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Computer Solutions to Heat and Diffraction Equations in High Energy Laser Windows
Volume II

PETER D. GIANINO
BERNARD BENDOW
N. GRIER PARKE, III
THEODORE A. BARRETT

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ROME AIR DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
GRIFFISS AIR FORCE BASE, NEW YORK 13441

APPROVAL SHEET

This technical report has been reviewed and approved by RADC (OI) for publication.

APPROVED:

Nicholas F. Yannoni

NICHOLAS F. YANNONI, Chief
Optical Techniques Branch
Solid State Sciences Division

APPROVED:

Robert M Barrett

ROBERT M. BARRETT
Director
Solid State Sciences Division

FOR THE COMMANDER: John P. Huss

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The LQ-10 Infrared Laser Window Program was initiated at AFCRL (now RADC/DET) in 1971 to develop a mechanically superior, highly transmitting optical window for CO_2 and chemical lasers to be used by the Air Force for military applications. From the earliest stages of that program it became evident that the principal failure mechanism of the window would be thermal lensing, that is, the distorting and defocusing of the laser beam as it propagated through the solid. For this reason analytical tools were

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20. Abstract (Continued)

developed to predict the extent of this lensing in various candidate materials under a variety of conditions. This work contributed to selection of appropriate materials, as well ~~as~~ to design of geometrical configurations, in which the lensing could be reduced. To quantify the effects of thermal lensing, an efficient computer program package was developed and programmed to run on a CDC6600 computer. The package was written to handle Gaussian-shaped beams incident on either a thin disc- or annular-shaped cylindrical window. Three coupled programs make up the package: TEMP5, which solves the full heat transport equation within the window for any given set of initial and boundary conditions on each surface; TIKIRK, which solves the vector Kirchhoff diffraction integrals for the beam transmitted to the far field; and DISPLAY, which plots these temperatures and/or intensities in a variety of ways, including three-dimensional perspective views. Volume I of this report lays the theoretical foundations underlying these programs and presents graphical results for two model problems using disc- and annular-shaped windows. Volume II is a "user's manual." It describes how each program functions, enumerates the constituent subroutines and subprograms, gives complete Fortran listings, and even provides typical detailed commands to initiate and run the programs in both the Intercom and Batch modes of operation. Results of this work should substantially aid engineers in planning configurations and specifications for current and conceptual systems.

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7. INTRODUCTION

In Volume II we will give a detailed documentation of the Fortran programs TEMP5, TIKIRK and DISPLAY, explaining how to implement them. This will include: listings of main and ancillary programs and subroutines, plus an explanation of their functions; derivations of how the heat, boundary condition (BC) and diffraction intensity equations are transformed into algorithms solvable by the computer; flow charts; and, glossaries of variables for some of the more important subroutines. Since programs TEMP5 and TIKIRK have been coded to permit systems operation under both an Intercom and Batch mode, we will list typical interactive commands and card deck setups which control these two types of operation. Because program DISPLAY can function only in the Batch mode, we will list typical card deck setups for its operation.

Much of the details presented in Volume II appeared originally in the following unpublished reports from Parke Mathematical Laboratories, Inc., Carlisle, Mass.:

(i) N.G. Parke, III, "Program TEMP5," Sci. Rpt. No. 1 (April 1973); also documented as AFCRL Rpt TR-73-0039 by the same author.

(Received for publication 26 November 1976)

(ii) T.B. Barrett, "An Interactive Set of Programs Using Program TEMP5 for the Determination of Calorimetric Material Parameters from Experimental Data on Cylindrical IR Laser Window Materials," Tech. Memo. No. 16 (Oct. 1973).

(iii) T.B. Barrett, "TIKIRK Program," PML Rpt. 110, with revision (April 1974).

(iv) T.B. Barrett, "GETDATA Subroutine," PML Rpt. 111 (May 1974).

(v) T.B. Barrett, "DISPLAY Program," PML Rpt. 116 (May 1974).

8. TEMP5 PROGRAM

8.1 Introductory Remarks

Initial attempts to code the numerical solution to the heat and BC equations used the Crank-Nicolson method.[11] This procedure leads to a pentagonal system of linear difference equations, which are usually solved by an appropriate iteration technique.[12] However, if the edges of the "net" of points – at which the temperature is to be evaluated – is situated at the boundaries, three problems arise:

(1) Iteration techniques must be used.

(2) Symmetry dictates that along the window axis ($\rho = 0$) there be no heat flow across the window center, that is, $\partial u/\partial \rho = 0$. Under this condition, however, the term $(1/\rho)(\partial u/\partial \rho)$ which occurs in the partial differential equation would be indeterminate.

(3) A satisfactory finite-difference analog must be found for the general BC's, which have the form:

$$\partial u/\partial \nu + hu = g \quad . \tag{38}$$

[cf, Eq. (32) of Volume I].

These difficulties were resolved as follows:

(1) The Crank-Nicolson method was replaced by the Implicit Alternating Difference (IAD) method.[11] This procedure reduces the algebraic problem at each stage to the inversion of a tridiagonal matrix. The Thomas algorithm is employed and iteration is avoided. The cost of this approach for a problem involving two space variables is a two-time-level pair of difference equations.

[11] Carnahan, B., Luther, H.A., and Wilkes, J.O. (1969) Applied Numerical Methods, Wiley and Sons, Inc., New York.

[12] Parke, N.G., III (1971) Technical Memorandum No. 4, Parke Mathematical Laboratories, Inc., Carlisle, Massachusetts, unpublished.

(2) By applying L'Hospital's rule along the cylinder axis there results: $\lim_{\rho \to o} (\rho^{-1})(\partial u/\partial \rho) = \partial^2 u/\partial \rho^2$.

(3) A suitable finite difference analog for Eq. (38) is established by shifting the "net" half an increment off the boundaries.

To see how the finite difference method is applied, consider a transverse cross-sectional cut through the window's center (that is, the plane of the cross-section is perpendicular to the window's faces). The borders of the resulting rectangular cross-section are parallel to the ρ and ζ axes (see Figure 1, Volume I). Because of the rotational symmetry, only one half of the section need be shown. The geometry of the choice of net points superimposed on this cut is indicated in Figure 19. The window faces occur at the lines marked $\zeta = \zeta_1$, and $\zeta = \zeta_2$; the inner and outer cylindrical surfaces are denoted by the lines marked $\rho = \rho_1$ and 1, respectively. The ρ, ζ coordinates of each net point are represented by the indices i, j, respectively, with i running from 0 to M+1, and, j running from 0 to N+1. That is,

$$\begin{aligned} \rho_i &= \rho_1 + \left(i - \frac{1}{2}\right) \cdot \Delta\rho \quad , \quad i = 0, 1, \ldots, M+1 \\ \zeta_j &= \zeta_1 + \left(j - \frac{1}{2}\right) \cdot \Delta\zeta \quad , \quad j = 0, 1, \ldots, N+1 \quad . \end{aligned} \tag{39}$$

These coordinates are measured relative to the surfaces ρ_1 and ζ_1, respectively. All of the net points bearing one or both of the indices 0, M+1 and N+1 fall outside of the window itself and are considered to be "fictitious" or "corner" points.

8.2 Finite Difference Analogs for the General BC's

It is now possible to write the finite difference analog of the general BC's for the shifted net. First, we note that the derivative term $\partial u/\partial \nu$ in Eq. (38) differs for each surface due to the sign conventions chosen for ρ and ζ. For example, at the surfaces $\rho = \rho_1$ and $\rho = 1$, the term $\partial u/\partial \nu$ becomes - and + $\partial u/\partial \rho$, respectively; while at the surfaces $\zeta = \zeta_1$, and $\zeta = \zeta_2$ it becomes - and + $\partial u/\partial \zeta$, respectively. Thus, the finite difference analogs of the BC's become:

$$\frac{u_{o,j} - u_{1,j}}{\Delta\rho} + h_1 \frac{u_{o,j} + u_{1,j}}{2} = g_1 \text{ at } \rho = \rho_1 \tag{40}$$

$$\frac{u_{M+1,j} - u_{M,j}}{\Delta\rho} + h_2 \frac{u_{M+1,j} + u_{M,j}}{2} = g_2 \text{ at } \rho = 1 \tag{41}$$

for j = 1, 2, . . . , N-1

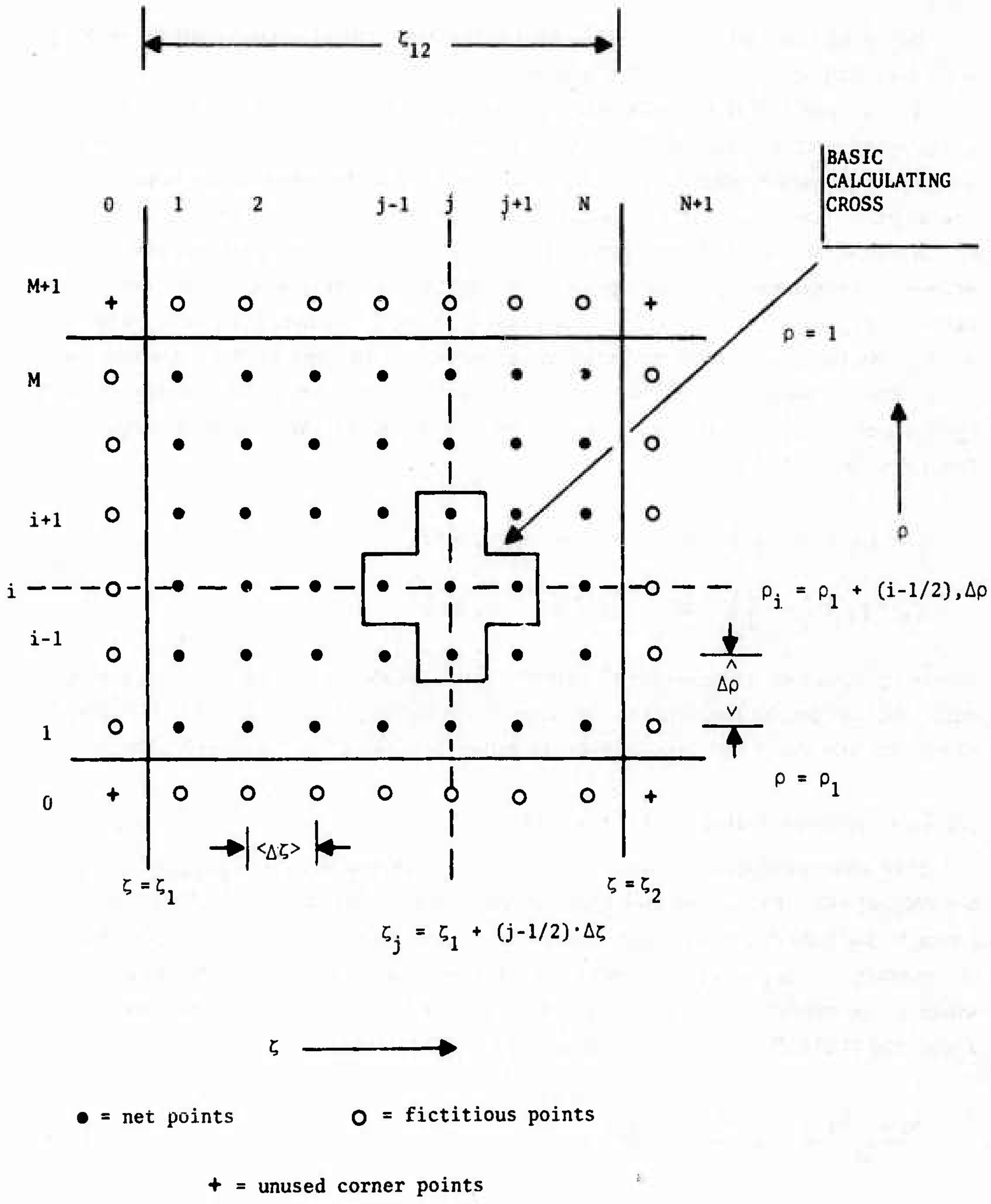

Figure 19. Geometry of Finite Difference Net. The boundaries are straddled by a net point and a fictitious point

$$\frac{u_{i,o} - u_{i,1}}{\Delta\varsigma} + h_3 \frac{u_{i,o} + u_{i,1}}{2} = g_3 \text{ at } \varsigma = \varsigma_1 \tag{42}$$

$$\frac{u_{i,N+1} - u_{i,N}}{\Delta\varsigma} + h_4 \frac{u_{i,N+1} + u_{i,N}}{2} = g_4 \text{ at } \varsigma = \varsigma_2 \tag{43}$$

When these are solved for the "fictitious" points, one obtains

$$u_{o,j} = \left[\frac{2 - h_1 \cdot \Delta\rho}{2 + h_1 \cdot \Delta\rho}\right] u_{1,j} + \left[\frac{2 \cdot \Delta\rho \cdot g_1}{2 + h_1 \cdot \Delta\rho}\right] \tag{44}$$

$$u_{M+1,j} = \left[\frac{2 - h_2 \cdot \Delta\rho}{2 + h_2 \cdot \Delta\rho}\right] u_{M,j} + \left[\frac{2 \cdot \Delta\rho \cdot g_2}{2 + h_2 \cdot \Delta\rho}\right] \tag{45}$$

$$u_{i,o} = \left[\frac{2 - h_3 \cdot \Delta\varsigma}{2 + h_3 \cdot \Delta\varsigma}\right] u_{i,1} + \left[\frac{2 \cdot \Delta\varsigma \cdot g_3}{2 + h_3 \cdot \Delta\varsigma}\right] \tag{46}$$

$$u_{i,N+1} = \left[\frac{2 - h_4 \cdot \Delta\varsigma}{2 + h_4 \cdot \Delta\varsigma}\right] u_{i,N} + \left[\frac{2 \cdot \Delta\varsigma \cdot g_4}{2 + h_4 \cdot \Delta\varsigma}\right] . \tag{47}$$

We saw in Section 3.3, Volume I, that all BC's of practical interest can be represented by appropriate choices of the g_i and h_i. With this capability in the above analogs, the resulting computer program becomes very flexible.

8.3 Finite Difference Equations for I.A.D. Method

Having set up the "net," we shall now use the I.A.D. method on the parabolic heat equation having the general form [cf Eq. (29), Volume I] :

$$\partial u/\partial\tau = \partial^2 u/\partial\rho^2 + \rho^{-1}\partial u/\partial\rho + \partial^2 u/\partial\varsigma^2 + q \tag{48}$$

where

$$q = A \exp(-\rho^2/2\sigma_e^2).$$

In the first finite difference equation set, the analog of the partial derivatives with respect to ρ will be written at the new time level n + 1, and the analog of the ξ-derivative written at the old level n. Here, n is even starting with n = 0. To complete the cycle, the second finite difference equation set is written at the new time level n + 2 for derivatives in the ξ direction. In other words, the equations are now implicit in ξ-direction and explicit in the ρ-direction. Partial derivatives with respect to ρ are written in terms of values of u at the, now old, time level n + 1. These "intermediate" values of u are sometimes designated u^* (meaning a correction). They are not accurate representations of the u. This point is discussed in detail by von Rosenberg.[13]

Our analogs for the various partial derivatives take the forms:

$$(u_{\rho\rho})_{i,j,n+1} = \frac{u_{i+1,j,n+1} - 2u_{i,j,n+1} + u_{i-1,j,n+1}}{(\Delta\rho)^2} , \tag{49}$$

$$\left(\frac{1}{\rho} u_{\rho}\right)_{i,j,n+1} = \frac{u_{i+1,j,n+1} - u_{i-1,j,n+1}}{2\rho_i(\Delta\rho)} , \tag{50}$$

$$(u_{\xi\xi})_{i,j,n} = \frac{u_{i,j+1,n} - 2u_{i,j,n} + u_{i,j-1,n}}{(\Delta\xi)^2} , \tag{51}$$

$$(u_{\tau})_{i,j,n+1/2} = \frac{u_{i,j,n+1} - u_{i,j,n}}{(\Delta\tau)} , \tag{52}$$

and

$$q(\rho_i, \xi_j) = q_{i,j} . \tag{53}$$

The subscripts i, j merely represent generalized indices and extend over the generalized ranges: i = 1, 2, . . . , M and j = 1, 2, . . . , N. After substitution, the first set of I. A. D. equations are:

[13] von Rosenberg, D. U. (1969) Methods for the Numerical Solution of Partial Differential Equations, American-Elsevier Publishing Co., Inc., New York.

$$\frac{u_{i+1,j,n+1} - 2u_{i,j,n+1} + u_{i-1,j,n+1}}{(\Delta\rho)^2} + \frac{u_{i+1,j,n+1} - u_{i-1,j,n+1}}{2\rho_i(\Delta\rho)}$$

$$+ \frac{u_{i,j+1,n} - 2u_{i,j,n} + u_{i,j-1,n}}{(\Delta\zeta)^2} + q_{i,j} = \frac{u_{i,j,n+1} - u_{i,j,n}}{\Delta\tau} \quad . \tag{54}$$

The second set of I.A.D. equations is:

$$\frac{u_{i+1,j,n+1} - 2u_{i,j,n+1} + u_{i-1,j,n+1}}{(\Delta\rho)^2} + \frac{u_{i+1,j,n+1} - u_{i-1,j,n+1}}{2\rho_i(\Delta\rho)}$$

$$+ \frac{u_{i,j+1,n+2} - 2u_{i,j,n+2} + u_{i,j-1,n+2}}{(\Delta\zeta)^2} + q_{i,j} = \frac{u_{i,j,n+2} - u_{i,j,n+1}}{\Delta\tau} \, . \tag{55}$$

It is convenient to introduce the parameters

$$\lambda = \frac{\Delta\tau}{(\Delta\rho)^2} \quad , \quad \mu = \frac{\Delta\tau}{(\Delta\zeta)^2} \quad . \tag{56}$$

Observe that Eqs. (54) are tridiagonal, containing the unknowns

$$u_{i+1,j,n+1} \quad , \quad u_{i,j,n+1} \quad , \quad u_{i-1,j,n+1}$$

and can be solved by the Thomas algorithm. Likewise, Eqs. (55) are tridiagonal, containing the unknowns

$$u_{i,j+1,n+2} \; , \; u_{i,j,n+2} \quad , \quad u_{i,j-1,n+2}$$

and can likewise be solved by the Thomas algorithm.

Before continuing, let us take up the mathematics of the Thomas algorithm (which will be incorporated in the subroutine TRIDAG, to be explained later).

8.4 The Solution of a Tridiagonal System of Equations

The whole purpose of the implicit-alternating direction method is to reduce the number of unknown variables at the "next" time level to three in any one equation. Such a set of equations is called a tridiagonal system that has a relatively simple solution. This strategy avoids "iteration" techniques of the Crank-Nicolson approach, described in Parke.[12]

The general form of a tridiagonal system of equations is

$$
\begin{aligned}
& b_1 v_1 + c_1 v_2 = d_1 \\
& a_2 v_1 + b_2 v_2 + c_2 v_3 = d_1 \\
& a_3 v_2 + b_3 v_3 + c_3 v_4 = d_2 \\
& \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
& a_i v_{i-1} + b_i v_i + c_i v_{i+1} = d_i \\
& \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
& a_{N-1} v_{N-2} + b_{N-1} v_{N-1} + c_{N-1} v_N = d_{N-1} \\
& a_N v_{N-1} + b_N v_N = d_N
\end{aligned}
\qquad (57)
$$

where*

d_i .=. known quantities

a_i, b_i, c_i .=. known coefficients

v_i .=. unknown quantities .

The tridiagonal matrix is defined as the matrix of coefficients a, b, c alone.

We follow the treatment in Carnahan.[11] To continue, the validity of the form

$$v_i = \gamma_i - \frac{c_i}{\beta_i} v_{i+1} \qquad (58)$$

can be demonstrated. The constants γ_i and β_i are to be determined. Indeed, substitution into the i-th equation of (57) gives

$$a_i \left(\gamma_{i-1} - \frac{c_{i-1}}{\beta_{i-1}} v_i \right) + b_i v_i + c_i v_{i+1} = d_i \quad .$$

*The symbol .=. means "is defined as."

As a result

$$v_i = \frac{d_i - a_i\gamma_{i-1}}{b_i - \frac{a_i c_{i-1}}{\beta_{i-1}}} - \frac{c_i\, v_{i+1}}{b_i - \frac{a_i c_{i-1}}{\beta_{i-1}}}$$

where we have the recursion relations

$$\beta_i = b_i - \frac{a_i c_{i-1}}{\beta_{i-1}} \quad ; \quad \gamma_i = \frac{d_i - a_i\gamma_{i-1}}{\beta_i} . \tag{59}$$

From the first of Eqs. (57), we have

$$v_1 = \frac{d_1}{b_1} - \frac{c_1\, v_2}{b_1}$$

where

$$\beta_1 = b_1 \quad , \quad \gamma_1 = d_1/\beta_1 \quad . \tag{60}$$

Finally, from the last of Eqs. (57), we have

$$v_N = \frac{d_N - a_N v_{N-1}}{b_N} = \frac{d_N - a_N\left(\gamma_{N-1} - \frac{c_{N-1}}{\beta_{N-1}} v_N\right)}{b_N} \tag{61}$$

where

$$v_N = \frac{d_N - a_N(\gamma_{N-1})}{b_N - \frac{a_N c_{N-1}}{\beta_{N-1}}} = \frac{d_N - a_N\gamma_{N-1}}{\beta_N} = \gamma_N \quad . \tag{61a}$$

To summarize the complete algorithm for the solution of the tridiagonal system, we have

$$v_N = \gamma_N$$

$$v_i = \gamma_i - \frac{c_i \, v_{i+1}}{\beta_i} \quad ; \quad i = N-1, N-2, \ldots, 1 \tag{62}$$

where the β's and γ's are determined by the recursion formulae

$$\begin{aligned}
&\beta_1 = b_1 \quad , \quad \gamma_1 = d_1/\beta_1 \\
&\beta_i = b_i - \frac{a_i \, c_{i-1}}{\beta_{i-1}} \qquad i = 2, 3, \ldots, N \\
&\gamma_i = \frac{d_i - a_i \gamma_{i-1}}{\beta_i} \qquad i = 2, 3, \ldots, N \ .
\end{aligned} \tag{63}$$

8.5 Putting the I.A.D. Equations into Tridiagonal Form

Using Eqs. (56), the first I. A. D. set becomes, from Eq. (54)

$$\begin{aligned}
&\lambda[u_{i+1,\,j,\,n+1} - 2u_{i,\,j,\,n+1} + u_{i-1,\,j,\,n+1}] + \frac{\lambda \cdot \Delta\rho}{2(\rho_1 + (i - 1/2) \cdot \Delta\rho)}^{*} \times \\
&\times [u_{i+1,\,j,\,n+1} - u_{i-1,\,j,\,n+1}] = d_i + u_{i,\,j,\,n+1} \ .
\end{aligned} \tag{64}$$

Writing in the standard form

$$\begin{aligned}
&b_1 u_{1,\,j,\,n+1} + c_1 u_{2,\,j,\,n+1} = d_1 \\
&\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
&a_i u_{i-1,\,j,\,n+1} + b_i u_{i,\,j,\,n+1} + c_i u_{i+1,\,j,\,n+1} = d_i \\
&\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
&a_M u_{M-1,\,j,\,n+1} + b_M u_{M,\,j,\,n+1} = d_M
\end{aligned} \tag{65}$$

we find that, in general, that is, for $i \neq 1$, $i \neq M$

$$a_i = \lambda \left(1 - \frac{\Delta\rho}{2\rho_1 + (2i - 1) \cdot \Delta\rho}\right) = \lambda \left(1 - \frac{\Delta\rho}{2\rho_i}\right) \tag{66}$$

* $\dfrac{\lambda \cdot \Delta\rho}{2\rho_i}$

$$b_i = -(2\lambda + 1) \tag{67}$$

$$c_i = \lambda \left(1 + \frac{\Delta\rho}{2\rho_1 + (2i - 1)\cdot\Delta\rho}\right) = \lambda\left(1 + \frac{\Delta\rho}{2\rho_i}\right) \tag{68}$$

$$d_i = -\mu(u_{i,j+1,n} - 2u_{i,j,n} + u_{i,j-1,n}) - \Delta\tau \cdot q_{ij} - u_{i,j,n} \quad . \tag{69}$$

We notice that from Eq. (44)

$$a_1 u_{o,j,n+1} = a_1 \left\{ \left[\frac{2 - h_1 \cdot \Delta\rho}{2 + h_1 \cdot \Delta\rho}\right] u_{1,j} + \left[\frac{2 \cdot \Delta\rho \cdot g_1}{2 + h_1 \cdot \Delta\rho}\right]\right\} \quad . \tag{70}$$

Hence, we have to change b_1 according to

$$b_1 \leftarrow b_1 + a_1 \left[\frac{2 - h_1 \cdot \Delta\rho}{2 + h_1 \cdot \Delta\rho}\right] \quad . \tag{71}$$

We also have to change d_1

$$d_1 \leftarrow d_1 - a_1 \left[\frac{2 \cdot \Delta\rho \cdot g_1}{2 + h_1 \cdot \Delta\rho}\right] \quad . \tag{72}$$

Similarly we have to change b_M

$$b_M \leftarrow b_M + c_M \left[\frac{2 - h_2 \cdot \Delta\rho}{2 + h_2 \cdot \Delta\rho}\right] \tag{73}$$

using Eq. (45). Likewise

$$d_M \leftarrow d_M - c_M \left[\frac{2 \cdot \Delta\rho \cdot g_2}{2 + h_2 \cdot \Delta\rho}\right] \quad . \tag{74}$$

It should be observed that as long as $j \neq 1$ or $j = N$, the d's require no further modification because their computation involves only "net" points at time level n. However, when $j = 1$, the fictitious points $u_{i,o,n}$ are involved. Also, when $j = N$, the fictitious points $u_{i, N+1, n}$ are involved. The simplest way to handle this is to "border" the $u_{i, j, n}$ array by computing $u_{i, o, n}$ with Eq. (46) and $u_{i, N+1, n}$ with Eq. (47) just before computing the first sets of a, b, c, d for the ξ-explicit, ρ-implicit I. A. D. set.

To summarize, in step I we modify b_1, d_1, b_M, d_M having extended $u_{i, j, n}$ with Eqs. (46) and (47).

Now let us turn to step II of the I. A. D. method. We begin with Eqs. (55) and write

$$\mu[u_{i, j+1, n+2} - 2u_{i, j, n+2} + u_{i, j-1, n+2}] = d_j + u_{i, j, n+2} - \Delta\tau \cdot q_{ij} \quad . \tag{75}$$

These equations are to be written in the standard form:

$$\begin{aligned} & b_1 u_{i, 1, n+2} + c_1 u_{i, 2, n+2} = d_1 \\ & \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ & a_j u_{i, j-1, n+2} + b_j u_{i, j, n+2} + c_j u_{i, j+1, n+2} = d_j \\ & \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ & a_N\, u_{i, N-1, n+2} + b_{N-1}\, u_{i, N, n+2} = d_N \quad . \end{aligned} \tag{76}$$

We find again that, in general, that is, for j ≠ 1 or j ≠ N

$$a_j = \mu \quad , \quad b_j = -(2\mu + 1) \quad , \quad c_j = \mu \quad ,$$

$$\begin{aligned} d_j = & -\lambda[u_{i+1, j, n+1} - 2u_{i, j, n+1} + u_{i-1, j, n+1}] - \frac{\lambda \cdot \Delta\rho^*}{2\rho_1 + (2i - 1) \cdot \Delta\rho} \\ & [u_{i+1, j, n+1} - u_{i-1, j, n+1}] - \Delta\tau \cdot q_{ij} - u_{i, j, n+1} \quad . \end{aligned} \tag{77}$$

Using Eq. (46) for $u_{i, o, n+2}$, we change b_1 to

$$b_1 \leftarrow b_1 + a_1 \left[\frac{2 - h_3 \cdot \Delta\xi}{2 + h_3 \cdot \Delta\xi}\right] \quad . \tag{78}$$

[*] $-\lambda\Delta\rho / 2\rho_i$

We also change d_1 to

$$d_1 \leftarrow d_1 - a_1 \left[\frac{2 \cdot \Delta\xi \cdot g_3}{2 + h_3 \cdot \Delta\xi} \right] . \qquad (79)$$

Similarly we use Eq. (47) for $u_{i,N,n+2}$ to change b_{N-1} to

$$b_N \leftarrow b_N + c_N \left[\frac{2 - h_4 \cdot \Delta\xi}{2 + h_4 \cdot \Delta\xi} \right] . \qquad (80)$$

and

$$d_N \leftarrow d_N - c_N \left[\frac{2 \cdot \Delta\xi \cdot g_4}{2 + h_4 \cdot \Delta\xi} \right] . \qquad (81)$$

Again, as long as $i \neq 1$, or $i \neq M$, the d's require no further modification because their computation involves only "net" points at time level n + 1. However, when i = 1, the fictitious points $u_{o,j,n+1}$ are involved. Also, when i = M, the fictitious points $u_{M+1,j,n+1}$ are involved. The simplest way to handle this is to "border" the $u^* = u_{i,j,n+1}$ array by computing $u_{o,j,n+1}$ with Eq. (44) and $u_{M+1,j,n+1}$ with Eq. (45) before starting on the second half of the I. A. D. set. We shall keep the 0, 2, . . . , n even level u's in an array U(I, J). We shall keep the 1, 3, . . . n odd level u's in an array USTAR(I, J).

8.6 The Time Coordinate

The time coordinate τ_n is constructed so as to be controlled by an integer n and an increment $\Delta\tau$ in a special way. Because we are using the I. A. D. method, the "net" values of temperature are only valid when u is an even integer. In addition, it should be noted that $\Delta\tau$ may be changed before entering a new cycle involving an alternating difference pair of finite difference equations.

Initially, temperature varies relatively rapidly with time. This means that rather closely spaced time units should be selected at which to calculate the temperature. Later, as the temperature approaches its steady state value, its change is less rapid so that it seems reasonable, especially from the viewpoint of conserving computer time, to calculate temperatures at much larger intervals of time. This can be accomplished by allowing the time interval $\Delta\tau$ at a particular choice of n to increase according to the scheme:

$$\Delta\tau(n) = 2^{n/n_o} \Delta\tau_o \quad . \qquad (82)$$

$\Delta\tau_o$ is some arbitrarily-selected initial value of $\Delta\tau$, n is a positive even integer and n_o is some arbitrary positive integer, called the "doubling count number," because when n reaches n_o, $\Delta\tau$ will double to $2\Delta\tau_o$. Making n_o very large is equivalent to holding $\Delta\tau(n) = \Delta\tau_o$.

Meanwhile, the time coordinate τ_n is formed according to the prescription:

$$\tau_n = 2\sum_{k=o}^{n} \Delta\tau(k) = 2\Delta\tau_o \sum_{k=o}^{n} 2^{k/n_o} \tag{83}$$

in which k is incremented in steps of 2 up to n. This prescription will hold up to the limit $n = n_L$. The actual value of n_L will be determined by the parameter n_{max}, a positive integer which is inputted at the start of the program. The integer n_L will be equal to $n_{max} - 2$ if n_{max} is even, or, to $n_{max} - 1$ if n_{max} is odd. At $n = n_L$, the increment is designated by $\Delta\tau(n_L)$ and the time by τ_{n_L}. That is:

$$\Delta\tau(n_L) = 2^{n_L/n_o} \Delta\tau_o \tag{84}$$

$$\tau_{n_L} = 2\,\Delta\tau_o \sum_{k=o}^{n_L} 2^{k/n_o} \quad . \tag{85}$$

For times greater than τ_{n_L}, corresponding to $n > n_L$, the increment will remain fixed at $\Delta\tau(n_L)$, whereas the time will be given by:

$$\tau_n = \tau_{n_L} + \Delta\tau(n_L) \cdot (n - n_L)/2 \quad . \tag{86}$$

The time τ_n will keep increasing by these fixed increments until it reaches some arbitrarily-fixed upper limit τ_{max}, at which point the program initiates a termination procedure.

By virtue of another time-control parameter, the program also makes provision for turning the source off and then determining the temperature changes as the window cools off. This occurs at $\tau = \tau_{off}$, where, of course, τ_{off} must be $\leq \tau_{max}$.

Should τ_n, as determined by Eq. (86), become greater than τ_{off} at the start of a time loop, and if $\tau_{off} < \tau_{max}$, then the time-incrementing procedure is reinitiated. On the other hand, should τ_n exceed τ_{off} at the start of a time loop, and if $\tau_{off} = \tau_{max}$, then the subroutine CYLTMP (to be described later) does not continue with the calculation, but returns control to the main program. Thus, the actual maximum time value will usually be slightly less than τ_{off} if the window is being irradiated, and will be slightly less than τ_{max} if the window is experiencing a cooling phase.

From the analysis above, we see that, apart from the running index n, usually 4, or, at most 5, parameters are required to control the time coordinate, viz, n_o, n_{max}, $\Delta\tau_o$, τ_{max} and τ_{off}. The time interval $\Delta\tau$ can be enlarged by increasing $\Delta\tau_o$ or n_{max}, or by decreasing n_o.

8.7 The Main Program and Principal Subroutines

The coding necessary to input all of the data, to carry out all of the required calculations, including the I. A. D. prescriptions, and finally, to print out the results constitutes a major programmed package, named the TEMP5 program. This package consists of eight principal subroutines called into execution by one very short main program. This latter program has also been designated as TEMP5. However, whenever we use the term "TEMP5 program" throughout this report we will always mean the collective "package" rather than this one main program, unless stated otherwise.

The TEMP5 program is composed of the following:

(1) TEMP5 - a very short program whose principal purpose is to call the 2 principal subroutines DATINIT and CYLTMP.

(2) DATINIT - a subroutine which inputs all required parameters necessary for program operation by a call to subroutine GETDATA. It initializes the principal arrays used by subroutine CYLTMP. It also calls subroutine GAUSS.

(3) CYLTMP - the "core" subroutine of the TEMP5 program. It calculates the temperature u according to the I. A. D. method using both subroutines TRIDAG and SPLNI and then the related integrals F1 and F2 again using SPLNI. It stores u, F1 and F2 in unformatted form on a file named TAPE3. These temperatures (u) are calculated at the RHO, ZED lattice points and are designated by the variable name U(I, J).

(4) TRIDAG - the subroutine which implements the Thomas algorithms for solving a system of simultaneous linear equations having a tridiagonal coefficient matrix.

(5) GAUSS - a subroutine for loading the volume heating source term Q with a truncated Gaussian distribution into the program.

(6) SPLNI - The subroutine which finds the third order spline function for a function y(x) given at the points (X(I), Y(I)). It is used both for integrating the F1 and F2 functions as well as for interpolating values of u at the RFIN, ZFIN lattice points, which occur halfway between the RHO, ZED lattice points. These interpolated temperatures are designated by the variable name UFIN(I, J). They enable

us to calculate temperatures out to the window's edges. SPLNI, which follows Chapter 8 of Ralston and Wilf,[14] is a modification of the IBM standard Scientific Subroutine Package subroutine SPLIE.

(7) GETDATA - obtains data from the operator. It can be used as a universal inputting subroutine for either the Batch or Intercom modes of operation of any program requiring input data. (More will be said about these two modes later.) However, it was written mainly for Intercom operation. It also calls on subroutines SSWTCH and RJUST.

(8) SSWTCH - reads in the first three data values (and prints out appropriate messages) for GETDATA control. (It should be noted that SSWTCH is not the same as the CDC Fortran subroutine bearing the same name.)

(9) RJUST - right adjusts all numerical values.

The TEMP5 program has been coded to permit operation under either Batch processing or Intercom. The latter mode permits relatively easy interactive use, as implemented under CDC Scope 3.4 with the CDC6600.

The complete Fortran listings for each of the above are given in Appendix A.

8.8 Implementation of Some of the Subroutines

8.8.1 DATINIT

The implementation of the TEMP5 program begins with the inputting of all required program parameters and the initializing of the working arrays which will eventually be used by CYLTMP. DATINIT accomplishes all of this by a call to GETDATA. Furthermore, DATINIT assigns default values to the VALUE portion of DATAIN, which is an array of TEMP5 parameters, and also assigns names and format codes to the NAME and FORMAT portions of DATAIN. This will be described in more detail in Section 8.8.4 on GETDATA.

A complete tabulation of all the required input data is given in Table 2. The table lists both the data and the variable names, their corresponding default values, formats, the particular major programming package in which each quantity is ultimately used, and a succinct description. The default values listed in Table 2 for the material properties such as refractive index, absorption coefficient, etc., pertain to KCl.

It should be noted that although all of the variables itemized in Table 2 may be inputted at this stage of the program, not all of them will actually be used in TEMP5. Many of them will be called up later in the TIKIRK and DISPLAY programs.

[14] Ralston, A., and Wilf, H. S. (1967) Mathematical Methods for Digital Computers, Vol. II, Wiley and Sons, Inc., New York.

Another factor to be noted in Table 2 is that the values of M and N have been chosen to be 80 and 20, respectively. Since the indices on the RHO and ZED coordinates extend from 0 to M+1, and, 0 to N+1, respectively, this means that the net depicted in Figure 3 consists of 82 points along the radial direction and 22 points along the axis. Meanwhile, since the indices on the RFIN, ZFIN coordinates extend from 1 to M+1, and, 1 to N+1, respectively, then the array of points at which interpolation occurs consists of 81 points along the radial direction and 21 points along the axis.

8.8.2 CYLTMP

The temperature-related terms U, F1 and F2 really constitute the principal output of the entire TEMP5 program. Computation of these quantities, as prescribed by Eqs. (29), (30), (16) and (17), are actually carried out by the subroutine CYLTMP, with the aid of TRIDAG and SPLNI. Figure 20 shows a flow chart for the CYLTMP algorithm. Table 3 gives a glossary of the variable names.

Source turn-off is accomplished in subroutine CYLTMP by setting the volume source term (array q) and "boundary" source term (array g) to 0 at the appropriate time. At the end of each τ-cycle through CYLTMP, the temperature distribution at $\tau + \Delta\tau$ has been computed where τ is the time at the start of the cycle. Thus, a check is made at the start of each cycle to see if $\tau + \Delta\tau$ is less than τ_{off}. If it is, then the cycle continues normally with the source terms "on." When $\tau + \Delta\tau$ first becomes equal to or greater than τ_{off}, a "flag" is set and a new $\Delta\tau$ is computed such that $\tau + \Delta\tau = \tau_{off}$ and the cycle continues. When the subroutine returns to the start of the next cycle, the source term is set to 0. In addition the variable NN is reset to 0 and $\Delta\tau$ is computed as was done for source turn-on.

8.8.3 TRIDAG

This is a subroutine for solving a system of linear simultaneous equations having a tridiagonal coefficient matrix. The equations are numbered from IF through L, and their subdiagonal, diagonal, and superdiagonal coefficients are stored in arrays A, B, C. The computed solution vector (V(IF), ..., V(L)) is stored in array V.

The mathematical details of all of the steps involved in solving the tridiagonal equations have been given in Section 8.4.

The coding for subroutine TRIDAG is taken from Carnahan et al[11] on page 446.

8.8.4 GETDATA

8.8.4.1 Description

This subroutine is designed for inputting problem data when a program is run under CDC6600 INTERCOM control. It may also be used, however, for inputting

Table 2. Input Data for the Implementation of the TEMP5 Program

(1) DATAIN Seq. No.	(2) Datum Name	(3) Variable Name	(4) Default Value	(5) Format Code	(6) Useage Code	(7) Description
1*	I1	I1	2	0	T	Print/punch F1, F2 and parameters.
2*	I2	I2	2	0	T, K	Print TAU, LMDA, MU, MN, N$\underline{0}$, INIT, ICNTR. Also, use 1 if IKIRKP option is desired; use 2 for IKIRK option. (see Sec. 9. 2.)
3*	I3	I3	2	0	T	Print arrays: KK, A, B, C, D, UPRIM in CYLTMP; also initial values of U, USTAR, etc.
4*	I4	I4	2	0	T	Print U and Q after initial data read-in or computation.
5*	I5	I5	2	0	T	Print array UFIN at every fifth value of both RFIN and ZFIN.
6*	I6	I6	2	0	T	Punch array UFIN and parameters.
7*	I7	I7	2	0	T	Print array U at the following RHO(I) and ZED(J) points: I=2, 2+MI, 2+2MI, 2+3MI, . . ., ≤ 81 J=2, 2+NI, 2+2NI, 2+3NI, . ., ≤ 21.
8	M	M	80	0	T	M+1 is the number of radial points at which temperature data is outputted.
9	N	N	20	0	T	N+1 is the number of axial points at which temperature data is outputted.

*For I1 through I7: If the value is set equal to 1, then appropriate output will be printed; if the value is set equal to 2, then output will be suppressed.

Table 2. Input Data for the Implementation of the TEMP5 Program (Cont.)

(1) DATAIN Seq. No.	(2) Datum Name	(3) Variable Name	(4) Default Value	(5) Format Code	(6) Useage Code	(7) Description
10	MI	MI	1	0	T	Every MI-th point in the radial direction is printed (see I 7).
11	NI	NI	1	0	T	Every NI-th point in the axial direction is printed (see I7).
12	ICNT	ICNT	1	0	T	Array U is printed out for every ICNT-th time cycle (see I7).
13	IU	IU	0	0	T	If 0, temperature distribution U initialized to U0. If 1, initial temperature distribution read-in on file tape ICARD.
14	IQ	IQ	1	0	T	If IQ = 0, initialize source Q to zero. If IQ = 1, initialize source Q to Gaussian. If IQ ≠ 0, 1 read source Q from file tape ICARD.
15	N0	N0	2	0	T	The arbitrary positive integer n_o in Eq. (82) of text.
16	NMX	NMX	11	0	T	n_{max} (see Sec. 8.6).
17	IRUN	IRUN	100	0		Not used.
18	ICARD	ICARD	5	0	T	Input file for some of the input controlled by IU, IQ.

Table 2. Input Data for the Implementation of the TEMP5 Program (Cont.)

(1) DATAIN Seq. No.	(2) Datum Name	(3) Variable Name	(4) Default Value	(5) Format Code	(6) Useage Code	(7) Description
19	IPRINT	IPRINT	6	0	T	Output file for all TEMP5 output except for some of the "interactive" output and unformatted temperature output.
20	IPNCH	IPNCH	-	0	N	In original TEMP5, identifies "punch" output file.
21	ITAP3	ITAP3	3	0	T	Unformatted output file for time-temperature.
22	ITAP4	ITAP4	4	0	T	"Interactive" input file.
23	RHO1	RHO1	0	1	T	ρ_1
24	RHO12	RHO12	1	1	T	ρ_{12}
25	ZED1	ZED1	-.5546	1	T	ζ_1
26	ZED12	ZED12	1.1092	1	T	ζ_{12}
27	DTAU0	DTAU0	.0035	1	T	$\Delta\tau_o$
28	TAUMX	TAUMX	5.0	1	T, K	τ_{max} (see Sec. 8.6).
29	TAUOFF	TAUOFF	5.0	1	T	τ_{off} (see Sec. 8.6).
30	SIG	SIG	.1292	1	T, K	Either σ or σ_e (see Eq. (33) or (37)).
31	Q0	Q0	0	1	T	If you want $A = \Delta\tau_c/2\sigma^2$ (see Eq. 37), then set Q0 = A. (Be sure $A \geq .001$; highly unlikely to be otherwise). If you want $A = 1/2\,\sigma_e^2$ (see Eq. 33), then set Q0 < .001 (say, 0).
32	U0	U0	0	1	T	Initial (uniform) temperature distribution.

Table 2. Input Data for the Implementation of the TEMP5 Program (Cont.)

(1) DATAIN Seq. No.	(2) Datum Name	(3) Variable Name	(4) Default Value	(5) Format Code	(6) Useage Code	(7) Description
33	EPS	EPS	.001	1	T	Error tolerance in spline interpolation.
34 to 37	G1(1), G1(2), G1(3), G1(4)	G1	0, 0, 0, 0	1	T	Surface heat flux (see Eqs. (33) or (37)).
38 to 41	H1(1), H1(2), H1(3), H1(4)	H1	0, .0113 .0113 .0113	1	T	Surface heat transfer coefficient (see Eqs. (33) or (37)).
42	MATERIAL	MATER	KCL	-1		Cylinder material identifier. Used for identification purposes only. It is not "used" by any program, but can, of course, be printed in TIKIRK listings and on DISPLAY plots.
43	REF. IND.	NX	1.47	1	K	Cylinder refractive index.
44	BETA	BETA	.00048	1	K	Bulk absorption coefficient (cm^{-1}).
45	THER. COND	K	.0653	1	K	Thermal conductivity (W/cm-^oC).
46	LAMBDA	LAMBDA	10.6	1	K	Wavelength (microns).
47	S1R	S1R	-.34E-5	1	K	Stress optic coefficient $S_1^\rho (^oC)^{-1}$.
48	S1T	S1T	.05E-5	1	K	Stress optic coefficient $S_1^\theta (^oC)^{-1}$.
49	S2R	S2R	.1E-5	1	K	Stress optic coefficient $S_2^\rho (^oC)^{-1}$.
50	S2T	S2T	-.1E-5	1	K	Stress optic coefficient $S_2^\theta (^oC)^{-1}$.
51	DENSITY	DEN	1.98	1	K	Density (gm/cm^3).
52	SPEC. HEAT	CP	.691	1	K	Specific heat (J/gm-^oC).
53	RADIUS	R	1.258	1	K	Radius (cm).

Table 2. Input Data for the Implementation of the TEMP5 Program (Cont.)

(1) DATAIN Seq. No.	(2) Datum Name	(3) Variable Name	(4) Default Value	(5) Format Code	(6) Useage Code	(7) Description
54	EXPER	EXPER	2	-1		Not used.
55	PWR	PW	24.7	1	K	Transmitted power P_t, in watts (see Eq. 9).
56	R1	R1	81	0		Not used.
57	Z1	Z1	11	0		Not used.
58	R2	R2	1	0		Not used.
59	PLT ? IY, 2N	IPLOT	1	0		Not used.
60	PROBNO	PROBNO	2347	-1		Problem number-for plot identification.
61	TICU	TICU	.5	1		Not used.
62	XLEN	XLEN	20.	1		Not used.
63	YLEN	YLEN	9.	1		Not used.
64	X-SCALE	SCALEX	12.	1		Not used.
65	Y1-SCALE	SCALEY1	.2	1		Not used.
66	Y2-SCALE	SCALEY2	.2	1		Not used.
67 to 71	XTITLE1 2, 3, 4, 5	XTITLE	time	-1	D	The x-axis is given a title of the form "XTITLE scale is n units/tic" where n may be scalex. Also parameter title.
72 to 76	YTITLE1 2, 3, 4, 5	YTITLE1	temp-deg. C above amb	-1	D	Similar to XTITLE, "surface" title in DISPLAY.
77 to 81	YTITLE2 2, 3, 4, 5	YTITLE2	mean temp above amb	-1		Not used.
82	OPERATOR	NAME	GIANINO	-1	D	Plot identification (required for picking up plots at central site).

Table 2. Input Data for the Implementation of the TEMP5 Program (Cont.)

(1) DATAIN Seq. No.	(2) Datum Name	(3) Variable Name	(4) Default Value	(5) Format Code	(6) Useage Code	(7) Description
83 to 87	XTI 2, 3, 4, 5		radial distance rho-(cm)	-1	D	Title for "x-axis" in DISPLAY.
88 to 92	YT1 2, 3, 4, 5		axial distance, z-(cm)	-1	D	Title for "y-axis" in DISPLAY.

N.B. 0 means "zero"; 0 means "oh".

Explanation of Columns

(1) The sequence number of the datum stored in array DATAIN.

(2) Datum name used by operator when he inputs the data. This name is a character string. E.g., I1 means 2HI1 in Hollerith notation.

(3) The symbolic name used in the TEMP5 program. The same quantity may be given a different variable name in other programs that used the quantity.

(4) The value that will be assigned to each item listed, unless a different value is inputted.

(5) 0 ≡ integer (I10) format.
1 ≡ floating point (E10.0) format.
-1 ≡ character string (6A10) format, that is, up to 60 characters are permitted.

(6) N ≡ not used.
Y ≡ used in TEMP5 program.
K ≡ used in TIKIRK program.
D ≡ used in DISPLAY program.

Table 3. Glossary of Variable Names*†

A(I)	.=.	Tridiagonal system .=. coefficient vectors.
B(I)	.=.	Tridiagonal system .=. coefficient vectors.
BETA(I)	.=.	Auxiliary variable: Thomas Algorithm for TRIDAG matrix inversion.
C(I)	.=.	Tridiagonal system .=. coefficient vectors.
D(I)	.=.	Tridiagonal system .=. coefficient vectors.
DRHO	.=.	Program control parameter .=. $\Delta\rho = (\rho_2 - \rho_1)/M$.
DTAU	.=.	Time increment parameter .=. $\Delta\tau$.
DTAU0	.=.	Time increment parameter .=. $\Delta\tau_o$.
DZED	.=.	Program control parameter .=. $\Delta\zeta = (\zeta_2 - \zeta_1)/N$.
E(I)	.=.	Space increment array .=. DRHO, DZED.
EPS	.=.	Error tolerance in iterative steps.
F1(I)	.=.	An array of integrals.
F2(I)	.=.	An array of integrals.
G(I)	.=.	Coefficient in general boundary condition.
GAMMA	.=.	Auxiliary working variables-Thomas Algorithm (see Eq. (58)).
GAUSS	.=.	Subroutine for loading Q with a truncated Gaussian distribution.
GF(X, Y, Z)	.=.	Statement function = (2.*Y*Z)/(2.+X*Y).
G/H	.=.	Given nondimensional surface temperature.
G(I)	.=.	g_1, g_2, g_3, g_4, .=. boundary condition parameter.
G1(I)	.=.	Buffer to retain input G(I). G(I) modified during program execution.
H(I)	.=.	h_1, h_2, h_3, h_4 .=. boundary condition parameter. Film coefficient.
HF(X, Y)	.=.	Statement function .=. boundary condition .=. (2.-X*Y)/(2.+X*Y) (see Eqs. (44)-(47)).

*The symbol .=. means "is defined as."

† 0 means "zero"; 0 means "oh."

Table 3. Glossary of Variable Names (Cont.)

H=0, G=0		.=.	No heat crosses boundary .=. physical significance of H and G.
H1(I)		.=.	Buffer to retain input H(I). H(I) is modified during program execution.
I		.=.	Indexing variable.
ICARD		.=.	Logical device number for card reader.
ICNT		.=.	Number of I. A. D. cycles between printouts.
ICNTR		.=.	Number of I. A. D. cycles since last printouts.
IF		.=.	Indexing variable.
II		.=.	I-1.
IKEY		.=.	Logical device number for keyboard (or card) input.
IPM(I)		.=.	Basic program parameters integer: see equivalence statements.
IPNCH		.=.	Logical device number for the card punch.
IPRINT		.=.	Logical device number for line printer.
IQ	= 0	.=.	Initialize Q to zero .=. no absorption.
	= 1	.=.	Calculated Q for Gaussian distribution.
	= 2	.=.	Read in value of Q.
IRUN		.=.	Run number.
ITAP3		.=.	Logical device number for TAPE3.
ITAP4		.=.	Logical device number for TAPE4.
ITYPE		.=.	Printing out on operators terminal (if possible). Logical device number.
IU	= 0	.=.	Initialize U (temp) to zero.
	= 1	.=.	Read in initial value of U.
I1		.=.	Punch and print F1, F2, and parameters. Control for output.
I2		.=.	Print TAU, LMDA, MU, NN, NO, ICNT, ICNTR. Control for output.
I3		.=.	Print KK, A, B, C, D, UPRIM .=. Initialize values of U, USTAR, etc. TRIDAG debug.
I4		.=.	Print U and Q after initial data read-in or computed.

Table 3. Glossary of Variable Names (Cont.)

I5	.=.	Print I, J, UFIN(I, J, K).
I6	.=.	Punch UFIN and parameters.
I7	.=.	Print I, J, U(I, J) on half increment shifted lattice.
J	.=.	Indexing variable.
JJ	.=.	Varies with J for indexing.
K	.=.	Indexing variable .=. see cross reference.
KK, KS, L	.=.	Indexing variables.
LMDA	.=.	$\lambda = \Delta\zeta(\Delta\rho)$.=. Special parameter.
M	.=.	ρ-net length .=. $M \cdot \Delta\rho = 1 - \rho_1$.
MI	.=.	Step size for output do-loop .=. ρ-direction.
MS	.=.	Number of given data points.
MU	.=.	$\mu = \Delta\tau/(\Delta\zeta)^2$.
M1	.=.	M+1. Loop indexing variable.
M2	.=.	M1+1. Loop indexing variable.
N	.=.	Special parameter .=. Count of Tau increments.
NF	.=.	Number of time intervals.
NFF	.=.	Duplicate storage for NF.
NI	.=.	Step size for output do-loop .=. zed direction.
NMX	.=.	N_{max}.
NN	.=.	n.
NS	.=.	Number of Spline Interpolated arguments.
NSEQ	.=.	Sequencing index for punched card output.
N0	.=.	Delta Tau doubling count.
N1	.=.	N+1.
N2	.=.	N1+1.
PARAM(I)	.=.	Basic program parameters, REAL, see equivalence statements.
Q(I, J)	.=.	Source distribution.

Table 3. Glossary of Variable Names (Cont.)

QQ	.=.	Working variable used in do-loop for Q(I, J).
QUA(I)	.=.	Values of integral SS from X(I) to X(N).
Q0	.=.	Control parameter for calculation of Q(I, J) in GAUSS.
REX	.=.	RNN/RNO.
RFIN(I)	.=.	Even R-Lattice point coordinates.
RHO(I)	.=.	Half-interval shifted.
RHO1	.=.	ρ_1.
RHO12	.=.	$1 - \rho_1$.
RI	.=.	II.
RJ	.=.	JJ .=. RJ/2.
RM	.=.	M.
RN	.=.	N.
RNN	.=.	Real representation of NN to avoid mixed mode in Delta Tau calculation.
RN0	.=.	Real representation of N0 to avoid mixed mode in Delta Tau calculation.
RRR(I)	.=.	RFIN(I).
SIG	.=.	Variance of Gaussian beam intensity dist.
SIG2	.=.	SIG squared.
SS1(I)	.=.	First derivatives of U.
SS2(I)	.=.	Second derivatives of U.
TAU	.=.	Nondimensional time .=. τ.
TAUMX	.=.	Maximum tau to be computed .=. τ_{max}.
TFIN	.=.	Array of τ-values for which we take printed or punched output.
U(I, J)	.=.	Array of nondimensional temperatures on RHO-ZED lattice.
UCARD	.=.	UFIN buffer for card and line printer output.
UFIN(I, J, K)	.=.	U on RFIN-ZFIN lattice at Kth time.

Table 3. Glossary of Variable Names (Cont.)

UPRIM(I)	.=.	Storage of results of solutions to tridiagonal equations.
USPLN(I)	.=.	Temporary work space used between Rho-splining and Zed-splining.
USTAR(I, J)	.=.	Intermediate temperature distribution in I. A. D. method.
U0	.=.	U(I, J). For uniform initial temperature option.
V	.=.	Computed solution vectors in TRIDAG.
X(I)	.=.	Array of strictly increasing abscissa.
XR(I)	.=.	RHO(I).
XX	.=.	Work space for desired abscissas.
XZ(I)	.=.	RHO protection.
YU(I)	.=.	UFIN(I, J).
ZED(I)	.=.	Nondimensional axial coordinate [cm] .=. Z/A.
ZED1	.=.	Lower Zed boundary .=. ζ_1.
ZED12	.=.	$\zeta_2 - \zeta_1$.
ZFIN(I)	.=.	Lattice coordinates that land on boundary instead of half shifted position. Used for CYLTMP Algorithm.
ZJ	.=.	JJ.
ZZZ(I)	.=.	ZFIN(I).

