AD-A258 872

SMC-TR-92-52

AEROSPACE REPORT NO.
TR-92(2930)-4

Plotting the Magnitude and Direction of Waveguide Surface Currents in Three Dimensions

DTIC
ELECTE
DEC 8 1992
S C D

Prepared by

T. J. PETERS
Communications Systems Subdivision

30 September 1992

Prepared for

SPACE AND MISSILE SYSTEMS CENTER
AIR FORCE MATERIEL COMMAND
Los Angeles Air Force Base
P.O. Box 92960
Los Angeles, CA 90009-2960

Engineering and Technology Group

THE AEROSPACE CORPORATION
El Segundo, California

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED

92-30955

This report was submitted by The Aerospace Corporation, El Segundo, CA 90245-4691, under Contract No. F04701-88-C-0089 with the Space Systems Division. P. O. Box 92960, Los Angeles, CA 90009-2960. It was reviewed and approved for The Aerospace Corporation by J. M. Straus, Principal Director, Communications Systems Subdivision. James Goble, Capt, USAF, was the project officer for the Mission-Oriented Investigation and Experimentation (MOIE) program.

This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

QUANG BUI, Lt, USAF
MOIE Program Manager

James R. Goble, Capt, USAF
DSCS Advanced Technology Manager

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) TR-92(2930)-4	5. MONITORING ORGANIZATION REPORT NUMBER(S) SMC-TR-92-52
6a. NAME OF PERFORMING ORGANIZATION The Aerospace Corporation Communications Systems Subdivision 6b. OFFICE SYMBOL *(If applicable)*	7a. NAME OF MONITORING ORGANIZATION Space and Missile Systems Center
6c. ADDRESS *(City, State, and ZIP Code)* El Segundo, CA 90245	7b. ADDRESS *(City, State, and ZIP Code)* Los Angeles Air Force Base Los Angeles, CA 90009-2960
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL *(If applicable)*	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F04701-88-C-0089
8c. ADDRESS *(City, State, and ZIP Code)*	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE *(Including Security Classification)*
Plotting the Magnitude and Direction of Waveguide Surface Currents in Three Dimensions

12. PERSONAL AUTHOR(S) Peters, T. J.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT *(Year, Month, Day)*	15. PAGE COUNT
	FROM _____ TO _____	30 September 1992	119

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
FIELD	GROUP	SUB-GROUP	Computer graphics Electromagnetic waveguides

18. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

A method is presented to plot the magnitude and direction of the current induced on the inside surface of a rectangular or circular waveguide. The method requires the geometry of each waveguide to be modeled using a triangular mesh and assumes that the surface current values are known only at the vertices. Since a simple mapping exists between a two-dimensional rectangular region and the surface of a rectangular or circular waveguide, the plotting algorithm is designed to process two-dimensional data and then perform a mapping to a three-dimensional surface.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE *(Include Area Code)* / 22c. OFFICE SYMBOL

Contents

I. Introduction 5
II. Drawing Vectors on Triangular Grids 7
III. Initial, Terminal, and Critical Points 11
IV. TE Wave Surface Currents 13
V. Conclusion 19
References 21
Appendix A: Vector-Line Differential Equation Solution ... 23
Appendix A References 27
Appendix B: Computer Programs 29
Appendix B References 117
About the Author 119

DTIC QUALITY INSPECTED 8

Accession For
NTIS GRA&I ☑
DTIC TAB ☐
Unannounced ☐
Justification
By
Distribution/
Availability Codes
Dist Avail and/or Special
A-1

Figures

1. Node and Triangle Connections 8

2. Critical Points for Diverging, Converging, or Closed-Loop Vector Fields 12

3. Magnitude and Direction of TE_{10} Surface Current Plotted on Unfolded Rectangular Waveguide 15

4. Magnitude and Direction of TE_{10} Surface Current Plotted on Rectangular Waveguide 16

5. Magnitude and Direction of TE_{11} Surface Current Plotted on Unfolded Circular Waveguide 17

6. Magnitude and Direction of TE_{11} Surface Current Plotted on Circular Waveguide 18

I. Introduction

Understanding the flow of energy through a bounded waveguide region is enhanced by the ability to visualize surface-current vector fields. Also, determining the position and size of slots cut into the wall of a waveguide requires a knowledge of the current-flow magnitude and direction on the inside surface. Applications have been developed to represent waveguide modes [1]-[3], radiation fields [4], and static fields [5]-[6]; however, all are limited to only two dimensions. These methods usually exclude the flow direction of each vector and show only the tangent line. The magnitude either is not shown or is represented simply by variable line density or line thickness.

The purpose of this study is to develop a method of plotting the magnitude and direction of numerically computed current induced on the inside surface of a rectangular or circular waveguide. The inside surface is assumed to be described by a triangular mesh. This is consistent with a finite-element analysis using tetrahedral elements of the interior of a waveguide. Since the waveguide surface can be described by two variables of an orthogonal coordinate system, the vector field can be represented by a simple two-dimensional to three-dimensional mapping. This allows all processing to be done in two dimensions. The procedure will be to combine the three-dimensional contoured-surface representation technique developed in [7]-[8] with a two-dimensional vector drawing algorithm. The flow will be indicated by a continuous line with arrowhead markers, and the normalized magnitude by grayscale-shaded contours.

II. Drawing Vectors on Triangular Grids

Tetrahedral volume elements are used frequently for the finite-element analysis of the interior of a waveguide. This is especially true if the waveguide is nonuniformly filled, contains a scattering obstacle, or has a nonplanar surface. The tetrahedral element has four sides, which are all triangles. This implies that the surface of the waveguide is approximated by a triangular mesh, so that the numerical value of both vector components is computed at each node. Since three points determine a plane, a linear interpolation function is implied over every triangle. Therefore, each vector component has piecewise continuity between adjacent triangles.

The numbering scheme for the nodes and triangles of a region is completely arbitrary. Figure 1 indicates a possible configuration for six nodes and four triangles. The convention used in this study, to establish the connection between a triangle number and the three associated node numbers, is to store the relationship in a matrix called the triangle-to-node connection matrix, denoted by **C**. This matrix is defined when the original triangular grid is formed. The relevant matrix for the configuration of Fig. 1 is given as

$$\mathbf{C} = \begin{bmatrix} 1 & 2 & 3 \\ 2 & 3 & 4 \\ 3 & 4 & 5 \\ 3 & 5 & 6 \end{bmatrix} \tag{1}$$

where each row represents a triangle and each column represents one of the three triangle nodes. This matrix is used for the indirect addressing of the coordinates of each triangle.

The matrix **C** implicitly contains enough information to yield the triangle-to-triangle connection relationship between a particular triangle's three vertex nodes and all other triangles connected to one of these nodes. Unfortunately, to establish this relationship the entire matrix must be searched. This is quite time consuming, but it can be avoided by precomputing an auxilary matrix called the node-to-triangle connection matrix, denoted by **T**. For the geometry of Fig. 1, **T** is given by

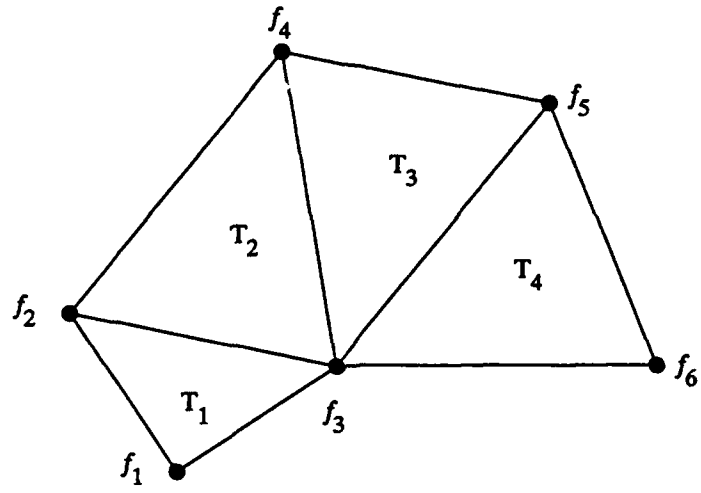


Fig. 1. Node and Triangle Connections

$$\mathbf{T} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 2 & 0 & 0 & 0 & 0 \\ 1 & 2 & 3 & 4 & 0 & 0 \\ 2 & 3 & 0 & 0 & 0 & 0 \\ 3 & 4 & 0 & 0 & 0 & 0 \\ 4 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \tag{2}$$

where each row represents a node number and each column gives a triangle number connected to that node. The formation of this matrix is trivial once C is known. For a triangular grid, there will be no more than six triangles connected to each node. This implies that there are no more than twelve triangles connected to any particular triangle

The interpolation function of a vector in the plane of each triangle is given by

$$\bar{f} = f_x\hat{x} + f_y\hat{y} \tag{3}$$

where

$$f_y = Ax + By + E \tag{4}$$

$$f_x = Cx + Dy + F. \tag{5}$$

By equating the function to the numerical values at the three vertices of the triangle,

the coefficients are computed as

$$A = [f_{y1}(y_2 - y_3) - f_{y2}(y_1 - y_3) + f_{y3}(y_1 - y_2)]/w \tag{6}$$

$$B = [-f_{y1}(x_2 - x_3) + f_{y2}(x_1 - x_3) - f_{y3}(x_1 - x_2)]/w \tag{7}$$

$$E = [f_{y1}(x_2y_3 - x_3y_2) - f_{y2}(x_1y_3 - x_3y_2) + f_{y3}(x_1y_2 - x_2y_1)]/w \tag{8}$$

$$C = [f_{x1}(y_2 - y_3) - f_{x2}(y_1 - y_3) + f_{x3}(y_1 - y_2)]/w \tag{9}$$

$$D = [-f_{x1}(x_2 - x_3) + f_{x2}(x_1 - x_3) - f_{x3}(x_1 - x_2)]/w \tag{10}$$

$$F = [f_{x1}(x_2y_3 - x_3y_2) - f_{x2}(x_1y_3 - x_3y_2) + f_{x3}(x_1y_2 - x_2y_1)]/w \tag{11}$$

where

$$w = x_1y_2 - x_1y_3 - x_2y_1 + x_3y_1 + x_2y_3 - x_3y_2. \tag{12}$$

For a given an observation point, the appropriate triangle is located using **C** and **T**, then the magnitude and direction of the vector field can be computed using Eqs. (4) and (5).

Although each component of the interpolated vector field changes linearly across each triangle, the path of the vector itself is nonlinear. The slope of a line tangent to the vector field at any point in the triangle is given by

$$\frac{dy}{dx} = \frac{Ax + By + E}{Cx + Dy + F}. \tag{13}$$

This is a nonlinear first-order differential equation. For a given starting point within a triangle, a vector path is uniquely defined by the solution to this differential equation. (The solution is given in Appendix A.) Unfortunately, the solution is an implicit function of the form $W(x,y) = 0$, which is not very convenient for rapid plotting. Fortunately, the method proposed and used in this study is much faster and easier to implement. Given some initial point, the vector is simply incremented in the positive or negative direction. This simple method allows arrows to be placed and accurately spaced on the lines. Also, the plotting speed is controlled entirely by the step size. The step size could be adaptively adjusted to reflect the variation in the vector direction, although that has not been attempted here. The vector position is

incremented as

$$x^{n+1} = x^n + \Delta \frac{f_x^n}{|\bar{f}^n|} \tag{14}$$

$$y^{n+1} = y^n + \Delta \frac{f_y^n}{|\bar{f}^n|} \tag{15}$$

where Δ is a positive or negative adaptive step size and

$$|\bar{f}^n| = \sqrt{(f_x^n)^2 + (f_y^n)^2}. \tag{16}$$

The vector length is accumulated as

$$l^{n+1} = l^n + \sqrt{(x^{n+1} - x^n)^2 + (y^{n+1} - y^n)^2} \tag{17}$$

and is used to provide equal spacing between arrowhead markers.

This method is designed for two-dimensional vector fields. However, since there is a point-to-point mapping between a rectangular two-dimensional region and the corresponding surface of the three-dimensional waveguide, then the vector lines can be mapped onto the waveguide surface. The three-dimensional surface is drawn by the method developed in [7]-[8]. Once this is complete, the visible portion of each vector line is drawn onto the surface.

III. Initial, Terminal, and Critical Points

Each vector has an initial point and a terminal point. In some cases these points may even coincide. Choosing an appropriate initial point requires some knowledge about the points at which the vector magnitude goes to zero. These are called critical points [9]-[12]. For an interactive computer application, a convenient way to locate the critical points is to view a contour plot of the magnitude of one or both of the field components. A region can be selected by means of a cursor and a limited numerical search can be performed. Usually, a vector's initial point is in a region of high magnitude and a terminal point is either a boundary point or a critical point.

Several types of critical points can be used to characterize the flow of a vector field. Each type is based on the eigenvalues of the Jacobian matrix evaluated in the vicinity of the critical point. Let $\mathbf{J}$ denote the Jacobian of the vector components at some specified point so that

$$\mathbf{J} = \begin{bmatrix} \frac{\partial f_x}{\partial x} & \frac{\partial f_x}{\partial y} \\ \frac{\partial f_y}{\partial x} & \frac{\partial f_y}{\partial y} \end{bmatrix} = \begin{bmatrix} C & D \\ A & B \end{bmatrix}. \tag{18}$$

For a triangular grid with vertex-specified vector values, the Jacobian is constant over each triangle. The type of critical point can be determined by looking at the eigenvalues of the Jacobian for a particular triangle. Letting $\mathbf{I}$ denote the identity matrix, the eigenvalue equation is formed by taking the determinant

$$\det|\mathbf{J} - \gamma\mathbf{I}| = 0 \tag{19}$$

which yields a quadratic equation in the variable γ:

$$\gamma^2 - (B + C)\gamma + BC - AD = 0. \tag{20}$$

This equation has the solution

$$\gamma = \gamma_r + j\gamma_i = \frac{1}{2}\left[(B + C) \pm \sqrt{(B + C)^2 - 4(BC - AD)}\right]. \tag{21}$$

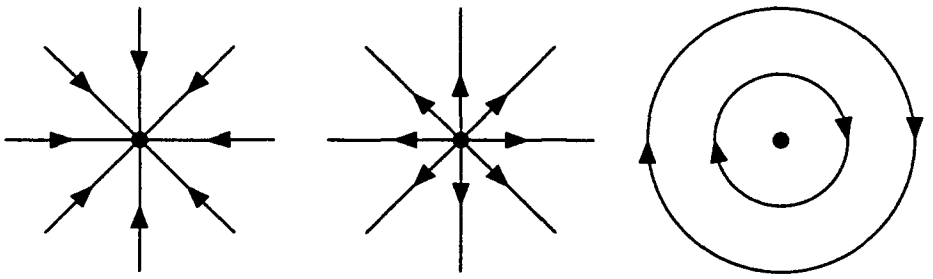


Fig. 2. Critical Points for (a) Diverging, (b) Converging, or (c) Closed Loop Vector Fields

Figure 2 shows the most common critical points encountered in plotting vector fields in electromagnetics. Figure 2(a) shows a field that converges to a point; this is represented mathematically as $\gamma_r < 0$ and $\gamma_i = 0$. Figure 2(b) shows a field that diverges from a point; this is represented mathematically as $\gamma_r > 0$ and $\gamma_i = 0$. Figure 2(c) shows a field that forms closed loops; this is represented mathematically as $\gamma_r = 0$ and $\gamma_i \neq 0$. The diverging or converging critical points are sufficient to describe a surface-current vector field. Closed-loop critical points are necessary for drawing propagating electric and magnetic fields, such as those in the interior of the waveguide.

Once the critical points have been established, appropriate initial points can be specified. Since the vector-direction error accumulates with each increment, vectors are started at points of large magnitude so that roundoff error can be minimized. Each vector is drawn in two directions until a terminal point is reached. This reduces the error by half and causes the greatest error to occur at the terminal points (which are usually critical points). It can also help provide symmetry in the vector lines when appropriate. For the purposes of this study, vectors are drawn in groups that have initial points spaced equally along a line. The boundary points for each line can be easily controlled interactively by a cursor.

IV. TE Wave Surface Currents

Although the plotting procedure is designed to handle numerically computed data, for convenience it is tested by means of well-known analytic expressions for the surface current induced on the inside of a rectangular or circular waveguide excited by transverse electric (TE) waves. The magnitude and direction of the current flow is shown by superimposing the vector lines onto a contour plot of the normalized magnitude. The vector field can be viewed either on a two-dimensional surface or on the actual three-dimensional surface.

The TE_{mn}-mode magnetic-field components for a rectangular waveguide centered about the origin such that $-a/2 \leq x \leq a/2$ and $-b/2 \leq y \leq b/2$ are given by

$$H_x = -\frac{m\pi\beta H_0}{ak_c^2} \sin\psi_x \cos\psi_y \sin(\omega t - \beta z) \tag{22}$$

$$H_y = -\frac{n\pi\beta H_0}{bk_c^2} \cos\psi_x \sin\psi_y \sin(\omega t - \beta z) \tag{23}$$

$$H_z = H_0 \cos\psi_x \cos\psi_y \cos(\omega t - \beta z) \tag{24}$$

where $\beta = \sqrt{k_0^2 - k_c^2}$, $k_x = m\pi/a$, $k_y = n\pi/b$, $k_c^2 = k_x^2 + k_y^2$, $\psi_x = k_x(x - a/2)$, and $\psi_y = k_y(y - b/2)$. Defining a unit vector normal to each inside wall as $\hat{n}$, the surface current components on the inside of the waveguide are given by

$$K_x = n_y H_z - n_z H_y \tag{25}$$

$$K_y = n_z H_x - n_x H_z \tag{26}$$

$$K_z = n_x H_y - n_y H_x \tag{27}$$

Figure 3 shows the magnitude and direction of the surface-current for the TE_{10}-mode for $t = 0$. The waveguide dimensions are $a = 1\lambda_0$, $b = 0.5\lambda_0$, and $0 \leq z \leq 5\pi/\beta$. There are 27 nodes across each wide side, 9 samples across each narrow side, and 62 samples along the longitudinal direction. This results in a total of 4278 nodes and 8296 triangles. Figure 4 shows the same vector field mapped to the outside surface of the waveguide.

The TE_{nm}-mode magnetic field components for a circular waveguide of radius a

are given by

$$H_\phi = \frac{-nk_0^2 H_0}{k_c \beta} \frac{J_n(k_c r)}{k_c r} \sin(n\phi) \sin(\omega t - \beta z) \tag{28}$$

$$H_z = H_0 J_n(k_c r) \cos(n\phi) \cos(\omega t - \beta z) \tag{29}$$

where $k_c = p'_{nm}/a$. The variable p'_{nm} is the mth root of $dJ_n(k_c r)/dr = 0$ evaluated at $r = a$. The surface current components on the inside of the waveguide are given by

$$K_\phi = H_z \tag{21}$$

$$K_z = -H_\phi. \tag{22}$$

Figure 5 shows the magnitude and direction of the surface current for the TE_{11} mode for $t = 0$. The waveguide has radius $a = 1\lambda_0$ and length $5\pi/\beta$ in the range $0 \leq z \leq 5\pi/\beta$. There are 45 nodes in the ϕ direction and 62 nodes in the longitudinal direction, for a total of 2790 nodes and 5368 triangles. Figure 6 shows the same vector field mapped to the outside surface of the waveguide.

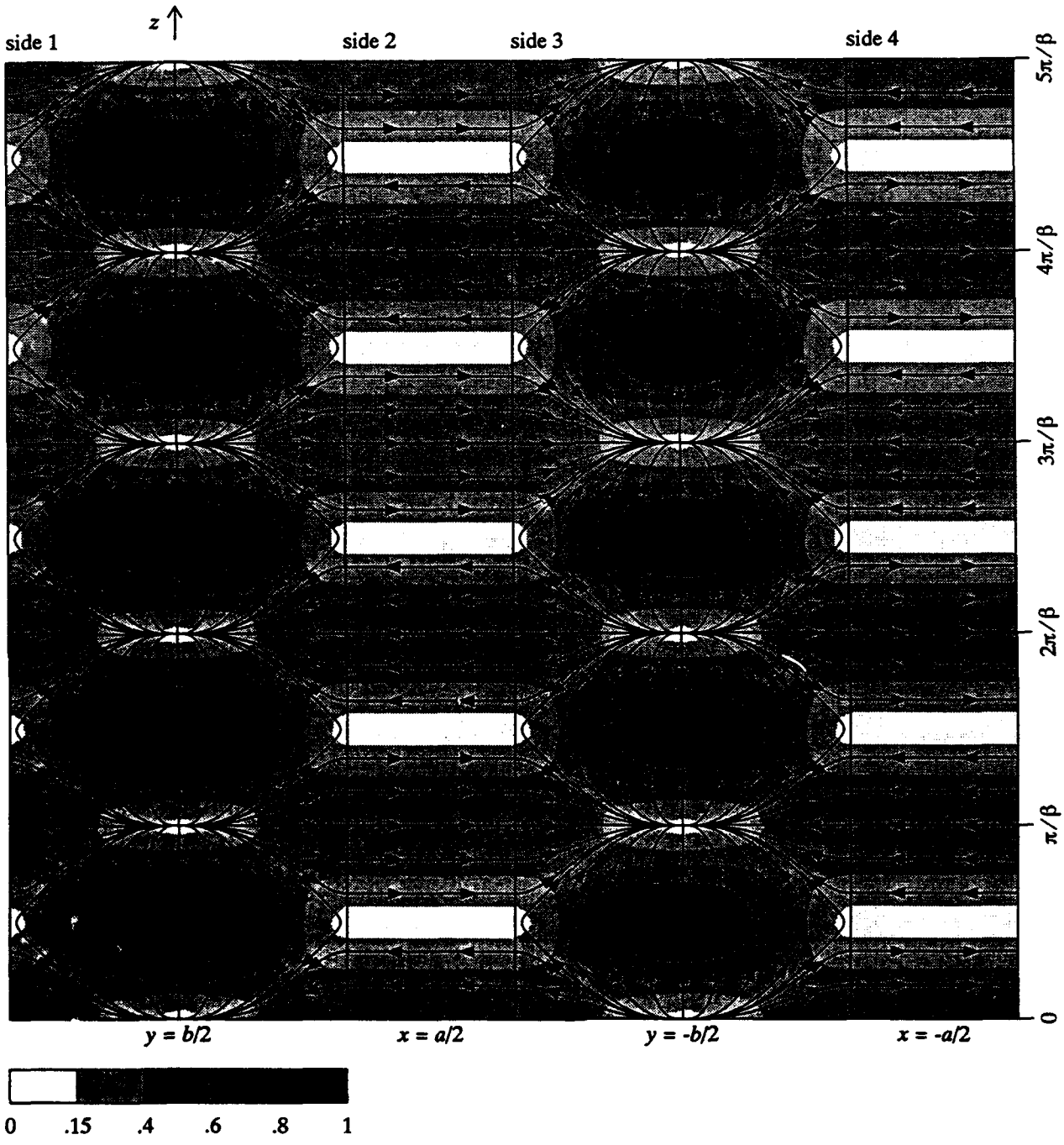


Fig. 3. Magnitude and Direction of TE_{10} Surface Current Plotted on Unfolded Rectangular Waveguide

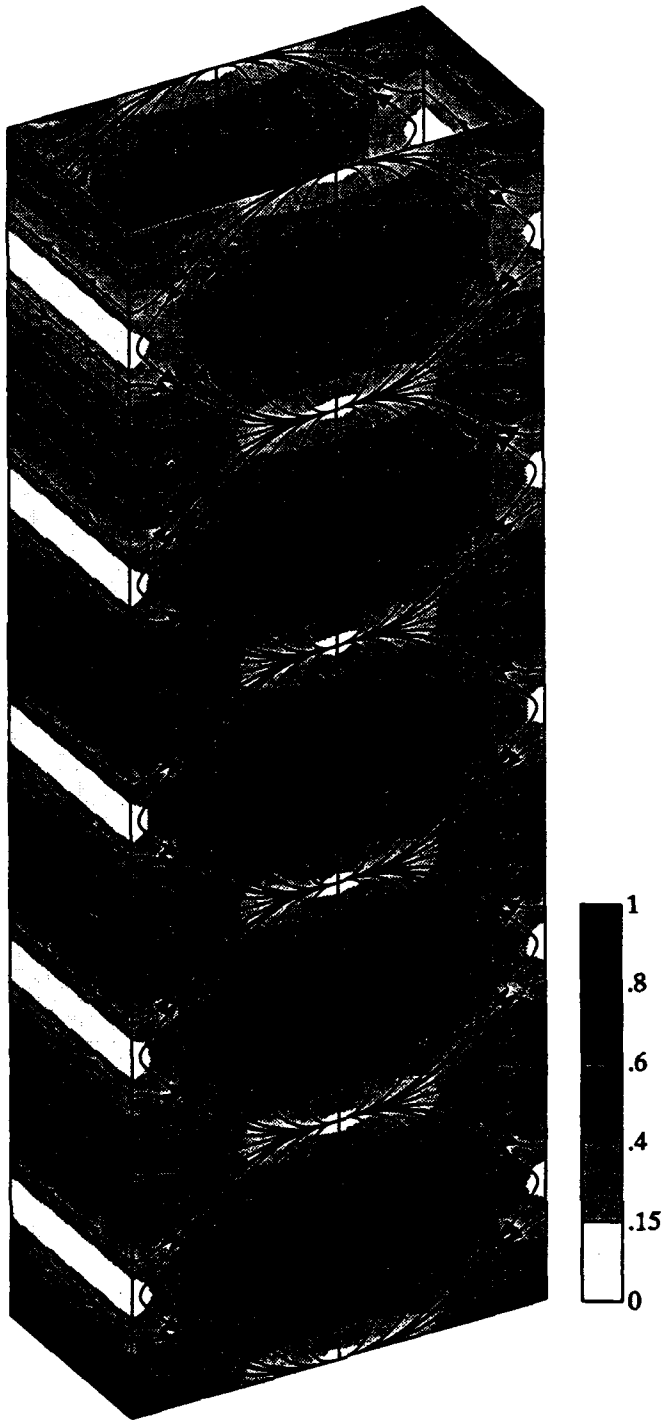


Fig. 4. Magnitude and Direction of TE_{10} Surface Current Plotted on Rectangular Waveguide

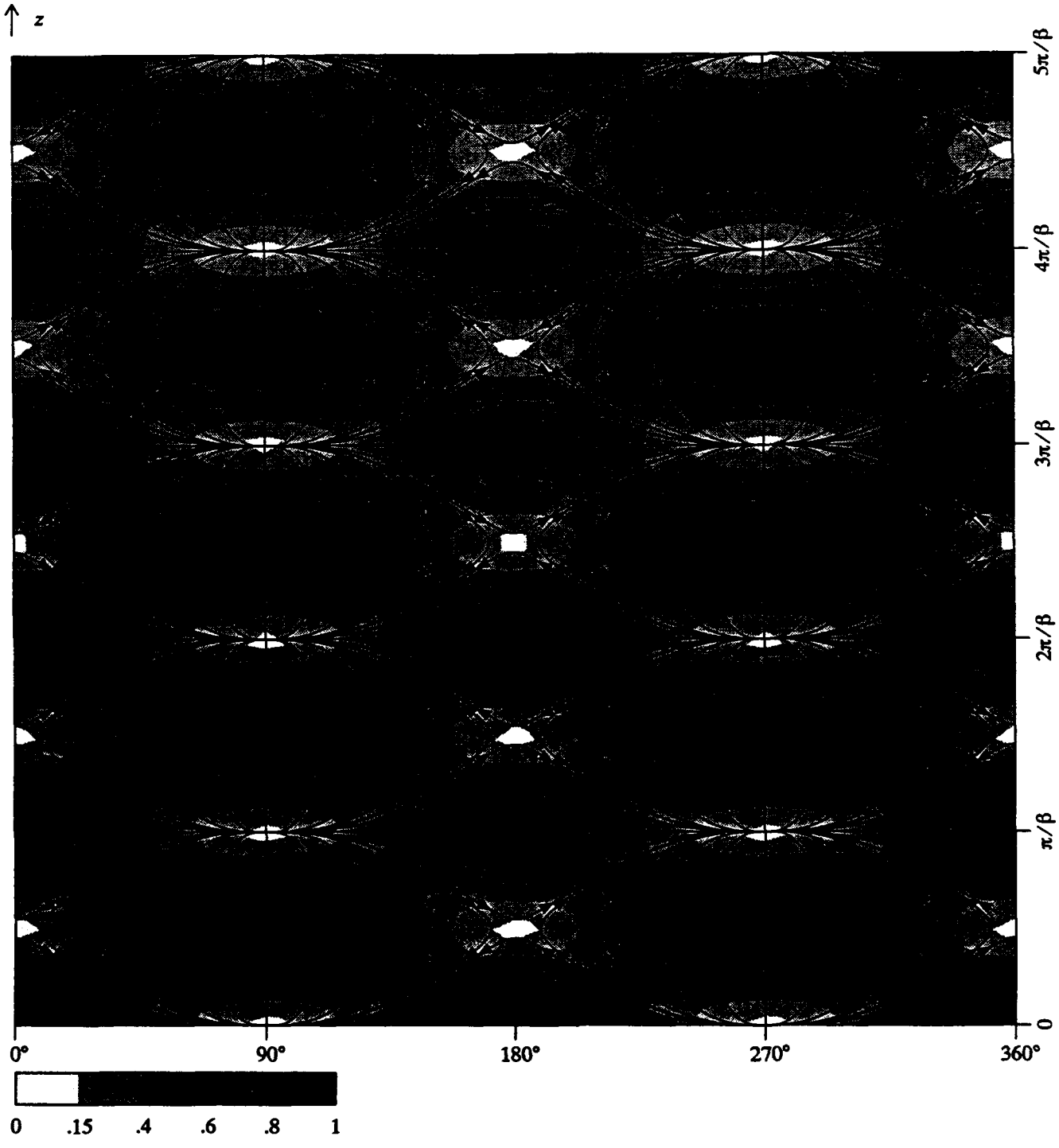


Fig. 5. Magnitude and Direction of TE_{11} Surface Current Plotted on Unfolded Circular Waveguide

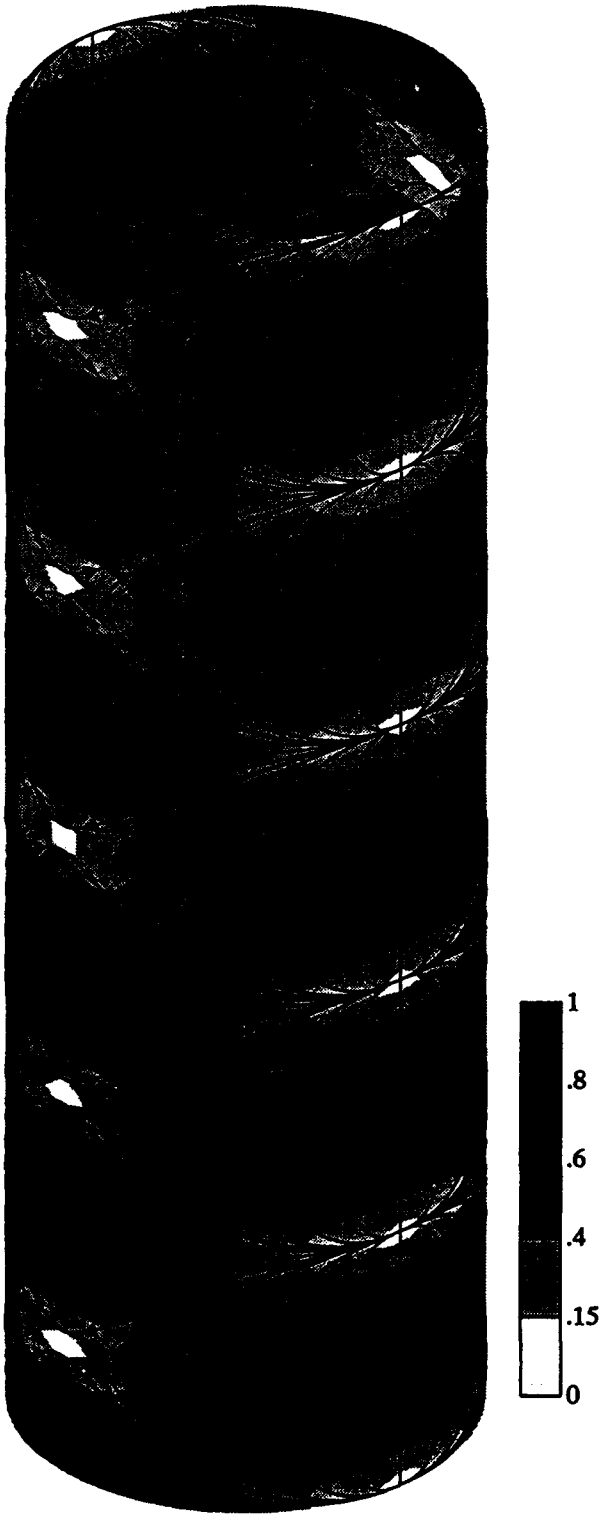


Fig. 6. Magnitude and Direction of TE_{11} Surface Current Plotted on Circular Waveguide

VI. Conclusion

An algorithm has been presented for plotting the magnitude and direction of the current induced on the inside surface of a rectangular or circular waveguide. The algorithm is capable of plotting either a two- or three-dimensional view of the surface-current field. The use of a triangularized mesh is consistent with the output generated by a finite-element solution. Test cases for the lower-order modes of a rectangular and circular waveguide yielded excellent results.

REFERENCES

[1] P. E. Moller and R. H. Macphie, "On the Graphical Representation of Electric Field Lines in Waveguide," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-33, pp. 187-192, Mar. 1985.

[2] C. S. Lee, S. W. Lee, and S. L. Chuang, "Plot of Modal Field Distribution in Rectangular and Circular Waveguides," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-33, pp. 271-274, Mar. 1985.

[3] D. Kajfez and J. A. Gerald, "Plotting Vector Fields with a Personal Computer," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-35, pp. 1069-1072, Nov. 1987.

[4] K. W. Kark and R. Dill, "A General Theory on the Graphical Representation of Antenna-Radiation Fields," *IEEE Trans. Antennas Propagat.*, vol. AP-38, pp. 160-165, Feb. 1990.

[5] A. A. Read, "Computers and Computer Graphics in the Teaching of Field Phenomena," *IEEE Trans. Educ.*, vol. E-33, pp. 95-103, Feb. 1990.

[6] F. G. Stremler, S. A. Klein, F. F. Luo, and Y. Liao, "Numerical Solutions and Mapping of Electrostatic Fields using the Apple Macintosh Computer," *IEEE Trans. Educ.*, vol. E-33, pp. 104-110, Feb. 1990.

[7] T. J. Peters, "A Fast Algorithm for Plotting Antenna and Scattering Patterns in Three Dimensions," The Aerospace Corp., Los Angeles, CA, Tech. Rep. TR-0091(6925-05)-6, August 1991.

[8] T. J. Peters, "A Fast Algorithm for Plotting and Contour Filling Radiation Patterns in Three Dimensions," *IEEE Trans. Antennas Propagat.*, vol. AP-40, pp. 453-456, April. 1992.

[9] A. E. Perry and M. S. Chong, "A Description of Eddying Motions and Flow Patterns using Critical Point Concepts," *Ann. Rev. Fluid Mechanics*, vol. 19, pp. 125-155, 1987.

