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TITLE- PAP - Parametric Analysis Program

TM-70-1032-1

DATE- January 21, 1970

FILING CASE NO(S)- 804

AUTHOR(S)- P. F. Long

FILING SUBJECT(S)- (ASSIGNED BY AUTHOR(S))- Parameter Studies
Systems of Nonlinear Functions

ABSTRACT

PAP provides a systematic approach to Parametric Analysis of systems whose characteristics (dependent variables) are continuous functions of the system parameters (independent variables). It is designed to explore the parameter space of a system using as few system evaluations as possible. This is achieved by:

1. Program design features which reduce the number of approaches to the computer required to obtain a given degree of coverage of the parameter space.
2. Algorithms specifically designed to minimize the number of system evaluations.
3. Extensive use of interpolation and extrapolation.
4. The provision of a flexible contour plotting capability..

The approach taken by PAP is to apply n-2 (n is the number of system parameters) constraints to the parameter space for fixed values of the remaining two parameters. Determine solutions to this nonlinear constraint problem and map the solutions found to the points of a grid determined by the domains of the two parameters previously fixed. This gives rise to a number of functions of two variables defined at discrete points which represent the behavior of the constrained system. PAP provides an interpolation scheme to generate contours of these functions and a flexible plotting capability so that they may be displayed in various combinations.

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TECHNICAL MEMORANDUM

INTRODUCTION

The nature of parametric analysis is exploratory. A number of different systems must be studied to determine the one most likely to accomplish the required goals. Each system usually involves a number of parameters (independent variables) which determine the characteristics (dependent variables) of that system. Parametric analysis involves the study of the various characteristics of a system as functions of its parameters. By getting an overview of how the system characteristics behave as the parameters vary over their permissible values, the most promising systems can be selected for more careful study. At the single system level, this overview permits the determination of subsets of the permissible values of the parameters for which the characteristics are favorable. More careful attention can then be given to these subsets.

A few standard mathematical notions necessary for the following discussion will be reviewed here. Standard set notation is used, e.g., $\{x: 1 \leq x \leq 2\}$ is the set of all real numbers between and including 1 and 2, alternately denoted by $[1,2]$. The notation (a,b) is used to denote the ordered pair a,b. Let A and B be arbitrary sets, then AxB is defined to be the set $\{(a,b): a \varepsilon A, b \varepsilon B\}$, where "$\varepsilon$" means "is an element of". More generally, if $D_1, D_2, \ldots, D_k$ are arbitrary sets, then $D_1 \times D_2 \times \ldots \times D_k = \{(d_1, d_2, \ldots, d_k): d_i \varepsilon D_i, i=1,\ldots,k\}$. Let D and R be arbitrary sets, the set $\{(x,y): x \varepsilon D, y \varepsilon R\} = F$ is a function if and only if $(x,y_1) \varepsilon F$ and $(x,y_2) \varepsilon F$ implies that $y_1 = y_2$. D is called the domain of the function and R its range. Note that D and R are arbitrary sets; in particular, they may be sets of n and m dimensional vectors respectively. In which case, the function associates with each vector in D a unique vector in R.

Parametric analysis is equivalent to the study of m functions, $c_1, c_2, \ldots, c_m$, (the system characteristics) of n variables, $p_1, p_2, \ldots, p_n$, (the system parameters). Using vector notation let $C = (c_1, c_2, \ldots, c_m)$ and $P = (p_1, p_2, \ldots, p_n)$, then parametric analysis is the study of the function $\{(P, C(P)): P \varepsilon D\}$ where $D = D_1 \times D_2 \times \ldots \times D_n$ and D_i is the domain of p_i, $i = 1, 2, \ldots, n$. D is called the parameter space of the system. The objective of parametric analysis is to determine regions of the parameter space in which the characteristics are suitable. More precise simulation and/or more careful study can then be used to narrow these regions even further. In the final analysis, a single point of the parameter space will be chosen which represents what is hoped to be the best system for the required purpose.

Parametric analysis is often performed as follows: Suppose that n parameters are available, equality constraints are imposed on n-1 of the characteristics (for convenience say $c_1, c_2, \ldots, c_{n-1}$), i.e., for a fixed value of one of the parameters (say p_1) $p_2, p_3, \ldots, p_n$ are determined such that $c_i = k_i$, $i = 1, 2, \ldots, n-1$. This process is repeated for different values of p_1, until its domain is adequately covered. Various variables are then plotted as functions of p_1. This memorandum describes a method of parametric analysis (and the computer program which implements it) which substantially improves upon this procedure.

Functional Description

PAP uses a general technique for parametric analysis that is independent of, but easily adaptable to, particular studies. A number of procedures (PROC's) supplied by the user adapt PAP to the user's application. The system under study must be simulated by a number of user supplied subroutines. These subroutines and procedures are defined in detail later.

Consider a system described by the characteristics $C = (c_1, c_2, \ldots, c_m)$ which are continuous functions of the parameters $P = (p_1, p_2, \ldots, p_n)$. Let the interval $D_i = [a_i, b_i]$ be the domain of p_i, $i = 1, 2, \ldots, n$. Suppose that for each p_i, a Δp_i is given which divides the interval $[a_i, b_i]$ into an

integral number of subintervals, i.e., $(b_i-a_i)/\Delta p_i=q_i$ is an integer, $i = 1, 2,..., n$. Define the sets $Q_i = \{v_j: v_j = a_i+(j-1)\Delta p_i, j = 1, 2,..., q_i+1\}$, $i = 1, 2,..., n$. PAP provides four major functions and an interface capability:

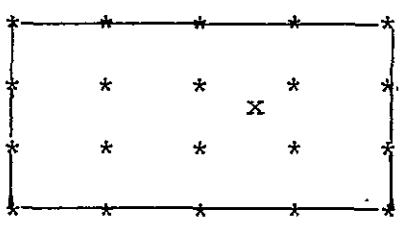
1. For a fixed point of $D_1 \times D_2$, an attempt is made to find all points of $D_3 \times D_4 \times ... \times D_n$ for which n-2 of the characteristics have specified values, i.e., for which $c_i = k_i$, $i = 1, 2,..., n-2$. This offers a number of advantages over the practice of making one attempt per run to find one solution:

    a. Potentially all solutions will be found.

    b. When none are found, it is strong evidence that no solutions exist for the given constraints in the particular parameter space under study.

    c. Given that complete coverage of the parameter space is required, the method provided tends to minimize the number of system evaluations required.

2. Consider the diagram below, $D_1 \times D_2$ is represented by the rectangle; $Q_1 \times Q_2$ is represented by the *'s; and the fixed point (p_1, p_2) is represented by x. An attempt is made to map each solution found at (p_1, p_2) to all points of $Q_1 \times Q_2$. This means that each solution found for the fixed point $(p_1, p_2) \varepsilon D_1 \times D_2$ is used as the initial value in the iterative attempt to determine the corresponding solution at some or all of its four nearest neighbors in $Q_1 \times Q_2$.



Digram

The solutions found at the four points of $Q_1 \times Q_2$ are used to determine the solutions at their neighbors in $Q_1 \times Q_2$. The resulting solutions are then used in a similar manner. This is continued until the solutions have been established for all points of $Q_1 \times Q_2$ or until failure to converge exhausts the untried neighbors. Given the initial solutions, this technique finds the solutions at the other points of $Q_1 \times Q_2$ in an efficient manner.

3. For the points of $Q_1 \times Q_2$ for which solutions are found, the remaining characteristics are computed and saved. This results in $p_3, p_4, \ldots, p_n, c_{n-1}, c_n, c_{n+1}, \ldots, c_m$ for each solution being expressed as a function of p_1 and p_2 defined over $Q_1 \times Q_2$.

4. An interface is provided for programs doing additional analysis and/or computations using the arrays of system characteristics as input.

5. A contour plotting capability is provided to plot the functions of two variables described in 3. It uses interpolation to approximate these functions over $D_1 \times D_2$. The methods used allow for the possibility that a particular solution is not determined for every point of $Q_1 \times Q_2$. In this case contours can be plotted over whatever subregions the available points of $Q_1 \times Q_2$ permit.

Methods

The methods used to perform the functions described above are as follows:

1. For convenience define $f_i = c_i - k_i$, $i = 1, 2, \ldots, n-2$ and let $F = (f_1, f_2, \ldots, f_{n-2})$; then $F=0$ means $c_i = k_i$, $i = 1, 2, \ldots, n-2$. Let $U = \sum_{i=1}^{n-2} f_i^2$ and note that $U = 0$ if and only if $F=0$. In order to find solutions, the Secant Method [1] for solving systems on nonlinear

functions is used in conjunction with a search strategy* designed to minimize the number of system evaluations required. The strategy is as follows:

a. Compute and save the value of U for each point of $Q_3 \times Q_4 \times \ldots \times Q_n$.

b. Find the smallest U not yet tried and use the corresponding point as the initial point for the Secant Method.

c. If the method converges to a new solution, save it; if the method moves toward a solution previously found, stop iterating; if the method fails to converge, record the number of successive failures.

d. Repeat steps b and c until the number of successive failures is greater than 10% of the number of points as yet untried.

A second search method (Total Domain Search Method) is available which starts the Secant Method at every point of $Q_3 \times Q_4 \times \ldots \times Q_n$. This method is a forerunner of the above method and is considerably less efficient in terms of system evaluations. It remains in the program in case all else fails or as a basis for comparison. Provisions are made for other search and iterative techniques that may be supplied by future users for their particular applications.

2. Solution mapping [2] is used to map each initial solution found to as many points of $Q_1 \times Q_2$ as possible. This is a technique whereby the extrapolation of the solutions found at two adjacent points is used as an initial guess for an iterative procedure in an effort to converge to solutions for the points on either side of the adjacent set. In the absence of adjacent sets, solutions at the four neighboring points are used as initial guesses.

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*Referred to hereafter as "Optimum Domain Search" method.

3. For each grid* point (p_1, p_2) and the corresponding solutions (p_3, p_4,..., p_n), the system characteristics are computed and stored.

4. To perform functions special to a particular application of PAP, control is transferred to the user supplied subroutine AUXPRO.

5. The set of grid points* for which a solution is found and the corresponding non-grid parameter and characteristics represent a number of functions of two variables. Two-directional parabolic interpolation is used in a scheme using nine grid points at a time to find the contours of the specified functions. If less than nine points are available, various combinations of parabolic and linear interpolation are used as the number of available grid points permits. Subroutine INGRID [4] generates the contours and PLTCON [3] plots them.

A number of features of the program that make it flexible and easy to use are:

1. The program structure provides for additional search methods and different methods for solving systems of nonlinear equations. Also, given the appropriate search and iterative methods, a more general problem may be studied using the program: Let H be a continuous function of P. For a given point of $D_1 \times D_2$, find the points of $D_3 \times D_4 \times \ldots \times D_n$ such that $F(P) = 0$ and $H(P)$ is optimum. This problem requires that $0 \leq r < n - 2$ where r is the number of equality constraints (r=0 means no equality constraints are imposed).

2. It is possible to stop the program after any of the five major functions have been performed, saving the data necessary to restart the program at this point.

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*The "set of grid points" or "the grid" means the set $Q_1 \times Q_2$.

3. A number of different grids and the corresponding characteristics can be made available to AUXPRO simultaneously.*

4. It is possible for the user to specify most of the input variable names. This makes it possible for him to select a set of input variables that are natural to his application and it could reduce the number of inputs required.*

The Simulator

The user must supply a number of procedures (PROC's) and subroutines which simulate the system under study and perform various I/O functions. When the procedures have been written as specified below, the main program, PAP, and subroutine RPD, must be compiled with the PDP element containing these PROC's. This creates relocatables for PAP and RPD which are particular to the application at hand. These relocatables, the relocatables for the other PAP subroutines, and the relocatables for the user's subroutines can then be collected into an absolute element and executed. The size of the program requires overlays, the modularity of the program makes this easy to do. This will be discussed in the Program Description section.

Description of User Supplied PROC's

The user may not need to make use of all the PROC's defined below; however, as PAP references each PROC name, at least a blank PROC by that name must be provided.

All but one of the Users PROC's are included (by a FORTRAN V Include statement)** in the main program PAP. These are discussed in the order they are included.

The first two PROC's contain documentation only. They are included at appropriate places to make the introductory commentary complete. Their suggested use is as follows:

RUNDOC — contains the names and definitions of the input variables in namelist RUNDAT which is specified by the user in PROC RUNNL defined below.

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*See [6] for an example of a use of this feature.

**See "INCLUDE Statements", UNIVAC 1108 FORTRAN V Programmers Reference Manual.

SAVDOC — contains the names and definitions of the input variables in namelist SAVDAT which is specified by the user in PROC SAVNL defined below.

The next procedure provides the means of communication between PAP and the user's subroutines.

KOMUSE — contains labeled common USE or other labeled commons not used by PAP and its subroutines.

The next two PROC's specify two namelists which are to be used as the means of defining all of the control variables required by the simulator and PAP except for the plot control variables which are read by namelist PLTDAT specified in PAP. The variables required by PAP are defined in Tables 1 and 2. Variables KON, IUNIT, ICHSA, and NFR must appear explicitly in namelist RUNDAT. The other variables in Tables 1 and 2 may appear in either namelist RUNDAT or SAVDAT or they may be defined in SIMDFN (a PROC defined below) using variables read by these two namelists. The PROC's specifying namelists RUNDAT and SAVDAT are defined as follows:

RUNNL — contains namelist RUNDAT which is used to read those input variables relevant to the current run only.

SAVNL — contains namelist SAVDAT which is used to read all input variables that may be needed in case of restart. These include the variables that control the simulation, analysis, and define the constraints. This namelist is saved each time a data set is saved.

The next PROC is included before any executable statements. It may be used to initialize variables at the beginning of a run, or to read in a data base. It may also be used to set the values of various inputs that are not often changed. These inputs can be changed when necessary by the subsequent reading of namelist RUNDAT, SAVDAT, and PLTDAT. In summary,

INITIL — contains the FORTRAN code that initializes various variables at the beginning of a run.

The next PROC is included after namelist RUNDAT, SAVDAT, and PLTDAT have been read. It may be used to derive from the variables read by namelists RUNDAT and SAVDAT the specific variables required by the simulation and PAP. If all of the control variables are defined in the namelists in

just the form required by PAP and the simulation, this procedure can be left empty. However, it is generally useful to choose the input variables in a way that make their functions easy to remember and the specification of a data case as simple as possible, letting the computer translate them to the exact form required by the program.

SIMDFN — contains the FORTRAN code which performs this translation.

The last PROC is included in subroutine RPD which reads namelist SAVDAT from the logical unit specified in its argument list. None of the information read is passed to other parts of the program. The need for this subroutine arises when plot data is to be read from more than one logical unit. Namelist SAVDAT is at the beginning of all these data files but only one reading of the namelist is required by the program. Subroutine RPD is called to read pass namelist SAVDAT. The PROC required by RPD is defined as follows:

RPDDS — contains a dimension statement for all variables in namelist SAVDAT. The dimension and size of each array must correspond to its dimension and size in PAP. This dimension statement may use the parameter statement found in the PROC PARSTA (see Appendix C for PARSTA listing).

Description of User Supplied Subroutines

Let CS be the vector of differences between the constraint functions and their desired (target) values.* A subroutine must be provided which computes CS as a function of the given values of the parameters, P. The subroutine's entry point must be

CONSTR(P,CS).

A subroutine must be provided which computes the characteristics, C, of the system for given values of the parameters, P. This subroutine's entry point must be

CHARAC(P,C).

---

*CS corresponds to $F = (f_1, f_2, \ldots, f_{n-2})$ discussed earlier.

The next subroutine whose entry point is

PRTCHA(P,C)

must be provided to print P and C in a format that suits the user.

The last subroutine whose entry point is

AUXPRO

may be used as an interface for other subroutines that perform functions that use the data generated by PAP and/or the plotting capability it provides.

Appendix B provides listings for the procedures and subroutines required by the test case discussed later.

Usage

The five major functions of PAP are performed respectively, by the five subroutines: INISOL, FILGRD, COMCHA, AUXPRO, and PLTCON. Each of these subroutines, except INISOL, requires data generated by some one of the other subroutines. The data generated by a call to one of the five major subroutines is called a data set for that subroutine. In order to start the program at any subroutine, other than INISOL, the necessary data set must have been generated and saved. Data sets for up to three calls each to INISOL, FILGRD, and COMCHA and two calls to AUXPRO can be saved during any execution of PAP. These data sets can subsequently be made available to the appropriate subroutines for further processing later in the same execution or in subsequent executions. The data sets are saved on logical units as follows:

Subroutine	Logical Units
INISOL	8, 9, 10
FILGRD	11, 12, 13
COMCHA	14, 15, 16
AUXPRO	17, 18

Figure 1 is a functional flowchart of PAP showing all of the possible paths through the program. Taking one of these paths is said to be a pass. A pass during which the data set from a particular major subroutine is saved is called

a save pass for that subroutine. A single pass may be a save pass for more than one major subroutine. Any number of passes may be made during any execution as long as the number of save passes does not exceed the limits stated earlier, i.e., three save passes each for INISOL, FILGRD, COMCHA, and two save passes for AUXPRO.

The functional blocks of Figure 1 are numbered 1 through 5. The return to the beginning of the program is numbered 6 and EXIT is numbered 7. These numbers are used to define the sequence of subroutine calls during the course of an execution. The user determines the sequence by setting an input variable (KON).

Figure 2 shows how data cases are read. If a pass begins at INISOL, namelists RUNDAT and SAVDAT are read from cards in that order. If a pass begins at any other point, RUNDAT is read from cards, SAVDAT is then read from IUNIT (an input variable), and finally at the option of the user, SAVDAT may be reread from cards. This feature gives the user the ability to stop a pass after any subroutine, save the necessary data set (namelist SAVDAT will be saved also), and studying the results before deciding whether or not to continue. If it is decided to continue, the data in namelist SAVDAT may be used as it was stored, or it may be altered by reading SAVDAT from cards before continuing. Namelist PLTDAT is read once for each frame to be generated.

Definition of PAP Input Variables

The names and descriptions of all input variables required by PAP are given in Tables 1, 2, and 3. Tables 1 and 2 contain all the PAP input variables that must be defined by means of namelists RUNDAT and SAVDAT. These two namelists must be specified by the user in PROC's, RUNNL and SAVNL. The variables KON, IUNIT, ICHSA, and NFR must appear explicitly in namelist RUNDAT. The remaining variables described in Tables 1 and 2 may appear in either namelist explicity or, they may be defined by user supplied FORTRAN code in PROC's INITIAL or SIMDFN. If some of the inputs to PAP do not change for a particular application, then they may be set once and for all in PROC INITIL. Those variables that change from run to run and therefore depend on the input variables read by namelists RUNDAT and SAVDAT may be defined by user supplied FORTRAN code in the PROC SIMDFN. Input variables required to define and control the user's simulation may be read using these namelists also.

Variables defined by means of namelist RUNDAT should pertain to the bookkeeping details of the run. Table 1 gives the PAP input variables usually defined by means of this namelist. Namelist SAVDAT is saved each time a data set is saved. It should contain the variables which define the type of simulation being done, the constraints being satisfied, and the number and bounds of the parameters. It should also contain any other variables that may be needed to identify the data or to restart the program later.

Namelist PLTDAT is specified in PAP and contains the variables required to define a single frame that is to be plotted. It is read NFR times in sequence storing the information so that it is related to the particular frame being defined. None of the input variables are distributed, therefore, a subsequent namelist PLTDAT need only contain the variables that differ from the preceding one.

TABLE 1

Name	Type/Size	Description
KON	INT/8	Control sequence indicator. KON(J) = I ($1 \leq I \leq 5$) causes subroutine I* to be called Jth in the sequence. KON(J) = 6* returns control to the beginning of the program. KON(J) $\geq$ 7* causes normal termination of the execution.
IUNIT	INT/	Initial data unit. Defines the logical unit from which SAVDAT and the appropriate data set are read if the program is to be stated at a point other than INISOL, i.e., if KON(1) > 1.
ICHSA	INT/	Data change indicator. If ICHSA = 1 and KON(1) > 1, namelist SAVDAT is read from logical unit 5 after it is read from logical unit IUNIT. If ICHSA $\neq$ 1 and KON(1) > 1, SAVDAT is read from IUNIT only. When KON(1) = 1, ICHSA has no effect.

*See Figure 1.

TABLE 1 (cond.)

Name	Type/Size	Description
NFR	INT/	Number of frames to be plotted. Causes namelist PLTDAT to be read NFR times.
NF14 NF15 NF16 NF17 NF18	INT/	Plot data file flags. Plot data is to be read from the logical unit indicated by the numerical suffix of the variable name when that variable is set to 1. If only one logical unit is being used, these variables may be ignored.
ISAI ISAF ISAC ISAA	INT/	Data set save flags. These flags when set to 1 cause the data set of the subroutine whose initial is the same as the last letter of the variable name to be saved.
IPRI	INT/	INISOL print flag. The solutions found are always printed. If IPRI = 1, the search progress is also printed.
IPRF	INT/	FILGRD print flag. A display of the grid points for which solution were found and the percentage of points converging is always printed. If IPRF = 1, solution mapping progress is printed also.
IPRC	INT/	COMCHA print flag. = 0, no results printed. = K, ($K \geq 1$) subrouting PRTCHA is called at the corner points of the grid and at points of the grid defined by the intersections of the Kth, 2Kth, 3Kth,..., grid lines.
IPRA	INT/	AUXPRO print flag. For use by the user.

TABLE 1 (cond.)

Name	Type/Size	Description
IPRP	INT/	PLTCON print flag. $\leq$ 0, no printing. $\geq$ 1, frame summary table, drum storage information, and function arrays printed. $\geq$ 2, function value and availability arrays printed by INGRID. $\geq$ 3, point selection map printed by INGRID.

TABLE 2

Name	Type/Size	Description
NP	INT/	Number of parameters (independent variables).
A	REA/10	Lower bounds for the domains of the parameters.
B	REA/10	Upper bounds for the domains of the parameters.
DELP	REA/10	Step size for the parameters. DELP(1) and DELP(2) determine the grid mesh. DELP(3), DELP(4),..., DELP(NP) determine the search step size.
P1I	REA/	The value of P(1) while the parameter space of P(3), P(4),..., P(NP) is being searched. $A(1) \leq P1I \leq B(1)$.
P2I	REA/	The value of P(2) while the parameter space of P(3), P(4),..., P(NP) is being searched. $A(2) \leq P2I \leq B(2)$.
NCS	INT/	The number of equality constraints to be satisfied, NCS = NP-2*.
EPS	REA/8	The maximum acceptable differences between the constraint functions and their target functions.
ISM	INT/	To use the Optimum Domain Search, set ISM=3. To use the Total Domain Search, set ISM=1. Provisions are made for three other techniques that may be required by future users. For these, use ISM=2, 4, or 5.

*At present this variable is superfluous. However, if optimization subject to equality constraints is implemented, it can be used as follows: $0 \leq NCS \leq NP-2$, where NCS=0 implies optimization only; NCS=NP-2 implies equality constraints only; and, $0 < NCS < NP-2$ implies optimization subject to NCS equality constraints.

TABLE 2 (cond.)

Name	Type/Size	Description
ICM	INT/	Iterative procedure selector. = 3, the secant method is used (subroutine CONV3). Provisions are made for four other methods which may be required by future applications. For these, use ICM = 1, 2, 4, or 5.
NSG	INT/	Number of initial solutions to be mapped. NSG $\leq$ 5.
ISGR	INT/5	If the Ith grid is to be mapped using the Jth solution as a starting point, set ISGR(I) = J. This grid will be identified by the number of the solution from which it is mapped.
NCG	INT/	The number of grids for which characteristics are to be computed.
ICCH	INT/5	If the Ith set of characteristics to be computed uses the grid mapped from the Jth solution, set ICCH(I) = J. Note that the Jth solution must have been mapped.
NC		Number of characteristics computed for each grid point.

TABLE 3

Name	Type/Size	Description
IOS	INT/	Plotting option selector. = 0, off-line plots only. = 1, printer plots only. = 2, both types.
FTLT	HOL/8	48 character frame title.
ALAB	HOL/8	48 character abscissa label.
OLAB	HOL/8	48 character ordinate label.
LABC	INT/	Not used at present.
AMI	REA/	Minimum value of the frame abscissa.
AMA	REA/	Maximum value of the frame abscissa.
OMI	REA/	Minimum value of the frame ordinate.
OMA	REA/	Maximum value of the frame ordinate.
NFU	INT/	Number of functions on this frame ($\leq$10).
IUN*	INT/10	Logical unit indicators. IUN(J) = I means that the Jth function of this frame is to be read from logical unit I.
ISO	INT/10	Solution numbers. ISO(J) = I means that the Jth function of this frame is from the Ith solution.

*The remaining variables in this table require a value corresponding to each function to be plotted on the present frame.

TABLE 3 (cond.)

