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A COMPUTER PROGRAM FOR HYDROSTATIC BEARINGS INCLUDING THE EFFECTS OF NON-UNIFORM FILM THICKNESS AND RELATIVE VELOCITY FOR VARIOUS METHODS OF LUBRICANT SUPPLY

by

J. G. Hinkle
V. Castelli
H. C. Rippel
C. D. Zimmerman, Jr.

April, 1964

Prepared for

CALIFORNIA INSTITUTE OF TECHNOLOGY
Jet Propulsion Laboratory

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Final Technical Report

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ABSTRACT

13316

This is a final report describing the development and use of a computer program for the determination of the load carrying capacity, flow requirements, and righting moments of hydrostatic bearings using an incompressible fluid, including the effects of variable film thickness, relative velocity, and method of lubricant supply. The basic equations, numerical approximations, method of solution, numerical treatment and Fortran Program are presented along with instructions on the use of the program and a sample problem. This work is an extension of that reported in Final Report No. F-B2015 dated January 11, 1963, prepared for California Institute of Technology, Jet Propulsion Laboratory.

Author

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INTRODUCTION

The increasing demands for bearings to support heavy loads have caused the development of hydrostatic lubrication to proceed at an accelerated pace. This was accompanied by a need for more sophisticated analysis of bearing characteristics. For some years hydrostatic bearings have been analyzed by techniques that fell short of a rigorous analysis. This was because of the impossibility of producing by hand an exact analytical solution and, therefore, the necessity for resorting to techniques yielding approximate results, e.g., the electric analog.[1*]

One of the major shortcomings of the conducting-sheet electric-analog is its inability to treat problems involving non-uniform film thicknesses and relative velocity of bearing members. These problems can often be adequately treated by numerical integration techniques, the utilization of which is only hampered by the extremely lengthy and tedious calculations they require. However, the recent development of high speed digital computers has eliminated this drawback, and numerical integration techniques are at present quite feasible.

In the case at hand, hydrostatic bearings are to be designed for the support of a large radio telescope antenna. A number of rectangular pads will transfer the load of the moving superstructure through the pressurized film of oil to a stationary member on the concrete base. While at first glance the analysis of the bearing (flat slider) appears to offer no problem; in reality, the unit loads are high enough to give rise to non-negligible distortions of the bearing members thus requiring the treatment of variable film thicknesses. While, the particular application involves relatively slow velocity of bearing members, there will be a significant contribution of hydrodynamic effects particularly for favorable film clearance distributions. A previous work[2] describes in detail the development of a computer program which did not include the effect of relative velocity of bearing members.

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*Superscript numerals refer to references at the end of this report.

This report is a complete development of the computer program for the evaluation of pressure distributions, loads, moments, and flows in a hydrostatically-lubricated, rectangular bearing-pad with four or six symmetrically placed rectangular recesses and includes the effect of velocity. The lubricant is to be incompressible, the clearance uniform or non-uniform, and the fluid supply one of the three specified types:

1. Separate pumps feeding each recess
2. Separate pumps feeding opposite pairs of recesses with capillary compensation.
3. Common manifold feeding all recesses with capillary compensation.

This report contains details of the hydrodynamic equations used to analyze the problem, of the numerical technique used for solution, and of the Fortran Program executing the solution complete with block diagrams and flow charts. A guide chart is furnished complete with all the information necessary for using the program and compiling the appropriate input data cards. A sample problem complete with output is also furnished.

BASIC EQUATIONS AND NUMERICAL APPROXIMATIONS

Utilizing the usual lubrication approximations for a continuous film bearing operating with an incompressible lubricant, Reynolds Equation governs the pressure distribution in the clearance space. For bearings with relative motion, Reynolds Equation assumes the following form[3]

$$\frac{\partial}{\partial x}\left(h^3 \frac{\partial p}{\partial x}\right) + \frac{\partial}{\partial y}\left(h^3 \frac{\partial p}{\partial y}\right) = - 6\mu\, U\left(\frac{\partial h}{\partial x}\right) \qquad [1]$$

For a bearing of rectangular geometry the length of one of the sides can be used as a characteristic length (say L). Then the following dimensionless quantities can be defined in an x-y rectangular coordinate system:

$$X = \frac{x}{L},$$

$$Y = \frac{y}{L},$$

$$H = \frac{h}{c},$$

$$P = \frac{p - p_a}{p_{ref} - p_a}$$

where c is a characteristic film thickness (any value), p_{ref} is a reference pressure (any value), p_a is the ambient pressure (any value), and h and p refer to film thickness and pressure respectively at location (x,y).

Reynolds equation now assumes the dimensionless form

$$\left(\frac{\partial^2 P}{\partial X^2} + \frac{\partial^2 P}{\partial Y^2}\right) + \frac{3}{H}\left(\frac{\partial H}{\partial X}\frac{\partial P}{\partial X} + \frac{\partial H}{\partial Y}\frac{\partial P}{\partial Y}\right) = -\frac{\Lambda}{H^3}\frac{\partial H}{\partial X} \qquad [2]$$

where $\Lambda = \dfrac{6\mu UL}{c^2 (p_{ref} - p_a)}$

Three types of bearing feed will be used:

(a) Specified flow to each recess as given by a positive displacement pump feeding the recess.

(b) Specified total flow to pairs of diametrically opposite recesses as fed by a single constant displacement pump through capillary compensation.

(c) Single manifold having a specified supply pressure feeding all recesses through capillary compensation.

METHOD OF SOLUTION

The solution of equation [2] can be split into two parts;

a) a particular solution of the non-homogenous equation.

b) the solution of the homogeneous equation.

Part (a) is accomplished by solving equation [2] numerically with the conditions that $P = 0$ on the boundaries and all recess areas. This solution shall be called $P_\Lambda(X,Y)$. Due to the linearity in P of equation [2], part (b) can be accomplished by the method of superposition. Namely, component solutions, $P_j(X,Y)$, are obtained corresponding to a value of the dimensionless pressure, P, equal to 1 in the j^{th} recess and 0 in all other recesses and at the free boundary. Then the pressure distribution, $P(X,Y)$, corresponding to any operating condition is expressible as the linear combination,

$$P(X,Y) = \sum_j \alpha_j P_j\,(X,Y) + P_\Lambda(X,Y) \qquad [3]$$

where α_j is a dimensionless number representing pressure in the j^{th} recess. Defining;

Q_{ij} = flow out of i^{th} recess corresponding to j^{th} component solution.

$Q_{i\Lambda}$ = flow out of i^{th} recess corresponding to $P_\Lambda(X,Y)$ solution.

The dimensionless flow q_i, out of the i^{th} recess when the pressure distribution $P(X,Y)$ exists is,

$$q_i = \sum_j \alpha_j Q_{ij} + Q_{i\Lambda} \qquad [4]$$

Integration of the pressure distribution and evaluation of the moments of the pressure distribution with respect to two non-parallel axes (say X and Y) produces the total load (W) and the location of the center of pressure (ξ, η) in the following manner (see Nomenclature):

$$W_j = \iint P_j(X,Y)\, dXdY \qquad j=1,\ldots,N,\Lambda \tag{5}$$

$$\xi_j = \iint \frac{P_j(X,Y)X\, dXdY}{W_j} \qquad j=1,\ldots,N,\Lambda \tag{6}$$

$$\eta_j = \iint \frac{P_j(X,Y)Y\, dXdY}{W_j} \qquad j=1,\ldots,N,\Lambda \tag{7}$$

For the total solution:

$$W = \sum_j \alpha_j W_j + W_\Lambda \, , \tag{8}$$

$$\xi = \sum_j \frac{\alpha_j \xi_j W_j}{W} + \frac{\xi_\Lambda W_\Lambda}{W} \, , \tag{9}$$

$$\eta = \sum_j \frac{\alpha_j \eta_j W_j}{W} + \frac{\eta_\Lambda W_\Lambda}{W} \, , \tag{10}$$

The attractive feature of the method of superposition is that a given set of component solutions can be utilized with any number of feeding methods as long as the bearing geometry is not altered. The computer program is equipped to take advantage of this feature. Specification of the values of the pertinent parameters in the feeding equations leads to the determination of the appropriate values of the coefficients α_j.

In correspondence to the three feeding methods under consideration the determining equations are:

A. Specified Flow to Each Recess:

It is necessary to solve the system

$$q_i = \sum_{j=1}^{N} \alpha_j Q_{ij} + Q_{i\Lambda} \quad (i = 1, \;.....N) \tag{11}$$

where

q_i = specified quantities (dimensionless)

$Q_{ij}, Q_{i\Lambda}$ = known quantities from component solutions (dimensionless)

Equations (11) form a non-homogeneous system of N algebraic equations in N unknowns (where N is the number of recesses) which can be solved by conventional methods.

B. Specified Flow to Pairs of Recesses With Capillary Compensation.

The following equations hold:

$$QQQ^{(1)} = q_1 + q_2 \tag{12}$$

$$QQQ^{(2)} = q_3 + q_4 \tag{13}$$

$$\left. QQQ^{(3)} = q_5 + q_6 \right\} \text{ only for } N = 6 \tag{14}$$

$$q_1 = f_1(p^{(1)} - \alpha_1) \tag{15}$$

$$q_2 = f_2(p^{(1)} - \alpha_2) \tag{16}$$

$$q_3 = f_3(p^{(2)} - \alpha_3) \tag{17}$$

$$q_4 = f_4(p^{(2)} - \alpha_4) \tag{18}$$

$$\left.\begin{aligned} q_5 &= f_5(p^{(3)}-\alpha_5) \\ q_6 &= f_6(p^{(3)}-\alpha_6) \end{aligned}\right\} \text{only for } N = 6 \qquad \begin{matrix}[19]\\ [20]\end{matrix}$$

$$q_i = \sum_{j=1}^{N} \alpha_j Q_{ij} + Q_{i\Lambda} \quad (i = 1,.....N) \qquad [21]$$

The system of 2.5N equations [12] through [21] has 2.5N unkowns q_i, $\alpha_{j=i}$ $(i = 1...N)$, $p^{(K)}$ $(K = 1...N/2)$ and can be solved by conventional methods. The quantities $QQQ^{(K)}$ $(K = 1...N/2)$ are specified and the f_i's are known characteristics of the N capillaries.

C. Common Reservoir With Specified Pressure and Capillary Feed to Each Recess.

The following equations hold

$$q_i = f_i(p^{(f)}-\alpha_i) \qquad i = 1,.....N \qquad [22]$$

$$q_i = \sum_{j=1}^{N} \alpha_j Q_{ij} + Q_{i\Lambda} \quad i = 1,.....N \qquad [23]$$

This system of 2N equations in the 2N unknowns q_i and α_i $(i = 1,...N)$, can be easily solved by conventional methods.

NUMERICAL TREATMENT

Equation [2] is approximated by numerical methods with the adoption of "three point, central difference" formulae. Thus the bearing area is divided in K by M rectangular elements, in the x and y directions respectively. The pressure distribution is represented by these values at the nodal points of the resulting grid.

The coordinates of the nodal points are

$$X_k = (i - 1)\Delta X, \qquad [24]$$

$$Y_m = (j - 1)\Delta Y, \qquad [25]$$

where i and j designate the location of a particular nodal point in the X and Y directions respectively. (Note that this use of i and j differs from the use of i and j as recess designations.)

For the pressures

$$P_{k,m} = P\left(X_k, Y_m\right), \qquad [26]$$

$$\left.\frac{\partial P}{\partial X}\right|_{X_k Y_m} = \frac{P_{i+1,\,j} - P_{i-1,\,j}}{2\,\Delta X}, \qquad [27]$$

$$\left.\frac{\partial P}{\partial Y}\right|_{X_k Y_m} = \frac{P_{i,\,j+1} - P_{i,\,j-1}}{2\,\Delta Y}, \qquad [28]$$

$$\left.\frac{\partial^2 P}{\partial X^2}\right|_{X_k Y_m} = \frac{P_{i+1,\,j} - 2P_{i,\,j} + P_{i-1,\,j}}{\Delta X^2} \qquad [29]$$

$$\left.\frac{\partial^2 P}{\partial Y^2}\right|_{X_k Y_m} = \frac{P_{i,\,j+1} - 2P_{i,\,j} + P_{i,\,j-1}}{\Delta Y^2}\,, \qquad [30]$$

Equation [2] becomes

$$\frac{P_{i+1,\,j} + P_{i-1,\,j}}{\Delta X^2} + \frac{P_{i,\,j+1} + P_{i,\,j-1}}{\Delta Y^2} - 2P_{i,j}\left(\frac{1}{\Delta X^2} + \frac{1}{\Delta Y^2}\right) \qquad [31]$$

$$+ \frac{3}{H_{k,m}}\left(\frac{P_{i+1,\,j} - P_{i-1,\,j}}{2\Delta X}\left.\frac{\partial H}{\partial X}\right|_{X_k Y_m} + \frac{P_{i,\,j+1} - P_{i,\,j-1}}{2\Delta Y}\left.\frac{\partial H}{\partial Y}\right|_{X_k Y_m}\right)$$

$$= -\frac{\Lambda}{H^3}\,\frac{\partial H}{\partial X}$$

which is solved for $P_{k,m}$.

$$P_{k,m}^{(\text{evaluated})} = \frac{1}{2(1+\alpha)}\left[P_{i+1,\,j} + P_{i-1,\,j} + \left\{P_{i+1,\,j} - P_{i-1,\,j} + \frac{2\Lambda\Delta X}{3H_{k,m}^2}\right\}\left(HX_{i,j}\right) + \alpha\left\{P_{i,\,j+1} + P_{i,\,j-1} + \left(P_{i,\,j+1} - P_{i,\,j-1}\right)\left(HY_{i,j}\right)\right\}\right]$$

$$\alpha = \left[\frac{\Delta X}{\Delta Y}\right]^2$$

where

$$HX_{i,j} = 1.5\left.\frac{\partial H}{\partial X}\right|_{i,j}\frac{\Delta X}{H_{i,j}}$$

$$HY_{i,j} = 1.5\left.\frac{\partial H}{\partial Y}\right|_{i,j}\frac{\Delta Y}{H_{i,j}}$$

Starting with an assumed pressure distribution (P = 1 in the j^{th} recess and P = 0 at the boundaries and in all other recesses for the j^{th} component solution or P = 0 at the boundaries and in all recesses for the N + 1 component solution), a value of the pressure, $P_{k,m}$, at a grid point is evaluated in terms of the pressure at its four immediately neighboring grid points.

Assuming

$$P'_{k,m} = \gamma P^{(evaluated)}_{k,m} + (1 - \gamma)\ P^{(old)}_{k,m} \qquad [32]$$

to be a new pressure distribution, the process is repeated until negligible changes are obtained from any one iteration. γ is called a "relaxation factor" and its magnitude sets the rate of growth of the pressure distribution. Limiting the value of γ is the well known phenomena of numerical instability.

For excessive values of γ, the rate of growth can be seen to increase steadily in time thereby indicating lack of convergence of the iteration. The occurrence of this phenomenon is internally detected and is automatically eliminated by successive reduction of the value of γ by the factor 0.8. An initial value of $\gamma = 1.5$ was used and was revealed to be overly-optimistic. Hence, an initial value of 1.1 was adopted for this program in order to avoid waste of computer time in unstable interations.

COMPUTER PROGRAM

The computer program is functionally separated into the following four sub-programs.

(1) Subroutine FORMH

Generation of the bearing geometry gridwork and the clearance distribution either by evaluation of appropriate analytic function or by direct input.

(2) Subroutine TILTH

Tilting by any specifiable amount of the clearance distribution already existing in core storage.

(3) Subroutine REYN

Generation of the component solutions P_j (X,Y) and the corresponding component solution values of the loads W_j, center of pressure coordinates ξ_j, and η_j, and flows $Q_{i,j}$.

(4) Subroutine FLOW

Matching of the component solutions with the proper feeding equations and evaluation of the corresponding pressure distribution P (X,Y), load W, center of pressure coordinates ξ and η, and flows out of each recess, q_j, for any specified feeding conditions.

The program is such that for any given clearance distribution and velocity, the loading and moment results for any of the other feeding methods can be evaluated by repeated, direct entry into Subroutine Flow. It is also possible to make available to the computer the essential results of component solutions W_j, ξ_j, η_j, $Q_{i,j}$ by direct input, so that new feeding conditions can be studied in combination with component solutions obtained during a previous group of runs.

The internal generation of the clearance distribution is executed by a function of the following type.

$$\text{Define}\quad X - X_o = s \quad \text{where} \quad X_o = A_{22}$$

$$Y - Y_o = t \qquad\qquad Y_o = A_{23}$$

then

$$\begin{aligned} H_1(X,Y) = {} & A_1 + A_2 s + A_3 t + A_4 s^2 + A_5 t^2 + A_6 st + A_7 s^3 \\ & + A_8 t^3 + A_9 s^2 t + A_{10} st^2 + A_{11} \sqrt{A_{12} + A_{13} s^2 + A_{14} t^2} \\ & + A_{15} \cos\left(A_{16} s\right) + A_{17} \cos\left(A_{18} t\right) + A_{19} \cos\left(A_{16} s\right) \cos\left(A_{18} t\right) \\ & - A_{20} \left\{ e^{-A_{21} X} \cos\left(A_{21} X\right) + e^{-A_{21}(1-X)} \cos\left[A_{21}(1 - X)\right] \right. \\ & \left. -2e^{-\frac{1}{2}A_{21}} \left[\cos\left(\tfrac{1}{2}A_{21}\right)\right] \right\} \end{aligned} \qquad [33]$$

The inclusion of the part of the preceeding expression containing the coefficients A_{20} and A_{21} was motivated by the results of analyses of the deformation of a beam on elastic foundations under a uniformly distributed load over a finite region[4].

The constants A_{20} and A_{21} are defined as,

$$A_{20} = \frac{\text{load per unit length}}{2kc}$$

$$A_{21} = \Lambda' = \lambda L$$

where

$$\lambda = \sqrt[4]{k/4\ E\ I}$$

It should be noticed that these terms detract from any clearance distribution given by the remainder of the formula an amount equal to the difference between the deflection at the center and the deflection at any point. It is also the task of FORMH to compile an internal tabulation of the derivatives of the clearance distribution necessary for the solution.

Subroutine TILTH acts by the use of the following formula:

$$H(X,Y) = H_1(X,Y) + T_x(X-X1) + T_y(Y-Y1) \qquad [34]$$

where: $H_1(X,Y)$ represents the distribution of clearance which is to be modified (tilted).

This corresponds to saying that the line,

$$T_x(X - X1) + T_y(Y - Y1) = 0$$

is the hinge and that the bearing is tilted in space by an amount,

$$\beta = T_x^2 + T_y^2 \qquad [35]$$

This feature is particularly useful in the evaluation of restoring moments corresponding to misalignments. The use of TILTH is optional.

In the use of subroutine REYN, it is important to adopt an appropriate value of the truncation constant (TRUNC). Indeed, a large value of TRUNC will accept component solutions that are only a rough approximation to the asymptotic solution, whereas, exceedingly small values of TRUNC will result in wastefully long computation time.

Originally, TRUNC was evaluated within the computer program as the change in the summation of pressure values at all of the active sill points from one iteration to the next divided by the number of active sill points. This was found to be unrealistic in that for a given value of TRUNC the degree of convergence varied considerably depending upon total grid size (X + 1 by M + 1) and relative recess sizes (with respect to bearing size). After further study it was found that a more realistic truncation criteria is the change in the summation of pressure values at all of the active sill points from one iteration to the next multiplied by the total number of grid points and divided by the product of γ and the summation of the pressure values at all of the active sill points.

Figure 1 shows the number of iterations required (as a function of TRUNC) to satisfy various assigned values of TRUNC for a typical large-size grid. Figure 2 shows the convergence of the dimensionless recess pressures and dimensionless recess loads. It can be seen that a truncation constant (TRUNC) of approximately 0.3 yields results that agree with the probable asymptotic value within less than one percent and require approximately 230 iterations. This is a reasonable compromise between accuracy and computer time. Several other gridwork sizes and configurations investigated have yielded satisfactory results using 0.3 for the truncation constant.

It was mentioned previously that the value of the relaxation factor γ is internally adjusted to cope with numerical instability. However, if persistent occurrence of this phenomenon forces the adoption of a value of γ lower than 0.16, subroutine REYN abandons the solution, and a note to this effect is introduced in the output tape.

Use of subroutine REYN requires the specification of the quantity LITER. Termination of the iteration is forced whenever a number of iterations equal to LITER have been performed regardless of the truncation criterion. As presently set up, the program will allow a

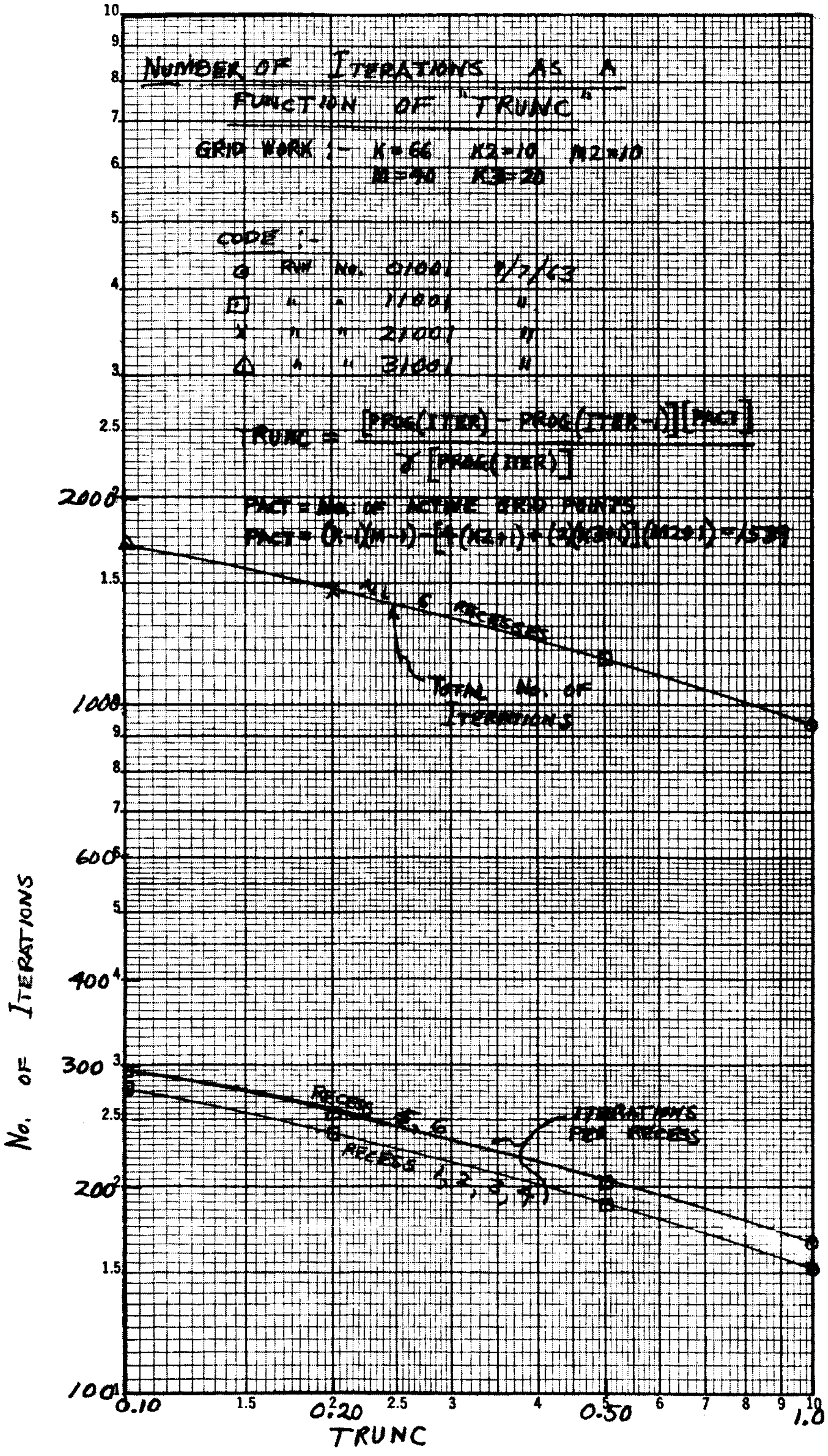


Fig. 1 - NUMBER OF ITERATIONS AS A FUNCTION OF "TRUNC"

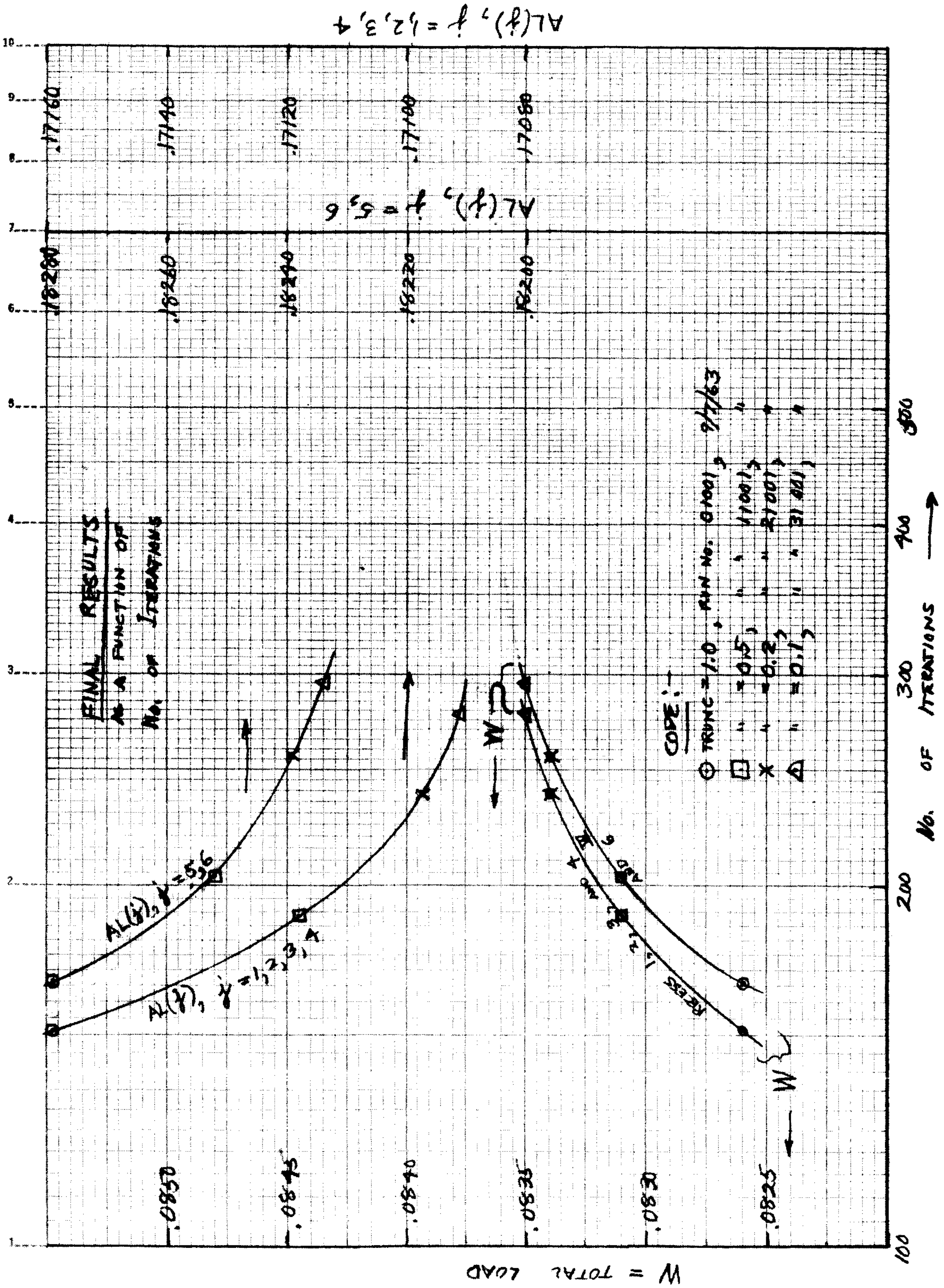


Fig. 2 - FINAL RESULTS AS A FUNCTION OF THE NUMBER OF ITERATIONS

value of LITER up to 1000. If larger values become desirable, the dimension of PROG in Subroutine REYN should be altered to the maximum value of LITER.