[10] J. L. Helman and L. Hessenlink, "Representation and Display of Vector Field Topology in Fluid Flow Data Sets," *Computer*, vol. 22, pp. 27-36, Aug. 1989.

[11] J. L. Helman and L. Hessenlink, "Visualizing Vector Field Topology in Fluid Flows,", *IEEE Comput. Graph. Appl.*, vol. 11, pp. 36-46, May. 1991.

[12] G. M. Nielson, T. A. Foley, B. Hamann, and D. Lane, "Visualizing and Modeling Scattered Multivariate Data," *IEEE Comput. Graph. Appl.*, vol. 11, pp. 47-55, May. 1991.

Appendix A: Vector-Line Differential Equation Solution

The slope of a line tangent to the vector field over a triangle determines a first-order nonlinear differential equation of the form

$$\frac{dy}{dx} = \frac{Ax + By + E}{Cx + Dy + F}. \tag{A1}$$

The solution of this differential equation is given by Davis [A1] and is presented below. The first step is to convert the equation to homogeneous form through the definitions

$$x = u + h \tag{A2}$$

$$y = v + g. \tag{A3}$$

Substituting these expressions into Eq. (A1) yields the homogeneous differential equation

$$\frac{dv}{du} = \frac{Au + Bv}{Cu + Dv} \tag{A3}$$

where it is assumed that h and g satisfy the linear equations

$$Ah + Bg = -E \tag{A4}$$

$$Ch + Dg = -F \tag{A5}$$

such that

$$h = \frac{BF - DE}{AD - BC} \tag{A6}$$

$$g = \frac{CE - AF}{AD - BC}. \tag{A7}$$

Assuming that $u > 0$ is satisfied over the triangle, define the variable $s = v/u$ and substitute into Eq. (A4) such that

$$\frac{dv}{du} = s + u\frac{ds}{du}. \tag{A8}$$

This equation can then be separated as

$$\frac{1}{u}du = \frac{C + Ds}{A + (B - C)s - Ds^2}ds \tag{A9}$$

to allow the integration of both sides, yielding an implicit function of the form

$$W(x, y) = 0. \tag{A10}$$

This function can be expressed as

$$W(x, y) = \ln(x - h) - L(x, y) + c_0 \tag{A11}$$

where

$$L(x, y) = \int \left[\frac{C + Ds}{A + (B - C)s - Ds^2}\right] ds \tag{A12}$$

and c_0 is an integration constant chosen to match the initial position of the vector. The integral identity has the form given by [A2]:

$$\int \left[\frac{C + Ds}{A + (B - C)s - Ds^2}\right] ds = -\frac{1}{2}\ln[A + (B - C)s - Ds^2] + H(s) \tag{A13}$$

where

$$H(s) = \begin{cases} \dfrac{B + C}{T}\tan^{-1}\left[\dfrac{B - C - 2Ds}{T}\right] & \Delta > 0 \\ \dfrac{B + C}{2T}\ln\left[\dfrac{B - C - T - 2Ds}{B - C + T - 2Ds}\right] & \Delta < 0 \end{cases} \tag{A14}$$

and

$$\Delta = -4AD - (B - C)^2 \tag{A15}$$

$$T = \sqrt{|\Delta|}. \tag{A16}$$

This identity allows Eq. (A12) to be evaluated as

$$L(x, y) = \ln(x - h) - \frac{1}{2}\ln[A(x - h)^2 + (B - C)(x - h)(y - g) - D(y - g)^2] + H(x, y) \tag{A17}$$

where

$$H(x, y) = \begin{cases} \dfrac{B + C}{T}\tan^{-1}\left[\dfrac{(B - C)(x - h) - 2D(y - g)}{T(x - h)}\right] & \Delta > 0 \\ \dfrac{B + C}{2T}\ln\left[\dfrac{(B - C - T)(x - h) - 2D(y - g)}{(B - C + T)(x - h) - 2D(y - g)}\right] & \Delta < 0 \end{cases} \tag{A18}$$

Thus, Eq. (A11) can be written as

$$W(x,y) = \frac{1}{2}\ln[A(x-h)^2 + (B-C)(x-h)(y-g) - D(y-g)^2] - H(x,y) + c_0. \tag{A19}$$

The implicit form of the equation of the line makes this solution fairly slow to plot a vector field. However, it can be a useful way to judge interactively the appropriateness of the step size. A viewer-selected triangle can be enlarged and the vector drawn using either the incremental method described previously, or the analytic solution. A comparison of both methods can indicate the correctness of the step size or the triangle grid size.

Appendix A References

[A1] H. T. Davis, "*Introduction to Nonlinear Differential and Integral Equations*," (New York: Dover, 1962), pp. 38-45.

[A2] I. S. Gradshteyn and I. M. Ryzhik, "*Table of Integrals, Series, and Products*," (New York: Academic Press, 1980), p. 57.

Appendix B: Computer Programs

This appendix contains the programs and subroutines used to generate the graphics found in this report. All source code is written in standard Fortran 77 [B1]. The output graphic is generated as an encapsulated PostScript (EPS) file [B2]-[B4]. The program WAVEDR generates the geometry of the waveguide, as well as that of the node-to-triangle matrix and the triangle-to-node matrix. The program UNFOLD plots the surface-current vector field on an unfolded circular or rectangular waveguide. The program FLDREC plots the surface-current vector field directly on the outside surface of a rectangular waveguide. The program FLDCIR plots the surface-current vector field directly on the outside surface of a circular waveguide. Figure B.1 shows the interdependency of the programs and subroutines.

