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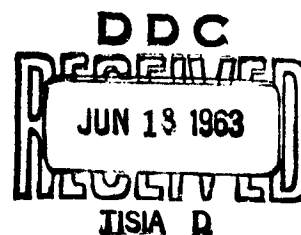
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MATHEMATICAL SHIP LOFTING

PART 1. THEORY

Technical Report 1.0.0-1
Volume 2 of Final Report
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March 1963

TODD SHIPYARDS CORPORATION
LOS ANGELES DIVISION SAN PEDRO CALIFORNIA

FORWARD

This publication is Volume 2 of six volumes of the final report on Mathematical Ship Lofting and Numerical Control of Shipyard Fabricating Equipment. The work reported on herein was performed under Bureau of Ships Contract NObs-4427, Code 770, during the period from April 1961 to March 1963.

The volumes of this final report have the following titles:

- Vol. 1. Project Summary Report (Technical Report 9.0.0)
- Vol. 2. Mathematical Ship Lofting -
 - Part 1. - Theory (Technical Report 1.0.0-1)
 - Part 2. - Operating Manual (Technical Report 1.0.0-2)
- Vol. 3. Mathematical Ship Lofting - Summary Report (Technical Report 1.5.0)
- Vol. 4. Programming System for Numerically Controlled Flame Cutting of Ships Parts - Operating Manual (Technical Report 5.0.0)
- Vol. 5. Development and Testing of Programming System for Numerically Controlled Flame Cutting of Ships' Parts - Summary Report (Technical Report 5.5.0)
- Vol. 6. Numerically Controlled Shipyard Fabricating Equipment - Summary Report (Technical Report 3.0.0)

The work was accomplished by the Research and Development Group of the Los Angeles Division of Todd Shipyards Corporation, San Pedro, Calif. Mr. Thomas G. Smith was Project Manager for the work, and Dr. Henry A. Schade of the University of California, Berkeley, was Principal Consultant.

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ABSTRACT

A method of fairing ships' hulls and obtaining a surface equation representing the ships' hull through the use of linear programming is presented. Methods for producing loft data from this equation are also presented.

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Section I

INTRODUCTION

The mathematical tool called "Linear Programming" has been in existence for many years. Since 1951, when George Dantzig* first published the simplex method for solving linear programming problems, and through increased availability of large-scale digital computers, linear programming use has become widespread. Primarily, this use of linear programming has been confined to economic studies of product mixes, ship scheduling, plant locations, etc. In this report a new use of linear programming is described: that of curve and surface fitting.

This use of linear programming has enabled the formulation of a more sophisticated approach to the problem of defining a ship's hull mathematically. Specifically, it is possible to require that the curve or surface meet certain conditions of fairness and that the curve come as close to the offsets as possible while meeting these conditions.

Also presented are some methods for extracting the information required to construct the ship from the faired curve or surface.

*T. C. Koopmans, ed., Activity Analysis of Production and Allocation, Chap. XXI, New York, Wiley, 1951

Section II

CRITERIA AND BACKGROUND

CRITERIA

The title, "Mathematical Lofting," is meant to apply to:

1. The overall process of mathematically fairing a ship's hull
2. Providing from this hull, all of the information necessary to cut and shape parts influenced by the hull

Mathematical fairing is the basic key to this process; however, mathematical fairing becomes most efficient when integrated into a system which meets the following criteria:

- (1) The system should accept as data the preliminary information on hull definition developed by the naval architect.
- (2) It should include a method for eliminating gross errors in this input data.
- (3) It should, from this data, obtain a fully faired hull form from which the ship can be produced.
- (4) The fairing process should operate with as little human intervention as possible.
- (5) The system should develop, as much as is practicable, complete loft information now provided by the manual loft.

Criterion (3) requires that the hull be fully faired. The term "fair" has been in use for a long time with many varied interpretations. To provide a basis for a mathematical fairing method, we must reduce the subjective definition of the word "fair" to a more precise mathematical definition. Curves which meet the following mathematical requirements also meet the subjective requirements of experienced loftsmen:

- 1-a The curve $Y(X)$ must be continuous
- 1-b Its first derivative must be continuous
- 1-c Its second derivative must be continuous*
- 1-d The curve must be completely free of extraneous inflection points while possessing those inherent in the data.
- 1-e Deviation from scaled offsets must be as small as possible, provided above four conditions hold.
- 1-f Curve must look good to the eye.

