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ANALYSIS OF MULTIMODE FIBER COUPLERS, TAPERS AND MODE CONVERTER--ETC(U)

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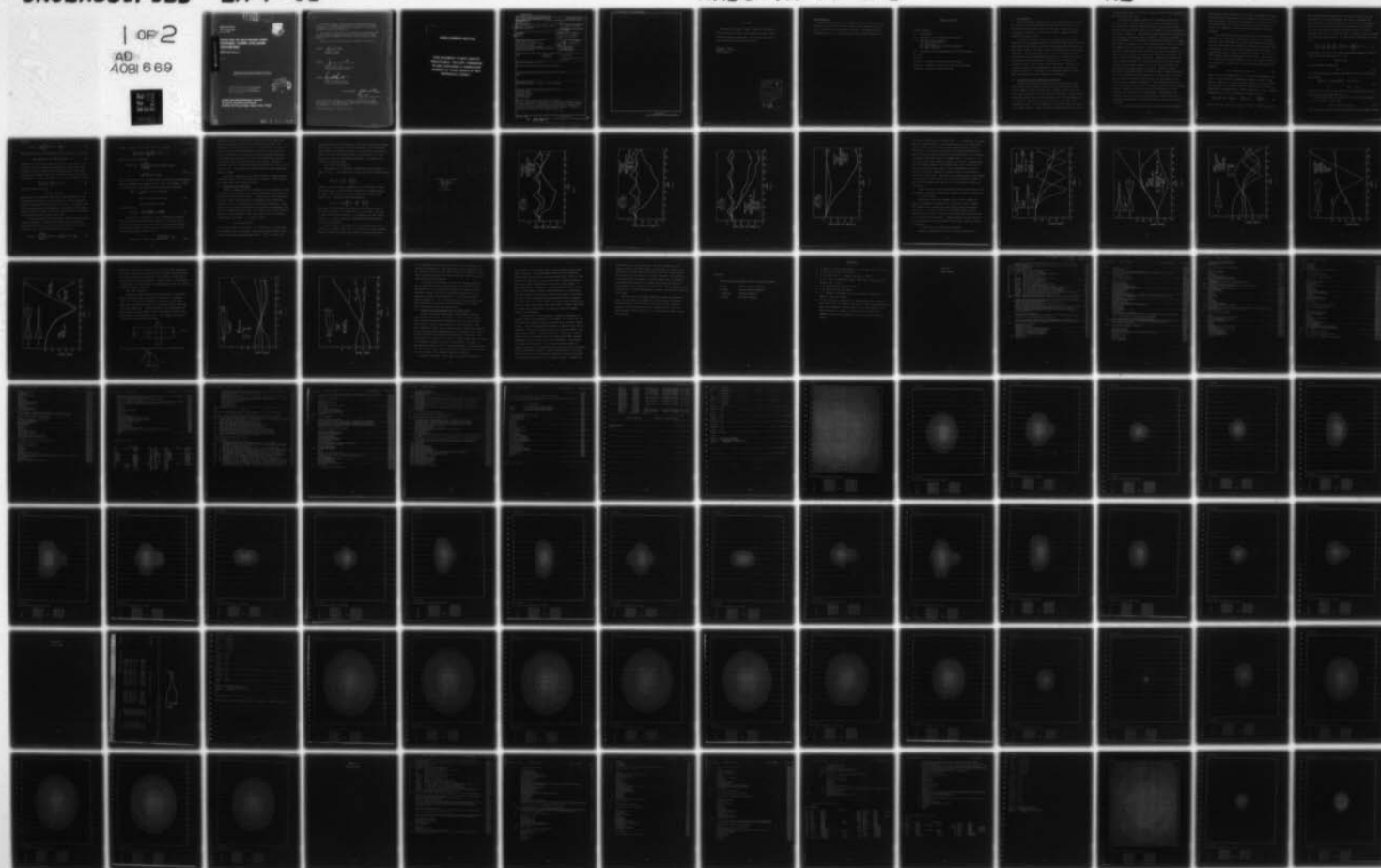
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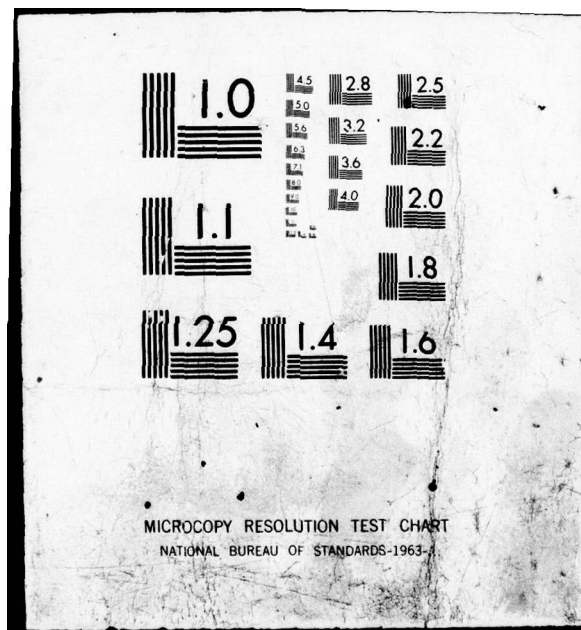
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Final Technical Report
January 1980



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ANALYSIS OF MULTIMODE FIBER COUPLERS, TAPERS AND MODE CONVERTERS

EMTEC Engineering Inc.

C. Yeh

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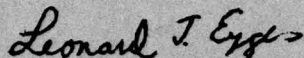
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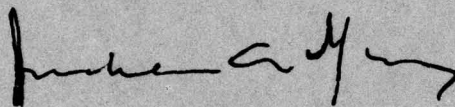
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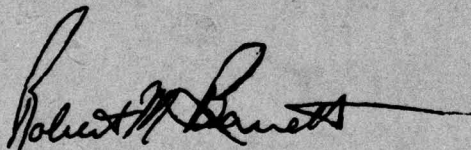
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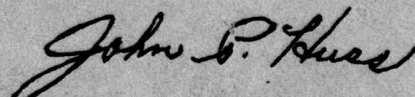
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16. ABSTRACT (Continue on reverse side if necessary and identify by block number) This is a final report on the analysis of multimode fiber couplers, tapers and mode converters. A method based on the fast Fourier transform technique of scalar wave equation has been successfully developed to yield numerical results on a number of practical multimode fiber components. Included in this report are listings of the computer programs.		

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EVALUATION

This contract has provided computer simulation of the behavior of of various components of fiber optic transmission systems, relevant to TPO 3B, Optical Communications. The results obtained will be useful in optimizing the design of such systems.

Leonard J. Eyges
LEONARD J. EYGES
Project Engineer

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Personnel

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- Appendix B Intensity Profiles for Beam in Fiber Tapers
- Appendix C Program for Mode Converter

I. Introduction

This final report summarizes the work performed under Contract No. F19628-78-C-0206 which the Electronic Systems Division of the Air Force Systems Command granted to the EMtec Engineering, Inc. Los Angeles, California. The work was begun in August, 1978 and completed in August, 1979.

The major objectives of this R & D study were to perform theoretical and numerical analysis of multimode fiber optic components. Specifically, the following multimode components were studied: (a) Dual Fiber Couplers, (b) Fiber Tapers, (c) Fiber Horns and Branching Waveguides, and (d) Mode Converters. In the following we shall first present some background information on this subject and then our mathematical approach will be delineated. In Section III selected results of our study are then summarized. Finally, the concluding remarks and recommendations for future work will be given in Section IV. Listings of the important computer programs that we developed are also included in the Appendix.

II. Background and The Mathematical Approach

There are currently strong trends in system design toward microminiaturization digital processing and system level integration in order to achieve smaller size, weight, and power consumption, along with lower cost and improved reliability. These trends naturally point to data bus multiplexing, i.e., the interconnection of a number of spatially distributed terminals via fiber optic waveguides cables. The key component for any fiber data bus system is the fiber coupler. Since multimode singlestrand fiber is used as

a communication link in a data bus system, multimode fiber couplers must be designed and used.

To design any coupler properly for a multimode single fiber data bus system, detailed analysis of waveguide propagation must be carried out. Existing techniques based on the finite elements method,¹ the coupled mode theory,² or the geometrical optics method³ are usually inadequate. (Detailed discussions have been included in a review paper which would appear shortly⁴.) Although the finite elements method is a very powerful approach when dealing with single-mode fibers or couplers, it is very inefficient and costly (in terms of computer time) to obtain any results for multimode structures. Similarly, coupled mode theory has been used quite successfully in predicting the coupling efficiencies of single-mode structures, but cannot be used for multimode structures. Although the geometrical optics method using the ray-tracing technique may yield zero-order results for multimode structures, it is too crude to predict the wave behavior of light signals in couplers. Recently, Arnard⁵ developed a technique based on the Cook adiabatic coupler principle⁶ to treat the multimode coupler problem. He claims that "it may be used to couple two optical fibers because the dimensions are not critical; only slowness is required". Our technique, given below, will provide more accurate results because it does not involve making a priori assumptions on the relevance of the dimensions of the structure and the slowness of the coupling. Furthermore, this technique may be used to study mode conversion effects due to the nonuniform distribution of dielectric material within the guided structure.

It is noted that analysis based on the scalar wave approxima-

tion has been very successful in predicting the properties of many optical devices whose characteristic dimensions are on the order of many wavelengths. The scalar wave approach is therefore preferred. We have developed an efficient numerical technique based on the scalar wave equations to solve problems dealing with multimode couplers.

It is well known that solving the exact electromagnetic equations for a spatially inhomogeneous medium is a formidable problem. Multimode couplers and mode converters can be approximated by structures with a spatially nonuniform dielectric medium. Fortunately, there are some approximations that can be made to simplify this task. First, the light wavelengths of interest are much shorter than the inhomogeneity scale length. This enables us to neglect polarization effects. Hence, the optical field can be derived from a scalar $u(\underline{x}, z)$ that satisfied the reduced wave equation⁷

$$[\nabla^2 + k^2 n^2(\underline{x}, z)] u(\underline{x}, z) = 0 \quad , \quad (1)$$

where k is the wavenumber $2\pi/\lambda$, λ is the laser wavelength, and $n(\underline{x}, z)$ is the spatially inhomogeneous refractive index of the medium. Second, if we write u as the product of a factor $e^{ikn_0 z}$ that accounts for the rapid change in the phase of u along the direction of propagation and a complex amplitude $A(\underline{x}, z)$, a further simplification of the calculational problem results:

$$\left[i2kn_0 \frac{\partial}{\partial z} + \nabla_T^2 + k^2 (n^2(\underline{x}, z) - n_0^2) \right] A(\underline{x}, z) = - \frac{\partial^2 A(\underline{x}, z)}{\partial z^2} \quad , \quad (2)$$

where ∇_T^2 is the transverse Laplacian $\partial^2/\partial x^2 + \partial^2/\partial y^2$ and n_0 is a

given constant which represents the refractive index of some uniform medium. At laser wavelengths, the complex amplitude $A(\underline{x})$ varies much more rapidly transverse to the direction of propagation than it does along the direction of propagation. This enables us to make the paraxial approximation and neglect the term on the right side of Eq. (2) (in the Russian literature this is called the parabolic approximation). So, the complex amplitude now satisfies

$$\left[i2kn_0 \frac{\partial}{\partial z} + \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + k^2 (n^2(\underline{x}, z) - n_0^2) \right] A(\underline{x}, z) = 0 \quad (3)$$

In addition to Eq. (3), the complex amplitude satisfies an initial condition on the fiber end; at $z = 0$,

$$A(\underline{x}, 0) = u(\underline{x}, 0) \quad (4)$$

and the boundary condition is

$$A(+\infty, z) = 0 \quad (5)$$

If a truncated gaussian beam is focused on one end of the optical guide, then

$$\begin{aligned} u(x, y, 0) &= u_0 \exp(-r^2/w^2) & \text{for } 0 \leq r \leq b \\ &= 0 & \text{for } r > b \end{aligned} \quad (6)$$

where $r^2 = x^2 + y^2$, w is the spot size of the beam, and b is the radius of the truncated beam at $z = 0$.

We have solved Eq. (3) numerically in the following manner.

Let us write $A(\underline{x}, z)$ in the form

$$A(\underline{x}, z) = \exp[\Gamma(\underline{x}, z)] v(\underline{x}, z) \quad (7)$$

where $\Gamma(\underline{x}, z)$ is a phase function associated with the medium inhom-

geneities

$$\Gamma(\underline{x}, z) = \frac{ik}{2n_0} \int_{z_0}^z \left[n^2(x, y, z') - n_0^2 \right] dz' \quad (8)$$

The modified complex amplitude $v(\underline{x}, z)$ then satisfies the equation

$$i2kn_0 \frac{\partial}{\partial z} v(\underline{x}, z) + e^{-\Gamma} \nabla_T^2 [e^{\Gamma} v(\underline{x}, z)] = 0 \quad (9)$$

Although Eq. (9) does not look any easier to solve than Eq. (3), it is easier to solve numerically because, for sufficiently small increments in the z direction and an appropriately chosen lower limit in the integral in Eq. (8), the value of $v(x, y, z + \Delta z)$ can be obtained to a good approximation by solving the simpler equation

$$\left[i2kn_0 \frac{\partial}{\partial z} + \nabla_T^2 \right] v(\underline{x}, z) = 0 \quad (10)$$

with the initial condition

$$v(x, y, 0) = u(x, y, 0) \quad (11)$$

Physically, these equations approximate the propagation in the inhomogeneous medium by a two-step process at each z increment. First, we propagate the field $u(\underline{x}, z)$ at z to $z + \Delta z$ assuming that the intervening space is homogeneous. The effect of the inhomogeneities between z and $z + \Delta z$ is then accounted for by multiplying this solution by the phase factor $\exp \Gamma$.

In this research we have solved Eq. (10) by the fast Fourier transform technique. Replacing the Laplacian by its finite difference equivalent but still retaining the z derivative, the solution of Eq. (10) can be expressed in the form

$$v(m, n, z) = \sum_{m'} \sum_{n'=0}^{N-1} V(m', n', z) \exp \left[\frac{i2\pi}{N} (mm' + nn') \right] \quad (12)$$

where $x = m\Delta x$, $y = n\Delta x$, and $V(m', n', z)$ satisfy

$$\left[i2kn_0 \frac{\partial}{\partial z} + \frac{f(m', n')}{(\Delta x)^2} \right] V(m', n', z) = 0 \quad (13)$$

with the initial conditions

$$V(m', n', z_i) = \frac{1}{N^2} \sum_{m,n=0}^{N-1} v(m, n, z_i) \exp[\Gamma(m, n, z_i)] \exp\left[-\frac{i2\pi}{N}(m'm + n'n)\right] \quad (14)$$

The function $f(m', n')$ is determined by the difference approximation used to represent the Laplacian in Eq. (10). For example, if $\nabla_T^2 v$ is approximated by the simple central difference expression

$$\begin{aligned} \nabla_T^2 v = & \frac{1}{(\Delta x)^2} [v(m+1, n, z) - 2v(m, n, z) \\ & + v(m-1, n, z) + v(m, n+1, z) \\ & - 2v(m, n, z) + v(m, n-1, z)] \end{aligned} \quad (15)$$

then $f(m', n')$ is

$$f(m', n') = -4 \left[\sin^2\left(\frac{\pi m'}{N}\right) + \sin^2\left(\frac{\pi n'}{N}\right) \right] \quad (16)$$

Note that the series in Eq. (12) is simply the discrete Fourier transform of the function $V(m', n', z)$, and thus can be evaluated numerically for a given $V(m', n', z)$ by a fast Fourier transform algorithm. Furthermore, the function $V(m', n', z)$ is readily determined from Eq. (13) as

$$V(m', n', z) = V(m', n', z_i) \exp\left[\frac{-if(m', n')}{2k(\Delta x)^2 n_0} (z - z_i)\right] \quad (17)$$

where $V(m', n', z_1)$ is given by the series in Eq. (14), which can also be evaluated by a fast Fourier transform algorithm. To summarize, we will step from z to $z + \Delta z$ as follows: (1) take the inverse discrete Fourier transform of $u(m, n, z) = [\exp \Gamma(m, n, z)] \cdot v(m, n, z)$ by means of an inverse fast Fourier transform algorithm; (2) multiply the result by $\exp [-if(m', n')\Delta z/2k(\Delta x)^2 n_0]$ and take the discrete Fourier transform with a fast Fourier transform algorithm; and (3) multiply the result by $\exp[\Gamma(m, n, z + \Delta z)]$ to yield $u(m, n, z + \Delta z)$. This process is repeated until we have reached the desired z plane.

Using this algorithm we have been successful in obtaining many meaningful results for various multimode structures. These results are summarized in the following section.

III Multimode Fiber Components

Before we proceed with the presentation of the numerical results, it should be recalled that we are dealing completely with total field quantities and not with the modes. In other words, we are interested in how the total field evolves as it propagates down the guiding structure; we are not interested in how each mode propagates. Nevertheless, it is recognized that the total field may be decomposed into a set of orthonormal guided modes. For example, an incident Gaussian beam with a given beamwidth w may excite many modes in a parabolic-index-profile fiber when $\alpha > 1$ or when $\alpha < 1$ with

$$\alpha = (2\lambda a)/[\pi n_a w^2 (2\delta)^{1/2}]$$

or may excite only one mode when $\alpha = 1$. Only the $\alpha = 1$ single mode will propagate down the parabolic-index-profile guide without experiencing the focusing and defocusing effects. For $\alpha \neq 1$ cases, the

input Gaussian beam will experience focusing and defocusing effects. Another way to interpret the above phenomenon is that multimodes with different propagation constants are excited by the input beam when $\alpha \neq 1$, while only single mode is excited when $\alpha = 1$. The stronger are the focusing-defocusing effects, the higher is the content of different modes.

(a) Dual Fiber Couplers

The geometry of a multimode inhomogeneous fiber coupler is shown in Fig. 1. Two graded-index fibers with index variation given by

$$n(r_{1,2}) = n_a \left(1 - \delta \frac{r_{1,2}^2}{a_{1,2}} \right),$$

where $r_{1,2}$ are the radial coordinates of 1 and 2 fibers, respectively, and n_a , δ , a are all known constants, are fused together as shown. The separation distance between the centers of the fibers is d . A Gaussian beam representable by

$$u(x,y) = u_0 \exp \left\{ \left[- \left(x + \frac{d}{2} \right)^2 - y^2 \right] / w^2 \right\},$$

where $u(x,y)$ is the scalar wave function of the beam, and u_0 , w are given constants, is incident on one of the fibers. We wish to learn how this beam evolves as it propagates down the coupled structure. In other words, the coupling distance and the beam shape will be obtained.

Results of our investigation on the multimode dual fiber couplers are shown in Figs. 2-5. It is seen that if two identical parabolic-index fibers were placed side by side with each other

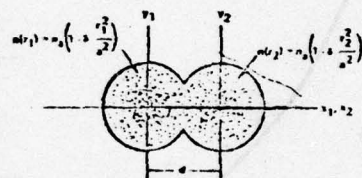


Fig. 1. The fiber coupler.

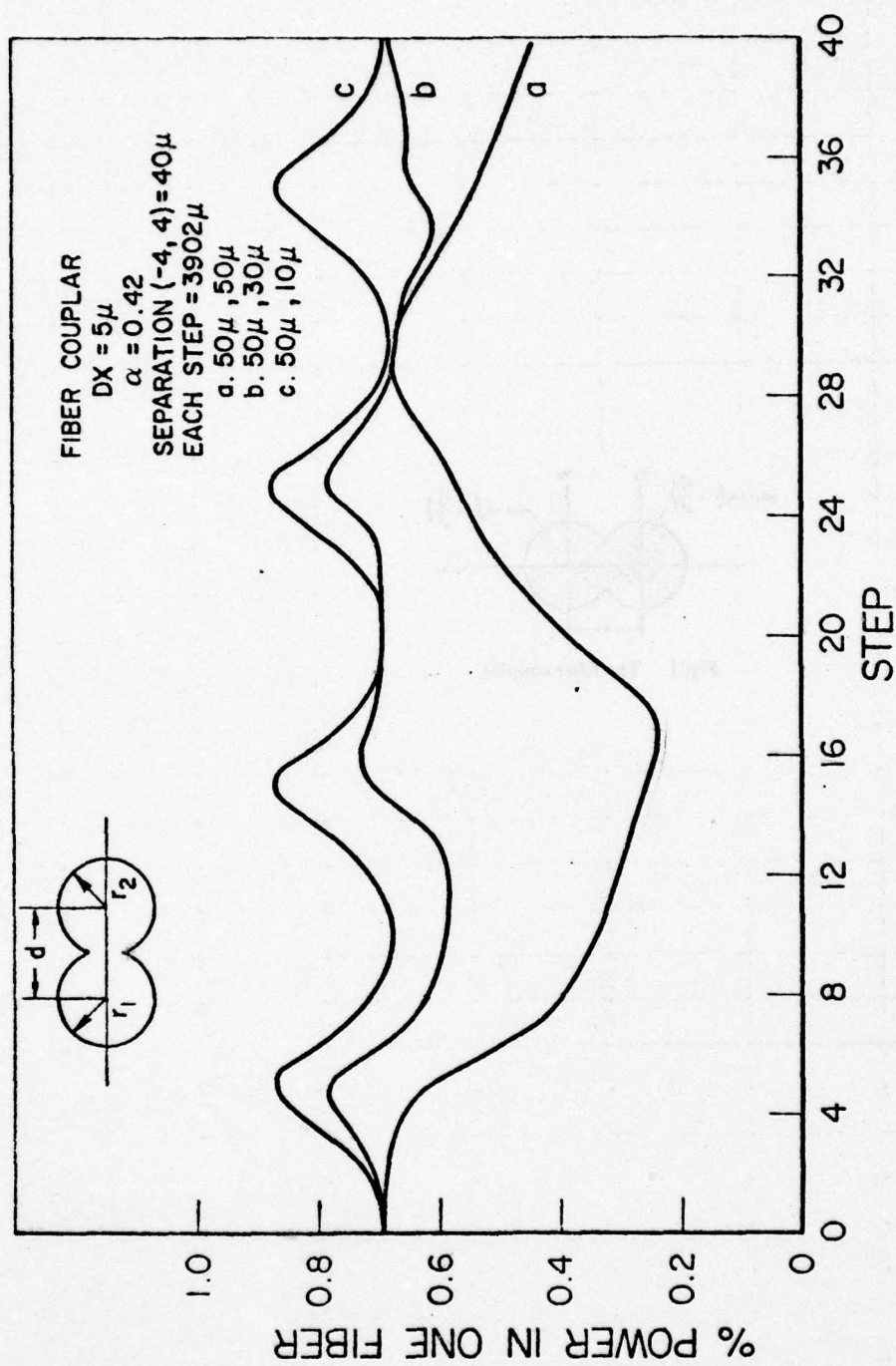


Figure 2

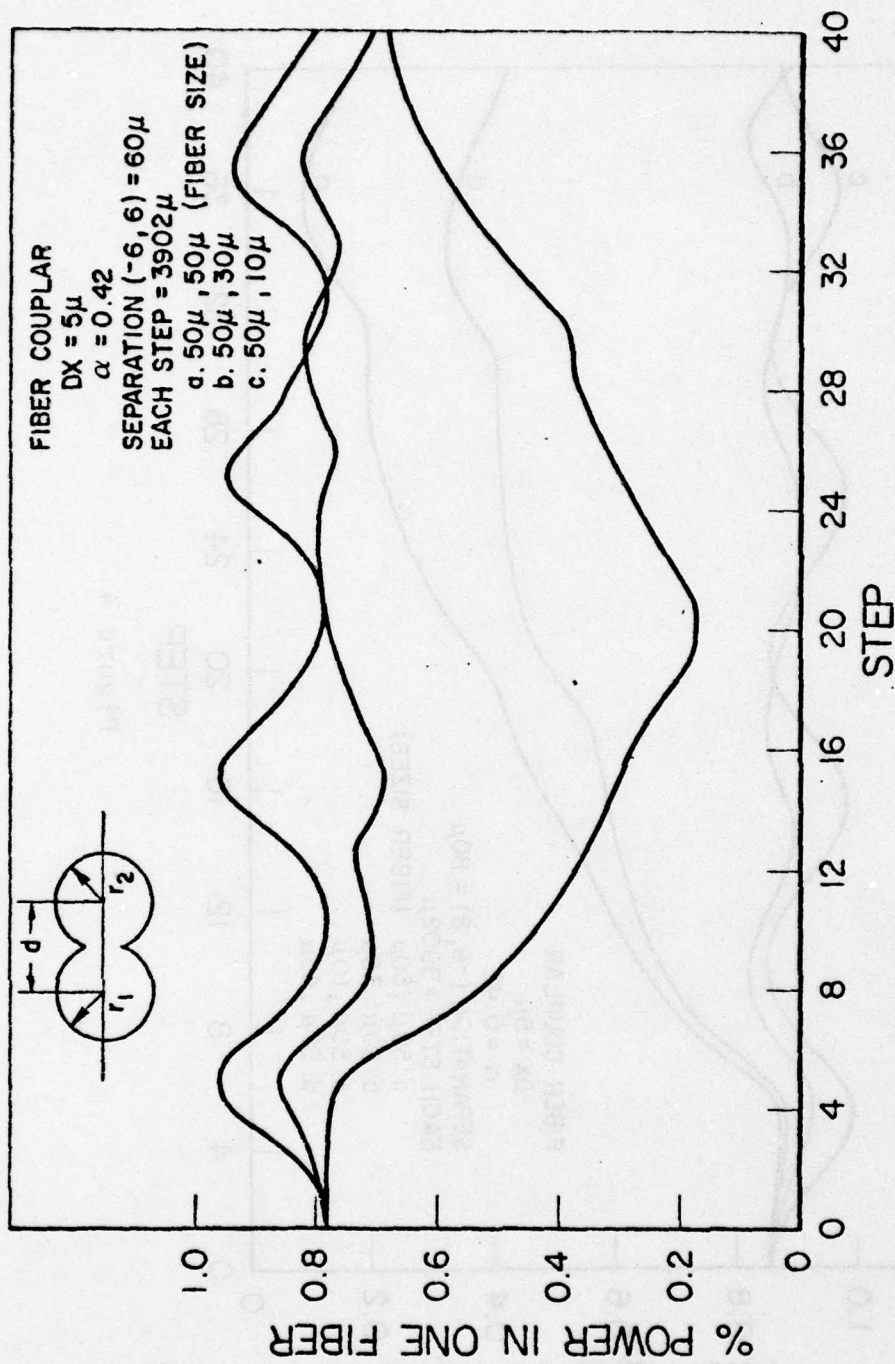


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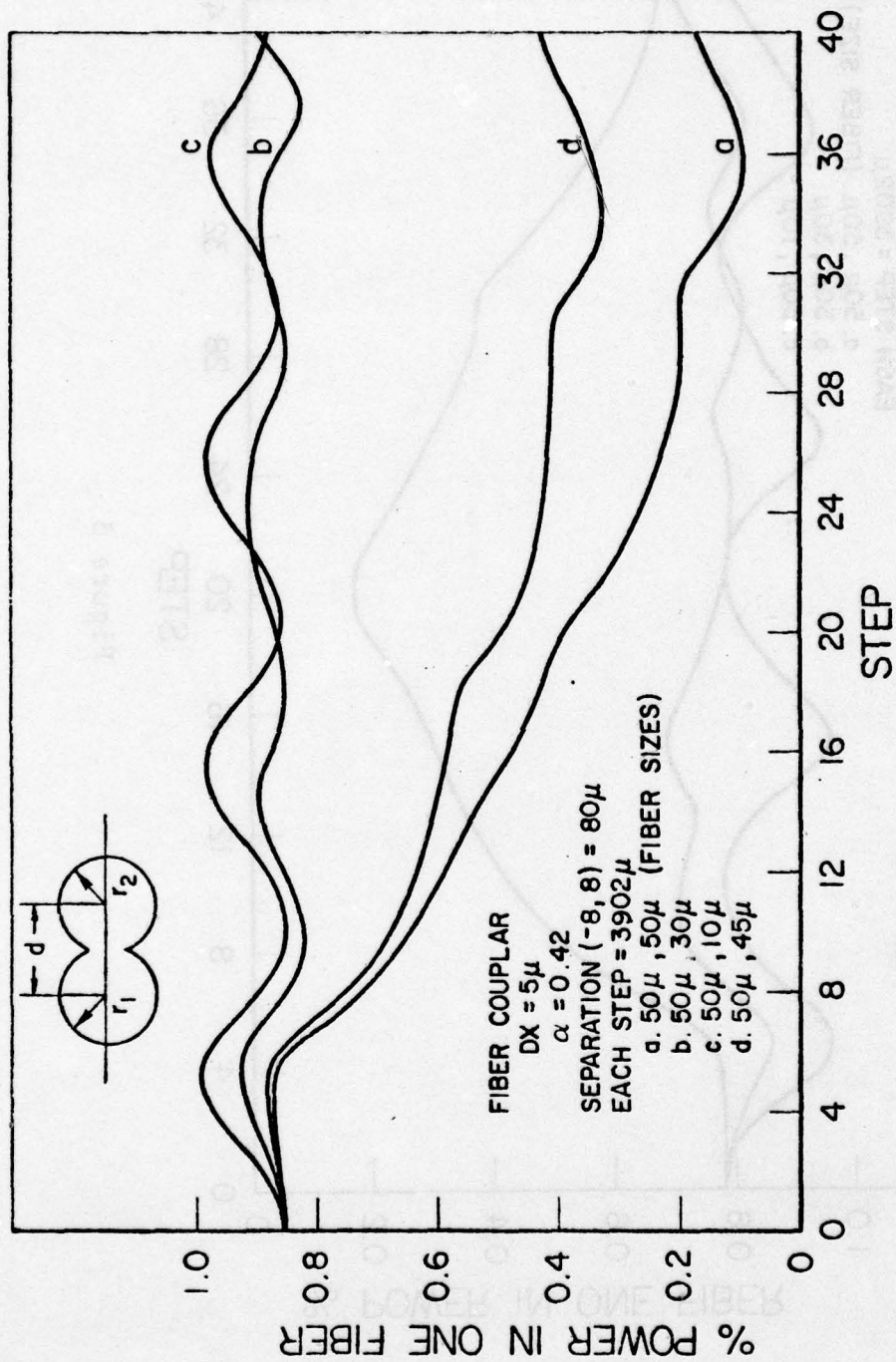


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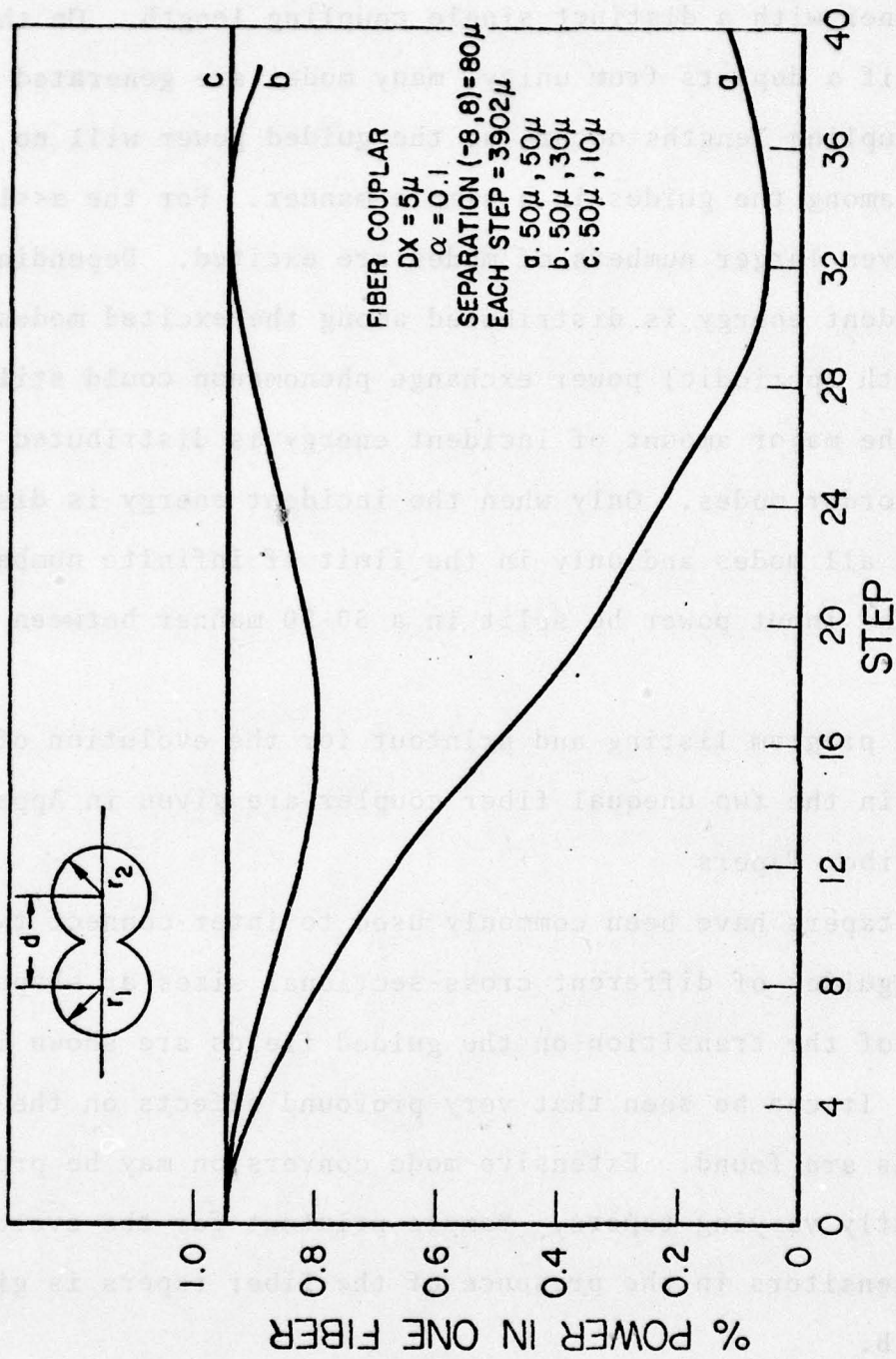


Figure 5

and if the beamwidth were so chosen that $\alpha = 1$ is obtained, one would expect the guided power to interchange between the two fibers in a periodic manner with a distinct single coupling length. On the other hand, if α departs from unity, many modes are generated and many beat coupling lengths occur, so the guided power will no longer interchange among the guides in a simple manner. For the $\alpha \ll 1$ or $\alpha \gg 1$ case, even larger numbers of modes are excited. Depending upon how the incident energy is distributed among the excited modes the back and forth (periodic) power exchange phenomenon could still prevail if the major amount of incident energy is distributed in several low-order modes. Only when the incident energy is distributed evenly among all modes and only in the limit of infinite number of modes will the input power be split in a 50-50 manner between the two fibers.

Sample program listing and printout for the evolution of field intensities in the two unequal fiber coupler are given in Appendix A.

(b) Fiber Tapers

Fiber tapers have been commonly used to inter-connect two optical waveguides of different cross-sectional sizes or shapes. The effects of the transition on the guided fields are shown in Figs. 6-10. It can be seen that very profound effects on the guided fields are found. Extensive mode conversion may be present even for gently varying tapers. Sample printout for the evolution of field intensities in the presence of the fiber tapers is given in Appendix B.

(c) Fiber Horns and Branching Waveguides.