The operation of Subroutine FLOW is controlled by the specification of NCASE which, assuming one of the values 1, 2, or 3, indicates the adoption of the first, second, or third feeding method respectively.

The quantity IOUT enables the user to obtain the pressure and clearance profiles on the output tape (IOUT = 1). A value of IOUT = 0 specifies that output of those distributions is not desired. If IOUT = 2, the pressure profile only will appear in the output. If IOUT = 3, the clearance profile only will appear in the output.

The information in Table I will be useful in handling the quantities used in the program.

Subroutine FLOW makes use of a FUNCTION subprogram (FUNCTION DETER) in order to evaluate 4 x 4 or 6 x 6 determinants.

The utilization of the above mentioned sub-programs in the solution of specific problems is coordinated by the MAIN program. Specification of the quantity NSWICH instructs the program to solve one of six possible problems:

NSWICH = 1; CALL EXIT

NSWICH = 2; Solve non-velocity flow problem only with read-in values of W_j, ξ_j, η_j, $Q_{i,j}$.

NSWICH = 3; Solve new flow problem with component solutions already existing in core storage.

Table I - PROGRAM QUANTITIES

Equation	Fortran Symbol	Output Name
$W_j = \frac{w_j}{L^2(p_{ref} - p_a)}$	W(I)	W(I)
$\xi_j = \frac{x_j}{L}$	CSI(I)	CSI(I)
$\eta_j = \frac{y_j}{L}$	ETA(I)	ETA(I)
$Q_{i,j} = \frac{q_{rc}\ (12\mu)}{(p_{ref} - p_a)c^3}$	Q(I,J)	Q(I,J)
$q_i = \frac{q_{ri}\ (12\mu)}{(p_{ref} - p_a)c^3}$	QQ(I)	QQ(I)
$QQQ^{(K)} = \frac{q_{2ri}\ (12\mu)}{(p_{ref} - p_a)c^3}$	QQQ(K)	Pump Flows
$f_i = 0.2945\ \frac{d^4}{lc^3}$	FF(I)	Capillary Factors F(I)
$p^{(f)} = \frac{p_s - p_a}{p_{ref} - p_a}$	PF	Common Constant Pressure
$P_{i,j} = \frac{p_{i,j} - p_a}{p_{ref} - p_a}$	PPPP(I,J)	Pressure Distribution
$\alpha_j = \frac{(p_r)_j - p_a}{p_{ref} - p_a}$	AL(L)	Recess Pressures, AL(j), j=1→N
$W = \frac{w}{L^2(p_{ref} - p_a)}$	WW	Total Load
$\xi = \frac{M_{x=0}}{wL}$	CCSI	CSI
$\eta = \frac{M_{y=0}}{wL}$	EETA	ETA

NSWICH = 4; Entirely new problem with or without velocity.

NSWICH = 5; Tilt clearance distribution existing in core storage and solve resulting problem.

NSWICH = 6; Solve the previous problem considering velocity.

In the event NSWICH = 2, the quantity NIMJ should be specified to inform the computer of the number of recesses in the pad under consideration.

Appendix I contains a block diagram of the entire program, the detailed flow charts, Fortran instrucution listings, and IBM 7094 compilation records of the six subprograms (MAIN, FLOW, REYN, TILTH, FORMH, DETER).

Appendix II contains the loading record for use with an IBM 7094. This information is essential if the allowable grid size of 67 x 45 is to be extended.

USE OF THE PROGRAM AND SAMPLE PROBLEMS

A. Input

In order to use the program, the proper input data for the problem to be solved must be put on cards in a prescribed manner. The Input Guide Chart shown in Appendix III indicates the necessary data to be put on cards, its proper format, and the proper sequence of such cards. Figure 3 shows the standard form which is used to facilitate the preparation of punched cards. All of the input data required for solving a single problem is entered in the proper blocks of Figure 3. The number at the upper right-hand corner of each block is for the convenience of the typist to obtain proper word location when right-indexing is used. The following is a detailed explanation of how to specify the numbers to be entered in Figure 3 for proper execution of the particular problem to be solved.

1. Card No. 1 (always required)

   The following input data are required in MAIN program

   a. NSWICH: - Any number 1 through 6 may be entered as dictated by the following:

      1 = Last problem has been solved. Terminate program.

      2 = Solve flow problem only using basic solution results contained on input cards. It should be noted that the input form, Fig. 3, does not allow for these required cards. See the Input Guide Chart in Appendix III for the proper formats and card sequence.

      3 = Solve new flow problem with basic solution already in machine (as obtained from previous problem solved).

      4 = New problem to be solved.

HYDROSTATIC BEARING PROGRAM INPUT DATA GUIDE

(CROSS OUT CARDS NOT USED)

Page ___ of ___ Pages

{CARD NUMBER}

① ARD

1	3	5
NSWICH	NIMJ	NIGNAL

② 1 CARD

3	6	9	12	15	18	21	24	27	43
K	M	INDEX 1	INDEX 2	K1	K2	K3	M1	M2	AL

③ ④ ⑤ ⑥ ⑦ 5 CARDS (INCLUDE ALL 5)

	14	28	42	56	70
③	A(1)	A(2)	A(3)	A(4)	A(5)
④	A(6)	A(7)	A(8)	A(9)	A(10)
⑤	A(11)	A(12)	A(13)	A(14)	A(15)
⑥	A(16)	A(17)	A(18)	A(19)	A(20)
⑦	A(21)	A(22)	A(23)	A(24)	A(25)

⑧ 1 CARD

15	30	45	60
X1	Y1	TX	TY

⑨ 1 CARD

5	21	37
LITER	TRUNC	PLAM

⑩ 1 CARD

5	7	9
NRUN	NCASE	IOUT

⑪ 1 CARD

12	24	36	48	60	72
QQ(1) QQQ(1)	QQ(2) QQQ(2)	QQ(3) QQQ(3)	QQ(4)	QQ(5)	QQ(6)

⑫ 1 CARD

10
PF

⑬ 1 CARD

12	24	36	48	60	72
FF(1)	FF(2)	FF(3)	FF(4)	FF(5)	FF(6)

⑭ 1 CARD

1
NSWICH

Fig. 3 - HYDROSTATIC BEARING PROGRAM INPUT DATA GUIDE

5 = The distribution of clearance already in the machine will be tilted and new basic solutions and final results for the new clearance distribution will be obtained.

6 = The previous zero-velocity problem will be solved considering velocity.

b. NIMJ: - If NSWICH = 2 is used, then the value of NIMJ is equal to the total number of recesses. Otherwise NIMJ is left blank.

c. NIGNAL: - A 1 is entered here if velocity (PLAM) is to be considered. Otherwise PLAM will not be used by the program.

2. <u>Card No. 2</u> (Only required when NSWICH = 4)

The following input data are required in Subroutine FORMH

a. K: - This is the number of cells in the X-direction formed by the gridwork which simulates the pad. (See Fig. 5). K must be even. The maximum value of K allowed is 66*. (See Section B below.)

b. M: - This is the number of cells in the Y-direction formed by the gridwork. (See Fig. 5). M must also be even. The maximum value of M allowed is 44*. (See Section B below.)

c. INDEX 1: - If the clearance distribution is to be read in from cards then the value 1 is used for INDEX 1. It should be noted that the standard input form, Fig. 3, does not allow for these required cards. Consult the Input Guide Chart in Appendix III for the proper format and card sequence. If the clearance distribution is to be generated within the machine, INDEX 1 is not equal to 1 (normally left blank).

d. INDEX 2: - If the clearance distribution as read in from cards or generated internally (per INDEX 1) is to be tilted, then INDEX 2 = 1. Otherwise, INDEX 2 is not equal to 1.

---

*The allowable gridwork size (K + 1) x (M + 1) may be increased by changing all of the subscripted dimension statements from (67,45) to $\left[(K+1)_{max}, (M+1)_{max}\right]$.

e. K1: - This is the number of cells in the X-direction between edges of pad and recesses 1, 2, 3 and 4. (See Section B below.)

f. K2: - This is the number of cells representing the length of recesses 1, 2, 3 and 4 in the X-direction. (See Section B below.)

g. K3: - This is the number of cells representing the length of recesses 5 and 6 in the X-direction. If only a total of four recesses are to be used, K3 = 0. K3 must be an even number (See Section B below.)

h. M1: - This is the number of cells in the Y-direction between edges of pad and all of the recesses. (See Section B below.)

i. M2: - This is the number of cells representing the width of the recesses in the Y-direction (See Section B below.)

j. AL: - This is the ratio of the length of the pad in the Y-direction and the length of the pad in the X-direction (See Fig. 4). AL = LY/LX. (See Section B below.)

3. Card Numbers 3 through 7 (Used only if NSWICH = 4 and INDEX $\neq$ 1)

The following input data are required in Subroutine FORMH.

a. A(1) thru A(23): - These are the values of the 23 constants used to generate the clearance distribution within the computer. It is important to note that all five cards must be used even if the values contained on any of them are all zeros.

4. Card No. 8 (Used only when; NSWICH = 4 and INDEX 2 = 1, or NSWICH = 5)

The following input data are required in Subroutine TILTH.

a. X1: - The value to be used is the dimensionless distance in the X-direction to the line about which it is desired to rotate the pad. X1 can be any value between 0 and 1. If X1 is 0 then the pad will be rotated about the I = 1 gridwork line. If X1 = 1, the pad will be rotated about the I = (K+1) gridwork line. If 1X = 0.5, the pad will be rotated about the center line I = K/2 + 1, and so forth.

The value of X1 need not necessarily fall on a gridwork line.

b. Y1: - The value to be used is the dimensionless distance in the Y-direction to the line about which it is desired to rotate the pad. Y1 can be any value between 0 and AL. If Y1 = 0 then the pad will be rotated about the J = 1 gridwork line. If Y1 = AL, the pad will be rotated about the J =(M+1) gridwork line, and so forth. The value of Y1 need <u>not</u> necessarily fall on a gridwork line.

c. TX: - The value of TX required to obtain a specific amount of tilt about X1 may be obtained using the following equation:

$$TX = [H(1, AL/2) - H(0, AL/2)] - [H_1(1, AL/2) - H_1(0, AL/2)] \qquad [36]$$

where $H(1, AL/2)$ = desired value of H at X = 1, Y = AL/2
$H(0, AL/2)$ = desired value of H at X = 0, Y = AL/2
$H_1(1, AL/2)$ = previous value of H at X = 1, Y = AL/2
$H_1(0, AL/2)$ = previous value of H at X = 0, Y = AL/2

d. TY: - The value of TY required to obtain a specific amount of tilt about Y1 may be obtained by using the following equation:

$$TY = [H(1/2, AL) - H(1/2, 0)] - [H_1(1/2, AL) - H_1(1/2, 0)] \qquad [37]$$

where $H(1/2, AL)$ = desired value of H at X = 1/2, Y = AL
$H(1/2, 0)$ = desired value of H at X = 1/2, Y = 0
$H_1(1/2, AL)$ = previous value of H at X = 1/2, Y = AL
$H_1(1/2, 0)$ = previous value of H at X = 1/2, Y = 0

5. Card No. 9 (used only if NSWICH = 4, 5 or 6)

The following input data are required in Subroutine REYN.

a. LITER: - Maximum number of iterations allowable to obtain a component solution. When this number of iterations is reached, the iteration procedure will stop and rest of problem will be solved using component solutions obtained.

b. TRUNC: - This is the value assigned to the truncation constant. Usually, a value of TRUNC = 0.30 yields adequate convergence. However, it is usually good practice to experimentally evaluate a satisfactory value for a particular grid work pattern by varying the assigned value of TRUNC and observing the convergence of the final results.

c. PLAM: - The number assigned to PLAM is Λ, where

$$\Lambda = \frac{6\mu U L}{(p_{ref} - p_a)c^2}$$

Since $(p_{ref}-p_a)$ is an unknown value prior to solution, PLAM is usually assigned a magnitude of 1.0 although any number may be used.

6. Card No. 10 (always used)

The following input data are required in Subroutine FLOW

a. NRUN: - The identifying run number is inserted in this block.

b. NCASE: - The method of feeding code number is inserted in this block per the following:

1 = separate constant displacement pumps feeding each recess.

2 = one constant displacement pump feeding two opposite recesses, i.e., in Fig. 4, one pump feeds recesses 1 and 2, one pump feeds recesses 3 and 4, and the third pump (if used) feeds recesses 5 and 6 with capillary tubes used between pumps and recesses they feed.

3 = common pressure regulated supply manifold feeding each recess through capillary tubes.

c. IOUT: - The number used here dictates the output desired with regard to clearance and pressure distributions per the following code.

0 = do not print out clearance and pressure distribution.

1 = print out clearance and pressure distribution.

2 = print out pressure distribution only.

3 = print out clearance distribution only.

7. Card No. 11 (Used only if NCASE = 1 or 2)

   The following input data are required in Subroutine FLOW.

   a. QQ(1), ... QQ(N): - If NCASE = 1, the values of $q_i \ldots q_N$ are inserted in the first N blocks. N is either 4 recesses or 6 recesses. q_i is the constant flow to each recess.

   or,

   b. QQQ(1),.... QQ(N/2):-If NCASE = 2, the values of $q_1 \ldots q_{N/2}$ to be used are,

   $QQQ(1) = q_1 + q_2$

   $QQQ(2) = q_3 + q_4$

   $QQQ(3) = q_5 + q_6$ (if used)

   Note: - If NCASE = 3, this card (number 11) is not used.

8. Card No. 12 (Used only if NCASE = 3)

   The following input data is required in Subroutine FLOW.

   a. PF: - The number to be used here is the dimensionless manifold pressure, $p^{(f)}$, where

   $$p^{(f)} = \frac{(p_s - p_a)}{(p_{ref} - p_a)} = \frac{q_i}{f_i} + \alpha_j \qquad [38]$$

   Since q_i and α_j are unknown, a value of $p^{(f)} = 1.0$ is usually used although any number may be used.

9. Card No. 13 (Used only if NCASE = 2 or 3)

   The following input data is required in Subroutine FLOW.

   a. FF(1), ... FF(N): - Any number may be assigned for FF(I) (the capillary constant, fi). N is either 4 or 6 recesses. Hence 4 or 6 values of FF(I) are required.

10. Card No. 14 (Used only if previous cards are last problem to be solved).

    The following input data is required in the MAIN program.

    a. NSWICH: - The number 1 is used to indicate that last problem has been solved.

B. Selection and Specification of Gridwork Pattern to be Used

As has been previously indicated it is necessary that a proper balance be achieved between maximum and minimum number of grid points to be used in order to achieve reasonably accurate results without an undue amount of computer time. It should also be evident that there may have to be some compromise between recess size and locating dimensions and computer program gridwork. That is, some of the recess dimensions desired to be used may have to be slightly modified in order to fit into a finite grid point pattern.

Figure 4 shows the required geometry of a 6-recess pad. Note that if a four recess pad is to be considered, the dimension L_{x3} is equal to zero. In order to illustrate how a suitable grid work may be selected and specified, consider the pad of Figure 4 to have the following dimensions:

X-Direction	Y-Direction
LX = 32.0"	LY = 30.0"
L_{x1} = 3.0"	L_{y1} = 4.5"
L_{x2} = 5.0"	L_{y2} = 6.0"
L_{x3} = 8.0"	L_{y4} = 9.0"
L_{x4} = 4.0"	

The first step is to select the smallest <u>sill</u> dimension in the x-direction (L_{x1} or L_{x4} for 6-recesses, L_{x1} or $2L_{x4}$ for 4-recesses) and the y-direction (L_{y1} or L_{y4}). For the above problem we would select,

$$L_{x1} = 3.0'' \text{ and } L_{y1} = 4.5''$$

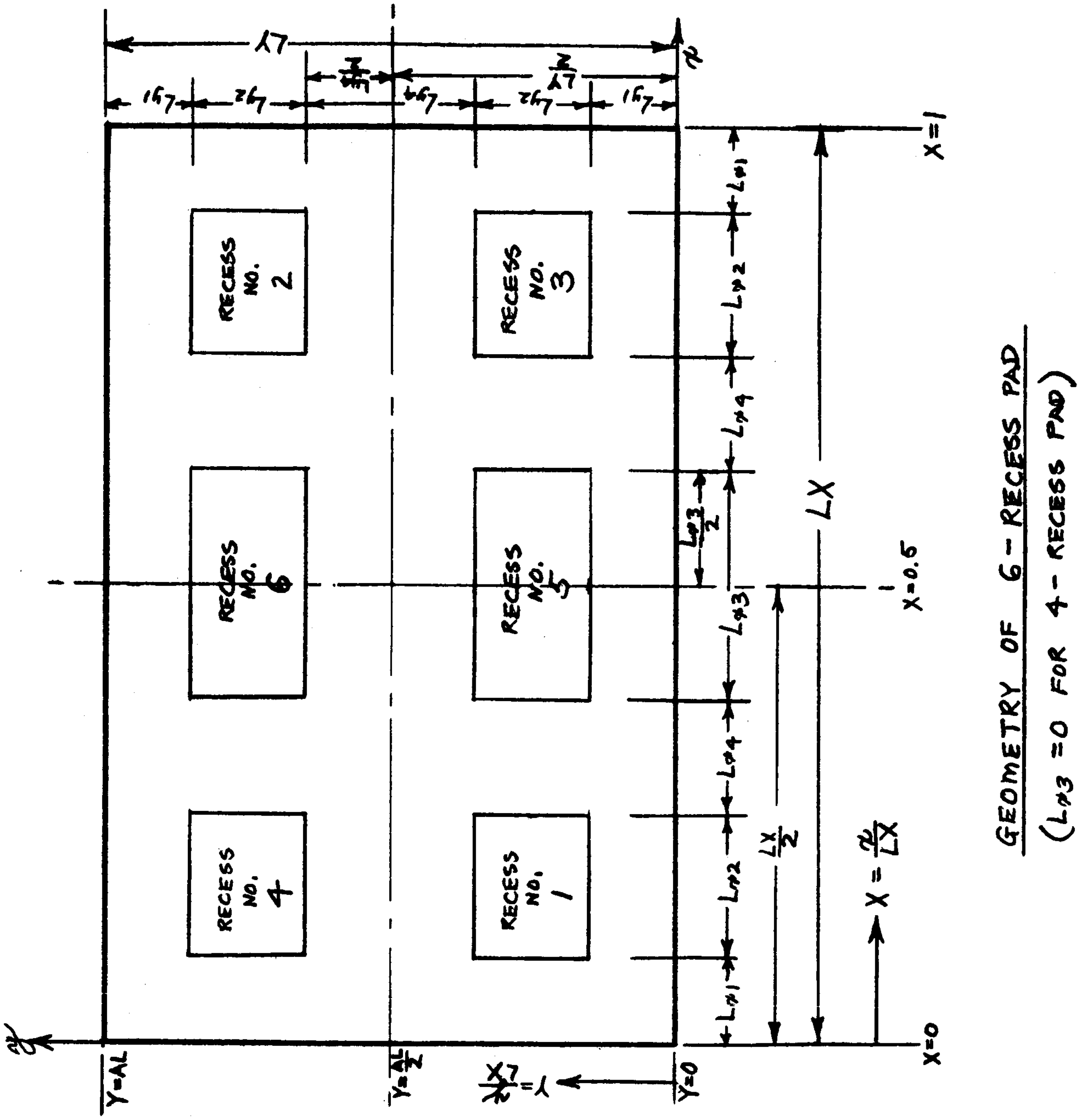


Fig. 4 - GEOMETRY OF 6-RECESS PAD

We can write the following equations;

$$\left.\begin{aligned} K2 &= K1\left(\frac{L_{x2}}{L_{x1}}\right) & M2 &= M1\left(\frac{L_{y2}}{L_{y1}}\right) \\ K3 &= K1\left(\frac{L_{x3}}{L_{x1}}\right) & M4 &= M1\left(\frac{L_{y4}}{L_{y1}}\right) \\ K4 &= K1\left(\frac{L_{x4}}{L_{x1}}\right) & M &= M1\left(\frac{LY}{L_{y1}}\right) \\ K &= K1\left(\frac{LX}{L_{x1}}\right) & & \end{aligned}\right\} \qquad [39]$$

Substituting the pad dimensions into equations [39] yields,

$$\left.\begin{aligned} K2 &= \frac{5}{3}(K1) & M2 &= \frac{4}{3}(M1) \\ K3 &= \frac{8}{3}(K1) & M4 &= 2(M1) \\ K4 &= \frac{4}{3}(K1) & M &= \frac{20}{3}(M1) \\ K &= \frac{32}{3}(K1) & & \end{aligned}\right\} \qquad [40]$$

If we now select a number of integer values for K1 we can evaluate all of the other values of interest. In order to have at least one grid point in the sill, K1, and M1 (or K4 and M4 if $L_{x4} < L_{x1}$, and $L_{y4} < L_{y1}$) must be at least 2. The following table summarizes the results obtained when various integer values of K1 are used in equations [40].

K1	K2	K3 (Even)	K4	K (Even)
2	3-1/3 = 3	5-1/3 = 6	2-2/3 = 3	21-1/3 = 22
3	5 = 5	8 = 8	4 = 4	32 = 32
4	6-2/3 = 7	10-2/3 = 10	5-1/3 = 5	42-2/3 = 42
5	8-1/3 = 8	13-1/3 = 14	6-2/3 = 7	53-1/3 = 54
6	10 = 10	16 = 16	8 = 8	64 = 64
7	11-2/3 = 12	18-2/3 = 18	9-1/3 = 9	74-2/3 = 74
8	13-1/3 = 13	21-1/3 = 22	10-2/3 = 11	85-1/3 = 86

M1	M2	M4 (Even)	—	M (Even)
2	2-2/3 = 3	4	—	13-1/3 = 14
3	4 = 4	6	—	20 = 20
4	5-1/3 = 5	8	—	26-2/3 = 26
5	6-2/3 = 7	10	—	33-1/3 = 34
6	8 = 8	12	—	40 = 40
7	9-1/3 = 9	14	—	46-2/3 = 46
8	10-2/3 = 11	16	—	53-1/3 = 54

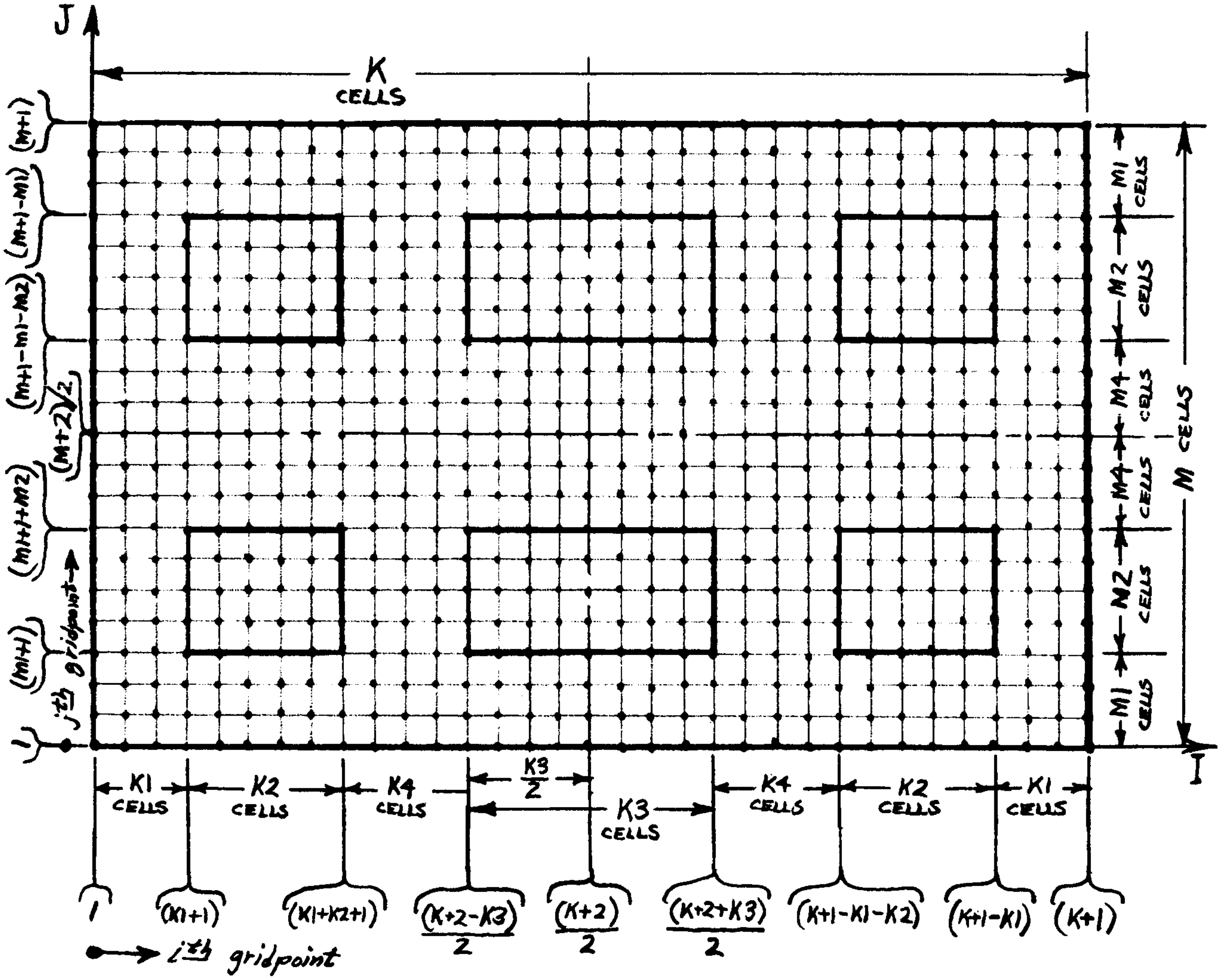
The following items should be noted in the above table.

