA.
     3.0E-8            TIME
 M.0077 ENTER DATA.
  2.29      7.40      12.5      17.6      22.7      27.8      20 DEG AND
 M.0077 ENTER DATA.
         1.        1.        1.        1.        1.        1.
     0.10392E 03    0.10285E 03    0.10021E 03    0.95902E 02    0.89809E 02    0.80874E 02    0.69822E 02    0.57167E 02
     0.45047E 02    0.34647E 02    0.25980E 02    0.18896E 02    0.13233E 02    0.88180E 01    0.53433E 01    0.27684E 01
     0.92332E 00    0.0            0.0
     0.10000E 01    0.98975E 00    0.96434E 00    0.92287E 00    0.86424E 00    0.77826E 00    0.67190E 00    0.55012E 00
     0.43349E 00    0.33341E 00    0.25091E 00    0.18184E 00    0.12734E 00    0.84856E-01    0.51419E-01    0.26640E-01
     0.88852E-02    0.0            0.0
 M.0077 ENTER DATA.
      8.E6      8.E4               VOLTS AND AMPA
 M.0077 ENTER DATA.
      1.0E0            RADS AT ONE METER
 M.0077 ENTER DATA.
     6.0E-8            TIME
 M.0077 ENTER DATA.
```

```
M.0077 ENTER DATA.
      1.0E0             RADS AT ONE METER
M.0077 ENTER DATA.
    6.0E-8            TIME
M.0077 ENTER DATA.

M.0077 ENTER DATA.
        1.         1.         1.          1.          1.          1.
   0.13705E 04   0.12185E 04   0.90547E 03   0.67750E 03   0.47433E 03   0.34139E 03   0.24538E 03   0.17619E 03
   0.12041E 03   0.90036E 02   0.64940E 02   0.46513E 02   0.33296E 02   0.23820E 02   0.17044E 02   0.12189E 02
   0.87105E 01   0.62328E 01   0.44570E 01
   0.10000E 01   0.88327E 00   0.65709E 00   0.47601E 00   0.34384E 00   0.24747E 00   0.17787E 00   0.12772E 00
   0.91636E-01   0.65702E-01   0.47079E-01   0.33717E-01   0.24130E-01   0.17271E-01   0.12355E-01   0.88301E-02
   0.63186E-02   0.45161E-02   0.32306E-02
M.0077 ENTER DATA.
     8.E6      8.E4               VOLTS AND AMPA
M.0077 ENTER DATA.
     1.0E0               RADS AT ONE METER
M.0077 ENTER DATA.
    6.0E-8            TIME
M.0077 ENTER DATA.
 .573      1.85      3.12       4.4      5.07       6.95       5 DEG ANG
M.0077 ENTER DATA.
        1.         1.         1.          1.          1.          1.
   0.10077E 04   0.96286E 03   0.83697E 03   0.65309E 03   0.48398E 03   0.35346E 03   0.25636E 03   0.18517E 03
   0.13337E 03   0.95654E 02   0.68773E 02   0.49272E 02   0.35258E 02   0.25293E 02   0.18000E 02   0.12846E 02
   0.91625E 01   0.65322E 01   0.46556E 01
   0.10000E 01   0.95553E 00   0.83060E 00   0.64812E 00   0.48030E 00   0.35077E 00   0.25441E 00   0.18376E 00
   0.13235E 00   0.95124E-01   0.68250E-01   0.48897E-01   0.34990E-01   0.25012E-01   0.17863E-01   0.12748E-01
   0.90927E-02   0.64625E-02   0.46202E-02
M.0077 ENTER DATA.
     8.E6      8.E4               VOLTS AND AMPA
M.0077 ENTER DATA.
     1.0E0               RADS AT ONE METER
M.0077 ENTER DATA.
    6.0E-8            TIME
M.0077 ENTER DATA.
1.15      3.79      6.25       8.8       11.35      13.9       10 DEG ANG
M.0077 ENTER DATA.
        1.         1.         1.          1.          1.          1.
   0.74765E 03   0.73012E 03   0.67989E 03   0.59840E 03   0.48774E 03   0.37219E 03   0.27421E 03   0.20073E 03
   0.14590E 03   0.10553E 03   0.76057E 02   0.54558E 02   [illegible]   0.28042E 02   0.20034E 02   0.14293E 02
   0.10186E 02   0.72524E 01   0.51603E 01
   0.10000E 01   0.97655E 00   0.90937E 00   0.80038E 00   0.65237E 00   [illegible]   0.36670E 00   0.26848E 00
   0.19515E 00   0.14115E 00   0.10173E 00   0.73199E-01   0.52415E-01   [illegible]   0.26790E-01   0.19117E-01
   0.13624E-01   0.97003E-02   0.69020E-02
```