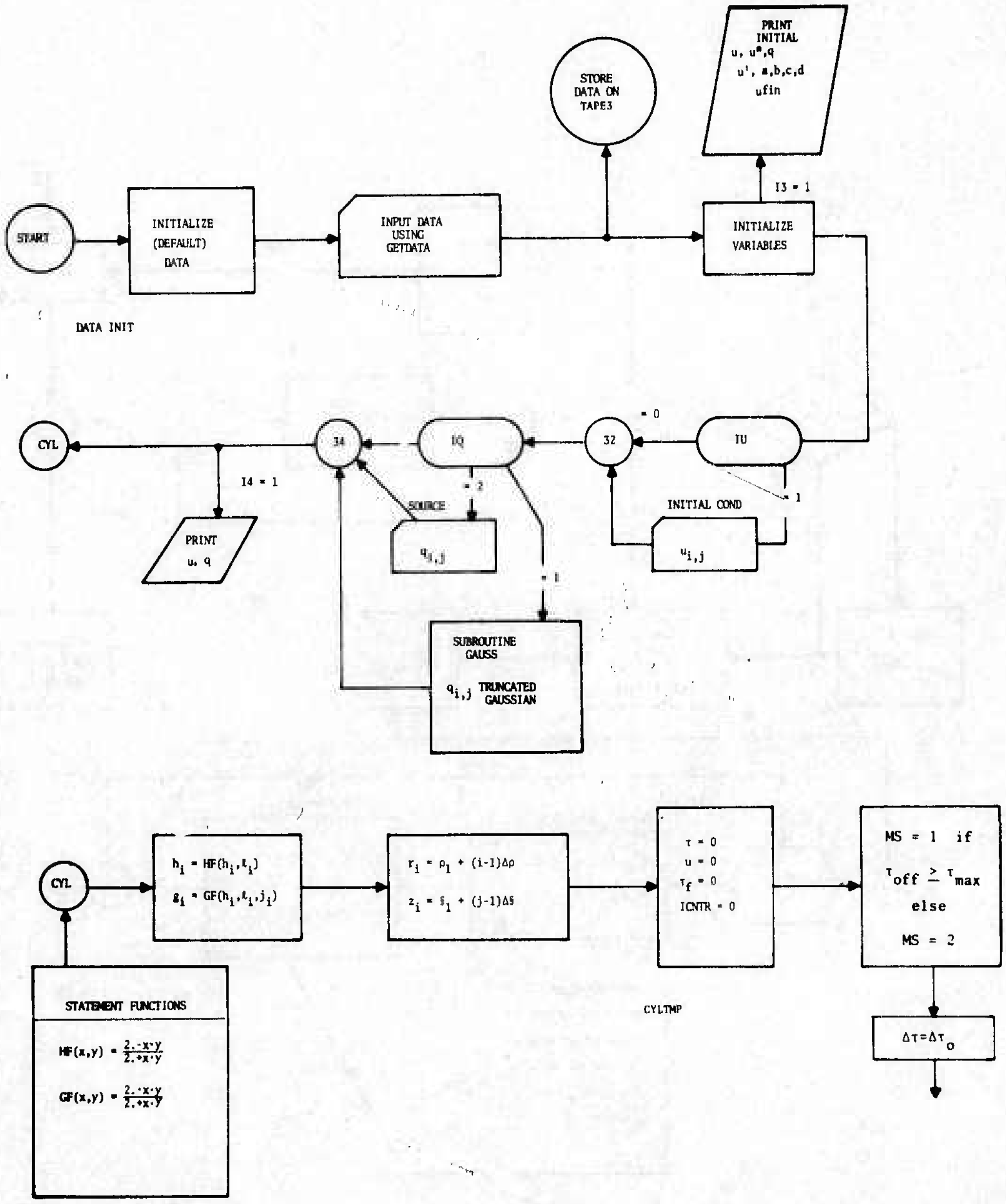

Figure 20. Flow Chart for the CYLTMP Algorithm (Sheet 1 of 4)

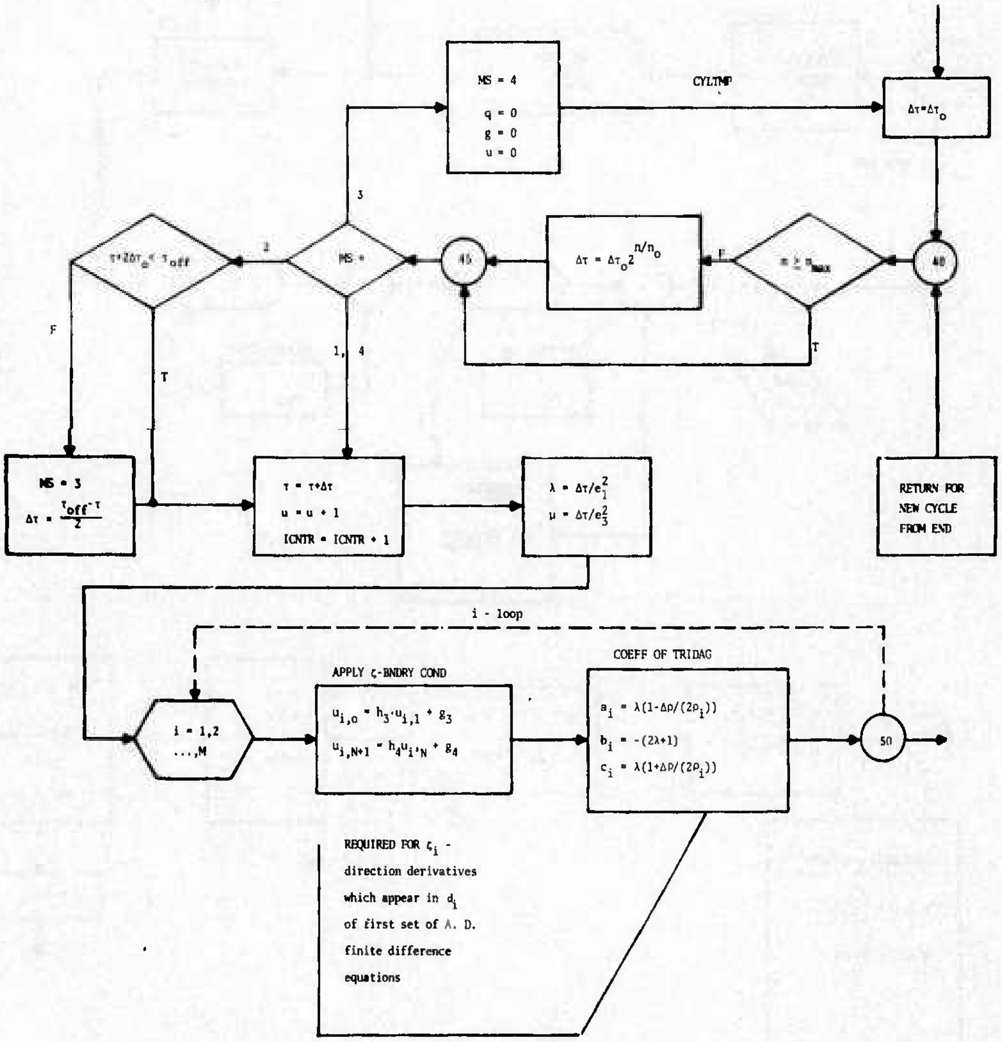

Figure 20. Flow Chart for the CYLTMP Algorithm (Sheet 2 of 4)

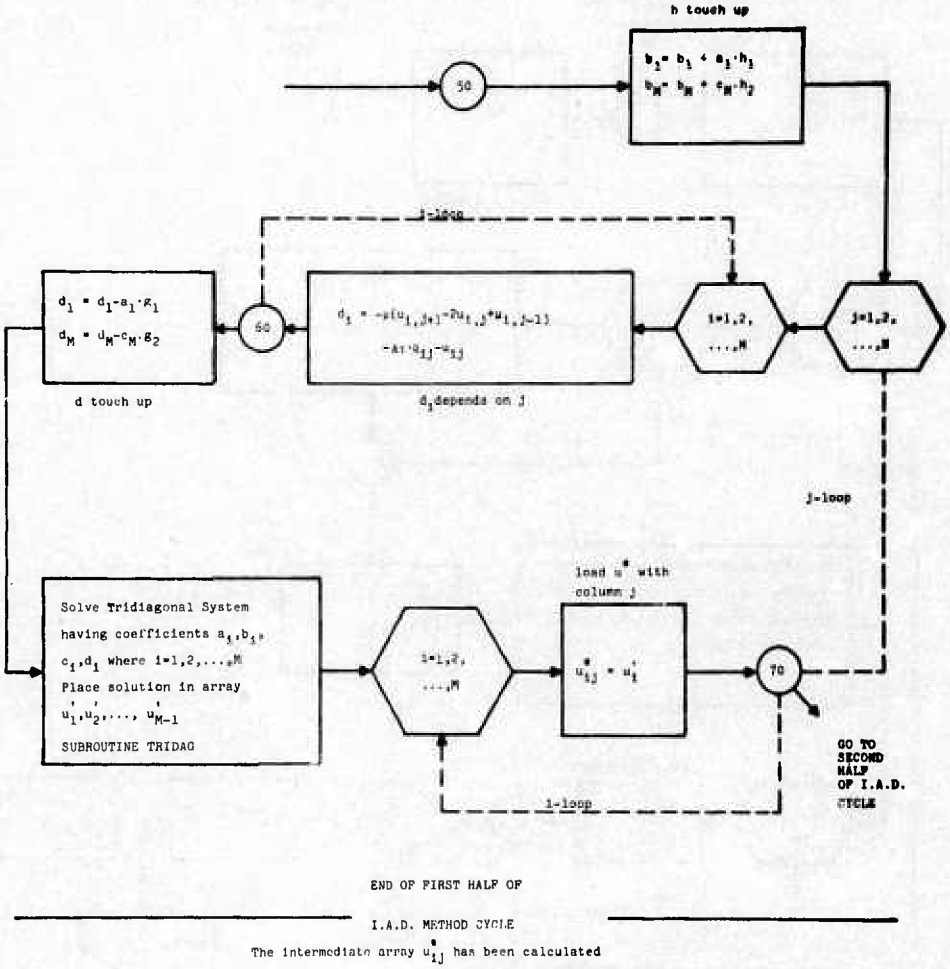
h touch up
$b_1 = b_1 + a_1 \cdot h_1$
$b_M = b_M + c_M \cdot h_2$
50
j-loop
$d_1 = d_1 - a_1 \cdot g_1$
$d_M = d_M - c_M \cdot g_2$
d touch up
60
$d_i = -\rho(u_{i,j+1} - 2u_{i,j} + u_{i,j-1})$
$-\Delta t \cdot q_{ij} - u_{ij}$
d_i depends on j
i=1,2,
...,M
j=1,2,
...,M
j-loop
Solve Tridiagonal System
having coefficients $a_i, b_i,$
c_i, d_i where i=1,2,...,M
Place solution in array
$u'_1, u'_2, \ldots, u'_{M-1}$
SUBROUTINE TRIDAG
i=1,2,
...,M
load u^* with
column j
$u^*_{ij} = u'_i$
70
GO TO
SECOND
HALF
OF I.A.D.
CYCLE
i-loop
END OF FIRST HALF OF
I.A.D. METHOD CYCLE
The intermediate array u^*_{ij} has been calculated

Figure 20. Flow Chart for the CYLTMP Algorithm (Sheet 3 of 4)

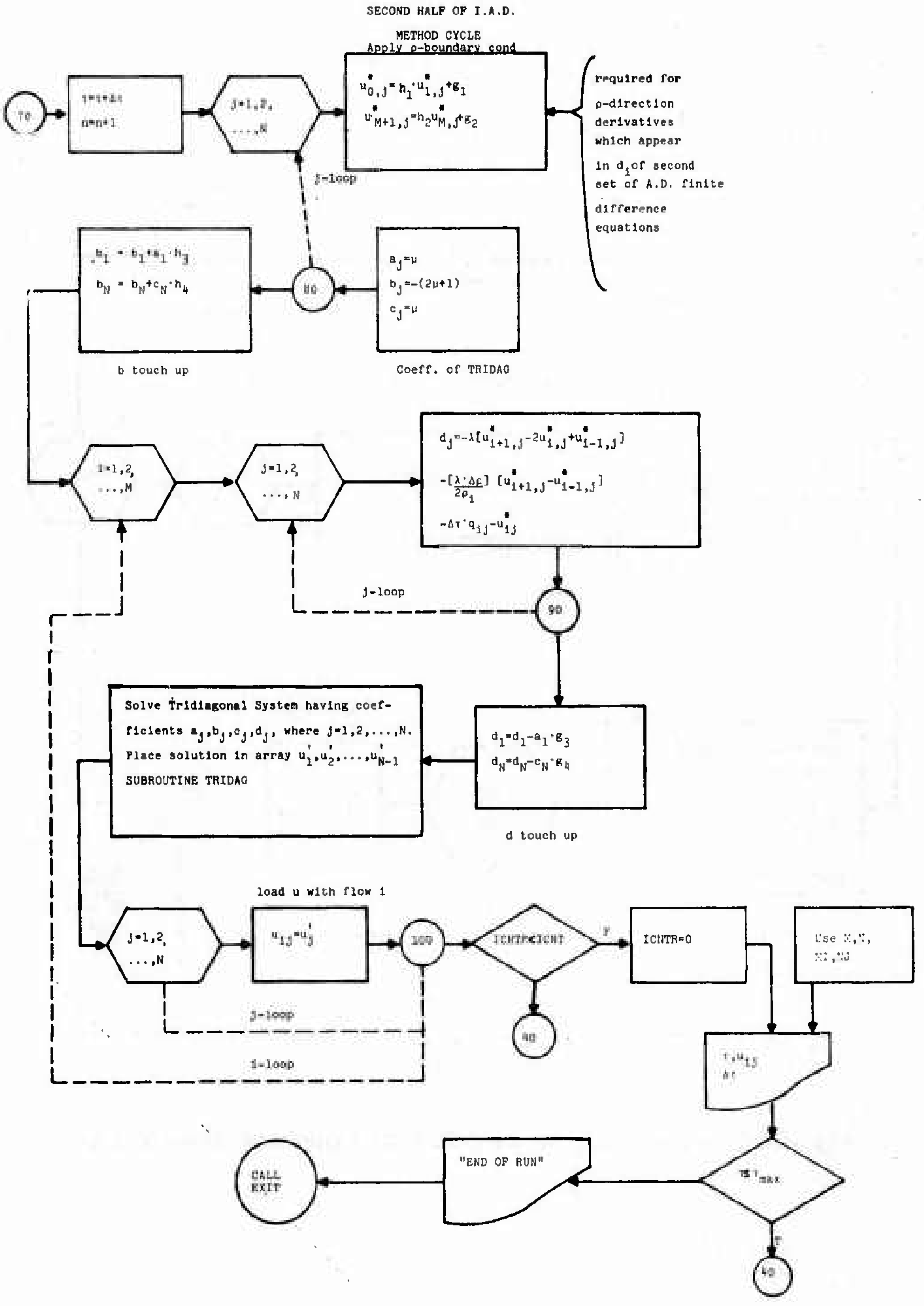
SECOND HALF OF I.A.D.
METHOD CYCLE
Apply ρ-boundary cond
TO
$\tau=\tau+\Delta\tau$
$n=n+1$
$j=1,2,\ldots,N$
$u^*_{0,j}=h_1 \cdot u^*_{1,j}+g_1$
$u^*_{M+1,j}=h_2 u^*_{M,j}+g_2$
required for ρ-direction derivatives which appear in d_i of second set of A.D. finite difference equations
j-loop
$b_1 = b_1+a_1 \cdot h_3$
$b_N = b_N+c_N \cdot h_4$
80
$a_j=\mu$
$b_j=-(2\mu+1)$
$c_j=\mu$
b touch up
Coeff. of TRIDAG
$i=1,2,\ldots,M$
$j=1,2,\ldots,N$
$d_j=-\lambda[u^*_{i+1,j}-2u^*_{i,j}+u^*_{i-1,j}]$
$-[\frac{\lambda \cdot \Delta\xi}{2\rho_i}]\,[u^*_{i+1,j}-u^*_{i-1,j}]$
$-\Delta\tau \cdot q_{ij}-u^*_{ij}$
j-loop
90
Solve Tridiagonal System having coefficients a_j,b_j,c_j,d_j, where $j=1,2,\ldots,N$. Place solution in array $u'_1,u'_2,\ldots,u'_{N-1}$
SUBROUTINE TRIDAG
$d_1=d_1-a_1 \cdot g_3$
$d_N=d_N-c_N \cdot g_4$
d touch up
load u with flow i
$j=1,2,\ldots,N$
$u_{ij}=u'_j$
100
ICNTR<ICNT
F
ICNTR=0
Use M,N, NI,NJ
40
j-loop
i-loop
τ,u_{ij}
$\Delta\tau$
$\tau\le\tau_{max}$
"END OF RUN"
CALL EXIT
T
40

Figure 20. Flow Chart for the CYLTMP Algorithm (Sheet 4 of 4)

data when the program is "batched." The data which is obtained through GETDATA is stored in array DATAIN as an n by 3 array, where n is the maximum number of data to be inputted. Each datum consists of three parts (hence n x 3), which is herein referred to as VALUE, NAME, and FORMAT. VALUE is the numerical or character string value which will be stored for the datum; NAME is a character string (up to ten characters) by which the datum may be identified. FORMAT is a code number (-1, 0, or 1) which is used to indicate that the datum is to be interpreted respectively as: character string, integer, or real (floating point) number.

The first three data required by GETDATA are not part of DATAIN, but are used to control the operation of GETDATA. In INTERCOM mode each of these three data are preceded by questions as follows:

1) READ DATA FILE -n?- (n is the file number)
2) DEFAULTS LISTED?-
3) NAME-VALUE MODE?-

The input data is either YES or NO (the default is NO). If the answer to 1) is YES, then array DATAIN is filled from the first record on TAPE-n. Normally, DATAIN should be filled with defaults in the calling program. These default values will then be replaced by new "default" values obtained from TAPE-n.

If the answer to 2) is YES, then the default DATAIN is printed out in the form:

NAME=VALUE.

FORMAT is indicated by the form in which VALUE is printed. Integers are numerical values with no decimal point; floating point numbers are printed with a decimal point and possibly an exponent. Character strings are indicated by single quotes. The default values are listed in the order in which they are stored in DATAIN.

If the answer to question 3) is YES, then the NAME-VALUE input-mode is used to input data; otherwise, the LIST mode is used. These two input modes are described in detail below.

After these "control" data have been inputted, the DATAIN data are inputted.

8.8.4.2 List Mode

In the LIST mode, GETDATA starts out by printing the first NAME in DATAIN and then waits for the operator to type the VALUE to be assigned to NAME. Similarly, it sequences up to the last NAME in DATAIN, and then prints out a message "data input complete," after the last VALUE in the sequence has been given by the operator. The operator defaults a value by punching the "space," "carriage return" keys (denoted below as SP, CR, respectively). If at any time the operator realizes that an error has been made in typing any preceding VALUE (not just the current one), it may be corrected by typing $, CR. This causes a shift to the NAME-VALUE mode, under which both the VALUE and NAME must be given by the operator. By this means, VALUES which were assigned earlier in the sequence can be changed. After the correct name and value have been given by the operator, the LIST mode continues where it left off. For example, if the NAME, OPERATOR was listed and the operator had typed $ next to this NAME, the same NAME would be typed again upon return from the NAME-VALUE mode. It might be noted that if a VALUE has been typed (and not signaled with $) which is incompatible with the FORMAT to be associated with that value, then the subroutine automatically goes into the NAME-VALUE mode after typing the message: "wrong data type-try again."

The NAME-VALUE mode has the feature of terminating input, whenever SP, CR are typed, when the program is waiting for a new NAME, VALUE pair. Thus, it may be convenient to terminate inputting when in the LIST mode, by typing $, then SP, CR after the NAME-VALUE mode has been initiated.

8.8.4.3 Name-Value Mode

In this mode, the program first types out the words "name" (6 blanks) "value......", and then waits expectantly with the type head directly under the "n" of "name." The operator must then type the NAME and corresponding VALUE, with the VALUE starting under or after the "v" of "value." The "....." after "value" indicate the maximum field for inputting numerical data. If the operator types a NAME which is unrecognizable, the message "try again" is typed, followed by another "name" (6 blanks) value.....". A mistake is corrected by merely typing the NAME of the datum to be corrected followed by its correct VALUE. (If a format mistake has been made--see LIST MODE--then the message "wrong data type-try again" is printed indicating that the name-value should be retyped. The "name   value....." header is printed only once (or every time an unrecognizable NAME has been inputted) since thereafter it is easy to start NAME and VALUES in the correct positions. (The typehead is always placed under "n" when new data is expected.)

Data input is terminated by typing SP, CR whenever the typehead is under the "n" column of the header.

The field width for all data is ten. Specifically, integers (format=0) are read under I10 format; reals (format=1) are read under E10.0 format. Character strings (format=-1) are read under A10 format, but up to 60 characters may be inputted "at once" provided contiguous space in DATAIN has been provided for them. For example, suppose that DATAIN(10, 2), DATAIN(11, 2), DATAIN(12, 2) are given the NAMES XTITLE(1), XTITLE(2), XTITLE(3), respectively (implying that space for up to 30 "XTITLE" characters has been provided for), then the entire "XTITLE" could be inputted as follows:

NAME VALUE.....

XTITLE(1) DISTANCE ALONG X-AXIS (INCHES)

In the LIST MODE it is also possible to input six numerical data values at "one time." This should only be done when the job is "batched," in which case six data values may be placed on one card, each one occupying a 10-column field. Data which is not to be changed should be replaced by blanks. All or some of the data may be defaulted by using an end-of-record card after the last data to be inputted, causing GETDATA to return to the program or subroutine. If no data is included in the input file a call to GETDATA will have no effect (default DATAIN as provided by the calling program will be used), except the end-of-file indicator INDIC will be set to 1.

GETDATA has a special "gimmick" in that if it is called with a value of INDIC other than 0, it may be used to input a single datum in the LIST mode. To be used in this mode, INDIC should be set equal to the location in DATAIN of the value desired, for example, 50 for DATAIN (50, 1).

According to standard Fortran practice, trailing blanks (of numerical values) are treated as zeros. For example, 10E1 would be interpreted as 10E1b̸b̸b̸b̸ (that is, 10^{10000}) and 1 would be interpreted as 1b̸b̸b̸b̸b̸b̸b̸b̸b̸ (that is, 1×10^9). GETDATA calls a subroutine (RJUST) which removes all trailing blanks from numerical (but not character string) data so that trailing blanks are not treated as zeros.

8.8.4.4 Entry-Parameter List:

SUBROUTINE GETDATA (DATAIN, NV, IIN, IOUT1, IOUT2, IIN1, ISIZE, ISIZET, INDIC) Parameters:

DATAIN - 3 dimensional array of values, names and formats.

NV - amount of data to be inputted.

IIN - input file number for GETDATA.

IOUT1 - "interactive" (primary) output file for GETDATA.

IOUT2 - secondary output file (stores formatted names and values which are returned by GETDATA).

IIN1 - "scratch" input/output file for reading in "default" values of DATAIN and outputting DATAIN as modified by GETDATA. (Unformatted i/o).

ISIZE - DATAIN is assumed to be dimensioned (ISIZE, 3) in the calling program. It is the size of the first dimension of DATAIN.

ISIZET - 3* ISIZE.

INDIC - an end of file indicator. A value of 1 is returned if an end-of-file on input occurs. If INDIC is given a value other than 0 in the calling program, GETDATA will go into the LIST mode to obtain DATAIN (INDIC-).

When operating under INTERCOM, files IIN and IOUT1 should be "connected." The storage required for GETDATA plus its two required subroutines RJUST and SSWTCH is 266 words.

8.8.4.5 Algorithm

All data "cards" are read using 6A10 format. If the first word is blank, then the subroutine goes to the next "card" (LIST-mode) or terminates (NAME-VALUE mode). In the LIST mode, fields are searched for the first blank field, upon which the next "card" is read. In NAME-VALUE mode, the search is made only if the FORMAT code for the datum is -1, indicating a possible character string greater than 10 characters. In LIST mode, a search is made of each field to see if $ occurs using AFCRL subroutine MXGETX. If it does, a jump is made to the NAME-VALUE mode of input. All values which are to be interpreted as numbers (integer or real) have their character string representations right adjusted using PML subroutine RJUST. The conversion from character string to coded number is done with the DECODE statement using the appropriate format (I10, E10.0, or A10).

The CDC subroutine ERRSET is called in case of a bad format. A bad format causes a jump to NAME VALUE mode of input.

8.8.4.6 Special Caution and Features

There are three different formats recognized by GETDATA: floating point (E10.0), integer (I10), and character string (6A10).

These formats are given the codes 1, 0, -1, respectively. The E10.0 format converts any decimal number which can be "sensibly" written as a string of ten or less characters into CDC6600 floating point number representation. Examples of permissible character strings are:

```
328.5678E4
328.5678+4     (the E may be omitted)
3285678.
3285678        (a decimal point is not necessary)
-5.77E-10
```

Specifically, a floating point number may be written with or without an exponent (which may be indicated by the letter E followed by a signed or unsigned integer OR a signed integer). It may or may not have a decimal point. Blanks are ignored.

The I10 format converts any decimal integer which can be written as a sequence of 10 or less characters from the set [+, -, 0, . . . , 9] into a CDC6600 integer. Trailing, as well as leading blanks within the field are effectively ignored. This is convenient since it is easier to input 1 for instance, as opposed to b̸b̸b̸b̸b̸b̸b̸b̸b̸1 or 0000000001. Note, however, that 3b̸b̸2 would be interpreted as 3002, that is, intermediate blanks are considered to be zeros. (Note that an all blank field is NOT equivalent to 0 for GETDATA.)

The 6A10 format allows character strings of up to 60 characters to be inputted "at once." However, one must make sure that sufficient space has been provided to receive character strings of length greater than 10, since each computer word holds a maximum of 10 characters. Any of the 64 characters listed in Appendix A of the CDC Fortran Extended Manual (more or less equivalent to the set on an INTERCOM teletype terminal) are permissible characters in the string. However, the character $ has special significance. When operating in the LIST mode, its appearance signifies that a mistake has been made in inputting some value, and the subroutine temporarily reverts to the NAME-VALUE mode. In this mode, $ has no special significance and is accepted as a legitimate character.

GETDATA assumes that DATAIN has been filled with default VALUES, as well as with the desired NAMES and FORMATS. This initialization of DATAIN can be done by the calling program OR by GETDATA itself, by reading in a DATAIN record from file IIN1.

It is usually convenient to equivalence DATAIN to a block of variables in the calling program. This simplifies subsequent handling of the values returned by GETDATA to the calling program.

GETDATA also prints out the following error messages to aid the programmer:

i) "try again" — Occurs when in the NAME-VALUE mode and an unrecognizable NAME is given.

ii) "file n is empty" — Occurs when an attempt is made to fill DATAIN from an empty file.

iii) "wrong data type - try again" — Occurs when a bad format is given for the datum.

9. TIKIRK PROGRAM

9.1 Introductory Remarks

The principal objective of the TIKIRK program is to compute the Kirchhoff intensity function, as given in Eqs. (23) or (28), Volume I. Before this can be accomplished, however, the file TAPE3 containing the nondimensional temperature w versus nondimensional time τ, as outputted by program TEMP5, must be available. Besides providing the nondimensional mean temperacure distributions F1 and F2 mentioned previously, this file also provides as the first record an array of constants which are required to dimensionalize the data into real temperature versus real time (cf, Sections 3, 4, and 5 of Volume I and Table 2 of Volume II). For a more complete description of this file, see Section 9. 5.

9.2 Program Options

The TIKIRK program has been set up to operate under two different options; each one being brought into play by an appropriate choice of the parameter I2 in TEMP5 (see Table 2). The first option uses subroutine IKIRK, which calculates the intensity I as a function of space and time for a Gaussian source term. It does so using a 24-point Gaussian integration routine. It is the option that would be used under most circumstances. The second option constitutes a special test case. A subroutine called IKIRKP is used to evaluate the intensity functions on either one of the two mutually orthogonal axes going through the Gaussian focal point for the special case of a window having a uniform mean temperature.

Allowing the control parameter I2 in the TEMP5 program to remain equal to its default value of 2, causes the first option to be utilized, while setting I2=1 brings the second option into play.

Since the form of numerical quadrature employed in option #1 may not be accurate for all parameter values which occur in practice, a third option, which uses a subroutine called IKIRK1, is also available. This program is highly accurate (because its integration methods are more exact), but it is extremely slow. It should be used for relatively small ranges of the space-time variables, for example, as a "spot check" for IKIRK.

9.3 Principal Functions and Subroutines

The TIKIRK program requires that various operations, such as integration, interpolation, Bessel function computation, etc., be carried out during the process of its execution. These operations are performed by various function subprograms and subroutines. The names of these functions and subroutines are listed below, together with their principal tasks:

(1) TIKIRK - the main program which calls the other subroutines and subprograms into execution. It also acts as the input/output interface for the main real functions IKIRK, IKIRKP and IKIRK1 (see below).

(2) IKIRK - the main real function for option #1.

(3) PHI - the function which computes $\Phi^{\rho,\theta}$.

(4), (5) J0 and J1 - real functions; compute $J_0(\rho v)$ and $J_1(\rho v)$, respectively.

(6) RTAPE3 - subroutine; reads and linearly interpolates (in time) temperature values from TEMP5. It also linearly interpolates in time and then outputs the dimensionalized window temperature function in a form suitable for plotting via program DISPLAY.

(7), (8) ALI and ATSE - interpolation subroutines for PHI. ALI uses the Aitken-Lagrange method.

(9) DQG24A - subroutine; computes x-values for Gaussian integration.

(10) DQG24B - subroutine; does Gaussian integration.

(11) IKIRKP - the main real function for option #2.

(12) COMPUTE - subroutine; computes the approximations to the integrals which are used in option IKIRKP.

(13) JI - a real function which computes moments of Bessel functions.

(14), (15) BESJF and BESJ - a function and a subroutine, respectively, which compute the Bessel function for a given argument and order.

(16) GETDATA - a subroutine for interactively inputting data.

(17), (18) SSWTCH and RJUST - subroutine used by GETDATA. (See Sections 8.7 and 8.8 for more detailed explanations of GETDATA, SSWTCH and RJUST.) The listings for these two subroutines have already been given in Appendices A.8 and A.9.

(19) PRT - printed output subroutine.

All three options mentioned above use the same "core package" of the following function subprograms and subroutines in their execution: TIKIRK, PHI, J0, J1, RTAPE3, ALI, ATSE, GETDATA, SSWTCH, RJUST and PRT. In addition to these, option #1 uses IKIRK plus the subroutines DQG24A and DQG24B, while option #2 utilizes IKIRKP plus COMPUTE, JI, BESJF and BESJ.

We have given this entire package of 19 main programs, subroutines, etc., constituting the TIKIRK program for options #1 and #2 only, the permanent file name (PFN) of TIBX.

The complete Fortran listings for each of the above function subprograms and subroutines are given in Appendix B.

9.4 Inputting the Data

After program TEMP5 has been executed, output file TAPE3 has been produced and the TIKIRK program attached, various program control data and constants pertaining to the calculation of the intensity function must be inputted, regardless of the option desired. A list of these data is given in Table 4. (The array containing this information is called DATAIN1 in the TIKIRK program.) The column headings are identical with those of Table 2, except that there is no Useage Code column included here. Their meanings are cited in a footnote in the table.

The total "load" storage required for the TIKIRK program is 56133 B words. (The program will operate with a core memory of 60K.) Single precision is used for most calculations. In fact, a comparison of IKIRK and IKIRKP indicates agreement to 4 significant figures.

Since the maximum number of sample "v-values" is 100, then MP should be ≤100. If more sample values are required, then array BUF should be dimensioned accordingly. Producing the full array of 100 × 100 function values takes 327 cpu secs (with OPT=1).

9.5 Program Files

The TIKIRK program depends on unformatted output from the TEMP5 program and requires up to 6 files. The names of the files used are (in the order they appear in the program statement):

TAPE4 - "Interactive" input file for inputting data via GETDATA. It is used for formatted read and must be set to INPUT for batch operation.

TAPE5 - "Interactive" output file for outputting messages from GETDATA and and for outputting a small amount of program flow information.

TAPE3 - Unformatted file outputted by TEMP5. This file, among other things, contains the mean temperature distribution functions F1 and F2 required by IKIRK and IKIRKP. In addition, the first record is the 100 by 3 array referred to as DATAIN containing various constants required by TIKIRK and contained in Table 2. The following temperature records are assumed to be of the form:

NF, TFIN, RFIN(82), ZFIN(22), UFIN(82, 22), F1(82), F2(82)

TAPE7 - Unformatted file containing the intensity distribution function in a form suitable for DISPLAY. The first two records are the 100 by 3 data arrays DATAIN and DATAIN1, the contents of which contain all pertinent program parameters as well as labeling information for DISPLAY. All subsequent records are of the form:

Table 4. Program Control Data and Constants Pertaining to the Calculation of the Intensity Function. The column headings are identical with those of Table 2, except that there is no Useage Code column included here.

(1)	(2)	(3)	(4)	(5)	(6)
Seq.	Datum	Variable	Default	Format	
No.	Name	Name	Value	Code	Description
1	X0	X0	1500.	1	Gaussian focus X_o (meters).
2	X1	X1	1000.	1	Minimum X-value (meters).
3	X2	X2	2000.	1	Maximum X-value (meters).
4	RHOP1	RHOP1	0.	1	Minimum ρ'-value (cm).
5	RHOP2	RHOP2	2.	1	Maximum ρ'-value (cm).
6	MP	MP	100	0	To calculate J values of intensity along the ρ' (or v) axis, where J = any integer, and have each calculation spaced by ρ'_{max}/J (or v_{max}/J) units, set MP = J + 1.
7	NP	NP	100	0	To calculate K values of intensity along the X (or u) axis, where K = any integer, and have each calculation spaced by $(X_{max} - X_{min})/K$ [or, $(u_{max} - u_{min})/K$] units, set NP = K + 1.
8	T1	TIM(1)	10.	1	Array of time values for function evaluation (seconds). Note that if $t_{i+1} < t_i$ then the program stops. Never set T1 = 0; use some small number instead, e.g., 1E-6.
9	T2	TIM(2)	-1	1	
-	-	-	-	-	
17	T10	TIM(10)	-1	1	
18	EPSI	EPSI	.001	1	Used by IBM Sci. Sub. ALI in interpolation of Φ^ρ, Φ^θ.
19	MINT	MINT	6	0	Used by IBM Sci. Sub. ALI and ATSE in interpolation of Φ^ρ and Φ^θ, MINT is the number of points used in the interpolation.
20	IPRNT	IPRINT	1	0	Use 1 for controlling debug output. Use 2 when producing a TAPE8 file for plotting purposes.
21	NGAUS	NGAUS	24	0	Number of points for Gaussian integration. Note that this number should be changed if and only if the Gaussian integration subroutine is changed.

Table 4. Program Control Data and Constants Pertaining to the Calculation of the Intensity Function. The column headings are identical with those of Table 2, except that there is no Useage Code column included here. (Cont.)

(1)	(2)	(3)	(4)	(5)	(6)
Seq. No.	Datum Name	Variable Name	Default Value	Format Code	Description
22	MODE	MODE	2	0	Use 1 if you want I(X, ρ', t). Use 2 if you want I'(u, v, t). (See Eqs. (28) and (23)).
23	UMIN	UMIN	-40.	1	Minimum u-value.
24	UMAX	UMAX	40.	1	Maximum u-value.
25	VMIN	VMIN	0.	1	Minimum v-value.
26	VMAX	VMAX	10.	1	Maximum v-value.
27 to 31	ST1 2, 3, 4, 5	-	Kirchhoff intensity function	-1	"Surface" title (see DISPLAY).
32 to 36	PTI 2, 3, 4, 5	-	Time (seconds)	-1	"Parameter" title (see DISPLAY).
37 to 41	XTI 2, 3, 4, 5	-	Nondimensional radial distance, V	-1	"X-axis" title (see DISPLAY and note below).
42 to 46	YTI 2, 3, 4, 5	-	Nondimensional axial distance, U	-1	"Y-axis" title (see DISPLAY and note below).
47	MSKIP	-	5	0	Of the J values of intensity calculated along the ρ' (or v) axis (see MP), every MSKIP-th value will be printed out.
48	NSKIP	-	5	0	Of the K values of intensity calculated along the X (or u) axis (see NP), every NSKIP-th value will be printed out.

NOTE: If mode = 1, then the above x, y-titles are replaced by "radial distance, rho-prime (cm)" and "axial distance, X (relative to gauss focus) (cm)," respectively.

N.B. 0 means "zero; o means "oh".

Explanation of Columns

(1) The sequence number of the datum stored in array DATAIN1.
(2) Same as in Table 2.
(3) The symbolic name used in the TIKIRK program. A blank variable name means that that part of DATAIN1 has not been equivalenced to another variable.
(4) Same as Table 2.
(5) Same as Table 2.

I, NP, U, T, MP, XMIN, XMAX, (MP intensity values)

where

I = 1, ... NP for each value of time, T

NP = number of axial points

U = axial distance (either u or x depending on mode)

T = dimensionalized time

MP = number of radial points

XMIN = minimum radial distance (either VMIN or RHOP1 depending on mode)

XMAX = maximum radial distance (either VMAX or RHOP2 depending on mode)

TAPE8 - Unformatted file containing the temperature distribution function in a form suitable for display. The first record contains the 100 by 3 data array DATAIN. All subsequent records have the same form as that listed above for TAPE7 except:

U = distance along window axis (cm)

XMIN = inner window radius (usually 0)

XMAX = outer window radius

(MP temperature values)

TAPE6 - Formatted "output" file. This file contains output suitable for printing in the following sequence:

1) Contents of DATAIN
2) Contents of DATAIN1
3) Array of x-values used for Gaussian integration (if IPRNT=1 and IKIRK is called).
4) I, U, XMIN, XMAX, T every r^{th} I value
Intensity (I, J), J=1, MP, 5 if IPRNT=1

9.6 Implementing the Program

9.6.1 GENERAL INSTRUCTIONS

All of the TIKIRK data listed on Table 4 are inputted by two calls to subroutine GETDATA, regardless of the option desired. Normally, in the first call to GETDATA the required data (viz, the first DATAIN array) are obtained from file

TAPE3 by answering "yes" to the query READ DATA FILE-3? Then no changes are made to these data by returning a "space" in the "name value" mode of inputting data. On the second call to GETDATA, the operator always answers "no" to the query READ DATA FILE-7? and "yes" to the query NAME-VALUE MODE? At this point he enters the names and values of all of the input data whose numerical values differ from the default values as shown in Table 4.

The above information is sufficient for inputting the data when using the first option (that is, IKIRK). However, for those circumstances in which options #2 or #3 are desired, additional instructions are required and will be discussed in the next two sections.

Typical detailed commands which can be used to run all of the programs in both the Intercom and Batch modes are listed in various Attachments after Section 11. The "A" attachments pertain to full system operation in the Intercom mode; the "B" attachments exhibit typical control deck setups used to operate the system in the Batch mode.

Attachment 1 shows how to initiate and run a typical TEMP5- and TIKIRK-type calculation, catalog the results on permanent file and then print out these results. If a TEMP5 calculation has already been made and cataloged, Attachment 2 reveals how to change a few of the input variables so that a new temperature distribution may be obtained. If the TEMP5 calculation has been completed and cataloged, Attachment 3 indicates how to make changes in the TIKIRK parameters so that either a different portion of the former diffraction pattern or a completely new diffraction pattern will be produced with each change. Attachment 4 lists the commands necessary to produce the file, called TAPE8, which contains the temperature distribution in the window. This file is required in order to plot the temperatures.

Throughout all of the attachments, PFN stands for "permanent file name" and LFN for "logical file name."

9.6.2 SPECIAL INSTRUCTIONS FOR IKIRKP OPTION

As mentioned previously, the IKIRKP option will be employed when I2=1 in TEMP5. It then calculates the intensities along either the X- or the ρ'-axes if MODE is set equal to 1, or, along either the u- or the v-axes if MODE=2. The choice of the value for MODE is made, of course, at the second call to GETDATA when inputting the data for the TIKIRK program. Specifically, IKIRKP assumes that the window temperature is constant throughout and that it may or may not be a function of time. This assumption considerably simplifies the integrations delineated in Eq. (23), Volume I, which lead to the intensity function. The details of the mathematics leading to the evaluation of $I'(u, 0, t)$ and $I'(0, v, t)$ are enumerated in Appendix C.

In addition to this choice of I2, a few other input parameters in TEMP5 must be fixed to assure that all of the conditions imposed on the window are properly accounted for. If the window temperature is to remain fixed with time (implying that there is no source), the IQ must be set to zero and U0 to the appropriate temperature. Also, all H1(I) must equal zero, otherwise, if the window temperature is allowed to vary with time, then IQ must be set equal to 1, U0 to the appropriate initial temperature and all H1(I) to zero. Furthermore, the numerical value of σ must be ≥ 0.601 (corresponding to $\alpha \leq 0.8325$), otherwise, the message "α* * 2 is out of range" will be outputted. The reason for this restriction on σ is given in Appendix C.

In Table 5 we list the values that should be used for certain TIKIRK input parameters whenever IKIRKP is employed.

Table 5. Values Used for Certain TIKIRK Input Parameters Whenever IKIRKP is Employed.

MODE	Intensity Function Wanted	MP	NP	X1	X2	RHOP2
1	I(X, 0, t)	1	*	*	*	-
	I(0, ρ', t)	*	1	$\lvert X\underline{0} \rvert$	-	*
MODE	Intensity Function Wanted	MP	NP	UMIN	UMAX	VMAX
2	I'(u, 0, t)	1	*	*	*	-
	I'(0, v, t)	*	1	$\underline{0}$	-	*

*Means that operator should insert whatever value he desires.

-Means that that particular parameter is of no consequence.

The commands listed in the attachments apply equally as well to the IKIRKP option. The only responses which the operator will change will be those special values of the input parameters discussed above.

9.7 The IKIRK1 Option and an Alternate TIKIRK Package

The IKIRK1 option #3 is not contained in the TIKIRK program as described in Sections 9.1 through 9.6. However, a second TIKIRK program package has been assembled which not only offers option #3 but incorporates #1 and #2 as well. Thus, it can be substituted for the original program, if desired. This package consists essentially of four parts, each one to be stored in the computer under its own PFN. The first part contains a main program, also called TIKIRK, plus those function subprograms and subroutines making up the "core package" listed in Section 9.3 (viz, PHI, J0, J1, RTAPE3, ALI, ATSE, GETDATA, SSWTCH, RJUST and PRT). This "core package" will be utilized by the last three parts. The main program, called TIKIRK, is a slightly modified form of the main program TIKIRK first introduced in Section 8.3. As before, its principal role is to call the other subroutines and subprograms into execution. Since this first part would play a major role in computing the diffraction pattern of the transmitted beam and call upon the various options, it too has been given the PFN of TIBX by us, whenever it has been used.

The next three parts pertain to options #3, #1, and #2 in that order and we have assigned them their own particular PFN. Each one of these parts includes a major function subroutine which is also given the name IKIRK. The modified TIKIRK main program mentioned above, summons a given option by putting in a call to IKIRK. Which IKIRK (and its concomitant subroutines) gets executed depends upon which one was attached just previous to the call. (It should be noted that in this alternate TIKIRK package, the control parameter I2 no longer plays any role in determining which option will be utilized.) This procedure is demonstrated in Attachment 5, which lists typical control commands for running this new TIKIRK package under either Intercom or Batch mode of operation:

The second part, as noted above, pertains to option #3 (IKIRK1). Besides its major function subroutine IKIRK, it contains the following three subroutines:

(1) FREAL1 - computes the products of the functions $f_w f_x$ and $f_w f_y$ (see Eqs. 23-27, Volume I). It has 4 entry points since actually 4 functions have to be integrated.

(2) DCADRE - an integration subroutine from the IMSL set of routines. It requires the external function subroutine FREAL1 as one of the arguments.

(3) UERTST - required by DCADRE to output error messages.

We have stored this second part under the PFN of IK1BX.

The third part pertains to option #1, which was also referred to as IKIRK in Sections 9.2-9.6. Besides its major function subroutine, called IKIRK, it contains the two subroutines DQG24A and DQG24B, mentioned in Section 9.3. To this part, we have given the PFN of IKBX.

The fourth part contains option #2 (IKIRKP). Besides its major function subroutine, called IKIRK, it utilizes the four subroutines COMPUTE, JI, BESJF and BESJ, previously mentioned in Section 9.3. We have given the PFN of IKPBX to this part.

The Fortran listings for the modified TIKIRK program — the three major function subroutines which are each called IKIRK and which lead into each of the three options, as well as the subroutines FREAL1, DCADRE and UERTST — are given in Appendix D. All of the other subprograms and subroutines mentioned above are the same as those listed in Appendix B.

It has already been noted that option #3 (IKIRK1) is exceedingly slow. However, it may be possible to speed it up by increasing the absolute and relative errors which are presently set at 10^{-3} and 10^{-6}, respectively. In addition, the maximum value of the error parameter IER in DCADRE, as well as the maximum estimated bound on the absolute error in integration, is always printed out.

Whenever the results of IKIRK1 disagree with the results of IKIRK (option #1), those of the former should be preferred because of its greater inherent accuracy.

10. DISPLAY PROGRAM

10.1 Introductory Remarks

Program DISPLAY is a general purpose program for displaying two-dimensional arrays of numbers which, intuitively at least, can be thought of as a surface which has been sampled over an evenly spaced grid. The array size is essentially limited (by computer storage capabilities) to a maximum of 100 by 100; there is no minimum size other than the practical one that it does not make good sense to use a program such as this to display a single point. However, it may make sense to use the program to display one-dimensional arrays; for example, an array of size 1 by n. As will be explained in detail later, three types of display are offered by the program: contour map, perspective view, and multiple cross sections (parallel to two rectangular coordinate axes only). Moreover, the program is designed to display several such arrays at one RUN with the idea in mind that these arrays represent the evolution in time (or with some other parameter) of a function of two variables.

In addition to merely plotting the arrays in one or more of the above mentioned forms, this program labels all plots (provided the labeling information is furnished) and lists pertinent experimental parameters (if desired). Most of this labeling information is supplied in one or more data arrays, the structure of which has been described in DATAIN (see Section 8.8). The rest of the labeling information is provided in the records which contain the array rows.

Program control is afforded by a set of input "commands" which are supplied by input cards. The program interprets each command, obeys each command, and terminates when all commands have been followed (or when time runs out).

Before the program is used, it must be somewhat "tailored to fit." This is accomplished through the use of a fixed number of input data which must be supplied in entirety. Examples of such data are: plot id, maximum plot size, array of indices for obtaining labeling information, etc. A complete list of such data is provided in Section 10.2.

The program allows for selection of the starting "time" and its increment assuming that the surface to be displayed is a function of "time." ("Time" may be any suitable parameter.) A surface cross-section may be displayed as a function of time on a single coordinate frame.

10.2 General Instructions

The surfaces to be displayed are assumed to be stored on file TAPE3 in unformatted records where each logical record consists of one "row" of the mp x np array of floating point numbers representing the surface. In addition, each record contains the information: row number (I), total number of rows (NP), y-value to be associated with that row (Y), parameter value (if any) to be associated with (T), number of samples in the row (MP), x-value to be associated with the first element of the row (XMIN), x-value to be associated with the last element of the row (XMAX). Specifically, each record must have the form:

I, NP, Y, T, MP, XMIN, XMAX, (F(I, J;T), J=1, MP)

where F(·, ·;T) is the function to be displayed. Thus, for each value of the parameter T, NP logical records represent one "surface." Several such "surfaces" corresponding to several values of T may be stored on file TAPE3 and exhibited by DISPLAY.

In addition to the above mentioned "surfaces," file TAPE3 may contain any number (including 0) of "information" records, the contents of which include information (such as experimental parameters) which should be printed on each plot and plot titles. Each such information record must be an array (which will be called here DATAIN) of the form DATAIN(100, 3). Thus, each datum is represented by three parts called (in the order in which they appear) VALUE, NAME, and FORMAT. DATAIN is stored in unformatted form. VALUE is the numerical or character string value of the datum, NAME is a character string of up to ten characters which may be used to identify the datum, while FORMAT is a format code number (-1, 0 or 1) which specifies whether the datum value is to be interpreted as a character string (-1), integer (0), or floating point number (1). (See GETDATA, Section 8.8.4.)

These DATAIN records (if any) must be the first records on file TAPE3. Titles (if any) must appear only in the last DATAIN record.

10.3 Data Cards

The following data cards must be inputted to tailor the program for the user's particular application. The number in parenthesis in front of each datum name is the card column at which to start the datum. The number in parenthesis following the datum is the default value of the datum. If the default value is to be used, leave the corresponding card field blank.

Data Card #1

(1)	XMAX	(100.)	Maximum plot length in inches.
(11)	YMAX	(12.)	Maximum plot width in inches.
(21)	PPI	(10.)	Number of points/inch for contours.
(31)	TICU	(.5)	Number of inches between tic-marks for user defined x-y plots.
(41)	XLEN	(10.)	x-y plot coordinate frame x-size.
(51)	YLEN	(8.)	x-y plot coordinate frame y-size.
(61)	SCALEX	(1.)	x-y plot x-scale, that is, no. of x-units/tic-mark.
(71)	SCALEY	(1.)	x-y plot y-scale, that is, no. of y-units/tic-mark.

Data Card #2

(1)	XMIN	(0.)	The minimum x-value and y-value to be plotted for user-defined x-y coordinate frame x-y plots.
(11)	YMIN	(0.)	
(21)	NAME	(GIANINO)	User's name to appear on plot.
(31)	PROB. NO.	(2347)	4-digit user's problem number.

Data Card #3

This card provides information for the two-dimensional array INDEX, which is the index of locations for labeling information assumed to be contained in the last DATAIN on the file containing the surfaces to be plotted. INDEX consists of pairs of numbers wherein the first number is the starting location of the label and the second number is the length of the label. If there is no such data, then this card may be left blank and the labeling will not be done. If the letter D is placed in column 1 of this card, the default values shown below are used. In addition to the values of INDEX, the field starting in column 41 should contain the number of DATAIN arrays on TAPE3.

(1)	INDEX(1, 1)	(1)	Surface title.
(6)	INDEX(1, 2)	(30)	Surface title length (characters).
(11)	INDEX(2, 1)	(4)	Parameter title.
(16)	INDEX(2, 2)	(30)	Parameter title length.
(21)	INDEX(3, 1)	(7)	x-title.
(26)	INDEX(3, 2)	(30)	x-title length.
(31)	INDEX(4, 1)	(10)	y-title.
(36)	INDEX(4, 2)	(30)	y-title length.
(41)	NDA	(2)	Number of DATAIN arrays on TAPE3. The INDEX information is taken from the last DATAIN array.

We employ the following numerical values on data card #3 for displaying the intensity (using TAPE7) and the temperature (using TAPE8):

for TAPE7:	27	29	32	14	37	33	42	32	
for TAPE8:	72	20	67	13	83	24	88	31	1

Data Cards #4A, 4B, etc.

These cards contain the sequence numbers of data in DATAIN which are to be listed at the beginning of each run of DISPLAY. The sequence numbers pertaining to the TEMP5 parameters have been listed in Table 2, while those pertaining to the TIKIRK parameters have been listed in Table 4. There must be one card for each DATAIN array (see the last entry number in data card #3 above). For example, in our particular data card #3 above for the TAPE7 case, the default value of 2 is implied as the NDA entry, signifying that 2 cards must be used. The first card contains the sequence numbers of the TEMP5 parameters, while the second contains the sequence numbers of the TIKIRK parameters. The objective is to list both sets of parameters on the plots. In data card #3 above for the TAPE8 case, the NDA value of 1 was employed, indicating that only one card is to be used, viz, that containing the sequence numbers of the TEMP5 parameters which are to be listed on the plots.

The sequence numbers start in columns 1, 3, 5, 7, ... for a total of up to 40 indices per card. The default is a blank card. When the default is used, no DATAIN data is to be listed.

The above cards comprise the mandatory data cards. The remaining cards are the "command" cards which indicate what kinds of plots are wanted.

10.4 Command Cards

As stated previously, the DISPLAY program has the capability of 3 different types of plots, viz, multiple x-y, perspective view and contour map. Consequently, there is a command to control each type and they are indicated by the keywords PLOT, PERSPECTIVE and CONTOUR, respectively. The abbreviations PL, P and C, respectively, may also be used. These keywords are modified by certain parameters p_i. We now enumerate all of the modifying parameters of these command keywords and their meanings:

(1) Command: PLOT (p_1, p_2, p_3, p_4, p_5, p_6)

The parameters p_1, p_2, p_4 and p_5 are integers. In the process of creating a TAPE7 or TAPE8 file, up to ten times had to be chosen at each of which a temperature or an intensity distribution was calculated. These ten times were designated by the datum names T1, T2, ..., T10 (see Table 4). The first two parameters in the above command allow for control in selecting which times are to be chosen in the DISPLAY program. For example, the above command directs that the appropriate data corresponding to every p_1-th time value is to be displayed, starting with the p_2-th value (that is, Tp_2).

Recall that both the temperature and the intensity can be plotted either as a function of radial distance or of axial distance. The parameter p_3 can account for either of these two types of plots by taking on the code symbol X when it is a radial distance plot that is desired, or, the code symbol Y, when the axial distance plot is wanted.

For a temperature calculation, the TEMP5 program sets up a net of 82 temperature points in the radial direction (r), extending from the inner to the outer window radius, and 22 temperature points in the axial direction (z), extending from the entrance to the exit faces. Consequently, there are 22 cross-sectional surfaces of T versus r (that is, 22 type-X plots) and 82 cross-sectional surfaces of T versus z (that is, 82 type-Y plots). Thus, depending on the symbol given by p_3, the above PLOT command directs that on one coordinate frame every p_4-th T-versus-distance surface is to be plotted starting with the p_5-th surface.

On the other hand, for intensity calculations, the TIKIRK program establishes a net in the far field consisting of NP intensity points along the axial line (X), extending from some minimum to some maximum axial distance, and MP intensity points in the radial direction (ρ'), starting from the axial line and going perpendicular to it. Consequently, there are NP cross-sectional surfaces of I versus r (that is, NP type-X plots) and MP cross-sectional surfaces of I versus z (that is, MP type-Y plots). Again, depending on the symbol given by p_3, the PLOT command directs that every p_4-th I-versus-distance surface is to be plotted on one coordinate frame starting with the p_5-th surface.*

The parameter p_6 can take on any one of the following code symbols: NA, NAS, NE, NES, DN or DNS. These symbols will be explained in Section 10.4, paragraph (4).

The default values for the above 6 parameters are: $p_1 = p_2 = p_4 = p_5 = 1$, $p_3 = X$ and $p_6 = NA$.

(2) Command: PERSPECTIVE (p_1, p_2, p_3, p_4)

The parameters p_1 and p_2 are the same as in the PLOT command above. The numerical value p_3 is the magnitude of the view angle in degrees, measured from the plane of the window's exit face. Parameter p_4 can take on the code symbols NA or NE only.

The default values are: $p_1 = p_2 = 1$, $p_3 = 45$ and $p_4 = NA$.

(3) Command: CONTOUR (p_1, p_2, p_3, p_4)

The parameters p_1 and p_2 are the same as in the PLOT command above. The integer p_3 refers to the number of contour levels of constant temperature, or intensity, that are to be plotted, up to a maximum of 50. Parameter p_4 can take on any one of the code symbols NA, NE or DN.

The default values are: $p_1 = p_2 = 1$, $p_3 = 10$ and $p_4 = NA$.

Note that in the above three commands, parameters are separated by commas. Missing parameters are indicated by commas (with no blank spaces between commas), or by a right parenthesis. If the keyword only appears, then default parameters are assumed.

(4) Meaning of Code Symbols NA, NAS, NE, NES, DN and DNS

The letter N means that the functions to be displayed are first normalized before being plotted, that is, the transformation

$$z \rightarrow \frac{c}{(zmax - zmin)} (z - zmin)$$

(where z refers to the value of the ordinate) is made, where the value of c = 100 for CONTOUR plots; for PERSPECTIVE plots, it depends on the size of the array to be displayed. The latter N has a slightly different connotation for X-Y plots. Here, it means that the array is scaled such that it will fit in a coordinate frame with nice scale values. The second letter A or E indicates whether the normalization is over all (A) surfaces or whether each (E) surface is normalized separately, that is, the zmax, zmin are searched for over all arrays or over each array indiv.dually. The letters DN mean don't normalize, that is, do not do the above

*There is a circumstance in which the above meaning for p_4 does not apply. See Section 10.4, paragraph (4).

transformation. Note that for PERSPECTIVE displays normalization always occurs. Therefore, DN should never be used. This is done mainly to force the plot to remain within the plot paper boundaries. Again, for X-Y plots the connotation is slightly different, in that in this case the user must provide plot scale values.

The letter S indicates that there will be superimposed on a single coordinate frame many time curves (as chosen by p_1 and p_2) for a given cross-section, rather than having several cross-sections appear on a single frame for one particular time. Since the time variable can have as many as 10 values, then there can be as many as 10 time surfaces, that is, curves, superimposed on one frame. If it is desired to have one coordinate frame for each value of time that has been utilized, then the S should be omitted. This situation definitely pertains to CONTOUR and PERSPECTIVE plots.

When NA or NAS is used, the values assigned to SCALEX, SCALEY on data card #1 and XMIN, YMIN on data card #2 are ignored, so then the computer selects values which are more appropriate for the ranges of ordinate and abscissa involved. When NE or NES is used, the operator must select his own values for these data.

For X-Y plots, it is recommended that either NA or NAS be used. If NE or NES is employed instead, the operator should beware of erroneous coordinate scaling by ensuring that the values for any subsequent maxima and minima do not exceed those of the initial maximum and minimum. If the S is used in these plots, then parameter p_4 has no effect since several surfaces corresponding to several time values at one cross-section are to be plotted, rather than several cross-sections for one time value.

If no command card is included, then the default command of PERSPECTIVE is assumed. Several commands, one per card, may be given for any single run of the program. For example, a perspective display might be followed by a contour display or several perspective displays from several view angles might be called for by a sequence of PERSPECTIVE commands.

Typical detailed commands used for running the DISPLAY program in the Batch mode only are listed in Attachment 6. We do not run this program in the Intercom mode because usually there is not sufficient space allocated on Intercom to allow the program to run to completion.

10.5 Examples of the Use of the Three Different Plotting Commands

In Section 6 of Volume I, we presented many examples of the three different kinds of plots that program DISPLAY was capable of generating, listing in the figure captions the plot commands which controlled the actual plotting of these curves. We are now in a position to understand and to analyze how these commands control the graphing.

For example, in Figure 3 the command is PLOT (1, 1, Y, 100, 1, NAS). The keyword PLOT indicates that a multiple X-Y plot is involved. The first two parameters (1, 1) mean that every time value available is to be utilized, starting with time value #1 (that is, T1). In this example, there were 9 time curves used (T1 through T9), which are shown on the right hand side of the figure. Whether the curves drawn will represent temperature – or intensity – versus distance depends on whether the permanent file attached previously to the PLOT command was a TAPE8 – or TAPE7 – type file, respectively. For this particular case, it was a TAPE8 file. The third parameter (Y) signifies that the abscissa is the axial distance through the window. The fourth and fifth parameters (100, 1) signify that every 100th T - versus - z surface is to be plotted, starting with the first (that is, starting with the surface existing at zero radial distance, which is through the center of the window). Since there are only 82 T - versus - z surfaces, then setting $p_4 = 100$ can be seen as a ploy for selecting only the first surface ($p_5 = 1$) to the exclusion of all others. In other words, the selection of any value of p_4 greater than 82 would have ensured the same result. The sixth parameter (NAS) indicates that the normalization is to occur over all surfaces and that all of the (9) time curves are to be superimposed on one coordinate frame.

In Figures 4 and 5 the same kind of information was desired except that the T - versus - ? profiles were to occur at constant radial distances of 15 and 30 cm, respectively. Since these distances represent ~50 percent and ~100 percent of the radial distance up the window, the parameter p_5 was chosen to be equal to 41 and 81, respectively. (Actually, because of the way the 82 radial positions were chosen, p_5-values of 1, 41 and 81 represent distances of 0.6 percent, 49.4 percent and 99.4 percent up the radial axis, respectively.)

In Figure 6 we wanted to superimpose plots of T - versus - z at the above 3 radial positions at the fixed time of 5 sec, which is the 8th time value. The p_1, p_2 pair of 4, 8 signifies that every 4th time value is to be plotted, starting with T8. As above, this is a ploy to select only T8 and to exclude the others, since there are only 9 times available. Any $p_1 > 2$ would have produced the same result. The p_4, p_5 pair of 40, 1 means that every 40th surface is to be plotted, starting with surface #1. Thus, surfaces #1, 41 and 81 are plotted. Because we want these 3 surfaces, properly normalized, to be superimposed on one coordinate frame at the one fixed time, we leave off the letter S in the parameter p_6.

Temperature is plotted against radial distance for the same model problem in Figure 7 (hence, $p_3 = X$). Here, we wanted to plot all 21 T - versus - r surfaces (therefore, $p_4 = p_5 = 1$) at 1 and 5 sec. (The reason for there being only 21 rather than 22 surfaces is due to the way we chose the points; the 22nd point falls outside of the window.) Thus, we choose p_1 and p_2 to be 3 and 5, respectively, meaning that every 3rd time is selected, starting with T5 (=1 sec). As before, dropping the letter S in parameter p_6 ensures one coordinate frame for each time chosen.

Figures 8 and 9 are examples of T - versus - r temperature plots at approximately 1/4 and 3/4 of the way through the window (hence, p_5 = 6 and 16), respectively. Note that setting $p_1 = p_2 = 1$ assures that all times are accounted for and are superimposed because of the S in p_6. Letting p_4 be greater than 22 (here, 100) assures that only that one particular surface will be plotted.

Figures 10 and 11 pertain to the annular-shaped window. Setting p_5 = 11 and 21 results in plots for T - versus - r surfaces through the middle and at the exit face of the window, respectively.

Figures 12-14 show multiple X-Y plots for intensity. In Figure 12 we wanted every time included (hence, $p_1 = p_2 = 1$) of T - versus - axial distance plots (hence, p_3 = Y) along the axis (p_5 = 1), with no other radial distances included (p_4 = 100); and all of the time curves are to be superimposed (hence, S in p_6). In this particular example, we let MP = 100. Thus, any p_4 - value ≥100 would have ensured that only those surfaces along the axis would be used.

The axial range is covered by NP points; in our particular example, NP = 61. In Figure 13 we wanted to have superimposed time plots of I - versus - ρ' (hence, p_3 = X) at the center of the axial range only (hence, p_4 = 100, p_5 = 31). At a time of 3 sec (that is, p_2 = 7), the Gaussian focal point occurs at a distance of 830 m along the axis (corresponding to p_5 = 34). Figure 14 displays the I - versus - ρ' graph for this time only.

The plot command for the PERSPECTIVE graphs of Figures 15 and 16 use the default values. Even though a 3D plot was drawn for all 9 times, only a few representative cases are presented here.

For contour plots we wanted the time values of 2 and 8 sec only. Hence, p_1 = 3 and p_2 = 6 in Figures 17 and 18. Twenty contour lines are shown (thus, p_3 = 20). Since we wanted each one of these contours to be labeled with its dimensioned temperature value, rather than a normalized value, we chose the code symbol DN for p_4.

In summary, we can say that program DISPLAY is used mainly to provide a "readable" output of functions of two variables. The PERSPECTIVE plot furnishes a very good general "view" of the function in question. CONTOUR also provides a good view as well as quantitative knowledge of the function values. PLOT (either X-cross-sections or Y-cross-sections) supplies the most quantitative output but usually the least satisfactory overall "view" of the function. It should be pointed out that PLOT can be used for functions of one variable.

10.6 Principal Functions and Subroutines

The various operations associated with the DISPLAY program are carried out by the following subprograms, subroutines and functions:

(1) DISPLAY - the main program which calls the other subroutines and functions into execution.

All of the following are subroutines:

(2) PLOTT1 - draws and titles coordinate frame. It also does the scaling, if it isn't supplied by the user.

(3) PARMPLT - prints out parameters at the beginning of each plotting run.

(4) FILL - selects data from DATAIN and places it in a 2D array which, in turn, is passed to PARMPLT for printing.

(5) CFRAME - draws and labels the coordinate frame for contour and perspective plots.

(6) INTERP - converts user commands and command parameters to subroutine control arguments. It also calls subroutine NUMB to decode parameters.

(7) NUMB - used by INTERP to convert display code numbers in the commands to the proper internal representation of numbers in the computer.