1. The fractional values when obtained for K2, K4 are rounded-off to the nearest odd or even integer.
2. The fractional values when obtained for K3, K, M4 and M are rounded-off to the nearest <u>even</u> integer.
3. The values obtained for K1 = 7 and K1 = 8 should not be considered since K > 66. (maximum value currently permissible).

While it is permissible to use any combination of the above listed values of K1 and M1 (except K1 = 7 or 8) we can further narrow down the combination to be selected by considering the following:

1. The maximum value of K1, M1, K4 and M4 should not be greater than 8 in order to yield 7 or less active sill grid points between adjacent recesses or between any recess and the outer periphery of the pad in order to keep computer time within reasonable limits. On this basis we would, therefore, eliminate from consideration K1 = 7 or 8, M1 = 5, 6, 7 or 8.
2. While it is permissible to use only one active sill point (K1 = 2 and M1 = 2) it is not recommended if other permissible values exist. On this basis we would, therefore, eliminate from consideration K1 = 2 and M1 = 2.
3. This leaves us with possible combinations of K1 = 3, 4, 5 or 6 and M1 = 3 or 4. Notice that for K1 =4 and 5 and for M1 =4, that non-integer values were obtained. This means for these values, the resulting grid work will only approximate the actual pad and recess dimensional relationship. On this basis, we therefore eliminate from consideration K1 = 4 and 5 and M1 = 4.
4. This leaves us with two possible combinations, K1 = 3, M1 = 3 or K1 = 6, M1 = 3. Of these two we would select the smaller grid combination (K1 = 3, M1 = 3) in order to conserve computer time.

The resulting grid work for K1 = 3 and M1 = 3 is shown in Figure 5. The values of K1 = 3, K2 = 5, K3 = 8, K = 32, M1 = 3, M2 = 4 and M = 20 are the values that would be entered on input card no. 2 of Fig. 3.



GRIDWORK FOR 6-RECESS PAD

(K3 = 0 FOR 4-RECESS PAD)

Fig. 5 - GRIDWORK FOR A 6-RECESS PAD

C. Output

The output of the program consists of two result pages and a listing of the pressure and clearance distributions over the grid. The first output page contains:

1. Run number
2. Title containing information on bearing type (hybrid includes velocity), number of recesses, and feeding method.
3. Value of Lambda, if used
4. Grid work data
5. Clearance distribution coefficients (for non-zero values)
6. Values of essential results of the component solutions.
7. Final results
8. Recess pressures

The second page contains:

1. Run number
2. Title containing information on bearing type (hybrid includes velocity), number of recesses, and feeding method.
3. A digit array representing configuration of pad with the following code.

   0 = external boundary point

   1 = recess point

   2 = sill point

D. Relationships Among the Dimensionless Variables

A number of dimensionless quantities are defined and evaluated by the computer program. These are:

$$\underline{\text{Load Factor}} \;=\; W = \frac{w}{L^2(p_{ref} - p_a)} \qquad [41]$$

$$\underline{\text{Flow Factor}} \;=\; q_i = \frac{q_{ri}\ (12\mu)}{c^3(p_{ref} - p_a)} \qquad [42]$$

$$\underline{\text{Film Thickness Factor}} \;=\; H_{i,j} = \frac{h_{i,j}}{c} \qquad [43]$$

$$\underline{\text{Velocity Factor}} \;=\; \Lambda = \frac{6\mu UL}{c^2(p_{ref} - p_a)} \qquad [44]$$

$$\underline{\text{Recess Pressure Factor}} \;=\; \alpha_j = \frac{(p_r)_j - p_a}{(p_{ref} - p_a)} \qquad [45]$$

<u>Supply Pressure Factors</u>

Separate pumps feeding each recess (Case 1)

$$\alpha_{js} = \alpha_j \qquad [46]$$

One pump feeding two recess thru capillary tubes (Case 2)

$$p_i^{(K)} = \frac{q_i}{f_i} + \alpha_j \qquad [47]$$

Each recess fed through capillary tubes from a common supply manifold (Case 3)

$$p^{(f)} = \frac{q_i}{f_i} + \alpha_j = PF \qquad [48]$$

Capillary Factors

Case 1; $$f_i = \infty \qquad [49]$$

Case 2; $$f_i = \frac{q_i}{(p_i^{(K)} - \alpha_j)} \qquad [50]$$

Case 3; $$f_i = \frac{q_i}{(p^{(f)} - \alpha_j)} \qquad [51]$$

Moment Factors

Component about X = 0

$$\xi = \frac{M_{xo}}{wL} \qquad [52]$$

Component about Y = 0

$$\eta = \frac{M_{yo}}{wL} \qquad [53]$$

Depending upon the feeding method used, the values of the above mentioned dimensionless quantities are either assigned as input or evaluated within the computer program. The following table indicates whether the quantities are specified as input, (I), appear as output (O), or are able to be evaluated from the output (E).

Dimensionless Factor	FEEDING METHOD		
	Separate Pumps Feeding Each Recess	Separate Pumps Feeding Two Recesses Through Capillaries	Common Manifold at Fixed Pressure Through Capillaries
W	0	0	0
q_i	I	I	0
$H_{i,j}$	I	I	I
Λ	I	I	I
α_j	0	0	0
ξ	0	0	0
η	0	0	0
$p^{(K)}$	–	E	–
$p^{(f)}$	–	–	I
f_i	–	I	I

From the above listed dimensionless factors we can obtain relations useful for evaluating the dimensional quantities of the variables of interest. The following relationships may be derived using the above listed dimensionless factors.

Load-Film Thickness-Flow Coefficient

$$\frac{w(h_{i,j})^3}{L^2 q_{ri}\ \mu} = \frac{12(W)(H_{i,j})^3}{(q_i)} = (\overline{LHQ_i}) \qquad [54]$$

Load-Film Thickness-Velocity Coefficient

$$\frac{L^3\ \mu\ U}{w(h_{i,j})^2} = \frac{(\Lambda)}{6(W)(H_{i,j})^2} = (\overline{LHV}) \qquad [55]$$

Film Thickness-Flow-Velocity Coefficient

$$\frac{UL(h_{i,j})}{q_{ri}} = \frac{2(\Lambda)(H_{i,j})}{(q_i)} = (\overline{HQ_iV}) \qquad [56]$$

Load-Flow-Velocity Coefficient

$$U\left[\frac{L^5\mu}{q_{ri}^{\ 2}\ w}\right]^{1/3} = \frac{2(\Lambda)}{\left[12(W)(q_i)^2\right]^{1/3}} = (\overline{LQ_iV}) \qquad [57]$$

Load-Film Thickness-Flow-Velocity Coefficient

$$\frac{w(h_{i,j})^4\ U}{q_{ri}^{\ 2}\ L\ \mu} = \frac{24(W)(H_{i,j})^4(\Lambda)}{(q_i)^2} = (\overline{LHQ_iV}) \qquad [58]$$

Recess Pressure Coefficient

$$\frac{(p_{rj} - p_a)L^2}{w} = \frac{(\alpha_j)}{(W)} = (\overline{PR_jW}) \qquad [59]$$

Supply Pressure Coefficients

Case 1 feed method;

$$\frac{(p_{sj} - p_a)L^2}{w} = \frac{(\alpha_j)}{(W)} = (\overline{PS_jW1}) \qquad [60]$$

Case 2 feed method;

$$\frac{(p_{sj} - p_a)L^2}{w} = \frac{(q_i/f_i) + (\alpha_j)}{(W)} = (\overline{PS_jW2}) \qquad [61]$$

Case 3 feed method;

$$\frac{(p_{sj} - p_a)L^2}{w} = \frac{(q_i/f_i) + (\alpha_j)}{(W)} = (\overline{PS_jW3}) \qquad [62]$$

Pressure Ratio Coefficients

Case I feed method;

$$\frac{(p_{rj} - p_a)}{(p_{sj} - p_a)} = 1.0 = (\overline{\beta_j1}) \qquad [63]$$

Case 2 feed method;

$$\frac{(p_{rj} - p_a)}{(p_{sj} - p_a)} = \frac{(\alpha_j)}{(q_i/f_i) + (\alpha_j)} = (\overline{\beta_j2}) \qquad [64]$$

Case 3 feed method;

$$\frac{(p_{rj} - p_a)}{(p_{sj} - p_a)} = \frac{(\alpha_j)}{(p^{(f)})} = (\overline{\beta_j3}) \qquad [65]$$

Pad Righting Moment-Load Coefficients (about pad center)

Component (about X = 0.5)

$$\frac{M_x}{wL} = (0.5 - \xi) = (\overline{MXW}) \quad [66]$$

Component [about Y = 0.5 (AL)]

$$\frac{M_y}{wL} = [0.5(AL) - \eta] = (\overline{MYW}) \quad [67]$$

Total moment coefficient (about pad center)

$$\frac{M}{wL} = \left[(1/2 - \xi)^2 + (AL/2 - \eta)^2\right]^{\frac{1}{2}} = (\overline{MW}) \quad [68]$$

Direction Angle

$$\phi = \tan^{-1}\left\{\frac{(AL/2 - \eta)}{(1/2 - \xi)}\right\} = (\overline{MANG}) \quad [69]$$

Pad Righting Moment-Film Thickness-Flow Coefficient

Component about X = 0.5

$$\frac{M_x (h_{i,j})^3}{L^3 \; q_{ri} \; \mu} = \frac{12(1/2 - \xi)(W)(H_{i,j})^3}{(q_i)} = (\overline{MXHQ_i}) \quad [70]$$

Component about Y = 0.5(AL)

$$\frac{M_y (h_{i,j})^3}{L^3 \; q_{ri} \; \mu} = \frac{12(AL/2 - \eta)(W)(H_{i,j})^3}{(q_i)} = (\overline{MYHQ_i}) \quad [71]$$

Total moment

$$\frac{M(h_{i,j})^3}{L^3\, q_{ri}\, \mu} = \frac{12(W)(H_{i,j})^3}{(q_i)} \left[(1/2 - \xi)^2 + (AL/2 - \eta)^2\right]^{1/2} \qquad [72]$$

E. Sample Problems

A flat bearing pad having the dimensions shown in Figure 6 is to be analyzed using the computer program. Each recess is fed from a separate constant displacement pump for the following conditions of clearance distribution and velocity.

Run Number	Clearance Distribution	Velocity
7701	Uniform clearance all over	0
7702	Tilted about $X = 1/2$, $(H_{1,j} = 0.5)$, $(H_{KK,j} = 1.5)$	0
7703	Tilted about $X = 1/2$ $(H_{1,j} = 0.5)$, $(H_{KK,j} = 1.5)$	$\Lambda = 1.0$

Copies of the input data sheets for these three runs are shown in Appendix IV.

For convenience, let the dimensionless clearance at the center of the pad be

$$H_c = H\left(\frac{K+2}{2}, \frac{M+2}{2}\right) \qquad [73]$$

For all three runs, $H_c = 1.0$

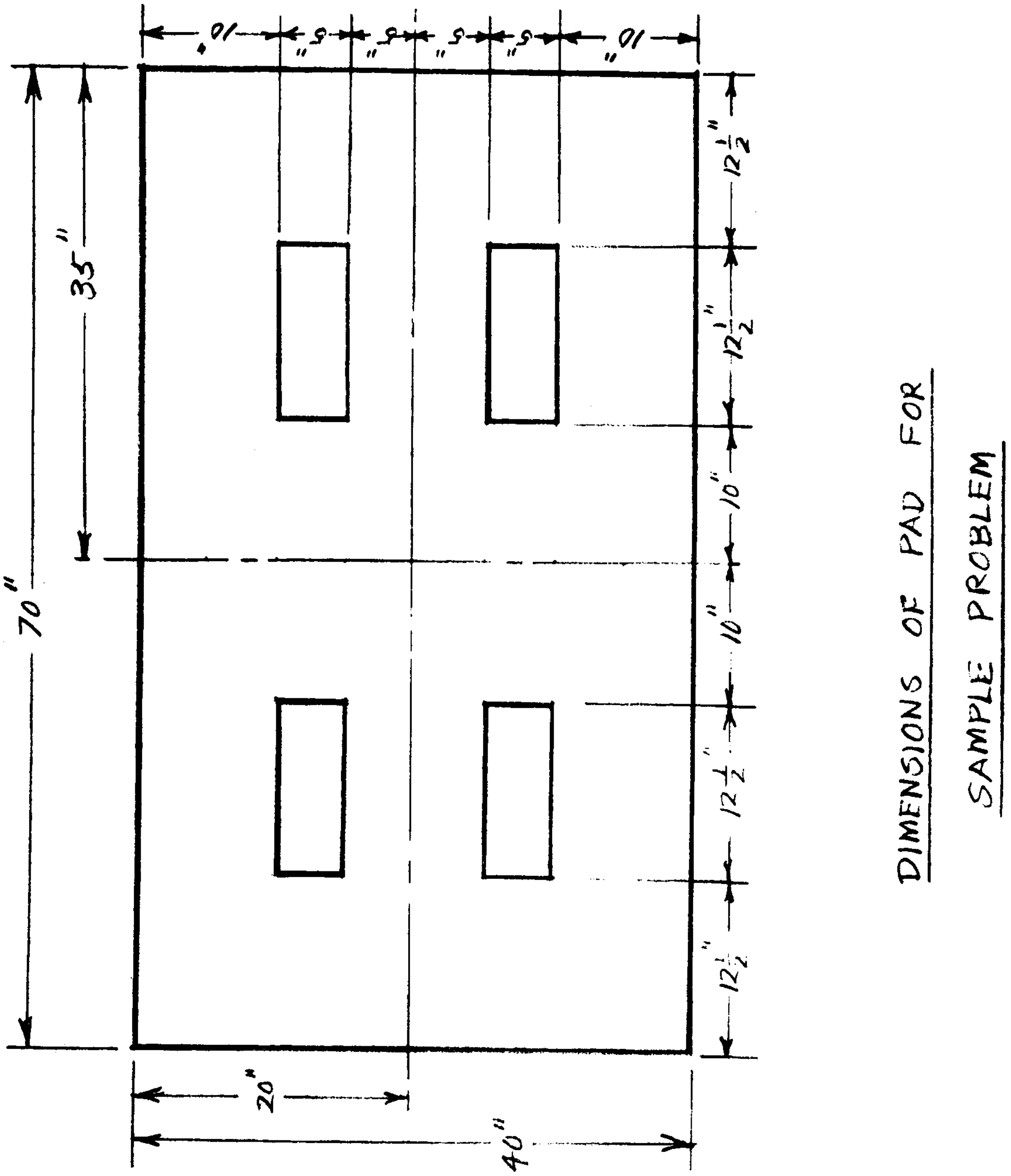


Fig. 6 - DIMENSIONS OF PAD FOR SAMPLE PROBLEM

The dimensionless computer input and output data are summarized below.

Dimensionless Factors	Run Number		
	7701	7702	7703
W	0.0933	0.1187	0.1308
q_i	1.0	1.0	1.0
H_c	1.0	1.0	1.0
ξ	0.5000	0.3708	0.3694
η	0.2857	0.2857	0.2857
α_1	0.30184	0.60023	0.64679
α_2	0.30184	0.17013	0.18384
α_3	0.30184	0.17013	0.18384
α_4	0.30184	0.60023	0.64679
Λ	0	0	1.0

Dimensionless performance coefficients in terms of H_c may be evaluated using equations [54] through [72], yielding the results listed below:

Performance Coefficients	Run Number		
	7701	7702	7703
$\overline{LHQ_i}$	1.1196	1.4244	1.5696
$\overline{LHV}$	0	0	1.275
$\overline{HQ_iV}$	0	0	2.0
$\overline{LQ_iV}$	0	0	1.72
$\overline{LHQ_iV}$	0	0	3.14
$\overline{PR_jW}$	3.23	5.07 for 1 & 4 1.44 for 2 & 3	4.95 for 1 & 4 1.40 for 2 & 3
$\overline{PS_jW1}$	3.23	5.07 for 1 & 4 1.44 for 2 & 3	4.95 for 1 & 4 1.40 for 2 & 3
$\overline{\beta_j1}$	1.0	1.0	1.0
$\overline{MXW}$	0	0.1292	0.1306
$\overline{MYW}$	0	0	0
$\overline{MW}$	0	0.1292	0.1306
$\overline{MANG}$	0	0	0
$\overline{MXHQ_i}$	0	15.48	15.32
$\overline{MYHQ_i}$	0	0	0
$\overline{MHQ_i}$	0	15.48	15.32

Problem 1: - Determine the recess and supply pressure required for a load $w = 1.5 \times 10^6$ pounds, and the given pad length of L = 70".

The equations to be used are,

$$\frac{(p_{rj} - p_a)L^2}{w} = \overline{PR_jW}$$

$$\frac{(p_{sj} - p_a)L^2}{w} = PS_jW1$$

For the given pad length of L = 70".

$$(p_{rj} - p_a) = (\overline{PR_jW})\ \frac{1.5 \times 10^6}{4900} = 306(\overline{PR_jW})$$

Since $\overline{PR_jW} = \overline{PS_jW1}$,

$$(p_{sj} - p_a) = (p_{rj} - p_a) = 306(PR_jW)$$

Using the computed values of $\overline{PR_jW}$, The values of recess pressure and supply pressure (pump discharge) in psig are,

Recess No.	Run Number		
	7701	7702	7703
1	988	1550	1515
2	988	441	428
3	988	441	428
4	988	1550	1515

Problem 2: - Determine the required flow to each recess for a film thickness at the center of the pad of $h_c = 10 \times 10^{-3}$ in, at a load $w = 1.5 \times 10^6$ pounds.

To evaluate the flow, we use the performance coefficient relating load, film thickness and flow.

$$\overline{LHQ_i} = \frac{w(h_c)^3}{L^2 q_{ri} \mu}$$

$$q_{ri} = \frac{w(h_c)^3}{(\overline{LHQ_i}) L^2 \mu}$$

Assuming an SAE 30 oil at an operating temperature of 100°F, $\mu = 15 \times 10^{-6}$ lb-sec/in^2. Since the same flow is supplied to each recess,

$$q_{ri} = q_r = \frac{1.5 \times 10^6 \, (10 \times 10^{-3})^3}{(\overline{LHQ_i})(70)^2 \, (15 \times 10^{-6})}$$

$$q_r = \frac{20.4}{(\overline{LHQ_i})}$$

Using the computed values of $\overline{LHQ_i}$ for the three runs gives,

Run No.	$\overline{LHQ_i}$	q_r, (in^3/sec)	q_r, (GPM)
7701	1.1196	18.23	4.74
7702	1.4244	14.33	3.73
7703	1.5696	13.00	3.38

Problem 3: - What will be the film thickness at the center of the pad if the flow for all recesses in all three cases is 11.53 in^3/sec (3 GPM) for a load of $w = 1.5 \times 10^6$ lbs with $\mu = 15 \times 10^{-6}$ lb-sec/in^2.

Case 7701

$$\frac{w(h_c)^3}{L^2 q_{ri} \mu} = (\overline{LHQ_i}) = 1.1196$$

$$h_c = \left[\frac{1.1196\ (4900)(11.53)(15 \times 10^{-6})}{1.5 \times 10^{+6}} \right]^{1/3}$$

$h_c = 0.0086$ in.

Case 7702

$$h_c = (h_c \text{ for } 7701) \left[\frac{\overline{LHQ_i} \text{ for } 7702}{\overline{LHQ_i} \text{ for } 7701} \right]^{1/3} = 0.0086 \left(\frac{1.4244}{1.1196} \right)^{1/3}$$

$h_c = 0.0093$ in.

Case 7703

$$h_c = (h_c \text{ for } 7701) \left[\frac{\overline{LHQ_i} \text{ for } 7703}{\overline{LHQ_i} \text{ for } 7701} \right]^{1/3} = 0.0086 \left(\frac{1.5696}{1.1196} \right)^{1/3}$$

$h_c = 0.0096$ in.

Problem 4: - What velocity of relative motion will yield a film thickness at the center of 0.010 inch for a 13.0 in^3/sec flow and a load of 1.5 x 10^6 pounds for Run No. 7703.

Using the relationship

$$\overline{HQ_i V} = \frac{UL(h_c)}{q_{ri}} = 2.0$$

$$U = \frac{2.0(13.0)}{(70)(10 \times 10^{-3})}$$

$$U = 37.2 \text{ in./sec.}$$

Problem 5: - What is the pad righting moment for all three cases when the load is 1.5 x 10^6 lbs.

To find the pad righting moment,

$$\frac{M}{wL} = (\overline{MW})$$

$$\therefore M = (\overline{MW})wL = (\overline{MW})(1.5 \times 10^6)(70)$$

For the three runs

Run No.	$\overline{MW}$	M(in - lb)
7701	0	0
7702	.1292	13.6 x 10^6
7703	.1306	13.7 x 10^6

CLOSURE

In the interim between when the above described computer program was first successfully compiled and the writing of this report, a large number of problems have been run. The operating experience compiled has indicated that the program can readily handle a large variety of hydrostatic bearing design and analysis problems. To date, the computer program results have shown good correlation with the results obtained from the electric analog field plotter technique[1] (uniform clearance, zero velocity). It should be mentioned here that in two similar, previously developed hydrostatic bearing computer programs (which allowed the solution of bearing geometries capable of being solved analytically) the correlation between computer program results and known analytical solutions was extremely good.

An experimental program currently underway at The Franklin Institute (being conducted for the Jet Propulsion Laboratory, Contract No. 950-735) is directed toward establishing the correlation between computer program results and those obtainable experimentally (zero velocity, non-uniform film clearance).

In the course of working with the above described computer program, a number of possible additions, modifications and refinements aimed at making the program more efficient and useful have occurred to Jet Propulsion Laboratory and Franklin Institute personnel. They are enumerated below for the record.

1. <u>Input</u>:- The format of the required input information should be changed in order to make key punching and checking of the same much more convenient.
2. <u>Internal Changes</u>:
    a. The initial value of gamma should be reduced to 1.0 from 1.1.

b. Assign a new FORTRAN name to the ratio of pad y-direction length to x-direction length. Change from "AL" to "YOX". The name AL is confusing since AL (I) is also used as a superscripted variable.

c. Evaluate the following quantities for subsequent appearance as output.

$$\mathrm{HC} = \mathrm{H} \ @ \ \frac{\mathrm{KK}+1}{2}, \frac{\mathrm{MM}+1}{2}$$

$$\mathrm{ALHCQ(I)} = 12(\mathrm{W})(\mathrm{HC})^3/[\mathrm{QQ(I)}]$$

$$\mathrm{ALHCV} = (\Lambda)/[6(\mathrm{W})(\mathrm{HC})^2]$$

$$\mathrm{HCQV(I)} = 2(\Lambda)(\mathrm{HC})/[\mathrm{QQ(I)}]$$

$$\mathrm{PRW(I)} = [\mathrm{AL(I)}]/(\mathrm{W})$$

$$\mathrm{PSW1(I)} = [\mathrm{AL(I)}]/(\mathrm{W})$$

$$\mathrm{PSW2(I)} = \{[\mathrm{QQ(I)}]/[\mathrm{FF(I)}] + [\mathrm{AL(I)}]\}/(\mathrm{W})$$

$$\mathrm{PSW3(I)} = (\mathrm{PF})/(\mathrm{W})$$

$$\mathrm{BETA1(I)} = [\mathrm{PRW(I)}]/[\mathrm{PSW1(I)}]$$

$$\mathrm{BETA2(I)} = [\mathrm{PRW(I)}]/[\mathrm{PSW2(I)}]$$

$$\mathrm{BETA3(I)} = [\mathrm{PRW(I)}]/[\mathrm{PSW3(I)}]$$

$$\mathrm{AMXW} = (0.50 - \mathrm{CCSI})$$

$$\mathrm{AMYW} = [0.50(\mathrm{YOX}) - \mathrm{EETA}]$$

$$\mathrm{AMW} = \{(\mathrm{AMXW})^2 + (\mathrm{AMYW})^2\}^{\frac{1}{2}}$$

$$\mathrm{AMANG} \doteq \tan^{-1}\left\{\frac{(\mathrm{AMYW})}{(\mathrm{AMXW})}\right\}$$

d. Two recommendations are suggested for reducing the computer time required to obtain the component solutions within subroutine REYN. The first is to initially assign active sill point pressure values other than the currently used value of zero. This would, however, require considerable study before changing. A second possibility is to have the program recognize beforehand when identical component solutions for the individual recesses will be obtained. For example a symmetrical distribution of clearance in both the x and y-directions yields identical component solutions for recess combinations 1, 2, 3 and 4 and also for 5 and 6. Tilting of such a symmetrical film distribution about only X1 produces identical component solutions for recess combinations 1 and 4, 2 and 3, and 5 and 6. Tilting of a symmetrical film distribution about only Y1 produces identical solutions for recess combinations 1 and 3, and 2 and 4.

3. Output: -

   a. The numerical values of the following quantities should also be written for inclusion in the output:
   YOX, X1, Y1, TX, TY, LITER, TRUNC, PLAM, HC, ALHCQ(I), HCQV(I), ALHCV, PRW(I), PSW1(I), PSW2(I), PSW3(I), BETA1(I), BETA2(I) BETA3(I), AMXW, AMYW, AMW, and AMANG.

   Appropriate titles should also be used for these quantities (See equations [54] through [69].

   b. Eliminate writing out all "progress indicators". Write out only the last two or three values of PROG(ITER). The run number (NRUN) should also be written out in this portion of the output.

In the judgement of the personnel of The Franklin Institute, all of the goals set forth in our work proposal have been achieved during the course of this program.

James G. Hinkle
J. G. Hinkle
Project Engineer

Approved by:

WWShugarts Jr
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N R Droulard
N. R. Droulard
Technical Director

Joseph R. Feldmeier
Joseph R. Feldmeier
Director of Laboratories

REFERENCES

1. Loeb, A. M., "The Determination of the Characteristics of Hydrostatic Bearings through the use of the Electric Analog Field Plotter," ASLE Transactions, Vol. 1, No. 1, April, 1958.