```
    8.E6      8.E4              VOLTS AND AMPS
M.0077 ENTER DATA.
    1.0E0              RADS AT ONE METER
M.0077 ENTER DATA.
    6.0E-8             TIME
M.0077 ENTER DATA.
 1.72       5.55       9.37       10.7       13.2       20.9       15 DEG ANG
M.0077 ENTER DATA.
       1.         1.         1.         1.         1.         1.
    0.61549E 03    0.60610E 03    0.58063E 03    0.53130E 03    0.45296E 03    0.37189E 03    0.28820E 03    0.21552E 03
    0.15883E 03    0.11595E 03    0.84122E 02    0.60746E 02    0.43707E 02    0.31355E 02    0.22440E 02    0.16028E 02
    0.11420E 02    0.81395E 01    0.57909E 01
    0.10000E 01    0.98475E 00    0.94337E 00    0.80322E 00    0.73593E 00    0.60407E 00    0.46824E 00    0.35026E 00
    0.25806E 00    0.18839E 00    0.13668E 00    0.98997E-01    0.71012E-01    0.53944E-01    0.38459E-01    0.26041E-01
    0.18570E-01    0.13225E-01    0.94086E-02
M.0077 ENTER DATA.
    8.E6      8.E4              VOLTS AND AMPS
M.0077 ENTER DATA.
    1.0E0              RADS AT ONE METER
M.0077 ENTER DATA.
    6.0E-8             TIME
M.0077 ENTER DATA.
 2.29       7.40       12.5       17.6       22.7       27.8       20 DEG ANG
M.0077 ENTER DATA.
       1.         1.         1.         1.         1.         1.
    0.43283E 03    0.42807E 03    0.4181-E 03    0.40196E 03    0.37741E 03    0.34336E 03    0.29850E 03    0.24291E 03
M.0065 TRANSMISSION ERROR.
M.0065 TRANSMISSION ERROR.
    0.18588E 03    0.13894E 03    0.10245E 03    0.74655E 02    0.54333E 02    0.39239E 02    0.28226E 02    0.20240E 02
    0.14476E 02    0.10332E 02    0.73032E 01
    0.10000E 01    0.98900E 00    0.96599E 00    0.92866E 00    0.87196E 00    0.79328E 00    0.68964E 00    0.56121E 00
    0.42946E 00    0.32101E 00    0.23070E 00    0.17294E 00    0.12553E 00    0.90857E-01    0.65213E-01    0.46761E-01
    0.33444E-01    0.23872E-01    0.17012E-01
```

```
    10.E6     10.E4          VOLTS AND AMPS
 M.0077 ENTER DATA.
    1.0E0                RADS AT ONE METER
 M.0077 ENTER DATA.
    6.0E-8               TIME
 M.0077 ENTER DATA.

 M.0077 ENTER DATA.
        1.          1.          1.          1.          1.          1.
    0.27998E 04   0.24919E 04   0.17896E 04   0.12088E 04   0.80728E 03   0.53840E 03   0.35543E 03   0.23503E 03
    0.15516E 03   0.10230E 03   0.67362E 02   0.44312E 02   0.29125E 02   0.19139E 02   0.12559E 02   0.82424E 01
    0.54090E 01   0.35499E 01   0.23305E 01
    0.10000E 01   0.89000E 00   0.63919E 00   0.43170E 00   0.28830E 00   0.19158E 00   0.12694E 00   0.83944E-01
    0.55419E-01   0.36537E-01   0.24059E-01   0.15827E-01   0.10402E-01   0.68325E-02   0.44855E-02   0.29439E-02
    0.55419E-01   0.36537E-01   0.24059E-01   0.15827E-01   0.10402E-01   0.68325E-02   0.44855E-02   0.29439E-02
    0.19319E-02   0.12079E-02   0.83235E-03
 M.0077 ENTER DATA.
    10.E6     10.E4          VOLTS AND AMPS