Name	Type/Size	Description
IVA	INT/10	Variable numbers. IVA(J) = I means that the Jth function of this frame is the Ith variable of the solution.
P1IN	REA/10	Interpolation increments for the first independent variables. DELP(1)/P1IN should be a positive integer.
P2IN	REA/10	Interpolation increments for the second independent variables. DELP(2)/P2IN should be a positive integer.
ICD	INT/10	Contour plane indicators. = 0, constant function contours. = 1, first variable constant contours. = 2, second variable constant contours.
IAOS	INT/10	Abscissa-ordinate selectors. = 0, P(1)/P(2), P(2)/F, or P(1)/F is the abscissa/ordinate. = 1, the reverse is true.
CMI	REA/10	Minimum contour values (used when ICD=0).
CMA	REA/10	Maximum contour values (used when ICD=0).
CIN	REA/10	Step size between contours (used when ICD=0).
INS	INT/10	Indices of the initial contours (used when ICD=1 or 2).
LAS	INT/10	Indices of the final contours (used when ICD=1 or 2).
ISI	INT/10	Increments of indices (used when ICD=1, or 2).

Test Case

It should be pointed out and emphasized that PAP does not require that the system under study be represented by a set of closed form equations. On the contrary, the most valuable applications of PAP are those which require considerable effort to compute the system characteristics and constraints, e.g., see Reference [6]. However, to test and to illustrate the use of PAP, a contrived system which is represented by a set of closed form equations was chosen. This avoids the needless confusion introduced by a complicated simulation and allows full attention to be given to the method.

To simplify notation let $(u,v,w,x,y,z) = (p_1, p_2, \ldots, p_6)$. Consider the system described by the following characteristics:

$$c_1 = wxe^{(yz+uv)}$$

$$c_2 = 10wx\sin(yz+uv)$$

$$c_3 = wy^2 + 5xz + uv$$

$$c_4 = 10wxyz - uv$$

$$c_5 = u^2 + v^2 + (1-w)^2 + (1-x)^2 + y^2 + z^2$$

Let

$$f_1 = c_2 - 9.093$$

$$f_2 = c_3 - 7.0$$

$$f_3 = c_4 - 9.0$$

$$f_4 = c_5 - 4.0$$

Let the interval domains of the parameters be [0,1.4], [0,1.4], [.75, 1.25], [.75, 1.25], [.75, 1.25], and [.75, 1.25]; and let $\Delta p_i = (.2, .2, .25, .25, .25, .25)$.

With $p_1 = 1.$ and $p_2 = .75$, $D_3 \times D_4 \times \ldots \times D_6$ was searched. Two solutions were found and mapped to as many points of $Q_1 \times Q_2$ as possible. Appendix A contains selected pages of the output and a number of the resulting plots. Appendix B contains listings of the test case simulation subroutines and PROC's.

Program Description

Listings for the following are given in Appendix C:

PAP	COMCHA	VCP
PAPSPC	PLTCON	CONV3
RPD	SEEK1	GAUSS
INISOL	SEEK3	INPR
FILGRD	CONV	GRIDMK
		FRMPLT

The introductory commentary contained in these subroutines describes their functions (see Purpose) as related to the overall program. Subroutines PLTCON and FRMPLT are slight variations of those documented by [3, 4, 5]. The subroutines they reference are unchanged and are described in the above references. Two other subroutines are referenced - OCLOCK and RKPLOT; they are available from the Bellcomm Applications Program Library.

When executing the test case, the following overlay scheme required a maximum of $(41000)_{10}$ words of core storage:

PAP

INISOL

FILGRD

COMCHA

AUXPRO

PLTCON

Paul F. Long

1032-PFL-prs P. F. Long

Attachments

REFERENCES

1. "The Secant Method for Simultaneous Nonlinear Equations", Philip Wolfe, Comm. A.C.M. 2 (12), 1956.

2. "Solution Mapping - a Method of Parametric Analysis", P. F. Long, Bellcomm Memorandum for File, April 16, 1968.

3. "Description of PLTCON - Contour Plotting Program", P. F. Long, Bellcomm Memorandum for File, June 25, 1969.

4. "INGRID - A Contour Generating Program", M. P. Odle, Bellcomm Memorandum for File, June 30, 1969.

5. "Computer Program Abstract and Write-Up for SCPLOT - A General Purpose Interface to the S-C 4020 Plotter", O. R. Pardo, Bellcomm Memorandum for File, August 18, 1969.

6. "INTAP - Interplanetary Trajectory Analysis Program", R. W. Grutzner, Bellcomm Technical Memorandum (in preparation).

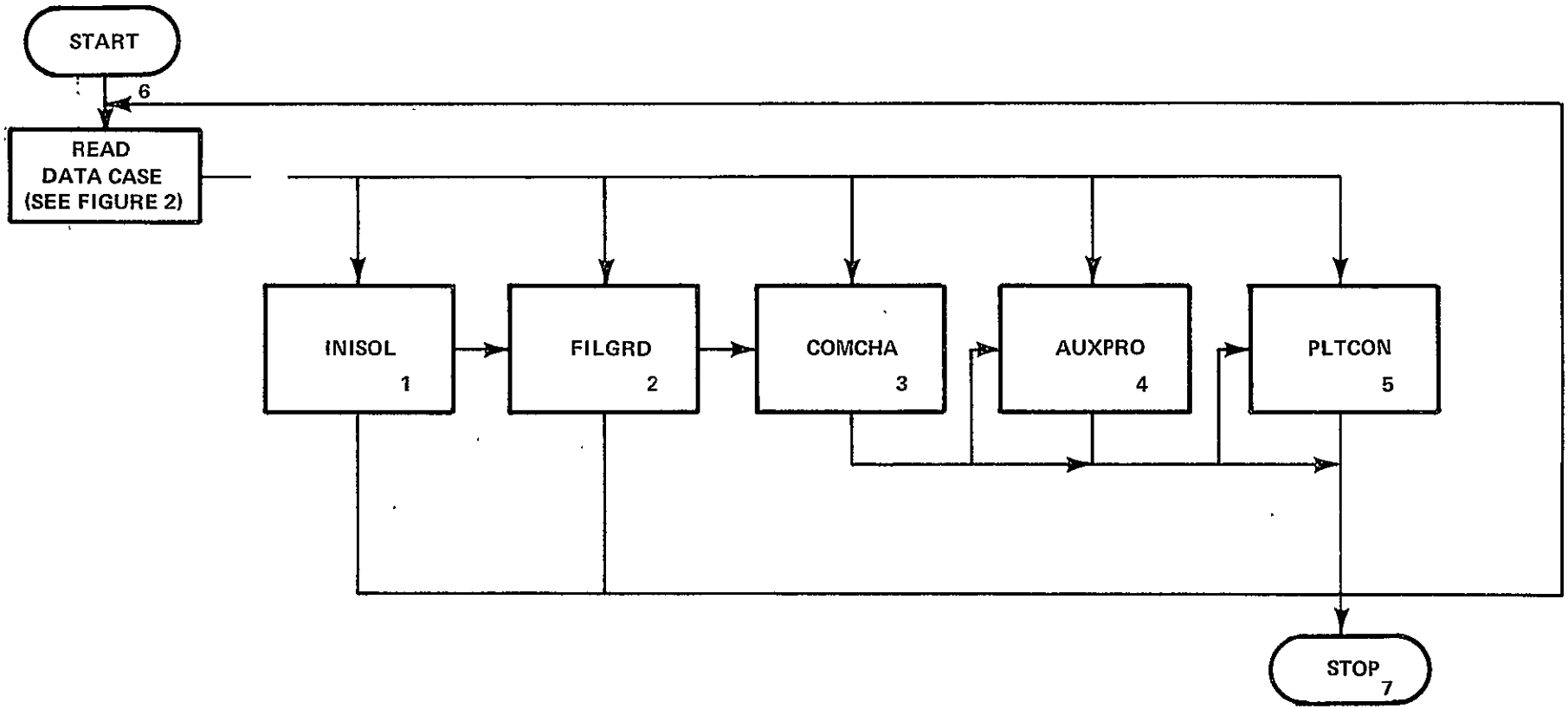


FIGURE 1 – FUNCTIONAL FLOWCHART OF PAP

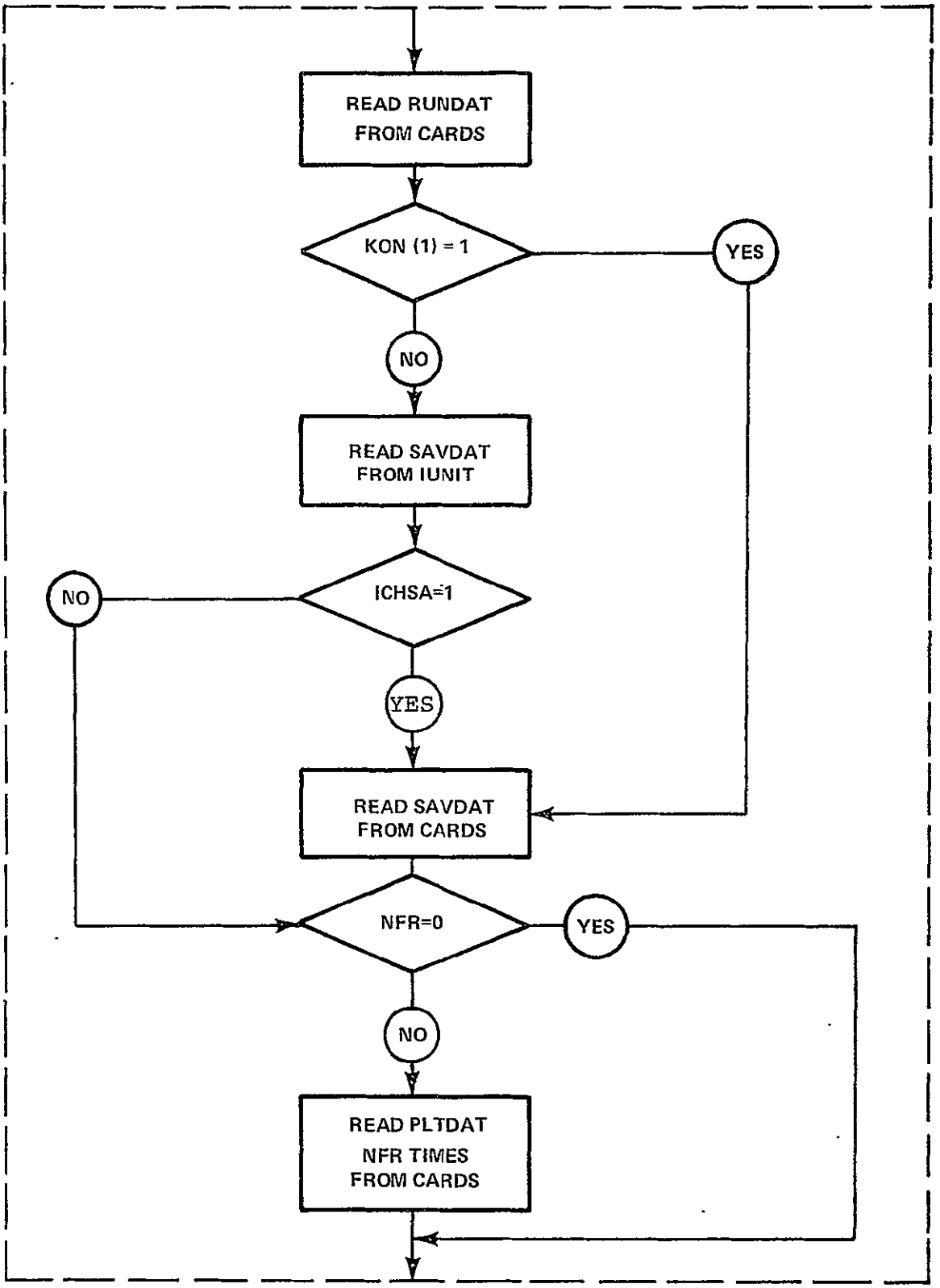


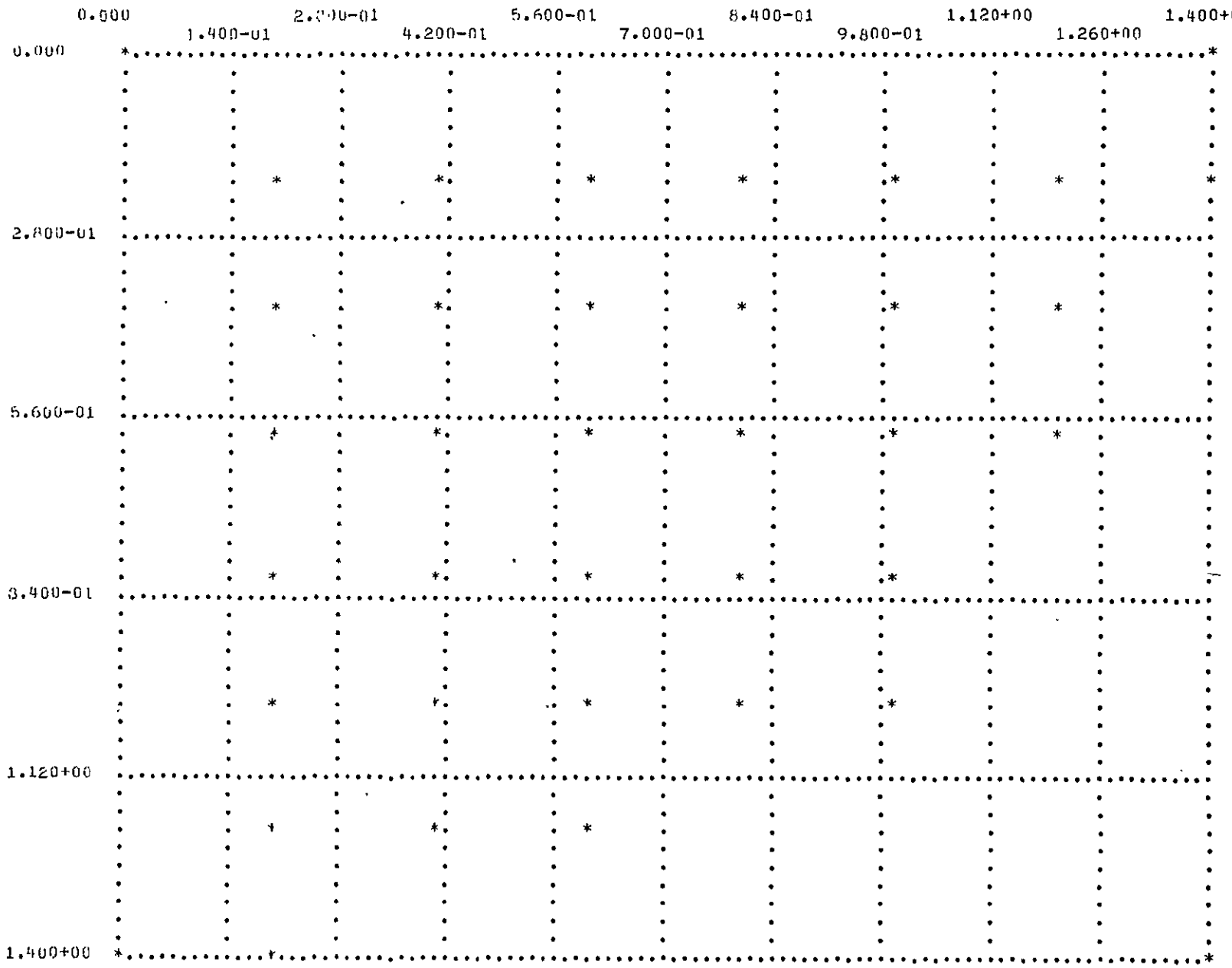
FIGURE 2 - READ DATA CASE

APPENDIX A

Selected Pages of
Test Case Output and Plots

```
$        XOT      ,OCM11,PAPLNK
 KO=1,2,3,5,7,NPN=5,
 IPNP=1,
 ISO=3,ICO=3,
 $END
 ISO=2,NCO=2,ISOR=1,2,ICOH=1,2,
 A=2*.8,4*.75,
 B=2*1.4,4*1.25,
 DELP=2*.2,4*.25,
 P11=1.,P21=.75
 NP=6,NCS=4,NC=5,
 EPS=4*.0001,
 IFS=2,4,5,3,
 TV=9.093,9.,4.,7.,
 $END
 FTLT='   P(3) OF SOLUTION 1 ',
 IOS=2,ALAB='        P(1)        ',OLAB='        P(2)
 AMA=1.4,OMA=1.4,NFU=1,IUN=26,ISO=1,IVA=1,
 P11N=.01,P21N=.01,CMI=.5,CMA=.9,CIN=.05,
 $END
 FTLT='   P(4) OF SOLUTION 1 ',
 IVA=2,CMI=1.,CMA=2.5,CIN=.2,
 $END
 FTLT='   P(5) OF SOLUTION 1 ',
 IVA=3,CMI=.9,CMA=1.6,CIN=.1,
 $END
 FTLT='   P(6) OF SOLUTION 1 ',
 IVA=4,CMI=.4,CMA=1.1,CIN=.1,
 $END
 FTLT='   C(1) OF SOLUTION 1 ',
 IVA=5,CMI=2.,CMA=8.,CIN=1.,
 $END

*****CALL INISOL AT TIME 13:24:43.545*****

     2 SOLUTION(S) FOUND

         1   .10000000+01   .75000000+00   .75656846+00   .12328266+01   .12920982+01   .80901879+00
         2   .10000000+01   .75000000+00   .11190744+01   .83346562+00   .78293543+00   .13351467+01

*****SYSTEM EVALUATED  135 TIMES IN INISOL*****

*****CALL FILGRD AT TIME 13:25:27.253*****

*****MAP SOLUTION NO.  1*****

*****PERCENTAGE OF POINTS CONVERGING =  51.563*****

*****PERCENTAGE OF POINTS CONVERGING =  51.563*****
```

STANDARD 4-D PAP TEST DATE 122369 PAGE 4



POINTS FOR WHICH SOLUTIONS WERE FOUND - P1 VERTICAL AXIS, P2 HORIZONTAL AXIS, PERCENTAGE 51.563

STANDARD 4-G PAP TEST DATE 122369 PAGE 8

PAGE NO.	PLOT OP.	AMIN	AMAX	OMIN	OMAX									
		UNIT	SOL.NO.	VAR.NO.	XY OP.	DELP1	DELP2	CMIN	CMAX	CDEL	IVS	IS	LS	INC
1	2	.0	1.4	.0	1.4									
		26	1	1	0	.01	.01	.50	.90	.05	0	0	0	0
2	2	.0	1.4	.0	1.4									
		26	1	2	0	.01	.01	1.00	2.50	.20	0	0	0	0
3	2	.0	1.4	.0	1.4									
		26	1	3	0	.01	.01	.90	1.60	.10	0	0	0	0
4	2	.0	1.4	.0	1.4									
		26	1	4	0	.01	.01	.40	1.10	.10	0	0	0	0
5	2	.0	1.4	.0	1.4									
		26	1	5	0	.01	.01	2.00	8.00	1.00	0	0	0	0

STANDARD 4-D PAP TEST. DATE 122369 PAGE 10

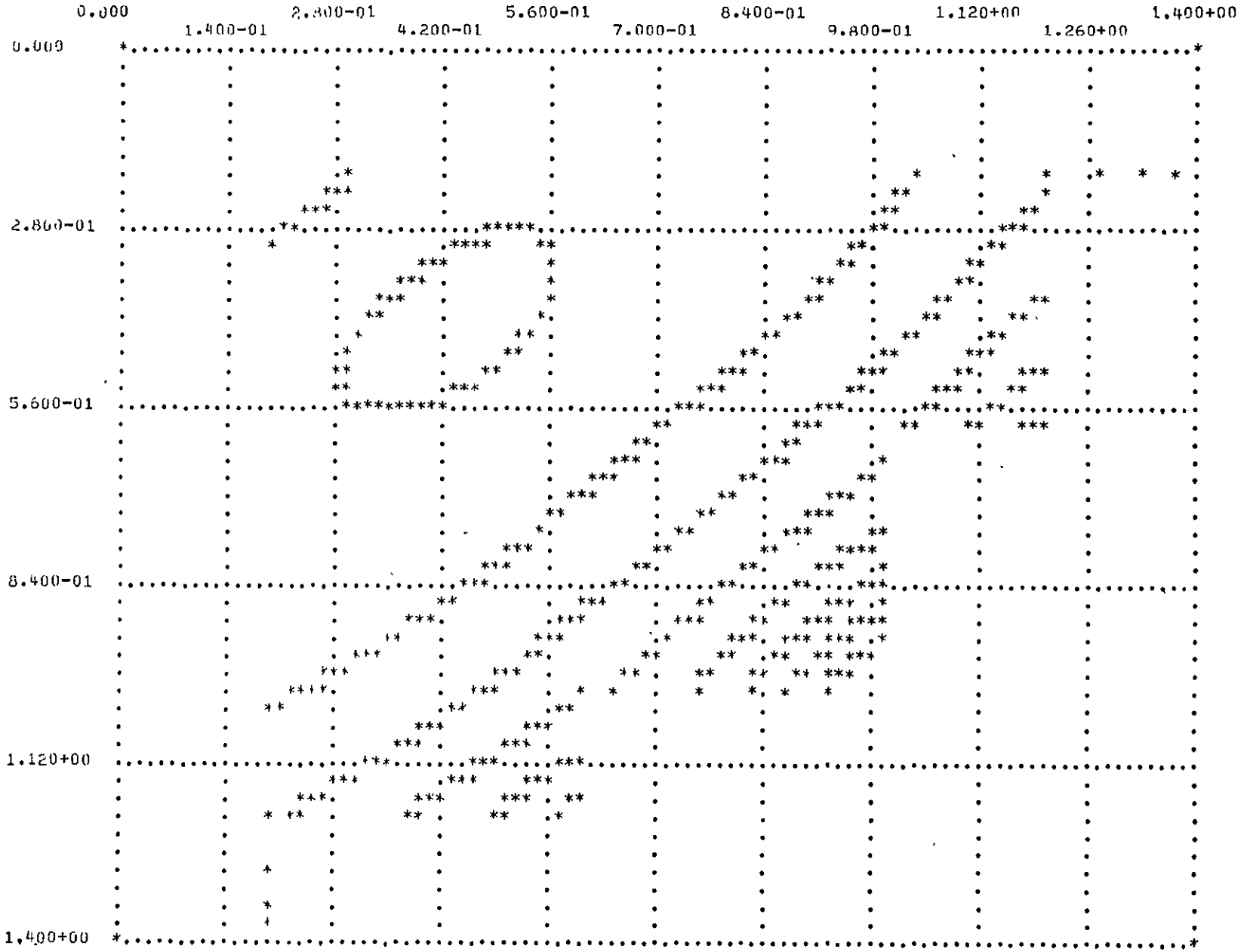
FUNCTION ARRAY 1 FROM UNIT 26 SOLUTION 1 AND VARIABLE 1