(8) ARROW - draws the arrow used above the rectangular coordinate frame in perspective plots.

(9) APLACE - locates arrow-head for perspective view angle.

(10) RD1 - reads TAPE3 and fills up appropriate arrays to be plotted. Finds maxima and minima of the surfaces to be plotted, if necessary.

(11) CLEV - returns various equispaced contour levels.

(12) SKIP - skips over a designated number of records (that is, "surfaces") while reading TAPE3.

(13) FACE - a system library program which draws the PERSPECTIVE plots. It also uses the library subroutines HIDE, DRAW, SORT and PARFIT.

(14) CONTOR - a system library program which draws the CONTOUR plots. It also calls the library subroutines NEIBOR and FOUR as well as the Calcomp plot subroutines.

(15) RJUST - right adjusts all numerical input data. Its Fortran listing is given in Appendix A. 9.

(16) SYMBL - converts a floating point number using a G10. 3 format to a display code.

The complete Fortran listings for each of the above programs, subroutines and functions are given in Appendix E.

10.7 Algorithms

10.7.1 MULTIPLE X-Y DISPLAYS

The PLOT display graphs either $f(\cdot, y_i)(p_3 = X)$ or $f(x_i, \cdot)(p_3 = Y)$ for selected values of y_i or x_i determined by command parameters p_4 and p_5. Specifically:

$$i = p_5 + (k - 1) \cdot p_4 \qquad (k = 1, \ldots\ldots) \ .$$

Subroutine PLOTT1 is called after each "surface" array has been filled by subroutine RD1. One of two types of coordinate frames are then drawn by PLOTT1 depending on command parameter p_6. If p_6 = NA or NE, the scaling is done by the Calcomp subroutine SCALE and the coordinate axes are drawn by Calcomp subroutine AXIS. If p_6 = DN, then the user-provided scale is used and the coordinate frame is drawn by a set of statements within PLOTT1.

After the coordinate frame has been drawn, the individual surface "cross-sections" represented by $f(\cdot, y_i)$ or $f(x_i, \cdot)$ are plotted as continuous curves. Each curve is labeled with a symbol and symbol table.

10.7.2 PERSPECTIVE DISPLAY

For perspective displays the surface is always normalized in such a way that the display will approximately fill the same plot area regardless of the size of the surface array. The view elevation angle is fixed at approximately 45 degrees while the view azimuthal angle can be any value (given by the parameter p_3 of the PERSPECTIVE command). To produce a better display, the surface is always bordered by zeroes.

The complete perspective display is produced by calls from the main program to four subroutines (which may, in turn, call other subroutines): APLACE, FACE, CFRAME, and ARROW.

After establishing some display constants, a call is made to APLACE which returns the point at which to place the head of the view direction arrow. Next, a surface of constant height is produced and a call made to FACE with a "switch" positioned such that FACE merely returns values of XMIN, YMIN, DX, DY which will be used on subsequent calls to FACE. The surface is next normalized and a "display frame" is plotted. Because of the difficulty of drawing a coordinate frame for a perspective display, a coordinate frame quite similar to that used for the contour display is drawn adjacent to each perspective display. The only difference is that an angle of view arrow is drawn on the frame. This frame, then, is produced by calls to CFRAME (see Section 10.7.3 on contour display) followed by a call to ARROW which plots an arrow at the point found by APLACE. Finally, FACE is called to produce the perspective display.

10.7.3 CONTOUR DISPLAY

The contour display is produced by calls to three subroutines: CLEV, CFRAME, and CONTOR. Subroutine CLEV returns p_3 contour levels in array ZLEVS, evenly spaced between the surface maximum and minimum (but exclusive of the surface minimum). The surface may or may not be normalized according to parameter p_4.

After CLEV has been called, the contour "frame" is drawn by a call to subroutine CFRAME. An example of the frame produced by CFRAME is shown below (small letters indicate numerical or character-string values which are inserted):

surface title
ALL FUNCTION VALUES HAVE
BEEN SCALED ACCORDING TO -

$$z \Rightarrow \frac{c \cdot (Z - ZMIN)}{(ZMAX - ZMIN)}$$

WHERE ZMAX = zmax
ZMIN = zmin
ARE THE MAX. AND MIN.
VALUES OVER ALL SURFACES
or (VALUES OF THE SURFACE)
parameter = value

The contour map is then drawn by a call to CONTOR. Each contour level line is identified by a unique (mod 13) symbol which is printed next to the contour map along with the contour level value which the symbol represents.

10.8 Batch and Intercom Modes

Attachment 6 gives a typical set of commands for running the DISPLAY program under the Batch mode only. The Intercom mode does not have sufficient capacity to handle most plotting jobs, since approximately 142,000 octal words are required in the central memory to run the program (including the plot software). The program will run under Intercom if the arrays in unlabeled common are changed from (102, 102) to (22, 22).

Running time of the program is determined by the size of the array to be displayed, the number of commands and the command parameters. As an example, a 100 by 100 array was displayed with CONTOUR (20 levels), PLOT (10 cross-sections) and PERSPECTIVE in a total CP time of 82.8 sec.

10.9 Other Features

Various quantities which might be useful for debugging purposes are outputted on file TAPE6. These quantities are:

1) XMAX, YMAX, PPI, TICU
2) XLEN, YLEN, SCALEX, SCALEY
3) XMIN, YMIN
4) INDEX (8 integers)
5) NDA (if not 0)
6) IND (four lines of integers representing the locations in DATAIN of data to be plotted).
7) 4) and 5) repeated for each DATAIN.
8) Command parameters. (Note that the command itself can be inferred from the form of the parameters.)
9) NP, MP
10) ZMAX, ZMIN, TIM, ZMIN
11) XMAX, YMIN, YMAX, FLAG1 (Note: FLAG1 is a logical variable which is "FALSE" if an end-of-file has been reached on file TAPE3.)
12) 9) and 10) possibly repeated.
13) XMINF, YMINF, DX, DY (Only for perspective display; these are scale parameters.)

In addition to the output which comes directly from program DISPLAY, the subroutine CONTOR (used in contour display) and FACE (used in perspective display) output various quantities (see subroutine listings).

10.10 Program Files

In addition to OUTPUT, which is used only by the operating system to output messages, DISPLAY uses files TAPE4, TAPE6 and TAPE3.

TAPE3: TAPE3 is the main input file containing the surfaces to be displayed as well as the information records containing titles, etc. All records are unformatted. The file structure is as follows:

record 1:	datain-1 (100, 3)	
record 2:	datain-2 (100, 3)	
.	.	
.	.	These records may be absent (nda=0)
.	.	
record nda:	datain-nda (100, 3)	
.	.	
.	.	
.	.	
record nda+1	row 1 of surface 1	
.	.	
.	.	
.	.	
record nda+np	row np of surface 1	
	row 1 of surface 2	
.	.	
.	.	
.	.	
.	row np of surface 2	
.		
	.	
	.	
last record	row np of surface N	

Each "row" of the surface has a record of the form given in the first paragraph of Section 10. 2.

TAPE4: TAPE4 is the "card" input file. It uses formatted data as described in the first paragraph of Section 10. 3.

TAPE6: TAPE6 is the formatted output file for messages and debug quantities. See Section 10. 8 for a partial listing of TAPE6 records.

11. OTHER CAPABILITIES

The computer programs described in this report either have been extended, or are capable of being extended, to various other aspects of the window problem. For example, a program has been written and successfully implemented in fitting the theoretical temperature distribution produced by program TEMP5 to various experimentally measured temperature distributions. More specifically, the temperature at one or more points on the window's surfaces are measured as a function of time, as a source is turned on, then off. The theoretical temperature rise and fall is made to approximate the experimental values by a judicious choice of various parameters (such as absorption coefficient, β, and the theoretical boundary conditions, as given by the h_i and g_i) which describe the thermal properties of the window material. The details of this procedure are contained in Technical Memorandum No. 16 by T.B. Barrett, Parke Mathematical Labs. (Oct. 1973).

Another phenomenon which could definitely affect the diffraction pattern in the far field would be multiple internal reflections of the laser beam within the window.[15] Analysis shows that this condition can be handled effectively if each exponential term in Eqs. (25), (26) and (27) is replaced according to the prescription:

$$\exp(ik\Phi^\gamma) \rightarrow t_1 t_2 \exp\{ik\Phi^\gamma\}/[1 - r_1 r_2 \exp\{2ik(\Phi^\gamma + \Phi')\}] \qquad (87)$$

in which Φ^γ is still determined by Eq. (18) and the extra phase factor Φ' is given by:

$$\Phi'(\rho) = nL + \Delta L_b(\rho) \quad , \qquad (88)$$

where ΔL_b is the amount by which the window bulges when heated by the beam. The t's and r's are amplitude transmission and reflection coefficients, respectively. The subscript 1 refers to the window's entrance face, and 2 to its exit face. They are given by Weil:[8]

$$\begin{aligned} t_1 &= 2/(n+1) \\ t_2 &= 2n/(n+1) \\ r_1 &= r_2 = -(n-1)/(n+1) \quad . \end{aligned} \qquad (89)$$

Another capability inherent in the program is allowing an axial (that is, z) dependency in the volume heating source term Q. There are two alternate ways in which this could be effected:

(1) Replace subroutine GAUSS (refer to Appendix A. 5) by another, which is also to be called GAUSS. This new subroutine is to have the same arguments as before (see card #7120 in Appendix A. 5). However, now the Q-array will contain

[15] Bendow, B., Gianino, P.D., Hordvik, A., and Skolnik, L.H. (1973) Optics Commun. 7:219; and Skolnik, L.H., Bendow, B., Gianino, P.D., and Cross, E.F. (1974) AFCRL-TR-74-0085 (III), p. 967.

the appropriate z-dependence. The variable names in the argument are defined in the glossary in Table 3.

(2) If the Batch mode is to be employed, an alternate procedure would be to insert the following data cards in the GETDATA stack. Referring to Attachment 1B, use

IQ 2

ICARD 4

on line 34, and, after the blank card on line 35 insert the desired Q-array using format 7F10. 3. At present, Q is dimensioned (82, 22).

Other possible extensions of the computer program include:

(1) Temperature dependence of some of the material parameters, such as refractive index n, thermal conductivity K and thermal lensing parameters S_i^γ.

(2) Multiple layers, or coatings, on the window to eliminate reflections and/ or to compensate the thermal lensing.[16]

(3) Time dependence in the volume source term Q.

Trying to account for an angular (that is, θ) asymmetry in the beam's cross-section would not be a feasible extension, for it would necessitate a complete rewriting of the program, expanding it from a 2-dimensional to a 3-dimensional treatment.

[16] Bendow, B., and Gianino, P.D. (1975) Appl. Optics 14:277; and Bendow, B., Gianino, P.D., Flannery, M., and Marburger, J. (1975) Proc. of the Fourth Annual Conf. on Infrared Laser Window Materials, C.R. Andrews and C.L. Strecker (Editors), Advanced Research Project Agcy., Arlington, Virginia, p. 299.

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Attachment 1

Commands to Run TEMP5 and TIKIRK

Here, the goal is to initiate and run a specified TEMP5 and a TIKIRK calculation, then print out and catalog the results on permanent file (PF). Before beginning this job, one should have previously stored in the computer the following two PF's: TEBX (the PFN for the TEMP5 program), and, TIBX (the PFN for the TIKIRK program described in Sections 6. 1 - 6. 6). A third ancillary program, T3D, whose use is optional, is available to be added to the previous two. Given the PFN of T3BX, it prints out functions F1 and F2 (see Eqs. (16) and (17), Volume I). The Fortran listing for program T3D is given in Appendix F. Incidentally, the third letter (B) in each of the above PFN's means that the PF is in binary form.

A. Intercom Commands

The following is a typical set of Intercom commands:

Line No.	Computer types out. .	Operator Response	Comments
1	COMMAND-	ETL(450)	Extends time length to 450 octal sec.
2	COMMAND-	CONNECT(TAPE4,TAPE5)	

Line No.	Computer types out. .	Operator Response	Comments
	. . . . . Start of TEMP5 calculation.		
3	COMMAND-	ATTACH(TEB, TEBX, ID=GIANINO)	TEB is LFN for TEBX.
4	COMMAND-	TEB	
5	READ DATA FILE-3?	N	N=no (because you want to create a new TAPE3)
6	DEFAULTS LISTED?-	N	Customary answer.
7	NAME-VALUE MODE?-	Y	Y=yes.
8	NAME VALUE. . . .	BETA .003 I7 1 etc. - - - - - - - - -	(i) Enter the new TEMP5 variables here. See Table 2 Volume II. (ii) The name of the variable starts under N in NAME; its numerical value under V in VALUE.
9	DATA INPUT COMPLETE WORK OF DATINIT COMPLETE. . . WORK OF CYLTMP COMPLETE. . . END OF RUN EXIT ----CP SECS EXECUTION. . .		
	. . . . . TEMP5 Calculation has been completed.		
10	COMMAND	CONNECT(OUTFUT)	Lines 10-13 cause F1 and F2 to be printed out at remote terminal facility (AU). They may be omitted, if desired.
11	COMMAND-	ATTACH(T3B, T3BX, ID=GIANINO)	T3B is LFN for T3BX.
12	COMMAND-	T3B, , A	A is merely a surrogate name.
	END T3D . . CP SECS EXECUTION. .		
13	COMMAND-	ROUTE, A, ST=RMT, FID=GIAAU, DC=PR.	
14	COMMAND-	REQUEST(PAT, *PF)	Lines 14-17 create a new TAPE3-type PF. We arbitrarily give it the PFN of T3NX. PAT is merely a LFN.

Line No.	Computer types out..	Operator Response	Comments
15	COMMAND-	REWIND(TAPE3)	
16	COMMAND-	COPY(TAPE3, PAT)	
17	COMMAND-	CATALOG(PAT, T3NX, ID=GIANINO, RP=999)	
18	COMMAND-	ROUTE, TAPE6, ST=RMT, FID=GIAAU, DC=PR.	Causes the information on TAPE6, containing the TEMP5 results, to be printed out at remote terminal facility (AU). Also clears TAPE6.

(ASIDE: If all that is desired is the temperature distribution in the window, this would be a convenient place to stop).

..... Start of TIKIRK calculation.....

Line No.	Computer types out..	Operator Response	Comments
19	COMMAND-	ATTACH(TIB, TIBX, ID=GIANINO)	TIB is LFN for TIBX.
20	COMMAND-	TIB	
21	READ DATA FILE-3?	Y	Because you want to use information from the "new" TAPE3, viz. T3NX.
22	DEFAULTS LISTED?-	N	
23	NAME-VALUE MODE?-	Y	
24	NAME VALUE...	(space, return)	Do not enter any value here; just hit the "space" and "return" keys.
	DATA INPUT COMPLETE		
25	READ DATA FILE-7?-	N	Answer here is always "no".
26	DEFAULTS LISTED?-	N	
27	NAME-VALUE MODE?-	Y	
28	NAME VALUE...	X1 800 NP 26 - - - - - -	(i) Enter the new TIKIRK variables here. See Table 4, Volume II. (ii) See Comment (ii) on Line 8.
29	DATA INPUT COMPLETE		TIKIRK calculation has been completed.

Line No.	Computer types out..	Operator Response	Comments
	NEW VALUE OF TAU IS... - - - -		Prints out the 10 values of TAU corresponding to time values T1 through T10. See Eq. (13), Volume I.
30	COMMAND-	ROUTE, TAPE6, ST=RMT, FID=GIAAU, DC=PR.	Routes the TAPE6 information, containing the TIKIRK results, to remote terminal (AU) for printout.
31	COMMAND-	REQUEST(PIT, *PF)	Lines 31-34 create a new TAPE7-type PF. We arbitrarily give it the PFN of TKX. PIT is merely a LFN. This new PF can be used as the input in the DISPLAY program for plotting the intensity.
32	COMMAND-	REWIND(TAPE7)	
33	COMMAND-	COPY(TAPE7, PIT)	
34	COMMAND-	CATALOG(PIT, TKX, ID=GIANINO, RP=999)	

B. Batch Commands

Card No.	Command	Comments
1	Job ID with T=2000, core memory=170K	
2	ATTACH(TEB, TEBX, ID=GIANINO)	
3	REQUEST(TAPE3, *PF)	Assigns TAPE3 to permanent file.
4	TEB(INPUT, OUTPUT)	Loads and executes TEBX.
5	REWIND(TAPE6)	
6	COPY(TAPE6, OUTPUT)	Prints output.
7	CATALOG(TAPE3,T3NX, ID=GIANINO,RP=999)	
8	ATTACH(TIB, TIBX, ID=GIANINO)	
9	REQUEST(TAPE7, *PF)	
10	REWIND(TAPE6)	
11	TIB(INPUT)	
12	REWIND(TAPE6)	
13	COPY(TAPE6, OUTPUT)	

Card No.	Command		Comments
14	CATALOG(TAPE7, TKX, ID=GIANINO, RP=999)		
15	EXIT, S.		All commands after EXIT, S. are executed if and only if TEB terminates abnormally, e. g., exceeds time limit.
16	REWIND(TAPE6)		
17	COPY(TAPE6, OUTPUT)		
18	CATALOG(TAPE3, T3NX, ID=GIANINO, RP=999)		
19	CATALOG(TAPE7, TKX, ID=GIANINO, RP=999)		
20	7/8/9		EOR Card.
21	N		
22	N		
23	Y		
24A	BETA	.003	Name starts in col. 1; numerical value starts in col. 11.
B	I7	1	
-	-	-	
-	-	-	
-	-	-	
25	-----		Blank card.
26	7/8/9		EOR card.
27	Y		
28	N		
29	Y		
30	------		Blank card.
31	N		
32	N		
33	Y		
34A	X1	800	Name starts in col. 1; numerical value starts in col. 11.
B	NP	26	
-	-	-	
-	-	-	
-	-	-	
35	-----		Blank card.
36	6/7/8/9		EOF card.

If only temperature distribution in the window is desired, the above series of commands would be reduced to the following:

Card No.	Command	
C1	Job ID with T=60, corememory=60K	
C2	ATTACH(TEB, TEBX, ID=GIANINO)	
C3	REQUEST(TAPE3,*PF)	
C4	TEB(INPUT, OUTPUT)	
C5	REWIND(TAPE6)	
C6	COPY(TAPE6, OUTPUT)	
C7	CATALOG(TAPE3, T3NX, ID=GIANINO, RP=999)	
C8	EXIT, S.	
C9	REWIND(TAPE6)	
C10	COPY(TAPE6, OUTPUT)	
C11	CATALOG(TAPE3, T3NX, ID=GIANINO, RP=999)	
C12	7/8/9	
C13	N	
C14	N	
C15	Y	
C16A	BETA	.003
B	I7	1
-	-	-
-	-	-
-	-	-
C17	(blank card)	
C18	6/7/8/9	

Attachment 2

Commands to Modify a Temperature Distribution

Assume that a TEMP5 calculation has already been performed and the results cataloged under the PFN of T3NX (cf. lines 14-17 in Attach. 1A). Further, assume that one wants to change only a few of the input variables and then calculate a new temperature distribution. The following commands indicate how the previous results may be utilized.

A. Intercom Commands

Line No.	Computer types out..	Operator Response	Comments
1	COMMAND-	ETL(450)	
2	COMMAND-	CONNECT(TAPE4, TAPE5)	
3	COMMAND-	REWIND(TAPE6)	Clears TAPE6.
4	COMMAND-	REWIND(TAPE7)	Clears TAPE7.
5	COMMAND-	ATTACH(PET, T3NX, ID=GIANINO)	Attaches former TAPE3 with LFN of PET.
6	COMMAND-	COPY(PET, TAPE3)	Copies "former" TAPE3 onto a "new" TAPE3, which is given the LFN of TAPE3. Thus, the original file (T3NX) is still intact and available for future use.

Line No.	Computer types out..	Operator Response	Comments
7	COMMAND-	ATTACH(TEB, TEBX, ID=GIANINO)	
8	COMMAND-	TEB	
9	READ DATA FILE-3?-	N	
10	DEFAULTS LISTED?-	N	
11	NAME-VALUE MODE?-	Y	
12	NAME VALUE.....	SIG .4 PWR 1E7 - - - - - -	Enter those TEMP5 variables which are to be changed. Also, see Comment (ii) on Line 8, Attach. 1A.
13 et seq.	Same as line 9, et seq., Attach. 1A. However, when one gets to the equivalent of line 17, Attach. 1A, one should give the new PF a new PFN, say, T3QX.		

B. Batch Commands

Card No.	Command	Comments
1	Job ID with T=1000, CM=60K	
2	ATTACH(PET, T3NX, ID=GIANINO)	Attaches old TAPE3.
3	REQUEST(TAPE,*PF)	If new TAPE3 is to be permanent.
4	COPY(PET, TAPE3)	
5	RETURN(PET)	Return if you want to use at a later date. Otherwise, could purge it.
6	ATTACH(TEB, TEBX, ID=GIANINO)	
7	TEB(INPUT, OUTPUT)	
8	CATALOG(TAPE3,T3QX,ID=GIANINO,RP=999)	The new TAPE3 is given the PFN of T3QX.
9	REWIND(TAPE6)	
10	COPY(TAPE6)	
11	7/8/9	EOR card.
12	Y	
13	N	

Card No.	Command		Comments
14	Y		
15A	SIG	.4	Enter those TEMP5 variables which are to be changed. Also, see comment on line 34, Attach. 1B.
B	PWR	1E7	
	-	-	
	-	-	
	-	-	
16	(blank card)		
17	6/7/8/9		EOF card.

Attachment 3

Commands to Recalculate TIKIRK, Given TEMP5 Results

There are certain input variables which will affect the computed spatial intensity pattern (and possibly even the dimensioned temperature distribution in the window), but not the normalized temperature distribution. The input parameters which belong to this category are most of the variables found in Table 4 and those in Table 2 which are accompanied by the code letter K in the Useage Code column (Col. # 6).

As in Attach. 2, we assume that a previous TEMP5 calculation is available under the PFN of T3NX. Now, we desire to observe the effects which changes in the above-mentioned variables have on the computed intensity pattern. For each set of changes made, the TIKIRK program must be executed. The following gives a representative series of typical commands necessary to implement this procedure.

A. Intercom Commands

Line No.	Computer types out...	Operator Response	Comments
1-4	Same as in Attach. 2A.		
5	COMMAND-	ATTACH(TAPE3, T3NX, ID=GIANINO)	Attaches PF with LFN of TAPE3.

Line No.	Computer types out...	Operator Response	Comments
6-21	Repeat lines 19 through 34, inclusive, from Attach. 1A. However, on line 24 enter the desired TEMP5 variables, if any, which you want to change and which do not affect the normalized temperature distribution in the window. (Note that TEMP5 parameters are being entered at this stage, even though the TIKIRK program currently has control.) On line 28 enter only those TIKIRK variables whose magnitudes are to be different from the default values. On line 34 select a different PFN for the new TAPE7-type PF just completed. .....End of TIKIRK calculation.....		

If you want to change the variables again and repeat the TIKIRK calculation:

22	COMMAND-	TIB	
23	Repeat lines 21 through 34, inclusive, from Attach. 1A, subject to the same comments as noted in line 6 above.		

Each time the variables are to be changed and the TIKIRK calculation is to be recomputed, repeat lines 22 and 23 above.

B. Batch Commands

If run as a separate problem, assume that the TEMP5 PF having PFN of T3NX has already been created.

Card No.	Command
1	Job ID with T=2000, CM=170K
2	ATTACH(TIB, TIBX, ID=GIANINO)
3	ATTACH(TAPE3, T3NX, ID=GIANINO)
4	REQUEST(TAPE7, *PF)
5	TIB(INPUT)
6	REWIND(TAPE6)
7	COPY(TAPE6, OUTPUT)
8	CATALOG(TAPE7, TKX, ID=GIANINO)

Plus cards #26-#36, inclusive, of Attach. 1B.

Attachment 4

Commands to Produce a TAPE8 for Temperature Plots

The temperature distribution information contained on the file called TAPE3 is not in the proper format for plotting purposes. Rather, this information must be transferred in the appropriate format to another file, called TAPE8, which is suitable for plotting by the DISPLAY program. This attachment gives all of the commands required to generate and catalog a TAPE8 file, provided that the temperature results are already on a TAPE3-type PF. We assume that this latter file has already been created and given the PFN of T3NX.

A. Intercom Commands

Line No.	Computer types out...	Operator Response	Comments
1	COMMAND-	ETL(450)	
2	COMMAND-	CONNECT(TAPE4, TAPE5)	
3	COMMAND-	REWIND(TAPE6)	
4	COMMAND-	REWIND(TAPE7)	
5	COMMAND-	ATTACH(TAPE3, T3NX, ID=GIANINO)	
6	COMMAND-	ATTACH(TIB, TIBX, ID=GIANINO)	

Line No.	Computer types out..	Operator Response	Comments
7	COMMAND-	TIB	
8	READ DATA FILE=3?-	Y	
9	DEFAULTS LISTED?-	N	
10	NAME-VALUE MODE?-	Y	
11	NAME VALUE....	(space, return)	
12	READ DATA FILE-7?-	N	
13	DEFAULTS LISTED?-	N	
14	NAME-VALUE MODE?-	Y	
15	NAME VALUE.....	NP 1 MP 1 IPRNT 2 T1 time value - #1 (in sec) - - - T10 time value #10(in sec)	(i) Only the data shown here can be entered. (ii) See Comment (ii) on line 8, Attach. 1A. (iii) Only those temperatures will be plotted which correspond to the (dimensioned) times given by T1, T2, etc. Linear interpolation is done, if necessary.
16	COMMAND-	REQUEST(DOG, *PF)	Lines 16-19 create a new TAPE8-type PF whose PFN is TEMPX and whose LFN is DOG.
17	COMMAND-	REWIND(TAPE8)	
18	COMMAND-	COPY(TAPE8, DOG)	
19	COMMAND-	CATALOG(DOG, TEMPX, ID=GIANINO, RP=999)	

ASIDE: If you want to calculate the diffraction pattern concomitant with the temperature distribution contained in the permanent file T3NX as mentioned above, refer to Attach. 3A., starting with line #22.

B. Batch Commands

Card No.	Command	Comments
1	Job card, T=20, CM=60K	
2	ATTACH(TAPE3, T3NX, ID=GIANINO)	
3	REQUEST(TAPE8, *PF)	
4	ATTACH(TIB, TIBX, ID=GIANINO)	

Card No.	Command	Comments
5	TIB(INPUT)	
6	CATALOG(TAPE8, TEMPX, ID=GIANINO	
7	7/8/9	EOR card.
8	Y	
9	N	
10	Y	
11	----	Blank card.
12	N	
13	N	
14	Y	
15	NP 1	For cards #15-27, see comments, line 15, Attach. 4A.
16	MP 1	
17	IPRNT 2	
18	T1 time value #1	On cards #18-27, all time values are in seconds.
-	-	
-	-	
-	-	
-	-	
-	-	
27	T10 time value #10	
28	-----	Blank card.
29	6/7/8/9	EOF card.

Attachment 5

Commands for Running Alternate TIKIRK Program

Assume that the alternate TIKIRK program, introduced in Section 9.7, Volume II, has been stored in the computer and is available for use, rather than the original TIKIRK program (as discussed in Sections 9.1-9.6). This alternate program is also given the PFN of TIBX. Let us further assume that we want to utilize option #3, which has the PFN of IK1B. The revised commands to run this alternate program are:

A. Intercom Commands

Line No.	Computer types out..	Operator Response	Comments
1-19	Same as Attach. 1A.		
20	COMMAND-	ATTACH(IKB, IK1B, ID=GIANINO)	IKB is the LFN for this file.
21	COMMAND-	XEQ	Indicates the following commands are loader commands.
22	OPTION =	LOAD=TIB, IKB	Causes loading of the main program TIKIRK and subroutine IKIRK.

Line No.	Computer types out..	Operator Response	Comments
23	OPTION =	EXECUTE=TIKIRK	Initiates execution.
24-37	Same as lines 21-34, inclusive, Attach. 1A.		

The above commands would be the same for the other two options (#1 and 2), except that on line 20 the appropriate PFN would be entered in place of IK1B. However, the LFN of IKB must be maintained.

B. Batch Commands.

Card No.	Command
1	Job card, T=2000, CM=170K
2	ATTACH(TIB, TIBX, ID=GIANINO)
3	ATTACH(TAPE3, T3NX, ID=GIANINO)
4	ATTACH(IKB, IK1B, ID=GIANINO)
5	REQUEST(TAPE7, *PF)
6	LOAD(TIB, IKB)
7	EXECUTE(TIKIRK)
8	REWIND(TAPE6)
9	COPY(TAPE6)
10	CATALOG(TAPE7, TKX, ID=GIANINO, RP=999)
11	7/8/9
12	Y
13	N
14	Y
15	(blank card)
16	N
17	N
18	Y

Card No.	Command	
19A	X1	800
B	NP	26
-	-	-
-	-	-
20	(blank card)	
21	6/7/8/9	

Attachment 6

Batch Commands for Running DISPLAY Program

(1) Intensity Plots

Let us assume that a TAPE7-type file, having the PFN of T7X and containing the intensity information to be plotted, has already been created.

Card No.	Command	Comments
1	Job ID, T=300, CM=170000	
2	ATTACH(DISB, DISBX, ID=GIANINO)	Attaches the DISPLAY program, whose PFN is DISBX and whose LFN is DISB.
3	ATTACH(TAPE3, T7X, ID=GIANINO)	Attaches the permanent file T7X, using the LFN of TAPE3.
4	ATTACH(PEN, ONLINEPEN)	Cards #4-13 control the plotting process.
5	LIBRARY(PEN)	
6	LDSET(PRESET=ZERO)	
7	DISB(INPUT)	

Card No.	Command	Comments
8	REWIND(TAPE6)	
9	COPY(TAPE6)	
10	DISPOSE, PLOT, *OL.	
11	EXIT.	
12	REWIND(TAPE6)	
13	COPY(TAPE6)	
14	7/8/9	
15	Data card #1	See Section 10. 3 for details on data cards.
16	Data card #2	
17	Data card #3	Use the values pertaining to TAPE7.
18A B	Data card #4A Data card #4B	Cards 18A and 18B contain the sequence nos. of those TEMP5 and TIKIRK parameters, respectively, which are to be listed with the plots.
19	Plot command cards (one or more)	See Section 10. 4 for details on plot command cards.
20	6/7/8/9	

(2) Temperature Plots

Suppose that a TAPE8-type file has already been created, having the PFN of TEMPX and containing the temperature distribution within the window. Then, the commands to obtain temperature plots are the same as in Part (1), above, with the following exceptions:

Card No.	Command	Comments
3	ATTACH(TAPE3, TEMPX, ID=GIANINO)	Again, the PF is given the LFN of TAPE 3.
17	Data card #3	Use the values pertaining to TAPE8.
18B	(Remove data card #4B)	

If it is desired to have any of the above plots drawn with red ink, card #10 above would be replaced by the following:

Card No.	Command	Comments
10	DISPOSE, PLOT, *PL. RED INK PLEASE	The word RED starts in col. 21.

Appendix A

Fortran Listings for TEMP5 Program

A.1 Main Program TEMP5

```
      PROGRAM TEMP5(TAPE4=128,TAPE5=128,TAPE3,TAPE6=128,OUTPUT=128)    000100
C                                                                      000110
C     TEMP5 IS THE PROGRAM NAME ASSIGNED TO A PROGRAM BEING ADAPTED    000120
C     FROM PROGRAM TEMP4 FOR THE PURPOSE OF REDUCTION OF EXPERIMENTAL  000130
C     DATA ( H VS T ) TO  DETERMINE H AND BETA. JUNE 1972 BY N.G.PARKE. 000140
C     THE MEANING OF THE SYMBOLS AND PARAMETERS FOR THIS PROGRAM       000150
C     ARE DESCRIBED IN THE COMMENT CARDS WITH SUBROUTINE DTAFT WHICH IS 000160
C     CALLED BY THIS PROGRAM AFTER IT HAS READ IN  THE INITIAL         000170
C     PARAMETERS AND DATA.  A PARAMETER AND DATA DECK IS PUNCHED       000180
C     OUT BY DTAFT.  DTAFT ALSO PRINTS OUT ANY DEBUG DATA INDICATED    000190
C     BY PARAMETERS I1 - I7.                                           000200
C                                                                      000210
C     SUBROUTINE DTAFT IS A MODIFICATION  OF SUBROUTINE TMP88          000220
C     FOR AFCRL BY N.G.PARKE IN  JUNE 1972                             000230
C                                                                      000240
C     THIS  SUBROUTINE  WAS ORIGINALLY MODIFIED ON 4 APRIL 1972 TO SHIFT 000250
C     THE DATA TO EVEN INCREMENTS, USING SPLINE INTERPOLATION AND      000260
C     THE CHOSEN ARBITRARY BOUNDARY CONDITIONS.  THIS MODIFICATION     000270
C     WAS MADE BY N.G.PARKE.                                           000280
C                                                                      000290
C     THE PARENT PROGRAM WAS TEMP4 FOR CALCULATING THE UNSTEADY HEAT   000300
C     CONDUCTION IN A FINITE CYLINDER SUBJECT TO GENERAL BOUNDARY      000310
C     CONDITIONS ON ALL ZED AND RHO SURFACES. IT THEN COMPUTES THE     000320
C     INTEGRALS F1 AND F2, REQUIRED BY DR. RENDOW AND PUNCHES THE      000330
C     INPUT PARAMETERS AND F1 AND F2, IF I1 = 1.                       000340
C                                                                      000350
C     THE CYLINDER IS HEATED BY A VOLUME SOURCE DISTRIBUTION.          000360
C     CYLINDRICAL SYMMETRY IS ASSUMED, I.E., THE PARABOLIC             000370
C     PARTIAL DIFFERENTIAL EQUATION IS IN CYLINDRICAL COORDINATES      000380
C     WITH THE ANGLE VARIABLE MISSING.                                 000390
C                                                                      000400
C     THE NET OF SPACE POINTS IS SHIFTED HALF AN INCREMENT FROM        000410
C     BOUNDARIES WHICH ARE RECTANGULAR IN CYLINDRICAL COORDINATES.     000420
C     THIS NET IS BOUNDED BY A FICTITIOUS SET OF POINTS THAT           000430
C     ALLOW THE EASY WRITING OF GENERAL BOUNDARY CONDITIONS.           000440
C     TEMP4 IS A PROGRAM WHICH IS BASED ON                             000450
C     THE IMPLICIT ALTERNATING DIFFERENCE METHOD OF INTEGRATING        000460
C     A PARABOLIC PARTIAL DIFFERENTIAL EQUATION. IT IS CALLED          000470
C     THE I.A.D. METHOD FOR SHORT.                                     000480
C                                                                      000490
C     IN ADDITION TO THE USUAL LIBRARY OF MATHEMATICAL                 000500
C     AND SYSTEM SUBROUTINES, TEMP4 REQUIRED THE SUBROUTINES TRIDAG    000510
C     AND GAUSS, AS WELL AS THE SSP ROUTINE QSF FOR INTEGRATING.       000520
C                                                                      000530
C                                                                      000540
C     THE THEORETICAL BASIS FOR THIS PROGRAM IS FULLY DOCUMENTED       000550
C     IN TM NO. 5, NATHAN GRIER PARKE III, PARKE MATHEMATICAL LABS.    000560
C     INC., ONE RIVER ROAD, CARLISLE, MASS.01741, NOVEMBER 1971.       000570
C     MODIFICATIONS FOR VERSION TEMP4 WILL APPEAR IN TM NO.7.          000580
C                                                                      000590
C     INPUT AND INITIALIZATION CONTROL CHARACTERS                      000600
C     IU = 0 .=. TEMP DISTRIB U INITIALIZED TO U0                      000610
C     IU = 1 .=. TEMP INITIAL DISTRIBUTION READ IN ON <ICARD<          000620
C     IQ = 0 .=. SOURCE DISTRIB Q INITIALIZED TO ZERO                  000630
C     IQ = 1 .=. CALCULATE AND INITIALIZE Q AS A TRUNCATED GAUSSIAN    000640
C              DISTRIBUTION.                                           000650
C     IQ = 2 .=. SOURCE DISTRIBUTION READ IN ON ICARD.                 000660
C                                                                      000670
C     USE OF THE BOUNDARY CONDITION PARAMETERS G AND H*                000680
C                                                                      000690
C     A PERFECT INSULATING BOUNDARY IS CHARACTERIZED BY G = 0, H = 0   000700
C     NEWTONS LAW OF COOLING IS CHARACTERIZED BY G = 0, H = FILM COEFF 000710
C     GIVEN HEAT INPUT IS CHARACTERIZED BY G = INPUT, H = 0            000720
C     GIVEN TEMPERATURE IS CHARACTERIZED BY G/H = TEMP AND             000730
C     BOTH G AND H VERY LARGE, E.G., G = TEMP * E25,  H = 1.E25.       000740
C                                                                      000750
C                                                                      000760
C                                                                      000770
C     HF(X,Y) AND GF(X,Y,Z) ARE STATEMENT FUNCTIONS OF THE FORM        000780
C     USED IN EQUATIONS (19),....(22) IN TM NO. 5 TO  APPLY THE        000790
C     THE GENERAL BOUNDARY CONDITIO S RE CALCULATING THE  FICTITIOUS   000800
C     POINTS IN THE U AND USTAR ARRAYS.....                            000810
C                                                                      000820
```

```
C.....ASSIGN LOGICAL NUMBERS TO ICARD.IKEY.IPRINT AND ITYPE USING                000830
C     INPUT DEVICE 1. OR CHANGE THE FIRST READ CARD TO REQIRED DEVICE NO         000840
C     THIS MAKES THE PROGRAM EASILY  TRANSFERABLE  TO  COMPUTERS WITH            000850
C     DIFFERENT LOGICAL DEVICE NUMBER ASSIGNMENTS.                               000860
C                                                                                000870
C     PARAMETERS I1.....I7 FOR CONTROLLING THE PRESENCE AND ABSENCE OF           000880
C     OUTPUT   1 .=. OUTPUT    2 .=. INHIBIT.                                    000890
C     I1  . =. PUNCH AND PRINT F1.F2. AND PARAM                                  000900
C     I2 .=. PRINT TAU.LMDA.MU.NN.NU.ICNT.ICNTR                                  000910
C     I3 .=. PRINT KK.A.B.C.D.UPRIM.ALSO INITIAL VALUES OF U.USTAR ETC           000920
C     I4 .=. PRINT U AND R AFTER INITIAL DATA READ IN OR COMPUTED                000930
C     I5 .=. PRINT I.J.UFIN(I.J.K).                                              000940
C     I6 .=. PUNCH UFIN AND PARAMETERS.                                          000950
C     I7 .=. PRINT I.J.U(I.J) ON HALF INCREMENT SHIFTED LATTICE.                 000960
C     THE HALF INCREMENT SHIFTED LATTICE IS THE ONE USED BY US TO                000970
C     WRITE THE PROGRAM EASILY FOR GENERAL BOUNDARY CONDITIONS.                  000980
C                                                                                000990
C     SUBROUTINE SPLNI(N.M.EPS.X.Y.I.SS.SS1.SS2.QUA)                             001000
C     THIS IS A MODIFICATION OF SSP SUBROUTINE SPLIE TO MAKE QUA AN              001010
C     ARRAY TO MAKE THE INTEGRAL A FUNCTION OF X                                 001020
C     QUA = INTEGRAL OF SS FROM X(1) TO X(N) - QUA IS AN ARRAY                   001030
C                                                                                001040
C     FIND THIRD ORDER SPLINE FCT  FOR A FCT Y(X) GIVEN AT THE                   001050
C     POINTS (X(I).Y(I))                                                         001060
C     FOLLOWING CHAP.8 OF VOL2 OF RALSTON + WILF                                 001070
C                                                                                001080
C     N = NO.OF GIVEN DATA POINTS                                                001090
C     M = NO.OF SPECIFIED ARGUMENTS T(I) FOR WHICH THE SPLINE                    001100
C       SS.ITS FIRST DER.SS1 AND SECOND DER.SS2 ARE TO BE COMPUTED               001110
C     EPS = ERROR TOLERANCE  IN ITERATIVE STEPS                                  001120
C     X= ARRAY OF STRICTLY INCREASING ABSCISSAS                                  001130
C     Y = ARRAY OF FCT VALUES                                                    001140
C     T = ARRAY PF DESIRED ABSCISSAS                                             001150
C     SS = ARRAY OF SPLINE VALUES . SS1.SS2 DERIVATIVES                          001160
C     LIMITATIONS  N  NOT LARGER THAT 50                                         001170
C                                                                                001180
C     THE ADDITION OF THE SPLINE SUBROUTINE HAS MADE IT NECESSARY TO             001190
C     INTRODUCE SOME NEW SYMBOLS AND ARRAYS                                      001200
C     EPS .=. ERROR TOLERANCE IN THE ITERATIVE STEPS                             001210
C     X(22) .=. WORK SPACE FOR ARRAY OF STRICTLY INCREASING ABSCISSAS            001220
C     Y(22) .=. WORK SPACE FOR ARRAY OF FCT VALUES                               001230
C     XX(22) .=. WORK SPACE  FOR DESIRED ABSCISSAS                               001240
C     SS(22) .=. SPLINE VALUE OF U                                               001250
C     SS1 .=. SPLINE VALUE OF FIRST DERIVATIVE OF U                              001260
C     SS2(22) .=. SPLINE SECOND DERIVATIVE OF U                                  001270
C     QUA .=. INTEGRAL OF SS FROM X(1).X(NN)                                     001280
C     USPLN(22.22) .=. TEMPORARY WORK SPACE. USED BETWEEN RHO-SPLINING           001290
C     AND ZED SPLINING                                                           001300
C     MS .=. NO. OF GIVEN DATA POINTS                                            001310
C     NS .=. NO. OF SPLINE INTERPOLATED ARGUMENTS                                001320
C                                                                                001330
C                                                                                001340
C ---------------------- PROGRAM STATEMENTS ------------------------------       001350
C                                                                                001360
C     WRITE <PROGRAM TEMP5 - A PROGRAM FOR CALLING A SUBROUTINE CYLTMP.          001370
C     WHICH USES PROGRAM TEMP4 MODIFIED  AND DETERMINES H AND BETA FROM          001380
C     EXPERIMENTAL RUNS OF TEMPERATURE VS TIME.<                                 001390
C                                                                                001400
      WRITE(6.215)                                                               001410
      WRITE(6.216)                                                               001420
      WRITE(6.217)                                                               001430
      WRITE(6.218)                                                               001440
C                                                                                001450
      CALL DATINIT                                                               001460
      WRITE(5.300)                                                               001470
      CALL CYLTMP                                                                001480
      WRITE(5.310)                                                               001490
      WRITE(5.320)                                                               001500
      CALL EXIT                                                                  001510
C                                                                                001520
  210 FORMAT(6E12.5)                                                             001530
  215 FORMAT(1H0.*PROGRAM TEMP5 -  A PROGRAM FOR CALLING A SUBROUTINE*)          001540
  216 FORMAT(1H0.*CYLTMP. WHICH  USES PROGRAM TEMP4 MODIFIED TO*)                001550
  217 FORMAT(1H0.*DETERMINE H AND BETA FROM EXPERIMENTAL RUNS OF *)              001560
  218 FORMAT(1H0.*TEMPERATURE VS TIME.*)                                         001570
  300 FORMAT(1H0.* WORK OF DATINIT COMPLETE - RETURNED TO TEMP5*)                001580
  310 FORMAT(1H0.*WORK OF CYLTMP COMPLETE - RETURNED TO TEMP5*)                  001590
  320 FORMAT(1H0.*END OF RUN*)                                                   001600
C                                                                                001610
      END                                                                        001620
```

A.2 Subroutine DATINIT

```
      SUBROUTINE DATINIT                                                 001630
C                                                                        001640
      REAL LMDA, MU                                                      001650
      COMMON A(82),B(82),C(82),D(82),UPRIM(82),RHO(82),RFIN(82),         001660
     +U(82,22),USTAR(82,22),Q(82,22),UFIN(82,22),USPLN(82,22),           001670
     +ZFIN(22),ZED(22),F(4),G(4),H(4),LMDA,MU,NN,M1,N1,M2,N2,NF          001680
C                                                                        001690
C                                                                        001700
      REAL NX,K,IO                                                       001710
      INTEGER R1,Z1,R2                                                   001720
      INTEGER DATAIN                                                     001730
      DIMENSION DATAIN(100,3)                                            001740
      COMMON/BLOCK1/                                                     001750
     +      I1,I2,I3,I4,I5,I6,I7,M,N,MI,NI,ICNT,IU,IQ,NO,NMX,IRUN,       001760
     +ICARD,IPRINT,IPNCH,ITAP3,ITAP4,RHO1,RHO12,ZED1,ZED12,DTAU0,        001770
     +TAUMX,TAUOFF,SIG  ,Q0,U0,    EPS,G1(4),H1(4),MATER,NX,BETA,        001780
     +K,LAMBDA,S1R,S1T,S2R,S2T,                                          001790
     +DEN,CP,R,EXPER,PW,R1,Z1,R2,IPLOT,PROBNO,TICU,XLEN,YLEN,SCALEX,     001800
     +SCALEY1,SCALEY2,XTITLE(5),YTITLE1(5),YTITLE2(5),NAME               001810
      EQUIVALENCE (I1,DATAIN)                                            001820
      DATA (DATAIN(I,1),I=1,92)/7*2,80,20,3*1,0,1,2,11,100,4,6,6,3,      001830
     +4,0,.1,,-.5546,1.1092,.0035,5.,5.,.1292,2*0.,.001,4*0.,0.,3*.015,  001840
     +3HKCL,1.47,4.8E-4,.0653,10.6,-.34E-5,.05E-5,.1E-5,-.1E-5,1.98,     001850
     +.691,1.258,1H1,24.7,81,11,1,1,4H7204,.5,20.,9.,30.,.1,.1,          001860
     +10HTIME(SECON,3HDS),3*1H ,10HTEMP-DEGC ,10H ABOVE AMB,             001870
     +3*1H ,10HMEAN TEMP ,10H ABOVE AMB,3*1H ,7HBARRETT,                 001880
     +10HRADIAL DIS,10HTANCE,RHO-,4H(CM),1H ,1H ,10HAXIAL DIST,          001890
     +10HANCE,Z-(CM,1H),1H ,1H /                                         001900
      DATA (DATAIN(I,2),I=1,92)/2HI1,2HI2,2HI3,2HI4,2HI5,                001910
     +2HI6,2HI7,1HM,1HN,2HMI,2HNI,4HICNT,2HIU,2HIQ,2HNO,3HNMX,           001920
     +4HIRUN,5HICARD,6HIPRINT,5HIPNCH,5HITAP3,5HITAP4,4HRHO1,            001930
     +5HRHO12,4HZED1,5HZED12,5HDTAU0,5HTAUMX,6HTAUOFF,3HSIG,             001940
     +2HQ0,2HU0,3HEPS,5HG1(1),5HG1(2),5HG1(3),5HG1(4),5HH1(1),           001950
     +5HH1(2),5HH1(3),5HH1(4),8HMATERIAL,8HREF.IND.,4HBETA,              001960
     +9HTHER.COND,6HLAMBDA,3HS1R,3HS1T,3HS2R,3HS2T,                      001970
     +          7HDENSITY,9HSPEC.HEAT,6HRADIUS,5HEXPER,                  001980
     +3HPWR     ,3HR1#,3HZ1#,3HR2#,9HPLT?1Y,2N,6HPROBNO,4HTICU,          001990
     +4HXLEN,4HYLEN,7HX-SCALE,8HY1-SCALE,8HY2-SCALE,6HXTITLE,            002000
     +1H2,1H3,1H4,1H5,7HYTITLE1,1H2,1H3,1H4,1H5,7HYTITLE2,1H2,           002010
     +1H3,1H4,1H5,8HOPERATOR,3HXT1,3HXT2,3HXT3,                          002020
     +3HXT4,3HXT5,3HYT1,3HYT2,3HYT3,3HYT4,3HYT5/                         002030
      DATA (DATAIN(I,3),I=1,92)/22*0,19*1,-1,11*1,-1,1,4*0,              002040
     +-1,6*1,26*-1/                                                      002050
      I1=I2=I3=I4=I5=I6=I7=2                                             002060
      ICARD=5                                                            002070
      INDIC=0                                                            002080
      IPRINT=6                                                           002090
      ITAP3=3                                                            002100
      ITAP4=4                                                            002110
      M=80                                                               002120
      N=20                                                               002130
      MI=NI=1                                                            002140
      ICNT=1                                                             002150
      IU=0                                                               002160
      IQ=1                                                               002170
      NO=2                                                               002180
      NMX=11                                                             002190
      IRUN=100                                                           002200
      RHO1=0.                                                            002210
      RHO12=1.                                                           002220
      ZED1=-.5546                                                        002230
      ZED12=1.1092                                                       002240
      DTAU0=.0035                                                        002250
      TAUMX=5.0                                                          002260
      TAUOFF=5.0                                                         002270
      SIG=.1292                                                          002280
      Q0=U0=0.                                                           002290
      EPS=.001                                                           002300
      G1(1)=G1(2)=G1(3)=G1(4)=0.                                         002310
      H1(1)=0.                                                           002320
      H1(2)=H1(3)=H1(4)=.0113                                            002330
      MATER=10HKCL                                                       002340
      NX=1.47                                                            002350
      BETA=4.8E-4                                                        002360
      K=.0653
      DEN=1.980
      CP=.691
      R=1.258
      EXPER=10**2
      T0=24.7
      R1=A1
      Z1=11
      R2=1
      IPLOT=1
      NAME=10HBARRETT
      PROPNO=10H7204
      TICH=.5
      XLEN=20.
      YLEN=9E0
      SCALEX=12E0
      SCALEY1=.2E0
      SCALEY2=.2E0
      XTITLE(1)=10HTIME(SECON
      XTITLE(2)=10HDS)
      YTITLE1(1)=10HTEMP-DEGC
      YTITLE1(2)=10H ABOVE AMB
      YTITLE2(1)=10HMEAN TEMP.
      YTITLE2(2)= 10HABOVE AMB.
 1210 CALL GETDATA (DATAIN,92,4,5,6,3,100,300,INDIC)
      WRITE(ITAP3) DATAIN
      NF=0
      M1=M+1
      N1=N+1
      M2=M1+1
      N2=N1+1
C
C......CALCULATE THE INCREMENT ARRAY, E(I)...
C
      RM=M
      RN=N
      E(1)=RHO12/RM
      E(2)=E(1)
      E(3)=ZED12/RN
      E(4)=E(3)
      DRHO=E(1)
      DZED=E(3)
      NSEQ=0
C
C...................INITIALIZE U,USTAR,Q,UPRIM,A,B,C,D.................
C
      DO 20 I = 1,M2
      UPRIM(I) = 0.
      A(I) = 0.
      B(I) = 0.
      C(I) = 0.
      D(I) = 0.
      DO 20 J = 1,N2
      U(I,J) = U0
      USTAR(I,J) = 0.
   20 Q(I,J) = 0.
C
C     USTAR,Q,UPRIM,A,B,C,D, INITIALIZED TO ZERO.  U = U0
      DO 21 I = 1,M1
      DO 21 J = 1,N1
   21 UFIN(I,J) = 0
C
C     UFIN HAS BEEN INITIALIZED TO ZERO
C
C     PUTS ZETA - COORD IN ZFIN(J)
C
      DO 17 J = 1,N1
      JJ = J - 1
      ZJ = JJ
   17 ZFIN(J) = ZED1 + ZJ*DZED
C
C     PUTS RHO-COORD IN RFIN(I)
C
      DO 18 I=1,M1
      II = I - 1
      RI = II                                                           003120
   18 RFIN(I) = RHO1 + RI*DRHO                                          003130
C                                                                       003140
C     PUTS HALF-INC RHO-COORD IN RHO(I)                                 003150
C                                                                       003160
      DO 46 I = 1,M2                                                    003170
      II = 2*I-3                                                        003180
      RI = II                                                           003190
      RI = RI/2.                                                        003200
   46 RHO(I) = RHO1 + RI*DRHO                                           003210
      WRITE(IPRINT,290)(I,RHO(I),I=1,M2)                                003220
C                                                                       003230
C                                                                       003250
C     PUTS HALF-INC ZED-COORD IN ZEU(J)                                 003240
      DO 55 J = 1,N2                                                    003260
      JJ = 2*J-3                                                        003270
      RJ = JJ                                                           003280
      RJ = RJ/2.                                                        003290
   55 ZED(J) = ZED1 + RJ*DZED                                           003300
      WRITE(IPRINT,292) (J,ZED(J),J=1,N2)                               003310
C                                                                       003320
C     DEBUG PRINTOUT CONTROLLED BY I3                                   003330
C                                                                       003340
      GO TO (2,3), I3                                                   003350
    2 WRITE(IPRINT,260) U                                               003360
      WRITE(IPRINT,260) USTAR                                           003370
      WRITE(IPRINT,260) Q                                               003380
      WRITE(IPRINT,260) UPRIM                                           003390
      WRITE(IPRINT,260) A                                               003400
      WRITE(IPRINT,260) B                                               003410
      WRITE(IPRINT,260) C                                               003420
      WRITE(IPRINT,260) D                                               003430
      WRITE(IPRINT,260) UFIN                                            003440
    3 IF(TU.EQ.0) GO TO 32                                              003450
      READ(ICARD,225) U                                                 003460
   32 IF(TQ.EQ.0) GO TO 34                                              003470
      IF(TQ.EQ.1) GO TO 33                                              003480
      READ(ICARD,225) Q                                                 003490
      GO TO 34                                                          003500
   33 CALL GAUSS(IPRINT,SIG,RHO,M2,N2,Q,Q0)                             003510
   34 GO TO (35,36), I4                                                 003520
   35 WRITE(IPRINT,260) U                                               003530
      WRITE(IPRINT,260) ((Q(I,J),I=2,M1),J=2,N1)                        003540
   36 NN = 0                                                            003550
C                                                                       003560
      WRITE(IPRINT,280)                                                 003570
C                                                                       003580
      RETURN                                                            003590
C                                                                       003600
  210 FORMAT(6E12.5)                                                    003610
  220 FORMAT(7I5,T71,I5,I5)                                             003620
  225 FORMAT(7F10.3)                                                    003630
  260 FORMAT(1H0,10(E10.3,3X))                                          003640
  280 FORMAT(1H0,*END OF DATINIT*)                                      003650
  290 FORMAT(1H0,*I,RHO(I) =*,5(I5,F8.4))                               003660
  292 FORMAT(1H0,*J,ZED(J) =*,5(I5,F8.4))                               003670
  330 FORMAT(11I5,T71,I5,I5)                                            003680
  331 FORMAT(7I5,T71,I5,I5)                                             003690
  335 FORMAT(5E12.5,T71,I5,I5)                                          003700
  336 FORMAT(4E12.5,T71,I5,I5)                                          003710
      END                                                               003720
```