 M.0077 ENTER DATA.
    1.0E0                RADS AT ONE METER
 M.0077 ENTER DATA.
    6.0E-8               TIME
 M.0077 ENTER DATA.
 .573      1.85      3.12        4.4     5.67       6.95      5 DEG ANG
 M.0077 ENTER DATA.
        1.          1.          1.          1.          1.          1.
    0.19118E 04   0.18275E 04   0.15889E 04   0.12190E 04   0.85017E 03   0.57759E 03   0.38764E 03   0.25838E 03
    0.17139E 03   0.11327E 03   0.74633E 02   0.49053E 02   0.32173E 02   0.21064E 02   0.13771E 02   0.89928E 01
    0.58674E 01   0.38260E 01   0.24942E 01
    0.10000E 01   0.55594E 00   0.83114E 00   0.63701E 00   0.44471E 00   0.30208E 00   0.20277E 00   0.13515E 00
    0.89051E-01   0.59246E-01   0.39039E-01   0.25659E-01   0.10829E-01   0.11018E-01   0.72034E-02   0.47039E-02
    0.30691E-02   0.20013E-02   0.13040E-02
 M.0077 ENTER DATA.
    10.E6     10.E4          VOLTS AND AMPS
 M.0077 ENTER DATA.
    1.0E0                RADS AT ONE METER
 M.0077 ENTER DATA.
    6.0E-8               TIME
 M.0077 ENTER DATA.
 1.15      3.70      6.25       8.8        11.35      13.9       10 DEG ANG
 M.0077 ENTER DATA.
        1.          1.          1.          1.          1.          1.
    0.13387E 04   0.13081E 04   0.12227E 04   0.10708E 04   0.87029E 03   0.65537E 03   0.43997E 03   0.29877E 03
    0.20050E 03   0.13359E 03   0.88459E 02   0.58305E 02   0.38285E 02   0.25066E 02   0.16301E 02   0.10058E 02
    0.69316E 01   0.45021E 01   0.29215E 01
    0.10000E 01   0.97712E 00   0.91338E 00   0.80588E 00   0.65457E 00   0.47386E 00   0.32888E 00   0.22318E 00
    0.14982E 00   0.99700E-01   0.66079E-01   0.43554E-01   0.28589E-01   0.18721E-01   0.12221E-01   0.79018E-02
    0.51779E-02   0.33031E-02   0.21826E-02
```

```
    10.E6     10.E4       VOLTS AND AMPS
 M.0077 ENTER DATA.
     1.0E0             RADS AT ONE METER
 M.0077 ENTER DATA.
    6.0E-8            TIME
 M.0077 ENTER DATA.
 1.72       5.55       9.37       10.7       13.2       20.9       15 DEG ANG
 M.0077 ENTER DATA.
       1.        1.        1.        1.        1.        1.
     0.10654E 04    0.10505E 04    0.10140E 04    0.93953E 03    0.79613E 03    0.63864E 03    0.48250E 03    0.33902E 03
     0.23211E 03    0.15657E 03    0.10457E 03    0.69320E 02    0.45690E 02    0.29975E 02    0.19590E 02    0.12764E 02
     0.82953E 01    0.53868E 01    0.34853E 01
     0.10000E 01    0.98595E 00    0.95170E 00    0.88183E 00    0.74723E 00    0.59942E 00    0.45287E 00    0.31820E 00
     0.21786E 00    0.14696E 00    0.98145E-01    0.65063E-01    0.42824E-01    0.28134E-01    0.18387E-01    0.11980E-01
     0.77859E-02    0.50503E-02    0.32712E-02
 M.0077 ENTER DATA.
    10.E6     10.E4       VOLTS AND AMPS
 M.0077 ENTER DATA.
     1.0E0             RADS AT ONE METER
 M.0077 ENTER DATA.
    6.0E-8            TIME
 M.0077 ENTER DATA.
 2.29       7.40       12.5       17.6       22.7       27.8       20 DEG ANG
 M.0077 ENTER DATA.
       1.        1.        1.        1.        1.        1.
     0.71087E 03    0.70243E 03    0.68958E 03    0.66820E 03    0.63349E 03    0.58303E 03    0.51139E 03    0.41441E 03
     0.30013E 03    0.20911E 03    0.14258E 03    0.95879E 02    0.63833E 02    0.42177E 02    0.27702E 02    0.18108E 02
     0.11793E 02    0.76567E 01    0.49602E 01
     0.10000E 01    0.98812E 00    0.97005E 00    0.93998E 00    0.89115E 00    0.82016E 00    0.71938E 00    0.58296E 00
     0.42220E 00    0.29415E 00    0.20058E 00    0.13488E 00    0.89795E-01    0.59331E-01    0.38969E-01    0.25474E-01
     0.16589E-01    0.10771E-01    0.69777E-02
 M.0077 ENTER DATA.
 /CANCEL
 M.0006 ACTIVITY TERMINATED.
 M.0072 BEGIN ACTIVITY.
```

```
  12.E6     12.E4               VOLTS AND AMPS
M.0077 ENTER DATA.
   1.0E0             RADS AT ONE METER
M.0077 ENTER DATA.
   6.0E-8            TIME
M.0077 ENTER DATA.

M.0077 ENTER DATA.
          1.         1.         1.         1.         1.         1.