Numerical computations to obtain the field behavior in a

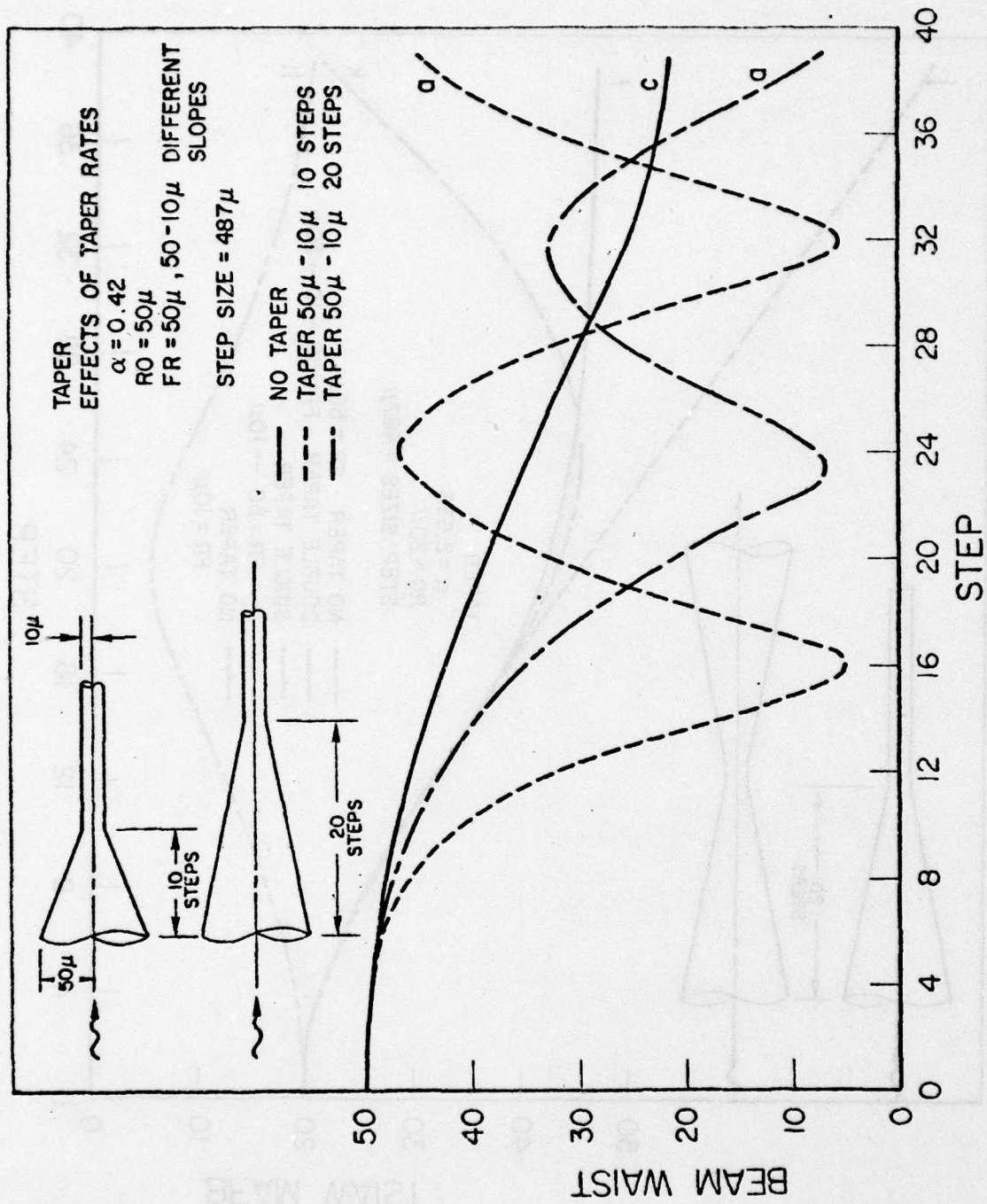


Figure 6

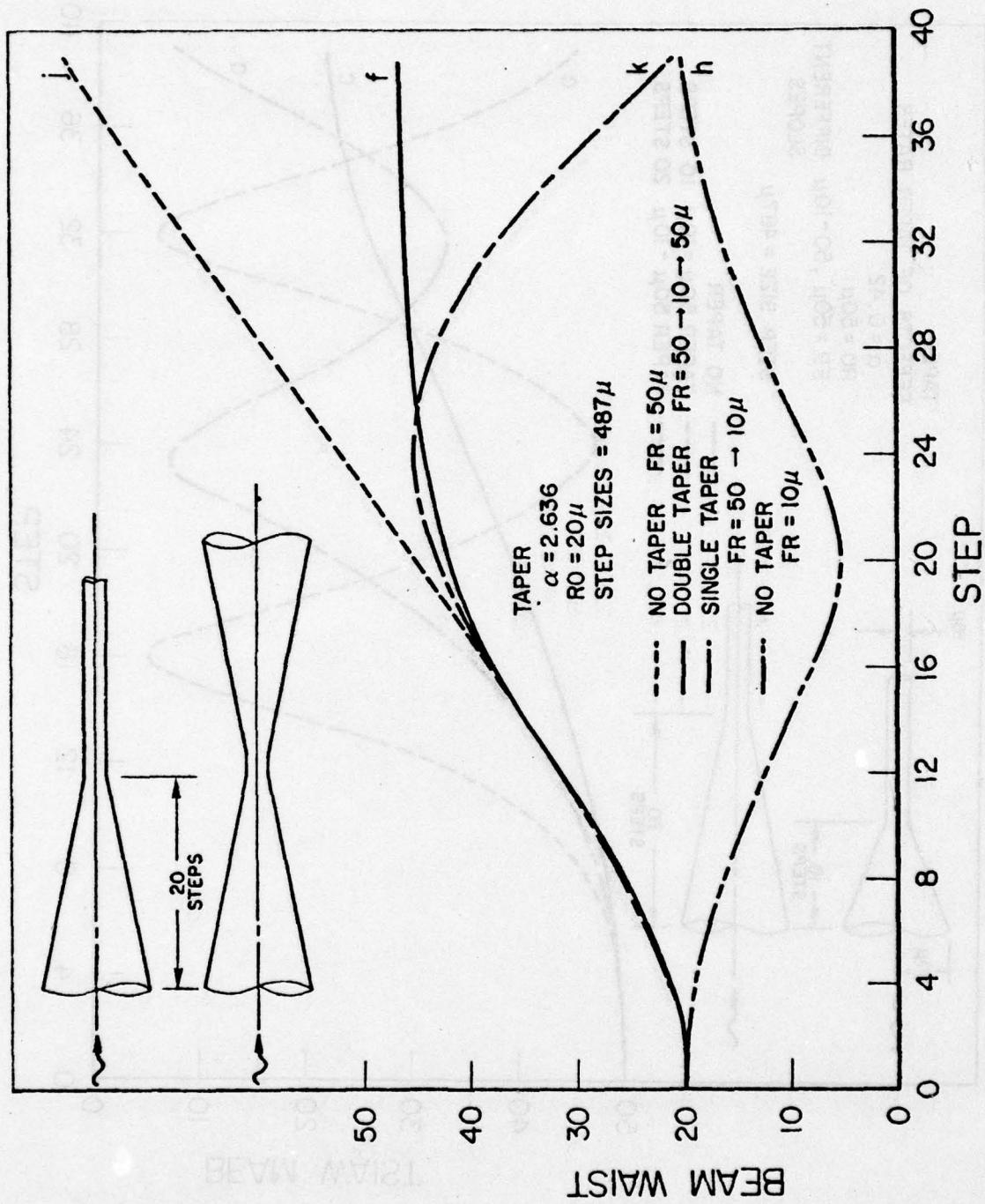


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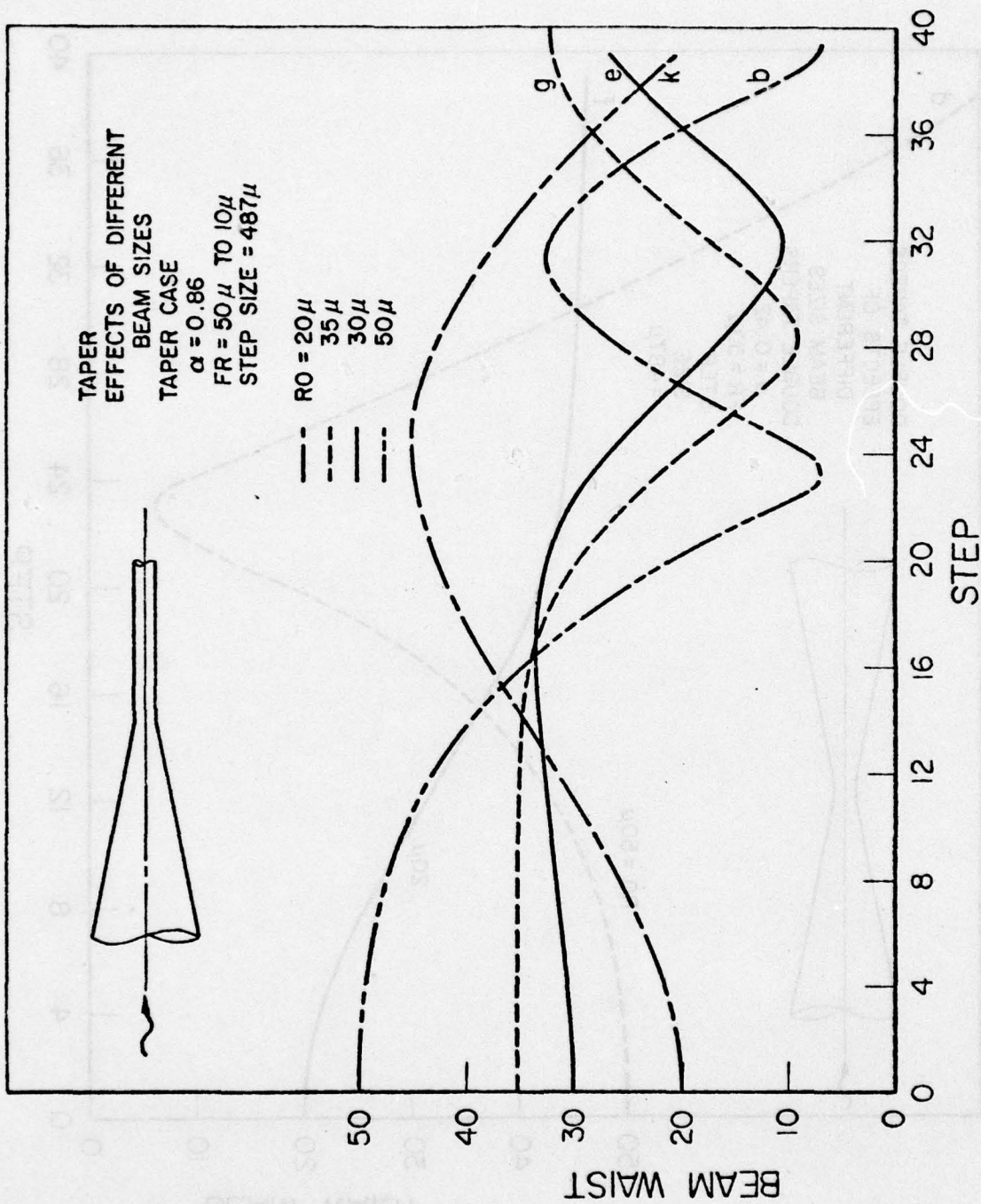


Figure 8

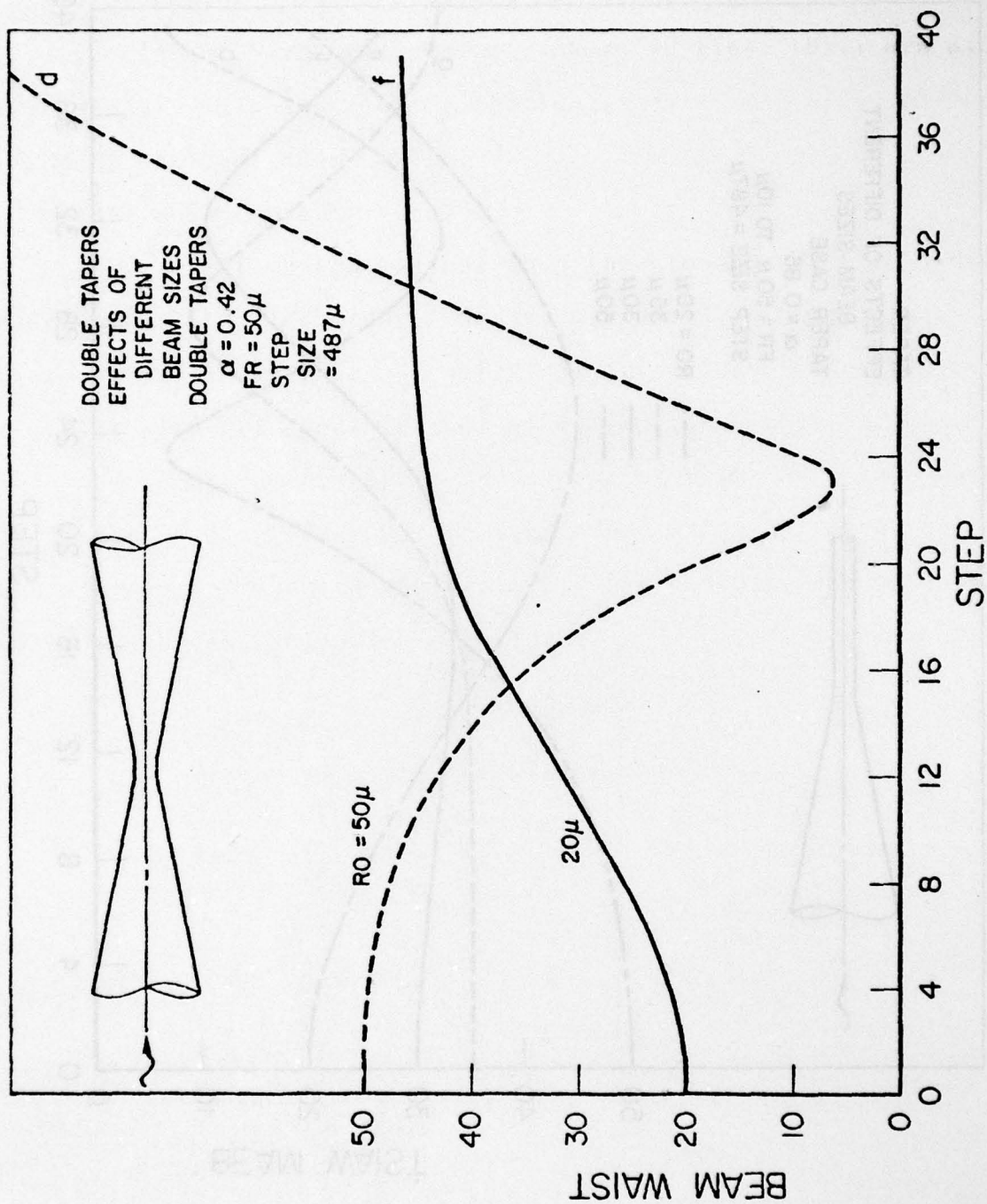


Figure 9

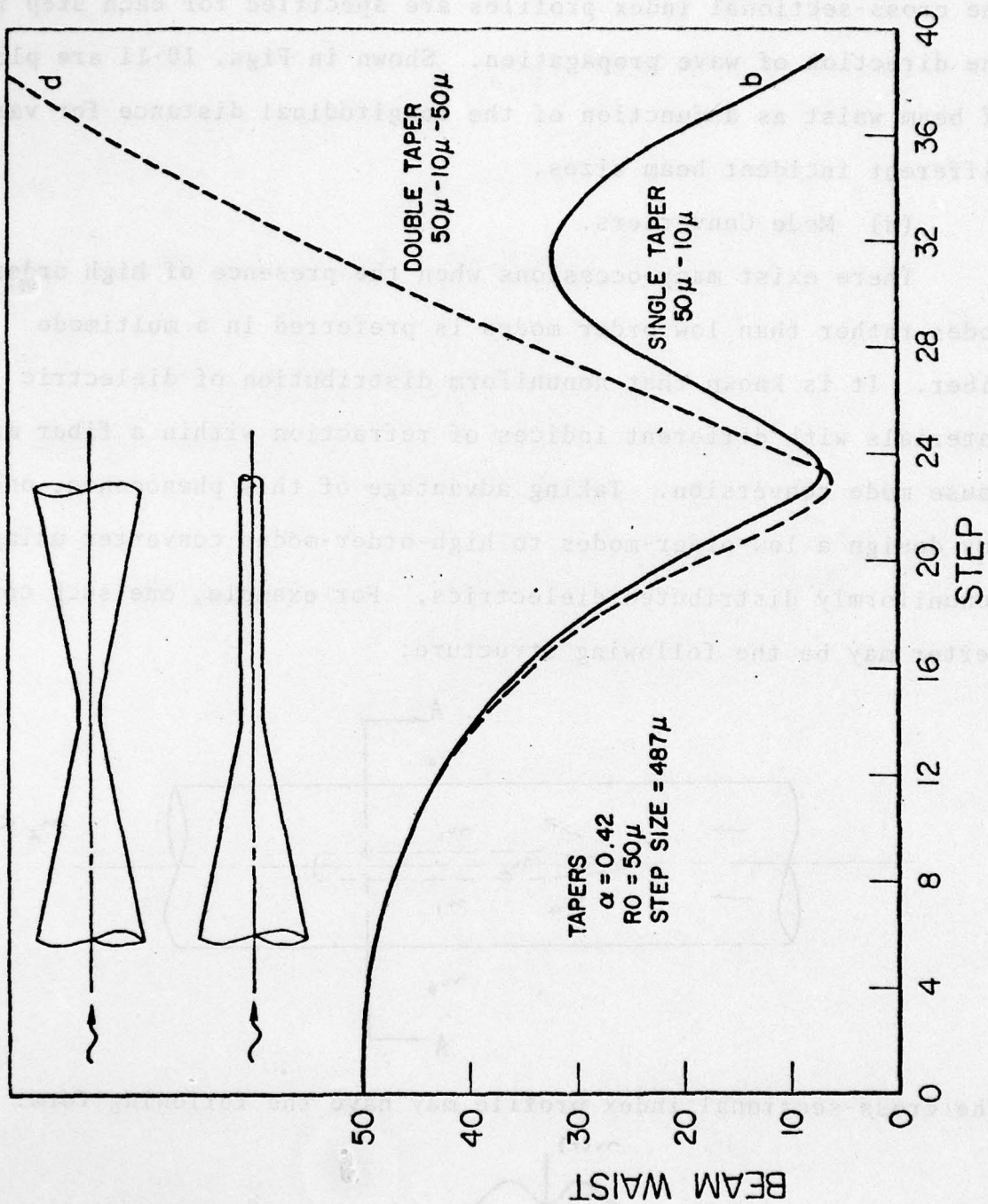
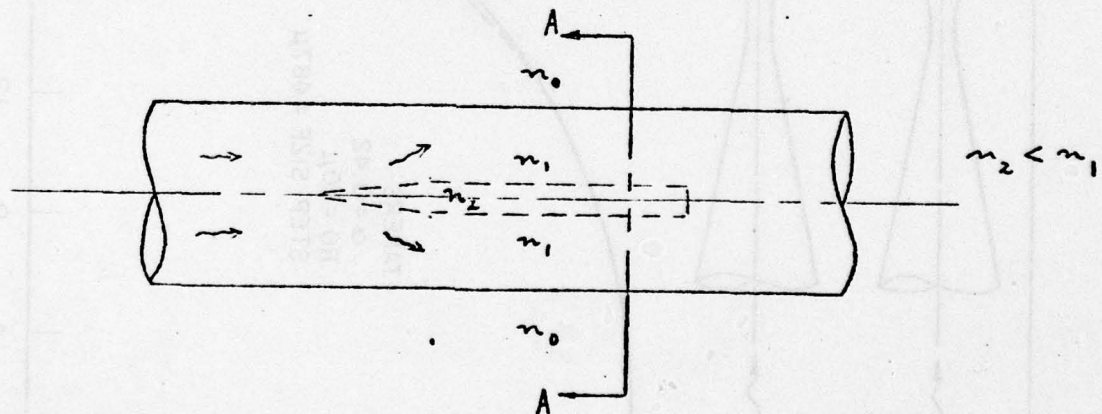


Figure 10

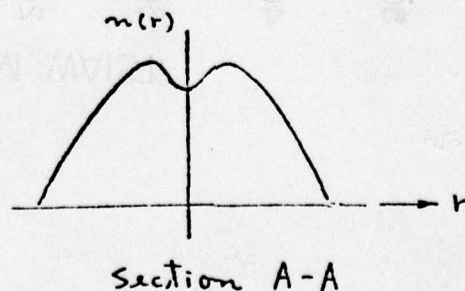
multimode fiber horn structure or in a branching fiber guide have also been carried out using the similar technique outlined earlier. The cross-sectional index profiles are specified for each step in the direction of wave propagation. Shown in Figs. 10-11 are plots of beam waist as a function of the longitudinal distance for various different incident beam sizes.

(d) Mode Converters.

There exist many occasions when the presence of high order modes rather than low order modes is preferred in a multimode fiber. It is known that nonuniform distribution of dielectric materials with different indices of refraction within a fiber may cause mode conversion. Taking advantage of this phenomenon, one may design a low-order-modes to high-order-modes converter using nonuniformly distributed dielectrics. For example, one such converter may be the following structure:



The cross-sectional index profile may have the following form:



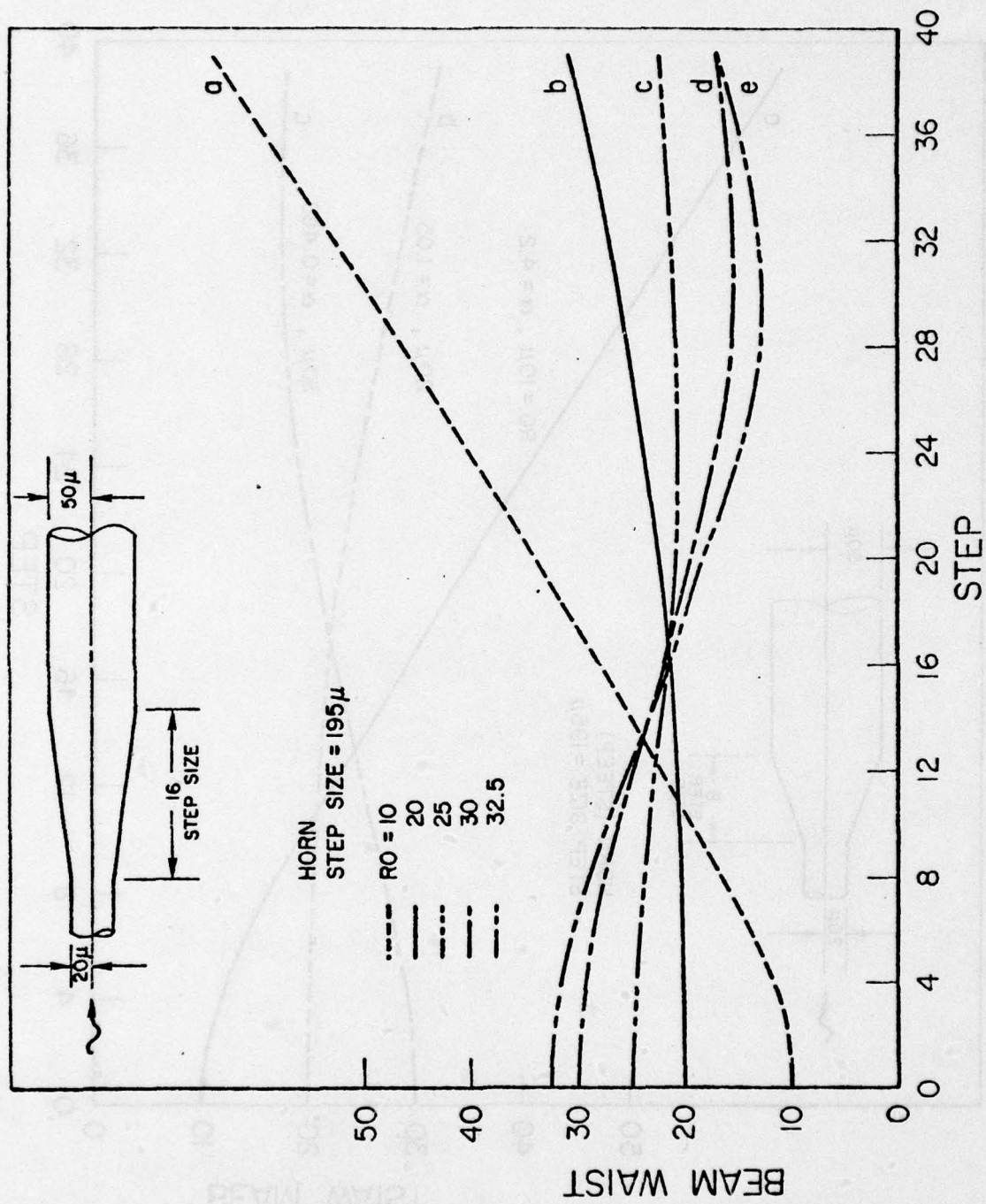


Figure 11

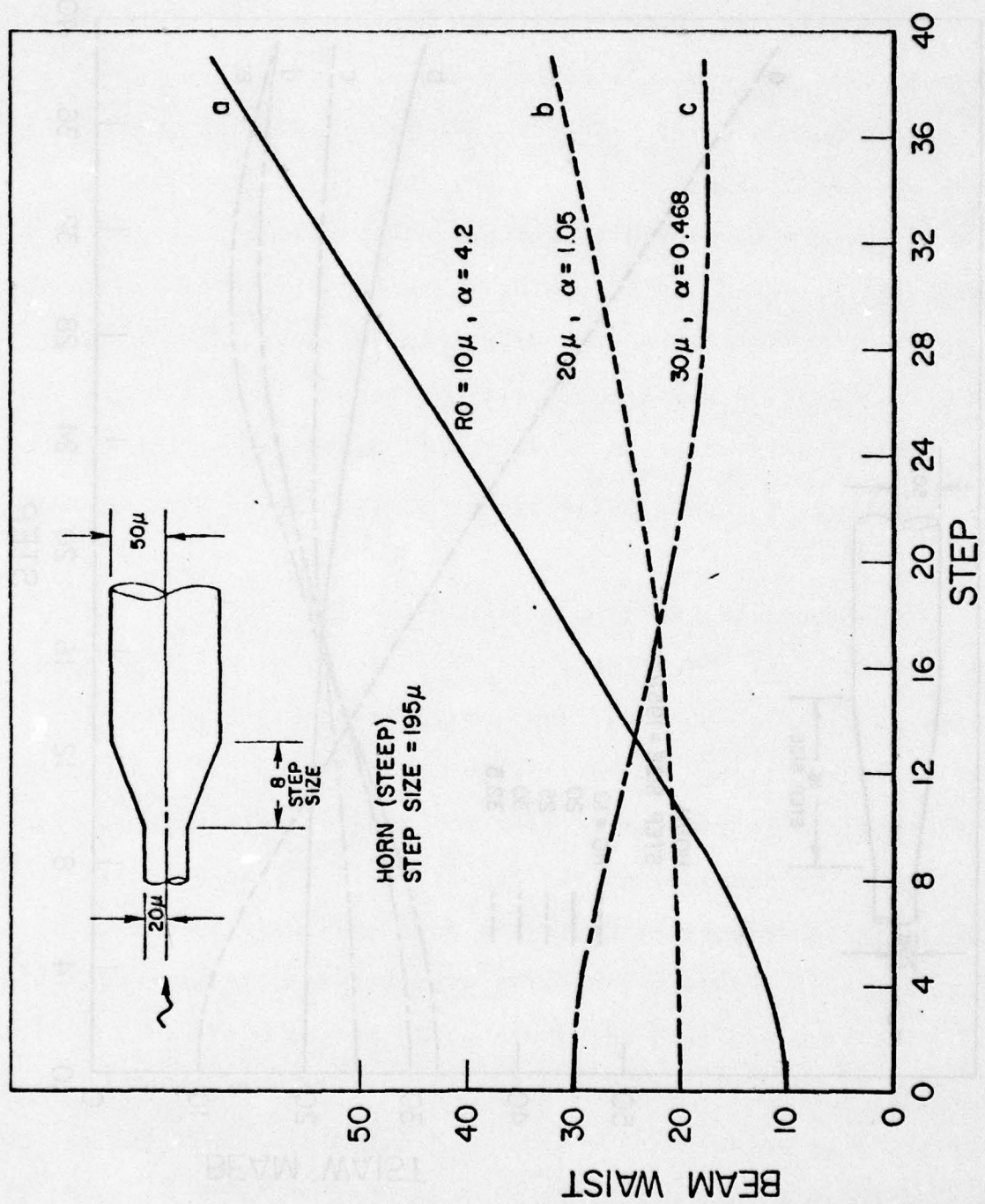


Figure 12

It is anticipated that the low order modes will be affected more by the discontinuities. Thus energy in the low order modes may be converted into that of the high order modes as expected. Other means of generating high order modes using variations of the above scheme may also be envisioned.

To evaluate the efficiency of this type of mode converter, and to learn the intensity distribution of the resultant field, the evolution of an incident beam through this channel should be obtained. We have successfully developed a program which is capable of providing such information. Illustrative example is given in Appendix C. It can be seen that ring-shaped higher order modes can easily be generated by the introduction of a slight dip in the index profile as proposed above.

IV. Conclusions and Recommendations for Future Work

We have successfully developed a computational technique, based on the scalar wave - FFT method, to treat problems dealing with various multimode fiber components, such as, fiber couplers, fiber tapers or horns, fiber branches or mode converters. The only significant restriction to keep in mind is that index variations of the structure under consideration must be gentle⁸. This consideration is normally satisfied in most practical situations. The basic objective of this R & D study is, thereby accomplished. Listing of the computer program is given in the Appendix. By simply specifying the index profile at each longitudinal z-step and knowing the initial beam shape, one may generate the propagation characteristics of the beam as it propagates down the structure.

Using this program, we were able to trace the evolution of

a given beam as it propagates down a given multimode graded index fiber structure. If the multimode structure were a multimode coupler made with two or more parallel graded index fibers in close proximity of each other, we can predict the coupling distances as well as the power distribution of the beam in such coupler; if the structure were a tapered or a flared multimode fiber, we were able to learn whether a given tapered structure or a given horn structure could still confine or guide a given beam; if the structure were a mode converter made with multimode fiber containing an on-axis dip in its index profile, we can learn the effectiveness of such a dip in converting lower order modes to higher order modes. To achieve such capabilities, an extensive amount of computer software was developed.

In the course of these studies, a number of important new research topics were generated. For example, it is known that the FFT scalar wave approach requires that the index profile be gently varying. But the quantitative definition of "gently" must still be specified. (We wish to push our ability to deal with almost step-index profile fibers.) Initial indication (through our computer results) seem to show that even with rather steep index gradient, adequately accurate results were still obtainable. This problem also leads to the need for us to study the possible usage of adaptive coordinates to improve the beam resolution as it propagates down the multimode structure. Another problem which is directly related to the case of induced beam radiation caused by variations in the guiding structure is also of great interest. Perhaps the

introduction of a lossy surface for the outer boundary of our computer mesh may provide a means of estimating the radiation loss. Associated with beam radiation problem in the case of beam reflection caused by variations in the guiding structure, the reflection coefficient may be obtained by correctly summing over incremental reflection coefficients (i.e., taking into account the phases of the reflected waves) which occur whenever wave energy propagates from a region with a certain index value to another region with a different index value.

With the help of our newly developed program, the principal thrust of the future work should be to study realistic multimode fiber structures, such as data-bus type multi-channel couplers, tapered or flared transition joints, multimode fibers with non-ideal parabolic index profiles and to obtain data for these realistic situations.

Personnel:

The principal contributors of this contract have been:

C. Yeh	Senior Research Engineer
K. Casey	Senior Research Engineer
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S. Chang	Research Engineer

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Appendix A

Fiber Coupler

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 7. J. W. Goodman, "Introduction to Fourier Optics," McGraw-Hill Book Co., New York (1968).
 8. C. Yeh, "Asymptotic Approach for Inhomogeneous Fiber Problems," *Appl. Phys. Lett.*, **21**, 512 (1972).
- dielectric waveguide problem based on a scalar wave equation has been obtained by J. E. Sipe, P. Choia and E. J. Murphy.
- ("Modes of dielectric waveguides of arbitrary cross-sectional shape").

```

PROGRAM OPTFIB(INPUT,OUTPUT,FILEO,TAPES=INPUT,TAPEO=OUTPUT,
+ TAPE7=FILEO)
C *****
C INPUT PARAMETERS
C CARD 1 (15 FORMAT)
C NCASES NUMBER OF CASES TO BE READ
C CARD 2 (NAMELIST FORMAT-$DEFAULT)
C LAMBDA WAVE LENGTH (MICRONS)
C RO 1/E POINT IN IRRADIANCE (MICRONS)
C FR FIBER RADIUS (MICRONS)
C NO REFRACTIVE INDEX
C PCORP PERCENT DROP AT R=FR OF N/NO
C OUTRAD OUTER RADIUS (MICRONS)
C DX MESH SPACING (MICRONS)
C NSTEPS NUMBER OF Z-STEPS
C NDZINC LENGTH OF Z-STEP = ZMIN/NDZINC
C IOUT DEVICE NUMBER FOR OUTPUT
C IGREY DEVICE NUMBER FOR GREYSC OUTPUT
C PGREY IF TRUE PRINT IRRADIANCE PROFILE AT EACH STEP
C PWAIST IF TRUE WRITE 2ND MOMENTS AT EACH STEP
C PLTWST IF TRUE PLOT 2ND MOMENTS VS DISTANCE
C PLTMAX IF TRUE PLOT PEAK INTENSITY VS DISTANCE
C PLTFLO IF TRUE PLOT FIELD IRRAD AT END OF PROPAGATION ALONG I
C PLTFLE IF TRUE DO ABOVE PLOT AT EVERY STEP
C MESH GRID SIZE (32, 64, OR 128)
C *****
C COMMON /LCM2/REFNDX(16384),SN(128),CS(128),ZTSQ(128),PQSQ(128)
+ ,AMPARY(16384),RADARY(16384)
C LEVEL 2,REFNDX,SN,CS,ZTSQ,PQSQ,AMPARY,RADARY
C DIMENSION WORK(256),MU(2)
C DIMENSION X0(3),Y0(3),PCORPA(3),FRA(3),REFCFA(3)
C COMMON /ARRAYS/V(32768)
C COMMON /PARAM/DZINC,MESH,LAMBDA,RO,FR,NO,PCORP,OUTRAD,DX,NSTEPS,
+ NDZINC,MESHQ,MESHQ2,PI,WAVENH,DXSI,MS,NS,NF,NF,MESHPTS
C COMMON /PRNTPLT/PGREY,PWAIST,PLTWST,PLTMAX,PLTFLO,PLTFLE,LAST,IOUT,IGREY
+ ,PLTFLO,PLTFLE
C
C REAL LAMBDA,NO,NOSQ,N2
C LOGICAL PGREY,PWAIST,PLTWST,PLTMAX,PLTFLO,PLTFLE,LAST,CALLPR
C
C DATA PI/3.141592657,ICNTCS/17,ICNT/707
C
C NAMELIST /DEFAULT/LAMBDA,RO,FR,NO,PCORP,OUTRAD,DX,NSTEPS,NDZINC,
+ IOUT,IGREY,PGREY,PWAIST,PLTWST,PLTMAX,PLTFLO,PLTFLE,MESH
C
C READ(5,1000) NCASES
C READ(5,*) XB,YB
C READ(5,1000) NFIB
C READ(5,*) (X0(I),Y0(I),I=1,NFIB)
C WRITE(6,*) (X0(I),Y0(I),I=1,NFIB)
C READ(5,*) (PCORPA(K),K=1,NFIB)
C READ(5,*) (FRA(K),K=1,NFIB)
C WRITE(6,*) (PCORPA(K),K=1,NFIB)
C WRITE(6,*) (FRA(K),K=1,NFIB)
1000 FORMAT(15)
1 READ(5,DEFAULT)

```



```

C      ICNTE=0
      FLAG=NO/ABS(NO)
      NO=ABS(NO)
      IF (FLAG.LT.0.) WRITE(IOUT,2050)
2050  FORMAT(7,47H THE REFRACTIVE INDEX IS A CONSTANT EQUAL TO NO)
      PCORP=PCORPA(1)
      FR=FRA(1)
      WRITE(IOUT,DEFAULT)

C      CALCULATE CONSTANTS
C
      MESH2=2*MESH
      MESHSG=MESH**2
      NSHSG2=2*MESHSG
      RN2NO=.02*PCORP/FR**2
      ZMIN=PI/(2.*SQRT(RN2NO))
      DZINC=ZMIN/NDZINC
      DXSI=DZINC/ZMIN
      DXSIH=DXSI/2.
      DZET=DX/RO
      WAVENM=2.*PI/LAMBDA
      BETAH=(2.*ZMIN*DXSI/(WAVENM*NO))*(PI/(MESH*DZET*RO))**2
      FTCNST=(1.-1./MESH)*PI
      XYO=MESH/2.
      RADNRM=(OUTRAD/RO)**2
      RNURM=1./MESHSG
      N2=NO*RN2NO
      REFCF=N2*RO**2/2.
      ALPHA=2.*ZMIN/(PI*WAVENM*NO*RO**2)
      NOSQ=NO**2
      MU(1)=MESH
      MU(2)=MESH
      XSIMUL=DXSI
      LAST=.F.
      IF (FLAG.LT.0.) REFCF=0.
      CALLPR=PGREY.OR.PWAIST.OR.PLTWST.OR.PLTMAX.OR.PLTFLD.OR.PLIFLE

C      WRITE THE IMPORTANT CALCULATED PARAMETERS
C
      WRITE(IOUT,2000) ZMIN,DZINC,RN2NO,ALPHA
2000  FORMAT(7,8H ZMIN = ,F10.4,1X,7H MICRONS,/,9H DZINC = ,F10.4,1X,
+ 7H MICRONS,/,9H RN2NO = ,E10.3,1X,13H MICRONS**(-2),/,
+ 9H ALPHA = ,F10.5,/)

C      CALCULATE NECESSARY ARRAYS
C
      DO 800 K=1,NFIB
      X0(K)=X0(K)+XYO
      Y0(K)=Y0(K)+XYO
      RECFKA(K)=NO*.02*PCORPA(K)*(RO/FRA(K))**2/2.
800  CONTINUE
      DO 100 K=1,MESH
      RK=K-1
      ARG=FTCNST*RK
      CS(K)=COS(ARG)
      SN(K)=SIN(ARG)