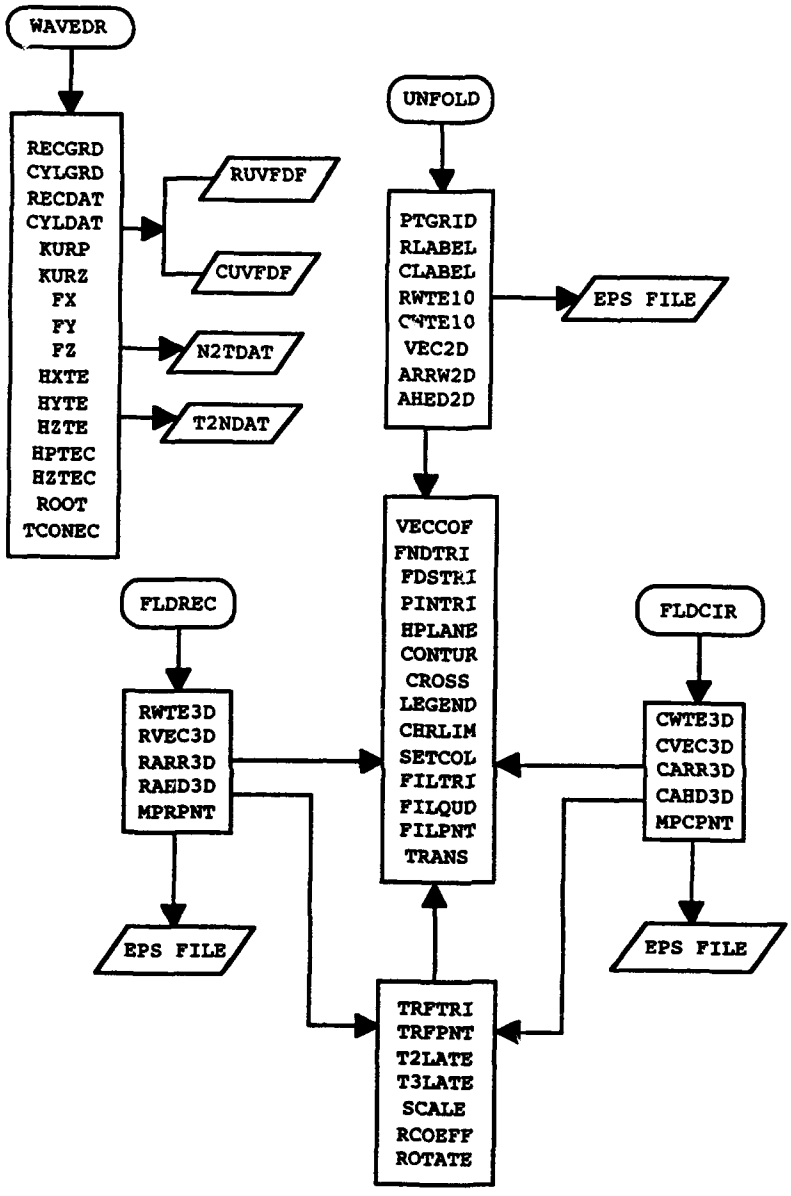


Fig. B.1 Program and Subroutine Dependencies

```
      PROGRAM WAVEDR
C     ******************************************************************
C     * THIS PROGRAM GENERATES THE DATA FILES FOR PLOTTING SURFACE     *
C     * CURRENT MAGNITUDE AND DIRECTION ON A RECTANGULAR OR CIRCULAR   *
C     * WAVEGUIDE AT TIME T=0.                                         *
C     ******************************************************************
C     * TIMOTHY J. PETERS                                LAST UPDATED  *
C     * THE AEROSPACE CORPORATION                        5/14/92       *
C     * 2350 EAST EL SEGUNDO BOULEVARD                                 *
C     * EL SEGUNDO, CA 90245                                           *
C     ******************************************************************
      PARAMETER (MN=6000,MT=12000,MP=6)
      REAL*4 U(MN),V(MN),KC2
      INTEGER*4 N2T(MT,3),T2N(MN,MP)
      PI=.3141593E+01
C     ******************************************************************
C     * INPUTS:                                                        *
C     *                                                                *
C     *     MN  - MAXIMUM NUMBER OF NODES.                             *
C     *     MT  - MAXIMUM NUMBER OF TRIANGLES                          *
C     *     MP  - MAXIMUM NUMBER OF TRIANGLES CONNECTED TO A NODE.     *
C     *   IGEO  -  IGEO=1 (RECTANGULAR) IGEO=2 (CIRCULAR) WAVEGUIDE.   *
C     *      A  - SIDE WIDTH -A/2 <=X<=A/2 FOR RECTANGULAR GUIDE OR    *
C     *           RADIUS FOR CIRCULAR GUIDE (WAVELENGTHS).             *
C     *      B  - SIDE WIDTH -B/2 <=Y<=B/2 FOR RECTANGULAR GUIDE.      *
C     *     KM  - NUMBER OF LONGITUDINAL HALF CYCLES.                  *
C     *     M,N - MODE NUMBERS FOR TE_{MN} FOR RECTANGULAR GUIDE.      *
C     *     N,M - MODE NUMBERS FOR TE_{NM} FOR CIRCULAR GUIDE.         *
C     *    NUA  - NUMBER OF POINTS ALONG X DIRECTION.                  *
C     *    NUB  - NUMBER OF POINTS ALONG Y DIRECTION.                  *
C     ******************************************************************
      IGEO=2
      IF (IGEO .EQ. 1) THEN
C       ****************************************************************
C       * RECTANGULAR WAVEGUIDE.                                       *
C       ****************************************************************
        A=1.0
        B=0.5
        M=1
        N=0
        KM=5
        NV=62
        NUA=27
        NUB=9
        KC2=(M*PI/A)*(M*PI/A)+(N*PI/B)*(N*PI/B)
        BETA=SQRT(4*PI*PI-KC2)
        C=KM*PI/BETA
        NU=2*(NUA+NUB)-3
        NN=NU*NV
        NT=2*(NU-1)*(NV-1)
C       ****************************************************************
C       * GENERATE THE N2T COORDINATES AND THE CONNECTION MATRIX.       *
C       ****************************************************************
        CALL RECGRD(A,B,C,NUA,NUB,NU,NV,MN,MT,U,V,N2T)
C       ****************************************************************
C       * WRITE OUT THE COORDINATE DATA AND VECTOR FUNCTION DATA TO A   *
C       * FILE.                                                        *
C       ****************************************************************
        CALL RECDAT(A,B,C,KM,NUA,NUB,NV,NN,MN,U,V,M,N)
```

```
      ELSE
        NU=45
        NV=62
        NN=NU*NV
        NT=2*(NU-1)*(NV-1)
        A=0.5
        N=1
        M=1
        PNL=ROOT(N,M)
        KC2=PNL*PNL/(A*A)
        BETA=SQRT(4*PI*PI-KC2)
        KM=5
        C=KM*PI/BETA
        CALL CYLGRD(A,C,NU,NV,MN,MT,U,V,N2T)
C       ***********************************************************************
C       * WRITE OUT THE COORDINATE DATA AND VECTOR FUNCTION DATA TO A  *
C       * FILE.                                                        *
C       ***********************************************************************
        CALL CYLDAT(A,C,KM,NU,NV,NN,MN,U,V,N,M)
      END IF
C     ***********************************************************************
C     * WRITE OUT THE NODE TO TRIANGLE CONNECTION DATA.              *
C     ***********************************************************************
      OPEN(UNIT=1,FILE='N2TDAT')
      WRITE(1,*) NT
      DO 1 I=1,NT
        WRITE(1,*)  N2T(I,1),N2T(I,2),N2T(I,3)
    1 CONTINUE
      CLOSE(1)
C     ***********************************************************************
C     * GENERATE THE MATRIX OF TRIANGLES CONNECTED TO THE SAME N2T.   *
C     ***********************************************************************
      CALL TCONEC(MT,N2T,NT,MN,MP,T2N)
      WRITE(*,*) 'TRIANGLE TO NODE CONNECTION MATRIX GENERATED'
      OPEN(UNIT=1,FILE='T2NDAT')
      WRITE(1,*) NN
      DO 2 I=1,NN
        WRITE(1,*) T2N(I,1),T2N(I,2),T2N(I,3),T2N(I,4),T2N(I,5),T2N(I,6)
    2 CONTINUE
      CLOSE(1)
      END

      SUBROUTINE RECGRD(A,B,C,NUA,NUB,NU,NV,MN,MT,U,V,N2T)
C     ***********************************************************************
C     * THIS SUBROUTINE GENERATES THE UNFOLDED COORDINATES OF A       *
C     * SECTION OF RECTANGULAR WAVEGUIDE.  THESE COORDINATES REPRESENT *
C     * THE VERTICES OF TRIANGLES.  NODE TO TRIANGLE CONNECTION MATRIX *
C     * IS ALSO GENERATED.                                            *
C     ***********************************************************************
C     * INPUTS:                                                       *
C     *                                                               *
C     *   A -   WIDTH OF WAVEGUIDE IN X DIRECTION -A/2 <=X<= A/2.     *
C     *   B -   WIDTH OF WAVEGUIDE IN Y DIRECTION -B/2 <=Y<= B/2.     *
C     *   C -   LENGTH OF WAVEGUIDE IN Z DIRECTION.                   *
C     *   NUA - NUMBER OF POINTS ALONG X DIRECTION.                   *
C     *   NUB - NUMBER OF POINTS ALONG Y DIRECTION.                   *
C     *   NU - TOTAL NUMBER OF U POINTS.                              *
C     *   NV - TOTAL NUMBER OF V POINTS.                              *
C     *   MN - MAXIMUM DIMENSION OF VECTORS U AND V.                  *
```

```
C     *   MT - MAXIMUM NUMBER OF TRIANGLES.                          *
C     *                                                              *
C     * OUTPUTS:                                                     *
C     *                                                              *
C     *   U(MN) - COORDINATES OF EACH DATA POINT.                    *
C     *   V(MN)                                                      *
C     *   N2T(MT,3)  MATRIX OF N2T NUMBERS CONNECTED TO EACH         *
C     *                TRIANGLE.                                     *
C     ****************************************************************
      REAL*4 U(MN),V(MN)
      INTEGER*4 N2T(MT,3)
      PI=.3141593E+01
C     ****************************************************************
C     * GENERATE THE N2T COORDINATES.                                *
C     ****************************************************************
      DUA=A/(NUA-1)
      DUB=B/(NUB-1)
      DV=C/(NV-1)
C     ****************************************************************
C     * SECTION 1 HORIZONTAL COORDINATE.                             *
C     ****************************************************************
      K=0
      DO 1 I=0,NUA-2
        K=K+1
        U(K)=-B-A+I*DUA
1     CONTINUE
C     ****************************************************************
C     * SECTION 2 HORIZONTAL COORDINATE.                             *
C     ****************************************************************
      DO 2 I=0,NUB-2
        K=K+1
        U(K)=-B+I*DUB
2     CONTINUE
C     ****************************************************************
C     * SECTION 3 HORIZONTAL COORDINATE.                             *
C     ****************************************************************
      DO 3 I=0,NUA-2
        K=K+1
        U(K)=I*DUA
3     CONTINUE
C     ****************************************************************
C     * SECTION 4 HORIZONTAL COORDINATE.                             *
C     ****************************************************************
      DO 4 I=0,NUB-1
        K=K+1
        U(K)=A+I*DUB
4     CONTINUE
C     ****************************************************************
C     * LONGITUDINAL (VERTICAL) COORDINATE.                          *
C     ****************************************************************
      K=0
      DO 5 I=0,NV-1
        K=K+1
        V(K)=I*DV
5     CONTINUE
C     ****************************************************************
C     * GENERATE THE CONNECTION MATRIX.                              *
C     ****************************************************************
      K=0
```

```
      N=0
      DO 6 I=1,NU-1
        DO 7 J=1,NV-1
      N=N+1
          K=K+1
          N2T(K,1)=N
          N2T(K,2)=N+1
          N2T(K,3)=N+NV+1
          K=K+1
          N2T(K,1)=N
          N2T(K,2)=N+NV
          N2T(K,3)=N+NV+1
    7   CONTINUE
        N=N+1
    6 CONTINUE
      RETURN
      END

      SUBROUTINE CYLGRD(A,C,NU,NV,MN,MT,U,V,N2T)
C     ******************************************************************
C     * THIS SUBROUTINE GENERATES THE UNFOLDED COORDINATES OF A        *
C     * SECTION OF RECTANGULAR WAVEGUIDE.  THESE COORDINATES REPRESENT *
C     * THE VERTICES OF TRIANGLES.  NODE TO TRIANGLE CONNECTION MATRIX *
C     * IS ALSO GENERATED.                                             *
C     ******************************************************************
C .   * INPUTS:                                                        *
C     *                                                                *
C     *   A -     WIDTH OF WAVEGUIDE IN X DIRECTION.                   *
C     *   B -     WIDTH OF WAVEGUIDE IN Y DIRECTION.                   *
C     *   C -     LENGTH OF WAVEGUIDE IN Z DIRECTION.                  *
C     *   NUA - NUMBER OF POINTS ALONG X DIRECTION.                    *
C     *   NUB - NUMBER OF POINTS ALONG Y DIRECTION.                    *
C     *   NU - TOTAL NUMBER OF U POINTS.                               *
C     *   NV - TOTAL NUMBER OF V POINTS.                               *
C     *   MN - MAXIMUM DIMENSION OF VECTORS U AND V.                   *
C     *   MT - MAXIMUM NUMBER OF TRIANGLES.                            *
C     *                                                                *
C     * OUTPUTS:                                                       *
C     *                                                                *
C     *   U(MN) - COORDINATES OF EACH DATA POINT.                      *
C     *   V(MN)                                                        *
C     *   N2T(MT,3)  MATRIX OF N2T NUMBERS CONNECTED TO EACH           *
C     *                TRIANGLE.                                       *
C     ******************************************************************
      REAL*4 U(MN),V(MN)
      INTEGER*4 N2T(MT,3)
      TP=.62831853E+01
C     ******************************************************************
C     * GENERATE THE N2T COORDINATES.                                  *
C     ******************************************************************
      DU=TP*A/(NU-1)
      DV=C/(NV-1)
C     ******************************************************************
C     * SECTION 1 HORIZONTAL COORDINATE.                               *
C     ******************************************************************
      K=0
      DO 1 I=0,NU-1
        K=K+1
        U(K)=I*DU
```

```
 1       CONTINUE
 C       ************************************************************************
 C       * LONGITUDINAL (VERTICAL) COORDINATE.                                  *
 C       ************************************************************************
         K=0
         DO 5 I=0,NV-1
           K=K+1
           V(K)=I*DV
 5       CONTINUE
 C       ************************************************************************
 C       * GENERATE THE CONNECTION MATRIX.                                      *
 C       ************************************************************************
         K=0
         N=0
         DO 6 I=1,NU-1
           DO 7 J=1,NV-1
         N=N+1
             K=K+1
             N2T(K,1)=N
             N2T(K,2)=N+1
             N2T(K,3)=N+NV+1
             K=K+1
             N2T(K,1)=N
             N2T(K,2)=N+NV
             N2T(K,3)=N+NV+1
   7       CONTINUE
           N=N+1
   6     CONTINUE
         RETURN
         END

         SUBROUTINE RECDAT(A,B,C,KM,NUA,NUB,NV,NN,MN,U,V,M,N)
 C       ************************************************************************
 C       * THIS SUBROUTINE WRITES OUT THE COORDINATE AND FUNCTION DATA          *
 C       * FOR A RECTANGULAR WAVEGUIDE TO A FILE.                               *
 C       ************************************************************************
         REAL*4 U(MN),V(MN)
         DX=A/(NUA-1)
         DY=B/(NUB-1)
         DZ=C/(NV-1)
         OPEN(UNIT=1,FILE='RUVFDF')
         WRITE(1,*) A,B,C,KM,M,N
         WRITE(1,*) NUA,NUB,NV
         WRITE(1,*) NN
 C       ************************************************************************
 C       * SIDE 1.                                                              *
 C       ************************************************************************
         Y=B/2.0
         VX=0.0
         VY=-1.0
         VZ=0.0
         K=0
         DO 1 I=0,NUA-1
           X=-A/2.0+I*DX
           K=K+1
           DO 2 J=0,NV-1
             Z=J*DZ
             CALL FZ(A,B,M,N,X,Y,Z,VX,VY,VZ,FZV)
             CALL FX(A,B,M,N,X,Y,Z,VX,VY,VZ,FXV)
```

```
29            WRITE(1,*) U(K),V(J+1),FXV,FZV
30 2        CONTINUE
31 1      CONTINUE
32 C      ************************************************************************
33 C      * SIDE 2.                                                              *
34 C      ************************************************************************
35        X=A/2.0
36        VX=-1.0
37        VY=0.0
38        VZ=0.0
39        DO 3 I=1,NUB-1
40          Y=B/2.0-I*DY
41          K=K+1
42          DO 4 J=0,NV-1
43            Z=J*DZ
44            CALL FZ(A,B,M,N,X,Y,Z,VX,VY,VZ,FZV)
45            CALL FY(A,B,M,N,X,Y,Z,VX,VY,VZ,FYV)
46            WRITE(1,*) U(K),V(J+1),-FYV,FZV
47 4        CONTINUE
48 3      CONTINUE
49 C      ************************************************************************
50 C      * SIDE 3.                                                              *
51 C      ************************************************************************
52        Y=-B/2.0
53        VX=0.0
54        VY=1.0
55        VZ=0.0
56        DO 5 I=1,NUA-1
57          X=A/2.0-I*DX
58          K=K+1
59          DO 6 J=0,NV-1
60            Z=J*DZ
61            CALL FZ(A,B,M,N,X,Y,Z,VX,VY,VZ,FZV)
62            CALL FX(A,B,M,N,X,Y,Z,VX,VY,VZ,FXV)
63            WRITE(1,*) U(K),V(J+1),-FXV,FZV
64 6        CONTINUE
65 5      CONTINUE
66 C      ************************************************************************
67 C      * SIDE 4.                                                              *
68 C      ************************************************************************
69        X=-A/2.0
70        VX=1.0
71        VY=0.0
72        VZ=0.0
73        DO 7 I=1,NUB-1
74          Y=-B/2.0+I*DY
75          K=K+1
76          DO 8 J=0,NV-1
77            Z=J*DZ
78            CALL FZ(A,B,M,N,X,Y,Z,VX,VY,VZ,FZV)
79            CALL FY(A,B,M,N,X,Y,Z,VX,VY,VZ,FYV)
80            WRITE(1,*) U(K),V(J+1),FYV,FZV
81 8        CONTINUE
82 7      CONTINUE
83        CLOSE(1)
84        RETURN
85        END

 1        SUBROUTINE CYLDAT(A,C,KM,NU,NV,NN,MN,U,V,N,M)
```

```
C     ************************************************************************
C     * THIS SUBROUTINE WRITES OUT THE COORDINATE AND FUNCTION DATA    *
C     * FOR A CIRCULAR WAVEGUIDE TO A FILE.                            *
C     ************************************************************************
      REAL*4 U(MN),V(MN)
      TP=.628318531E+01
      DP=TP/(NU-1)
      DZ=C/(NV-1)
      OPEN(UNIT=1,FILE='CUVFDF')
      WRITE(1,*) A,C,KM,N,M
      WRITE(1,*) NU,NV
      WRITE(1,*) NN
C     ************************************************************************
C     * SIDE 1.                                                        *
C     ************************************************************************
      R=A
      K=0
      DO 1 I=0,NU-1
        P=I*DP
        K=K+1
        DO 2 J=0,NV-1
          Z=J*DZ
          CALL KURP(A,N,M,R,P,Z,FPV)
          CALL KURZ(A,N,M,R,P,Z,FZV)
          WRITE(1,*) U(K),V(J+1),FPV,FZV
2       CONTINUE
1     CONTINUE
      CLOSE(1)
      RETURN
      END

      SUBROUTINE KURP(A,N,L,R,P,Z,F)
C     ************************************************************************
C     * THIS SUBROUTINE COMPUTES THE SURFACE CURRENT FLOWING IN THE X  *
C     * DIRECTION.                                                     *
C     ************************************************************************
      CALL HZTEC(A,N,L,R,P,Z,HZ)
      F=HZ
      RETURN
      END

      SUBROUTINE KURZ(A,N,L,R,P,Z,F)
C     ************************************************************************
C     * THIS SUBROUTINE COMPUTES THE SURFACE CURRENT FLOWING IN THE X  *
C     * DIRECTION.                                                     *
C     ************************************************************************
      CALL HPTEC(A,N,L,R,P,Z,HP)
      F=-HP
      RETURN
      END

      SUBROUTINE FX(A,B,M,N,X,Y,Z,VX,VY,VZ,F)
C     ************************************************************************
C     * THIS SUBROUTINE COMPUTES THE SURFACE CURRENT FLOWING IN THE X  *
C     * DIRECTION.                                                     *
C     ************************************************************************
      CALL HZTE(X,Y,Z,A,B,M,N,HZ)
      CALL HYTE(X,Y,Z,A,B,M,N,HY)
      F=VY*HZ-VZ*HY
```

```
      RETURN
      END

      SUBROUTINE FY(A,B,M,N,X,Y,Z,VX,VY,VZ,F)
C     ************************************************************************
C     * THIS SUBROUTINE COMPUTES THE SURFACE CURRENT FLOWING IN THE Y        *
C     * DIRECTION.                                                           *
C     ************************************************************************
      CALL HXTE(X,Y,Z,A,B,M,N,HX)
      CALL HZTE(X,Y,Z,A,B,M,N,HZ)
      F=VZ*HX-VX*HZ
      RETURN
      END

      SUBROUTINE FZ(A,B,M,N,X,Y,Z,VX,VY,VZ,F)
C     ************************************************************************
C     * THIS SUBROUTINE COMPUTES THE SURFACE CURRENT FLOWING IN THE Z        *
C     * DIRECTION.                                                           *
C     ************************************************************************
      CALL HYTE(X,Y,Z,A,B,M,N,HY)
      CALL HXTE(X,Y,Z,A,B,M,N,HX)
      F=VX*HY-VY*HX
      RETURN
      END

      SUBROUTINE HXTE(X,Y,Z,A,B,M,N,HX)
C     ************************************************************************
C     * THIS SUBROUTINE COMPUTES THE X COMPONENT OF THE MAGNETIC FIELD       *
C     * ON THE SURFACE OF A RECTANGULAR WAVEGUIDE FOR A TE MODE.             *
C     ************************************************************************
      PI=.3141593E+01
      TP2=.394784176E+02
      ARGX=(M*PI/A)*(X-A/2.0)
      ARGY=(N*PI/B)*(Y-B/2.0)
      H2=(M*PI/A)*(M*PI/A)+(N*PI/B)*(N*PI/B)
      BETA=SQRT(TP2-H2)
      ARGZ=-BETA*Z
      H2=(M*PI/A)*(M*PI/A)+(N*PI/B)*(N*PI/B)
      HX=(-M*PI*BETA/(A*H2))*SIN(ARGX)*COS(ARGY)*SIN(ARGZ)
      RETURN
      END

      SUBROUTINE HYTE(X,Y,Z,A,B,M,N,HY)
C     ************************************************************************
C     * THIS SUBROUTINE COMPUTES THE X COMPONENT OF THE MAGNETIC FIELD       *
C     * ON THE SURFACE OF A RECTANGULAR WAVEGUIDE FOR A TE MODE.             *
C     ************************************************************************
      PI=.3141593E+01
      TP2=.394784176E+02
      ARGX=(M*PI/A)*(X-A/2.0)
      ARGY=(N*PI/B)*(Y-B/2.0)
      H2=(M*PI/A)*(M*PI/A)+(N*PI/B)*(N*PI/B)
      BETA=SQRT(TP2-H2)
      ARGZ=-BETA*Z
      HY=(-N*PI*BETA/(B*H2))*COS(ARGX)*SIN(ARGY)*SIN(ARGZ)
      RETURN
      END

      SUBROUTINE HZTE(X,Y,Z,A,B,M,N,HZ)
```

```
C     ************************************************************
C     * THIS SUBROUTINE COMPUTES THE Z COMPONENT OF THE MAGNETIC FIELD *
C     * ON THE SURFACE OF A RECTANGULAR WAVEGUIDE FOR A TE MODE.      *
C     ************************************************************
      PI=.3141593E+01
      TP2=.394784176E+02
      ARGX=(M*PI/A)*(X-A/2.0)
      ARGY=(N*PI/B)*(Y-B/2.0)
      H2=(M*PI/A)*(M*PI/A)+(N*PI/B)*(N*PI/B)
      BETA=SQRT(TP2-H2)
      ARGZ=-BETA*Z
      HZ=COS(ARGX)*COS(ARGY)*COS(ARGZ)
      RETURN
      END

      SUBROUTINE HPTEC(A,N,L,R,P,Z,HP)
C     ************************************************************
C     * THIS SUBROUTINE COMPUTES THE PHI COMPONENT OF THE MAGNETIC    *
C     * FIELD ON THE SURFACE OF A CIRCULAR WAVEGUIDE FOR A TE_{NL}    *
C     * MODE AT TIME T=0. NOTE THAT THE BESSEL FUNCTION IS NOT        *
C     * INCLUDED SINCE IT WILL DROP OUT WHEN THE CURRENT IS NORMALIZED.*
C     ************************************************************
      REAL KC
      PI=.3141593E+01
      TP2=.394784176E+02
      PNL=ROOT(N,L)
      KC=PNL/A
      BETA=SQRT(TP2-KC*KC)
      ARGZ=-BETA*Z
      HP=(-N*TP2/(KC*KC*BETA*R))*SIN(N*P)*SIN(ARGZ)
      RETURN
      END

      SUBROUTINE HZTEC(A,N,L,R,P,Z,HZ)
C     ************************************************************
C     * THIS SUBROUTINE COMPUTES THE Z COMPONENT OF THE MAGNETIC FIELD *
C     * ON THE SURFACE OF A CIRCULAR WAVEGUIDE FOR A TE_{NL} MODE.    *
C     * NOTE THAT THE BESSEL FUNCTION IS NOT INCLUDED SINCE IT WILL   *
C     * DROP OUT WHEN THE CURRENT IS NORMALIZED.                      *
C     ************************************************************
      REAL KC
      PI=.3141593E+01
      TP2=.394784176E+02
      PNL=ROOT(N,L)
      KC=PNL/A
      BETA=SQRT(TP2-KC*KC)
      ARGZ=-BETA*Z
      HZ=COS(N*P)*COS(ARGZ)
      RETURN
      END

      FUNCTION ROOT(N,L)
C     ************************************************************
C     * THIS FUNCTION RETURNS THE LTH ROOT OF THE FIRST               *
C     * DERIVATIVE OF A BESSEL FUNCTION OF ORDER N.                   *
C     ************************************************************
      REAL*4 PNL(0:2,4)
      PNL(0,1)=3.832
      PNL(0,2)=7.016
```

```
      PNL(0,3)=10.174
      PNL(0,4)=13.324
      PNL(1,1)=1.841
      PNL(1,2)=5.331
      PNL(1,3)=8.536
      PNL(1,4)=11.706
      PNL(2,1)=3.054
      PNL(2,2)=6.706
      PNL(2,3)=9.970
      PNL(2,4)=13.170
      ROOT=PNL(N,L)
      RETURN
      END

      SUBROUTINE TCONEC(MT,N2T,NT,MN,MP,T2N)
C     ************************************************************************
C     * THIS SUBROUTINE GENERATES A MATRIX WITH GIVES ALL THE                *
C     * TRIANGLES CONNECTED TO EACH N2T.                                     *
C     ************************************************************************
C     * INPUTS:                                                              *
C     *                                                                      *
C     *   MT - MAXIMUM NUMBER OF TRIANGLES.                                  *
C     *   N2T(MT,3)   MATRIX OF NODE NUMBERS CONNECTED TO EACH               *
C     *               TRIANGLE.                                              *
C     *   MN - MAXIMUM NUMBER OF NODES.                                      *
C     *   MP - MAXIMUM NUMBER OF POINTS CONNECTED TO EACH TRIANGLE.          *
C     *                                                                      *
C     * OUTPUT:                                                              *
C     *                                                                      *
C     *   T2N(MN,MP)  MATRIX OF TRIANGLE NUMBERS CONNECTED TO EACH           *
C     *               NODE.                                                  *
C     ************************************************************************
      INTEGER*4 N2T(MT,3),T2N(MN,MP)
C     ************************************************************************
C     * INITIALIZE THE MATRIX.                                               *
C     ************************************************************************
      DO 1 I=1,MN
        DO 2 J=1,MP
          T2N(I,J)=0
    2   CONTINUE
    1 CONTINUE
C     ************************************************************************
C     * FILL IN NON ZERO ENTRIES.                                            *
C     ************************************************************************
      DO 3 I=1,NT
        DO 4 J=1,3
          IFLAG=0
          DO 5 K=1,MP
            IF ((T2N(N2T(I,J),K) .EQ. 0) .AND. (IFLAG .EQ. 0)) THEN
              T2N(N2T(I,J),K)=I
              IFLAG=1
            ELSE
            END IF
    5     CONTINUE
    4   CONTINUE
    3 CONTINUE
      RETURN
      END
```

```
      PROGRAM UNFOLD
C     ************************************************************************
C     * THIS PROGRAM GENERATES A VECTOR PLOT OF A TRIANGULARIZED              *
C     * UNFOLDED RECTANGULAR WAVEGUIDE.                                      *
C     ************************************************************************
C     * TIMOTHY J. PETERS                                    LAST UPDATED    *
C     * THE AEROSPACE CORPORATION                            5/12/92         *
C     * 2350 EAST EL SEGUNDO BOULEVARD                                       *
C     * EL SEGUNDO, CA 90245                                                 *
C     ************************************************************************
      PARAMETER (MN=6000,MT=12000,MP=6,NC=5,NL=6)
      REAL*4 X(MN),Y(MN),FX(MN),FY(MN),PHI(50),CA(NC),CB(NC)
      REAL*8 ARG
      INTEGER LC(NC)
      CHARACTER*30 LABEL(NL)
      INTEGER*4 N2T(MT,3),T2N(MN,MP)
      PI=.3141593E+01
      TP=.6283153E+01
      RAD=.17453293E-01
C     ************************************************************************
C     * INPUTS:                                                              *
C     *                                                                      *
C     *     MN    - MAXIMUM NUMBER OF NODES.                                 *
C     *     MT    - MAXIMUM NUMBER OF TRIANGLES.                             *
C     *     MP    - MAXIMUM NUMBER OF TRIANGLES CONNECTED TO A NODE.         *
C     *   IGEO    -  IGEO=1 (RECTANGULAR) IGEO=2 (CIRCULAR) WAVEGUIDE.       *
C     *     A     - SIDE WIDTH -A/2 <=X<=A/2 FOR RECTANGULAR GUIDE OR        *
C     *             RADIUS FOR CIRCULAR GUIDE (WAVELENGTHS).                 *
C     *     B     - SIDE WIDTH -B/2 <=Y<=B/2 FOR RECTANGULAR GUIDE.          *
C     *    KM     - NUMBER OF LONGITUDINAL HALF CYCLES.                      *
C     *   NUA     - NUMBER OF POINTS ALONG X DIRECTION.                      *
C     *   NUB     - NUMBER OF POINTS ALONG Y DIRECTION.                      *
C     ************************************************************************
C     ************************************************************************
C     * READ THE COORDINATE DATA AND VECTOR FUNCTION DATA FROM A FILE.       *
C     ************************************************************************
      IGEO=2
      IF (IGEO .EQ. 1) THEN
C       ***************************************************************
C       * RECTANGULAR WAVEGUIDE.                                      *
C       ***************************************************************
        OPEN(UNIT=1,FILE='RUVFDF')
        READ(1,*) A,B,C,KM,M,N
        READ(1,*) NUA,NUB,NV
        READ(1,*) NN
        VMAX=0.0
        DO 1 I=1,NN
          READ(1,*) X(I),Y(I),FX(I),FY(I)
      VMAG=SQRT(FX(I)*FX(I)+FY(I)*FY(I))
          IF (VMAG .GT. VMAX) THEN
            VMAX=VMAG
          ELSE
          END IF
    1   CONTINUE
        CLOSE(1)
        WRITE(*,*) NN,' DATA POINTS READ IN'
      ELSE
C       ***************************************************************
C       * CIRCULAR WAVEGUIDE.                                         *
```

```
C       ********************************************************************
        OPEN(UNIT=1,FILE='CUVFDF')
        READ(1,*) A,C,KM,N,M
        READ(1,*) NU,NV
        READ(1,*) NN
        VMAX=0.0
        DO 2 I=1,NN
          READ(1,*) X(I),Y(I),FX(I),FY(I)
      VMAG=SQRT(FX(I)*FX(I)+FY(I)*FY(I))
          IF (VMAG .GT. VMAX) THEN
            VMAX=VMAG
          ELSE
          END IF
  2     CONTINUE
        CLOSE(1)
        WRITE(*,*) NN,' DATA POINTS READ IN'
      END IF
C     ********************************************************************
C     * NORMALIZE THE VECTOR COMPONENTS SO THAT THE MAXIMUM MAGNITUDE  *
C     * IS 1.0.                                                        *
C     ********************************************************************
      DO 3 I=1,NN
        FX(I)=FX(I)/VMAX
        FY(I)=FY(I)/VMAX
  3   CONTINUE
C     ********************************************************************
C     * READ THE NODE TO TRIANGLE CONNECTION MATRIX.                   *
C     ********************************************************************
      OPEN(UNIT=1,FILE='N2TDAT')
      READ(1,*) NT
      DO 4 I=1,NT
        READ(1,*)  N2T(I,1),N2T(I,2),N2T(I,3)
  4   CONTINUE
      CLOSE(1)
      WRITE(*,*) 'NODE TO TRIANGLE DATA READ IN'
C     ********************************************************************
C     * READ THE TRIANGLE TO NODE CONNECTION MATRIX.                   *
C     ********************************************************************
      OPEN(UNIT=1,FILE='T2NDAT')
      READ(1,*) NN
      DO 5 I=1,NN
        READ(1,*)  (T2N(I,J),J=1,MP)
  5   CONTINUE
      CLOSE(1)
      WRITE(*,*) 'TRIANGLE TO NODE DATA READ IN'
C     ********************************************************************
C     * COMPUTE THE CENTER OF THE PLOT REGION.                         *
C     ********************************************************************
      IF (IGEO .EQ. 1) THEN
        XMIN=-B-A
        XMAX=A+B
      ELSE
        XMIN=0.0
        XMAX=TP*A
      END IF
      YMIN=0.0
      YMAX=C
      XC=(XMIN+XMAX)/2.0
      YC=(YMIN+YMAX)/2.0
```

```
C     ************************************************************************
C     * COMPUTE THE CENTER OF THE PRINTING DEVICE PAGE.                      *
C     ************************************************************************
      XO=72*8.5/2.0
      YO=72*11.0/2.0+72.0
C     ************************************************************************
C     * COMPUTE THE SCALE CONSTANTS.                                         *
C     ************************************************************************
      GS=150.0
      BX=XO-GS*XC
      BY=YO-GS*YC
C     ************************************************************************
C     * SET THE GRAPHIC BOUNDING BOX.                                        *
C     ************************************************************************
      WX=(XMAX-XMIN)
      WY=(YMAX-YMIN)
      WIDTH=GS*WX
      HEIGHT=GS*WY
      UA=XO-WIDTH/2.0
      UB=XO+WIDTH/2.0+21.0
      VA=YO-HEIGHT/2.0-53.0
      VB=YO+HEIGHT/2.0+25.0
C     ************************************************************************
C     * COMPUTE THE BOUNDING BOX FOR THE POSTSCRIPT IN THE DEFAULT           *
C     * COORDINATE SYSTEM.                                                   *
C     ************************************************************************
      OPEN(UNIT=1,FILE='Waveguide.ps')
      REWIND 1
      WRITE(1,*) '%!PS-Adobe-1.0'
      WRITE(1,*) '%%Creator: Timothy J. Peters'
      WRITE(1,*) '%%Title: Unfolded Waveguide'
      WRITE(1,*) '%%CreationDate: 5-12-92'
      WRITE(1,100) '%%BoundingBox:',INT(UA),INT(VA),INT(UB),INT(VB)
100   FORMAT(A14,4(1X,I3))
      WRITE(1,*) '%%EndComments'
      WRITE(1,*) '/dot2 {2 0 360 arc 0 setgray fill stroke} def'
      WRITE(1,*) '/dot3 {3 0 360 arc 0 setgray fill stroke} def'
      WRITE(1,*) '/dot4 {4 0 360 arc 0 setgray fill stroke} def'
      WRITE(1,*) '/black {0 0 0 setrgbcolor} def'
      WRITE(1,*) '/white {1 1 1 setrgbcolor} def'
      WRITE(1,*) '/gray-lt {0.92 0.92 0.92 setrgbcolor} def'
      WRITE(1,*) '/gray-lt-med {0.65 0.65 0.65 setrgbcolor} def'
      WRITE(1,*) '/gray {0.45 0.45 0.45 setrgbcolor} def'
      WRITE(1,*) '/gray-dk-med {0.3 0.3 0.3 setrgbcolor} def'
      WRITE(1,*) '/gray-dk {0.14 0.14 0.14 setrgbcolor} def'
      WRITE(1,*) '/red {1 0 0 setrgbcolor} def'
      WRITE(1,*) '/magenta {1 0 1 setrgbcolor} def'
      WRITE(1,*) '/green {0 1 0 setrgbcolor} def'
      WRITE(1,*) '/blue {0 0 1 setrgbcolor} def'
      WRITE(1,*) '/cyan {0 1 1 setrgbcolor} def'
      WRITE(1,*) '/yellow {1 1 0 setrgbcolor} def'
      WRITE(1,*) '/orange {1 0.5 0 setrgbcolor} def'
      WRITE(1,*) '/brown {0.5 0.5 0 setrgbcolor} def'
      WRITE(1,*) '/kakhi {0.5 1 0 setrgbcolor} def'
      WRITE(1,*) '/blue-lt {0.5 1 1 setrgbcolor} def'
      WRITE(1,*) '/green-lt {0.5 1 0.5 setrgbcolor} def'
      WRITE(1,*) '/green-blue {0 1 0.5 setrgbcolor} def'
      WRITE(1,*) '/purple {0.6 0 1.0 setrgbcolor} def'
      WRITE(1,*) '/filtri {moveto lineto lineto'
```

```
      WRITE(1,*) '            closepath fill stroke} def'
      WRITE(1,*) '/filqud {moveto lineto lineto lineto closepath fill'
      WRITE(1,*) '                                      stroke} def'
      WRITE(1,*) '/filpnt {moveto lineto lineto lineto'
      WRITE(1,*) '             lineto closepath fill stroke} def'
      WRITE(1,*) '%%EndProlog'
      WRITE(1,*) '1 setlinejoin .4 setlinewidth'
C     ********************************************************************
C     * ASSIGN CONTOUR VALUES AND LABELS.                                *
C     ********************************************************************
      CA(1)=0.0
      CB(1)=0.15
      CA(2)=0.15
      CB(2)=0.4
      CA(3)=0.4
      CB(3)=0.6
      CA(4)=0.6
      CB(4)=0.8
      CA(5)=0.8
      CB(5)=1.0
      LABEL(1)='0'
      LABEL(2)='.15'
      LABEL(3)='.4'
      LABEL(4)='.6'
      LABEL(5)='.8'
      LABEL(6)='1'
C     ********************************************************************
C     * ASSIGN THE COLORS.  SEE SUBROUTINE SETCOL FOR COLOR CHOICES.     *
C     ********************************************************************
C GRAY SCALE
      LC(1)=2
      LC(2)=3
      LC(3)=4
      LC(4)=5
      LC(5)=6
C  COLOR
c      LC(1)=18
c      LC(2)=14
c      LC(3)=12
c      LC(4)=16
c      LC(5)=13
C     ********************************************************************
C     * DRAW THE CONTOUR PLOT.                                           *
C     ********************************************************************
      WRITE(1,*) 'gsave'
      DO 6 I=1,NT
        N1=N2T(I,1)
        N2=N2T(I,2)
        N3=N2T(I,3)
        X1=X(N1)
        Y1=Y(N1)
        X2=X(N2)
        Y2=Y(N2)
        X3=X(N3)
        Y3=Y(N3)
        U1=TRANS(GS,BX,X1)
        V1=TRANS(GS,BY,Y1)
        U2=TRANS(GS,BX,X2)
        V2=TRANS(GS,BY,Y2)
```

```
237         U3=TRANS(GS,BX,X3)
238         V3=TRANS(GS,BY,Y3)
239       F1=SQRT(FX(N1)*FX(N1)+FY(N1)*FY(N1))
240       F2=SQRT(FX(N2)*FX(N2)+FY(N2)*FY(N2))
241       F3=SQRT(FX(N3)*FX(N3)+FY(N3)*FY(N3))
242         CALL CONTUR(U1,V1,U2,V2,U3,V3,F1,F2,F3,CA,CB,NC,LC)
243     6   CONTINUE
244         WRITE(1,*) 'grestore'
245 C       ***********************************************************************
246 C       * DRAW THE GRAPH FRAME.                                               *
247 C       ***********************************************************************
248         WRITE(1,*) 'gsave 0.5 setlinewidth 0 setgray'
249         WRITE(1,*) TRANS(GS,BX,XMIN),TRANS(GS,BY,YMIN),' moveto'
250         WRITE(1,*) TRANS(GS,BX,XMAX),TRANS(GS,BY,YMIN),' lineto'
251         WRITE(1,*) TRANS(GS,BX,XMAX),TRANS(GS,BY,YMAX),' lineto'
252         WRITE(1,*) TRANS(GS,BX,XMIN),TRANS(GS,BY,YMAX),' lineto'
253         WRITE(1,*) 'closepath stroke grestore'
254 C       ***********************************************************************
255 C       * DRAW THE EPS BOUNDING BOX.                                          *
256 C       ***********************************************************************
257 C        WRITE(1,*) 'gsave 0.2 setlinewidth'
258 C        WRITE(1,*) UA,VA,' moveto'
259 C        WRITE(1,*) UB,VA,' lineto'
260 C        WRITE(1,*) UB,VB,' lineto'
261 C        WRITE(1,*) UA,VB,' lineto'
262 C        WRITE(1,*) 'closepath stroke grestore'
263 C       ***********************************************************************
264 C       * LABEL EACH SECTION.                                                 *
265 C       ***********************************************************************
266         IF (IGEO .EQ. 1) THEN
267 C         *********************************************************************
268 C         * RECTANGULAR.                                                      *
269 C         *********************************************************************
270           CALL RLABEL(XMIN,XMAX,YMIN,YMAX,GS,BX,BY,A,B,KM)
271           SL=30.0
272           SH=15.0
273           DDS=0.0
274           ITYPE=2
275           US=TRANS(GS,BX,XMIN)
276           VS=TRANS(GS,BY,YMIN)-2.5*SH
277           CALL LEGEND(US,VS,NC,NL,LC,LABEL,SL,SH,DDS,ITYPE)
278         ELSE
279           KM=5
280           CALL CLABEL(XMIN,XMAX,YMIN,YMAX,GS,BX,BY,A,KM)
281           SL=30.0
282           SH=15.0
283           DDS=0.0
284           ITYPE=2
285           US=TRANS(GS,BX,XMIN)
286           VS=TRANS(GS,BY,YMIN)-2.5*SH
287           CALL LEGEND(US,VS,NC,NL,LC,LABEL,SL,SH,DDS,ITYPE)
288         END IF
289 C       ***********************************************************************
290 C       * IF REQUESTED SHOW THE TRIANGULAR GRID.                              *
291 C       ***********************************************************************
292 C        CALL PTGRID(MN,MT,MT,N2T,GS,BX,BY,X,Y)
293 C       ***********************************************************************
294 C       * DRAW THE APPROPRIATE VECTOR ROUTINE.                                *
295 C       ***********************************************************************
```

```
      BANG=20.0
      S=7.0
      MNAR=1
      DS=.003
      IF (IGEO .EQ. 1) THEN

        CALL RWTE10(MN,MT,MP,NT,N2T,T2N,X,Y,A,B,KM,M,N,XMIN,XMAX
     &                        ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
      ELSE
        CALL CWTE10(MN,MT,MP,NT,N2T,T2N,X,Y,A,C,KM,N,M,XMIN,XMAX
     &                        ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
      END IF
C     ************************************************************************
C     * DRAW THE PAGE.                                                       *
C     ************************************************************************
      WRITE(1,*) 'showpage'
      CLOSE(1)
      END

      SUBROUTINE PTGRID(MN,MT,NT,N2T,GS,BX,BY,X,Y)
C     ************************************************************************
C     * THIS SUBROUTINE DRAWS THE TRIANGULAR GRID.                           *
C     ************************************************************************
      REAL*4 X(MN),Y(MN)
      INTEGER N2T(MT,3)
C     ************************************************************************
C     * LOOP THROUGH EACH TRIANGLE AND DRAW THE PERIMETER.                   *
C     ************************************************************************
      WRITE(1,*) 'gsave o setgray 0.3 setlinewidth '
      DO 1 I=1,NT
        X1=X(N2T(I,1))
        Y1=Y(N2T(I,1))
        X2=X(N2T(I,2))
        Y2=Y(N2T(I,2))
        X3=X(N2T(I,3))
        Y3=Y(N2T(I,3))
        U1=TRANS(GS,BX,X1)
        V1=TRANS(GS,BY,Y1)
        U2=TRANS(GS,BX,X2)
        V2=TRANS(GS,BY,Y2)
        U3=TRANS(GS,BX,X3)
        V3=TRANS(GS,BY,Y3)
        CALL MOVETO(U1,V1)
        CALL LINETO(U2,V2)
        CALL MOVETO(U2,V2)
        CALL LINETO(U3,V3)
        CALL MOVETO(U3,V3)
        CALL LINETO(U1,V1)
    1 CONTINUE
      WRITE(1,*) 'grestore'
      RETURN
      END

      SUBROUTINE RLABEL(XMIN,XMAX,YMIN,YMAX,GS,BX,BY,A,B,KM)
C     ************************************************************************
C     * THIS SUBROUTINE DRAWS THE LABELS FOR THE RECTANGULAR GUIDE.          *
C     ************************************************************************
C     ************************************************************************
C     * SECTION LINES.                                                       *
```

```
C     ***********************************************************************
      UD=TRANS(GS,BX,XMIN+A)
      VD=TRANS(GS,BY,YMIN)
      WRITE(1,*) UD,VD,' moveto'
      UD=TRANS(GS,BX,XMIN+A)
      VD=TRANS(GS,BY,YMAX)
      WRITE(1,*) UD,VD,' lineto stroke'
      UD=TRANS(GS,BX,XMIN+A+B)
      VD=TRANS(GS,BY,YMIN)
      WRITE(1,*) UD,VD,' moveto'
      UD=TRANS(GS,BX,XMIN+A+B)
      VD=TRANS(GS,BY,YMAX)
      WRITE(1,*) UD,VD,' lineto stroke'
      UD=TRANS(GS,BX,XMAX-B)
      VD=TRANS(GS,BY,YMIN)
      WRITE(1,*) UD,VD,' moveto'
      UD=TRANS(GS,BX,XMAX-B)
      VD=TRANS(GS,BY,YMAX)
      WRITE(1,*) UD,VD,' lineto stroke'
C     ***********************************************************************
C     * SIDE LABELS.                                                        *
C     ***********************************************************************
      WRITE(1,*) '/Times-Roman findfont 10 scalefont setfont'
      XE=XMIN
      YE=YMAX
      UD=TRANS(GS,BX,XE)
      VD=TRANS(GS,BY,YE)
      WRITE(1,*) UD,VD+6.0,' moveto'
      WRITE(1,*) '(side 1) show'
      XE=XMIN+A/2
      YE=YMIN
      UD=TRANS(GS,BX,XE)
      VD=TRANS(GS,BY,YE)
      WRITE(1,*) UD,VD,' moveto'
      WRITE(1,*) '/Times-Italic findfont 10 scalefont setfont'
      WRITE(1,*) '(y = b/2) stringwidth pop neg 2 div -10 rmoveto'
      WRITE(1,*) '(y = b) show'
      WRITE(1,*) '/Times-Roman findfont 10 scalefont setfont'
      WRITE(1,*) '(/2) show'
      XE=XMIN+A/2.0
      YE=YMAX
      UD=TRANS(GS,BX,XE)
      VD=TRANS(GS,BY,YE)
      WRITE(1,*) '0.4 setlinewidth'
      A0=10.0
      WRITE(1,*) UD,VD+A0,' moveto'
      WRITE(1,*) UD,VD+A0+15.0,' lineto stroke'
      WRITE(1,*) UD-3,VD+A0+15.0-5.0,' moveto'
      WRITE(1,*) UD,VD+A0+15.0,' lineto'
      WRITE(1,*) UD+3,VD+A0+15.0-5.0,' lineto stroke'
      WRITE(1,*) UD-11.0,VD+15.0,' moveto'
      WRITE(1,*) '/Times-Italic findfont 10 scalefont setfont'
      WRITE(1,*) '(z) show'
      XE=-B
      YE=YMAX
      UD=TRANS(GS,BX,XE)
      VD=TRANS(GS,BY,YE)
      WRITE(1,*) UD,VD+6.0,' moveto'
      WRITE(1,*) '/Times-Roman findfont 10 scalefont setfont'
```

```
      WRITE(1,*) '(side 2) show'
      XE=XMIN+A+B/2
      YE=YMIN
      UD=TRANS(GS,BX,XE)
      VD=TRANS(GS,BY,YE)
      WRITE(1,*) UD,VD,' moveto'
      WRITE(1,*) '/Times-Italic findfont 10 scalefont setfont'
      WRITE(1,*) '(x = a/2) stringwidth pop neg 2 div -10 rmoveto'
      WRITE(1,*) '(x = a) show'
      WRITE(1,*) '/Times-Roman findfont 10 scalefont setfont'
      WRITE(1,*) '(/2) show'
      XE=0.0
      YE=YMAX
      UD=TRANS(GS,BX,XE)
      VD=TRANS(GS,BY,YE)
      WRITE(1,*) UD,VD+6.0,' moveto'
      WRITE(1,*) '/Times-Roman findfont 10 scalefont setfont'
      WRITE(1,*) '(side 3) show'
      XE=XMIN+A+B+A/2
      YE=YMIN
      UD=TRANS(GS,BX,XE)
      VD=TRANS(GS,BY,YE)
      WRITE(1,*) UD,VD,' moveto'
      WRITE(1,*) '/Times-Italic findfont 10 scalefont setfont'
      WRITE(1,*) '(y = -b/2) stringwidth pop neg 2 div -10 rmoveto'
      WRITE(1,*) '(y = -b) show'
      WRITE(1,*) '/Times-Roman findfont 10 scalefont setfont'
      WRITE(1,*) '(/2) show'
      XE=A
      YE=YMAX
      UD=TRANS(GS,BX,XE)
      VD=TRANS(GS,BY,YE)
      WRITE(1,*) UD,VD+6.0,' moveto'
      WRITE(1,*) '/Times-Roman findfont 10 scalefont setfont'
      WRITE(1,*) '(side 4) show'
      XE=XMAX-B/2
      YE=YMIN
      UD=TRANS(GS,BX,XE)
      VD=TRANS(GS,BY,YE)
      WRITE(1,*) UD,VD,' moveto'
      WRITE(1,*) '/Times-Italic findfont 10 scalefont setfont'
      WRITE(1,*) '(x = -a/2) stringwidth pop neg 2 div -10 rmoveto'
      WRITE(1,*) '(x = -a) show'
      WRITE(1,*) '/Times-Roman findfont 10 scalefont setfont'
      WRITE(1,*) '(/2) show'
C     ************************************************************************
C     * Z-AXIS LABELS.                                                       *
C     ************************************************************************
      TL=7.0
      PL=10.0
      KT=KM+1
      XE=XMAX
      UD=TRANS(GS,BX,XE)
      DY=(YMAX-YMIN)/(KT-1)
      DO 1 I=0,KT-1
        YE=YMIN+I*DY
        VD=TRANS(GS,BY,YE)
        WRITE(1,*) UD,VD,' moveto'
        WRITE(1,*) UD+TL,VD,' lineto stroke'
```

```
125   1   CONTINUE
126       VD=TRANS(GS,BY,YMIN)
127       WRITE(1,*) UD+TL+PL,VD,' moveto gsave'
128       WRITE(1,*) UD+TL+PL,VD,' translate 90 rotate'
129       WRITE(1,*) '/Times-Roman findfont 10 scalefont setfont'
130       WRITE(1,*) '(0) stringwidth pop 2 div neg 0 rmoveto'
131       WRITE(1,*) '(0) show'
132       WRITE(1,*) 'grestore'
133       VD=TRANS(GS,BY,YMIN+DY)
134       WRITE(1,*) UD+TL+PL,VD,' moveto gsave'
135       WRITE(1,*) UD+TL+PL,VD,' translate 90 rotate'
136       WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
137       WRITE(1,*) '(\160 \244 \142) stringwidth pop 2 div neg 0 rmoveto'
138       WRITE(1,*) '(\160 \244 \142) show'
139       WRITE(1,*) 'grestore'
140       VD=TRANS(GS,BY,YMIN+2*DY)
141       WRITE(1,*) UD+TL+PL,VD,' moveto gsave'
142       WRITE(1,*) UD+TL+PL,VD,' translate 90 rotate'
143       WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
144       WRITE(1,*) '(2\160 \244 \142) stringwidth pop 2 div neg 0 rmoveto'
145       WRITE(1,*) '(2\160 \244 \142) show'
146       WRITE(1,*) 'grestore'
147       VD=TRANS(GS,BY,YMIN+3*DY)
148       WRITE(1,*) UD+TL+PL,VD,' moveto gsave'
149       WRITE(1,*) UD+TL+PL,VD,' translate 90 rotate'
150       WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