    0.47377E 04   0.42023E 04   0.30410E 04   0.19277E 04   0.11950E 04   0.73414E 03   0.44867E 03   0.27318E 03
    0.16584E 03   0.10042E 03   0.60686E 02   0.36008E 02   0.22052E 02   0.13200E 02   0.73793E 01   0.47968E 01
    0.28830E 01   0.17340E 01   0.10441E 01
    0.10000E 01   0.89966E 00   0.64187E 00   0.40688E 00   0.25223E 00   0.15495E 00   0.94701E-01   0.57660E-01
    0.35004E-01   0.21197E-01   0.12809E-01   0.77269E-02   0.46545E-02   0.28000E-02   0.16842E-02   0.10125E-02
    0.60870E-03   0.36612E-03   0.22039E-03
M.0077 ENTER DATA.
   12.E6   12.E4                VOLTS AND AMPS
M.0077 ENTER DATA.
   1.0E0             RADS AT ONE METER
M.0077 ENTER DATA.
   6.0E-8            TIME
M.0077 ENTER DATA.
 .573      1.85      3.12        4.4       5.67       6.95       5 DEG ANG
M.0077 ENTER DATA.
          1.         1.         1.         1.         1.         1.
    0.30455E 04   0.29195E 04   0.25637E 04   0.19826E 04   0.13177E 04   0.83574E 03   0.51989E 03   0.31980E 03
    0.19520E 03   0.11844E 03   0.71523E 02   0.43018E 02   0.25787E 02   0.15410E 02   0.91950E 01   0.54755E 01
    0.32569E 01   0.19562E 01   0.11509E 01
    0.10000E 01   0.95863E 00   0.84180E 00   0.65099E 00   0.43256E 00   0.27442E 00   0.17071E 00   0.10501E 00
    0.64095E-01   0.38891E-01   0.23485E-01   0.14125E-01   0.84675E-02   0.50612E-02   0.30192E-02   0.17979E-02
    0.10694E-02   0.63575E-03   0.37790E-03
M.0077 ENTER DATA.
   12.E6   12.E4                VOLTS AND AMPS
M.0077 ENTER DATA.
   1.0E0             RADS AT ONE METER
M.0077 ENTER DATA.
   6.0E-8            TIME
M.0077 ENTER DATA.
 1.15      3.70      6.25        8.8       11.35      13.9       10 DEG ANG
M.0077 ENTER DATA.
          1.         1.         1.         1.         1.         1.
    0.20318E 04   0.19880E 04   0.18756E 04   0.16745E 04   0.13720E 04   0.97700E 03   0.63638E 03   0.40130E 03
    0.24872E 03   0.15232E 03   0.92457E 02   0.55728E 02   0.33327E 02   0.19920E 02   0.11834E 02   0.70058E 01
    0.41409E 01   0.24423E 01   0.14320E 01
    0.10000E 01   0.97244E 00   0.92311E 00   0.82413E 00   0.67567E 00   0.48138E 00   0.31320E 00   0.19754E 00
    0.12241E 00   0.74965E-01   0.45504E-01   0.27427E-01   0.16437E-01   0.98437E-02   0.58244E-02   0.34435E-02
    0.20380E-02   0.12020E-02   0.70819E-03
```

```
    12.E6    12.E4              VOLTS AND AMPS
M.0077 ENTER DATA.
    1.0E0              RADS AT ONE METER
M.0077 ENTER DATA.
   6.0E-8              TIME
M.0077 ENTER DATA.
1.72       5.55       9.37       10.7       13.2       20.9       15 DEG ANG
M.0077 ENTER DATA.
       1.         1.         1.         1.         1.         1.
    0.15725E 04    0.15528E 04    0.15160E 04    0.14331E 04    0.12295E 04    0.96788E 03    0.73211E 03    0.48683E 03
    0.31028E 03    0.19325E 03    0.11856E 03    0.71938E 02    0.43274E 02    0.25852E 02    0.15357E 02    0.90808E 01
    0.53504E 01    0.31441E 01    0.18441E 01
    0.10000E 01    0.98750E 00    0.90410E 00    0.91139E 00    0.78191E 00    0.61552E 00    0.46558E 00    0.30960E 00
    0.19732E 00    0.12290E 00    0.75308E-01    0.45748E-01    0.27520E-01    0.16448E-01    0.97659E-02    0.57748E-02
    0.34026E-02    0.19934E-02    0.11728E-02
M.0077 ENTER DATA.
    12.E6    12.E4              VOLTS AND AMPS
M.0077 ENTER DATA.
    1.0E0              RADS AT ONE METER
M.0077 ENTER DATA.
   6.0E-8              TIME
M.0077 ENTER DATA.
2.29       7.40       12.5       17.6       22.7       27.8       20 DEG ANG
M.0077 ENTER DATA.
       1.         1.         1.         1.         1.         1.
    0.10138E 04    0.99902E 03    0.98780E 03    0.96443E 03    0.92043E 03    0.86921E 03    0.78073E 03    0.64772E 03
    0.44707E 03    0.29071E 03    0.18304E 03    0.11204E 03    0.68708E 02    0.41350E 02    0.24670E 02    0.14628E 02
    0.86251E 01    0.50651E 01    0.29557E 01
    0.10000E 01    0.98632E 00    0.97437E 00    0.95132E 00    0.91383E 00    0.85739E 00    0.77012E 00    0.63891E 00
    0.44099E 00    0.28070E 00    0.18555E 00    0.11141E 00    0.67773E-01    0.40788E-01    0.24341E-01    0.14429E-01
    0.85078E-02    0.49963E-02    0.29254E-02
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3