```



```

      ZTSQ(K)=((RK-XYO)*DZET)**2
      PQSQ(K)=(RK-XYO+.5)**2
100  CONTINUE
C
C      SET UP REFRACTIVE INDEX ARRAY
C
      M=0
      DO 120 J=1,MESH
      DO 120 I=1,MESH
      M=M+1
      TMPNDX=0.
      DO 110 K=1,NFIB
      Z1=((J-1.-YO(K))*DZET)**2
      Z2=((I-1.-XO(K))*DZET)**2
      RAD=Z1+Z2
      TMPNDX=AMAX1(TMPNDX,(NO-REFCFA(K)*RAD))
110  CONTINUE
      REFNDX(M)=AMAX1(TMPNDX,1.)
      IF(1.EQ.52.OR.1.EQ.58) WRITE(1OUT,*) REFNDX(M)
C
120  CONTINUE
      IF(MESH.NE.128) GO TO 10
      MS=MESH/4+1
      MF=MS+MESH/2-1
      NS=MS
      NF=MF
      GO TO 40
10   CONTINUE
      MS=1
      NS=1
      MF=MESH
      NF=MESH
40   CONTINUE
      DO 130 K=1,MESH5Q
      REFNDX(K)=REFNDX(K)**2-NUSQ
130  CONTINUE
      CALL GREYSC(IGREY,10,REFNDX,MESH,MESH,NS,MF,1,NS,MF,1,0.,0.,
      + 6HREFNDX,5)
C
C      SET UP INITIAL FIELD
C
      M=-1
      K=0
      CH=WAVENM*ZMIN*DXSIH/(2.*NO)
      DO 140 J=1,MESH
      Z1=((J-XYO-YB-1)*DZET)**2
      DO 140 I=1,MESH
      K=K+1
      M=M+2
      MP1=M+1
      Z2=((I-XYO-XB-1)*DZET)**2
      RAD=Z1+Z2
      IF(RAD.GT.RADNRM) GO TO 20
      AMP=EXP(-RAD/2.)
      ARG=CH*REFNDX(K)
      V(M)=AMP*COS(ARG)
      V(MP1)=AMP*SIN(ARG)
      GO TO 140

```

20	CONTINUE	OPTF16
	V(M)=0.	OPTF16
	V(MP1)=0.	OPTF16
140	CONTINUE	OPTF16
	IF(CALLPR) CALL PRINTER(ICNT)	OPTF16
C	DO PROPAGATION	OPTF16
C	DO 500 ICNT=1,NSTEPS	OPTF16
C	CONDITION V FOR TRANSFORM	OPTF16
C	K=-1	OPTF16
	DO 160 J=1,MESH	OPTF16
	SNJ=SN(J)	OPTF16
	CSJ=CS(J)	OPTF16
	DO 160 I=1,MESH	OPTF16
	K=K+2	OPTF16
	KP1=K+1	OPTF16
	SNI=SN(I)	OPTF16
	CSI=CS(I)	OPTF16
	AR=CSJ*CSI-SNJ*SNI	OPTF16
	AI=-(CSJ*SNI+CSI*SNJ)	OPTF16
	VR=V(K)	OPTF16
	VI=V(KP1)	OPTF16
	V(K)=VR*AR-VI*AI	OPTF16
	V(KP1)=VI*AR+VR*AI	OPTF16
160	CONTINUE	OPTF16
C	DO TRANSFORM	OPTF16
C	CALL FOURT(V,MU,2,1,1,WORK)	OPTF16
C	SOLVE FIRST ORDER ODE	OPTF16
C	K=-1	OPTF16
	DO 160 J=1,MESH	OPTF16
	PHI1=BETAHT*PQSQ(J)	OPTF16
	DO 160 I=1,MESH	OPTF16
	K=K+2	OPTF16
	KP1=K+1	OPTF16
	PHI2=BETAHT*PQSQ(I)	OPTF16
	VR=V(K)	OPTF16
	VI=V(KP1)	OPTF16
	ANG=-(PHI1+PHI2)	OPTF16
	CANG=COS(ANG)	OPTF16
	SANG=SIN(ANG)	OPTF16
	V(K)=(VR*CANG-VI*SANG)*RNORM	OPTF16
	V(KP1)=(VR*SANG+VI*CANG)*RNORM	OPTF16
160	CONTINUE	OPTF16
C	DO INVERSE TRANSFORM	OPTF16
C	CALL FOURT(V,MU,2,-1,1,WORK)	OPTF16
C	RECONDITION V BECAUSE OF TRANSFORM	OPTF16
C		OPTF16


```

K=-1
DO 200 J=1,MESH
SNJ=SN(J)
CSJ=CS(J)
DO 200 I=1,MESH
K=K+2
KP1=K+1
SNI=SN(I)
CSI=CS(I)
AR=CSJ*CSI-SNJ*SNI
AI=CSJ*SNI+SNJ*CSI
VR=V(K)
VI=V(KP1)
V(K)=VR*AR-VI*AI
V(KP1)=VR*AI+VI*AR
200 CONTINUE

NOW INCLUDE EITHER FULL STEP OR HALF STEP REFRACTIVE
INDEX EFFECTS DEPENDING ON WHERE IN THE PATH YOU ARE

IF(ICNT.EQ.NSTEPS) XSIMUL=DXSIN
K=-1
CH=WAVENM*ZMIN*XSIMUL/(2.*NO)
DO 220 M=1,MESH2
ARG=REFNDX(M)*CH
AR=COS(ARG)
AI=SIN(ARG)
K=K+2
KP1=K+1
VR=V(K)
VI=V(KP1)
V(K)=VR*AR-VI*AI
V(KP1)=VR*AI+VI*AR
220 CONTINUE
IF(ICNT.EQ.NSTEPS) LAST=.T.
IF(CALLPR) CALL PRNTER(ICNT)
500 CONTINUE

CALCULATE IRRADIANCE PATTERN AND PRINT

IF(PGREY) GO TO 30
M=0
DO 240 K=1,MSHSQ2,2
KP1=K+1
VR=V(K)
VI=V(KP1)
M=M+1
RADARY(M)=VR**2+VI**2
240 CONTINUE
CALL GREYSC(IGREY,10,RADARY,MESH,MESH,MS,MF,1,NS,NF,1,0.,0.,
+ 10,IRRADIANCE,10)
30 CONTINUE
ICNTCS=ICNTCS+1
IF(ICNTCS.LE.NCASES) GO TO 1
END

```



```

SUBROUTINE PEAK(VMAX)
COMMON /LCM2/REFNDX(16384),SN(128),CS(128),ZISQ(128),PGSQ(128)
+ ,AMPARY(16384),RADARY(16384)
LEVEL 2,REFNDX,SN,CS,ZISQ,PGSQ,AMPARY,RADARY
COMMON /ARRAYS/VI(32/68)
COMMON /PARAM/DZINC,MESH,LAMBDA,RO,FR,NO,PCORP,OUTRAD,LX,NSTEPS,
+ NDZINC,MESHQ,MSHSQ2,PI,WAVERN,DXSI,YS,NS,MF,RF,MSHPTS
L=0
SUML=0.
SUMR=0.
VMAX=0.
DO 10 K=1,MSHSQ2,2
VR=V(K)
L=L+1
KPI=K+1
VI=V(KPI)
VRAD=VI**2+VR**2
IF(K.LE.MESHQ) SUML=SUML+VRAD
IF(K.GT.MESHQ) SUMR=SUMR+VRAD
VMAX=AMAX1(VMAX,VRAD)
RADARY(L)=VRAD
10 CONTINUE
TOT=SUML+SUMR
SUML=SUML/TOT
SUMR=SUMR/TOT
WRITE(6,2000) SUML,SUMR
2000 FORMAT(/,1X,7HSUML = ,E14.7,3X,7HSUMR = ,E14.7,/)
RETURN
END

```

PEAK
 LCM2
 LCM2
 LCM2
 ARRAYS
 PARAM
 PARAM
 TEMP
 TEMP
 PEAK
 PEAK
 PEAK
 PEAK
 PEAK
 TEMP
 TEMP
 PEAK
 PEAK
 TEMP
 TEMP
 TEMP
 TEMP
 TEMP
 PEAK
 PEAK

REFERENCE MAP (R=1)

TYPE	RELOCATION	ADDRESS	NAME	TYPE	RELOCATION	ADDRESS	NAME
REAL	ARRAY	LCM2	40200 CS	REAL	ARRAY	LCM2	
REAL		PARAM	17 DXSI	REAL		PARAM	
REAL		PARAM	4 FR	REAL		PARAM	
INTEGER			51 KPI	INTEGER			
INTEGER			2 LAMBDA	INTEGER		PARAM	
INTEGER		PARAM	13 MESHQ	INTEGER		PARAM	
INTEGER		PARAM	20 MS	INTEGER		PARAM	
INTEGER		PARAM	14 MSHSQ2	INTEGER		PARAM	
INTEGER		PARAM	23 NF	INTEGER		PARAM	
INTEGER		PARAM	21 NS	INTEGER		PARAM	
INTEGER		PARAM	7 OUTRAD	REAL		PARAM	
REAL		PARAM	15 PI	REAL		PARAM	
REAL	ARRAY	LCM2	101000 RADARY	REAL	ARRAY	LCM2	
REAL	ARRAY	LCM2	3 RO	REAL		PARAM	
REAL	ARRAY	LCM2	45 SUML	REAL			
REAL			54 TOT	REAL			
REAL	ARRAY	ARRAYS	52 VI	REAL			

```

SUBROUTINE GREYSC(IFILE1,NLEVEL,AMAT,IDIM,JDIM,IMIN,IMAX,IDEL,
+ JMIN,JMAX,JDEL,AMIN,AMAX,TITLE,NCHAR)
  LEVEL=2,AMAT
  DIMENSION ICHARS(10,3),LINE(132,3),LEVEL(10),AMAT(IDIM,JDIM)
  DIMENSION TITLE(20)
  DATA ICHARS/1H,1H,1H,1H,1H,60000000000000000000,1H,3*1H0
+ ,6*1H,1H,1H,1H,2*00000000000000000000,9*1H,1H*/
  DATA IBORDR/1H*,1BLANK/1H /
  DATA LEVEL/0*1,3*2,3/
  DATA NCP/10/
  DATA NLMAX /59/
  IFILEX=-IFILE1

```

GREYSC

PURPOSE--PRODUCES A SHADED (GREY-SCALE) LINE PRINTER PLOT OF
A TWO-DIMENSIONAL, REAL MATRIX.

USAGE--CALL GREYSC(IFILE,NLEVEL,AMAT,IDIM,JDIM,IMIN,IMAX,IDEL,
JMIN,JMAX,JDEL,AMIN,AMAX,TITLE,NCHA-)

IFILEX (OUTPUT FILE CODE..+ FOR LBL, - FOR OTHER SYSTEMS OR TERMINAL
NLEVEL (NO. OF GREY-LEVELS TO BE PRINTED)
AMAT (THE 2D MATRIX TO BE DISPLAYED)
IDIM (THE FIRST DIMENSION OF MATRIX AMAT)
JDIM (THE SECOND DIMENSION OF MATRIX AMAT)
IMIN (THE BEGINNING I-COORDINATE FOR THE PLOT)
IMAX (THE ENDING I-COORDINATE FOR THE PLOT)
IDEL (USED IN THE SENSE ...I=IMIN,IMAX,IDEL)
JMIN,JMAX,JDEL (SEE IMIN,IMAX, AND IDEL DESCRIPTIONS)
AMIN (THE MINIMUM VALUE USED FOR SCALING--SEE BELOW)
AMAX (THE MAXIMUM VALUE USED FOR SCALING--SEE BELOW)
TITLE (CHARACTER VECTOR OR HOLLERITH STRING FOR TITLE)
NCHAR (NO. OF CHARACTERS IN TITLE VECTOR)

SUBPROGRAM REFERENCES--(NONE)

COMMENTS--

1. CREATED 7/2/74 BY C. SOUTH
2. NLEVEL CAN BE NO LARGER THAN 10. IF =5, CHARACTERS
ARE NOT OVERPRINTED. IF BETWEEN 6 AND 9, CHARACTERS WILL BE
OVERPRINTED NO MORE THAN ONCE. IF =10, THE DENSEST CHARACTER
WILL BE OVERPRINTED TWICE.
3. SCALING IS LINEAR BETWEEN AMIN AND AMAX. IF AMIN=AMAX,
SCALING WILL BE AUTOMATICALLY SET TO FULL RANGE FOR THE MATRIX.
4. MACHINE COMPATIBILITY--CHANGE VARIABLE NCP IN DATA STATEMENT
TO INDICATE NUMBER OF CHARACTERS PER WORD FOR THE MACHINE.
5. PLOT BORDER--DEFAULT IS A BORDER OF ASTERISKS. TO RESET THE
CHARACTER, CHANGE THE VARIABLE IBORDR IN THE DATA STATEMENT
(ALGORITHM WILL CORRECTLY HANDLE THE BLANK BORDER CASE).
6. CHANGED 7/31/74 TO HANDLE CASE OF 5 CHARS/WORD.
7. CHANGED 8/12/74 TO CHANGE SIXTH CHARACTER TO A SIMPLE '*'.
8. CHANGED 8/27/74 TO DEFINE CHAR. 5-7 AS (*), (NUM SIGN), (* PLUS X).
9. CHANGED 9/12/77 TO ALTER PAGE HANDLING. THIS ROUTINE WILL NOW
TRY TO FIT BOTH THE SCALING INFORMATION AND THE GREYSCALE PLOT
ON THE SAME PAGE, WITH SCALING INFORMATION BELOW THE PLOT.
NLMAX REPRESENTS THE MAXIMUM ROWS FOR THE INPUT MATRIX STILL

ALLOWING THE SCALING INFORMATION TO APPEAR ON THE SAME PAGE.

SCALE, IF NECESSARY

```

AMX=AMAX
IFILE=1A6S(IFILEX)
AMN=AMIN
IF (AMAX.GT.AMIN) GO TO 100
AMN=1.E20
AMX=-1.E20
DO 50 I=IMIN,IMAX,IDEL
DO 50 J=JMIN,JMAX,JDEL
AMN=AMINI(AMN,AMAT(I,J))
AMX=AMAXI(AMX,AMAT(I,J))
50 CONTINUE

```

PRINT HEADER

```

NWORDS=(NCHAR-1)/NCPW+1
IF (NCPW.EQ.6) WRITE(IFILE,1040) (TITLE(I),I=1,NWORDS)
IF (NCPW.EQ.4) WRITE(IFILE,1041) (TITLE(I),I=1,NWORDS)
IF (NCPW.EQ.10) WRITE(IFILE,1042) (TITLE(I),I=1,NWORDS)
IF (NCPW.EQ.5) WRITE(IFILE,1043) (TITLE(I),I=1,NWORDS)
IF (AMX.EQ.AMN) RETURN

```

PREPARE A LINE FOR PRINTING

```

LINE(1,1)=IBORDR
JLOC=(JMAX-JMIN)/JDEL+3
LINE(JLOC+2,1)=IBORDR
LINE(1,2)=IBLANK
LINE(1,3)=IBLANK
LINE(JLOC+2,2)=IBLANK
LINE(JLOC+2,3)=IBLANK
LASTLI=JLOC+2
NLA STL=LASTLI-1
WRITE(IFILE,1045) (IBORDR,I=1,LA STL)
DO 400 I=IMIN,IMAX,IDEL
DO 250 II=1,3
DO 250 J=2,NLA STL
250 LINE(J,II)=IBLANK
LEV=1
J=2
DO 300 JJ=JMIN,JMAX,JDEL
J=J+1
L=(AMAT(I,JJ)-AMN)/(AMX-AMN)*FLOAT(NLEVEL)+1.
L=MAX0(1,L)
L=MIN0(NLEVEL,L)
LEV=MAX0(LEV,LEVEL(L))
LEVNOW=LEVEL(L)
DO 300 K=1,LEVNOW
LINE(J,K)=ICHARS(L,K)
300 CONTINUE

```

FIND LAST PRINT POSITION


```

      DO 400 KL=1,LEV
      DO 350 K=1,LASTLI
      KK=LASTLI-K+1
      IF(LINE(KK,KL).NE.IBLANK) GO TO 375
350  CONTINUE
375  CONTINUE
      IF(IFILEX.GT.0.AND.KL.EQ.LEV) WRITE(IFILE,1050) (LINE(II,KL),
      1 II=1,KK)
      IF(IFILEX.LT.0.AND.KL.EQ.1) WRITE(IFILE,1050) (LINE(II,KL),
      1 II=1,KK)
      IF(IFILEX.GT.0.AND.KL.NE.LEV) WRITE(IFILE,1060) (LINE(II,KL),
      1 II=1,KK)
      IF(IFILEX.LT.0.AND.KL.NE.1) WRITE(IFILE,1060) (LINE(II,KL),
      1 II=1,KK)
400  CONTINUE
C
C      WRITE LAST LINE (BORDER)
C
C      WRITE(IFILE,1070) (ISORDR,I=1,LASTLI)
C
C      PRINT TRAILING SCALE INFORMATION
C
      IF(NCPW.EQ.6) WRITE(IFILE,1000) (TITLE(I),I=1,NWORDS)
      IF(NCPW.EQ.4) WRITE(IFILE,1001) (TITLE(I),I=1,NWORDS)
      IF(NCPW.EQ.10) WRITE(IFILE,1002) (TITLE(I),I=1,NWORDS)
      IF(NCPW.EQ.5) WRITE(IFILE,1003) (TITLE(I),I=1,NWORDS)
      WRITE(IFILE,1010)
      DELTA=(AMX-AMN)/FLOAT(NLEVEL)
      DO 200 I=1,NLEVEL
      XMIN=FLOAT(I-1)/FLOAT(NLEVEL)*(AMX-AMN)+AMN
      XMAX=XMIN+DELTA
      LEV=LEVEL(I)
      DO 175 J=1,LEV
      IF(IFILEX.GT.0.AND.J.EQ.LEV) WRITE(IFILE,1020) ICHARS(I,J),XMIN,
      1 XMAX
      IF(IFILEX.LT.0.AND.J.EQ.1) WRITE(IFILE,1020) ICHARS(I,J),XMIN,
      1 XMAX
      IF(IFILEX.GT.0.AND.J.NE.LEV) WRITE(IFILE,1030) ICHARS(I,J)
      IF(IFILEX.LT.0.AND.J.NE.1) WRITE(IFILE,1030) ICHARS(I,J)
175  CONTINUE
200  CONTINUE
      RETURN
1000 FORMAT(1H0,20A6)
1001 FORMAT(1H0,20A4)
1002 FORMAT(1H0,12A10)
1003 FORMAT(1H0,24A5)
1010 FORMAT(1H0,32HGREY-SCALE CHARACTERS AND RANGES/1X)
1020 FORMAT(5X,A1,5X,E15.6,5X,E15.6)
1030 FORMAT(1H+,4X,A1)
1039 FORMAT(1H1)
1040 FORMAT(1H1/1X,20A6)
1041 FORMAT(1H1/1X,20A4)
1042 FORMAT(1H1/1X,12A10)
1043 FORMAT(1H1/1X,24A5)
1045 FORMAT(1H0,132A1)
1050 FORMAT(1X,132A1)
1060 FORMAT(1H+,132A1)

```

SUBROUTINE SIZE (ARRAY, MESHM, MESHN, X0, Y0, X2, Y2)

THIS ROUTINE DETERMINES THE LOCATION OF THE CENTROID AND THE
MEAN SQUARE WIDTH OF AN ARRAY

PARAMETERS

ARRAY TWO DIMENSIONAL INPUT ARRAY
MESH ARRAY HAS DIMENSION MESHX MESHY
X0, Y0 X, Y COORDINATES OF CENTROID
X2, Y2 X AND Y RMS WIDTHS OF ARRAY

LEVEL 2, ARRAY
DIMENSION ARRAY (MESHM, MESHN)

MIDM=MESHM/2+1

MIDN=MESHN/2+1

MID=MESH/2+1

SUM1=0.

SUM2=0.

SUM3=0.

SUM4=0.

SUM5=0.

DO 10 M=1, MESHM

RM=M-MIDM

RMSQ=RM*RM

DO 10 N=1, MESHN

RN=N-MIDN

RNSQ=RN*RN

ARMN=ARRAY (M, N)

SUM1=SUM1+RM*ARMN

SUM2=SUM2+RN*ARMN

SUM3=SUM3+RMSQ*ARMN

SUM4=SUM4+RNSQ*ARMN

SUM5=SUM5+ARMN

10 CONTINUE

SNORM=1./SUM5

X0=SNORM*SUM2

Y0=SNORM*SUM1

X2=SNORM*SUM3-X0*X0

Y2=SNORM*SUM4-Y0*Y0

X2=SQRT(X2)

Y2=SQRT(Y2)

RETURN

END

REFERENCE MAP (R=1)

SYS.RM	127615	40	SL-SYSIO	11/08/77	COMPASS	3. 4-452
ERR.RM	127655	406	SL-SYSIO	11/08/77	COMPASS	3. 4-452
CHWP.SU	130263	7	SL-SYSIO	11/08/77	COMPASS	3. 4-452
USUB.RM	130272	71	SL-SYSIO	11/08/77	COMPASS	3. 4-452
UPEN.SU	130363	257	SL-SYSIO	11/08/77	COMPASS	3. 4-452
OPEX.SQ	130642	14	SL-SYSIO	11/08/77	COMPASS	3. 4-452
/PUT.RT/	130656	11				
RLEQ.RM	130667	50	SL-SYSIO	11/08/77	COMPASS	3. 4-452
CLSF.SQ	130737	136	SL-SYSIO	11/08/77	COMPASS	3. 4-452
/CLSV.FO/	131075	7				
CLSV.SU	131104	137	SL-SYSIO	11/08/77	COMPASS	3. 4-452
/REW.FO/	131243	7				
REW.SQ	131252	42	SL-SYSIO	11/08/77	COMPASS	3. 4-452
/GET.FO/	131314	7				
/RPAR.XX/	131323	1				
/GET.RT/	131324	11				
GET.SQ	131335	1070	SL-SYSIO	11/08/77	COMPASS	3. 4-452
Z.SQ	132425	125	SL-SYSIO	11/08/77	COMPASS	3. 4-452
FSU.SQ	132552	107	SL-SYSIO	11/08/77	COMPASS	3. 4-452
/LCM2/	40000000	141000				

.213 CP SECONDS

1502006 CM STORAGE USED

0. -8. 0. 6.
 .00081 .00081
 50. 25.

LAMBDA = .8E+00,

RU = .5E+02,

FR = .5E+02,

RU = .15E+01,

PCDRP = .81E-03,

OUTRAD = .1E+04,

DX = .5E+01,

NSTEPS = 40,

NDZINC = 5,

IDUT = 6,

IGREY = 6,

PGREY = T,

PNAIST = T,

PLTNST = F,

PLTMAX = F,

PLTFLO = F,

PLTFLE = F,

MESH = 128,

SEND

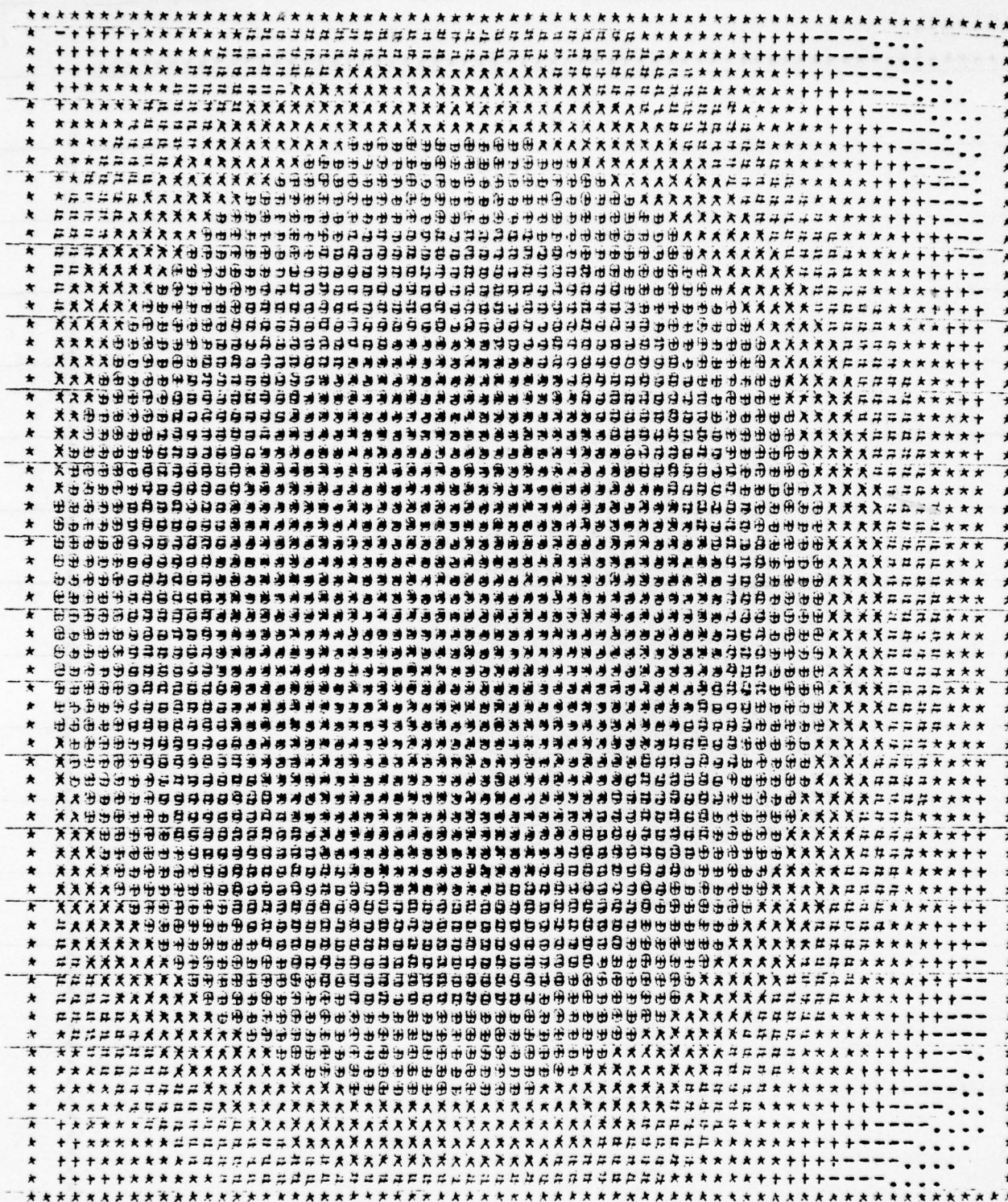
ZMIN = 19513.3742 MICRONS

DZINC = 3902.6748 MICRONS

RN2NO = .648E-08 MICRONS**(-2)

ALPHA = .42179

REFNOX

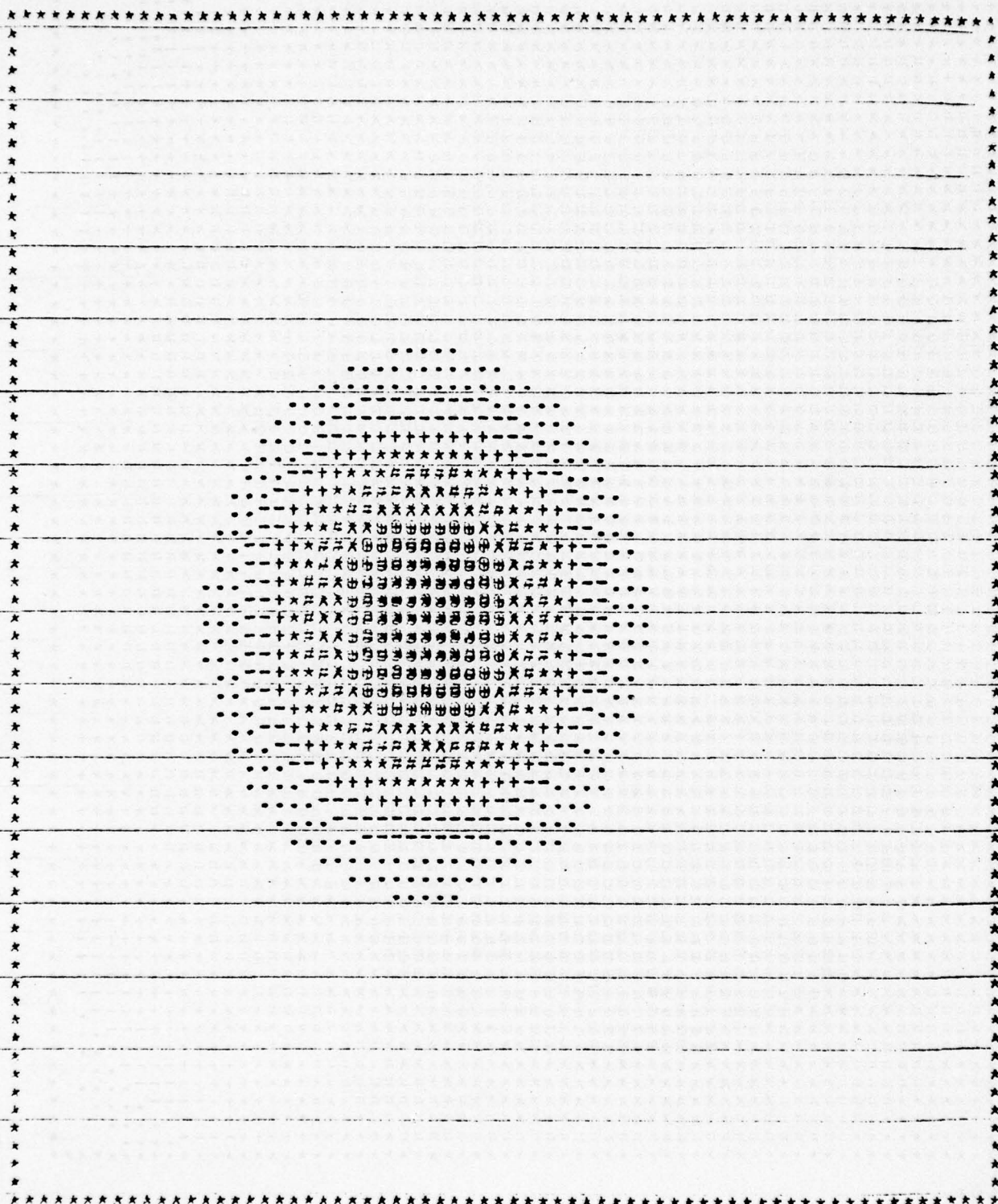


REFNOX

GREY-SCALE CHARACTERS AND RANGES

-	.872164E-03	-	.784948E-03
+	.784948E-03	-	.697731E-03
*	.697731E-03	-	.610515E-03
o	.610515E-03	-	.523298E-03
o	.523298E-03	-	.436082E-03
o	.436082E-03	-	.348866E-03
o	.348866E-03	-	.261649E-03
o	.261649E-03	-	.174433E-03
o	.174433E-03	-	.087216E-04
o	.087216E-04	-	.000000E-04

IRRADIANCE

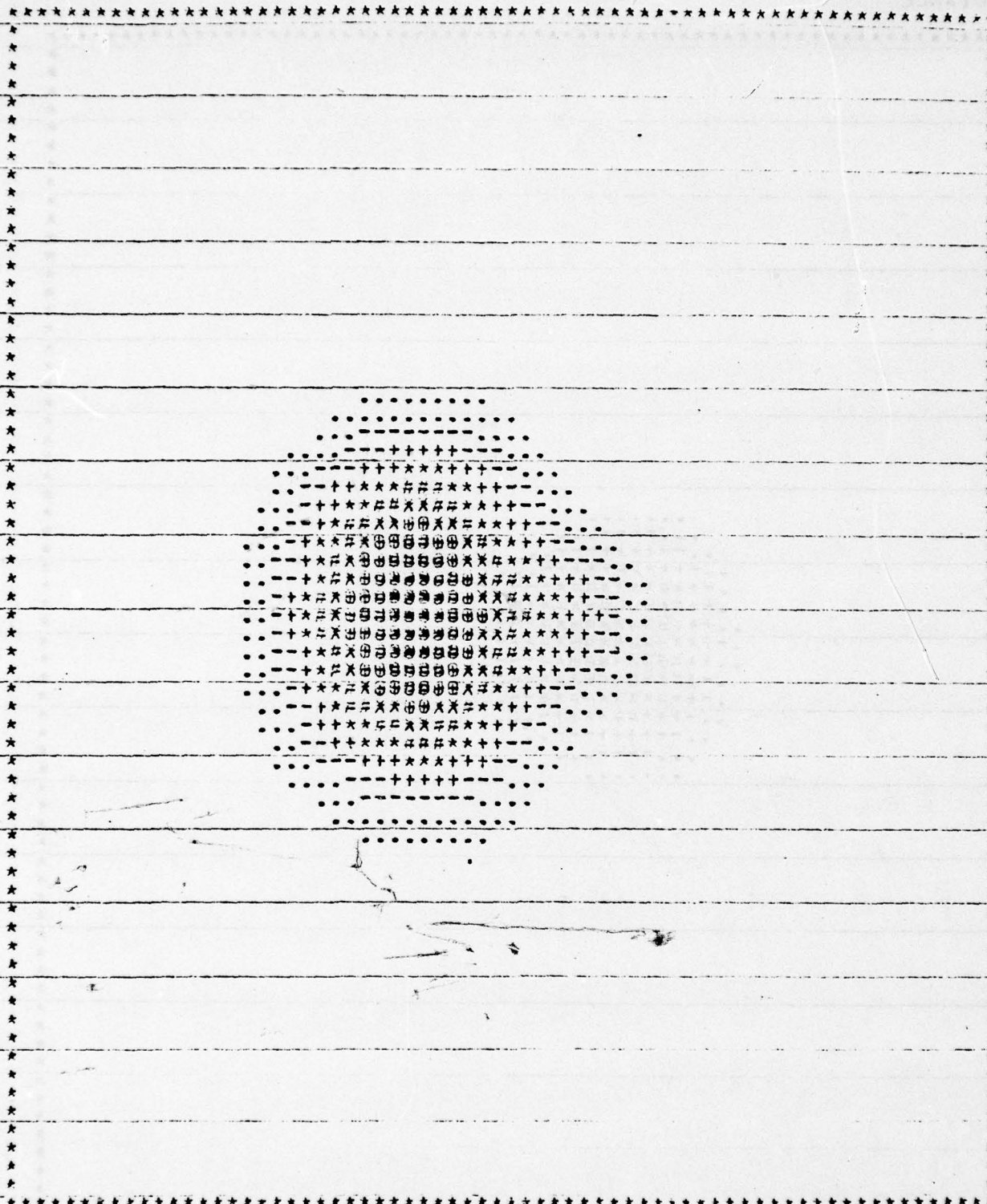


IRRADIANCE

GRAY-SCALE CHARACTERS AND RANGES

D B E X E	.404886E-10	.100000E+00
	.100000E+00	.200000E+00
	.200000E+00	.300000E+00
	.300000E+00	.400000E+00
	.400000E+00	.500000E+00
	.500000E+00	.600000E+00
	.600000E+00	.700000E+00
	.700000E+00	.800000E+00
	.800000E+00	.900000E+00
	.900000E+00	.100000E+00