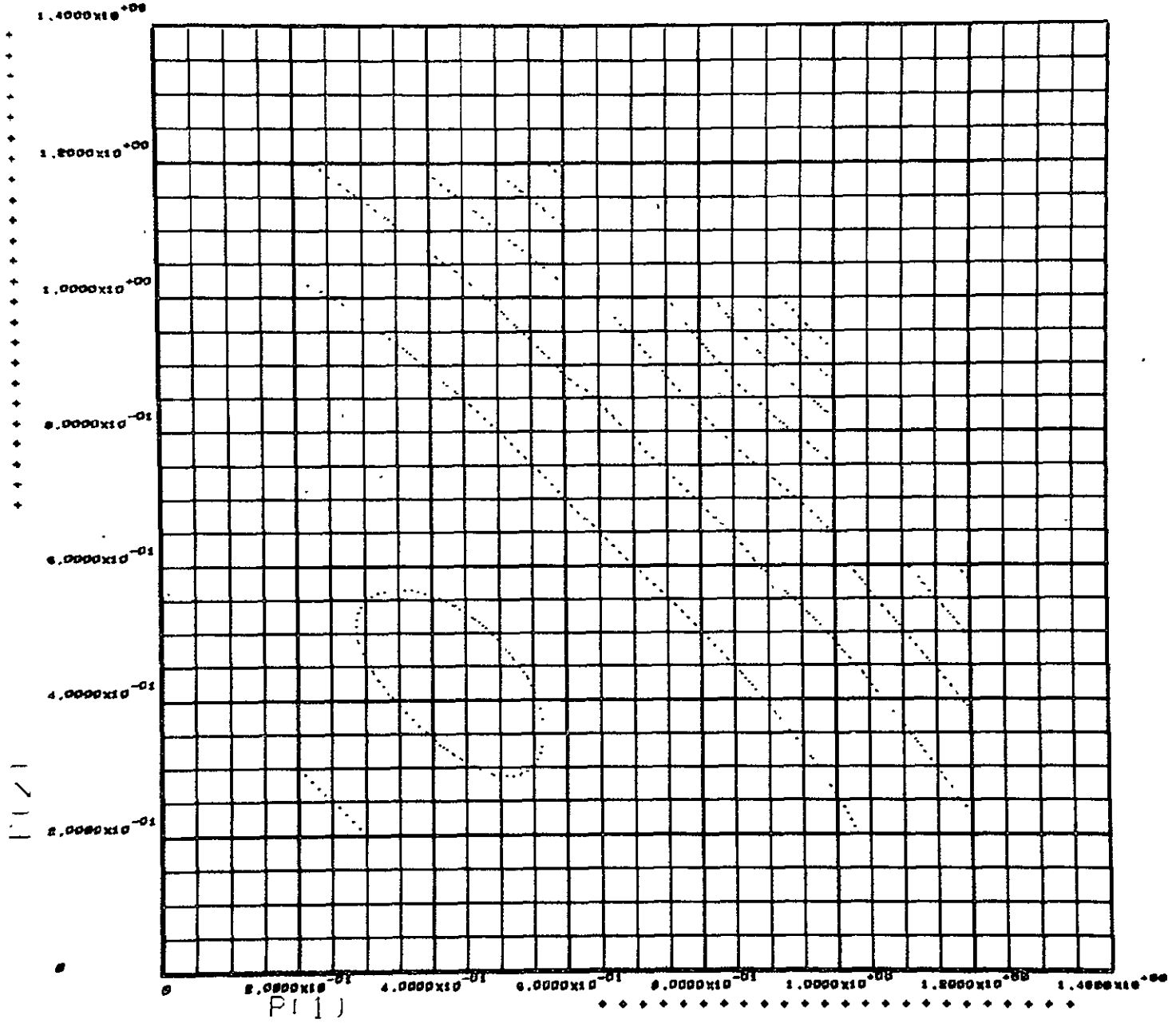
NP1 = 8 NP2 = 8

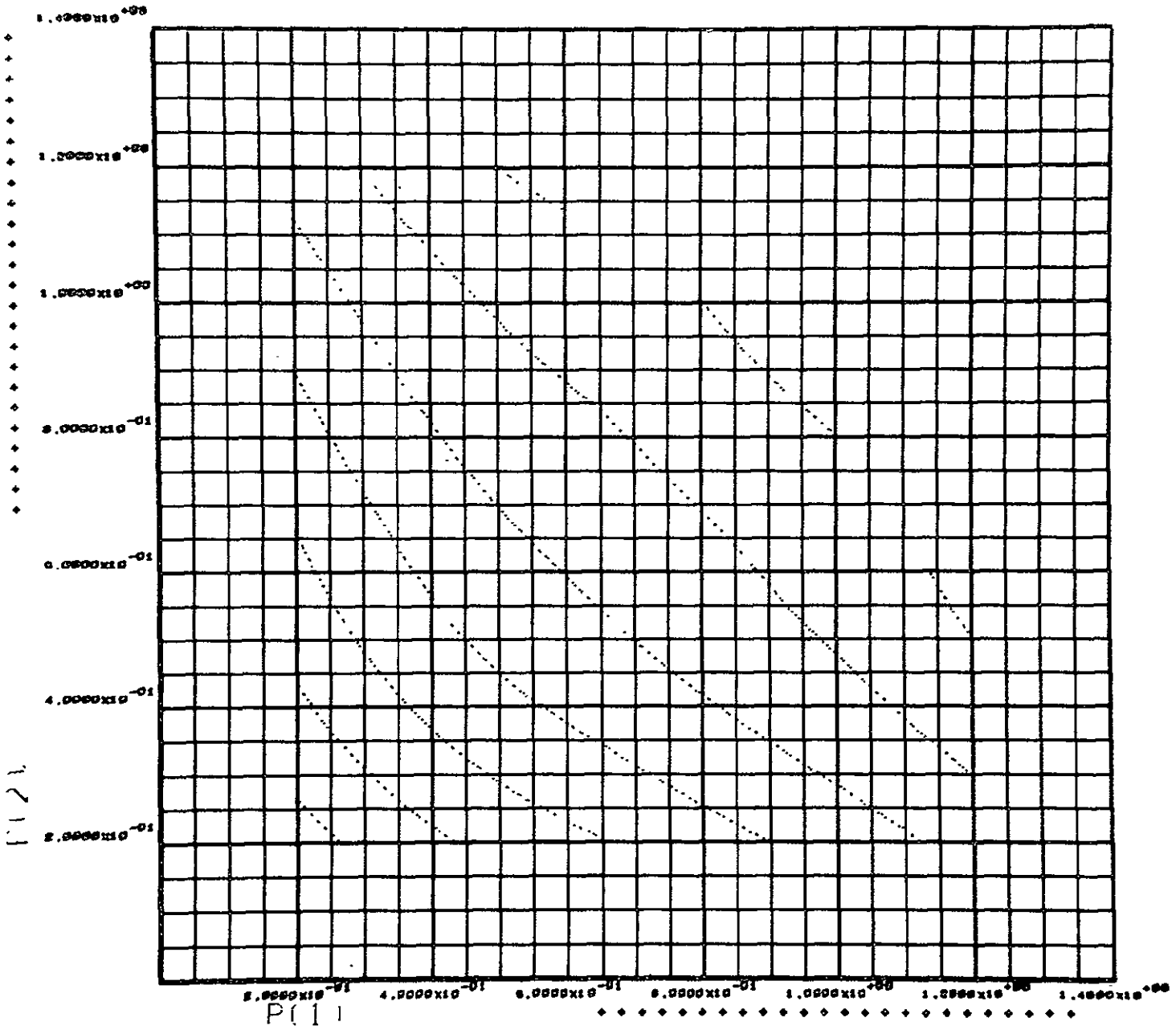
P1(.) =	.00000000	.20000002+00	.40000000+00	.60000000+00	.80000000+00	.10000000+01	.12000000+01	.14000000+01
P2(.) =	.00000000	.20000002+00	.40000000+00	.60000000+00	.80000000+00	.10000000+01	.12000000+01	.14000000+01
F(1,.) =	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
F(2,.) =	.00000000	.64045120+01	.57353177+00	.56048664+00	.56872883+00	.59407602+00	.64463036+00	.82982851+00
F(3,.) =	.00000000	.57353178+00	.54587185+00	.55534592+00	.58195781+00	.62631900+00	.70664830+00	.00000000
F(4,.) =	.00000000	.56048349+00	.55534592+00	.58141367+00	.62483601+00	.68996587+00	.81553596+00	.00000000
F(5,.) =	.00000000	.56872645+00	.58195775+00	.62483587+00	.68842107+00	.78383573+00	.00000000	.00000000
F(6,.) =	.00000000	.59407719+00	.62632402+00	.68996467+00	.78385219+00	.99851991+00	.00000000	.00000000
F(7,.) =	.00000000	.64463158+00	.70664390+00	.81554317+00	.00000000	.00000000	.00000000	.00000000
F(8,.) =	.00000000	.82981560+00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

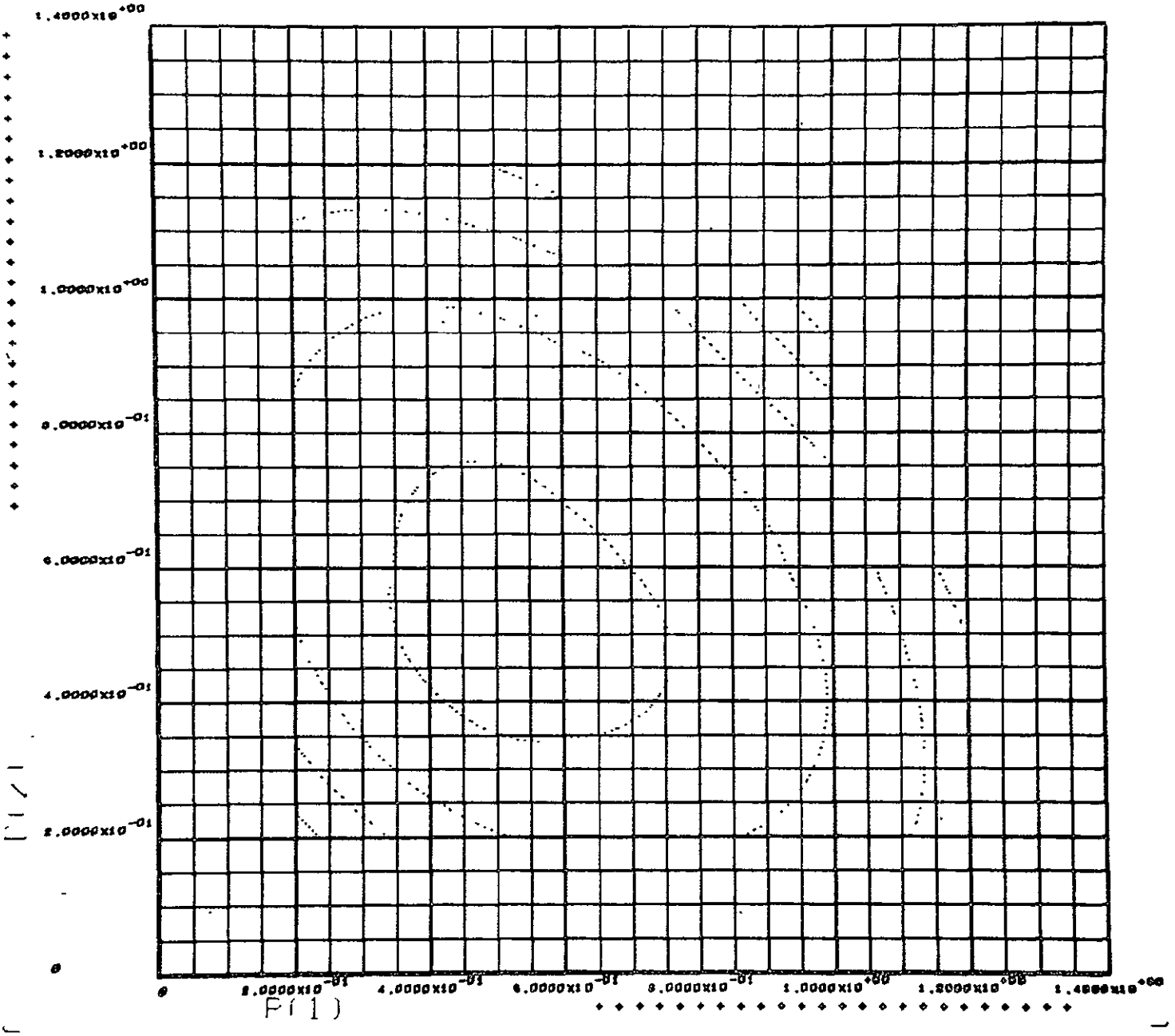
*****CALL TO INGRID FOR INTERPOLATION*****

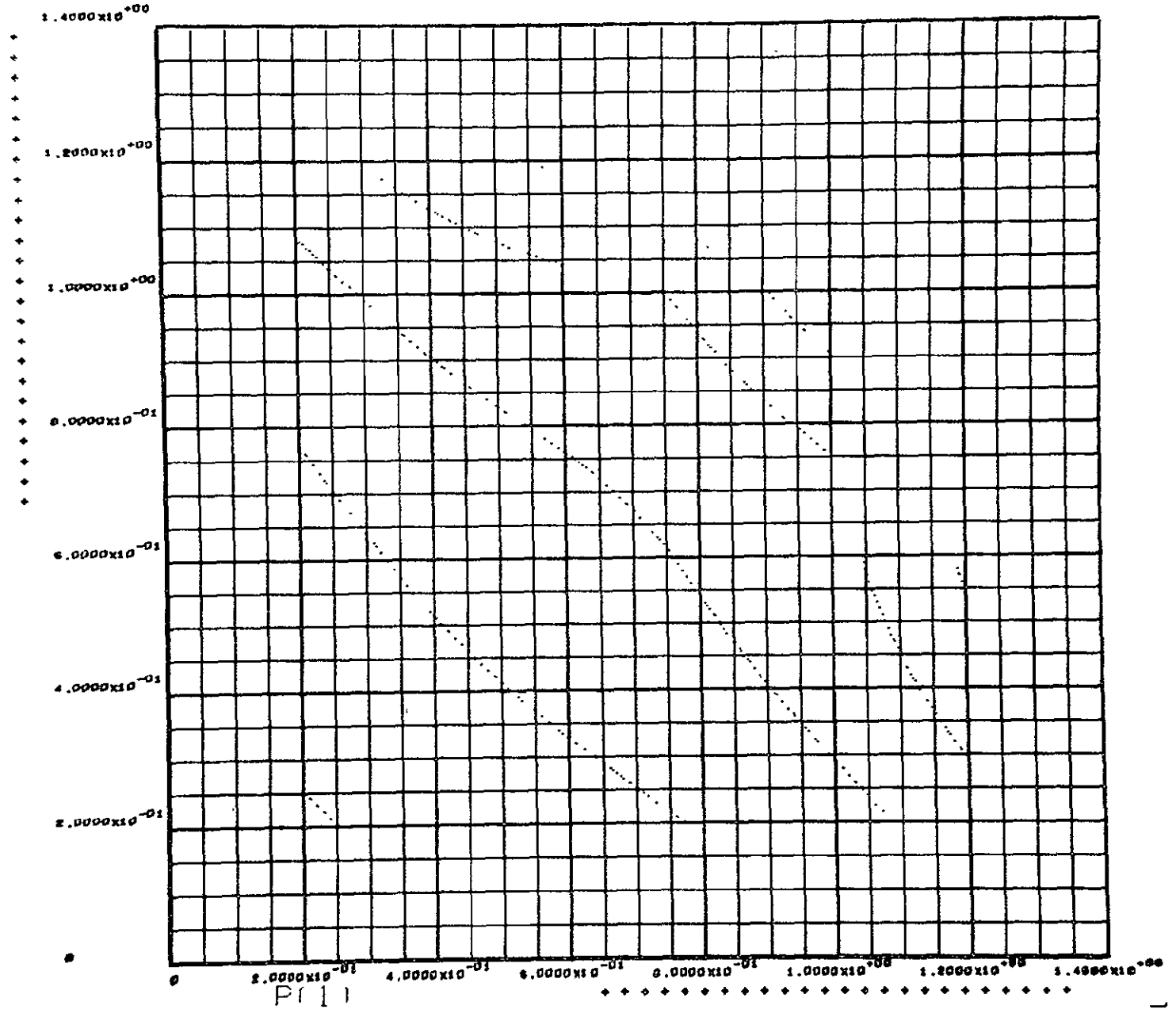
STANDARD 4-D PAP TEST DATE 122369 PAGE 11

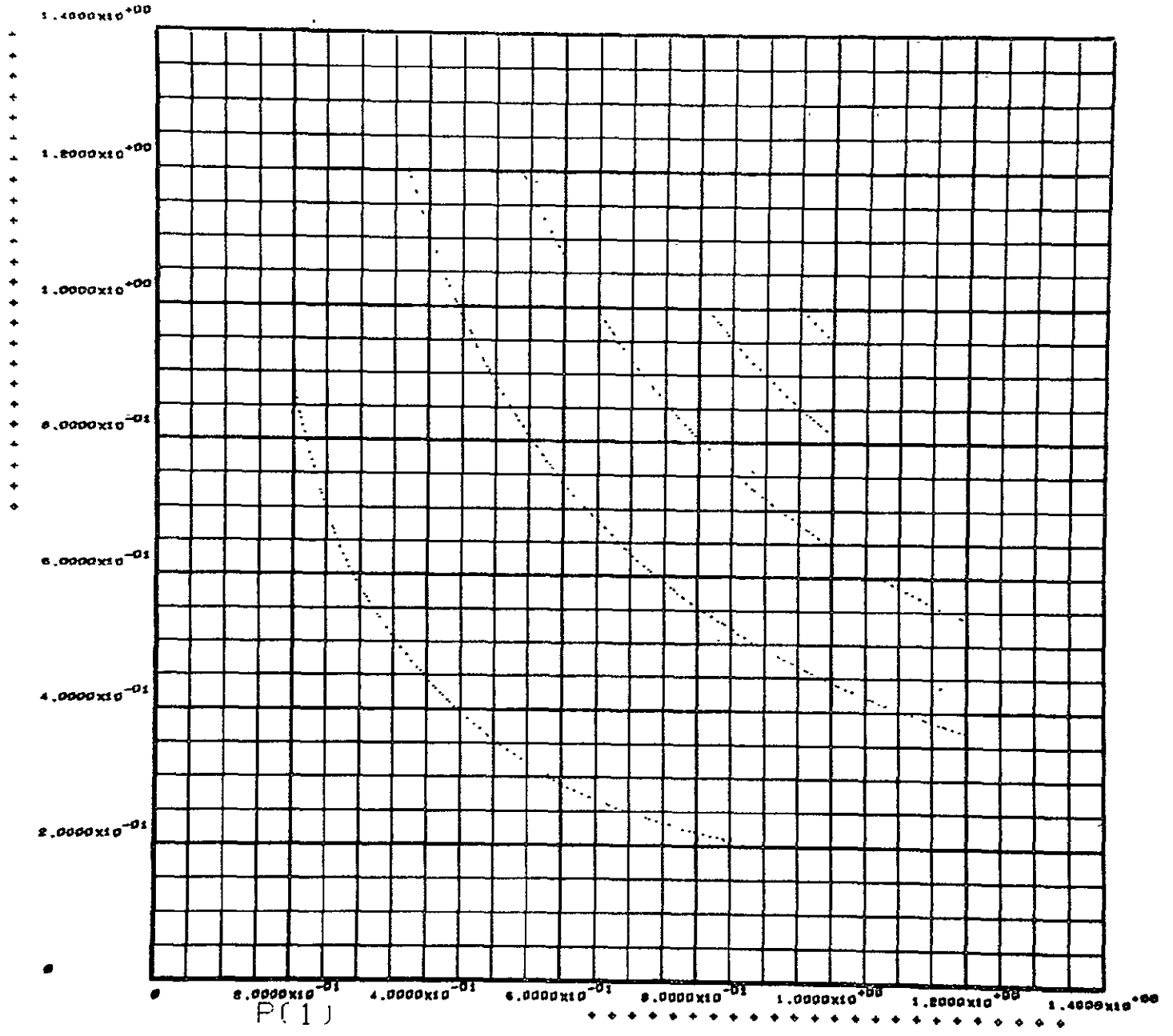



1.4000x10+00
1.2000x10+00
1.0000x10+00
8.0000x10-01
6.0000x10-01
4.0000x10-01
2.0000x10-01
0
2.0000x10-01
4.0000x10-01
6.0000x10-01
8.0000x10-01
1.0000x10+00
1.2000x10+00
1.4000x10+00
P(1)


P(1)


1.4000x10+00
1.2000x10+00
1.0000x10+00
8.0000x10-01
6.0000x10-01
4.0000x10-01
2.0000x10-01
0
0
2.0000x10-01
4.0000x10-01
6.0000x10-01
8.0000x10-01
1.0000x10+00
1.2000x10+00
1.4000x10+00


1.4000x10+00
1.2000x10+00
1.0000x10+00
8.0000x10-01
6.0000x10-01
4.0000x10-01
2.0000x10-01
0
2.0000x10-01
4.0000x10-01
6.0000x10-01
8.0000x10-01
1.0000x10+00
1.2000x10+00
1.4000x10+00


1.4000x10+00
1.2000x10+00
1.0000x10+00
8.0000x10-01
6.0000x10-01
4.0000x10-01
2.0000x10-01
0
0
2.0000x10-01
4.0000x10-01
6.0000x10-01
8.0000x10-01
1.0000x10+00
1.2000x10+00
1.4000x10+00
P(1)

APPENDIX B

Listings for Simulation Subroutines and PROC's

```
BCM11.CONSTR
      C TITLE          CONSTR - COMPUTE CONSTRAINTS
      C
      C AUTHOR         P.F. LONG
      C
      C DATE           7/17/68
      C
      C PURPOSE        TO COMPUTE THE DIFFERENCE BETWEEN THE FUNCTIONS AT P AND
      C                THE TARGET VALUES
      C
      C CALL           CALL CONSTR(P,CS)
      C
      C INPUT          BY ARGUMENT LIST
      C
      C                P        INDEPENDENT VARIABLES(PARAMETERS)
      C
      C                THROUGH COMMON USE
      C
      C                INP      NUMBER OF PARAMETERS
      C                INC      NUMBER OF CONSTRAINTS
      C                IOP      =1, IF OPTIMIZING
      C                TV(I)    TARGET VALUE OF ITH CONSTRAINT FUNCTION
      C                IFS(I)   NUMBER OF THE ITH CONSTRAINT FUNCTION
      C
      C OUTPUT         CS       VALUE OF THE DIFFERENCES
      C
      C          SUBROUTINE STATEMENT
                       SUBROUTINE CONSTR(P,CS)
      C
      C        SPECIFICATION STATEMENTS
      C
                       DIMENSION P(1),CS(1)
                       INCLUDE KOMUSE,LIST
      C
      C        DEFINE FUNCTIONS
      C
      C
      C        COMMON USE PROVIDES AN INTERFACE BETWEEN ALL USER SUBROUTINES
      C        AND RAP
      C
                       F1(U,V,W,X,Y,Z)=W*X*EXP(Y*Z+U*V)
                       F2(U,V,W,X,Y,Z)=10.*W*X*SIN(Y*Z+U*V)
                       F3(U,V,W,X,Y,Z)=W*Y**2+5.*X*Z+U*V
                       F4(U,V,W,X,Y,Z)=10.*W*X*Y*Z-U*V
                       F5(U,V,W,X,Y,Z)=Y**2+Z**2+(1.-W)**2+(1.-X)**2+U**2+V**2
      C
      C     SET U,V,W,X,Y,Z
      C
                       U=P(1)
                       V=P(2)
                       W=P(3)
                       X=P(4)
                       Y=P(5)
                       Z=P(6)
      C
      C        COMPUTE THE DIFFERENCE BETWEEN THE FUNCTION AND TARGET VALUE
      C
```

```
                DO 100  J=1,INC
                ICON=IFS(J)
                GO TO (30,40,50,60,70),ICON
     30         CS(J)=F1(U,V,W,X,Y,Z)-TV(J)
                GO TO 100
     40         CS(J)=F2(U,V,W,X,Y,Z)-TV(J)
                GO TO 100
     50         CS(J)=F3(U,V,W,X,Y,Z)-TV(J)
                GO TO 100
     60         CS(J)=F4(U,V,W,X,Y,Z)-TV(J)
                GO TO 100
     70         CS(J)=F5(U,V,W,X,Y,Z)-TV(J)
    100         CONTINUE
                NSE=NSE+1
                RETURN
                END
```

```
F BCM11.CHARAC
      C TITLE          CHARAC-COMPUTE CHARACTERISTICS
      C
      C AUTHOR         P.F. LONG
      C
      C DATE           6/18/68
      C
      C PURPOSE        TO COMPUTE THE CHARACTERISTICS OF A SYSTEM FOR A GIVEN
      C                SET OF VALUES OF THE PARAMETERS
      C
      C CALL           CALL CHARAC(P,C)
      C
      C INPUT          BY ARGUEMENT LIST
      C
      C                P          VECTOR OF PARAMETERS
      C
      C OUTPUT         C          VECTOR OF CHARACTERISTICS
      C
      C       SUBROUTINE STATEMENT
      C
                       SUBROUTINE CHARAC(P,C)
      C
      C       SPECIFICATION STATEMENTS
      C
                       DIMENSION P(1),C(1)
      C
      C       DEFINE FUNCTIONS
      C
                       F1(U,V,W,X,Y,Z)=W*X*EXP(Y*Z+U*V)
                       F2(U,V,W,X,Y,Z)=10.*W*X*SIN(Y*Z+U*V)
                       F3(U,V,W,X,Y,Z)=W*Y**2+5.*X*Z+U*V
                       F4(U,V,W,X,Y,Z)=10.*W*X*Y*Z-U*V
                       F5(U,V,W,X,Y,Z)=Y**2+Z**2+(1.-W)**2+(1.-X)**2+U**2+V**2
      C
      C       SET U,V,W,X,Y,Z
      C
                       U=P(1)
                       V=P(2)
                       W=P(3)
                       X=P(4)
                       Y=P(5)
                       Z=P(6)
      C
      C       COMPUTE THE CHARACTERISTICS
      C
                       C(1)=F1(U,V,W,X,Y,Z)
                       C(2)=F2(U,V,W,X,Y,Z)
                       C(3)=F3(U,V,W,X,Y,Z)
                       C(4)=F4(U,V,W,X,Y,Z)
                       C(5)=F5(U,V,W,X,Y,Z)
                       RETURN
                       END
```

```
BCM11.PRTCHA
C  TITLE          PRTCHA-PRINT CHARACTERISTICS
C
C  AUTHOR         P.F. LONG
C
C  DATE           7/19/68
C
C  PURPOSE        TO PRINT THE CHARACTERISTICS AND PARAMETERS FOR A GIVEN
C                 GRID POINT
C
C  CALL           CALL PRTCHA(P,C)
C
C  INPUT          THROUGH CALL LIST
C
C                 P          VECTOR OF PARAMETERS
C                 C          VECTOR OF CHARACTERISTICS
C
C  OUTPUT         PRINTER
C
C                 SAME AS INPUT
C
C       SUBROUTINE STATEMENT
C
                  SUBROUTINE PRTCHA(P,C)
C
C       SPECIFICATION STATEMENTS
C
                  DIMENSION P(1),C(1)
                  COMMON/USE/INP,INC,IOP,IFS(5),TV(5)
C
C       PRINT OUTPUTS
C
                  WRITE(6,1001)(P(J),J=1,INP)
                  WRITE(6,1002)(C(J),J=1,5)
                  RETURN
C
C       FORMAT STATEMENTS
C
 1001             FORMAT(1H0,' P = ',8E15.8/6X,8E15.8)
 1002             FORMAT(1H ,' C = ',5E15.8/)
                  END
```

```
-PLTCON - P
  PAP2*APR26.PAPUSE,PAPUSE
D BY UNIVAC 1108 PDP ON 17 NOV 69 AT 15:38:19 1102-0007


    RUNNL           PROC
    C
    C       NAMELIST RUNDAT - THESE VARIABLES ARE RELEVANT TO THE RUN BEING
    C       MADE AND ARE NOT SAVED ON THE SAVE FILES
    C
                    NAMELIST/RUNDAT/KON,ISM,ICM,ISAI,ISAF,ISAC,ISAA,IPRI,
                    IPRF,IPRC,IPRA,IPRP,IUNIT,NFR,ICHSA,NF14,NF15,NF16,
                    NF17,NF18
     END
    SAVNL           PROC
    C
    C       NAMELIST SAVDAT - THESE VARIABLES DEFINE THE SIMULATOR AND THE
    C       ANALYSIS PERFORMED.  THIS NAMELIST IS SAVED ON ALL SAVE FILES.
    C
                    NAMELIST/SAVDAT/NP,NC,A,B,DELP,P1I,P2I,NCS,EPS,
                    NSG,ISGR,NCG,ICCH,IFS,TV
     END
    RUNDOC          PROC
    C
    C               NAMELIST RUNDAT
    C
    C               NAME    TYPE/SIZE   DEFINITION
    C
    C               KON     INT/8       FUNCTION SEQUENCE INDICATOR
    C               ISM     INT/        SEARCH METHOD SELECTOR
    C               ICM     INT/        ITERATIVE METHOD SELECTOR
    C               ISAI    INT/        FLAG,=1 SAVE INISOL OUTPUT
    C               ISAF    INT/        FLAG,=1 SAVE FILGRD OUTPUT
    C               ISAC    INT/        FLAG,=1 SAVE COMCHA OUTPUT
    C               ISAA    INT/        FLAG,=1 SAVE AUXPRO OUTPUT
    C               IPRI    INT/        PRINT LEVEL CONTROL FOR INISOL
    C               IPRF    INT/        PRINT LEVEL CONTROL FOR FILGRD
    C               IPRC    INT/        PRINT LEVEL CONTROL FOR COMCHA
    C               IPRA    INT/        PRINT LEVEL CONTROL FOR AUXPRO
    C               IPRP    INT/        PRINT LEVEL CONTROL FOR PLTCON
    C               IUNIT   INT/        FILE FROM WHICH SAVDAT IS READ
    C               NFR     INT/        NUMBER OF FRAMES TO BE PLOTTED
    C               ICHSA   INT/        FLAG,=1 AFTER READING SAVDAT FROM
    C                                   IUNIT,READ(5,SAVDAT)
    C               NF14    INT/        FLAG,=1 READ PAST SAVDAT ON UNIT 14
    C               NF15    INT/        FLAG,=1 READ PAST SAVDAT ON UNIT 15
    C               NF16    INT/        FLAG,=1 READ PAST SAVDAT ON UNIT 16
    C               NF17    INT/        FLAG,=1 READ PAST SAVDAT ON UNIT 17
    C               NF18    INT/        FLAG,=1 READ PAST SAVDAT ON UNIT 18
     END
    SAVDOC          PROC
    C
    C               NAMELIST SAVDAT
    C
    C               NAME    TYPE/SIZE   DEFINITION
    C
    C               NP      INT/        NUMBER OF INDEPENDENT VARIABLES
```