A.3 Subroutine CYLTMP

```
      SUBROUTINE CYLTMP                                                 003730
      REAL LMDA, MU                                                     003740
      COMMON/BLOCK1/                                                    003750
     *        I1,I2,I3,I4,I5,I6,I7,M,N,MI,NI,ICNT,IU,IQ,NO,NMX,IRUN,    003760
     *ICARD,IPRINT,IPNCH,ITAP3,ITAP4,RHO1,RHO12,ZED1,ZED12,DTAU0,       003770
     *TAUMX,TAUOFF,SIG  ,D0,U0,    EPS,G1(4),H1(4),MATER,NX,BETA,       003780
     *K,LAMBDA,S1R,S1T,S2R,S2T,                                         003790
     *DEN,CP,R,EXPER,PW,R1,Z1,R2,IPLOT,PROBNO,TICU,XLEN,YLEN,SCALEX,    003800
     *SCALEY1,SCALEY2,XTITLE(5),YTITLE1(5),YTITLE2(5),NAME              003810
      COMMON A(82),B(82),C(82),D(82),UPRIM(82),RHO(82),RFIN(82),        003820
     *U(82,22),USTAR(82,22),Q(82,22),UFIN(82,22),USPLN(82,22),          003830
     *ZFIN(22),ZED(22),E(4),G(4),H(4),LMDA,MU,NN,M1,N1,M2,N2,NF         003840
      DIMENSION F1(82),F2(82),X(82),Y(82),SS(82),SS1(82),SS2(82),       003850
     *QUA(82),YU(82),RRR(82),XR(82),ZZZ(22),XZ(22),T(1)                 003860
      HF(X,Y) = (2.-X*Y)/(2.+X*Y)                                       003870
      GF(X,Y,Z) = 2.*Y*Z/(2.+X*Y)                                       003880
      DO 12 I = 1,4                                                     003890
      G(I) = G1(I)                                                      003900
   12 H(I) = H1(I)                                                      003910
      WRITE(IPRINT,255) E                                               003920
      DRHO = E(1)                                                       003930
      DZED = E(3)                                                       003940
C                                                                       003950
C......NOW WE RELOAD ARRAYS H AND G , USING FUNCTIONS HF AND GF         003960
C                                                                       003970
      DO 10 I = 1,4                                                     003980
      G(I) = GF(H(I),E(I),G(I))                                         003990
   10 H(I) = HF(H(I),E(I))                                              004000
C                                                                       004010
      DO 3 I=1,M1                                                       004020
 3    RRR(I)=RFIN(I)                                                    004030
      DO 4 I=1,N1                                                       004040
 4    ZZZ(I)=ZFIN(I)                                                    004050
C......WE NOW WRITE OUT THE NEW VALUES OF ARRAYS G AND H.               004060
C                                                                       004070
      WRITE(IPRINT,250) G                                               004080
      WRITE(IPRINT,245) H                                               004090
      TAU = 0.                                                          004100
      ICNTR = 0                                                         004110
      NF = 0                                                            004120
      TFIN = 0.0                                                        004130
      MS=2                                                              004140
      IF (TAUOFF .GE. TAUMX) MS=1                                       004150
C                                                                       004160
C ............. MAIN ENTRY FOR NEW I.A.D. CYCLE .......................  004170
C                                                                       004180
 55   DTAU=DTAU0                                                        004190
   40 IF(NN.GE.NMX) GO TO 45                                            004200
      IF (NO .EQ. 0) GOTO 45                                            004210
C                                                                       004220
C       CONDITIONAL CALCULATION OF DTAU, WHEN NN.LT.NMX                 004230
C                                                                       004240
      RNN = NN                                                          004250
      RNO = NO                                                          004260
      REX = RNN/RNO                                                     004270
      DTAU = DTAU0*2.**REX                                              004280
C                                                                       004290
C..........INCREMENT TAU,NN,ICNTR..............                          004300
C                                                                       004310
 45   GOTO (330,340,360,330) MS                                         004320
 340  IF (TAU+2E0*DTAU .LT. TAUOFF) GOTO 330                            004330
      MS=3                                                              004340
      DTAU=(TAUOFF-TAU)/2E0                                             004350
      GOTO 330                                                          004360
 360  MS=4                                                              004370
      DO 350 J=1,N2                                                     004380
      DO 350 I=1,M2                                                     004390
      Q(I,J)=0E0                                                        004400
 350  CONTINUE                                                          004410
      G(1)=G(2)=G(3)=G(4)=0.                                            004420
      NN=0                                                              004430
      GOTO 55                                                           004440
 330  TAU=TAU+DTAU                                                      004450
      NN = NN + 1                                                       004460
      ICNTR = ICNTR + 1                                                 004470
      LMDA = DTAU/DRHO**2                                               004480
      MU = DTAU/DZED**2                                                 004490
      GO TO (47,48),I2                                                  004500
   47 WRITE(IPRINT,265)TAU,LMDA,MU,NN,NO,ICNT,ICNTR                     004510
   48 DO 50 I = 2,M1                                                   004520
      U(I,1) = H(3)*U(I,2)+G(3)                                        004530
      U(I,N2) = H(4)*U(I,N1)+G(4)                                      004540
      A(I) = LMDA*(1.-E(1)/2./RHO(I))                                  004550
      B(I) = -(2.*LMDA+1.)                                             004560
   50 C(I) = LMDA*(1.+E(1)/2./RHO(I))                                  004570
C                                                                      004580
C     COMPLETE THE BORDERING OF THE COMPUTATION LATTICE                004590
C                                                                      004600
      DO 13 J = 2,N1                                                   004610
      U(1,J) = H(1)*U(2,J)+G(1)                                        004620
   13 U(M2,J) = H(2)*U(M1,J)+G(2)                                      004630
C                                                                      004640
C ...TOUCH UP OF COEFFICIENTS B(I).....                                004650
      B(2) = B(2) + A(2)*H(1)                                          004660
      B(M1) = B(M1) + C(M1)*H(2)                                       004670
      DO 70 J = 2,N1                                                   004680
      DO 60 I = 2,M1                                                   004690
   60 D(I) = -MU*(U(I,J+1)-2.*U(I,J)+U(I,J-1))-DTAU*Q(I,J)-U(I,J)      004700
C                                                                      004710
C.... TOUCH UP OF THE D COEFFICIENTS........                           004720
C                                                                      004730
      D(2) = D(2) - A(2)*G(1)                                          004740
      D(M1) = D(M1) - C(M1)*G(2)                                       004750
      CALL TRIDAG(2,M1,A,B,C,D,UPRIM)                                  004760
C                                                                      004770
C....WE HAVE JUST SOLVED THE TRIDIAGONAL EQUATIONS......                004780
C....THE RESULTS ARE STORED IN UPRIM.. THE CONTENS OF UPRIM..          004790
C....MUST NOW BE TRANSFERED TO COLUMN J OF ARRAY USTAR.......          004800
C                                                                      004810
      DO 63 KK = 2,M1                                                  004820
      GO TO (63,64), I3                                                004830
   63 WRITE(IPRINT,285) KK,A(KK),B(KK),C(KK),D(KK),UPRIM(KK)           004840
   64 DO 70 K = 2,M1                                                   004850
   70 USTAR(K,J) = UPRIM(K)                                            004860
C                                                                      004870
C                                                                      004880
C     CALCULATE U ON BOUNDARY AND EVEN LATTICE POINTS BY               004890
C     BENDOW INTERNAL SPLINE EXTRATULATION TO BOUNDARY POINTS.         004900
C                                                                      004910
      IF (ICNTR.GT.1) GO TO 16                                         004920
      NF = NF+1                                                        004930
      TFIN = TAU - DTAU                                                004940
C                                                                      004950
C     BENDOW MODIFICATION OF SPLINE INTERPOLATION BEGINS AT THIS POINT 004960
C     IT CONATSTS OF EXTRAPOLATIONS TO THE BOUNDARY, USING SLOPE SSU   004970
C     AND VALUE SS AT INTERIOR POINTS RHO(2),RHO(M1),ZED(2),ZED(N1).   004980
C     OTHER CALCULATIONS ARE MADE BY THIRD ORDER SPLINE INTERPOLATION  004990
C     AND THE ACCURACY OF THE INTERPOLATION IS CONTROLLED BY THE       005000
C     CHOICE OF OF EPS                                                 005010
C                                                                      005020
C      THE FIRST STEP IN THE PROCESS IS SPLINE INTERPOLATION OF U(I,J) 005030
C     RELATIVE TO RHO-VALUES. INDEX I.                                 005040
C                                                                      005050
      DO 160 I = 2,M1                                                  005060
  160 X(I-1) = RHO(I)                                                  005070
      DO 161 J = 1,M1                                                  005080
  161 XR(J)=RRR(J)                                                     005090
      XR(1) = RHO(2)                                                   005100
      XR(M1) = RHO(M1)                                                 005110
      DO 162 J = 2,N1                                                  005120
      DO 163 I = 2,M1                                                  005130
  163 Y(I-1) = U(I,J)                                                  005140
C                                                                      005150
C     IF(J.GT.3) GO TO 1                                               005160
C     WRITE(IPRINT,210)                                                005170
C     WRITE(IPRINT,200) X                                              005180
C     WRITE(IPRINT,200) Y                                              005190
C     WRITE(IPRINT,200) XR                                             005200
C   1 CALL SPLNI(M,M1,EPS,X,Y,XR,SS,SS1,SS2,QUA)                       005210
      CALL SPLNI(M,M1,EPS,X,Y,XR,SS,SS1,SS2,QUA)                       005220
C                                                                      005230
C     SS AND SS1 ARE USED AT THE END POINTS IN THE BB VERSION.         005240
C                                                                      005250
      DO 164 KS = 1,M1                                                 005260
```

```
                                                                        005270
  164 USPLN(KS,J) = SS(KS)                                              005280
C     EXTRAPOLATION TO BOUNDARY, USING SS AND SS1                       005290
      USPLN (1,J) = SS(1)+(RFIN(1)-RHO(2))*SS1(1)                       005300
      USPLN (M1,J) = SS(M1)+(RFIN(M1)-RHO(M1))*SS1(M1)                  005310
  162 CONTINUE                                                          005320
C                                                                       005330
C     WE NOW HAVE EVEN  RHO-INTERPOLATED VALUES OF U.  WE NEED EVEN     005340
C     ZED-INTERPOLATED VALUES OF U TO INSERT IN UFIN(I,J,K).            005350
C                                                                       005360
C     THE FOLLOWING STEP DOES SPLINE INTERPOLATION IN THE ZED-DIRECTION 005370
C                                                                       005380
      DO 166 I = 2,N1                                                   005390
  166 X(I-1) = ZED(I)                                                   005400
      DO 167 J = 1,N1                                                   005410
  167 XZ(J)=ZZZ(J)                                                      005420
      XZ(1) = ZED(2)                                                    005430
      XZ(N1) = ZED(N1)                                                  005440
      DO 168 I = 1,M1                                                   005450
      DO 169 J = 2,N1                                                   005460
  169 Y(J-1) = USPLN(I,J)                                               005470
C                                                                       005480
C     IF(I.GT.3) GO TO 2                                                005490
C     WRITE(IPRINT,210)                                                 005500
C     WRITE(IPRINT,200) X                                               005510
C     WRITE(IPRINT,200) Y                                               005520
C     WRITE(IPRINT,200) XZ                                              005530
C   2 CALL SPLNI(N,N1,EPS,X,Y,XZ,SS,SS1,SS2,QUA)                        005540
      CALL SPLNI(N,N1,EPS,X,Y,XZ,SS,SS1,SS2,QUA)                        005550
C                                                                       005560
C     THE INTERPOLATED RESULT IS NOW STORED IN UFIN                     005570
C                                                                       005580
      DO 170 J = 1,N1                                                   005590
  170 UFIN(I,J) = SS(J)                                                 005600
C     EXTRAPOLATION TO BOUNDARY, USING SS AND SS1                       005610
      UFIN(I,1) = SS(1)+(ZFIN(1)-ZED(2))*SS1(1)                         005620
      UFIN(I,N1) = SS(N1)+(ZFIN(N1)-ZED(N1))*SS1(N1)                    005630
  168 CONTINUE                                                          005640
C                                                                       005650
C     THIS COMPLETES THE CALCULATION OF UFIN(I,J) FOR THE CURRENT       005660
C     VALUE OF K = NF BY THIRD ORDER SPLINE INTERPOLATION AND           005670
C     EXTRAPOLATION TO THE BOUNDARIES.                                  005680
C                                                                       005690
      DO 130 I = 1,M1                                                   005700
      DO 132 J = 1, N1                                                  005710
  132 YU(J) = UFIN(I,J)                                                 005720
      T(1) = ZFIN(1)                                                    005730
      CALL SPLNI(N1,1,EPS,ZFIN,YU,T,SS,SS1,SS2,QUA)                     005740
  130 F1(I) = QUA(N1)                                                   005750
C                                                                       005760
C     THIS COMPLETES THE CALCULATION OF F1                              005770
C                                                                       005780
      DO 136 I = 1,M1                                                   005790
  136 YU(I) = F1(I)*RFIN(I)                                             005800
      T(1) = RFIN(1)                                                    005810
      CALL SPLNI(M1,1,EPS,RFIN,YU,T,SS,SS1,SS2,QUA)                     005820
      DO 138 II = 2,M1                                                  005830
  138 F2(II) = QUA(II)/RFIN(II)**2                                      005840
      F2(1) = 0.5*F1(1)                                                 005850
C                                                                       005860
C     THIS COMPLETES THE CALCULATION OF F2                              005870
C                                                                       005880
      WRITE(ITAP3) NF,TFIN,RFIN,ZFIN,UFIN,F1,F2                         005890
C                                                                       005900
C     IF I1 = 1 TYPE OUT F1 AND F2.                                     005910
C     IF I5 = 1 TYPE OUT UFIN.                                          005920
C                                                                       005930
      IF(I1.EQ.2.AND.I5.EQ.2) GOTO 370                                  005940
      IF(I1.NE.1) GOTO 371                                              005950
      WRITE(IPRINT,380)                                                 005960
      DO 373 I=1,M1,5                                                   005970
  373 WRITE (IPRINT,381) I,F1(I),F2(I)                                  005980
  371 IF(I5.NE.1) GOTO 370                                              005990
      WRITE(IPRINT,382)                                                 006000
      DO 374 I=1,M1,5                                                   006010
  374 WRITE(IPRINT,383) I,(UFIN(I,J),J=1,N1,5)
  370 CONTINUE
C     THE RECORD OF THE SPLINE CALCULATION AND INTEGRATION HAVE BEEN
C     WRITTEN AS THE NEXT RECOR ON TAPE 3.
C..... THIS IS THE END OF THE FIRST HALF OF THE I.A.D. CYCLE..
C..... THE INTERMEDIATE ARRAY USTAR HAS BEEN CALCULATED.......
C
   16 TAU = TAU + DTAU
      NN = NN + 1
C
C............APPLY THE RHO BOUNDARY CONDITIONS...........
C
      DO 80 J = 2,N1
      USTAR(1,J)=H(1)*USTAR(2,J)+G(1)
      USTAR(M2,J)=H(2)*USTAR(M1,J)+G(2)
      A(J) = MU
      B(J) = -(2.*MU+1.)
   80 C(J) = MU
C
C.....COEFFICIENT B TOUCH UP....
C
      B(2) = B(2) + A(2)*H(3)
      B(N1) = B(N1) + C(N1)*H(4)
C
C......CALCULATION OF COEFFICIENTS D ........
C
      DO 100 I = 2,M1
      DO 90 J = 2,N1
      D(J) = -LMDA*(USTAR(I+1,J)-2.*USTAR(I,J)+USTAR(I-1,J))
      D(J) = D(J)- LMDA*DRHO/2./RHO(I)*(USTAR(I+1,J)-USTAR(I-1,J))
   90 D(J) = D(J) - DTAU*Q(I,J) - USTAR(I,J)
C
C.... TOUCH UP OF THE D COEFFICIENTS....
C
      D(2) = D(2) - A(2)*G(3)
      D(N1) = D(N1) - C(N1)*G(4)
C
C.....CALL TRIDAG TO SOLVE THE TRIDIAGONAL SYSTEM OF EQUATIONS..
C......THE RESULT WILL BE RETURNED IN UPRIM ARRAY...........
C
      CALL TRIDAG(2,N1,A,B,C,D,UPRIM)
      DO 93 KK = 2,N1
      GO TO (93,94),I3
   93 WRITE(IPRINT,285)KK,A(KK),B(KK),C(KK),D(KK),UPRIM(KK)
   94 DO 100 J = 2,N1
  100 U(I,J) = UPRIM(J)
      IF(ICNTR.LT.ICNT) GO TO 40
C
C.............AT EACH RETURN TO 40 BEGINS ANOTHER I.A.D. CYCLE...
C
      ICNTR = 0
      GO TO (111,112),I7
  111 CONTINUE
      WRITE(IPRINT,270) TAU,DTAU
      DO 110 I = 2,M1,MT
      WRITE(IPRINT,275) I,RHO(I)
  110 WRITE(IPRINT,320)(U(I,J),J=2,N1,NI)
  112 CONTINUE
      IF(TAU.LE.TAUMX) GO TO 40
C     WHEN TAU EXCEEDS TAUMX, THIS SUBROUTE RETURNS TO THE MAIN PROGRAM
C     TEMP5, AFTER PRINTING <TAU.GT.TAUMX - CYLTMP RET TO TEMP5<
C.......................END OF I.A.D. CYCLE ...............
      WRITE(IPRINT,11)
      RETURN
   11 FORMAT(1H0,*TAU.GT.TAUMX - CYCLTMP RET TO TEMP5*)
  200 FORMAT(1H0,10F10.4)
  210 FORMAT(1H0,*DEBUG* X,Y,XX*)
  245 FORMAT(1H0,*H1,H2,H3,H4 =*,4(E10.3,3X))
  250 FORMAT(1H0,*G1,G2,G3,G4 =*,4(E10.3,3X))
  255 FORMAT(1H0,*E1,E2,E3,E4 =*,4(E10.3,3X))
  265 FORMAT(1H0,*TAU,LMDA,MU,NN,NO,ICNT,INCTR =*,3(E10.3,3X)/4I5)
  270 FORMAT(1H0,*TAU = *,F10.3,*DTAU = *,E10.3)
  275 FORMAT(1H0,*I,RHO =*I5,F10.4)
  285 FORMAT(1H0,I5,3X,5(F10.3,3X))
  320 FORMAT(1H ,10(E10.3,3X))
  380 FORMAT (/,1H0,*    I*,7X,*F1(I)*,8X,*F2(I)*,/)
  381 FORMAT (1H0,I5,2(3X,F10.3))
  382 FORMAT (/,1H0,*    I*,10X,*UFIN(I,J) FROM J= 1 TO NI *,/)
  383 FORMAT (1H0,I5,10(3X,F10.3),/,1H0,10X,9(3X,E10.3),/,
     +1H0,23X,4(3X,E10.3))
      END
```

A.4 Subroutine TRIDAG

```
      SUBROUTINE TRIDAG (IF,L,A,B,C,D,V)
C
C      THE SUBROUTINE FOR SOLVING A SYSTEM OF LINEAR SIMULTANEOUS
C     EQUATIONS HAVING  A TRIDIAGONAL COEFFICIENT MATRIX.
C     THE EQUATIONS ARE NUMBERED FROM IF THROUGH L, AND THEIR
C     SUB-DIAGONAL, DIAGONAL, AND SUPER-DIAGONAL COEFFICIENTS ARE
C     STORED IN ARRAYS A,B,C.  THE COMPUTED SOLUTION VECTOR
C     V(IF),.....,V(L) IS STORED IN ARRAY V.
C
      DIMENSION A(1),B(1),C(1),D(1),V(1),BETA(82),GAMMA(82)
C
C     ....COMPUTE ARRAYS BETA AND GAMMA........
C
      BETA(IF) = B(IF)
      GAMMA(IF) = D(IF)/BETA(IF)
      IFP1 = IF + 1
      DO 1 I = IFP1,L
      BETA(I) = B(I) - A(I)*C(I-1)/BETA(I-1)
    1 GAMMA(I) = (D(I)-A(I)*GAMMA(I-1))/BETA(I)
C
C     .....COMPUTE FINAL SOLUTION VECTOR V ......
C
      V(L) = GAMMA(L)
      LAST = L - IF
      DO 2 K = 1,LAST
      I = L-K
    2 V(I) = GAMMA(I) - C(I)*V(I+1)/BETA(I)
      RETURN
C
      END
```

A.5 Subroutine GAUSS

```
       SUBROUTINE GAUSS(IPRINT,SIG,RHO,M,N,Q,Q0)                        007120
      DIMENSION RHO(1),Q(M,N)                                           007130
      IF(SIG.EQ.0.) GO TO 20                                            007140
      SIG2 = SIG**2                                                     007150
      IF(Q0.GE..001) GO TO 5                                            007160
 1000 Q0=.5/SIG2                                                        007170
    5 M1 = M-1                                                          007180
      N1=N-1                                                            007190
      DO  10 I = 2,M1                                                   007200
      RHO2 = RHO(I)**2                                                  007210
      QTEST=.5*RHO2/SIG2                                                007220
      IF (QTEST .GT. 220.) 1020,1030                                    007230
 1020 QQ=0.                                                             007240
      GOTO 1040                                                         007250
 1030 QQ=Q0*EXP(-QTEST)                                                 007260
 1040 CONTINUE                                                          007270
      DO 10 J = 2,N1                                                    007280
   10 Q(I,J) = QQ                                                       007290
      RETURN                                                            007300
   20 WRITE(IPRINT,100)                                                 007310
  100 FORMAT(1H0,*SIG = 0. DEFAULT OPTION IS  Q = 0*)                   007320
      RETURN                                                            007330
       END                                                              007340
```

A.6 Subroutine SPLNI

```
      SUBROUTINE SPLNI(N,M,EPS,X,Y,T,SS,SS1,SS2,QUA)                    007350
C                                                                       007360
C     FIND THIRD ORDER SPLINE FCT  FOR A FCT Y(X) GIVEN AT THE          007370
C     POINTS (X(I),Y(I))                                                007380
C     FOLLOWING CHAP.9 OF VOL2 OF RALSTON + WILF                        007390
C                                                                       007400
C     N = NO.OF GIVEN DATA POINTS                                       007410
C     M = NO.OF SPECIFIED ARGUMENTS T(I) FOR WHICH THE SPLINE           007420
C       SS,ITS FIRST DER,SS1 AND SECOND DER,SS2 ARE TO BE COMPUTED      007430
C     EPS = ERROR TOLERANCE  IN ITERATIVE STEPS                         007440
C     X= ARRAY OF STRICTLY INCREASING ABSCISSAS                         007450
C     Y = ARRAY OF FCT VALUES                                           007460
C     T = ARRAY PF DESIRED ABSCISSAS                                    007470
C     SS = ARRAY OF SPLINE VALUES , SS1,SS2 DERIVATIVES                 007480
C     QUA = ARRAY OF VALUES OF INTEGRAL FROM X(1) TO X(N)               007490
C     LIMITATIONS N NOT LARGER THAN 50                                  007500
C                                                                       007510
      DIMENSION X(1),Y(1),T(1),SS(1),SS1(1),SS2(1),QUA(1)               007520
      DIMENSION H (82),H2(82),DELY(82),B(82),DELSY(82)                  007530
      DIMENSION S2(82),C(82),S3(82)                                     007540
      DATA OMEGA/1.0717968/                                             007550
      N1=N-1                                                            007560
 3    DO 51 I=1,N1                                                      007570
      H(I)=X(I+1)-X(I)                                                  007580
 51   DELY(I)=(Y(I+1)-Y(I))/H(I)                                        007590
 4    DO 52 I=2,N1                                                      007600
      H2(I)=H(I-1)+H(I)                                                 007610
      B(I)= .5*H(I-1)/ H2(I)                                            007620
      DELSY(I)=(DELY(I)-DELY(I-1))/H2(I)                                007630
      S2(I)=2.*DELSY(I)                                                 007640
 52   C(I)=3.*DELSY(I)                                                  007650
      S2(1)=0.                                                          007660
      S2(N)=0.                                                          007670
 5    ETA=0.                                                            007680
 6    DO 10 I=2,N1                                                      007690
 7    W=(C(I)-B(I)*S2(I-1)-(.5-B(I))*S2(I+1)-S2(I))*OMEGA               007700
 8    IF (ABS(W)-ETA) 10,10,9                                           007710
 9    ETA=ABS(W)                                                        007720
 10   S2(I)=S2(I)+W                                                     007730
```

```
   13  IF (ETA-EPS) 14,5,5                                                      007740
   14  DO 53 I=1,N1                                                             007750
   53  S3(I)=(S2(I+1)-S2(I))/H(I)                                               007760
   15  DO 61 J=1,M                                                              007770
   16  I=1                                                                      007780
   54  IF (T(J)-X(1)) 58,17,55                                                  007790
   55  IF (T(J)-X(N)) 57,59,58                                                  007800
   56   IF (T(J)-X(I)) 60,17,57                                                 007810
   57  I=I+1                                                                    007820
       GO TO 56                                                                 007830
   58  WRITE (6,44) J                                                           007840
   44  FORMAT (I4,24HTH ARGUMENT OUT OF RANGE)                                  007850
       GO TO 61                                                                 007860
   59  I=N                                                                      007870
   60  I=I-1                                                                    007880
   17  HT1=T(J)-X(I)                                                            007890
       HT2=T(J)-X(I+1)                                                          007900
       PROD=HT1*HT2                                                             007910
       SS2(J)=S2(I)+HT1*S3(I)                                                   007920
       DELSS=(S2(I)+S2(I+1)+SS2(J))/6.                                          007930
       SS(J)=Y(I)+HT1*DELY(I)+PROD*DELSS                                        007940
       SS1(J)=DELY(I)+(HT1+HT2)*DELSS+PROD*S3(I)/6.                             007950
   61  CONTINUE                                                                 007960
    20 QUA(1) = 0.0                                                             007970
       DO 62 I=1,N1                                                             007980
    62 QUA(I+1)=QUA(I)+.5*H(I)*(Y(I)+Y(I+1))-H(I)**3*(S2(I)+S2(I+1))/24.        007990
       RETURN                                                                   008000
       END                                                                      008010
```

A.7 Subroutine GETDATA

```
      SUBROUTINE GETDATA(DATAIN,NV,IIN,IOUT1,IOUT2,IIN1,ISIZE                   008020
     +,ISIZET,INDIC)                                                            008030
C THE MAIN PURPOSE OF THIS SUBROUTINE IS TO INPUT CHARACTER STRING OR            008040
C NUMERICAL DATA IN A ≡CONVERSATIONAL≡ MODE I.E. FOR INPUTTING DATA             008050
C TO PROGRAMS BEING RUN UNDER INTERCOM.                                         008060
C IT ALSO MAY BE USED FOR BATCH PROCESSING-IN WHICH CASE THE DATA               008070
C SHOULD APPEAR 6 VALUES TO A CARD. DATA WHICH IS NOT TO BE CHANGED             008080
C SHOULD BE REPLACED BY BLANKS. FOR BATCH ALL OR SOME OF THE DATA MAY           008090
C BE DEFAULTED BY USING AN EOR AFTER THE LAST DATA TO BE INPUTTED.              008100
C THE SUBROUTINE ASSUMES THAT DEFAULT VALUES HAVE BEEN ASSIGNED                 008110
C AND WILL PRINT OUT THESE DEFAULT VALUES BEFORE ASKING FOR DATA INPUT.         008120
C IT ASKS FOR NEW VALUES BY PRINTING OUT THE ≡NAMES≡ OF THE DATA AND THEN      008130
C SKIPPING A LINE. VALUES TO BE ASSIGNED TO THE NAMES SHOULD BE                 008140
C ENTERED STARTING IN THE SAME COLUMN AS THE START OF THE NAME.                 008150
C EACH DATUM IS ASSIGNED 10 COLUMNS AND UP TO 6 ITEMS MAY BE INPUTTED           008160
C IN A SINGLES ROW.                                                             008170
C ARGUMENTS**********************                                               008180
C D TAIN  (DIMENSION (NV,3) WHERE NV IS THE TOTAL # OF DATA                     008190
C     TO BE INPUTTED)                                                           008200
C DATAIN HOLDS THE FOLLOWING INFORMATION ABOUT EACH DATUM-                      008210
C NAME,VALUE,CODE WHERE-                                                        008220
C NAME => NAME BY WHICH THE DATUM IS IDENTIFIED TO THE USER (IT MAY OR          008230
C MAY NOT BE EQUAL TO THE FORTRAN VARIABLE NAME TO BE ASSIGNED TO THE           008240
C DATUM.)                                                                       008250
C VALUE => NUMERICAL OR CHARACTER STRING VALUE TO BE ASSIGNED (THE DATUM)      008260
C CODE => HOW THE DATUM IS TO BE INTERPRETED                                    008270
C    -1 => CHARACTER STRING                                                     008280
C     0 => INTEGER                                                              008290
C     1 => FLOATING POINT NUMBER                                                008300
C NV TOTAL NUMBER OF DATUM TO BE INPUTTED                                       008310
C IIN FILE NO. FOR INPUTTING                                                    008320
C IOUT1 PRIMARY OUTPUT FILE                                                     008330
C IOUT2 SECONDARY OUTPUT FILE                                                   008340
C ISIZE =>  SIZE OF FIRST DIMENSION OF DATAIN                                   008350
```

```
      DIMENSION DATAIN(ISIZET),IA(6)                                    008360
      COMMON/SENSE/IINNN,IOUTNN,INDICC                                  008370
      INTEGER DATAIN,F                                                  008380
      EXTERNAL SSWTCH                                                   008390
      CALL ERRSET(KOUNT,20000)                                          008400
      KOUNT1=KOUNT                                                      008410
      IF(INDIC.NE.0) 200,210                                            008420
  200 ISW=2                                                             008430
      LL=0                                                              008440
      L=INDIC-1                                                         008450
      GOTO 1055                                                         008460
  210 CONTINUE                                                          008470
      ISW=1                                                             008480
      IDOL=00000000000000000053B                                        008490
      IINNN=IIN                                                         008500
      IOUTNN=IOUT1                                                      008510
      IOUTT=IOUT1                                                       008520
      ISN=1                                                             008530
      IBLANK=10H                                                        008540
      CALL SSWTCH(IIN1,ISW3,10HREAD DATA ,5HFILE-),RETURNS(1060)        008550
      IF (ISW3 .EQ. 1) 1300,1290                                        008560
 1300 WRITE (IOUT1,17) IIN1                                             008570
      REWIND IIN1                                                       008580
      READ(IIN1) DATAIN                                                 008590
      REWIND IIN1                                                       008600
      IF (EOF(IIN1)) 1400,1290                                          008610
 1400 WRITE(IOUT1,24) IIN1                                              008620
 1290 CONTINUE                                                          008630
      CALL SSWTCH(0,ISW4,10HDEFAULTS L,5HISTED),RETURNS(1060)           008640
      IF (ISW4 .NE. 1) GOTO 1150                                        008650
      WRITE(IOUT1,1)                                                    008660
 1140 DO 110 I=1,NV                                                     008670
      II=ISIZE+I                                                        008680
      III=I                                                             008690
      II2=II+ISIZE                                                      008700
      IF (DATAIN(II2)) 1020,1030,1040                                   008710
 1020 WRITE(IOUTT,2) DATAIN(II),DATAIN(III)                             008720
      GOTO 110                                                          008730
 1030 WRITE (IOUTT,3) DATAIN(II),DATAIN(III)                            008740
      GOTO 110                                                          008750
 1040 WRITE(IOUTT,4) DATAIN(II),DATAIN(III)                             008760
 110  CONTINUE                                                          008770
      GOTO (1150,1130) ISN                                              008780
 1150 CALL SSWTCH(0,ISW5,10HNAME-VALUE,5H MODE),RETURNS(1060)           008790
      IF (ISW5 .EQ. 1) 1270,1050                                        008800
 1050 L=1                                                               008810
      ISW=2                                                             008820
      LL=0                                                              008830
 1055 L=L+LL                                                            008840
      IF (L .GT. NV) GOTO 1060                                          008850
 1310 WRITE (IOUT1,18) DATAIN(ISIZE+L)                                  008860
      LL=7                                                              008870
      DO 100 J=1,6                                                      008880
      IA(J)=10H                                                         008890
 100  CONTINUE                                                          008900
      READ(IIN,10) (IA(J),J=1,6)                                        008910
      IF (EOF(IIN)) 1320,1070                                           008920
 1320 INDICC=1                                                          008930
      GOTO 1060                                                         008940
 1070 IF (IA(1) .EQ. IBLANK) GOTO 1055                                  008950
      DO 180 J=1,6                                                      008960
      DO 180 K=1,10                                                     008970
      IF (MXGETX(IA(J),K,1) .EQ. IDOL) GOTO 1270                        008980
 180  CONTINUE                                                          008990
      DO 190 J=1,6                                                      009000
      JR=L+J-1                                                          009010
      F=DATAIN(JR+2*ISIZE)                                              009020
      IF (F) 1090,1100,1110                                             009030
 1090 IF (IA(J) .NE. IBLANK) DECODE(10,11,IA(J)) DATAIN(JR)             009040
      GOTO 1080                                                         009050
 1100 CALL RJUST(IA(J))                                                 009055
      IF (IA(J) .NE. IBLANK) DECODE(10,12,IA(J)) DATAIN(JR)             009060
      GOTO 1080                                                         009070
 1110 CALL RJUST(IA(J))                                                 009075
      IF (IA(J) .NE. IBLANK) DECODE(10,13,IA(J)) DATAIN(JR)             009080
 1080 IF (IA(J) .EQ. IBLANK) GOTO 1081                                  009090
 190  CONTINUE                                                          009100
 1081 LL=J-1                                                            009110
      IF(INDIC.NE.0) LL=1000                                            009120
      IF (KOUNT .EQ. KOUNT1) GOTO 1055                                  009130
      KOUNT1=KOUNT
      WRITE(IOUT1,25)
 1270 WRITE(IOUT1,23)
 1250 WRITE(IOUT1,8)
      DO 150 I=1,6
      IA(I)=10H
 150  CONTINUE
      READ(IIN,10) (IA(I),I=1,6)
      IF (EOF(IIN)) 1330,1085
 1330 INDICC=1
      GOTO 1060
 1085 II=IA(1)
      IF (II .EQ. IBLANK) GOTO 1060
      DO 130 I=1,NV
      J=I+ISIZE
      IF (II .EQ. DATAIN(J)) GOTO 1160
 130  CONTINUE
      WRITE(IOUT1,16)
      GOTO 1270
 1160 F=DATAIN(J+ISIZE)
      JJ=J-ISIZE
      IF (F) 1170,1180,1190
 1170 DO 160 I=2,6
      IF (IA(I) .EQ. IBLANK  .AND. I.GT.2) GOTO 1240
      DECODE(10,11,IA(I)) DATAIN(JJ+I-2)
 160  CONTINUE
      GOTO 1240
 1180 CALL RJUST(IA(2))
      DECODE(10,12,IA(2)) DATAIN(JJ)
      GOTO 1240
 1190 CALL RJUST(IA(2))
      DECODE(10,13,IA(2)) DATAIN(JJ)
 1240 IF (KOUNT .EQ. KOUNT1) GOTO (1250,1310) ISW
      KOUNT1=KOUNT
      WRITE(IOUT1,25)
      GOTO 1250
 1060 WRITE (IOUT1,14)
      IF (IOUT2 .EQ. 0) GOTO 1130
      WRITE (IOUT2,15)
      IOUTT=IOUT2
      ISN=2
      GOTO 1140
 1130 INDIC=INDICC
      RETURN
 1    FORMAT(/,* THE DEFAULT INPUT DATA ARE*)
 2    FORMAT(1X,A10,*=*,A10,***)
 3    FORMAT(1X,A10,*=*,I10)
 4    FORMAT(1X,A10,*=*,G16.6)
 5    FORMAT(///)
 6    FORMAT(/,* ENTER DATA. START IN COL. BENEATH START OF NAME*)
 7    FORMAT(8X,6A10)
 8    FORMAT(8X)
 10   FORMAT(6A10)
 11   FORMAT(A10)
 12   FORMAT(I10)
 13   FORMAT(E10.0)
 14   FORMAT(/,* DATA INPUT COMPLETE*)
 15   FORMAT(/,* THE INPUT DATA VALUES ARE*,/)
 16   FORMAT(1X,* TRY AGAIN*)
 17   FORMAT(/,1X,* READING DATA FROM *,I5)
 18   FORMAT(1X,A10,*-*)
 23   FORMAT(8X,*NAME       VALUE.....*)
 24   FORMAT(1X,* FILE*,I5,* IS EMPTY*)
 25   FORMAT(1X,* WRONG DATA TYPE-TRY AGAIN*)
      END
```

A.8 Subroutine SSWTCH

```
      SUBROUTINE SSWTCH(I,J,M1,M2),RETURNS(M)                           009770
      COMMON/SENSE/IIN,IOUT1,INDIC                                      009780
      IF (I .EQ. 0) GOTO 100                                            009790
      WRITE(IOUT1,1) M1,M2,I                                            009800
      GOTO 110                                                          009810
100   WRITE(IOUT1,2) M1,M2                                              009820
110   READ(IIN,3) JJ                                                    009830
      J=2                                                               009840
      IF(JJ .EQ. 1HY) J=1                                               009850
      INDIC=EOF(IIN)                                                    009860
      IF (INDIC) 1000,1010                                              009870
1000  RETURN M                                                          009880
1010  RETURN                                                            009890
1     FORMAT(1X,A10,A5,I2,*?-*)                                         009900
2     FORMAT(1X,A10,A5,*?-*)                                            009910
3     FORMAT(A1)                                                        009920
      END                                                               009930
```

A.9 Subroutine RJUST

```
      SUBROUTINE RJUST(L)                                               009940
      DIMENSION LC(9)                                                   009950
      DATA (LC=77555555555555555555B,77775555555555555555B,            009960
     +77777755555555555555B,77777777555555555555B,                      009970
     +77777777775555555555B,77777777777755555555B,                      009980
     +77777777777777555555B,77777777777777775555B,                      009990
     +77777777777777777755B)                                            010000
      LB=1                                                              010010
      IBITS=0                                                           010020
      DO 100 I=1,9                                                      010030
      IBITS=IBITS+6                                                     010040
      LB=MASK(IBITS).OR.LB                                              010050
      IF (LB.EQ.LC(I)) GOTO 110                                         010060
100   CONTINUE                                                          010070
      GOTO 120                                                          010080
110   L=SHIFT(L,IBITS)                                                  010090
120   RETURN                                                            010100
      END                                                               010110
```

Appendix B

Fortran Listings for TIKIRK Program, Options No. 1 and No. 2 Only

B.1 Main Program TIKIRK

```
      PROGRAM TIKIRK(TAPE4=80/80,TAPE5=80/80,TAPE3,TAPE7,TAPE8,                 000100
     +TAPE6=80/80,OUTPUT=80)                                                    000110
C THIS PROGRAM CAN BEST BE DESCRIBED AS THE I/O INTERFACE FOR FUNCTION          000120
C SUBROUTINE IKIRK WHICH COMPUTES THE KIRKHOFF INTENSITY FUNCTION AS            000130
C DESCRIBED IN AFCRL-72-0565.                                                   000140
C    THE INPUT FALLS INTO THREE CLASSES*                                        000150
C  1) INPUT HAVING TO DO WITH PROPERTIES OF THE WINDOW MATERIAL AND             000160
C THE LASER BEAM,NAMELY% (QUANTITIES CGS UNLESS OTHERWISE INDICATED)            000170
C SIG    =>  VALUE OF SIGMA IN GAUSSIAN BEAM                                    000180
C LAMBDA =>  WAVELENGTH OF THE LIGHT BEAM IN MICRONS                            000190
C P      =>  TOTAL BEAM POWER                                                   000200
C R      =>  WINDOW RADIUS                                                      000210
C BETA   =>  BULK ABSORPTION COEFFICIENT                                        000220
C K      =>  THERMAL CONDUCTIVITY                                               000230
C NX     =>  INDEX OF REFRACTION                                                000240
C S1R    =>  S SUB-1,SUP-RHO                                                    000250
C S1T    =>  S SUB-1,SUP-THETA                                                  000260
C S2R    =>  S SUB-2,SUP-RHO                                                    000270
C S2T    =>  S SUB-2,SUP-THETA                                                  000280
C T      =>  TIME AT WHICH IKIRK IS TO BE EVALUATED                             000290
C  2) INPUT HAVING TO DO WITH THE EVALUATION DOMAIN OF THE FUNCTION             000300
C IKIRK,NAMELY%                                                                 000310
C      X0   => GAUSSIAN FOCAL DISTANCE (METERS)                                 000320
C      X1     => MINIMUM X-VALUE FOR FUNCTION EVALUATION (METERS)               000330
C      X2     => MAXIMUM X-VALUE FOR FUNCTION EVALUATION (METERS)               000340
C      RHOP1  => MINIMUM RADIUS VALUE FOR FUNCTION EVALUATION                   000350
C      RHOP2  => MAXIMUM RADIUS VALUE FOR FUNCTION EVALUATION                   000360
C      MP     => NUMBER OF EVALUATION POINTS IN THE RADIAL DIRECTION            000370
C      NP     => NUMBER OF EVALUATION POINTS IN THE AXIAL (X) DIRECTION         000380
C      TIM    => ARRAY (UP TO 10) OF TIME VALUES FOR FUNCTION EVALUATION        000390
C          (TIME VALUES SHOULD BE IN INCREASING SEQUENCE)                       000400
C      UMIN   => MINIMUM U-VALUE FOR FUNCTION EVALUATION (SEE MODE)             000410
C      UMAX   => MAXIMUM U-VALUE FOR FUNCTION EVALUATION                        000420
C      VMIN   => MINIMUM V-VALUE FOR FUNCTION EVALUATION                        000430
C      VMAX   => MAXIMUM V-VALUE FOR FUNCTION EVALUATION                        000440
C   3) INPUT HAVING TO DO WITH PROGRAM CONTROL,NAMELY%                          000450
C      EPST   => ERROR VALUE FOR INTERPOLATION OF THE TEMPERATURE               000460
C FUNCTION OUTPUTTED BY TEMP5 AND INTERPOLATED BY IBM SCI. SUB. ALI.            000470
C      MINT   => NUMBER OF TEMPERATURE FUNCTION POINTS TO BE USED IN            000480
C THE INTERPOLATION (DEFAULT=6)                                                 000490
C      IPRNT => USED TO CONTROL DEBUG OUTPUT (1 CAUSES DEBUG OUTPUT)             000500
C               (2 CAUSES WINDOW TEMPERATURE DISTRIBUTION SUITABLE FOR          000510
C               DISPLAY TO BE OUTPUT)                                           000520
C      NGAUS => NUMBER OF FUNCTION VALUES FOR GAUSSIAN INTEGRATION              000530
C      MODE   => IF MODE=1 THEN THE INTENSITY FUNCTION IS EVALUATED AT          000540
C EQUI-SPACED X AND RHOP-PRIME VALUES; IF MODE=2 IT IS EVALUATED AT             000550
C EQUI-SPACED U AND V VALUES.                                                   000560
C      I2      => IF 1 USE IKIRK, IF 2 USE IKIRKP                               000570
C              (NOTE THAT IKIRKP SHOULD ONLY BE USED ON THE AXES                000580
C               FOR CONSTANT TEMPERATURE WINDOW)                                000590
C ALL THE ABOVE MENTIONED DATA IS OBTAINED BY TWO CALLS TO THE                  000600
C INTERACTIVE INPUT SUBROUTINE GETDATA DESCRIBED IN PML TM-16. IN THE           000610
C FIRST CALL ALL DATA IN THE FIRST CATEGORY IS OBTAINED. IN THE                 000620
C SECOND CALL ALL DATA IN  THE SECOND AND THIRD CATEGORIES ARE                  000630
C OBTAINED.  AN EXCEPTION TO THIS IS I2 (CONTROLS USE OF                        000640
C IKIRK AND IKIRKP) WHICH IS OBTAINED ON THE FIRST CALL TO GETDATA.             000650
C  FOR A LISTING OF DEFAULT INPUT DATA IT IS RECOMMENDED THAT                   000660
C TIKIRK BE RUN INTERACTIVELY UNDER INTERCOM AFTER GIVING THE COMMAND           000670
C CONNECT(TAPE4,TAPE5).                                                         000680
C THE MAIN OUTPUT OF TIKIRK IS A SEQUENCE OF UNFORMATTED RECORDS                000690
C OF INTENSITY VALUES WITH CORRESPONDING DOMAIN VALUES. EACH RECORD             000700
C CONSISTS OF THE FOLLOWING SEQUENCE OF VALUES*                                 000710
C RECORD NO., NUMBER(MP) OF INTENSITY VALUES IN THE AXIAL DIRECTION,            000720
C AXIAL COORDINATE X OR U, TIME VALUE (T) IN SECONDS, NUMBER (NP)               000730
C OF INTENSITY VALUES IN THE RADIAL DIRECTION, MINIMUM RADIAL                   000740
C COORDINATE RHOP1 OR VMIN, MAXIMUM RADIAL COORDINATE RHOP2 OR                  000750
C VMAX, MP INTENSITY VALUES.                                                    000760
C FOR EACH VALUE OF T, NP RECORDS ARE OUTPUTTED CORRESPONDING TO THE            000770
C NP X EVALUATION POINTS. THE RECORD NUMBER RUNS FROM 1 TO NP FOR               000780
C EACH TIME VALUE.                                                              000790
C THERE ARE SIX FILES ASSOCIATED WITH THIS PROGRAM (NOT INCLUDING FILE          000800
C *OUTPUT*). THE FILES ARE REFERRED TO IN THE PROGRAM AND ASSOCIATED            000810
C SUBROUTINES AS IT3,IT4,IT5,IT6,IT7,IT8. THE FILE VALUES ARE IN TURN           000820
C ASSIGNED TO THE USUAL FORTRAN *TAPEN* BY A DATA STATEMENT AND PROGRAM         000830
```

```
C ASSOCIATION IT IS NECESSARY TO CHANGE  EITHER OR BOTH THE DATA AND      000850
C PROGRAM STATEMENTS.                                                     000860
C THESE FILES SERVE THE FOLLOWING PURPOSES%                               000870
C    IT3 => FILE OUTPUTTED BY PROGRAM TEMP5                               000880
C    IT4 => @INTERACTIVE@ INPUT FILE (SEE GETDATA)                        000890
C    IT5 => @INTERACTIVE@ OUTPUT FILE (SEE GETDATA)                       000900
C    IT6 => LISTING OF ALL INPUT PARAMETERS AND DEBUG OUTPUT              000910
C    IT7 => UNFORMATTED INTENSITY VALUES. ALSO MAY BE USED TO INSERT      000920
C    IT8 => UNFORMATTED TEMPERATURE DISTRIBUTION VALUES                   000930
C           SUITABLE FOR DISPLAY PURPOSES                                 000940
C        PREASSIGNED DATA IN CATEGORIES 2 AND 3                           000950
C IN ADDITION TO THE ABOVE FACTS. THE USER SHOULD BE AWARE OF TWO         000960
C PROGRAM @CONSTANTS@. THE FIRST UNDER THE VARIABLE NAME NT IS THE NUM-   000970
C BER OF TIME VALUES PERMITTED. AT PRESENT THIS IS SET TO 10. (THE        000980
C DIMENSION OF THE TIME ARRAY TIM). ALSO NOTE THAT ALL THE TIME           000990
C DEFAULT VALUES ARE ZERO EXCEPT THE FIRST AND THAT THE PROGRAM STOPS     001000
C AS SOON AS A SUCCEEDING TIME VALUE IS LESS THAN THE PRECEEDING          001010
C TIME VALUE.                                                             001020
C THE SECOND @CONSTANT@ HAS TO DO WITH THE SIZE OF THE RECORD OUTPUTTED   001030
C BY TEMP5. THE SUBROUTINE RTAPE3 READS THE TEMP5 OUTPUT UNDER THE        001040
C ASSUMPTION THAT ALL @RADIAL@ ARRAYS ARE OF DIMENSION 82 AND @AXIAL@     001050
C ARRAYS ARE OF DIMENSION 22.SEE COMMENTS WITHIN SUBROUTINE RTAPE3.       001060
C THE INTENSUTY FUNCTION IKIRK IS DEFINED EXPLICITLY AS A FUNCTION OF     001070
C THE NONDIMENSIONAL VARIABLES U AND V AND IMPLICITLY AS A FUNCTION       001080
C OF NON-DIMENSIONAL TIME TAU THROUGH THE TIME DEPENDANT FUNCTIONS        001090
C PHI-THETA AND PHI-RHO AS DEFINED IN THE ABOVE REFERENCE. THESE          001100
C VARIABLES ARE PASSED THROUGH AN ARGUMENT LIST. ALL PARAMETERS           001110
C REQUIRED FOR EVALUATION OF IKIRK ARE PASSED THROUGH BLOCK COMMON        001120
C .PHIBLK. THESE PARAMETERS ARE%                                          001130
C    CS1R    => C*S1R (SEE IKIRK COMMENTS)                                001140
C    CS2R    => C*S2R          "                                          001150
C    CS1R    => C*S1T          "                                          001160
C    CS2T    => C*S2T          "                                          001170
C    XS      => STARTING ARGUMENT FOR FUNCTIONS F1.F2 (SEE FUNCTION       001180
C               PHI COMMENTS)                                             001190
C    DX      => INTERVAL BETWEEN EQUI-SPACED ARGUMENTS OF F1,F2.          001200
C    NF      => NUMBER OF VALUES OF F1.F2                                 001210
C    MNNT    => MINT (SEE INPUT DATA)                                     001220
C    EPP     => EPS1           "                                          001230
                                                                          001240
C    F1(200)=> HOLDS VALUES OF F1 FROM TEMP5                              001250
C    F2(200)=> HOLDS VALUES OF F2 FROM TEMP5                              001260
C    HOLD    => STORES PHI-THETA (PHI-RHO AND PHI-THETA ARE EVALUATED     001270
C                     SIMULTANEOUSLY)                                     001280
C    A       => 1/SQRT(2)/SIG (=ALPHA IN THE ABOVE REFERENCE)             001290
C    KE      => WAVE NUMBER                                               001300
C    TLAST   => STORES TIME VALUE READ FROM TEMP5 RECORD                  001310
C    TNEXT   =>                 "                                         001320
C    IERR    => ERROR INDICATOR FOR RTAPE3 (INDICATES OUT OF RANGE        001330
C                TIME OR OUT OF SEQUENCE TIME)                            001340
C    IP      => DEBUG OUTPUT @SWITCH@                                     001350
C    MP1     => =NF                                                       001360
C    ISW     => SWITCH FOR GAUSSIAN INTEGRATION. WHEN ISW=1 THEN THE      001370
C         X-VALUES FOR GAUSSIAN INTEGRATION ARE FOUND.                    001380
C    NGAUSS => NUMBER OF POINTS USED IN THE GAUSSIAN INTEGRATION          001390
C          (NOTE THAT IS NGAUSS IS CHANGED THEN THE GAUSSIAN INTEGRATION  001400
C          SUBROUTINE MUST ALSO BE CHANGED.)                              001401
C    RAD     => WINDOW RADIUS                                             001402
C    NP1     => NUMBER OF TEMPERATURE SAMPLES IN AXIAL DIRECTION          001403
C                (USED FOR OUTPUTTING DISPLAY COMPATIBLE                  001404
C                TEMPERATURE DATA)                                        001405
C    C3      => CONSTANT TO DIMENSIONALIZE TEMPERATURE DATA               001406
C                FOR DISPLAY                                              001407
C    C1      => CONSTANT USED TO DIMENSIONALIZE TIME FOR                  001410
      REAL K,IKIRK,LAMBDA,NX,KE                                           001420
      REAL IKIRKP                                                         001430
      LOGICAL S                                                           001440
      DIMENSION BUF(100)                                                  001450
      COMMON/IFILES/IT3,IT4,IT5,IT6,IT7,IT8                               001460
      COMMON/PHIBLK/CS1R,CS2R,CS1T,CS2T,XS,DX,NF,MNNT,EPP,F1(200),        001470
     +F2(200),HOLD,A,KE,TLAST,TNEXT,IERR,IP,MP1,ISW,NGAUSS,               001480
     +RAD,NP1,C3,C1                                                       001490
      INTEGER DATAIN(100,3),DATAIN1(100,3)                                001500
      COMMON/BLOCK2/X0,X1,X2,RHOP1,RHOP2,MP,NP,TIM(10),EPS1               001508
C              TEMPERATURE DISPLAY
```

```
     +.MINT.IPRNT.NGAUS.MODE.UMIN.UMAX.VMIN.VMAX.DUM(20).MSKIP.NSKIP
      COMMON/BLOCK1/
     +      I1.I2.I3.I4.I5.I6.I7.M.N.MI.NI.ICNT.IU.IO.NO.NMX.IRUN.
     +ICARD.IPRINT.IPNCH.ITAP3.ITAP4.RHO1.RHO12.ZED1.ZED12.DTAUU.
     +TAUMX.TAUOFF.SIG  .QQ.UQ.     EPS.G1(4).H1(4).MATER.NX.BETA.
     +K.LAMBDA.S1R.S1T.S2R.S2T.
     +DEN.CP.R.EXPER.PW.R1.Z1.R2.IPLOT.PROBNO.TICU.XLEN.YLEN.SCALEX.
     +SCALEY1.SCALEY2.XTITLE(5).YTITLE1(5).YTITLE2(5).NAME
      EQUIVALENCE (I1.DATAIN).(X0.DATAIN1)
      DATA (DATAIN(I.1).I=1.92)/7*2.80.20.3*1.0.1.2.11.100.4.6.6.3.
     +4.0.,1.,-.5546.1.1092.,0035.5 .5.,.1292.2*0.,.001.4*0.,0.,3*.015.
     +3HKCL.1.47.4.8E-4.,0653.10.6.-.34E-5.,05E-5.,1E-5.-.1E-5.1.98.
     +.691.1.258.1H1.24.7.81.11.1.1.4H7204.,5.20.,9.,30.,.1.,1.
     +10HTIME(SECON.3HDS).3*1H .10HTEMP-DEGC .10H ABOVE AMB.
     +3*1H .10HMEAN TEMP .10H ABOVE AMB.3*1H .7HBARRETT.
     +10HRADIAL DIS.10HTANCE.RHO-.4H(CM).1H .1H .10HAXIAL DIST.
     +10HANCE.Z-(CM.1H).1H .1H /
      DATA (DATAIN(I.2).I=1.92)/2HI1.2HI2.2HI3.2HI4.2HI5.
     +2HI6.2HI7.1HM.1HN.2HMI.2HNI.4HICNT.2HIU.2HIQ.2HNO.3HNMX,
     +4HIRUN.5HICARD.6HIPRINT.5HIPNCH.5HITAP3.5HITAP4.4HRHO1.
     +5HRHO12.4HZED1.5HZED12.5HDTAUU.5HTAUMX.6HTAUOFF.3HSIG.
     +2HQQ.2HUQ.3HEPS.5HG1(1).5HG1(2).5HG1(3).5HG1(4).5HH1(1),

     +5HH1(2).5HH1(3).5HH1(4).8HMATERIAL.8HREF.IND..4HBETA.
     +9HTHER.COND.6HLAMBDA.3HS1R.3HS1T.3HS2R.3HS2T.
     +             7HDENSITY.9HSPEC.HEAT.6HRADIUS.5HEXPER.
     +3HPWR      .3HR1#.3HZ1#.3HR2#.4HPLT?1Y.2N.6HPROBNO.4HTICU.
     +4HXLEN.4HYLEN.7HX-SCALE.8HY1-SCALE.8HY2-SCALE.6HXTITLE.
     +1H2.1H3.1H4.1H5.7HYTITLE1.1H2.1H3.1H4.1H5.7HYTITLE2.1H2,
     +1H3.1H4.1H5.8HOPERATOR.
     +3HXT1.3HXT2.3HXT3.3HXT4.3HXT5.3HYT1.3HYT2.3HYT3.3HYT4.
     +3HYT5/
      DATA (DATAIN(I.3).I=1.92)/22*0.19*1.-1.11*1.-1.1.4*0.
     +-1.6*1.26*-1/
      DATA (DATAIN1(I.1).I=1.48)/1500..1000..2000..0..2..100.100.10..
     +9*-1...001.6.1.24.2.-40..40..0..10..
     +10HKIRKHOFF I.10HNTENSITY F.9HUNCTION.I.1H .1H .10HTIME IN SE.
     +5HCONDS.1H .1H .1H .10HNON-DIMENS.10HIONAL RADI.10HAL DISTANC.
     +3HE.V.1H .10HNON-DIMENS.10HIONAL AXIA.10HL DISTANCE.2H.U.1H .5.5/
      DATA (DATAIN1(I.2).I=1.48)/2HX0.2HX1.2HX2.5HRHOP1.5HRHOP2.2HMP.
     +2HNP.2HT1.2HT2.2HT3.2HT4.2HT5.2HT6.2HT7.2HT8.2HT9.3HT10.
     +4HEPS1.4HMINT.5HIPRNT.5HNGAUS.4HMODE.4HUMIN.4HUMAX.
     +4HVMIN.4HVMAX.3HST1.3HST2.3HST3.3HST4.3HST5.3HPT1.3HPT2.
     +3HPT3.3HPT4.3HPT5.3HXT1.3HAT2.3HXT3.3HXT4.3HXT5.3HYT1.
     +3HYT2.3HYT3.3HYT4.3HYT5.5HMSKIP.5HNSKIP/
      DATA (DATAIN1(I.3).I=1.48)/5* .2*0.11*1.4*0.4*1.20*-1.2*0/
      DATA IT3.IT4.IT5.IT6.IT7.IT8/3.4.5.6.7.8/
      INDIC=0
      S=.F.
      ISW=1
      NT=10
      CALL GETDATA(DATAIN.92.4.5.6.3.100.300.INDIC)
      CALL GETDATA(DATAIN1.48.4.5.6.7.100.300.INDIC)
      IF (MODE .NE. 1) GOTO 150
      DATAIN1(37.1)=10HRADIAL DIS
      DATAIN1(38.1)=10HTANCE.RHO-
      DATAIN1(39.1)=10HPRIME (CM)
      DATAIN1(40.1)=10H
      DATAIN1(42.1)=10HAXIAL DIST
      DATAIN1(43.1)=10HANCE.X (CM
      DATAIN1(44.1)=1H)
  150 WRITE (IT7) DATAIN
      WRITE (IT7) DATAIN1
      IF (MODE .EQ. 1) S=.T.
      REWIND IT3
      READ(IT3)
      TLAST=TNEXT=0.
      KE=6.28318E4/LAMBDA
      EPP=EPS1
      IP=IPRNT
      NGAUSS=NGAUS
      XS=0.
      DX=1./M
      MNNT=MINT
      MP1=M+1
      NF=MP1
      IF (S) GOTO 120
      XMAX=VMAX
      XMIN=VMIN
      GOTO 140
  120 XMIN=RHOP1
      XMAX=RHOP2
  140 CONTINUE
      A=.5/SIG
      C=PW*(NX**2+1)/2./NX
      C=C*R*BETA/3.14159/K
      CS1R=C*S1R
      CS2R=C*S2R
      CS1T=C*S1T
      CS2T=C*S2T
      RSQ=R*R
      X0=X0*100.
      X1=X1*100.
      X2=X2*100.
      C1=K/RSQ/DEN/CP
      DELX=(X2-X1)/(AMAX0(1,NP-1))
      DELRHO=(RHOP2-RHOP1)/(AMAX0(1,MP-1))
      DELV=(VMAX-VMIN)/(AMAX0(1,MP-1))
      DELU=(UMAX-UMIN)/(AMAX0(1,NP-1))
      RAD=R
      NP1=N+1
      C3=C/R
      X0I=1./X0
      NREC=0
      IT=1
      TR=T=TIM(1)
      IF (T .LT. 0.) GOTO 2000
      IF(IP.EQ.2)  WRITE(IT8) DATAIN
 1000 T=T*C1
      WRITE(IT5,2) T
      IF (T .GT. TAUMX) GOTO 2000
      X1T=X1
      X1I=1./X1T
      U=UMIN
      DO 100 I=1,NP
      CX=(X0*X1I)**2
      IF (S) U=KE*RSQ*(X0I-X1I)
      RHOP=RHOP1
      V=VMIN
      DO 110 J=1,MP
      IF (S) V=KE*R*X1I*RHOP
      GOTO (220,200) I2
  220  BUF(J)=CX*IKIRKP(U,V,T)
      GOTO 210
  200  BUF(J)=CX*IKIRK(U,V,T)
   210 RHOP=RHOP+DELRHO
       V=V+DELV
  110  CONTINUE
       P=U
       IF(S) P=X1T
       WRITE (IT7) I,NP,P,TR,MP,XMIN,XMAX,(BUF(J),J=1,MP)
       CALL PRT(BUF,MODE,I,IT,MP,NP,MSKIP,NSKIP,RHOP1,
      +DELRHO,VMIN,DELV,X1T,U,TR,T,IT6)
       NREC=NREC+1
       X1T=X1T+DELX
       X1I=1./X1T
       U=U+DELU

  100  CONTINUE
       IT=IT+1
       IF (IT .GT. NT) GOTO 2000
       TR=T=TIM(IT)
       IF (T .GT. TIM(IT-1)) GOTO 1000
 2000 WRITE(IT5,1) NREC
 1     FORMAT(1X,* THE NUMBER OF RECORDS IS-*,I10)
 2     FORMAT(1X,* NEW VALUE OF TAU IS*,E13.5)
 3     FORMAT(1X,I6,4E12.4)
 4     FORMAT(1X,4E13.5)
   5   FORMAT(1X,I6,4G12.4,3(/,5X,5G13.5))
       END
```

B.2 Function IKIRK

```
      REAL FUNCTION IKIRK(U.V.T)                                            002970
C FUNCTION IKIRK IS THE KIRKHOFF INTENSITY FUNCTION DESCRIBED IN           002990
C -BENDOW.B. AND GIANINO.P. @OPTICAL PERFORMANCE EVALUATION OF             003000
C INFRARED TRANSMITTING WINDOWS@ AFCRL-72-0565. ASSUMING A GAUSSIAN        003010
C SHAPED UNPOLARIAZED SOURCE. THE INTENSITY FUNCTION CAN BE WRITTEN*       003020
C  IKIRK(U.V)=2(A!2/(1-EXP(-A!2)))!2*(1I(0.1.DX)(FW*FX)]!2+                003030
C                     1I(0.1.DX)(FW*FY)]!2                                 003040
C WHERE*                                                                    003050
C      FW(X.U)=EXP(-(A*X)!2)*EXP(-I*U*X!2/2)                               003060
C      FX(X.V)=X*J0(X*V)*EXP(I*K*PHIR(X))-FZ(X,V)                          003070
C      FY(X.V)=X*J0(X*V)*EXP(I*K*PHIT(X))+FZ(X,V)                          003080
C      FZ(X.V)=J1(X*V)*(EXP(I*K*PHIR(X))-EXP(I*K*PHIT(X)))/(V)            003090
C      A=1/SQRT(2)/SIG**2                                                  003100
C      K=WAVE NO. (OMEGA/C)                                                003110
C    NOTATION*                                                              003120
C      ! => EXPONENTIATION                                                  003130
C      I => @IMAGINARY@                                                     003140
C      I(0.1.DX)(.) MEANS INTEGRATION  OF THE FUNCTION WITHIN () W.R.T.X   003150
C      OVER THE INTERVAL (0.1).                                            003160
C J0 AND J1 ARE BESSEL FUNCTIONS OF THE FIRST KIND.ZEROTH AND FIRST        003170
C ORDER RESPECTIVELY.                                                       003180
C PHIR(X) AND PHIT(X) ARE THE FUNCTIONS PHI-SUPERSCRIPT-RHO AND PHI-       003190
C SUPERSCRIPT-THETA RESPECTIVELY IN THE ABOVE REFERENCE.                   003200
C THESE FUNCTIONS ARE GIVEN BY*                                             003210
C PHIR(X)=C*S1R*F1(X)+4*C*S2R*F2(X)                                        003220
C PHIT(X)=C*S1T*F1(X)+4*C*S2T*F2(X)                                        003230
C WHERE*                                                                    003240
C      C=B!3*P0*BETA/KT                                                    003250
C      B=WINDOW RADIUS (CM)                                                003260
C      P0=MEAN INCIDENT POWER DENSITY (WATTS/CM!2)                         003270
C      BETA=BULK ABSORPTION COEFFICIENT (1/CM)                             003280
C      KT=THERMAL CONDUCTIVITY (WATTS/(CM DEGC)                            003290
C      S1R.S2R.S1T.S2T ARE MATERIAL CONSTANTS DEFINED IN THE ABOVE REF.    003300
C      F1.F2 ARE THE FUNCTIONS DELTBAR-PRIME(X) AND                        003310
C      (1/X!2)I(0.X.DS)(DELTBAR-PRIME(S))                                  003320
C      GIVEN IN THE ABOVE REFERENCE AND WHICH ARE PROVIDED AT SELECTED     003330
C      ARGUMENTS BY PROGRAM @TEMPS@.                                       003340
*************************************************************************** 003350
      COMMON/PHIBLK/CS1R,CS2R,CS1T.CS2T,XS.DZ,NF.MINT.EPS.F1(200).         003360
     +F2(200).HOLD.A,K ,TLAST.TNEXT,IERR.IP,MP1,ISW,N.                     003370
     +RAD.NP1.C3.C1                                                        003380
      COMMON/IFILES/IT3.IT4.IT5,IT6.IT7.IT8                                003390
      COMPLEX Q1.EXPR.EXPT.FX.FY.FZ.FW                                     003400
      REAL J0. J1                                                          003410
      REAL K                                                               003420
      DIMENSION XA(100).YR(100),YI(100),ZR(100),ZI(100)                    003430
      A2=A*A                                                               003440
      IF (A2 .GT. 220.) 1020.1030                                          003450
 1020 CONST=2.*A2*A2                                                       003460
      GOTO 1040                                                            003470
 1030 CONST=2.*(A2/(1.-EXP(-A2)))**2                                       003480
 1040 UD2=U/2E0                                                            003490
C IF ISW=1 THEN THE ARRAY OF POINTS FOR GAUSSIAN INTEGRATION               003500
C MUST BE FOUND                                                            003510
      GOTO (1050.1060) ISW                                                 003520
 1050 ISW=2                                                                003530
      CALL DQG24A(0E0.1E0.XA)                                              003540

      IF (IP .EQ. 1) WRITE(IT6.1) (XA(I),I=1,N)                            003550
 1060 CALL RTAPE3(T)                                                       003560
      IF (IERR .NE. 0) GOTO 2000                                           003570
      DO 100 I=1.N                                                         003580
      X=XA(I)                                                              003590
      X2=X*X                                                               003600
      XV=X*V                                                               003610
      FW=EXP(-A2*X2)*CEXP(CMPLX(0E0,-UD2*X2))                              003620
      EXPR=CEXP(CMPLX(0E0.K*PHI(X)))                                       003630
      EXPT=CEXP(CMPLX(0E0.K*HOLD))                                         003640
      IF (V .EQ. 0.) FZ=(EXPR-EXPT)*X/2.                                   003650
      IF (V .NE. 0.) FZ=(EXPR-EXPT)*J1(XV)/V                               003660
      Q1=X*J0(XV)                                                          003670
      FX=Q1*EXPR-FZ                                                        003680
      FY=Q1*EXPT+FZ                                                        003690
      Q1=FW*FX                                                             003700
      YR(I)=REAL(Q1)                                                       003710
      YI(I)=AIMAG(Q1)                                                   003720
      Q1=FW*FY                                                          003730
      ZR(I)=REAL(Q1)                                                    003740
      ZI(I)=AIMAG(Q1)                                                   003750
 100  CONTINUE                                                          003760
 1    FORMAT(5(1X,G12.5))                                               003770
      CALL DOG24B(0E0,1E0,YR,YRI)                                       003780
      CALL DOG24B(0E0,1E0,YI,YII)                                       003790
      CALL DOG24B(0E0,1E0,ZR,ZRI)                                       003800
      CALL DOG24B(0E0,1E0,ZI,ZII)                                       003810
      IKIRK=CONST*(YRI*YRI+YII*YII+ZRI*ZRI+ZII*ZII)                     003820
 2000 RETURN                                                            003830
      END                                                               003840
```