151       WRITE(1,*) '(3\160 \244 \142) stringwidth pop 2 div neg 0 rmoveto'
152       WRITE(1,*) '(3\160 \244 \142) show'
153       WRITE(1,*) 'grestore'
154       VD=TRANS(GS,BY,YMIN+4*DY)
155       WRITE(1,*) UD+TL+PL,VD,' moveto gsave'
156       WRITE(1,*) UD+TL+PL,VD,' translate 90 rotate'
157       WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
158       WRITE(1,*) '(4\160 \244 \142) stringwidth pop 2 div neg 0 rmoveto'
159       WRITE(1,*) '(4\160 \244 \142) show'
160       WRITE(1,*) 'grestore'
161       VD=TRANS(GS,BY,YMIN+5*DY)
162       WRITE(1,*) UD+TL+PL,VD,' moveto gsave'
163       WRITE(1,*) UD+TL+PL,VD,' translate 90 rotate'
164       WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
165       WRITE(1,*) '(5\160 \244 \142) stringwidth pop 2 div neg 0 rmoveto'
166       WRITE(1,*) '(5\160 \244 \142) show'
167       WRITE(1,*) 'grestore'
168       RETURN
169       END

  1       SUBROUTINE CLABEL(XMIN,XMAX,YMIN,YMAX,GS,BX,BY,A,KM)
  2 C     ****************************************************************
  3 C     * THIS SUBROUTINE DRAWS THE LABELS FOR THE CIRCULAR GUIDE.      *
  4 C     ****************************************************************
  5 C     ****************************************************************
  6 C     * Z-AXIS LABELS.                                               *
  7 C     ****************************************************************
  8       XE=XMIN
  9       YE=YMAX
 10       UD=TRANS(GS,BX,XE)
 11       VD=TRANS(GS,BY,YE)
 12       WRITE(1,*) '0.4 setlinewidth'
 13       A0=10.0
```

```
      WRITE(1,*) UD,VD+A0,' moveto'
      WRITE(1,*) UD,VD+A0+15.0,' lineto stroke'
      WRITE(1,*) UD-3,VD+A0+15.0-5.0,' moveto'
      WRITE(1,*) UD,VD+A0+15.0,' lineto'
      WRITE(1,*) UD+3,VD+A0+15.0-5.0,' lineto stroke'
      WRITE(1,*) UD+11.0,VD+15.0,' moveto'
      WRITE(1,*) '/Times-Italic findfont 10 scalefont setfont'
      WRITE(1,*) '(z) show'
      TL=7.0
      PL=10.0
      KT=KM+1
      XE=XMAX
      UD=TRANS(GS,BX,XE)
      DY=(YMAX-YMIN)/(KT-1)
      DO 1 I=0,KT-1
        YE=YMIN+I*DY
        VD=TRANS(GS,BY,YE)
        WRITE(1,*) UD,VD,' moveto'
        WRITE(1,*) UD+TL,VD,' lineto stroke'
1     CONTINUE
      VD=TRANS(GS,BY,YMIN)
      WRITE(1,*) UD+TL+PL,VD,' moveto gsave'
      WRITE(1,*) UD+TL+PL,VD,' translate 90 rotate'
      WRITE(1,*) '/Times-Roman findfont 10 scalefont setfont'
      WRITE(1,*) '(0) stringwidth pop 2 div neg 0 rmoveto'
      WRITE(1,*) '(0) show'
      WRITE(1,*) 'grestore'
      VD=TRANS(GS,BY,YMIN+DY)
      WRITE(1,*) UD+TL+PL,VD,' moveto gsave'
      WRITE(1,*) UD+TL+PL,VD,' translate 90 rotate'
      WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
      WRITE(1,*) '(\160 \244 \142) stringwidth pop 2 div neg 0 rmoveto'
      WRITE(1,*) '(\160 \244 \142) show'
      WRITE(1,*) 'grestore'
      VD=TRANS(GS,BY,YMIN+2*DY)
      WRITE(1,*) UD+TL+PL,VD,' moveto gsave'
      WRITE(1,*) UD+TL+PL,VD,' translate 90 rotate'
      WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
      WRITE(1,*) '(2\160 \244 \142) stringwidth pop 2 div neg 0 rmoveto'
      WRITE(1,*) '(2\160 \244 \142) show'
      WRITE(1,*) 'grestore'
      VD=TRANS(GS,BY,YMIN+3*DY)
      WRITE(1,*) UD+TL+PL,VD,' moveto gsave'
      WRITE(1,*) UD+TL+PL,VD,' translate 90 rotate'
      WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
      WRITE(1,*) '(3\160 \244 \142) stringwidth pop 2 div neg 0 rmoveto'
      WRITE(1,*) '(3\160 \244 \142) show'
      WRITE(1,*) 'grestore'
      VD=TRANS(GS,BY,YMIN+4*DY)
      WRITE(1,*) UD+TL+PL,VD,' moveto gsave'
      WRITE(1,*) UD+TL+PL,VD,' translate 90 rotate'
      WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
      WRITE(1,*) '(4\160 \244 \142) stringwidth pop 2 div neg 0 rmoveto'
      WRITE(1,*) '(4\160 \244 \142) show'
      WRITE(1,*) 'grestore'
      VD=TRANS(GS,BY,YMIN+5*DY)
      WRITE(1,*) UD+TL+PL,VD,' moveto gsave'
      WRITE(1,*) UD+TL+PL,VD,' translate 90 rotate'
      WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
```

```
      WRITE(1,*) '(5\160 \244 \142) stringwidth pop 2 div neg 0 rmoveto'
      WRITE(1,*) '(5\160 \244 \142) show'
      WRITE(1,*) 'grestore'
C     ***********************************************************************
C     * PHI-AXIS LABELS.                                                    *
C     ***********************************************************************
      YE=YMIN
      VD=TRANS(GS,BY,YE)
      NPT=5
      DX=(XMAX-XMIN)/(NPT-1)
      DO 2 I=0,NPT-1
        XE=XMIN+I*DX
        UD=TRANS(GS,BX,XE)
        WRITE(1,*) UD,VD,' moveto'
        WRITE(1,*) UD,VD-TL,' lineto stroke'
2     CONTINUE
      UD=TRANS(GS,BX,XMIN)
      WRITE(1,*) UD,VD-TL-PL,' moveto'
      WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
      WRITE(1,*) '(0) stringwidth pop 2 div neg 0 rmoveto'
      WRITE(1,*) '(0) show'
      WRITE(1,*) '(\260) show'
      UD=TRANS(GS,BX,XMIN+DX)
      WRITE(1,*) UD,VD-TL-PL,' moveto'
      WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
      WRITE(1,*) '(90) stringwidth pop 2 div neg 0 rmoveto'
      WRITE(1,*) '(90) show'
      WRITE(1,*) '(\260) show'
      UD=TRANS(GS,BX,XMIN+2*DX)
      WRITE(1,*) UD,VD-TL-PL,' moveto'
      WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
      WRITE(1,*) '(180) stringwidth pop 2 div neg 0 rmoveto'
      WRITE(1,*) '(180) show'
      WRITE(1,*) '(\260) show'
      UD=TRANS(GS,BX,XMIN+3*DX)
      WRITE(1,*) UD,VD-TL-PL,' moveto'
      WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
      WRITE(1,*) '(270) stringwidth pop 2 div neg 0 rmoveto'
      WRITE(1,*) '(270) show'
      WRITE(1,*) '(\260) show'
      UD=TRANS(GS,BX,XMIN+4*DX)
      WRITE(1,*) UD,VD-TL-PL,' moveto'
      WRITE(1,*) '/Symbol findfont 10 scalefont setfont'
      WRITE(1,*) '(360) stringwidth pop 2 div neg 0 rmoveto'
      WRITE(1,*) '(360) show'
      WRITE(1,*) '(\260) show'
      RETURN
      END

      SUBROUTINE RWTE10(MN,MT,MP,NT,N2T,T2N,X,Y,A,B,KM,M,N,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
C     ***********************************************************************
C     * THIS SUBROUTINE DRAWS VECTOR LINES FOR A RECTANGULAR                *
C     * WAVEGUIDE WITH TE10 MODE FIELDS.                                    *
C     ***********************************************************************
C     * INPUTS:                                                             *
C     *                                                                     *
C     *   MN  - MAXIMUM NUMBER OF COORDINATE POINTS.                        *
C     *   MT  - MAXIMUM NUMBER OF TRIANGLES.                                *
```

```
C     *   N2T(MT,3)  - NODE MATRIX WHERE FIRST INDEX REPRESENTS        *
C     *                EACH TRIANGLE AND SECOND INDEX REPRESENTS       *
C     *                THE NODE NUMBERS.                               *
C     *   T2N(MN,MP)  -  MATRIX OF TRIANGLE TO NODE CONNECTIONS       *
C     *                WHERE THE FIRST INDEX IS THE NODE NUMBER        *
C     *                AND THE SECOND IS THE LOCAL TRIANGLE NUMBER.    *
C     *   X(MN) - COORDINATE VECTORS OF GRID.                          *
C     *   Y(MN)                                                        *
C     *   FX(MN) - VECTOR FUNCTION FIELD VALUES AT EACH COORDINATE.    *
C     *   FY(MN)                                                       *
C     *   AX,BX  - GRAPHICAL SCALE CONSTANTS.                          *
C     *   AY,BY                                                        *
C     *   VL     - SPACING BETWEEN ARROWHEADS IN REAL COORDINATES.     *
C     *   BANG   - ARROW APEX HALF ANGLE IN DEGREES.                   *
C     *   S      - ARROW HEAD SIDE LENGTH IN POINT SIZE.               *
C     *   MNAR   - MAXIMUM NUMBER OF ARROWS ALLOWED.                   *
C     *   DS     - STEP SIZE.                                          *
C     *                                                                *
C     * OUTPUTS:                                                       *
C     *                                                                *
C     ******************************************************************
      REAL*4 X(MN),Y(MN),FX(MN),FY(MN),KC2
      INTEGER N2T(MT,3),T2N(MN,MP)
      PI=.3141593E+01
      RAD=.17453293E-01
      KC2=(M*PI/A)*(M*PI/A)+(N*PI/B)*(N*PI/B)
      BETA=SQRT(4*PI*PI-KC2)
C     ******************************************************************
C     * SET GLOBAL VECTOR INPUTS.                                      *
C     ******************************************************************
      AH=S*COS(RAD*BANG)
C     ******************************************************************
C     * SET SPACING PARAMETERS BASED ON CRITICAL POINT LOCATIONS.      *
C     ******************************************************************
      TAUY=0.7
      NPY=5
      NPX=9
      TAUX=0.96
      DL=PI/BETA
      DX=TAUX*A/(NPX-1)
      DY=(TAUY*DL)/(NPY-1)
C     ******************************************************************
C     * SIDE 1 (Y=B/2).                                                *
C     ******************************************************************
C     ******************************************************************
C     * DRAW VECTOR LINES ALONG A VERTICAL LINE WHICH ORIGINATE ON     *
C     * THE PERIMETER OF SIDE 1 AND TERMINATE AT CRITICAL POINT 1.     *
C     ******************************************************************
      K=0
      DO 1 I=1,(NPY-1)/2
        K=K+1
        WRITE(*,*) 'DRAWING VECTOR ',K
        YE=I*DY
        XE=-B
        CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
        NDIR=0
        VL=20.0/GS
        CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
```

```
70          NDIR=0
71          XE=-B-A
72          VL=20.0/GS
73          CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
74          CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
75         &                   ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
76    1     CONTINUE
77  C       ***********************************************************************
78  C       * DRAW VECTOR LINES ALONG A HORIZONTAL LINE WHICH ORIGINATE ON   *
79  C       * CRITICAL POINT 2 AND TERMINATE ON CRITICAL POINT 1.            *
80  C       ***********************************************************************
81          DXOFF=(1.0-TAUX)*A/2
82          DO 2 I=0,KM-1
83            YE=0.5*DL+I*DL
84            DO 3 J=0,NPX-1
85              K=K+1
86              WRITE(*,*) 'DRAWING VECTOR ',K
87              XE=-B-A+DXOFF+J*DX
88              CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
89              NDIR=0
90              VL=27.0/GS
91              CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
92         &                   ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
93              NDIR=1
94              VL=27.0/GS-AH/GS
95              CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
96         &                   ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
97    3       CONTINUE
98    2     CONTINUE
99  C       ***********************************************************************
100 C       * DRAW VECTOR LINES ALONG A VERTICAL LINE WHICH ORIGINATE AT      *
101 C       * CRITICAL POINT 2 AND TERMINATE ON THE PERIMETER OF SIDE 1.      *
102 C       ***********************************************************************
103         DO 4 I=0,KM-2
104           YCE=(1.0-TAUY)*0.5*DL+0.5*DL+I*DL
105           IS=(-1)**I
106           IF (IS > 0) THEN
107             NDIR=1
108             VL=20.0/GS-S/GS
109           ELSE
110             NDIR=0
111             VL=20.0/GS
112           END IF
113           DO 5 J=0,NPY-1
114             K=K+1
115             WRITE(*,*) 'DRAWING VECTOR ',K
116             YE=YCE+J*DY
117             XE=-B
118             CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
119             CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
120        &                   ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
121             XE=-B-A
122             CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
123             CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
124        &                   ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
125   5       CONTINUE
126   4     CONTINUE
127 C       ***********************************************************************
128 C       * DRAW VECTOR LINES ALONG A VERTICAL LINE WHICH ORIGINATE AT      *
```

```
C     * CRITICAL POINT 5 AND TERMINATE ON THE PERIMETER OF SIDE 1.     *
C     ***********************************************************************
      NP=(NPY-1)/2
      DO 6 I=0,NP-1
        K=K+1
        WRITE(*,*) 'DRAWING VECTOR ',K
        YE=4.5*DL+(1.0-TAUY)*0.5*DL+I*DY
        XE=-B
        CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
        NDIR=1
        VL=27.0/GS-AH/GS
        CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
        NDIR=1
        VL=27.0/GS-AH/GS
        XE=-B-A
        CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
        CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
    6 CONTINUE
C     ***********************************************************************
C     * SIDE 3 (Y=-B/2).                                                    *
C     ***********************************************************************
C     ***********************************************************************
C     * DRAW VECTOR LINES ALONG A VERTICAL LINE WHICH ORIGINATE ON     *
C     * THE PERIMETER OF SIDE 1 AND TERMINATE AT CRITICAL POINT 1.     *
C     ***********************************************************************
      DO 7 I=1,(NPY-1)/2
        K=K+1
        WRITE(*,*) 'DRAWING VECTOR ',K
        YE=I*DY
        XE=0
        CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
        NDIR=1
        VL=20.0/GS-AH/GS
        CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
        NDIR=1
        XE=A
        VL=20.0/GS-AH/GS
        CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
        CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
    7 CONTINUE
C     ***********************************************************************
C     * DRAW VECTOR LINES ALONG A HORIZONTAL LINE WHICH ORIGINATE ON   *
C     * CRITICAL POINT 2 AND TERMINATE ON CRITICAL POINT 1.            *
C     ***********************************************************************
      DXOFF=(1.0-TAUX)*A/2
      DO 8 I=0,KM-1
        YE=0.5*DL+I*DL
        DO 9 J=0,NPX-1
          K=K+1
          WRITE(*,*) 'DRAWING VECTOR ',K
          XE=DXOFF+J*DX
          CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
          NDIR=0
          VL=27.0/GS
          CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
```

```
188       &                    ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
189            NDIR=1
190            VL=27.0/GS-AH/GS
191            CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
192       &                    ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
193     9      CONTINUE
194     8    CONTINUE
195 C        ***********************************************************************
196 C        * DRAW VECTOR LINES ALONG A VERTICAL LINE WHICH ORIGINATE AT     *
197 C        * CRITICAL POINT 2 AND TERMINATE ON THE PERIMETER OF SIDE 1.     *
198 C        ***********************************************************************
199          DO 10 I=0,KM-2
200            YCE=(1.0-TAUY)*0.5*DL+0.5*DL+I*DL
201            IS=(-1)**(I+1)
202            IF (IS > 0) THEN
203              NDIR=1
204              VL=20.0/GS-S/GS
205            ELSE
206              NDIR=0
207              VL=20.0/GS
208            END IF
209            DO 11 J=0,NPY-1
210              K=K+1
211              WRITE(*,*) 'DRAWING VECTOR ',K
212              YE=YCE+J*DY
213              XE=0
214              CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
215              CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
216       &                    ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
217              XE=A
218              CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
219              CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
220       &                    ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
221    11      CONTINUE
222    10    CONTINUE
223 C        ***********************************************************************
224 C        * DRAW VECTOR LINES ALONG A VERTICAL LINE WHICH ORIGINATE AT     *
225 C        * CRITICAL POINT 5 AND TERMINATE ON THE PERIMETER OF SIDE 1.     *
226 C        ***********************************************************************
227          NP=(NPY-1)/2
228          DO 12 I=0,NP-1
229            K=K+1
230            WRITE(*,*) 'DRAWING VECTOR ',K
231            YE=4.5*DL+(1.0-TAUY)*0.5*DL+I*DY
232            XE=0
233            CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
234            NDIR=0
235            VL=27.0/GS
236            CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
237       &                    ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
238            NDIR=0
239            VL=27.0/GS
240            XE=A
241            CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
242            CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
243       &                    ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
244    12    CONTINUE
245 C        ***********************************************************************
246 C        * SIDE 2 (X=A/2).                                                *
```

```
C     ***********************************************************************
C     ***********************************************************************
C     * END POINT CONTRIBUTIONS.                                            *
C     ***********************************************************************
      XMIN=-B
      XMAX=0.0
      XE=(XMIN+XMAX)/2.0
      NP=(NPY-1)/2
      DO 13 I=0,NP-1
        YE=4.5*DL+(1.0-TAUY)*0.5*DL+I*DY
        K=K+1
        WRITE(*,*) 'DRAWING VECTOR ',K
        CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
        NDIR=0
        VL=20.0/GS
        CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
        NDIR=1
        VL=20.0/GS-S/GS
        CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
        CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
        YE=(I+1)*DY
        K=K+1
        WRITE(*,*) 'DRAWING VECTOR ',K
        CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
        NDIR=0
        VL=20.0/GS
        CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
        NDIR=1
        VL=20.0/GS-S/GS
        CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
        CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)

 13   CONTINUE
C     ***********************************************************************
C     * INTERIOR CONTRIBUTIONS.                                             *
C     ***********************************************************************
      DO 14 I=0,KM-2
        YCE=(1.0-TAUY)*0.5*DL+0.5*DL+I*DL
        DO 15 J=0,NPY-1
          K=K+1
          WRITE(*,*) 'DRAWING VECTOR ',K
          YE=YCE+J*DY
          NDIR=1
          VL=20.0/GS-S/GS
          CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
          CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
          NDIR=0
          VL=20.0/GS
          CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
          CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
 15     CONTINUE
 14   CONTINUE
C     ***********************************************************************
```

```
C     * SIDE 4 (X=-A/2).                                                *
C     ******************************************************************
C     ******************************************************************
C     * END POINT CONTRIBUTIONS.                                        *
C     ******************************************************************
      XMIN=A
      XMAX=A+B
      XE=(XMIN+XMAX)/2.0
      NP=(NPY-1)/2
      DO 16 I=0,NP-1
        YE=4.5*DL+(1.0-TAUY)*^.5*DL+I*DY
        K=K+1
        WRITE(*,*) 'DRAWING VECTOR ',K
        CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
        NDIR=0
        VL=20.0/GS
        CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
        NDIR=1
        VL=20.0/GS-S/GS
        CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
        CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
        YE=(I+1)*DY
        K=K+1
        WRITE(*,*) 'DRAWING VECTOR ',K
        CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
        NDIR=0
        VL=20.0/GS
        CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
        NDIR=1
        VL=20.0/GS-S/GS
        CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
        CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)

 16   CONTINUE
C     ******************************************************************
C     * INTERIOR CONTRIBUTIONS.                                         *
C     ******************************************************************
      DO 17 I=0,KM-2
        YCE=(1.0-TAUY)*0.5*DL+0.5*DL+I*DL
        DO 18 J=0,NPY-1
          K=K+1
          WRITE(*,*) 'DRAWING VECTOR ',K
          YE=YCE+J*DY
          NDIR=1
          VL=20.0/GS-S/GS
          CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
          CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
          NDIR=0
          VL=20.0/GS
          CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
          CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
 18     CONTINUE
 17   CONTINUE
```

```
      RETURN
      END

      SUBROUTINE CWTE10(MN,MT,MP,NT,N2T,T2N,X,Y,A,C,KM,N,M,XMIN,XMAX
     &                  ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
C     ***********************************************************************
C     * THIS SUBROUTINE DRAWS VECTOR LINES FOR A CIRCULAR                   *
C     * WAVEGUIDE WITH TE11 MODE FIELDS.                                    *
C     ***********************************************************************
C     * INPUTS:                                                             *
C     *                                                                     *
C     *   XE,YE  - FIRST COORDINATE OF VECTOR LINE.                         *
C     *   MN  - MAXIMUM NUMBER OF COORDINATE POINTS.                        *
C     *   MT  - MAXIMUM NUMBER OF TRIANGLES.                                *
C     *   N2T(MT,3)  - NODE MATRIX WHERE FIRST INDEX REPRESENTS             *
C     *                EACH TRIANGLE AND SECOND INDEX REPRESENTS            *
C     *                THE NODE NUMBERS.                                    *
C     *   T2N(MN,MP)  -  MATRIX OF TRIANGLE TO NODE CONNECTIONS             *
C     *                WHERE THE FIRST INDEX IS THE NODE NUMBER             *
C     *                AND THE SECOND IS THE LOCAL TRIANGLE NUMBER.         *
C     *   X(MN) - COORDINATE VECTORS OF GRID.                               *
C     *   Y(MN)                                                             *
C     *   FX(MN) - VECTOR FUNCTION FIELD VALUES AT EACH COORDINATE.         *
C     *   FY(MN)                                                            *
C     *   AX,BX  - GRAPHICAL SCALE CONSTANTS.                               *
C     *   AY,BY                                                             *
C     *   VL     - SPACING BETWEEN ARROWHEADS IN REAL COORDINATES.          *
C     *   BANG   - ARROW APEX HALF ANGLE IN DEGREES.                        *
C     *   S      - ARROW HEAD SIDE LENGTH IN POINT SIZE.                    *
C     *   MNAR   - MAXIMUM NUMBER OF ARROWS ALLOWED.                        *
C     *   DS     - STEP SIZE.                                               *
C     *                                                                     *
C     * OUTPUTS:                                                            *
C     *                                                                     *
C     ***********************************************************************
      REAL*4 X(MN),Y(MN),FX(MN),FY(MN)
      INTEGER N2T(MT,3),T2N(MN,MP)
      PI=.3141593E+01
      TP=.6283185E+01
      RAD=.17453293E-01
      K=0
C     ***********************************************************************
C     * SET GLOBAL VECTOR INPUTS.                                           *
C     ***********************************************************************
      AH=S*COS(RAD*BANG)
C     ***********************************************************************
C     * SET SPACING PARAMETERS BASED ON CRITICAL POINT LOCATIONS.            *
C     ***********************************************************************
      TAUY=0.9
      NPY=5
      DY=(TAUY*C/KM)/(NPY-1)
C     ***********************************************************************
C     * LEFT REGION HORIZONTAL LINES.                                       *
C     ***********************************************************************
      XE=0.0
      DO 1 I=0,KM
        YMIN=-C/(2*KM)+I*C/KM
        YMAX=YMIN+C/KM
        DO 2 J=0,NPY-1
```

```
57            YE=YMIN+(C/KM)*(1.0-TAUY)/2.0+J*DY
58            IF ((YE .GT. DY/2.0) .AND. (YE .LT. C-DY/2.0)) THEN
59              K=K+1
60              WRITE(*,*) 'DRAWING VECTOR ',K
61              CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
62              NDIR=0
63              VL=20.0/GS
64              CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
65       &                        ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
66              NDIR=1
67              VL=20.0/GS-S/GS
68              CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
69       &                        ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
70            ELSE
71            END IF
72   2      CONTINUE
73   1     CONTINUE
74 C       ************************************************************************
75 C       * LEFT REGION VERTICAL LINES.                                          *
76 C       ************************************************************************
77        XWIDTH=PI*A
78        TAUX=0.90
79        NPX=9
80        DX=TAUX*XWIDTH/(NPX-1)
81        DO 3 I=0,KM-1
82          YE=C/(2*KM)+I*C/KM
83          YMIN=YE-C/(2*KM)
84          YMAX=YE+C/(2*KM)
85          DO 4 J=0,NPX-1
86            K=K+1
87            WRITE(*,*) 'DRAWING VECTOR ',K
88            XE=XWIDTH*(1.0-TAUX)/2.0+J*DX
89            CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
90            NDIR=0
91            VL=20.0/GS
92            CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
93       &                        ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
94            NDIR=1
95            VL=20.0/GS-S/GS
96            CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
97       &                        ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
98   4      CONTINUE
99   3     CONTINUE
100 C       ************************************************************************
101 C       * CENTER REGION HORIZONTAL LINES.                                      *
102 C       ************************************************************************
103       XE=PI*A
104       DO 5 I=0,KM
105         YMIN=-C/(2*KM)+I*C/KM
106         YMAX=YMIN+C/KM
107         DO 6 J=0,NPY-1
108           YE=YMIN+(C/KM)*(1.0-TAUY)/2.0+J*DY
109           IF ((YE .GT. DY/2.0) .AND. (YE .LT. C-DY/2.0)) THEN
110             K=K+1
111             WRITE(*,*) 'DRAWING VECTOR ',K
112             CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
113             NDIR=0
114             VL=20.0/GS
115             CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
```

```
116      &                      ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
117            NDIR=1
118            VL=20.0/GS-S/GS
119            CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
120      &                      ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
121          ELSE
122          END IF
123   6    CONTINUE
124   5   CONTINUE
125 C     ************************************************************
126 C     * RIGHT REGION VERTICAL LINES.                             *
127 C     ************************************************************
128       XWIDTH=PI*A
129       TAUX=0.90
130       DX=TAUX*XWIDTH/(NPX-1)
131       DO 7 I=0,KM-1
132         YE=C/(2*KM)+I*C/KM
133         YMIN=YE-C/(2*KM)
134         YMAX=YE+C/(2*KM)
135         DO 8 J=0,NPX-1
136           K=K+1
137           WRITE(*,*) 'DRAWING VECTOR ',K
138           XE=PI*A+XWIDTH*(1.0-TAUX)/2.0+J*DX
139           CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
140           NDIR=0
141           VL=20.0/GS
142           CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
143      &                      ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
144           NDIR=1
145           VL=20.0/GS-S/GS
146           CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
147      &                      ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
148   8       CONTINUE
149   7     CONTINUE
150 C     ************************************************************
151 C     * RIGHT REGION HORIZONTAL LINES.                           *
152 C     ************************************************************
153       XE=TP*A
154       DO 9 I=0,KM
155         YMIN=-C/(2*KM)+I*C/KM
156         YMAX=YMIN+C/KM
157         DO 10 J=0,NPY-1
158           YE=YMIN+(C/KM)*(1.0-TAUY)/2.0+J*DY
159           IF ((YE .GT. DY/2.0) .AND. (YE .LT. C-DY/2.0)) THEN
160             K=K+1
161             WRITE(*,*) 'DRAWING VECTOR ',K
162             CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
163             NDIR=0
164             VL=20.0/GS
165             CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
166      &                      ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
167             NDIR=1
168             VL=20.0/GS-S/GS
169             CALL VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
170      &                      ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
171           ELSE
172           END IF
173  10     CONTINUE
174   9    CONTINUE
```

```
175         RETURN
176         END

  1         SUBROUTINE VEC2D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
  2        &                        ,YMIN,YMAX,FX,FY,GS,BX,BY,VL,BANG,S,MNAR,DS)
  3  C     ********************************************************************
  4  C     * THIS SUBROUTINE DRAWS A VECTOR IN TWO DIMENSIONS.                *
  5  C     ********************************************************************
  6  C     * INPUTS:                                                          *
  7  C     *                                                                  *
  8  C     *   XE,YE  - FIRST COORDINATE OF VECTOR LINE.                      *
  9  C     *   MN  - MAXIMUM NUMBER OF COORDINATE POINTS.                     *
 10  C     *   MT  - MAXIMUM NUMBER OF TRIANGLES.                             *
 11  C     *   N2T(MT,3)  - NODE MATRIX WHERE FIRST INDEX REPRESENTS          *
 12  C     *                EACH TRIANGLE AND SECOND INDEX REPRESENTS          *
 13  C     *                THE NODE NUMBERS.                                 *
 14  C     *   T2N(MN,MP)  -  MATRIX OF TRIANGLE TO NODE CONNECTIONS          *
 15  C     *                WHERE THE FIRST INDEX IS THE NODE NUMBER          *
 16  C     *                AND THE SECOND IS THE LOCAL TRIANGLE NUMBER.      *
 17  C     *   X(MN) - COORDINATE VECTORS OF GRID.                            *
 18  C     *   Y(MN)                                                          *
 19  C     *   FX(MN) - VECTOR FUNCTION FIELD VALUES AT EACH COORDINATE.      *
 20  C     *   FY(MN)                                                         *
 21  C     *   AX,BX  - GRAPHICAL SCALE CONSTANTS.                            *
 22  C     *   AY,BY                                                          *
 23  C     *   VL     - SPACING BETWEEN ARROWHEADS IN REAL COORDINATES.       *
 24  C     *   BANG   - ARROW APEX HALF ANGLE IN DEGREES.                     *
 25  C     *   S      - ARROW HEAD SIDE LENGTH IN POINT SIZE.                 *
 26  C     *   MNAR   - MAXIMUM NUMBER OF ARROWS ALLOWED.                     *
 27  C     *   DS     - STEP SIZE.                                            *
 28  C     *                                                                  *
 29  C     * OUTPUTS:                                                         *
 30  C     *                                                                  *
 31  C     ********************************************************************
 32        REAL*4 X(MN),Y(MN),FX(MN),FY(MN)
 33        INTEGER N2T(MT,3),T2N(MN,MP)
 34        MXSTEP=300
 35  C     ********************************************************************
 36  C     * STORE THE FIRST TRIANGLE NUMBER.                                 *
 37  C     ********************************************************************
 38        IFIRST=ID
 39  C     ********************************************************************
 40  C     * STORE THE FIRST POINT.                                           *
 41  C     ********************************************************************
 42        XFIRST=XE
 43        YFIRST=YE
 44        XAT=TRANS(GS,BX,XE)
 45        YAT=TRANS(GS,BY,YE)
 46        WRITE(1,100) XAT,YAT,' moveto'
 47  C     ********************************************************************
 48  C     * BEGIN THE VECTOR SEGMENTS.                                       *
 49  C     ********************************************************************
 50        K=0
 51        VSUM=0.0
 52        KAR=0
 53        XA=XE
 54        YA=YE
 55  999   CONTINUE
 56        K=K+1
```

```
57 C       WRITE(*,*) 'SEGMENT NUMBER= ',K,' TRIANGLE NUMBER= ',ID
58 C      ************************************************************************
59 C      * IF THIS IS NOT THE FIRST LINE THEN DETERMINE WHAT TRIANGLE     *
60 C      * THE DRAWN LINE CONNECTS TO BY LOOKING AT THE TWO NODES NA AND  *
61 C      * NB FORMING THE LAST INTERSECTION.                              *
62 C      ************************************************************************
63         IF (K .GT. 1) THEN
64           IF (K .GT. MXSTEP) THEN
65             WRITE(*,*) 'MAX STEPS EXCEEDED '
66             GO TO 99
67           ELSE
68           END IF
69           XA=XF
70           YA=YF
71           IF (ID .EQ. 0) THEN
72 C            ************************************************************
73 C            * THERE IS NO NEXT TRIANGLE WHICH MEANS THE VECTOR          *
74 C            * TERMINATES ON A BOUNDARY.                                 *
75 C            ************************************************************
76            WRITE(*,*) 'TERMINATE ON BOUNDARY TRIANGLE'
77             GO TO 99
78           ELSE IF (ID .EQ. IFIRST) THEN
79 C            WRITE(*,*) 'BACK TO ORIGINAL TRIANGLE'
80 C             GO TO 99
81           ELSE
82           END IF
83         ELSE
84         END IF
85 C      ************************************************************************
86 C      * FIND THE VECTOR FUNCTION VALUE AT THE POINT (XA,YA).           *
87 C      ************************************************************************
88         CALL VECCOF(MN,MT,ID,X,Y,XA,YA,N2T,FX,FY,A,B,E,C,D,F)
89 C      ************************************************************************
90 C      * GET THE VECTOR COMPONENTS AT THE POINT (XA,YA).                *
91 C      ************************************************************************
92         FYA=A*XA+B*YA+E
93         FXA=C*XA+D*YA+F
94         FM=SQRT(FXA*FXA+FYA*FYA)
95         FXN=FXA/FM
96         FYN=FYA/FM
97 C      ************************************************************************
98 C      * INCREMENT OR DECREMENT THE VECTOR FROM THE POINT (XA,YA).      *
99 C      ************************************************************************
100        IF (NDIR .EQ. 0) THEN
101C         ************************************************************
102C         * INCREMENT.                                                *
103C         ************************************************************
104          XF=XA+DS*FXN
105          YF=YA+DS*FYN
106        ELSE
107C         ************************************************************
108C         * DECREMENT.                                                *
109C         ************************************************************
110          XF=XA-DS*FXN
111          YF=YA-DS*FYN
112        END IF
113C      ************************************************************************
114C      * GET THE NEXT TRIANGLE NUMBER.                                 *
115C      ************************************************************************
```

```
116         IDOLD=ID
117         CALL FDSTRI(XF,YF,MN,X,Y,MT,MP,NT,N2T,T2N,IDOLD,ID)
118         IF (ID .EQ. IFIRST) THEN
119 C          XF=XFIRST
120 C          YF=YFIRST
121         ELSE IF (ID .EQ. 0) THEN
122 C          WRITE(*,*) 'BOUNDARY NODE'
123 C         **********************************************************
124 C         * ADJUST THE POINT IF IT IS OUTSIDE THE BOUNDARY.        *
125 C         **********************************************************
126           IF (XF .LT. XMIN) THEN
127             XF=XMIN
128           ELSE IF (XF .GT. XMAX) THEN
129             XF=XMAX
130           ELSE
131           END IF
132           IF (YF .LT. YMIN) THEN
133             YF=YMIN
134           ELSE IF (YF .GT. YMAX) THEN
135             YF=YMAX
136           ELSE
137           END IF
138 C         **********************************************************
139 C         * DRAW THE LINE FROM (XA,YA) TO (XF,YF).                 *
140 C         **********************************************************
141           XFT=TRANS(GS,BX,XF)
142           YFT=TRANS(GS,BY,YF)
143           WRITE(1,100) XFT,YFT,' lineto'
144           GO TO 99
145         END IF
146 C       **********************************************************
147 C       * ADJUST THE POINT IF IT IS OUTSIDE THE BOUNDARY.        *
148 C       **********************************************************
149         IF (XF .LT. XMIN) THEN
150           XF=XMIN
151         ELSE IF (XF .GT. XMAX) THEN
152           XF=XMAX
153         ELSE
154         END IF
155         IF (YF .LT. YMIN) THEN
156           YF=YMIN
157         ELSE IF (YF .GT. YMAX) THEN
158           YF=YMAX
159         ELSE
160         END IF
161 C       **********************************************************
162 C       * DRAW THE LINE FROM (XA,YA) TO (XF,YF).                 *
163 C       **********************************************************
164         XFT=TRANS(GS,BX,XF)
165         YFT=TRANS(GS,BY,YF)
166         WRITE(1,100) XFT,YFT,' lineto'
167 C       **********************************************************
168 C       * DRAW ARROW OR ARROWS IF APPROPRIATE.                   *
169 C       **********************************************************
170         DAR=SQRT((XA-XF)*(XA-XF)+(YA-YF)*(YA-YF))
171         IF (DAR .GT. 0.0) THEN
172           IF (NDIR .EQ. 0) THEN
173             CALL ARRW2D(MNAR,VL,BANG,S,XA,YA,XF,YF,FXN,FYN,VSUM,KAR
174       &                                                  ,GS,BX,BY)
```

```
175          ELSE
176            CALL ARRW2D(MNAR,VL,BANG,S,XF,YF,XA,YA,FXN,FYN,VSUM,KAR
177         &                                                  ,GS,BX,BY)
178          END IF
179        ELSE
180        END IF
181 C      ***************************************************************
182 C      * STOP IF VECTOR MAGNITUDE DROPS BELOW TOLERANCE.             *
183 C      ***************************************************************
184        IF (FM .LT. .001) THEN
185 C         WRITE(*,*) 'CLOSE TO AN UNKNOWN CRITICAL POINT'
186          GO TO 99
187        ELSE
188        END IF
189        GO TO 999
190 C      ***************************************************************
191 C      * STOP.                                                       *
192 C      ***************************************************************
193   99   CONTINUE
194        WRITE(1,*) 'stroke'
195  100   FORMAT(2(F6.2,1X),A7)
196        ID=IFIRST
197        RETURN
198        END

  1        SUBROUTINE ARRW2D(MNAR,VL,BANG,S,XA,YA,XF,YF,FXN,FYN,VSUM,KAR
  2       &                                                  ,GS,BX,BY)
  3 C      ***************************************************************
  4 C      * THIS SUBROUTINE CONTROLS THE DRAWING OF ARROWHEADS ON A LINE. *
  5 C      ***************************************************************
  6 C      * INPUTS:                                                     *
  7 C      *                                                             *
  8 C      *   MNAR     - MAXIMUM NUMBER OF ARROWS ALLOWED.              *
  9 C      *   VL       - SPACING BETWEEN ARROWHEADS IN REAL COORDINATES. *
 10 C      *   BANG     - ARROW APEX HALF ANGLE IN DEGREES.              *
 11 C      *   S        - ARROW HEAD SIDE LENGTH IN POINT SIZE.          *
 12 C      *   XA,YA    - BASE OF ARROW.                                 *
 13 C      *   XF,YF    - TIP OF ARROW.                                  *
 14 C      *   FXN,FYN  - NORMALIZED VECTOR FUNCTION VALUES.             *
 15 C      *   VSUM     - ACCUMULATED LINE LENGTH.                       *
 16 C      *   KAR      - NUMBER OF ARROWS DRAWN SO FAR.                 *
 17 C      *   AX,BX    - GRAPHICAL SCALE CONSTANTS.                     *
 18 C      *   AY,BY                                                     *
 19 C      ***************************************************************
 20        D=SQRT((XA-XF)*(XA-XF)+(YA-YF)*(YA-YF))
 21        STEP=VSUM+D
 22        IF (STEP .GT. VL) THEN
 23          KAR=KAR+1
 24          IF (KAR .GT. MNAR) THEN
 25            GO TO 2
 26          ELSE
 27          END IF
 28 C        ***************************************************************
 29 C        * THE NEXT LINE SEGMENT IS LONGER THAN THE ARROW SPACING.     *
 30 C        * SO AN ARROW SHOULD BE DRAWN.                                *
 31 C        ***************************************************************
 32          RAT=(VL-VSUM)/D
 33          XFW=XA+RAT*(XF-XA)
 34          YFW=YA+RAT*(YF-YA)
```

```
C     ************************************************************
C     * DRAW THE ARROW.                                          *
C     ************************************************************
      XFJ=TRANS(GS,BX,XFW)
      YFJ=TRANS(GS,BY,YFW)
      CALL AHED2D(BANG,S,XFJ,YFJ,FXN,FYN)
C     ************************************************************
C     * COMPUTE THE AMOUNT LEFT OVER AFTER THE ARROW IS DRAWN.   *
C     ************************************************************
      DLT=SQRT((XF-XFW)*(XF-XFW)+(YF-YFW)*(YF-YFW))
      IF (DLT .LT. VL) THEN
C       ******************************************************
C       * NO MORE ARROWS ARE DRAWN ON THIS SEGMENT.          *
C       ******************************************************
        VSUM=DLT
      ELSE
C       ******************************************************
C       * MORE THAN ONE ARROW IS DRAWN ON THIS SEGMENT.      *
C       ******************************************************
        NAR=DLT/VL
        DO 1 I=1,NAR
          KAR=KAR+1
          IF (KAR .GT. MNAR) THEN
            GO TO 2
          ELSE
          END IF
          RAT=(VL-VSUM+I*VL)/D
          XFW=XA+RAT*(XF-XA)
          YFW=YA+RAT*(YF-YA)
          XFJ=TRANS(GS,BX,XFW)
          YFJ=TRANS(GS,BY,YFW)
          CALL AHED2D(BANG,S,XFJ,YFJ,FXN,FYN)
    1   CONTINUE
        VSUM=SQRT((XF-XFW)*(XF-XFW)+(YF-YFW)*(YF-YFW))
      END IF
      ELSE
C       ******************************************************
C       * THE LINE LENGTH PLUS THE ACCUMULATED DISTANCE IS STILL LESS  *
C       * THAN THE ARROW SPACING. NO ARROW SHOULD BE DRAWN JUST        *
C       * ACCUMULATE THE DISTANCE.                           *
C       ******************************************************
        VSUM=VSUM+D
      END IF
    2 CONTINUE
      RETURN
      END

      SUBROUTINE AHED2D(BANG,S,X2,Y2,FXN,FYN)
C     ************************************************************
C     * THIS SUBROUTINE DRAWS A ARROW FROM (X1,Y1) TO (X2,Y2).   *
C     ************************************************************
C     * INPUTS:                                                  *
C     *                                                          *
C     *   BANG  - ARROW APEX HALF ANGLE IN DEGREES.              *
C     *   S     - ARROWHEAD SIDE LENGTH.                         *
C     *   X2,Y2  - TIP OF ARROW.                                 *
C     *   FXN,FYN - NORMALIZED VECTOR FUNCTION VALUES.           *
C     ************************************************************
      RAD=.17453293E-01
```

```
      X1=X2-FXN
      Y1=Y2-FYN
      D=SQRT((X2-X1)*(X2-X1)+(Y2-Y1)*(Y2-Y1))
      A=1.0-S/D
      X3=X1+A*(X2-X1)
      Y3=Y1+A*(Y2-Y1)
C     ************************************************************************
C     * TRANSLATE THE ORIGIN TO (X2,Y2) AND ROTATE (X3,Y3) PLUS AND    *
C     * MINUS BANG DEGREES TO GENERATE THE VERTICES OF THE ARROW.      *
C     ************************************************************************
      X0=X2
      Y0=Y2
      XA=X3-X2
      YA=Y3-Y2
      ARG=RAD*BANG
      CA=COS(ARG)
      SA=SIN(ARG)
      XCA=XA*CA
      XSA=XA*SA
      YCA=YA*CA
      YSA=YA*SA