PLTCON - P

```
C       NC      INT/        NUMBER OF SYSTEM CHARACTERISTICS
C       A       REA/MP*     LOWER BOUNDS FOR PARAMETERS
C       B       REA/MP*     UPPER BOUNDS FOR PARAMETERS
C       DELP    REA/MP*     STEP SIZE FOR PARAMETERS
C       P1I     REA/        INITIAL VALUE OF GRID PARAMETER 1
C       P2I     REA/        INITIAL VALUE OF GRID PARAMETER 2
C       NCS     INT/        NUMBER OF EQUALITY CONSTRAINTS
C       NTS     INT/        =NCS+1 IF OPTIMIZING,=NCS OTHERWISE
C       EPS     INT/MC*     TOLERANCE ON CONSTRAINTS
C       NSG     INT/        NUMBER OF SOLUTIONS TO BE DEVELOPED
C       ISGR    INT/MG*     ISGR(I)=J,JTH SOLUTION USED TO
C                           START THE ITH GRID
C       NCG     INT/        NUMBER OF GRIDS FOR WHICH
C                           CHARACTERISTICS ARE TO BE COMPUTED
C       ICCH    INT/MH*     ICCH(I)=J,USE THE GRID DEVELOPED FROM
C                           THE JTH SOLUTION TO COMPUTE THE ITH
C                           CHARACTERISTIC SET
C       IFS     INT/5       INDICATES WHICH FUNCTIONS TO USE
C                           AS CONSTRAINTS
C       TV      REA/5       TARGET VALUE FOR THE FUNCTIONS
C
C       * SEE PARAMETER STATEMENT FOR NUMERICAL VALUE
C
KOMUSE  PROC
C
C     COMMON USE PROVIDES AN INTERFACE BETWEEN ALL USER SUBROUTINES
C     AND PAP
C
        COMMON/USE/INP,INC,IOP,IFS(5),TV(5),NSE
  END
INITIL  PROC
        NOI=0
        NOF=0
        NOC=0
  END
SIMDFN  PROC
C
C     DEFINE SIMULATOR
C
        INP=NP
        INC=NCS
  END
RPDOS   PROC
        DIMENSION ISGR(MG),ICCH(MH),A(MP),B(MP),
       .DELP(MP),EPS(MC),IFS(5),TV(5)
  END
```

APPENDIX C

Listings of
PAP and Subroutines

ARD 4-D PAP TEST D

APR26.PAP
EVEL 3

```
C TITLE         PAP - PARAMETRIC ANALYSIS PROGRAM
C
C AUTHOR        P.F. LONG
C
C DATE          4-3-68
C
C PURPOSE       CONSIDER A SYSTEM WHOSE CHARACTERISTICS ARE CONTINUOUS
C               FUNCTIONS OF THE PARAMETERS P(1),P(2),...,P(NP). PAP
C               DIRECTS CONTROL TO SUBROUTINES INISOL, FILGRD, COMCHA,
C               AUXPRO, AND PLTCON AS REQUIRED TO PERFORM THE FOLLOWING
C               FUNCTIONS:
C
C                  1. THE PARAMETER SPACE FORMED BY HOLDING P(1) AND P(2)
C                  FIXED IS SEARCHED FOR POINTS SATISFYING SPECIFIED
C                  CONSTRAINTS.
C
C                  2. AN ATTEMPT IS MADE TO MAP THE SOLUTIONS FOUND TO
C                  ALL POINTS OF A GRID FORMED FROM THE DOMAINS OF P(1)
C                  AND P(2).
C
C                  3. FOR THE SOLUTIONS FOUND, THE SYSTEM CHARACTERISTICS
C                  ARE COMPUTED AND STORED.
C
C                  4. AN INTERFACE IS PROVIDED FOR PROGRAMS DOING
C                  ADDITIONAL COMPUTATION BASED ON THE GRIDS DEVELOPED.
C
C                  5. CONTOUR PLOTS OF THE CHARACTERISTICS AND THE
C                  NON-GRID PARAMETERS ARE PLOTTED AS SPECIFIED.
C
C METHOD        INPUTS ARE READ WHICH DEFINE THE SIMULATION AND ANALYSES
C               TO BE PERFORMED. THE REQUIRED SUBSEQUENCE OF THE MAJOR
C               SUBROUTINES IS CALLED.
C
C INPUT
                INCLUDE RUNDOC,LIST
                INCLUDE SAVDOC,LIST
C
C               NAME    TYPE/SIZE   DEFINITION
C
C               IOS     INT/        PLOTTING OPTION SELECTOR
C                                   =0, OFF-LINE PLOTS ONLY
C                                   =1, PRINTER PLOTS ONLY
C                                   =2, BOTH TYPES
C               FTLT    HOL/8       48 CHARACTER FRAME TITLE
C               ALAB    HOL/8       48 CHARACTER ABSCISSA LABEL
C               OLAB    HOL/8       48 CHARACTER ORDINATE LABEL
C               LABC    INT/        NOT CURRENTLY USED
C               AMI     REA/        MINIMUM VALUE OF ABSCISSA
C               AMA     REA/        MAXIMUM VALUE OF ABSCISSA
C               OMI     REA/        MINIMUM VALUE OF ORDINATE
C               OMA     REA/        MAXIMUM VALUE OF ORDINATE
C               NFU     INT/        NUMBER OF FUNCTIONS ON THIS FRAME
C               IUN     INT/MU*     UNITS WHERE FUNCTIONS ARE TO BE FOUND
C               ISO     INT/MU*     SOLUTION NUMBERS OF FUNCTIONS
C               IVA     INT/MU*     VARIABLE NUMBERS OF FUNCTIONS
```

ARO 4-D PAP TEST D

```
C                ICD       INT/MU*    CONTOUR DIRECTION INDICATOR
C                                     =0, FUNCTION CONSTANT CONTOURS
C                                     =1, P1 CONSTANT CONTOURS
C                                     =2, P2 CONSTANT CONTOURS
C                IAOS      INT/MU*    ABSCISSA-ORDINATE INDICATOR
C                                     =0, P1/P2, P2/F, OR P1/F IS THE
C                                     ABSCISSA/ORDINATE
C                                     =1, THE REVERSE IS TRUE
C                P1IN      INT/MU*    INTERPOLATION INCREMENTS FOR P1
C                P2IN      INT/MU*    INTERPOLATION INCREMENTS FOR P2
C                CMI       REA/MU*    MINIMUM CONTOUR IF IDC=0
C                CMA       REA/MU*    MAXIMUM CONTOUR IF IDC=0
C                CIN       REA/MU*    STEP SIZE BETWEEN CONTOURS IF IDC=0
C                INS       INT/MU*    IF IDC=J, PJ(INS) IS THE FIRST
C                                     CONTOUR VALUE, J=1 OR 2.
C                LAS       INT/MU*    IF IDC=J, PJ(LAS) IS THE LAST
C                                     CONTOUR VALUE, J=1 OR 2
C                ISI       INT/MU*    IF IDC=J, PJ(INS+K*ISI), K=0, L WHERE
C                                     L=ISI.LE.LAS, ARE THE CONTOUR VALUES
C                                     PLOTTED, J=1 OR 2
C
C
C SUBROUTINES    NAME       PURPOS=
C
C                RPD        TO READ PAST NAMELIST SAVDAT ON PLOTFILES
C                OCLOCK     TO GIVE THE TIME
C                INISOL     TO FIND INITIAL SOLUTIONS
C                FILGRD     TO USE INITIAL SOLUTIONS FOUND TO FORM A GRID
C                COMCHA     TO COMPUTE THE SYSTEM CHARACTERISTICS AT EACH
C                           GRID POINT
C                AUXPRO     TO PROVIDE AN INTERFACE WITH OTHER PROGRAMS
C                PLTCON     TO PLOT CONTOURS OF THE SYSTEM CHARACTERISTICS.
C
C SIMULATOR      THE USER MUST SUPPLY THE FOLLOWING SUBROUTINE ENTRY
C                POINTS:
C
C                    CONSTR(P,CS) WHICH COMPUTES THE VALUE OF THE
C                    CONSTRAINT FUNCTIONS (CS) AT P.
C
C                    CHARAC(P,C) WHICH COMPUTES THE CHARACTERISTICS OF
C                    THE SYSTEM (C) AS A FUNCTION OF THE PARAMETERS (P).
C
C                    PRTCHA(P,C) WHICH PRINTS P AND C AS REQUIRED BY
C                    THE USER.
C
C                    AUXPRO WHICH PERFORMS OPERATIONS USEFUL TO THE
C                    CURRENT STUDY BUT NOT PROVIDED FOR BY PAP.
C
C                IN ADDITION TO THESE SUBROUTINE ENTRY POINTS, THE USER
C                MUST SUPPLY A PROCEDURE ELEMENT WITH THE FOLLOWING ENTRY
C                POINTS AND CONTENTS:
C
C                    RUNDOC CONTAINS THE NAMES AND DEFINITIONS OF THE
C                    VARIABLES IN NAMELIST RUNDAT.
C
C                    SAVDOC CONTAINS THE NAMES AND DEFINITIONS OF THE
C                    VARIABLES IN NAMELIST SAVDAT.
```

```
C
C     KOMUSE CONTAINS COMMON USE WHICH IS USED FOR COMMUNI-
C     CATION BETWEEN USER SUBROUTINES.
C
C     RUNNL CONTAINS THE NAMELIST RUNDAT. THIS NAMELIST
C     MUST CONTAIN THOSE INPUTS REVELENT TO THE CURRENT
C     RUN ONLY. INPUTS KON, IUNIT, ICHSA, AND NFR MUST BE
C     IN THIS NAMELIST. THIS NAMELIST IS NOT SAVED ON THE
C     SAVE FILES.
C
C     SAVNL CONTAINS THE NAMELIST SAVDAT WHICH MUST
C     CONTAIN THE INPUTS WHICH DEFINE THE CONSTRAINTS
C     AND THE SIMULATOR. THESE INPUTS WILL BE NEEDED IF
C     FURTHER PROCESSING IS DONE AND ARE WRITTEN ON ALL
C     SAVE FILES. NAMELISTS RUNDAT AND SAVDAT MUST CONTAIN
C     ALL INPUTS REQUIRED TO DEFINE THE SYSTEM, THE
C     CONSTRAINTS TO BE SATISFIED, AND THE INPUTS FOR PAP.
C
C     INITIL CONTAINS THE FORTRAN CODE THAT SETS THE
C     VALUES OF ANY VARIABLES THAT MUST BE INITILIZED
C     AT THE BEGINNING OF EACH PASS. VARIOUS INPUTS WHICH
C     ARE NOT OFTEN CHANGED CAN BE SET HERE. THEIR VALUE
C     CAN BE CHANGED BY THE SUBSEQUENT READ NAMELISTS
C     RUNDAT AND SAVEDAT.
C
C     SIMDEN CONTAINS THE FORTRAN CODE WHICH DERIVES FROM
C     THE INPUTS IN RUNDAT AND SAVDAT THE INFORMATION
C     NECESSARY TO DEFINE THE SYSTEM CONFIGURATION, THE
C     CONSTRAINTS TO BE SATISFIED, AND THE INPUTS TO PAP.
C
C     RPDDS CONTAINS A DIMENSION STATEMENT FOR ALL
C     VARIABLES IN NAMELIST SAVDAT. THE DIMENSION AND SIZE
C     OF THESE VARIABLES MUST CORRESPOND TO THOSE GIVEN
C     TO THE VARIABLES IN PAP.
C
C
C     SPECIFICATION STATEMENTS
C
C
      INCLUDE PARSTA,LIST
      INCLUDE PARDOC,LIST
      INCLUDE KOMMCL,LIST
      INCLUDE MCLDOC,LIST
      INCLUDE KOMUSE,LIST
      INCLUDE RUNNL,LIST
      INCLUDE SAVNL,LIST
      DIMENSION IUN(MU),ISO(MU),IVA(MU),CMI(MU),CMA(MU),
     .CIN(MU),ICD(MU),INS(MU),LAS(MU),ISI(MU),FILT(8),ALAB(8),
     .OLAB(8),IAOS(MU),P1IN(MU),P2IN(MU)
      DIMENSION TIME(2)
      DATA SUB1/6HINISOL/SUB2/6HFILORD/SUB3/6HCOMCHA/SUB4/
     .6HAUXPRO/SUB5/6HPLTCON/
C
C     NAMELIST PLTDAT-THIS NAMELIST DEFINES ONE PLOTTING
C     FRAME. WHEN SPECIFYING NFR FRAMES, THIS NAMELIST WILL
C     BE READ NFR TIMES IN SEQUENCE STORING THE INPUTS BY
```

```
C       FRAMES.
C
                NAMELIST/PLTDAT/IOS,IUN,ISO,IVA,FTLT,ALAB,OLAB,LABC,
      .         AMI,AMA,OMI,OMA,CMI,CMA,IAOS,P1IN,P2IN,CIN,ICD,INS,LAS,
      .         ISI,NFU
                EQUIVALENCE (J,JX)
C
C       INITIALIZE
C
                INCLUDE INITIL,LIST
C
C       READ NAMELIST RUNDAT
C
 1              READ(5,RUNDAT)
C
C       READ NAMELIST SAVDAT FROM FILE IUNIT, 5, OR BOTH (5 IS READ LAST)
C
                IF(KON(1).EQ.1) GO TO 10
                REWIND IUNIT
                READ(IUNIT,SAVDAT)
                IF(ICHSA.NE.1)GO TO 20
10              READ(5,SAVDAT)
C
C       READ PLOT DATA IF NFR GT 0
C
20              IF(NFR.EQ.0) GO TO 30
C
C       READ INPUTS THAT DEFINE A SINGLE FRAME AND STORE IN ARRAYS WHICH
C       HAVE ONE OF THEIR SUBSCRIPTS CORRESPONDING TO THE FRAME NUMBER
C
                DO 25 J=1,NFR
                READ(5,PLTDAT)
                IPOP(J)=IOS
                LAC(J)=LABC
                AMIN(J)=AMI
                AMAX(J)=AMA
                OMIN(J)=OMI
                OMAX(J)=OMA
                DO 22 L=1,8
                TLT(L,J)=FTLT(L)
                ALA(L,J)=ALAB(L)
22              OLA(L,J)=OLAB(L)
                NFN(J)=NFU
                DO 25 K=1,NFU
                IFLU(J,K)=IUN(K)
                ISOL(J,K)=ISO(K)
                IVAR(J,K)=IVA(K)
                IAO(J,K)=IAOS(K)
                P1INC(J,K)=P1IN(K)
                P2INC(J,K)=P2IN(K)
                CMIN(J,K)=CMI(K)
                CMAX(J,K)=CMA(K)
                DELC(J,K)=CIN(K)
                IVS(J,K)=ICD(K)
                IS(J,K)=INS(K)
                LS(J,K)=LAS(K)
25              INCS(J,K)=ISI(K)
```

RD 4-D PAP TEST DA

```
   30              CONTINUE
                   INCLUDE SIMDFN,LIST
C
C------POSITION PLOT FILES BEING USED PAST USRDAT
C
                   IF(NF14.NE.1.OR.NF14.EQ.IUNIT) GO TO 101
                   REWIND 14
                   CALL RPD(14)
  101              IF(NF15.NE.1.OR.NF15.EQ.IUNIT) GO TO 102
                   REWIND 15
                   CALL RPD(15)
  102              IF(NF16.NE.1.OR.NF16.EQ.IUNIT) GO TO 103
                   REWIND 16
                   CALL RPD(16)
  103              IF(NF17.NE.1.OR.NF17.EQ.IUNIT) GO TO 104
                   REWIND 17
                   CALL RPD(17)
  104              IF(NF18.NE.1.OR.NF18.EQ.IUNIT) GO TO 105
                   REWIND 18
                   CALL RPD(18)
C
C------WRITE SAVDAT ON FILES BEING SAVED THIS PASS
C
  105              IF(ISAI.EQ.0) GO TO 106
                   LOI=8+NOI
                   NOI=NOI+1
                   IF(LOI.GT.10) GO TO 190
                   REWIND LOI
                   WRITE(LOI,SAVDAT)
  106              IF(ISAF.EQ.0) GO TO 107
                   LOF=11+NOF
                   NOF=NOF+1
                   IF(LOF.GT.13) GO TO 190
                   REWIND LOF
                   WRITE(LOF,SAVDAT)
  107              IF(ISAC.EQ.0) GO TO 108
                   LOC=14+NOC
                   NOC=NOC+1
                   IF(LOC.GT.16) GO TO 190
                   REWIND LOC
                   WRITE(LOC,SAVDAT)
  108              IF(ISAA.EQ.0) GO TO 109
                   LOA=17+NOA
                   NOA=NOA+1
                   IF(LOA.GT.18) GO TO 190
                   REWIND LOA
                   WRITE(LOA,SAVDAT)
  109              CONTINUE
C
C------GO TO THE FUNCTION TO BE PERFORMED NEXT
C
                   J=1
  120              KN=KON(J)
                   GO TO (130,140,150,160,170),KN
C
C------CALL INISOL
C
```