IRRADIANCE

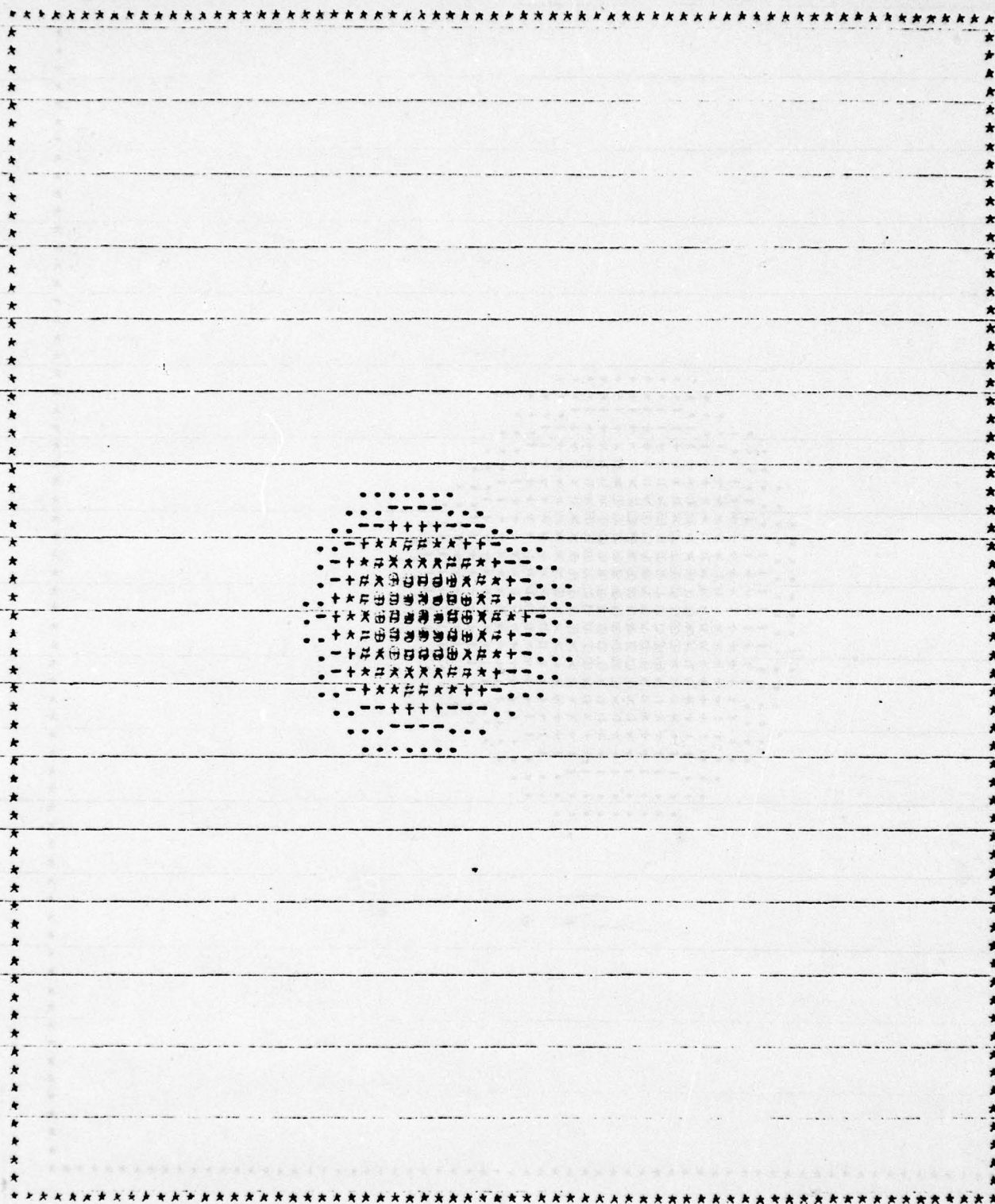


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

- + x =	.482299E-10	.139260E+00
	.139260E+00	.276520E+00
	.276520E+00	.417779E+00
	.417779E+00	.557039E+00
	.557039E+00	.696299E+00
	.696299E+00	.835559E+00
	.835559E+00	.974819E+00
	.974819E+00	.111408E+01

IRRADIANCE



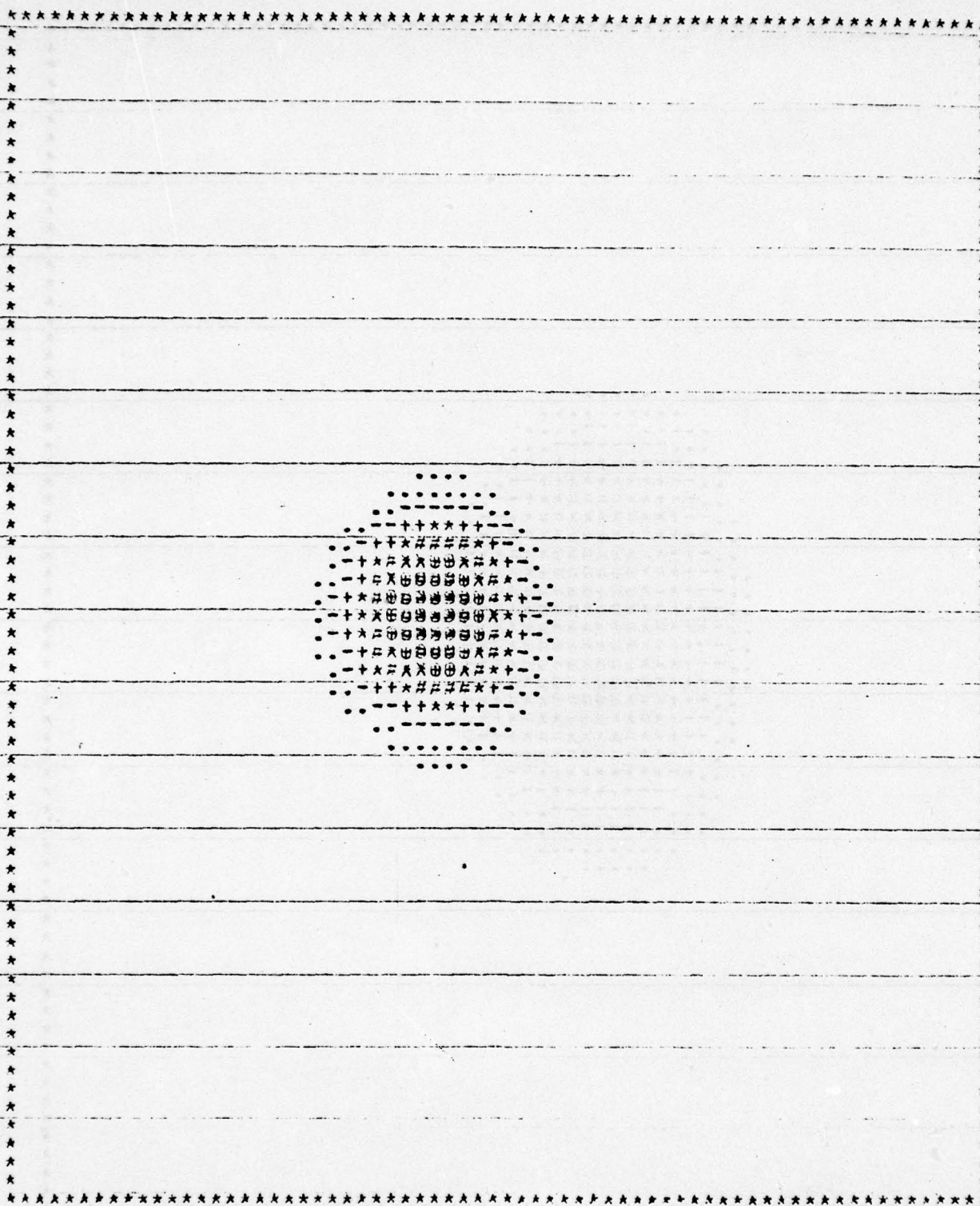
IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.133750E-07	.534463E+00
+	.334463E+00	.668927E+00
+	.668927E+00	.100339E+01
+	.100339E+01	.133785E+01
+	.133785E+01	.167232E+01
+	.167232E+01	.200678E+01
+	.200678E+01	.234124E+01
+	.234124E+01	.267571E+01
+	.267571E+01	.301017E+01

- 46 -

IRRADIANCE

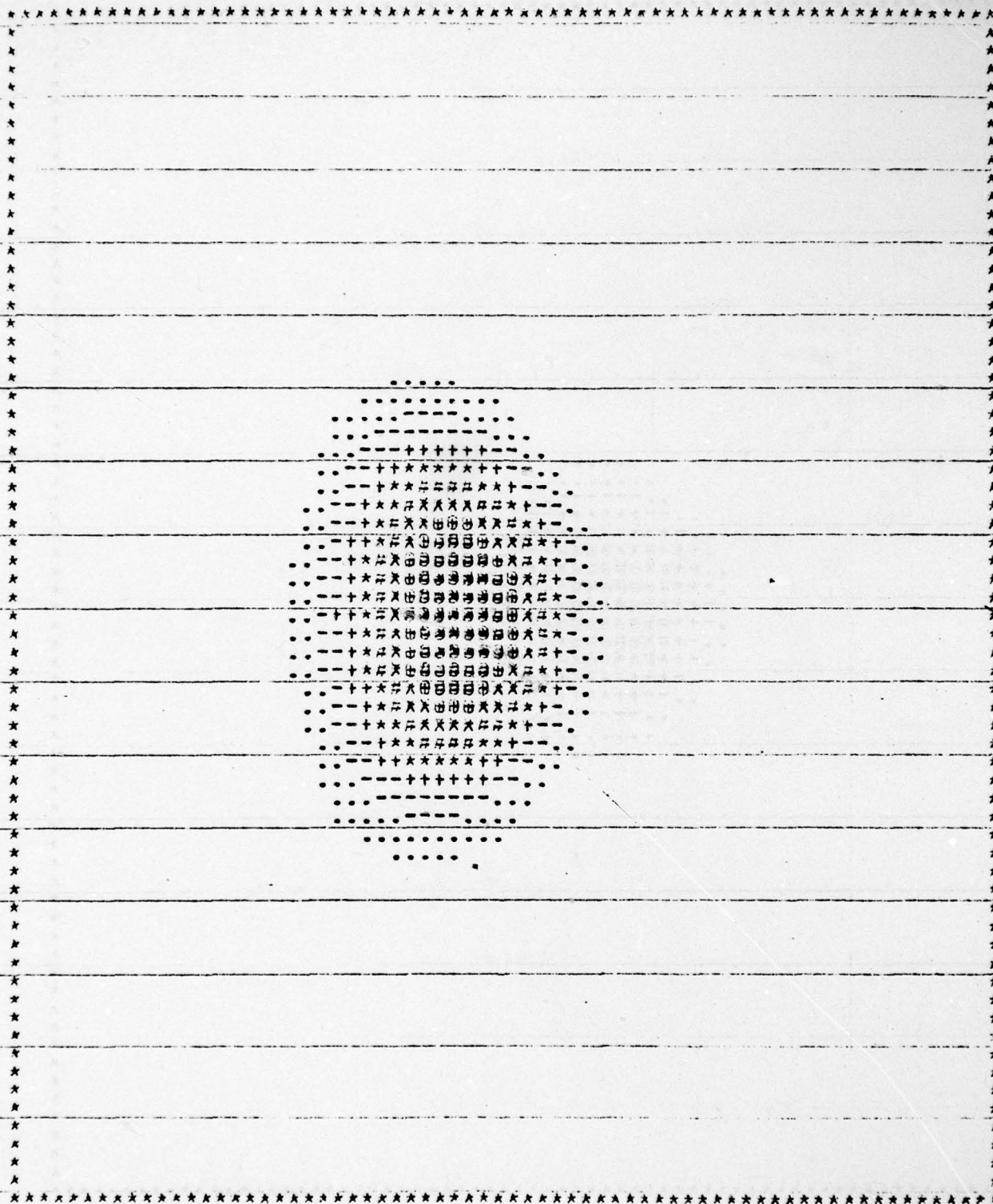


IRRADIANCE

GREY-SCALE CHARACTER AND RANGE

.	.597046E-08	.335547E+00
+	.335547E+00	.671094E+00
*	.671094E+00	.100604E+01
#	.100604E+01	.134219E+01
\$	.134219E+01	.167773E+01
%	.167773E+01	.201328E+01
@	.201328E+01	.234883E+01
	.234883E+01	.268437E+01

IRRADIANCE

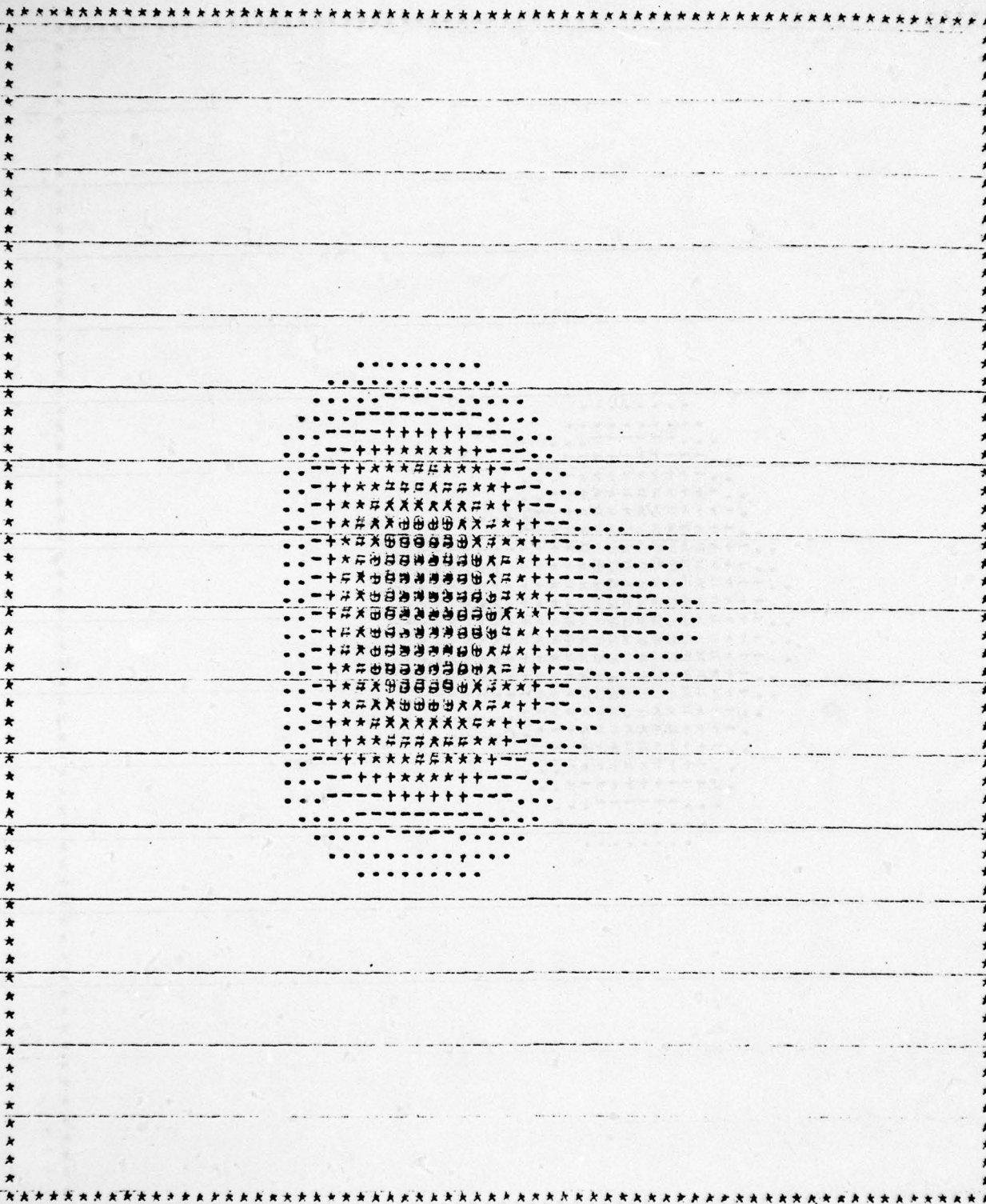


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.203232E-06	.155352E+00
+	.155352E+00	.310703E+00
*	.310703E+00	.466054E+00
#	.466054E+00	.621406E+00
x	.621406E+00	.776757E+00
o	.776757E+00	.932109E+00
o	.932109E+00	.108746E+01
o	.108746E+01	.124281E+01
o	.124281E+01	.139816E+01

IRRADIANCE

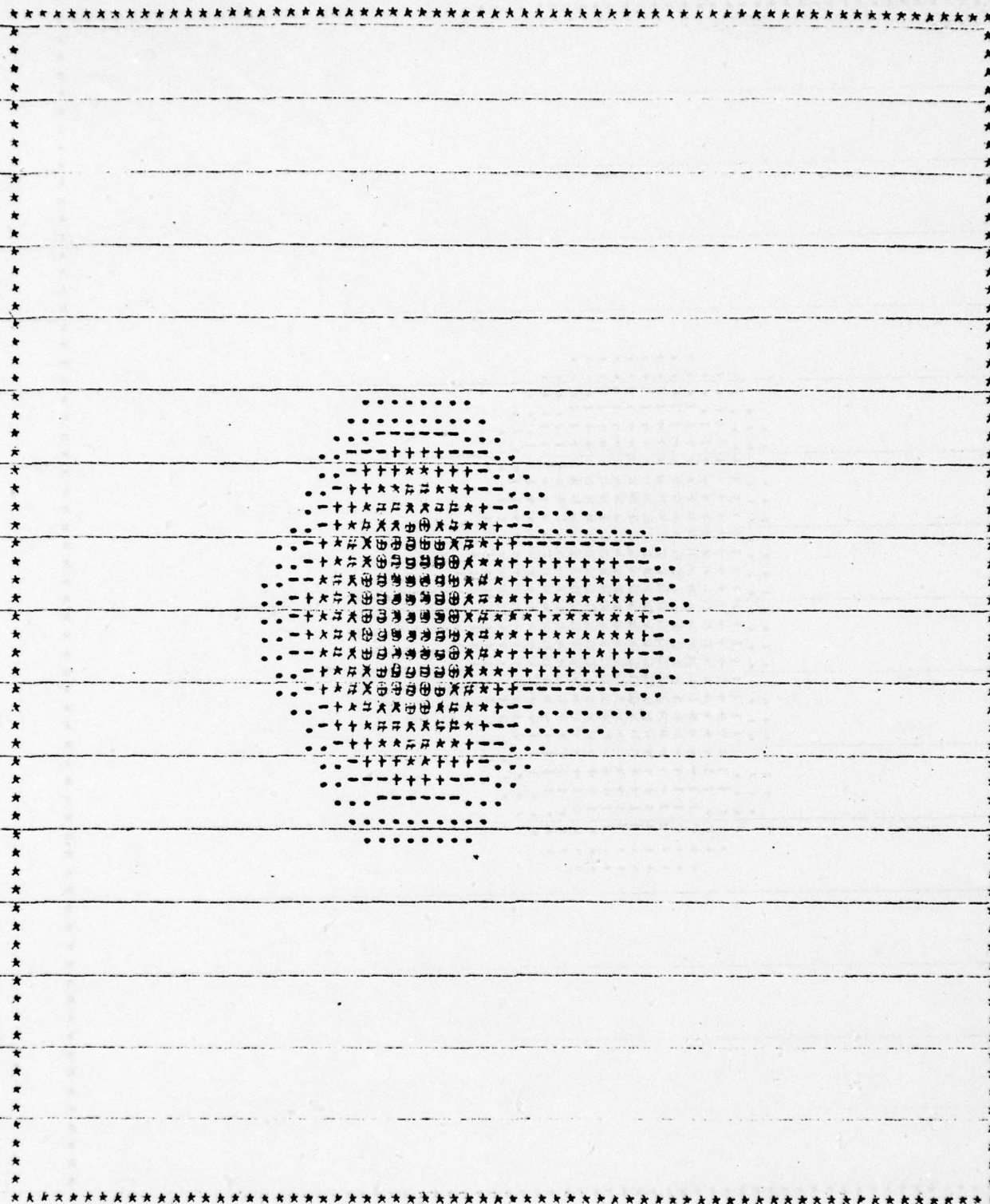


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.128679E-00	.125381E+00
.	.125381E+00	.250761E+00
.	.250761E+00	.376142E+00
.	.376142E+00	.501523E+00
.	.501523E+00	.626903E+00
.	.626903E+00	.752284E+00
.	.752284E+00	.877665E+00
.	.877665E+00	1.003045E+01

IRRADIANCE

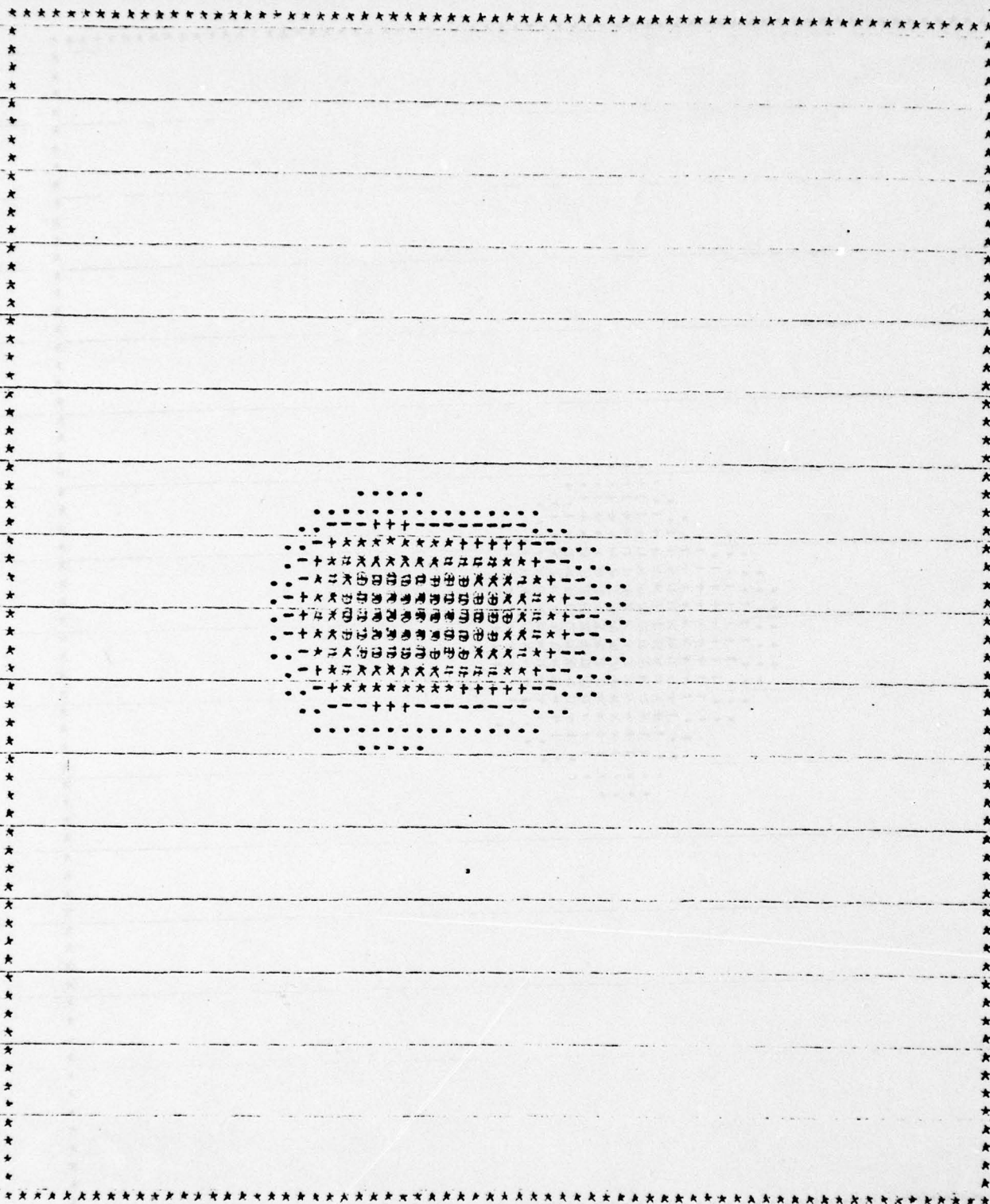


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.968125E-07	.150833E+00
+	.150833E+00	.301707E+00
*	.301707E+00	.452650E+00
*	.452650E+00	.603533E+00
*	.603533E+00	.754417E+00
*	.754417E+00	.905300E+00
*	.905300E+00	.105618E+01
*	.105618E+01	.120707E+01
*	.120707E+01	.135795E+01

IRRADIANCE

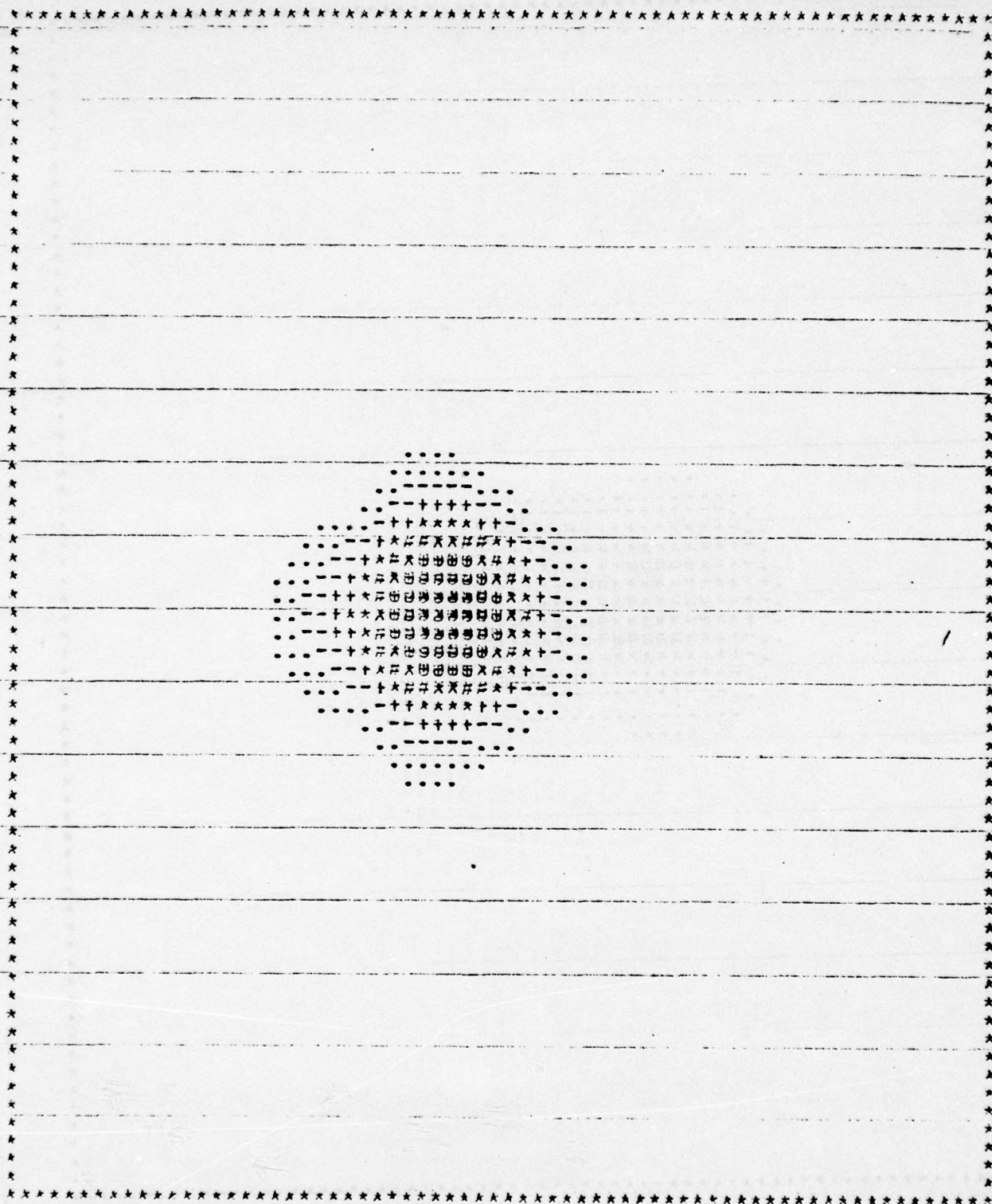


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.540033E-08	.238902E+00
+	.238902E+00	.477904E+00
*	.477904E+00	.716940E+00
#	.716940E+00	.955928E+00
%	.955928E+00	.119491E+01
^	.119491E+01	.143389E+01
&	.143389E+01	.167257E+01
1	.167257E+01	.191186E+01
2	.191186E+01	

IRRADIANCE

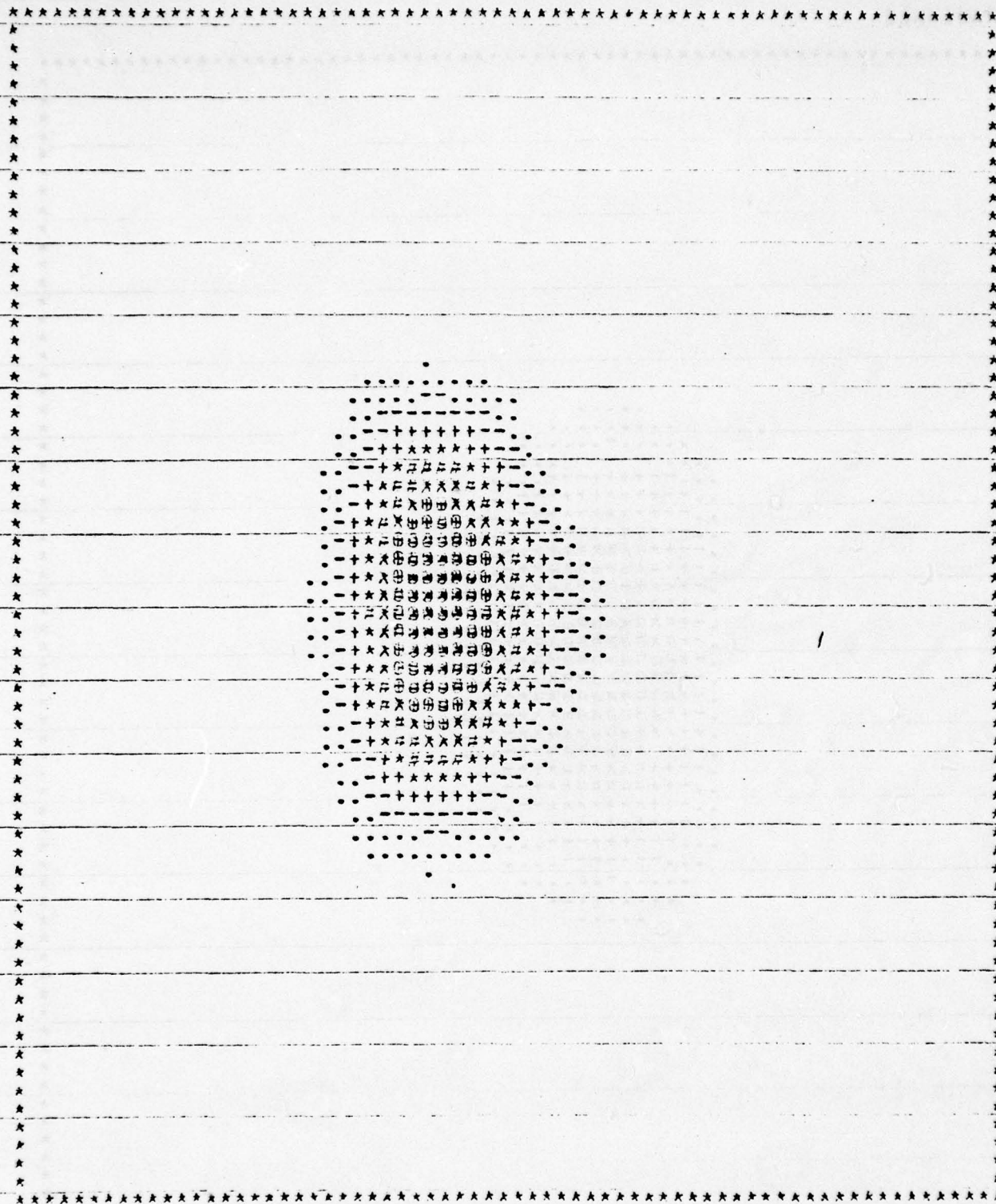


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.791205E-08	.250854E+00
+	.250854E+00	.501708E+00
*	.501708E+00	.752562E+00
*	.752562E+00	.100342E+01
*	.100342E+01	.125427E+01
*	.125427E+01	.150512E+01
*	.150512E+01	.175598E+01
*	.175598E+01	.200683E+01
*	.200683E+01	.225768E+01

IRRADIANCE

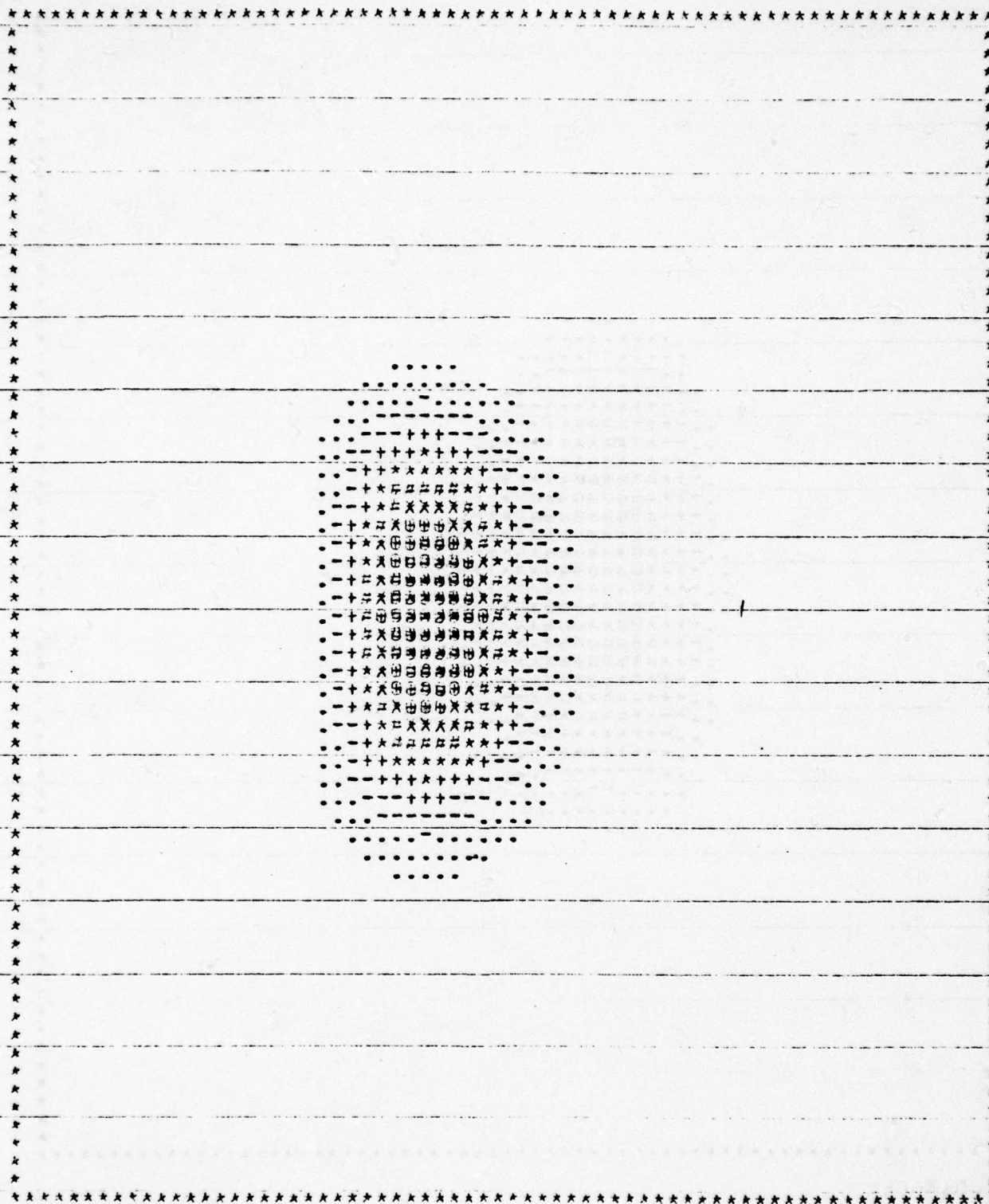


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.274744E-07	.158942E+00
+	.158942E+00	.317884E+00
*	.317884E+00	.476827E+00
*	.476827E+00	.635769E+00
*	.635769E+00	.794711E+00
*	.794711E+00	.953653E+00
*	.953653E+00	.111260E+01
*	.111260E+01	.127154E+01
*	.127154E+01	.143048E+01