Condition 1-e is added for completeness when beginning with scaled offsets; it, and 1-f are also the only conditions possibly possessing any subjectivity in their interpretation. Condition 1-d is imperative if the faired curves are to be used for construction purposes as opposed to mathematical expressions used for hydrodynamic studies only.

A system designed to meet the above criteria would start with a table of roughly faired offsets and other information from the naval architect's preliminary lines drawing. It should then provide a method for eliminating any gross errors due, for example, to misreading a scale or transcribing the wrong information.

From this data, it should provide, with a minimum of human intervention or decision, a mathematical description of a fair hull. Next, it must be able to extract from the mathematical definition of the hull sufficient information to produce the ship. A diagram of such a system is presented in Fig. 1.

* Continuity of first and second derivatives is equivalent to continuous slope and curvature.

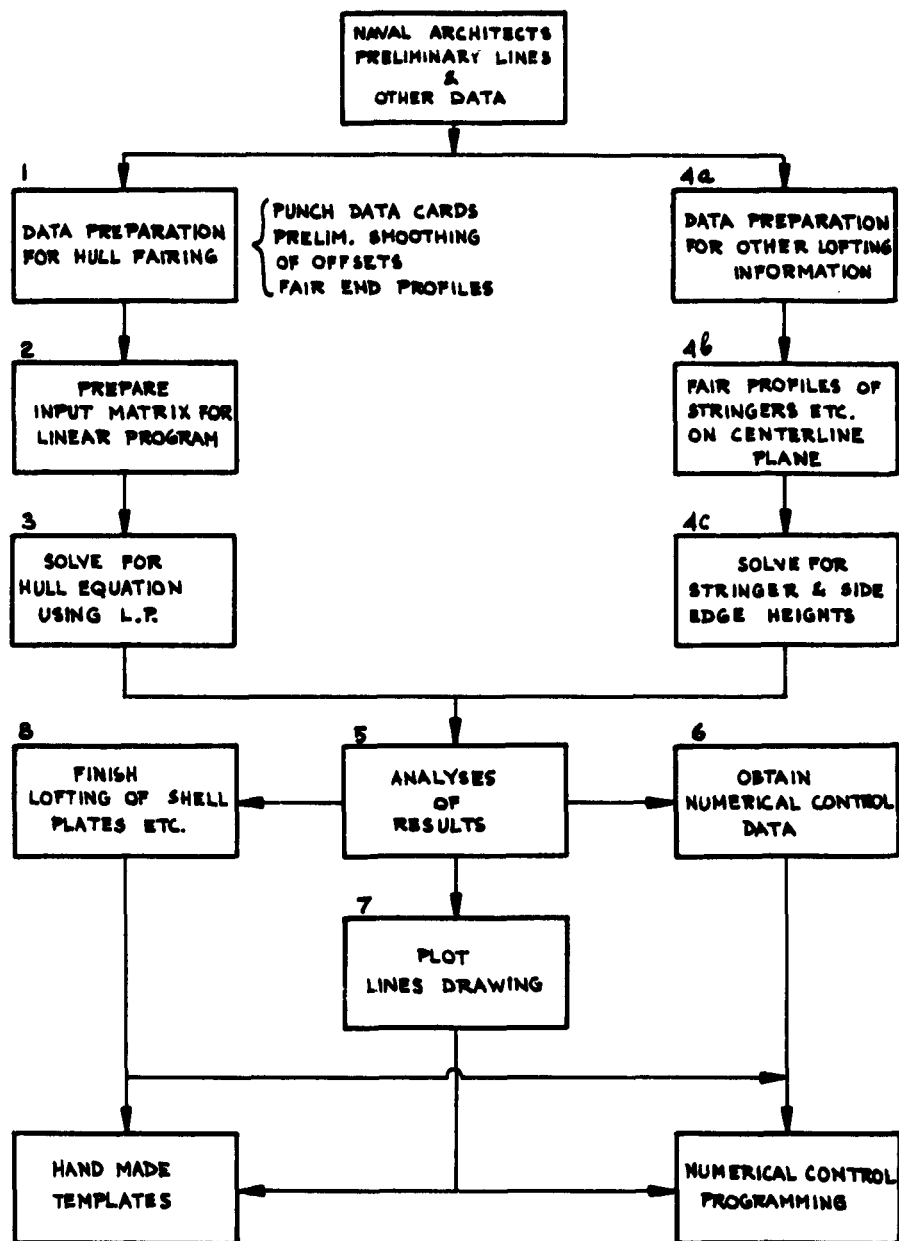


Fig. 1 Mathematical Lofting System

BACKGROUND

An extensive study of most methods proposed for mathematical lofting was undertaken prior to the initial formulation of the present system. This study revealed that all proposed systems fail, in one way or another, to meet the criteria required of a system oriented toward production. From the system which most fully met the criteria (method proposed by F. Theilheimer*), was borrowed the class of function with which to represent ships-form, as well as the notation for this function.

*Feodor Theilheimer and William Starkweather, The Fairing of Ship Lines on a High-Speed Computer, David W. Taylor Model Basin, Appl. Math. Lab., Report No. 1474, Jan 1961

Section III

MATHEMATICAL FAIRING

A. GENERAL DISCUSSION

The manual loft has used the batten (graphical-spline) very satisfactorily for interpolating between points as well as "fairing" points. We feel it would be desirable to mathematically-fair with the mathematical equivalent of the graphical-spline, the "analytic-spline."

Analytic Spline

Thin beam theory (based on the Bernoulli-Euler Equation) shows that a thin beam (e.g., batten) supported at a finite number of points, under small deflections, can be represented by a series of cubic equations (a single cubic in each interval defined by two successive points of support) with any two neighboring cubics having equal ordinate values, first derivatives and second derivatives at the point of support common to both curves. The third derivatives at this common point are not necessarily equal, resulting in a discontinuous third derivative for the curve representing the spline. The discontinuity of the third derivative at the juncture point is proportional to the force applied to the beam at this point.