2. Hinkle, J. G. and V. Castelli, "A Computer Solution for Hydrostatic Bearings with Variable Film Thickness," Franklin Institute Final Report No. F-B2015, January 11, 1963, Prepared for Jet Propulsion Laboratory, Contract No. 950 448.

3. Shaw, M. C. and E. F. Macks, "Analysis and Lubrication of Bearings," McGraw Hill, 1949, N. Y., N. Y.

4. Hetenji, M., "Beams on Elastic Foundation," The University of Michigan Press.

NOMENCLATURE

AL = ratio of pad y-length/pad x-length
A_n = dimensionless clearance coefficients
E = Youngs Modulus (psi)
H = dimensionless film thickness = h/c
K = the number of grid cells in the x-direction
L = length of pad in the x-direction, inches
M = the number of grid cells in the y-direction
M_x = moment about $x = \frac{1}{2}$ axis (in-lbs)
M_y = moment about $y = \frac{AL}{2}$ axis (in-lbs)
N = total number of recesses
P_{ij} = dimensionless pressure at grid point i,j
Q_{ij} = dimensionless flow out of ith recess corresponding to jth component solution
$QQQ^{(k)}$ = dimensionless flow out of kth pair of opposite recesses
T_x = dimensionless tilt components in x-direction
T_y = dimensionless tilt components in y-direction
U = relative velocity of bearing members, in./sec.
W = dimensionless load
W_j = dimensionless load of the jth component solution
X = dimensionless x-coordinate = (x/L)
Y = dimensionless y-coordinate = (x/L)
c = a characteristic film thickness, (in.)
d = capillary diameter (in.)
f_i = capillary flow factor for ith recess
h = film thickness, (in.)
i = grid index
j = grid index
k = modulus of the foundation (lb/in^2) as defined in reference 4
l = capillary length (in.)
p = pressure, (psia)

NOMENCLATURE (Cont'd)

p_a = ambient pressure, (psia)

$p^{(f)}$ = dimensionless supply manifold pressure

p_r = recess pressure, (psia)

p_{ref} = reference pressure, (psia)

p_s = supply manifold pressure, (psia)

q_i = dimensionless flow out of the i^{th} recess

q_{ri} = volume flow out of i^{th} recess (in^3/sec)

q_{rc} = volume flow out of i^{th} recess corresponding to j^{th} component solution (in^3/sec)

q_{2r} = total volume flow out of one pair of opposite recesses (in^3/sec)

$s = X - X_o$

$t = Y - Y_o$

w = total load, (lbs)

w_j = load carried by j^{th} recess, (lbs)

x = cartesian coordinate, (in.)

x_j = distance in x-direction to center of pressure of component solution (in.)

y = cartesian coordinate, (in.)

y_j = distance in y-direction to center of pressure of component solution (in.)

Λ = velocity factor = $\dfrac{6\mu UL}{c^2(p_{ref} - p_a)}$

$\Lambda' = \lambda L$

$\alpha = \left[\dfrac{\Delta X}{\Delta Y}\right]^2$

α_j = dimensionless recess pressure

β = slope of tilted pad in h, x, y space

γ = relaxation factor governing pressure distribution growth

$\Delta X = 1/K$

$\Delta Y = \dfrac{AL}{M}$

NOMENCLATURE (Cont'd)

η = dimensionless y coordinate of center of pressure

η_j = dimensionless y coordinate of center of pressure for i^{th} component solution

λ = $\sqrt[4]{\frac{k}{4 E l}}$

μ = absolute viscosity coefficient (reyns)

ξ = dimensionless x coordinate of center of pressure

ξ_j = dimensionless x coordinate center of pressure for i^{th} component solution

APPENDIX I

PROGRAM BLOCK DIAGRAM

MAIN SUBPROGRAM

Fortran Instruction Listings
IBM 7094 Compilation Records
Flow Chart

FLOW SUBPROGRAM

Fortran Instruction Listings
IBM 7094 Compilation Records
Flow Chart

REYN SUBPROGRAM

Fortran Instruction Listings
IBM 7094 Compilation Records
Flow Chart

FORMH SUBPROGRAM

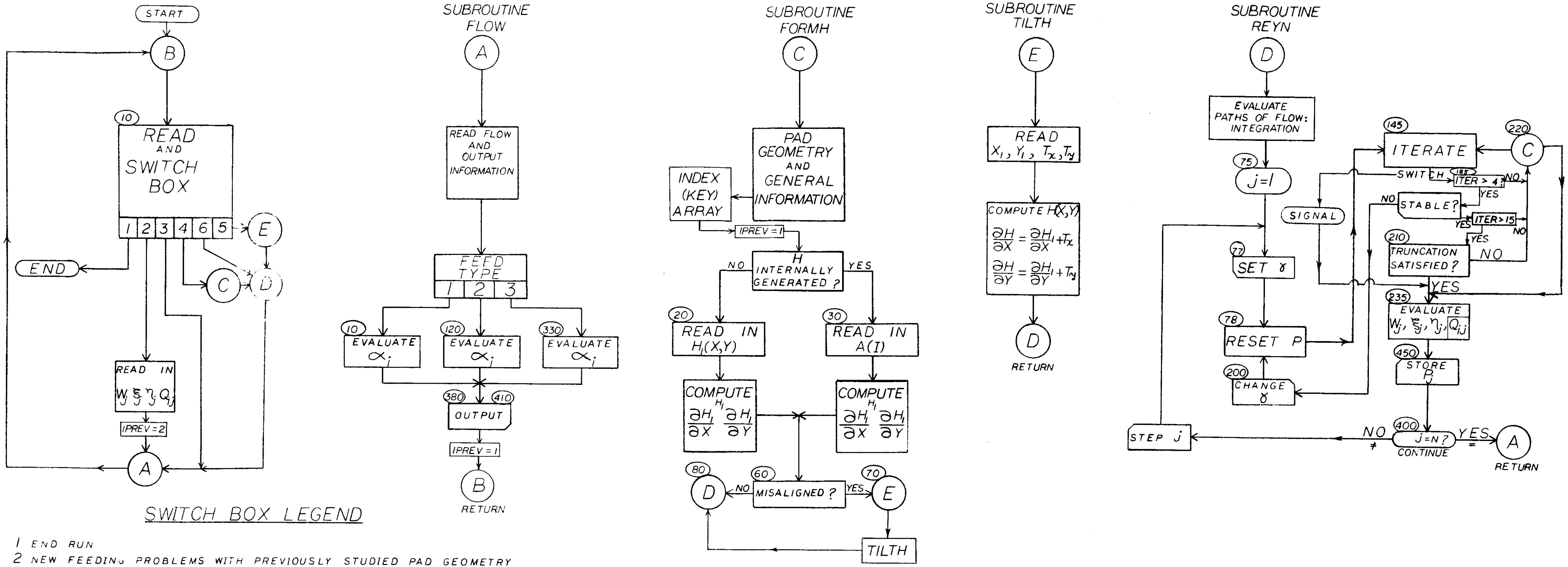
Fortran Instruction Listings
IBM 7094 Compilation Records
Flow Chart

TILTH SUBPROGRAM

Fortran Instruction Listings
IBM 7094 Compilation Records
Flow Chart

FUNCTION DETER SUBPROGRAM

Fortran Instruction Listings
IBM 7094 Compilation Records
Flow Chart



SWITCH BOX LEGEND

1 END RUN
2 NEW FEEDING PROBLEMS WITH PREVIOUSLY STUDIED PAD GEOMETRY
3 NEW FEEDING PROBLEMS WITH NEW PAD GEOMETRY
4 INTRODUCE NEW GEOMETRY
5 GENERATE NEW DATA FOR SAME GEOMETRY WITH MISALIGNMENT
6 GENERATE NEW DATA FOR SAME GEOMETRY WITH VELOCITY (LAMBDA)

J.P.L. VARIABLE FILM HYDROSTATIC BEARING PROGRAM-- BLOCK DIAGRAM

```
       MAIN PROGRAM FOR HYDROSTATIC BEARINGS WITH VARIABLE FILM THICKNES
C      DEVELOPED FOR J.P.L.  JH/VC  NOVEMBER, 1962
      DIMENSION H(67,45), HX(67,45), HY(67,45), Q(6,7), W(7), CSI(7),
     1 ETA(7), KEY(67,45), P(67,45), A(23)
      COMMON KK,MM,DX,DY,H,HX,HY,K1,K2,K3,M1,M2,TRUNC,Q,LIMJ,W,CSI,ETA,
     1 IPREV,KEY,LITER,P,NIGNAL,PLAM,X1,Y1,TX,TY,A,INDEX1,INDEX2
      REWIND 15
   10 READ INPUT TAPE 5, 1, NSWICH, NIMJ, NIGNAL
    1 FORMAT ( I1, 2I2)
      GO TO (20,30,40,50,60,70) , NSWICH
   20 CONTINUE
      CALL EXIT
   30 READ INPUT TAPE 5, 2,(W(J),J=1,6),(CSI(J),J=1,6),(ETA(J),J=1,6),((
     1Q(I,J), J=1,6), I=1,NIMJ)
    2 FORMAT (6E12.6)
      LIMJ = NIMJ
      IPREV = 2
      NIGNAL = 0
      CALL FLOW
      GO TO 10
   40 CALL FLOW
      GO TO 10
   50 CALL FORMH
      CALL REYN
      CALL FLOW
      GO TO 10
   60 CALL TILTH
      CALL REYN
      CALL FLOW
      GO TO 10
   70 CALL REYN
      CALL FLOW
      GO TO 10
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
MAIN PROGRAM FOR HYDROSTATIC BEARINGS WITH VARIABLE FILM THICKNES

                                         STORAGE NOT USED BY PROGRAM

         DEC   OCT                     DEC   OCT
         112 00160                   17379 41743

                              STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

         DEC   OCT                     DEC   OCT                     DEC   OCT                     DEC   OCT                     DEC   OCT
      A 17404 41774             CSI 23456 55640              DX 32559 77457              DY 32558 77456             ETA 23449 55631
      H 32557 77455              HX 29542 71546              HY 26527 63637          INDEX1 17381 41745          INDEX2 17380 41744
  IPREV 23442 55622              K1 23512 55730              K2 23511 55727              K3 23510 55726             KEY 23441 55621
     KK 32561 77461            LIMJ 23464 55650           LITER 20426 47712              M1 23509 55725              M2 23508 55724
     MM 32560 77460          NIGNAL 17410 42002            PLAM 17409 42001               P 20425 47711               Q 23506 55722
  TRUNC 23507 55723              TX 17406 41776              TY 17405 41775               W 23463 55647              X1 17408 42000
     Y1 17407 41777

               STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

         DEC   OCT                     DEC   OCT                     DEC   OCT                     DEC   OCT                     DEC   OCT
   NIMJ   111 00157          NSWICH   110 00156

                              SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

         EFN   LOC                     EFN   LOC                     EFN   LOC                     EFN   LOC                     EFN   LOC
    8)1     1 00154             8)2     2 00152

                              LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

         DEC   OCT                     DEC   OCT                     DEC   OCT                     DEC   OCT                     DEC   OCT
     2)    94 00136              4) 32767 77777              6)    99 00143            C)GO   109 00155           D)401    16 00020
    E)2    38 00046             E)E    77 00115             E)F    80 00120             E)G    85 00125             E)H    90 00132

                                         LOCATIONS OF NAMES IN TRANSFER VECTOR

         DEC   OCT                     DEC   OCT                     DEC   OCT                     DEC   OCT                     DEC   OCT
   EXIT     4 00004            FLOW     5 00005           FORMH     6 00006            REYN     7 00007           TILTH     8 00010
  (FPT)     0 00000           (RTN)     3 00003           (RWT)     1 00001           (TSH)     2 00002

                                    ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

EXIT          FLOW          FORMH         REYN          TILTH         (FPT)         (RTN)         (RWT)         (TSH)

                   EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

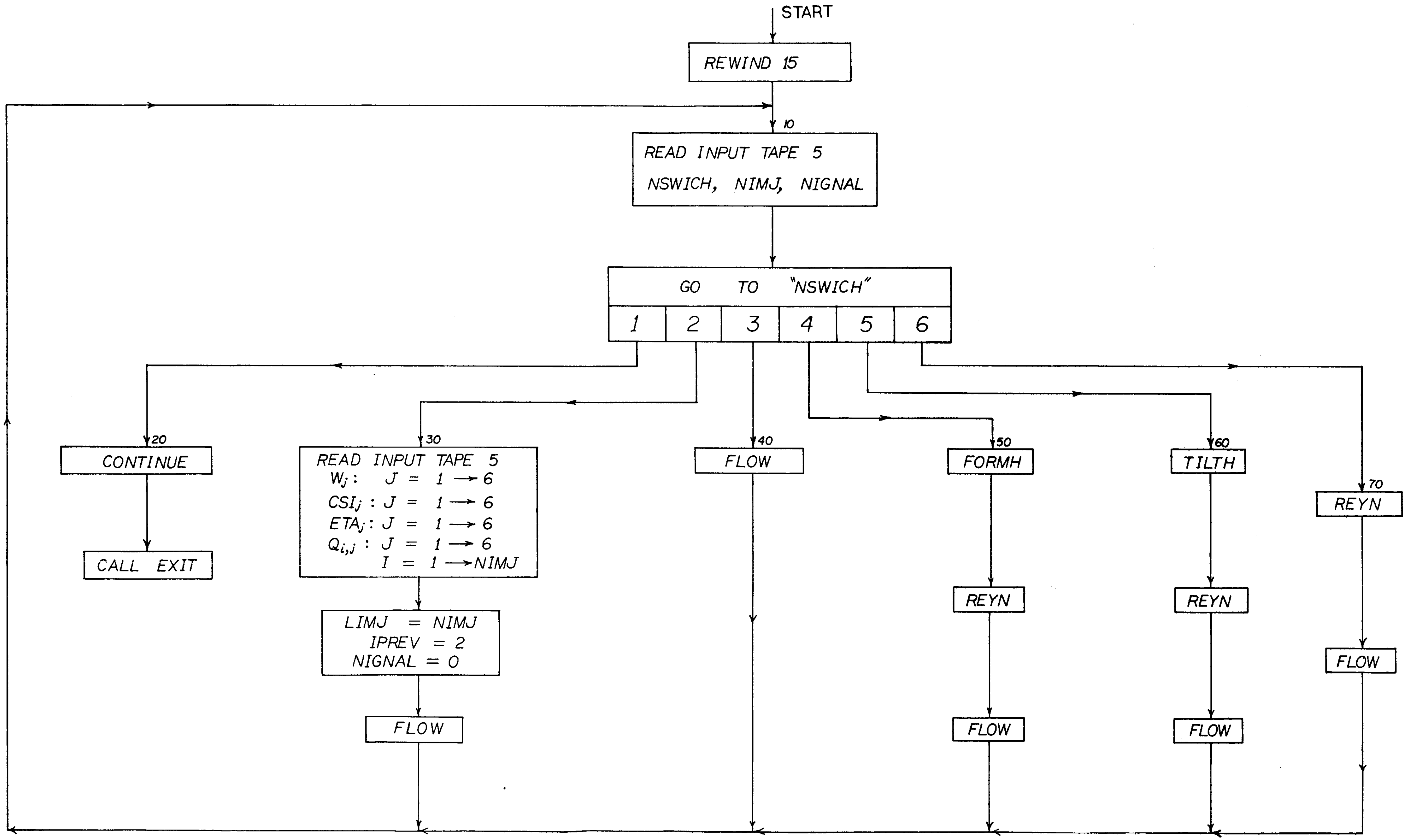
  EFN   IFN   LOC             EFN   IFN   LOC             EFN   IFN   LOC             EFN   IFN   LOC             EFN   IFN   LOC
   10     7 00021              20    10 00047              30    12 00050              40    33 00116              50    35 00121
   60    39 00126              70    43 00133
```

MAIN PROGRAM

JET PROPULSION LABORATORY'S VARIABLE FILM HYDROSTATIC BEARING PROGRAM -- BLOCK DIAGRAM

DIMENSION: H, HX, HY, Q, W, CSI, ETA, KEY, P, A

COMMON : KK, MM, DX, DY, H, HX, HY, K1, K2, K3, M1, M2, TRUNC, Q, LIMJ, W, CSI, ETA, IPREV, KEY, LITER, P, NIGNAL, PLAM, X1, Y1, TX, TY, INDEX1, INDEX2



```
      SUBROUTINE FLOW

      SUBROUTINE FLOW
      DIMENSION H(67,45), HX(67,45), HY(67,45), Q(6,7), W(7), CSI(7),
     1 ETA(7),AL(7), AA(6,7), F(6,6), D(6), QQQ(6), FF(6), PQ(6),
     1 P(67,45), PPPP(67,45), KEY(67,45), MK(10), T(6,6), TT(6), QQ(6),
     1 A(23),B(23),LOO(6),NC(23)
      COMMON KK,MM,DX,DY,H,HX,HY,K1,K2,K3,M1,M2,TRUNC,Q,LIMJ,W,CSI,ETA,
     1 IPREV,KEY,LITER,P,NIGNAL,PLAM,X1,Y1,TX,TY,A,INDEX1,INDEX2
      READ INPUT TAPE 5,1, NRUN, NCASE, IOUT
    1 FORMAT(I5,2I2)
      IF (NIGNAL - 1) 111, 1112, 111
  111 LLLL = LIMJ
      GO TO 1115
 1112 LLLL = LIMJ + 1
      AL(LLLL) = 1.0
 1115 GO TO (10, 120, 330) , NCASE
   10 READ INPUT TAPE 5, 2, (QQ(III),III=1,LIMJ)
    2 FORMAT (6E12.4)
      DO 80 LK = 1,LIMJ
      DO 40 I = 1, LIMJ
      DO 40 J = 1, LIMJ
      IF (J - LK) 30, 20, 30
   20 IF (NIGNAL - 1) 26, 27, 26
   26 AA(I,J) = QQ(I)
      GO TO 40
   27 AA(I,J) = QQ(I) - Q(I,LLLL)
      GO TO 40
   30 AA(I,J) = Q(I,J)
   40 CONTINUE
      D(LK) = DETER(AA,LIMJ)
   80 CONTINUE
      DQ = DETER(Q,LIMJ)
      DO 115 LK = 1, LIMJ
  115  AL(LK) = D(LK) / DQ
      GO TO 380
  120 LIMJ2 = LIMJ / 2
      READ INPUT TAPE 5, 2, (QQQ(III),III=1,LIMJ2)
      READ INPUT TAPE 5, 2, (FF(III), III=1,LIMJ)
      DO 130 I = 1, LIMJ, 2
      DO 130 J = 1, LIMJ
      T(I,J) = Q(I,J) + Q(I+1,J)
  130 CONTINUE
      IF (NIGNAL - 1) 132, 135, 132
  132 DO 133 I = 1,LIMJ, 2
      II = (I+1)/2
  133 TT(I) = QQQ(II)
      GO TO 139
  135 DO 138 I = 1, LIMJ, 2
      II = (I+1)/2
      TT(I)=QQQ(II) - Q(I,LIMJ+1) - Q(I+1,LIMJ+1)
  138 CONTINUE
  139 DO 200 I = 2,LIMJ,2
      IF ( NIGNAL - 1) 142, 145, 142
  142 TT(I) = 0.0
      GO TO 146
  145 TT(I) = Q(I,LIMJ+1)/FF(I) - Q(I-1,LIMJ+1)/FF(I-1)
  146 DO 200 J = 1, LIMJ
```

```
      SUBROUTINE FLOW

      IF (I-1-J) 140, 150, 140
  140 DEL = 0.0
      GO TO 160
  150 DEL = 1.0
  160 IF (I-J) 170, 180, 170
  170 DDEL = 0.0
      GO TO 190
  180 DDEL = 1.0
  190 T(I,J) = (Q(I-1,J)+DEL*FF(I-1))/FF(I-1)-(Q(I,J)+DDEL*FF(I))/FF(I)
  200 CONTINUE
  205 DO 270 LK = 1, LIMJ
      DO 230 I = 1, LIMJ
      DO 230 J = 1, LIMJ
      IF (J-LK) 220, 210, 220
  210 AA(I,J) = TT(I)
      GO TO 230
  220 AA(I,J) = T(I,J)
  230 CONTINUE
      D(LK) = DETER(AA,LIMJ)
  270 CONTINUE
      DT = DETER (T,LIMJ)
      DO 305 LK = 1, LIMJ
  305 AL(LK) = D(LK) / DT
      DO 310 I = 1, LIMJ
      QQ(I) = 0.0
      DO 310 J = 1, LLLL
  310 QQ(I) = QQ(I) + AL(J) * Q (I,J)
      IF (NCASE - 2 )  315, 315, 380
  315 DO 320 I = 1, LIMJ2
  320 PQ(1)=QQ(2*I-1)/FF(2*I-1) +AL(2*I-1)
      GO TO 380
  330 READ INPUT TAPE 5, 5, PF
    5 FORMAT  (F10.4)
      READ INPUT TAPE 5, 2, (FF(III), III=1,LIMJ)
      DO 370 I = 1, LIMJ
      IF ( NIGNAL - 1) 332, 333, 332
  332 TT(I) = PF * FF(I)
      GO TO 335
  333 TT(I) = PF * FF(I) - Q(I,LIMJ+1)
  335 DO 370 J = 1, LIMJ
      IF (I-J) 340, 350, 340
  340 DDEL = 0.0
      GO TO 360
  350 DDEL = 1.0
  360 T(I,J) = Q(I,J) + DDEL * FF(I)
  370 CONTINUE
      GO TO 205
  380 WW = 0.0
      DO 390 I = 1, LLLL
  390 WW = WW + AL(I) * W(I)
      CCSI = 0.0
      EETA = 0.0
      DO  400 I = 1,LLLL
      CCSI = CCSI + AL(I) * CSI(I)*W(I)/WW
  400 EETA = EETA + AL(I) * ETA(I) * W(I)/ WW
      IF ( NIGNAL - 1) 402, 403, 402
```

```
      SUBROUTINE FLOW
  402 WRITE OUTPUT TAPE 6,6,NRUN,LIMJ
      GO TO 410
  403 WRITE OUTPUT TAPE 6,32, NRUN, LIMJ
  410 GO TO (420, 430, 440),NCASE
  420 WRITE OUTPUT TAPE 6,7
    7 FORMAT (31X 58HFEEDING = POSITIVE DISPLACEMENT PUMPS FEEDING EACH
     1RECESS.   /)
      GO TO 450
  430 WRITE OUTPUT TAPE  6,8
    8 FORMAT(14X 92HFEEDING = POSITIVE DISPLACEMENT PUMPS FEEDING PAIRS
     1OF RECESSES WITH CAPILLARY COMPENSATION.    )
      GO TO 450
  440 WRITE OUTPUT TAPE 6,9,PF
    9 FORMAT (5X 36HFEEDING = COMMON CONSTANT PRESSURE (F7.3,67H ATM.) R
     1ESERVOIR FEEDING ALL RECESSES WITH CAPILLARY COMPENSATION.   /)
  450 IF (NCASE - 2) 452, 451, 452
  451 WRITE OUTPUT TAPE 6,15,(QQQ(I), I=1,LIMJ2)
   15 FORMAT ( 11H PUMP FLOWS  3E18.7   )
  452 GO TO (460, 480), IPREV
  460 K = KK - 1
      M = MM - 1
      IF ( NIGNAL - 1) 454, 453, 454
  453 WRITE OUTPUT TAPE 6,28, PLAM
   28 FORMAT ( 10H LAMBDA = F8.4)
   29 FORMAT ( 17H GRID POINTS, K = I3,2X 4H M = I3, 5X 5H K1 = I3, 2X
     1 5H K2 = I3, 2X 5H K3 = I3, 3X 5H M1 = I3, 2X 5H M2 = I3   )
  454 WRITE OUTPUT TAPE 6,29, K, M, K1, K2, K3, M1, M2
      IF ( INDEX1 - 1) 455, 459, 455
  455 KI = 0
      DO 458  L = 1, 23
      IF ( ABSF(A(L)) - 0.1E-06)  458, 456, 456
  456 KI = KI + 1
      B (KI) = A(L)
      NC(KI) = L
  458 CONTINUE
      WRITE OUTPUT TAPE 6,4441,(NC(I),B(I), I = 1,KI)
 4441 FORMAT (24H CLEARANCE COEFFICIENTS /5(4H ,AA I2,3H)= E14.8))
  459 IF (INDEX2 - 1) 4460, 461, 4460
 4460 IF (NSWICH - 5) 462, 461, 462
  461 WRITE OUTPUT TAPE 6,31, X1, Y1, TX, TY
   31 FORMAT ( 19H TILTED PAD, X1 =  E15.8, 2X 6H Y1 = E15.8, 2X 6H TX =
     1  E15.8, 2X 6H TY =  E15.8 )
  462 CONTINUE
      GO TO 480
C      START A  NEW PAGE OF OUTPUT
 4620 IF (NIGNAL - 1)  463, 464, 463
  463 WRITE OUTPUT TAPE 6, 6, NRUN, LIMJ
      GO TO 465
  464 WRITE OUTPUT TAPE 6,32, NRUN, LIMJ
   32 FORMAT (12H1RUN NUMBER I5, 26X  25H HYBRID BEARING PAD WITH  I1,
     1 10H RECESSES )
  465 GO TO ( 466,467,468),NCASE
  466 WRITE OUTPUT TAPE 6,7
      GO TO  469
  467 WRITE OUTPUT TAPE 6,8
      GO TO  469
```

```
      SUBROUTINE FLOW
  468 WRITE OUTPUT TAPE 6,9, PF
  469 WRITE OUTPUT TAPE 6,3, (KEY(I,1), I = 1,KK)
      DO 470 J = 2, MM
  470 WRITE OUTPUT TAPE 6,4,(KEY(I,J), I=1,KK )
      GO TO 549
    3 FORMAT(20H PAD CONFIGURATION.   67I1    )
    4 FORMAT ( 20X  67I1         )
  480 WRITE OUTPUT TAPE 6,4801
 4801 FORMAT ( // 54X 10H OUTPUT       )
      IF (LIMJ - 4) 490, 490, 500
  490 IF (NIGNAL - 1) 494, 496, 494
  494 WRITE OUTPUT TAPE 6,12,(QQ(I),I=1,4),(Q(1,J),J=1,4),(W(I),I=1,4) ,
     1(Q(2,J),J=1,4),(CSI(I),I=1,4),(Q(3,J),J=1,4),(ETA(I),I=1,4),(Q(4,J
     1) , J=1,4)
      GO TO 510
   12 FORMAT ( 8H QQ(I)= 4F9.2,10X10H** Q(I,J)= 4F9.4/8H W(I)=  4F9.4,10
     1X2H**8X 4F9.4/8H CSI(I)= 4F9.4,10X 2H** 8X 4F9.4/8H ETA(I)= 4F9.4,
     110X 2H** 8X 4F9.4 )
  496 WRITE OUTPUT TAPE 6,112,(QQ(I),I=1,4),(W(I),I=1,5),(CSI(I),I=1,5),
     1(ETA(I),I=1,5), ((Q(I,J),J=1,5),I=1,4)
      GO TO 510
  112 FORMAT ( 8H QQ(I)= 4F11.4/8H W(I)=  5F9.4/ 8H CSI(I)= 5F9.4/  8H E
     1TA(I)= 5F9.4// 10X 5H J=1, 4X 5H J=2, 4X 5H J=3, 4X 5H J=4, 4X
     1 5H J=5, / 8H Q(1,J)= 5F9.4/ 8H Q(2,J)= 5F9.4/ 8H Q(3,J)= 5F9.4/
     1 8H Q(4,J)= 5F9.4  )
  500 IF (NIGNAL - 1) 504, 506, 504
  504 WRITE OUTPUT TAPE 6,13,(QQ(I),I=1,6),(Q(1,J),J=1,6),(W(I),I=1,6)
     1,(Q(2,J),J=1,6),(CSI(I),I=1,6),(Q(3,J),J=1,6),(ETA(I),I=1,6),(Q(4,
     1J),J=1,6),(Q(5,J),J=1,6),(Q(6,J),J=1,6)
      GO TO 510
   13 FORMAT( 8H QQ(I)= 6F8.2, 2X 10H** Q(I,J)= 6F8.4/8H W(I)=  6F8.4,2X
     1 2H** 8X 6F8.4/8H CSI(I)= 6F8.4, 2X 2H** 8X 6F8.4/8H ETA(I)= 6F8.4
     1,2X 2H** 8X 6F8.4/58X 2H** 8X 6F8.4/58X 2H** 8X 6F8.4)
  506 WRITE OUTPUT TAPE 6,113,(QQ(I),I=1,6),(W(I),I=1,7),(CSI(I),I=1,7),
     1 (ETA(I),I=1,7),((Q(I,J),J=1,7),I=1,16)
  113 FORMAT ( 8H QQ(I)= 6F11.4/ 8H W(I)=  7F9.4/ 8H CSI(I)= 7F9.4/ 8H E
     1TA(I)= 7F9.4// 10X 5H J=1, 4X 5H J=2, 4X 5H J=3, 4X 5H J=4, 4X
     1 5H J=5, 4X 5H J=6,  4X 5H J=7,/  8H Q(1,J)= 7F9.4 / 8H Q(2,J)= 7F
     19.4/ 8H Q(3,J)= 7F9.4/ 8H Q(4,J)= 7F9.4/ 8H Q(5,J)= 7F9.4/
     1 8H Q(6,J)= 7F9.4 )
  510 IF (NCASE - 2) 530, 520, 520
  520 WRITE OUTPUT TAPE 6,14,(FF(I), I=1,LIMJ      )
   14 FORMAT(24H CAPILLARY FACTORS F(I)=   6E16.7 )
  530 QQQQ = 0.0
      DO 540 I=1,LIMJ
  540 QQQQ = QQQQ + QQ(I)
    6 FORMAT (12H1RUN NUMBER I5,23X 29HHYDROSTATIC BEARING PAD WITH  I1,
     1 10H RECESSES.  )
      WRITE OUTPUT TAPE 6,16,WW,CCSI,EETA,QQQQ
   16 FORMAT (28H FINAL RESULTS = TOTAL LOAD= F8.4, 6H  CSI=F7.4  , 6H E
     1TA= F7.4, 13H  TOTAL FLOW= E15.7  )
      DO 543 L = 1, LIMJ
  543 LOO(L) = L
      WRITE OUTPUT TAPE 6,5432,(LOO(L),AL(L), L = 1,LIMJ)
 5432 FORMAT (17H RECESS PRESSURES / 2X 6(6H,  AL( I1, 4H) = F8.5))
      GO TO (4620,549), IPREV
```