ARD 4-D PAP TEST DA

```
  130             CALL OCLOCK(TIME)
                  WRITE(6,1002)SUB1,TIME
                  NSE=0
                  CALL INISOL
                  WRITE(6,1003)NSE,SUB1
                  GO TO 180
C
C       CALL FILGRD
C
  140             CALL OCLOCK(TIME)
                  WRITE(6,1002)SUB2,TIME
                  NSE=0
                  CALL FILGRD
                  WRITE(6,1003)NSE,SUB2
                  GO TO 180
C
C       CALL COMCHA
C
  150             CALL OCLOCK(TIME)
                  WRITE(6,1002)SUB3,TIME
                  CALL COMCHA
                  GO TO 180
C
C       CALL AUXPRO
C
  160             CALL OCLOCK(TIME)
                  WRITE(6,1002)SUB4,TIME
                  CALL AUXPRO
                  GO TO 180
C
C       CALL PLTCON
C
  170             CALL OCLOCK(TIME)
                  WRITE(6,1002)SUB5,TIME
                  CALL PLTCON
  180             J=J+1
                  IF(KON(J)-6) 120,1,200
C
C       WRITE EXIT REASON MESSAGE
C
  190             WRITE(6,1001) NOI,NOF,NOC,NOA
C
C       CALL EXIT
C
  200             CALL EXIT
C
C       FORMAT STATEMENTS
C
 1001             FORMAT(1H ,'*****MORE THAN THE ALOTTED NUMBER OF SAVE '
                  'FILES WERE USED',' NOI = ',I3,2X,'NOF = ',I3,2X,'NOC = ',
                  I3,2X,'NOA = ',I3/)
 1002             FORMAT(1H0,'*****CALL ',A6,' AT TIME ',2A6,'*****'/)
 1003             FORMAT(1H0,'*****SYSTEM EVALUATED ',I4,' TIMES IN ',A6,
                  '*****'/)
                  END
```

```
PDP,LE APR26.PAPSRC
ED BY UNIVAC 1108 PDP ON 17 SEP 69 AT 08:39:10 1102-0005

KOMSOL          PROC
C
C       SPECIFICATION OF COMMON SOL
C
                COMMON/SOL/NS,SOLP(MP,MS),SOLC(MC,MS)
C
C       ...NAME         DEFINITION
C
C          NS           NUMBER OF DISTINCT SOLUTIONS FOUND (.LT.MS)
C          SOLP(I,J)    ITH COMPONENT OF JTH SOLUTION
C          SOLC(I,J)    FINAL VALUE OF ITH CONSTRAINT OF JTH SOLUTION
C
C       THIS COMMON IS INCLUDED IN SUBROUTINES INISOL AND FILGRD
C
 END
KOMMCL          PROC
C
C       SPECIFICATION OF COMMON MCL
C
                COMMON/MCL/KON(8),ISM,ICM,ISAI,ISAF,ISAC,ISAA,ISGR(MG),
     .          ICCH(MH),NFR,NP,NC,A(MP),B(MP),NCS,DELP(MP),
     .          P1I,P2I,EPS(MC),IPOP(ME),IPRI,IPRF,IPRC,IPRA,IPRP,
     .          NFN(MF),IFLU(MF,MU),ISOL(MF,MU),NSG,NCG,
     .          IVAR(ME,MU),TLI(8,ME),ALA(8,ME),OLA(8,ME),LAC(ME),
     .          AMIN(MF),AMAX(MF),OMIN(MF),OMAX(MF),
     .          CMIN(ME,MU),CMAX(ME,MU),DELC(ME,MU),IVS(ME,MU),IS(ME,MU),
     .          LS(ME,MU),INCS(ME,MU),LOI,LOF,LOC,LOA,IUNIT,NOI,NOF,
     .          NOC,NOA,JX,IAO(ME,MU),P1INC(ME,MU),P2INC(ME,MU)
 END
MCLDOC          PROC
C
C       DEFINITION OF VARIABLES IN MCL
C
C       ...VARIABLES THAT CONTROL BOOKEEPING FUNCTIONS
C
C       ...NAME         DEFINITION
C
C          ISAI         FLAG, =1 SAVE OUTPUT FROM INISOL
C          ISAF         FLAG, =1 SAVE OUTPUT FROM FILGRD
C          ISAC         FLAG, =1 SAVE OUTPUT FROM COMCHA
C          ISAA         FLAG, =1 SAVE OUTPUT FROM AUXPRO
C          IPRI         PRINTOUT LEVEL CONTROLE FOR INISOL
C          IPRF         PRINTOUT LEVEL CONTROLE FOR FILGRD
C          IPRC         PRINTOUT LEVEL CONTROLE FOR COMCHA
C          IPRA         PRINTOUT LEVEL CONTROLE FOR AUXPRO
C          IPRP         PRINTOUT LEVEL CONTROLE FOR PLTCON
C          IUNIT        UNIT (OR FILE) NUMBER TO READ INPUT DATA FROM
C          LOI          OUTPUT UNIT FOR INISOL
C          LOF          OUTPUT UNIT FOR FILGRD
C          LOC          OUTPUT UNIT FOR COMCHA
C          LOA          OUTPUT UNIT FOR AUXPRO
C          NOI          NUMBER OF PASSES THROUGH INISOL WITH ISAI=1
```

```
C          NOF          NUMBER OF PASSES THROUGH FILGRD WITH ISAF=1
C          NOC          NUMBER OF PASSES THROUGH COMCHA WITH ISAC=1
C          NOA          NUMBER OF PASSES THROUGH AUXPRO WITH ISAA=1
C          JX           CURRENT VALUE OF KON INDEX
C
C       ...VARIABLES THAT CONTROL THE ANALYSIS
C
C       ...NAME         DEFINITION
C
C          KON(I)       DIRECTS CONTROL
C          ISM          INDICATES SEARCH METHOD TO BE USED
C          ICM          INDICATES ITERATIVE METHOD TO BE USED
C          NP           NUMBER OF INDEPENDENT PARAMETERS
C          NC           NUMBER OF CHARACTERISTICS
C          A(I)         LOWER BOUND ON ITH INDEPENDENT PARAMETER
C          B(I)         UPPER BOUND ON ITH INDEPENDENT PARAMETER
C          DELP(I)      STEP SIZE FOR ITH INDEPENDENT PARAMETER
C          P1I          INITIAL VALUE OF ABSCISSA
C          P2I          INITIAL VALUE OF ORDINATE
C          NCS          NUMBER OF EQUALITY CONSTRAINTS
C          EPS(I)       TOLERANCE ON ITH CONSTRAINT
C          NSG          NUMBER OF SOLUTIONS TO BE DEVELOPED
C          ISGR(J)      =K, KTH SOLUTION USED TO START JTH GRID
C          NCG          NUMBER OF GRIDS TO BE DEVELOPED
C          ICCH(J)      =K, CHARACTERISTICS COMPUTED FOR GRID MAPPED
C                       FROM KTH SOLUTION
C
C       ...VARIABLES THAT CONTROL THE PLOTTING
C
C       ...NAME         DEFINITION
C
C          NFR          NUMBER OF PLOTTING FRAMES TO BE GENERATED
C          IPOP(I)      PLOTTING OPTION SELECTOR FOR ITH FRAME
C                       =0, OFF-LINE PLOTS ONLY
C                       =1, PRINTER PLOTS ONLY
C                       =2, BOTH TYPES
C          TLT(J,I)     42 CHARACTER ITH FRAME TITLE
C          ALA(J,I)     48 CHARACTER ITH FRAME ABSCISSA LABEL
C          OLA(J,I)     48 CHARACTER ITH FRAME ORDINATE LABEL
C          LAC(I)       FLAG, =1 LABEL CONTOURS ON ITH FRAME
C          AMIN(I)      MINIMUM VALUE OF ABSCISSA ITH FRAME
C          AMAX(I)      MAXIMUM VALUE OF ABSCISSA ITH FRAME
C          OMIN(I)      MINIMUM VALUE OF ORDINATE ITH FRAME
C          OMAX(I)      MAXIMUM VALUE OF ORDINATE ITH FRAME
C          NFN(I)       NUMBER OF FUNCTIONS TO BE PLOTTED ITH FRAME
C          IFLU(I,J)    FORTRAN LOGICAL UNIT DESIGNATOR FOR JTH
C                       FUNCTION OF ITH FRAME
C          ISOL(I,J)    SOLUTION DESIGNATOR FOR JTH FUNCTION OF ITH
C                       FRAME
C          IVAR(I,J)    VARIABLE DESIGNATOR FOR JTH FUNCTION OF ITH
C                       FRAME
C          P1INC(I,J)   INTERPOLATION INCREMENT P(1),JTH FUNCTION OF
C                       ITH FRAME
C          P2INC(I,J)   INTERPOLATION INCREMENT P(2),JTH FUNCTION OF
C                       ITH FRAME
C          IVS(I,J)     CONTOUR PLANE INDICATOR
C                       =0, CONSTANT FUNCTION CONTOURS
```

```
C                       =1, P1 CONSTANT COUNTOURS
C                       =2, P2 CONSTANT COUNTOURS
C          IAO(I,J)     ABSCISSA=ORDINATE INDICATOR
C                       =0, P1/P2,P2/F, OR P1/F IS THE ABSCISSA/ORDINATE
C                       =1, THE REVERSE IS TRUE
C          CMIN(I,J)    MINIMUM CONTOUR JTH FUNCTION ITH FRAME
C          CMAX(I,J)    MAXIMUM CONTOUR JTH FUNCTION ITH FRAME
C          DELC(I,J)    STEP SIZE BETWEEN CONTOURS JTH FUNCTION ITH FRAME
C          IS(I,J)      INITIAL SLICE INDICATOR ITH FRAME JTH FUNCTION
C          LS(I,J)      FINAL SLICE INDICATOR ITH FRAME JTH FUNCTION
C          INCS(I,J)    INCREMENT OF SLICES
C
C       THIS COMMON IS INCLUDED IN SUBROUTINES PAP,INISOL,
C          FILGRD,COMCHA,AUXPRO,AND PLTCON
C
 END
PARSIA          PROC
C
C       SPECIFICATION OF PARAMETER STATEMENT
C
                PARAMETER MP=10,MC=8,MF=5,MU=10,MS=25,MG=5,MH=5,MA=31,
                MO=MA,MK=1500
 END
PARDOC          PROC
C
C       DEFINITION OF PARAMETERS
C
C       ...NAME     DEFINITION
C
C          MP       MAXIMUM NUMBER OF INDEPENDENT PARAMETERS
C          MC       MAXIMUM NUMBER OF CONSTRAINTS
C          MF       MAXIMUM NUMBER OF FRAMES
C          MU       MAXIMUM NUMBER OF FUNCTIONS PER FRAME
C          MG       MAXIMUM NUMBER OF GRIDS THAT MAY BE DEVELOPED
C          MS       MAXIMUM NUMBER OF SOLUTIONS THAT MAY BE STORED
C          MH       MAXIMUM NUMBER OF GRIDS FOR WHICH CHARACTERISTICS MAY
C                   BE COMPUTED
C          MA       MAXIMUM NUMBER OF ABSCISSAS
C          MO       MAXIMUM NUMBER OF ORDINATES
C          MK       MAXIMUM NUMBER OF CHARACTERISTICS
C
C       PARAMETER STATEMENT INCLUDED IN ALL PAP SUBROUTINES
C
 END
```

```
F APR26.RPD
      C TITLE         RPD - READ PAST NAMELIST USRDAT
      C
      C AUTHOR        P. F. LONG
      C
      C DATE          7/26/68
      C
      C PURPOSE       TO POSITION FILE I PAST NAMELIST SAVDAT.
      C
      C METHOD        READ NAMELIST SAVDAT BUT DO NOT TRANSMIT DATA TO PAP.
      C
      C INPUT         THROUGH ARGUMENT LIST
      C
      C                I  FILE NUMBER TO BE READ
      C
      C OUTPUT        NONE
      C
      C       SUBROUTINE STATEMENT
      C
                      SUBROUTINE RPD(I)
                      INCLUDE PARSTA,LIST
                      INCLUDE RPDDS,LIST
                      INCLUDE SAVNL,LIST
                      READ(I,SAVDAT)
                      RETURN
                      END
```

```
APR26.INISOL
      C TITLE          INISOL - INITIAL SOLUTION SEARCH SCHEME CONTROL
      C
      C AUTHOR         P.F. LONG
      C
      C DATE           2-9-68
      C
      C PURPOSE        TO CALL REQUESTED SEARCH SCHEME AND TO PRINT AND STORE
      C                SOLUTIONS.
      C
      C CALL           CALL INISOL
      C
      C INPUT          THROUGH LABELLED COMMON MCL
      C
      C                ISM        SEARCH METHOD SELECTOR
      C                           =J, SEEKJ IS CALLED
      C                ISAI       =1, OUTPUT SAVED ON UNIT LOI
      C                LOI        OUTPUT UNIT NUMBER
      C
      C                A,B,DELP,P1I,P2I,NP,NCS,ICM,EPS,AND IPRI ARE PASSED ON
      C                TO THE VARIOUS SEARCH SUBROUTINES.
      C                THESE VARIABLES ARE DEFINED IN THE MAIN PROGRAM UNDER
      C                COMMON MCL.
      C
      C OUTPUT         NS,SOLP, AND SOLC ARE PRINTED,STORED IN COMMON SOL, AND
      C                IF ISAI=1, WRITTEN ON UNIT LOI.
      C                THESE VARIABLES ARE DEFINED BELOW UNDER COMMON SOL.
      C
      C SUBROUTINES    SEEK1,SEEK2,SEEK3,SEEK4,SEEK5
      C
      C
      C       SUBROUTINE STATEMENT
      C
                       SUBROUTINE INISOL
      C
      C       SPECIFICATION STATEMENTS
      C
                       INCLUDE PARSTA,LIST
                       INCLUDE KOMMCL,LIST
                       INCLUDE KOMSOL,LIST
      C
      C       CALL THE SEARCH METHOD INDICATED BY ISM TO FIND THE INITIAL
      C       SOLUTIONS
      C
                       GO TO(5,10,15,20,25),ISM
            5          CALL SEEK1(A,B,DELP,P1I,P2I,NP,NCS,ICM,EPS,NS,SOLP,SOLC,
                       IPRI)
                       GO TO 30
           10          CALL SEEK2(A,B,DELP,P1I,P2I,NP,NCS,ICM,EPS,NS,SOLP,SOLC,
                       IPRI)
                       GO TO 30
           15          CALL SEEK3(A,B,DELP,P1I,P2I,NP,NCS,ICM,EPS,NS,SOLP,SOLC,
                       IPRI)
                       GO TO 30
           20          CALL SEEK4(A,B,DELP,P1I,P2I,NP,NCS,ICM,EPS,NS,SOLP,SOLC,
                       IPRI)
                       GO TO 30
```

```
 25             CALL SEEK5(A,B,DELP,R1I,R2I,NP,NCS,ICM,EPS,NS,SOLP,SOLC,
                IPRI)
C
C       WRITE SOLUTIONS ON LOI
C
 30             IF(ISAI.NE.1)GO TO 35
                WRITE(LOI)NS,SOLP,SOLC
                END FILE LOI
                REWIND LOI
C
C       PRINT SOLUTIONS
C
 35             WRITE(6,1001)NS
                DO 40 J=1,NS
 40             WRITE(6,1002)J,(SOLP(I,J),I=1,NP)
                RETURN
C
C       FORMAT STATEMENTS
C
 1001           FORMAT(1H0,4X,I2,' SOLUTION(S) FOUND'/)
 1002           FORMAT(1H ,8X,I2,(8E15.8/11X))
                END
```

```
APR26.FILGRD
C TITLE         FILGRD - SOLUTION MAPPING CONTROL
C
C AUTHOR        P.F. LONG
C
C DATE          3-7-68
C
C PURPOSE       TO CALL GRIDMK WITH EACH INITIAL SOLUTION REQUESTED AND
C               STORE THE RESULTS ON UNIT LOF.
C
C METHOD        LOAD THE REQUESTED SOLUTIONS AND CALL GRIDMK FOR
C               SOLUTION MAPPING.
C
C CALL          CALL FILGRD
C
C INPUTS        THROUGH LABELLED COMMON MCL
C
C               KON,IUNIT,NSG,ISAF,LOF,A,B,DELP,ISGR,EPS,NP,NCS,ICM,IPRF
C               THESE VARIABLES ARE DEFINED IN THE MAIN PROGRAM UNDER
C               COMMON MCL.
C
C               THROUGH LABELLED COMMON SOL
C
C               NS,SOLP,SOLC  THESE VARIABLES ARE DEFINED BELOW UNDER
C               COMMON SOL.
C
C OUTPUT        ON UNIT LOF
C
C               NP1         NUMBER OF P(1)'S
C               NP2         NUMBER OF P(2)'S
C               NP          NUMBER OF PARAMETERS
C               ISGR(K)     NUMBER OF SOLUTION FROM WHICH GRID WAS MAPPED
C               GRD(I,J,K) RESULTING SOLUTION GRID. I=1,NP J=1,NP1
C                           K=1,NP2
C               COPT(J,K) OPTIMUM VALUE IF OPTIMIZING. J=1,1,NP1,K=1,NP2
C               IDCV(J,K) =1, SOLUTION FOUND FOR GRID POINT CORRESPONDING
C                           TO (J,K)
C
C SUBROUTINES   GRIDMK
C
C     SUBROUTINE STATEMENT
C
                SUBROUTINE FILGRD
C
C     SPECIFICATION STATEMENTS
C
                INCLUDE PARSTA,LIST
                INCLUDE KOMMCL,LIST
                INCLUDE KOMSOL,LIST
                DIMENSION GRD(MP,MA,MO),COPT(MA,MO),PINI(MP),IDCV(MA,MO)
C
C       IF FILGRD IS THE FIRST MAJOR SUBROUTINE CALLED THIS PASS, READ
C       NS,SOLP,SOLC FROM IUNIT
C
                IF(KON(1).NE.2)GO TO 10
                READ(IUNIT) NS,SOLP,SOLC
   10           IF(NS.LT.NSG) NSG=NS
```

```
C
C       DESIGNATE STORAGE DEVICE
C
                IF(ISAF.NE.1) LOF=25
C
C       COMPUTE NUMBER OF P(1)'S AND P(2)'S
C
                NP1=(B(1)-A(1))/DELP(1)+1.01
                NP2=(B(2)-A(2))/DELP(2)+1.01
C
C       CALL GRIDMK TO GENERATE THE GRIDS FOR THE INDICATED SOLUTIONS
C
                DO 100 K=1,NSG
C
C       ...SET INITIAL SOLUTION
C
                JJ=ISGR(K)
                DO 20 J=1,NP
 20             PINI(J)=SOLP(J,JJ)
C
C       ...IF JJ .GT. NS WRITE ERROR MESSAGE AND RETURN
C
                IF(JJ.GT.NS) GO TO 105
C
C       ...CALL GRIDMK TO DEVELOP THE GRID FOR THIS SOLUTION
C
                WRITE(6,1002) JJ
                CALL GRIDMK(A,B,DELP,EPS,PINI,NP,NCS,ICM,GRD,COPT,IDCV,
                IPRF)
C
C       WRITE GRIDS AND OPTIMUM VALUES ON UNIT LOF
C
 50             WRITE(LOF) NP1,NP2,NP,ISGR(K),GRD,COPT,IDCV
 100            CONTINUE
                REWIND LOF
                IF(LOF.NE.25.AND.KON(JX+1).EQ.3) CALL RPD(LOF)
 102            RETURN
C
C       WRITE ERROR MESSAGE
C
 105            WRITE(6,1001) JJ
                RETURN
C
C       FORMAT STATEMENTS
C
 1001           FORMAT (1H '****SOLUTION NUMBER ',I2,' NOT AVAILABLE')
 1002           FORMAT(1H0,'****MAP SOLUTION NO. ',I2,'*****'/)
                END
```

```
APR26.COMCHA
C TITLE         COMCHA-COMPUTE SYSTEM CHARACTEISTICS
C
C AUTHOR        P.F. LONG
C
C DATE          6-7-68
C
C PURPOSE       TO COMPUTE THE SYSTEM CHARACTERISTICS FOR EACH POINT AND
C               STORE FOR PLOTTING
C
C METHOD        THE INDICATED GRID AND THE CORRESPENDING SOLUTIONS ARE
C               READ AND THE CHARACTERISTICS ARE COMPUTED AND STORED FOR
C               EACH POINT. PRTCHA IS CALLED FOR ALL OR A SUBSET OF THE
C               POINTS TO PRINT THE SYSTEM PARAMETERS AND CHARACTERISTICS
C
C INPUT         THROUGH LABELLED COMMON MCL
C
C               KON,IUNIT,ISAC,NCG,ICCH,IPRC,NP,NC
C               THESE VARIABLES ARE DEFINED IN THE MAIN PROGRAM UNDER
C               COMMON MCL.
C
C               READ FROM UNIT LIC
C
C               NP1     NUMBER OF P(1)'S
C               NP2     NUMBER OF P(2)'S
C               NP      NUMBER OF PARAMETERS
C               ISNO    NUMBER OF SOLUTION FROM WHICH GRID WAS MAPPED
C               GRD(I,J,K) RESULTING SOLUTION GRID. I=1,NP J=1,NP1
C                       K=1,NP2
C               COPT(J,K) OPTIMUM VALUE IF OPTIMIZING. J=1,1,NP1,K=1,NP2
C               IDCV(J,K) =1, SOLUTION FOUND FOR GRID POINT CORRESPONDING
C                       TO (J,K)
C
C OUTPUT        PARAMETERS AND CHARACTERISTICS ARE PRINTED AND WRITTEN
C               ON UNIT LOC
C
C SUBROUTINES   CHARAC  COMPUTES THE SYSTEM CHARACTERISTICS GIVEN THE
C                       VALUES OF THE PARAMETERS
C               PRTCHA  PRINTS PARAMETERS AND CHARACTERISTICS FOR A
C                       SINGLE GRID POINT
C
C       SUBROUTINE STATEMENT
C
                SUBROUTINE COMCHA
C
C       SPECIFICATION STATEMENTS
C
                INCLUDE PARSTA,LIST
                INCLUDE KOMMCL,LIST
                DIMENSION GRD(MP,MA,MO),COPT(MA,MO),P(MP),IDCV(MA,MO),
                C(MK)
C
C       DETERMINE INPUT AND OUTPUT UNITS
C
                LIC=25
                IF(KON(1).EQ.3) LIC=IUNIT
                IF(ISAC.EQ.0) LOC=26
```

```
C
C       DEVELOP THE GRIDS
C
                DO 200 I=1,NCG
C
C       ...READ A GRID FROM FLU LIC
C
                READ(LIC)NP1,NP2,NP,ISNO,GRD,COPT,IDCV
C
C       ...IS THIS GRID TO BE DEVELOPED
C
                IF(ICCH(I)-ISNO)20,15,200
C
C       ...WRITE ERROR MESSAGE AND CONTINUE
C
 20             WRITE(6,1001)
                GO TO 200
C
C       ...WRITE IDENTIFING INFORMATION ON LEU LOC
C
 15             WRITE(LOC)ISNO,NP1,NP2,NP,NC
                WRITE(6,1002) ISNO
C
C       ...READ, COMPUTE, AND PRINT GRID POINT BY GRID POINT
C
                DO 190 J=1,NP1
                DO 190 K=1,NP2
C
C       ...SET PARAMETERS FOR THIS GRID POINT
C
                DO 30 L=1,NP
 30             P(L)=GRD(L,J,K)
                IF(IDCV(J,K).NE.0)   GO TO 40
                P(1)=A(1)+(J-1)*DELP(1)
                P(2)=A(2)+(K-1)*DELP(2)
                DO 35 K1=3,NP
 35             P(K1)=0.0
                DO 36  K1=1,NC
 36             C(K1)=0.0
C
C       ...IF A SOLUTION WAS FOUND FOR THIS POINT COMPUTE CHARACTERISTICS
C
 40             IF(IDCV(J,K).EQ.1)   CALL CHARAC(P,C)
C
C       WRITE P AND C ON PLOT TAPE
C
                WRITE(LOC)(IDCV(J,K),(P(II),II=1,NP),(C(JJ),JJ=1,NC))
C
C       ...IF THIS POINT IS TO BE PRINTED CALL PRTCHA
C
                IF(IPRC.EQ.0) GO TO 190
                IF(IDCV(J,K).NE.1) GO TO 190
                IF(MOD(J,IPRC).EQ.0.AND.MOD(K,IPRC).EQ.0.OR.J.EQ.1.OR.K
                .EQ.1.OR.J.EQ.NP1.OR.K.EQ.NP2) CALL PRTCHA(P,C)
 190            CONTINUE
 200            CONTINUE
                END FILE LOC
```

```
      REWIND LOC
      REWIND 25
  205 RETURN
C
C     FORMAT STATEMENTS
C
 1001 FORMAT(1H0,' ***** GRID REQUESTED WAS NOT MAPPED *****')
 1002 FORMAT(1H0,'*****COMPUTE CHARACTERISTICS FOR SOLUTION '
     1'NO. ',I2,'******'/)
      END
```

```
APR26.PLTCON
C TITLE         PLTCON - CONTOUR PLOTTING
C
C AUTHOR        M.T. HINMAN
C
C DATE          1/1/69
C
C PURPOSE       TO READ FUNCTIONS OF TWO VARIABLES FROM A NUMBER OF
C               FILES AND TO GENERATE AND PLOT CONTOURS OF THESE
C               FUNCTIONS
C
C METHOD        PLTCON DETERMINES IN ADVANCE WHAT FUNCTIONS ARE TO BE
C               READ SO THAT EACH FILE CAN BE READ IN ONE PASS. EACH
C               FUNCTION IS THEN STORED ON A SEPARATE FASTRDUM FILE.
C               PLTCON THEN CALLS ERMPLT WHICH PROVIDES FOR THE CONTOUR
C               GENERATION AND PLOTTING.
C
C INPUT         VIA COMMON MCL. SEE DOCUMENTATION OF MCL
C
C OUTPUT        SUMMARY TABLES,FUNCTION ARRAYS,PRINTER PLOTS,PLOT TAPE
C
C
C       SUBROUTINE STATEMENT
C
              SUBROUTINE PLTCON
C
C       SPECIFICATION STATEMENTS
C
              INCLUDE PARSTA,LIST
              INCLUDE KOMMCL,LIST
              INCLUDE MCLDOC,LIST
              INCLUDE KPFILE,LIST
              PARAMETER MFU=MF*MU,MPC=NP+MK
              INTEGER SKIP
              DIMENSION MIFLU(MFU),MISOL(MFU),MIVAR(MFU),FAINC(MFU),
     .  FOINC(MFU),FCMIN(MFU),FCMAX(MFU),FDELC(MFU),MIVS(MFU),MIS(MFU),
     .  MLS(MFU),MINCS(MFU),FAMIN(MFU),FAMAX(MFU),FOMIN(MFU),FOMAX(MFU),
     .        INSA(MFU),IFASTD(MFU),MIPOP(MFU)
              DIMENSION LHVAR(50),LHCI(50),LHNR(50),HP1(MA),HP2(MO),
     .        LHFLU(50),LHSOL(50)
              DIMENSION V(MPC),P(2)
C
C       SET NON-APPLICABLE STORAGE AREAS EQUAL TO ZERO
C
              DO 90 I=1,NFR
              JP = NFN(I)
              DO 90 J=1,JP
              IF(IVS(I,J).GT.0)   GO TO 80
              IVS(I,J) = 0
              IS(I,J) = 0
              LS(I,J) = 0
              INCS(I,J) = 0
              GO TO 90
   80         IF(IVS(I,J).EQ.1)   P1INC(I,J)=0
              IF(IVS(I,J).EQ.2)   P2INC(I,J)=0
              CMIN(I,J) = 0
              CMAX(I,J) = 0
```

```
                DELC(I,J) = 0
 90             CONTINUE
C
C       IDRUM = THE FIRST FASTDRUM NUMBER TO BE USED FOR STORAGE
C
                IDRUM = 31
                NTFN = 0
C
C       WRITE A FRAME BY FRAME SUMMARY OF PLOTTING TO BE DONE
C
                IF (IPRP.LT.1)  GO TO 150
                WRITE(6,5)
                WRITE(6,6)
                DO 120   I=1,NFR
                WRITE(6,7) I,IPOP(I),AMIN(I),AMAX(I),OMIN(I),OMAX(I)
                JL = NFN(I)
                DO 120   J = 1,JL
 120            WRITE(6,8) IFLU(I,J),ISOL(I,J),IVAR(I,J),IAO(I,J),
                P1INC(I,J),P2INC(I,J),CMIN(I,J),CMAX(I,J),DELC(I,J),
                IVS(I,J),IS(I,J),LS(I,J),INCS(I,J)
 150            CONTINUE
C
C       CALCULATE NUMBER OF VARIABLE REQUESTS
C
                DO 110   I=1,NFR
 110            NTFN = NTFN+NFN(I)
C
C       SET FASTDRUM FILE INDICATORS TO INITIAL CONDITION
C
                DO 130   I=1,100
                NIPOP(I) = 0
 130            NFORM(I) = 0
                DO 140   I=1,MFU
 140            IFASTD(I)=0
                ICT = 0