B.3 Function PHI

```
      FUNCTION PHI(X)                                                   003850
C IF SWI=.F. THEN PHIR(X)=C*S1R*F1(X)+4*S2R*F2(X) IS FOUND              003860
C IF SWI=.T. THEN PHIT(X)=C*S1T*F1(X)+C*S2T*F2(X) IS FOUND              003870
C WHERE C=B13*R0*BETA/KAPPA (SEE CALLING SUBROUTINE)                    003880
C THE PROGRAM IS DESIGNED TO BE CALLED IN THE ORDER .F., .T. FOR A      003890
C GIVEN VALUE OF X IN ORDER TO ELIMINATE DOUBLE CALLS TO THE INTERPOLATI 003900
C ROUTINE                                                               003910
C THE ARRAYS F1,F2 CONTAIN THE FUNCTION VALUES TO BE INTERPOLATED%      003920
C F1(1=XS),F1(2=XS+DX),,....,F1(NF). ETC AS PROVIDED BY TEMPS.          003930
C THE IBM SCI. SUB. ATSE (P. 251) RETURNS MINT FUNCTION VALUES AND      003940
C ARGUMENTS TO BE USED FOR INTERPOLATION IN ARRAYS ARG,VAL RESPECTIVELY. 003950
C GIVEN THE ARGUMENT X,ETC.                                             003960
C (THE ARGUMENT ICOL IN ATSE IS 1 IF THE FUNCTION IS STORED IN A        003970
C 1-DIMENSIONAL ARRAY)                                                  003980
C THE IBM SCI. SUB. ALI(P.241) DOES AITKEN-LAGRANGE INTERPOLATION       003990
C ON (ARG,VAL) AND RETURNS THE RESULTING VALUE Y. EPS IS AN ABSOLUTE    004000
C ERROR FIGURE AND IER IS AN ERROR @FLAG@.                              004010
      COMMON/PHIBLK/CS1R,CS2R,CS1T,CS2T,XS,DX,NF,MINT,EPS,F1(200),      004020
     *F2(200),HOLD,A,KE,TLAST,TNEXT,IERR,IP,MP1,ISW,N,                  004030
     *RAD,NP1,C3,C1                                                     004040
C HOLD IS USED TO STORE PHI(.T.,X)                                       004050
      DIMENSION ARG(20),VAL(20)                                         004060
 1010 CALL ATSE(X,XS,DX,F1,NF,1,ARG,VAL,MINT)                           004070
      CALL ALI(X,ARG,VAL,Y1,MINT,EPS,IER)                               004080
      CALL ATSE(X,XS,DX,F2,NF,1,ARG,VAL,MINT)                           004090
      CALL ALI(X,ARG,VAL,Y2,MINT,EPS,IER)                               004100
      PHI=CS1R*Y1+4E0*CS2R*Y2                                           004110
      HOLD=CS1T*Y1+4E0*CS2T*Y2                                          004120
 2000 RETURN                                                            004130
      END                                                               004140
```

B.4 Function JQ

```
      REAL FUNCTION J0(X)                                               004150
C J0 IS THE BESSEL FUNCTION OF THE FIRST KIND,ZEROTH ORDER. SEE         004160
C HANDBOOK OF MATHEMATICAL FUNCTIONS-AMS 55. FOR VALUES OF THE ARGUMENT 004170
C I=5 EQUATION 9.1.12 IS USED. OTHERWISE 9.4.3 IS USED.                 004180
      DIMENSION FACT(20)                                                004190
      DATA MT/0/                                                        004200
      IF(X.GT.5.) GO TO 1                                               004210
      IF(MT.NE.0) GO TO 2                                               004220
      MT=1                                                              004230
      FACT(1)=1.0                                                       004240
      DO 3 I=2.20                                                       004250
      FACT(I)=FACT(I-1)*FLOAT(I*I)                                      004260
    3 CONTINUE                                                          004270
      DO 4 I=2.20                                                       004280
      FACT(I)=1.0/FACT(I)                                               004290
    4 CONTINUE                                                          004300
    2 CONTINUE                                                          004310
      ANSP=0.0                                                          004320
      ANSN=0.0                                                          004330
      ARG=0.25*X*X                                                      004340
      ARGU=ARG                                                          004350
      DO 5 I=1.19.2                                                     004360
      ANSN=ANSN+ARGU*FACT(I)                                            004370
      J=I+1                                                             004380
      ARGU=ARGU*ARG                                                     004390
      ANSP=ANSP+ARGU*FACT(J)                                            004400
      ARGU=ARGU*ARG                                                     004410
    5 CONTINUE                                                          004420
      J0=1.0+(ANSP-ANSN)                                                004430
      RETURN                                                            004440
    1 CONTINUE                                                          004450
      TOX=3.0/X                                                         004460
      FZ=.79788456-.00000077*TOX-.0055274*TOX**2-.00009512*TOX**3+      004470
     1.00137237*TOX**4-.00072805*TOX**5+.00014476*TOX**6                004480
      THZ=X-.78539816-.04166397*TOX-.00003954*TOX**2+.00262573*TOX**3-  004490
     1.00054125*TOX**4-.00029333*TOX**5+.00013558*TOX**6                004500
      J0=FZ*COS(THZ)/SQRT(X)                                            004510
      RETURN                                                            004520
      END                                                               004530
```

B.5 Function J1

```
      REAL FUNCTION J1(X)                                               004540
C J1 IS THE BESSEL FUNCTION OF THE FIRST KIND,FIRST ORDER. SEE          004550
C HANDBOOK OF MATHERMATICAL FUNCTIONS-AMS 55. FOR VALUES OF THE         004560
C ARGUMENT I=10 EQUATION 9.1.10 IS USED. OTHERWISE 9.4.4 IS USED.       004570
      DIMENSION FACT(20)                                                004580
      DATA MT/0/                                                        004590
      IF(X.GT.10.) GO TO 1                                              004600
      IF(MT.NE.0) GO TO 2                                               004610
      MT=1                                                              004620
      FACT(1)=2.0                                                       004630
      DO 3 I=2.20                                                       004640
      FACT(I)=FACT(I-1)*FLOAT(I*(I+1))                                  004650
    3 CONTINUE                                                          004660
      DO 4 I=1.20                                                       004670
      FACT(I)=1.0/FACT(I)                                               004680
    4 CONTINUE                                                          004690
    2 CONTINUE                                                          004700
      ANSP=0.0                                                          004710
      ANSN=0.0                                                          004720
      ARGS=0.5*X                                                        004730
      ARG=0.25*X*X                                                      004740
      ARGU=ARG                                                          004750
      DO 5 I=1,19,2                                                     004760
      ANSN=ANSN+ARGU*FACT(I)                                            004770
      J=I+1                                                             004780
      ARGU=ARGU*ARG                                                     004790
      ANSP=ANSP+ARGU*FACT(J)                                            004800
      ARGU=ARGU*ARG                                                     004810
    5 CONTINUE                                                          004820
      J1=ARGS*(1.0+(ANSP-ANSN))                                         004830
      RETURN                                                            004840
    1 CONTINUE                                                          004850
      TOX=3.0/X                                                         004860
      F1=.79788456+.00000156*TOX+.01659667*TOX**2+.00017105*TOX**3      004870
     1-.00249511*TOX**4+.00113653*TOX**5-.00020033*TOX**6               004880
      TH1=X-2.35619449+.12499612*TOX+.00005650*TOX**2-.00637879*TOX**3  004890
     1+.00074348*TOX**4+.00079824*TOX**5-.00029166*TOX**6               004900
      J1=F1*COS(TH1)/SQRT(X)                                            004910
      RETURN                                                            004920
      END                                                               004930
```

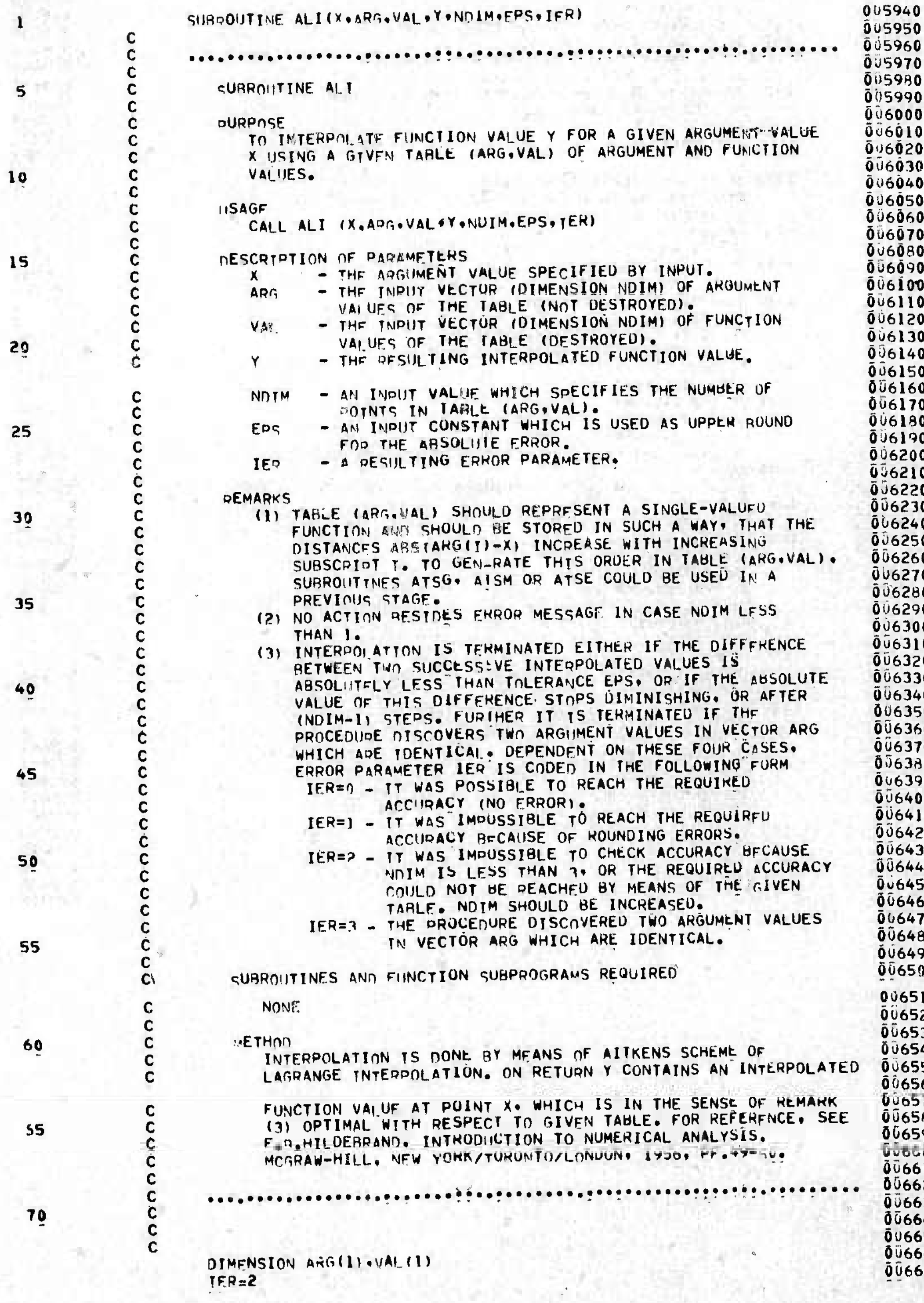
B.6 Subroutine RTAPE3

```
      SUBROUTINE RTAPE3(T)                                              004940
      COMMON/PHIBLK/CS1P,CS2P,CS1T,CS2T,XS,DX,NF,MINT,EPS,F1(200),      004950
     +F2(200),HOLD,A,KF,TLAST,TNEXT,IERR,IP,MP1,ISW,N,                  004960
     +RAD,NP1,C3,C1                                                     004970
      COMMON/FILES/IT3,IT4,IT5,IT6,IT7,IT8                              004980
      DIMENSION F1M(82),F2M(82),F1P(82),F2P(82),RFIN(82),ZFIN(22),      004990
     +UFINP(82,22),UFINM(82,22)                                         005000
      DATA ISW1/0/                                                      005010
C RTAPE3 CAN BE USED AS A GENERAL PURPOSE SUBROUTINE FOR LINEARLY        005020
C INTERPOLATING FUNCTION VALUES @BETWEEN RECORDS@, I.E. ASSUME          005030
C RECORD N INCLUDES THE INFORMATION TN,F(1:TN),F(2:TN),.....,..         005040
C AND RECORD N+1 INCLUDES TN+1,F(1:TN+1),F(2:TN+1),.........            005050
C THEN IF TN(=T(=TN+1 IS GIVEN, THE QUANTITIES F(1:T),F(2:T),.,.......  005060
C ARE RETURNED WHERE*                                                   005070
C  F(1:T)=F(1:TN)+C*(F(1:TN+1)-F(1:TN)): C=(T-TN)/(TN+1-TN), ETC.       005080
C IT IS ASSUMED THAT THE PARAMETER T INCREASES WITH INCREASING RECORD   005090
C NUMBER AND NO FILE REWINDS ARE PERMITTED. I.E. RTAPE3 SHOULD BE CALLED 005100
C WITH INCREASING VALUES OF T ONLY.                                     005110
C RTAPE3 RECOGNIZES TWO ERROR CONDITIONS WHICH SHOULD BE CHECKED FOR IN 005120
C THE CALLING PROGRAM. IF IERR=0 THEN NO ERROR HAS OCCURRED. IF IERR=1  005130
C THEN THE TIME VALUE IS LESS THAN THE TIME VALUE OF THE PRECEEDING CALL 005140
C TO RTAPE3.IF IERR=2 THEN THE TIME VALUE IS GREATER THAN THE TIME VALUE 005150
C ASSOCIATED WITH THE LAST INPUT RECORD.                                005160
C I  THE PRESENT VERSION OF RTAPE3 EACH OUTPUT RECORD (FROM TEMP5) IS   005170
C ASSUMED TO BE IN THE FORM%                                            005180
C    NF,TFIN,RFIN(82),ZFIN(22),UFIN(82,22),F1(82),F2(82)                005190
C WHERE TFIN IS THE TIME VALUE AND F1(82),F2(82) ARE THE DESIRED        005200
C FUNCTION VALUES CORRESPONDING TO TFIN.                                005210
C RTAPE3 ALSO OUTPUTS THE DIMENSIONALIZED (AND LINEARLY INTERPOLATED    005220
C IN TIME) WINDOW TEMPERATURE FUNCTIN IN A FORM SUITABLE FOR USE WITH   005230
C DISPLAY, PROVIDED IPRINT=2.                                           005240
      IERR=0                                                            005250
      TY=T/C1                                                           005255
      IF (ISW1) 1115,1100                                               005260
 1100 ISW1=1                                                            005270
      READ(IT3) NG,TLAST,RFIN,ZFIN,UFINM,F1M,F2M                        005280
      TT=TLAST                                                          005290
      RMIN=RFIN(1)*RAD                                                  005300
      RMAX=RFIN(MP1)*RAD                                                005310
      IF (EOF(IT3)) 1110,1120                                           005320
 1110 IERR=2                                                            005330
      GOTO 2000                                                         005340
 1120 IF (T-TLAST) 1130,1140,1140                                       005350
 1130 IERR=1                                                            005360
```

```
      GOTO 2000                                                         005370
 1140 READ(IT3) NG,TNEXT,RFIN,ZFIN,UFINP,F1P,F2P                        005380
 1115 IF (T .LT. TT) 1000,1010                                          005400
 1000 IERR=1                                                            005410
      GOTO 2000                                                         005420
C IF T .EQ. LASTT THEN NOTHING MORE TO DO                                005430
 1010 IF (T .EQ. TT) GOTO 2000                                          005440
C IF T .LT. TNEXT THEN A READ IS NOT REQUIRED                           005450
      IF (T .LT. TNEXT) GOTO 1020                                       005460
 1030 READ(IT3) NG,TLAST,RFIN,ZFIN,UFINM,F1M,F2M                        005470
      IF (EOF(IT3)) 1040,1050                                           005480
 1040 IERR=2                                                            005490
      GOTO 2000                                                         005500

 1050 IF (T .LE. TLAST) GOTO 1080                                       005510
      READ(IT3) NG,TNEXT,RFIN,ZFIN,UFINP,F1P,F2P                        005520
      IF (EOF(IT3)) 1060,1070                                           005530
 1060 IERR=2                                                            005540
      GOTO 2000                                                         005550
 1070 IF (T .LE. TNEXT) GOTO 1020                                       005560
      GOTO 1030                                                         005570
 1020 C=(T-TLAST)/(TNEXT-TLAST)                                         005580
      DO 100 I=1,MP1                                                    005590
      F1(I)=F1M(I)+C*(F1P(I)-F1M(I))                                    005600
      F2(I)=F2M(I)+C*(F2P(I)-F2M(I))                                    005610
 100  CONTINUE                                                          005620
      GOTO(2000,120) IP                                                 005630
  120 DO 130 I=1,NP1                                                    005640
      U=RAD*ZFIN(I)                                                     005650
      DO 140 J=1,MP1                                                    005660
      RFIN(J)=C3*(UFINM(J,I)+C*(UFINP(J,I)-UFINM(J,I)))                 005670
  140 CONTINUE                                                          005680
      WRITE(ITP) I,NP1,U,TM,MP1,RMIN,RMAX,(RFIN(J),J=1,MP1)             005690
 130  CONTINUE                                                          005700
      GOTO 2000                                                         005710
 1080 TTEMP=TLAST                                                       005720
      TLAST=TNEXT                                                       005730
      TNEXT=TTEMP                                                       005740
      DO 110 I=1,MP1                                                    005750
      FT=F1M(I)                                                         005760
      F1M(I)=F1P(I)                                                     005770
      F1P(I)=FT                                                         005780
      FT=F2M(I)                                                         005790
      F2M(I)=F2P(I)                                                     005800
      F2P(I)=FT                                                         005810
 110  CONTINUE                                                          005820
      GOTO(1020,150) IP                                                 005830
  150 DO 160 I=1,NP1                                                    005840
      DO 160 J=1,MP1                                                    005850
      FT=UFINM(J,I)                                                     005860
      UFINM(J,I)=UFINP(J,I)                                             005870
      UFINP(J,I)=FT                                                     005880
  160 CONTINUE                                                          005890
      GOTO 1020                                                         005900
 2000 TT=T                                                              005910
      RETURN                                                            005920
      END                                                               005930
```

B.7 Subroutine ALI



```
      SUBROUTINE ALI(X,ARG,VAL,Y,NDIM,EPS,IER)                            005940
C                                                                         005950
C     ..................................................................  005960
C                                                                         005970
C        SUBROUTINE ALI                                                   005980
C                                                                         005990
C        PURPOSE                                                          006000
C           TO INTERPOLATE FUNCTION VALUE Y FOR A GIVEN ARGUMENT VALUE    006010
C           X USING A GIVEN TABLE (ARG,VAL) OF ARGUMENT AND FUNCTION      006020
C           VALUES.                                                       006030
C                                                                         006040
C        USAGE                                                            006050
C           CALL ALI (X,ARG,VAL,Y,NDIM,EPS,IER)                           006060
C                                                                         006070
C        DESCRIPTION OF PARAMETERS                                        006080
C           X      - THE ARGUMENT VALUE SPECIFIED BY INPUT.               006090
C           ARG    - THE INPUT VECTOR (DIMENSION NDIM) OF ARGUMENT        006100
C                     VALUES OF THE TABLE (NOT DESTROYED).                006110
C           VAL    - THE INPUT VECTOR (DIMENSION NDIM) OF FUNCTION        006120
C                     VALUES OF THE TABLE (DESTROYED).                    006130
C           Y      - THE RESULTING INTERPOLATED FUNCTION VALUE.           006140
C                                                                         006150
C           NDIM   - AN INPUT VALUE WHICH SPECIFIES THE NUMBER OF         006160
C                     POINTS IN TABLE (ARG,VAL).                          006170
C           EPS    - AN INPUT CONSTANT WHICH IS USED AS UPPER ROUND       006180
C                     FOR THE ABSOLUTE ERROR.                             006190
C           IER    - A RESULTING ERROR PARAMETER.                         006200
C                                                                         006210
C        REMARKS                                                          006220
C           (1) TABLE (ARG,VAL) SHOULD REPRESENT A SINGLE-VALUED          006230
C               FUNCTION AND SHOULD BE STORED IN SUCH A WAY, THAT THE     006240
C               DISTANCES ABS(ARG(I)-X) INCREASE WITH INCREASING          006250
C               SUBSCRIPT I. TO GEN-RATE THIS ORDER IN TABLE (ARG,VAL),  006260
C               SUBROUTINES ATSG, AISM OR ATSE COULD BE USED IN A         006270
C               PREVIOUS STAGE.                                           006280
C           (2) NO ACTION BESIDES ERROR MESSAGE IN CASE NDIM LESS         006290
C               THAN 1.                                                   006300
C           (3) INTERPOLATION IS TERMINATED EITHER IF THE DIFFERENCE      006310
C               BETWEEN TWO SUCCESSIVE INTERPOLATED VALUES IS             006320
C               ABSOLUTELY LESS THAN TOLERANCE EPS, OR IF THE ABSOLUTE    006330
C               VALUE OF THIS DIFFERENCE STOPS DIMINISHING, OR AFTER      006340
C               (NDIM-1) STEPS. FURTHER IT IS TERMINATED IF THE           006350
C               PROCEDURE DISCOVERS TWO ARGUMENT VALUES IN VECTOR ARG     006360
C               WHICH ARE IDENTICAL. DEPENDENT ON THESE FOUR CASES,       006370
C               ERROR PARAMETER IER IS CODED IN THE FOLLOWING FORM        006380
C                IER=0 - IT WAS POSSIBLE TO REACH THE REQUIRED            006390
C                        ACCURACY (NO ERROR).                             006400
C                IER=1 - IT WAS IMPOSSIBLE TO REACH THE REQUIRED          006410
C                        ACCURACY BECAUSE OF ROUNDING ERRORS.             006420
C                IER=2 - IT WAS IMPOSSIBLE TO CHECK ACCURACY BECAUSE      006430
C                        NDIM IS LESS THAN 3, OR THE REQUIRED ACCURACY    006440
C                        COULD NOT BE REACHED BY MEANS OF THE GIVEN       006450
C                        TABLE. NDIM SHOULD BE INCREASED.                 006460
C                IER=3 - THE PROCEDURE DISCOVERED TWO ARGUMENT VALUES     006470
C                        IN VECTOR ARG WHICH ARE IDENTICAL.               006480
C                                                                         006490
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED                    006500
C           NONE                                                          006510
C                                                                         006520
C        METHOD                                                           006530
C           INTERPOLATION IS DONE BY MEANS OF AITKENS SCHEME OF           006540
C           LAGRANGE INTERPOLATION. ON RETURN Y CONTAINS AN INTERPOLATED 006550
C                                                                         006560
C           FUNCTION VALUE AT POINT X, WHICH IS IN THE SENSE OF REMARK    006570
C           (3) OPTIMAL WITH RESPECT TO GIVEN TABLE. FOR REFERENCE, SEE   006580
C           F.B.HILDEBRAND, INTRODUCTION TO NUMERICAL ANALYSIS.           006590
C           MCGRAW-HILL, NEW YORK/TORONTO/LONDON, 1956, PP.49-50.         006600
C                                                                         006610
C     ..................................................................  006620
C                                                                         006630
C                                                                         006640
C                                                                         006650
      DIMENSION ARG(1),VAL(1)                                             006660
      IER=2                                                               006670
      DELT2=0.                                                          006680
      IF(NDIM-1)9,7,1                                                   006690
C                                                                       006700
C     START OF AITKEN-LOOP                                              006710
    1 DO 6 J=2,NDIM                                                     006720
      DELT1=DELT2                                                       006730
      IEND=J-1                                                          006740
      DO 2 I=1,IEND                                                     006750
      H=ARG(I)-ARG(J)                                                   006760
      IF(H)2,13,2                                                       006770
    2 VAL(J)=(VAL(I)*(X-ARG(J))-VAL(J)*(X-ARG(I)))/H                    006780
      DELT2=ABS(VAL(J)-VAL(IEND))                                       006790
      IF(J-2)6,6,3                                                      006800
    3 IF(DELT2-EPS)10,10,4                                              006810
    4 IF(J-5)6,5,5                                                      006820
    5 IF(DELT2-DELT1)6,11,11                                            006830
    6 CONTINUE                                                          006840
C     END OF AITKEN-LOOP                                                006850
C                                                                       006860
    7 J=NDIM                                                            006870
    8 Y=VAL(J)                                                          006880
    9 RETURN                                                            006890
C                                                                       006900
C     THERE IS SUFFICIENT ACCURACY WITHIN NDIM-1 ITERATION STEPS        006910
   10 IER=0                                                             006920
      GOTO 8                                                            006930
C                                                                       006940
C     TEST VALUE DELT2 STARTS OSCILLATING                               006950
                                                                        006960
   11 IER=1                                                             006970
   12 J=IEND                                                            006980
      GOTO 8                                                            006990
C                                                                       007000
C     THERE ARE TWO IDENTICAL ARGUMENT VALUES IN VECTOR ARG             007010
   13 IER=3                                                             007020
      GOTO 12                                                           007030
      END                                                               007040
```

B.8 Subroutine ATSE

```
      SUBROUTINE ATSE (X,ZS,DZ,F,IROW,ICOL,ARG,VAL,NDIM)                007050
C                                                                       007060
C     ..................................................................007070
C                                                                       007080
C        SUBROUTINE ATSE                                                007090
C                                                                       007100
C                                                                       007110
C        PURPOSE                                                        007120
C           NDIM POINTS OF A GIVEN TABLE WITH EQUIDISTANT ARGUMENTS ARE 007130
C           SELECTED AND ORDERED SUCH THAT                              007140
C           ABS(ARG(I)-X).GE.ABS(ARG(J)-X) IF I.GT.J.                   007150
C                                                                       007160
C        USAGE                                                          007170
C           CALL ATSE (X,ZS,DZ,F,IROW,ICOL,ARG,VAL,NDIM)                007180
C                                                                       007190
C        DESCRIPTION OF PARAMETERS                                      007200
C           X      - THE SEARCH ARGUMENT.                               007210
C           ZS     - THE STARTING VALUE OF ARGUMENTS.                   007220
C           DZ     - THE INCREMENT OF ARGUMENT VALUES.                  007230
C           F      - IN CASE ICOL=1, F IS THE VECTOR OF FUNCTION VALUES 007240
C                    (DIMENSION IROW).                                  007250
C                    IN CASE ICOL=2, F IS AN IROW BY 2 MATRIX. THE FIRST 007260
C                    COLUMN SPECIFIES THE VECTOR OF FUNCTION VALUES AND 007270
C                    THE SECOND THE VECTOR OF DERIVATIVES.              007280
C           IROW   - THE DIMENSION OF EACH COLUMN IN MATRIX F.          007290
C           ICOL   - THE NUMBER OF COLUMNS IN F (I.E. 1 OR 2).          007300
C           ARG    - THE RESULTING VECTOR OF SELECTED AND ORDERED       007310
C                    ARGUMENT VALUES (DIMENSION NDIM).                  007320
C           VAL    - THE RESULTING VECTOR OF SELECTED FUNCTION VALUES   007330
```

```
C                 (DIMENSION NDIM) IN CASE ICOL=1. IN CASE ICOL=2.        007340
C                 VAL IS THE VECTOR OF FUNCTION AND DERIVATIVE VALUES     007350
C                 (DIMENSION 2*NDIM) WHICH ARE STORED IN PAIRS (I.E.      007360
C                 EACH FUNCTION VALUE IS FOLLOWED BY ITS DERIVATIVE       007370
C                 VALUE).                                                 007380
C        NDIM   - THE NUMBER OF POINTS WHICH MUST BE SELECTED OUT OF      007390
C                 THE GIVEN TABLE.                                        007400
C                                                                         007410
C     REMARKS                                                             007420
C        NO ACTION IN CASE IROW LESS THAN 1.                              007430
C        IF INPUT VALUE NDIM IS GREATER THAN IROW, THE PROGRAM            007440
C        SELECTS ONLY A MAXIMUM TABLE OF IROW POINTS.  THEREFORE THE      007450
C        USER OUGHT TO CHECK CORRESPONDENCE BETWEEN TABLE (ARG,VAL)       007460
C        AND ITS DIMENSION BY COMPARISON OF NDIM AND IROW, IN ORDER       007470
C        TO GET CORRECT RESULTS IN FURTHER WORK WITH TABLE (ARG,VAL).     007480
C        THIS TEST MAY BE DONE BEFORE OR AFTER CALLING                    007490
C        SUBROUTINE ATSE.                                                 007500
C                                                                         007510
C        SUBROUTINE ATSE ESPECIALLY CAN BE USED FOR GENERATING THE        007520
C        TABLE (ARG,VAL) NEEDED IN SUBROUTINES ALI, AHI, AND ACFI.        007530
C                                                                         007540
C     SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED                       007550
C        NONE                                                             007560
C                                                                         007570
C     METHOD                                                              007580
C        SELECTION IS DONE BY COMPUTING THE SUBSCRIPT J OF THAT           007590
C        ARGUMENT, WHICH IS NEXT TO X.                                    007600
C        AFTERWARDS NEIGHBOURING ARGUMENT VALUES ARE TESTED AND           007610
C        SELECTED IN THE ABOVE SENSE.                                     007620
C                                                                         007630
C     ..................................................................  007640
C                                                                         007650
C                                                                         007660
C                                                                         007670
      DIMENSION F(1),ARG(1),VAL(1)                                        007680
      IF(IROW-1)19,17,1                                                   007690
C                                                                         007700
C     CASE DZ=0 IS CHECKED OUT                                            007710
    1 IF(DZ)2,17,2                                                        007720
    2 N=NDIM                                                              007730
C                                                                         007740
C     IF N IS GREATER THAN IROW, N IS SET EQUAL TO IROW.                  007750
      IF(N-IROW)4,4,3                                                     007760
    3 N=IROW                                                              007770
C                                                                         007780
C     COMPUTATION OF STARTING SUBSCRIPT J.                                007790
    4 J=(X-ZS)/DZ+1.5                                                     007800
      IF(J)5,5,6                                                          007810
    5 J=1                                                                 007820
    6 IF(J-IROW)8,8,7                                                     007830
    7 J=IROW                                                              007840
C                                                                         007850
C     GENERATION OF TABLE ARG,VAL IN CASE DZ.NE.0.                        007860
    8 II=J                                                                007870
      JL=0                                                                007880
      JR=0                                                                007890
      DO 16 I=1,N                                                         007900
                                                                          007910
      ARG(I)=ZS+FLOAT(II-1)*DZ                                            007920
      IF(ICOL-2)9,10,10                                                   007930
    9 VAL(I)=F(II)                                                        007940
      GOTO 11                                                             007950
   10 VAL(2*I-1)=F(II)                                                    007960
      III=II+IROW                                                         007970
      VAL(2*I)=F(III)                                                     007980
   11 IF(J+JR-IROW)12,15,12                                               007990
   12 IF(J-JL-1)13,14,13                                                  008000
   13 IF((ARG(I)-X)*DZ)14,15,15                                           008010
   14 JR=JR+1                                                             008020
      II=J+JR                                                             008030
      GOTO 16                                                             008040
   15 JL=JL+1                                                             008050
      II=J-JL                                                             008060
   16 CONTINUE                                                            008070
      RETURN                                                              008080
      C                                                                   008100
      C        CASE DZ=0                                                  008110
            17 ARG(1)=ZS                                                  008120
               VAL(1)=F(1)                                                008130
               IF(ICOL-2)19,19,18                                         008140
            18 VAL(2)=F(2)                                                008150
            19 RETURN                                                     008160
               END
```

B.9 Subroutine DQG24A

```
            SUBROUTINE DQG24A(XL,XU,XA)                                   008170
      C                                                                   008180
      C     .............................................................. 008190
      C                                                                   008200
      C        SUBROUTINE DQG24                                           008210
      C                                                                   008220
      C        PURPOSE                                                    008230
      C           TO COMPUTE INTEGRAL(FCT(X), SUMMED OVER X FROM XL TO XU)  008240
      C                                                                   008250
      C        USAGE                                                      008260
      C           CALL DQG24 (XL,XU,FCT,Y)                                008270
      C           PARAMETER FCT REQUIRES AN EXTERNAL STATEMENT            008280
      C                                                                   008290
      C        DESCRIPTION OF PARAMETERS                                  008300
      C           XL     - DOUBLE PRECISION LOWER BOUND OF THE INTERVAL.  008310
      C           XU     - DOUBLE PRECISION UPPER BOUND OF THE INTERVAL.  008320
      C           FCT    - THE NAME OF AN EXTERNAL DOUBLE PRECISION FUNCTION  008330
      C                    SUBPROGRAM USED.                               008340
      C           Y      - THE RESULTING DOUBLE PRECISION INTEGRAL VALUE.  008350
      C                                                                   008360
      C        REMARKS                                                    008370
      C           NONE                                                    008380
      C                                                                   008390
      C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED              008400
      C           THE EXTERNAL DOUBLE PRECISION FUNCTION SUBPROGRAM FCT(X)  008410
      C           MUST BE FURNISHED BY THE USER.                          008420
      C                                                                   008430
      C        METHOD                                                     008440
      C           EVALUATION IS DONE BY MEANS OF 24-POINT GAUSS QUADRATURE  008450
      C           FORMULA, WHICH INTEGRATES POLYNOMIALS UP TO DEGREE 47   008460
      C           EXACTLY. FOR REFERENCE, SEE                             008470
      C           V.I.KRYLOV, APPROXIMATE CALCULATION OF INTEGRALS,       008480
      C           MACMILLAN, NEW YORK/LONDON, 1962, PP.100-111 AND 337-340.  008490
      C                                                                   008500
      C     .............................................................. 008510
      C                                                                   008520
      C                                                                   008530
      C                                                                   008540
            DIMENSION XA(1)                                               008550
      C                                                                   008560
            A=.5D0*(XU+XL)                                                008570
            B=XU-XL                                                       008580
            C=.49759360999851068D0*B                                      008590
            XA(1)=A+C                                                     008600
            XA(2)=A-C                                                     008610
            C=.48736427798565475D0*B                                      008620
            XA(3)=A+C                                                     008630
            XA(4)=A-C                                                     008640
            C=.46913727600136638D0*B                                      008650
            XA(5)=A+C                                                     008660
            XA(6)=A-C                                                     008670
            C=.44320776350220052D0*B                                      008680
            XA(7)=A+C                                                     008690
            XA(8)=A-C                                                     008700
            C=.41006899298695146D0*B                                      008710
            XA(9)=A+C                                                     008720
            XA(10)=A-C                                                    008730
      C=.2700620957892771900*B                                          008750
      XA(11)=A+C                                                        008760
      XA(12)=A-C                                                        008770
      C=.224046825968487790D0*B                                         008780
      XA(13)=A+C                                                        008790
      XA(14)=A-C                                                        008800
      C=.27271173569441977D0*B                                          008810
      XA(15)=A+C                                                        008820
      XA(16)=A-C                                                        008830
      C=.21689675381302257D0*B                                          008840
      XA(17)=A+C                                                        008850
      XA(18)=A-C                                                        008860
      C=.15752133984808169D0*B                                          008870
      XA(19)=A+C                                                        008880
      XA(20)=A-C                                                        008890
      C=.95559433373680815D-1*B                                         008900
      XA(21)=A+C                                                        008910
      XA(22)=A-C                                                        008920
      C=.2028446431302813D-1*B                                          008930
      XA(23)=A+C                                                        008940
      XA(24)=A-C                                                        008950
      RETURN                                                            008960
      END
```

B.10 Subroutine DQG24B

```
C                                                                       008970
      SUBROUTINE DQG24B(XL,XU,FCT,Y)                                    008980
C     ..................................................................008990
C                                                                       009000
C        SUBROUTINE DQG24                                               009010
C                                                                       009020
C        PURPOSE                                                        009030
C           TO COMPUTE INTEGRAL(FCT(X), SUMMED OVER X FROM XL TO XU)    009040
C                                                                       009050
C        USAGE                                                          009060
C           CALL DQG24 (XL,XU,FCT,Y)                                    009070
C           PARAMETER FCT REQUIRES AN EXTERNAL STATEMENT                009080
C                                                                       009090
C        DESCRIPTION OF PARAMETERS                                      009100
C           XL     - DOUBLE PRECISION LOWER BOUND OF THE INTERVAL.      009110
C           XU     - DOUBLE PRECISION UPPER BOUND OF THE INTERVAL.      009120
C           FCT    - THE NAME OF AN EXTERNAL DOUBLE PRECISION FUNCTION  009130
C                    SUBPROGRAM USED.                                   009140
C           Y      - THE RESULTING DOUBLE PRECISION INTEGRAL VALUE.     009150
C                                                                       009160
C        REMARKS                                                        009170
C           NONE                                                        009180
C                                                                       009190
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED                  009200
C           THE EXTERNAL DOUBLE PRECISION FUNCTION SUBPROGRAM FCT(X)    009210
C           MUST BE FURNISHED BY THE USER.                              009220
C                                                                       009230
C        METHOD                                                         009240
C           EVALUATION IS DONE BY MEANS OF 24-POINT GAUSS QUADRATURE    009250
C           FORMULA, WHICH INTEGRATES POLYNOMIALS UP TO DEGREE 47       009260
C           EXACTLY. FOR REFERENCE, SEE                                 009270
C           V.I.KRYLOV, APPROXIMATE CALCULATION OF INTEGRALS,           009280
C           MACMILLAN, NEW YORK/LONDON, 1962, PP.100-111 AND 337-340.   009290
C                                                                       009300
C     ..................................................................009310
C                                                                       009320
C                                                                       009330
C                                                                       009340
C                                                                       009350
      DIMENSION FCT(1)
```

```
C                                                                 009360
      B=XU-XL                                                     009370
      I=1                                                         009380
      Y=.61706148999935098D-2*(FCT(I)+FCT(I+1))                   009390
      I=I+2                                                       009400
      Y=Y+.14265694314466832D-1*(FCT(I)+FCT(I+1))                 009410
      I=I+2                                                       009420
      Y=Y+.22138719408709903D-1*(FCT(I)+FCT(I+1))                 009430
      I=I+2                                                       009440
      Y=Y+.29649292457718390D-1*(FCT(I)+FCT(I+1))                 009450
      I=I+2                                                       009460
      Y=Y+.36673240705540153D-1*(FCT(I)+FCT(I+1))                 009470
      I=I+2                                                       009480
      Y=Y+.43095080765976638D-1*(FCT(I)+FCT(I+1))                 009490
      I=I+2                                                       009500
      Y=Y+.48809326052056944D-1*(FCT(I)+FCT(I+1))                 009510
      I=I+2                                                       009520
      Y=Y+.53722135057982817D-1*(FCT(I)+FCT(I+1))                 009530

      I=I+2                                                       009540
      Y=Y+.57752834026862801D-1*(FCT(I)+FCT(I+1))                 009550
      I=I+2                                                       009560
      Y=Y+.60835236463901696D-1*(FCT(I)+FCT(I+1))                 009570
      I=I+2                                                       009580
      Y=Y+.62918728173414148D-1*(FCT(I)+FCT(I+1))                 009590
      I=I+2                                                       009600
      Y=B*(Y+.63969097673376078D-1*(FCT(I)+FCT(I+1)))             009610
      RETURN                                                      009620
      END                                                         009630
```

B.11 Function IKIRKP

```
      REAL FUNCTION IKIRKP(U,V,T)                                 009640
C     APRIL 11,1974                                               009650
C     THIS FUNCTION COMPUTES THE KIRKHOFF INTENSITY FUNCTION      009660
C     ALONG THE U=0 AND/OR V=0 AXIS OF THE PLANE.                 009670
C     SEE COMMENTS IN IKIRK AND COMPUTE FOR BACKGROUND INFO.      009680
C     IT IS VALID ONLY FOR CONSTANT TEMPERATURE WINDOWS.          009690
      DIMENSION AA(10)                                            009700
      COMMON/IFILES/IT3,IT4,IT5,IT6,IT7,IT8                       009710
      COMMON/VICTOR/VV                                            009720
      COMMON/PHIBLK/CS1R,CS2R,CS1T,CS2T,XS,DX,NF,MNNT,EPP,F1(200),  009730
     +F2(200),HOLD,ALPHA,KF,TLAST,TNEXT,IERR,IP,MP1,ISW,NGAUSS,    009740
     +RAD,NP1,C3,C1                                               009750
      COMPLEX AJ0Q,CRH0Q,CTHETAQ,A1Q,A2Q,A3Q,A4Q,A6Q,A7Q          009760
      REAL KE                                                     009765
      DATA (AA(I),I=1,10)/1.,-.99999999958,.4999999206,-.1666653019,  009770
     +.0416573475,-.0083013598,.0013298820,-.0001413161,0.,0./    009780
      VV=V                                                        009790
      CALL RTAPE3(T)                                              009800
      IF(IERR.NE.0) GOTO 2000                                     009810
      CTHETAQ=CS1T*F1(1)+4.*CS2T*F2(1)                            009820
      CTHETAQ=CTHETAQ*KE                                          009825
      CRH0Q=CS1R*F1(1)+4.*CS2R*F2(1)                              009830
      CRH0Q=CRH0Q*KE                                              009835
      AJ0Q=(0.,1.)                                                009840
      A2Q=CEXP(AJ0Q*CRH0Q)                                        009850
      A3Q=CEXP(AJ0Q*CTHETAQ)                                      009860
      A1Q=A2Q-A3Q                                                 009870
      A=-(ALPHA**2)                                               009880
      IF (A .LT. -1000) GOTO 110                                  009900
      EXPA=EXP(A)                                                 009910
      AS=2.*(A/(1.-EXPA))**2                                      009920
      GOTO 120                                                    009930
  110 EXPA=0.                                                     009940
      AS=2.*A*A                                                   009950
```

```
 120  B=U/2.                                                              009960
      IF(V.EQ.0) GOTO 200                                                 009970
      C=(ALPHA/V)**2                                                      009980
      IF(U.EQ.0) GOTO 100                                                 009990
 200  SINB=SIN(B)                                                         010000
      COSB=COS(B)                                                         010010
      ASQ=A**2                                                            010020
      BSQ=B**2                                                            010030
      A4QREAL=.5*((EXPA*(A*COSB+B*SINB))-A)/(ASQ+BSQ)                     010040
      A4QIMAG=-.5*((EXPA*(A*SINB-B*COSB))+B)/(ASQ+BSQ)                    010050
      A4Q=CMPLX(A4QREAL,A4QIMAG)                                          010060
      A6Q=A1Q/2.*A4Q                                                      010070
      IKIRKP=A5*((CABS(A2Q*A4Q-A6Q))**2+(CABS(A3Q*A4Q+A6Q))**2)           010080
      RETURN                                                              010090
 100  IF (-A .GT. .693) GOTO 1000                                         010095
      CALL COMPUTE(C,AA,FF1,FF2,IER)                                      010100
      IF(IER.EQ.2) GOTO 1000                                              010110
      A7Q=A1Q*FF2                                                         010120
      IKIRKP=A5*((CABS(A2Q*FF1-A7Q))**2+(CABS(A3Q*FF1+A7Q))**2)           010130
      RETURN                                                              010140
 1000 WRITE (TT5,10)                                                      010150
 10   FORMAT(/* ALPHA**2 IS OUT OF RANGE*)                                010160
 2000  RETURN                                                             010170
      END                                                                 010180
```

B.12 Subroutine COMPUTE

```
      SUBROUTINE COMPUTE (C,AA,F0,F1,IER)                                 010190
C     THIS SUBROUTINE RETURNS THE APPROXIMATION TO THE INTEGRAL           010200
C     F0= (1/V)**2* INTEGRAL (Y*J0(Y)*E**(-CY**2))DY) OVER (0,V)          010210
C     F1=(1/V)**2*INTEGRAL(J1(Y)*E**(-CY**2))DY) OVER (0,V) GIVEN BY      010220
C     F0=(1/V)**2*SUM(A(I)*(C**I)*(INTEGRAL(Y**(2I+1)*J0(Y)DY)))   AND    010230
C     F1=(1/V)**2*SUM(A(I)*(C**I)*INTEGRAL( Y**(2I)*J1(Y)DY))) OVER(0,V)  010240
C     FOR I=0,1,...,N                                                     010250
C     WHERE THE A(I) ARE GIVEN (FOR EXAMPLE) IN NBS 55 P. 71              010260
C     NOTE THAT FOR THE                                                   010270
C     APPROXIMATIONS TO BE VALID, 0L=C[=.693                              010280
      COMMON/VICTOR/V                                                     010290
      DIMENSION AA(1)                                                     010300
      REAL JI                                                             010310
      IER=1                                                               010320
      I=0                                                                 010330
      F0=F1=0.                                                            010340
  110 IF(AA(I+1).EQ.0.) GOTO 2000                                         010350
      F0=F0+AA(I+1)*(C**I)*JI(0,I)                                        010360
      F1=F1+AA(I+1)*(C**I)*JI(1,I)                                        010370
      I=I+1                                                               010380
      GOTO 110                                                            010390
 2000 F0=F0/V**2                                                          010400
      F1=F1/V**2                                                          010410
      RETURN                                                              010420
 1000 IER=2                                                               010430
      RETURN                                                              010440
      END                                                                 010450
```

B.13 Function JI

```
C                                                                      010460
      REAL FUNCTION JI(T,N)                                            010470
      REAL N11,N22                                                     010480
      COMMON/VICTOR/V                                                  010490
C     IF T=1, THEN THIS FUNCTION RETURNS%                              010500
C     INTEGRAL((T**2N)J1(T)DT) OVER(0,V)                               010510
C     IF T=0, THEN THIS FUNCTION RETURNS                               010520
C     INTEGRAL((T**(2 +1))J0(T)DT) OVER (0,V)                          010530
C     SEE LUKE,Y.L. "INTEGRALS OF BESSEL FUNCTIONS"                    010540
C     MCGRAW @ HILL 1962 (P.51)                                        010550
C     OR NBS 55 (P.480)                                                010560
      I1=T+1                                                           010570
      GOTO (110,100) I1                                                010580
  100 IF(N.NE.0) GOTO 120                                              010590
      JI=1.-BESJF(0)                                                   010600
      RETURN                                                           010610
  120 N1=-N                                                            010620
      JI=2.*BESJF(2)                                                   010630
      EXP=2*N                                                          010640
      K21=2                                                            010650
      GOTO 130                                                         010660
  110 N1=-(N+1)                                                        010670
      JI=BESJF(1)                                                      010680
      EXP=2*N+1                                                        010690
      K21=1                                                            010700
  130 N11=N22=1                                                        010710
      N2=N+2                                                           010720
  140 N1=N1+1                                                          010730
      IF(N1.EQ.0) GOTO 2000                                            010740
      K21=K21+2                                                        010750
      N11=N11*N1                                                       010760
      N22=N22*N2                                                       010770
      N2=N2+1                                                          010780
      JI=JI+K21*N11/N22*BESJF(K21)                                     010790
      GOTO 140                                                         010800
 2000 JI=V**EXP/(N+1)*JI                                               010810
      RETURN                                                           010820
      END                                                              010830
```

B.14 Function BESJF

```
C                                                                      010840
      FUNCTION BESJF (M)                                               010850
      COMMON/VICTOR/V                                                  010860
      COMMON/TFILES/IT3,IT4,IT5,IT6,IT7,IT8                            010870
      N=M                                                              010880
      D=.001                                                           010890
      CALL BESJ(V,N,BJ,D,IER)                                          010900
      IER=IER+1                                                        010910
      GOTO (10,20,30,40,50) IER                                        010920
   10 BESJF=BJ                                                         010930
      RETURN                                                           010940
   20 WRITE (IT5,200)                                                  010950
  200 FORMAT(* ORDER OF BES FUN NEG,PROGRAM STOP*)                     010960
      GOTO 1000                                                        010980
   30 WRITE (IT5,300)                                                  010990
  300 FORMAT(* ARG OF BES FUN NEG OR ZERO,PROGRAM STOP*)               011000
      GOTO 1000                                                        011020
   40 WRITE (IT5,400)                                                  011030
  400 FORMAT(* ACCURACY OF BES FUN NOT OBTAINED,PROGRAM CONTINUES*)    011040
      GOTO 10                                                          011060
   50 WRITE(IT5,500)                                                   011070
  500 FORMAT(* RANGE ERROR IN BES FUN. RANGE ADJUSTED*)                011080
      GOTO 10                                                          011100
 1000 STOP                                                             011110
      END                                                              011120
```

B.15 Function BESJ

```
      SUBROUTINE BESJ(X,N,BJ,D,IER)                                     011130
C     ..................................................................011140
C                                                                       011150
C        SUBROUTINE BESJ                                                011160
C                                                                       011170
C        PURPOSE                                                        011180
C           COMPUTE THE J BESSEL FUNCTION FOR A GIVEN ARGUMENT AND ORDER011190
C                                                                       011200
C        USAGE                                                          011210
C           CALL BESJ(X,N,BJ,D,IER)                                     011220
C                                                                       011230
C        DESCRIPTION OF PARAMETERS                                      011240
C           X  -THE ARGUMENT OF THE J BESSEL FUNCTION DESIRED           011250
C           N  -THE ORDER OF THE J BESSEL FUNCTION DESIRED              011260
C           BJ -THE RESULTANT J BESSEL FUNCTION                         011270
C           D  -REQUIRED ACCURACY                                       011280
C           IER-RESULTANT ERROR CODE WHERE                              011290
C              IER=0  NO ERROR                                          011300
C              IER=1  N IS NEGATIVE                                     011310
C              IER=2  X IS NEGATIVE OR ZERO                             011320
C              IER=3  REQUIRED ACCURACY NOT OBTAINED                    011330
C              IER=4  RANGE OF N COMPARED TO X NOT CORRECT (SEE REMARKS)011340
C                                                                       011350
C        REMARKS                                                        011360
C           N MUST BE GREATER THAN OR EQUAL TO ZERO, BUT IT MUST BE     011370
C           LESS THAN                                                   011380
C              20+10*X-X** 2/3   FOR X LESS THAN OR EQUAL TO 15         011390
C              90+X/2           FOR X GREATER THAN 15                   011400
C                                                                       011410
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED                  011420
C           NONE                                                        011430
C                                                                       011440
C        METHOD                                                         011450
C           RECURRENCE RELATION TECHNIQUE DESCRIBED BY H. GOLDSTEIN AND 011460
C           R.M. THALER,"RECURRENCE TECHNIQUES FOR THE CALCULATION OF   011470
C           BESSEL FUNCTIONS",M.T.A.C.,V.13,PP.102-108 AND I.A. STEGUN  011480
C           AND M. ABRAMOWITZ,"GENERATION OF BESSEL FUNCTIONS ON HIGH   011490
C           SPEED COMPUTERS",M.T.A.C.,V.11,1957,PP.255-257              011500
C                                                                       011510
C     ..................................................................011520
C                                                                       011530
C                                                                       011540
      BJ=.0                                                             011550
      IF(N)10,20,20                                                     011560
   10 IER=1                                                             011570
      RETURN                                                            011580
   20 IF(X)30,30,31                                                     011590
   30 IER=2                                                             011600
      RETURN                                                            011610
   31 IF(X-15.)32,32,34                                                 011620
   32 NTEST=20.+10.*X-X** 2/3                                           011630
      GO TO 36                                                          011640
   34 NTEST=90.+X/2.                                                    011650
   36 IF(N-NTEST)40,38,38                                               011660
   38 IER=4                                                             011670
      N=NTEST-1                                                         011680
      GOTO 41                                                           011690
   40 IER=0                                                             011700
41    N1=N+1                                                            011710
      BPREV=.0                                                          011720
C                                                                       011730
C     COMPUTE STARTING VALUE OF M                                       011740
C                                                                       011750
      IF(X-5.)50,60,60                                                  011760
   50 MA=X+6.                                                           011770
      GO TO 70                                                          011780
   60 MA=1.4*X+60./X                                                    011790
   70 MB=N+IFIX(X)/4+2                                                  011800
      MZERO=MAX0(MA,MB)                                                 011810
C                                                                       011820
C     SET UPPER LIMIT OF M                                              011830
C                                                                       011840
      MMAX=NTEST                                                        011850
  100 DO 190 M=MZERO,MMAX,3                                             011860
```

```
C                                                                       011870
C     SET F(M).F(M-1)                                                   011880
C                                                                       011890
      FM1=1.0E-28                                                       011900
      FM=.0                                                             011910
      ALPHA=.0                                                          011920
      IF(M-(M/2)*2)120,110,120                                          011930
  110 JT=-1                                                             011940
      GO TO 130                                                         011950
  120 JT=1                                                              011960
  130 M2=M-2                                                            011970
      DO 160 K=1,M2                                                     011980
      MK=M-K                                                            011990
      BMK=2.*FLOAT(MK)*FM1/X-FM                                         012000
      FM=FM1                                                            012010
      FM1=BMK                                                           012020
      IF(MK-N-1)150,140,150                                             012030
  140 BJ=BMK                                                            012040
  150 JT=-JT                                                            012050
      S=1+JT                                                            012060
      S=1+JT                                                            012070
  160 ALPHA=ALPHA+BMK*S                                                 012080
      BMK=2.*FM1/X-FM                                                   012090
      IF(N)180,170,180                                                  012100
  170 BJ=BMK                                                            012110
  180 ALPHA=ALPHA+BMK                                                   012120
      BJ=BJ/ALPHA                                                       012130
      IF(ABS(BJ-BPREV)-ABS(D*BJ))200,200,190                            012140
  190 BPREV=BJ                                                          012150
      IER=3                                                             012160
  200 RETURN                                                            012170
      END                                                               012180
```