This situation closely parallels the one existing when ships' lines are drawn from battens, and again when these curves are faired full-scale on the mold loft floor.

Definition: An analytic-spline through a set of points is a curve through these same points consisting of a cubic in each interval defined by two successive points with any two neighboring cubics having equal ordinates, first derivatives, and second derivatives at the point common to both curves.

Returning to the original requirements for fairness of a line (Page II-1) it can clearly be seen that all an analytic-spline needs in order for it to satisfy all fairness criteria, is that it possess only those inflection points inherent in the data, while minimizing the deviation between curve and points.

Having settled on the type of curve with which to represent ships-form, we must now devise a procedure for minimizing the deviation between curve and points while requiring the occurrence of inflection points to be compatible with the information inherent in the data.

One point we would like to emphasize is that in curve-fairing, as opposed to curve-fitting, the main objective is not to pass exactly through the data points, but that the curve be pleasing to the eye and possess only those inflection points as indicated by the data. Only after these fairness conditions have been satisfied can we ask for the curve which minimizes the deviation. The problem would be less complicated were it a curve-fitting problem and not a curve-fairing problem.

Linear Programming

One computer routine which can be very satisfactorily adapted to both curve-fitting and curve-fairing is entitled "Linear Programming." The general linear programming problem can be described as follows:

Given a set of M linear inequalities or equations in r variables, we wish to find non-negative values of these variables which will satisfy the constraints and maximize or minimize some linear function of the variables.*

The application of linear programming to curve fitting stems from the

*For a detailed definition of Linear Programming refer to G. Hadley, Linear Programming, Addison-Wesley Publishing Co., 1962

following use of linear programming:

Linear programming offers a method of obtaining an optimal solution to a set of linear equations which has an infinite number of solutions (i.e., a procedure for determining an optimal element from a set with an infinite number of elements).

The latter interpretation of linear programming indicates that the problem of fitting a curve to a set of points can be stated as a linear programming problem by requiring the linear programming code to select from the infinite number of curves in the neighborhood of the data points, the one which comes closest to these points (i.e., select the curve which satisfies all other fairness requirements and minimizes the deviation between curve and points).