C
C       RESTORE VARIABLES FOR SORTING
C
                DO 170   I=1,NFR
                JP = NFN(I)
                DO 160   J=1,JP
                ICT = ICT+1
                MIPOP(ICT) = IPOP(I)
                MIFLU(ICT) = IFLU(I,J)
                MISOL(ICT) = ISOL(I,J)
                MIVAR(ICT) = IVAR(I,J)
                FAINC(ICT) = P1INC(I,J)
                FOINC(ICT) = P2INC(I,J)
                FCMIN(ICT) = CMIN(I,J)
                FCMAX(ICT) = CMAX(I,J)
                FDELC(ICT) = DELC(I,J)
                MIVS(ICT) = IVS(I,J)
                MIS(ICT) = IS(I,J)
                MLS(ICT) = LS(I,J)
                MINCS(ICT) = INCS(I,J)
                IF(IAO(I,J).EQ.1)   GO TO 155
                FAMIN(ICT) = AMIN(I)
```

```
                  FAMAX(ICT) = AMAX(I)
                  FOMIN(ICT) = OMIN(I)
                  FOMAX(ICT) = OMAX(I)
                  GO TO 157
  155             FAMIN(ICT) = OMIN(I)
                  FAMAX(ICT) = OMAX(I)
                  FOMIN(ICT) = AMIN(I)
                  FOMAX(ICT) = AMAX(I)
  157             IF(IVS(I,J).NE.2)  GO TO 160
                  FOMIN(ICT) = FAMIN(ICT)
                  FOMAX(ICT) = FAMAX(ICT)
  160             INSA(ICT) = ICT
  170             CONTINUE
C
C       SORT UNIT NUMBER, SOLUTION NUMBER, AND VARIABLE NUMBER IN
C       ASCENDING ORDER
C
                  NUMRAY = 18
                  NUMELM = ICT
                  CALL ORDUP(NUMRAY,NUMELM,MIVAR,MIFLU,MISOL,FAINC,FOINC,
     .  ECMIN,ECMAX,EDELC,MIVS,MIS,MLS,MINCS,FAMIN,FAMAX,FOMIN,FOMAX,
     .  MIPOP,INSA,I,J)
                  CALL ORDUP(NUMRAY,NUMELM,MISOL,MIFLU,MIVAR,FAINC,FOINC,
     .  FCMIN,FCMAX,FDELC,MIVS,MIS,MLS,MINCS,FAMIN,FAMAX,FOMIN,FOMAX,
     .  MIPOP,INSA,I,J)
                  CALL ORDUP(NUMRAY,NUMELM,MIFLU,MISOL,MIVAR,FAINC,FOINC,
     .  ECMIN,ECMAX,EDELC,MIVS,MIS,MLS,MINCS,FAMIN,FAMAX,FOMIN,FOMAX,
     .  MIPOP,INSA,I,J)
C
C       STORE EACH UNIQUE SOLUTION VARIABLE REQUESTED IN A SEPARATE AREA
C       AND CHECK NUMBER OF REQUESTS FOR EACH SOLUTION VARIABLE
C
                  KFC = 1
                  LHFLU(1) = MIFLU(1)
                  LHSOL(1) = MISOL(1)
                  LHVAR(1) = MIVAR(1)
                  M1 = 2
                  M2 = NTFN
  280             DO 300  IL=M1,M2
                  IF(LHFLU(KFC).EQ.MIFLU(IL).AND.LHSOL(KFC).EQ.MISOL(JL)
     .  .AND.LHVAR(KFC).EQ.MIVAR(IL))  GO TO 300
                  GO TO 310
  300             CONTINUE
                  LHCT(KFC) = M2-M1+2
                  GO TO 330
  310             LHCT(KFC) = IL-M1+1
                  M1 = IL+1
                  KFC = KFC+1
                  LHFLU(KFC) = MIFLU(IL)
                  LHSOL(KFC) = MISOL(IL)
                  LHVAR(KFC) = MIVAR(IL)
                  IF(IL.LT.M2)   GO TO 280
                  LHCT(KEC) = 1
C
C       CHECK HOW MANY DIFFERENT REQUESTS FOR EACH UNIQUE VARIABLE
C       STORE THE NUMBER OF THE FASTORUM FILE WITH EACH REQUEST AND
C       STORE THE NUMBER OF DIFFERENT REQUESTS (THE NUMBER OF FILES TO BE
```

```
C       CREATED) FOR EACH UNIQUE VARIABLE
C
 330            IJ2 = 0
                NAD = 1
                NDR = IDRUM
 335            IJ = IJ2+1
                IJ2 = IJ2+LHCT(NAD)
 345            IJ1 = IJ+1
                IEASTD(IJ) = NDR
                IPOPS = MIPOP(IJ)
                IF(IPOPS.NE.0)  NIPOP(NDR)=1
                IF(IJ1.GT.IJ2)  GO TO 500
                DO 400  I=IJ1,IJ2
                IF(ABS(FAINC(IJ)-FAINC(I)).GT.1.0E-10)  GO TO 400
                IF(ABS(FOINC(IJ)-FOINC(I)).GT.1.0E-10)  GO TO 400
                IF(ABS(FCMIN(IJ)-FCMIN(I)).GT.1.0E-10)  GO TO 400
                IF(ABS(FCMAX(IJ)-FCMAX(I)).GT.1.0E-10)  GO TO 400
                IF(ABS(FDELC(IJ)-FDELC(I)).GT.1.0E-10)  GO TO 400
                IF(ABS(MIVS(IJ)-MIVS(I)).GT.1.0E-10)  GO TO 400
                IF(ABS(MIS(IJ)-MIS(I)).GT.1.0E-10)  GO TO 400
                IF(ABS(MLS(IJ)-MLS(I)).GT.1.0E-10)  GO TO 400
                IF(ABS(MINCS(IJ)-MINCS(I)).GT.1.0E-10)  GO TO 400
                IEASTD(I) = NDR
                NFORM(NDR) = 1
                IPOPS = IPOPS+MIPOP(I)
 400            CONTINUE
                IF(IPOPS.NE.0)  NIPOP(NDR)=1
                DO 450  I=IJ1,IJ2
                IF(IEASTD(I).EQ.0)  GO TO 470
 450            CONTINUE
                GO TO 500
 470            NDR = NDR+1
                IJ = I
                GO TO 345
 500            LHVR(NAD) = NDR
                IF(NAD.EQ.KFC)  GO TO 550
                NDR = NDR+1
                NAD = NAD+1
                GO TO 335
C
C       READ TAPE
C
 550            NAD = 1
                IF(IPRP.LT.1) GO TO 555
                WRITE(6,1)
 555            NFD1 = IDRUM
 560            NT = LHELU(NAD)
 570            READ(NT) NHSOL,NA,NO,NP,NC
                IF(IPRP.LT.1) GO TO 575
                WRITE(6,2) NT,NHSOL
 575            NTE = NA*NO
                IF(NHSOL.EQ.LHSOL(NAD))  GO TO 600
C
C       IF SOLUTION NUMBERS DO NOT MATCH, SKIP REST OF FILE
C
                DO 580  I=1,NTE
 580            READ(NT) SKIP
```

```
                GO TO 570
C
C       WRITE HEADER INFORMATION ON EACH FASTDRUM FILE NOW BEING PROCESSED
C
  600           IV = LHVAR(NAD)
                NFD2 = LHNR(NAD)
                NPC=NP+NC-2
                DO 602   ID = NFD1,NFD2
                WRITE(ID) NT,NHSOL,IV,NA,NO
                IF(IPRP.LT.1) GO TO 602
                WRITE(6,3) ID,NHSOL,IV
                REWIND ID
                READ(ID) NT,NHSOL,IV,NA,NO
  602           CONTINUE
                IF (NAD.EQ.KEC)   GO TO 610
                NAD1 = NAD+1
                DO 608   I=NAD1,KEC
                IF(LHFLU(NAD).EQ.LHFLU(I).AND.LHSOL(NAD).EQ.LHSOL(I))
                GO TO 605
                GO TO 610
  605           NFD3 = LHNR(I-1)+1
                NFD2 = LHNR(I)
                IV = LHVAR(I)
                DO 608   ID = NFD3,NFD2
                WRITE(ID) NT,NHSOL,IV,NA,NO
                IF(IPRP.LT.1) GO TO 608
                WRITE(6,3) ID,NHSOL,IV
  608           CONTINUE
  610           DO 710   ITA=1,NA
                DO 700   ITO=1,NO
                READ(NT) IDCV,P(1),P(2),(V(JJ),JJ=1,NPC)
C
C       WRITE FASTDRUM RECORD FOR EACH UNIQUE VARIABLE REQUEST
C
                HP2(ITO) = P(2)
                IV = LHVAR(NAD)
                NFD2 = LHNR(NAD)
                DO 650   ID=NFD1,NFD2
  650           WRITE(ID) IDCV,V(IV)
                IF(NAD.EQ.KFC)   GO TO 700
                DO 670   I=NAD1,KFC
                IF(LHFLU(NAD).EQ.LHFLU(I).AND.LHSOL(NAD).EQ.LHSOL(I))
                GO TO 660
                GO TO 700
  660           NFD3 = LHNR(I-1)+1
                IV = LHVAR(I)
                NFD2 = LHNR(I)
C
C       WRITE FASTDRUM RECORDS FOR EVERY OTHER UNIQUE VARIABLE REQUEST
C -     FOR THE SAME SOLUTION
C
                DO 665   ID = NFD3,NFD2
  665           WRITE(ID) IDCV,V(IV)
  670           CONTINUE
  700           CONTINUE
  710           HP1(ITA) = P(1)
C
```

```
C       WRITE GRID PARAMETERS FOR EACH FASTDRUM FILE
C
                NFD2 = LHNR(NAD)
                DO 720   ID=NFD1,NFD2
  720           WRITE(ID) (HP1(I),I=1,NA),(HP2(J),J=1,NO)
                IF(NAD.EQ.KFC)   GO TO 800
                DO 740   I=NAD1,KEC
                IF(LHFLU(NAD).EQ.LHFLU(I).AND.LHSOL(NAD).EQ.LHSOL(I))
                GO TO 735
                GO TO 800
  735           NFD3 = LHNR(I-1)+1
                NFD2 = LHNR(I)
                DO 740   ID=NFD3,NFD2
  740           WRITE(ID) (HP1(K),K=1,NA),(HP2(J),J=1,NO)
  800           IF(NAD.EQ.KFC)   GO TO 900
                DO 810   I=NAD1,KFC
                IF(LHFLU(NAD).EQ.LHFLU(I).AND.LHSOL(NAD).EQ.LHSOL(I))
                GO TO 810
                GO TO 820
  810           CONTINUE
                GO TO 900
  820           NAD = I
                NFD1 = LHNR(I-1)+1
                GO TO 560
  900           CONTINUE
C
C       REORDER AND STORE FASTDRUM FILE NUMBER INDICATOR FOR EACH
C       FUNCTION REQUEST
C
                ICT = 0
                CALL ORDUP(2,NUMELM,INSA,IFASTD,I1,I2,I3,I4,I5,I6,I7,I8,
                I9,I10,I11,I12,I13,I14,I15,I16,I17,I18)
                DO 920   I=1,NFR
                JP = NFN(I)
                DO 920   J=1,JP
                ICT = ICT+1
  920           IFD(I,J) = IFASTD(ICT)
C
C       REWIND FILES
C
                DO 950   N=IDRUM,NDR
                REWIND N
                READ(N) MT,NHSOL,IV,NA,NO
  950           REWIND N
C
C       CALL FRMPLT FOR CONTOUR GENERATION AND PLOTTING
C
                CALL FRMPLT
                RETURN
C
C       FORMAT STATEMENTS
C
    1           FORMAT(1H1)
    2           FORMAT(32H0PRESENT SOLUTION NUMBER ON UNIT,I3,5H   IS,I3)
    3           FORMAT(23H          FASTDRUM FILE,I3,26H  CONTAINS SOLUTI
      .ON NUMBER,I3,21H  AND VARIABLE NUMBER,I3)
    5           FORMAT(60H1FRAME NO.  PLOT OP.      AMIN      AMAX      O
```

```
     .MIN      OMAX)
   6           FORMAT(1H0,29X,103HUNIT  SOL.NO.  VAR.NO.  XY OP.     DELP
     .1    DELP2      CMIN       CMAX       CDEL       IVS   IS    LS   INCS/
     ./)
   7           FORMAT(1H0,I7,I10,4X,4E10.1/)
   8           FORMAT(29X,I4,3I8,2X,5F10.2,2X,4I5)
               END
```

```
E APR26.SEEK1
      C TITLE          SEEK1 - TOTAL DOMAIN SEARCH
      C
      C AUTHOR         P.F. LONG
      C
      C DATE           2-14-68
      C
      C PURPOSE        TO FIND ALL DISTINCT SOLUTIONS WITHIN THE GIVEN
      C                PARAMETER SPACE.
      C
      C METHOD         START AN ITERATIVE PROCEDURE AT EACH POINT OF A GRID
      C                FORMED FROM THE DOMAINS OF P(3),P(4),...,P(NA). RETURN
      C                THE RESULTING DISTINCT SOLUTIONS.
      C
      C CALL           SEEK1(A,B,DELP,P1I,P2I,NP,NCS,ICM,EPS,NS,SOL,SOLC,IPRI)
      C
      C INPUT          THROUGH ARGUMENT LIST
      C
      C                NAME     DEFINITION
      C
      C                A(I)     LOWER BOUND ON ITH INDEPENDENT PARAMETER
      C                B(I)     UPPER BOUND ON ITH INDEPENDENT PARAMETER
      C                DELP(I)  STEP SIZE FOR ITH INDEPENDENT PARAMETER
      C                P1I      VALUE OF P(1) WHILE SEARCHING
      C                P2I      VALUE OF P(2) WHILE SEARCHING
      C                NP       NUMBER OF INDEPENDENT PARAMETERS
      C                NCS      NUMBER OF EQUALITY CONSTRAINTS
      C                ICM      ITERATIVE METHOD SELECTOR
      C                EPS(I)   TOLERANCE ON ITH EQUALITY CONSTRAINT
      C                IPRI     PRINT CONTROL
      C
      C OUTPUT         THROUGH ARGUMENT LIST
      C
      C                NAME     DEFINITION
      C
      C                NS       NUMBER OF DISTINCT SOLUTIONS FOUND
      C                SOLP(I,J) ITH COMPONENT OF JTH SOLUTION
      C                SOLC(I,J) FINAL VALUE OF ITH CONSTRAINT OF JTH SOLUTION
      C
      C SUBROUTINES    CONV
      C
      C       SUBROUTINE STATEMENT
      C
                       SUBROUTINE SEEK1(A,B,DELP,P1I,P2I,NP,NCS,ICM,EPS,NS,
                      *SOLP,SOLC,IPRI)
      C
      C       SPECIFICATION STATEMENTS
      C
                       INCLUDE PARSTA.LIST
                       DIMENSION A(1),B(1),DELP(1),EPS(1),SOLP(MP,MS),
                      *SOLC(NC,MS),PI(MP),PE(MP),CSE(MC)
                       DIMENSION TYCO(5)
                       DATA TYCO/6HCONVER,6HNEASOL,6HNEAMIP,6HMAXITR,6HOUTBDS/
                       COMMON/SECO/ITR
      C
      C       INITIALIZE NS AND PI
      C
```

```
                NTC=1
                NS=0
                NPL2=NP-2
                PI(1)=P1I
                PI(2)=P2I
                DO 5 J=3,NP
 5              PI(J)=A(J)
C
C       CALL CONV TO ATTEMPT CONVERGENCE TO A SOLUTION USING CURRENT
C       VALUE OF PI AS INITIAL GUESS
C
 10             CALL CONV(ICM,PI,NP,DELP,NTC,EPS,ICONV,PF,CSF)
C
C       WRITE RESULTS OF CALL TO CONV
C
                IF(IPRI.NE.1) GO TO 11
                WRITE(6,1006)(PI(KK),KK=1,NP)
                WRITE(6,1007) TYCO(ICONV),ITR,(PF(KK),KK=1,NP)
C
C       IF THERE IS CONVERGENCE TO A NEW SOLUTION STORE, IF NOT STEP
C       UP PARAMETERS
C
 11             IF(ICONV.NE.1) GO TO 40
C
C       ...IS THIS FIRST SOLUTION
C
                IF(NS.EQ.0)GO TO 23
C
C       ...TEST FOR NEW SOLUTION
C
                DO 20 I=1,NS
                DO 15 J=3,NP
                IF(ABS(SOLP(J,I)-PF(J)).GT.0.25*DELP(J)) GO TO 20
 15             CONTINUE
                GO TO 40
 20             CONTINUE
C
C       ...THIS IS NEW SOLUTION THEREFOR STORE
C
 23             NS=NS+1
                IF(NS.GT.MS)GO TO 60
                DO 25 J=1,NP
 25             SOLP(J,NS)=PF(J)
                DO 30 J=1,NCS
 30             SOLC(J,NS)=CSF(J)
C
C       ...STEP UP PARAMETERS
C
 40             DO 50 J=1,NPL2
                JJ=NP+1-J
                PI(JJ)=PI(JJ)+DELP(JJ)
                IF(PI(JJ).LT.(B(JJ)+0.01*DELP(JJ)))GO TO 10
 50             PI(JJ)=A(JJ)
                RETURN
C
C       WRITE MAXIMUM NUMBER OF SOLUTIONS MESSAGE
C
```

```
   60          WRITE(6,1001)(PI(JJ),JJ=1,NP)
               RETURN
C---
C       FORMAT STATEMENTS
C
 1001          FORMAT(1H0,'***** NUMBER OF SOLUTIONS EXCEEDS ALLOTTED '
              'STORAGE. LAST SEARCH POINT WAS'/7X,10E12.5)
 1004          FORMAT(1H ,'NO. ITR. = ',I3,2X,'PF = ',(T23,6E15.8))
 1006          FORMAT(1H ,16X,'PI = ',(T23,6E15.8))
 1007          FORMAT(1H ,A6,I3,' ITRS  PF = ',(T23,6E15.8))
               END
```

```
APR26.SEEK3
C TITLE          SEEK3 - TOTAL DOMAIN SEARCH
C
C AUTHOR         P.F. LONG
C
C DATE           1/3/69
C
C PURPOSE        TO FIND ALL DISTINCT SOLUTIONS WITHIN THE GIVEN
C                PARAMETER SPACE.
C
C METHOD         OPTIMUM DOMAIN SEARCH
C
C CALL           SEEK3(A,B,DELP,P1I,P2I,NP,NCS,ICM,EPS,NS,SOL,SOLC,IPRI)
C
C INPUT          THROUGH ARGUMENT LIST
C
C                NAME        DEFINITION
C
C                A(I)        LOWER BOUND ON ITH INDEPENDENT PARAMETER
C                B(I)        UPPER BOUND ON ITH INDEPENDENT PARAMETER
C                DELP(I)     STEP SIZE FOR ITH INDEPENDENT PARAMETER
C                P1I         VALUE OF P(1) WHILE SEARCHING
C                P2I         VALUE OF P(2) WHILE SEARCHING
C                NP          NUMBER OF INDEPENDENT PARAMETERS
C                NCS         NUMBER OF EQUALITY CONSTRAINTS
C                ICM         ITERATIVE METHOD SELECTOR
C                EPS(I)      TOLERANCE ON ITH EQUALITY CONSTRAINT
C                IPRI        PRINT CONTROL
C
C OUTPUT         THROUGH ARGUMENT LIST
C
C                NAME        DEFINITION
C
C                NS          NUMBER OF DISTINCT SOLUTIONS FOUND
C                SOLP(I,J)   ITH COMPONENT OF JTH SOLUTION
C                SOLC(I,J)   FINAL VALUE OF ITH CONSTRAINT OF JTH SOLUTION
C
C SUBROUTINES    CONSTR,CONV3
C
C       SUBROUTINE STATEMENT
C
                 SUBROUTINE SEEK3(A,B,DELP,P1I,P2I,NP,NCS,ICM,EPS,NS,
                .SOLP,SOLC,IPRI)
C
C       SPECIFICATION STATEMENTS
C
                 PARAMETER MSP=10000
                 INCLUDE PARSTA,LIST
                 DIMENSION A(1),B(1),DELP(1),EPS(1),SOLP(MP,MS),
                .SOLC(MC,MS),PI(MP),PF(MP),CSF(MC),NGP(MP),
                .TYCO(5),E(MSP),DEL1(MP)
                 DATA TYCO/6HCONVER,6HNEASOL,6HNEAMIP,6HMAXITR,6HOUTBDS/
                 COMMON/SECO/ITR
                 LOGICAL CLOSE,VCP
C
C       INITIALIZE
C
```

```
                    NTC=0
                    IU=34
                    ITRY=0
                    IPER=10
                    NS=0
                    NPL2=NP-2
                    PI(1)=P1I
                    P1(2)=P2I
                    NPT=1
                    DO 4 J=1,NP
    4               DEL1(J)=1.01*DELP(J)
                    DO 5 J=3,NP
                    NGP(J)=(B(J)-A(J))/DELP(J)+1.01
                    NPT=NPT*NGP(J)
    5               PI(J)=A(J)
                    IF(NPT.GE.MSP)GO TO 100
                    NSI=(IPER*NPT)/100
                    NU=0
                    REWIND IU
      C
      C       COMPUTE SUM OF SQUARES FOR EACH GRID POINT
      C
   10               CALL CONSTR(PI,CSF)
                    NU=NU+1
                    E(NU)=0.
                    DO 15 J=1,NCS
   15               E(NU)=E(NU)+CSF(J)**2
      C
      C       WRITE E, P, AND CSF
      C
                    IF (IPRI .NE. 1)  GO TO 19
                    WRITE(6,1002)E(NU),(CSF(J),J=1,NCS)
                    WRITE(6,1003)(PI(J),J=3,NP)
      C
      C       STORE X AND E
      C
   19               WRITE(IU) (PI(J+2),J=1,NCS),(CSF(J),J=1,NCS)
      C
      C       STEP UP PARAMETERS
      C
                    DO 75 J=1,NPL2
                    JJ=NP+1-J
                    PI(JJ)=PI(JJ)+DELP(JJ)
                    IF(P1(JJ).LT.(B(JJ)+0.01*DELP(JJ)))GO TO 10
   75               PI(JJ)=A(JJ)
      C
      C       FIND THE NEXT SMALLEST E
      C
                    NCC=0
   35               IL=1
                    DO 40 J=2,NPT
                    IF(E(J).LT.E(IL))IL=J
   40               CONTINUE
                    E(IL)=1.E38
      C
      C       FIND GRID POINT IL ON THE DRUM
      C
```

```
                IW=IL-1
                REWIND IU
                IF (IW .EQ. 0)  GO TO 49
                DO 48  I=1,IW
   48           READ(IU) Q
   49           READ(IU)  (PI(J+2),J=1,NCS),(CSF(J),J=1,NCS)
                NCC=NCC+1
C
C       TEST FOR NEAR SOLUTION
C
                CLOSE=VCP(SOLP,PI,DEL1,NS,NP)
                IF(CLOSE) GO TO 35
C
C       CALL CONV3
C
                CALL CONV(ICM,PI,NP,DELP,NTC,EPS,ICONV,PF,CSF)
C
C       WRITE RESULTS OF CALL TO CONV
C
                IF(IPRI.NE.1)GO TO 51
                WRITE(6,1006)(PI(KK),KK=1,NP)
                WRITE(6,1007) TYCO(ICONV),ITR,(PF(KK),KK=1,NP)
   51           GO TO(23,65,70,70,70),ICONV
C
C       STORE SOLUTION
C
   23           NS=NS+1
                IF(NS.GT.MS)GO TO 60
                DO 25 J=1,NP
   25           SOLP(J,NS)=PF(J)
                DO 30 J=1,NCS
   30           SOLC(J,NS)=CSF(J)
C
C       RESET NUMBER OF TRYS FLAG
C
   65           ITRY=0
                NSI=(IPER*(NPT-NCC))/100
                GO TO 35
C
C       UPDATE ITRY
C
   70           ITRY=ITRY+1
                IF(ITRY.LT.NSI.AND.NCC.LT.NPT) GO TO 35
                REWIND IU
                RETURN
C
C       WRITE MAXIMUM NUMBER OF SOLUTIONS MESSAGE
C
   60           WRITE(6,1001)(PI(JJ),JJ=1,NP)
                REWIND IU
                RETURN
  100           WRITE(6,1004) NPT
                REWIND IU
                RETURN
C
C       FORMAT STATEMENTS
C
```

```
 1001 FORMAT(1H0,'***** NUMBER OF SOLUTIONS EXCEEDS ALLOTTED '
     'STORAGE. LAST SEARCH POINT WAS'/7X,10E12.5)
 1002 FORMAT(1H ,'E = ',E15.8,4X,'E = ',(T24,6E15.8))
 1003 FORMAT(1H ,23X,'X = ',(T28,6E15.8))
 1004 FORMAT(1H ,'******',I7,' TOTAL NUMBER OF GRID POINTS '
     ',EXCEEDS ALLOTTED STORAGE *****')
 1005 FORMAT(1H ,'***** NTRAN ERROR STOP *****')
 1006 FORMAT(1H ,16X,'PI = ',(T23,6E15.8))
 1007 FORMAT(1H ,A6,I3,' ITRS PF = ',(T23,6E15.8))
      END
```

```
APR26.CONV
C TITLE         CONV - ITERATIVE METHOD SELECTOR
C
C AUTHOR        P.F. LONG
C
C DATE          2-12-68
C
C PURPOSE       TO DIRECT CONTROLE TO ITERATIVE METHOD INDICATED BY ICM
C
C CALL          CONV(ICM,PI,NP,DELP,NCS,EPS,ICONV,PF,CSF)
C
C INPUT         NAME        DEFINITION
C
C               ICM         INDICATES ITERATIVE METHOD TO BE USED
C               PI(J)       INITIAL INDEPENDENT PARAMETER VECTOR
C               NP          NUMBER OF INDEPENDENT PARAMETERS
C               DELP(J)     STEP SIZE FOR JTH PARAMETER
C               NCS         NUMBER OF EQUALITY CONSTRAINTS
C               EPS(J)      TOLERANCE ON JTH CONSTRAINT
C
C
C OUTPUT        NAME        DEFINITION
C
C               ICONV       =1 ITERATIVE METHOD CONVERGED, =0 DID NOT
C               PF(J)       SOLUTION VECTOR IF ICONV = 1, LAST ITERATION
C                           PARAMETER VALUES IF ICONV = 0
C               CSF(J)      FINAL VALUE OF JTH CONSTRAINT
C
C SUBROUTINES   CONV1,CONV2,CONV3,CONV4,CONV5
C
C       SUBROUTINE STATEMENT
C
                SUBROUTINE CONV(ICM,PI,NP,DELP,NCS,EPS,ICONV,PF,CSF)
C
C       SPECIFICATION STATEMENTS
C
                DIMENSION PI(1),DELP(1),EPS(1),PF(1),CSF(1)
C
C       DIRECT CONTROLE TO ITERATIVE METHOD INDICATED BY ICM
C
                GO TO(5,10,15,20,25),ICM
    5           CALL CONV1(PI,NP,DELP,NCS,EPS,ICONV,PF,CSF)
                GO TO 30
   10           CALL CONV2(PI,NP,DELP,NCS,EPS,ICONV,PF,CSF)
                GO TO 30
   15           CALL CONV3(PI,NP,DELP,NCS,EPS,ICONV,PF,CSF)
                GO TO 30
   20           CALL CONV4(PI,NP,DELP,NCS,EPS,ICONV,PF,CSF)
                GO TO 30
   25           CALL CONV5(PI,NP,DELP,NCS,EPS,ICONV,PF,CSF)
   30           RETURN
                END
```

```
APR26.VCP
      C TITLE         VCP - VECTOR COMPARE
      C
      C AUTHOR        P. F. LONG
      C
      C DATE          11/22/68
      C
      C PURPOSE       TO DETERMINE IF A VECTOR IS SUFFICIENTLY CLOSE TO ANY
      C               ONE OF A SET OF VECTORS
      C
      C METHOD        COMPARE VECTORS COMPONENT BY COMPONENT
      C
      C INPUT         BY ARGUMENT LIST
      C
      C               VSET(I,J) ITH COMPONENT OF JTH VECTOR
      C               VEC(I)    ITH COMPONENT OF VECTOR TO BE COMPARED
      C               DEL(I)    DEFINES SUFFICIENTLY CLOSE
      C               NV        NUMBER OF VECTORS IN THE SET
      C               NC        NUMBER OF COMPONENTS
      C
      C OUTPUT        VEC = T   THE GIVEN VECTOR IS SUFFICIENTLY CLOSE TO
      C                         AT LEAST ONE OF THE SET