B.16 Subroutine GETDATA

```
      SUBROUTINE GETDATA(DATAIN,NV,IIN,IOUT1,IOUT2,IINI,ISIZE           012190
     *,ISIZET,INDIC)                                                    012200
C THE MAIN PURPOSE OF THIS SUBROUTINE IS TO INPUT CHARACTER STRING OR    012210
C NUMERICAL DATA IN A @CONVERSATIONAL@ MODE I.E. FOR INPUTTING DATA     012220
C TO PROGRAMS BEING RUN UNDER INTERCOM.                                 012230
C IT ALSO MAY BE USED FOR BATCH PROCESSING-IN WHICH CASE THE DATA       012240
C SHOULD APPEAR 6 VALUES TO A CARD. DATA WHICH IS NOT TO BE CHANGED     012250
C SHOULD BE REPLACED BY BLANKS. FOR BATCH ALL OR SOME OF THE DATA MAY   012260
C BE DEFAULTED BY USING AN EOR AFTER THE LAST DATA TO BE INPUTTED.      012270
C THE SUBROUTINE ASSUMES THAT DEFAULT VALUES HAVE BEEN ASSIGNED         012280
C AND WILL PRINT OUT THESE DEFAULT VALUES BEFORE ASKING FOR DATA INPUT. 012290
C IT ASKS FOR NEW VALUES BY PRINTING OUT THE @NAMES@ OF THE DATA AND THEN 012300
C SKIPPING A LINE. VALUES TO BE ASSIGNED TO THE NAMES SHOULD BE         012310
C ENTERED STARTING IN THE SAME COLUMN AS THE START OF THE NAME.         012320
C EACH DATUM IS ASSIGNED 10 COLUMNS AND UP TO 6 ITEMS MAY BE INPUTTED   012330
C IN A SINGLES ROW.                                                     012340
C ARGUMENTS**********************                                       012350
C DATAIN  (DIMENSION (NV,3) WHERE NV IS THE TOTAL # OF DATA             012360
C     TO BE INPUTTED)                                                   012370
C DATAIN HOLDS THE FOLLOWING INFORMATION ABOUT EACH DATUM-              012380
C NAME,VALUE,CODE WHERE-                                                012390
C NAME => NAME BY WHICH THE DATUM IS IDENTIFIED TO THE USER (IT MAY OR  012400
C MAY NOT BE EQUAL TO THE FORTRAN VARIABLE NAME TO BE ASSIGNED TO THE   012410
C DATUM.)                                                               012420
C VALUE => NUMERICAL OR CHARACTER STRING VALUE TO BE ASSIGNED (THE DATUM) 012430
C CODE => HOW THE DATUM IS TO BE INTERPRETED                            012440
C   -1 => CHARACTER STRING                                              012450
C    0 => INTEGER                                                       012460
C    1 => FLOATING POINT NUMBER                                         012470
C NV TOTAL NUMBER OF DATUM TO BE INPUTTED                               012480
C IIN FILE NO. FOR INPUTTING                                            012490
C IOUT1 PRIMARY OUTPUT FILE                                             012500
C IOUT2 SECONDARY OUTPUT FILE                                           012510
C ISIZE =>  SIZE OF FIRST DIMENSION OF DATAIN                           012520
```

```
      DIMENSION DATAIN(ISIZET),IA(6)
      COMMON/SENSE/IINNN,IOUTNN,INDICC
      INTEGER DATAIN,F
      EXTERNAL SSWTCH
      CALL ERRSET(KOUNT,21000)
      KOUNT1=KOUNT
      IF(INDIC.NE.0) 200,210
  200 ISW=2
      LL=0
      L=INDIC-1
      GOTO 1055
  210 CONTINUE
      ISW=1
      IDOL=00000000000000000053B
      IINNN=IIN
      IOUTNN=IOUT1
      IOUTT=IOUT1
      ISW=1
      IBLANK=1H
      CALL SSWTCH(IIN1,ISW3,10HREAD DATA ,5HFILE-),RETURNS(1060)
      IF (ISW3 .EQ. 1) 1300,1290
 1300 WRITE (IOUT1,17) IIN1
      REWIND IIN1
      READ(IIN1) DATAIN
      REWIND IIN1
      IF (EOF(IIN1)) 1400,1290
 1400 WRITE(IOUT1,24) IIN1
 1290 CONTINUE
      CALL SSWTCH(0,ISW4,10HDEFAULTS L,5HISTED),RETURNS(1060)
      IF (ISW4 .NE. 1) GOTO 1150
      WRITE(IOUT1,1)
 1140 DO 110 I=1,NV
      II=ISIZE+I
      II1=I
      II2=II+ISIZE
      IF (DATAIN(II2)) 1020,1030,1040
 1020 WRITE(IOUTT,2) DATAIN(II),DATAIN(II1)
      GOTO 110
 1030 WRITE (IOUTT,3) DATAIN(II),DATAIN(II1)
      GOTO 110
 1040 WRITE(IOUTT,4) DATAIN(II),DATAIN(II1)
 110  CONTINUE
      GOTO (1150,1130) ISW
 1150 CALL SSWTCH(0,ISW5,10HNAME-VALUE,5H MODE),RETURNS(1060)
      IF (ISW5 .EQ. 1) 1270,1050
 1050 L=1
      ISW=2
      LL=0
 1055 L=L+LL
      IF (L .GT. NV) GOTO 1060
 1310 WRITE (IOUT1,18) DATAIN(ISIZE+L)
      LL=0
      DO 100 J=1,6
      IA(J)=10H
 100  CONTINUE
      READ(IIN,10) (IA(J),J=1,6)
      IF (EOF(IIN)) 1320,1070
 1320 INDICC=1
      GOTO 1060
 1070 IF (IA(1) .EQ. IBLANK) GOTO 1055
      DO 180 J=1,6
      DO 180 K-1,10
      IF (MXGETX(IA(J),K,1) .EQ. IDOL) GOTO 1270
 180  CONTINUE
      DO 190 J=1,6
      JR=L+J-1
      F=DATAIN(JR+2*ISIZE)
      IF (F) 1090,1100,1110
 1090 IF (IA(J) .NE. IBLANK) DECODE(10,11,IA(J)) DATAIN(JR)
      GOTO 1080
 1100 CALL RJUST(IA(J))
      IF (IA(J) .NE. IBLANK) DECODE(10,12,IA(J)) DATAIN(JR)
      GOTO 1080
 1110 CALL RJUST(IA(J))
      IF (IA(J) .NE. IBLANK) DECODE(10,13,IA(J)) DATAIN(JR)
      GOTO 1080
 190  CONTINUE
 1080 LL=1
      IF(INDIC.NE.0) LL=1000
      IF (KOUNT .EQ. KOUNT1) GOTO 1055
      KOUNT1=KOUNT                                                      013320
      WRITE(IOUT1,25)                                                   013330
 1270 WRITE(IOUT1,23)                                                   013340
 1250 WRITE(IOUT1,8)                                                    013350
      DO 150 I=1,6                                                      013360
      IA(I)=10H                                                         013370
 150  CONTINUE                                                          013380
      READ(IIN,10) (IA(I),I=1,6)                                        013390
      IF (EOF(IIN)) 1330,1085                                           013400
 1330 INDICC=1                                                          013410
      GOTO 1060                                                         013420
 1085 II=IA(1)                                                          013430
      IF (II .EQ. IBLANK) GOTO 1060                                     013440
      DO 130 I=1,NV                                                     013450
      J=I+ISIZE                                                         013460
      IF (II .EQ. DATAIN(J)) GOTO 1160                                  013470
 130  CONTINUE                                                          013480
      WRITE(IOUT1,16)                                                   013490
      GOTO 1270                                                         013500
 1160 F=DATAIN(J+ISIZE)                                                 013510
      JJ= J-ISIZE                                                       013520
      IF (F) 1170,1180,1190                                             013530
 1170 DO 160 I=2,6                                                      013540
      IF (IA(I) .EQ. IBLANK) GOTO 1240                                  013550
      DECODE(10,11,IA(I)) DATAIN(JJ+I-2)                                013560
 160  CONTINUE                                                          013570
      GOTO 1240                                                         013580
 1180 CALL RJUST(IA(2))                                                 013590
      DECODE(10,12,IA(2)) DATAIN(JJ)                                    013600
      GOTO 1240                                                         013610
 1190 CALL RJUST(IA(2))                                                 013615
      DECODE(10,13,IA(2)) DATAIN(JJ)                                    013620
 1240 IF (KOUNT .EQ. KOUNT1) GOTO (1250,1310) ISW                       013630
      KOUNT1=KOUNT                                                      013640
      WRITE(IOUT1,25)                                                   013650
      GOTO 1250                                                         013660
 1060 WRITE (IOUT1,14)                                                  013670
      IF (IOUT2 .EQ. 0) GOTO 1130                                       013680
      WRITE (IOUT2,15)                                                  013690
      IOUT1=IOUT2                                                       013700
      ISN=2                                                             013710
      GOTO 1140                                                         013720
 1130 INDIC=INDICC                                                      013730
      RETURN                                                            013740
 1    FORMAT(/,* THE DEFAULT INPUT DATA ARE*)                           013750
 2    FORMAT(1X,A10,*=@*,A10,*@*)                                       013760
 3    FORMAT(1X,A10,*=*,I10)                                            013770
 4    FORMAT(1X,A10,*=*,G16.6)                                          013780
 5    FORMAT(///)                                                       013790
 6    FORMAT(/,* ENTER DATA. START IN COL. BENEATH START OF NAME*)      013800
 7    FORMAT(8X,6A10)                                                   013810
 8    FORMAT(8X)                                                        013820
 10   FORMAT(6A10)                                                      013830
 11   FORMAT(A10)                                                       013840
 12   FORMAT(I10)                                                       013850
 13   FORMAT(E10.0)                                                     013860
 14   FORMAT(/,* DATA INPUT COMPLETE*)                                  013870
 15   FORMAT(/,* THE INPUT DATA VALUES ARE*,/)                          013880
 16   FORMAT(1X,* TRY AGAIN*)                                           013890
 17   FORMAT(/,1X,* READING DATA FROM *,I5)                             013900
 18   FORMAT(1X,A10,*-*)                                                013910
 23   FORMAT(8X,*NAME       VALUE.....*)                                013920
 24   FORMAT(1X,*.FILE*,I5,* IS EMPTY*)                                 013930
 25   FORMAT(1X,* WRONG DATA TYPE-TRY AGAIN*)                           013940
      END                                                               013950
```

B.17 Subroutine PRT

```
      SUBROUTINE PRT(BUF•MODE•II•IT•MP•NP•MSKIP•NSKIP•RHOPI•           015000
     •DELRHO•VMIN•DELV•XIT•U•TR•T•IT6)                                 015010
      DIMENSION R(100)•BUF(1)•D(2)                                     015020
      DATA ITT/0/                                                      015030
      IF (ITT .EQ. IT) GOTO 100                                        015040
      WRITE(IT6•1) TR•T                                                015050
      DO 130 I=1•MP•MSKIP                                              015060
      GOTO (110•120) MODE                                              015070
 110  R(I)=RHOPI+DELRHO*(I-1)                                          015080
      GOTO 130                                                         015090
 120  R(I)=VMIN+DELV*(I-1)                                             015100
 130  CONTINUE                                                         015110
      GOTO (170•180) MODE                                              015120
 170  WRITE(IT6•2) (R(I)•I=1•MP•MSKIP)                                 015130
      GOTO 100                                                         015140
 180  WRITE(IT6•3) (R(I)•I=1•MP•MSKIP)                                 015150.
 100  GOTO (140•150) MODE                                              015160
 140  ENCODE(20•4•D) XIT                                               015170
      GOTO 160                                                         015180
 150  ENCODE(20•5•D) U                                                 015190
 160  IF (MOD(II-1•NSKIP) .EQ. 0) WRITE(IT6.6) D•                      015200
     •(BUF(J)• J=1•MP•MSKIP)                                           015205
      ITT=IT                                                           015210
 1000 RETURN                                                           015220
 1    FORMAT(//* TIME(SECONDS)= *G12.4* TAU= *G12.4/                   015230
     •*-------------------------------------------*)                   015240
 2    FORMAT(/* INTENSITIES EVALUATED AT RHO-PRIME=*/(5X•5G13.5))      015250
 3    FORMAT(/* INTENSITIES EVALUATED AT V=*/(5X•5G13.5))              015260
 4    FORMAT(* X= *G13.5)                                              015270
 5    FORMAT(* U= *G13.5)                                              015280
 6    FORMAT(/2A10/(5X•5G13.5))                                        015290
      END                                                              015300
```

Appendix C

The Evaluation of $I'(u,0,t)$ and $I'(0,v,t)$ Used in the IKIRKP Option

1. INTRODUCTION

Consider the circumstance when the temperature distribution is constant throughout the window but is a function of time only, viz, w(t). Then, returning to Eq. (16), Volume I, we see that:

$$F1(\rho,t) = \int_{\zeta_1}^{\zeta_2} w(t)\, d\zeta = (\zeta_2 - \zeta_1)\, w(t) = w(t)\, L/a = F1(t).$$

In a similar fashion, Eq. (17), Volume I, becomes:

$$F2(\rho,t) = \rho^{-2} \int_{o}^{\rho} d\rho\, \rho L w(t)/a = L\, w(t)/2a = F2(t).$$

Equation (18), Volume I, simplifies to:

$$\begin{aligned}\Phi^{\gamma}(\rho,t) &= a\Delta T_c \left[S_1^{\gamma}\, w(t)\, L/a + 4\, S_2^{\gamma}\, w(t)\, L/2a\right]\\ &= L w(t)\, \Delta T_c \left[S_1^{\gamma} + 2\, S_2^{\gamma}\right] \equiv d^{\gamma}(t).\end{aligned}$$

2. EVALUATION OF I′(u,0,t)

For the condition v = 0 and u arbitrary, then $J_o(0)=1$ and $\lim_{v\to 0} J_1(\rho v)/\rho v = 1/2$. Equations (25-27), Volume I, reduce to:

$$f_z(\rho,0,t) = \rho\left[\exp(i k d^{\rho}) - \exp(i k d^{\theta})\right]/2 \equiv \rho A_1(t)/2\,,$$

$$f_x(\rho,0,t) = \rho \exp(i k d^{\rho}) - f_z \equiv \rho A_2(t) - \rho A_1(t)/2,$$

$$f_y(\rho,0,t) = \rho \exp(i k d^{\theta}) + f_z \equiv \rho A_3(t) + \rho A_1(t)/2.$$

Then, from Eq. (23), Volume I,

$$\begin{aligned}I'(u,0,t) = 2\alpha^4\left(1-\exp(-\alpha^2)\right)^{-2} \Bigg\{ &\left|\int_o^1 \exp(-\alpha^2\rho^2)\exp(-iu\rho^2/2)(\rho A_2 - \rho A_1/2)\, d\rho\right|^2\\ &+ \left|\int_o^1 \exp(-\alpha^2\rho^2)\exp(-iu\rho^2/2)(\rho A_3 + \rho A_1/2)\, d\rho\right|^2 \Bigg\},\end{aligned}$$

$$I'(u,0,t) = 2\alpha^4\left(1-\exp(-\alpha^2)\right)^{-2}\left\{\left|(A_2-A_1/2)\int_0^1 \rho\ \exp(-\alpha^2\rho^2)\exp(-iu\rho^2/2)\,d\rho\right|^2\right.$$

$$\left. + \left|(A_3+A_1/2)\int_0^1 \rho\ \exp(-\alpha^2\rho^2)\ \exp\ (-iu\rho^2/2)\ d\rho\right|^2\right\} .$$

Expressing the integral in terms of sin and cos, we find:

$$\int_0^1 \rho\ \exp(-\alpha^2\rho^2)\exp(-iu\rho^2/2)\,d\rho = \int_0^1 \rho\ \exp(-\alpha^2\rho^2)\cos(u\rho^2/2)\ d\rho$$

$$-i\int_0^1 \rho\ \exp(-\alpha^2\rho^2)\sin(u\rho^2/2)\ d\rho\ .$$

Let $a = -\alpha^2$, $b = u/2$ and $y = \rho^2$, to get:

$$\frac{1}{2}\int_0^1 e^{ay}\cos by\ dy - \frac{i}{2}\int_0^1 e^{ay}\sin by\ dy = \frac{1}{2}\left\{\frac{e^a(a\cos b+b\sin b) - a}{a^2+b^2}\right\} -$$

$$\frac{i}{2}\left\{\frac{e^a\ (a\sin b - b\cos b) + b}{a^2+b^2}\right\} \equiv A_4 .$$

Thus, we get the final result:

$$I'(u,0,t) = 2\alpha^4\left(1-\exp(-\alpha^2)\right)^{-2}\left\{\left|(A_2 - A_1/2)\,A_4\right|^2 + \left|(A_3 + A_1/2)\,A_4\right|^2\right\}.$$

3. EVALUATION OF I'(0,v,t)

Consider when u = 0 and v is arbitrary. Then,

$f_w(\rho) = \exp\ (-\alpha^2\rho^2)$

$f_z(\rho,v,t) = v^{-1}\ J_1(\rho v)\ A_1(t)$

$f_x(\rho,v,t) = \rho\ J_o(\rho v)\ A_2(t) - f_z$

$f_y(\rho,v,t) = \rho\ J_o(\rho v)\ A_3(t) + f_z$.

Inserting these functions into Eq. (23), Volume I, the integral terms become:

$$| A_2 \int_{o.}^{1} \rho J_o(\rho v) \exp(-\alpha^2\rho^2)\, d\rho - A_1 v^{-1} \int_{o}^{1} J_1(\rho v) \exp(-\alpha^2\rho^2)\, d\rho |^2$$

$$+ | A_3 \int_{o}^{1} \rho J_o(\rho v) \exp(-\alpha^2\rho^2)\, d\rho + A_1 v^{-1} \int_{o}^{1} J_1(\rho v) \exp(-\alpha^2\rho^2)\, d\rho |^2 .$$

Thus, the integrals to consider are:

$$\int_{o}^{1} \rho J_o(\rho v) \exp(-\alpha^2\rho^2)\, d\rho \quad ; \quad v^{-1} \int_{o}^{1} J_1(\rho v) \exp(-\alpha^2\rho^2)\, d\rho$$

Let $y = \rho v$ and obtain:

$$v^{-2} \int_{o}^{v} y J_o(y) \exp(-\alpha^2 y^2/v^2)\, dy; \quad v^{-2} \int_{o}^{v} J_1(y) \exp(-\alpha^2 y^2/v^2)\, dy \ .$$

In order to perform these integrations, consider a polynomial approximation to $\exp(-\alpha^2 y^2/v^2)$. On p. 71 of Abramowitz and Stegun,[1] various approximations to e^{-x} are given, valid for the domain $0 \leq x \leq 0.693$. They all have the generic form: $e^{-x} = 1+a_1x+a_2x^2+a_3x^3+\ldots$. Since $\alpha^2 y^2/v^2$ is a maximum at $y = v$ (where $\rho = 1$) for any value of v, we get the condition that $0 \leq \alpha^2 \leq 0.693$. Using the polynomial approximations mentioned above, the typical n-th term from each of the above two integrals will have the form:

$$a_n \alpha^{2n} v^{-(2n+2)} \int_{o}^{v} y^{2n+1} J_o(y)\, dy; \quad a_n \alpha^{2n} v^{-(2n+2)} \int_{o}^{v} y^{2n} \ J_1(y)\, dy.$$

On p. 480 of Abramowitz and Stegun[1] or p. 51 of Luke,[2] we find:

$$J_{i_o}^{2n+1}(v) \equiv \int_{o}^{v} y^{2n+1} J_o(y)\, dy = \frac{v^{2n+1}}{n+1} \sum_{k=o}^{\infty} \frac{(2k+1)(-n)_k}{(n+2)_k} J_{2k+1}(v)$$

[1] Abramowitz, M., and Stegun, I.A., Editors (1964) Handbook of Mathematical Functions, National Bureau of Standards, Washington, D.C.

[2] Luke, Y.L. (1962) Integrals of Bessel Functions, McGraw-Hill Co., New York.

$$J_{i_1}^{n}(v) \equiv \int_{o}^{v} y^{n} J_1(y)\, dy = \frac{v^{2n}}{n+1} \sum_{k=o} \frac{(2k+2)(1-n)_k}{(n+2)_k} J_{2k+2}(v) \qquad (n \neq 0)$$

and

$$\int_{o}^{v} J_1(y)\, dy = 1 - J_o(v)$$

where:

$(a)_o = 1$

$(a)_k = a \cdot (a+1) \cdot (a+2) \ldots (a+k-1)$

Since $(-n)_k = 0$ for $k = n+1$ and $(1-n)_k = 0$ for $k = n$, the series terminates.

The above results have been coded in a function subroutine JI (i, n) which returns $J_{i_o}^{2n+1}(v)$ if $i = 0$ and $J_{i_1}^{n}(v)$ if $i = 1$. It uses the IBM Scientific Subroutine BESJ to compute the $J_{2k+1}(v)$ and $J_{2k+2}(v)$.

Appendix D

Fortran Listings for the Main Programs in the Altemate TIKIRK Package Containing All Three Options

D.1 Modified Main Program TIKIRK

```
      PROGRAM TIKIRK(TAPE4=65.TAPE5=65.TAPE3=513.TAPE7=513.TAPE8=513.      000100
     +TAPE6=65.OUTPUT=65)                                                   000110
C THIS PROGRAM CAN BEST BE DESCRIBED AS THE I/O INTERFACE FOR FUNCTION      000120
C SUBROUTINE IKIRK WHICH COMPUTES THE KIRKHOFF INTENSITY FUNCTION AS        000130
C DESCRIBED IN AFCRL-72-0565.                                               000140
C     THE INPUT FALLS INTO THREE CLASSES*                                   000150
C  1) INPUT HAVING TO DO WITH PROPERTIES OF THE WINDOW MATERIAL AND         000160
C THE LASER BEAM.NAMELY* (QUANTITIES CGS UNLESS OTHERWISE INDICATED)        000170
C SIG     =>  VALUE OF SIGMA IN GAUSSIAN BEAM                               000180
C LAMBDA  =>  WAVELENGTH OF THE LIGHT BEAM IN MICRONS                       000190
C PW      =>  TOTAL BEAM POWER                                              000200
C R       =>  WINDOW RADIUS                                                 000210
C BETA    =>  BULK ABSORPTION COEFFICIENT                                   000220
C K       =>  THERMAL CONDUCTIVITY                                          000230
C NX      =>  INDEX OF REFRACTION                                           000240
C S1R     =>  S SUB-1,SUP-RHO                                               000250
C S1T     =>  S SUB-1,SUP-THETA                                             000260
C S2R     =>  S SUB-2,SUP-RHO                                               000270
C S2T     =>  S SUB-2,SUP-THETA                                             000280
C T       =>  TIME AT WHICH IKIRK IS TO BE EVALUATED                        000290
C  2) INPUT HAVING TO DO WITH THE EVALUATION DOMAIN OF THE FUNCTION         000300
C IKIRK,NAMELY*                                                             000310
C       XC     => GAUSSIAN FOCAL DISTANCE (METERS)                          000320
C       X1     => MINIMUM X-VALUE FOR FUNCTION EVALUATION (METERS)          000330
C       X2     => MAXIMUM X-VALUE FOR FUNCTION EVALUATION (METERS)          000340
C       RHOP1  => MINIMUM RADIUS VALUE FOR FUNCTION EVALUATION              000350
C       RHOP2  => MAXIMUM RADIUS VALUE FOR FUNCTION EVALUATION              000360
C       MP     => NUMBER OF EVALUATION POINTS IN THE RADIAL DIRECTION       000370
C       NP     => NUMBER OF EVALUATION POINTS IN THE AXIAL (X) DIRECTION    000380
C       TIM    => ARRAY (UP TO 10) OF TIME VALUES FOR FUNCTION EVALUATION   000390
C          (TIME VALUES SHOULD BE IN INCREASING SEQUENCE)                   000400
C       UMIN   => MINIMUM U-VALUE FOR FUNCTION EVALUATION (SEE MODE)        000410
C       UMAX   => MAXIMUM U-VALUE FOR FUNCTION EVALUATION                   000420
C       VMIN   => MINIMUM V-VALUE FOR FUNCTION EVALUATION                   000430
C       VMAX   => MAXIMUM V-VALUE FOR FUNCTION EVALUATION                   000440
C    3) INPUT HAVING TO DO WITH PROGRAM CONTROL,NAMELY*                     000450
C       EPSI   => ERROR VALUE FOR INTERPOLATION OF THE TEMPERATURE          000460
C FUNCTION OUTPUTTED BY TEMPS AND INTERPOLATED BY IBM SCI. SUB. ALI.        000470
C       MINT   => NUMBER OF TEMPERATURE FUNCTION POINTS TO BE USED IN       000480
C THE INTERPOLATION (DEFAULT=6)                                             000490
C       IPRNT => USED TO CONTROL DEBUG OUTPUT (1 CAUSES DEBUG OUTPUT)       000500
C                  (2 CAUSES WINDOW TEMPERATURE DISTRIBUTION SUITABLE FOR   000510
C                  DISPLAY TO BE OUTPUT)                                    000520
C       NGAUS => NUMBER OF FUNCTION VALUES FOR GAUSSIAN INTEGRATION         000530
C       MODE   => IF MODE=1 THEN THE INTENSITY FUNCTION IS EVALUATED AT     000540
C EQUI-SPACED X AND RHOP-PRIME VALUES* IF MODE=2 IT IS EVALUATED AT         000550
C EQUI-SPACED U AND V VALUES.                                               000560
C       I2       => IF 1 USE IKIRK. IF 2 USE IKIRKP                         000570
C                 (NOTE THAT IKIRKP SHOULD ONLY BE USED ON THE AXES         000580
C                  FOR CONSTANT TEMPERATURE WINDOW)                         000590
C ALL THE ABOVE MENTIONED DATA IS OBTAINED BY TWO CALLS TO THE              000600
C INTERACTIVE INPUT SUBROUTINE GETDATA DESCRIBED IN PML TM-16. IN THE       000610
C FIRST CALL ALL DATA IN THE FIRST CATEGORY IS OBTAINED. IN THE             000620
C SECOND CALL ALL DATA IN  THE SECOND AND THIRD CATEGORIES ARE              000630
C OBTAINED.  AN EXCEPTION TO THIS IS I2 (CONTROLS USE OF                    000640
C IKIRK AND IKIRKP) WHICH IS OBTAINED ON THE FIRST CALL TO GETDATA.         000650
C  FOR A LISTING OF DEFAULT INPUT DATA IT IS RECOMMENDED THAT               000660

C TIKIRK BE RUN INTERACTIVELY UNDER INTERCOM AFTER GIVING THE COMMAND       000670
C CONNECT(TAPE4,TAPE5).                                                     000680
C THE MAIN OUTPUT OF TIKIRK IS A SEQUENCE OF UNFORMATTED RECORDS            000690
C OF INTENSITY VALUES WITH CORRESPONDING DOMAIN VALUES. EACH RECORD         000700
C CONSISTS OF THE FOLLOWING SEQUENCE OF VALUES*                             000710
C RECORD NO., NUMBER(MP) OF INTENSITY VALUES IN THE AXIAL DIRECTION,        000720
C AXIAL COORDINATE X OR U. TIME VALUE (T) IN SECONDS, NUMBER (NP)           000730
C OF INTENSITY VALUES IN THE RADIAL DIRECTION, MINIMUM RADIAL               000740
C COORDINATE RHOP1 OR VMIN. MAXIMUM RADIAL COORDINATE RHOP2 OR              000750
C VMAX. MP INTENSITY VALUES.                                                000760
C FOR EACH VALUE OF T. NP RECORDS ARE OUTPUTTED CORRESPONDING TO THE        000770
C NP X EVALUATION POINTS. THE RECORD NUMBER RUNS FROM 1 TO NP FOR           000780
C EACH TIME VALUE.                                                          000790
C THERE ARE SIX FILES ASSOCIATED WITH THIS PROGRAM (NOT INCLUDING FILE      000800
C @OUTPUT@). THE FILES ARE REFERRED TO IN THE PROGRAM AND ASSOCIATED        000810
C SUBROUTINES AS IT3,IT4,IT5,IT6,IT7,IT8. THE FILE VALUES ARE IN TURN       000820
C ASSIGNED TO THE USUAL FORTRAN @TAPEN@ BY A DATA STATEMENT AND PROGRAM     000830
```

```
C STATEMENT SUCH THAT IT3 I=> TAPE3.ETC. THUS TO CHANGE THE                 000840
C ASSOCIATION IT IS NECESSARY TO CHANGE  EITHER OR BOTH THE DATA AND        000850
C PROGRAM STATEMENTS.                                                       000860
C THESE FILES SERVE THE FOLLOWING PURPOSES%                                 000870
C   IT3 => FILE OUTPUTTED BY PROGRAM TEMPS                                  000880
C   IT4 => @INTERACTIVE@ INPUT FILE (SEE GETDATA)                           000890
C   IT5 => @INTERACTIVE@ OUTPUT FILE (SEE GETDATA)                          000900
C   IT6 => LISTING OF ALL INPUT PARAMETERS AND DEBUG OUTPUT                 000910
C   IT7 => UNFORMATTED INTENSITY VALUES. ALSO MAY BE USED TO INSERT         000920
C   IT8 => UNFORMATTED TEMPERATURE DISTRIBUTION VALUES                      000930
C          SUITABLE FOR DISPLAY PURPOSES                                    000940
C        PREASSIGNED DATA IN CATEGORIES 2 AND 3                             000950
C IN ADDITION TO THE ABOVE FACTS. THE USER SHOULD BE AWARE OF TWO           000960
C PROGRAM @CONSTANTS@. THE FIRST UNDER THE VARIABLE NAME NT IS THE NUM-     000970
C BER OF TIME VALUES PERMITTED. AT PRESENT THIS IS SET TO 10. (THE          000980
C DIMENSION OF THE TIME ARRAY TIM). ALSO NOTE THAT ALL THE TIME             000990
C D-FAULT VALUES ARE ZERO EXCEPT THE FIRST AND THAT THE PROGRAM STOPS       001000
C AS SOON AS A SUCCEEDING TIME VALUE IS LESS THAN THE PRECEDING             001010
C TIME VALUE.                                                               001020
C THE SECOND @CONSTANT@ HAS TO DO WITH THE SIZE OF THE RECORD OUTPUTTED     001030
C BY TEMPS. THE SUBROUTINE RTAPE3 READS THE TEMPS OUTPUT UNDER THE          001040
C ASSUMPTION THAT ALL @RADIAL@ ARRA S ARE OF DIMENSION 82 AND @AXIAL@       001050
C ARRAYS ARE OF DIMENSION 22.SEE COMMENTS WITHIN SUBROUTINE RTAPE3.         001060
C THE INTENSUTY FUNCTION IKIRK IS DEFINED EXPLICITLY AS A FUNCTION OF       001070
C THE NONDIMENSIONAL VARIABLES U AND V AND IMPLICITLY AS A FUNCTION         001080
C OF NON-DIMENSIONAL TIME TAU THROUGH THE TIME DEPENDANT FUNCTIONS          001090
C PHI-THETA AND PHI-RHO AS DEFINED IN THE ABOVE REFERENCE. THESE            001100
C VARIABLES ARE PASSED THROUGH AN ARGUMENT LIST. ALL @PARAMETERS@           001110
C REQUIRED FOR EVALUATION OF IKIRK ARE PASSED THROUGH BLOCK COMMON          001120
C .PHIBLK. THESE PARAMETERS ARE%                                            001130
C    CS1R    => C*S1R (SEE IKIRK COMMENTS)                                  001140
C    CS2R    => C*S2R       "                                               001150
C    CS1R    => C*S1T       "                                               001160
C    CS2T    => C*S2T       "                                               001170
C    XS      => STARTING ARGUMENT FOR FUNCTIONS F1.F2 (SEE FUNCTION         001180
C               PHI COMMENTS)                                               001190
C    DX      => INTERVAL BETWEEN EQUI-SPACED ARGUMENTS OF F1.F2.            001200
C    NF      => NUMBER OF VALUES OF F1.F2                                   001210
C    MNNT    => MINT (SEE INPUT DATA)                                       001220
C    EPP     => EPS1        "                                               001230
C    F1(200)=> HOLDS VALUES OF F1 FROM TEMPS                                001240
C    F2(200)=> HOLDS VALUES OF F2 FROM TEMPS                                001250
C    HOLD    => STORES PHI-THETA (PHI-RHO AND PHI-THETA ARE EVALUATED       001260
C                     SIMULTANEOUSLY)                                       001270
C    A       => 1/SQRT(2)/SIG (=ALPHA IN THE ABOVE REFERENCE)               001280
C    KE      => WAVE NUMBER                                                 001290
C    TLAST   => STORES TIME VALUE READ FROM TEMP5 RECORD                    001300
C    TNEXT   =>             "                                               001310
C    IERR    => ERROR INDICATOR FOR RTAPE3 (INDICATES OUT OF RANGE          001320
C               TIME OR OUT OF SEQUENCE TIME)                               001330
C    IP      => DEBUG OUTPUT @SWITCH@                                       001340
C    MP1     => =NF                                                         001350
C    ISW     => SWITCH FOR GAUSSIAN INTEGRATION. WHEN ISW=1 THEN THE        001360
C        X_VALUES FOR GAUSSIAN INTEGRATION ARE FOUND.                       001370
C    NGAUSS => NUMBER OF POINTS USED IN THE GAUSSIAN INTEGRATION            001380
C         (NOTE THAT IS NGAUSS IS CHANGED THEN THE GAUSSIAN INTEGRATION     001390
C         SUBROUTINE MUST ALSO BE CHANGED.)                                 001400
C    RAD     => WINDOW RADIUS                                               001410
C    NP1     => NUMBER OF TEMPERATURE SAMPLES IN AXIAL DIRECTION            001420
C               (USED FOR OUTPUTTING DISPLAY COMPATIBLE                     001430
C               TEMPERATURE DATA)                                           001440
C    C3      => CONSTANT TO DIMENSIONALIZE TEMPERATURE DATA                 001450
C               FOR DISPLAY                                                 001460
C    C1      => CONSTANT USED TO DIMENSIONALIZE TIME FOR                    001470
      REAL K.IKIRK.LAMBDA.NX.KE                                             001480
      REAL IKIRKP.IKIRK1                                                    001490
      LOGICAL S                                                             001500
      DIMENSION BUF(100)                                                    001510
      COMMON/IFILES/IT3.IT4.IT5.IT6.IT7.IT8                                 001520
      COMMON/PHIBLK/CS1R.CS2R.CS1T.CS2T.XS.DX.NF.MNNT.EPP.F1(200).          001530
     +F2(200).HOLD.A.KE.TLAST.TNEXT.IERR.IP.MP1.ISW.NGAUSS.                 001540
     +RAD.NP1.C3.C1.IERM.ERRORM                                             001550
      INTEGER DATAIN(100.3).DATAIN1(100.3)                                  001560
      COMMON/BLOCK2/X0.X1.X2.RHOP1.RHOP2.MP.NP.TIM(10).EPS1                 001570
C           TEMPERATURE DISPLAY                                             001580
     +.MINT.IPRNT.NGAUS.MODE.UMIN.UMAX.VMIN.VMAX.DUM(20).MSKIP.NSKIP        001590
      COMMON/BLOCK1/                                                        001600
     +        I1.I2.I3.I4.I5.I6.I7.M.N.MI.NI.ICNT.IU.IQ.NO.NMX.TRUN.        001610
     +ICARD.IPRINT.IPNCH.ITAP3.ITAP4.RHO1.RHO12.ZED1.ZED12.DTAU0.           001620
     +TAUMX.TAUOFF.SIG  .O0.U0.    EPS.G1(4).H1(4).MATER.NX.BETA.           001630
     +K.LAMBDA.S1R.S1T.S2R.S2T.                                         001640
     +DEN.CP.R.EXPER.PW.R1.Z1.R2.IPLOT.PROBNO.TICU.XLEN.YLEN.SCALEX.    001650
     +SCALEY1.SCALEY2.XTITLE(5).YTITLE1(5).YTITLE2(5).NAME              001660
      EQUIVALENCE (I1.DATAIN).(XU.DATAIN1)                              001670
      DATA (DATAIN(I.1).I=1.92)/7*2.80.20.3*1.0.1.2.11.100.4.6.6.3.     001680
     +4.0.1..-.5546.1.1092..0035.5..5..1292.2*0..001.4*0..0..3*.015.    001690
     +3HKCL.1.47.4.8E-4..0653.10.6.-.34E-5..05E-5..1E-5.-.1E-5.1.98.    001700
     +.691.1.278.1H1.24.7.91.11.1.1.4H7204..5.20..9..30...1..1.         001710
     +10HTIME(SECON.3HDS).3*1H .10HTEMP-DEGC .10H ABOVE AMB.            001720
     +3*1H .10HMEAN TEMP .10H ABOVE AMB.3*1H .7HBARRETT.                001730
     +10HRADIAL DIS.10HTANCE.RHO-.4H(CM).1H .1H .10HAXIAL DIST.         001740
     +10HANCE.Z-(CM.1H).1H .1H /                                        001750
      DATA (DATAIN(I.2).I=1.92)/2HI1.2HI2.2HI3.2HI4.2HI5.               001760
     +2HI6.2HI7.1HM.1HN.2HMT.2HNI.4HICNT.2HIU.2HIQ.2HNO.3HNMX.          001770
     +4HIOUJ.5HICARD.6HIPRINT.5HIPNCH.5HITAP3.5HITAP4.4HRHO1.           001780
     +5HRHO12.4HZED1.5HZED12.5HUTAU0.5HTAUMX.6HTAUOFF.3HSIG.            001790
     +2HQ0.2HU0.3HEPS.5HG1(1).5HG1(2).5HG1(3).5HG1(4).5HH1(1).          001800

     +5HH1(2).5HH1(3).5HH1(4).8HMATERIAL.8HREF.IND..4HBETA.             001810
     +9HTHER.COND.6HLAMBDA.3HS1R.3HS1T.3HS2R.3HS2T.                     001820
     +             7HDENSITY.9HSPEC.HEAT.6HRADIUS.5HEXPER.              001830
     +3HPWR      .3HR1*.3HZ1*.3HR2*.9HPLT?1Y.2N.6HPROBNO.4HTICU.        001840
     +4HXLEN.4HYLEN.7HX-SCALE.8HY1-SCALE.8HY2-SCALE.6HXTITLE.           001850
     +1H2.1H3.1H4.1H5.7HYTITLE1.1H2.1H3.1H4.1H5.7HYTITLE2.1H2.          001860
     +1H3.1H4.1H5.8HOPERATOR.                                           001870
     +3HXT1.3HXT2.3HXT3.3HXT4.3HXT5.3HYT1.3HYT2.3HYT3.3HYT4.            001880
     +3HYT5/                                                            001890
      DATA (DATAIN(I.3).I=1.92)/22*0.19*1.-1.11*1.-1.1.4*0.             001900
     +-1.4*1.25*-1/                                                     001910
      DATA (DATAIN1(I.1).I=1.48)/1500..1000..2000..0..2..100.100.10..   001920
     +9*-1...0.1.6.1.24.2.-40..40..0..10..                              001930
     +10HKIRKHOFF I.10HNTENSITY F.9HUNCTION.I.1H .1H .10HTIME IN SE.    001940
     +5HCONDS.1H .1H .1H .10HNON-DIMENS.10HIONAL RADI.10HAL DISTANC.    001950
     +3HE.V.1H .10HNON-DIMENS.10HIONAL AXIA.10HL DISTANCE.2H.U.1H .5.5/ 001960
      DATA (DATAIN1(I.2).I=1.48)/2HA0.2HX1.2HX2.5HRHOP1.5HRHOP2.2HMP.   001970
     +2HNP.2HT1.2HT2.2HT3.2HT4.2HT5.2HT6.2HT7.2HT8.2HT9.3HT10.          001980
     +4HEPS1.4HMINT.5HIPRNT.5HNGAUS.4HMODE.4HUMIN.4HUMAX.               001990
     +4HVMIN.4HVMAX.3HST1.3HST2.3HST3.3HST4.3HST5.3HPT1.3HPT2.          002000
     +3HPT3.3HPT4.3HPT5.3HXT1.3HXT2.3HXT3.3HXT4.3HXT5.3HYT1.            002010
     +3HYT2.3HYT3.3HYT4.3HYT5.5HMSKIP.5HNSKIP/                          002020
      DATA (DATAIN1(I.3).I=1.48)/5*1.2*0.11*1.4*0.4*1.20*-1.2*0/        002030
      DATA IT3.IT4.IT5.IT6.IT7.IT8/3.4.5.6.7.8/                         002040
      DATA IERM.ERRORM/0.1E-10/                                         002050
      INDIC=0                                                           002060
      S=.F.                                                             002070
      ISW=1                                                             002080
      NT=0                                                              002090
      CALL GETDATA(DATAIN.92.4.5.6.3.100.300.INDIC)                     002100
      CALL GETDATA(DATAIN1.48.4.5.6.7.100.300.INDIC)                    002110
      IF (MODE .NE. 1) GOTO 150                                         002120
      DATAIN1(37.1)=10HRADIAL DIS                                       002130
      DATAIN1(38.1)=10HTANCE.RHO-                                       002140
      DATAIN1(39.1)=10HPRIME (CM)                                       002150
      DATAIN1(42.1)=10HAXIAL DIST                                       002160
      DATAIN1(43.1)=10HANCE.X (RE                                       002170
      DATAIN1(44.1)=10HLATIVE TO                                        002180
      DATAIN1(45.1)=10HGAUSS FOCU                                       002190
      DATAIN1(46.1)=7HS) (CM)                                           002200
  150 WRITE (IT7) DATAIN                                                002210
      WRITE (IT7) DATAIN1                                               002220
      IF (MODE .EQ. 1) S=.T.                                            002230
      REWIND IT3                                                        002240
      READ(IT3)                                                         002250
      TLAST=TNEXT=0.                                                    002260
      KF=6.28318E4/LAMBDA                                               002270
      EPP=EPS1                                                          002280
      IP=IPRNT                                                          002290
      NGAUSS=NGAUS                                                      002300
      XS=0.                                                             002310
      DX=1./M                                                           002320
      MNNT=MINT                                                         002330
      MP1=M+1                                                           002340
      NF=MP1                                                            002350
      IF (S) GOTO 120                                                   002360
      XMAX=VMAX                                                         002370
      XMIN=VMIN                                                         002380
      GOTO 140                                                          002390
  120 XMIN=RHOP1                                                        002400
      XMAX=RHOP2                                                        002410
  140 CONTINUE                                                          002420
      A=.F/SIG                                                          002430
      C=P0*(NX**2+1)/2./NX                                              002440
      C=C*R*BETA/3.14159/K                                              002450
      CS1P=C*S1P                                                        002460
      CS2P=C*S2P                                                        002470
      CS1T=C*S1T                                                        002480
      CS2T=C*S2T                                                        002490
      RSQ=R*R                                                           002500
      X0=X0*100.                                                        002510
      X1=X1*100.                                                        002520
      X2=X2*100.                                                        002530
      C1=K/RSQ/DEN/CP                                                   002540
      DELX=(X2-X1)/(AMAX0(1,NP-1))                                      002550
      DELRHO=(RHOP2-RHOP1)/(AMAX0(1,MP-1))                              002560
      DELV=(VMAX-VMIN)/(AMAX0(1,MP-1))                                  002570
      DELU=(UMAX-UMIN)/(AMAX0(1,NP-1))                                  002580
      RAD=R                                                             002590
      NP1=N+1                                                           002600
      C3=C/R                                                            002610
      X0I=1./X0                                                         002620
      NREC=0                                                            002630
      IT=1                                                              002640
      TR=T=TIM(1)                                                       002650
      IF (T .LT. 0.) GOTO 2000                                          002660
      IF(IP.EQ.2)  WRITE(ITR) DATAIN                                    002670
 1000 T=T*C1                                                            002680
      WRITE(ITS,2) T                                                    002690
      IF (T .GT. TAUMX) GOTO 2000                                       002700
      X1T=X1                                                            002710
      X1I=1./X1T                                                        002720
      U=UMIN                                                            002730
      DO 100 I=1,NP                                                     002740
      CX=(X0*X1I)**2                                                    002745
      IF (S) U=KE*RSQ*(X0I-X1I)                                         002750
      RHOP=RHOP1                                                        002760
      V=VMIN                                                            002770
      DO 110 J=1,MP                                                     002780
      IF (S) V=KE*R*X1I*RHOP                                            002790
      BUF(J)=CX*IKIRK(U,V,T)                                            002800
      IF (IERR .NE. 0) GOTO 2000                                        002810
  210 RHOP=RHOP+DELRHO                                                  002820
      V=V+DELV                                                          002830
  110 CONTINUE                                                          002840
      WRITE (IT7) I,NP,U,TR,MP,XMIN,XMAX,(BUF(J),J=1,MP)                002850
      CALL PRT(BUF,MODE,I,IT,MP,NP,MSKIP,NSKIP,RHOP1,                   002860
     +DELRHO,VMIN,DELV,X1T,U,TR,I,I16)                                  002870
      NREC=NREC+1                                                       002880
      X1T=X1T+DELX                                                      002890
      X1I=1./X1T                                                        002900
      U=U+DELU                                                          002910
  100 CONTINUE                                                          002920
      IT=IT+1                                                           002930
      IF (IT .GT. NT) GOTO 2000                                         002940
      TR=T=TIM(IT)                                                      002950
      IF (T .GT. TIM(IT-1)) GOTO 1000                                   002960
 2000 WRITE(ITS,1) NREC                                                 002970
      WRITE(ITS,6) IERM,ERRORM                                          002980
    1 FORMAT(1X,* THE NUMBER OF RECORDS IS-*,I10)                       002990
    2 FORMAT(1X,* NEW VALUE OF TAU IS*,E13.5)                           003000
    3 FORMAT(1X,I6,4E12.4)                                              003010
    4 FORMAT(1X,4E13.5)                                                 003020
    5 FORMAT(1X,I6,4G12.4,3(/,5X,5G13.5))                               003030
    6 FORMAT(* MAX ERROR PARM= *I4* EST ABS. ERROR INTEG.= *E16.4)      003040
      END                                                               003050
```

D.2 Major Function IKIRK Pertaining to Option No. 3 (IKIRK1)

```
      REAL FUNCTION IKIRK(U,V,T)                                       014800
      COMMON/PHIBLK/CS1R,CS2R,CS1T,CS2T,XS,DZ,NF,MINT,EPS,F1(200),     014810
     +F2(200),HOLD,A,K,TLAST,TNEXT,IERR,IP,MP1,ISW,N,                  014820
     +RAD,NP1,C3,C1,IERM,ERRORM                                        014830
      COMMON/UV/U1,V1                                                  014835
      EXTERNAL FREAL1,FIMAG1,FREAL2,FIMAG2                             014840
      DATA AERR,RERR/1E-3,1E-6/                                        014850
      U1=U                                                             014852
      V1=V                                                             014854
      A2=A*A                                                           014860
      IF (A2 .GT. 220.) 1020,1030                                      014870
 1020 CONST=2.*A2*A2                                                   014880
      GOTO 1040                                                        014890
 1030 CONST=2.*(A2/(1.-EXP(-A2)))**2                                   014900
 1040 CALL RTAPE3(T)                                                   014910
      IF (IERR .NE. 0) GOTO 2000                                       014920
      YRI=DCADRE(FREAL1,0.,1.,AERR,RERR,ERROR,IER)                     014930
      IF (ERROR .GT. ERRORM) ERRORM=ERROR                              014940
      IF (IER .GT. IERM) IERM=IER                                      014950
      YII=DCADRE(FIMAG1,0.,1.,AERR,RERR,ERROR,IER)                     014960
      IF (ERROR .GT. ERRORM) ERRORM=ERROR                              014970
      IF (IER .GT. IERM) IERM=IER                                      014980
      ZRI=DCADRE(FREAL2,0.,1.,AERR,RERR,ERROR,IER)                     014990
      IF (ERROR .GT. ERRORM) ERRORM=ERROR                              015000
      IF (IER .GT. IERM) IERM=IER                                      015010
      ZII=DCADRE(FIMAG2,0.,1.,AERR,RERR,ERROR,IER)                     015020
      IF (ERROR .GT. ERRORM) ERRORM=ERROR                              015030
      IF (IER .GT. IERM) IERM=IER                                      015040
      IKIRK=CONST*(YRI*YRI+YII*YII+ZRI*ZRI+ZII*ZII)                    015050
 2000 RETURN                                                           015060
      END                                                              015070
```

D.3 Function FREAL1

```
      FUNCTION FREAL1(X)                                               015080
      COMMON/UV/U,V                                                    015090
      COMMON/PHIBLK/CS1R,CS2R,CS1T,CS2T,XS,DZ,NF,MINT,EPS,F1(200),     015100
     +F2(200),HOLD,A,K,TLAST,TNEXT,IERR,IP,MP1,ISW,N,                  015110
     +RAD,NP1,C3,C1,IERM,ERRORM                                        015120
      COMPLEX Q1,EXPR,EXPT,FX,FY,FZ,FW                                 015130
      REAL J0,J1,K                                                     015140
      A2=A*A                                                           015150
      UD2=.5*U                                                         015152
      ISW=1                                                            015154
      GOTO 100                                                         015156
      ENTRY FIMAG1                                                     015158
      ISW=2                                                            015160
      GOTO 100                                                         015162
      ENTRY FREAL2                                                     015164
      ISW=3                                                            015170
      GOTO 100                                                         015172
      ENTRY FIMAG2                                                     015174
      ISW=4                                                            015180
 100  X2=X*X                                                           015182
      XV=X*V                                                           015184
      FW=EXP(-A2*X2)*CEXP(CMPLX(0E0,-UD2*X2))                          015190
      EXPR=CEXP(CMPLX(0E0,K*PHI(X)))                                   015200
      EXPT=CEXP(CMPLX(0E0,K*HOLD))                                     015210
      IF (V .EQ. 0.) FZ=(EXPR-EXPT)*X/2.                               015220
      IF (V .NE. 0.) FZ=(EXPR-EXPT)*J1(XV)/V                           015230
      Q1=X*J0(XV)                                                      015240
      GOTO (110,120,130,140) ISW                                       015242
 110  FX=Q1*EXPR-FZ                                                    015250
```

```
      FREAL1=REAL(FW*FX)                                                015255
      RETURN                                                            015257
  120 FX=Q1*EXPP-FZ                                                     015260
      FREAL1=AIMAG(FW*FX)                                               015270
      RETURN                                                            015280
  130 FY=Q1*EXPT+FZ                                                     015300
      FREAL1=REAL(FW*FY)                                                015310
      RETURN                                                            015320
  140 FY=Q1*EXPT+FZ                                                     015340
      FREAL1=AIMAG(FW*FY)                                               015350
      RETURN                                                            015390
      END                                                               015400
```

D.4 Function DCADRE

```
      FUNCTION   DCADRE (F,A,B,AERR,RERR,ERROR,IER)                     015450
C                                                                       015460
C-DCADRE--------S-------LIBRARY 3---------------------------------------015470
C                                                                       015480
C   FUNCTION            - INTEGRATE F(X) FROM A TO B, USING CAUTIOUS    015490
C                           ADAPTIVE ROMBERG EXTRAPOLATION.             015500
C   USAGE               - FUNCTION DCADRE (F,A,B,AERR,RERR,ERROR,IER)   015510
C   PARAMETERS   DCADRE - ESTIMATE OF THE INTEGRAL OF F(X) FROM A TO B. 015520
C                F      - A SINGLE-ARGUMENT REAL FUNCTION SUBPROGRAM    015530
C                           SUPPLIED BY THE USER.  F MUST BE DECLARED   015540
C                           EXTERNAL IN THE CALLING PROGRAM.            015550
C                A,B    - THE TWO ENDPOINTS OF THE INTERVAL OF          015560
C                           INTEGRATION. (INPUT)                        015570
C                AERR   - DESIRED ABSOLUTE ERROR IN THE ANSWER. (INPUT) 015580
C                RERR   - DESIRED RELATIVE ERROR IN THE ANSWER. (INPUT) 015590
C                ERROR  - ESTIMATED BOUND ON THE ABSOLUTE ERROR OF      015600
C                           THE OUTPUT NUMBER, DCADRE.                  015610
C                IER    - ERROR PARAMETER                               015620
C                         WARNING ERROR(WITH FIX) = 64 + N              015630
C                           N = 1 IMPLIES THAT ONE OR MORE SINGULARITIES015640
C                             WERE SUCCESSFULLY HANDLED.                015650
C                           N = 2 IMPLIES THAT, IN SOME SUBINTERVAL(S), 015660
C                             THE ESTIMATE OF THE INTEGRAL WAS ACCEPTED 015670
C                             MERELY BECAUSE THE ESTIMATED ERROR WAS    015680
C                             SMALL, EVEN THOUGH NO REGULAR BEHAVIOR    015690
C                             WAS RECOGNIZED.                           015700
C                         TERMINAL ERROR = 128 + N                      015710
C                           N = 3 -- FAILURE DUE TO INSUFFICIENT        015720
C                             INTERNAL WORKING STORAGE.                 015730
C                           N = 4 -- FAILURE.  THIS MAY BE DUE TO TOO   015740
C                             MUCH NOISE IN THE FUNCTION (RELATIVE      015750
C                             TO THE GIVEN ERROR REQUIREMENTS) OR       015760
C                             DUE TO AN ILL-BEHAVED INTEGRAND.          015770
C                           N = 5 INDICATES THAT RERR IS GREATER THAN   015780
C                             0.1, OR RERR IS LESS THAN 0.0, OR RERR    015790
C                             IS TOO SMALL FOR THE PRECISION OF THE     015800
C                             MACHINE.                                  015810
C   PRECISION           - SINGLE                                        015820
C   REQD. IMSL ROUTINES - UERTST                                        015830
C   LANGUAGE            - FORTRAN                                       015840
C-----------------------------------------------------------------------015850
C   LATEST REVISION     - SEPTEMBER 17, 1974                            015860
C                                                                       015870
      DIMENSION          T(10,10),R(10),AIT(10),DIF(10),RN(4),TS(2049)  015880
      DIMENSION          IBEGS(30),BEGIN(30),FINIS(30),EST(30)          015890
      DIMENSION          REGLSV(30)                                     015900
      LOGICAL            H2CONV,AITKEN,RIGHT,REGLAR,REGLSV              015910
      REAL               LENGTH,JUMPTL                                  015920
      DATA               AITLOW,H2TOL,AITTOL,JUMPTL,MAXTS,MAXTBL,MXSTGE 015930
     1                   /1.1,.15,.1,.01,2049,10,30/                    015940
      DATA               RN(1),RN(2),RN(3),RN(4)/                       015950
     1                   .7142005,.3466282,.843751,.1263305/            015960
      DATA               ZERO,PI,HALF,ONE,TWO,FOUR,FOURP5,TEN,HUN       015970
     1                   /0.0,0.1,0.5,1.0,2.0,4.0,4.5,10.0,100.0/       015980
      ALG402 = ALOG10(TWO)                                              015990
      CADRE = ZERO                                                      016000
      ERROR = ZERO                                                      016010
      CUREST = ZERO
      VINT = ZERO
      IER = 0
      LENGTH = ABS(B-A)
      IF (LENGTH .EQ. ZERO) GO TO 215
      IF (RERR .GT. P1 .OR. RERR .LT. ZERO) GO TO 210
      IF (AERR .EQ. ZERO .AND. (RERR+HUN) .LE. HUN) GO TO 210
      ERRR = RERR
      ERRA = ABS(AERR)
      STEPMN = (LENGTH/FLOAT(2**MXSIGE))
      STEPNM = AMAX1(LENGTH,ABS(A),ABS(B))*TEN
      STAGE = HALF
      ISTAGE = 1
      FNSIZE = ZERO
      PREVER = ZERO
      REGLAR = .FALSE.
C                                          THE GIVEN INTERVAL OF INTEGRATION
C                                            IS THE FIRST INTERVAL CONSIDERED.

      BEG = A
      FBEG = F(BEG)*HALF
      TS(1) = FBEG
      IBEG = 1
      END = B
      FEND = F(END)*HALF
      TS(2) = FEND
      IEND = 2
    5 RIGHT = .FALSE.
C                                          INVESTIGATION OF A PARTICULAR
C                                            SUBINTERVAL BEGINS AT THIS POINT.

   10 STEP = END - BEG
      ASTEP =  ABS(STEP)
      IF (ASTEP .LT. STEPMN) GO TO 205
      IF (STEPNM+ASTEP .EQ. STEPNM) GO TO 205
      T(1,1) = FBEG + FEND
      TABS = ABS(FBEG) + ABS(FEND)
      L = 1
      N = 1
      H2CONV = .FALSE.
      AITKEN = .FALSE.
   15 LM1 = L
      L = L + 1
C                                          CALCULATE THE NEXT TRAPEZOID SUM,
C                                            T(L,1), WHICH IS BASED ON *N2* + 1
C                                            EQUISPACED POINTS. HERE,
C                                            N2 = N*2 = 2**(L-1).

      N2 = N*N
      FN = N2
      ISTEP = (IEND - IBEG)/N
      IF (ISTEP .GT. 1) GO TO 25
      II = IEND
      IEND = IEND + N
      IF (IEND .GT. MAXTS) GO TO 200
      HOVN = STEP/FN
      III = IEND
      FI = ONE
      DO 20 I=1,N2,2
         TS(III) = TS(II)
         TS(III-1) = F(END - FI * HOVN)
         FI = FI+TWO
         III = III-2
         II = II-1
   20 CONTINUE
      ISTEP = 2
   25 ISTEP2 = IBEG + ISTEP/2
      SUM = ZERO
      SUMABS = ZERO
      DO 30 I=ISTEP2,IEND,ISTEP
         SUM = SUM + TS(I)
         SUMABS = SUMABS + ABS(TS(I))
   30 CONTINUE
      T(L,1) = T(L-1,1)*HALF+SUM/FN
      TABS = TABS*HALF+SUMABS/FN
      ABST = ASTEP*TABS
      N = N2
```

```
C                                     GET PRELIMINARY VALUE FOR *VINT*       016760
C                                       FROM LAST TRAPEZOID SUM AND UPDATE   016770
C                                       THE ERROR REQUIREMENT *ERGOAL*       016780
C                                       FOR THIS SUBINTERVAL.                016790
      IT = 1                                                                 016800
      VINT = STEP*T(L•1)                                                     016810
      TABTLM = TABS*TEN                                                      016820
      FNSIZE = AMAX1(FNSIZE•ABS(T(L•1)))                                     016830
      ERGL = ASTEP*FNSIZE*TEN                                                016840
      ERGOAL = STAGE*AMAX1(ERRA•ERRR*ABS(CUREST•VINT))                       016850
C                                     COMPLETE ROW L AND COLUMN L OF *T*     016860
C                                       ARRAY.                               016870
      FEXTRP = ONE                                                           016880
      DO 35 I=1•LM1                                                          016890
         FEXTRP = FEXTRP*FOUR                                                016900
         T(I•L) = T(L•I) - T(L-1•I)                                          016910
         T(L•I+1) = T(L•I) + T(I•L)/(FEXTRP-ONE)                             016920
   35 CONTINUE                                                               016930
      ERRER = ASTEP*ABS(T(1•L))                                              016940
C                                     PRELIMINARY DECISION PROCEDURE         016950
C                                       IF L = 2 AND T(2•1) = T(1.1)•        016960
C                                       GO TO 135 TO FOLLOW UP THE           016970
C                                       IMPRESSION THAT INTERGRAND IS        016980
C                                       STRAIGHT LINE.                       016990
      IF (L .GT. 2) GO TO 40                                                 017000
      IF (TABS+P1*ABS(T(1•2)) .EQ. TABS) GO TO 135                           017010
      GO TO 15                                                               017020
C                                     CACULATE NEXT RATIOS FOR               017030
C                                       COLUMNS 1•...•L-2 OF T-TABLE         017040
C                                       RATIO IS SET TO ZERO IF DIFFERENCE   017050
C                                       IN LAST TWO ENTRIES OF COLUMN IS     017060
C                                       ABOUT ZERO                           017070
   40 DO 45 I=2•LM1                                                          017080
         DIFF = ZERO                                                         017090
         IF (TABTLM+ABS(T(I-1•L)).NE.TABTLM) DIFF = T(I-1•LM1)/T(I-1•L)      017100
         T(I-1•LM1) = DIFF                                                   017110
   45 CONTINUE                                                               017120
      IF (ABS(FOUR-T(1•LM1)) .LE. H2TOL) GO TO 60                            017130
      IF (T(1•LM1) .EQ. ZERO) GO TO 55                                       017140
      IF (ABS(TWO-ABS(T(1•LM1))) .LT. JUMPTL) GO TO 130                      017150

      IF (L .EQ. 3) GO TO 15                                                 017160
      H2CONV = .FALSE.                                                       017170
      IF (ABS((T(1•LM1)-T(1•L-2))/T(1•LM1)) .LE. AITTOL) GO TO 75            017180
   50 IF (REGLAR) GO TO 55                                                   017190
      IF (L .EQ. 4) GO TO 15                                                 017200
   55 IF (ERRER .GT. ERGOAL .AND. (ERGL+ERRER) .NE. ERGL) GO TO 175          017210
      GO TO 145                                                              017220
C                                     CAUTIOUS ROMBERG EXTRAPOLATION         017230
   60 IF (H2CONV) GO TO 65                                                   017240
      AITKEN = .FALSE.                                                       017250
      H2CONV = .TRUE.                                                        017260
   65 FEXTRP = FOUR                                                          017270
   70 IT = IT + 1                                                            017280
      VINT = STEP*T(L•IT)                                                    017290
      ERRER = ABS(STEP/(FEXTRP-ONE)*T(IT-1•L))                               017300
      IF (ERRER .LE. ERGOAL) GO TO 160                                       017310
      IF (ERGL+ERRER .EQ. ERGL) GO TO 160                                    017320
      IF (IT .EQ. LM1) GO TO 125                                             017330
      IF (T(IT•LM1) .EQ. ZERO) GO TO 70                                      017340
      IF (T(IT•LM1) .LE. FEXTRP) GO TO 125                                   017350
      IF (ABS(T(IT•LM1)/FOUR-FEXTRP)/FEXTRP .LT. AITTOL)                     017360
     1       FEXTRP = FEXTRP*FOUR                                            017370
      GO TO 70                                                               017380
C                                     INTEGRAND MAY HAVE X**ALPHA TYPE       017390
C                                       SINGULARITY                          017400
C                                       RESULTING IN A RATIO OF *SING*  =    017410
C                                       2**(ALPHA + 1)                       017420
   75 IF (T(1•LM1) .LT. AITLOW) GO TO 175                                    017430
      IF (AITKEN) GO TO 80                                                   017440
      H2CONV = .FALSE.                                                       017450
      AITKEN = .TRUE.                                                        017460
   80 FEXTRP = T(L-2•LM1)                                                    017470
      IF (FEXTRP .GT. FOURP5) GO TO 65                                       017480
      IF (FEXTRP .LT. AITLOW) GO TO 175                                      017490
      IF (ABS(FEXTRP-T(L-3•LM1))/T(1•LM1) .GT. H2TOL) GO TO 175              017500
      SING = FEXTRP                                                          017510
      FEXTM1 = ONE/(FEXTRP - ONE)                                            017520
      AIT(1) = ZERO                                                          017530
      DO 85 I=2,L                                                          017540
         AIT(I) = T(I,1) + (T(I,1)-T(I-1,1))*FEXTM1                        017550
         R(I) = T(1,I-1)                                                   017560
         DIF(I) = AIT(I) - AIT(I-1)                                        017570
   85 CONTINUE                                                             017580
      IT = 2                                                               017590
   90 VINT = STEP*AIT(L)                                                   017600
      ERRER = ERRER*FEXTM1                                                 017610
      IF (ERRER .GT. ERGOAL .AND. (ERGL+ERRER) .NE. ERGL) GO TO 95         017620
      ALPHA = ALOG10(SING)/ALG402 - ONE                                    017630
      IER = MAX0(IER,65)                                                   017640
      GO TO 160                                                            017650
   95 IT = IT + 1                                                          017660
      IF (IT .EQ. LM1) GO TO 125                                           017670
      IF (IT .GT. 3) GO TO 100                                             017680
      H2NEXT = FOUR                                                        017690
      SINGNX = SING+SING                                                   017700
  100 IF (H2NEXT .LT. SINGNX) GO TO 105                                    017710
      FEXTRP = SINGNX                                                      017720
      SINGNX = SINGNX+SINGNX                                               017730
      GO TO 110                                                            017740
  105 FEXTRP = H2NEXT                                                      017750
      H2NEXT = FOUR*H2NEXT                                                 017760
  110 DO 115 I=IT,LM1                                                      017770
         R(I+1) = ZERO                                                     017780
         IF (TABTLM+ABS(DIF(I+1)) .NE. TABTLM) R(I+1) = DIF(I)/DIF(I+1)    017790
  115 CONTINUE                                                             017800
      H2TFEX = -H2TOL*FEXTRP                                               017810
      IF (R(L) - FEXTRP .LT. H2TFEX) GO TO 125                             017820
      IF (R(L-1)-FEXTRP .LT. H2TFEX) GO TO 125                             017830
      ERRER = ASTEP*ABS(DIF(L))                                            017840
      FEXTM1 = ONE/(FEXTRP - ONE)                                          017850
      DO 120 I=IT,L                                                        017860
         AIT(I) = AIT(I) + DIF(I)*FEXTM1                                   017870
         DIF(I) = AIT(I) - AIT(I-1)                                        017880
  120 CONTINUE                                                             017890
      GO TO 90                                                             017900
C                                        CURRENT TRAPEZOID SUM AND RESULTING   017910
C                                          EXTRAPOLATED VALUES DID NOT GIVE    017920
C                                          A SMALL ENOUGH *ERRER*.             017930
C                                          NOTE -- HAVING PREVER .LT. ERRER    017940
C                                          IS AN ALMOST CERTAIN SIGN OF        017950
C                                          BEGINNING TROUBLE WITH IN THE FUNC- 017960
C                                          TION VALUES. HENCE, A WATCH FOR,    017970
C                                          AND CONTROL OF, NOISE SHOULD        017980
C                                          BEGIN HERE.                         017990
  125 FEXTRP = AMAX1(PREVER/ERRER,AITLOW)                                  018000
      PREVER = ERRER                                                       018010
      IF (L .LT. 5) GO TO 15                                               018020
      IF (L-IT .GT. 2 .AND. ISTAGE .LT. MXSTGE) GO TO 170                  018030
      ERRET = ERRER/(FEXTRP**(MAXTBL-L))                                   018040
      IF (ERRET .GT. ERGOAL .AND. (ERGL+ERRET) .NE. ERGL) GO TO 170         018050
      GO TO 15                                                             018060
C                                        INTEGRAND HAS JUMP (SEE NOTES)        018070
  130 IF (ERRER .GT. ERGOAL .AND. (ERGL+ERRER) .NE. ERGL) GO TO 170        018080
C                                        NOTE THAT  2*FN = 2**L                018090
      DIFF = ABS(T(1,L))*(FN+FN)                                           018100
      GO TO 160                                                            018110
C                                        INTEGRAND IS STRAIGHT LINE            018120
C                                          TEST THIS ASSUMPTION BY COMPARING   018130
C                                          THE VALUE OF THE INTEGRAND AT       018140
C                                          FOUR *RANDOMLY CHOSEN* POINTS WITH  018150
C                                          THE VALUE OF THE STRAIGHT LINE      018160
C                                          INTERPOLATING THE INTEGRAND AT THE  018170
C                                          TWO END POINTS OF THE SUB-INTERVAL. 018180
C                                          IF TEST IS PASSED, ACCEPT *VINT*    018190
  135 SLOPE = (FEND-FBEG)*TWO                                              018200
      FBEG2 = FBEG+FBEG                                                    018210
      DO 140 I=1,4                                                         018220
         DIFF = ABS(F(BEG+RN(I)*STEP) - FBEG2-RN(I)*SLOPE)                 018230
         IF (TABTLM+DIFF .NE. TABTLM) GO TO 155                            018240
  140 CONTINUE                                                             018250
      GO TO 160                                                            018260
C                                        NOISE MAY BE DOMINANT FEATURE         018270
C                                          ESTIMATE NOISE LEVEL BY COMPARING   018280
C                                          THE VALUE OF THE INTEGRAND AT       018290
```

```
                                          FOUR *RANDOMLY CHOSEN* POINTS WITH
C                                         THE VALUE OF THE STRAIGHT LINE
C                                         INTERPOLATING THE INTEGRAND AT THE
C                                         TWO ENDPOINTS. IF SMALL ENOUGH.
C                                         ACCEPT *VINT*
C
  145 SLOPE = (FEND-FBEG)*TWO
      FBEG2 = FBEG+FBEG
      I = 1
  150 DIFF = ABS(F(BEG+RN(I)*STEP) - FBEG2-RN(I)*SLOPE)
  155 ERRER = AMAX1(ERRER,ASTEP*DIFF)
      IF (ERRER .GT. ERGOAL .AND. (ERGL+ERRER) .NE. EPGL) GO TO 175
      I = I+1
      IF (I .LE. 4) GO TO 150
      IER = 66
C                                       INTERGRATION OVER CURRENT SUB-
C                                         INTERVAL SUCCESSFUL
C                                         ADD *VINT* TO *DCADRE* AND *ERRER*
C                                         TO *ERROR*. THEN SET UP NEXT SUB-
C                                         INTERVAL. IF ANY.
  160 CADRE = CADRE + VINT
      ERROR = ERROR + ERRER
      IF (RIGHT) GO TO 165
      ISTAGE = ISTAGE - 1
      IF (ISTAGE .EQ. 0) GO TO 220
      REGLAR = REGLSV(ISTAGE)
      BEG = BEGIN(ISTAGE)
      END = FINIS(ISTAGE)
      CUREST = CUREST - EST(ISTAGE+1) + VINT
      IEND = IBEG - 1
      FEND = TS(IEND)
      IBEG = IBEGS(ISTAGE)
      GO TO 180
  165 CUREST = CUREST + VINT
      STAGE = STAGE+STAGE
      IEND = IBEG
      IBEG = IBEGS(ISTAGE)
      END = BEG
      BEG = BEGIN(ISTAGE)
      FEND = FBEG
      FBEG = TS(IBEG)
      GO TO 5
C                                         INTEGRATTON OVER CURRENT SUBINTERVAL
C                                           IS UNSUCCESSFUL. MARK SUBINTERVAL
C                                           FOR FURTHER SUBDIVISION. SET UP
C                                           NEXT SUBINTERVAL.
  170 REGLAR = .TRUE.
  175 IF (ISTAGE .EQ. MXSTGE) GO TO 205
      IF (RIGHT) GO TO 185
      REGLSV(ISTAGE+1) = REGLAR
      BEGIN(ISTAGE) = BEG
      IBEGS(ISTAGE) = IBEG
      STAGE = STAGE*HALF
  180 RIGHT = .TRUE.
      BEG = (BEG+END)*HALF
      IBEG = (IBEG+IEND)/2
      TS(IBEG) = TS(IBEG)*HALF
      FBEG = TS(IBEG)
      GO TO 10
  185 NNLEFT = IBEG - IBEGS(ISTAGE)
      IF (IEND+NNLEFT .GE. MAXTS) GO TO 200
      III = IBEGS(ISTAGE)
      II = IEND
      DO 190 I=III,IBEG
         II = II + 1
         TS(II) = TS(I)
  190 CONTINUE
      DO 195 I=IBEG,II
         TS(III) = TS(I)
         III = III + 1
  195 CONTINUE
      IEND = IEND + 1
      IBEG = IEND - NNLEFT
      FEND = FBEG
      FBEG = TS(IBEG)
      FINIS(ISTAGE) = END
      END = BEG
      BEG = BEGIN(ISTAGE)
      BEGIN(ISTAGE) = END
      REGLSV(ISTAGE) = REGLAR
      ISTAGE = ISTAGE + 1                                              019090
      REGLAR = REGLSV(ISTAGE)                                          019100
      EST(ISTAGE) = VINT                                               019110
      CUREST = CUREST + EST(ISTAGE)                                    019120
      GO TO 5                                                          019130
C                                  FAILURE TO HANDLE GIVEN INTEGRA-    019140
C                                    TION PROBLEM                      019150
  200 IER = 131                                                        019160
      GO TO 215                                                        019170
  205 IER = 132                                                        019180
      GO TO 215                                                        019190
  210 IER = 133                                                        019200
  215 CADRE = CUREST + VINT                                            019210
  220 DCADRE = CADRE                                                   019220
 9000 CONTINUE                                                         019230
      IF (IER .NE. 0) CALL UERTST (IER,6HDCADRE)                       019240
 9005 RETURN                                                           019250
      END                                                              019260
```