      X4=X0+XCA-YSA
      Y4=Y0+XSA+YCA
      X5=X0+XCA+YSA
      Y5=Y0-XSA+YCA
c      X6=(X4+X5)/2.0
c      Y6=(Y4+Y5)/2.0
C      WRITE(1,*) X1,Y1,' moveto'
C      WRITE(1,*) X6,Y6,' lineto stroke'
C     ************************************************************************
C     * TRANSLATE THE ORIGIN TO (X2,Y2) AND ROTATE (X3,Y3) PLUS AND    *
C     * MINUS BANG DEGREES  TO GENERATE THE VERTICES OF THE ARROW      *
C     ************************************************************************
      WRITE(1,*) 'gsave newpath'
      WRITE(1,*) X2,Y2,' moveto ',X4,Y4,' lineto ',X5,Y5,' lineto'
      WRITE(1,*) 'closepath 0 setgray fill stroke grestore'
      RETURN
      END
```

```
      PROGRAM FLDREC
C     ************************************************************************
C     * THIS PROGRAM GENERATES A VECTOR PLOT OF THE TRIANGULARIZED     *
C     * REGION OF A RECTANGULAR WAVEGUIDE.                             *
C     ************************************************************************
C     * TIMOTHY J. PETERS                                LAST UPDATED  *
C     * THE AEROSPACE CORPORATION                        5/12/92       *
C     * 2350 EAST EL SEGUNDO BOULEVARD                                 *
C     * EL SEGUNDO, CA 90245                                           *
C     ************************************************************************
      PARAMETER (MN=6000,MT=12000,MP=6,NC=5,NL=6)
      REAL*4 U(MN),V(MN),FU(MN),FV(MN),PHI(50),CA(NC),CB(NC)
      REAL*4 XQ(3),YQ(3),ZQ(3)
      REAL*8 ARG
      INTEGER LC(NC),ITMIN(4),ITMAX(4),ISIDE(4)
      CHARACTER*30 LABEL(NL)
      INTEGER*4 N2T(MT,3),T2N(MN,MP)
      PI=.3141593E+01
      RAD=.17453293E-01
C     ************************************************************************
C     * INPUTS:                                                        *
C     *                                                                *
C     * GS - GRAPH SCALE CONSTANT.                                     *
C     * PO - PHI OBSERVATION ANGLE (DEGREES).                          *
C     * TO - THETA OBSERVATION ANGLE (DEGREES).                        *
C     ************************************************************************
      GS=180.0
      PO=60.0
      TO=60.0
C     ************************************************************************
C     * READ THE COORDINATE DATA AND VECTOR FUNCTION DATA FROM A FILE. *
C     ************************************************************************
      OPEN(UNIT=1,FILE='RUVFDF')
      READ(1,*) A,B,C,KM,M,N
      READ(1,*) NUA,NUB,NV
      READ(1,*) NN
      VMAX=0.0
      DO 1 I=1,NN
        READ(1,*) U(I),V(I),FU(I),FV(I)
     VMAG=SQRT(FU(I)*FU(I)+FV(I)*FV(I))
        IF (VMAG .GT. VMAX) THEN
          VMAX=VMAG
        ELSE
        END IF
    1 CONTINUE
      CLOSE(1)
      WRITE(*,*) NN,' DATA POINTS READ IN'
C     ************************************************************************
C     * NORMALIZE THE VECTOR COMPONENTS SO THAT THE MAXIMUM MAGNITUDE  *
C     * IS 1.0.                                                        *
C     ************************************************************************
      DO 2 I=1,NN
        FU(I)=FU(I)/VMAX
        FV(I)=FV(I)/VMAX
    2 CONTINUE
C     ************************************************************************
C     * READ THE TRIANGLE NODE DATA.                                   *
C     ************************************************************************
      OPEN(UNIT=1,FILE='N2TDAT')
```

```
      READ(1,*) NT
      DO 3 I=1,NT
        READ(1,*)  N2T(I,1),N2T(I,2),N2T(I,3)
    3 CONTINUE
      CLOSE(1)
      WRITE(*,*) 'NODE TO TRIANGLE DATA READ IN'
C     ************************************************************
C     * READ THE TRIANGLE TO NODE CONNECTION DATA.               *
C     ************************************************************
      OPEN(UNIT=1,FILE='T2NDAT')
      READ(1,*) NN
      DO 4 I=1,NN
        READ(1,*)  (T2N(I,J),J=1,MP)
    4 CONTINUE
      CLOSE(1)
      WRITE(*,*) 'TRIANGLE TO NODE DATA READ IN'
C     ************************************************************
C     * COMPUTE CENTROID OF GRAPH.                               *
C     ************************************************************
      XMIN=-B/2.0
      XMAX=B/2.0
      YMIN=-A/2.0
      YMAX=A/2.0
      ZMIN=0.0
      ZMAX=C
      XC=(XMIN+XMAX)/2.0
      YC=(YMIN+YMAX)/2.0
      ZC=(ZMIN+ZMAX)/2.0
C     ************************************************************
C     * CONVERT THE OBSERVATION ANGLES TO RADIANS.               *
C     ************************************************************
      RAD=.17453293E-01
      PI=.3141593E+01
      PI4=PI/4.0
      XD=XC
      YD=YC
      ZD=ZC
      CALL SCALE(GS,XD,YD,ZD)
C     ************************************************************
C     * CONVERT THE OBSERVATION ANGLES TO RADIANS.               *
C     ************************************************************
      POBS=RAD*PO
      TOBS=RAD*TO
C     ************************************************************
C     * COMPUTE THE ROTATION ANGLES WHICH YIELD THE DESIRED OBSERVATION*
C     * ANGLES.                                                  *
C     ************************************************************
      RP=-POBS-PI/2.0
      RT=TOBS
C     ************************************************************
C     * COMPUTE THE CONSTANTS FOR THE ROTATION MATRIX.           *
C     ************************************************************
      CALL RCOEFF(RP,RT,C1,C2,C3,C4,C5)
C     ************************************************************
C     * COMPUTE THE CENTER OF THE PRINTING DEVICE PAGE.          *
C     ************************************************************
      XO=72*8.5/2.0
      YO=72*11.0/2.0
C     ************************************************************
```

```
C     * SET THE GRAPHIC BOUNDING BOX.                                    *
C     ***********************************************************************
      WX=(XMAX-XMIN)
      WY=(YMAX-YMIN)
      WIDTH=GS*WX
      HEIGHT=GS*WY
      UA=XO-WIDTH/2.0-60.0
      UB=XO+WIDTH/2.0+100.0
      VA=YO-HEIGHT/2.0-180.0
      VB=YO+HEIGHT/2.0+180.0
C     ***********************************************************************
C     * COMPUTE THE BOUNDING BOX FOR THE POSTSCRIPT IN THE DEFAULT     *
C     * COORDINATE SYSTEM.                                              *
C     ***********************************************************************
      OPEN(UNIT=1,FILE='FoldedRect.ps')
      WRITE(1,*) '%!PS-Adobe-1.0'
      WRITE(1,*) '%%Creator: Timothy J. Peters'
      WRITE(1,*) '%%Title: Graph'
      WRITE(1,*) '%%CreationDate: 5-14-92'
      WRITE(1,100) '%%BoundingBox:',INT(UA),INT(VA),INT(UB),INT(VB)
100   FORMAT(A14,4(1X,I3))
      WRITE(1,*) '%%EndComments'
      WRITE(1,*) '/dot2 {2 0 360 arc 0 setgray fill stroke} def'
      WRITE(1,*) '/dot3 {3 0 360 arc 0 setgray fill stroke} def'
      WRITE(1,*) '/dot4 {4 0 360 arc 0 setgray fill stroke} def'
      WRITE(1,*) '/black {0 0 0 setrgbcolor} def'
      WRITE(1,*) '/white {1 1 1 setrgbcolor} def'
      WRITE(1,*) '/gray-lt {0.92 0.92 0.92 setrgbcolor} def'
      WRITE(1,*) '/gray-lt-med {0.65 0.65 0.65 setrgbcolor} def'
      WRITE(1,*) '/gray {0.45 0.45 0.45 setrgbcolor} def'
      WRITE(1,*) '/gray-dk-med {0.3 0.3 0.3 setrgbcolor} def'
      WRITE(1,*) '/gray-dk {0.14 0.14 0.14 setrgbcolor} def'
      WRITE(1,*) '/red {1 0 0 setrgbcolor} def'
      WRITE(1,*) '/magenta {1 0 1 setrgbcolor} def'
      WRITE(1,*) '/green {0 1 0 setrgbcolor} def'
      WRITE(1,*) '/blue {0 0 1 setrgbcolor} def'
      WRITE(1,*) '/cyan {0 1 1 setrgbcolor} def'
      WRITE(1,*) '/yellow {1 1 0 setrgbcolor} def'
      WRITE(1,*) '/orange {1 0.5 0 setrgbcolor} def'
      WRITE(1,*) '/brown {0.5 0.5 0 setrgbcolor} def'
      WRITE(1,*) '/kakhi {0.5 1 0 setrgbcolor} def'
      WRITE(1,*) '/blue-lt {0.5 1 1 setrgbcolor} def'
      WRITE(1,*) '/green-lt {0.5 1 0.5 setrgbcolor} def'
      WRITE(1,*) '/green-blue {0 1 0.5 setrgbcolor} def'
      WRITE(1,*) '/purple {0.6 0 1.0 setrgbcolor} def'
      WRITE(1,*) '/filtri {moveto lineto lineto'
      WRITE(1,*) '             closepath fill stroke} def'
      WRITE(1,*) '/filqud {moveto lineto lineto lineto closepath fill'
      WRITE(1,*) '                                    stroke} def'
      WRITE(1,*) '/filpnt {moveto lineto lineto lineto'
      WRITE(1,*) '              lineto closepath fill stroke} def'
      WRITE(1,*) '%%EndProlog'
      WRITE(1,*) '1 setlinejoin .4 setlinewidth'
C     ***********************************************************************
C     * DRAW THE EPS BOUNDING BOX.                                      *
C     ***********************************************************************
C      WRITE(1,*) 'gsave 0.2 setlinewidth'
C      WRITE(1,*) UA,VA,' moveto'
C      WRITE(1,*) UB,VA,' lineto'
```

```
178 C       WRITE(1,*) UB,VB,' lineto'
179 C       WRITE(1,*) UA,VB,' lineto'
180 C       WRITE(1,*) 'closepath stroke grestore'
181 C      ********************************************************************
182 C      * ASSIGN CONTOUR VALUES AND LABELS.                                 *
183 C      ********************************************************************
184        CA(1)=0.0
185        CB(1)=0.15
186        CA(2)=0.15
187        CB(2)=0.4
188        CA(3)=0.4
189        CB(3)=0.6
190        CA(4)=0.6
191        CB(4)=0.8
192        CA(5)=0.8
193        CB(5)=1.0
194        LABEL(1)='0'
195        LABEL(2)='.15'
196        LABEL(3)='.4'
197        LABEL(4)='.6'
198        LABEL(5)='.8'
199        LABEL(6)='1'
200 C      ********************************************************************
201 C      * ASSIGN THE COLORS.  SEE SUBROUTINE SETCOL FOR COLOR CHOICES.      *
202 C      ********************************************************************
203 C GRAY SCALE
204        LC(1)=2
205        LC(2)=3
206        LC(3)=4
207        LC(4)=5
208        LC(5)=6
209 C  COLOR
210 C       LC(1)=18
211 C       LC(2)=14
212 C       LC(3)=12
213 C       LC(4)=16
214 C       LC(5)=13
215 C      ********************************************************************
216 C      * CALCULATE AND STORE     *
217 C      ********************************************************************
218        N1MIN=1
219        N1MAX=N1MIN+2*(NUA-1)*(NV-1)-1
220        N2MIN=N1MAX+1
221        N2MAX=N2MIN+2*(NUB-1)*(NV-1)-1
222        N3MIN=N2MAX+1
223        N3MAX=N3MIN+2*(NUA-1)*(NV-1)-1
224        N4MIN=N3MAX+1
225        N4MAX=N4MIN+2*(NUB-1)*(NV-1)-1
226        IF ((P0 .GE. 0.0) .AND. (P0 .LE. 90.0)) THEN
227 C        ******************************************************************
228 C        * DRAW SIDES IN ORDER 3,4,2,1.                                    *
229 C        ******************************************************************
230          ISIDE(1)=3
231          ISIDE(2)=4
232          ISIDE(3)=2
233          ISIDE(4)=1
234          ITMIN(1)=N3MIN
235          ITMAX(1)=N3MAX
236          ITMIN(2)=N4MIN
```

```
237           ITMAX(2)=N4MAX
238           ITMIN(3)=N2MIN
239           ITMAX(3)=N2MAX
240           ITMIN(4)=N1MIN
241           ITMAX(4)=N1MAX
242         ELSE
243         END IF
244 C       ***********************************************************************
245 C       * STEP THROUGH EACH SIDE FROM BACK TO FRONT.                           *
246 C       ***********************************************************************
247         DO 6 J=1,4
248           WRITE(*,*) 'SIDE ',J
249 C         ***********************************************************************
250 C         * DRAW THE CONTOUR PLOT FOR THIS SIDE.                                *
251 C         ***********************************************************************
252           DO 7 I=ITMIN(J),ITMAX(J)
253             N1=N2T(I,1)
254             N2=N2T(I,2)
255             N3=N2T(I,3)
256         F1=SQRT(FU(N1)*FU(N1)+FV(N1)*FV(N1))
257         F2=SQRT(FU(N2)*FU(N2)+FV(N2)*FV(N2))
258         F3=SQRT(FU(N3)*FU(N3)+FV(N3)*FV(N3))
259             CALL MPRPNT(U(N1),V(N1),A,B,XQ(1),YQ(1),ZQ(1))
260             CALL MPRPNT(U(N2),V(N2),A,B,XQ(2),YQ(2),ZQ(2))
261             CALL MPRPNT(U(N3),V(N3),A,B,XQ(3),YQ(3),ZQ(3))
262 C           ***********************************************************************
263 C           * TRANSFORM THE 3 VERTICES OF THE TRIANGLE.                           *
264 C           ***********************************************************************
265             CALL TRFTRI(XQ,YQ,ZQ,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
266 C           ***********************************************************************
267 C           * DRAW THE CONTOUR.                                                   *
268 C           ***********************************************************************
269             CALL CONTUR(XQ(1),YQ(1),XQ(2),YQ(2),XQ(3),YQ(3),F1,F2,F3
270      &                                                    ,CA,CB,NC,LC)
271   7       CONTINUE
272 C         ***********************************************************************
273 C         * DRAW THE PERIMETER AROUND THE SIDE.                                 *
274 C         ***********************************************************************
275           IF (ISIDE(J) .EQ. 1) THEN
276             U1=-A-B
277             V1=0.0
278             U2=-B
279             V2=0.0
280             U3=-B
281             V3=C
282             U4=-A-B
283             V4=C
284           ELSE IF (ISIDE(J) .EQ. 2) THEN
285             U1=-B
286             V1=0.0
287             U2=0.0
288             V2=0.0
289             U3=0.0
290             V3=C
291             U4=-B
292             V4=C
293           ELSE IF (ISIDE(J) .EQ. 3) THEN
294             U1=0.0
295             V1=0.0
```

```
296           U2=A
297           V2=0.0
298           U3=A
299           V3=C
300           U4=0.0
301           V4=C
302         ELSE
303           U1=A
304           V1=0.0
305           U2=A+B
306           V2=0.0
307           U3=A+B
308           V3=C
309           U4=A
310           V4=C
311         END IF
312         CALL MPRPNT(U1,V1,A,B,X1,Y1,Z1)
313         CALL MPRPNT(U2,V2,A,B,X2,Y2,Z2)
314         CALL MPRPNT(U3,V3,A,B,X3,Y3,Z3)
315         CALL MPRPNT(U4,V4,A,B,X4,Y4,Z4)
316         CALL TRFPNT(X1,Y1,Z1,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
317         CALL TRFPNT(X2,Y2,Z2,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
318         CALL TRFPNT(X3,Y3,Z3,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
319         CALL TRFPNT(X4,Y4,Z4,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
320         WRITE(1,*) 'gsave 0 setgray 0.4 setlinewidth newpath'
321         WRITE(1,*) X1,Y1,' moveto ',X2,Y2,' lineto'
322         WRITE(1,*) X3,Y3,' lineto ',X4,Y4,' lineto'
323         WRITE(1,*) 'closepath stroke grestore'
324 C       ***********************************************************************
325 C       * DRAW THE VECTORS FOR THIS SIDE.                                     *
326 C       ***********************************************************************
327         BANG=20.0
328         S=8.0
329         MNAR=1
330         DS=.003
331         UMIN=-A-B
332         UMAX=A+B
333         VMIN=0.0
334         VMAX=5.0/SQRT(3.0)
335         WRITE(1,*) '0 setgray'
336         CALL RWTE3D(NDIR,MN,MT,MP,NT,N2T,T2N,U,V,A,B,KM,UMIN,UMAX
337      &  ,VMIN,VMAX,FU,FV,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
338      &  ,S,MNAR,DS,P0,ISIDE(J))
339    6  CONTINUE
340 C      ***********************************************************************
341 C      * DRAW THE LEGEND.                                                    *
342 C      ***********************************************************************
343        SL=15.0
344        SH=30.0
345        DS=0.0
346        ITYPE=1
347        US=420.0
348        VS=173.0
349        CALL LEGEND(US,VS,NC,NL,LC,LABEL,SL,SH,DS,ITYPE)
350 C      ***********************************************************************
351 C      * DRAW THE PAGE.                                                      *
352 C      ***********************************************************************
353        WRITE(1,*) 'showpage'
354        CLOSE(1)
```

```
355       END

  1       SUBROUTINE RWTE3D(NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,A,B,KM,XMIN,XMAX
  2      &,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
  3      &,S,MNAR,DS,P0,IS)
  4 C     ****************************************************************
  5 C     * THIS SUBROUTINE DRAWS VECTOR LINES FOR THE TE10 MODE FIELDS.   *
  6 C     ****************************************************************
  7 C     * INPUTS:                                                        *
  8 C     *                                                                *
  9 C     *   MN  - MAXIMUM NUMBER OF COORDINATE POINTS.                   *
 10 C     *   MT  - MAXIMUM NUMBER OF TRIANGLES.                           *
 11 C     *   N2T(MT,3)  - NODE MATRIX WHERE FIRST INDEX REPRESENTS        *
 12 C     *                EACH TRIANGLE AND SECOND INDEX REPRESENTS       *
 13 C     *                THE NODE NUMBERS.                               *
 14 C     *   T2N(MN,MP)  -  MATRIX OF TRIANGLE TO NODE CONNECTIONS        *
 15 C     *                WHERE THE FIRST INDEX IS THE NODE NUMBER        *
 16 C     *                AND THE SECOND IS THE LOCAL TRIANGLE NUMBER.    *
 17 C     *   X(MN) - COORDINATE VECTORS OF GRID.                          *
 18 C     *   Y(MN)                                                        *
 19 C     *   FX(MN) - VECTOR FUNCTION FIELD VALUES AT EACH COORDINATE.    *
 20 C     *   FY(MN)                                                       *
 21 C     *   AX,BX  - GRAPHICAL SCALE CONSTANTS.                          *
 22 C     *   AY,BY                                                        *
 23 C     *   VL     - SPACING BETWEEN ARROWHEADS IN REAL COORDINATES.     *
 24 C     *   BANG   - ARROW APEX HALF ANGLE IN DEGREES.                   *
 25 C     *   S      - ARROW HEAD SIDE LENGTH IN POINT SIZE.               *
 26 C     *   MNAR   - MAXIMUM NUMBER OF ARROWS ALLOWED.                   *
 27 C     *   DS     - STEP SIZE.                                          *
 28 C     *                                                                *
 29 C     * OUTPUTS:                                                       *
 30 C     *                                                                *
 31 C     ****************************************************************
 32       REAL*4 X(MN),Y(MN),FX(MN),FY(MN)
 33       INTEGER N2T(MT,3),T2N(MN,MP)
 34       PI=.3141593E+01
 35       RAD=.17453293E-01
 36       AH=S*COS(RAD*BANG)
 37 C     ****************************************************************
 38 C     * SET SPACING PARAMETERS BASED ON CRITICAL POINT LOCATIONS.      *
 39 C     ****************************************************************
 40       NPY=5
 41       NPX=9
 42       TAUX=0.96
 43       TAUY=0.7
 44       DL=1.0/SQRT(3.0)
 45       DX=TAUX*A/(NPX-1)
 46       DY=(TAUY*DL)/(NPY-1)
 47       IF (IS .EQ. 1) THEN
 48 C       ************************************************************
 49 C       * DRAW SIDE 1 (Y=B/2) VECTORS.                              *
 50 C       ************************************************************
 51         XMIN=-A-B
 52         XMAX=-B
 53 C       ************************************************************
 54 C       * DRAW VECTOR LINES ALONG A VERTICAL LINE WHICH ORIGINATE ON  *
 55 C       * THE PERIMETER OF SIDE 1 AND TERMINATE AT CRITICAL POINT 1.  *
 56 C       ************************************************************
 57         K=0
```

```
58          DO 1 I=1,(NPY-1)/2
59            K=K+1
60            WRITE(*,*) 'DRAWING VECTOR ',K
61            YE=I*DY
62            XE=-B
63            CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
64            NDIR=0
65            VL=20.0/GS
66            CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
67       &     ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
68       &     ,S,MNAR,DS)
69            NDIR=0
70            XE=-B-A
71            VL=20.0/GS
72            CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
73            CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
74       &     ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
75       &     ,S,MNAR,DS)
76    1     CONTINUE
77  C       ***********************************************************************
78  C       * DRAW VECTOR LINES ALONG A HORIZONTAL LINE WHICH ORIGINATE ON *
79  C       * CRITICAL POINT 2 AND TERMINATE ON CRITICAL POINT 1.          *
80  C       ***********************************************************************
81          DXOFF=(1.0-TAUX)*A/2
82          DO 2 I=0,KM-1
83            YE=0.5*DL+I*DL
84            DO 3 J=0,NPX-1
85              K=K+1
86              WRITE(*,*) 'DRAWING VECTOR ',K
87              XE=-B-A+DXOFF+J*DX
88              CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
89              NDIR=0
90              VL=27.0/GS
91              CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
92       &       ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
93       &       ,S,MNAR,DS)
94              NDIR=1
95              VL=27.0/GS-AH/GS
96              CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
97       &       ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
98       &       ,S,MNAR,DS)
99    3       CONTINUE
100   2     CONTINUE
101 C       ***********************************************************************
102 C       * DRAW VECTOR LINES ALONG A VERTICAL LINE WHICH ORIGINATE AT     *
103 C       * CRITICAL POINT 2 AND TERMINATE ON THE PERIMETER OF SIDE 1.     *
104 C       ***********************************************************************
105         DO 4 I=0,KM-2
106           YCE=(1.0-TAUY)*0.5*DL+0.5*DL+I*DL
107           IS=(-1)**I
108           IF (IS > 0) THEN
109             NDIR=1
110             VL=20.0/GS-S/GS
111           ELSE
112             NDIR=0
113             VL=20.0/GS
114           END IF
115           DO 5 J=0,NPY-1
116             K=K+1
```

```
117             WRITE(*,*) 'DRAWING VECTOR ',K
118             YE=YCE+J*DY
119             XE=-B
120             CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
121             CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
122      &      ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
123      &      ,S,MNAR,DS)
124             XE=-B-A
125             CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
126             CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
127      &      ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
128      &      ,S,MNAR,DS)
129   5       CONTINUE
130   4     CONTINUE
131 C       ********************************************************************
132 C       * DRAW VECTOR LINES ALONG A VERTICAL LINE WHICH ORIGINATE AT    *
133 C       * CRITICAL POINT 5 AND TERMINATE ON THE PERIMETER OF SIDE 1.    *
134 C       ********************************************************************
135         NP=(NPY-1)/2
136         DO 6 I=0,NP-1
137           K=K+1
138           WRITE(*,*) 'DRAWING VECTOR ',K
139           YE=4.5*DL+(1.0-TAUY)*0.5*DL+I*DY
140           XE=-B
141           CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
142           NDIR=1
143           VL=27.0/GS-AH/GS
144           CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
145      &    ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
146      &    ,S,MNAR,DS)
147           NDIR=1
148           VL=27.0/GS-AH/GS
149           XE=-B-A
150           CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
151           CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
152      &    ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
153      &    ,S,MNAR,DS)
154   6     CONTINUE
155       ELSE IF (IS .EQ. 2) THEN
156 C       ********************************************************************
157 C       * DRAW SIDE 2 VECTORS (X=A/2).                                     *
158 C       ********************************************************************
159 C       ********************************************************************
160 C       * END POINT CONTRIBUTIONS.                                         *
161 C       ********************************************************************
162         XMIN=-B
163         XMAX=0.0
164         XE=(XMIN+XMAX)/2.0
165         NP=(NPY-1)/2
166         K=0
167         DO 7 I=0,NP-1
168           YE=4.5*DL+(1.0-TAUY)*0.5*DL+I*DY
169           K=K+1
170           WRITE(*,*) 'DRAWING VECTOR ',K
171           CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
172           NDIR=0
173           VL=20.0/GS
174           CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
175      &    ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
```

```
     &     ,S,MNAR,DS)
           NDIR=1
           VL=20.0/GS-S/GS
           CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
           CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &     ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
     &     ,S,MNAR,DS)
           YE=(I+1)*DY
           K=K+1
           WRITE(*,*) 'DRAWING VECTOR ',K
           CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
           NDIR=0
           VL=20.0/GS
           CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &     ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
     &     ,S,MNAR,DS)
           NDIR=1
           VL=20.0/GS-S/GS
           CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
           CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &     ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
     &     ,S,MNAR,DS)
   7     CONTINUE
C        ************************************************************
C        * INTERIOR CONTRIBUTIONS.                                  *
C        ************************************************************
         DO 8 I=0,KM-2
           YCE=(1.0-TAUY)*0.5*DL+0.5*DL+I*DL
           DO 9 J=0,NPY-1
             K=K+1
             WRITE(*,*) 'DRAWING VECTOR ',K
             YE=YCE+J*DY
             NDIR=1
             VL=20.0/GS-S/GS
             CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
             CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &       ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
     &       ,S,MNAR,DS)
             NDIR=0
             VL=20.0/GS
             CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
             CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
     &       ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
     &       ,S,MNAR,DS)
   9       CONTINUE
   8     CONTINUE
       ELSE IF (IS .EQ. 3) THEN
C        ************************************************************
C        * DRAW SIDE 3 (Y=-B/2) VECTORS.                            *
C        ************************************************************
C        ************************************************************
C        * DRAW VECTOR LINES ALONG A VERTICAL LINE WHICH ORIGINATE ON  *
C        * THE PERIMETER OF SIDE 1 AND TERMINATE AT CRITICAL POINT 1.  *
C        ************************************************************
         K=0
         DO 10 I=1,(NPY-1)/2
           K=K+1
           WRITE(*,*) 'DRAWING VECTOR ',K
           YE=I*DY
```

```
235           XE=0
236           CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
237           NDIR=1
238           VL=20.0/GS-AH/GS
239           CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
240      &     ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
241      &     ,S,MNAR,DS)
242           NDIR=1
243           XE=A
244           VL=20.0/GS-AH/GS
245           CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
246           CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
247      &     ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
248      &     ,S,MNAR,DS)
249   10    CONTINUE
250 C       ***********************************************************************
251 C       * DRAW VECTOR LINES ALONG A HORIZONTAL LINE WHICH ORIGINATE ON *
252 C       * CRITICAL POINT 2 AND TERMINATE ON CRITICAL POINT 1.          *
253 C       ***********************************************************************
254           DXOFF=(1.0-TAUX)*A/2
255           DO 11 I=0,KM-1
256             YE=0.5*DL+I*DL
257             DO 12 J=0,NPX-1
258               K=K+1
259               WRITE(*,*) 'DRAWING VECTOR ',K
260               XE=DXOFF+J*DX
261               CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
262               NDIR=0
263               VL=27.0/GS
264               CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
265      &        ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
266      &        ,S,MNAR,DS)
267               NDIR=1
268               VL=27.0/GS-AH/GS
269               CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
270      &        ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
271      &        ,S,MNAR,DS)
272   12        CONTINUE
273   11    CONTINUE
274 C       ***********************************************************************
275 C       * DRAW VECTOR LINES ALONG A VERTICAL LINE WHICH ORIGINATE AT    *
276 C       * CRITICAL POINT 2 AND TERMINATE ON THE PERIMETER OF SIDE 1.    *
277 C       ***********************************************************************
278           DO 13 I=0,KM-2
279             YCE=(1.0-TAUY)*0.5*DL+0.5*DL+I*DL
280             IS=(-1)**(I+1)
281             IF (IS > 0) THEN
282               NDIR=1
283               VL=20.0/GS-S/GS
284             ELSE
285               NDIR=0
286               VL=20.0/GS
287             END IF
288             DO 14 J=0,NPY-1
289               K=K+1
290               WRITE(*,*) 'DRAWING VECTOR ',K
291               YE=YCE+J*DY
292               XE=0
293               CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
```

```
294              CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
295       &      ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
296       &      ,S,MNAR,DS)
297              XE=A
298              CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
299              CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
300       &      ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
301       &      ,S,MNAR,DS)
302   14       CONTINUE
303   13     CONTINUE
304 C        ************************************************************
305 C        * DRAW VECTOR LINES ALONG A VERTICAL LINE WHICH ORIGINATE AT   *
306 C        * CRITICAL POINT 5 AND TERMINATE ON THE PERIMETER OF SIDE 1.   *
307 C        ************************************************************
308          NP=(NPY-1)/2
309          DO 15 I=0,NP-1
310            K=K+1
311            WRITE(*,*) 'DRAWING VECTOR ',K
312            YE=4.5*DL+(1.0-TAUY)*0.5*DL+I*DY
313            XE=0
314            CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
315            NDIR=0
316            VL=27.0/GS
317            CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
318       &    ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
319       &    ,S,MNAR,DS)
320            NDIR=0
321            VL=27.0/GS
322            XE=A
323            CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
324            CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
325       &    ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
326       &    ,S,MNAR,DS)
327   15     CONTINUE
328        ELSE
329 C        ************************************************************
330 C        * DRAW SIDE 4 (X=-A/2) VECTORS.                              *
331 C        ************************************************************
332 C        ************************************************************
333 C        * END POINT CONTRIBUTIONS.                                   *
334 C        ************************************************************
335          XMIN=A
336          XMAX=A+B
337          XE=(XMIN+XMAX)/2.0
338          NP=(NPY-1)/2
339          K=0
340          DO 16 I=0,NP-1
341            YE=4.5*DL+(1.0-TAUY)*0.5*DL+I*DY
342            K=K+1
343            WRITE(*,*) 'DRAWING VECTOR ',K
344            CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
345            NDIR=0
346            VL=20.0/GS
347            CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
348       &    ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
349       &    ,S,MNAR,DS)
350            NDIR=1
351            VL=20.0/GS-S/GS
352            CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
```

```
353           CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
354       &     ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
355       &     ,S,MNAR,DS)
356           YE=(I+1)*DY
357           K=K+1
358           WRITE(*,*) 'DRAWING VECTOR ',K
359           CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
360           NDIR=0
361           VL=20.0/GS
362           CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
363       &     ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
364       &     ,S,MNAR,DS)
365           NDIR=1
366           VL=20.0/GS-S/GS
367           CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
368           CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
369       &     ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
370       &     ,S,MNAR,DS)
371    16     CONTINUE
372 C         ************************************************************************
373 C         * INTERIOR CONTRIBUTIONS.                                              *
374 C         ************************************************************************
375           DO 17 I=0,KM-2
376             YCE=(1.0-TAUY)*0.5*DL+0.5*DL+I*DL
377             DO 18 J=0,NPY-1
378               K=K+1
379               WRITE(*,*) 'DRAWING VECTOR ',K
380               YE=YCE+J*DY
381               NDIR=1
382               VL=20.0/GS-S/GS
383               CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
384               CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
385       &       ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
386       &       ,S,MNAR,DS)
387               NDIR=0
388               VL=20.0/GS
389               CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
390               CALL RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
391       &       ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
392       &       ,S,MNAR,DS)
393    18       CONTINUE
394    17     CONTINUE
395         END IF
396         RETURN
397         END

  1         SUBROUTINE RVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
  2       &  ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG
  3       &  ,S,MNAR,DS)
  4 C       ************************************************************************
  5 C       * THIS SUBROUTINE DRAWS A VECTOR LINE.                                 *
  6 C       ************************************************************************
  7 C       * INPUTS:                                                              *
  8 C       *                                                                      *
  9 C       *   XE,YE  - FIRST COORDINATE OF VECTOR LINE.                          *
 10 C       *   MN  - MAXIMUM NUMBER OF COORDINATE POINTS.                         *
 11 C       *   MT  - MAXIMUM NUMBER OF TRIANGLES.                                 *
 12 C       *   N2T(MT,3)  - NODE MATRIX WHERE FIRST INDEX REPRESENTS              *
 13 C       *                EACH TRIANGLE AND SECOND INDEX REPRESENTS             *
```

```
C     *                    THE NODE NUMBERS.                          *
C     *    T2N(MN,MP)  -  MATRIX OF TRIANGLE TO NODE CONNECTIONS      *
C     *                   WHERE THE FIRST INDEX IS THE NODE NUMBER    *
C     *                   AND THE SECOND IS THE LOCAL TRIANGLE NUMBER.*
C     *    X(MN) - COORDINATE VECTORS OF GRID.                        *
C     *    Y(MN)                                                      *
C     *    FX(MN) - VECTOR FUNCTION FIELD VALUES AT EACH COORDINATE.  *
C     *    FY(MN)                                                     *
C     *    AX,BX  - GRAPHICAL SCALE CONSTANTS.                        *
C     *    AY,BY                                                      *
C     *    VL     - SPACING BETWEEN ARROWHEADS IN REAL COORDINATES.   *
C     *    BANG   - ARROW APEX HALF ANGLE IN DEGREES.                 *
C     *    S      - ARROW HEAD SIDE LENGTH IN POINT SIZE.             *
C     *    MNAR   - MAXIMUM NUMBER OF ARROWS ALLOWED.                 *
C     *    DS     - STEP SIZE.                                        *
C     *                                                               *
C     * OUTPUTS:                                                      *
C     *                                                               *
C     *****************************************************************
      REAL*4 X(MN),Y(MN),FX(MN),FY(MN)
      INTEGER N2T(MT,3),T2N(MN,MP)
C     *****************************************************************
C     * STORE THE FIRST TRIANGLE NUMBER.                              *
C     *****************************************************************
      IFIRST=ID
C     *****************************************************************
C     * STORE THE FIRST POINT.                                        *
C     *****************************************************************
      AWIDTH=1.0
      BWIDTH=AWIDTH/2.0
      XFIRST=XE
      YFIRST=YE
C     *****************************************************************
C     * TRANSFORM THE INITIAL POINT.                                  *
C     *****************************************************************
      CALL MPRPNT(XE,YE,AWIDTH,BWIDTH,XAT,YAT,ZAT)
      CALL TRFPNT(XAT,YAT,ZAT,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
      WRITE(1,100) XAT,YAT,' moveto'
C     *****************************************************************
C     * BEGIN THE VECTOR SEGMENTS.                                    *
C     *****************************************************************
      K=0
      VSUM=0.0
      KAR=0
999   CONTINUE
      K=K+1
C      WRITE(*,*) 'SEGMENT NUMBER= ',K,' TRIANGLE NUMBER= ',ID
C     *****************************************************************
C     * IF THIS IS NOT THE FIRST LINE THEN DETERMINE WHAT TRIANGLE    *
C     * THE DRAWN LINE CONNECTS TO BY LOOKING AT THE TWO NODES NA AND *
C     * NB FORMING THE LAST INTERSECTION.                             *
C     *****************************************************************
      IF (K .GT. 1) THEN
        IF (K .GT. 300) THEN
          GO TO 99
        ELSE
        END IF
        IF (ID .EQ. 0) THEN
C         ***************************************************************
```

```
C         * THERE IS NO NEXT TRIANGLE WHICH MEANS THE VECTOR          *
C         * TERMINATES ON A BOUNDARY.                                  *
C         ***************************************************************
         WRITE(*,*) 'TERMINATE ON BOUNDARY TRIANGLE'
          GO TO 99
        ELSE IF (ID .EQ. IFIRST) THEN
C         WRITE(*,*) 'BACK TO ORIGINAL TRIANGLE'
C          GO TO 99
        ELSE
        END IF
        XA=XF
        YA=YF
      ELSE
        XA=XE
        YA=YE
      END IF
C     ***************************************************************
C     * FIND THE VECTOR FUNCTION VALUE AT THE POINT (XA,YA).        *
C     ***************************************************************
      CALL VECCOF(MN,MT,ID,X,Y,XA,YA,N2T,FX,FY,A,B,E,C,D,F)
C     ***************************************************************
C     * GET THE VECTOR COMPONENTS AT THE POINT (XA,YA).             *
C     ***************************************************************
      FYA=A*XA+B*YA+E
      FXA=C*XA+D*YA+F
      FM=SQRT(FXA*FXA+FYA*FYA)
      FXN=FXA/FM
      FYN=FYA/FM
      IF (NDIR .EQ. 0) THEN
        XF=XA+DS*FXN
        YF=YA+DS*FYN
      ELSE
        XF=XA-DS*FXN
        YF=YA-DS*FYN
      END IF
C     ***************************************************************
C     * GET THE NEXT TRIANGLE NUMBER.                               *
C     ***************************************************************
      IDOLD=ID
      CALL FDSTRI(XF,YF,MN,X,Y,MT,MP,NT,N2T,T2N,IDOLD,ID)
C      WRITE(*,*) 'ITERATION= ',K,IDOLD,ID,XF,YF,FXA,FYA
      IF (ID .EQ. IFIRST) THEN
C        XF=XFIRST
C        YF=YFIRST
      ELSE IF (ID .EQ. 0) THEN
C        WRITE(*,*) 'BOUNDARY NODE'
C       ***************************************************************
C       * ADJUST THE POINT IF IT IS OUTSIDE THE BOUNDARY.             *
C       ***************************************************************
        IF (XF .LT. XMIN) THEN
          XF=XMIN
        ELSE IF (XF .GT. XMAX) THEN
          XF=XMAX
        ELSE
        END IF
        IF (YF .LT. YMIN) THEN
          YF=YMIN
        ELSE IF (YF .GT. YMAX) THEN
          YF=YMAX
```

```
132           ELSE
133           END IF
134 C         ********************************************************************
135 C         * DRAW THE LINE FROM (XA,YA) TO (XF,YF).                           *
136 C         ********************************************************************
137           CALL MPRPNT(XF,YF,AWIDTH,BWIDTH,XFT,YFT,ZFT)
138           CALL TRFPNT(XFT,YFT,ZFT,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
139           WRITE(1,100) XFT,YFT,' lineto'
140           GO TO 99
141         END IF
142 C       ********************************************************************
143 C       * ADJUST THE POINT IF IT IS OUTSIDE THE BOUNDARY.                   *
144 C       ********************************************************************
145         IF (XF .LT. XMIN) THEN
146           XF=XMIN
147         ELSE IF (XF .GT. XMAX) THEN
148           XF=XMAX
149         ELSE
150         END IF
151         IF (YF .LT. YMIN) THEN
152           YF=YMIN
153         ELSE IF (YF .GT. YMAX) THEN
154           YF=YMAX
155         ELSE
156         END IF
157 C       ********************************************************************
158 C       * DRAW THE LINE FROM (XA,YA) TO (XF,YF).                           *
159 C       ********************************************************************
160 C       ********************************************************************
161 C       * TRANSFORM THE POINT.                                             *
162 C       ********************************************************************
163         CALL MPRPNT(XF,YF,AWIDTH,BWIDTH,XFT,YFT,ZFT)
164         CALL TRFPNT(XFT,YFT,ZFT,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
165         WRITE(1,100) XFT,YFT,' lineto'
166 C       ********************************************************************
167 C       * DRAW ARROW OR ARROWS IF APPROPRIATE.                             *
168 C       ********************************************************************
169         DAR=SQRT((XA-XF)*(XA-XF)+(YA-YF)*(YA-YF))
170         IF (DAR .GT. 0.0) THEN
171           IF (NDIR .EQ. 0) THEN
172             CALL RARR3D(MNAR,VL,BANG,S,XA,YA,XF,YF,FXN,FYN,VSUM,KAR
173      &                                ,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
174           ELSE
175             CALL RARR3D(MNAR,VL,BANG,S,XF,YF,XA,YA,FXN,FYN,VSUM,KAR
176      &                                ,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
177           END IF
178         ELSE
179         END IF
180         IF (FM .LT. .001) THEN
181           WRITE(*,*) 'CLOSE TO AN UNKNOWN CRITICAL POINT'
182           GO TO 99
183         ELSE
184         END IF
185         GO TO 999
186 C       ********************************************************************
187 C       * STOP.                                                            *
188 C       ********************************************************************
189  99     CONTINUE
190         WRITE(1,*) 'stroke'
```

```
191 100   FORMAT(2(F6.2,1X),A7)
192       ID=IFIRST
193       RETURN
194       END

  1       SUBROUTINE RARR3D(MNAR,VL,BANG,S,XA,YA,XF,YF,FXN,FYN,VSUM,KAR
  2      &                                ,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
  3 C     ************************************************************************
  4 C     * THIS SUBROUTINE CONTROLS THE DRAWING OF ARROWHEADS ON A LINE.        *
  5 C     ************************************************************************
  6 C     * INPUTS:                                                              *
  7 C     *                                                                      *
  8 C     *   MNAR     - MAXIMUM NUMBER OF ARROWS ALLOWED.                       *
  9 C     *   VL       - SPACING BETWEEN ARROWHEADS IN REAL COORDINATES.         *
 10 C     *   BANG     - ARROW APEX HALF ANGLE IN DEGREES.                       *
 11 C     *   S        - ARROW HEAD SIDE LENGTH IN POINT SIZE.                   *
 12 C     *   XA,YA    - BASE OF ARROW.                                          *
 13 C     *   XF,YF    - TIP OF ARROW.                                           *
 14 C     *   FXN,FYN  - NORMALIZED VECTOR FUNCTION VALUES.                      *
 15 C     *   VSUM     - ACCUMULATED LINE LENGTH.                                *
 16 C     *   KAR      - NUMBER OF ARROWS DRAWN SO FAR.                          *
 17 C     *   AX,BX    - GRAPHICAL SCALE CONSTANTS.                              *
 18 C     *   AY,BY                                                              *
 19 C     ************************************************************************
 20       D=SQRT((XA-XF)*(XA-XF)+(YA-YF)*(YA-YF))