      C               VEC = F   THE CONTRARY IS TRUE
      C
      C       FUNCTION STATEMENT
      C
                      LOGICAL FUNCTION VCP(VSET,VEC,DEL,NV,NC)
      C
      C       SPECIFICATION STATEMENT
      C
                      INCLUDE PARSIA,LIST
                      DIMENSION VSET(MP,MS),VEC(NC),DEL(NC)
      C
      C       INITIALIZE
      C
                      VCP=.FALSE.
                      IF(NV.EQ.0) RETURN
      C
      C       COMPARE VECTOR WITH SET
      C
                      DO 20 I=1,NV
                      DO 10 J=1,NC
                      IF(ABS(VSET(J,I)-VEC(J)).GT.DEL(J))GO TO 20
           10         CONTINUE
                      VCP=.TRUE.
                      RETURN
           20         CONTINUE
                      RETURN
                      END
```

```
C-R26.CONV3
      C TITLE          CONV3 - SOLUTION FOR A SYSTEM OF NON-LINEAR EQUATIONS
      C
      C AUTHOR         W.B. GRAGG AND J.M. ORTEGA (REVISED BY P.F. LONG)
      C
      C DATE           2-15-68
      C
      C PURPOSE        TO SOLVE A SYSTEM OF N NON-LINEAR EQUATIONS IN N UNKNOWNS
      C
      C METHOD         THE N DIMENSIONAL SECANT METHOD
      C
      C INPUT          THROUGH ARGUMENT LIST
      C
      C                NAME       DEFINITION
      C
      C                PI(J)      PI(1)=P1I,PI(2)=P2I
      C                           PI(J),J=3,NP IS THE STARTING POINT FOR THE
      C                           ITERATIVE PROCEDURE
      C                NP         NUMBER OF PARAMETERS (N=NP-2)
      C                DELP(J)    STEP SIZE FOR ITH INDEPENDENT PARAMETER
      C                NTC        IF NTC.NE.1, Y IS ASSUMED TO BE THE RESULTS
      C                           OF CALL CONSTR(PI,Y). IF NTC.EQ.1 THE CALL
      C                           WILL BE MADE.
      C                EPS(J)     TOLERANCE ON JTH CONSTRAINT
      C                CSF(J)     VALUE OF OF SYSTEM AT P(3),...,P(NP)
      C
      C OUTPUT         THROUGH ARGUMENT LIST
      C
      C                NAME       DEFINITION
      C
      C                ICONV      =1, METHOD CONVERGED
      C                           =2, NEAR OLD SOLUTION
      C                           =4, IN REPEATING LOOP
      C                           =5, OUT OF SEARCH AREA
      C                PF(J)      PF(1)=PI(1),PF(2)=PI(2),P(J),J=3,NP SOLUTION
      C                           OR LAST ITERATION
      C                Y(J)       FINAL VALUE OF EQUALITY CONSTRAINTS
      C
      C CALL           CONV3(PI,NP,DELP,NTC,EPS,ICONV,PF,Y)
      C
      C SUBROUTINES    GAUSS,CONSTR
      C
      C NOTE           CONV3 IS DESIGNED TO INTERFACE WITH PAP. BECAUSE OF THIS
      C                PI IS A VECTOR WITH NP COMPONENTS. TWO OF THESE ARE THE
      C                FIXED GRID PARAMETERS AND NP-2 ARE THE INITIAL POINT
      C                FOR THE SECANT METHOD, I.E., N=NP-2.
      C
      C     SUBROUTINE STATEMENT
      C
                       SUBROUTINE CONV3(PI,NP,DELP,NTC,EPS,ICONV,PF,Y)
      C
      C     SPECIFICATION STATEMENTS
      C
                       INCLUDE PARSTA,LIST
                       DIMENSION A(20,20),B(20),Y(20),X(MC),EPS(MC),CEN(MC),
                      .Q(MP,MP),W(MP),R(MP),PI(MP),PF(MP),P(MP),
                      .DELP(MP),DEL(MP)
```

```
      COMMON/SECO/LIR
      INCLUDE KOMSOL,LIST
      EQUIVALENCE (X(1),P(3))
      LOGICAL CLOSE,VCP
C
C     INITIALIZE
C
      N=NP-2
      ICONV=5
      BD=1.01
      IF(NTC.EQ.1) BD=2.
      ZINC=.1/FLOAT(N)
      M=N+1                                                        WOLF006
      PF(1)=PI(1)
      PF(2)=PI(2)
      DO 15 I=1,NP
      DEL(I)=BD*DELP(I)
   15 P(I)=PI(I)
      DO 16 I=1,N                                                  WOLF006
   16 CEN(I)=X(I)                                                  WOLF005
      L=0
C
C     IF NTC IS 1, COMPUTE INITIAL VALUE OF SYSTEM
C
      IF(NTC.EQ.1) CALL CONSTR(P,Y)
C                                                                  WOLF006
C     INITIALIZE THE MATRICES Q AND A AND THE VECTOR B             WOLF007
C                                                                  WOLF007
      DO 2 J=1,N                                                   WOLF007
      DO 1 I=1,N                                                   WOLF007
      Q(I,J)=X(I)                                                  WOLF007
    1 A(I,J)=Y(I)                                                  WOLF007
      A(M,J)=1.0                                                   WOLF007
      IF(J.EQ.M)GO TO 3                                            WOLF007
      B(J)=0.0                                                     WOLF007
      X(J)=X(J)+ZINC*DELP(J+2)
      CALL CONSTR(P,Y)
    2 CONTINUE                                                     WOLF008
    3 B(M)=1.0                                                     WOLF008
C                                                                  WOLF009
C     START MAIN ITERATION                                         WOLF009
C                                                                  WOLF010
      DO 13 I=1,20                                                 WOLF010
C                                                                  WOLF009
C     FORM WEIGHTS FOR F                                           WOLF008
C                                                                  WOLF009
      DO 5 I=1,N                                                   WOLF008
      W(I)=0.0                                                     WOLF008
      DO 4 J=1,M                                                   WOLF008
    4 W(I)=W(I)+A(I,J)**2                                          WOLF008
    5 W(I)=1.0/W(I)                                                WOLF009
C                                                                  WOLF009
C     FORM WEIGHTED RESIDUALS FOR INITIAL GUESSES                  WOLF009
C                                                                  WOLF009
      DO 6 J=1,M                                                   WOLF009
      R(J)=0.0                                                     WOLF009
      DO 6 I=1,N                                                   WOLF009
```

```
    6           R(J)=R(J)+W(I)*A(I,J)**2                                WOLF008
C                                                                       WOLF009
C       FIND MAXIMUM WEIGHTED RESIDUAL                                  WOLF010
C                                                                       WOLF011
                TEMP=0.0                                                WOLF012
                DO 7 J=1,M                                              WOLF013
                IF(R(J).LT.TEMP)GO TO 7                                 WOLF014
                TEMP=R(J)                                               WOLF015
                K=J                                                     WOLF016
    7           CONTINUE                                                WOLF017
C                                                                       WOLF018
C       FORM A NEW APPROXIMATION TO X AND EVALUATE F(X)                 WOLF019
C                                                                       WOLF020
                CALL GAUSS(M,1,A,B,Y,DET,EPR)                           WOLF021
                DO 9 I=1,N                                              WOLF022
                TEMP=0.0                                                WOLF023
                DO 8 J=1,M                                              WOLF024
    8           TEMP=TEMP+Y(J)*Q(I,J)                                   WOLF025
    9           X(I)=TEMP                                               WOLF026
C                                                                       WOLF027
C       IS X OUT OF SEARCH AREA                                         WOLF028
C                                                                       WOLF029
                DO 14 I=1,N
                IF(ABS(CEN(I)-X(I)).GT.BD*DELP(I+2)) GO TO 20
   14           CONTINUE
                IF(NTC.EQ.1) GO TO 17
C
C       IF X IS NEAR A PREVIOUS SOLUTION, RETURN
C
                CLOSE=VCP(SOLP,P,DEL,NS,NP)
                IF(CLOSE) ICONV=2
                IF(CLOSE) GO TO 20
C
C       CALL CONSTR
C
   17           CALL CONSTR(P,Y)
C                                                                       WOLF030
C       TEST FOR CONVERGENCE                                            WOLF031
C                                                                       WOLF032
                DO 11 I=1,N                                             WOLF033
   11           IF(ABS(Y(I)).GT.EPS(I))GO TO 12
                ICONV=1
                GO TO 20
C
C       TEST FOR REPEATING LOOP
C
   12           DO 26 I=1,N
                IF(ABS(X(I)-Q(I,K)).GT.1E-9) GO TO 25
   26           CONTINUE
                ICONV=4
                GO TO 20
C                                                                       WOLF034
C       GET READY FOR NEXT ITERATION                                    WOLF035
C                                                                       WOLF036
   25           R(K)=0.0
                DO 13 I=1,N                                             WOLF037
                Q(I,K)=X(I)                                             WOLF038
```

```
   13          A(I,K)=Y(I)                                          WOLF01
               ICONV=4
   20          DO 21 J=1,N
   21          PF(J+2)=X(J)
               ITR=1
               RETURN
               END                                                  WOLF01
```

```
F.APR26.GAUSS
      C
      C TITLE      GAUSS                                                    GAUS00C
      C                                                                     GAUS00C
      C AUTHOR     J.M. ORTEGA                                              GAUS00C
      C                                                                     GAUS00C
      C DATE       FEBRUARY 1963                                            GAUS00C
      C                                                                     GAUS00C
      C PURPOSE    TO SOLVE THE MATRIX EQUATION AX=B                        GAUS00C
      C                                                                     GAUS00C
      C CALL       GAUSS(N,M,A,B,X,DET,ERR)                                 GAUS00C
      C                                                                     GAUS00C
      C INPUT      N=DIMENSION OF THE SQUARE MATRIX A (N.LE.20)             GAUS00C
      C            M=NUMBER OF COLUMNS OF B (M.LE.20)                       GAUS00C
      C            A=THE MATRIX A                                           GAUS00C
      C            B=THE MATRIX B                                           GAUS00C
      C                                                                     GAUS00C
      C OUTPUT     X=NUMERICAL SOLUTION OF AX=B                             GAUS00C
      C            DET=DETERMINANT OF A                                     GAUS00C
      C            ERR=AN INDICATOR OF THE ACCURACY OF X                    GAUS00C
      C                                                                     GAUS00C
      C METHOD     GAUSSIAN ELIMINATION WITH ROW INTERCHANGES TO POSITION   GAUS00C
      C            THE MAXIMUM PIVOTAL ELEMENTS.  A FIRST PASS OBTAINS AN   GAUS00C
      C            APPROXIMATION X0 TO A**(-1)*B.  THE RESIDUAL R=B-A*X0 IS GAUS00C
      C            THEN COMPUTED IN DOUBLE PRECISION.  A SECOND PASS SOLVES GAUS00C
      C            A*DX0=R FOR DX0.  THEN X=X0+DX0.  THE QUANTITY ERR IS AN GAUS00C
      C            INDICATION OF THE CONDITION OF A.  IT IS DEFINED AS      GAUS00C
      C            MAX(ABS(DX0(I,J)/X(I,J)) FOR X(I,J).NE.0.0.  ERR IS      GAUS00C
      C            ROUGHLY THE MAXIMUM RELATIVE ERROR IN X.  A BYPRODUCT OF GAUS00C
      C            THE REDUCTION OF A IS ITS DETERMINANT.                   GAUS00C
      C                                                                     GAUS00C
      C                                                                     GAUS00C
      C                                                                     GAUS00C
      C                                                                     GAUS00C
      C                                                                     GAUS00C
            SUBROUTINE GAUSS(N,M,A,B,X,DET,ERR)                             GAUS00C
            DIMENSION A(20,20),AA(20,20),B(20,20),BB(20,20),X(20,20),       GAUS00C
           1          XX(20,20),IN(20)                                      GAUS00C
            DO 2 I=1,N                                                      GAUS00C
            DO 1 J=1,N                                                      GAUS00C
          1 AA(I,J)=A(I,J)                                                  GAUS00C
            DO 2 J=1,M                                                      GAUS00C
          2 BB(I,J)=B(I,J)                                                  GAUS00C
      C                                                                     GAUS00C
      C     PERFORM THE TRIANGULARIZATION OF A                              GAUS00C
      C                                                                     GAUS00C
            NN=N-1                                                          GAUS00C
            DO 6 L=1,NN                                                     GAUS00C
            IN(L)=0                                                         GAUS00C
            KP=0                                                            GAUS00C
            T=0.0                                                           GAUS00C
            DO 3 K=L,N                                                      GAUS00C
            TT=ABS(AA(K,L))                                                 GAUS00C
            IF(T.GT.TT)GO TO 3                                              GAUS00C
            T=TT                                                            GAUS00C
            KP=K                                                            GAUS00C
          3 CONTINUE                                                        GAUS00C
```

```
                IF(L.GE.KP)GO TO 5                                      GAUS00
                IN(L)=KP                                                GAUS00
                DO 4 J=L,N                                              GAUS00
                T=AA(L,J)                                               GAUS00
                AA(L,J)=AA(KP,J)                                        GAUS00
          4     AA(KP,J)=T                                              GAUS00
          5     LL=L+1                                                  GAUS00
                DO 6 K=LL,N                                             GAUS00
                R=AA(K,L)/AA(L,L)                                       GAUS00
                AA(K,L)=R                                               GAUS00
                DO 6 J=LL,N                                             GAUS00
          6     AA(K,J)=AA(K,J)-R*AA(L,J)                               GAUS00
          C                                                             GAUS00
          C     THIS COMPLETES THE REDUCTION OF A                       GAUS00
          C                                                             GAUS00
                DET=AA(N,N)*AA(N-1,N-1)                                 GAUS00
                J=N-2                                                   GAUS00
                DO 7 I=1,J                                              GAUS00
          7     DET=DET*AA(I,1)                                         GAUS00
                DO 8 I=1,NN                                             GAUS00
                IF(IN(I).NE.0)DET=-DET                                  GAUS00
          8     CONTINUE                                                GAUS00
                DO 19 IT=1,2                                            GAUS00
                IF(IT.EQ.1)GO TO 10                                     GAUS00
          C                                                             GAUS00
          C     COMPUTE RESIDUALS                                       GAUS00
          C                                                             GAUS00
                DO 9 J=1,M                                              GAUS00
                DO 9 I=1,N                                              GAUS00
                BB(I,J)=-B(I,J)                                         GAUS00
          9     CALL INPR(A(I,1),X(1,J),20,N,BB(I,J))                   GAUS00
          C                                                             GAUS00
          C     REDUCE RIGHT HAND SIDE                                  GAUS00
          C                                                             GAUS00
         10     DO 13 L=1,NN                                            GAUS00
                KP=IN(L)                                                GAUS00
                IF(KP.EQ.0)GO TO 12                                     GAUS00
                DO 11 J=1,M                                             GAUS00
                T=BB(KP,J)                                              GAUS00
                BB(KP,J)=BB(L,J)                                        GAUS00
         11     BB(L,J)=T                                               GAUS01
         12     LL=L+1                                                  GAUS01
                DO 13 K=LL,N                                            GAUS01
                R=AA(K,L)                                               GAUS01
                DO 13 J=1,M                                             GAUS01
         13     BB(K,J)=BB(K,J)-R*BB(L,J)                               GAUS01
          C                                                             GAUS01
          C     START BACK SUBSTITUTION                                 GAUS01
          C                                                             GAUS01
                DO 15 I=1,M                                             GAUS01
                XX(N,I)=BB(N,I)/AA(N,N)                                 GAUS01
                DO 15 L=2,N                                             GAUS01
                LL=N+1-L                                                GAUS01
                K=LL+1                                                  GAUS01
                T=0.0                                                   GAUS01
                DO 14 J=K,N                                             GAUS01
         14     T=T+AA(LL,J)*XX(J,I)                                    GAUS01
```

```
   15          XX(LL,I)=(BB(LL,I)-T)/AA(LL,LL)                          GAUS011
C                                                                       GAUS011
C     ADD CORRECTIONS.                                                  GAUS011
C                                                                       GAUS012
                  ERR=0.0                                               GAUS012
                  IF(IT.GT.1)GO TO 17                                   GAUS012
                  DO 16 I=1,N                                           GAUS012
                  DO 16 J=1,M                                           GAUS012
   16             X(I,J)=XX(I,J)                                        GAUS012
                  GO TO 19                                              GAUS012
   17             DO 18 I=1,N                                           GAUS012
                  DO 18 J=1,M                                           GAUS012
                  T=X(I,J)                                              GAUS012
                  TT=XX(I,J)                                            GAUS013
                  IF(ABS(T).LT.1E-37) GO TO 18                          GAUS013
                  TTT=ABS(TT/T)                                         GAUS013
                  IF(ERR.LT.TTT)ERR=TTT                                 GAUS013
   18             X(I,J)=T-TT                                           GAUS013
   19             CONTINUE                                              GAUS013
                  RETURN                                                GAUS013
                  END                                                   GAUS013
```

```
APR26.INPR
      C
      C TITLE          -INPR-
      C
      C AUTHOR         REWRITTEN BY M. TRIMBLE, JULY, 1967, FROM MAP TO FORTRAN
      C
      C PURPOSE        TO COMPUTE THE INNER PRODUCT OF VECTORS A AND B OF LENGTH
      C                J IN DOUBLE PRECISION AND ADD THE SINGLE PRECISION RESULT
      C                TO C
      C
      C CALL           INPR(A,B,I,J,C)
      C
      C                     WHERE
      C                          A = LOCATION OF FIRST WORD OF FIRST VECTOR ARRAY
      C                          B = LOCATION OF FIRST WORD OF SECOND VECTOR ARRAY
      C                          I = 1  IF A IS A ONE DIMENSIONAL ARRAY
      C                            = FIRST DIMENSIONAL SUBSCRIPT OF A IF ARRAY A
      C                              IS TWO DIMENSIONAL
      C                          J = THE NUMBER OF TERMS TO BE TAKEN FOR THE INNER
      C                              PRODUCT  (USUALLY THE FIRST DIMENSIONAL
      C                              SUBSCRIPT OF B WHICH SHOULD EQUAL THE SECOND