IRRADIANCE

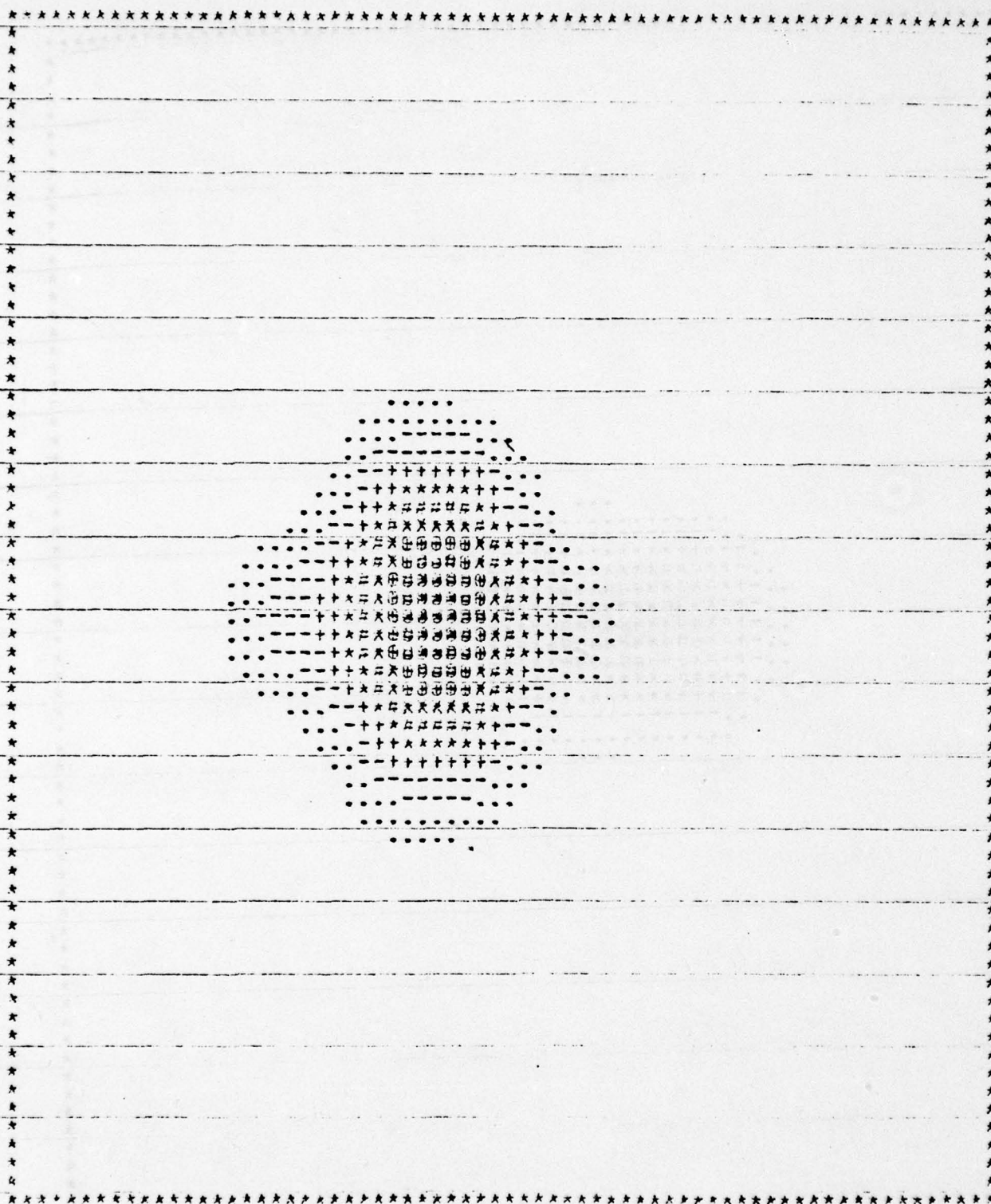


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

	.990012E-07		.163531E+00
	.163531E+00		.327062E+00
	.327062E+00		.490593E+00
	.490593E+00		.654124E+00
	.654124E+00		.817655E+00
	.817655E+00	- 54 -	.981186E+00
	.981186E+00		.114472E+01
	.114472E+01		.130825E+01
	.130825E+01		.147178E+01

IRRADIANCE

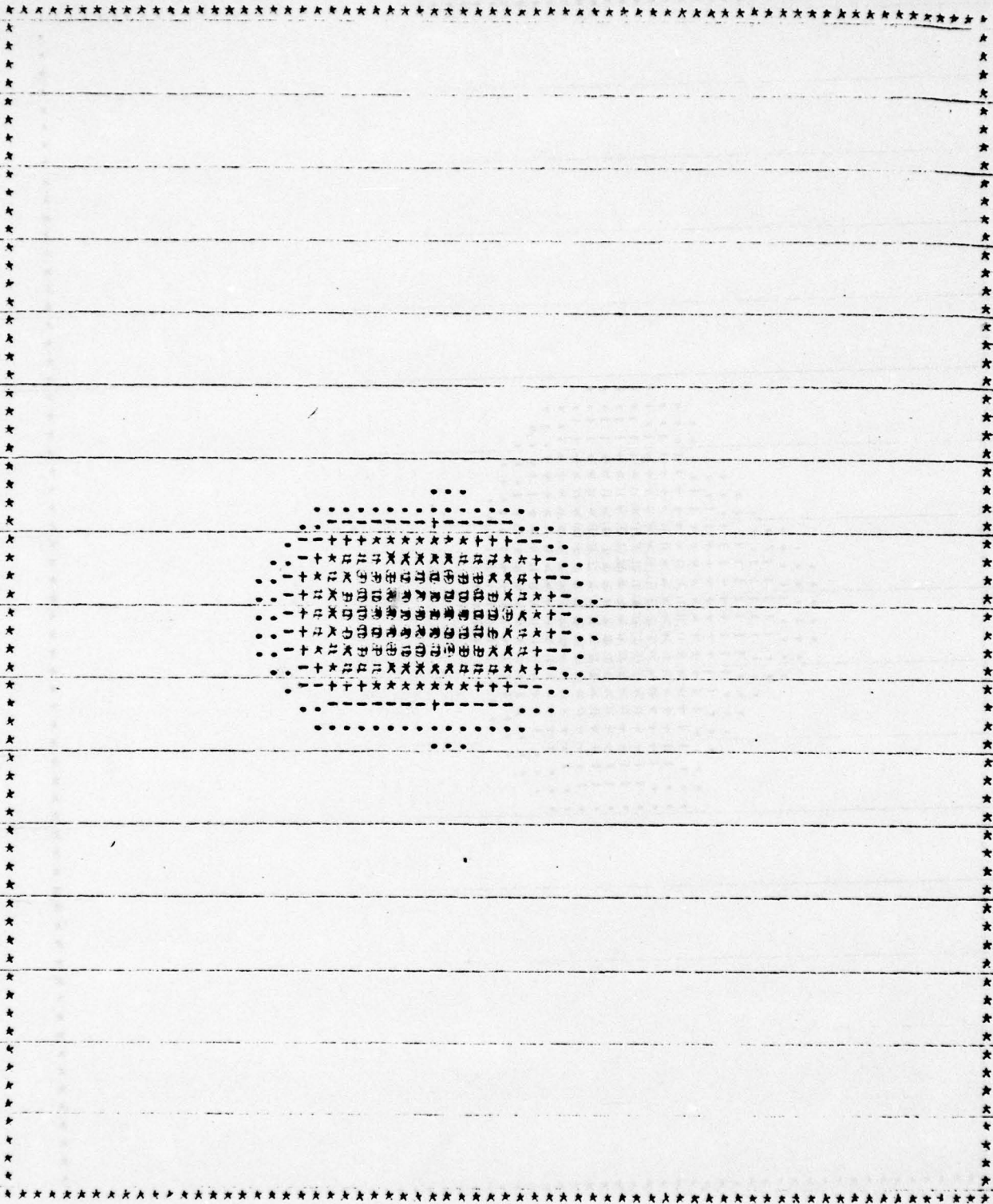


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.673243E-07		.174282E+00
+	.174282E+00		.348565E+00
*	.348565E+00		.522847E+00
*	.522847E+00		.697129E+00
*	.697129E+00		.871412E+00
*	.871412E+00	- 55 -	.104509E+01
*	.104509E+01		.121994E+01

IRRADIANCE

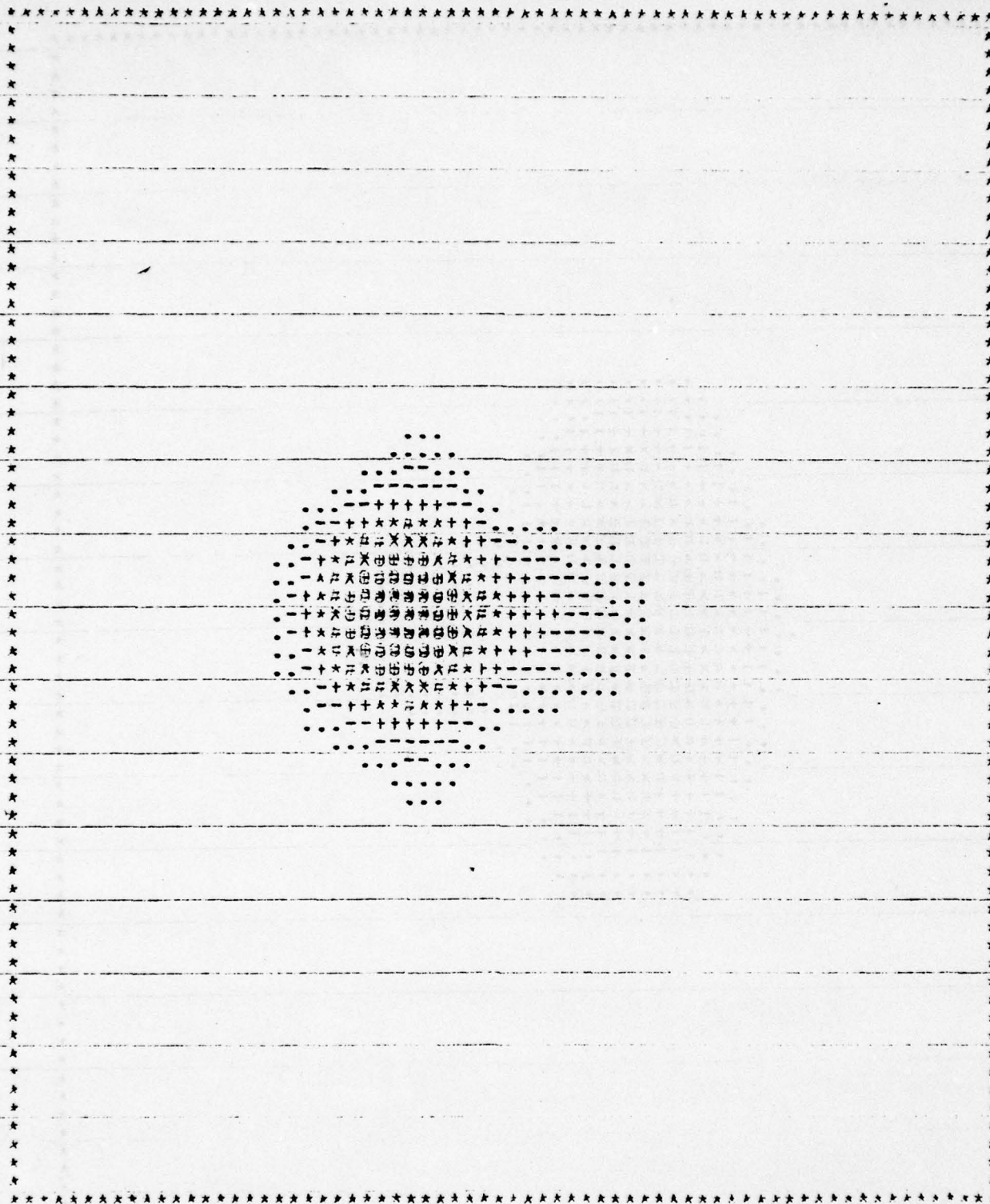


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.130120E-07		.247546E+00
+	.247546E+00		.495092E+00
*	.495092E+00		.742639E+00
+	.742639E+00		.990185E+00
*	.990185E+00	- 56 -	.123773E+01
+	.123773E+01		.148528E+01
*	.148528E+01		.173282E+01
+	.173282E+01		.198037E+01
*	.198037E+01		.222792E+01

IRRADIANCE

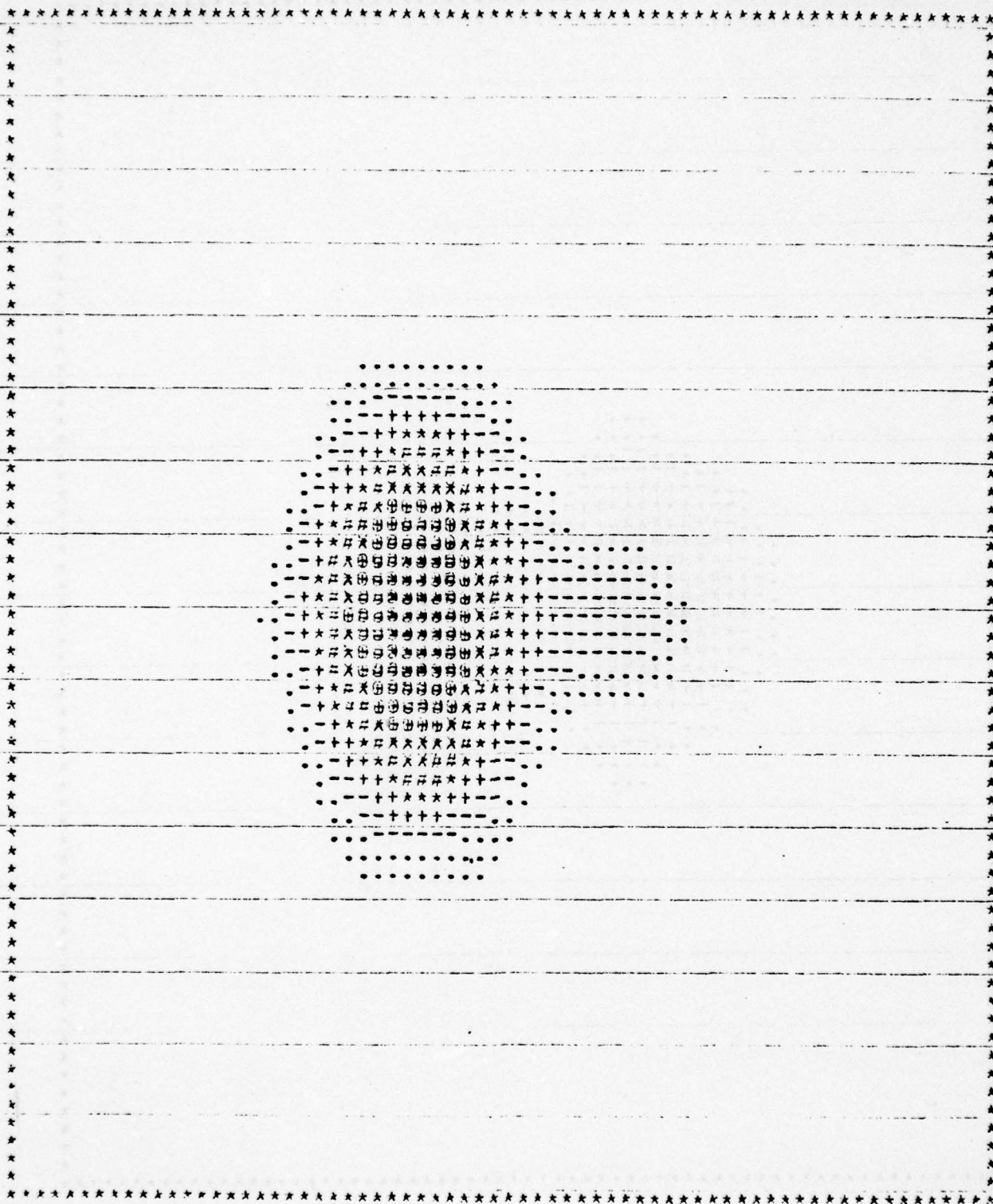


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

1	.585799E-07	.226294E+00
2	.226294E+00	.452587E+00
3	.452587E+00	.678881E+00
4	.678881E+00	.905174E+00
5	.905174E+00	.113147E+01
6	.113147E+01	.135776E+01
7	.135776E+01	.158405E+01
8	.158405E+01	.181035E+01

IRRADIANCE

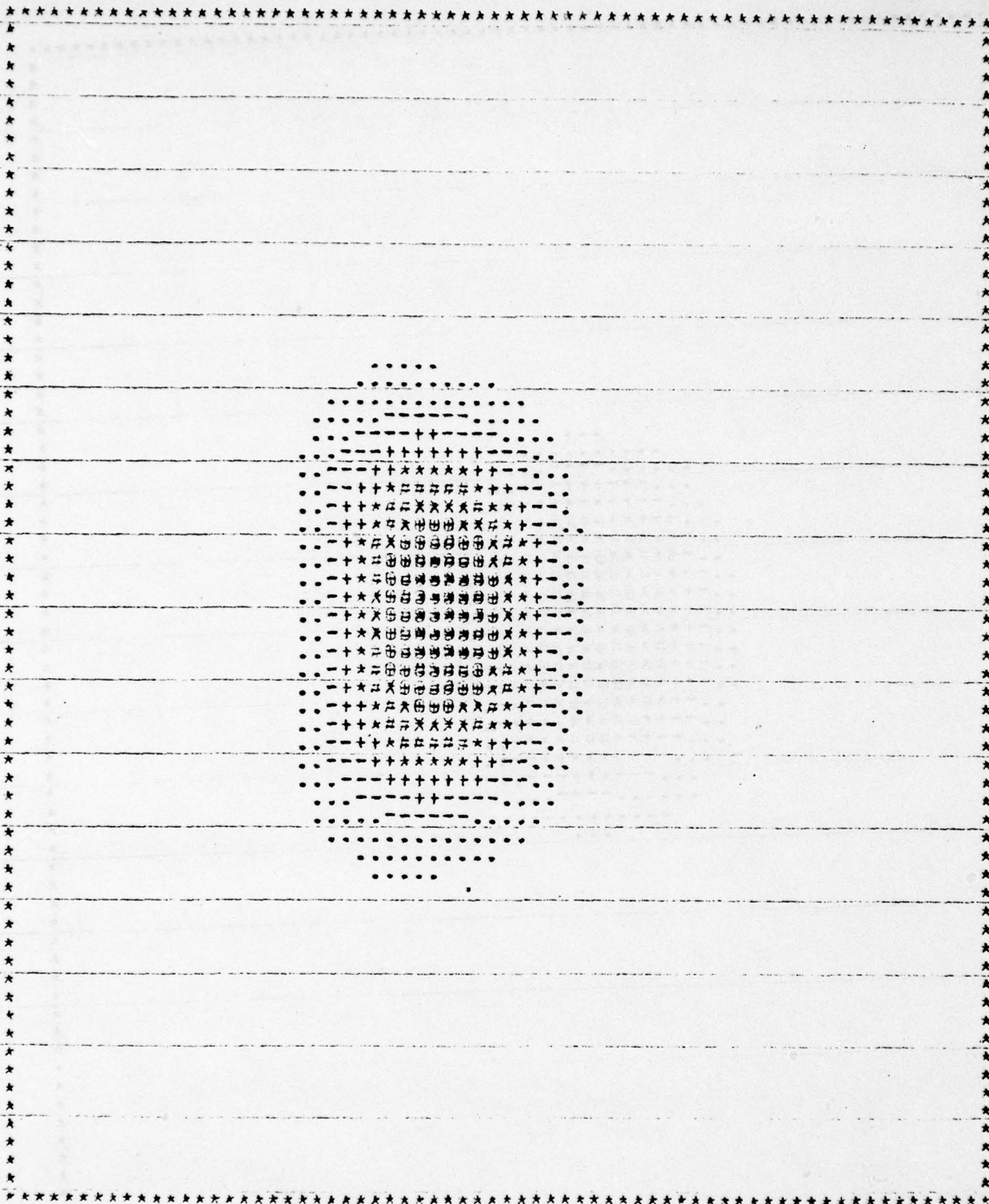


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.863345E-07	.131651E+00
.131651E+00	.263303E+00
.263303E+00	.394954E+00
.394954E+00	.526605E+00
.526605E+00	.658257E+00
.658257E+00	.789908E+00
.789908E+00	.921559E+00
.921559E+00	.105321E+01
.105321E+01	.118486E+01

IRRADIANCE

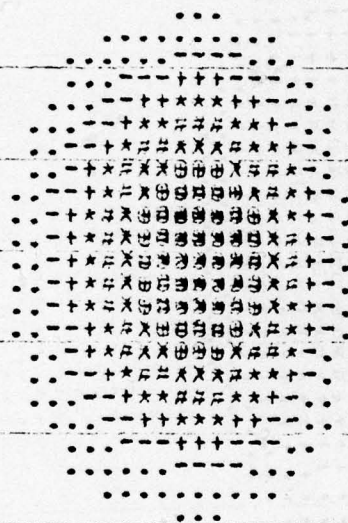


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

一
十
★
口
人
田
均
火

.990657E-07	.146420E+00
.146420E+00	.292840E+00
.292840E+00	.439259E+00
.439259E+00	.585679E+00
.585679E+00	.732099E+00
.732099E+00	.878519E+00
.878519E+00	.102494E+01
.102494E+01	.117136E+01
.117136E+01	.131770E+01
.131770E+01	

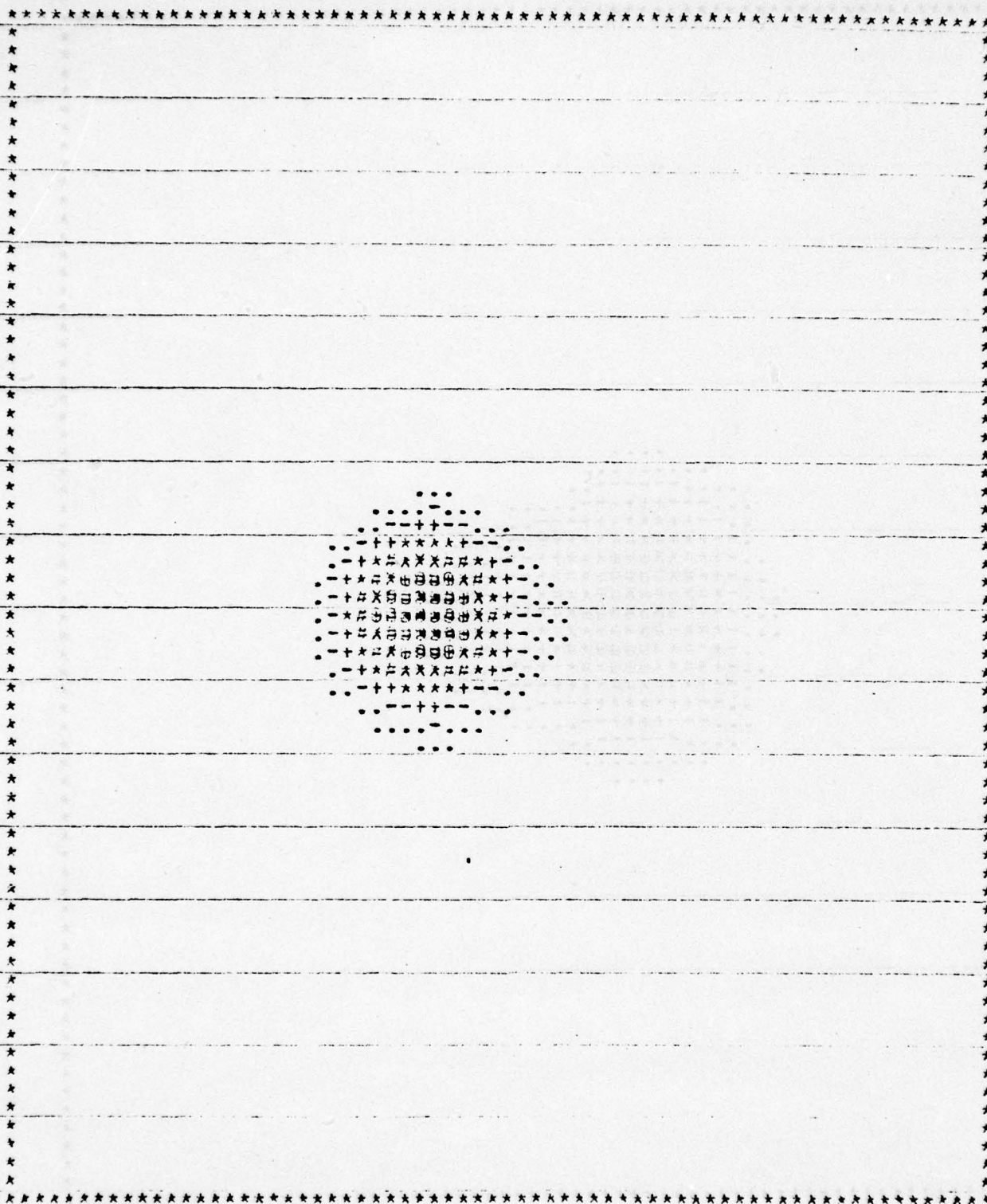


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.290271E-07	.203481E+00
+	.203481E+00	.405961E+00
*	.405961E+00	.610442E+00
+	.610442E+00	.815923E+00
*	.815923E+00	.101740E+01
+	.101740E+01	.122088E+01
*	.122088E+01	.142436E+01
+	.142436E+01	.162785E+01
*	.162785E+01	.183133E+01
+	.183133E+01	.203481E+01

IRRADIANCE

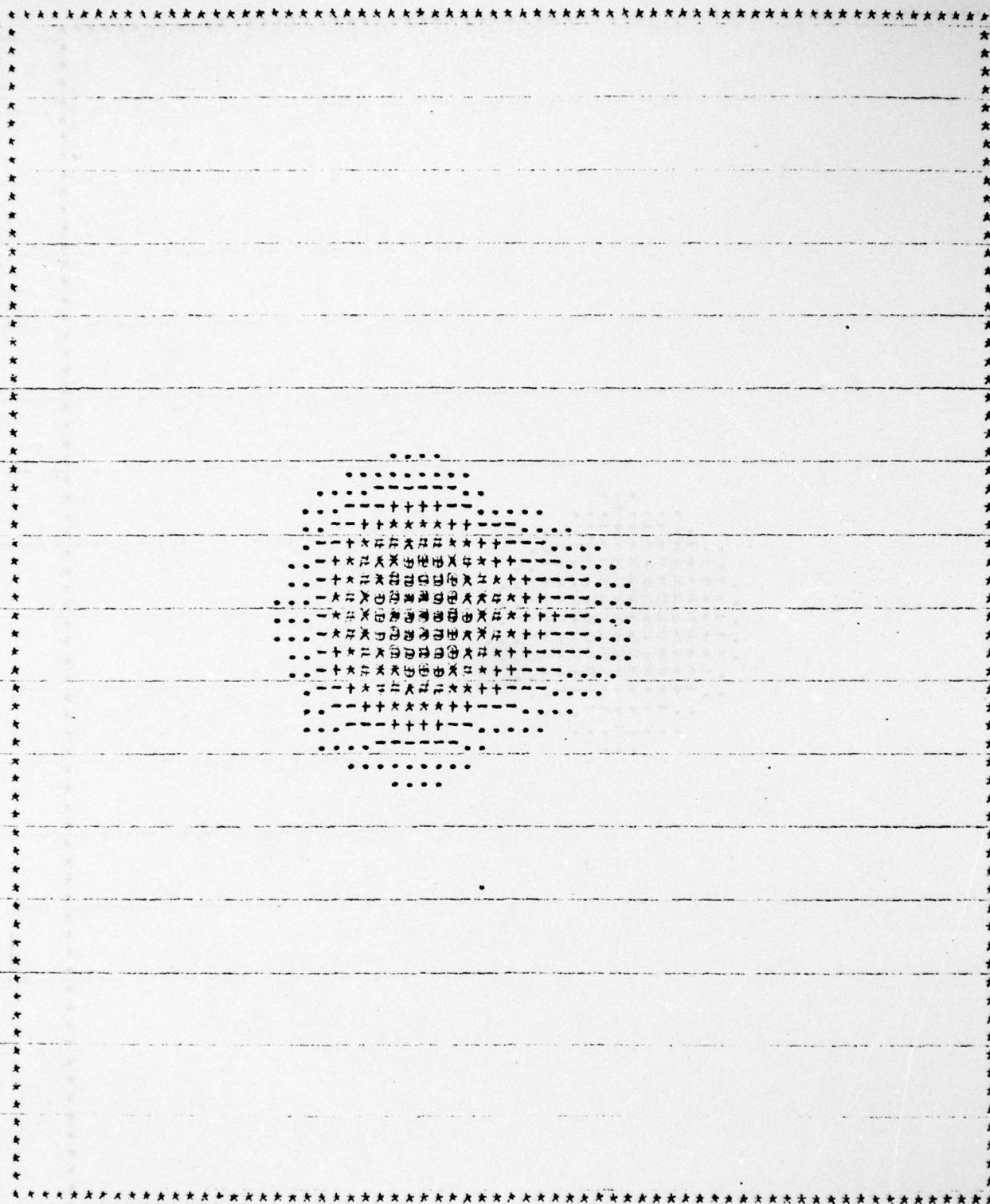


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.285086E+00		.370406E+00
+	.370406E+00		.740813E+00
*	.740813E+00		.111122E+01
x	.111122E+01		.148163E+01
#	.148163E+01		.185203E+01
\$	.185203E+01	- 61 -	.222244E+01
%	.222244E+01		.259284E+01
^	.259284E+01		.296325E+01

IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

·
+
*
X
B
B

.460035E-09	.236776E+00
.238776E+00	.477552E+00
.477552E+00	.716328E+00
.716328E+00	.955103E+00
.955103E+00	.119388E+01
.119388E+01	.143266E+01
.143266E+01	.167143E+01
.167143E+01	.191021E+01
.191021E+01	.214898E+01
.214898E+01	.238776E+01

Appendix B Fiber Taper



SOFAULT

LAMBDA = .8E+00,

RO = .5E+02,

FR = .5E+02,

NU = .15E+01,

PCCRP = .81E-03,

OUTRAD = .1E+04,

DX = .3E+01,

NSTEPS = 40,

NDZINC = 40,

IOUT = 6,

IGREY = 6,

PGREY = T,

PWAIST = T,

PLTGST = F,

PLTMAX = F,

PLTFLO = F,

PLTFLE = F,

MESH = 128,

SEND

ZMIN = 19513.3742 MICRONS

DZINC = 487.8344 MICRONS

RN2NG = .648E-08 MICRONS**(-2)

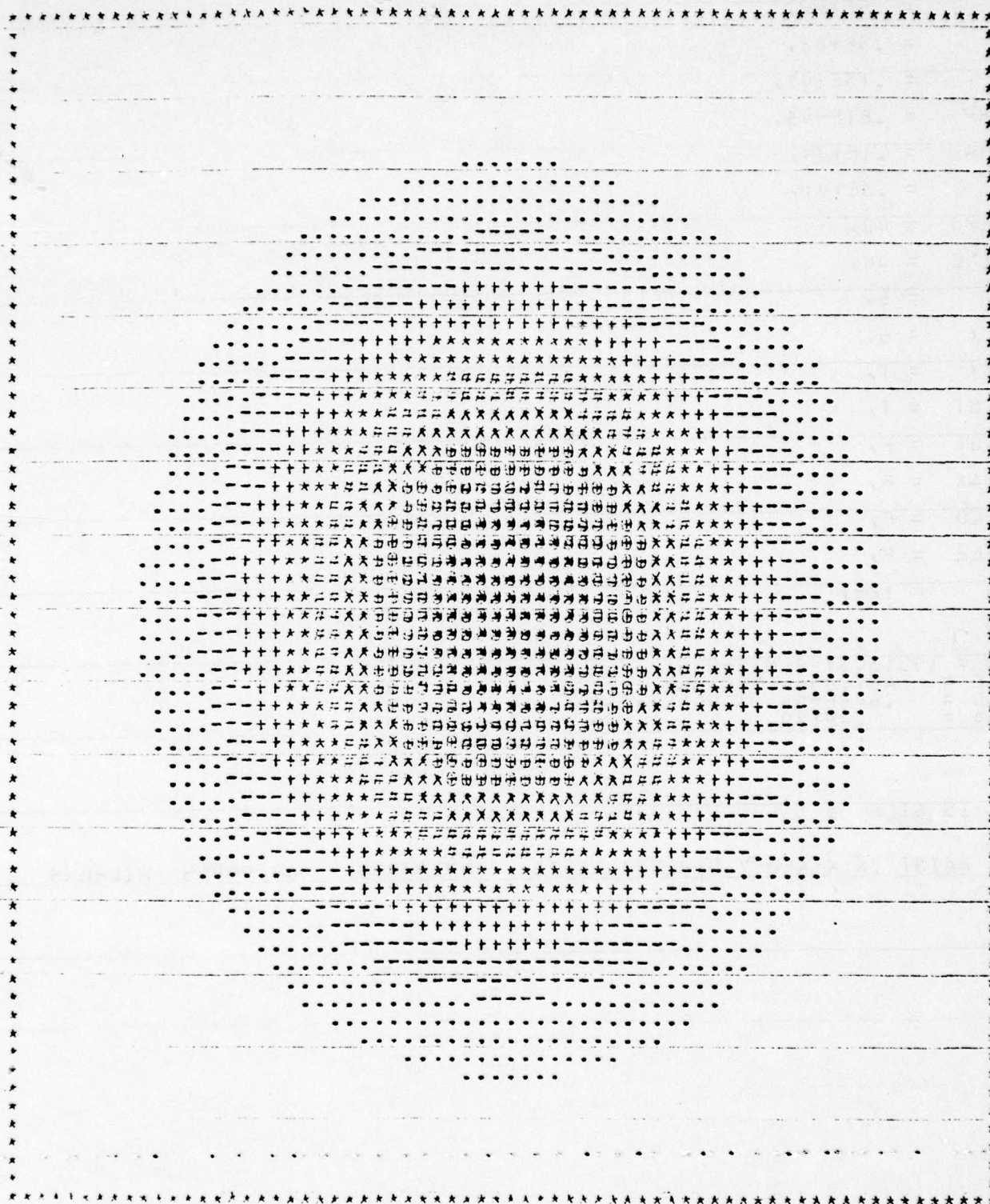
ALPHA = .42179

50.