 21       STEP=VSUM+D
 22       IF (STEP .GT. VL) THEN
 23         KAR=KAR+1
 24         IF (KAR .GT. MNAR) THEN
 25           GO TO 2
 26         ELSE
 27         END IF
 28 C       ************************************************************************
 29 C       * THE NEXT LINE SEGMENT IS LONGER THAN THE ARROW SPACING.              *
 30 C       * SO AN ARROW SHOULD BE DRAWN.                                         *
 31 C       ************************************************************************
 32         RAT=(VL-VSUM)/D
 33         XFW=XA+RAT*(XF-XA)
 34         YFW=YA+RAT*(YF-YA)
 35 C       ************************************************************************
 36 C       * DRAW THE ARROW.                                                      *
 37 C       ************************************************************************
 38         CALL RAHD3D(BANG,GS,S,XFW,YFW,FXN,FYN,XD,YD,ZD,C1,C2
 39      &                                              ,C3,C4,C5,X0,Y0)
 40 C       ************************************************************************
 41 C       * COMPUTE THE AMOUNT LEFT OVER AFTER THE ARROW IS DRAWN.               *
 42 C       ************************************************************************
 43         DLT=SQRT((XF-XFW)*(XF-XFW)+(YF-YFW)*(YF-YFW))
 44         IF (DLT .LT. VL) THEN
 45 C         ************************************************************************
 46 C         * NO MORE ARROWS ARE DRAWN ON THIS SEGMENT.                          *
 47 C         ************************************************************************
 48           VSUM=DLT
 49         ELSE
 50 C         ************************************************************************
 51 C         * MORE THAN ONE ARROW IS DRAWN ON THIS SEGMENT.                      *
 52 C         ************************************************************************
 53           NAR=DLT/VL
 54           DO 1 I=1,NAR
```

```
55              KAR=KAR+1
56              IF (KAR .GT. MNAR) THEN
57                GO TO 2
58              ELSE
59              END IF
60              RAT=(VL-VSUM+I*VL)/D
61              XFW=XA+RAT*(XF-XA)
62              YFW=YA+RAT*(YF-YA)
63              CALL RAHD3D(BANG,GS,S,XFW,YFW,FXN,FYN,XD,YD,ZD,C1,C2
64         &                                                  ,C3,C4,C5,X0,Y0)
65    1       CONTINUE
66            VSUM=SQRT((XF-XFW)*(XF-XFW)+(YF-YFW)*(YF-YFW))
67          END IF
68        ELSE
69 C        ***************************************************************
70 C        * THE LINE LENGTH PLUS THE ACCUMULATED DISTANCE IS STILL LESS  *
71 C        * THAN THE ARROW SPACING. NO ARROW SHOULD BE DRAWN JUST        *
72 C        * ACCUMULATE THE DISTANCE.                                    *
73 C        ***************************************************************
74          VSUM=VSUM+D
75        END IF
76    2   CONTINUE
77        RETURN
78        END

 1        SUBROUTINE RAHD3D(BANG,GS,S,X2,Y2,FXN,FYN,XD,YD,ZD,C1,C2
 2       &,C3,C4,C5,X0,Y0)
 3 C      ***************************************************************
 4 C      * THIS SUBROUTINE DRAWS A ARROW HEAD FROM (X1,Y1) TO (X2,Y2).  *
 5 C      ***************************************************************
 6 C      * INPUTS:                                                     *
 7 C      *                                                             *
 8 C      *   BANG  - ARROW APEX HALF ANGLE IN DEGREES.                 *
 9 C      *   S     - ARROWHEAD SIDE LENGTH.                            *
10 C      *   X2,Y2  - TIP OF ARROW.                                    *
11 C      *   FXN,FYN - NORMALIZED VECTOR FUNCTION VALUES.              *
12 C      ***************************************************************
13        RAD=.17453293E-01
14        X1=X2-FXN
15        Y1=Y2-FYN
16        D=SQRT((X2-X1)*(X2-X1)+(Y2-Y1)*(Y2-Y1))
17        A=1.0-S/(GS*D)
18        X3=X1+A*(X2-X1)
19        Y3=Y1+A*(Y2-Y1)
20 C      ***************************************************************
21 C      * TRANSLATE THE ORIGIN TO (X2,Y2) AND ROTATE (X3,Y3) PLUS AND  *
22 C      * MINUS BANG DEGREES TO GENERATE THE VERTICES OF THE ARROW.    *
23 C      ***************************************************************
24        XA=X3-X2
25        YA=Y3-Y2
26        ARG=RAD*BANG
27        CA=COS(ARG)
28        SA=SIN(ARG)
29        XCA=XA*CA
30        XSA=XA*SA
31        YCA=YA*CA
32        YSA=YA*SA
33        X4=X2+XCA-YSA
34        Y4=Y2+XSA+YCA
```

```
      X5=X2+XCA+YSA
      Y5=Y2-XSA+YCA
c      X6=(X4+X5)/2.0
c      Y6=(Y4+Y5)/2.0
C      WRITE(1,*) X1,Y1,' moveto'
C      WRITE(1,*) X6,Y6,' lineto stroke'
C     ************************************************************************
C     * TRANSLATE THE ORIGIN TO (X2,Y2) AND ROTATE (X3,Y3) PLUS AND          *
C     * MINUS BANG DEGREES  TO GENERATE THE VERTICES OF THE ARROW            *
C     ************************************************************************
      AWIDTH=1.0
      BWIDTH=0.5
      CALL MPRPNT(X2,Y2,AWIDTH,BWIDTH,X2T,Y2T,Z2T)
      CALL MPRPNT(X4,Y4,AWIDTH,BWIDTH,X4T,Y4T,Z4T)
      CALL MPRPNT(X5,Y5,AWIDTH,BWIDTH,X5T,Y5T,Z5T)
      CALL TRFPNT(X2T,Y2T,Z2T,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
      CALL TRFPNT(X4T,Y4T,Z4T,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
      CALL TRFPNT(X5T,Y5T,Z5T,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
      WRITE(1,*) 'gsave newpath'
      WRITE(1,*) X2T,Y2T,' moveto ',X4T,Y4T,' lineto '
     &                                ,X5T,Y5T,' lineto'
      WRITE(1,*) 'closepath 0 setgray fill stroke grestore'
      RETURN
      END

      SUBROUTINE MPRPNT(U,V,A,B,X,Y,Z)
C     ************************************************************************
C     * THIS SUBROUTINE MAPS A POINT FROM THE UNNFOLDED WAVEGUIDE            *
C     * (U,V) SPACE TO THE (X,Y,Z) FOLDED WAVEGUIDE SPACE.                   *
C     ************************************************************************
C     * INPUTS:                                                              *
C     *                                                                      *
C     *   U,V  - COORDINATES OF THE UNFOLDED WAVEGUIDE POINT.                *
C     *   A    - X DIMENSION OF WAVEGUIDE SUCH THAT -A/2 <= X <= A/2.        *
C     *   B    - X DIMENSION OF WAVEGUIDE SUCH THAT -B/2 <= Y <= B/2.        *
C     *                                                                      *
C     * OUTPUTS:                                                             *
C     *                                                                      *
C     *   X,Y,Z  -  COORDINATES OF MAPPED POINT.                             *
C     ************************************************************************
      IF ((U .GE. -A-B) .AND. (U .LT. -B)) THEN
        X=U+B+A/2.0
        Y=B/2.0
      ELSE IF ((U .GE. -B) .AND. (U .LT. 0.0)) THEN
        X=A/2.0
        Y=-U-B/2.0
      ELSE IF ((U .GE. 0.0) .AND. (U .LT. A)) THEN
        X=-U+A/2.0
        Y=-B/2.0
      ELSE
        X=-A/2.0
        Y=U-A-B/2.0
      END IF
      Z=V
      RETURN
      END
```

```
      PROGRAM FLDCIR
C     ************************************************************************
C     * THIS PROGRAM GENERATES A VECTOR PLOT OF THE TRIANGULARIZED     *
C     * REGION OF A CIRCULAR WAVEGUIDE.                               *
C     ************************************************************************
C     * TIMOTHY J. PETERS                                LAST UPDATED  *
C     * THE AEROSPACE CORPORATION                        5/12/92       *
C     * 2350 EAST EL SEGUNDO BOULEVARD                                 *
C     * EL SEGUNDO, CA 90245                                           *
C     ************************************************************************
      PARAMETER (MN=6000,MT=12000,MP=6,NC=5,NL=6)
      REAL*4 U(MN),V(MN),FU(MN),FV(MN),PHI(50),CA(NC),CB(NC)
      REAL*4 XQ(3),YQ(3),ZQ(3)
      REAL*8 ARG
      INTEGER LC(NC)
      CHARACTER*30 LABEL(NL)
      INTEGER*4 N2T(MT,3),T2N(MN,MP)
      PI=.3141593E+01
      TP=.6283153E+01
      RAD=.17453293E-01
C     ************************************************************************
C     * INPUTS:                                                        *
C     *                                                                *
C     * GS - GRAPH SCALE CONSTANT.                                     *
C     * PO - PHI OBSERVATION ANGLE (DEGREES).                          *
C     * TO - THETA OBSERVATION ANGLE (DEGREES).                        *
C     ************************************************************************
      PO=50.0
      TO=60.0
C     ************************************************************************
C     * READ THE COORDINATE DATA AND VECTOR FUNCTION DATA FROM A FILE. *
C     ************************************************************************
        OPEN(UNIT=1,FILE='CUVFDF')
        READ(1,*) A,C,KM,N,M
        READ(1,*) NU,NV
        READ(1,*) NN
        VMAX=0.0
        DO 1 I=1,NN
          READ(1,*) U(I),V(I),FU(I),FV(I)
      VMAG=SQRT(FU(I)*FU(I)+FV(I)*FV(I))
          IF (VMAG .GT. VMAX) THEN
            VMAX=VMAG
          ELSE
          END IF
    1   CONTINUE
        CLOSE(1)
        WRITE(*,*) NN,' DATA POINTS READ IN'
C     ************************************************************************
C     * NORMALIZE THE VECTOR COMPONENTS SO THAT THE MAXIMUM MAGNITUDE  *
C     * IS 1.0.                                                        *
C     ************************************************************************
      DO 2 I=1,NN
        FU(I)=FU(I)/VMAX
        FV(I)=FV(I)/VMAX
    2 CONTINUE
C     ************************************************************************
C     * READ THE TRIANGLE NODE DATA.                                   *
C     ************************************************************************
      OPEN(UNIT=1,FILE='N2TDAT')
```

```
      READ(1,*) NT
      DO 3 I=1,NT
        READ(1,*)  N2T(I,1),N2T(I,2),N2T(I,3)
    3 CONTINUE
      CLOSE(1)
      WRITE(*,*) 'NODE TO TRIANGLE DATA READ IN'
C     ************************************************************
C     * READ THE TRIANGLE TO NODE CONNECTION DATA.               *
C     ************************************************************
      OPEN(UNIT=1,FILE='T2NDAT')
      READ(1,*) NN
      DO 4 I=1,NN
        READ(1,*)  (T2N(I,J),J=1,MP)
    4 CONTINUE
      CLOSE(1)
      WRITE(*,*) 'TRIANGLE TO NODE DATA READ IN'
C     ************************************************************
C     * COMPUTE CENTROID OF GRAPH.                               *
C     ************************************************************
      GS=180.0
      XMIN=-A/2.0
      XMAX=A/2.0
      YMIN=-A/2.0
      YMAX=A/2.0
      ZMIN=0.0
      ZMAX=C
      XC=(XMIN+XMAX)/2.0
      YC=(YMIN+YMAX)/2.0
      ZC=(ZMIN+ZMAX)/2.0
C     ************************************************************
C     * CONVERT THE OBSERVATION ANGLES TO RADIANS.               *
C     ************************************************************
      RAD=.17453293E-01
      PI=.3141593E+01
      PI4=PI/4.0
      XD=XC
      YD=YC
      ZD=ZC
      CALL SCALE(GS,XD,YD,ZD)
C     ************************************************************
C     * CONVERT THE OBSERVATION ANGLES TO RADIANS.               *
C     ************************************************************
      POBS=RAD*P0
      TOBS=RAD*T0
C     ************************************************************
C     * COMPUTE THE ROTATION ANGLES WHICH YIELD THE DESIRED OBSERVATION*
C     * ANGLES.                                                  *
C     ************************************************************
      RP=-POBS-PI/2.0
      RT=TOBS
C     ************************************************************
C     * COMPUTE THE CONSTANTS FOR THE ROTATION MATRIX.           *
C     ************************************************************
      CALL RCOEFF(RP,RT,C1,C2,C3,C4,C5)
C     ************************************************************
C     * COMPUTE THE CENTER OF THE PRINTING DEVICE PAGE.          *
C     ************************************************************
      X0=72*8.5/2.0
      Y0=72*11.0/2.0
```

```
C     ************************************************************************
C     * SET THE GRAPHIC BOUNDING BOX.                                        *
C     ************************************************************************
      WX=(XMAX-XMIN)
      WY=(YMAX-YMIN)
      WIDTH=GS*WX
      HEIGHT=GS*WY
      UA=X0-WIDTH/2.0-48.0
      UB=X0+WIDTH/2.0+91.0
      VA=Y0-HEIGHT/2.0-243.0
      VB=Y0+HEIGHT/2.0+239.0
C     ************************************************************************
C     * COMPUTE THE BOUNDING BOX FOR THE POSTSCRIPT IN THE DEFAULT           *
C     * COORDINATE SYSTEM.                                                   *
C     ************************************************************************
      OPEN(UNIT=1,FILE='FoldedCirc.ps')
      REWIND 1
      WRITE(1,*) '%!PS-Adobe-1.0'
      WRITE(1,*) '%%Creator: Timothy J. Peters'
      WRITE(1,*) '%%Title: Graph'
      WRITE(1,*) '%%CreationDate: 5-14-92'
      WRITE(1,100) '%%BoundingBox:',INT(UA),INT(VA),INT(UB),INT(VB)
100   FORMAT(A14,4(1X,I3))
      WRITE(1,*) '%%EndComments'
      WRITE(1,*) '/dot2 {2 0 360 arc 0 setgray fill stroke} def'
      WRITE(1,*) '/dot3 {3 0 360 arc 0 setgray fill stroke} def'
      WRITE(1,*) '/dot4 {4 0 360 arc 0 setgray fill stroke} def'
      WRITE(1,*) '/black {0 0 0 setrgbcolor} def'
      WRITE(1,*) '/white {1 1 1 setrgbcolor} def'
      WRITE(1,*) '/gray-lt {0.92 0.92 0.92 setrgbcolor} def'
      WRITE(1,*) '/gray-lt-med {0.65 0.65 0.65 setrgbcolor} def'
      WRITE(1,*) '/gray {0.45 0.45 0.45 setrgbcolor} def'
      WRITE(1,*) '/gray-dk-med {0.3 0.3 0.3 setrgbcolor} def'
      WRITE(1,*) '/gray-dk {0.14 0.14 0.14 setrgbcolor} def'
      WRITE(1,*) '/red {1 0 0 setrgbcolor} def'
      WRITE(1,*) '/magenta {1 0 1 setrgbcolor} def'
      WRITE(1,*) '/green {0 1 0 setrgbcolor} def'
      WRITE(1,*) '/blue {0 0 1 setrgbcolor} def'
      WRITE(1,*) '/cyan {0 1 1 setrgbcolor} def'
      WRITE(1,*) '/yellow {1 1 0 setrgbcolor} def'
      WRITE(1,*) '/orange {1 0.5 0 setrgbcolor} def'
      WRITE(1,*) '/brown {0.5 0.5 0 setrgbcolor} def'
      WRITE(1,*) '/kakhi {0.5 1 0 setrgbcolor} def'
      WRITE(1,*) '/blue-lt {0.5 1 1 setrgbcolor} def'
      WRITE(1,*) '/green-lt {0.5 1 0.5 setrgbcolor} def'
      WRITE(1,*) '/green-blue {0 1 0.5 setrgbcolor} def'
      WRITE(1,*) '/purple {0.6 0 1.0 setrgbcolor} def'
      WRITE(1,*) '/filtri {moveto lineto lineto'
      WRITE(1,*) '            closepath fill stroke} def'
      WRITE(1,*) '/filqud {moveto lineto lineto lineto closepath fill'
      WRITE(1,*) '                                      stroke} def'
      WRITE(1,*) '/filpnt {moveto lineto lineto lineto'
      WRITE(1,*) '             lineto closepath fill stroke} def'
      WRITE(1,*) '%%EndProlog'
      WRITE(1,*) '1 setlinejoin .4 setlinewidth'
C     ************************************************************************
C     * DRAW THE EPS BOUNDING BOX.                                           *
C     ************************************************************************
C      WRITE(1,*) 'gsave 0.2 setlinewidth'
```

```
C      WRITE(1,*) UA,VA,' moveto'
C      WRITE(1,*) UB,VA,' lineto'
C      WRITE(1,*) UB,VB,' lineto'
C      WRITE(1,*) UA,VB,' lineto'
C      WRITE(1,*) 'closepath stroke grestore'
C     ********************************************************************
C     * ASSIGN CONTOUR VALUES AND LABELS.                                *
C     ********************************************************************
      CA(1)=0.0
      CB(1)=0.15
      CA(2)=0.15
      CB(2)=0.4
      CA(3)=0.4
      CB(3)=0.6
      CA(4)=0.6
      CB(4)=0.8
      CA(5)=0.8
      CB(5)=1.0
      LABEL(1)='0'
      LABEL(2)='.15'
      LABEL(3)='.4'
      LABEL(4)='.6'
      LABEL(5)='.8'
      LABEL(6)='1'
C     ********************************************************************
C     * ASSIGN THE COLORS.  SEE SUBROUTINE SETCOL FOR COLOR CHOICES.     *
C     ********************************************************************
C GRAY SCALE
      LC(1)=2
      LC(2)=3
      LC(3)=4
      LC(4)=5
      LC(5)=6
C  COLOR
c      LC(1)=18
c      LC(2)=14
c      LC(3)=12
c      LC(4)=16
c      LC(5)=13
        IF (P0 .LE. 90.0) THEN
          XCMIN=(RAD*(P0+90.0))*A
          XCMAX=(RAD*(P0+270.0))*A
        ELSE
        END IF
      XMIN=0.0
      XMAX=TP*A
      YMIN=0.0
      YMAX=C
C     ********************************************************************
C     * DRAW THE BACK SIDE OF THE CYLINDER.                              *
C     ********************************************************************
      KUS=INT(1+(NU-1)*(P0+90.0)/360.0)
      ITMIN=2*(KUS-1)*(NV-1)+1
      KUSM=KUS+(NU+1)/2
      ITMAX=2*(KUSM-1)*(NV-1)
C     ********************************************************************
C     * PROCESS TRIANGLES.                                               *
C     ********************************************************************
      DO 5 I=ITMIN,ITMAX
```

```
237           N1=N2T(I,1)
238           N2=N2T(I,2)
239           N3=N2T(I,3)
240         F1=SQRT(FU(N1)*FU(N1)+FV(N1)*FV(N1))
241         F2=SQRT(FU(N2)*FU(N2)+FV(N2)*FV(N2))
242         F3=SQRT(FU(N3)*FU(N3)+FV(N3)*FV(N3))
243           CALL MPCPNT(U(N1),V(N1),A,XQ(1),YQ(1),ZQ(1))
244           CALL MPCPNT(U(N2),V(N2),A,XQ(2),YQ(2),ZQ(2))
245           CALL MPCPNT(U(N3),V(N3),A,XQ(3),YQ(3),ZQ(3))
246 C         ******************************************************************
247 C         * TRANSFORM THE 3 VERTICES OF THE TRIANGLE.                      *
248 C         ******************************************************************
249           CALL TRFTRI(XQ,YQ,ZQ,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
250 C         ******************************************************************
251 C         * DRAW THE CONTOUR.                                              *
252 C         ******************************************************************
253           CALL CONTUR(XQ(1),YQ(1),XQ(2),YQ(2),XQ(3),YQ(3),F1,F2,F3
254       &                                                  ,CA,CB,NC,LC)
255     5     CONTINUE
256 C       ******************************************************************
257 C       * DRAW THE VECTORS ON THE BACK SIDE.                             *
258 C       ******************************************************************
259         ICLIP=1
260         BANG=20.0
261         S=8.0
262         MNAR=1
263         DS=.003
264         XMIN=0.0
265         XMAX=TP*A
266         YMIN=0.0
267         YMAX=C
268         WRITE(1,*) '0 setgray'
269         CALL CWTE3D(MN,MT,MP,NT,N2T,T2N,U,V,A,C,KM,XMIN,XMAX,YMIN,YMAX
270       & ,FU,FV,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,BANG,S,MNAR,DS
271       & ,XCMIN,XCMAX,ICLIP)
272 C       ******************************************************************
273 C       * DRAW THE FRONT SIDE OF THE CYLINDER.                           *
274 C       ******************************************************************
275         DO 6 I=ITMAX+1,NT
276           N1=N2T(I,1)
277           N2=N2T(I,2)
278           N3=N2T(I,3)
279         F1=SQRT(FU(N1)*FU(N1)+FV(N1)*FV(N1))
280         F2=SQRT(FU(N2)*FU(N2)+FV(N2)*FV(N2))
281         F3=SQRT(FU(N3)*FU(N3)+FV(N3)*FV(N3))
282           CALL MPCPNT(U(N1),V(N1),A,XQ(1),YQ(1),ZQ(1))
283           CALL MPCPNT(U(N2),V(N2),A,XQ(2),YQ(2),ZQ(2))
284           CALL MPCPNT(U(N3),V(N3),A,XQ(3),YQ(3),ZQ(3))
285 C         ******************************************************************
286 C         * TRANSFORM THE 3 VERTICES OF THE TRIANGLE.                      *
287 C         ******************************************************************
288           CALL TRFTRI(XQ,YQ,ZQ,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
289 C         ******************************************************************
290 C         * DRAW THE CONTOUR.                                              *
291 C         ******************************************************************
292           CALL CONTUR(XQ(1),YQ(1),XQ(2),YQ(2),XQ(3),YQ(3),F1,F2,F3
293       &                                                  ,CA,CB,NC,LC)
294     6     CONTINUE
295         DO 7 I=1,ITMIN-1
```

```
296           N1=N2T(I,1)
297           N2=N2T(I,2)
298           N3=N2T(I,3)
299         F1=SQRT(FU(N1)*FU(N1)+FV(N1)*FV(N1))
300         F2=SQRT(FU(N2)*FU(N2)+FV(N2)*FV(N2))
301         F3=SQRT(FU(N3)*FU(N3)+FV(N3)*FV(N3))
302           CALL MPCPNT(U(N1),V(N1),A,XQ(1),YQ(1),ZQ(1))
303           CALL MPCPNT(U(N2),V(N2),A,XQ(2),YQ(2),ZQ(2))
304           CALL MPCPNT(U(N3),V(N3),A,XQ(3),YQ(3),ZQ(3))
305 C         ****************************************************************
306 C         * TRANSFORM THE 3 VERTICES OF THE TRIANGLE.                    *
307 C         ****************************************************************
308           CALL TRFTRI(XQ,YQ,ZQ,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
309 C         ****************************************************************
310 C         * DRAW THE CONTOUR.                                            *
311 C         ****************************************************************
312           CALL CONTUR(XQ(1),YQ(1),XQ(2),YQ(2),XQ(3),YQ(3),F1,F2,F3
313        &                                                  ,CA,CB,NC,LC)
314     7     CONTINUE
315 C       ****************************************************************
316 C       * DRAW THE VECTORS ON THE FRONT SIDE.                          *
317 C       ****************************************************************
318         ICLIP=2
319         XMIN=0.0
320         XMAX=TP*A
321         YMIN=0.0
322         YMAX=C
323         BANG=20.0
324         S=8.0
325         MNAR=1
326         DS=.003
327         WRITE(1,*) '0 setgray'
328         CALL CWTE3D(MN,MT,MP,NT,N2T,T2N,U,V,A,C,KM,XMIN,XMAX,YMIN,YMAX
329        & ,FU,FV,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,BANG,S,MNAR,DS
330        & ,XCMIN,XCMAX,ICLIP)
331 C       ****************************************************************
332 C       * DRAW THE LEGEND.                                             *
333 C       ****************************************************************
334         SL=15.0
335         SH=30.0
336         DS=0.0
337         ITYPE=1
338         US=409.0
339         VS=155.0
340         CALL LEGEND(US,VS,NC,NL,LC,LABEL,SL,SH,DS,ITYPE)
341 C       ****************************************************************
342 C       * DRAW THE PAGE.                                               *
343 C       ****************************************************************
344         WRITE(1,*) 'showpage'
345         CLOSE(1)
346         END

  1         SUBROUTINE CWTE3D(MN,MT,MP,NT,N2T,T2N,X,Y,A,C,KM,XMIN,XMAX,YMIN
  2        & ,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,BANG,S,MNAR,DS
  3        & ,XCMIN,XCMAX,ICLIP)
  4 C       ****************************************************************
  5 C       * THIS SUBROUTINE DRAWS VECTOR LINES FOR A CIRCULAR            *
  6 C       * WAVEGUIDE WITH TE11 MODE FIELDS.                             *
  7 C       ****************************************************************
```

```
C     * INPUTS:                                                        *
C     *                                                               *
C     *   MN  - MAXIMUM NUMBER OF COORDINATE POINTS.                  *
C     *   MT  - MAXIMUM NUMBER OF TRIANGLES.                          *
C     *   MP  - MAXIMUM NUMBER OF TRIANGLES CONNECTED TO A SINGLE     *
C     *         NODE.                                                 *
C     *   NT  - NUMBER OF TRIANGLES.                                  *
C     *   N2T(MT,3)  - NODE MATRIX WHERE FIRST INDEX REPRESENTS       *
C     *                EACH TRIANGLE AND SECOND INDEX REPRESENTS      *
C     *                THE NODE NUMBERS.                              *
C     *   T2N(MN,MP)  -  MATRIX OF TRIANGLE TO NODE CONNECTIONS       *
C     *                WHERE THE FIRST INDEX IS THE NODE NUMBER       *
C     *                AND THE SECOND IS THE LOCAL TRIANGLE NUMBER.   *
C     *   X(MN) - COORDINATE VECTORS OF GRID.                         *
C     *   Y(MN)                                                       *
C     *    A     - RADIUS OF CIRCULAR WAVEGUIDE (WAVELENGTHS).        *
C     *    C     - LENGTH OF CIRCULAR WAVEGUIDE (WAVELENGTHS).        *
C     *   XMIN,XMAX     - DIMENSIONS OF UNFOLDED CIRCULAR WAVEGUIDE   *
C     *   YMIN,YMAX       (WAVELENGTHS).                              *
C     *   FX(MN) - VECTOR FUNCTION FIELD VALUES AT EACH COORDINATE.   *
C     *   FY(MN)                                                      *
C     *   GS     - GRAPHICAL SCALE CONSTANT.                          *
C     *   BX,BY  - GRAPHICAL OFFSETS.                                 *
C     *   VL     - SPACING BETWEEN ARROWHEADS IN REAL COORDINATES.    *
C     *   BANG   - ARROW APEX HALF ANGLE IN DEGREES.                  *
C     *   S      - ARROW HEAD SIDE LENGTH IN POINT SIZE.              *
C     *   MNAR   - MAXIMUM NUMBER OF ARROWS ALLOWED.                  *
C     *   DS     - STEP SIZE.                                         *
C     *   XCMIN,XCMAX  - HORIZONTAL CLIPPING BOUNDARY (WAVELENGTHS)   *
C     *   ICLIP  - ICLIP=1 MEANS THAT ALL LINES OUTSIDE THE CLIPPING  *
C     *            BOUNDARY ARE CLIPPED.  ICLIP=2 MEANS THAT ALL      *
C     *            LINES INSIDE THE CLIPPING BOUNDARY ARE CLIPPED.    *
C     ****************************************************************
      REAL*4 X(MN),Y(MN),FX(MN),FY(MN)
      INTEGER N2T(MT,3),T2N(MN,MP)
      PI=.3141593E+01
      TP=.6283185E+01
      RAD=.17453293E-01
      K=0
C     ****************************************************************
C     * SET SPACING PARAMETERS BASED ON CRITICAL POINT LOCATIONS.     *
C     ****************************************************************
      XWIDTH=PI*A
      TAUX=0.84
      NPX=9
      DX=TAUX*XWIDTH/(NPX-1)
      TAUY=0.9
      NPY=5
      DY=(TAUY*C/KM)/(NPY-1)
C     ****************************************************************
C     * SET GLOBAL VECTOR INPUTS.                                     *
C     ****************************************************************
      AH=S*COS(RAD*BANG)
C     ****************************************************************
C     * LEFT REGION HORIZONTAL LINES.                                 *
C     ****************************************************************
      XE=0.0
      DO 1 I=0,KM
        YZ=-C/(2*KM)+I*C/KM
```

```
67          DO 2 J=0,NPY-1
68            YE=YZ+(C/KM)*(1.0-TAUY)/2.0+J*DY
69            IF ((YE .GT. DY/2.0) .AND. (YE .LT. C-DY/2.0)) THEN
70              K=K+1
71              WRITE(*,*) 'DRAWING VECTOR ',K
72              CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
73              NDIR=0
74              VL=20.0/GS
75              WRITE(1,*) '% begin direction 1 of vector ',K
76              CALL CVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
77       &      ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG,S
78       &                                    ,MNAR,DS,XCMIN,XCMAX,ICLIP)
79              WRITE(1,*) '% end direction 1 of vector ',K
80              NDIR=1
81              VL=20.0/GS-S/GS
82              WRITE(1,*) '% begin direction 2 of vector ',K
83  C            CALL CVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
84  C     &                  ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,VL,BANG,S,MNAR,DS
85  C     &                                          ,XCMIN,XCMAX,ICLIP)
86              CALL CVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
87       &      ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG,S
88       &                                    ,MNAR,DS,XCMIN,XCMAX,ICLIP)
89              WRITE(1,*) '% end direction 2 of vector ',K
90            ELSE
91            END IF
92    2     CONTINUE
93    1   CONTINUE
94  C     ************************************************************************
95  C     * LEFT REGION VERTICAL LINES.                                          *
96  C     ************************************************************************
97          DO 3 I=0,KM-1
98            YE=C/(2*KM)+I*C/KM
99            DO 4 J=0,NPX-1
100             K=K+1
101             WRITE(*,*) 'DRAWING VECTOR ',K
102             XE=XWIDTH*(1.0-TAUX)/2.0+J*DX
103             CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
104             NDIR=0
105             VL=20.0/GS
106             WRITE(1,*) '% begin direction 1 of vector ',K
107             CALL CVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
108      &      ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG,S
109      &                                    ,MNAR,DS,XCMIN,XCMAX,ICLIP)
110             WRITE(1,*) '% end direction 1 of vector ',K
111           NDIR=1
112           VL=20.0/GS-S/GS
113           WRITE(1,*) '% begin direction 2 of vector ',K
114           CALL CVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
115      &    ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG,S
116      &                                    ,MNAR,DS,XCMIN,XCMAX,ICLIP)
117           WRITE(1,*) '% begin direction 2 of vector ',K
118   4     CONTINUE
119   3   CONTINUE
120 C     ************************************************************************
121 C     * CENTER REGION HORIZONTAL LINES.                                      *
122 C     ************************************************************************
123         XE=PI*A
124         DO 5 I=0,KM
125           YZ=-C/(2*KM)+I*C/KM
```

```
126           DO 6 J=0,NPY-1
127             YE=YZ+(C/KM)*(1.0-TAUY)/2.0+J*DY
128             IF ((YE .GT. DY/2.0) .AND. (YE .LT. C-DY/2.0)) THEN
129               K=K+1
130               WRITE(*,*) 'DRAWING VECTOR ',K
131               CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
132               NDIR=0
133               VL=20.0/GS
134               WRITE(1,*) '% begin direction 1 of vector ',K
135               CALL CVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
136      &       ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG,S
137      &                                          ,MNAR,DS,XCMIN,XCMAX,ICLIP)
138               WRITE(1,*) '% end direction 1 of vector ',K
139               NDIR=1
140               VL=20.0/GS-S/GS
141               WRITE(1,*) '% begin direction 2 of vector ',K
142               CALL CVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
143      &       ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG,S
144      &                                          ,MNAR,DS,XCMIN,XCMAX,ICLIP)
145               WRITE(1,*) '% end direction 2 of vector ',K
146             ELSE
147             END IF
148    6      CONTINUE
149    5     CONTINUE
150  C       ************************************************************************
151  C       * RIGHT REGION VERTICAL LINES.                                         *
152  C       ************************************************************************
153           DO 7 I=0,KM-1
154             YE=C/(2*KM)+I*C/KM
155             DO 8 J=0,NPX-1
156               K=K+1
157               WRITE(*,*) 'DRAWING VECTOR ',K
158               XE=PI*A+XWIDTH*(1.0-TAUX)/2.0+J*DX
159               CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
160               NDIR=0
161               VL=20.0/GS
162               WRITE(1,*) '% begin direction 1 of vector ',K
163                 CALL CVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
164      &       ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG,S
165      &                                          ,MNAR,DS,XCMIN,XCMAX,ICLIP)
166               WRITE(1,*) '% end direction 1 of vector ',K
167               NDIR=1
168               VL=20.0/GS-S/GS
169                 WRITE(1,*) '% begin direction 2 of vector ',K
170                 CALL CVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
171      &       ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG,S
172      &                                          ,MNAR,DS,XCMIN,XCMAX,ICLIP)
173                 WRITE(1,*) '% end direction 2 of vector ',K
174    8      CONTINUE
175    7     CONTINUE
176  C       ************************************************************************
177  C       * RIGHT REGION HORIZONTAL LINES.                                       *
178  C       ************************************************************************
179           XE=TP*A
180           DO 9 I=0,KM
181             YZ=-C/(2*KM)+I*C/KM
182             DO 10 J=0,NPY-1
183               YE=YZ+(C/KM)*(1.0-TAUY)/2.0+J*DY
184               IF ((YE .GT. DY/2.0) .AND. (YE .LT. C-DY/2.0)) THEN
```

```
185              K=K+1
186              WRITE(*,*) 'DRAWING VECTOR ',K
187              WRITE(1,*) '% begin direction 1 of vector ',K
188              CALL FNDTRI(XE,YE,MN,X,Y,MT,NT,N2T,ID)
189              NDIR=0
190              VL=20.0/GS
191              CALL CVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
192         &     ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG,S
193         &                                        ,MNAR,DS,XCMIN,XCMAX,ICLIP)
194              WRITE(1,*) '% end direction 1 of vector ',K
195              NDIR=1
196              VL=20.0/GS-S/GS
197              WRITE(1,*) '% begin direction 2 of vector ',K
198              CALL CVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
199         &     ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG,S
200         &                                        ,MNAR,DS,XCMIN,XCMAX,ICLIP)
201              WRITE(1,*) '% end direction 2 of vector ',K
202            ELSE
203            END IF
204  10      CONTINUE
205   9    CONTINUE
206  99    CONTINUE
207        RETURN
208        END

  1        SUBROUTINE CVEC3D(XE,YE,ID,NDIR,MN,MT,MP,NT,N2T,T2N,X,Y,XMIN,XMAX
  2        &   ,YMIN,YMAX,FX,FY,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,VL,BANG,S
  3        &                                        ,MNAR,DS,XCMIN,XCMAX,ICLIP)
  4  C     ************************************************************************
  5  C     * THIS SUBROUTINE DRAWS A VECTOR LINE.                                 *
  6  C     ************************************************************************
  7  C     * INPUTS:                                                              *
  8  C     *                                                                      *
  9  C     *   XE,YE  - FIRST COORDINATE OF VECTOR LINE.                          *
 10  C     *   MN  - MAXIMUM NUMBER OF COORDINATE POINTS.                         *
 11  C     *   MT  - MAXIMUM NUMBER OF TRIANGLES.                                 *
 12  C     *   N2T(MT,3)  - NODE MATRIX WHERE FIRST INDEX REPRESENTS              *
 13  C     *                EACH TRIANGLE AND SECOND INDEX REPRESENTS             *
 14  C     *                THE NODE NUMBERS.                                     *
 15  C     *   T2N(MN,MP)  -  MATRIX OF TRIANGLE TO NODE CONNECTIONS              *
 16  C     *                WHERE THE FIRST INDEX IS THE NODE NUMBER              *
 17  C     *                AND THE SECOND IS THE LOCAL TRIANGLE NUMBER.          *
 18  C     *   X(MN) - COORDINATE VECTORS OF GRID.                                *
 19  C     *   Y(MN)                                                              *
 20  C     *   FX(MN) - VECTOR FUNCTION FIELD VALUES AT EACH COORDINATE.          *
 21  C     *   FY(MN)                                                             *
 22  C     *   AX,BX  - GRAPHICAL SCALE CONSTANTS.                                *
 23  C     *   AY,BY                                                              *
 24  C     *   VL     - SPACING BETWEEN ARROWHEADS IN REAL COORDINATES.           *
 25  C     *   BANG   - ARROW APEX HALF ANGLE IN DEGREES.                         *
 26  C     *   S      - ARROW HEAD SIDE LENGTH IN POINT SIZE.                     *
 27  C     *   MNAR   - MAXIMUM NUMBER OF ARROWS ALLOWED.                         *
 28  C     *   DS     - STEP SIZE.                                                *
 29  C     *                                                                      *
 30  C     * OUTPUTS:                                                             *
 31  C     *                                                                      *
 32  C     ************************************************************************
 33        REAL*4 X(MN),Y(MN),FX(MN),FY(MN)
 34        INTEGER N2T(MT,3),T2N(MN,MP)
```

```
      RADIUS=0.5
C     ************************************************************************
C     * STORE THE FIRST TRIANGLE NUMBER.                                     *
C     ************************************************************************
      IFIRST=ID
C     ************************************************************************
C     * STORE THE FIRST POINT.                                               *
C     ************************************************************************
      XFIRST=XE
      YFIRST=YE
C     ************************************************************************
C     * BEGIN THE VECTOR SEGMENTS.                                           *
C     ************************************************************************
      K=0
      VSUM=0.0
      KAR=0
999   CONTINUE
      K=K+1
C      WRITE(*,*) 'SEGMENT NUMBER= ',K,' TRIANGLE NUMBER= ',ID
C     ************************************************************************
C     * IF THIS IS NOT THE FIRST LINE THEN DETERMINE WHAT TRIANGLE           *
C     * THE DRAWN LINE CONNECTS TO BY LOOKING AT THE TWO NODES NA AND        *
C     * NB FORMING THE LAST INTERSECTION.                                    *
C     ************************************************************************
      IF (K .GT. 1) THEN
        IF (K .GT. 300) THEN
          WRITE(*,*) 'MAX STEPS EXCEEDED '
          WRITE(1,*) '% maximum steps exceeded'
          GO TO 99
        ELSE
        END IF
C       ************************************************************************
C       * SET THE BASE LOCATION OF THE VECTOR TO THE HEAD LOCATION OF          *
C       * THE PREVIOUS VECTOR.                                                 *
C       ************************************************************************
        XA=XF
        YA=YF
        IF (ID .EQ. 0) THEN
C         ************************************************************************
C         * THERE IS NO NEXT TRIANGLE WHICH MEANS THE VECTOR                     *
C         * TERMINATES ON A BOUNDARY.                                            *
C         ************************************************************************
          WRITE(*,*) 'TERMINATE ON BOUNDARY TRIANGLE'
          GO TO 99
        ELSE IF (ID .EQ. IFIRST) THEN
C         WRITE(*,*) 'BACK TO ORIGINAL TRIANGLE'
C          GO TO 99
        ELSE
        END IF
      ELSE
C       ************************************************************************
C       * SET THE BASE LOCATION OF THE VECTOR TO THE INITIAL POINT.            *
C       ************************************************************************
        XA=XE
        YA=YE
      END IF
C     ************************************************************************
C     * FIND THE VECTOR FUNCTION VALUE AT THE BASE POINT LOCATION            *
C     * (XA,YA).                                                             *
```

```
94 C     ************************************************************************
95       CALL VECCOF(MN,MT,ID,X,Y,N2T,FX,FY,A,B,E,C,D,F)
96 C     ************************************************************************
97 C     * GET THE VECTOR COMPONENTS AT THE POINT (XA,YA).                       *
98 C     ************************************************************************
99       FYA=A*XA+B*YA+E
100      FXA=C*XA+D*YA+F
101      FM=SQRT(FXA*FXA+FYA*FYA)
102      FXN=FXA/FM
103      FYN=FYA/FM
104 C     ************************************************************************
105 C     * COMPUTE THE LOCATION (XF,YF) OF THE HEAD OF THE VECTOR.               *
106 C     ************************************************************************
107      IF (NDIR .EQ. 0) THEN
108        XF=XA+DS*FXN
109        YF=YA+DS*FYN
110      ELSE
111        XF=XA-DS*FXN
112        YF=YA-DS*FYN
113      END IF
114 C     ************************************************************************
115 C     * IF THIS IS THE FIRST TIME THROUGH THE LOOP THEN CHECK TO SEE          *
116 C     * IF THE ENTIRE VECTOR SHOULD BE SKIPPED.                               *
117 C     ************************************************************************
118      IF (K .EQ. 1) THEN
119        IF ((XF .LT. XMIN) .OR. (XF .GT. XMAX) .OR.
120     &          (YF .LT. YMIN) .OR. (YF .GT. YMAX)) THEN
121          WRITE(1,*) '% vector skipped'
122          GO TO 104
123        ELSE
124        END IF
125      ELSE
126      END IF
127 C     ************************************************************************
128 C     * ADJUST THE HEAD POINT IF IT IS OUTSIDE THE GRAPH BOUNDARY.            *
129 C     ************************************************************************
130      IF (XF .LT. XMIN) THEN
131        XF=XMIN
132      ELSE IF (XF .GT. XMAX) THEN
133        XF=XMAX
134      ELSE
135      END IF
136      IF (YF .LT. YMIN) THEN
137        YF=YMIN
138      ELSE IF (YF .GT. YMAX) THEN
139        YF=YMAX
140      ELSE
141      END IF
142 C     ************************************************************************
143 C     * CHECK THE BASE AND HEAD POINTS OF THE VECTOR AGAINST THE              *
144 C     * CLIPPING BOUNDARY.                                                    *
145 C     ************************************************************************
146      IF ((XA .GE. XCMIN) .AND. (XA .LE. XCMAX)) THEN
147 C       *********************************************************************
148 C       * THE BASE POINT IS WITHIN THE CLIPPING BOUNDARY.                     *
149 C       *********************************************************************
150        IAFLAG=1
151      ELSE
152 C       *********************************************************************
```

```
C       * THE BASE POINT IS OUTSIDE THE CLIPPING BOUNDARY.             *
C       ****************************************************************
        IAFLAG=2
      END IF
      IF ((XF .GE. XCMIN) .AND. (XF .LE. XCMAX)) THEN
C       ****************************************************************
C       * THE HEAD POINT IS WITHIN OR ON THE CLIPPING BOUNDARY.         *
C       ****************************************************************
        IFFLAG=1
      ELSE
C       ****************************************************************
C       * THE HEAD POINT IS OUTSIDE THE CLIPPING BOUNDARY.              *
C       ****************************************************************
        IFFLAG=2
      END IF
C     ****************************************************************
C     * GET THE TRIANGLE NUMBER CONTAINING THE HEAD POINT.            *
C     ****************************************************************
      IDOLD=ID
      CALL FDSTRI(XF,YF,MN,X,Y,MT,MP,NT,N2T,T2N,IDOLD,ID)
c      write(*,*) K,IAFLAG,IFFLAG
c      write(1,*) '% K IAFLAG IFFLAG ',K,IAFLAG,IFFLAG
C     ****************************************************************
C     * HANDLE EACH CASE FOR DRAWING OR NOT DRAWING A VECTOR.         *
C     ****************************************************************
      IF (((IAFLAG .EQ. 1) .AND. (IFFLAG .EQ. 1) .AND. (ICLIP .EQ. 1))
     & .OR. ((IAFLAG .EQ. 2) .AND. (IFFLAG .EQ. 2)
     & .AND. (ICLIP .EQ. 2))) THEN
C       ****************************************************************
C       * THE BASE AND HEAD ARE BOTH VISIBLE.                           *
C       ****************************************************************
        IF (K .EQ. 1) THEN
          CALL MPCPNT(XA,YA,RADIUS,XAT,YAT,ZAT)
          CALL TRFPNT(XAT,YAT,ZAT,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
          WRITE(1,100) XAT,YAT,' moveto'
        ELSE
          CALL MPCPNT(XF,YF,RADIUS,XFT,YFT,ZFT)
          CALL TRFPNT(XFT,YFT,ZFT,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
          WRITE(1,100) XFT,YFT,' lineto'
        END IF
C       ****************************************************************
C       * DRAW ARROW OR ARROWS IF APPROPRIATE.                          *
C       ****************************************************************
        DAR=SQRT((XA-XF)*(XA-XF)+(YA-YF)*(YA-YF))
        IF (DAR .GT. 0.0) THEN
            IF (NDIR .EQ. 0) THEN
              CALL CARR3D(MNAR,VL,BANG,S,XA,YA,XF,YF,FXN,FYN,VSUM,KAR
     &           ,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,IAFLAG,IFFLAG,ICLIP)
            ELSE
              CALL CARR3D(MNAR,VL,BANG,S,XF,YF,XA,YA,FXN,FYN,VSUM,KAR
     &           ,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,IAFLAG,IFFLAG,ICLIP)
            END IF
        ELSE
        END IF
      ELSE IF ( ((IAFLAG .EQ. 1) .AND. (IFFLAG .EQ. 2) .AND.
     &           (ICLIP .EQ. 1) .AND. (K .NE. 1)) .OR.
     &          ((IAFLAG .EQ. 2) .AND. (IFFLAG .EQ. 1) .AND.
     &           (ICLIP .EQ. 2) .AND. (K .NE. 1)) ) THEN
C       ****************************************************************
```

```
C       * THE BASE IS VISIBLE AND THE HEAD IS NOT VISIBLE.  THIS       *
C       * OCCURS AT A CLIPPING BOUNDARY.                               *
C       ****************************************************************
        CALL MPCPNT(XF,YF,RADIUS,XFT,YFT,ZFT)