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      SUBROUTINE FLOW

  549 IOUT = IOUT + 1
      GO TO ( 550, 555, 555, 695),IOUT
  550 IPREV=1
      WRITE OUTPUT TAPE 6,8888
 8888 FORMAT (1H1)
      RETURN
   17 FORMAT (8E15.8  )
  555 GO TO(560,556),IPREV
  556 WRITE OUTPUT TAPE 6,5555
 5555 FORMAT(52HOPRESSURE AND CLEARANCE DISTRIBUTIONS NOT AVAILABLE.    )
      GO TO 550
  560 DO 570 I=1,KK
      DO 570 J=1,MM
  570 PPPP(I,J) = 0.0
      REWIND  15
      DO 580 II = 1, LIMJ
      READ TAPE 15,P
      DO 580 I=1,KK
      DO 580 J = 1, MM
  580 PPPP(I,J) = PPPP(I,J) + AL(II) * P( I,J)
      REWIND  15
      KK1 = 0
  590 IF (KK - KK1 - 10) 600, 600, 610
  600 KK2 = KK
      GO TO 620
  610 KK2 = KK1 + 10
  620 DO 630  L = 1,10
  630 MK(L) = KK1 + L
      IF (KK-KK2) 640, 640, 650
  640 KK3 = KK2 - KK1
      WRITE OUTPUT TAPE 6, 18, NRUN,  (MK(L),L = 1,KK3)
      GO TO 660
  650 WRITE OUTPUT TAPE 6, 18,  NRUN, (MK(L), L = 1,10 )
  660 KK11 = KK1 + 1
      DO 670 J = 1, MM
  670 WRITE OUTPUT TAPE 6, 19,J,(PPPP(I,J),I=KK11,KK2)
   19 FORMAT (3H J= I3, 4H,     10F11.4)
      IF ( KK - KK2)  690, 690, 680
  680 KK1 = KK1 + 10
      GO TO 590
   18 FORMAT ( 1H1 49X 22H PRESSURE DISTRIBUTION//5H RUN I5, 5X 2HI= I3
     1,9(8H       I=  I3)/)
  690 CONTINUE
      IF (IOUT - 2) 550, 695, 550
  695 KK1 = 0
  700 IF (KK-KK1 - 10) 710, 710, 720
  710 KK2 = KK
      GO TO 730
  720 KK2 = KK1 + 10
  730 DO 740 L = 1, 10
  740 MK(L) = KK1 + L
      IF (KK - KK2) 750, 750, 760
  750 KK3 =  KK2 - KK1
      WRITE OUTPUT TAPE 6, 21, NRUN, (MK(L), L = 1,KK3)
   21 FORMAT ( 1H1 49X 22HCLEARANCE DISTRIBUTION //5H RUN  I5, 6H    I=
     1I3, 9( 8H      I= I3)/)
```

```
    SUBROUTINE FLOW

    GO TO 770
760 WRITE OUTPUT TAPE 6, 21, NRUN,(MK(L),L=1,10)
770 KK11 = KK1 + 1
    DO 780  J = 1, MM
780 WRITE OUTPUT TAPE 6, 22, J,(H(I,J), I = KK11,KK2)
 22 FORMAT (3H J= I3, 4H,    10F11.7 )
    IF (KK - KK2)  550, 550, 790
790 KK1 = KK1 + 10
    GO TO 700
    END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
SUBROUTINE FLOW

                                 STORAGE NOT USED BY PROGRAM

       DEC   OCT             DEC   OCT
      5109 11765            17379 41743

                   STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

       DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT
    A 17404 41774        CSI 23456 55640        DX 32559 77457        DY 32558 77456        ETA 23449 55631
    H 32557 77455         HX 29542 71546        HY 26527 63637    INDEX1 17381 41745     INDEX2 17380 41744
IPREV 23442 55622         K1 23512 55730        K2 23511 55727        K3 23510 55726        KEY 23441 55621
   KK 32561 77461       LIMJ 23464 55650     LITER 20426 47712        M1 23509 55725         M2 23508 55724
   MM 32560 77460     NIGNAL 17410 42002      PLAM 17409 42001         P 20425 47711          Q 23506 55722
TRUNC 23507 55723         TX 17406 41776        TY 17405 41775         W 23463 55647         X1 17408 42000
   Y1 17407 41777

              STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

       DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT
   AA  5003 11613         AL  5108 11764         B  5055 11677         D  5101 11755         FF  5089 11741
    F  4961 11541        LOO  5032 11650        MK  5077 11725        NC  5026 11642       PPPP  4925 11475
   PQ  5083 11733        QQQ  5095 11747        QQ  5061 11705         T  1910 03566         TT  5067 11713

         STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

       DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT
 CCSI  1874 03522       DDEL  1873 03521       DEL  1872 03520        DQ  1871 03517         DT  1870 03516
 EETA  1869 03515         II  1868 03514      IOUT  1867 03513         I  1866 03512          J  1865 03511
   KI  1864 03510       KK11  1863 03507       KK1  1862 03506       KK2  1861 03505        KK3  1860 03504
    K  1859 03503      LIMJ2  1858 03502        LK  1857 03501      LLLL  1856 03500          L  1855 03477
    M  1854 03476      NCASE  1853 03475      NRUN  1852 03474    NSWICH  1851 03473         PF  1850 03472
 QQQQ  1849 03471         WW  1848 03470

                       SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

       EFN   LOC              EFN   LOC              EFN   LOC              EFN   LOC              EFN   LOC
  8)1     1 03447        8)2     2 03445       8)3     3 03254       8)4     4 03246        8)5     5 03443
  8)6     6 03014        8)7     7 03441       8)8     8 03425       8)9     9 03403        8)C    12 03235
  8)D    13 03140        8)E    14 03023       8)F    15 03356       8)G    16 02777        8)H    17 02744
  8)I    18 02723        8)J    19 02730       8)L    21 02705       8)M    22 02667        8)S    28 03351
  8)T    29 03345        8)V    31 03310      8)10    32 03271      8)3G   112 03204       8)3H   113 03102
8)4AP  4441 03321      8)4M1  4801 03242     8)590  5432 02757     8)5DJ  5555 02742      8)8LO  8888 02745

                      LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

       DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT
   1)  1832 03450         2)  1440 02640        3)  1450 02652        6)  1453 02655       C)G0  1836 03454
 C)G1  1837 03455       C)G3  1838 03456      C)G4  1839 03457      C)G5  1840 03460       C)G8  1841 03461
 C)GA  1842 03462       C)GB  1843 03463     C)100  1844 03464     C)101  1845 03465      C)102  1846 03466
C)200  1847 03467      D)108    88 00130     D)114   276 00424     D)11J   353 00541      D)127   484 00744
D)130   628 01164      D)23B   716 01314     D)27D  1324 02454     D)27E  1329 02461      D)314   275 00423
D)327   483 00743      D)37D  1323 02453     D)37E  1328 02460     D)40E   114 00162      D)420   580 01104
D)43T   841 01511      D)714   274 00422     D)727   482 00742       E)C   105 00151       E)29   492 00754
```

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SUBROUTINE FLOW

                                    LOCATIONS OF NAMES IN TRANSFER VECTOR

           DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT              DEC   OCT
 DETER       2 00002     (FIL)      4 00004     (RLR)      8 00010     (RTN)      1 00001     (RWT)      5 00005
 (SLI)       7 00007     (STH)      3 00003     (TSB)      6 00006     (TSH)      0 00000

                                 ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

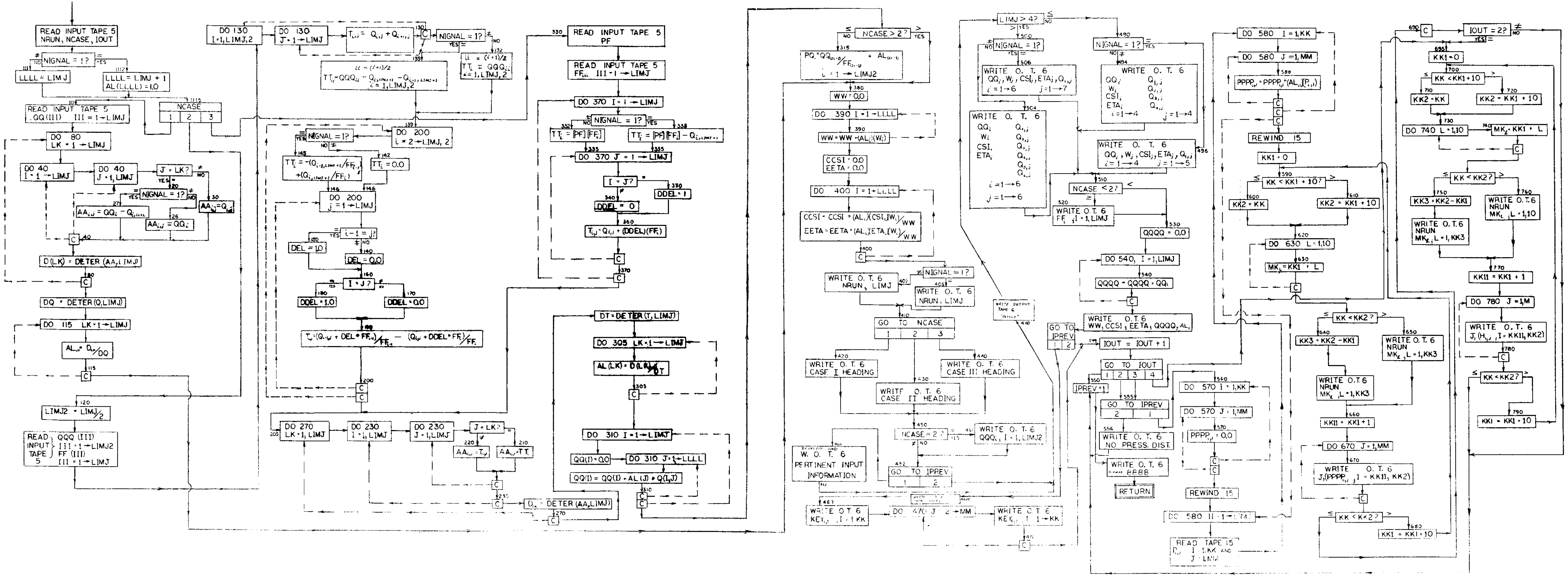
DETER       (FIL)       (RLR)       (RTN)       (RWT)       (SLI)       (STH)       (TSB)       (TSH)

                    EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

 EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC
 111    38 00045         1112    40 00052         1115    42 00061           10    43 00064           20    52 00143
  26    53 00146           27    55 00152           30    57 00157           40    58 00163           80    61 00204
 115    65 00217          120    67 00225          130    81 00277          132    83 00307          133    85 00325
 135    87 00333          138    90 00370          139    91 00374          142    93 00430          145    95 00433
 146    96 00443          140    98 00454          150   100 00457          160   101 00461          170   102 00464
 180   104 00467          190   105 00471          200   106 00505          205   107 00522          210   111 00554
 220   113 00557          230   114 00561          270   117 00577          305   121 00612          310   125 00636
 315   127 00656          320   128 00662          330   130 00673          332   139 00750          333   141 00755
 335   142 00761          340   144 00771          350   146 00774          360   147 00776          370   148 01002
 380   150 01020          390   152 01025          400   157 01050          402   159 01063          403   162 01074
 410   164 01105          420   165 01110          430   167 01117          440   169 01126          450   171 01140
 451   172 01145          452   177 01165          460   178 01167          453   181 01202          454   183 01214
 455   186 01245          456   189 01262          458   192 01273          459   198 01315         4460   199 01320
 461   200 01325          462   202 01341         4620   204 01342          463   205 01345          464   208 01362
 465   210 01376          466   211 01401          467   213 01410          468   215 01417          469   217 01431
 470   223 01467          480   229 01512          490   231 01524          494   232 01527          496   259 01610
 500   279 01655          504   280 01660          506   313 01753          510   332 02017          520   333 02024
 530   338 02043          540   340 02050          543   344 02102          549   351 02133          550   353 02144
 555   357 02161          556   358 02164          560   360 02173          570   362 02206          580   369 02247
 590   372 02270          600   373 02275          610   375 02300          620   376 02303          630   377 02306
 640   379 02320          650   387 02345          660   393 02364          670   395 02410          680   402 02442
 690   404 02446          695   406 02455          700   407 02462          710   408 02467          720   410 02472
 730   411 02475          740   412 02500          750   414 02512          760   422 02537          770   428 02556
 780   430 02602          790   437 02634
```

F L O W

DIMENSION: H, HY, Q, AL, A, F, D, QQQ, FF, PQ, W, CSI, ETA, P, PPPP, KEY, MK, T, TT, QQ, HX, AA, B, LOO, NC
COMMON: KK, MM, DX, DY, H, HX , HY, K1, K2, K3, M1, M2, TRUNC, Q, LIMJ, W, CSI, ETA, IPREV, KEY, LITER, P, NIGNAL, PLAM, X1, Y1, TX, TY, A, INDEX1, INDEX2



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      SUBROUTINE REYN

      SUBROUTINE REYN
      DIMENSION H(67,45), HX(67,45), HY(67,45), Q(6,7), W(7), CSI(7),
     1 ETA(7), A(23), PPP(67), P(67,45), PROG(1000),KR(6),KRR(6),MR(6),
     1 MRR(6), KEY(67,45)
      COMMON KK,MM,DX,DY,H,HX,HY,K1,K2,K3,M1,M2,TRUNC,Q,LIMJ,W,CSI,ETA,
     1 IPREV,KEY,LITER,P,NIGNAL,PLAM,X1,Y1,TX,TY,A,INDEX1,INDEX2
      READ INPUT TAPE 5,1, LITER, TRUNC, PLAM
    1 FORMAT (I5, 2E16.8)
      ALPHA = (DX * DX) /(DY * DY )
      FACTOR = 1.0/(2.0*(1.0 + ALPHA))
      K = KK- 1
       M = MM-1
      NREL = K + M - K1 - K2 - M1 - M2 - 2
      FK = K
      FM = M
      NACT = (K-1)*(M-1)-(4*(K2+1)+ 2*(K3+1)) *(M2+1)
      PACT = NACT
      IF(K3) 10, 10, 20
   10 LIMJ = 4
      NACT = (K-1)*(M-1) - 4*(K2+1)*(M2+1)
      PACT = NACT
      GO TO 30
   20 LIMJ = 6
   30 KR(1) = 2
      MR(1) = 2
      MR(3) = 2
      KRR(3) = K
      MRR(4) = M
      KR(4) =  2
      KRR(2) = K
      MRR(2) =  M
      IF (LIMJ-4) 50,50,40
   40 MR(5) = 2
      MRR(6) = M
   50 MR(4) = M/2+1
      MRR(1) = M/2+1
      MR(6) = M/2+1
      MRR(5) = M/2+1
      MR(2) = M/2+1
      MRR(3) = M/2+1
      REWIND 15
      IF (LIMJ -4)  60,60,70
   60 KRR(1) = K/2+1
      KR(3) = K/2 + 1
      KRR(4) = K/2+1
      KR(2) = K/2+1
      GO TO 71
   70 KKRC = (K-K3+2*K1+2*K2+4)/4
      KRR(1) = KKRC
      KRR(4) = KKRC
      KR (6) = KKRC
      KR (5) = KKRC
      KRR(5) = K - KKRC + 2
      KRR(6) = K - KKRC + 2
      KR (2) = K - KKRC + 2
      KR (3) = K - KKRC + 2
```

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      SUBROUTINE REYN
   71 IF (NIGNAL - 1) 72, 74, 72
   72 LLLL = LIMJ
      GO TO 75
   74 LLLL = LIMJ + 1
   75 DO 460 JJJ = 1, LLLL
   77 GAMMA = 1.1
   78 DO 140 I = 1,KK
      DO 140 J = 1,MM
      IF ( JJJ-LIMJ-1) 79, 80, 80
   79 KEYIJ = KEY(I,J) + 1
      GO TO ( 80, 90, 80), KEYIJ
   80 P(I,J) = 0.0
      GO TO 140
   90 IF (I-KR(JJJ)) 80,100, 100
  100 IF(I-KRR(JJJ)) 110,110,80
  110 IF (J - MR(JJJ))  80, 120, 120
  120 IF (J-MRR(JJJ)) 130, 130, 80
  130 P(I,J) = 1.0
  140  CONTINUE
      PGAMMA = 1.0 - GAMMA
  145 DO 220 ITER = 1, LITER
      PROG(ITER) = 0.0
      DO 146 I = 2,K
  146 PPP(I) = P (I,1)
      IF ( JJJ - LIMJ - 1) 147, 1147,1147
  147 DO 170 J = 2,M
      DO 170 I = 2,K
      KEYIJ = KEY(I,J) + 1
      GO TO (150, 150, 160) , KEYIJ
  150 PP  = P(I,J)
      GO TO 165
  160 PPRIME=FACTOR*(P(I+1,J)+P(I-1,J)+(P(I+1,J)-P(I-1,J))*HX(I,J)+ALPHA
     1*(P(I,J+1)+P(I,J-1)+(P(I,J+1) - P(I,J-1))*HY(I,J)))
      PP = GAMMA * PPRIME + PGAMMA * P(I,J)
      PROG(ITER) = PROG(ITER) + PP
  165 P(I,J-1) = PPP(I)
      PPP(I) = PP
  170 CONTINUE
      GO TO 179
 1147 DO 1170 J = 2, M
      DO 1170 I = 2, K
      KEYIJ = KEY(I,J) + 1
      GO TO (1150,  1150, 1160), KEYIJ
 1150 PP = P(I,J)
      GO TO 1165
 1160 PPRIME=FACTOR*(P(I+1,J)+P(I-1,J)+(P(I+1,J)-P(I-1,J)+(PLAM/1.5)*DX/
     1(H(I,J)*H(I,J)))*HX(I,J) + ALPHA*(P(I,J+1)+P(I,J-1)+(P(I,J+1) -
     1P(I,J-1))*HY(I,J)))
      PP = GAMMA * PPRIME + PGAMMA * P(I,J)
      PROG(ITER) = PROG(ITER) + PP
 1165 P(I,J-1) = PPP(I)
      PPP(I) = PP
 1170 CONTINUE
  179 DO 180 I = 2, K
  180 P(I,M) = PPP(I)
      IF ( GAMMA - 0.16) 181,181, 185
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```
      SUBROUTINE REYN
  181 WRITE OUTPUT TAPE 6,3333, ITER
 3333 FORMAT (25H FORCED OUT AT ITERATION  I4, 21H, SOLUTION NOT VALID )
      GO TO 235
  185 IF (ITER - 6) 220, 220, 190
  190 IF(PROG(ITER) -2.0*PROG(ITER-1)+PROG(ITER-2)) 210, 210, 200
  200 GAMMA = GAMMA *0.8
      WRITE OUTPUT TAPE 6, 1111,JJJ,GAMMA,ITER
 1111 FORMAT (7H RECESS I3, 19H, GAMMA CHANGED TO  F10.4, 11H, ITERATION
     1 I5)
      GO TO 78
  210 IF (ITER - NREL) 220, 220, 215
  215 IF((PROG(ITER)-PROG(ITER-1))*PACT/(GAMMA*PROG(ITER))-TRUNC) 230,
     1 230, 220
  220 CONTINUE
      ITER = LITER
  230 WRITE OUTPUT TAPE 6,2222,JJJ,ITER,(PROG(LKK), LKK = 1,ITER)
 2222 FORMAT (7H RECESS I3, 25H, CONVERGED AT ITERATION I5 / 20H PROGRES
     1S INDICATORS / (10F11.6))
  235 AAW=0.0
      AACSI = 0.0
      AAETA = 00.0
      J1 = 2
      J2 = M
      J3 = 2
  240 DO 310 J =J1,J2,J3
      AW = 0.0
      ACSI = 0.0
      AETA = 0.0
      FJ = J-1
      I1 = 2
      I2 = K
      I3 = 2
  250 DO 260 I = I1, I2, I3
      FI = I-1
      AW = AW + P(I,J)
      ACSI = ACSI + FI*P(I,J)
  260 AETA = AETA + FJ*P(I,J)
      IF (I3 - K )  270, 300, 300
  270 AW = 2.0 * AW
      ACSI = 2.0 * ACSI
      AETA = 2.0 * AETA
      IF(I1-2) 280, 280, 290
  280 I1 = 3
      GO TO 250
  290 I1 = 1
      I2 = KK
      I3 =  K
       GO TO  250
  300 AAW = AAW + AW
      AACSI = AACSI + ACSI
  310   AAETA = AAETA + AETA
      IF (J3 - M) 320, 350, 350
  320 AAW = AAW * 2.0
      AACSI = AACSI * 2.0
      AAETA = AAETA * 2.0
      IF (J1-2)  330, 330, 340
```

```
      SUBROUTINE REYN
  330 J1 = 3
      GO TO 240
  340 J1 = 1
      J2 = MM
      J3 = M
      GO TO 240
  350 W(JJJ) = AAW * DX * DY / 9.0
      CSI(JJJ) = AACSI * DX * DX * DY / (9.0*W(JJJ))
      ETA(JJJ) = AAETA * DX * DY * DY / (9.0*W(JJJ))
  360 DO 440 III = 1, LIMJ
      QQ = 0.0
      J = MR(III)
      I1=KR(III)
      I2=KRR(III)
  370 DO 380 I = I1, I2
  380 QQ=QQ-H(I,J)*H(I,J)*H(I,J)*(P(I,J+1) - P(I,J-1))
      QQ=QQ+0.5*(H(I1,J)*H(I1,J)*H(I1,J)*(P(I1,J+1)-P(I1,J-1))+(H(I2,J)*
     1H(I2,J)*H(I2,J)*(P(I2,J+1)-P(I2,J-1))))
      IF (J - MR(III)) 400, 390, 400
  390 QQ = -QQ
      J = MRR(III)
      GO TO 370
  400 TT = 0.0
      I = KR(III)
      J1=MR(III)
      J2=MRR(III)
  410 IF (JJJ- LIMJ- 1) 420, 1420,1420
  420 DO 421 J = J1, J2
  421 TT = TT - H(I,J)*H(I,J)*H(I,J)*(P(I+1,J) - P(I-1,J))
      TT = TT + 0.5*(H(I,J1)*H(I,J1)*H(I,J1)*(P(I+1,J1)-P(I-1,J1))+ H(I,
     1J2)*H(I,J2)*H(I,J2)*(P(I+1,J2) - P(I-1,J2)))
      GO TO 425
 1420 DO 1421 J = J1, J2
 1421 TT = TT - H(I,J)*H(I,J)*H(I,J)*(P(I+1,J)-P(I-1,J)) - 2.0*PLAM*DX
     1 * H(I,J)
      TT = TT + 0.5*(H(I,J1)*H(I,J1)*H(I,J1)*(P(I+1,J1) - P(I-1,J1)) +
     1 H(I,J2)*H(I,J2)*H(I,J2)*(P(I+1,J2)-P(I-1,J2)) + 2.0*DX*PLAM*
     1(H(I,J2) + H(I,J1)))
  425 IF (I - KR(III)) 440, 430, 440
  430 TT = - TT
      I = KRR(III)
      GO TO 410
  440 Q(III,JJJ) = QQ*DX*0.5/DY+TT*DY*0.5/DX
  450 WRITE TAPE 15,P
    2 FORMAT (8E15.8)
  460 CONTINUE
      END FILE 15
      REWIND 15
      RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
   SUBROUTINE REYN

                                 STORAGE NOT USED BY PROGRAM

        DEC   OCT               DEC   OCT
        2418 04562             17379 41743

                        STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

        DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
     A 17404 41774         CSI 23456 55640         DX 32559 77457         DY 32558 77456         ETA 23449 55631
     H 32557 77455          HX 29542 71546         HY 26527 63637     INDEX1 17381 41745      INDEX2 17380 41744
 IPREV 23442 55622          K1 23512 55730         K2 23511 55727         K3 23510 55726         KEY 23441 55621
    KK 32561 77461        LIMJ 23464 55650      LITER 20426 47712         M1 23509 55725          M2 23508 55724
    MM 32560 77460      NIGNAL 17410 42002       PLAM 17409 42001          P 20425 47711           Q 23506 55722
 TRUNC 23507 55723          TX 17406 41776         TY 17405 41775          W 23463 55647          X1 17408 42000
    Y1 17407 41777

                 . STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

        DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
   KRR  1344 02500          KR  1350 02506        MRR  1332 02464         MR  1338 02472         PPP  2417 04561
  PROG  2350 04456

              STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

        DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
 AACSI  1326 02456       AAETA  1325 02455        AAW  1324 02454       ACSI  1323 02453        AETA  1322 02452
 ALPHA  1321 02451          AW  1320 02450     FACTOR  1319 02447         FI  1318 02446          FJ  1317 02445
    FK  1316 02444          FM  1315 02443      GAMMA  1314 02442         I1  1313 02441          I2  1312 02440
    I3  1311 02437           I  1310 02436       ITER  1309 02435         J1  1308 02434          J2  1307 02433
    J3  1306 02432         JJJ  1305 02431          J  1304 02430      KEYIJ  1303 02427        KKRC  1302 02426
     K  1301 02425        LLLL  1300 02424          M  1299 02423       NACT  1298 02422        NREL  1297 02421
  PACT  1296 02420      PGAMMA  1295 02417     PPRIME  1294 02416         PP  1293 02415          QQ  1292 02414
    IT  1291 02413

                         SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

        EFN   LOC               EFN   LOC               EFN   LOC               EFN   LOC               EFN   LOC
   8)1     1 02365         8)2     2 02316      8)12N  1111 02350      8)25E  2222 02335       8)385  3333 02362

                        LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

        DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
    1)  1270 02366          2)  1205 02265         3)  1214 02276         6)  1223 02307       A)103  1153 02201
 A)104  1166 02216       A)105  1179 02233      A)106  1192 02250       C)G1  1278 02376        C)G2  1279 02377
  C)G3  1280 02400        C)G6  1281 02401      C)100  1282 02402      C)103  1283 02403       C)104  1284 02404
 C)105  1285 02405       C)106  1286 02406      C)107  1287 02407      C)204  1288 02410       C)205  1289 02411
 C)206  1290 02412       D)11S   689 01261      D)20D   315 00473      D)212   469 00725       D)21A   548 01044
 D)21M   641 01201       D)210   648 01210      D)40C   311 00467      D)40H   347 00533       D)40Q   395 00613
   E)G   337 00521         E)M   373 00565       E)11   435 00663       E)13   477 00735        E)19   506 00772
  E)1B   556 01054        E)23   775 01407      E)10H   349 00535      E)20H   349 00535

                              LOCATIONS OF NAMES IN TRANSFER VECTOR
```