THIS IS STEP 0

BEAM WAIST IN X AND Y DIRECTIONS IS 49.99995 49.99995 MICRONS

IRRADIANCE

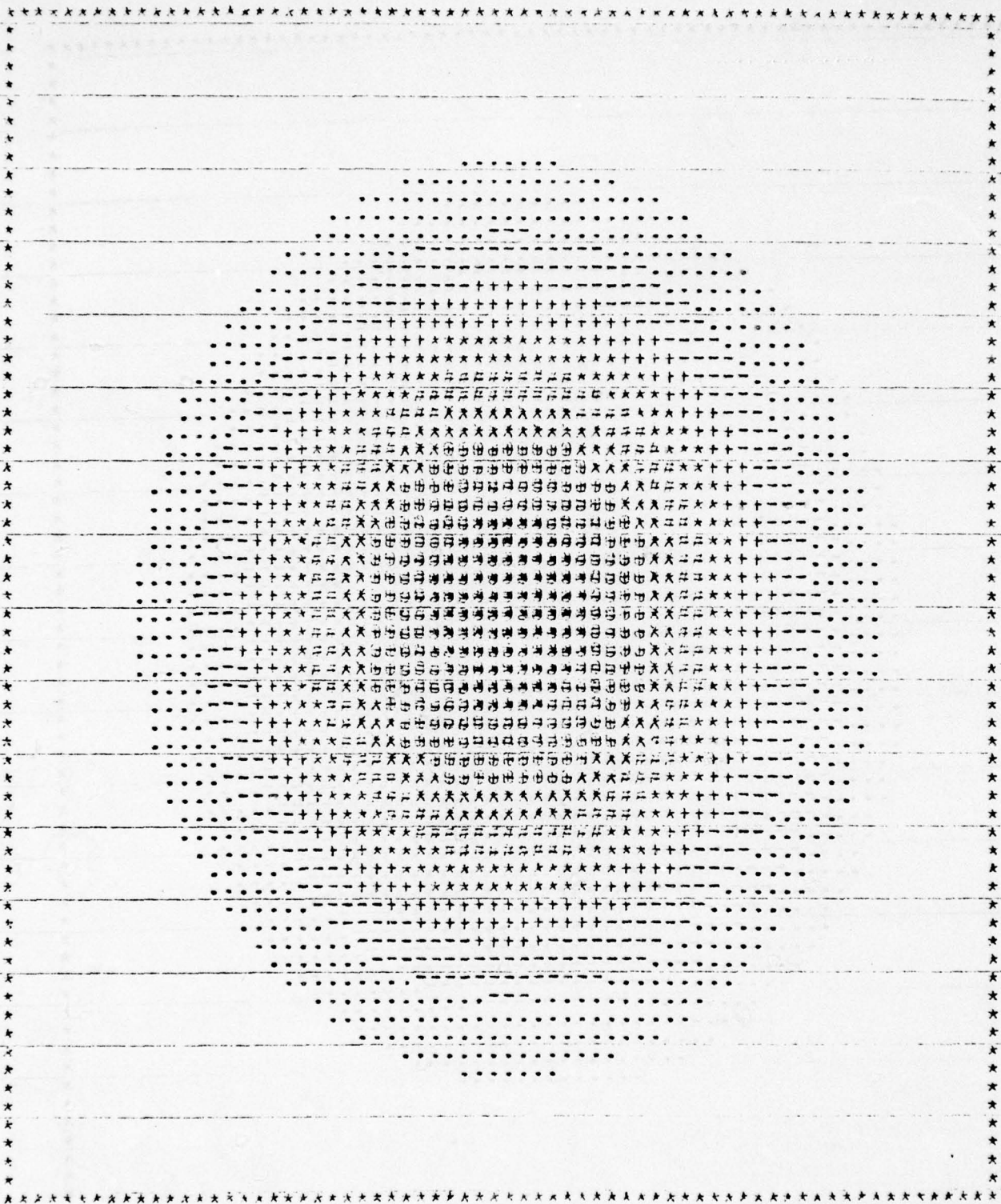


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.020107E+03	.100505E+00
+	.100505E+00	.200502E+00
+	.200502E+00	.300410E+00
+	.300410E+00	.400377E+00
+	.400377E+00	.500314E+00
+	.500314E+00	.600251E+00
+	.600251E+00	.700188E+00
+	.700188E+00	.800125E+00
+	.800125E+00	.900062E+00

IRRADIANCE



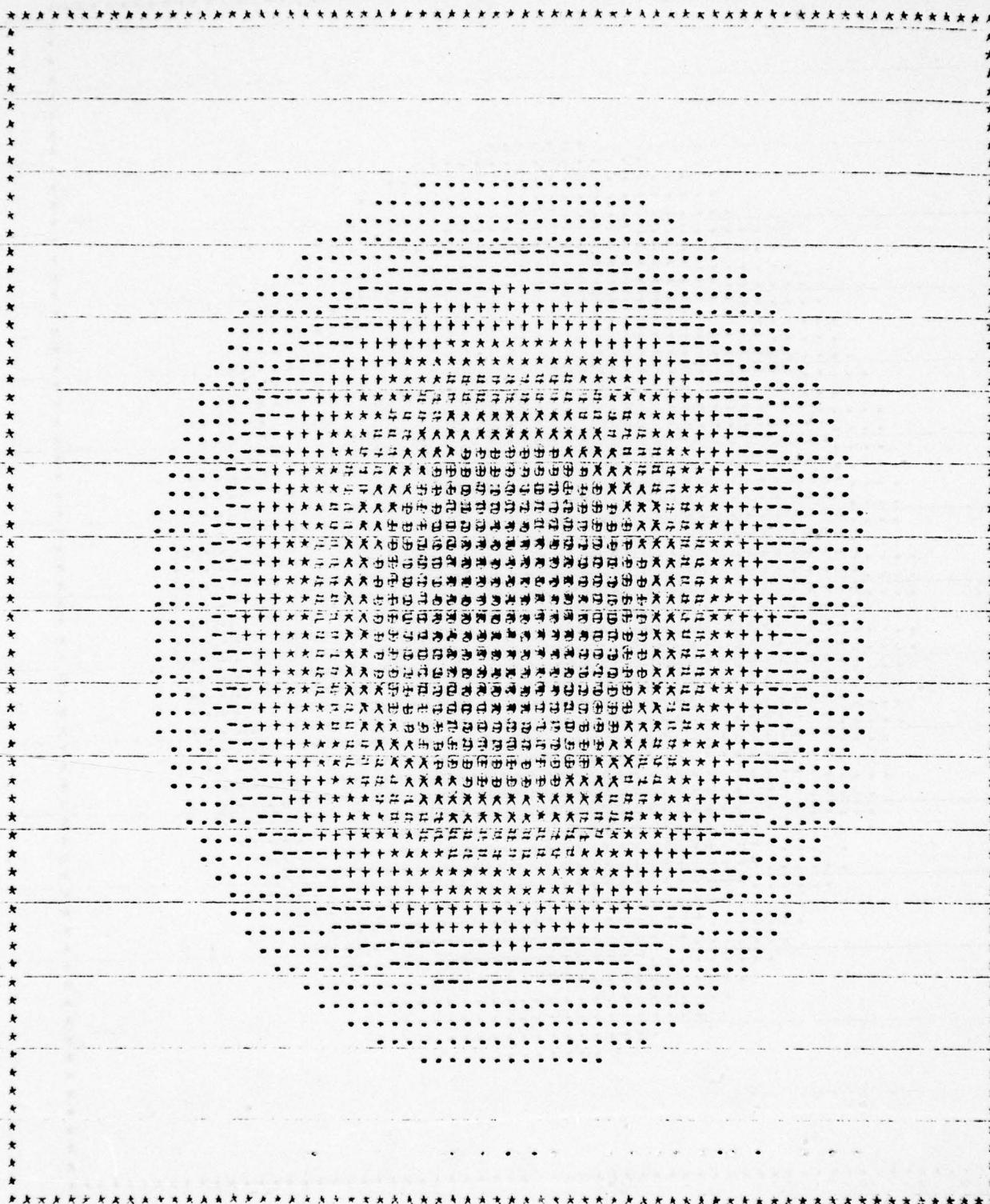
IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.0055862E+03	.101110E+00
+	.101110E+00	.201615E+00
=	.201615E+00	.302119E+00
*	.302119E+00	.402624E+00
*	.402624E+00	.503128E+00
*	.503128E+00	.603633E+00
*	.603633E+00	.704137E+00
*	.704137E+00	.804642E+00
*	.804642E+00	.905146E+00

- 67 -

IRRADIANCE

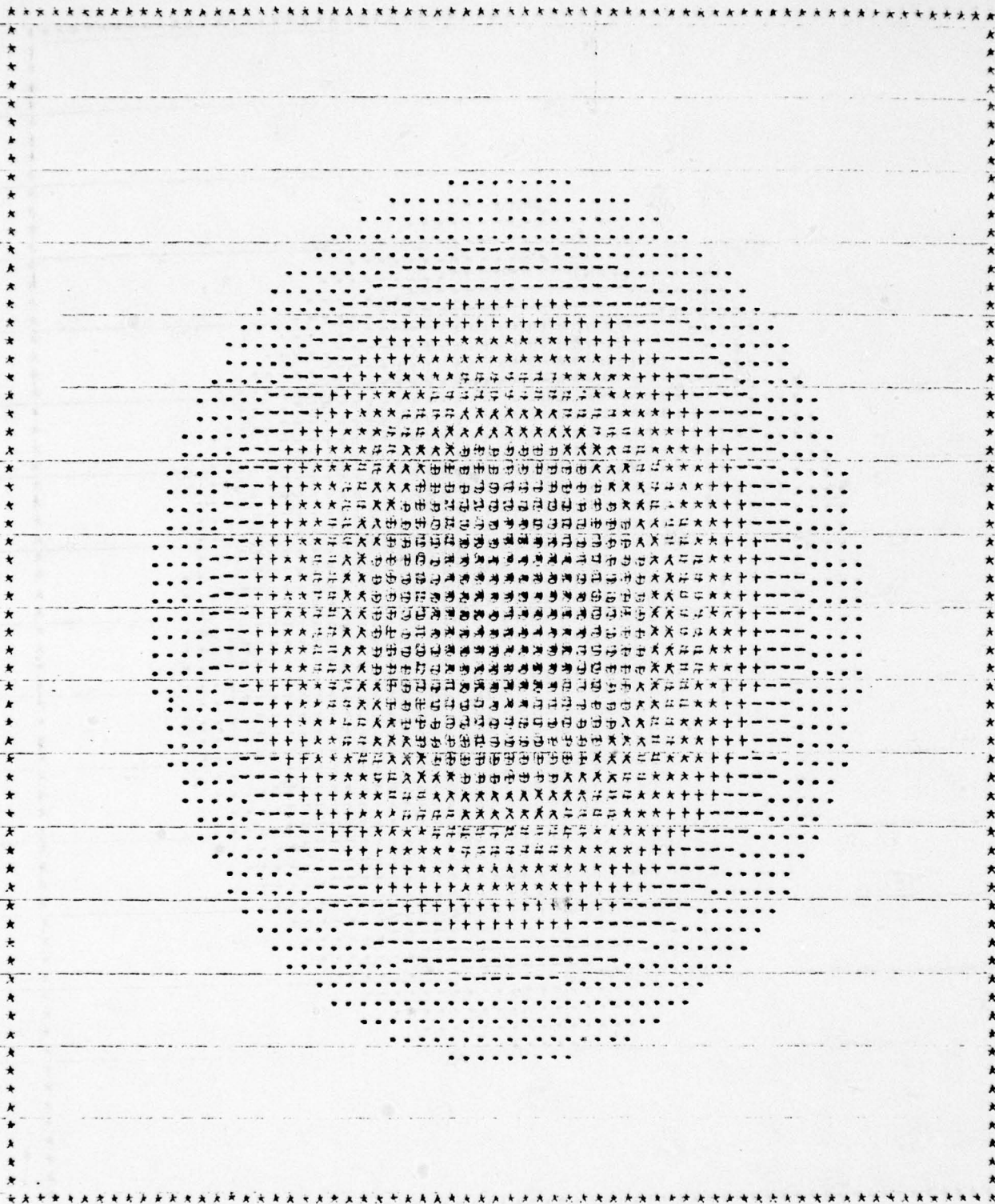


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.526300E+03	.103200E+00
-	.103200E+00	.295671E+00
+	.295671E+00	.308542E+00
*	.308542E+00	.411214E+00
x	.411214E+00	.513835E+00
=	.513835E+00	.615556E+00
A	.615556E+00	.717227E+00
B	.717227E+00	.821898E+00
	.821898E+00	.924569E+00

IRRADIANCE



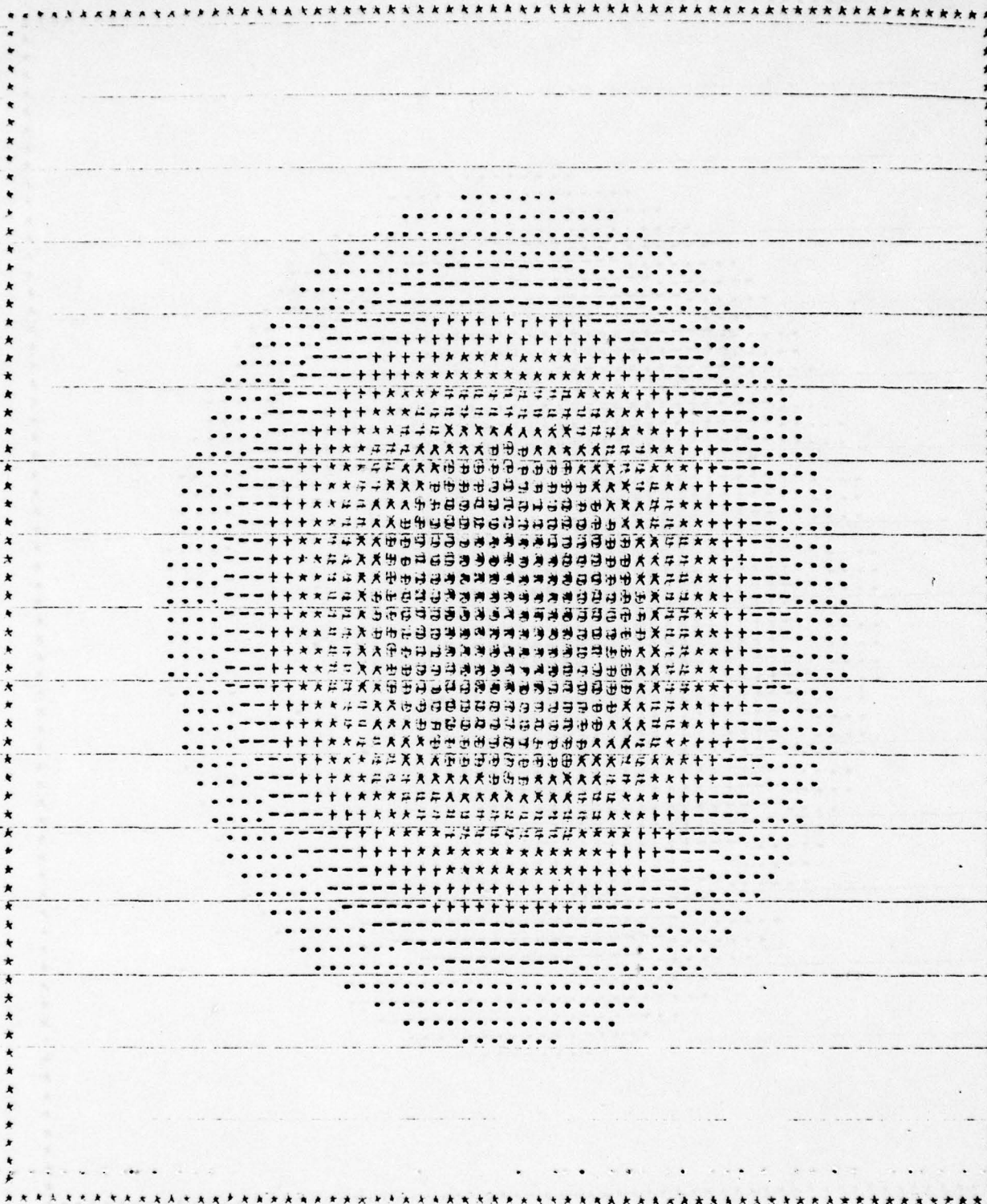
IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.584330E+03	.108001E+00
+	.108001E+00	.215617E+00
*	.215617E+00	.323233E+00
x	.323233E+00	.430849E+00
e	.430849E+00	.538465E+00
	.538465E+00	.646081E+00
	.646081E+00	.753697E+00
	.753697E+00	.861314E+00
	.861314E+00	

= 69

IRRADIANCE

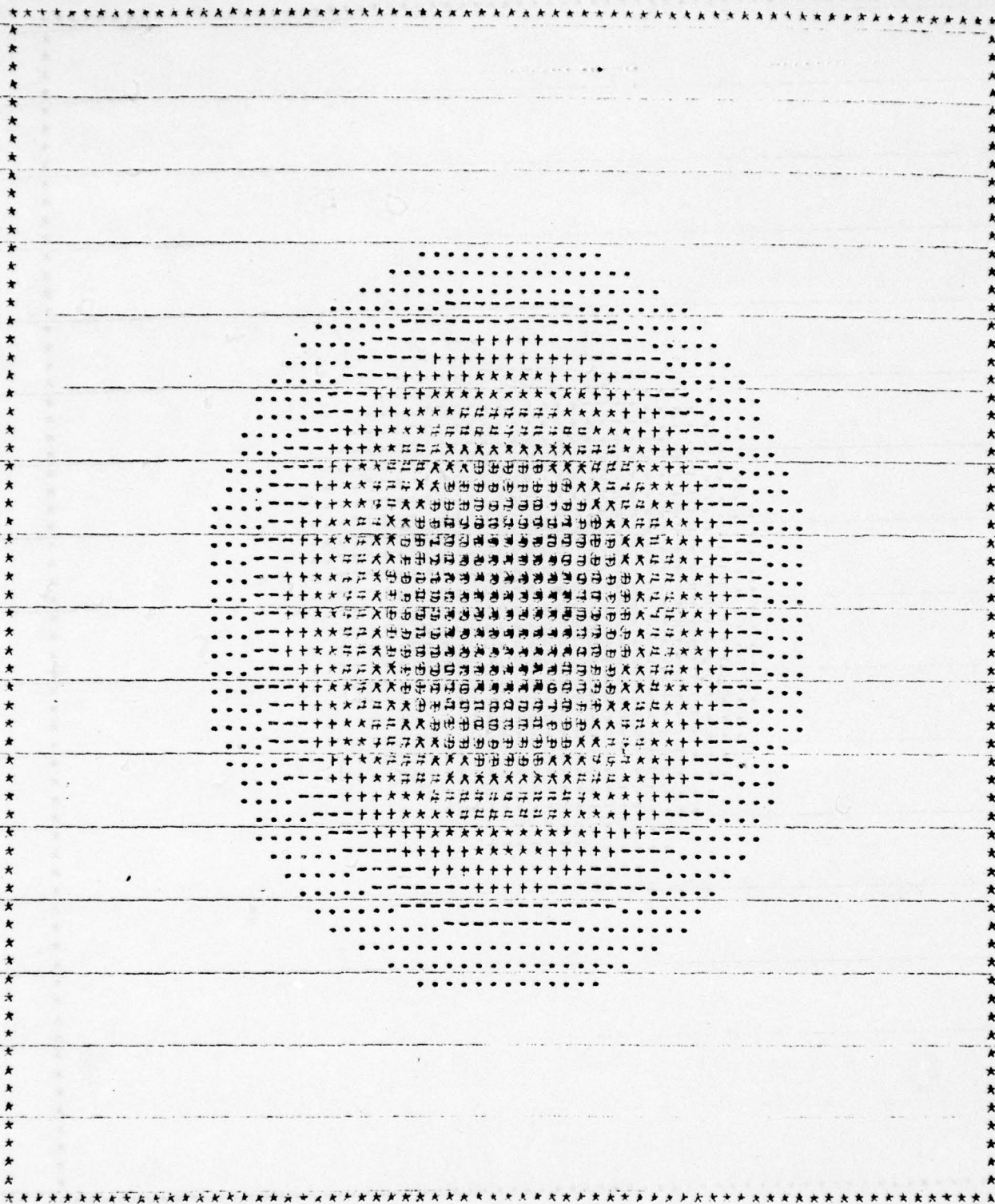


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

•	.192622E+03	.116466E+00
+	.116466E+00	.256749E+00
*	.256749E+00	.555013E+00
•	.555013E+00	.475287E+00
+	.475287E+00	.591560E+00
*	.591560E+00	.769834E+00
•	.769834E+00	.826107E+00
+	.826107E+00	.946361E+00
*	.946361E+00	.105455E+01
•	.105455E+01	

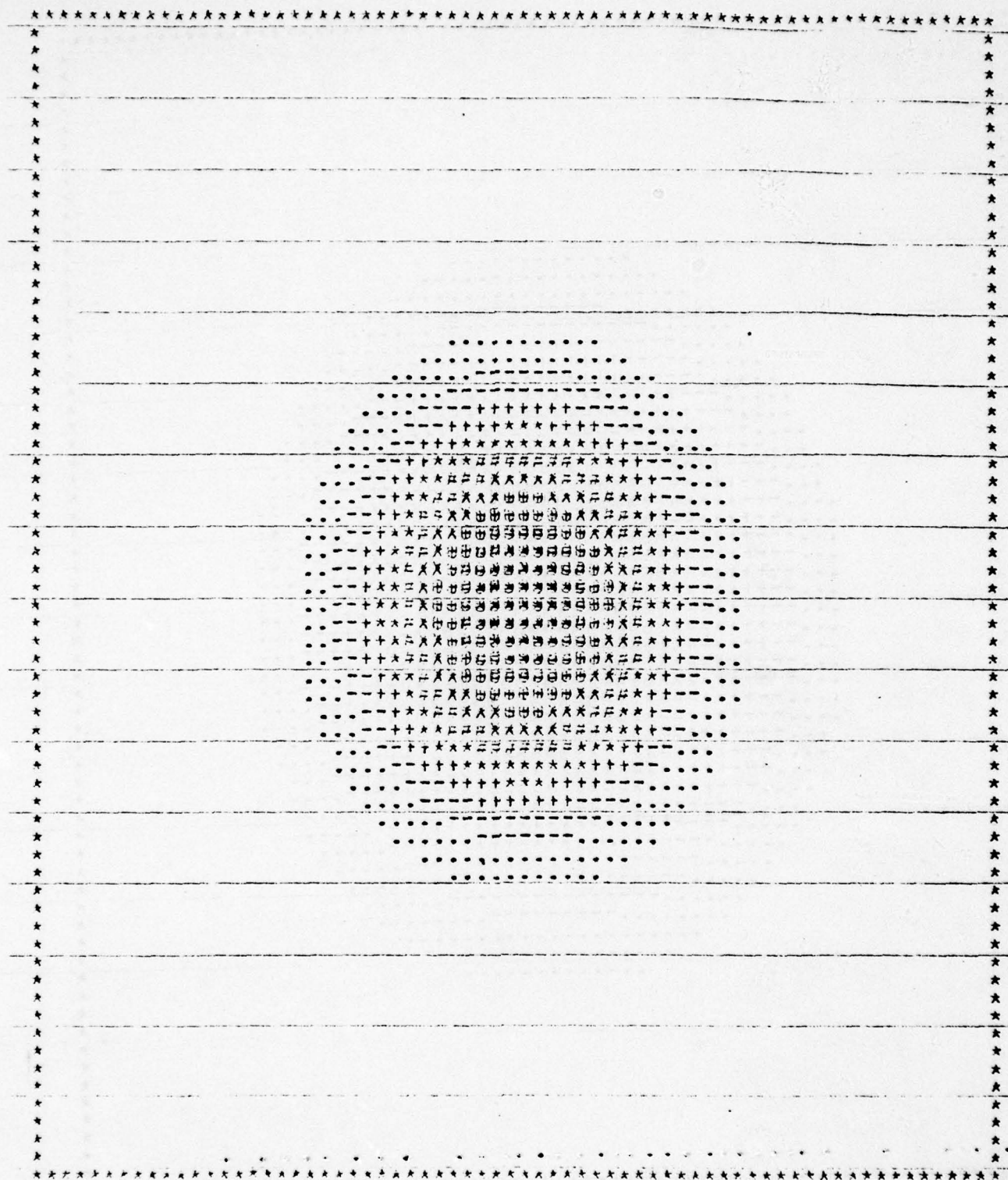
IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.325035E+04	.145203E+00
+	.145203E+00	.290494E+00
*	.290494E+00	.435725E+00
*	.435725E+00	.580956E+00
*	.580956E+00	.726167E+00
*	.726167E+00	.871418E+00
*	.871418E+00	.101605E+01
*	.101605E+01	.116188E+01
*	.116188E+01	.130711E+01

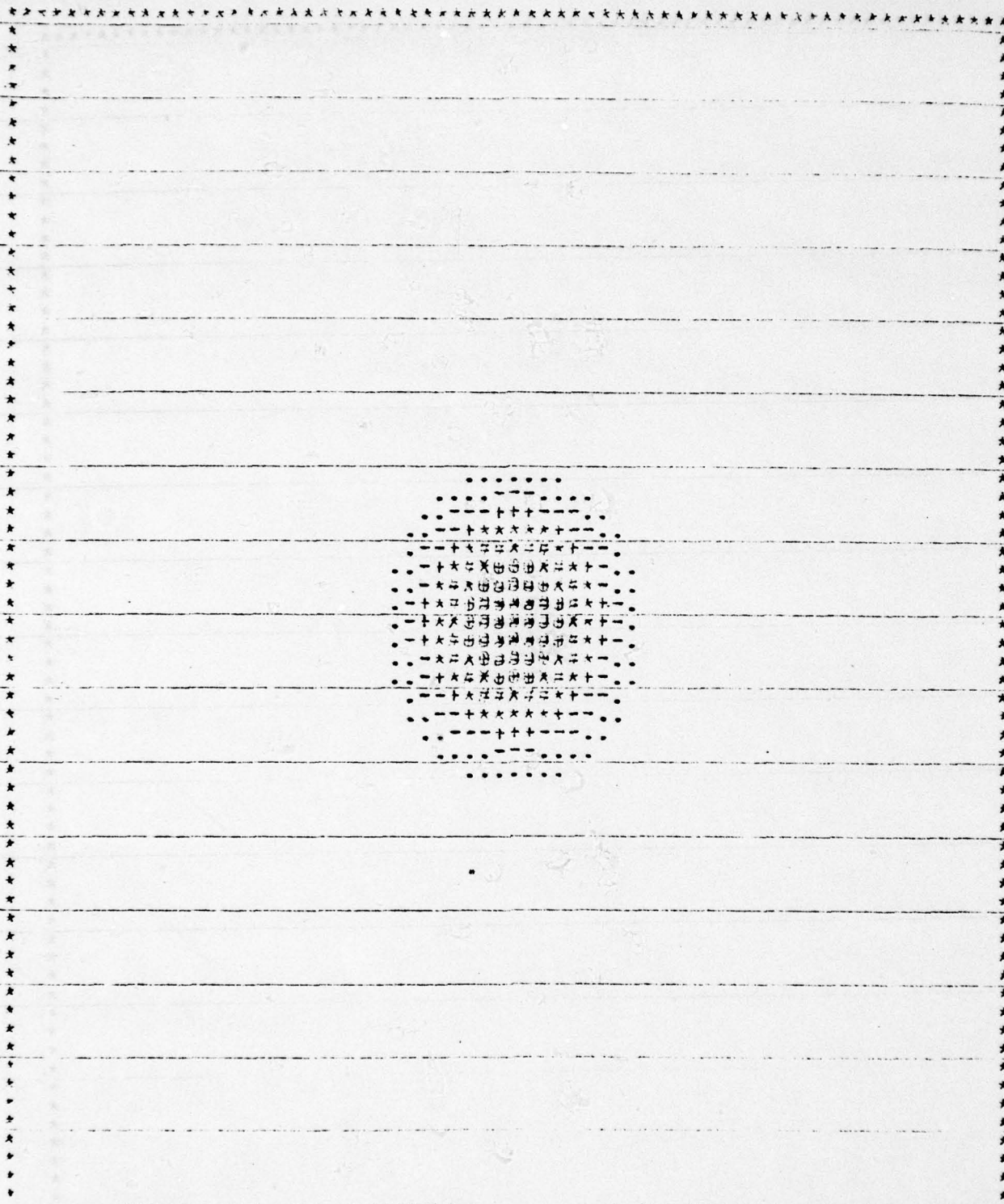


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

•	.239586E+07	.250055E+00
•	.250055E+00	.500110E+00
•	.500110E+00	.750164E+00
•	.750164E+00	.100022E+01
•	.100022E+01	.125027E+01
•	.125027E+01	.150033E+01
•	.150033E+01	.175038E+01
•	.175038E+01	.200044E+01
•	.200044E+01	.225049E+01
•	.225049E+01	.250055E+01

IRRADIANCE

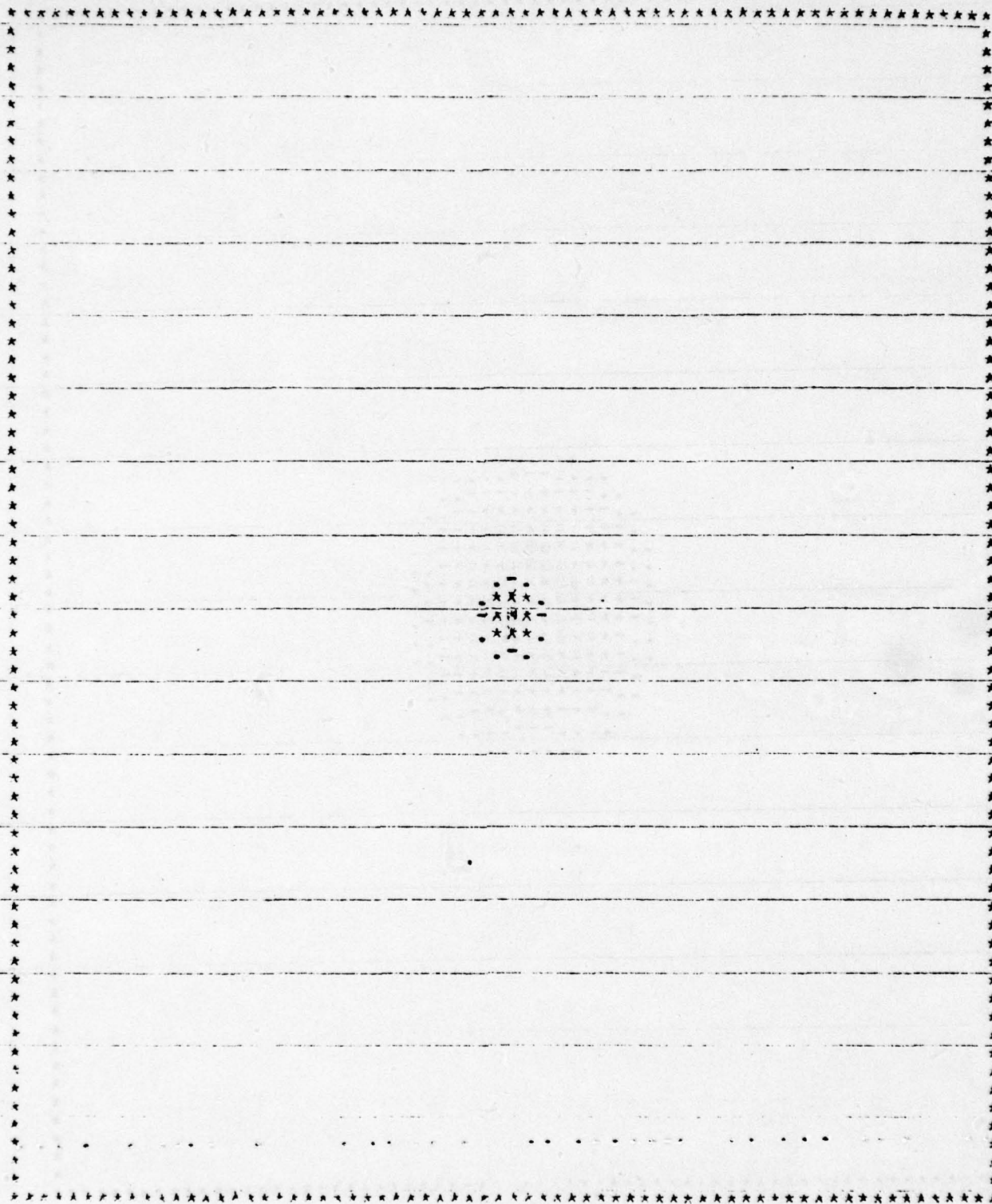


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

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	.840708E+00		.159358E+01
	.159358E+01		.254037E+01
	.254037E+01		.335715E+01
	.335715E+01		.423394E+01
	.423394E+01	- 73 -	.505073E+01
	.505073E+01		.592752E+01
	.592752E+01		

IRRADIANCE

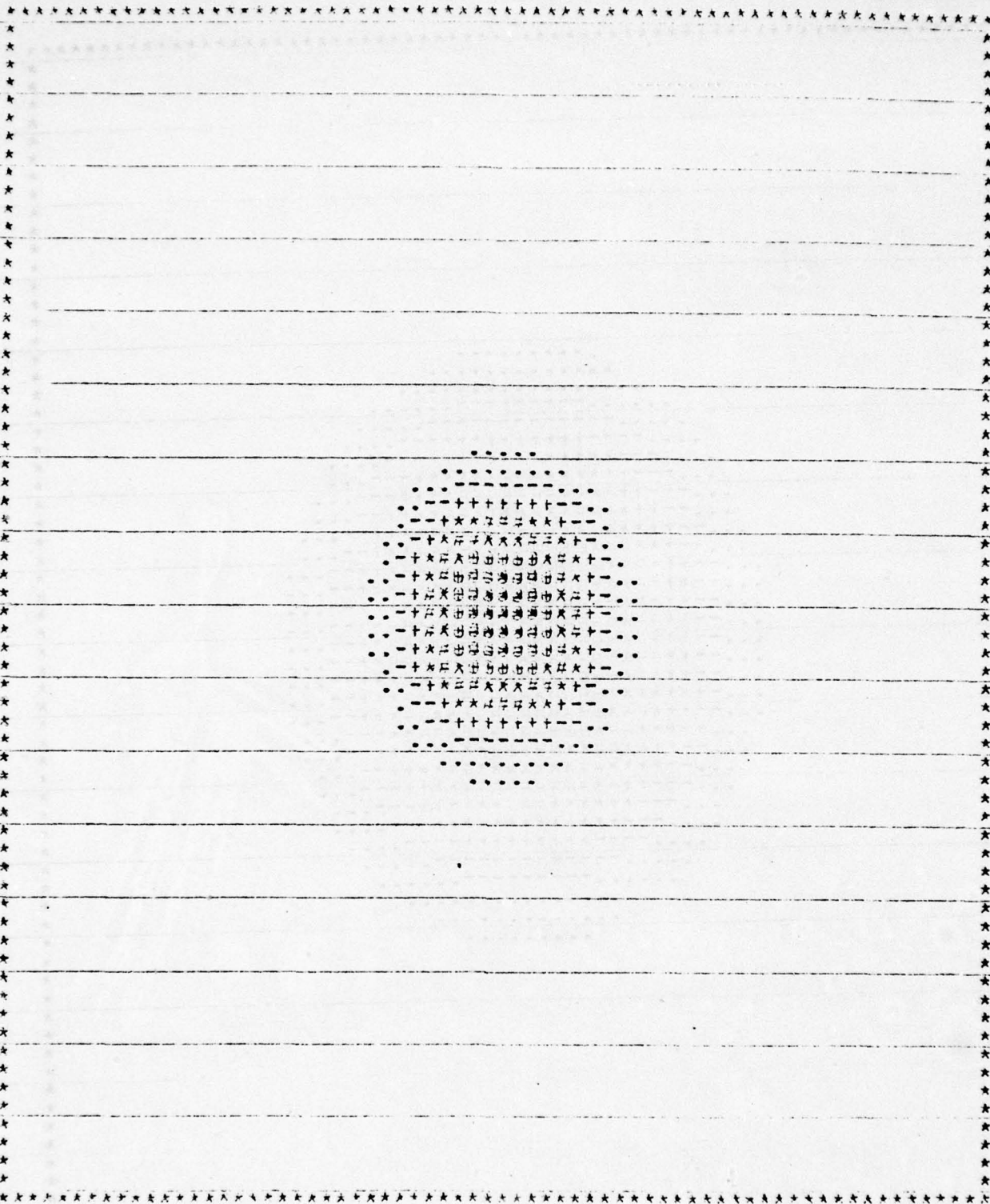


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

•	.249612E-16	.110759E+02
•	.110759E+02	.221478E+02
•	.221478E+02	.332217E+02
•	.332217E+02	.442957E+02
•	.442957E+02	.553696E+02
•	.553696E+02	.664435E+02
•	.664435E+02	.775174E+02
•	.775174E+02	.885913E+02
•	.885913E+02	.996652E+02

IRRADIANCE

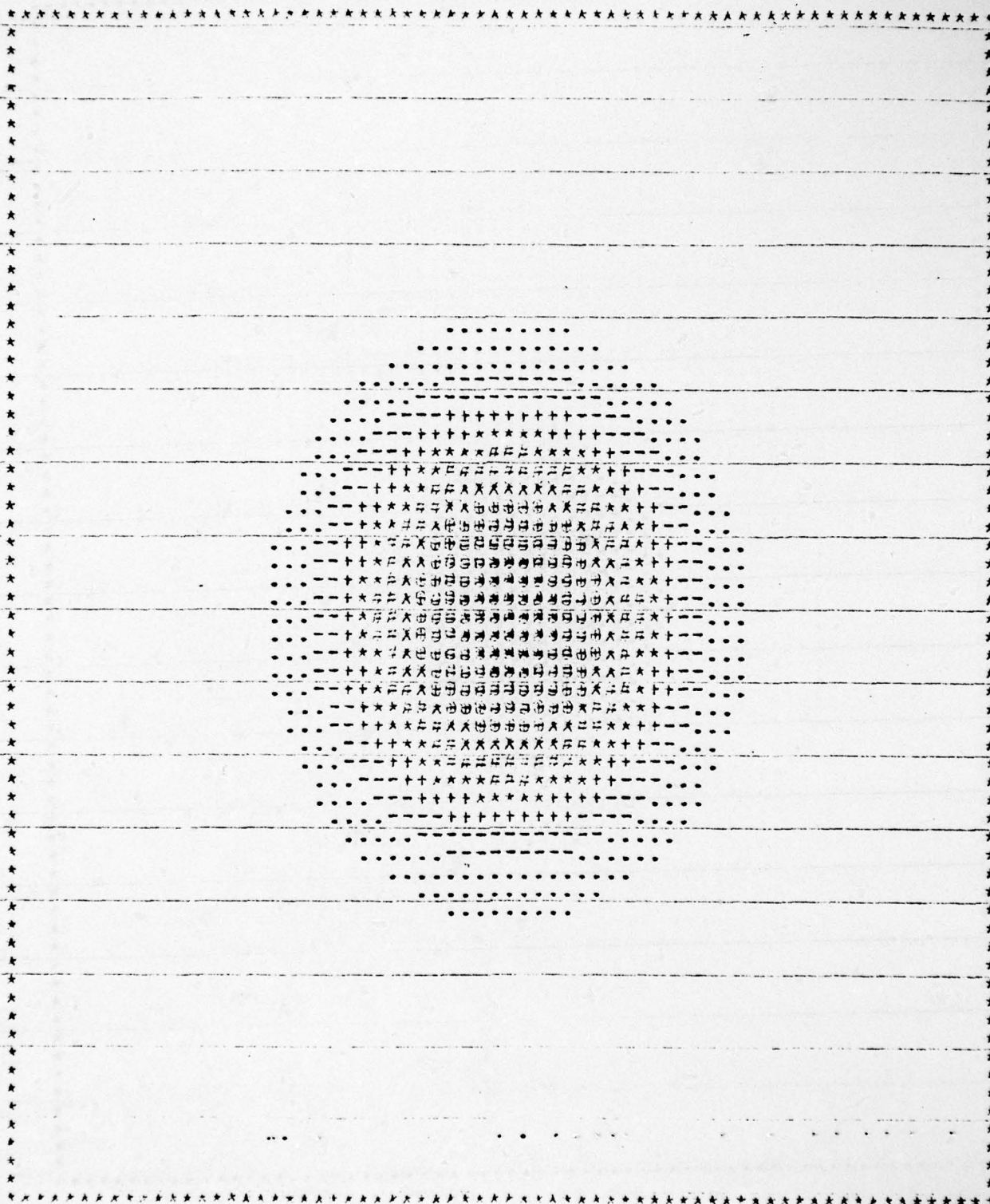


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

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.730691E+00	.146138E+01
.146138E+01	.219297E+01
.219297E+01	.292277E+01
.292277E+01	.365346E+01
.365346E+01	.438415E+01
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.511484E+01	.584553E+01
.584553E+01	.657622E+01