        CALL TRFPNT(XFT,YFT,ZFT,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
        WRITE(1,101) XFT,YFT,' lineto stroke'
        WRITE(1,*) '% termined at clipping boundary'
       ELSE IF (((IAFLAG .EQ. 2) .AND. (IFFLAG .EQ. 1) .AND.
      &          (ICLIP .EQ. 1))  .OR. ((IAFLAG .EQ. 1) .AND.
      &         (IFFLAG .EQ. 2) .AND.(ICLIP .EQ. 2))) THEN
        CALL MPCPNT(XF,YF,RADIUS,XFT,YFT,ZFT)
        CALL TRFPNT(XFT,YFT,ZFT,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
        WRITE(1,*) '% start of visible vector section'
        WRITE(1,*) ' newpath'
        WRITE(1,100) XFT,YFT,' moveto'
       ELSE
C       ****************************************************************
C       * BOTH POINTS ARE HIDDEN. JUST ACCUMULATE THE VECTOR LENGTH.   *
C       ****************************************************************
        DAR=SQRT((XA-XF)*(XA-XF)+(YA-YF)*(YA-YF))
        IF (DAR .GT. 0.0) THEN
            IF (NDIR .EQ. 0) THEN
              CALL CARR3D(MNAR,VL,BANG,S,XA,YA,XF,YF,FXN,FYN,VSUM,KAR
      &           ,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,IAFLAG,IFFLAG,ICLIP)
            ELSE
              CALL CARR3D(MNAR,VL,BANG,S,XF,YF,XA,YA,FXN,FYN,VSUM,KAR
      &           ,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,IAFLAG,IFFLAG,ICLIP)
            END IF
        ELSE
        END IF
       END IF
C      ****************************************************************
C      * STOP IF VECTOR MAGNITUDE DROPS BELOW TOLERANCE.              *
C      ****************************************************************
       IF (FM .LT. .001) THEN
         WRITE(1,*) '% magnitude below tolerance'
         GO TO 99
       ELSE
       END IF
       GO TO 999
C      ****************************************************************
C      * STOP.                                                        *
C      ****************************************************************
 99    CONTINUE
       IF ( (((IAFLAG .EQ. 1).OR.(IFFLAG .EQ. 1)) .AND. (ICLIP .EQ. 1))
      & .OR.
      &   (((IAFLAG .EQ. 2) .OR. (IFFLAG .EQ. 2)) .AND. (ICLIP .EQ. 2)))
      & THEN
         WRITE(1,*) 'stroke'
       ELSE
       END IF
100    FORMAT(2(F6.2,1X),A7)
101    FORMAT(2(F6.2,1X),A14)
104    CONTINUE
       ID=IFIRST
       RETURN
       END

       SUBROUTINE CARR3D(MNAR,VL,BANG,S,XF,YF,XA,YA,FXN,FYN,VSUM,KAR
```

```
2       &           ,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0,IAFLAG,IFFLAG,ICLIP)
3  C     ************************************************************************
4  C     * THIS SUBROUTINE CONTROLS THE DRAWING OF ARROWHEADS ON A LINE.  *
5  C     ************************************************************************
6  C     * INPUTS:                                                        *
7  C     *                                                                *
8  C     *   MNAR     - MAXIMUM NUMBER OF ARROWS ALLOWED.                 *
9  C     *   VL       - SPACING BETWEEN ARROWHEADS IN REAL COORDINATES.    *
10 C     *   BANG     - ARROW APEX HALF ANGLE IN DEGREES.                  *
11 C     *   S        - ARROW HEAD SIDE LENGTH IN POINT SIZE.              *
12 C     *   XA,YA    - BASE OF ARROW.                                     *
13 C     *   XF,YF    - TIP OF ARROW.                                      *
14 C     *   FXN,FYN - NORMALIZED VECTOR FUNCTION VALUES.                  *
15 C     *   VSUM     - ACCUMULATED LINE LENGTH.                           *
16 C     *   KAR      - NUMBER OF ARROWS DRAWN SO FAR.                     *
17 C     *   AX,BX    - GRAPHICAL SCALE CONSTANTS.                         *
18 C     *   AY,BY                                                         *
19 C     ************************************************************************
20       D=SQRT((XA-XF)*(XA-XF)+(YA-YF)*(YA-YF))
21       STEP=VSUM+D
22       IF (STEP .GT. VL) THEN
23         KAR=KAR+1
24         IF (KAR .GT. MNAR) THEN
25           GO TO 2
26         ELSE
27         END IF
28 C       ************************************************************************
29 C       * THE NEXT LINE SEGMENT IS LONGER THAN THE ARROW SPACING.      *
30 C       * SO AN ARROW SHOULD BE DRAWN.                                 *
31 C       ************************************************************************
32         RAT=(VL-VSUM)/D
33         XFW=XA+RAT*(XF-XA)
34         YFW=YA+RAT*(YF-YA)
35 C       ************************************************************************
36 C       * DRAW THE ARROW.                                              *
37 C       ************************************************************************
38         IF ( ((IAFLAG .EQ. 1).AND.(IFFLAG .EQ. 1) .AND. (ICLIP .EQ. 1))
39      &    .OR.
40      &      ((IAFLAG .EQ. 2) .AND. (IFFLAG .EQ. 2) .AND. (ICLIP .EQ. 2)))
41      &    THEN
42           CALL CAHD3D(BANG,GS,S,XFW,YFW,FXN,FYN,XD,YD,ZD,C1,C2
43      &                                                  ,C3,C4,C5,X0,Y0)
44         ELSE
45         END IF
46 C       ************************************************************************
47 C       * COMPUTE THE AMOUNT LEFT OVER AFTER THE ARROW IS DRAWN.       *
48 C       ************************************************************************
49         DLT=SQRT((XF-XFW)*(XF-XFW)+(YF-YFW)*(YF-YFW))
50         IF (DLT .LT. VL) THEN
51 C         ************************************************************************
52 C         * NO MORE ARROWS ARE DRAWN ON THIS SEGMENT.                    *
53 C         ************************************************************************
54           VSUM=DLT
55         ELSE
56 C         ************************************************************************
57 C         * MORE THAN ONE ARROW IS DRAWN ON THIS SEGMENT.                *
58 C         ************************************************************************
59           NAR=DLT/VL
60           DO 1 I=1,NAR
```

```
61              KAR=KAR+1
62              IF (KAR .GT. MNAR) THEN
63                GO TO 2
64              ELSE
65              END IF
66              RAT=(VL-VSUM+I*VL)/D
67              XFW=XA+RAT*(XF-XA)
68              YFW=YA+RAT*(YF-YA)
69            IF ( ((IAFLAG .EQ. 1).AND.(IFFLAG .EQ. 1) .AND. (ICLIP .EQ. 1))
70     &     .OR.
71     &       ((IAFLAG .EQ. 2) .AND. (IFFLAG .EQ. 2) .AND. (ICLIP .EQ. 2)))
72     &     THEN
73              CALL CAHD3D(BANG,GS,S,XFW,YFW,FXN,FYN,XD,YD,ZD,C1,C2
74     &                                                    ,C3,C4,C5,X0,Y0)
75            ELSE
76            END IF
77   1        CONTINUE
78            VSUM=SQRT((XF-XFW)*(XF-XFW)+(YF-YFW)*(YF-YFW))
79          END IF
80        ELSE
81 C        ***************************************************************
82 C        * THE LINE LENGTH PLUS THE ACCUMULATED DISTANCE IS STILL LESS  *
83 C        * THAN THE ARROW SPACING. NO ARROW SHOULD BE DRAWN JUST        *
84 C        * ACCUMULATE THE DISTANCE.                                     *
85 C        ***************************************************************
86          VSUM=VSUM+D
87        END IF
88   2    CONTINUE
89        RETURN
90        END

 1        SUBROUTINE CAHD3D(BANG,GS,S,X2,Y2,FXN,FYN,XD,YD,ZD,C1,C2
 2       &,C3,C4,C5,X0,Y0)
 3 C      ***************************************************************
 4 C      * THIS SUBROUTINE DRAWS A ARROW FROM (X1,Y1) TO (X2,Y2).       *
 5 C      ***************************************************************
 6 C      * INPUTS:                                                      *
 7 C      *                                                              *
 8 C      *   BANG  - ARROW APEX HALF ANGLE IN DEGREES.                  *
 9 C      *   S     - ARROWHEAD SIDE LENGTH.                             *
10 C      *   X2,Y2  - TIP OF ARROW.                                     *
11 C      *   FXN,FYN - NORMALIZED VECTOR FUNCTION VALUES.               *
12 C      ***************************************************************
13        RAD=.17453293E-01
14        X1=X2-FXN
15        Y1=Y2-FYN
16        D=SQRT((X2-X1)*(X2-X1)+(Y2-Y1)*(Y2-Y1))
17        A=1.0-S/(GS*D)
18        X3=X1+A*(X2-X1)
19        Y3=Y1+A*(Y2-Y1)
20 C      ***************************************************************
21 C      * TRANSLATE THE ORIGIN TO (X2,Y2) AND ROTATE (X3,Y3) PLUS AND  *
22 C      * MINUS BANG DEGREES TO GENERATE THE VERTICES OF THE ARROW.    *
23 C      ***************************************************************
24        XA=X3-X2
25        YA=Y3-Y2
26        ARG=RAD*BANG
27        CA=COS(ARG)
28        SA=SIN(ARG)
```

```
      XCA=XA*CA
      XSA=XA*SA
      YCA=YA*CA
      YSA=YA*SA
      X4=X2+XCA-YSA
      Y4=Y2+XSA+YCA
      X5=X2+XCA+YSA
      Y5=Y2-XSA+YCA
c      X6=(X4+X5)/2.0
c      Y6=(Y4+Y5)/2.0
C      WRITE(1,*) X1,Y1,' moveto'
C      WRITE(1,*) X6,Y6,' lineto stroke'
C     ***********************************************************************
C     * TRANSLATE THE ORIGIN TO (X2,Y2) AND ROTATE (X3,Y3) PLUS AND     *
C     * MINUS BANG DEGREES  TO GENERATE THE VERTICES OF THE ARROW       *
C     ***********************************************************************
      RADIUS=0.5
      CALL MPCPNT(X2,Y2,RADIUS,X2T,Y2T,Z2T)
      CALL MPCPNT(X4,Y4,RADIUS,X4T,Y4T,Z4T)
      CALL MPCPNT(X5,Y5,RADIUS,X5T,Y5T,Z5T)
      CALL TRFPNT(X2T,Y2T,Z2T,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
      CALL TRFPNT(X4T,Y4T,Z4T,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
      CALL TRFPNT(X5T,Y5T,Z5T,GS,XD,YD,ZD,C1,C2,C3,C4,C5,X0,Y0)
      WRITE(1,*) 'gsave newpath'
      WRITE(1,*) X2T,Y2T,' moveto ',X4T,Y4T,' lineto '
     &                              ,X5T,Y5T,' lineto'
      WRITE(1,*) 'closepath 0 setgray fill stroke grestore'
      RETURN
      END

      SUBROUTINE MPCPNT(U,V,A,X,Y,Z)
C     ***********************************************************************
C     * THIS SUBROUTINE MAPS A POINT FROM THE UNNFOLDED CIRCULAR        *
C     * WAVEGUIDE (U,V) SPACE TO THE (X,Y,Z) FOLDED WAVEGUIDE SPACE.    *
C     ***********************************************************************
C     * INPUTS:                                                         *
C     *                                                                 *
C     *   U,V  - COORDINATES OF THE UNFOLDED WAVEGUIDE POINT.           *
C     *   A    - RADIUS OF CIRCULAR WAVEGUIDE (WAVELENGTHS).            *
C     *                                                                 *
C     * OUTPUTS:                                                        *
C     *                                                                 *
C     *   X,Y,Z  -  COORDINATES OF MAPPED POINT.                        *
C     ***********************************************************************
      X=A*COS(U/A)
      Y=A*SIN(U/A)
      Z=V
      RETURN
      END
```

```
      SUBROUTINE TRFTRI(X,Y,Z,GS,XC,YC,ZC,C1,C2,C3,C4,C5,X0,Y0)
C     ********************************************************************
C     * THIS SUBROUTINE TRANSFORMS EACH POINT OF A TRIANGLE.             *
C     ********************************************************************
C     * INPUTS:                                                          *
C     *                                                                  *
C     *   X(3)  -  COORDINATES OF EACH VERTEX OF A TRIANGLE.             *
C     *   Y(3)                                                           *
C     *   Z(3)                                                           *
C     *   GS - GRAPH SCALE FACTOR.                                       *
C     *   XC,YC,ZC - CENTER OF ROTATION.                                 *
C     *   C1,C2,C3 - ROTATION MATRIX COEFFICIENTS.                       *
C     *   C4,C5                                                          *
C     *   X0,V0    - HORIZONTAL AND VERTICAL DEVICE OFFSETS.             *
C     *                                                                  *
C     * OUTPUT:                                                          *
C     *                                                                  *
C     *   X(3)  -  TRANSFORMED COORDINATES OF EACH CORNER OF THE         *
C     *   Y(3)     PROJECTED ONTO THE X-Y PLANE.                         *
C     ********************************************************************
      REAL*4 X(3),Y(3),Z(3)
      DO 1 I=1,3
        CALL SCALE(GS,X(I),Y(I),Z(I))
        CALL T3LATE(X(I),Y(I),Z(I),XC,YC,ZC)
        CALL ROTATE(X(I),Y(I),Z(I),C1,C2,C3,C4,C5)
        CALL T3LATE(X(I),Y(I),Z(I),-XC,-YC,-ZC)
        CALL T2LATE(X(I),Y(I),X0,Y0)
    1 CONTINUE
      RETURN
      END

      SUBROUTINE TRFPNT(X,Y,Z,GS,XC,YC,ZC,C1,C2,C3,C4,C5,X0,Y0)
C     ********************************************************************
C     * THIS SUBROUTINE TRANSFORMS A POINT.                              *
C     ********************************************************************
C     * INPUTS:                                                          *
C     *                                                                  *
C     *   X,Y,Z  -  COORDINATES OF A POINT.                              *
C     *   GS - GRAPH SCALE FACTOR.                                       *
C     *   XC,YC,ZC - CENTER OF ROTATION.                                 *
C     *   C1,C2,C3 - ROTATION MATRIX COEFFICIENTS.                       *
C     *   C4,C5                                                          *
C     *   X0,V0    - HORIZONTAL AND VERTICAL DEVICE OFFSETS.             *
C     *                                                                  *
C     * OUTPUT:                                                          *
C     *                                                                  *
C     *   X,Y  -  TRANSFORMED COORDINATES OF EACH CORNER OF THE          *
C     *           PROJECTED ONTO THE X-Y PLANE.                          *
C     ********************************************************************
      CALL SCALE(GS,X,Y,Z)
      CALL T3LATE(X,Y,Z,XC,YC,ZC)
      CALL ROTATE(X,Y,Z,C1,C2,C3,C4,C5)
      CALL T3LATE(X,Y,Z,-XC,-YC,-ZC)
      CALL T2LATE(X,Y,X0,Y0)
      RETURN
      END

      SUBROUTINE T3LATE(X,Y,Z,XC,YC,ZC)
C     ********************************************************************
```

```
C     * THIS SUBROUTINE TRANSLATES THE ORIGIN TO THE POINT (XC,YC,ZC). *
C     ****************************************************************
      X=X-XC
      Y=Y-YC
      Z=Z-ZC
      RETURN
      END

      SUBROUTINE T2LATE(X,Y,XC,YC)
C     ****************************************************************
C     * THIS SUBROUTINE TRANSLATES THE POINT (X,Y) TO THE POINT       *
C     *  TO THE POINT (XC,YC).                                        *
C     ****************************************************************
      X=X+XC
      Y=Y+YC
      RETURN
      END

      SUBROUTINE SCALE(GS,X,Y,Z)
C     ****************************************************************
C     * THIS SUBROUTINE SCALES A POINT.                               *
C     ****************************************************************
      X=GS*X
      Y=GS*Y
      Z=GS*Z
      RETURN
      END

      SUBROUTINE RCOEFF(RP,RT,C1,C2,C3,C4,C5)
C     ****************************************************************
C     * THIS SUBROUTINE COMPUTES THE ROTATION COEFFICIENTS.           *
C     ****************************************************************
      CP=COS(RP)
      SP=SIN(RP)
      C1=CP
      C2=-SP
      CT=COS(RT)
      C3=CT*SP
      C4=CT*CP
      C5=SIN(RT)
      RETURN
      END

      SUBROUTINE ROTATE(X,Y,Z,C1,C2,C3,C4,C5)
C     ****************************************************************
C     * THIS SUBROUTINE ROTATES POINTS IN THREE DIMENSIONS AND TAKES   *
C     * THE PARALLEL PROJECTION ONTO THE X-Y PLANE.                   *
C     ****************************************************************
      XR=X
      YR=Y
      X=C1*XR+C2*YR
      Y=C3*XR+C4*YR+C5*Z
      RETURN
      END
```

```
      SUBROUTINE VECCOF(MN,MT,ID,X,Y,XA,YA,N2T,FX,FY,A,B,E,C,D,F)
C     ************************************************************************
C     * THIS SUBROUTINE RETURNS THE VECTOR FUNCTION COEFFICIENTS FOR   *
C     * THE IDTH TRIANGLE.                                             *
C     ************************************************************************
      REAL*4 X(MN),Y(MN),FX(MN),FY(MN)
      INTEGER N2T(MT,3)
      X1=X(N2T(ID,1))
      Y1=Y(N2T(ID,1))
      X2=X(N2T(ID,2))
      Y2=Y(N2T(ID,2))
      X3=X(N2T(ID,3))
      Y3=Y(N2T(ID,3))
      FX1=FX(N2T(ID,1))
      FX2=FX(N2T(ID,2))
      FX3=FX(N2T(ID,3))
      FY1=FY(N2T(ID,1))
      FY2=FY(N2T(ID,2))
      FY3=FY(N2T(ID,3))
      DEN=X1*Y2-X1*Y3-X2*Y1+X3*Y1+X2*Y3-X3*Y2
      A=(FY1*(Y2-Y3)-FY2*(Y1-Y3)+FY3*(Y1-Y2))/DEN
      B=(-FY1*(X2-X3)+FY2*(X1-X3)-FY3*(X1-X2))/DEN
      E=(FY1*(X2*Y3-X3*Y2)-FY2*(X1*Y3-X3*Y1)+FY3*(X1*Y2-X2*Y1))/DEN
      C=(FX1*(Y2-Y3)-FX2*(Y1-Y3)+FX3*(Y1-Y2))/DEN
      D=(-FX1*(X2-X3)+FX2*(X1-X3)-FX3*(X1-X2))/DEN
      F=(FX1*(X2*Y3-X3*Y2)-FX2*(X1*Y3-X3*Y1)+FX3*(X1*Y2-X2*Y1))/DEN
      RETURN
      END

      SUBROUTINE FNDTRI(XA,YA,MN,X,Y,MT,NT,N2T,ID)
C     ************************************************************************
C     * THIS SUBROUTINE SORTS THROUGH THE TRIANGLES AND FINDS THE ONE  *
C     * CONTAINING THE POINT XA,YA.                                    *
C     ************************************************************************
      REAL*4 X(MN),Y(MN)
      INTEGER N2T(MT,3)
      ID=0
      DO 1 I=1,NT
        X1=X(N2T(I,1))
        Y1=Y(N2T(I,1))
        X2=X(N2T(I,2))
        Y2=Y(N2T(I,2))
        X3=X(N2T(I,3))
        Y3=Y(N2T(I,3))
        CALL PINTRI(XA,YA,X1,Y1,X2,Y2,X3,Y3,IFLAG)
        IF (IFLAG .EQ. 1) THEN
          ID=I
        ELSE
        END IF
    1 CONTINUE
C      WRITE(*,*) XA,YA,' IN TRIANGLE ',ID
      RETURN
      END

      SUBROUTINE FDSTRI(XA,YA,MN,X,Y,MT,MP,NT,N2T,T2N,IA,ID)
C     ************************************************************************
C     * THIS SUBROUTINE SORTS THROUGH THE TRIANGLES CONNECTED TO THE   *
C     * THREE NODES OF THE IATH TRIANGLE TO FIND THE ONE CONTAINING    *
C     * THE POINT XA,YA.                                               *
```

```
C     ************************************************************************
      REAL*4 X(MN),Y(MN)
      INTEGER N2T(MT,3),T2N(MN,MP)
      ID=0
C     ************************************************************************
C     * CHECK TO SEE IF THE POINT IS IN THE IATH TRIANGLE.                   *
C     ************************************************************************
      DO 2 I=1,3
        N=N2T(IA,I)
C        WRITE(*,*) 'NODE ',N,' CONNECTED TO TRIANGLE ',IA
        DO 3 J=1,MP
          IF (T2N(N,J) .NE. 0) THEN
C             WRITE(*,*) 'TRIANGLE NUMBER ',N,J,T2N(N,J)
            X1=X(N2T(T2N(N,J),1))
            Y1=Y(N2T(T2N(N,J),1))
            X2=X(N2T(T2N(N,J),2))
            Y2=Y(N2T(T2N(N,J),2))
            X3=X(N2T(T2N(N,J),3))
            Y3=Y(N2T(T2N(N,J),3))
            CALL PINTRI(XA,YA,X1,Y1,X2,Y2,X3,Y3,IFLAG)
            IF (IFLAG .EQ. 1) THEN
              ID=T2N(N,J)
              GO TO 99
            ELSE
            END IF
          ELSE
          END IF
    3     CONTINUE
    2 CONTINUE
   99 CONTINUE
      RETURN
      END

      SUBROUTINE PINTRI(X,Y,X1,Y1,X2,Y2,X3,Y3,IFLAG)
C     ************************************************************************
C     * THIS SUBROUTINE DETERMINES WHETHER THE POINT (X,Y) LIES INSIDE       *
C     * THE TRIANGLE DETERMINED BY THE POINTS (X1,Y1), (X2,Y2) AND           *
C     * (X3,Y3).                                                             *
C     ************************************************************************
      IFLAG=0
C     ************************************************************************
C     * CHECK TO SEE IF THE POINT IS IN THE SAME HALF PLANE AS POINT         *
C     * (X1,Y1).                                                             *
C     ************************************************************************
      CALL HPLANE(X1,Y1,X2,Y2,X3,Y3,I)
      CALL HPLANE(X,Y,X2,Y2,X3,Y3,J)
      IF ((I .EQ. J) .OR. (J .EQ. 0)) THEN
C       ***********************************************************************
C       * CHECK TO SEE IF THE POINT (X,Y) IS IN THE SAME HALF PLANE AS         *
C       * POINT (X2,Y2).                                                      *
C       ***********************************************************************
        CALL HPLANE(X2,Y2,X3,Y3,X1,Y1,I)
        CALL HPLANE(X,Y,X3,Y3,X1,Y1,J)
        IF ((I .EQ. J) .OR. (J .EQ. 0)) THEN
C         *********************************************************************
C         * CHECK TO SEE IF THE POINT (X,Y) IS IN THE SAME HALF PLANE          *
C         * AS POINT (X3,Y3).                                                 *
C         *********************************************************************
          CALL HPLANE(X3,Y3,X1,Y1,X2,Y2,I)
```

```
27            CALL HPLANE(X,Y,X1,Y1,X2,Y2,J)
28            IF ((I .EQ. J) .OR. (J .EQ. 0)) THEN
29              IFLAG=1
30            ELSE
31            END IF
32          ELSE
33          END IF
34        ELSE
35        END IF
36        RETURN
37        END

 1        SUBROUTINE HPLANE(X,Y,X1,Y1,X2,Y2,I)
 2 C      ************************************************************************
 3 C      * THIS SUBROUTINE DETERMINES WHETHER THE POINT (X,Y) LIES ON      *
 4 C      * ABOVE OR BELOW THE LINE DETERMINED BY THE POINTS (X1,Y1) AND    *
 5 C      * (X2,Y2).                                                        *
 6 C      ************************************************************************
 7        REAL*8 D
 8        D=(X-X1)*(Y2-Y1)-(X2-X1)*(Y-Y1)
 9        IF (D .LT. 0.0) THEN
10          I=-1
11        ELSE IF (D .GT. 0.0) THEN
12          I=1
13        ELSE
14          I=0
15        END IF
16        RETURN
17        END

 1        SUBROUTINE CONTUR(X1,Y1,X2,Y2,X3,Y3,Z1,Z2,Z3,CA,CB,NC,LC)
 2 C      ************************************************************************
 3 C      * THIS SUBROUTINE DRAWS CONTOURS ON A SINGLE TRIANGLE.            *
 4 C      ************************************************************************
 5 C      * INPUTS:                                                         *
 6 C      *
 7 C      * (X1,Y1), (X2,Y2), (X3,Y3) - TRIANGLE VERTICES.                  *
 8 C      * Z1,Z2,Z3  - TRIANGLE VERTEX FUNCTION VALUES.                    *
 9 C      ************************************************************************
10        REAL CA(NC),CB(NC)
11        INTEGER LC(NC)
12 C      ************************************************************************
13 C      * LOOP THROUGH EACH CONTOUR PAIR.                                 *
14 C      ************************************************************************
15        DO 1 I=1,NC
16          CMIN=CA(I)
17          CMAX=CB(I)
18 C        ************************************************************************
19 C        * 3 POINTS WITHIN THE CONTOUR RANGE.                            *
20 C        ************************************************************************
21          IF ((Z1 .GE. CMIN) .AND. (Z1 .LE. CMAX) .AND.
22       &      (Z2 .GE. CMIN) .AND. (Z2 .LE. CMAX) .AND.
23       &      (Z3 .GE. CMIN) .AND. (Z3 .LE. CMAX)) THEN
24            CALL SETCOL(LC(I))
25            CALL FILTRI(X1,Y1,X2,Y2,X3,Y3)
26 C        ************************************************************************
27 C        * VERTEX 1 AND 2 ARE IN RANGE AND VERTEX 3 IS OUT OF RANGE.     *
28 C        ************************************************************************
29          ELSE IF (((Z3 .LT. CMIN) .OR. (Z3 .GT. CMAX)).AND.
```

```
30      &            (Z1 .GE. CMIN) .AND. (Z1 .LE. CMAX) .AND.
31      &            (Z2 .GE. CMIN) .AND. (Z2 .LE. CMAX)) THEN
32           IF (Z3 .LT. CMIN) THEN
33             CV=CMIN
34           ELSE
35             CV=CMAX
36           END IF
37           CALL CROSS(CV,X3,Y3,Z3,X1,Y1,Z1,XL,YL)
38           CALL CROSS(CV,X2,Y2,Z2,X3,Y3,Z3,XQ,YQ)
39           CALL SETCOL(LC(I))
40           CALL FILQUD(XL,YL,X1,Y1,X2,Y2,XQ,YQ)
41 C       ***********************************************************
42 C       * VERTEX 2 AND 3 ARE IN RANGE AND VERTEX 1 IS OUT OF RANGE.    *
43 C       ***********************************************************
44        ELSE IF (((Z1 .LT. CMIN) .OR. (Z1 .GT. CMAX)).AND.
45      &          (Z2 .GE. CMIN) .AND. (Z2 .LE. CMAX) .AND.
46      &          (Z3 .GE. CMIN) .AND. (Z3 .LE. CMAX)) THEN
47           IF (Z1 .LT. CMIN) THEN
48              CV=CMIN
49           ELSE
50             CV=CMAX
51           END IF
52           CALL CROSS(CV,X1,Y1,Z1,X2,Y2,Z2,XL,YL)
53           CALL CROSS(CV,X3,Y3,Z3,X1,Y1,Z1,XQ,YQ)
54           CALL SETCOL(LC(I))
55           CALL FILQUD(XL,YL,X2,Y2,X3,Y3,XQ,YQ)
56 C       ***********************************************************
57 C       * VERTEX 3 AND 1 ARE IN RANGE AND VERTEX 2 IS OUT OF RANGE.    *
58 C       ***********************************************************
59        ELSE IF (((Z2 .LT. CMIN) .OR. (Z2 .GT. CMAX)).AND.
60      &          (Z1 .GE. CMIN) .AND. (Z1 .LE. CMAX) .AND.
61      &          (Z3 .GE. CMIN) .AND. (Z3 .LE. CMAX)) THEN
62           IF (Z2 .LT. CMIN) THEN
63             CV=CMIN
64           ELSE
65             CV=CMAX
66           END IF
67           CALL CROSS(CV,X2,Y2,Z2,X3,Y3,Z3,XL,YL)
68           CALL CROSS(CV,X1,Y1,Z1,X2,Y2,Z2,XQ,YQ)
69           CALL SETCOL(LC(I))
70           CALL FILQUD(XL,YL,X3,Y3,X1,Y1,XQ,YQ)
71 C       ***********************************************************
72 C       * VERTEX 1 IS IN RANGE AND VERTEX 2 AND 3 ARE BOTH EITHER      *
73 C       * ABOVE OR BELOW THE RANGE.                                    *
74 C       ***********************************************************
75        ELSE IF ((Z1 .GE. CMIN) .AND. (Z1 .LE. CMAX) .AND.
76      &          (((Z2 .LT. CMIN) .AND. (Z3 .LT. CMIN)) .OR.
77      &          ((Z2 .GT. CMAX) .AND. (Z3 .GT. CMAX)))) THEN
78           IF ((Z2 .LT. CMIN) .AND. (Z3 .LT. CMIN)) THEN
79             CV=CMIN
80           ELSE
81             CV=CMAX
82           END IF
83           CALL CROSS(CV,X1,Y1,Z1,X2,Y2,Z2,XL,YL)
84           CALL CROSS(CV,X3,Y3,Z3,X1,Y1,Z1,XQ,YQ)
85           CALL SETCOL(LC(I))
86           CALL FILTRI(X1,Y1,XL,YL,XQ,YQ)
87 C       ***********************************************************
88 C       * VERTEX 2 IS IN RANGE AND VERTEX 3 AND 1 ARE BOTH EITHER      *
```

```
C       * ABOVE OR BELOW THE RANGE.                                    *
C       ****************************************************************
        ELSE IF ((Z2 .GE. CMIN) .AND. (Z2 .LE. CMAX) .AND.
     &           (((Z3 .LT. CMIN) .AND. (Z1 .LT. CMIN)) .OR.
     &            ((Z3 .GT. CMAX) .AND. (Z1 .GT. CMAX)))) THEN
          IF ((Z3 .LT. CMIN) .AND. (Z1 .LT. CMIN)) THEN
            CV=CMIN
          ELSE
            CV=CMAX
          END IF
          CALL CROSS(CV,X2,Y2,Z2,X3,Y3,Z3,XL,YL)
          CALL CROSS(CV,X1,Y1,Z1,X2,Y2,Z2,XQ,YQ)
          CALL SETCOL(LC(I))
          CALL FILTRI(X2,Y2,XL,YL,XQ,YQ)
C       ****************************************************************
C       * VERTEX 3 IS IN RANGE AND VERTEX 1 AND 2 ARE BOTH EITHER      *
C       * ABOVE OR BELOW THE RANGE.                                    *
C       ****************************************************************
        ELSE IF ((Z3 .GE. CMIN) .AND. (Z3 .LE. CMAX) .AND.
     &           (((Z1 .LT. CMIN) .AND. (Z2 .LT. CMIN)) .OR.
     &            ((Z1 .GT. CMAX) .AND. (Z2 .GT. CMAX)))) THEN
          IF ((Z1 .LT. CMIN) .AND. (Z2 .LT. CMIN)) THEN
            CV=CMIN
          ELSE
            CV=CMAX
          END IF
          CALL CROSS(CV,X3,Y3,Z3,X1,Y1,Z1,XL,YL)
          CALL CROSS(CV,X2,Y2,Z2,X3,Y3,Z3,XQ,YQ)
          CALL SETCOL(LC(I))
          CALL FILTRI(X3,Y3,XL,YL,XQ,YQ)
C       ****************************************************************
C       * VERTEX 1 IS IN RANGE AND VERTEX 2 IS BELOW AND VERTEX 3      *
C       * IS ABOVE.                                                    *
C       ****************************************************************
        ELSE IF ((Z1 .GE. CMIN) .AND. (Z1 .LE. CMAX) .AND.
     &           (Z2 .LT. CMIN) .AND. (Z3 .GT. CMAX)) THEN
          CALL CROSS(CMIN,X1,Y1,Z1,X2,Y2,Z2,XL,YL)
          CALL CROSS(CMIN,X2,Y2,Z2,X3,Y3,Z3,XQ,YQ)
          CALL CROSS(CMAX,X2,Y2,Z2,X3,Y3,Z3,XR,YR)
          CALL CROSS(CMAX,X3,Y3,Z3,X1,Y1,Z1,XS,YS)
          CALL SETCOL(LC(I))
          CALL FILPNT(X1,Y1,XL,YL,XQ,YQ,XR,YR,XS,YS)
C       ****************************************************************
C       * VERTEX 1 IS IN RANGE AND VERTEX 2 IS ABOVE AND VERTEX 3 IS   *
C       * BELOW RANGE.                                                 *
C       ****************************************************************
        ELSE IF ((Z1 .GE. CMIN) .AND. (Z1 .LE. CMAX) .AND.
     &           (Z2 .GT. CMAX) .AND. (Z3 .LT. CMIN)) THEN
          CALL CROSS(CMAX,X1,Y1,Z1,X2,Y2,Z2,XL,YL)
          CALL CROSS(CMAX,X2,Y2,Z2,X3,Y3,Z3,XQ,YQ)
          CALL CROSS(CMIN,X2,Y2,Z2,X3,Y3,Z3,XR,YR)
          CALL CROSS(CMIN,X3,Y3,Z3,X1,Y1,Z1,XS,YS)
          CALL SETCOL(LC(I))
          CALL FILPNT(X1,Y1,XL,YL,XQ,YQ,XR,YR,XS,YS)
C       ****************************************************************
C       * VERTEX 2 IS IN RANGE AND VERTEX 3 IS BELOW AND VERTEX 1      *
C       * IS ABOVE.                                                    *
C       ****************************************************************
        ELSE IF ((Z2 .GE. CMIN) .AND. (Z2 .LE. CMAX) .AND.
```

```
148      &           (Z3 .LT. CMIN) .AND. (Z1 .GT. CMAX)) THEN
149            CALL CROSS(CMIN,X2,Y2,Z2,X3,Y3,Z3,XL,YL)
150            CALL CROSS(CMIN,X3,Y3,Z3,X1,Y1,Z1,XQ,YQ)
151            CALL CROSS(CMAX,X3,Y3,Z3,X1,Y1,Z1,XR,YR)
152            CALL CROSS(CMAX,X1,Y1,Z1,X2,Y2,Z2,XS,YS)
153            CALL SETCOL(LC(I))
154            CALL FILPNT(X2,Y2,XL,YL,XQ,YQ,XR,YR,XS,YS)
155 C          ******************************************************************
156 C          * VERTEX 2 IS IN RANGE AND VERTEX 3 IS ABOVE AND VERTEX 1 IS   *
157 C          * BELOW RANGE.                                                 *
158 C          ******************************************************************
159          ELSE IF ((Z2 .GE. CMIN) .AND. (Z2 .LE. CMAX) .AND.
160      &           (Z3 .GT. CMAX) .AND. (Z1 .LT. CMIN)) THEN
161            CALL CROSS(CMAX,X2,Y2,Z2,X3,Y3,Z3,XL,YL)
162            CALL CROSS(CMAX,X3,Y3,Z3,X1,Y1,Z1,XQ,YQ)
163            CALL CROSS(CMIN,X3,Y3,Z3,X1,Y1,Z1,XR,YR)
164            CALL CROSS(CMIN,X1,Y1,Z1,X2,Y2,Z2,XS,YS)
165            CALL SETCOL(LC(I))
166            CALL FILPNT(X2,Y2,XL,YL,XQ,YQ,XR,YR,XS,YS)
167 C          ******************************************************************
168 C          * VERTEX 3 IS IN RANGE AND VERTEX 1 IS BELOW AND VERTEX 2      *
169 C          * IS ABOVE.                                                    *
170 C          ******************************************************************
171          ELSE IF ((Z3 .GE. CMIN) .AND. (Z3 .LE. CMAX) .AND.
172      &           (Z1 .LT. CMIN) .AND. (Z2 .GT. CMAX)) THEN
173            CALL CROSS(CMIN,X3,Y3,Z3,X1,Y1,Z1,XL,YL)
174            CALL CROSS(CMIN,X1,Y1,Z1,X2,Y2,Z2,XQ,YQ)
175            CALL CROSS(CMAX,X1,Y1,Z1,X2,Y2,Z2,XR,YR)
176            CALL CROSS(CMAX,X2,Y2,Z2,X3,Y3,Z3,XS,YS)
177            CALL SETCOL(LC(I))
178            CALL FILPNT(X3,Y3,XL,YL,XQ,YQ,XR,YR,XS,YS)
179 C          ******************************************************************
180 C          * VERTEX 3 IS IN RANGE AND VERTEX 1 IS ABOVE AND VERTEX 2 IS   *
181 C          * BELOW RANGE.                                                 *
182 C          ******************************************************************
183          ELSE IF ((Z3 .GE. CMIN) .AND. (Z3 .LE. CMAX) .AND.
184      &           (Z1 .GT. CMAX) .AND. (Z2 .LT. CMIN)) THEN
185            CALL CROSS(CMAX,X3,Y3,Z3,X1,Y1,Z1,XL,YL)
186            CALL CROSS(CMAX,X1,Y1,Z1,X2,Y2,Z2,XQ,YQ)
187            CALL CROSS(CMIN,X1,Y1,Z1,X2,Y2,Z2,XR,YR)
188            CALL CROSS(CMIN,X2,Y2,Z2,X3,Y3,Z3,XS,YS)
189            CALL SETCOL(LC(I))
190            CALL FILPNT(X3,Y3,XL,YL,XQ,YQ,XR,YR,XS,YS)
191 C          ******************************************************************
192 C          * VERTEX 1 IS BELOW OR ABOVE RANGE AND VERTEX 2 AND 3 ARE BOTH *
193 C          * ABOVE OR BELOW RANGE.                                        *
194 C          ******************************************************************
195          ELSE IF (((Z1 .LT. CMIN) .AND. (Z2 .GT. CMAX)
196      &                                  .AND. (Z3 .GT. CMAX)) .OR.
197      &           ((Z1 .GT. CMAX) .AND. (Z2 .LT. CMIN)
198      &                                  .AND. (Z3 .LT. CMIN))) THEN
199            CALL CROSS(CMIN,X1,Y1,Z1,X2,Y2,Z2,XL,YL)
200            CALL CROSS(CMAX,X1,Y1,Z1,X2,Y2,Z2,XQ,YQ)
201            CALL CROSS(CMAX,X3,Y3,Z3,X1,Y1,Z1,XR,YR)
202            CALL CROSS(CMIN,X3,Y3,Z3,X1,Y1,Z1,XS,YS)
203            CALL SETCOL(LC(I))
204            CALL FILQUD(XL,YL,XQ,YQ,XR,YR,XS,YS)
205 C          ******************************************************************
206 C          * VERTEX 2 IS BELOW OR ABOVE RANGE AND VERTEX 3 AND 1 ARE BOTH *
```

```
C       * ABOVE OR BELOW RANGE.                                          *
C       ******************************************************************
        ELSE IF (((Z2 .LT. CMIN) .AND. (Z3 .GT. CMAX)
     &                             .AND. (Z1 .GT. CMAX)) .OR.
     &          ((Z2 .GT. CMAX) .AND. (Z3 .LT. CMIN)
     &                             .AND. (Z1 .LT. CMIN))) THEN
          CALL CROSS(CMIN,X2,Y2,Z2,X3,Y3,Z3,XL,YL)
          CALL CROSS(CMAX,X2,Y2,Z2,X3,Y3,Z3,XQ,YQ)
          CALL CROSS(CMAX,X1,Y1,Z1,X2,Y2,Z2,XR,YR)
          CALL CROSS(CMIN,X1,Y1,Z1,X2,Y2,Z2,XS,YS)
          CALL SETCOL(LC(I))
          CALL FILQUD(XL,YL,XQ,YQ,XR,YR,XS,YS)
C       ******************************************************************
C       * VERTEX 3 IS BELOW OR ABOVE RANGE AND VERTEX 1 AND 2 ARE BOTH *
C       * ABOVE OR BELOW RANGE.                                          *
C       ******************************************************************
        ELSE IF (((Z3 .LT. CMIN) .AND. (Z1 .GT. CMAX)
     &                             .AND. (Z2 .GT. CMAX)) .OR.
     &          ((Z3 .GT. CMAX) .AND. (Z1 .LT. CMIN)
     &                             .AND. (Z2 .LT. CMIN))) THEN
          CALL CROSS(CMIN,X3,Y3,Z3,X1,Y1,Z1,XL,YL)
          CALL CROSS(CMAX,X3,Y3,Z3,X1,Y1,Z1,XQ,YQ)
          CALL CROSS(CMAX,X2,Y2,Z2,X3,Y3,Z3,XR,YR)
          CALL CROSS(CMIN,X2,Y2,Z2,X3,Y3,Z3,XS,YS)
          CALL SETCOL(LC(I))
          CALL FILQUD(XL,YL,XQ,YQ,XR,YR,XS,YS)
        ELSE
        END IF
    1   CONTINUE
        RETURN
        END

        SUBROUTINE CROSS(CV,XA,YA,ZA,XB,YB,ZB,XI,YI)
C       ******************************************************************
C       * THIS SUBROUTINE COMPUTES THE INTERSECTION OF A CONTOUR LINE    *
C       * WITH A TRIANGLE BOUNDARY LINE.                                 *
C       ******************************************************************
C       * INPUTS:                                                        *
C       *                                                                *
C       * CV    - CONTOUR VALUE.                                         *
C       * XA,YA - COORDINATES OF END POINTS.                             *
C       * XB,YB                                                          *
C       * ZA,ZB - FUNCTION VALUES AT THE END POINTS.                     *
C       *                                                                *
C       * OUTPUTS:                                                       *
C       *                                                                *
C       * XI,YI - INTERCEPT COORDINATES.                                 *
C       ******************************************************************
        WA=CV-ZA
        WB=CV-ZB
        DF=(ZB-ZA)
        XI=(WA*XB-WB*XA)/DF
        YI=(WA*YB-WB*YA)/DF
        RETURN
        END

        SUBROUTINE LEGEND(US,VS,NC,NL,LC,LABEL,SL,SH,DS,ITYPE)
C       ******************************************************************
C       * THIS SUBROUTINE DRAWS THE LEGEND.                              *
```

```
C     ***********************************************************************
C     * DRAW THE COLOR KEY.                                                 *
C     *                                                                     *
C     * (US,VS) - LOWER LEFT CORNER OF LEGEND.                              *
C     * NC - NUMBER OF COLORS.                                              *
C     * NL - NUMBER OF LABELS.                                              *
C     * LABEL(NC) - LABEL STRINGS.                                          *
C     * LC(K) - LABEL RECTANGLE COLOR CODE.                                 *
C     * SL - SIDE LENGTH OF EACH RECTANGLE.                                 *
C     * SH - SIDE HEIGHT OF EACH RECTANGLE.                                 *
C     * DS - SPACING BETWEEN ADJACENT RECTANGLES.                           *
C     ***********************************************************************
      CHARACTER*30 LABEL(NL)
      CHARACTER*37 PSC
      INTEGER LC(NC)
      PSC=') stringwidth pop 2 div neg 0 rmoveto'
C     ***********************************************************************
C     * DEFINE THE SQUARES.                                                 *
C     ***********************************************************************
      IF (ITYPE .EQ. 1) THEN
C       ***********************************************************************
C       * DRAW A VERTICAL BLOCK TYPE LEGEND.                                  *
C       ***********************************************************************
        DO 1 I=1,NC
          U=US
          V=VS+(I-1)*(SH+DS)
C         ***********************************************************************
C         * FILL EACH RECTANGLE.                                                *
C         ***********************************************************************
          WRITE(1,*) 'gsave'
          WRITE(1,*) U,V,' moveto'
          WRITE(1,*) U+SL,V,' lineto'
          WRITE(1,*) U+SL,V+SH,' lineto'
          WRITE(1,*) U+SL,V+SH,' lineto'
          WRITE(1,*) U,V+SH,' lineto closepath'
          CALL SETCOL(LC(I))
          WRITE(1,*) ' fill stroke'
          WRITE(1,*) 'grestore'
C         ***********************************************************************
C         * DRAW THE PERIMETER AROUND EACH RECTANGLE.                           *
C         ***********************************************************************
          WRITE(1,*) 'gsave 0 setgray 0.5 setlinewidth'
          WRITE(1,*) U,V,' moveto'
          WRITE(1,*) U+SL,V,' lineto'
          WRITE(1,*) U+SL,V+SH,' lineto'
          WRITE(1,*) U+SL,V+SH,' lineto'
          WRITE(1,*) U,V+SH,' lineto closepath stroke grestore'
C         ***********************************************************************
C         * DRAW THE RECTANGLE LABEL.                                           *
C         ***********************************************************************
          WRITE(1,*) '0 setgray'
          WRITE(1,*) '/Times-Roman findfont 10 scalefont setfont'
          WRITE(1,*) U+SL+2.0,V-3.0,' moveto'
          CALL CHRLIM(LABEL(I),MINCHR,MAXCHR)
          WRITE(1,*) '('//LABEL(I)(MINCHR:MAXCHR)//') show'
          IF (I .EQ. NC) THEN
            WRITE(1,*) '0 setgray'
            WRITE(1,*) '/Times-Roman findfont 10 scalefont setfont'
            WRITE(1,*) U+SL+2.0,V+SH-3.0,' moveto'
```

```
63              CALL CHRLIM(LABEL(I+1),MINCHR,MAXCHR)
64              WRITE(1,*) '('//LABEL(I+1)(MINCHR:MAXCHR)//') show'
65            ELSE
66            END IF
67    1     CONTINUE
68        ELSE
69  C       ********************************************************************
70  C       * DRAW A HORIZONTAL BLOCK TYPE LEGEND.                             *
71  C       ********************************************************************
72          DO 2 I=1,NC
73            U=US+(I-1)*SL
74            V=VS
75  C         ********************************************************************
76  C         * FILL EACH RECTANGLE.                                             *
77  C         ********************************************************************
78            WRITE(1,*) 'gsave'
79            WRITE(1,*) U,V,' moveto'
80            WRITE(1,*) U+SL,V,' lineto'
81            WRITE(1,*) U+SL,V+SH,' lineto'
82            WRITE(1,*) U+SL,V+SH,' lineto'
83            WRITE(1,*) U,V+SH,' lineto closepath'
84            CALL SETCOL(LC(I))
85            WRITE(1,*) ' fill stroke'
86            WRITE(1,*) 'grestore'
87  C         ********************************************************************
88  C         * DRAW THE PERIMETER AROUND EACH RECTANGLE.                        *
89  C         ********************************************************************
90            WRITE(1,*) 'gsave 0 setgray 0.5 setlinewidth'
91            WRITE(1,*) U,V,' moveto'
92            WRITE(1,*) U+SL,V,' lineto'
93            WRITE(1,*) U+SL,V+SH,' lineto'
94            WRITE(1,*) U+SL,V+SH,' lineto'
95            WRITE(1,*) U,V+SH,' lineto closepath stroke grestore'
96  C         ********************************************************************
97  C         * DRAW THE RECTANGLE LABEL.                                        *
98  C         ********************************************************************
99            WRITE(1,*) '0 setgray'
100           WRITE(1,*) '/Times-Roman findfont 10 scalefont setfont'
101           WRITE(1,*) U,V-.9*SH,' moveto'
102           CALL CHRLIM(LABEL(I),MINCHR,MAXCHR)
103           WRITE(1,*) '('//LABEL(I)(MINCHR:MAXCHR)//PSC
104           WRITE(1,*) '('//LABEL(I)(MINCHR:MAXCHR)//') show'
105           IF (I .EQ. NC) THEN
106             WRITE(1,*) '0 setgray'
107             WRITE(1,*) '/Times-Roman findfont 10 scalefont setfont'
108             WRITE(1,*) U+SL,V-.9*SH,' moveto'
109             CALL CHRLIM(LABEL(I+1),MINCHR,MAXCHR)
110             WRITE(1,*) '('//LABEL(I+1)(MINCHR:MAXCHR)//PSC
111             WRITE(1,*) '('//LABEL(I+1)(MINCHR:MAXCHR)//') show'
112           ELSE
113           END IF
114   2     CONTINUE
115       END IF
116       RETURN
117       END

  1       SUBROUTINE CHRLIM(CS,MINCHR,MAXCHR)
  2 C     ********************************************************************
  3 C     * THIS SUBROUTINE DETERMINES THE MINIMUM AND MAXIMUM NONBLANK      *
```

```
C     * CHARACTER IN A CHARACTER STRING.                              *
C     ***************************************************************
      CHARACTER*(*) CS
      MAX=LEN(CS)
      MINCHR=1
      MAXCHR=MAX
      DO 1 I=1,MAX
        IF (CS(I:I) .NE. ' ') THEN
          MINCHR=I
          GO TO 2
        ELSE
        END IF
1     CONTINUE
2     CONTINUE
      DO 3 I=MAX,1,-1
        IF (CS(I:I) .NE. ' ') THEN
          MAXCHR=I
          GO TO 4
        ELSE
        END IF
3     CONTINUE
4     CONTINUE
      RETURN
      END

      SUBROUTINE SETCOL(I)
C     ***************************************************************
C     * THIS SUBROUTINE SETS THE DRAWING COLOR.                       *
C     ***************************************************************
      IF (I .EQ. 0) THEN
         WRITE(1,*) 'black'
      ELSE IF (I .EQ. 1) THEN
         WRITE(1,*) 'white'
      ELSE IF (I .EQ. 2) THEN
         WRITE(1,*) 'gray-lt'
      ELSE IF (I .EQ. 3) THEN
         WRITE(1,*) 'gray-lt-med'
      ELSE IF (I .EQ. 4) THEN
         WRITE(1,*) 'gray'
      ELSE IF (I .EQ. 5) THEN
         WRITE(1,*) 'gray-dk-med'
      ELSE IF (I .EQ. 6) THEN
         WRITE(1,*) 'gray-dk'
      ELSE IF (I .EQ. 7) THEN
         WRITE(1,*) 'red'
      ELSE IF (I .EQ. 8) THEN
         WRITE(1,*) 'magenta'
      ELSE IF (I .EQ. 9) THEN
         WRITE(1,*) 'green'
      ELSE IF (I .EQ. 10) THEN
         WRITE(1,*) 'blue'
      ELSE IF (I .EQ. 11) THEN
         WRITE(1,*) 'cyan'
      ELSE IF (I .EQ. 12) THEN
         WRITE(1,*) 'yellow'
      ELSE IF (I .EQ. 13) THEN
         WRITE(1,*) 'orange'
      ELSE IF (I .EQ. 14) THEN
         WRITE(1,*) 'brown'
```

```
      ELSE IF (I .EQ. 15) THEN
         WRITE(1,*) 'kakhi'
      ELSE IF (I .EQ. 16) THEN
         WRITE(1,*) 'blue-lt'
      ELSE IF (I .EQ. 17) THEN
         WRITE(1,*) 'green-lt'
      ELSE IF (I .EQ. 18) THEN
         WRITE(1,*) 'green-blue'
      ELSE IF (I .EQ. 19) THEN
         WRITE(1,*) 'purple'
      ELSE
         WRITE(1,*) 'white'
      END IF
      RETURN
      END

      SUBROUTINE FILTRI(X1,Y1,X2,Y2,X3,Y3)
C     ************************************************************************
C     * THIS SUBROUTINE FILLS A TRIANGLE WITH THE CURRENT COLOR.             *
C     ************************************************************************
      WRITE(1,1) X1,Y1,X2,Y2,X3,Y3,' filtri'
1     FORMAT(6(F6.2,1X),A7)
      RETURN
      END

      SUBROUTINE FILQUD(X1,Y1,X2,Y2,X3,Y3,X4,Y4)
C     ************************************************************************
C     * THIS SUBROUTINE FILLS A QUADRILATERAL WITH THE CURRENT COLOR.        *
C     ************************************************************************
      WRITE(1,1) X1,Y1,X2,Y2,X3,Y3,X4,Y4,' filqud'
1     FORMAT(8(F6.2,1X),A7)
      RETURN
      END

      SUBROUTINE FILPNT(X1,Y1,X2,Y2,X3,Y3,X4,Y4,X5,Y5)
C     ************************************************************************
C     * THIS SUBROUTINE FILLS A PENTAGON WITH THE CURRENT COLOR.             *
C     ************************************************************************
      WRITE(1,1) X1,Y1,X2,Y2,X3,Y3,X4,Y4,X5,Y5,' filpnt'
1     FORMAT(10(F6.2,1X),A7)
      RETURN
      END

      FUNCTION TRANS(A,B,S)
      TRANS=A*S+B
      RETURN
      END
```