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    15.E6    15.E4            VOLTS AND AMPS
M.0077 ENTER DATA.
   1.0E0           RADS AT ONE METER
M.0077 ENTER DATA.
   6.0E-8          TIME
M.0077 ENTER DATA.

M.0077 ENTER DATA.
       1.        1.        1.        1.        1.        1.
   0.82413E 04  0.75503E 04  0.56163E 04  0.33245E 04  0.18581E 04  0.10186E 04  0.55153E 03  0.29045E 03
   0.15835E 03  0.84151E 02  0.44520E 02  0.23475E 02  0.12366E 02  0.64789E 01  0.33972E 01  0.17812E 01
   0.93473E 00  0.49137E 00  0.25895E 00
   0.10000E 01  0.91615E 00  0.88148E 00  0.40339E 00  0.22547E 00  0.12353E 00  0.66922E-01  0.35971E-01
   0.19215E-01  0.10211E-01  0.54028E-02  0.28466E-02  0.14972E-02  0.78616E-03  0.41221E-03  0.21613E-03
   0.11342E-03  0.59823E-04  0.31421E-04
M.0077 ENTER DATA.
    15.E6    15.E4            VOLTS AND AMPS
M.0077 ENTER DATA.
   1.0E0           RADS AT ONE METER
M.0077 ENTER DATA.
   6.0E-8          TIME
M.0077 ENTER DATA.
 .573     1.85     3.12       4.4     5.67     6.95     5 DEG ANG
M.0077 ENTER DATA.
       1.        1.        1.        1.        1.        1.
   0.49184E 04  0.47423E 04  0.42690E 04  0.34218E 04  0.22448E 04, 0.12990E 04  0.72355E 03  0.39461E 03
   0.21219E 03  0.11288E 03  0.59503E 02  0.31141E 02. 0.16198E 02  0.83037E 01  0.43228E 01  0.22231E 01
   0.11410E 01  0.58607E 00  0.30112E 00
   0.10000E 01  0.96541E 00  0.86796E 00  0.69571E 00  0.45640E 00  0.26415E 00  0.14711E 00  0.80231E-01
   0.43141E-01  0.22947E-01  0.12098E-01  0.63314E-02  0.32933E-02. 0.17045E-02  0.87889E-03  0.45198E-03
   0.23210E-03  0.11910E-03  0.61223E-04
M.0077 ENTER DATA.
    15.E6    15.E4            VOLTS AND AMPS
M.0077 ENTER DATA.
   1.0E0           RADS AT ONE METER
M.0077 ENTER DATA.
   6.0E-8          TIME
M.0077 ENTER DATA.
1.15      3.70     6.25       8.8      11.35     13.9      10 DEG ANG
M.0077 ENTER DATA.
       1.        1.        1.        1.        1.        1.
   0.31139E 04  0.30512E 04  0.29242E 04  0.26091E 04  0.23015E 04  0.16975E 04  0.10144E 04  0.57490E 03
   0.31579E 03  0.16090E 03  0.99098E 02  0.47190E 02  0.24473E 02  0.12588E 02  0.64316E 01  0.32691E 01
   0.10554E 01  0.83625E 00  0.42291E 00
   0.10000E 01  0.97986E 00  0.93910E 00  0.86889E 00  0.73912E 00  0.54506E 00  0.32570E 00  0.18462E 00
   0.10141E 00  0.54581E-01  0.28834E-01  0.15155E-01  0.78540E-02  0.40425E-02  0.20655E-02  0.10499E-02
   0.53102E-03  0.26856E-03  0.13550E-03
```