IRRADIANCE

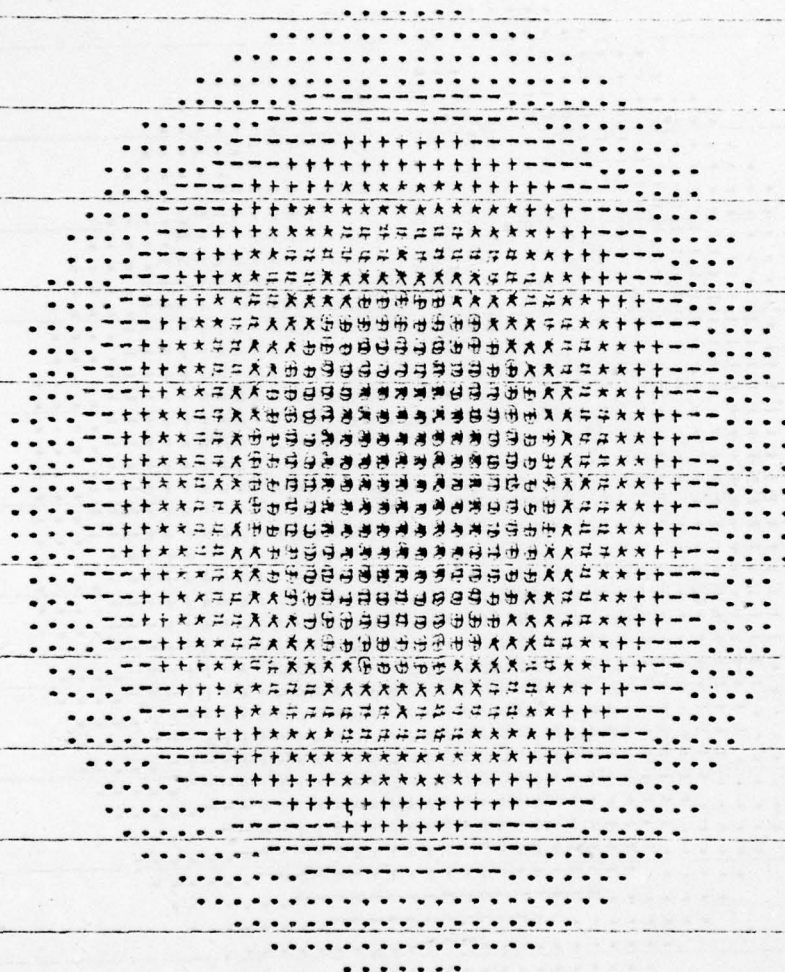


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

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+	.234518E+00	.467036E+00
*	.467036E+00	.705554E+00
*	.705554E+00	.938072E+00
*	.938072E+00	.117259E+01
*	.117259E+01	.140711E+01
*	.140711E+01	.164163E+01
*	.164163E+01	.187614E+01
*	.187614E+01	.211065E+01

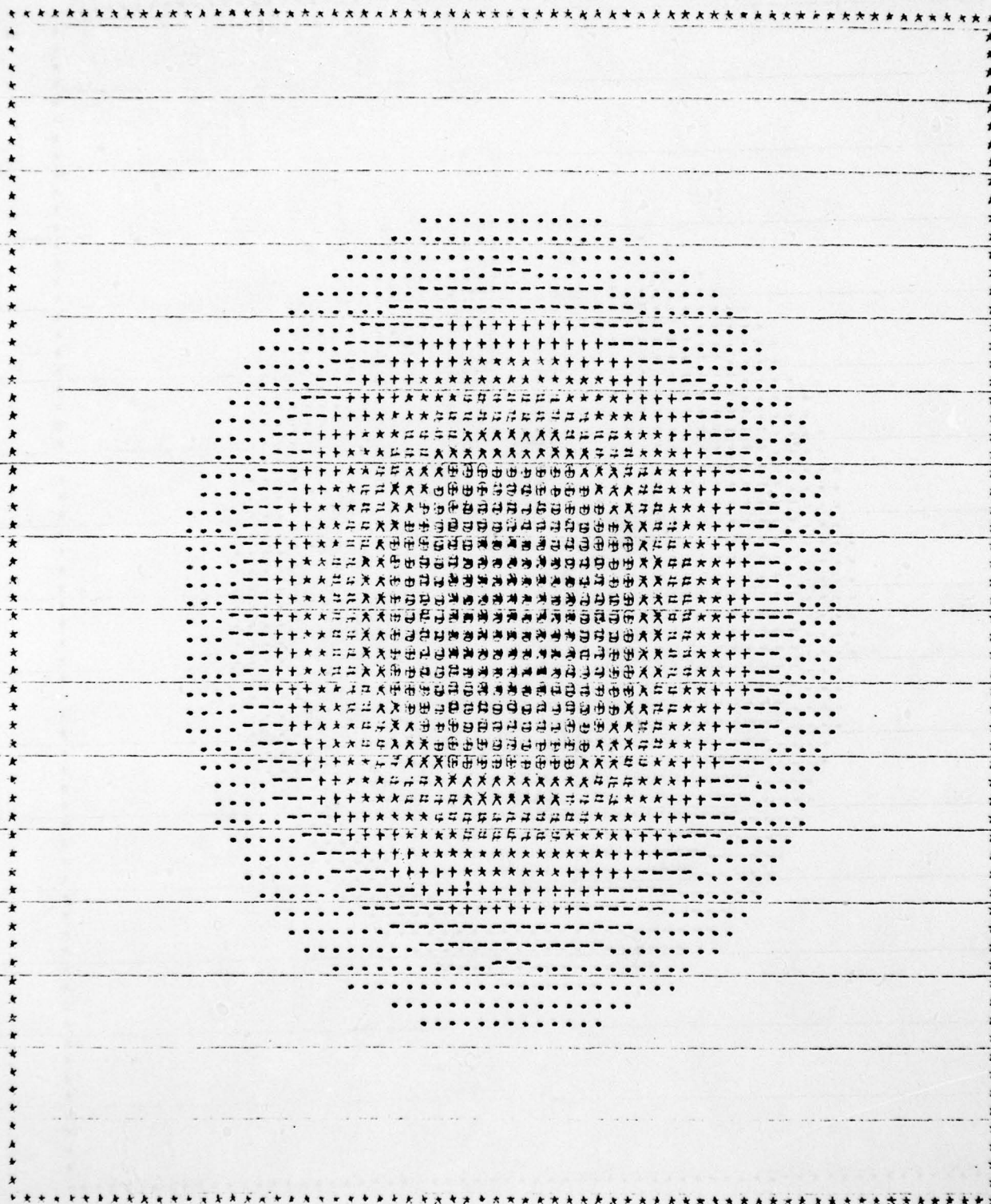
IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.415870E-00	.141307E+00
+	.141307E+00	.282692E+00
x	.282692E+00	.424017E+00
x	.424017E+00	.565342E+00
x	.565342E+00	.706667E+00
2	.706667E+00	.847992E+00
x	.847992E+00	.989317E+00
x	.989317E+00	.113004E+01
2	.113004E+01	.127197E+01
2	.127197E+01	

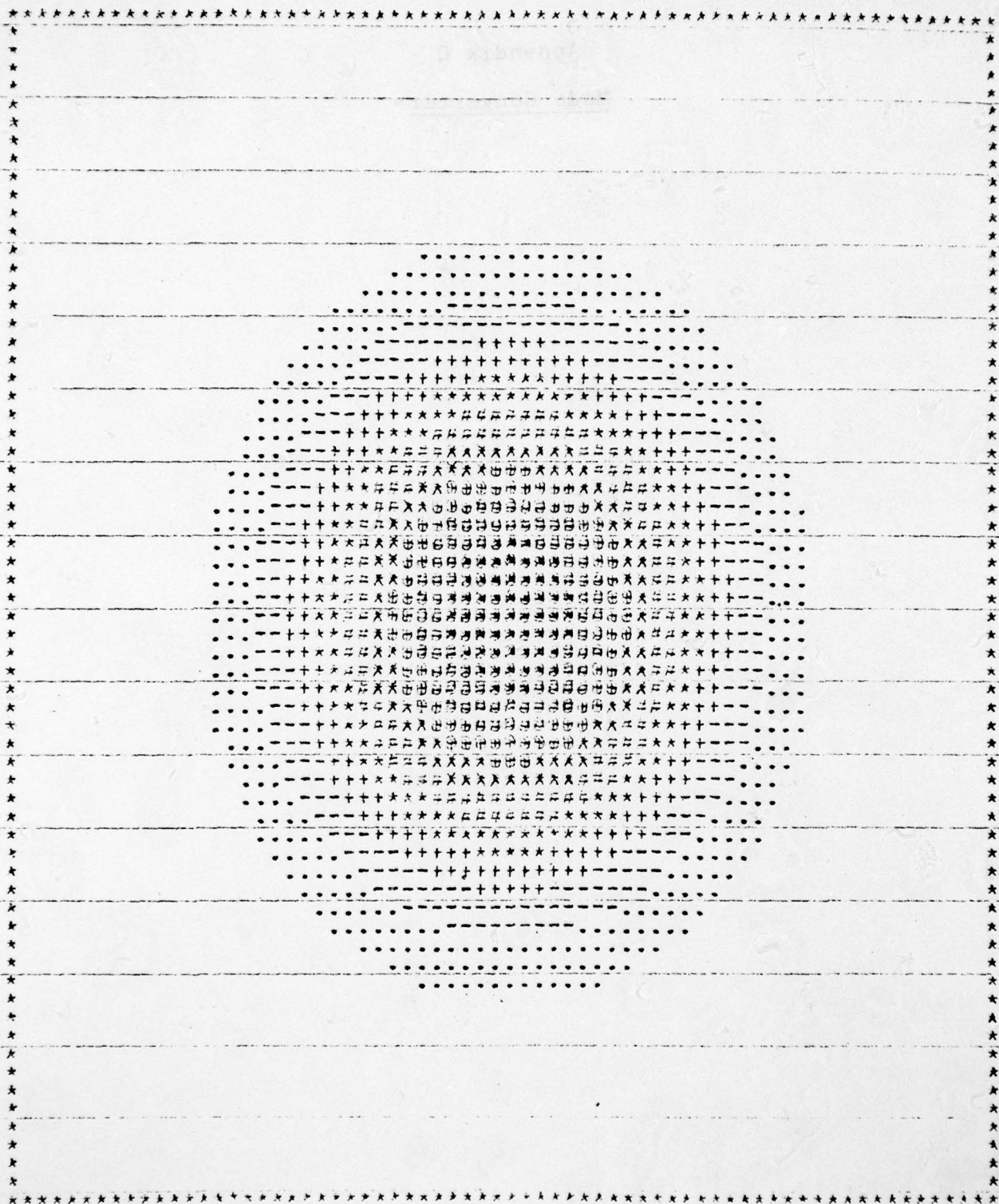


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

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+	.122854E+00	.245562E+00
+	.245562E+00	.368270E+00
+	.368270E+00	.490978E+00
+	.490978E+00	.613686E+00
+	.613686E+00	.736394E+00
+	.736394E+00	.859103E+00
+	.859103E+00	.981811E+00
+	.981811E+00	.110452E+01
+	.110452E+01	.122723E+01

IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.314935E+04	.145895E+00
.145895E+00	.291750E+00
.291750E+00	.437623E+00
.437623E+00	.583487E+00
.583487E+00	.729351E+00
.729351E+00	.875215E+00
.875215E+00	.102106E+01
.102106E+01	.116694E+01
.116694E+01	.131282E+01

Appendix C
Mode Converter

- 81 -

```

C
C
C      CALCULATE CONSTANTS
      MESH2=2*MESH
      MESH3Q=MESH**2
      MSHSQ2=2*MESH3Q
      RN2NU=.02*PCURP/FR**2
      ZMIN=PI/(2.*SQRT(RN2NU))
      DZINC=ZMIN/NOZINC
      DASI=DZINC/ZMIN
      DXSI=DXSI/2.
      DZET=DX/R0
      WAVENM=2.*PI/LAMBDA
      DETANT=(2.*ZMIN*DXSI/(WAVENM*NO))*(PI/(MESH*DZET*RU))**2
      FICNST=(1.-1./MESH)*PI
      XYU=MESH/2.
      RADNRN=(CUTRAD/R0)**2
      RNORM=1./MESH3Q
      R2=NO*RN2NU
      REFCF=R2*RU**2/2.
      ALPHA=2.*ZMIN/(PI*WAVENM*NO*RU**2)
      NOSQ=NO**2
      MU(1)=MESH
      MU(2)=MESH
      XSIMUL=DASI
      LAST=.F.
      IF (FLAG.LT.0.) REFCF=0.
      CALLPR=PGREY.UR.PNAIST.OR.PLTWST.OR.PLTMAX.OR.PLTFLD.OR.PLTFLC
C
C      WRITE THE IMPORTANT CALCULATED PARAMETERS
      WRITE(1000,2000) ZMIN,DZINC,RN2NU,ALPHA
2000  FORMAT(/,9H ZMIN = ,F10.4,1X,7HMICRONS,/,9H DZINC = ,F10.4,1X,
+ 7HMICRONS,/,9H RN2NU = ,E10.3,1X,13HMICRONS**(-2),/,
+ 9H ALPHA = ,F10.5,/)
C
C      CALCULATE NECESSARY ARRAYS
      DO 100 K=1,MESH
      RK=K-1
      ARG=FICNST*RK
      CS(K)=COS(ARG)
      SN(K)=SIN(ARG)
      ZISQ(K)=((RK-XYU)*DZET)**2
      POSQ(K)=(RK-XYU+.5)**2
100  CONTINUE
C
C      SET UP REFRACTIVE INDEX ARRAY
      IF (MESH.NE.128) GO TO 10
      MS=MESH/4+1
      MF=MS+MESH/2-1
      NS=MS
      NF=MF
      GO TO 40
10  CONTINUE
      MS=1

```



```

C
C
C
40  NS=1
    MF=MESH
    NF=MESH
    CONTINUE
    CALL RINDEX(DSPX,DSPY,NOSJ,DZET,XYO,REFCF,1)

C
C
C    SET UP INITIAL FIELD

    M=-1
    K=0
    CH=WAVENM*ZMIN*DKSIH/(2.*NO)
    DO 140 J=1,MESH
      Z1=ZISG(J)
      DO 140 I=1,MESH
        K=K+1
        M=M+2
        MP1=M+1
        Z2=ZISG(I)
        RAD=Z1+Z2
        IF(RAD.GT.RADMRM) GO TO 20
        AMP=EXP(-RAD/2.)
        ARG=CH*REFNDX(K)
        V(M)=AMP*COS(ARG)
        V(MP1)=AMP*SIN(ARG)
      GO TO 140
    CONTINUE
    V(M)=0.
    V(MP1)=0.
20  CONTINUE
140 IF(CALLPR) CALL PRINTER(ICNT)

C
C
C    DO PROPAGATION

    DO 500 ICNT=1,NSTEPS

C
C
C    CONDITION V FOR TRANSFORM

    K=-1
    DO 160 J=1,MESH
      SNJ=SN(J)
      CSJ=CS(J)
      DO 160 I=1,MESH
        K=K+2
        KP1=K+1
        SNI=SN(I)
        CSI=CS(I)
        AR=CSJ*CSI-SNJ*SNI
        AI=-(CSJ*SNI+CSI*SNJ)
        VR=V(K)
        VI=V(KP1)
        V(K)=VR*AR-VI*AI
        V(KP1)=VI*AR+VR*AI
      CONTINUE
160 DO TRANSFORM

C
C
C    CALL FOURT(V,MU,2,1,1,WORK)

```

[illegible]

```

C SOLVE FIRST ORDER ODE
C
K=-1
DO 180 J=1,MESH
PHI1=BETAH1*PQSQ(J)
DO 180 I=1,MESH
K=K+2
KP1=K+1
PHI2=BETAHT*PQSQ(I)
VR=V(K)
VI=V(KP1)
ANG=-(PHI1+PHI2)
CANG=COS(ANG)
SANG=SIN(ANG)
V(K)=(VR*CANG-VI*SANG)*RNORM
V(KP1)=(VR*SANG+VI*CANG)*RNORM
180 CONTINUE

DO INVERSE TRANSFORM

CALL FOURT(V,MU,2,-1,1,WORK)

RECONDITION V BECAUSE OF TRANSFORM

K=-1
DO 200 J=1,MESH
SNJ=SN(J)
CSJ=CS(J)
DO 200 I=1,MESH
K=K+2
KP1=K+1
SNI=SN(I)
CSI=CS(I)
AR=CSJ*CSI-SNJ*SNI
AI=CSJ*SNI+SNJ*CSI
VR=V(K)
VI=V(KP1)
V(K)=VR*AR-VI*AI
V(KP1)=VR*AI+VI*AR
200 CONTINUE

NOW INCLUDE EITHER FULL STEP OR HALF STEP REFRACTIVE
INDEX EFFECTS DEPENDING ON WHERE IN THE PATH YOU ARE

IF(ICNT.EQ.NSTEPS) XSIMUL=DXSIH
K=-1
CH=NAVERH*ZMIN*XSIMUL/(2.*NO)
ICNT1=ICNT+1
CALL PINDEX(DSPX,DXPY,NDSQ,DZET,XYO,REFCF,ICNT1)
DO 220 M=1,MESHSG
ARG=REFMOX(M)*CH
AR=COS(ARG)
AI=SIN(ARG)
K=K+2
KP1=K+1
VM=V(K)

```

OPTF I
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OPTF I


```

230      VI=V(KP1)
      V(K)=VR*AR-VI*AI
      V(KP1)=VR*AI+VI*AR
220      CONTINUE
      IF(ICNT.EQ.NSTEPS) LAST=.T.
      IF(CALLPR) CALL PRINTER(ICNT)
235      500 CONTINUE
      C
      C      CALCULATE IRRADIANCE PATTERN AND PRINT
      C
240      IF(PUREY) GO TO 30
      M=0
      DO 240 K=1,MSHSQ2,2
      KP1=K+1
      VR=V(K)
      VI=V(KP1)
      M=M+1
      RADARY(M)=VR**2+VI**2
245      240 CONTINUE
      CALL GREYSC(IGREY,10,RADARY,MESH,MESH,MS,MF,1,MS,NF,1,0.,0.,
+ 1,0,IRRADIANCE,10)
250      30 CONTINUE
      ICNTCS=ICNTCS+1
      IF(ICNTCS.LE.NCASES) GO TO 1
      END

```

SYMBOLIC REFERENCE MAP (K=1)

100 POINTS
218 OPTFIB

RIAGLES	SN	TYPE	RELOCATION			
105 AI	REAL		7051	ALPHA	REAL	
076 AMP	REAL		41000	AMPARY	REAL	ARRAY
112 ANG	REAL		7104	AR	REAL	
065 ARG	REAL		7053	BETANT	REAL	
041 CALLPR	LOGICAL		7113	CANG	REAL	
067 CH	REAL		40200	CS	REAL	ARRAY
103 CSI	REAL		7100	CSJ	REAL	
043 DSPX	REAL		7044	DSPY	REAL	
10 DX	REAL	PARAM	7116	DAPY	REAL	
17 DXSI	REAL	PARAM	7051	DXSIH	REAL	
052 UZET	REAL		0	DZINC	REAL	
045 FLAG	REAL		4	FR	REAL	
054 FTCONST	REAL		7072	I	INTEGER	
073 ICNT	INTEGER		6672	ICNTCS	INTEGER	
1115 ICNT1	INTEGER		6	IGREY	INTEGER	
5 ICNT	INTEGER		7070	J	INTEGER	
063 K	INTEGER	PRNIPLT	7101	KP1	INTEGER	
2 LAMBDA	REAL	PARAM	4	LAST	LOGICAL	
065 M	INTEGER		1	MESH	INTEGER	
13 MESHSG	INTEGER	PARAM	7046	MESH2	INTEGER	
22 PF	INTEGER	PARAM	7073	MF1	INTEGER	

```

1      SUBROUTINE RINDEX(DSPX,DSPLY,NUSQ,DZET,XYU,REFCF,ICNT)
      COMMON /PRNTPLT/PGREY,PAAIST,PLTAST,PLTMAX,LAST,IOUT,IGREY
      + ,PLIFLD,PLTFLE
5      COMMON /PARAM/DZINC,MESH,LAMBDA,RO,FR,NO,PCDOP,OUTRAD,DX,MSTEPS
      + DZINC,MESHSH,MESHSG2,PI,WAVERF,DXSI,MS,NS,MF,NF,MSHPTS
      COMMON /LCM2/REFNDX(16384),SN(128),CS(128),ZTSG(128),PUSG(128)
      + ,AMPARY(16384),RADARY(16384)
      LEVEL 2,REFNDX,SN,CS,ZTSG,PUSG,AMPARY,RADARY
10     REAL LAMBDA,NO,NUSQ,NZ
      AZ=.0
      CZ=REFCF*EXP(AZ*(ICNT-1))
      CONS1=1.
      CONS2=.01
      ACUN1=.000
      ACUN2=.01
      BCUN=25./RO
      M=0
      DO 120 J=1,MESH
      Z1=ZTSG(J)
20     DO 120 I=1,MESH
      M=M+1
      Z2=ZTSG(1)
      RAD=Z1+Z2
      REFNDX(M)=(NO-CZ*RAD)*(CONS1*EXP(-ACUN1*RAD)+CONS2*EXP(-ACUN2
25     + *((SQRT(RAD)-BCUN)**2)))
      IF(REFNDX(M).LT.1.) REFNDX(M)=1.
120    CONTINUE
      IF(ICNT.GT.1) GO TO 125
      CALL GREYSC(IGREY,10,REFNDX,MESH,MESH,MS,MF,1,NS,NF,1,0.,0.,
50     + 6HREFNDX,5)
125    CONTINUE
      DO 130 K=1,MESHSG
      REFNDX(K)=REFNDX(K)**2-NUSQ
130    CONTINUE
      RETURN
      END

```

SYMBOLIC REFERENCE MAP (K=1)

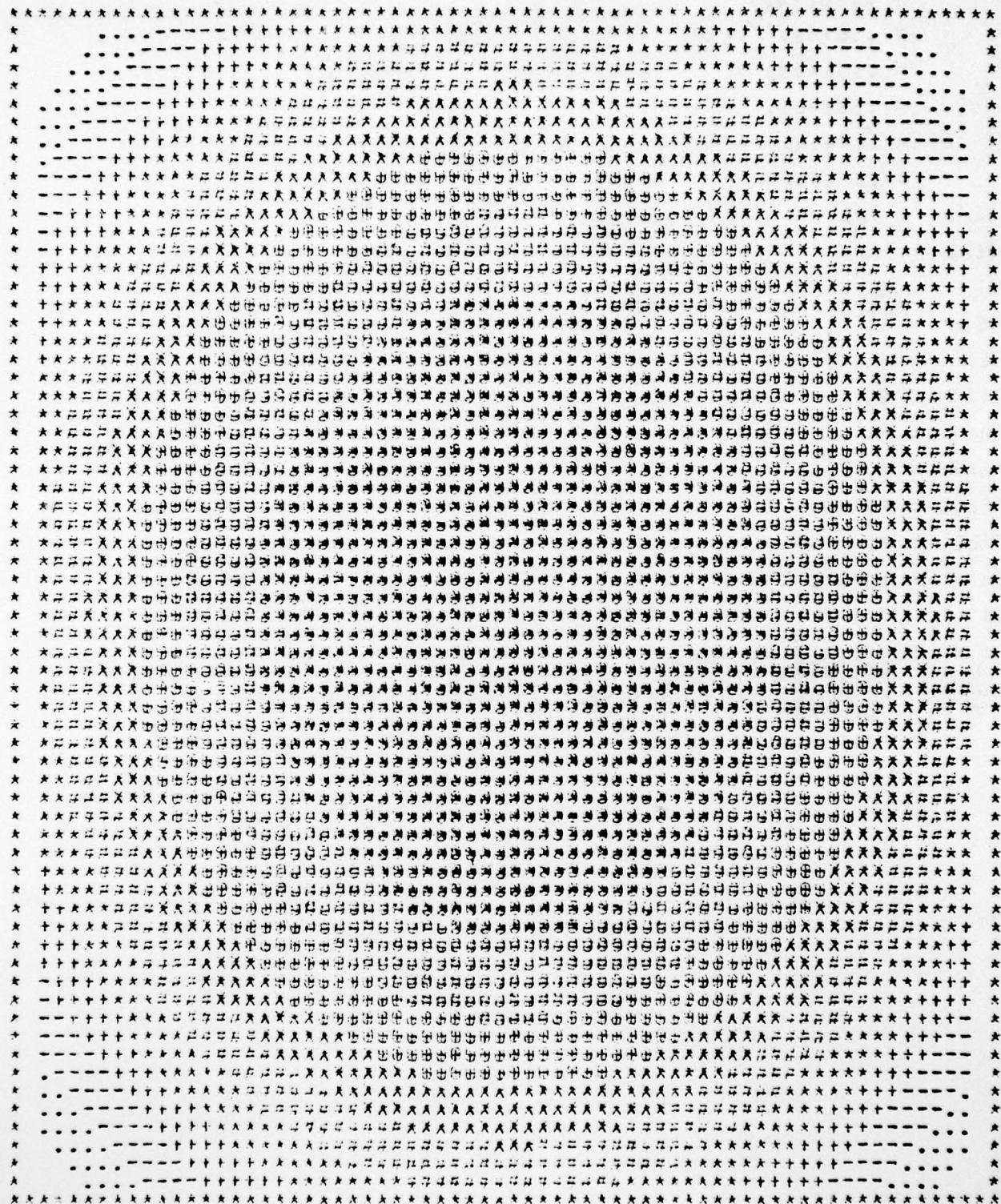
41 POINTS
5 RINDEX

TABLES	SN	TYPE	RELOCATION				
22	ACUN1	REAL		123	ACUN2	REAL	
23	AMPARY	REAL	ARRAY	116	AZ	REAL	
24	BCUN	REAL		120	CONS1	REAL	
21	CONS2	REAL		40200	CS	REAL	ARRAY
17	CZ	REAL		0	DX	REAL	*UNUSED
9	DSPLY	REAL	*UNUSED	10	DZET	REAL	*UNUSED
17	DXSI	REAL		6	FR	REAL	
9	DZINC	REAL		4	ICNT	INTEGER	
30	1	INTEGER		5	IOUT	INTEGER	
5	IGREY	INTEGER	PRNTPLT				

SDFAULT

LAMBDA = .8E+00,
 RU = .125E+02,
 FR = .5E+02,
 NO = .15E+01,
 PCORP = .33E-01,
 OUTRAD = .1E+04,
 DX = .3E+01,
 NSTEPS = 40,
 NDZINC = 10,
 IOUT = 6,
 IGREY = 6,
 PGREY = T,
 PWAIST = T,
 PLTAST = F,
 PLTMAX = F,
 PLTFLO = F,
 PLTFLE = F,
 NESH = 128,
 SEND
 ZMIN = 3057.1582 MICRONS
 DZINC = 305.7158 MICRONS
 RN2ND = .264E-06 MICRONS**(-2)
 ALPHA = 1.05730

REFNOX



REFNOX

GREY-SCALE CHARACTERS AND RANGES

.	.150317E+01	.150435E+01
-	.150435E+01	.150552E+01
+	.150552E+01	.150669E+01
*	.150669E+01	.150786E+01
E	.150786E+01	.150904E+01
X	.150904E+01	.151021E+01
	.151021E+01	.151138E+01
	.151138E+01	.151255E+01
	.151255E+01	.151372E+01

IRRADIANCE

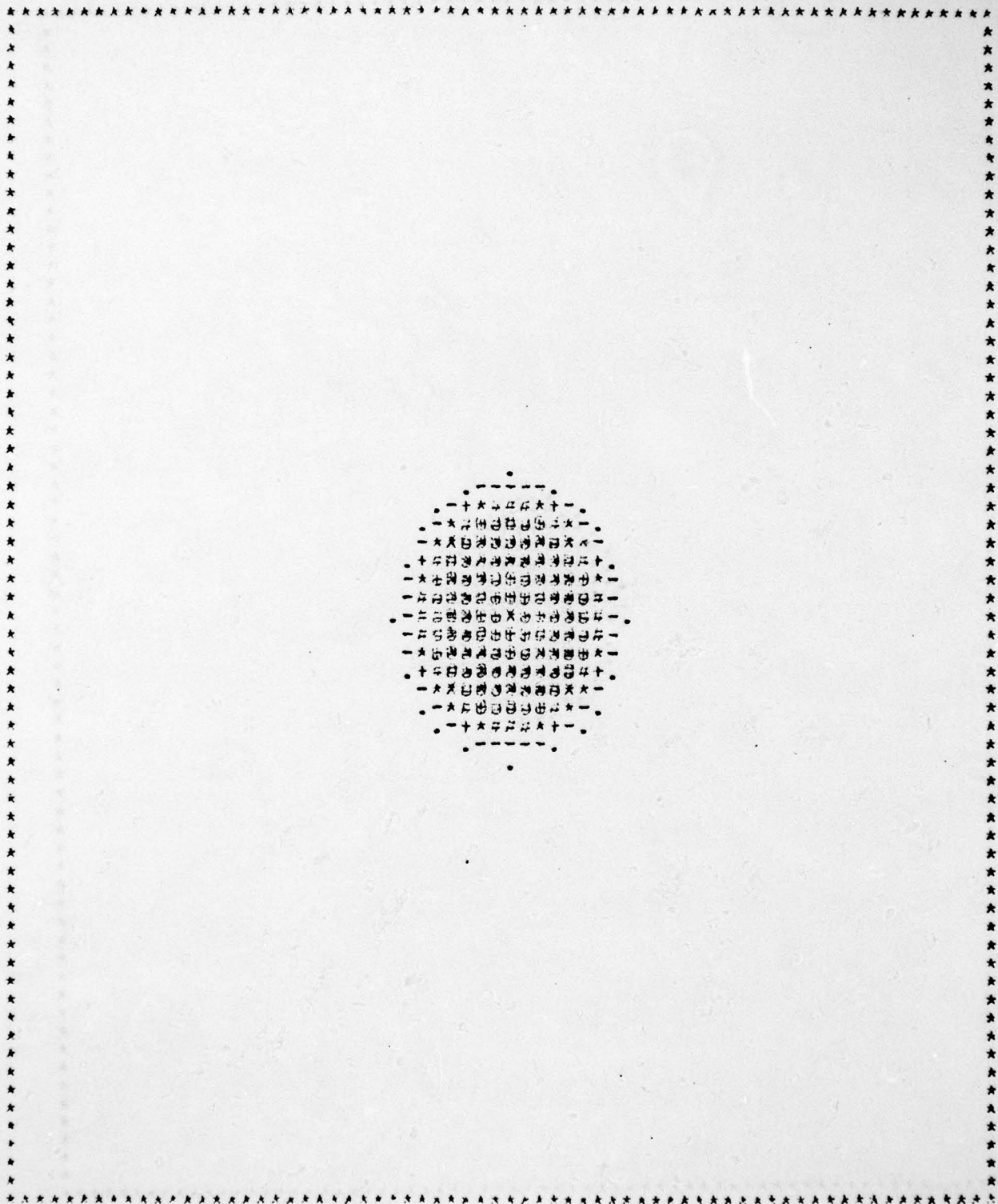


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.580865E-51	.100000E+00
+	.100000E+00	.200000E+00
*	.200000E+00	.300000E+00
*	.300000E+00	.400000E+00
*	.400000E+00	.500000E+00
*	.500000E+00	.600000E+00
*	.600000E+00	.700000E+00
	.700000E+00	.800000E+00
	.800000E+00	.900000E+00
	.900000E+00	1.000000E+00

IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

•	.035191E-12		.442255E-01
+	.442255E-01		.684507E-01
•	.684507E-01		.132676E+00
+	.132676E+00		.170902E+00
•	.170902E+00	- 90 -	.221127E+00
+	.221127E+00		.265353E+00
•	.265353E+00		.309578E+00
+	.309578E+00		.353804E+00
•	.353804E+00		.398029E+00

AD-A081 669

EMTEC ENGINEERING INC LOS ANGELES CA

F/G 20/6

ANALYSIS OF MULTIMODE FIBER COUPLERS, TAPERS AND MODE CONVERTER--ETC(U)