Appendix B References

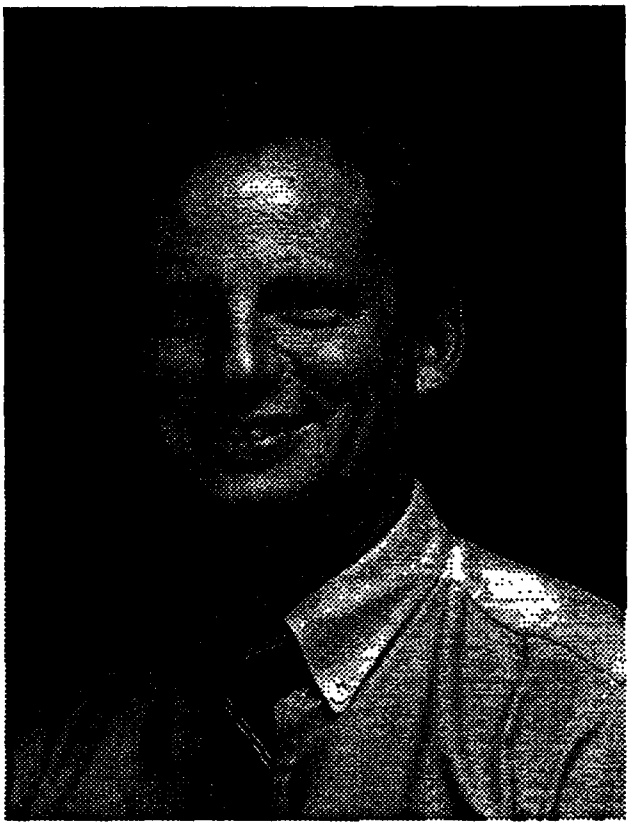
[B1] T. M. R. Ellis, "*A structured approach to Fortran 77 programming*," Addison Wesley, 1982.

[B2] Adobe Systems Inc., "*Postscript language reference manual*," Addison Wesley, 1986.

[B3] Adobe Systems Inc., "*Postscript language tutorial and cookbook*," Addison Wesley, 1986.

[B4] G. C. Reid, "*Postscript language program design*," Addison Wesley, 1988.

About The Author



Timothy John Peters was born in Pontiac, Michigan on January 25, 1959. He received the B.A. degree in Accounting and the B.S. degree in Electrical Engineering from Michigan State University, East Lansing in 1983 and the M.S. and Ph.D. degrees in Electrical Engineering from The University of Michigan, Ann Arbor in 1984 and 1988 respectively.

He is currently with The Aerospace Corporation, Antennas and Propagation Department in El Segundo, California. His primary research activity is the development of numerical methods for the analysis of antenna and scattering problems.