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SUBROUTINE REYN

        DEC   OCT             DEC   OCT             DEC   OCT             DEC   OCT             DEC   OCT
(EFT)     8 00010     (FIL)     4 00004     (RTN)     1 00001     (RWT)     2 00002     (SLO)     6 00006
(STB)     5 00005     (STH)     3 00003     (TSH)     0 00000     (WLR)     7 00007

                         ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

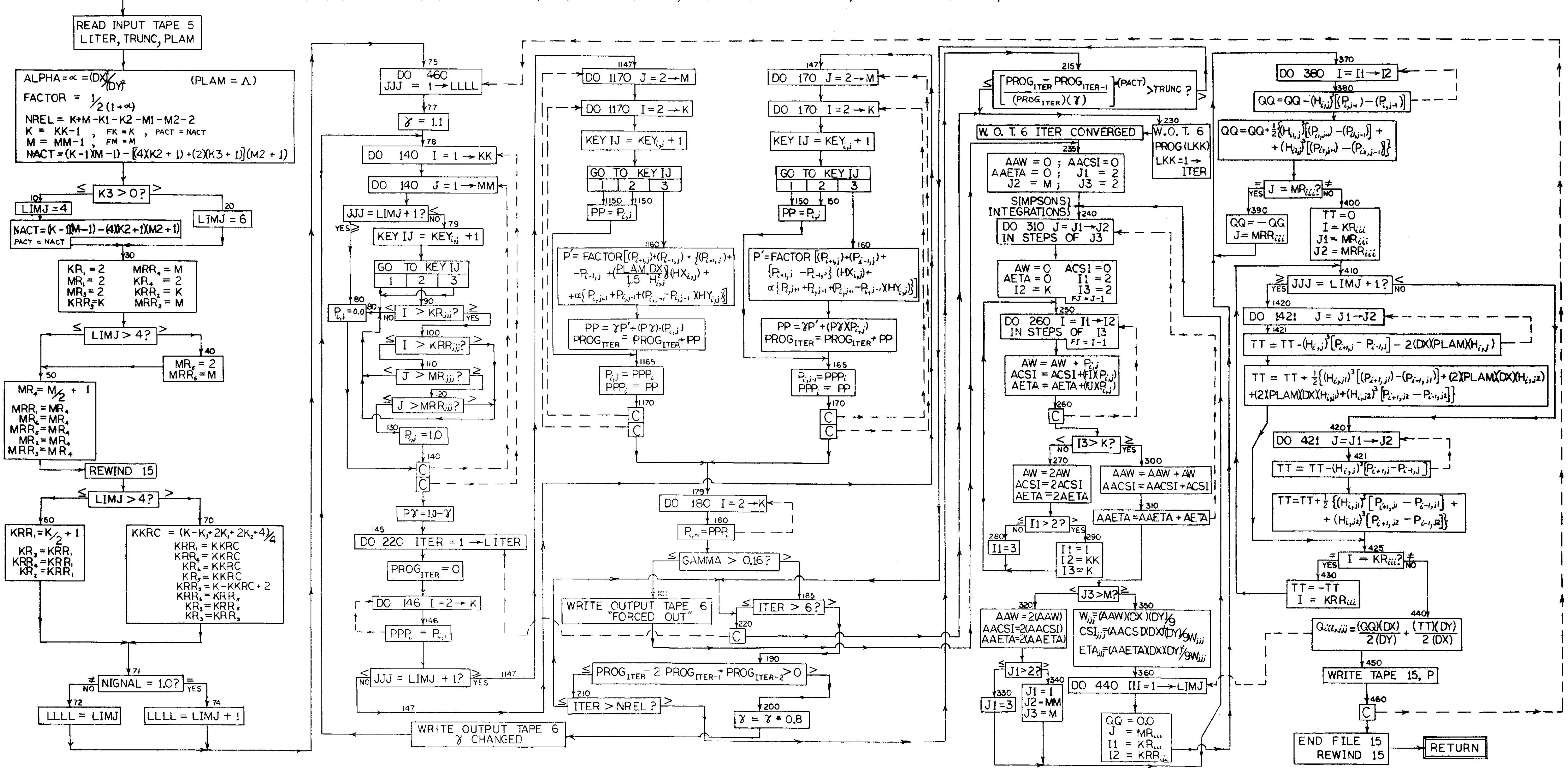
(EFT)        (FIL)        (RTN)        (RWT)        (SLO)        (STB)        (STH)        (TSH)        (WLR)

                    EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

 EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC
  10    22 00153           20    26 00212           30    27 00214           40    36 00241           50    38 00245
  60    46 00333           70    51 00374           71    60 00444           72    61 00447           74    63 00452
  75    64 00455           77    65 00470           78    66 00474           79    69 00523           80    71 00537
  90    73 00542          100    74 00550          110    75 00554          120    76 00561          130    77 00566
 140    78 00571          145    80 00605          146    83 00622          147    85 00634          150    89 00660
 160    91 00665          165    94 00726          170    96 00732         1147    98 00743         1150   102 00767
1160   104 00774         1165   107 01045         1170   109 01051          179   110 01061          180   111 01075
 181   113 01106          185   116 01121          190   117 01126          200   118 01137          210   122 01161
 215   123 01166          220   124 01202          230   126 01211          235   132 01234          240   138 01262
 250   146 01314          260   150 01353          270   152 01367          280   156 01404          290   158 01410
 300   162 01417          310   164 01425          320   166 01437          330   170 01454          340   172 01461
 350   176 01474          360   179 01526          370   184 01562          380   185 01576          390   188 01652
 400   191 01665          410   195 01707          420   196 01714          421   197 01730         1420   200 01777
1421   201 02013          425   203 02103          430   204 02111          440   207 02124          450   208 02146
 460   210 02156
```

REYN

DIMENSION: H, HX, HY, A, PPP, P, PROG, KR, KRR, MR, MRR, Q, W, CSI, ETA, KEY
COMMON: KK, MM, DX, DY, H, HX, HY, K1, K2, K3, M1, M2, TRUNC, Q, LIMJ, W, CSI, ETA, IPREV, KEY, LITER, P, NIGNAL, PLAM, X1, Y1, TX, TY, A, INDEX1, INDEX2



```
     SUBROUTINE  FORMH

     SUBROUTINE  FORMH
    DIMENSION H(67,45), HX(67,45), HY(67,45), A(23), KEY(67,45),
   1 Q(6,7), W(7), CSI(7), ETA(7), P(67,45)
    COMMON KK,MM,DX,DY,H,HX,HY,K1,K2,K3,M1,M2,TRUNC,Q,LIMJ,W,CSI,ETA,
   1 IPREV,KEY,LITER,P,NIGNAL,PLAM,X1,Y1,TX,TY,A,INDEX1,INDEX2
  1 FORMAT(9I3;E16.8)
    READ INPUT TAPE 5, 1,K,M,INDEX1,INDEX2,K1,K2,K3,M1,M2,AL
    KK = K + 1
    MM = M + 1
    FK = K
    FM = M
    DX = 1.0/FK
    DY = AL/FM
    FX = 0.5/DX
    FY = 0.5/DY
    DO 11  J = 2,M
    KEY(1,J) = 0
    KEY(KK,J)  = 0
    DO 11  I = 2, K
 11 KEY(I,J) = 1
    DO 21  I = 1, KK
    KEY(I,1) = 0
 21 KEY(I,MM) = 0
    KK1 = K1 + K2 + 2
    KK2 = (K - K3)/2
    DO 51  J = 2, M
    DO 31  I = 2, K1
    II = K + 2 - I
    KEY(I,J) = 2
 31 KEY(II,J) = 2
    DO 41  I = KK1, KK2
    II = K + 2 - I
    KEY(I,J)  =  2
 41 KEY(II,J) = 2
    IF (K3) 42,42,51
 42 II = K/2 + 1
    KEY(II,J) = 2
 51 CONTINUE
    MM2 = M - M1 - M2
    MM1 = M1 + M2 + 2
    DO 81  I = 2, K
    DO  61  J = 2, M1
    JJ = M + 2 - J
    KEY(I,J) = 2
 61 KEY(I,JJ) = 2
    DO  71  J = MM1, MM2
 71 KEY(I,J)  =  2
 81  CONTINUE
    IPREV = 1
  2 FORMAT (6E11.8)
    IF(INDEX1 - 1)  30, 20, 30
 20 READ INPUT TAPE 5,2,((H(I,J), I=1,KK), J=1,MM)
    DO 25 I = 2, K
    DO 25 J =  2, M
     HX(I,J) = (H(I+1,J)-H(I-1,J))*.75/H(I,J)
 25 HY(I,J) = (H(I,J+1)-H(I,J-1))*.75/H(I,J)
```

```
       SUBROUTINE  FORMH
    3 FORMAT (5E14.8)
      GO TO 60
   30 READ INPUT TAPE 5,3,(A(L), L = 1,23)
      CON = EXPF(-0.5*A(21))*COSF(A(21)*0.5) * 2.0
      DO 50  I = 1,KK
      FI = I
      X = (FI - 1.0) * DX
      S = (FI - 1.0) * DX - A(22)
      SS = S * S
      SSS = SS * S
      DO 50  J = 1, MM
      FJ  =  J
      T = (FJ - 1.0) * DY - A(23)
      TT = T * T
      TTT = TT * T
      H(I,J)=A(1)+A(2)*S +A(3)*T+A(4)*SS+A(5)*TT+A(6)*S*T+A(7)*SSS+A(8)*
     1TTT+A(9)*SS*T+A(10)*S*TT+A(11)*SQRTF(A(12)+A(13)*SS+A(14)*TT)+
     1 A(15)*COSF(A(16)*S)+A(17)*COSF(A(18)*T)+A(19)*COSF(A(16)*S)*COSF(
     1A(I8)*T)-A(20)*(EXPF(-A(21)*X)*COSF(A(21)*X)+EXPF(-A(21)*(1.0-X))*
     1COSF(A(21)*(1.0-X))-CON)
      HX(I,J) = (A(2)+2.*A(4)*S+A(6)*T+3.*A(7)*SS+2.*A(9)*S*T+A(10)*TT-
     1A(16)*SINF(A(16)*S)*(A(15)+A(19)*COSF(A(18)*T)))*1.5*DX/H(I,J)+A(
     120)*A(21)*(EXPF(-A(21)*X)*(COSF(A(21)*X)+SINF(A(21)*X))-EXPF(-A(21
     1)*(1.0-X))*(COSF(A(21)*(1.0-X))+SINF(A(21)*(1.0-X))))*1.5*DX/H(I,
     1 J)
      HY(I,J)=(A(3)+2.*A(5)*T+A(6)*S+3.*A(8)*TT+A(9)*SS-A(18)*SINF(A(18)
     1*T)*(A(17)+A(19)*COSF(A(16)*S)))*1.5*DY/H(I,J)
      SL = A(12)+A(13)*SS+A(14)*TT
      IF (SL) 50, 50, 40
   40 SLL = A(11)/SQRTF(SL)
      HX(I,J) = HX(I,J)+SLL*A(13)*S*1.5*DX/H(I,J)
      HY(I,J) = HY(I,J) + SLL*A(14)*T*1.5*DY/H(I,J)
   50 CONTINUE
   60 IF (INDEX2 - 1)  80, 70, 80
   70 CALL TILTH
   80 RETURN
      END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
     SUBROUTINE  FORMH

                                             STORAGE NOT USED BY PROGRAM

        DEC   OCT               DEC   OCT
        941 01655             17379 41743

                                 STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

        DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
    A 17404 41774          CSI 23456 55640          DX 32559 77457          DY 32558 77456          ETA 23449 55631
    H 32557 77455           HX 29542 71546          HY 26527 63637      INDEX1 17381 41745      INDEX2 17380 41744
IPREV 23442 55622           K1 23512 55730          K2 23511 55727          K3 23510 55726          KEY 23441 55621
   KK 32561 77461         LIMJ 23464 55650       LITER 20426 47712          M1 23509 55725           M2 23508 55724
   MM 32560 77460       NIGNAL 17410 42002        PLAM 17409 42001           P 20425 47711            Q 23506 55722
TRUNC 23507 55723           TX 17406 41776          TY 17405 41775           W 23463 55647           X1 17408 42000
   Y1 17407 41777

                   STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

        DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
   AL   940 01654          CON   939 01653          FI   938 01652          FJ   937 01651           FK   936 01650
   FM   935 01647           FX   934 01646          FY   933 01645          II   932 01644            I   931 01643
   JJ   930 01642            J   929 01641         KK1   928 01640         KK2   927 01637            K   926 01636
  MM1   925 01635          MM2   924 01634           M   923 01633         SLL   922 01632           SL   921 01631
    S   920 01630           SS   919 01627         SSS   918 01626           T   917 01625           TT   916 01624
  TTT   915 01623            X   914 01622

                                  SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

        EFN   LOC                EFN   LOC                EFN   LOC                EFN   LOC                EFN   LOC
  8)1     1 01552          8)2     2 01550          8)3     3 01546

                                 LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

        DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
   1)   875 01553           2)   850 01522          3)   857 01531          6)   863 01537        A)105   824 01470
A)106   837 01505         C)G2   903 01607       C)100   904 01610       C)101   905 01611        C)102   906 01612
C)105   907 01613        C)106   908 01614       C)200   909 01615       C)201   910 01616        C)203   911 01617
C)206   912 01620        C)208   913 01621       D)20A   194 00302       D)30A   193 00301        D)40I   318 00476
D)411   436 00664          E)C   215 00327

                                           LOCATIONS OF NAMES IN TRANSFER VECTOR

        DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
  COS     2 00002          EXP     3 00003         SIN     5 00005        SQRT     4 00004        TILTH     6 00006
(RTN)     1 00001        (TSH)     0 00000

                                      ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

CUS          EXP          SIN          SQRT          TILTH          (RTN)          (TSH)

                  EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS
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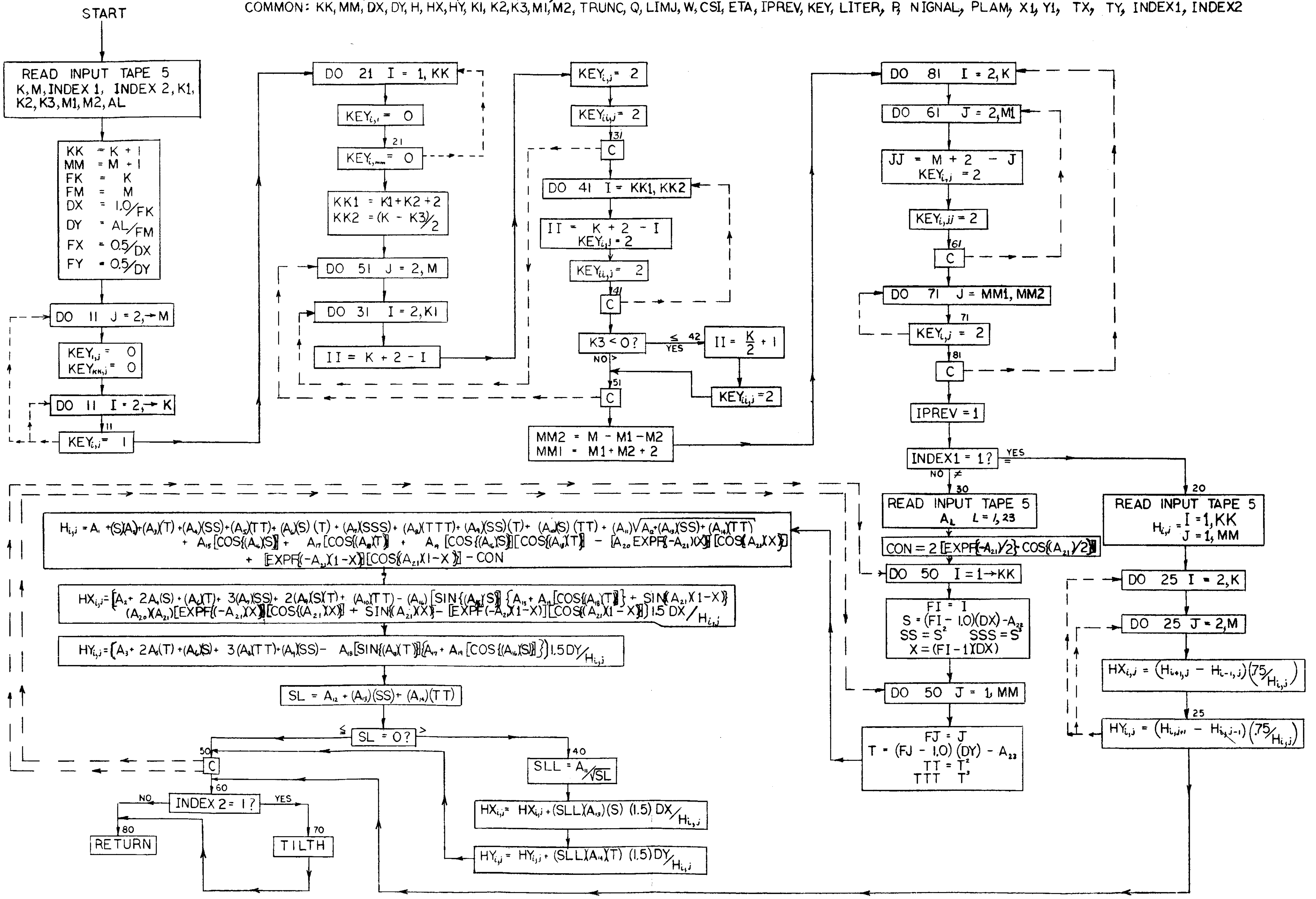
```
     SUBROUTINE   FORMH

EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC          EFN   IFN   LOC
 11    22 00141           21    25 00172           31    32 00263           41    36 00315           42    38 00330
 51    40 00346           61    47 00467           71    49 00477           81    50 00504           20    53 00526
 25    63 00606           30    65 00621           40    87 01407           50    90 01443           60    91 01456
 70    92 01463           80    93 01464
```

FORMH

DIMENSION: H, HX, HY, A, KEY, Q, W, CSI, ETA, P
COMMON: KK, MM, DX, DY, H, HX, HY, K1, K2, K3, M1, M2, TRUNC, Q, LIMJ, W, CSI, ETA, IPREV, KEY, LITER, P, NIGNAL, PLAM, X1, Y1, TX, TY, INDEX1, INDEX2



```
    SUBROUTINE  TILTH

    SUBROUTINE  TILTH
   DIMENSION H(67,45), HX(67,45), HY(67,45), KEY(67,45), Q(6,7), W(7)
  1, CSI(7), ETA(7), A(23), P(67,45)
   COMMON KK,MM,DX,DY,H,HX,HY,K1,K2,K3,M1,M2,TRUNC,Q,LIMJ,W,CSI,ETA,
  1 IPREV,KEY,LITER,P,NIGNAL,PLAM,X1,Y1,TX,TY,A,INDEX1,INDEX2
   READ INPUT TAPE  5, 1, X1, Y1, TX, TY
 1 FORMAT (4E15.8  )
   DO 90 I = 1, KK
   FI = I
   X = (FI - 1.0)* DX - X1
   DO 90  J = 1, MM
   FJ = J
   H(I,J) = H(I,J)+TX*X+TY*((FJ-1.)*DY-Y1)
   HX(I,J) = HX(I,J) + TX * 1.5 * DX / H(I,J)
   HY(I,J) = HY(I,J) + TY * 1.5 * DY / H(I,J)
90 CONTINUE
   RETURN
   END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
     SUBROUTINE  TILTH

                                          STORAGE NOT USED BY PROGRAM

         DEC   OCT               DEC   OCT
         115 00163             17379 41743

                                 STORAGE LOCATIONS FOR VARIABLES APPEARING IN COMMON STATEMENTS

         DEC   OCT               DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
      A 17404 41774         CSI 23456 55640          DX 32559 77457          DY 32558 77456          ETA 23449 55631
      H 32557 77455          HX 29542 71546          HY 26527 63637      INDEX1 17381 41745       INDEX2 17380 41744
  IPREV 23442 55622          K1 23512 55730          K2 23511 55727          K3 23510 55726          KEY 23441 55621
     KK 32561 77461        LIMJ 23464 55650       LITER 20426 47712          M1 23509 55725           M2 23508 55724
     MM 32560 77460      NIGNAL 17410 42002        PLAM 17409 42001           P 20425 47711            Q 23506 55722
  TRUNC 23507 55723          TX 17406 41776          TY 17405 41775           W 23463 55647           X1 17408 42000
     Y1 17407 41777

                 STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

         DEC   OCT               DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
     FI  114 00162          FJ   113 00161          I    112 00160          J    111 00157          X    110 00156

                             SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

         EFN   LOC               EFN   LOC                EFN   LOC                EFN   LOC                EFN   LOC
    8)1    1 00151

                             LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

         DEC   OCT               DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
     1)  106 00152         2)     93 00135         3)     96 00140         6)     98 00142

                                       LOCATIONS OF NAMES IN TRANSFER VECTOR

         DEC   OCT               DEC   OCT                DEC   OCT                DEC   OCT                DEC   OCT
  (RTN)    1 00001      (TSH)      0 00000

                                   ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRAR■

  (RTN)       (TSH)

                    EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

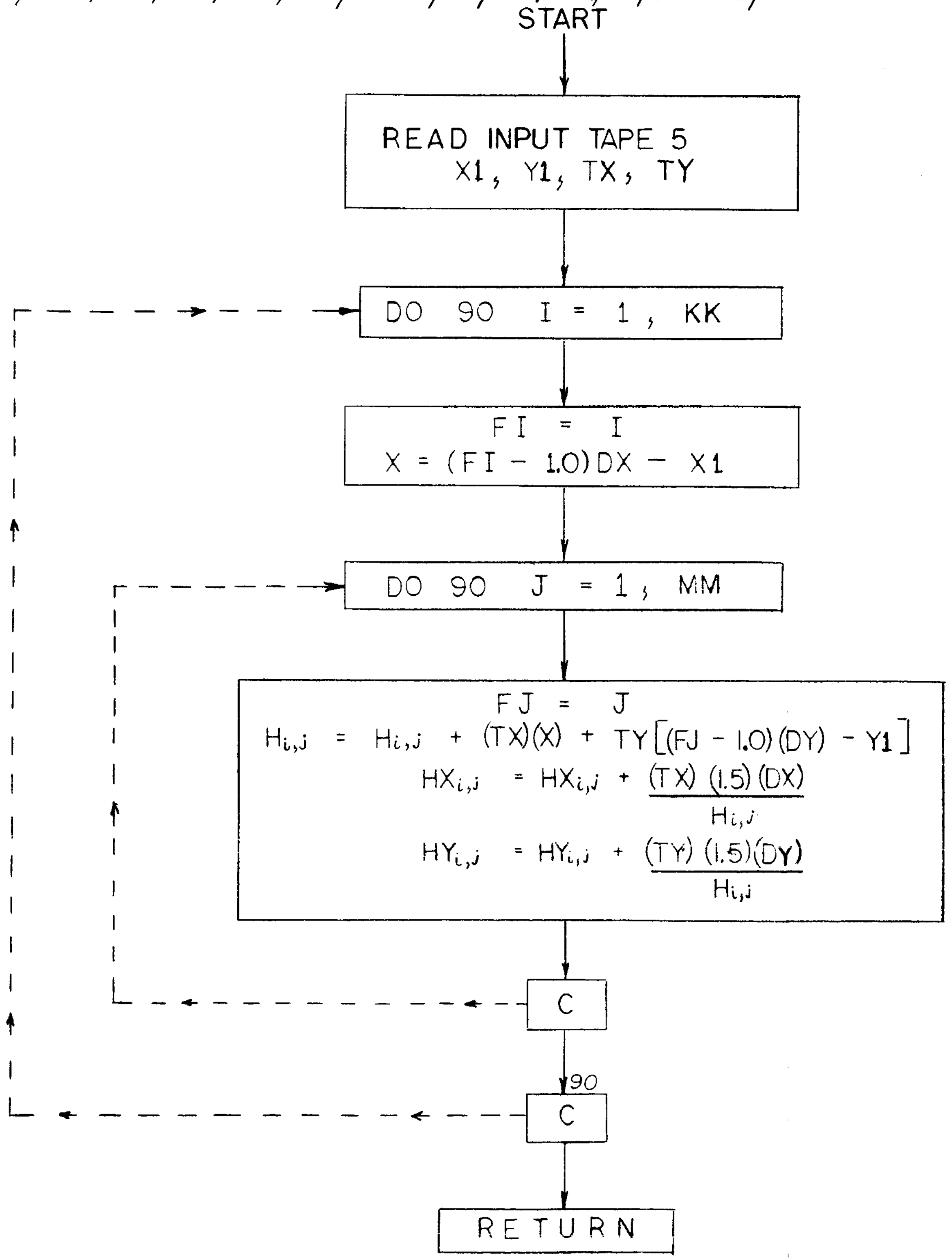
    EFN   IFN   LOC           EFN   IFN   LOC           EFN   IFN   LOC           EFN   IFN   LOC           EFN   IFN   LOC
     90    16 00120
```