```
   15.E6     15.E4              VOLTS AND AMPS
M.0077 ENTER DATA.
   1.050            RADS AT ONE METER
M.0077 ENTER DATA.
   6.0E-8           TIME
M.0077 ENTER DATA.
 1.72       5.55       8.37       10.7       13.2       20.8       15 DEG ANG
M.0077 ENTER DATA.
      1.          1.          1.          1.          1.          1.
   0.23339E 04  0.23069E 04  0.22985E 04  0.22601E 04  0.20029E 04  0.15655E 04  0.12304E 04  0.78135E 03
   0.44096E 03  0.24847E 03  0.13308E 03  0.70594E 02  0.36740E 02  0.18899E 02  0.96500E 01  0.48700E 01
   0.24486E-01  0.12261E-01  0.61947E 00
   0.10000E 01  0.98845E 00  0.98484E 00  0.96840E 00  0.85828E 00  0.67970E 00  0.52075E 00  0.33479E 00
   0.19280E 00  0.10043E 00  0.57280E-01  0.30240E-01  0.15742E-01  0.80970E-02  0.41262E-02  0.20807E-02
   0.10492E-02  0.52537E-03  0.20243E-03
M.0077 ENTER DATA.
   15.E6     15.E4              VOLTS AND AMPS
M.0077 ENTER DATA.
   1.050            RADS AT ONE METER
M.0077 ENTER DATA.
   6.0E-8           TIME
M.0077 ENTER DATA.
 2.29       7.40       12.5       17.6       22.7       27.8       20 DEG ANG
M.0077 ENTER DATA.
      1.          1.          1.          1.          1.          1.
   0.14779E 04  0.14497E 04  0.14452E 04  0.14126E 04  0.13916E 04  0.13567E 04  0.12819E 04  0.10821E 04
   0.76133E 03  0.44882E 03  0.25027E 03  0.13594E 03  0.71235E 02  0.36945E 02  0.18908E 02  0.95756E 01
   0.48100E-01  0.24014E-01  0.11039E 01
   0.10000E 01  0.98089E 00  0.97789E 00  0.95988E 00  0.94162E 00  0.91797E 00  0.86736E 00  0.73221E 00
   0.51514E 00  0.30389E 00  0.18934E 00  0.91372E-01  0.46200E-01  0.24306E-01  0.12794E-01  0.64792E-02
   0.32540E-02  0.16240E-02  0.80784E-03
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   20.E6     20.E4              VOLTS AND AMPS
M.0077 ENTER DATA.
   1.0E0             RADS AT ONE METER
M.0077 ENTER DATA.
  6.0E-8             TIME
M.0077 ENTER DATA.

M.0077 ENTER DATA.
       1.          1.          1.          1.          1.          1.
   0.13783E 05  0.13007E 05  0.10753E 05  0.60282E 04  0.33484E 04  0.15375E 04  0.68412E 03  0.29001E 03
   0.12767E 03  0.53038E 02  0.22521E 02  0.93131E 01  0.38235E 01  0.15927E 01  0.63763E 00  0.26057E 00
   0.10697E 00  0.44237E-01  0.18471E-01
   0.10000E 01  0.94372E 00  0.78016E 00  0.40561E 00  0.24295E 00  0.11155E 00  0.49635E-01  0.21021E-01
   0.92028E-02  0.39133E-02  0.16339E-02  0.67509E-03  0.27741E-03  0.11330E-03  0.46262E-04  0.18905E-04
   0.77009E-05  0.32095E-05  0.13401E-05
M.0077 ENTER DATA.
   20.E6     20.E4              VOLTS AND AMPS
M.0077 ENTER DATA.
   1.0E0             RADS AT ONE METER
M.0077 ENTER DATA.
  6.0E-8             TIME
M.0077 ENTER DATA.
.573      1.85       3.12       4.4       5.67       6.95       5-DEG-ANG
M.0077 ENTER DATA.
       1.          1.          1.          1.          1.          1.
   0.76597E 04  0.74717E 04  0.70240E 04  0.61635E 04  0.46750E 04  0.25088E 04  0.11836E 04  0.53022E 03
   0.22385E 03  0.97201E 02  0.40272E 02  0.16300E 02  0.65800E 01  0.26100E 01  0.10261E 01  0.40126E 00
   0.15660E 00  0.61218E-01  0.24050E-01
   0.10000E 01  0.97566E 00  0.93708E 00  0.80466E 00  0.61054E 00  0.32750E 00  0.15453E 00  0.69222E-01
   0.30008E-01  0.12620E-01  0.52577E-02  0.21600E-02  0.88010E-03  0.35475E-03  0.13397E-03  0.52385E-04
   0.20445E-04  0.7[illegible]22E-05  0.33398E-05
M.0077 ENTER DATA.
   20.E6     20.E4              VOLTS AND AMPS
M.0077 ENTER DATA.
   1.0E0             RADS AT ONE METER
M.0077 ENTER DATA.
  6.0E-8             TIME
M.0077 ENTER DATA.
1.15      3.70       6.25       8.8       11.35      13.9       16-DEG-ANG
M.0077 ENTER DATA.
       1.          1.          1.          1.          1.          1.
   0.46071E 04  0.45765E 04  0.44750E 04  0.43195E 04  0.40[illegible]E 04  0.3[illegible]E 04  0.21097E 04  0.10200E 04
   0.46255E 03  0.19961E 03  0.83412E 02  0.33976E 02  0.13547E 02  0.5[illegible]E 01  0.20481E 01  0.78189E 00
   0.29025E 00  0.11182E 00  0.42201E-01
   0.10000E 01  0.97431E 00  0.95203E 00  0.81934E 00  0.65170E 00  0.711[illegible] 00  0.44914E 00  0.21642E 00
   0.88455E-01  0.42495E-01  0.17790E-01  0.72335E-02  0.2[illegible]E-02  0.11[illegible]E-02  0.45004E-03  0.18[illegible]E-03
   0.63070E-04  0.23886E-04  0.88643E-05
```