D.5 Subroutine UERTST

```
      SUBROUTINE UERTST (IER,NAME)                                     019270
C                                                                      019280
C-UERTST----------------LIBRARY 3-------------------------------------- 019290
C                                                                      019300
C   FUNCTION            - ERROR MESSAGE GENERATION                     019310
C   USAGE               - CALL UERTST(IER,NAME)                        019320
C   PARAMETERS   IER    - ERROR PARAMETER, TYPE + N  WHERE             019330
C                           TYPE= 128 IMPLIES TERMINAL ERROR           019340
C                                  64 IMPLIES WARNING WITH FIX         019350
C                                  32 IMPLIES WARNING                  019360
C                           N    = ERROR CODE RELEVANT TO CALLING ROUTINE 019370
C                NAME   - INPUT SCALAR CONTAINING THE NAME OF THE      019380
C                           CALLING ROUTINE AS A 6-CHARACTER LITERAL   019390
C                           STRING.                                    019400
C   LANGUAGE            - FORTRAN                                      019410
C--------------------------------------------------------------------- 019420
C   LATEST REVISION     - AUGUST 1, 1973                               019430
C                                                                      019440
      DIMENSION          ITYP(2,4),IBIT(4)                             019450
      INTEGER            WARN,WARF,TERM,PRINTR                         019460
      EQUIVALENCE        (IBIT(1),WARN),(IBIT(2),WARF),(IBIT(3),TERM)  019470
      DATA      ITYP      /10HWARNING   ,10H          ,                019480
     *                     10HWARNING(WI,10HTH FIX)   ,                019490
     *                     10HTERMINAL  ,10H          ,                019500
     *                     10HNON-DEFINE,10HD         /,               019510
     *          IBIT      / 32,64,128,0/                               019520
      DATA               PRINTR/6LOUTPUT/                              019530
      IER2=IER                                                         019540
      IF (IER2 .GE. WARN) GO TO 5                                      019550
C                                  NON-DEFINED                         019560
      IER1=4                                                           019570
      GO TO 20                                                         019580
    5 IF (IER2 .LT. TERM) GO TO 10                                     019590
C                                  TERMINAL                            019600
      IER1=3                                                           019610
      GO TO 20                                                         019620
   10 IF (IER2 .LT. WARF) GO TO 15                                     019630
C                                  WARNING(WITH FIX)                   019640
      IER1=2                                                           019650
      GO TO 20                                                         019660
C                                  WARNING                             019670
   15 IER1=1                                                           019680
C                                  EXTRACT *N*                         019690
   20 IER2=IER2-IBIT(IER1)                                             019700
C                                  PRINT ERROR MESSAGE                 019710
      WRITE (PRINTR,25) (ITYP(I,IER1),I=1,2),NAME,IER2,IER             019720
   25 FORMAT(26H *** I M S L(UERTST) ***  ,2A10,4X,A6,4X,I2,           019730
     1   8H (IER = ,I3,1H))                                            019740
      RETURN                                                           019750
      END                                                              01977()
```

D.6 Major Function IKIRK Pertaining to Option No. 1 (IKIRK)

```
      REAL FUNCTION IKIRK(U.V.T)
C FUNCTION IKIRK IS THE KIRKHOFF INTENSITY FUNCTION DESCRIBED IN
C -BENDOW.B. AND GIANINO.P. @OPTICAL PERFORMANCE EVALUATION OF
C INFRARED TRANSMITTING WINDOWS* AFCRL-72-0565. ASSUMING A GAUSSIAN
C SHAPED UNPOLARIAZED SOURCE. THE INTENSITY FUNCTION CAN BE WRITTEN*
C  IKIRK(U.V)=2(A!2/(1-EXP(-A!2)))!2*(]I(0.1.DX)(FW*FX)]!2+
C                      ]I(0.1.DX)(FW*FY)]!2
C WHERE*
C      FW(X.U)=EXP(-(A*X)!2)*EXP(-I*U*X!2/2)
C      FX(X.V)=X*J0(X*V)*EXP(I*K*PHIR(X))-FZ(X.V)
C      FY(X.V)=X*J0(X*V)*EXP(I*K*PHIT(X))+FZ(X.V)
C      FZ(X.V)=J1(X*V)*(EXP(I*K*PHIR(X))-EXP(I*K*PHIT(X)))/(V)
C      A=1/SQRT(2)/SIG**2
C      K=WAVE NO. (OMEGA/C)
C    NOTATION*
C      ! => EXPONENTIATION
C      I => @IMAGINARY@
C      I(0.1.DX)(.) MEANS INTEGRATION  OF THE FUNCTION WITHIN () W.R.T.X
C      OVER THE INTERVAL (0.1).
C J0 AND J1 ARE BESSEL FUNCTIONS OF THE FIRST KIND.ZEROTH AND FIRST
C ORDER RESPECTIVELY.
C PHIR(X) AND PHIT(X) ARE THE FUNCTIONS PHI-SUPERSCRIPT-RHO AND PHI-
C S PERSCRIPT-THETA RESPECTIVELY IN THE ABOVE REFERENCE.
C THESE FUNCTIONS ARE GIVEN BY*
C PHIR(X)=C*S1R*F1(X)+4*C*S2R*F2(X)
C PHIT(X)=C*S1T*F1(X)+4*C*S2T*F2(X)
C WHERE*
C      C=B!3*P0*BETA/KT
C      B=WINDOW RADIUS (CM)
C      P0=MEAN INCIDENT POWER DENSITY (WATTS/CM!2)
C      BETA=BULK ABSORPTION COEFFICIENT (1/CM)
C      KT=THERMAL CONDUCTIVITY (WATTS/(CM DEGC)
C      S1R.S2R.S1T.S2T ARE MATERIAL CONSTANTS DEFINED IN THE ABOVE REF.
C      F1.F2 ARE THE FUNCTIONS DELTBAR-PRIME(X) AND
C      (1/X!2)I(0.X.DS)(DELTBAR-PRIME(S))
C      GIVEN IN THE ABOVE REFERENCE AND WHICH ARE PROVIDED AT SELECTED
C      ARGUMENTS BY PROGRAM @TEMP5@.
*************************************************************************
      COMMON/PHIBLK/CS1R.CS2R.CS1T.CS2T.XS.DZ.NF.MINT.EPS.F1(200).
     +F2(200).HOLD.A.K .TLAST.TNEXT.IERR.IP.MP1.ISW.N.
     +RAD.NP1.C3.C1.IERM.ERRORM
      COMMON/IFILES/IT3.IT4.IT5.IT6.IT7.IT8
      COMMON/UV/UU.VV
      COMPLEX Q1.EXPR.EXPT.FX.FY.FZ.FW
      REAL J0.J1
      REAL K
      DIMENSION XA(100).YR(100).YI(100).ZR(100).ZI(100)
      UU=U
      VV=V
      A2=A*A
      IF (A2 .GT. 220.) 1020.1030
 1020 CONST=2.*A2*A2
      GOTO 1040
 1030 CONST=2.*(A2/(1.-EXP(-A2)))**2
 1040 UD2=U/2E0
C IF ISW=1 THEN THE ARRAY OF POINTS FOR GAUSSIAN INTEGRATION
C M ST BE FOUND
      GOTO (1050.1060) ISW
 1050 ISW=2
      CALL DQG24A(0E0.1E0.XA)
      IF (IP .EQ. 1) WRITE(IT6.1) (XA(I).I=1.N)
 1060 CALL RTAPE3(T)
      IF (IERR .NE. 0) GOTO 2000
      DO 100 I=1.N
      X=XA(I)
      X2=X*X
      XV=X*V
      FW=EXP(-A2*X2)*CEXP(CMPLX(0E0.-UD2*X2))
      EXPR=CEXP(CMPLX(0E0.K*PHI(X)))
      EXPT=CEXP(CMPLX(0E0.K*HOLD))
      IF (V .EQ. 0.) FZ=(EXPR-EXPT)*X/2.
      IF (V .NE. 0.) FZ=(EXPR-EXPT)*J1(XV)/V
      Q1=X*J0(XV)
      FX=Q1*EXPR-FZ
      FY=Q1*EXPT+FZ                                                     000840
      Q1=FW*FX                                                          000850
      YR(I)=REAL(Q1)                                                    000860
      YI(I)=AIMAG(Q1)                                                   000870
      Q1=FW*FY                                                          000880
      ZR(I)=REAL(Q1)                                                    000890
      ZI(I)=AIMAG(Q1)                                                   000900
100   CONTINUE                                                          000910
1     FORMAT(5(1X,G12.5))                                               000920
      CALL DQG24B(0E0,1E0,YR,YRI)                                       000930
      CALL DQG24B(0E0,1E0,YI,YII)                                       000940
      CALL DQG24B(0E0,1E0,ZR,ZRI)                                       000950
      CALL DQG24B(0E0,1E0,ZI,ZII)                                       000960
      IKIRK=CONST*(YRI*YRI+YII*YII+ZRI*ZRI+ZII*ZII)                     000970
2000  RETURN                                                            000980
      END                                                               000990
```

D.7 Major Function IKIRK Pertaining to Option No. 2 (IKIRKP)

```
      REAL FUNCTION IKIRK(U,V,T)                                        009800
C     APRIL 11,1974                                                     009810
C     THIS FUNCTION COMPUTES THE KIRKHOFF INTENSITY FUNCTION            009820
C     ALONG THE U=0 AND/OR V=0 AXIS OF THE PLANE.                       009830
C     SEE COMMENTS IN IKIRK AND COMPUTE FOR BACKGROUND INFO.            009840
C     IT IS VALID ONLY FOR CONSTANT TEMPERATURE WINDOWS.                009850
      DIMENSION AA(10)                                                  009860
      COMMON/IFILES/IT3,IT4,IT5,IT6,IT7,IT8                             009870
      COMMON/VICTOR/VV                                                  009880
      COMMON/PHIBLK/CS1R,CS2R,CS1T,CS2T,XS,DX,NF,MNNT,EPP,F1(200),      009890
     +F2(200),HOLD,ALPHA,KE,TLAST,TNEXT,IERR,IP,MP1,ISW,NGAUSS,         009900
     +RAD,NP1,C3,C1                                                     009910
      COMPLEX AJ0Q,CRHOQ,CTHETAQ,A1Q,A2Q,A3Q,A4Q,A6Q,A7Q                009920
      REAL KE                                                           009930
      DATA (AA(I),I=1,10)/1.,-.99999999958,.4999999206,-.1666653019,    009940
     +.0416573475,-.0083013598,.0013298820,-.0001413161,0.,0./          009950
      VV=V                                                              009960
      CALL RTAPE3(T)                                                    009970
      IF(IERR.NE.0) GOTO 2000                                           009980
      CTHETAQ=CS1T*F1(1)+4.*CS2T*F2(1)                                  009990
      CTHETAQ=CTHETAQ*KE                                                010000
      CRHOQ=CS1R*F1(1)+4.*CS2R*F2(1)                                    010010
      CRHOQ=CRHOQ*KE                                                    010020
      AJ0Q=(0.,1.)                                                      010030
      A2Q=CEXP(AJ0Q*CRHOQ)                                              010040
      A3Q=CEXP(AJ0Q*CTHETAQ)                                            010050
      A1Q=A2Q-A3Q                                                       010060
      A=-(ALPHA**2)                                                     010070
      IF (A .LT. -1000) GOTO 110                                        010080
      EXPA=EXP(A)                                                       010090
      AS=2.*(A/(1.-EXPA))**2                                            010100
      GOTO 120                                                          010110
110   EXPA=0.                                                           010120
      AS=2.*A*A                                                         010130
120   B=U/2.                                                            010140
      IF(V.EQ.0) GOTO 200                                               010150
      C=(ALPHA/V)**2                                                    010160
      IF(U.EQ.0) GOTO 100                                               010170
200   SINB=SIN(B)                                                       010180
      COSB=COS(B)                                                       010190
      ASQ=A**2                                                          010200
      BSQ=B**2                                                          010210
      A4QREAL=.5*((EXPA*(A*COSB+B*SINB))-A)/(ASQ+BSQ)                   010220
      A4QIMAG=-.5*((EXPA*(A*SINB-B*COSB))+B)/(ASQ+BSQ)                  010230
      A4Q=CMPLX(A4QREAL,A4QIMAG)                                        010240
      A6Q=A1Q/2.*A4Q                                                    010250
      IKIRKP=AS*((CABS(A2Q*A4Q-A6Q))**2+(CABS(A3Q*A4Q+A6Q))**2)         010260
      RETURN                                                            010270
100   IF (-A .GT. .693) GOTO 1000                                       010280
```

```
      CALL COMPUTE (C,AA,FF1,FF2,IER)
      IF(IER.EQ.2) GOTO 1000
      A7Q=A1Q*FF2
      IKIPK =A5*((CABS(A2Q*FF1-A7Q))**2+(CABS(A3Q*FF1+A7Q))**2)
      RETURN
 1000 WRITE (IT5,10)
 10   FORMAT(/* ALPHA**2 IS OUT OF RANGE*)
 2000  RETURN
      END
```

Appendix E

Fortran Listings for DISPLAY Program

E.1 Main Program DISPLAY

```
      PROGRAM DISPLAY(TAPE4=80/80,TAPE6=80/80,TAPE3,OUTPUT=80)          000100
C REVISION---JUNE 11,1976                                               000105
      COMMON Z(103,103),XT(103,103),YT(103,103)                         000110
      COMMON/BLOCK3/NP2,MP2,XMINF,YMINF,DX,DY,SW1,IT6                   000120
      DIMENSION DATA(8)                                                 000130
      DIMENSION PROGID(3),CODE(7),DATAIN(100,3),PARM(80)                000140
      DIMENSION IND(40),ZLEVS(50),INDEX(4,2)                            000150
      INTEGER CCODE                                                     000160
      LOGICAL FLAG,FLAG1,SWT                                            000170
      DATA IT4,IT6,IT3/4,6,3/                                           000180
      DATA XS,YS/0.,0./                                                 000190
      DATA (PROGID=7HGIANINO,7HID 2347,7HDISPLAY)                       000200
      DATA (CODE=1,1,45.,2HNA,1,1)                                      000210
      BLANK=10H                                                         000220
      IBLANK=1OH                                                        000230
C THE FOLLOWING DATA CARDS MUST BE INPUTTED TO TAILOR THE PROGRAM       000240
C FOR THE USERS PARTICULAR APPLICATION. THE NUMBER IN PARENTHESIS IN    000250
C FRONT OF EACH DATAUM NAME IS THE CARD COLUMN AT WHICH TO START THE    000260
C DATUM. THE NUMBER IN PARENTHESIS FOLLOWING THE DATUM IS THE DEFAULT   000270
C VALUE OF THE DATUM. IF THE DEFAULT VALUE IS TO BE USED LEAVE THE      000280
C CORRESPONDING CARD FIELD BLANK.                                       000290
C CARD 1                                                                000300
C (1)    XMAX           (100.)    MAXIMUM PLOT LENGTH IN INCHES         000310
C (11)   YMAX           (12.)     MAXIMUM PLOT WIDTH IN INCHES          000320
C (21)   PPI            (10.)     NUMBER OF POINTS/INCH FOR CONTOURS    000330
C (31)   TICU           (.5)      NUMBER OF INCHES BETWEEN TIC-MARKS    000340
C                                 FOR USER DEFINED X-Y PLOTS            000350
C (41)   XLEN           (10.)     X-Y PLOT COORDINATE FRAME X-SIZE      000360
C (51)   YLEN           (8.)      X-Y PLOT COORDINATE FRAME Y-SIZE      000370
C (61)   SCALEX         (1.)      X-Y PLOT X-SCALE (UNITS/TIC)          000380
C (71)   SCALEY         (1.)      X-Y PLOT Y-SCALE (UNITS/TIC)          000390
C                                                                       000400
C CARD2                                                                 000410
C (01)   XMIN           (0.)      X-Y PLOT XMIN                         000420
C (11)   YMIN           (0.)      Y-Y PLOT YMIN                         000430
C (21)   NAME           (BARRETT) NAME ON PLOT                          000440
C (31)   PROB. #        (2734)    PLOT PROBLEM NUMBER                   000450
C                                                                       000460
C CARD 3                                                                000470
C (CARD 3 CONTAINS THE 2-D ARRAY 'INDEX' WHICH IS THE INDEX OF          000480
C LOCATIONS FOR LABELING INFORMAITON ASSUMED TO BE CONTAINED IN THE     000490
C LAST DATAIN ON THE FILE CONTAINING THE SURFACES. IF THERE IS NO       000500
C SUCH DATA THEN THIS CARD MAY BE LEFT BLANK AND THE LABELING WILL      000510
C NOT BE DONE. INDEX CONSISTS OF PAIRS OF NUMBERS WHEREIN THE FIRST     000520
C NUMBER IS THE STARTING LOCATION OF THE LABEL AND THE SECOND NUMBER    000530
C IS THE LENGTH OF THE LABEL.                                           000540
C IF THE LETTER 'D' IS PLACED IN COLUMN 1 OF CARD 2, THE FOLLOWING      000550
C DEFAULT LOCATIONS ARE USED FOR TITLE INFORMATION-                     000560
C (1)    INDEX(1,1)      (1)       SURFACE TITLE                        000570
C (6)    INDEX(1,2)      (30)       SURFACE TITLE LENGTH (CHARACTERS)   000580
C (11)   INDEX(2,1)      (4)       PARAMETER TITLE                      000590
C (16)   INDEX(2,2)      (31)       PARAMETER TITLE LENGTH              000600
C (21)   INDEX(3,1)      (7)       X-TITLE                              000610
C (26)   INDEX(3,2)      (34)       X-TITLE LENGTH                      000620
C (31)   INDEX(4,1)      (10)      Y-TITLE                              000630
C (36)   INDEX(4,2)      (39)       Y-TITLE LENGTH                      000640
C (41)   NDA             (2)       NUMBER OF 'DATAIN' ARRAYS            000650
C                                                                       000660
C CARD 4-CARD NDA+2                                                     000670
C CARD 4-      CONTAIN THE INDICES OF DATA IN 'DATAIN' WHICH ARE TO     000680
C BE PLOTTED AT THE BEGINNING OF EACH RUN OF DISPLAY. THERE MUST BE     000690
C ONE CARD FOR EACH 'DATAIN' EVEN THOUGH FOR SOME 'DATAIN' NO DATA IS   000700
C TO BE PLOTTED (A BLANK CARD IS ACCEPTABLE). THE INDEX NUMBERS START   000710
C IN COLUMNS 1,3,5,7,..... FOR A TOTAL OF UP TO 40 INDICES PER CARD.    000720
C THE DEFAULT IS A BLANK CARD,I.E. NO 'DATAIN' DATA IS TO BE PLOTTED.   000730
      PXMAX=100.                                                        000740
      PYMAX=11.                                                         000750
      PPI=10.                                                           000760
      TICU=.5                                                           000770
      XLEN=10.                                                          000780
      YLEN=8.                                                           000790
      SCALEX=SCALEY=1.                                                  000800
      XMINX=YMINY=0.                                                    000810
      INDEX(1,1)=1                                                      000820
      INDEX(1,2)=30                                                     000830
      INDEX(2,1)=4                                                      000840
      INDEX(2,2)=30                                                     000850
      INDEX(3,1)=7                                                      000860
      INDEX(3,2)=30                                                     000870
      INDEX(4,1)=10                                                     000880
      INDEX(4,2)=30                                                     000890
      NDA=2                                                             000900
      READ(IT4,5) (DATA(I),I=1,8)                                       000910
      IF (DATA(1) .NE. BLANK) DECODE(10,6,DATA(1)) PXMAX                000920
      IF (DATA(2) .NE. BLANK) DECODE(10,6,DATA(2)) PYMAX                000930
      IF (DATA(3) .NE. BLANK) DECODE(10,6,DATA(3)) PPI                  000940
      IF (DATA(4) .NE. BLANK) DECODE(10,6,DATA(4)) TICU                 000950
      IF (DATA(5) .NE. BLANK) DECODE(10,6,DATA(5)) XLEN                 000960
      IF (DATA(6) .NE. BLANK) DECODE(10,6,DATA(6)) YLEN                 000970
      IF (DATA(7) .NE. BLANK) DECODE(10,6,DATA(7)) SCALEX               000980
      IF (DATA(8) .NE. BLANK) DECODE(10,6,DATA(8)) SCALEY               000990
      WRITE(IT6,10) PXMAX,PYMAX,PPI,TICU,XLEN,YLEN,SCALEX,SCALEY        001000
      READ(IT4,5) (DATA(I),I=1,8)                                       001010
      IF (DATA(1) .NE. BLANK) DECODE(10,6,DATA(1)) XMINX                001020
      IF (DATA(2) .NE. BLANK) DECODE(10,6,DATA(2)) YMINY                001030
      IF (DATA(3) .NE. BLANK) DECODE(10,4,DATA(3)) PROGID(1)            001040
      IF (DATA(4) .NE. BLANK) DECODE(10,4,DATA(4)) PROGID(2)            001050
      WRITE(IT6,10) XMINX,YMINY                                         001060
      READ(IT4,7) (DATA(I),I=1,8),NDAT                                  001070
      II=0                                                              001080
      DO 91 I=1,4                                                       001090
      DO 91 J=1,2                                                       001100
      II=II+1                                                           001110
      IF (II .GT. 1) GOTO 84                                            001120
      IF (DATA(1) .EQ. 1HD) GOTO 85                                     001130
 84   IF (DATA(II) .EQ. BLANK) 92,93                                    001140
 92   INDEX(I,J)=0                                                      001150
      GOTO 91                                                           001160
  93 CALL RJUST (DATA(II))                                              001170
      DECODE(10,8,DATA(II)) INDEX(I,J)                                  001180
 91   CONTINUE                                                          001190
 85   WRITE(IT6,14) ((INDEX(I,J),J=1,2),I=1,4)                          001200
C INITIALIZE THE PLOTTER                                                001210
      CALL PLTID3(PROGID,PXMAX,PYMAX,1E0)                               001220
C PLOT DATA BLOCKS                                                      001230
      REWIND IT3                                                        001240
      XPT=0.                                                            001250
      IF (NDAT .EQ. IBLANK) GOTO 94                                     001260
      CALL RJUST(NDAT)                                                  001270
      DECODE(10,8,NDAT) NDA                                             001280
      IF (NDA .EQ. 0) GOTO 70                                           001290
 94   DO 96 I=1,NDA                                                     001300
      READ(IT4,9) (IND(J), J=1,40)                                      001310
      DO 97 J=1,40                                                      001320
      IF (IND(J) .EQ. IBLANK) 98,99                                     001330
 98   IND(J)=0                                                          001340
      GOTO 97                                                           001350
 99   CALL RJUST(IND(J))                                                001360
      DECODE(10,8,IND(J)) IND(J)                                        001370
 97   CONTINUE                                                          001380
      WRITE(IT6,11) NDA,(IND(K),K=1,40)                                 001390
      READ(IT3) DATAIN                                                  001400
      CALL FILL(DATAIN,PARM,IND,100,1,NN)                               001410
      CALL PARMPLT(XPT,0E0,.1E0,PARM,1,NN)                              001420
      XPT=XPT+3.                                                        001430
 96   CONTINUE                                                          001440
 70   CALL PLOT(XPT,0.,-3)                                              001450
C START THE MAIN DISPLAY LOOP. INTERP READS AND INTERPRETS THE DISPLAY  001460
C COMMANDS. IT RETURNS A FLAG VALUE OF .FALSE. IF THE LAST COMMAND HAS  001470
C     BEEN READ.                                                        001480
      FLAG=.T.                                                          001490
      INDIC=1                                                           001500
 100  DO 101 K=1,7                                                      001510
      CODE(K)=BLANK                                                     001520
 101  CONTINUE                                                          001530
      INDIX=0                                                           001540
      XP=.5                                                             001550
      IPEN=2                                                            001560
      CALL INTERP(CCODE,CODE,FLAG,IT4)                                  001570
      IF (.NOT. FLAG .AND. INDIC .EQ. 2) GOTO 2000                      001580
      IF (CCODE .EQ. 1) WRITE(IT6,15) (CODE(K),K=1,5)                   001590
      IF (CCODE .EQ. 2) WRITE(IT6,12) (CODE(K),K=1,4)                   001600
      IF (CCODE .EQ. 3) WRITE(IT6,16) (CODE(K),K=1,7)                   001610
      FLAG1=.T.                                                         001620
      IF (NDA .LE. 0) GOTO 82
      REWIND IT3
      DO 81 I=1,NDA
      READ(IT3)
81    CONTINUE
82    INDIC=2
      ZMINA=1E100
      ZMAXA=-1E100
      NSTART=CODE(2) .OR. 0
      NSTART=NSTART-1
      IF (NSTART .LE. 0) GOTO 72
      DO 74 I=1,NSTART
      CALL RD1(IT3,D1,D2,D3,D4,4,FLAG1,D5,D6,D7,D8,D9)
      IF (.N. FLAG1) GOTO 100
74    CONTINUE
72    NSKIP=CODE(1) .OR. 0
      NSKIP=NSKIP-1
      GOTO (110,120,130) CCODE
C 110 => CONTOUR
C 120 => PERSPECTIVE
C 130 => PLOT
C CONTOUR- IF CONTOURS ARE TO BE NORMALIZED OVER ALL SURFACES, FIND THE
C MAX. AND MIN. OVER ALL SURFACES.
 110  IF (CODE(4) .EQ. 2HDN .OR. CODE(6) .EQ. 2HDN) GOTO 150
 160  CALL RD1(IT3,NP,MP,ZMAX,ZMIN,1,FLAG1,TIM,XMIN,XMAX,YMIN,YMAX)
      WRITE(IT6,13) NP,MP,ZMAX,ZMIN,TIM,XMIN,XMAX,YMIN,YMAX,FLAG1
      IF (CODE(4) .EQ. 2HNE .OR. CODE(6) .EQ. 2HNE) GOTO 140
      CALL SKIP(IT3,NSKIP,FLAG1,NP)
      IF (ZMAX .GT. ZMAXA) ZMAXA=ZMAX
      IF (ZMIN .LT. ZMINA) ZMINA=ZMIN
      IF (FLAG1) GOTO 160
 140  REWIND IT3
      FLAG1=.T.
      IF (NDA .LE. 0) GOTO 145
      DO 83 I=1,NDA
      READ (IT3)
 83   CONTINUE
 145  IF(NSTART .LE. 0) GOTO 150
      DO 115 I=1,NSTART
      CALL RD1(IT3,DUM1,DUM2,DUM3,DUM4,4,FLAG1,DUM5,DUM6,DUM7,DUM8,
     +DUM9)
 115  CONTINUE
 150  GOTO (155,250,350) CCODE
C NEXT FILL THE Z-ARRAY,DETERMINE CONTOUR LEVELS AND DRAW THE CONTOUR MA
 155  CALL RD1(IT3,NP,MP,ZMAX,ZMIN,2,FLAG1,TIM,XMIN,XMAX,YMIN,YMAX)
      IF (.NOT. FLAG1) GOTO 100
      IF (CODE(4) .EQ. 2HDN) 170,180
 170  CALL CLEV(CODE(3),ZMAX,ZMIN,ZLEVS)
      GOTO 190
 180  IF (CODE(4) .EQ. 2HNA) 200,210
 200  ZMAX=ZMAXA
      ZMIN=ZMINA
 210  C=100./(ZMAX-ZMIN)
      DO 220 J=1,MP
      DO 220 I=1,NP
      Z(I,J)=(Z(I,J)-ZMIN)*C
 220  CONTINUE
      CALL CLEV(CODE(3),100.,0.,ZLEVS)
 190  XLEN1=AMIN1((MP-1)/PPI,PYMAX-1.)
      YLEN1=AMIN1((NP-1)/PPI,PYMAX-1.)
      IF (CODE(5) .EQ. 2HSP .A. INDIX .EQ. 1) GOTO 205
      CALL CFRAME(INDEX,ZMIN,ZMAX,CODE(4),NP,MP,TIM,PPI,100.,6.,0.,
     +XMIN,XMAX,YMIN,YMAX,DATAIN,XLEN1,YLEN1,CCODE)
      INDIX=1
 205  SYM=SYMBL(TIM)
      NX=INDEX(2,2)
      IF (NX .EQ. 0) GOTO 222
      CALL SYMBOL(XLEN1+XP,PYMAX-1.1,.1E0,DATAIN(INDEX(2,1),1),0.,NX)
      GOTO 223
 222  CALL SYMBOL(XLEN1+XP,PYMAX-1.1,.1E0,9HPARAMETER,0.,9)
 223  CALL SYMBOL(999E0,999E0,.1E0,SYM,0E0,10)
      CALL CONTOR(NP,MP,CODE(3),ZLEVS,BLANK,XLEN1,YLEN1,XP,PYMAX-1.2)
      IF (CODE(5) .NE. 2HSP) GOTO 215
      XP=XP+4.
      IPEN=IPEN+1
      IF (IPEN .GT. 3) IPEN=1
      CALL NEWPEN(IPEN)
      GOTO 196
 215  CALL PLOT(XLEN1+12.,0.,-3)
 196  IF (FLAG1) 195,106
 105  CALL SKIP(IT3,NSKIP,FLAG1,NP)
      IF (FLAG1) 155,106
 106  IF (CODE(5) .NE. 2HSP) GOTO 100
      CALL NEWPEN(2)
      CALL PLOT(XLEN1+XP+8.,0E0,-3)
      GOTO 100
C START OF PERSPECTIVE PLOTS. FIRST FIND ZMAX,ZMIN FOR NORMALIZATION IF
C NORMALIZATION IS OVER ALL SURFACES.
 120  GOTO 110
 250  PP1=10.
      IF (MP .GT. NP) GOTO 390
      XLEN1=5.*MP/FLOAT(NP)
      YLEN1=5.
      GOTO 400
 390  YLEN1=5.*NP/FLOAT(MP)
      XLEN1=5.
C THE NEXT TASK IS TO FIND SCALING FACTORS FOR THE DISPLAY BY CALLING
C FACE WITH A RECTANGLE FUNCTION.
 400  NP1=NP+1
      MP1=MP+1
      NP2=NP1+1
      MP2=MP1+1
      X2=MP2**2
      Y2=NP2**2
      H=SQRT(X2+Y2)
      THETA1=.785398164
      THETA2=CODE(3)/180.*3.14159265
      X=.5*MP2+H*COS(THETA2)
      Y=.5*NP2+H*SIN(THETA2)
      C1=.5*H
      CALL APLACE(XP,YP,XLEN1,YLEN1,CODE(3))
C THIS SUBROUTINE FINDS THE POINT AT WHICH TO PLACE THE VIEW-ANGLE
C ARROW
      DO 260 K=1,NP2
      Z(K,1)=Z(K,MP2)=0.
 260  CONTINUE
      DO 270 K=2,MP1
      Z(NP2,K)=Z(1,K)=0.
 270  CONTINUE
      DO 280 I=2,NP1
      DO 280 J=2,MP1
      Z(I,J)=C1
 280  CONTINUE
      SW1=.F.
C IF SWT IS OFF (.F.) THEN FACE RETURNS XMIN,YMIN,DX,DY ONLY AND DOES NO
C PLOTTING
      CALL FACE(X,Y,H,THETA1,THETA2,0)
      SWT=.T.
      WRITE(IT6,2) XMINF,YMINF,DX,DY
 2    FORMAT(1X,4E15.5)
C NOW FILL UP THE Z-ARRAY
 290  CALL RD1(IT3,NP,MP,ZMAX,ZMIN,3,FLAG1,TIM,XMIN,XMAX,YMIN,YMAX)
      IF (.NOT. FLAG1) GOTO 100
      IF (CODE(4) .EQ. 2HNE) GOTO 300
      ZMIN=ZMINA
      ZMAX=ZMAXA
C NOW DRAW LABELS,ETC.
 30   C=C1/(ZMAX-ZMIN)
      DO 310 J=2,MP1
      DO 310 K=2,NP1
      Z(K,J)=(Z(K,J)-ZMIN)*C
 310  CONTINUE
      PP=.1*AMAX0(NP,MP)
      CALL CFRAME(INDEX,ZMIN,ZMAX,CODE(4),NP,MP,TIM,PP,C1,6E0,1E0,
     +XMIN,XMAX,YMIN,YMAX,DATAIN,XLEN1,YLEN1,CCODE)
      CALL ARROW(XP,YP,1.,CODE(3),10HVIEW ANGLE,10)
      XPT=XLEN1+4E0
      YPT=-1E0
      CALL PLOT(XPT,YPT,-3)
C NOW DRAW PERSPECTIVE DISPLAY
      CALL FACE(X,Y,H,THETA1,THETA2,0)
      CALL PLOT(12E0,0E0,-3)
      IF (FLAG1) 320,100
 320  CALL SKIP(IT3,NSKIP,FLAG1,NP)
      IF (FLAG1) 290,100
C START OF X-Y PLOTS. FIRST FIND ZMAX,ZMIN FOR SCALING IF SCALING IS
C OVER ALL SURFACES
 130  GOTO 110
 350  CALL RD1(IT3,NP,MP,ZMAX,ZMIN,2,FLAG1,TIM,XMIN,XMAX,YMIN,YMAX)
      IF (.NOT. FLAG1) GOTO 105
      IF (CODE(6) .EQ. 2HNE) GOTO 370                                  003180
      IF (CODE(6) .EQ. 2HDN) GOTO 370                                  003190
      ZMIN=ZMINA                                                       003200
      ZMAX=ZMAXA                                                       003210
 370  CONTINUE                                                         003220
      IF (CODE(7) .NE. 2HSP) XS=YS=0.                                  003230
      CALL PLOTT1(TICH,SCALEX,SCALEY,XLEN,YLEN,TIM,NP,MP,IT6,INDEX,    003240
     +DATAIN,XMIN,XMAX,YMIN,YMAX,XS,YS,ZMIN,ZMAX,CODE,XMINX,YMINY)     003250
      IF (FLAG1) 380,105                                               003260
 380  CALL SKIP(IT3,NSKIP,FLAG1,NP)                                    003270
      IF (FLAG1) 350,105                                               003280
 105  IF (CODE(7) .EQ. 2HSP) CALL PLOT(XLEN+6.,0.,-3)                  003290
      XS=YS=0.                                                         003300
      GOTO 100                                                         003310
2000  CALL ENDPLT                                                      003320
16    FORMAT(1X,2I5,3X,A1,2I5,3X,A2,3XA2)                              003330
15    FORMAT(1X,3I5,3X,A2,3XA2)                                        003340
14    FORMAT(1X,8I5)                                                   003350
13    FORMAT(1X,2I10/1X,4G10.2/1X,3G10.2,L10)                          003360
12    FORMAT(1X,2I5,3X,G10.2,3X,A2,3XA2,3XA2)                          003370
11    FORMAT(1X,I5,4(/1X,10I5))                                        003380
10    FORMAT(1X,4G10.2/1X,4G10.2)                                      003390
9     FORMAT(40A2)                                                     003400
8     FORMAT(I10)                                                      003410
7     FORMAT(9A5)                                                      003420
6     FORMAT(E10.0)                                                    003430
5     FORMAT(8A10)                                                     003440
4     FORMAT(A10)                                                      003450
      END                                                              003460
```

E.2 Subroutine PLOTT1

```
      SUBROUTINE PLOTT1(TICH,SCALXX,SCALYY,XLEN,YLEN,TIM,NP,MP,IT6,     003470
     +INDEX,DATAIN,XMINX,XMAXX,YMINY,YMAXY,XSS,YSS,ZMIN,ZMAX,CODE,     003480
     +XMINXX,YMINYY)                                                   003490
      DIMENSION PTITLE(5),TITLE(5),XTITLE(5),YTITLE(5)                 003500
      DIMENSION INDEX(4,2),DATAIN(100,3),XARRAY(101),YARRAY(101),CODE(7) 003510
      COMMON Z(103,103)                                                003520
C IN THE FIRST PART OF PLOTT1 THE COORDINATE FRAME IS DRAWN AND         003530
C TITLED. IF CODE(7) IS ON THEN SCALING IS OBTAINED FROM THE USER.      003540
C OTHERWISE SCALING IS DONE BY SUBROUTINE SCALE.                        003550
C THE INDEX ARRAY IS USED AS IN SUBROUTINE CFRAME TO OBTAIN VARIOUS     003560
C TITLING INFORMATION. THE PLOT Y-ARRAY IS OBTAINED FROM Z(I,J) AS      003570
C YARRAY(.)=Z(.,N) IF CODE(3)=X AND AS YARRAY(.)=Z(N,.) IF CODE(3)      003580
C =Y. WHERE N STARTS AT CODE(4) AND IS INCREMENTED BY CODE(3). THE      003590
C CALL PLOTT1 MUST SUPPLY THE FOLLOWING ARGUMENTS-                      003600
      MI=CODE(4) .OR. 0                                                003610
      IF (CODE(7) .EQ. 2HSP .A. XSS .NE. 0.) GOTO 430                  003620
      XS=YS=0.                                                         003630
 370  YMIN=YARRAY(1)=ZMIN                                              003640
      YARRAY(2)=ZMAX                                                   003650
      CALL SCALE(YARRAY,YLEN,2,1,20.,YMIN1,DELY)                       003660
      IF (CODE(3) .EQ. 1HX) 380,390                                    003670
 380  XMIN=XMINX                                                       003680
      XMAX=XMAXX                                                       003690
      PMIN=YMINY                                                       003700
      PMAX=YMAXY                                                       003710
      DELX=(XMAX-XMIN)/AMAX0(1,MP-1)                                   003720
      DELP=(PMAX-PMIN)/AMAX0(1,NP-1)                                   003730
      DO 382 I=1,MP                                                    003740
      XARRAY(I)=XMIN+(I-1)*DELX                                        003750
 382  CONTINUE                                                         003760
      NX=INDEX(3,2)                                                    003770
      NN=(NX+9)/10                                                     003780
      IF (NX .NE. 0) GOTO 505                                          003790
      NX=7                                                             003800
      XTITLE(1)=7HX-VALUE                                              003810
      GOTO 500                                                         003820
 505  II=INDEX(3,1)                                                    003830
      DO 384 I=1,NN                                                    003840
      XTITLE(I)=DATAIN(II,1)                                           003850
      II=II+1
  384 CONTINUE
  500 NT=INDEX(4,2)
      NN=(NT+9)/10
      IF (NT .NE. 0) GOTO 515
      NT=7
      TITLE(1)=7HY-VALUE
      GOTO 510
  515 II=INDEX(4,1)
      DO 386 I=1,NN
      TITLE(I)=DATAIN(II,1)
      II=II+1
  386 CONTINUE
  510 NPTS=NP
      NLIM=NP
      GOTO 400
  390 XMIN=YMINY
      XMAX=YMAXY
      PMIN=XMINX
      PMAX=XMAXX
      DELY=(XMAX-XMIN)/AMAX0(1,NP-1)
      DELP=(PMAX-PMIN)/AMAX0(1,MP-1)
      DO 392 I=1,NP
      XARRAY(I)=XMIN+(I-1)*DELX
  392 CONTINUE
      NX=INDEX(4,2)
      NN=(NX+9)/10
      IF (NX .NE. 0) GOTO 525
      NX=7
      XTITLE(1)=7HY-VALUE
      GOTO 520
  525 II=INDEX(4,1)
      DO 394 I=1,NN
      XTITLE(I)=DATAIN(II,1)
      II=II+1
  394 CONTINUE
  520 NT=INDEX(3,2)
      NN=(NT+9)/10
      IF (NT .NE. 0) GOTO 535
      NT=7
      TITLE(1)=7HX-VALUE
      GOTO 530
  535 II=INDEX(3,1)
      DO 396 I=1,NN
      TITLE(I)=DATAIN(II,1)
      II=II+1
  396 CONTINUE
  530 NPTS=NP
      NLIM=MP
  400 CALL SCALE(XARRAY,XLEN,NPTS,1,20.,XMIN1,DELX)
      NY=INDEX(1,2)
      NN=(NY+9)/10
      IF (NY .NE. 0) GOTO 545
      NY=7
      YTITLE(1)=7HZ-VALUE
      GOTO 540
  545 II=INDEX(1,1)
      DO 410 I=1,NN
      YTITLE(I)=DATAIN(II,1)
      II=II+1
  410 CONTINUE
  540 NB=INDEX(2,2)
      IF (NB .NE. 0) GOTO 555
      NN=(NB+9)/10
      NB=10
      PTITLE(1)=10HPARAMETER=
      GOTO 550
  555 II=INDEX(2,1)
      DO 420 I=1,NN
      PTITLE(I)=DATAIN(II,1)
      II=II+1
  420 CONTINUE
  550 ISYM=0
      M=CODE(5) .OR. 0
      ISWTCH=3
      IF (CODE(6) .EQ. 2HON) GOTO 430
      ISWTCH=2
      SCALEX=DELX
      XMIN=XMIN1
      SCALEY=DELY
      YMIN=YMIN1
C START OF MAIN PLOTTING LOOP
  430 IF (M .GT. NLIM) GOTO 440
      IF (CODE(3) .EQ. 1HY) GOTO 450
      DO 460 I=1.NPTS
      YARRAY(I)=Z(I.M)
  460 CONTINUE
      GOTO 470
  450 DO 480 I=1.NPTS
      YARRAY(I)=Z(M.I)
  480 CONTINUE
  470 CURVE=PMIN+(M-1)*DELP
      IF (CODE(7) .NE. 2HSP) GOTO 425
      TIMT=TIM
      TIM=CURVE
      CURVE-TIMT
      DO 215 I=1.5
      TIMT=PTITLE(I)
      PTITLE(I)=TITLE(I)
      TITLE(I)=TIMT
  215 CONTINUE
      TIMT=NB
      NB=NT
      NT=TIMT
      IF (XSS .NE. 0.) GOTO 200
  425 GOTO (200.220.210.200) ISWTCH
  210 CALL PLOT(XS.YS.3)
      ISWTCH=4
      XS=YS=0.
      SCAY=TICU/SCALXX
      SCAY=TICU/SCALYY
      ENCODE(10.1.ISYMB) YMINYY
      CALL SYMBOL(-.1.0E0..1E0.ISYMB.90E0.10)
      CALL SYMBOL(XS-.2E0.YS+1.2E0..1E0.YTITLE.90E0.NY)
      CALL SYMBOL(999E0.999E0..1E0.10H SCALE IS .90E0.10)
      ENCODE(10.1.ISYMB) SCALYY
      CALL SYMBOL(999E0.999E0..1E0.ISYMB.90E0.10)
      CALL SYMBOL(999E0.999E0..1E0.10H UNITS/TIC.90E0.11)
      ENCODE(10.1.ISYMB) XMINXX
      CALL SYMBOL(0E0.-.25E0..1E0.ISYMB.0E0.10)
      CALL SYMBOL(1.2E0.-.3E0..1E0.XTITLE.0E0.NX)
      CALL SYMBOL(999E0.999E0..1E0.10H SCALE IS .0E0.10)
      ENCODE(10.1.ISYMB) SCALXX
      CALL SYMBOL(999E0.999E0..1E0.ISYMB.0E0.10)
      CALL SYMBOL(999E0.999E0..1E0.10H UNITS/TIC.0E0.11)
      CALL PLOT(0E0.0E0.3)
      YPT=0.
      DO 100 I=1.100000
      N=I
      XPT=I*TICU
      IF (XPT .GT. XLEN) GOTO 1000
      CALL PLOT(XPT.YPT.2)
      CALL PLOT(XPT.YPT+.1.2)
      CALL PLOT(XPT.YPT.2)
  100 CONTINUE
 1000 XPT=(N-1)*TICU
      DO 110 I=1.10000
      N=I
      YPT=I*TICU
      IF (YPT .GT. YLEN) GOTO 1010
      CALL PLOT(XPT.YPT.2)
      CALL PLOT(XPT-.1.YPT.2)
      CALL PLOT(XPT.YPT.2)
  110 CONTINUE
 1010 YPT=(N-1)*TICU
      XPTT=XPT
      DO 120 I=1.10000
      N=I
      XPT=XPTT-I*TICU
      IF (XPT .LT. XS) GOTO 1020
      CALL PLOT(XPT.YPT.2)
      CALL PLOT(XPT.YPT-.1.2)
      CALL PLOT(XPT.YPT.2)
  120 CONTINUE
 1020 YPTT=YPT
      XPT=XS
      CALL PLOT(XS.YPT.2)
      CALL PLOT(XS.YPT.3)
      DO 130 I=1.10000
      YPT=YPTT-I*TICU
      IF (YPT .LT. YS) GOTO 1030
      CALL PLOT(XPT,YPT,2)
      CALL PLOT(XPT+.1,YPT,2)
      CALL PLOT(XPT,YPT,2)
 130  CONTINUE
 1030 CALL PLOT(XS,YS,2)
      GOTO 230
 220  CALL PLOT(XS,YS,3)
      ISWTCH=1
      XS=YS=0E0
      CALL AXIS(XS,YS,XTITLE,-NX,XLEN,0E0,XMIN,SCALEX,20.)
      CALL AXIS(XS,YS,YTITLE,NY,YLEN,90E0,YMIN,SCALEY,20.)
C NEXT PLOT PARAMETER AND CURVE TITLES
 230  CALL SYMBOL(XS+1E0,YS+YLEN+.2,.1E0,PTITLE,0E0,NB)
      SYM=SYMBL(TIM)
      CALL SYMBOL(999E0,999E0,.1E0,SYM,0E0,10)
      XSS=XLEN+1E0
      YSS=YLEN-1E0
      CALL SYMBOL(XSS,YSS,.1E0,TITLE,0E0,NT)
C PLOT CURVE
 200  CALL PLOT(0E0,0E0,3)
      GOTO (240,240,250,250) ISWTCH
 240  CALL LINE(XARRAY,YARRAY,NPTS,1,5,ISYM,XMIN,SCALEX,YMIN,
     +SCALEY,.07)
      GOTO 1050
 250  XQ=YQ=-.1
      XLEM=XLEN+.1
      YLEM=YLEN+.1
      IP=2
      DO 140 I=1,NPTS
      N=I
      XPT=(XARRAY(I)-XMINXX)*SCAX
      YPT=(YARRAY(I)-YMINYY)*SCAY
      IF (XPT .GE. XQ .AND. YPT .GE. YQ .AND. YPT .LE. YLEM) GOTO 1040
 140  CONTINUE
      WRITE(IT6,2)
      GOTO 1050
 2    FORMAT(1X,* NO POINTS PLOTTED*)
 1040 IF (ISYM) 1070,1070,1080
 1070 CALL PLOT(XPT,YPT,IP)
      IP=2
      GOTO 1060
 1080 CALL SYMBOL(XPT,YPT,.1,ISYM,0.,-1)
 1060 N=N+1
      IF (N .GT. NPTS) GOTO 1050
      YPT=(YARRAY(N)-YMINYY)*SCAY
      IF (YPT .GT. YLEM .OR. YPT .LT. YQ) GOTO 1065
      XPT=(XARRAY(N)-XMINXX)*SCAX
      IF (XPT .GT. XLEM .OR. XPT .LT. XQ) GOTO 1065
      GOTO 1040
 1065  IP=3
      GOTO 1060
 1050 IF (ISYM .LT. 0) ISYM=15
      YSS=YSS-.15
      IF (YSS .GT. 0.) GOTO 260
      YSS=YLEN-1.15
      XSS=XSS+2.
 260  CALL SYMBOL(XSS,YSS,.1E0,ISYM,0E0,-1)
      CALL SYMBOL(999E0,999E0,.1E0,2H  ,0E0,2)
      ENCODE(10,1,ISYMB) CURVE
      CALL SYMBOL(999E0,999E0,.1E0,ISYMB,0E0,10)
      ISYM=MOD(ISYM+1,13)
      IF (CODE(7) .EQ. 2HSP) GOTO 560
      M=M+MI
      GOTO 430
 440  XPT=XLEN+6E0
      CALL PLOT(XPT,0E0,-3)
 560  RETURN
 1    FORMAT(G10.3)
      END
```

E.3 Subroutine PARMPLT

```
      SUBROUTINE PARMPLT(XS,YS,HT,PARM,NS,N)                            006160
C THIS SUBROUTINE PLOTS N PARAMETERS IN 'PARM' STARTING AT LOCATION     006170
C XS,YS. HT IS THE HEIGHT OF THE LETTERS (INCHES),NS IS THE ''STARTING  006180
C LOCATION '' IN PARM AT WHICH TO LOOK FOR DATA FOR PLOTTING.           006190
      DIMENSION PARM(1)                                                 006200
      IF (N .LT. 0) GOTO 2000                                           006210
      XPT=XS                                                            006220
      YPT=YS                                                            006230
      NS1=NS-1                                                          006240
      DO 100 I=1,N,2                                                    006250
      II=NS1+I                                                          006260
      CALL SYMBOL(XPT,YPT,HT,PARM(II),0E0,20)                           006270
      YPT=YPT-2.*HT                                                     006280
 100  CONTINUE                                                          006290
 2000 RETURN                                                            006300
      END                                                               006310
```

E.4 Subroutine FILL

```
      SUBROUTINE FILL(DATAIN,PARM,INDEX,ISIZE,NS,N)                     006320
C THIS SUBROUTINE SELECTS DATA FROM DATAIN(ISIZE,3) AND PLACES IT IN    006330
C 2-D ARRAY PARM STARTING AT NS ACCORDING TO NUMBERS IN INDEX. THE      006340
C PARM VALUES ARE CHACTER-STRINGS SUITABLE FOR PLOTTING.                006350
      DIMENSION DATAIN(1),PARM(1),INDEX(1)                              006360
      EQUIVALENCE (IF,FI)                                               006370
      II=2*NS-3                                                         006380
      DO 100 I=1,40                                                     006390
      K=INDEX(I)                                                        006400
      IF (K .EQ. 0) GOTO 100                                            006410
      II=II+2                                                           006420
      K1=K+ISIZE                                                        006430
      K2=K1+ISIZE                                                       006440
      FI=DATAIN(K2)                                                     006450
      PARM(II)=DATAIN(K1)                                               006460
      IF (IF) 1000,1010,1020                                            006470
 1000 ENCODE (10,1,PARM(II+1)) DATAIN(K)                                006480
      GOTO 100                                                          006490
 1010 ENCODE (10,2,PARM(II+1)) DATAIN(K)                                006500
      GOTO 100                                                          006510
 1020 ENCODE (10,3,PARM(II+1)) DATAIN(K)                                006520
 100  CONTINUE                                                          006530
      N=II                                                              006540
      RETURN                                                            006550
 1    FORMAT(A10)                                                       006560
 2    FORMAT(I10)                                                       006570
 3    FORMAT(G10.3)                                                     006580
      END                                                               006590
```