TILTH

JPL VARIABLE FILM HYDROSTATIC BEARING PROGRAM -- BLOCK DIAGRAM

DIMENSION : H, HX, HY, A, KEY, Q, W, CSI, ETA, A, P

COMMON : KK, MM, DX, DY, H, HX, HY, ... X1, Y1, TX, TY, A, INDEX1, INDEX2



```
    FUNCTION DETER(AA,LIMJ)

    FUNCTION DETER(AA,LIMJ)
    DIMENSION AA(6,7)
     DETER = 0.0
    IF (LIMJ/2 - 2) 100, 100, 110
100 SIGN =  1.0
    GO TO 1
110 SIGN = -1.0
  1 DO 13 I = 1,LIMJ
  2 DO 12 J = 1,LIMJ
    CONTINUE
    IF (I-J) 21, 12, 21
 21 SIGN = -SIGN
  3 DO 11 K = 1,LIMJ
    IF(I-K) 31, 11, 31
 31 IF(J-K) 4, 11, 4
  4 DO 10 L = 1,LIMJ
    IF(I-L) 41, 10, 41
 41 IF(J-L) 42, 10, 42
 42 IF(K-L) 43, 10, 43
 43 PROD = AA(1,I)*AA(2,J)*AA(3,K)*AA(4,L)
    SIGN = -SIGN
    IF (LIMJ-4)44,44,5
 44 DETER = DETER + PROD *SIGN
    GO TO 10
  5 DO 9 M= 1,LIMJ
    IF (I-M) 51, 9, 51
 51 IF (J-M) 52, 9, 52
 52 IF(K-M) 53, 9, 53
 53 IF(L-M) 6, 9, 6
  6 DO 8 N = 1,LIMJ
    IF(I-N) 61, 8, 61
 61 IF(J-N) 62, 8, 62
 62 IF(K-N) 63, 8, 63
 63 IF(L-N)  64, 8, 64
 64 IF(M-N)7,8,7
  7 PRODD = - PROD * AA(5,M)*AA(6,N) * SIGN
    SIGN = -SIGN
    DETER = DETER + PRODD
  8 CONTINUE
  9 CONTINUE
 10 CONTINUE
 11 CONTINUE
 12 CONTINUE
 13 CONTINUE
    RETURN
    END(1,0,0,0,0,0,0,0,0,1,0,0,0,0,0)
```

```
FUNCTION DETER(AA,LIMJ).

                                  STORAGE NOT USED BY PROGRAM

     DEC   OCT               DEC   OCT
     264 00410             32561 77461

          STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

     DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
DETER  263 00407       I     262 00406       J     261 00405       K     260 00404       L     259 00403
    M  258 00402       N     257 00401   PRODD     256 00400    PROD     255 00377    SIGN     254 00376

                       LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

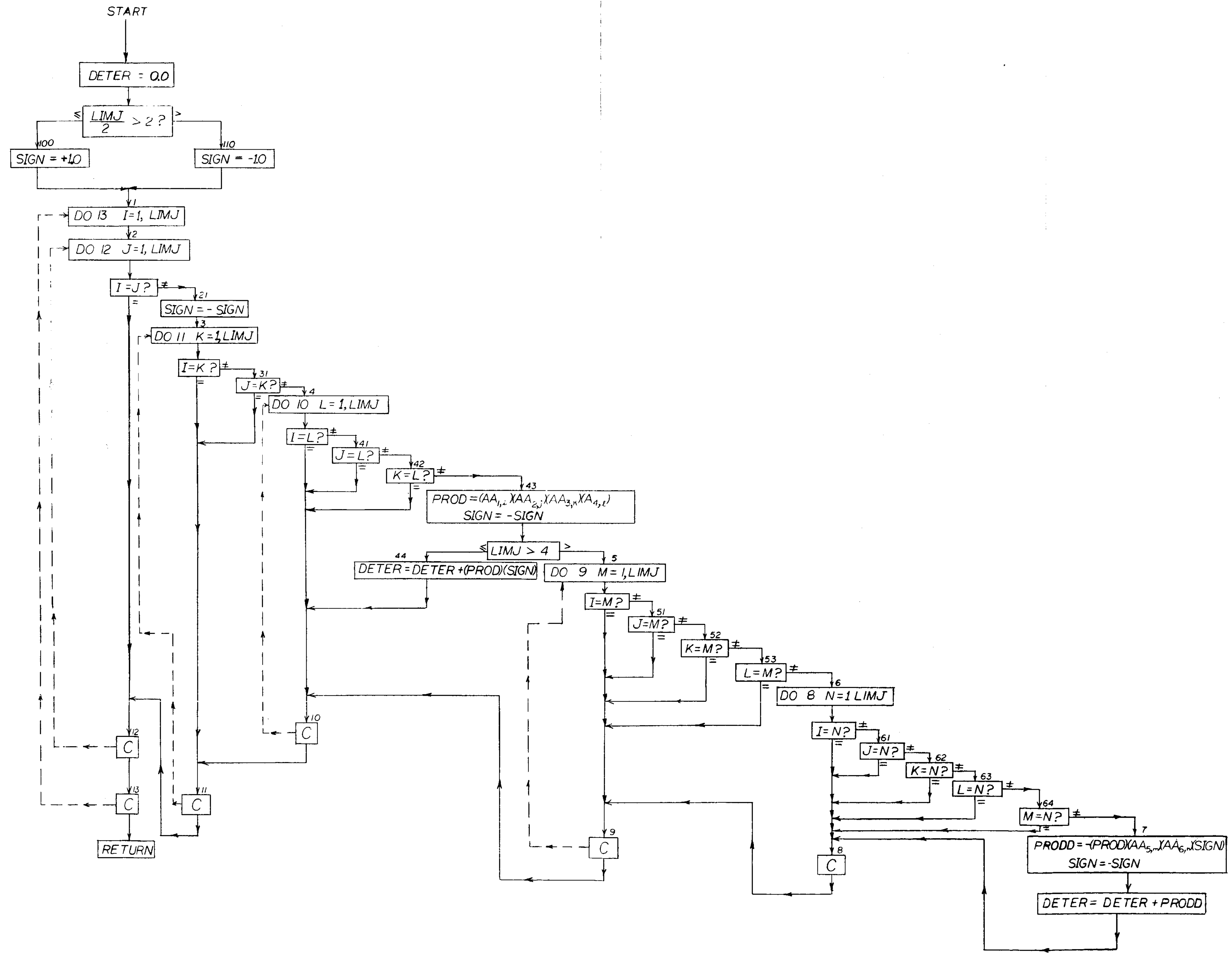
     DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT               DEC   OCT
   2)  227 00343      3)     230 00346      6)     232 00350      9)     238 00356   C)100    242 00362
C)101  243 00363   C)102     244 00364   C)103     245 00365   C)104     246 00366   C)105    247 00367
C)200  248 00370   C)201     249 00371   C)202     250 00372   C)203     251 00373   C)204    252 00374
C)205  253 00375   D)105      63 00077   D)107      77 00115   D)20T     185 00271   D)30T    184 00270
D)40V  193 00301   D)60V     192 00300     E)C      96 00140     E)H     131 00203     E)R    176 00260
  E)S  183 00267     E)T     187 00273    E)11     199 00307   E)10R     176 00260   E)10T    187 00273
E)111  199 00307   E)20R     176 00260   E)30T     187 00273

            EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

EFN  IFN   LOC        EFN  IFN   LOC        EFN  IFN   LOC        EFN  IFN   LOC        EFN  IFN   LOC
100    6 00052        110    8 00055          1    9 00057          2   10 00067         21   13 00103
  3   14 00105         31   16 00121          4   17 00124         41   19 00135         42   20 00143
 43   21 00146         44   24 00165          5   26 00172         51   28 00204         52   29 00207
 53   30 00212          6   31 00215         61   33 00226         62   34 00231         63   35 00234
 64   36 00237          7   37 00242          8   40 00263          9   41 00274         10   42 00302
 11   43 00310         12   44 00316         13   45 00326
```

FUNCTION DETER

DIMENSION: AA



APPENDIX II

IBM 7094 LOADING RECORD

(Six Subprograms)

```
ENTRY POINTS TO SUBROUTINES REQUESTED FROM LIBRARY,
     (FPT)          (RWT)          (TSHM)         (RTN)          EXIT           (STHM)         (FIL)          (TSB)          (SLI)          (RLR)
     (STB)          (SLO)          (WLR)          (EFT)          COS            EXP            SQRT           SIN

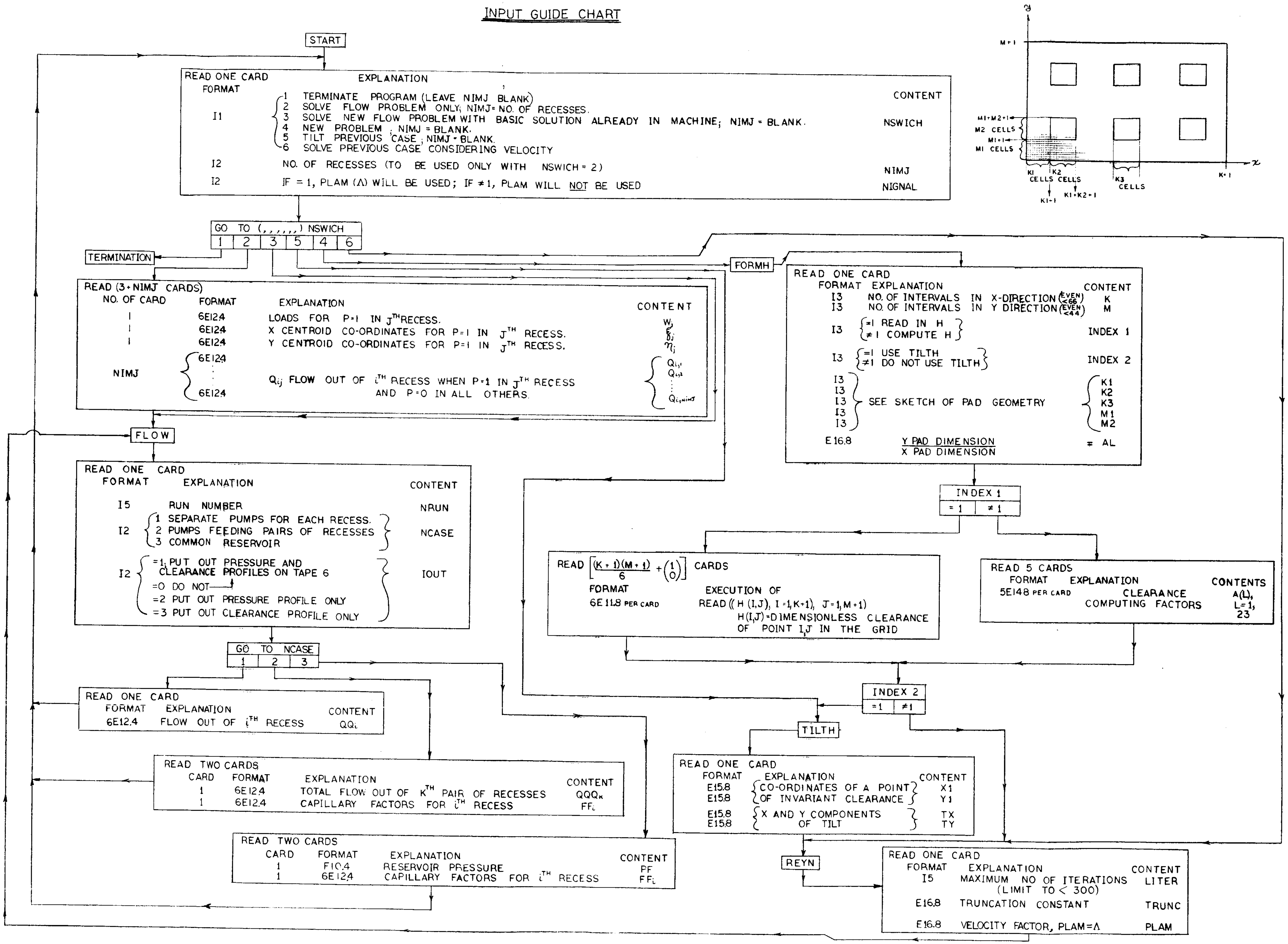
   ENTRY NAME     ENTRY ADD.     NO. OF TRANSFERS     LOAD ADD.
      MAIN          00155              00011          00144
     FLOW           00341              00011          00324
     REYN           12326              00011          12311
     TILTH          17101              00002          17073
     FORMH          17271              00007          17256
     DETER          21137              00000          21133
     ERRDMP         21544              00001          21543
     EXIT           21547
     (TES)          21571              00000          21571
     (FPT)          21572              00000          21572
     EXP            21630              00000          21630
     SIN            21710              00000          21707
     COS            21707
     SQRT           22060              00000          22060
     (RLR)          22221              00011          22134
     (TSB)          22145
     (WLR)          22267              00007          22236
     (STB)          22245
     (TSHM)         22334              00006          22323
     (TSH)          22331
     (STHD)         22401              00006          22360
     (STHM)         22371
     (STH)          22366
     (EFT)          22512              00002          22510
     (RWT)          22521              00002          22517
     (SLI)          22542              00000          22542
     (SLO)          22557              00000          22557
     (RDC)          22625              00007          22574
     (RER)          22603
     (WTC)          22704              00012          22641
     (WER)          22653
     (SET)          23011              00001          22734
     (BUF)          23013
     (EXB)          23016
     (IOB)          22735
     (RTN)          25571              00002          24026
     (FIL)          25560
     (IOH)          24030
     (ICO)          26037              00003          25745
     (TEF)          26036
     (RCH)          26035
     (ETT)          26034
     (REW)          26033
     (WEF)          26032
     (BSR)          26031
     (WRS)          26030
     (RDS)          26027
     (IOS)          25750
     (TRC)          26040
     )PRNT(         26333              00002          26074
     (EXEM)         26076
     (IOU)          26707              00000          26704
LOGICAL    MACHINE       TOTAL        TOTAL         NOISE RECORDS         TOTAL REDUNDANCIES          POSITIONING
 TAPE       TAPE        WRITES        READS       WRITING     READING     WRITING     READING           ERRORS

   1         A 1            0           493           0   (II-1) 0          0           0                0
   2         B 2         1008          1142           0          0          0           0                0
```

APPENDIX III

INPUT GUIDE CHART

INPUT GUIDE CHART



READ ONE CARD

FORMAT	EXPLANATION	CONTENT
I1	1 TERMINATE PROGRAM (LEAVE NIMJ BLANK) 2 SOLVE FLOW PROBLEM ONLY; NIMJ = NO. OF RECESSES. 3 SOLVE NEW FLOW PROBLEM WITH BASIC SOLUTION ALREADY IN MACHINE; NIMJ = BLANK. 4 NEW PROBLEM ; NIMJ = BLANK. 5 TILT PREVIOUS CASE ; NIMJ = BLANK. 6 SOLVE PREVIOUS CASE CONSIDERING VELOCITY	NSWICH
I2	NO. OF RECESSES (TO BE USED ONLY WITH NSWICH = 2)	NIMJ
I2	IF = 1, PLAM (Λ) WILL BE USED; IF ≠ 1, PLAM WILL NOT BE USED	NIGNAL

READ (3+NIMJ CARDS)

NO. OF CARD	FORMAT	EXPLANATION	CONTENT
1	6E12.4	LOADS FOR P=1 IN J^{TH} RECESS.	W_j
1	6E12.4	X CENTROID CO-ORDINATES FOR P=1 IN J^{TH} RECESS.	ξ_j
1	6E12.4	Y CENTROID CO-ORDINATES FOR P=1 IN J^{TH} RECESS.	η_j
NIMJ	6E12.4 ⋮ 6E12.4	Q_{ij} FLOW OUT OF i^{TH} RECESS WHEN P=1 IN J^{TH} RECESS AND P=0 IN ALL OTHERS.	$Q_{i,1}$ $Q_{i,2}$ ⋮ $Q_{i,NIMJ}$

READ ONE CARD

FORMAT	EXPLANATION	CONTENT
I5	RUN NUMBER	NRUN
I2	1 SEPARATE PUMPS FOR EACH RECESS. 2 PUMPS FEEDING PAIRS OF RECESSES 3 COMMON RESERVOIR	NCASE
I2	=1, PUT OUT PRESSURE AND CLEARANCE PROFILES ON TAPE 6 =0 DO NOT =2 PUT OUT PRESSURE PROFILE ONLY =3 PUT OUT CLEARANCE PROFILE ONLY	IOUT

READ ONE CARD

FORMAT	EXPLANATION	CONTENT
6E12.4	FLOW OUT OF i^{TH} RECESS	QQ_i

READ TWO CARDS

CARD	FORMAT	EXPLANATION	CONTENT
1	6E12.4	TOTAL FLOW OUT OF K^{TH} PAIR OF RECESSES	QQQ_K
1	6E12.4	CAPILLARY FACTORS FOR i^{TH} RECESS	FF_i

READ TWO CARDS

CARD	FORMAT	EXPLANATION	CONTENT
1	F10.4	RESERVOIR PRESSURE	PF
1	6E12.4	CAPILLARY FACTORS FOR i^{TH} RECESS	FF_i

READ ONE CARD

FORMAT	EXPLANATION	CONTENT
I3	NO. OF INTERVALS IN X-DIRECTION (EVEN < 66)	K
I3	NO. OF INTERVALS IN Y DIRECTION (EVEN < 44)	M
I3	=1 READ IN H ≠1 COMPUTE H	INDEX 1
I3	=1 USE TILTH ≠1 DO NOT USE TILTH	INDEX 2
I3 I3 I3 I3 I3	SEE SKETCH OF PAD GEOMETRY	K1 K2 K3 M1 M2
E16.8	$\frac{\text{Y PAD DIMENSION}}{\text{X PAD DIMENSION}}$	= AL

READ $\left[\frac{(K+1)(M+1)}{6}+\binom{1}{0}\right]$ CARDS

FORMAT	EXECUTION OF
6E11.8 PER CARD	READ ((H (I,J), I=1,K+1), J=1,M+1) H(I,J) = DIMENSIONLESS CLEARANCE OF POINT I,J IN THE GRID

READ 5 CARDS

FORMAT	EXPLANATION	CONTENTS
5E14.8 PER CARD	CLEARANCE COMPUTING FACTORS	A(L), L=1, 23

READ ONE CARD

FORMAT	EXPLANATION	CONTENT
E15.8 E15.8	CO-ORDINATES OF A POINT OF INVARIANT CLEARANCE	X1 Y1
E15.8 E15.8	X AND Y COMPONENTS OF TILT	TX TY

READ ONE CARD

FORMAT	EXPLANATION	CONTENT
I5	MAXIMUM NO OF ITERATIONS (LIMIT TO < 300)	LITER
E16.8	TRUNCATION CONSTANT	TRUNC
E16.8	VELOCITY FACTOR, PLAM=Λ	PLAM

APPENDIX IV

SAMPLE PROBLEM INPUT DATA

AND

OUTPUT RESULTS

HYDROSTATIC BEARING PROGRAM INPUT DATA

CROSS OUT CARDS NOT USED

1. CARD

1	3	5
4		0
NSWICH		NIGNAL

2. 1 CARD

3	6	9	12	15	18	21	24	27	43
28	16	0	0	5	5	0	4	2	0.57142857
K	M	INDEX1	INDEX2	K1	K2	K3	M1	M2	AL

3.–7. 5 CARDS (INCLUDE ALL 5)

	14	28	42	56	70
3.	1.0 A(1)	0.0 A(2)	0.0	0.0	0.0
4.	0.0	0.0	0.0	0.0	0.0
5.	0.0	0.0	0.0	0.0	0.0
6.	0.0	0.0	0.0	0.0	0.0
7.	0.0	0.0	0.0 A(23)	0.0	0.0

8. ~~1 CARD~~

15	30	45	60

9. 1 CARD

5	21	37
1000	0.30	0.0
LITER	TRUNC	PLAM

10. 1 CARD

5	7	9
7701	1	1
NRUN	NCASE	IOUT

11. 1 CARD

12	24	36	48	60	72
1.0	1.0	1.0	1.0	—	—
QQ(1)	QQ(2)	QQ(3)	QQ(4)		

12. ~~1 CARD~~

10

13. ~~1 CARD~~

12	24	36	48	6	72

14. ~~1 CARD~~

1

HYDROSTATIC BEARING PROGRAM INPUT DATA

CROSS OUT CARDS NOT USED

1. CARD

1	3	5
5		0
NSWICH		NIGNAL

~~2. 1 CARD~~

3	6	9	12	15	18	21	24	27	43

~~3.~~

~~4.~~

5. 5 CARDS (INCLUDE ALL 5)

~~6.~~

~~7.~~

14	28	42	56	70

8. 1 CARD

15	30	45	60
0.50	0.28571429	1.0	0.0
XI	YI	TX	TY

9. 1 CARD

5	21	37
1000	0.30	1.0
LITER	TRUNC	PLAM

10. 1 CARD

5	7	9
.7702	1	1
NRUN	NCASE	IOUT

11. 1 CARD

12	24	36	48	60	72
1.0	1.0	1.0	1.0	—	—
QQ(1)	QQ(2)	QQ(3)	QQ(4)		

~~12. 1 CARD~~

10

~~13. 1 CARD~~

12	24	36	48	6	72

~~14. 1 CARD~~

1

HYDROSTATIC BEARING PROGRAM INPUT DATA

CROSS OUT CARDS NOT USED

1. CARD

1	3	5
6		1
NSWICH		NIGNAL

~~2. 1 CARD~~

3	6	9	12	15	18	21	24	27	43

~~3.~~
~~4.~~
~~5. 5 CARDS~~ (INCLUDE ALL 5)
~~6.~~
~~7.~~

14	28	42	56	70

~~8. 1 CARD~~

15	30	45	60

9. 1 CARD

5	21	37
1000	0.30	1.0
LITER	TRUNC	PLAM

10. 1 CARD

5	7	9
7703	1	2
NRUN	NCASE	IOUT

11. 1 CARD

12	24	36	48	60	72
1.0	1.0	1.0	1.0	—	—
QQ(1)	QQ(2)	QQ(3)	QQ(4)		