```
   20.E6     20.E4             VOLTS AND AMPS
M.0077 ENTER DATA.
     1.0E0              RADS AT ONE METER
M.0077 ENTER DATA.
    0.0E-8              TIME
M.0077 ENTER DATA.
1.72        5.55        9.37        10.7        13.2        20.0        15 DEG ANG
M.0077 ENTER DATA.
       1.          1.          1.          1.          1.          1.
   0.34141E 04   0.33453E 04   0.34430E 04   0.30135E 04   0.34031E 04   0.28853E 04   0.21032E 04   0.16861E 04
   0.84807E 03   0.38534E 03   0.15534E 03   0.60224E 02   0.27314E 02   0.14471E 02   0.40862E 01   0.15401E 01
   0.57303E 00   0.21202E 00   0.78080E-01
   0.10000E 01   0.97986E 00   0.10085E 01   0.10584E 01   0.10229E 01   0.86220E 00   0.93360E 00   0.49380E 00
   0.24840E 00   0.11287E 00   0.42420E-01   0.19983E-01   0.80083E-02   0.31255E-02   0.11969E-02   0.45110E-03
   0.16802E-03   0.62100E-04   0.22870E-04
M.0077 ENTER DATA.
    20.E6     20.E4            VOLTS AND AMPS
M.0077 ENTER DATA.
     1.0E0              RADS AT ONE METER
M.0077 ENTER DATA.
    0.0E-8              TIME
M.0077 ENTER DATA.
2.29        7.40        12.5        17.0        22.7        27.8        20 DEG ANG
M.0077 ENTER DATA.
       1.          1.          1.          1.          1.          1.
   0.22437E 04   0.21657E 04   0.21576E 04   0.21064E 04   0.21543E 04   0.22154E 04   0.21262E 04   0.20165E 04
   0.18027E 04   0.92033E 03   0.42030E 03   0.17944E 03   0.73298E 02   0.28979E 02   0.11168E 02   0.42176E 01
   0.15683E 01   0.57074E 00   0.21096E 00
   0.10000E 01   0.96523E 00   0.96164E 00   0.93882E 00   0.96016E 00   0.98742E 00   0.94766E 00   0.89876E 00
   0.80344E 00   0.41019E 00   0.18733E 00   0.79974E-01   0.32609E-01   0.12513E-01   0.49774E-02   0.18798E-02
   0.69898E-03   0.25705E-03   0.93891E-04
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```
   25.E6     25.E4              VOLTS AND AMPS
M.0077 ENTER DATA.
     1.0E0              RADS AT ONE METER
M.0077 ENTER DATA.
     6.0E-8             TIME
M.0077 ENTER DATA.