      C                              DIMENSIONAL SUBSCRIPT OF A)
      C                          C = LOCATION TO WHICH THE RESULT OF COMPUTATION
      C                              IS TO BE ADDED
      C
      C
                       SUBROUTINE INPR(A,B,I,J,C)
      C
      C        SPECIFICATION STATEMENTS
      C
                       DIMENSION A(1),B(1)
                       DOUBLE PRECISION HA,HB,HOLD,HC
      C
      C        INITIALIZATION
      C
                       HC = 0.0
                       M = I*J
                       IJ = 0
      C
      C        DO INNER PRODUCT OF VECTORS
      C
                       DO 100    II = 1,M,I
                       IJ = IJ+1
                       HA = A(II)
                       HB = B(IJ)
                       HOLD = HA*HB
       100             HC = HC+HOLD
      C
      C        ADD RESULT TO PREVIOUS RESULT
      C
                       C = HC+C
                       RETURN
                  END
```

```
APR26.GRIDMK
      C TITLE         GRIDMK - SOLUTION MAPPING ROUTINE
      C
      C AUTHOR        MARILYN R. TRIMBLE
      C
      C SPONSOR       A. A. VANDERVEEN
      C
      C DATE          12-1-67
      C
      C PURPOSE       TO MAP A GIVEN SOLUTION TO ALL POINTS OF A GRID.
      C
      C METHOD        SOLUTIONS ARE FOUND FOR THE GRID POINTS NEAR THE GIVEN
      C               SOLUTION. THE EXTRAPLATION OF THE SOLUTIONS FOUND AT
      C               TWO ADJACENT POINTS IS USED AS AN INITIAL GUESS FOR AN
      C               ITERATIVE PROCEDURE IN AN EFFORT TO CONVERGE TO SOLUTIONS
      C               FOR THE POINTS ON EITHER SIDE OF THE ADJACENT SET. IN
      C               THE ABSENCE OF ADJACENT SETS, SOLUTIONS AT THE FOUR
      C               NEIGHBORING POINTS ARE USED AS INITIAL GUESSES.
      C
      C CALL          CALL GRIDMK(A,B,DELP,EPS,PINI,NP,NCS,ICM,GRD,COPT,IDCV,
      C               IPRE)
      C
      C INPUT         THROUGH CALL LIST
      C
      C               A(J)       MINIMUM VALUE FOR JTH PARAMETER
      C               B(J)       MAXIMUM VALUE FOR JTH PARAMETER
      C               DELP(J)    DELP(1) AND DELP(2) DETERMINE THE GRID MESH
      C               EPS(J)     TOLERANCE ON JTH CONSTAINT FOR CONV
      C               PINI(J)    INITIAL SOLUTION VALUE FOR JTH PARAMETER
      C               NP         NUMBER OF PARAMETERS
      C               NCS        NUMBER OF EQUALITY CONSTRAINTS
      C               ICM        INDICATOR FOR ITERATIVE METHOD TO BE USED BY CONV
      C
      C OUTPUT        THROUGH THE CALL LIST
      C
      C               GRD(I,J,K) RESULTING SET OF SOLUTIONS. I=1,NP J=1,NP1
      C                          K=1,NP2  WHERE NP1 AND NP2 ARE THE NUMBER OF
      C                          P(1)'S AND P(2)'S RESPECTIVELY
      C               COPT(J,K)  OPTIMUM VALUE WHEN OPTIMIZING
      C               IDCV(J,K)  CONVERGENCE INDICATOR
      C                          =1  CONVERGED
      C                          =0  DID NOT CONVERGE
      C
      C SUBROUTINES   CONV       SUBROUTINE TO BE USED TO FIND CONVERGENCE
      C
      C       SUBROUTINE STATEMENT
      C
                      SUBROUTINE GRIDMK(A,B,DELP,EPS,PINI,NP,NCS,ICM,GRD,COPT,
                     .IDCV,IPRE)
      C
      C       SPECIFICATION STATEMENTS
      C
                      INCLUDE PARSIA,LIST
      C
                      DIMENSION PINI(1),A(1),B(1),DELP(1),GRD(MP,MA,MO),
                     .UHOLD(2),DELX(4),DELY(4),UCOMP(2),USTART(2),UBASE(2),
                     .NLOOP(4),NLP(4),NDIM(2),PI(MP),PE(MP),IDCV(MA,MO),
```

```
      COPT(NA,MO),CSE(KC),XX(1000),AN(2),BX(2),YY(1000)
      DIMENSION TYCO(5)
      DATA TYCO/6HCONVER,6HNEASOL,6HNEAMIP,6HMAXITR,6HOUTBDS/
      COMMON/SECO/ITR
C
C     INITIALIZE PROGRAM
C
      IGR=1
      PER=0.0
      ISTART=0
      DO 10   I=1,2
   10 NDIM(I)=(B(I)-A(I))/DELP(I)+1.01
      IGP=NDIM(2)*NDIM(1)
      CGP=0.0
C
      I1=NDIM(1)
      I2=NDIM(2)
      DO 15   J=1,I2
      DO 15   I=1,I1
   15 IDCV(I,J)=0
C
C     SET MINIMUN AND MAXIMUM VALUES FOR SEARCH
C
      AN(1) = A(1)-DELP(1)/10.0
      AN(2) = A(2)-DELP(2)/10.0
      BX(1) = B(1)+DELP(1)/10.0
      BX(2) = B(2)+DELP(2)/10.0
C
C     SET INCREMENTS FOR A TWO DIMENSIONAL GRID
C
  100 DELX(1)=DELP(1)
      DELX(2)=DELP(1)
      DELX(3)=-DELP(1)
      DELX(4)=-DELP(1)
      DELY(1)=DELP(2)
      DELY(2)=-DELP(2)
      DELY(3)=-DELP(2)
      DELY(4)=DELP(2)
C
C     FIND INITIAL POINT ON THE GRID
C
      DO 125   I=1,2
      UHOLD(I)=A(I)
  115 UHOLD(I)=UHOLD(I)+DELP(I)
      IF (UHOLD(I).GT.PIMI(I))   GO TO 125
      GO TO 115
  125 UHOLD(I)=UHOLD(I)-DELP(I)
      DO 135   I=3,NP
  135 PI(I)=PIMI(I)
C
C     ATTEMPT TO FIND A SOLUTION AT FOUR SURROUNDING POINTS AND CHOOSE
C     A STARTING POINT AS BASE
C
      IND=1
  145 IF(UHOLD(1).LT.AN(1).OR.UHOLD(1).GT.BX(1)) GO TO 155
      IF(UHOLD(2).LT.AN(2).OR.UHOLD(2).GT.BX(2)) GO TO 155
      IS1=(UHOLD(1)-A(1))/DELP(1)+1.1
```

```
                IS2=(UHOLD(2)-A(2))/DELP(2)+1.1
                DO 147   I=1,2
  147           PI(I)=UHOLD(I)
                CALL CONV(ICONV,PI,NP,DELP,IGR,EPS,ICONV,PF,CSF)
C
C     WRITE RESULTS OF CALL TO CONV
C
                IF(IPRF.NE.1)GO TO 148
                WRITE(6,1006)(PI(KK),KK=1,NP)
                WRITE(6,1007) TYCO(ICONV),ITR,(PF(KK),KK=1,NP)
  148           CORT(IS1,IS2)=CSF(1)
                IF(ICONV.NE.1) GO TO 155
                CGP=CGP+1.0
                DO 150   I=1,NP
  150           GRD(I,IS1,IS2)=PF(I)
                IDCV(IS1,IS2)=1
                IF(ISTART.NE.0)   GO TO 155
                USTART(1)=UHOLD(1)
                USTART(2)=UHOLD(2)
                ISTART=1
  155           GO TO (160,162,164,170),IND
  160           UHOLD(1)=UHOLD(1)+DELP(1)
                IND=2
                GO TO 145
  162           UHOLD(1)=UHOLD(1)-DELP(1)
                UHOLD(2)=UHOLD(2)+DELP(2)
                IND=3
                GO TO 145
  164           UHOLD(1)=UHOLD(1)+DELP(1)
                IND=4
                GO TO 145
  170           IF(ISTART.EQ.0)   GO TO 750
  200           UBASE(1)=USTART(1)
                UBASE(2)=USTART(2)
C
C     SET UP INDEXING TO COVER ALL POINTS OF GRID FROM INITIAL BASE
C     POINT
C
  210           DO 215   I=1,4
  215           NLP(I)=1
                DO 600   KL=0,1000
                NEND=0
                DO 280   I=1,4
  280           NLOOP(I)=0
                DO 500   JL=1,4
C
C     IF PRESENT BASE SIDE HAS NO BASE POINTS WITHIN LIMITS OF GRID GO
C     TO FIRST BASE POINT OF NEXT BASE SIDE
C
                IF(NLP(JL).NE.0)   GO TO 300
                UBASE(1)=UBASE(1)+KL*DELX(JL)
                UBASE(2)=UBASE(2)+KL*DELY(JL)
                GO TO 500
  300           DO 450   IL=1,KL
C
C     DETERMINE IF PRESENT BASE POINT HAS A SOLUTION
C
```

```
      IF(UBASE(1).LT.AN(1).OR.UBASE(1).GT.BX(1)) GO TO 420
      IF(UBASE(2).LT.AN(2).OR.UBASE(2).GT.BX(2)) GO TO 420
      IJ1=(UBASE(1)-A(1))/DELP(1)+1.1
      IJ2=(UBASE(2)-A(2))/DELP(2)+1.1
      NLOOP(JL)=1
      IF(IDCV(IJ1,IJ2).EQ.0)    GO TO 420
  310 NEND=1
C
C     FIND FIRST OF FOUR POINTS SURROUNDING BASE POINT AND ITS OPPOSITE
C
      UHOLD(1)=UBASE(1)-DELP(1)
      UHOLD(2)=UBASE(2)
      UCOMP(1)=UBASE(1)+DELP(1)
      UCOMP(2)=UBASE(2)
C
C     ATTEMPT TO FIND SOLUTION IF POINT IS WITHIN LIMITS OF GRID AND IF
C     POINT DOES NOT ALREADY HAVE SOLUTION
C
      DO 400   J=1,4
      IF(UHOLD(1).LT.AN(1).OR.UHOLD(1).GT.BX(1)) GO TO 370
      IF(UHOLD(2).LT.AN(2).OR.UHOLD(2).GT.BX(2)) GO TO 370
      IS1=(UHOLD(1)-A(1))/DELP(1)+1.1
      IS2=(UHOLD(2)-A(2))/DELP(2)+1.1
      IF(IDCV(IS1,IS2).EQ.1)    GO TO 370
C
C     DETERMINE INITIAL GUESS FOR SOLUTION FROM BASE POINT SOLUTION AND
C     FROM OPPOSITE POINT SOLUTION IF PRESENT
C
      DO 333   I=1,2
  333 PI(I)=UHOLD(I)
      IF(UCOMP(1).LT.AN(1).OR.UCOMP(1).GT.BX(1)) GO TO 335
      IF(UCOMP(2).LT.AN(2).OR.UCOMP(2).GT.BX(2)) GO TO 335
      IC1=(UCOMP(1)-A(1))/DELP(1)+1.1
      IC2=(UCOMP(2)-A(2))/DELP(2)+1.1
      IF(IDCV(IC1,IC2).EQ.1)    GO TO 345
  335 DO 340   I=3,NP
  340 PI(I)=GRD(I,IJ1,IJ2)
      GO TO 350
  345 DO 346   I=3,NP
  346 PI(I)=2.0*GRD(I,IJ1,IJ2)-GRD(I,IC1,IC2)
C
C     CALL CONV FOR SOLUTION
C
  350 IF(IPRF.NE.1) GO TO 351
      WRITE(6,1006)(PI(KK),KK=1,NP)
  351 CALL CONV(ICM,PI,NP,DELP,IGR,EPS,ICONV,PF,CSF)
C
C     WRITE RESULTS OF CALL TO CONV
C
      IF(IPRF.NE.1) GO TO 355
      WRITE(6,1007) TYCO(ICONV),IIR,(PF(KK),KK=1,NP)
  355 IF(ICONV.NE.1) GO TO 370
      CGP=CGP+1.0
      DO 360   I=1,NP
  360 GRD(I,IS1,IS2)=PF(I)
      IDCV(IS1,IS2)=1
C
```

```
C       CALCULATE NEXT POINT NEAR PRESENT BASE POINT
C
  370           UHOLD(1)=UHOLD(1)+DELX(J)
                UHOLD(2)=UHOLD(2)+DELY(J)
                UCOMP(1)=UCOMP(1)-DELX(J)
                UCOMP(2)=UCOMP(2)-DELY(J)
  400           CONTINUE
C
C       CALCULATE NEXT BASE POINT ON PRESENT BASE LINE
C
  420           UBASE(1)=UBASE(1)+DELX(JL)
                UBASE(2)=UBASE(2)+DELY(JL)
  450           CONTINUE
                IF(NLOOP(JL).EQ.0)    NLP(JL)=0
  500           CONTINUE
C
C       IF THERE ARE NO REMAINING BASE POINTS WITH A SOLUTION RETURN TO
C       MAIN PROGRAM
C
                IF(NEND.EQ.0)    GO TO 650
C
C       CALCULATE INITIAL BASE POINT FOR NEW BASE LINE
C
                UBASE(1)=UBASE(1)-DELP(1)
  600           CONTINUE
C
C       CALCULATE PERCENTAGE OF TOTAL POINTS THAT CONVERGED TO A SOLUTION
C
  650           PERH=PER
                PER=(CGP/TGP)*100.0
                WRITE(6,1004) PER
                IF(PER-99.9)    660,660,700
  660           IF(PER-PERH)    700,700,200
  700           CONTINUE
C
C       PLOT THE GRID POINTS THAT CONVERGED
C
                K=0
                DO 745 N=1,I1
                DO 740    M=1,I2
                IF(IDCV(N,M).EQ.0) GO TO 740
  730           K=K+1
                XX(K)=GRD(1,N,M)
                YY(K)=GRD(2,N,M)
  740           CONTINUE
  745           CONTINUE
                K=K+1
                XX(K)=A(1)
                YY(K)=A(2)
                K=K+1
                XX(K)=A(1)
                YY(K)=B(2)
                K=K+1
                XX(K)=B(1)
                YY(K)=A(2)
                K=K+1
                XX(K)=B(1)
```

```
                YY(K)=B(2)
                CALL RKPLOT(XX,YY,K)
  750           WRITE(6,1005) PER
                RETURN
C
C       FORMAT STATEMENTS
C
 1001           FORMAT(1H ,16X,'PI = ',(T23,6E15.8))
 1004           FORMAT(1H0,'***PERCENTAGE OF POINTS CONVERGING = ',
     .          F7.3,'******')
 1005           FORMAT(1H0,'POINTS FOR WHICH SOLUTIONS WERE FOUND = P1 '
     .          'VERTICAL AXIS, P2 HORIZONTAL AXIS, PERCENTAGE ',F7.3///)
 1006           FORMAT(1H ,16X,'PI = ',(T23,6E15.8))
 1007           FORMAT(1H ,A6,I3,' ITRS  PF = ',(T23,6E15.8))
        END
```

```
L APR26.FRMPLT
      C TITLE         FRMPLT - INTERPOLATION AND PLOTTING CONTROL
      C
      C AUTHOR        M. T. HINMAN
      C
      C PURPOSE.      TO READ FUNCTIONS FROM FASTDRUM AND CALL INTERPOLATION
      C               AND PLOTTING ROUTINES.
      C
      C METHOD        FRMPLT READS THE FUNCTION TO BE PLOTTED FROM ITS FASTDRUM
      C               FILE. IF IT HAS NOT PREVIOUSLY BEEN INTERPOLATED, INGRID
      C               IS CALLED. THE CONTOURS ARE PLOTTED AND THEN SAVED IF
      C               THEY ARE TO BE USED AGAIN.
      C
      C INPUT         VARIABLES FROM COMMON MCL
      C               VARIABLES FROM COMMON INP
      C               THE FASTDRUM FILES GENERATED BY PLTCON
      C
      C       SUBROUTINE STATEMENT
      C
                      SUBROUTINE FRMPLT                                   FRMPLT
      C
      C       SPECIFICATION STATEMENTS
      C
                      INCLUDE PARSTA,LIST                                 FRMPLT
                      INCLUDE KOMMCL,LIST                                 FRMPLT
                      INCLUDE GRIDSP,LIST
                      INCLUDE KPFILE,LIST
                      PARAMETER IMAXSF = 4
      C
      C       IMAXSF IS THE MAXIMUM NUMBER OF SCRATCH UNITS AVAILABLE FOR
      C       INTERMEDIATE STORAGE AT THE PRESENT TIME
      C
                      DIMENSION TTLT(8),ATLT(8),OTLT(8),IDCV(MA,MO),F(MA,MO),  FRMPLT
                     *HP1(MA),HP2(MO),DELTA(2),NTABSU(10)
      C
      C       NTABSU CONTAINS THE NUMBERS OF THE AVAILABLE SCRATCH UNITS
      C
                      DATA NTABSU/21,22,23,24,1,2,3,4,2*0/
      C
      C
      C       SET NUMBER OF SCRATCH UNIT FOR OVERFLOW DURING INTERPOLATION
      C
                      NF = 20
      C
      C       SET VARIABLES FOR CALLING SCPLOT
      C
                      NDEN=1
                      NCHAR=42
                      GRIDD=20.
                      NX=2
                      NY=2
                      LX=0
                      LY=0
                      NV=1
                      NS=2
                      NG=2
      C                                                                   FRMPLT
```

```
C       SET INITIAL CONDITIONS
C                                                                       FRMPLT
                  III = MA
                  IPAC = 0
                  IFRM=0                                                ERMPLT
                  NFILE=1                                               FRMPLT
                  IOVFU = 0
                  CALL CAMRAV(935)
            CALL LSIG(5,5)
C                                                                       FRMPLT
C       SET LOOP FOR PROCESSING ONE FRAME AT A TIME                     ERMPLT
C                                                                       FRMPLT
  130             IFRM=IFRM+1                                           ERMPLT
                  JFUNC=0                                               FRMPLT
C                                                                       ERMPLT
C       SET FRAME LABELS                                                FRMPLT
C                                                                       ERMPLT
                  XL=AMIN(IFRM)                                         FRMPLT
                  XR=AMAX(IFRM)                                         ERMPLT
                  YL=OMIN(IFRM)                                         FRMPLT
                  YU=OMAX(IFRM)                                         ERMPLT
                  DO 150 I=1,8                                          FRMPLT
                  TTLT(I)=TLT(I,IFRM)                                   ERMPLT
                  ATLT(I)=ALA(I,IFRM)                                   FRMPLT
  150             OTLT(I)=OLA(I,IFRM)                                   ERMPLT
                  NFADV = 1
C                                                                       ERMPLT
C       SET LOOP FOR ONE FUNCTION AT A TIME                             FRMPLT
C                                                                       FRMPLT
  170             JFUNC = JFUNC+1
                  IDRM=IFD(IFRM,JFUNC)                                  FRMPLT
C                                                                       FRMPLT
C       IF PLOTTING ARRAY IS ALREADY INTERPOLATED TRANSFER TO READ IN   FRMPLT
C                                                                       FRMPLT
                  IDM = NEDRM(IDRM)
                  IF(IDM.GT.1.OR.IDM.LT.0)   GO TO 500
C                                                                       ERMPLT
C       READ FUNCTION ARRAY FROM DRUM FILE                              FRMPLT
C                                                                       ERMPLT
                  READ(IDRM) NT,NHSOL,IVRH,NA,NO
                  DO 200 IT1=1,NA                                       ERMPLT
                  DO 200 IT2=1,NO                                       FRMPLT
  200             READ(IDRM)IDCV(IT1,IT2),F(IT1,IT2)                    FRMPLT
                  READ(IDRM)(HP1(I),I=1,NA),(HP2(J),J=1,NO)             FRMPLT
C
C       PRINT FUNCTION ARRAY IF REQUESTED
C
                  IF (IPRP.LT.1)   GO TO 210
                  IPAC = IPAC+1
                  WRITE(6,2) IPAC,NT,NHSOL,IVRH
                  CALL PRTOUT(NA,NO,HP1,HP2,F)
C
C       SET VARIABLES FOR INTERPOLATION
C
  210             BP1=HP1(1)
                  BP2=HP2(1)
                  NP1=NA
```

```
                NP2=NO
                DP1=HP1(2)-HP1(1)                                       FRMPLT
                DP2=HP2(2)-HP2(1)                                       FRMPLT
                DELTA(1)=P1INC(IFRM,JFUNC)                              FRMPLT
                DELTA(2)=P2INC(IFRM,JFUNC)                              FRMPLT
                IPRT=IPRP-2
C                                                                       FRMPLT
C       TRANSFER TO VERTICAL CONTOUR SLICING ROUTINE IF REQUESTED       FRMPLT
C                                                                       FRMPLT
                IF(IVS(IFRM,JFUNC).GT.0)   GO TO 350
C                                                                       FRMPLT
C       CALL INTERPOLATION ROUTINE FOR LEVEL SLICING                    FRMPLT
C                                                                       FRMPLT
                CMNV = CMIN(IFRM,JFUNC)
                CMXV = CMAX(IFRM,JFUNC)
                CDELV = DELC(IFRM,JFUNC)
                CALL INGRID(BP1,BP2,DP1,DP2,F,NP1,NP2,IDCV,CMNV,CMXV,   FRMPLT
               .CDELV,DELTA)                                            FRMPLT
                REWIND NF
                REWIND NFUI
                GO TO 400                                               FRMPLT
C
C       CALL INTERPOLATION ROUTINE FOR VERTICAL SLICING
C
  350           IDS=IVS(IFRM,JFUNC)                                     FRMPLT
                ISMIN=IS(IFRM,JFUNC)                                    FRMPLT
                ISMAX=LS(IFRM,JFUNC)                                    FRMPLT
                ISINC=INCS(IFRM,JFUNC)                                  FRMPLT
                IF(IDS.EQ.1)DELTA(1)=DELTA(2)                           FRMPLT
                CALL VSLIC(BP1,BP2,DP1,DP2,F,NP1,NP2,IDCV,IDS,ISMIN,    FRMPLT
               .ISMAX,ISINC,DELTA)                                      FRMPLT
C
C
  400           NFUO = IDRM
                NFUI = NF
                IF(NTOF.EQ.0)   GO TO 410
                IF(NEDRM(IDRM).EQ.0)   GO TO 410
                IOVFU = IOVFU+1
                IF(IOVFU.GT.IMAXSF)   NEDRM(IDRM)=0
                NFUO = NTABSU(IOVFU)
  410           IF (NIPOP(IDRM) .EQ. 0)   GO TO 550
                IF(NTOF.NE.0)   GO TO 440
C
C       WRITE HEADING FOR ON-LINE PLOT
C
                IK=IKOUNT
                IF (IVS(IFRM,JFUNC) .GT. 0)   GO TO 420
                XX(IKOUNT+1)=HP1(1)
                YY(IKOUNT+1)=HP2(1)
                XX(IKOUNT+2)=HP1(1)
                YY(IKOUNT+2)=HP2(NO)
                XX(IKOUNT+3)=HP1(NA)
                YY(IKOUNT+3)=HP2(1)
                XX(IKOUNT+4)=HP1(NA)
                YY(IKOUNT+4)=HP2(NO)
                IK = IKOUNT+4
  420           CALL BKPLOT(XX,YY,IK)
```

```
C
C       WRITE MESSAGE STATING THAT THERE ARE TOO MANY POINTS TO BE
C       PLOTTED ON-LINE
C
                GO TO 550
 440            WRITE(6,2) IPAC,NT,NHSOL,IVRH
                WRITE(6,3)
                GO TO 550
 500            IF(NEDRM(IDRM).GT.1)  GO TO 505
                IN = -NFDRM(IDRM)
                NEUI = NTABSU(IN)
                GO TO 510
 505            NEUI = IDRM
 510            READ(NFUI) IKOUNT,NTOF
                READ(NEU1) (XX(I),YY(I),I=1,IKOUNT)
 550            IF (NFDRM(IDRM) .NE. 1)  GO TO 570
                REWIND NEUO
                WRITE(NFUO) IKOUNT,NTOF
                WRITE(NEUO) (XX(I),YY(I),I=1,IKOUNT)
 570            CONTINUE
C
C       PLOT
C
                IF(IAO(IFRM,JFUNC).EQ.1)   GO TO 580
                CALL SCPLOT(LX,LY,XX,YY,IKOUNT,NDEN,NV,NS,NCHAR,NEADV,
     .          NG,GRIDD,GRIDD,NX,XL,XR,NY,YL,YU,TTLT,ATLT,OTLT)
                GO TO 590
 580            CALL SCPLOT(LX,LY,YY,XX,IKOUNT,NDEN,NV,NS,NCHAR,NFADV,
     .          NG,GRIDD,GRIDD,NX,XL,XR,NY,YL,YU,TTLT,ATLT,OTLT)
 590            NFADV = 2
                IF(NTOE.NE.0)   GO TO 600
                REWIND NFUI
                IF(NEDRM(IDRM).EQ.0)   GO TO 700
                REWIND NFUO
                NEDRM(IDRM) = 2
                GO TO 700
 600            DO 650   IL = 1,NTOF
                READ(NFUI) (XX(I),YY(I),I=1,IMAXC)
                IF(NEDRM(IDRM).NE.1)   GO TO 620
                WRITE(NFUO) (XX(I),YY(I),I=1,IMAXC)
 620            CONTINUE
C
C               PLOT
C
                IKOUNT = IMAXC
                IF(IAO(IFRM,JFUNC).EQ.1)   GO TO 630
                CALL SCPLOT(LX,LY,XX,YY,IKOUNT,NDEN,NV,NS,NCHAR,NEADV,
     .          NG,GRIDD,GRIDD,NX,XL,XR,NY,YL,YU,TTLT,ATLT,OTLT)
                GO TO 650
 630            CALL SCPLOT(LX,LY,YY,XX,IKOUNT,NDEN,NV,NS,NCHAR,NFADV,
     .          NG,GRIDD,GRIDD,NX,XL,XR,NY,YL,YU,TTLT,ATLT,OTLT)
 650            CONTINUE
                REWIND NEUI
                IF(NFDRM(IDRM).NE.1)   GO TO 700
                REWIND NEUO
                NFDRM(IDRM) = -IOVFU
 700            IF(JFUNC.LT.NEN(IERM))   GO TO 170
```

```
      IF(IERM.LT.NER)  GO TO 130
      CALL EOFTV
      RETURN
C
C     FORMAT STATEMENTS
C
    2 FORMAT(1H1,//16H FUNCTION ARRAY ,I3,10X,10H FROM UNIT,I3,
     .      11H   SOLUTION,I3,15H   AND VARIABLE,I3//)
    3 FORMAT(1H ,10X,'THERE ARE TOO MANY POINTS FOR ON LINE PLO
     .TTING.')
      END
```