E.5 Subroutine CFRAME

```
      SUBROUTINE CFRAME(INDEX,ZMIN,ZMAX,CODE,NP,MP,TIM,PPI,C,XS,YS,
     *XMIN,XMAX,YMIN,YMAX,DATAIN,XLEN,YLEN,CCODE)
C INDEX IS A 2-D ARRAY OF INTEGERS (IN SEQUENCE) DENOTING THE
C STARTING LOCATION AND NUMBER OF WORDS IN DATAIN CONTAINING THE
C FOLLOWING INFORMATION-
C 1.1  FUNCTION TITLE
C 1.2  F-TITLE LENGTH (WORDS)
C 2.1  PARAMETER LABEL
C 2.2 P-LABEL LENGTH
C 3.1  X-LABEL
C 3.2  X-LABEL LENGTH
C 4.1  Y-LABEL
C 4.2  Y-LABEL LENGTH
C C IS THE FUNCTION NORMALIZATION CONSTANT
C XS,YS IS THE STARTING POINT OF THE FRAME
C T IS SUBROUTINE ASSUMES THAT THE PRECEDING PLOT WAS TERMINATED AT THE
C LOWER RIGHT CORNER OF ITS ALLOTTED SPACE (AND THIS IS THE NEW ORIGIN)
C
      DIMENSION DATAIN(100,3),INDEX(4,2)
      INTEGER CCODE,CODE
      TICU=5/PPI
C FIRST DRAW TITLE,SCALING INFO,PARAMETER
      NX=INDEX(1,2)
      IF (NX .EQ. 0) GOTO 170
      CALL SYMBOL(1E0,8.5E0,.15E0,DATAIN(INDEX(1,1),1),0E0,NX)
  170 IF (CCODE .EQ. 1) GOTO 215
      SYM-SYMBL(TIM)
      NX=INDEX(2,2)
      IF (NX .EQ. 0) GOTO 200
      CALL SYMBOL(1.5E0,8.2E0,.1E0,DATAIN(INDEX(2,1),1),0E0,NX)
      GOTO 210
  200 CALL SYMBOL(1.5E0,8.2E0,.1E0,9HPARAMETER,0E0,9)
  210 CALL SYMBOL(999E0,999E0,.1E0,SYM,0E0,10)
  215 IF (CODE .EQ. 2HDN) GOTO 220
      CALL SYMBOL(1E0,8.E0,.1E0,24HALL FUNCTION VALUES HAVE,0E0,24)
      CALL SYMBOL(1E0,7.8E0,.1E0,25HBEEN SCALED ACCORDING TO-,0E0,25)
      CALL SYMBOL(1.E0,7.45E0,.1E0,1HZ,0E0,1)
      CALL ARROW(1.5,7.5,.3,180.,1H ,0)
      ENCODE(10,1,SYM) C
      CALL SYMBOL(1.6E0,7.6E0,.1E0,SYM,0E0,10)
      CALL SYMBOL(999.E0,999.E0,.1E0,9H*(Z-ZMIN),0E0,9)
      CALL PLOT(1.9E0,7.5E0,3)
      CALL PLOT(3.1E0,7.5E0,2)
      CALL SYMBOL(2E0,7.3E0,.1E0,11H(ZMAX-ZMIN),0E0,11)
      ENCODE(10,1,SYM) ZMAX
      CALL SYMBOL(1E0,7.1E0,.1E0,11HWHERE ZMAX=,0E0,11)
      CALL SYMBOL(999E0,999E0,.1E0,SYM,0E0,10)
      ENCODE(10,1,SYM) ZMIN
    1 FORMAT(G10.3)
      CALL SYMBOL(1E0,6.9E0,.1E0,11H      ZMIN=,0E0,11)
      CALL SYMBOL(999E0,999E0,.1E0,SYM,0E0,10)
      CALL SYMBOL(1E0,6.7E0,.1E0,20HARE THE MAX. AND MIN.,0E0,20)
      IF (CODE .EQ. 2HNA) 110,120
  110 CALL SYMBOL(1E0,6.5E0,.1E0,24HVALUES OVER ALL SURFACES,0E0,24)
      GOTO 100
  120 CALL SYMBOL(1E0,6.5E0,.1E0,21HVALUES OF THE SURFACE,0E0,21)
  100 CONTINUE
C NEXT SET THE PLOT ORIGIN AT THE ORIGIN OF THE SURFACE COORDINATE
C FRAME,DRAW THE FRAME AND LABEL IT.
  220 CALL PLOT(XS,YS,-3)
C THE COORDINATE FRAME IS DRAWN WITH THE TIC-MARKS EVERY TICU (INCHES).
      ENCODE(10,1,SYM) XMIN
      CALL SYMBOL(0E0,-.2E0,.1E0,SYM,0E0,10)
      NX=INDEX(3,2)
      IF (NX .EQ. 0) GOTO 180
      CALL SYMBOL(0E0,-.5E0,.1E0,DATAIN(INDEX(3,1),1),0E0,NX)
  180 ENCODE(10,1,SYM) XMAX
      XPT=0E0
      YPT=0E0
      CALL PLOT(XPT,YPT,3)
      DO 130 I=1,100000
      N=I
      XPT=I*TICU
      IF (XPT .GT. XLEN) GOTO 1000
      CALL PLOT(XPT,0E0,2)
      CALL PLOT(XPT,+.1,2)
      CALL PLOT(XPT,0E0,2)
130   CONTINUE
1000  XPTT=N*TICU
      XPT=XLEN
      CALL PLOT(XPT,0E0,2)
      CALL SYMBOL(XPT-.5,-.2,.1,SYM,0E0,10)
      CALL PLOT(XPT,0E0,3)
      DO 140 I=1,100000
      N=I
      YPT=I*TICU
      IF (YPT .GT. YLEN) GOTO 1010
      CALL PLOT(XPT,YPT,2)
      CALL PLOT(XPT-.1,YPT,2)
      CALL PLOT(XPT,YPT,2)
140   CONTINUE
1010  YPTT=N*TICU
      YPT=YLEN
      CALL PLOT(XPT,YPT,2)
      DO 150 I=1,100000
      N=I
      XPT=XPTT-I*TICU
      IF (XPT .LT. 0E0) GOTO 1020
      CALL PLOT(XPT,YPT,2)
      CALL PLOT(XPT,YPT-.1,2)
      CALL PLOT(XPT,YPT,2)
150   CONTINUE
1020  XPT=0E0
      CALL PLOT(XPT,YPT,2)
      ENCODE(10,1,SYM) YMAX
      YPTS=YPT-.5
      IF (YPT .GT. 9.5) YPTS=9.0
      CALL SYMBOL(-.1E0,YPTS,.1E0,SYM,90E0,10)
      CALL PLOT(0E0,YPT,3)
      DO 160 I=1,100000
      YPT=YPTT-I*TICU
      IF (YPT .LT. 0E0) GOTO 1030
      CALL PLOT(XPT,YPT,2)
      CALL PLOT(XPT+.1,YPT,2)
      CALL PLOT(XPT,YPT,2)
160   CONTINUE
1030  CALL PLOT(0E0,0E0,2)
      ENCODE(10,1,SYM) YMIN
      CALL SYMBOL(-.1E0,0E0,.1E0,SYM,90.,10)
      NX=INDEX(4,2)
      IF (NX .EQ. 0) GOTO 190
      CALL SYMBOL(-.4E0,0E0,.1E0,DATAIN(INDEX(4,1),1),90.,NX)
190   CALL PLOT(0E0,0E0,3)
      RETURN
      END
```

E.6 Subroutine INTERP

```
      SUBROUTINE INTERP(CCODE,CODE,FLAG,ICARD)
      COMMON/LET/LETTER(80)
      DIMENSION CODE(7)
      LOGICAL FLAG
      INTEGER CCODE,BLANK,C,L,LPAREN,RPAREN,Y,D,E
      DATA BLANK,C,L,LPAREN,RPAREN,Y,D,E/00000000000000000055B,
     +00000000000000000003B,00000000000000000014B,00000000000000000051B
     +,00000000000000000052B,00000000000000000031B,
     +00000000000000000004B,00000000000000000005B/
      CCODE=2
      CODE(2)=1 .OR.
      DO 90 I=1,80
      LETTER(I)=BLANK
90    CONTINUE
```

```
      READ(ICARD,1) (LETTER(I),I=1,80)                                  007990
      IF (EOF(ICARD)) 115,100                                           008000
  115 FLAG=.F.                                                          008010
      GOTO 110                                                          008020
  100 CONTINUE                                                          008030
1     FORMAT(80R1)                                                      008040
      DO 120 I=1,80                                                     008050
      N=I                                                               008060
      IF (LETTER(I) .NE. BLANK) GOTO 130                                008070
  120 CONTINUE                                                          008080
  130 IF (I .EQ. 81) GOTO 110                                           008090
      IF (LETTER(N) .EQ. C) CCODE=1                                     008100
      IF (LETTER(N+1) .EQ. L) CCODE=3                                   008110
      GOTO (131,134,133) CCODE                                          008120
C SET DEFAULT VALUES OF CODE                                             008130
  131 CODE(1)=1 .OR. 0                                                  008140
      CODE(3)=10 .OR. 0                                                 008150
      CODE(4)=2HNA                                                      008160
      CODE(5)=10H                                                       008170
      GOTO 132                                                          008180
  134 CODE(1)=1 .OR. 0                                                  008190
      CODE(3)=45.                                                       008200
      CODE(4)=2HNA                                                      008210
      GOTO 132                                                          008220
  133 CODE(1)=1 .OR. 0                                                  008230
      CODE(3)=1HX                                                       008240
      CODE(4)=1 .OR. 0                                                  008250
      CODE(5)=1 .OR. 0                                                  008260
      CODE(6)=2HNA                                                      008270
      CODE(7)=10H                                                       008280
  132 DO 140 I=N,80                                                     008290
      M=I                                                               008300
      IF (LETTER(I) .EQ. LPAREN) GOTO 150                               008310
  140 CONTINUE                                                          008320
  150 IF (I .EQ. 81) GOTO 110                                           008330
      CALL NUMB(CODE(1),M,1)                                            008340
C IF M=0 THEN A RIGHT PAREN HAS BEEN FOUND,OTHERWISE IT RETURNS          008350
C THE POSITION OF THE COMMA.                                            008360
      IF (M .EQ. 0) GOTO 110                                            008370
      CALL NUMB(CODE(2),M,1)                                            008380
      IF (M .EQ. 0) GOTO 110                                            008390
      GOTO (160,170,180) CCODE                                          008400
  160 CALL NUMB(CODE(3),M,1)                                            008410
      IF (M .EQ. 0) GOTO 110                                            008420
      CODE(4)=2HNA                                                      008430
      IF (LETTER(M+1) .EQ. D) CODE(4)=2HDN                              008440
      IF (LETTER(M+2) .EQ. E) CODE(4)=2HNE                              008450
      IF (LETTER(M+3) .EQ. 23B) CODE(5)=2HSP                            008460
      GOTO 110                                                          008470
  170 CALL NUMB(CODE(3),M,2)                                            008480
      IF (M .EQ. 0) GOTO 110                                            008490
      IF (LETTER(M+2) .EQ. E) CODE(4)=2HNE                              008500
      GOTO 110                                                          008510
  180 IF (LETTER(M+1) .EQ. Y) CODE(3)=1HY                               008520
      IF (LETTER(M+2) .EQ. RPAREN) GOTO 110                             008530
      IF (LETTER(M+1) .EQ. 56B) M=M-1                                   008540
      M=M+2                                                             008550
      CALL NUMB(CODE(4),M,1)                                            008560
      IF (M .EQ. 0) GOTO 110                                            008570
      CALL NUMB(CODE(5),M,1)                                            008580
      IF (M .EQ. 0) GOTO 110                                            008590
      CODE(6)=2HNA                                                      008600
      IF (LETTER(M+1) .EQ. D) CODE(6)=2HDN                              008610
      IF (LETTER(M+2) .EQ. E) CODE(6)=2HNE                              008620
      IF (LETTER(M+3) .EQ. 23B) CODE(7)=2HSP                            008630
  110 RETURN                                                            008640
      END                                                               008650
```

E.7 Subroutine NUMB

```
      SUBROUTINE NUMB(PARAM.M.IFORMAT)                                        008660
      COMMON/LET/LETTER(80)                                                   008670
      INTEGER RPAREN.COMMA                                                    008680
      DATA RPAREN.COMMA/00000000000000000052B.00000000000000000056B/          008690
      IPARAM=10H                                                              008700
C IFORMAT IS THE FORMAT CODE FOR DECODING-1=>INTEGER.2=>FLOAT.                 008710
C M IS THE POSITION IN LETTER OF A 'DELIMITER' SUCH AS ( OR .. NUMB             008720
C RETURNS M=0 IF A ) IS FOUND.                                                  008730
      M1=M+1                                                                  008740
      NUM=0                                                                   008750
      DO 100 I=M1.80                                                          008760
      M=I                                                                     008770
      IF (LETTER(I) .EQ. RPAREN) 110.120                                      008780
 110  M=0                                                                     008790
      GOTO 130                                                                008800
 120  IF (LETTER(I) .EQ. COMMA) 130.150                                       008810
 150  NUM=NUM+1                                                               008820
C STORE THE RIGHT MOST CHARACTER FORM LETTER(I) AT CHARACTER                   008830
C NUM OF IPARAM.                                                                008840
      IPARAM=MYPUTX(LETTER(I).IPARAM.NUM)                                     008850
 100  CONTINUE                                                                008860
 130  IF (I .EQ. M1) GOTO 160                                                 008870
      IF(IFORMAT.EQ.1)  170.180                                               008880
 170  CALL RJUST(IPARAM)                                                      008890
      DECODE (10.1.IPARAM) PARAM                                              008900
 1    FORMAT(I10)                                                             008910
      GOTO 160                                                                008920
 180  CALL RJUST(IPARAM)                                                      008925
      DECODE (10.2.IPARAM)PARAM                                               008930
 2    FORMAT(F10.0)                                                           008940
 160  RETURN                                                                  008950
      END                                                                     008960
```

E.8 Subroutine ARROW

```
       SUBROUTINE ARROW(XP.YP.L.THETAD.LABEL.NC)                              008970
C      THETAD IS THE ARROW ANGLE WRT X-AXIS IN DEGREES                        008980
C      L IS THE LENGTH OF THE ARRAW IN INCHES                                 008990
C      THE LOCATION OF THE ARROW TIP (XP.YP) IS RETURNED                      009000
C NC IS THE NUMBER OF CHARACTERS IN THE ARROW LABEL                           009010
       REAL L                                                                 009020
       DIMENSION LABEL(1)                                                     009030
       THETA=THETAD*3.1415927/180.                                            009040
       XXP=L*COS(THETA)+YP                                                    009050
       YYP=L*SIN(THETA)+YP                                                    009060
       XL=.2*L*COS(THETA-.1745)+XP                                            009070
       YL=.2*L*SIN(THETA-.1745)+YP                                            009080
       XU=.2*L*COS(THETA+.1745)+XP                                            009090
       YU=.2*L*SIN(THETA+.1745)+YP                                            009100
       CALL PLOT(XP.YP.3)                                                     009110
       CALL PLOT(XXP.YYP.2)                                                   009120
       CALL PLOT(XP.YP.3)                                                     009130
       CALL PLOT(XL.YL.2)                                                     009140
       CALL PLOT(XP.YP.3)                                                     009150
       CALL PLOT(XU.YU.2)                                                     009160
       XU=.25*L*COS(THETA+.0873)+XP                                           009170
       YU=.25*L*SIN(THETA+.0873)+YP                                           009180
       IF (NC .LE. 0) GOTO 1000                                               009190
       CALL SYMBOL(XU.YU..1.LABEL.THETAD.NC)                                  009200
 1000  RETURN                                                                 009210
       END                                                                    009220
```

E.9 Subroutine APLACE

```
      SUBROUTINE APLACE(XP,YP,XLEN1,YLEN1,THETA2)                       009230
C THIS SUBROUTINE FINDS THE X,Y, COORDINATES (XP,YP) FOR THE TIP        009240
C OF THE ARROW WHICH INDICATES THE VIEW ANGLE (THETA2-DEGREES)          009250
C FOR PERSPECTIVE PLOTS                                                 009260
      X2=.5*XLEN1                                                       009270
      Y2=.5*YLEN1                                                       009280
      PI180=3.1415927/180.                                              009290
      TH=PI180*THETA2                                                   009300
      R=SQRT((X2+.5)**2+(Y2+.5)**2)                                     009310
      XP=X2+R*COS(TH)                                                   009320
      YP=Y2+R*SIN(TH)                                                   009330
      RETURN                                                            009340
      END                                                               009350
```

E.10 Subroutine RD1

```
      SUBROUTINE RD1(IT3,NP,MP,ZMAX,ZMIN,ISW,FLAG,TIM,XMIN,XMAX,YMIN,   009360
     +YMAX)                                                             009370
      COMMON Z(103,103)                                                 009380
      DIMENSION BUF(101)                                                009390
      LOGICAL FLAG                                                      009400
C THIS SUBROUTINE FILLS UP THE 'SURFACE ARRAY' Z(...) AND/OR FINDS THE  009410
C SURFACE MAX. AND MIN. (ZMAX,ZMIN). IT ALSO RETURNS THE SIZE OF THE    009420
C SURFACE (MP X NP) AND THE SURFACE PARAMETER VALUE, TIM. THE LOGICAL   009430
C VARIABLE, FLAG, IS .TRUE. UNTIL AN END-OF-FILE IS REACHED AT WHICH    009440
C POINT IT BECOMES FALSE. EACH UNFORMATTED RECORD OF THE INPUT FILE,IT3, 009450
C IS ASSUMED TO BE OF THE FORM-                                         009460
C     I        ROW NUMBER                                               009470
C     NP       TOTAL NO. OF ROWS                                        009480
C     Y        Y-VALUE CORRESPONDING TO THIS ROW                        009490
C     TIM      SURFACE PARAMETER VALUE (E.G. TIME)                      009500
C     MP       TOTAL NO. OF COLUMNS                                     009510
C     XMIN     VALUE ASSOCIATED WITH THE FIRST COLUMN                   009520
C     XMAX     VALUE ASSOCIATED WITH THE LAST COLUMN                    009530
C     BUF(J)   MP SURFACE ELEMENTS OF THE I-TH ROW                      009540
C ISW ACTS AS A SWITCH TO CONTROL THE ACTION OF RD1 AS FOLLOWS-         009550
C ISW=1 => RETURN ZMAX,ZMIN ONLY                                        009560
C ISW=2 => RETURN SURFACE Z AND ZMAX,ZMIN                               009570
C ISW=3 => RETURN SURFACE Z BORDERED BY ZEROES AND ZMAX,ZMIN            009580
C ISW=4 => SKIP A SURFACE                                               009585
C NOTE THAT THE FIRST RECORD READ IS ASSUMED TO INCLUDE THE FIRST       009590
C 'ROW' OF THE SURFACE                                                  009600
 100  READ(IT3) I,NP,Y,TIM,MP,XMIN,XMAX,(BUF(J),J=1,MP)                 009610
      IF (EOF(IT3)) 110,120                                             009620
 110  FLAG=.F.                                                          009630
      GOTO 1000                                                         009640
 120  IF (ISW .EQ. 4) GOTO 230                                          009645
      I1=I+1                                                            009650
      Z(I1,1)=Z(I1,MP+2)=0.                                             009660
      IF (I .EQ. 1) 210,220                                             009670
 210  ZMIN=ZMAX=BUF(1)                                                  009680
      YMIN=Y                                                            009690
      MP2=MP+2                                                          009700
      DO 90 J=1,MP2                                                     009710
 90   Z(1,J)=0.                                                         009720
 220  IF (I .EQ. NP) YMAX=Y                                             009730
      DO 160 J=1,MP                                                     009740
      ZT=BUF(J)                                                         009750
      IF (ZT .LT. ZMIN) ZMIN=ZT                                         009760
      IF (ZT .GT. ZMAX) ZMAX=ZT                                         009770
      GOTO (160,170,180) ISW                                            009780
 170  Z(I,J)=ZT                                                         009790
      GOTO 160                                                          009800
 180  Z(I1,J+1)=ZT                                                      009810
      GOTO 160                                                          009820
 140  CONTINUE                                                          009830
 230  IF (I .LT. NP) GOTO 100                                           009840
      GOTO (1000,1000,190,1000) ISW                                     009850
 190  MP2=MP+2                                                          009860
      NP2=NP+2                                                          009870
      DO 200 J=1,MP2                                                    009880
 200  Z(NP2,J)=0.                                                       009890
1000  RETURN                                                            009900
      END                                                               009910
```

E.11 Subroutine CLEV

```
      SUBROUTINE CLEV(NLEV,ZMAX,ZMIN,ZLEVS)                             009920
      DIMENSION ZLEVS(1)                                                009930
C THIS SUBROUTINE RETURNS NLEV EQUI-SPACED CONTOUR LEVELS BETWEEN ZMIN   009940
C AND ZMAX (BUT NOT INCLUDING ZMIN)                                     009950
      DEL=(ZMAX-ZMIN)/NLEV                                              009960
      DO 100 I=1,NLEV                                                   009970
      ZLEVS(I)=ZMIN+I*DEL                                               009980
 100  CONTINUE                                                          009990
      RETURN                                                            010000
      END                                                               010010
```

E.12 Subroutine SKIP

```
      SUBROUTINE SKIP(ITAPE,NSKIP,FLAG,N)                               010020
      LOGICAL FLAG                                                      010030
      IF (NSKIP .EQ. 0) GOTO 120                                        010040
      NREC=N*NSKIP                                                      010050
      DO 100 I=1,NREC                                                   010060
      READ(ITAPE)                                                       010070
      IF (EOF(ITAPE)) 110,100                                           010080
 100  CONTINUE                                                          010090
      GOTO 120                                                          010100
 110  FLAG=.F.                                                          010110
 120  RETURN                                                            010120
      END                                                               010130
```

E.13 Subroutine FACE

```
      SUBROUTINE FACE(XP1,YP1,ZPP,THETA1,THETA2,NREFIN)                 010140
      DIMENSION R(3,3)                                                  010150
      COMMON/BLOCK3/INUN, JNUN,XMIN,YMIN,DX,DY,SWI,IT6                  010160
      COMMON DATA(103,103,2)                                            010170
      WRITE(IT6,101)XP1,YP1,ZPP,THETA1,THETA2,INUN,JNUN,NREFIN          010180
 101  FORMAT(3(F6.2,1X),2(F7.4,1X),3(I3,1X))                            010190
      YES=3HYES                                                         010200
      YNO=2HNO                                                          010210
      INUM=INUN                                                         010220
      JNUM=JNUN                                                         010230
      YP=YPP=YP1                                                        010240
      XP=XPP=XP1                                                        010250
      XB = ZPP*COS(THETA2)/TAN(THETA1)                                  010260
      YB = ZPP*SIN(THETA2)/TAN(THETA1)                                  010270
      XBAR = XPP-XB
      YBAR = YPP-YB
      XPP = XPP-XBAR
      YPP = YPP-YBAR
      DIS = SQRT(XPP*XPP+YPP*YPP+ZPP*ZPP)
      R(1,1) = -SIN(THETA2)
      R(1,2) = COS(THETA2)
      R(1,3) = 0.0
      R(2,1) = -SIN(THETA1)*COS(THETA2)
      R(2,2) = -SIN(THETA1)*SIN(THETA2)
      R(2,3) = COS(THETA1)
      R(3,1) = COS(THETA1)*COS(THETA2)
      R(3,2) = COS(THETA1)*SIN(THETA2)
      R(3,3) = SIN(THETA1)
      DO 20 I=1,INUM
      A = FLOAT(I)
      Y = A-YBAR
      DO 20 J=1,JNUM
      B = FLOAT(J)
      X = B-XBAR
      Z = DATA(I,J,1)
      DATA(I,J,1) = R(1,1)*X + R(1,2)*Y + R(1,3)*Z
      DATA(I,J,2) = R(2,1)*X + R(2,2)*Y + R(2,3)*Z
      Z = DIS-(R(3,1)*X + R(3,2)*Y + R(3,3)*Z)
      DATA(I,J,1) = DATA(I,J,1)/Z
   20 DATA(I,J,2) = DATA(I,J,2)/Z
      INUM1 = INUM/2
      JNUM1 = JNUM/2
      IF (YP .LE. 1.0) GO TO 45
      IF (YP .GE. FLOAT(INUM)) GO TO 39
      IF (XP .LE. 1.0) GO TO 40
      IF (XP .GE. FLOAT(JNUM)) GO TO 39
   30 DO 35 J=1,JNUM
      DO 35 I=1,INUM1
      T1 = DATA(I,J,1)
      T2 = DATA(I,J,2)
      DATA(I,J,1) = DATA(INUM+1-I,J,1)
      DATA(I,J,2) = DATA(INUM+1-I,J,2)
      DATA(INUM+1-I,J,1) = T1
   35 DATA(INUM+1-I,J,2) = T2
      GO TO 45
   39 XP = YES
   40 ITEMP = INUM
      INUM = JNUM
      JNUM = ITEMP
      ITEMP = MAX0(INUM,JNUM)
      DO 42 I=1,ITEMP
      DO 41 J=1,I
      T1 = DATA(I,J,1)
      T2 = DATA(I,J,2)
      DATA(I,J,1) = DATA(J,I,1)
      DATA(J,I,1) = T1
      DATA(I,J,2) = DATA(J,I,2)
   41 DATA(J,I,2) = T2
   42 CONTINUE
      IF (XP .EQ. YES) GO TO 30
   45 IF (DATA(1,1,1) .LT. DATA(1,JNUM,1)) GO TO 46
      IF (DATA(INUM,JNUM,1) .LT. DATA(1,JNUM,1)) GO TO 50
      GO TO 99
   46 IF (DATA(1,JNUM,1) .LT. DATA(INUM,JNUM,1)) GO TO 50
      GO TO 99
   50 DO 55 I=1,INUM
      DO 55 J=1,JNUM1
      T1 = DATA(I,J,1)
      T2 = DATA(I,J,2)
      DATA(I,J,1) = DATA(I,JNUM+1-J,1)
      DATA(I,J,2) = DATA(I,JNUM+1-J,2)
      DATA(I,JNUM+1-J,1) = T1
   55 DATA(I,JNUM+1-J,2) = T2
   99 CALL HIDE
 1000 CONTINUE
      RETURN
      END
```

E.14 Subroutine HIDE

```
      SUBROUTINE HIDE                                                   011010
      COMMON DATA(103,103,2)/BLOCK1/TEST(500,2),TEST1(500,2),NUM/BLOCK2/ 011020
     1P(2),Q(2),JCUT                                                    011030
      COMMON/BLOCK3/INUM, JNUM,XMIN,YMIN,DX,DY,SWI,IT6                  011040
      LOGICAL SWI                                                       011050
      SIZE=8.                                                           011060
      KFLAG = 0                                                         011070
      JFLAG = 0                                                         011080
      IF (SWI) GOTO 2000                                                011090
      SMALL = DATA(1,1,1)                                               011100
      BIG = SMALL                                                       011110
      DO 5 J=1,JNUM                                                     011120
      DO 5 I=1,INUM                                                     011130
      IF (DATA(I,J,1) .LT. SMALL) SMALL = DATA(I,J,1)                   011140
5     IF (DATA(I,J,1) .GT. BIG) BIG = DATA(I,J,1)                       011150
      XMIN = SMALL                                                      011160
      DX = (BIG-SMALL)/SIZE                                             011170
      SMALL = DATA(1,1,2)                                               011180
      BIG = SMALL                                                       011190
      DO 6 I=1,INUM                                                     011200
      DO 6 J=1,JNUM                                                     011210
      IF (DATA(I,J,2) .LT. SMALL) SMALL = DATA(I,J,2)                   011220
6     IF (DATA(I,J,2) .GT. BIG) BIG = DATA(I,J,2)                       011230
      YMIN = SMALL                                                      011240
      DY = (BIG-SMALL)/SIZE                                             011250
      D = DY                                                            011260
      IF (DX .GE. DY) D=DX                                              011270
      DY = D                                                            011280
      DX = D                                                            011290
      GOTO 2010                                                         011300
2000  DO 10 I=1,JNUM                                                    011310
      TEST(I,1) = DATA(1,I,1)                                           011320
      TEST(I,2) = DATA(1,I,2)                                           011330
10    TEST1(I,1) = TEST(I,2)                                            011340
      CALL LINE(TEST,TEST1,JNUM,1,0,0,XMIN,DX,YMIN,DY,0.)               011350
      I = 1                                                             011360
      NUM = JNUM                                                        011370
      JCUT = 0                                                          011380
      ICUT = 2                                                          011390
20    JCUT = JCUT + 1                                                   011400
      KFLAG = 0                                                         011410
      JFLAG = 0                                                         011420
      IF (JCUT .EQ. JNUM+1) GO TO 100                                   011430
30    J = 0                                                             011440
      DO 35 I=2,NUM                                                     011450
      IF ((DATA(ICUT,JCUT,1) .LE. TEST(I,1)) .AND. (DATA(ICUT,JCUT,1)   011460
     1.GE. TEST(I-1,1))) GO TO 31                                       011470
      IF ((DATA(ICUT,JCUT,1) .LT. TEST(I,1)) .OR. (DATA(ICUT,JCUT,1)    011480
     1.GT. TEST(I-1,1))) GO TO 35                                       011490
31    B = (TEST(I,2)-TEST(I-1,2))/(TEST(I,1)-TEST(I-1,1))               011500
      C = TEST(I,2) - B*TEST(I,1)                                       011510
      Y = B*DATA(ICUT,JCUT,1) + C                                       011520
      IF (Y .LE. DATA(ICUT,JCUT,2)) GO TO 35                            011530
      J = J + 1                                                         011540
35    CONTINUE                                                          011550
      IF (2*(J/2) .EQ. J) GO TO 120                                     011560
      GO TO 400                                                         011570
100   JCUT = 1                                                          011580
      ICUT = ICUT + 1                                                   011590
      IF (ICUT .NE. INUM+1) GO TO 30                                    011600
      RETURN                                                            011610
120   IF (JCUT .EQ. 1) GO TO 200                                        011620
      P(1) = DATA(ICUT, JCUT,1)                                         011630
      P(2) = DATA(ICUT, JCUT-1,1)                                       011640
      Q(1) = DATA(ICUT, JCUT,2)                                         011650
      Q(2) = DATA(ICUT, JCUT-1,2)                                       011660
      IF (P(2) .GE. 6.0) GO TO 130                                      011670
      X = P(2)                                                          011680
      Y = Q(2)                                                          011690
      GO TO 200                                                         011700
130   CALL DRAW(X,Y,K,KFLAG)                                            011710
      IF (K .GT. NUM) GO TO 365                                         011720
200   P(1) = DATA(ICUT, JCUT,1)                                         011730
      P(2) = DATA(ICUT-1, JCUT,1)                                       011740
      Q(1) = DATA(ICUT.JCUT.2)
      Q(2) = DATA(ICUT-1.JCUT.2)
      IF (P(2) .GE. 6.0) GO TO 210
      X1 = P(2)
      Y1 = Q(2)
      GO TO 300
  210 CALL DRAW(X1.Y1.J.JFLAG)
      IF (J .GT. NUM) GO TO 365
  300 IF (JCUT .NE. 1) GO TO 305
      K = I
      GO TO 314
  305 CONTINUE
  600 FORMAT (5H HERE)
      IF (KFLAG .EQ. 1) GO TO 314
      DO 310 I=1.NUM
      IF ((X .EQ. TEST(I.1)) .AND. (Y .EQ. TEST(I.2)))GO TO 313
  310 CONTINUE
  311 FORMAT (10H 310 ERROR)
      GO TO 365
  313 K = I
  314 IF (JFLAG .EQ. 1) GO TO 320
      DO 315 I=1.NUM
      IF ((X1 .EQ. TEST(I.1)) .AND. (Y1 .EQ. TEST(I.2))) GO TO 318
  315 CONTINUE
  316 FORMAT (10H 316 ERROR)
      GO TO 365
  318 J = I
C     IF IFLAG IS SET. WE ARE LOOKING AT THE BACK OF THE SQUARE PIECE
C WHOSE CORNER IS DATA(ICUT.JCUT).  IN THIS CASE WE DO NOT DRAW THE
C LINE TO DATA(ICUT.JCUT-1). AND WE DO NOT INCLUDE IT IN THE SKYLINE.
C I.E. TEST.
  320 IFLAG = 0
      IF (JFLAG .EQ. 0) J = J + 1
      IF (J .LT. K) IFLAG = 1
      IF ((J .EQ. K) .AND. (ABS(X1-TEST(J.1)) .GT. ABS(X-TEST(J.1))))
     1IFLAG = 1
      JFLAG = 0
      KFLAG = 0
      I1 = 0
      DO 330 I=J.NUM
      I1 = I1 + 1
      TEST1(I1.1) = TEST(I.1)
  330 TEST1(I1.2) = TEST(I.2)
      IF (IFLAG .EQ. 0) GO TO 331
      K = J
      X = X1
      Y = Y1
      GO TO 335
  331 IF (JCUT .NE. 1) GO TO 335
      K = K - 1
      GO TO 340
  335 TEST(K.1) = X
      TEST(K.2) = Y
  340 TEST(K+1.1) = DATA(ICUT.JCUT.1)
      TEST(K+1.2) = DATA(ICUT.JCUT.2)
      TEST(K+2.1) = X1
      TEST(K+2.2) = Y1
      K = K + 2
      IF (J .EQ. (NUM + 1)) GO TO 350
      DO 345 I=1.I1
      K = K + 1
      TEST(K.1) = TEST1(I.1)
  345 TEST(K.2) = TEST1(I.2)
  601 FORMAT (1H .3I10)
  350 NUM = K
      IF (JCUT .EQ. 1) GO TO 355
      IF (IFLAG .EQ. 1) GO TO 355
      P(2) = X
      Q(2) = Y
      CALL LINE(P.Q.2.1.0.0.XMIN.DX.YMIN.DY.0.)
  355 P(2) = X1
      Q(2) = Y1
      CALL LINE(P.Q.2.1.0.0.XMIN.DX.YMIN.DY.0.)
  365 GO TO 20
  400 CONTINUE
  401 FORMAT (4H 400.2X.I10)
      IF (JCUT .EQ. 1) GO TO 500
      P(1) = DATA(ICUT.JCUT-1.1)
      P(2) = DATA(ICUT.JCUT.1)
      Q(1) = DATA(ICUT, JCUT-1,2)
      Q(2) = DATA(ICUT, JCUT,2)
      IF (P(1) .GE. 6.0) GO TO 500
      CALL DRAW(X,Y,K,KFLAG)
      IF (K .GT. NUM) GO TO 545
      P(2) = X
      Q(2) = Y
      CALL LINE(P,Q,2,1,0,0,XMIN,DX,YMIN,DY,0.)
  420 IC = ICUT
      JC = JCUT - 1
      CALL SORT(IC,JC,K,X,Y)
  500 P(1) = DATA(ICUT-1, JCUT,1)
      P(2) = DATA(ICUT, JCUT,1)
      Q(1) = DATA(ICUT-1, JCUT,2)
      Q(2) = DATA(ICUT, JCUT,2)
      IF (P(1) .GE. 6.0) GO TO 545
      CALL DRAW(X,Y,J,JFLAG)
      IF (J .GT. NUM) GO TO 545
      P(2) = X
      Q(2) = Y
      CALL LINE(P,Q,2,1,0,0,XMIN,DX,YMIN,DY,0.)
  520 IC = ICUT - 1
      JC = JCUT
      CALL SORT(IC,JC,J,X,Y)
  545 DATA(ICUT,JCUT,1) = DATA(ICUT,JCUT,1) + SIZE
      GO TO 365
 2010 RETURN
      END
```

E.15 Subroutine DRAW

```
      SUBROUTINE DRAW(X,Y,K,KFLAG)
      COMMON /BLOCK1/TEST(500,2),TEST1(500,2),NUM/BLOCK2/P(2),Q(2),JCUT
      SIZE=0.
      DIS = 0.
      IF (P(2) .GE. 6.0) GO TO 10
      GO TO 15
   10 P(2) = P(2) - SIZE
   15 Y = 15.0
      S = .00001
      B1 = (Q(2)-Q(1))/(P(1)-P(2))
      IP = LEGVAR(B1)
      IF (IP .NE. 0) GO TO 20
      C1 = Q(1) + B1*P(1)
   20 DO 90 I=2,NUM
      DX - TEST(I,1)-TEST(I-1,1)
      DY - TEST(I,2)-TEST(I-1,2)
      DS - S*SQRT(DX*DX+DY*DY)
      B2 = (TEST(I-1,2)-TEST(I,2))/(TEST(I,1)-TEST(I-1,1))
      IT = LEGVAR(B2)
      IF (IT .NE. 0) GO TO 35
      C2 = TEST(I,2) + B2*TEST(I,1)
      IF (IP .NE. 0) GO TO 40
      XX = (C2-C1)/(B2-B1)
      IF (LEGVAR(XX) .NE. 0) GO TO 90
      YY = C1-B1*XX
   25 IF ((TEST(I-1,1)-DS .LE.XX) .AND. (XX.LE. TEST(I,1)+DS)) GO TO 30
      IF ((TEST(I,1)-DS .LE.XX) .AND. (XX.LE. TEST(I-1,1)+DS)) GO TO 30
      GO TO 90
   30 IF ((P(1)-DS .LE.XX) .AND. (XX.LE. P(2)+DS)) GO TO 45
      IF ((P(2)-DS .LE.XX) .AND. (XX.LE. P(1)+DS)) GO TO 45
      GO TO 90
   35 IF (IP .NE. 0) GO TO 90
      XX = TEST(I,1)
      YY = C1-B1*XX
      IF ((TEST(I-1,2)-DS .LE.YY) .AND. (YY.LE. TEST(I,2)+DS)) GO TO 30
      IF ((TEST(I,2)-DS .LE.YY) .AND. (YY.LE. TEST(I-1,2)+DS)) GO TO 30
      GO TO 90
   40 XX = P(1)
      YY - C2-B2*XX
      IF ((Q(1)-DS .LE.YY) .AND. (YY.LE. Q(2)+DS)) GO TO 25
      IF ((Q(2)-DS .LE.YY) .AND. (YY.LE. Q(1)+DS)) GO TO 25             013220
      GO TO 90                                                          013230
 45   DX = P(1)-XX                                                      013240
      DY = Q(1)-YY                                                      013250
      D = SQRT(DX*DX+DY*DY)                                             013260
      IF (D .LT. DIS) GO TO 90                                          013270
      DIS = D                                                           013280
 153  FORMAT (1H ,F10.3)                                                013290
      X=XX                                                              013300
      Y=YY                                                              013310
      K = I                                                             013320
 90   CONTINUE                                                          013330
      IF (Y .EQ. 15.0) GO TO 110                                        013340
 152  FORMAT (1H ,I10,1X,2F10.3)                                        013350
      KFLAG = 1                                                         013360
 151  FORMAT (4H 150,2X,I10)                                            013370
      RETURN                                                            013380
 110  K = NUM + 1                                                       013390
 171  FORMAT (15H ERROR AT JCUT=,I2)                                    013400
      RETURN                                                            013410
      END                                                               013420
```

E.16 Subroutine SORT

```
      SUBROUTINE SORT(IC,JC,K,X,Y)                                      013430
      COMMON DATA(103,103,2)/BLOCK1/TEST(500,2),TEST1(500,2),NUM        013440
      COMMON/BLOCK3/INUM, INUM,XMIN,YMIN,DX,DY,SW1,IT6                  013450
      DO 10 I=1,NUM                                                     013460
      IF (TEST(I,1) .NE. DATA(IC,JC,1)) GO TO 10                        013470
      IF (TEST(I,2) .NE. DATA(IC,JC,2)) GO TO 10                        013480
      J = I                                                             013490
      GO TO 20                                                          013500
 10   CONTINUE                                                          013510
 431  FORMAT (4H 430,2X,4HK = ,I3,I10)                                  013520
      GO TO 99                                                          013530
 20   IF (J .LT. K) GO TO 30                                            013540
      IF (J .EQ. K) GO TO 99                                            013550
      KK = J                                                            013560
      JJ = K                                                            013570
      GO TO 40                                                          013580
 30   KK = K                                                            013590
      JJ = J + 1                                                        013600
 40   I1 = 0                                                            013610
      DO 50 I=KK,NUM                                                    013620
      I1 = I1 + 1                                                       013630
      TEST1(I1,1) = TEST(I,1)                                           013640
 50   TEST1(I1,2) = TEST(I,2)                                           013650
      TEST(JJ,1) = X                                                    013660
      TEST(JJ,2) = Y                                                    013670
      DO 60 I=1,I1                                                      013680
      JJ = JJ + 1                                                       013690
      TEST(JJ,1) = TEST1(I,1)                                           013700
 60   TEST(JJ,2) = TEST1(I,2)                                           013710
      NUM = JJ                                                          013720
 99   RETURN                                                            013730
      END                                                               013740
```

E.17 Subroutine PARFIT

```
      SUBROUTINE PARFIT(Y1,Y2,Y3,YF1,YF2)                                013750
C THIS SUBROUTINE FIT? A PARABOLA TO THREE DATA POINTS Y1,Y2,Y3, TAKEN    013760
C  AT EQUAL INTERVALS AND COMPUTES POINTS YF1,YF2, ON THE FITTED PARABOL  013770
C  , AT THE MIDDLE OF THE INTERVALS                                      013780
C                                                                        013790
      A=(Y1+Y3-2.*Y2)/8.                                                 013800
      B=(Y3-Y1)/4.                                                       013810
      C=Y2                                                               013820
      YF1=A-B+C                                                          013830
      YF2=A+B+C                                                          013840
      RETURN                                                             013850
      END                                                                013860
```

E.18 Subroutine CONTOR

```
      SUBROUTINE CONTOR(M,N,NLEVS,HLEVS,BLANK,XLEN,YLEN,XP,YP)           013870
C                                                                        013880
C     DRAW PENPLOT CONTOURS FROM RECTANGULAR GRID INPUT                  013890
C                                                                        013900
C     PARAMETERS                                                         013910
C                                                                        013920
C     Z           THE GIVEN FUNCTION                                     013930
C     M           NUMBER OF ROWS IN Z ARRAY                              013940
C     N           NUMBER OF COLS IN Z ARRAY                              013950
C     XT          TEMPORARY ARRAY     SIZE=(M*N)                         013960
C     YT          TEMPORARY ARRAY     SIZE=(M*N)                         013970
C     NLEVS       NUMBER OF CONTOURS                                     013980
C     HLEVS       CONTOUR VALUES                                         013990
C     BLANK       MSNG DATA CODE                                         014000
C     XLEN        LENGTH OF X-AXIS IN INCHES                             014010
C     YLEN        LENGTH OF Y-AXIS IN INCHES                             014020
C                                                                        014030
C        Z(I,J) ASSUMED TO BE IN ASSENDING ORDER BY X AND Y              014040
C             IE   Z(1,1) = Z(XMIN,YMIN)                                 014050
C                  Z(M,N) = Z(XMAX,YMAX)                                 014060
C                                                                        014070
C                                                                        014080
C     PROGRAM WILL PLOT ANY NUMBER OF CONTOURS                           014090
C            LINES ARE LABELED BY CHARACTERS 0 - 12                      014100
C                 CHARACTERS ARE REPEATED AS NECESSARY                   014110
C                                                                        014120
C     USES SUBROUTINES NETBOR AND FOUR                                   014130
C                                                                        014140
      DIMENSION HLEVS(1)                                                 014150
      COMMON Z(103,103),XT(103,103),YT(103,103)                          014160
      DIMENSION T(150)                                                   014170
      DIMENSION SX(3),SY(3),IC(4)                                        014180
      DIMENSION IO(16),IP(16)                                            014190
      DATA (IO(I),I=1,16,1)/-1,-1,-2,-1,-1,-2,-1,-1,-1,0,0,0,0,0,0,-1/   014200
      DATA(IP(I),I=1,16,1)/-1,-1,-1,0,0,0,1,0,0,1,0,0,0,-1,-1,-1/        014210
C                                                                        014220
      K=75                                                               014230
      XMIN=YMIN=0E0                                                      014240
      IFLAG=1                                                            014250
      YSYMB=YP-.2                                                        014260
      XPLT=XLEN+XP                                                       014270
      JLINE=8                                                            014280
C                                                                        014290
      CALL PLOT (0.0,0.0,3)                                              014300
      XSIZE=FLOAT(N-1)/XLEN                                              014310
      YSIZE=FLOAT(M-1)/YLEN                                              014320
      UD=M*N                                                             014330
C                                                                        014340
C  FIND ZMAX, ZMIN                                                       014350
```

```
C
      IMAX=0
      DO 13 I=1,M
      DO 12 J=1,N
      IF (Z(I,J).EQ.BLANK) GO TO 12
      IMAX=IMAX+1
      IF (IMAX.GT.1) GO TO 11
      ZMAX=Z(I,J)
      ZMIN=Z(I,J)
      GO TO 12
11    IF (Z(I,J).GT.ZMAX) ZMAX=Z(I,J)
      IF (Z(I,J).LT.ZMIN) ZMIN=Z(I,J)
12    CONTINUE
13    CONTINUE
      PRINT  100, ZMIN,ZMAX,NLEVS,(HLEVS(I),I=1,NLEVS)
C
C  GET H.
C
      ILEVS=0
99    ILEVS=ILEVS+1
      LLINE=ILEVS-1
      IF (ILEVS.GT.NLEVS) GO TO 999
      H=HLEVS(ILEVS)
      PRINT  200, H
      IDONE=0
      IF ((H.GE.ZMIN).AND.(H.LE.ZMAX)) GO TO 101
      PRINT  300
      GO TO 99
C
C  PREPARE THE XT-TABLE
C
101   DO 102 I=1,M
      DO 102 J=1,N
      XT(I,J)=UD
      IF (I.EQ.M) GO TO 102
      IF (Z(I   ,J).EQ.BLANK) GO TO 102
      IF (Z(I+1,J).EQ.BLANK) GO TO 102
      IF (((Z(I,J)-H)*(Z(I+1,J)-H)).GE.0.0) GO TO 102
      XT(I,J)=-ABS(FLOAT(I-1)+((H-Z(I,J))/(Z(I+1,J   )-Z(I,J))))
102   CONTINUE
C
C  PREPARE THE YT-TABLE
C
      DO 103 I=1,M
      DO 103 J=1,N
      YT(I,J)=UD
      IF (J.EQ.N) GO TO 103
      IF (Z(I,J   ).EQ.BLANK) GO TO 103
      IF (Z(I,J+1).EQ.BLANK) GO TO 103
      IF (((Z(I,J)-H)*(Z(I,J+1)-H)).GE.0.0) GO TO 103
      YT(I,J)=-ABS(FLOAT(J-1)+((H-Z(I,J))/(Z(I   ,J+1)-Z(I,J))))
103   CONTINUE
C
      DO 201 I1=1,4
201   IC(I1)=0
      DO 207 I=1,M
      DO 207 J=1,N
      IF (Z(I,J).NE.H) GO TO 207
C
C     COUNT ENTRANCES AND EXITS IN SURROUNDING BLOCKS
C
      DO 202 I2=1,16
      II=IO(I2)+I
      IF (II.LT.1.OR.II.GT.M) GO TO 202
      JJ=IP(I2)+J
      IF (JJ.LT.1.OR.JJ.GT.N) GO TO 202
      I1=(I2-1)/4+1
      IF((XT(II,JJ).NE.UD) .OR. (YT(II,JJ).NE.UD))IC(I1)=IC(I1)+1
202   CONTINUE
      IHOLD=0
      DO 206 I2=1,4
      IC(I2)=MOD(IC(I2),2)
      IF (IC(I2).EQ.0) GO TO 206
      IF (IHOLD.NE.0) GO TO 203
      IHOLD=I2
      GO TO 206
203   IF (I2-IHOLD.EQ.1) GO TO 204
      IF (IHOLD.EQ.1.AND.I2.EQ.4) GO TO 205
      GO TO 301
204   IF (I2+IHOLD.EQ.5) GO TO 205
```

```
      I3=I+I2-3
      XT(I3,J)=-ABS(FLOAT(I3-1)+.001)
      GO TO 207
205   I3=I-1
      J4=J+4-I2
      YT(I3.J4)=-ABS(FLOAT(J4)+.001)
      GO TO 207
206   CONTINUE
207   CONTINUE
C
301   IL=-30
      JL=-30
      KL=-30
      XF=UD
      YF=UD
C
C     COMPILE A LIST
C
302   CONTINUE
      DO 303 I=1.M
      DO 303 J=1.N
      KEY=1
      IF (XT(I.J).NE.UD) GO TO 304
      KEY=2
      IF (YT(I.J).NE.UD) GO TO 304
303   CONTINUE
C
      IF (IDONE.EQ.0) PRINT  400
      GO TO 99
C
304   IX=0
      IF (NEIBOR(KEY.I.J.KL.IL.JL).LE.0) GO TO 305
      IX=2
      T(1)=XF
      T(2)=YF
305   IL=I
      JL=J
      KL=KEY
      LB=1
      GO TO (306.307). KEY
306   XF=XT(I.J)
      YF=J-1
      GO TO 401
307   XF=I-1
      YF=YT(I.J)
C
C  ADD A POINT TO THE LIST
C
401   XS=XF
      YS=YF
      ISAVE=I
      JSAVE=J
      KSAVE=KEY
402   IF ((IX-K+2).LT.0) GO TO 404
      I47=1
      GO TO 801
403   CONTINUE
      T(1)=T(IX-1)
      T(2)=T(IX)
      IX=2
404   IX=IX+2
      T(IX-1)=ABS(XS)
      T(IX)=ABS(YS)
      IF (I47.EQ.1) GO TO 405
      IF (IX.LT.6) GO TO 406
405   IF (KSAVE.EQ.1) XT(ISAVE.JSAVE)=UD
      IF (KSAVE.EQ.2) YT(ISAVE,JSAVE)=UD
406   IF (IX.EQ.2) GO TO 501
      GO TO (407.409). KEY
C
C  THE POINT IS ON AN HORIZONTAL LINK
C
407   IF (XT(I.J).GE.0.0) GO TO 408
      XT(I.J)=ABS(XT(I.J))
      GO TO 501
409   XT(I.J)=UD
      GO TO 501
C
C     THE POINT IS ON A VERTICAL LINK
C
```

```
409   IF (YT(I.J).GE.0.0) GO TO 410
      YT(I.J)=ABS(YT(I.J))
      GO TO 501
410   YT(I.J)=UD
C
C     INTO BOX - IS THERE A WAY OUT
C
501   KH=0
      ISAVE=I
      JSAVE=J
      KSAVE=KEY
      GO TO (502.601). KEY
502   CONTINUE
      IF (LB.EQ.2) GO TO 505
      IF (J.EQ.N) GO TO 701
      IF (XT(I.J+1).EQ.UD) GO TO 503
      KH=KH+1
      KS=1
      SX(1)=XT(I.J+1)
      SY(1)=J
503   CONTINUE
      IF (YT(I.J).EQ.UD) GO TO 504
      KH=KH+1
      KS=2
      SX(2)=I-1
      SY(2)=YT(I.J)
504   CONTINUE
      IF (I.EQ.M) GO TO 508
      IF (YT(I+1.J).EQ.UD) GO TO 508
      KH=KH+1
      KS=3
      SX(3)=I
      SY(3)=YT(I+1.J)
      GO TO 508
505   CONTINUE
      IF (J.EQ.1) GO TO 701
      IF (XT(I.J-1).EQ.UD) GO TO 506
      KH=KH+1
      KS=4
      SX(1)=XT(I.J-1)
      SY(1)=J-2
506   CONTINUE
      IF (YT(I.J-1).EQ.UD) GO TO 507
      KH=KH+1
      KS=5
      SX(2)=I-1
      SY(2)=YT(I.J-1)
507   CONTINUE
      IF (I.EQ.M) GO TO 508
      IF (YT(I+1.J-1).EQ.UD) GO TO 508
      KH=KH+1
      KS=6
      SX(3)=I
      SY(3)=YT(I+1.J-1)
508   IF (KH.EQ.0.OR.KH.EQ.2) GO TO 701
      IF (KH.NE.1) CALL FOUR (T.IX.SX.SY.KS.KEY)
      GO TO (509.510.511.512.513.514). KS
509   KEY=1
      LB=1
      J=J+1
      GO TO 516
510   KEY=2
      LB=2
      GO TO 516
511   KEY=2
      I=I+1
      LB=1
      GO TO 516
512   KEY=1
      LB=2
      GO TO 515
513   KEY=2
      LB=2
      GO TO 515
514   KEY=2
      I=I+1
      LB=1
515   KS=KS-3
      J=J-1
516   XS=SX(KS)
```

```
      YS=SY(KS)
      IFLAG=2
      GO TO 402
C
C
  601 CONTINUE
      IF (LR.EQ.2) GO TO 604
      IF (I.EQ.M) GO TO 701
      IF (XT(I,J).EQ.UD) GO TO 602
      KH=KH+1
      KS=1
      SX(1)=XT(I,J)
      SY(1)=J-1
  602 CONTINUE
      IF (J.EQ.N) GO TO 603
      IF (XT(I,J+1).EQ.UD) GO TO 603
      KH=KH+1
      KS=2
      SX(2)=XT(I,J+1)
      SY(2)=J
  603 CONTINUE
      IF (I.EQ.M) GO TO 607
      IF (YT(I+1,J).EQ.UD) GO TO 607
      KH=KH+1
      KS=3
      SX(3)=I
      SY(3)=YT(I+1,J)
      GO TO 607
  604 CONTINUE
      IF (I.EQ.1) GO TO 701
      IF (XT(I-1,J).EQ.UD) GO TO 605
      KH=KH+1
      KS=4
      SX(1)=XT(I-1,J)
      SY(1)=J-1
  605 CONTINUE
      IF (J.EQ.N) GO TO 606
      IF (XT(I-1,J+1).EQ.UD) GO TO 606
      KH=KH+1
      KS=5
      SX(2)=XT(I-1,J+1)
      SY(2)=J
  606 CONTINUE
      IF (YT(I-1,J).EQ.UD) GO TO 607
      KH=KH+1
      KS=6
      SX(3)=I-2
      SY(3)=YT(I-1,J)
  607 CONTINUE
      IF (KH.EQ.0.OR.KH.EQ.2) GO TO 701
      IF (KH.NE.1) CALL FOUR (I,IX,SX,SY,KS,KEY)
      GO TO (608,609,610,611,612,613), KS
  608 KEY=1
      LR=2
      GO TO 615
  609 KEY=1
      LR=1
      J=J+1
      GO TO 615
  610 KEY=2
      I=I+1
      LR=1
      GO TO 615
  611 KEY=1
      LR=2
      GO TO 614
  612 KEY=1
      LR=1
      J=J+1
      GO TO 614
  613 KEY=2
      LR=2
  614 I=I-1
      KS=KS-3
  615 XS=SX(KS)
      YS=SY(KS)
      IFLAG=2
      GO TO 402
C
C   NO MORE POINTS
```

```
C
701   IF (NEIBOR(KEY,I,J,KL,IL,JL).LE.0) GO TO 704
      IF (IX.LT.6) GO TO 704
      IF (T(1).EQ.T(IX-1).AND.T(2).EQ.T(IX)) GO TO 704
      IX=IX+2
      T(IX-1)=ABS(XF)
      T(IX)=ABS(YF)
C
      GO TO (702,703), KEY
702   XT(I,J)=UD
      GO TO 704
703   YT(I,J)=UD
      GO TO (302,704), IFLAG
704   I47=2
C
801   LLINE=MOD(LLINE,13)
      IF (IX.NE.2) GO TO 901
      IF (LB.EQ.2) GO TO 802
      LB=2
      GO TO 501
802   IF(KEY .EQ. 1) XT(I,J)=UD
      IF(KEY .EQ. 2) YT(I,J)=UD
      GO TO 902
C
C
901   IDONE=IDONE+1
      CALL LINE (T(2),T(1),IX/2,2,JLINE,LLINE,XMIN,XSIZE,YMIN,YSIZE,.06)
      IF (IDONE.GT.1) GO TO 902
      YSYMB=YSYMB-0.2
      IF (YSYMB .LT. 0.) 110,120
 110  YSYMB=YP-.2
      XPLT=XPLT+2.
 120  CALL SYMBOL (XPLT ,YSYMB,0.09,LLINE,0.0,-1)
      CALL SYMBOL(3HOLD,3HOLD,.09,1H=,0.,1)
      ENCODE(10,1,ISYM) H
      CALL SYMBOL(3HOLD,3HOLD,.09,ISYM,0.0,10)
      PRINT  500, LLINE
902   IF(I47 .EQ. 1) GO TO 403
      IFLAG=1
      I=II
      J=JI
      KEY=KL
      GO TO 301
C
 1    FORMAT(G10.3)
100   FORMAT (*1BEGIN CONTOUR PLOT*,2G13.5,I5/(5X,10G13.5))
200   FORMAT (* CONTOUR*,G13.5)
300   FORMAT (10X,*OUTSIDE GRID*)
400   FORMAT (10X,*NO DATA*)
500   FORMAT (10X,*PLOTTED CHARACTER*,I3)
C
990   RETURN
      END
```

E.19 Subroutine NEIBOR

```
      FUNCTION NEIBOR (KA,IA,JA,KB,IB,JB)                               018090
C                                                                       018100
C                                                                       018110
C     NEIBOR=-1  IF NOT NEIGHBORS                                       018120
C     NEIBOR = 1  IF NEIGHBORS                                          018130
C                                                                       018140
C                                                                       018150
      DIMENSION K1(14),K2(14),IT(14),JT(14)                             018160
      DATA K1/1,1,1,1,1,1,2,2,2,2,2,2,1,2/                              018170
      DATA K2/1,1,2,2,2,2,1,1,1,1,2,2,1,2/                              018180
      DATA IT/0,0,0,0,1,1,0,0,-1,-1, 1,-1,0,0/                          018190
      DATA JT/-1,1,0,-1,-1,0,1,0,1,0,0,0,0,0/                           018200
      ID = IB-IA                                                        018210
      JD = JB-JA                                                        018220
      DO 90 I=1,14                                                      018230
      IF (KA-K1(I)) 80,50,80                                            018240
   50 IF (KB-K2(I)) 80,60,80                                            018250
   60 IF (ID-IT(I)) 80,70,80                                            018260
   70 IF (JD-JT(I)) 80,90,80                                            018270
   80 CONTINUE                                                          018280
      NEIBOR = -1                                                       018290
      GO TO 100                                                         018300
   90 NEIBOR = 1                                                        018310
      RETURN                                                            018320
  100 CONTINUE                                                          018330
      RETURN                                                            018340
      END                                                               018350
```

E.20 Subroutine FOUR

```
      SUBROUTINE FOUR(T,IX,SX,SY,KS,KEY)                                018360
      DIMENSION T(150),SX(3),SY(3)                                      018370
      IF(IX.GE.4) GO TO 498                                             018380
      KS=2                                                              018390
      RETURN                                                            018400
  498 SLOPT=(T(IX)-T(IX-2))/(T(IX-1)-T(IX-3))                           018410
      DO 515 I1=1,3                                                     018420
      XS=ABS(SX(I1))                                                    018430
      YS=ABS(SY(I1))                                                    018440
      SLOPE=(T(IX)-YS)/(T(IX-1)-XS)                                     018450
      IF(SLOPT*SLOPE .LT. 0.0) GO TO 515                                018460
      IF(KEY.EQ.1 .AND. I1.EQ.1) GO TO 515                              018470
      IF(KEY.EQ.2 .AND. I1.EQ.3) GO TO 515                              018480
      IF(KS.LE.3) GO TO 1                                               018490
      KS=I1+3                                                           018500
      RETURN                                                            018510
    1 KS=I1                                                             018520
      RETURN                                                            018530
  515 CONTINUE                                                          018540
      RETURN                                                            018550
      END                                                               018560
```

E.21 Function SYMBL

```
      FUNCTION SYMBL(TIM)                                              018750
      IF (MVGETX(TIM,1,1) .EQ. 55B) GOTO 100                           018760
      ENCODE(10,1,SYMBL) TIM                                           018770
      RETURN                                                           018780
  100 SYMBL=TIM                                                        018790
      RETURN                                                           018800
    1 FORMAT(G10.3)                                                    018810
      END                                                              018820
```

Appendix F

Fortran Listing for Program T3D

```
      PROGRAM T30(TAPE3,OUTPUT)
C REVISION---SEPT 18,1975
C PURPOSE---DISPLAY VALUES OF Fi AND F2 FROM TAPE3 (TEMP5 OUTPUT)
C     USING LINEAR INTERPOLATION BETWEEN TIMES.
C SUBROUTINE---
C    RTAPE3
      INTEGER DATAIN(100,3)
      EQUIVALENCE(I1,DATAIN)
      DATA IT3/3/
      REWIND IT3
      READ(IT3) DATAIN
      TLAST=TNEXT=0.
      IP=1
      DELT=.1*TAUMX
      WRITE 1,N0,NMX,DTAU0,TAUMX
      DO 100 I=1,10
      T=DELT*I
      CALL RTAPE3(T)
      WRITE 2,T
      WRITE 3,(F1(J),J=1,81,10)
      WRITE 3,(F2(J),J=1,81,10)
100   CONTINUE
1     FORMAT(1H1,* N0=*I3*, NMX=*I3*, DTAU0=*E13.6* TAUMX=*E13.6/
     +* VALUES OF F1 AND F2 AT 1,11,...,81*)
2     FORMAT(/* TAU=*E13.6)
3     FORMAT(/(4E13.6))
      END
```

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