~~12. 1 CARD~~

10

~~13. 1 CARD~~

12	24	36	48	60	72

14. 1 CARD

1
1
NSWICH

```
RUN NUMBER  7701                          HYDROSTATIC BEARING PAD WITH 4 RECESSES.
                                   FEEDING = POSITIVE DISPLACEMENT PUMPS FEEDING EACH RECESS.
GRID POINTS, K = 28   M = 16        K1 =  5   K2 =  5   K3 =  0    M1 =  4   M2 =  2
CLEARANCE COEFFICIENTS
,AA 1)= 0.09999999E 01 ,AA


                                                        OUTPUT
QQ(I)=      1.00      1.00      1.00      1.00         ** Q(I,J)=   5.4774  -0.1477  -0.2798  -1.7369
W(I)=     0.0773    0.0773    0.0773    0.0773         **          -0.1477   5.4774  -1.7369  -0.2798
CSI(I)=   0.2922    0.7078    0.7078    0.2922         **          -0.2798  -1.7369   5.4774  -0.1477
ETA(I)=   0.1900    0.3815    0.1900    0.3815         **          -1.7369  -0.2798  -0.1477   5.4774
FINAL RESULTS = TOTAL LOAD=  0.0933  CSI= 0.5000 ETA=  0.2857  TOTAL FLOW=  0.4000000E 01
RECESS PRESSURES
 ,  AL(1) =  0.30184,  AL(2) =  0.30184,  AL(3) =  0.30184,  AL(4) =  0.30184,  AL(


RUN NUMBER  7701                          HYDROSTATIC BEARING PAD WITH 4 RECESSES.
                                   FEEDING = POSITIVE DISPLACEMENT PUMPS FEEDING EACH RECESS.
PAD CONFIGURATION. 0000000000000000000000000000
                   0222222222222222222222222220
                   0222222222222222222222222220
                   0222222222222222222222222220
                   0222211111122222211111122220
                   0222211111122222211111122220
                   0222211111122222211111122220
                   0222222222222222222222222220
                   0222222222222222222222222220
                   0222222222222222222222222220
                   0222211111122222211111122220
                   0222211111122222211111122220
                   0222211111122222211111122220
                   0222222222222222222222222220
                   0222222222222222222222222220
                   0222222222222222222222222220
                   0000000000000000000000000000
```

```
                                        PRESSURE DISTRIBUTION
RUN  7701   I=  1    I=  2    I=  3    I=  4    I=  5    I=  6    I=  7    I=  8    I=  9    I= 10
J=  1,      0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
J=  2,      0.       0.0117   0.0237   0.0362   0.0487   0.0596   0.0665   0.0699   0.0708   0.0694
J=  3,      0.       0.0230   0.0470   0.0725   0.0991   0.1232   0.1365   0.1425   0.1438   0.1412
J=  4,      0.       0.0334   0.0687   0.1077   0.1519   0.1977   0.2140   0.2198   0.2208   0.2180
J=  5,      0.       0.0419   0.0866   0.1379   0.2031   0.3018   0.3018   0.3018   0.3018   0.3018
J=  6,      0.       0.0477   0.0980   0.1543   0.2209   0.3018   0.3018   0.3018   0.3018   0.3018
J=  7,      0.       0.0508   0.1036   0.1604   0.2243   0.3018   0.3018   0.3018   0.3018   0.3018
J=  8,      0.       0.0520   0.1051   0.1596   0.2143   0.2632   0.2835   0.2918   0.2942   0.2922
J=  9,      0.       0.0523   0.1052   0.1586   0.2101   0.2534   0.2770   0.2879   0.2912   0.2887
J= 10,      0.       0.0520   0.1051   0.1596   0.2143   0.2632   0.2835   0.2918   0.2942   0.2922
J= 11,      0.       0.0508   0.1036   0.1604   0.2243   0.3018   0.3018   0.3018   0.3018   0.3018
J= 12,      0.       0.0477   0.0980   0.1543   0.2209   0.3018   0.3018   0.3018   0.3018   0.3018
J= 13,      0.       0.0419   0.0866   0.1379   0.2031   0.3018   0.3018   0.3018   0.3018   0.3018
J= 14,      0.       0.0334   0.0687   0.1077   0.1519   0.1977   0.2140   0.2198   0.2208   0.2180
J= 15,      0.       0.0230   0.0470   0.0725   0.0991   0.1232   0.1365   0.1425   0.1438   0.1412
J= 16,      0.       0.0117   0.0237   0.0362   0.0487   0.0596   0.0665   0.0699   0.0708   0.0694
J= 17,      0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
```

```
                                        PRESSURE DISTRIBUTION
RUN  7701   I= 11    I= 12    I= 13    I= 14    I= 15    I= 16    I= 17    I= 18    I= 19    I= 20
J=  1,      0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
J=  2,      0.0657   0.0600   0.0545   0.0507   0.0494   0.0507   0.0545   0.0600   0.0657   0.0694
J=  3,      0.1337   0.1201   0.1076   0.0995   0.0967   0.0995   0.1076   0.1201   0.1337   0.1412
J=  4,      0.2082   0.1797   0.1573   0.1439   0.1396   0.1439   0.1573   0.1797   0.2082   0.2180
J=  5,      0.3018   0.2340   0.1989   0.1808   0.1752   0.1808   0.1989   0.2340   0.3018   0.3018
J=  6,      0.3018   0.2562   0.2249   0.2071   0.2013   0.2071   0.2249   0.2562   0.3018   0.3018
J=  7,      0.3018   0.2649   0.2390   0.2234   0.2182   0.2234   0.2390   0.2649   0.3018   0.3018
J=  8,      0.2843   0.2639   0.2447   0.2318   0.2273   0.2318   0.2447   0.2639   0.2843   0.2922
J=  9,      0.2798   0.2630   0.2461   0.2343   0.2301   0.2343   0.2461   0.2630   0.2798   0.2887
J= 10,      0.2843   0.2639   0.2447   0.2318   0.2273   0.2318   0.2447   0.2639   0.2843   0.2922
J= 11,      0.3018   0.2649   0.2390   0.2234   0.2182   0.2234   0.2390   0.2649   0.3018   0.3018
J= 12,      0.3018   0.2562   0.2249   0.2071   0.2013   0.2071   0.2249   0.2562   0.3018   0.3018
J= 13,      0.3018   0.2340   0.1989   0.1808   0.1752   0.1808   0.1989   0.2340   0.3018   0.3018
J= 14,      0.2082   0.1797   0.1573   0.1439   0.1396   0.1439   0.1573   0.1797   0.2082   0.2180
J= 15,      0.1337   0.1201   0.1076   0.0995   0.0967   0.0995   0.1076   0.1201   0.1337   0.1412
J= 16,      0.0657   0.0600   0.0545   0.0507   0.0494   0.0507   0.0545   0.0600   0.0657   0.0694
J= 17,      0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
```

```
                                                  PRESSURE DISTRIBUTION

RUN  7701      I= 21       I= 22       I= 23       I= 24       I= 25       I= 26       I= 27       I= 28       I= 29       I=
J=  1,         0.          0.          0.          0.          0.          0.          0.          0.          0.
J=  2,         0.0708      0.0699      0.0665      0.0596      0.0487      0.0362      0.0237      0.0117      0.
J=  3,         0.1438      0.1425      0.1365      0.1232      0.0991      0.0725      0.0470      0.0230      0.
J=  4,         0.2208      0.2198      0.2140      0.1977      0.1519      0.1077      0.0687      0.0334      0.
J=  5,         0.3018      0.3018      0.3018      0.3018      0.2031      0.1379      0.0866      0.0419      0.
J=  6,         0.3018      0.3018      0.3018      0.3018      0.2209      0.1543      0.0980      0.0477      0.
J=  7,         0.3018      0.3018      0.3018      0.3018      0.2243      0.1604      0.1036      0.0508      0.
J=  8,         0.2942      0.2918      0.2835      0.2632      0.2143      0.1596      0.1051      0.0520      0.
J=  9,         0.2912      0.2879      0.2770      0.2534      0.2101      0.1586      0.1052      0.0523      0.
J= 10,         0.2942      0.2918      0.2835      0.2632      0.2143      0.1596      0.1051      0.0520      0.
J= 11,         0.3018      0.3018      0.3018      0.3018      0.2243      0.1604      0.1036      0.0508      0.
J= 12,         0.3018      0.3018      0.3018      0.3018      0.2209      0.1543      0.0980      0.0477      0.
J= 13,         0.3018      0.3018      0.3018      0.3018      0.2031      0.1379      0.0866      0.0419      0.
J= 14,         0.2208      0.2198      0.2140      0.1977      0.1519      0.1077      0.0687      0.0334      0.
J= 15,         0.1438      0.1425      0.1365      0.1232      0.0991      0.0725      0.0470      0.0230      0.
J= 16,         0.0708      0.0699      0.0665      0.0596      0.0487      0.0362      0.0237      0.0117      0.
J= 17,         0.          0.          0.          0.          0.          0.          0.          0.          0.
```

```
                                                   CLEARANCE DISTRIBUTION

RUN  7701     I=  1      I=  2      I=  3      I=  4      I=  5      I=  6      I=  7      I=  8      I=  9      I= 10
J=  1,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  2,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  3,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  4,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  5,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  6,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  7,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  8,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  9,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 10,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 11,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 12,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 13,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 14,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 15,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 16,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 17,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000


                                                   CLEARANCE DISTRIBUTION

RUN  7701     I= 11      I= 12      I= 13      I= 14      I= 15      I= 16      I= 17      I= 18      I= 19      I= 20
J=  1,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  2,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  3,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  4,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  5,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  6,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  7,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  8,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  9,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 10,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 11,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 12,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 13,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 14,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 15,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 16,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J= 17,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
```

```
                                                   CLEARANCE DISTRIBUTION

RUN  7701     I= 21      I= 22      I= 23      I= 24      I= 25      I= 26      I= 27      I= 28      I= 29      I=
J=   1,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=   2,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=   3,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=   4,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=   5,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=   6,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=   7,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=   8,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=   9,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  10,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  11,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  12,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  13,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  14,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  15,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  16,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
J=  17,     1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000  1.0000000
```

```
RUN NUMBER  7702                      HYDROSTATIC BEARING PAD WITH 4 RECESSES.
                                  FEEDING = POSITIVE DISPLACEMENT PUMPS FEEDING EACH RECESS.
GRID POINTS, K = 28   M = 16       K1 =  5   K2 =  5   K3 =  0    M1 =  4   M2 =  2
CLEARANCE COEFFICIENTS
,AA 1)= 0.09999999E 01 ,AA


                                                            OUTPUT
QQ(I)=       1.00      1.00      1.00      1.00            ** Q(I,J)=   2.5957  -0.1453  -0.2683  -0.8124
W(I)=      0.0762    0.0800    0.0800    0.0762            **          -0.1379  10.5371  -3.2231  -0.2692
CSI(I)=    0.2746    0.6943    0.6943    0.2746            **          -0.2692  -3.2231  10.5371  -0.1379
ETA(I)=    0.1889    0.3802    0.1913    0.3826            **          -0.8124  -0.2683  -0.1453   2.5957
FINAL RESULTS = TOTAL LOAD=  0.1187  CSI= 0.3708 ETA=  0.2857  TOTAL FLOW=  0.4000000E 01
RECESS PRESSURES
 ,  AL(1) =  0.60023,  AL(2) =  0.17013,  AL(3) =  0.17013,  AL(4) =  0.60023,  AL(


  RUN NUMBER  7702                      HYDROSTATIC BEARING PAD WITH 4 RECESSES.
                                    FEEDING = POSITIVE DISPLACEMENT PUMPS FEEDING EACH RECESS.
  PAD CONFIGURATION. 00000000000000000000000000000
                     02222222222222222222222222220
                     02222222222222222222222222220
                     02222222222222222222222222220
                     02222111111222222211111122220
                     02222111111222222211111122220
                     02222111111222222211111122220
                     02222222222222222222222222220
                     02222222222222222222222222220
                     02222222222222222222222222220
                     02222111111222222211111122220
                     02222111111222222211111122220
                     02222111111222222211111122220
                     02222222222222222222222222220
                     02222222222222222222222222220
                     02222222222222222222222222220
                     00000000000000000000000000000
```

```
                                                 PRESSURE DISTRIBUTION

RUN   7702      I=  1      I=  2      I=  3      I=  4      I=  5      I=  6      I=  7      I=  8      I=  9      I= 10
J=  1,          0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
J=  2,          0.         0.0337     0.0623     0.0878     0.1100     0.1273     0.1367     0.1398     0.1379     0.1310
J=  3,          0.         0.0661     0.1230     0.1746     0.2218     0.2603     0.2788     0.2846     0.2816     0.2694
J=  4,          0.         0.0956     0.1788     0.2572     0.3353     0.4088     0.4321     0.4382     0.4356     0.4236
J=  5,          0.         0.1196     0.2245     0.3265     0.4408     0.6002     0.6002     0.6002     0.6002     0.6002
J=  6,          0.         0.1360     0.2539     0.3649     0.4784     0.6002     0.6002     0.6002     0.6002     0.6002
J=  7,          0.         0.1453     0.2691     0.3810     0.4883     0.6002     0.6002     0.6002     0.6002     0.6002
J=  8,          0.         0.1494     0.2746     0.3827     0.4757     0.5482     0.5745     0.5819     0.5782     0.5627
J=  9,          0.         0.1505     0.2757     0.3820     0.4701     0.5347     0.5653     0.5746     0.5696     0.5495
J= 10,          0.         0.1494     0.2746     0.3827     0.4757     0.5482     0.5745     0.5819     0.5782     0.5627
J= 11,          0.         0.1453     0.2691     0.3810     0.4883     0.6002     0.6002     0.6002     0.6002     0.6002
J= 12,          0.         0.1360     0.2539     0.3649     0.4784     0.6002     0.6002     0.6002     0.6002     0.6002
J= 13,          0.         0.1196     0.2245     0.3265     0.4408     0.6002     0.6002     0.6002     0.6002     0.6002
J= 14,          0.         0.0956     0.1788     0.2572     0.3353     0.4088     0.4321     0.4382     0.4356     0.4236
J= 15,          0.         0.0661     0.1230     0.1746     0.2218     0.2603     0.2788     0.2846     0.2816     0.2694
J= 16,          0.         0.0337     0.0623     0.0878     0.1100     0.1273     0.1367     0.1398     0.1379     0.1310
J= 17,          0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
```

```
                                                 PRESSURE DISTRIBUTION

RUN   7702      I= 11      I= 12      I= 13      I= 14      I= 15      I= 16      I= 17      I= 18      I= 19      I= 20
J=  1,          0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
J=  2,          0.1182     0.0997     0.0811     0.0658     0.0546     0.0473     0.0433     0.0416     0.0413     0.0412
J=  3,          0.2443     0.2020     0.1615     0.1297     0.1071     0.0926     0.0849     0.0823     0.0828     0.0830
J=  4,          0.3922     0.3084     0.2387     0.1885     0.1546     0.1335     0.1228     0.1206     0.1248     0.1258
J=  5,          0.6002     0.4111     0.3048     0.2377     0.1942     0.1674     0.1540     0.1532     0.1701     0.1701
J=  6,          0.6002     0.4496     0.3439     0.2716     0.2231     0.1921     0.1747     0.1683     0.1701     0.1701
J=  7,          0.6002     0.4601     0.3620     0.2914     0.2416     0.2081     0.1875     0.1763     0.1701     0.1701
J=  8,          0.5267     0.4444     0.3650     0.3001     0.2512     0.2170     0.1947     0.1813     0.1739     0.1705
J=  9,          0.5081     0.4377     0.3648     0.3024     0.2542     0.2197     0.1969     0.1830     0.1750     0.1705
J= 10,          0.5267     0.4444     0.3650     0.3001     0.2512     0.2170     0.1947     0.1813     0.1739     0.1705
J= 11,          0.6002     0.4601     0.3620     0.2914     0.2416     0.2081     0.1875     0.1763     0.1701     0.1701
J= 12,          0.6002     0.4496     0.3439     0.2716     0.2231     0.1921     0.1747     0.1683     0.1701     0.1701
J= 13,          0.6002     0.4111     0.3048     0.2377     0.1942     0.1674     0.1540     0.1532     0.1701     0.1701
J= 14,          0.3922     0.3084     0.2387     0.1885     0.1546     0.1335     0.1228     0.1206     0.1248     0.1258
J= 15,          0.2443     0.2020     0.1615     0.1297     0.1071     0.0926     0.0849     0.0823     0.0828     0.0830
J= 16,          0.1182     0.0997     0.0811     0.0658     0.0546     0.0473     0.0433     0.0416     0.0413     0.0412
J= 17,          0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
```

```
                                                     PRESSURE DISTRIBUTION

RUN  7702     I= 21      I= 22      I= 23      I= 24      I= 25      I= 26      I= 27      I= 28      I= 29      I=
J=  1,        0.         0.         0.         0.         0.         0.         0.         0.         0.
J=  2,        0.0407     0.0394     0.0368     0.0323     0.0256     0.0185     0.0117     0.0055     0.
J=  3,        0.0823     0.0802     0.0758     0.0671     0.0524     0.0371     0.0232     0.0109     0.
J=  4,        0.1255     0.1238     0.1195     0.1091     0.0810     0.0554     0.0340     0.0159     0.
J=  5,        0.1701     0.1701     0.1701     0.1701     0.1094     0.0712     0.0430     0.0200     0.
J=  6,        0.1701     0.1701     0.1701     0.1701     0.1190     0.0797     0.0487     0.0228     0.
J=  7,        0.1701     0.1701     0.1701     0.1701     0.1206     0.0827     0.0513     0.0242     0.
J=  8,        0.1679     0.1644     0.1580     0.1446     0.1139     0.0818     0.0519     0.0248     0.
J=  9,        0.1670     0.1623     0.1538     0.1381     0.1112     0.0811     0.0519     0.0249     0.
J= 10,        0.1679     0.1644     0.1580     0.1446     0.1139     0.0818     0.0519     0.0248     0.
J= 11,        0.1701     0.1701     0.1701     0.1701     0.1206     0.0827     0.0513     0.0242     0.
J= 12,        0.1701     0.1701     0.1701     0.1701     0.1190     0.0797     0.0487     0.0228     0.
J= 13,        0.1701     0.1701     0.1701     0.1701     0.1094     0.0712     0.0430     0.0200     0.
J= 14,        0.1255     0.1238     0.1195     0.1091     0.0810     0.0554     0.0340     0.0159     0.
J= 15,        0.0823     0.0802     0.0758     0.0671     0.0524     0.0371     0.0232     0.0109     0.
J= 16,        0.0407     0.0394     0.0368     0.0323     0.0256     0.0185     0.0117     0.0055     0.
J= 17,        0.         0.         0.         0.         0.         0.         0.         0.         0.
```

```
                                              CLEARANCE DISTRIBUTION

RUN  7702     I=  1      I=  2      I=  3      I=  4      I=  5      I=  6      I=  7      I=  8      I=  9      I= 10
J=  1,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J=  2,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J=  3,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J=  4,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J=  5,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J=  6,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J=  7,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J=  8,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J=  9,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J= 10,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J= 11,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J= 12,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J= 13,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J= 14,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J= 15,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J= 16,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
J= 17,      0.5000000  0.5357143  0.5714286  0.6071429  0.6428571  0.6785714  0.7142857  0.7500000  0.7857143  0.8214286
```

```
                                              CLEARANCE DISTRIBUTION

RUN  7702     I= 11      I= 12      I= 13      I= 14      I= 15      I= 16      I= 17      I= 18      I= 19      I= 20
J=  1,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J=  2,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J=  3,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J=  4,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J=  5,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J=  6,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J=  7,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J=  8,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J=  9,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J= 10,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J= 11,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J= 12,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J= 13,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J= 14,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J= 15,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J= 16,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
J= 17,      0.8571429  0.8928571  0.9285714  0.9642857  1.0000000  1.0357143  1.0714286  1.1071429  1.1428571  1.1785714
```

```
                                                    CLEARANCE DISTRIBUTION

RUN  7702    I= 21      I= 22      I= 23      I= 24      I= 25      I= 26      I= 27      I= 28      I= 29       I=
J=  1,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J=  2,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J=  3,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J=  4,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J=  5,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J=  6,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J=  7,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J=  8,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J=  9,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J= 10,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J= 11,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J= 12,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J= 13,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J= 14,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J= 15,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J= 16,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
J= 17,     1.2142857  1.2500000  1.2857143  1.3214286  1.3571429  1.3928571  1.4285714  1.4642857  1.5000000
```

```
RUN NUMBER  7703                              HYBRID BEARING PAD WITH 4 RECESSES
                                    FEEDING = POSITIVE DISPLACEMENT PUMPS FEEDING EACH RECESS.
LAMBDA =   1.0000
GRID POINTS, K = 28   M = 16      K1 =  5   K2 =  5   K3 =  0    M1 =  4   M2 =  2
CLEARANCE COEFFICIENTS
,AA 1)= 0.09999999E 01 ,AA


                                                         OUTPUT
QQ(I)=      1.0000     1.0000     1.0000     1.0000
W(I)=     0.0762   0.0800   0.0800   0.0762   0.0028
CSI(I)=   0.2746   0.6943   0.6943   0.2746   0.2974
ETA(I)=   0.1889   0.3802   0.1913   0.3826   0.2857

          J=1,     J=2,     J=3,     J=4,     J=5,
Q(1,J)=   2.5957  -0.1453  -0.2683  -0.8124  -0.0774
Q(2,J)=  -0.1379  10.5371  -3.2231  -0.2692  -0.0813
Q(3,J)=  -0.2692  -3.2231  10.5371  -0.1379  -0.0813
Q(4,J)=  -0.8124  -0.2683  -0.1453   2.5957  -0.0774
FINAL RESULTS = TOTAL LOAD=  0.1308  CSI= 0.3694 ETA=  0.2857  TOTAL FLOW=  0.4000000E 01
RECESS PRESSURES
 ,  AL(1) =  0.64679,  AL(2) =  0.18384,  AL(3) =  0.18384,  AL(4) =  0.64679,  AL(



RUN NUMBER  7703                              HYBRID BEARING PAD WITH 4 RECESSES
                                    FEEDING = POSITIVE DISPLACEMENT PUMPS FEEDING EACH RECESS.
PAD CONFIGURATION. 00000000000000000000000000000
                   02222222222222222222222222220
                   02222222222222222222222222220
                   02222222222222222222222222220
                   02222111111222222211111122220
                   02222111111222222211111122220
                   02222111111222222211111122220
                   02222222222222222222222222220
                   02222222222222222222222222220
                   02222222222222222222222222220
                   02222111111222222211111122220
                   02222111111222222211111122220
                   02222111111222222211111122220
                   02222222222222222222222222220
                   02222222222222222222222222220
                   02222222222222222222222222220
                   00000000000000000000000000000
```

```
                                   PRESSURE DISTRIBUTION

RUN  7703   I=  1     I=  2     I=  3     I=  4     I=  5     I=  6     I=  7     I=  8     I=  9     I= 10
J=  1,      0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
J=  2,      0.        0.0363    0.0672    0.0946    0.1185    0.1371    0.1473    0.1507    0.1486    0.1412
J=  3,      0.        0.0712    0.1325    0.1881    0.2390    0.2805    0.3005    0.3067    0.3034    0.2903
J=  4,      0.        0.1030    0.1927    0.2771    0.3613    0.4406    0.4656    0.4722    0.4694    0.4565
J=  5,      0.        0.1289    0.2419    0.3519    0.4750    0.6468    0.6468    0.6468    0.6468    0.6468
J=  6,      0.        0.1466    0.2736    0.3932    0.5155    0.6468    0.6468    0.6468    0.6468    0.6468
J=  7,      0.        0.1566    0.2900    0.4106    0.5262    0.6468    0.6468    0.6468    0.6468    0.6468
J=  8,      0.        0.1610    0.2959    0.4123    0.5126    0.5907    0.6190    0.6270    0.6230    0.6063
J=  9,      0.        0.1621    0.2971    0.4116    0.5066    0.5762    0.6091    0.6192    0.6138    0.5922
J= 10,      0.        0.1610    0.2959    0.4123    0.5126    0.5907    0.6190    0.6270    0.6230    0.6063
J= 11,      0.        0.1566    0.2900    0.4106    0.5262    0.6468    0.6468    0.6468    0.6468    0.6468
J= 12,      0.        0.1466    0.2736    0.3932    0.5155    0.6468    0.6468    0.6468    0.6468    0.6468
J= 13,      0.        0.1289    0.2419    0.3519    0.4750    0.6468    0.6468    0.6468    0.6468    0.6468
J= 14,      0.        0.1030    0.1927    0.2771    0.3613    0.4406    0.4656    0.4722    0.4694    0.4565
J= 15,      0.        0.0712    0.1325    0.1881    0.2390    0.2805    0.3005    0.3067    0.3034    0.2903
J= 16,      0.        0.0363    0.0672    0.0946    0.1185    0.1371    0.1473    0.1507    0.1486    0.1412
J= 17,      0.        0.        0.        0.        0.        0.        0.        0.        0.        0.

                                   PRESSURE DISTRIBUTION

RUN  7703   I= 11     I= 12     I= 13     I= 14     I= 15     I= 16     I= 17     I= 18     I= 19     I= 20
J=  1,      0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
J=  2,      0.1273    0.1074    0.0874    0.0710    0.0589    0.0511    0.0467    0.0449    0.0447    0.0445
J=  3,      0.2632    0.2177    0.1741    0.1398    0.1155    0.0999    0.0916    0.0889    0.0894    0.0896
J=  4,      0.4226    0.3324    0.2573    0.2033    0.1668    0.1441    0.1325    0.1303    0.1348    0.1359
J=  5,      0.6468    0.4430    0.3286    0.2562    0.2094    0.1806    0.1662    0.1655    0.1838    0.1838
J=  6,      0.6468    0.4846    0.3707    0.2929    0.2406    0.2073    0.1886    0.1818    0.1838    0.1838
J=  7,      0.6468    0.4959    0.3902    0.3141    0.2605    0.2246    0.2024    0.1904    0.1838    0.1838
J=  8,      0.5676    0.4790    0.3935    0.3235    0.2710    0.2341    0.2101    0.1958    0.1879    0.1842
J=  9,      0.5475    0.4718    0.3933    0.3260    0.2741    0.2371    0.2126    0.1976    0.1890    0.1842
J= 10,      0.5676    0.4790    0.3935    0.3235    0.2710    0.2341    0.2101    0.1958    0.1879    0.1842
J= 11,      0.6468    0.4959    0.3902    0.3141    0.2605    0.2246    0.2024    0.1904    0.1838    0.1838
J= 12,      0.6468    0.4846    0.3707    0.2929    0.2406    0.2073    0.1886    0.1818    0.1838    0.1838
J= 13,      0.6468    0.4430    0.3286    0.2562    0.2094    0.1806    0.1662    0.1655    0.1838    0.1838
J= 14,      0.4226    0.3324    0.2573    0.2033    0.1668    0.1441    0.1325    0.1303    0.1348    0.1359
J= 15,      0.2632    0.2177    0.1741    0.1398    0.1155    0.0999    0.0916    0.0889    0.0894    0.0896
J= 16,      0.1273    0.1074    0.0874    0.0710    0.0589    0.0511    0.0467    0.0449    0.0447    0.0445
J= 17,      0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
```

```
                                          PRESSURE DISTRIBUTION
RUN  7703    I= 21     I= 22     I= 23     I= 24     I= 25     I= 26     I= 27     I= 28     I= 29     I=
J=  1,       0.        0.        0.        0.        0.        0.        0.        0.        0.
J=  2,       0.0440    0.0425    0.0397    0.0349    0.0277    0.0199    0.0126    0.0060    0.
J=  3,       0.0889    0.0867    0.0819    0.0725    0.0566    0.0401    0.0250    0.0118    0.
J=  4,       0.1356    0.1337    0.1291    0.1178    0.0875    0.0598    0.0367    0.0172    0.
J=  5,       0.1838    0.1838    0.1838    0.1838    0.1182    0.0770    0.0464    0.0216    0.
J=  6,       0.1838    0.1838    0.1838    0.1838    0.1286    0.0861    0.0526    0.0246    0.
J=  7,       0.1838    0.1838    0.1838    0.1838    0.1303    0.0893    0.0554    0.0262    0.
J=  8,       0.1814    0.1777    0.1708    0.1562    0.1231    0.0884    0.0561    0.0268    0.
J=  9,       0.1804    0.1753    0.1662    0.1492    0.1201    0.0876    0.0561    0.0269    0.
J= 10,       0.1814    0.1777    0.1708    0.1562    0.1231    0.0884    0.0561    0.0268    0.
J= 11,       0.1838    0.1838    0.1838    0.1838    0.1303    0.0893    0.0554    0.0262    0.
J= 12,       0.1838    0.1838    0.1838    0.1838    0.1286    0.0861    0.0526    0.0246    0.
J= 13,       0.1838    0.1838    0.1838    0.1838    0.1182    0.0770    0.0464    0.0216    0.
J= 14,       0.1356    0.1337    0.1291    0.1178    0.0875    0.0598    0.0367    0.0172    0.
J= 15,       0.0889    0.0867    0.0819    0.0725    0.0566    0.0401    0.0250    0.0118    0.
J= 16,       0.0440    0.0425    0.0397    0.0349    0.0277    0.0199    0.0126    0.0060    0.
J= 17,       0.        0.        0.        0.        0.        0.        0.        0.        0.
```