JAN 80 C YEH

F19628-78-C-0206

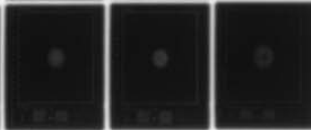
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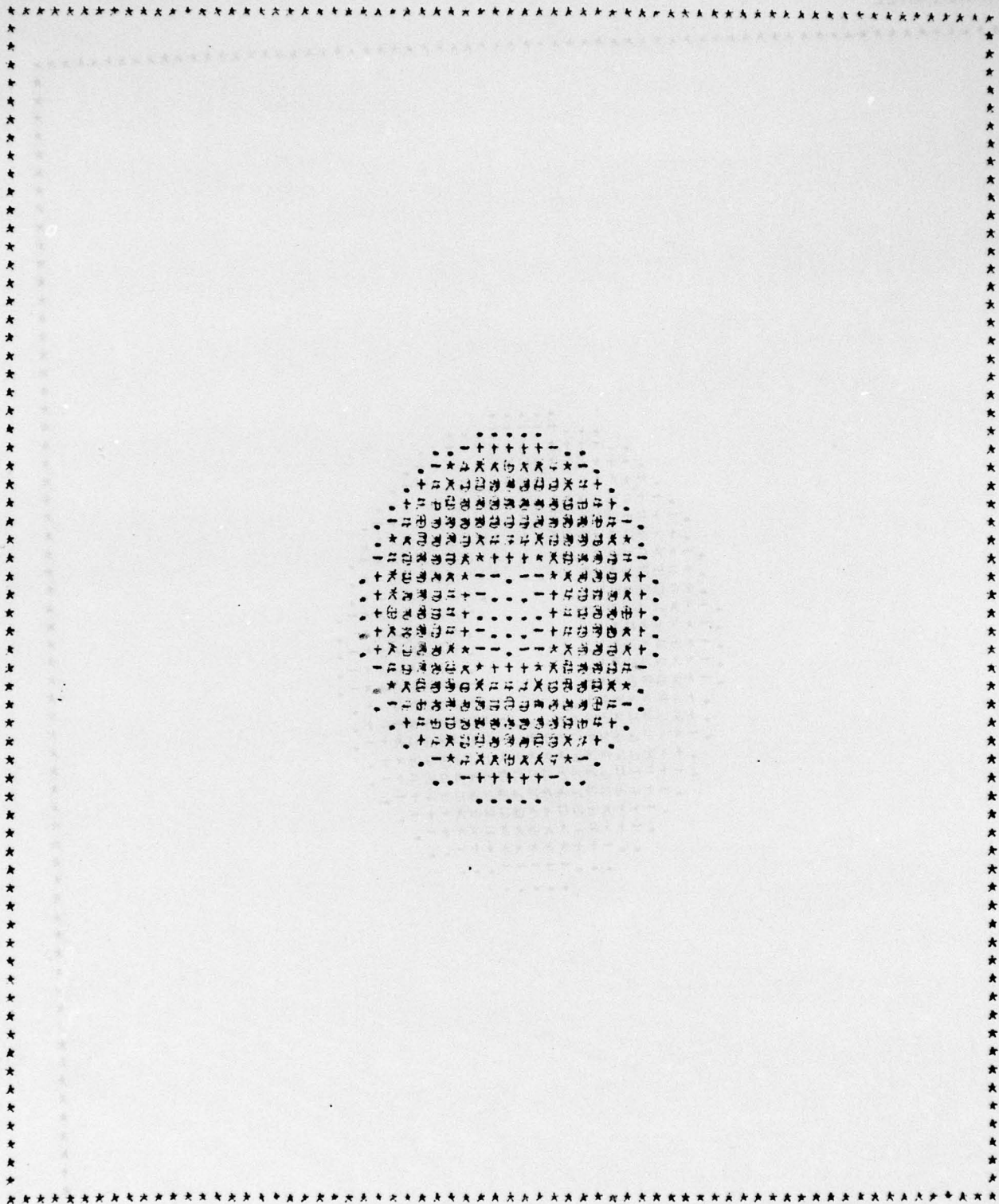
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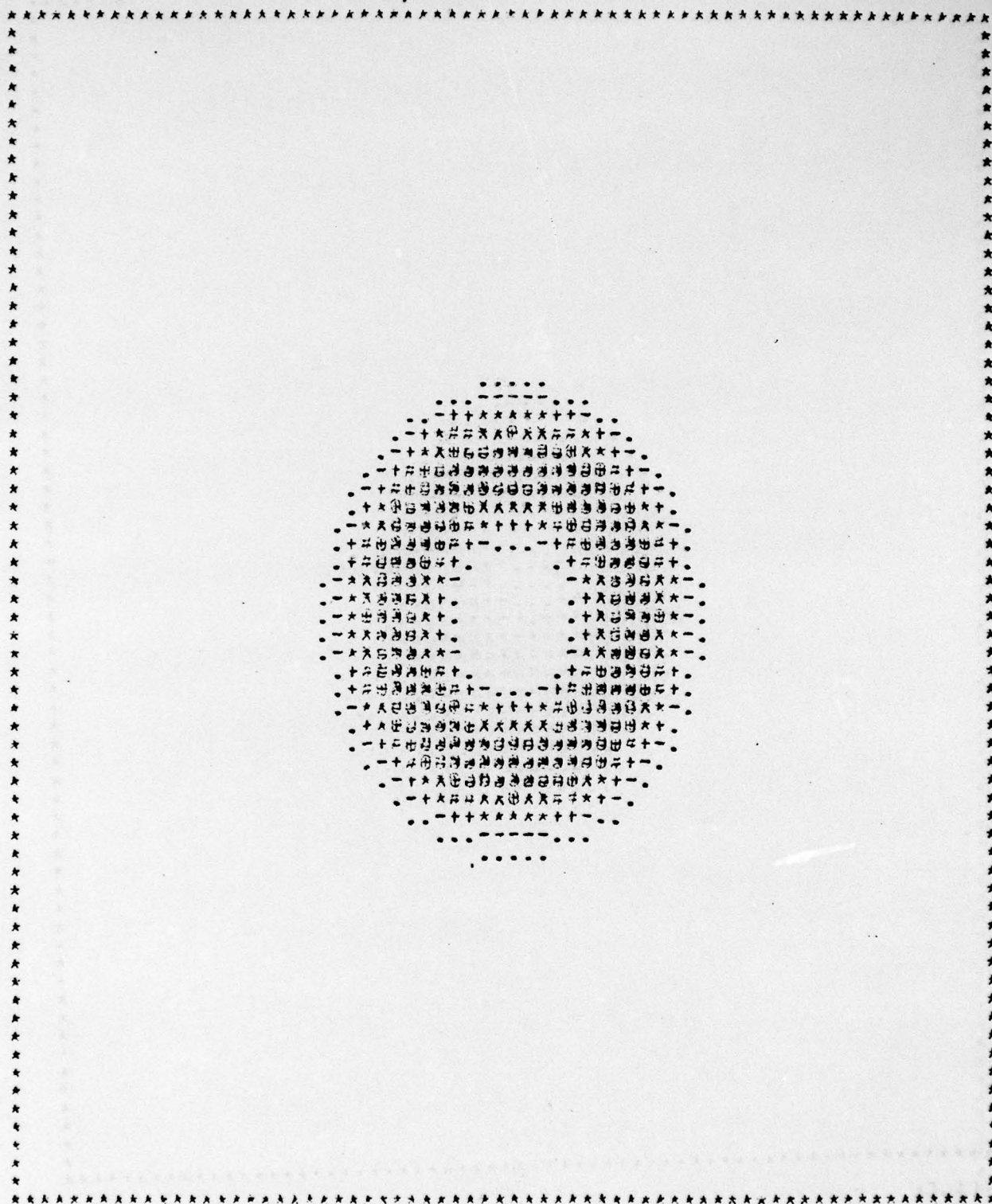
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GREY-SCALE CHARACTERS AND RANGES

- 91 -

IRRADIANCE

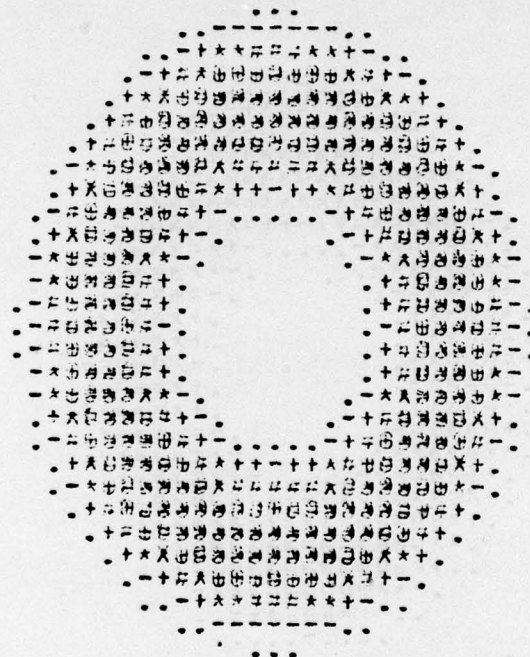


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.690653E-07	.186048E-01
+	.186048E-01	.375095E-01
*	.375095E-01	.564142E-01
*	.564142E-01	.752189E-01
*	.752189E-01	.940237E-01
*	.940237E-01	.112828E+00
*	.112828E+00	.131633E+00
*	.131633E+00	.150436E+00
*	.150436E+00	.169213E+00

IRRADIANCE

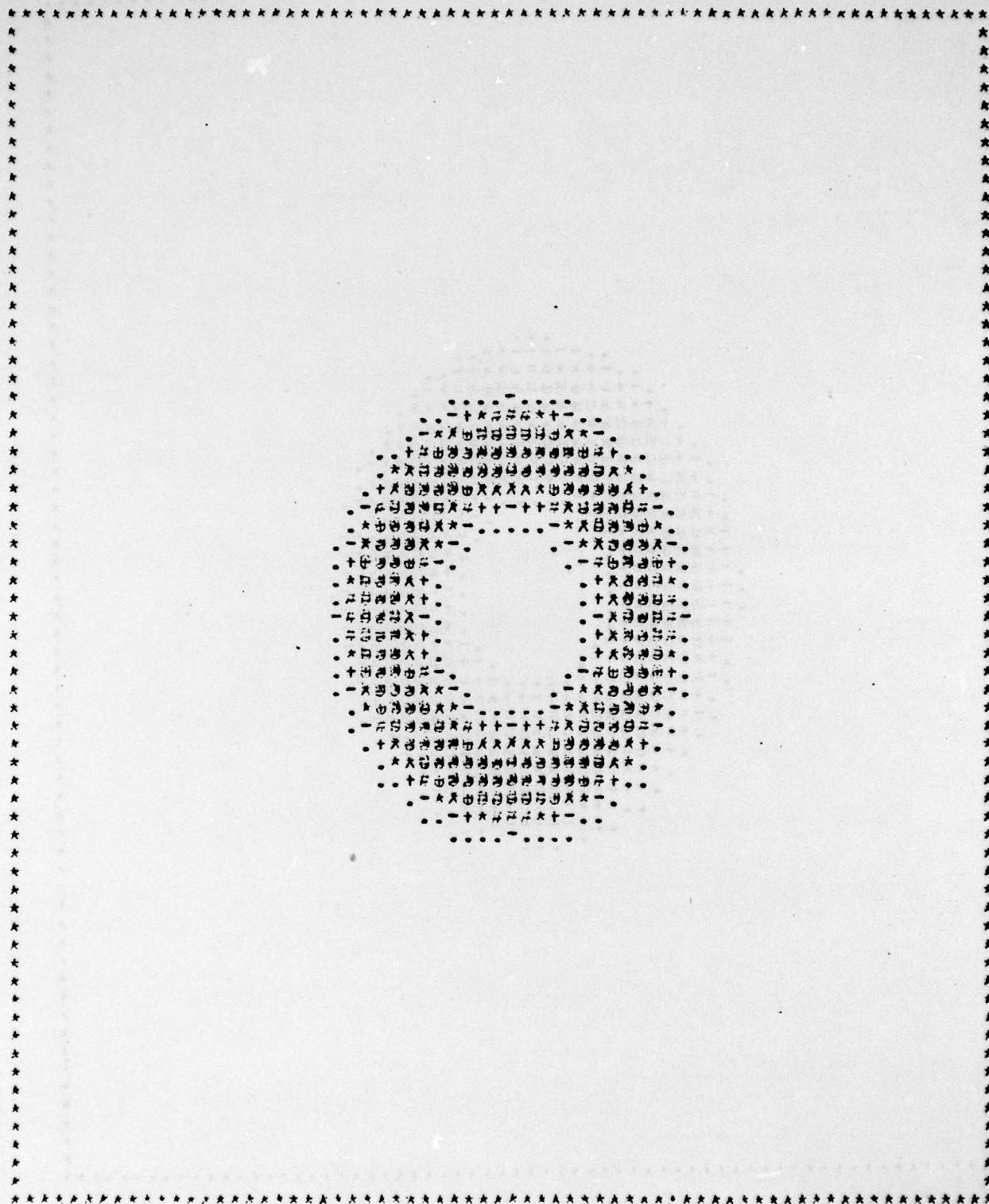


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.154559E-03	.166307E-04
+	.166307E-01	.332614E-01
*	.332614E-01	.498922E-01
#	.498922E-01	.665229E-01
\$	.665229E-01	.831536E-01
%	.831536E-01	.997843E-01
	.997843E-01	.116415E+00
	.116415E+00	.133046E+00

IRRADIANCE

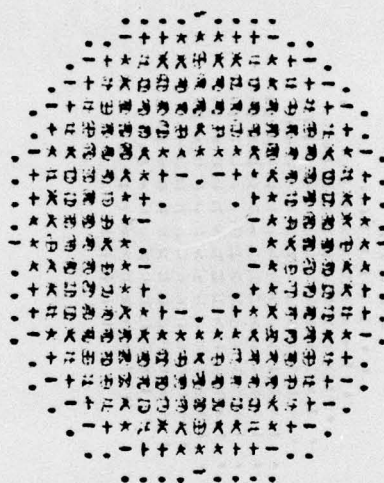


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.261002E-09		.210601E-01
+	.210601E-01		.421202E-01
*	.421202E-01		.631802E-01
x	.631802E-01		.842403E-01
x	.842403E-01		.105300E+00
x	.105300E+00	- 94 -	.126300E+00
x	.126300E+00		.147421E+00
x	.147421E+00		.168401E+00

IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

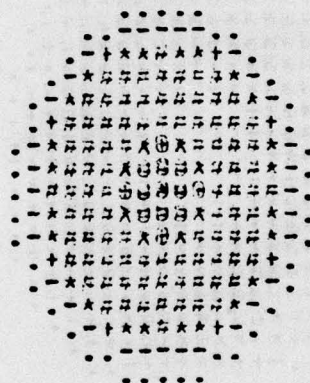
0.1 + 0.001

.025269E-11
.277914E-01
.555828E-01
.833742E-01
.111166E+00
.136957E+00
.162748E+00
.194540E+00
.222351E+00

- 95 -

.277914E-01
.555828E-01
.833742E-01
.111166E+00
.136957E+00
.162748E+00
.194540E+00
.222351E+00
.250133E+00

IRRADIANCE

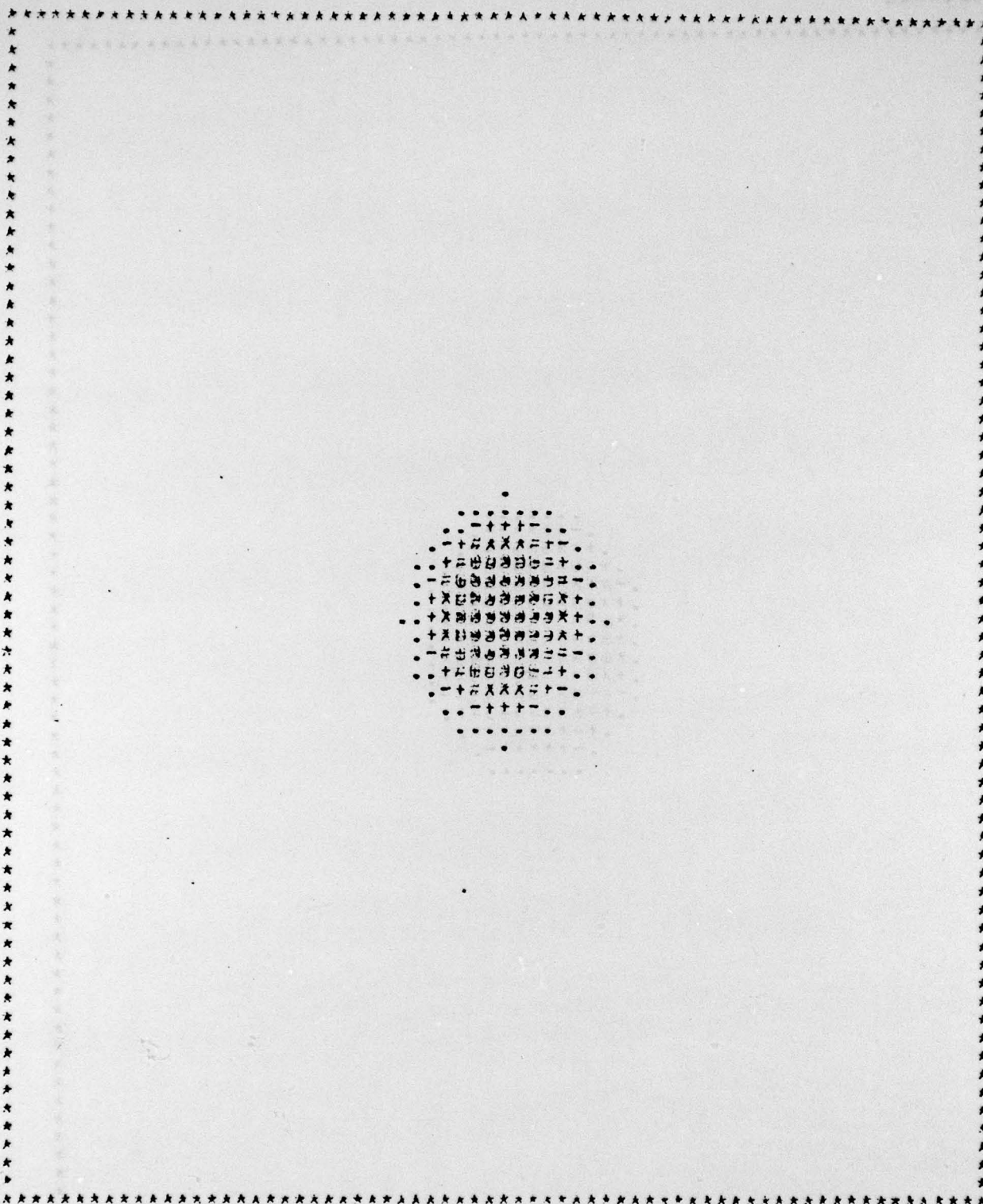


IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.172623E+00	.547302E+01
-	.547302E+01	.109860E+00
+	.109860E+00	.164791E+00
*	.164791E+00	.214721E+00
#	.214721E+00	.274651E+00
\$	.274651E+00	.324581E+00
%	.324581E+00	.374511E+00
^	.374511E+00	.424442E+00
&	.424442E+00	.474372E+00

IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

•	.219571E-08	.695730E-01
+	.695730E-01	.139358E+00
x	.139358E+00	.209056E+00
o	.209056E+00	.275715E+00
1	.275715E+00	.348394E+00
	.348394E+00	.413073E+00
	.413073E+00	.487751E+00
	.487751E+00	.557430E+00
	.557430E+00	.627109E+00

IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

• + x x x x x x x x	.624851E-07	.4-1306E-01
	.481306E-01	.962611E-01
	.962611E-01	.123392E+00
	.144392E+00	.192522E+00
	.192522E+00	.240653E+00
	.240653E+00	.288783E+00
	.288783E+00	.336914E+00
	.336914E+00	.385044E+00
	.385044E+00	.433175E+00
	.433175E+00	.481306E+00

IRRADIANCE



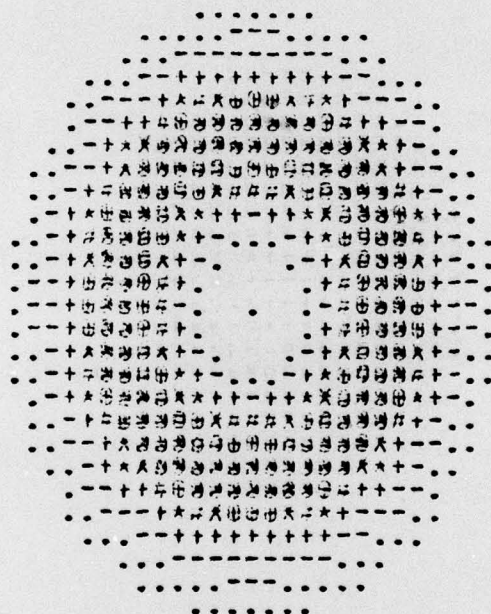
IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.105300E-07	.280749E-01
+	.280749E-01	.561498E-01
*	.561498E-01	.842246E-01
*	.842246E-01	.112300E+00
*	.112300E+00	.140374E+00
*	.140374E+00	.168449E+00
*	.168449E+00	.196524E+00
*	.196524E+00	.224599E+00
*		

- 99 -

IRRADIANCE



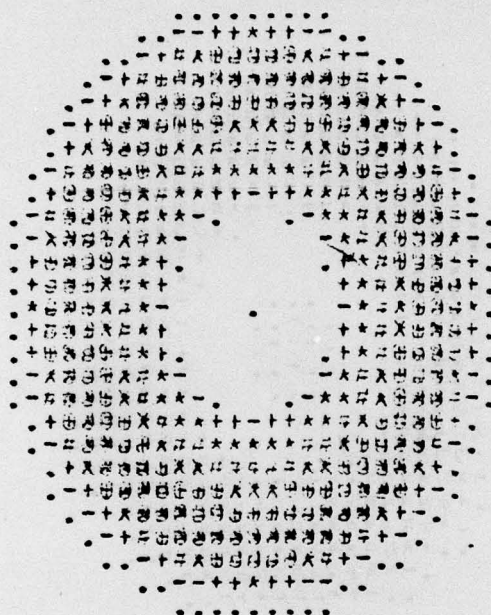
IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

100 -

.045125E-02	.205773E-01
.205773E-01	.407546E-01
.407546E-01	.611319E-01
.611319E-01	.815092E-01
.815092E-01	.101886E+00
.101886E+00	.122264E+00
.122264E+00	.142641E+00
.142641E+00	.163018E+00
.163018E+00	.183396E+00

IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

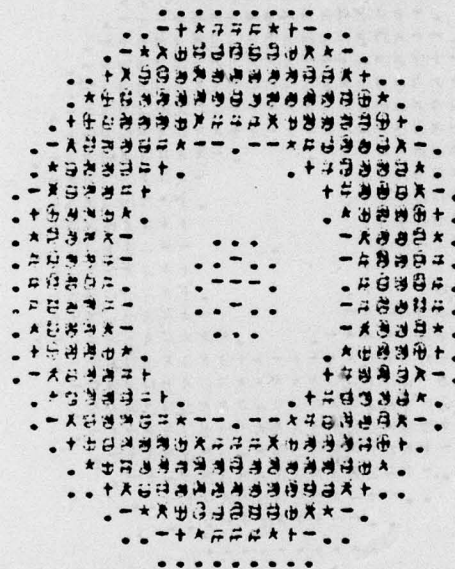
•
+
*

X
@

.437399E-08	.179758E-01
.179758E-01	.359476E-01
.359476E-01	.539215E-01
.539215E-01	.718953E-01
.718953E-01	.898691E-01
.898691E-01	.107843E+00
.107843E+00	.125817E+00
.125817E+00	.145791E+00

- 101 -

IRRADIANCE

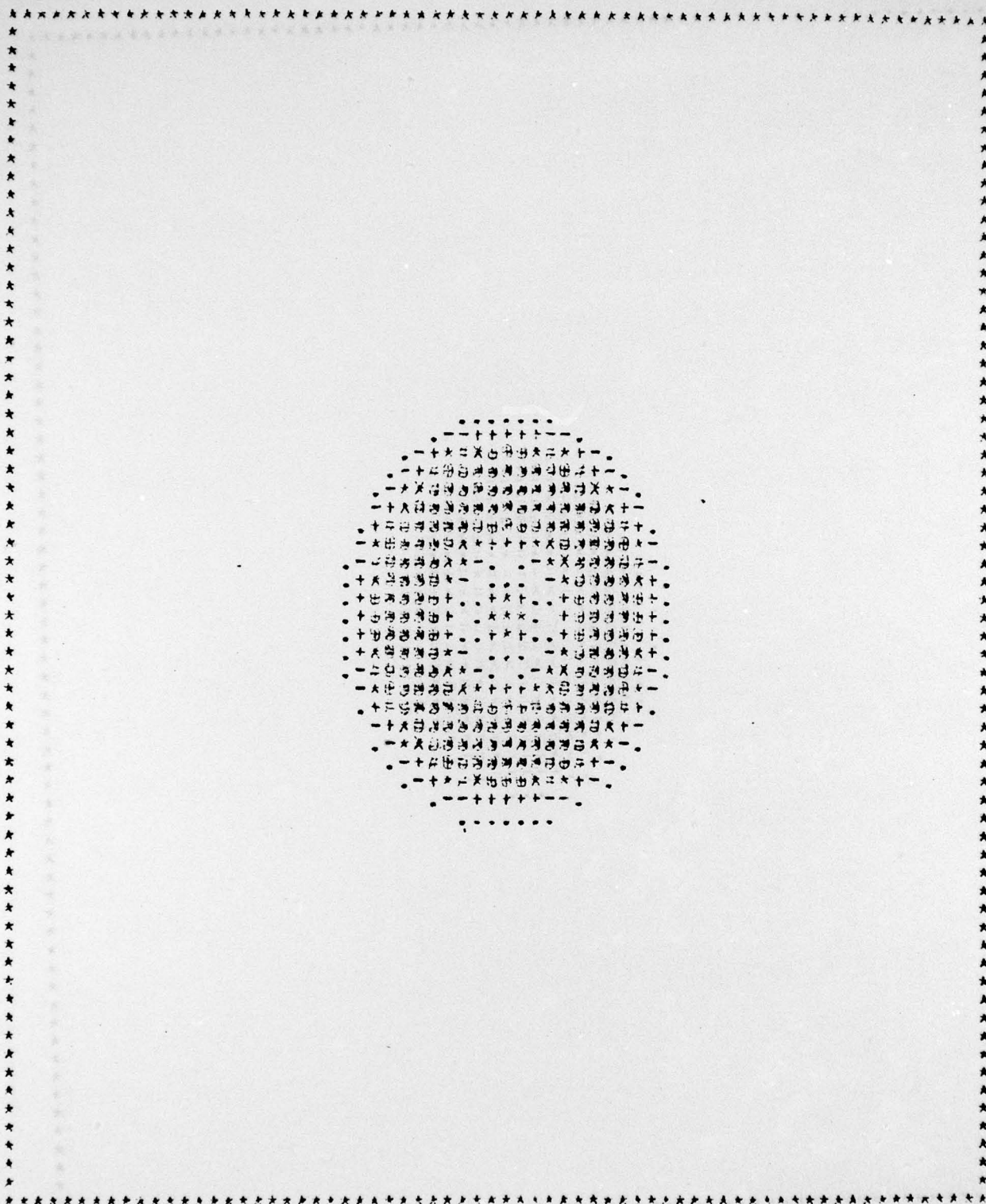


IRRADIANCE

GREY-SCALE CHARACTERS AND VALUES

.	.934771E-09	.218659E-01
+	.218659E-01	.437319E-01
*	.437319E-01	.655978E-01
0	.655978E-01	.874637E-01
1	.874637E-01	.109330E+00
2	.109330E+00	.131179E+00
3	.131179E+00	.153062E+00
4	.153062E+00	.174927E+00
5	.174927E+00	.196793E+00

IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.368173E-07	.221918E-01
+	.221918E-01	.442836E-01
*	.442836E-01	.664254E-01
*	.664254E-01	.885672E-01
*	.885672E-01	.110709E+00
*	.110709E+00	.132851E+00
.	.132851E+00	

IRRADIANCE



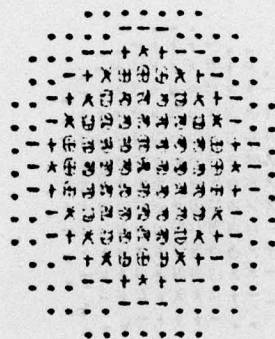
IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

• + x =	.574430E-07	.407600E-01
	.407600E-01	.315199E-01
	.315199E-01	.122250E+00
	.122250E+00	.163040E+00
	.163040E+00	.203600E+00
	.203600E+00	.244560E+00
	.244560E+00	.285320E+00
	.285320E+00	.326080E+00
	.326080E+00	.366840E+00
	.366840E+00	.407600E+00

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IRRADIANCE



IRRADIANCE

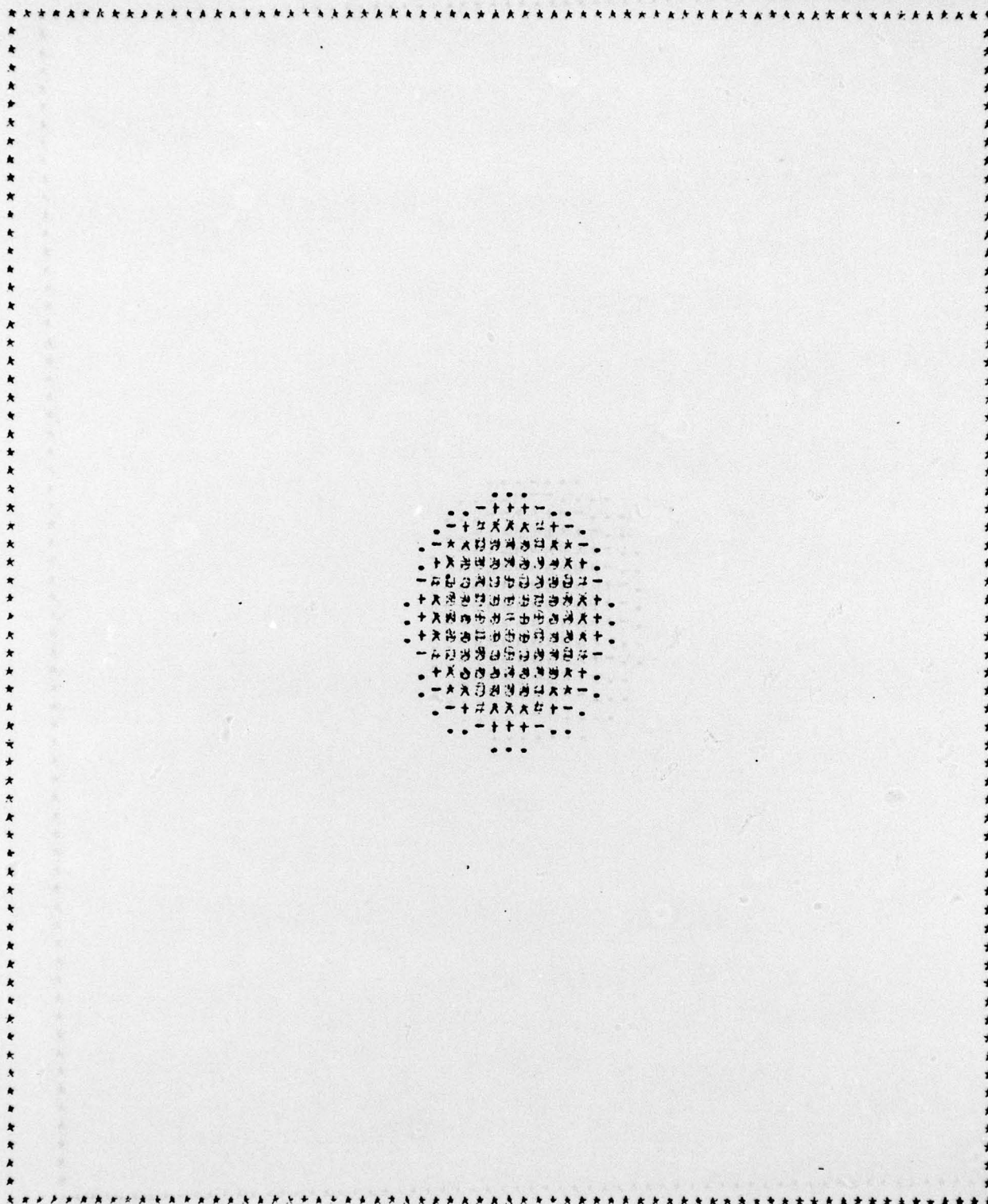
GREY-SCALE CHARACTERS AND RANGES

•
+
*
x
E

.207193E-07	.590478E-01
.590478E-01	.116096E+00
.116096E+00	.177143E+00
.177143E+00	.236191E+00
.236191E+00	.295239E+00
.295239E+00	.354287E+00
.354287E+00	.413334E+00
.413334E+00	.472382E+00

- 105 -

IRRADIANCE



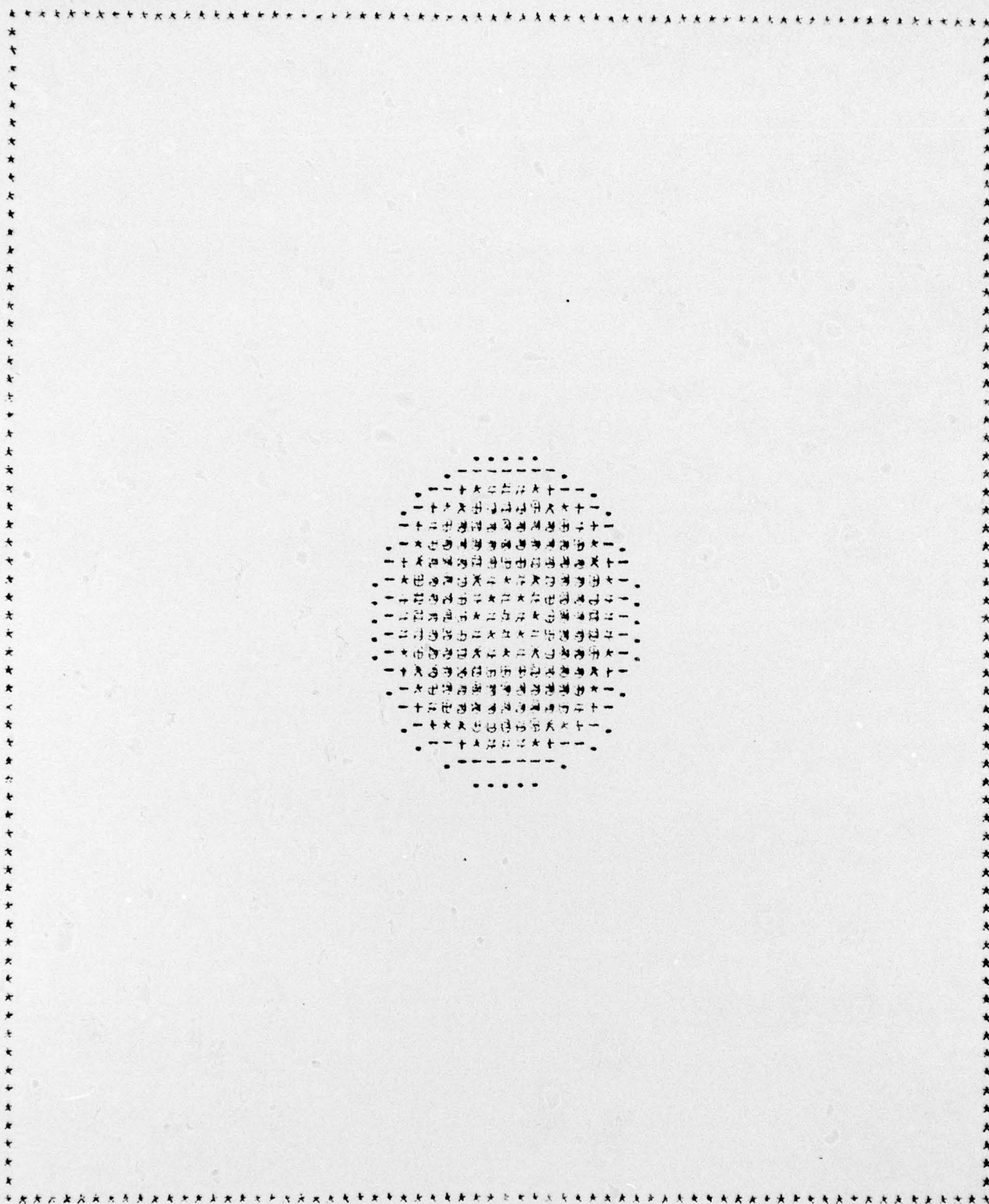
IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

•
+
*
#

.376973E+00	.534977E+01
.534977E+01	.106095E+00
.106095E+00	.160073E+00
.160073E+00	.213991E+00
.213991E+00	.267489E+00
.267489E+00 - 106 -	.320985E+00
.320985E+00	.374484E+00
.374484E+00	.427982E+00
.427982E+00	.481480E+00

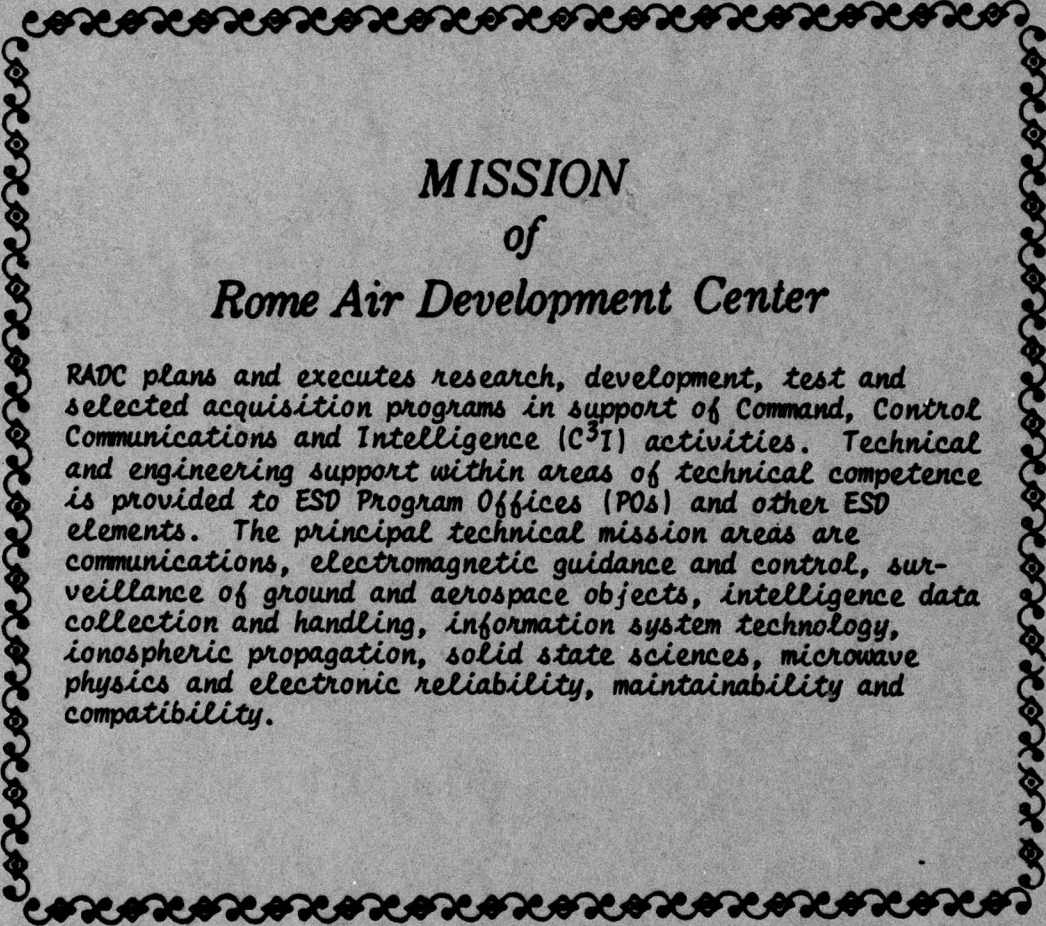
IRRADIANCE



IRRADIANCE

GREY-SCALE CHARACTERS AND RANGES

.	.231558E-07		.525728E-01
+	.525728E-01		.651455E-01
*	.651455E-01		.977182E-01
*	.977182E-01		.130291E+00
*	.130291E+00	- 107 -	.102654E+00
*	.102654E+00		.195435E+00
*	.195435E+00		.223009E+00
*	.223009E+00		.223009E+00



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