M.0077 ENTER DATA.
          1.      1.          1.          1.          1.          1.
     0.17088E 05     0.10488E 05     0.14932E 05     0.11080E 05     0.61833E 04     0.28811E 04     0.92043E 03     0.32590E 03
     0.11132E 03     0.30872E 02     0.11887E 02     0.37447E 01     0.11580E 01     0.35371E 00     0.10751E 00     0.32797E-01
     0.10132E-01     0.31981E-02     0.10359E-02
     0.10000E 01     0.90501E 00     0.87350E 00     0.80120E 00     0.30189E 00     0.14521E 00     0.53870E-01     0.19074E-01
     0.65150E-02     0.21580E-02     0.68574E-03     0.21910E-03     0.67776E-04     0.20701E-04     0.62920E-05     0.19195E-05
     0.59301E-06     0.18706E-06     0.60626E-07
M.0077 ENTER DATA.
     25.E6     25.E4            VOLTS AND AMPS
M.0077 ENTER DATA.
     1.0E0              RADS AT ONE METER
M.0077 ENTER DATA.
     6.0E-8             TIME
M.0077 ENTER DATA.
.573        1.85        3.12        4.4        5.67        6.95        5 DEG AMP
M.0077 ENTER DATA.
          1.      1.          1.          1.          1.          1.
     0.94665E 04     0.91899E 04     0.89805E 04     0.86100E 04     0.74812E 04,    0.59826E 04     0.21606E 04     0.81040E 03
     0.28420E 03     0.94033E 02     0.30455E 02     0.94300E 01     0.28310E 01     0.82052E 00     0.23768E 00     0.67343E-01
     0.19000E-01     0.53926E-02     0.15521E-02
     0.10000E 01     0.97079E 00     0.94806E 00     0.90952E 00     0.79022E 00     0.53090E 00     0.22823E 00     0.85607E-01
     0.30022E-01     0.10028E-01     0.32171E-02     0.99621E-03     0.29912E-03     0.87521E-04     0.25107E-04     0.71138E-05
     0.20077E-05     0.50966E-06     0.16396E-06
M.0077 ENTER DATA.
     25.E6     25.E4            VOLTS AND AMPS
M.0077 ENTER DATA.
     1.0E0              RADS AT ONE METER
M.0077 ENTER DATA.
     6.0E-8             TIME
M.0077 ENTER DATA.
1.15        3.70        6.25        8.8        11.35        13.[illegible]        10 DEG AMP
M.0077 ENTER DATA.
          1.      1.          1.          1.          1.          1.
     0.59392E 04     0.56084E 04     0.56067E 04     0.50083E 04     0.55850E 04     0.53551E 04     0.44309E 04     0.20594E 04
     0.78047E 03     0.27000E 03     0.88338E 02     0.27[illegible] 02     [illegible] 01     [illegible]     [illegible] 00     0.18144E 00
     0.46923E-01     0.13104E-01     0.35108E-02
     0.10000E 01     0.95441E 00     0.94602E 00     0.84420E 00     [illegible] 00     [illegible]71E 00     0.74750E 00     0.35074E 00
     0.13141E 00     0.45562E-01     0.14874E-01     0.45273E-02     0.15822E-02     0.3[illegible]E-03     0.11260E-03     0.38549E-04
     0.62373E-05     0.22063E-05     0.59213E-0[illegible]
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     25.E6     25.E4           VOLTS AND AMPS
 M.0077 ENTER DATA.
      1.0E0            RADS AT ONE METER
 M.0077 ENTER DATA.
     6.0E-8           TIME
 M.0077 ENTER DATA.
 1.72       5.55       9.37       10.7       15.2       20.9       15 DEG AMP
 M.0077 ENTER DATA.
          1.        1.        1.        1.        1.        1.
    0.42878E 04   0.41027E 04   0.43335E 04   0.45261E 04   0.49307E 04   0.44300E 04   0.32334E 04   0.29054E 04
    0.18368E 04   0.70482E-03   0.24147E-03   0.70850E-02   0.23134E-02   0.66501E-01   0.18386E-01   0.49329E 00
    0.12923E 00   0.33302E-01   0.85838E-02
    0.10000E 01   0.95083E 00   0.10107E 01   0.10558E 01   0.11500E 01   0.10383E 01   0.75411E 00   0.67761E 00
    0.42839E 00   0.16438E 00   0.56317E-01   0.17925E-01   0.53954E-02   0.15509E-02   0.42903E-03   0.11505E-03
    0.30140E-04   0.77807E-05   0.19973E-05
 M.0077 ENTER DATA.
     25.E6     25.E4           VOLTS AND AMPS
 M.0077 ENTER DATA.
      1.0E0            RADS AT ONE METER
 M.0077 ENTER DATA.
     6.0E-8           TIME
 M.0077 ENTER DATA.
 2.29       7.40       12.5       17.6       22.7       27.8       20 DEG AMP
 M.0077 ENTER DATA.
          1.        1.        1.        1.        1.        1.
    0.30158E 04   0.28668E 04   0.27726E 04   0.28865E 04   0.29940E 04   0.28289E 04   0.29288E 04   0.33015E 04
    0.27985E 04   0.21176E 04   0.80092E-03   0.26034E-03   0.83637E-02   0.24499E-02   0.68535E-01   0.18482E-01
    0.48463E 00   0.12464E 00   0.31713E-01
    0.10000E 01   0.95059E 00   0.91935E 00   0.89082E 00   0.99279E 00   0.93803E 00   0.97117E 00   0.10947E 01
    0.92794E 00   0.70215E 00   0.26557E 00   0.89309E-01   0.27733E-01   0.81236E-02   0.22725E-02   0.61285E-03
    0.16070E-03   0.41327E-04   0.10516E-04
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