Point Smoothing and Second Derivative Requirement

The data-points which serve as input to the lofting system (mathematical of manual) are traditional offsets scaled from a preliminary design drawing prepared by a naval architect. This drawing is approximately one-fiftieth the size of the actual ship. The smallness of this drawing, although being beneficial to the naval architect, invariably causes small reading errors in the scaled offsets. There are many opportunities for errors aside from those described above to enter into the data. These errors are usually quite large and result from human frailty. These errors could be typically:

- (1) An error resulting from using the wrong scale or incorrectly using the right one,
- (2) An error due to transcribing incorrectly,
- (3) A writing error, such as laying the point down incorrectly on the mold loft floor, or correspondingly mispunching a data card for a computer.

It is highly probable that a few points will be totally in error and will not contain any information of value. Superimposed on these and the rest of the points will be small, random errors due to reading inaccuracy.

Our first problem is then to separate the points having errors which do not at all reflect the naval architect's intention from the rest. In the mold loft this operation is done by eye. Before the loftman proceeds with putting fair lines through the preliminary offsets, he checks them to see if they seem to fit in well with one another. Those points which seem to be in error are rechecked with the lines plan and perhaps even re-scaled. However, this is a liberty not usually afforded the computers in the modern approach; therefore, it is crucial that this process of rejection of bad points be executed if the naval architect's intentions are to be preserved in a later computation with these points (e.g., fitting a fair surface to them).

A fair curve does not have too many or too closely-spaced inflection points. One can easily verify for himself that two, closely-spaced inflection points in a curve causes it to have a "bump" in that region. Such bumps are not considered fair by a naval architect. In a similar way, three closely-spaced inflection points correspond to two "bumps." Thus, inflection points need to be relatively isolated from one another to prevent the occurrence of "bumps."

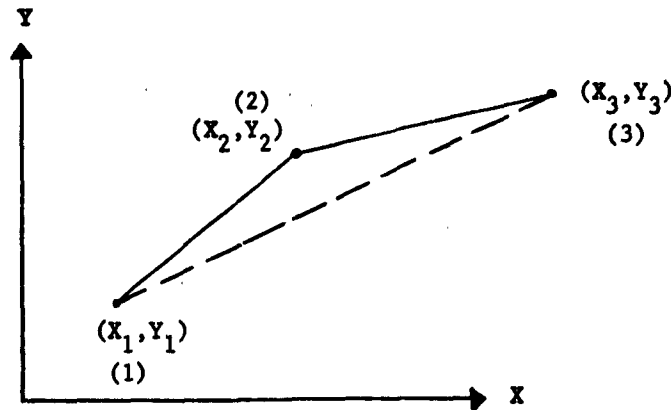


Fig. 2 Interpretation of Second Differences

Consider the set of three points shown in Fig. 2. Suppose any continuous curve which has continuous first and second derivatives passes through these points. Since, as shown, the middle point (2) lies above the line connecting the two other points, (1) and (3), there must be some portion of the curve with negative curvature. This can easily be deduced by repeated use of the Theorem of the Mean Value and the fact that the curve is required to have a continuous second derivative. One can present this result in a slightly different way. The "second difference" of the given three points is given by:

$$(1) \quad r_2 = \frac{2}{X_3 - X_1} \left[\frac{Y_3 - Y_2}{X_3 - X_2} - \frac{Y_2 - Y_1}{X_2 - X_1} \right]$$

For convenience we refer to this as the second difference evaluated at point (2), even though it obviously depends on points (1) and (3) also. This second difference has the property of being negative when (2) lies above the line connecting (1) and (3), and positive when (2) lies below this line. In Fig. 2 the

second difference evaluated at (2) is negative since (2) lies above the line. Finally, we arrive at the well-known result for a curve satisfying I-c.* There must be a portion of it in an interval which has curvature of the same sign as the second difference computed for that interval.

It can be seen that unlike signs of second differences at two neighboring points indicates an inflection point in the interval between these two points. We can now develop a criterion for detecting points with large errors in them. If, in any set of three consecutive points, the second difference changes signs twice we have a "bad" point. The "bad point" can now be moved an appropriate amount requiring it to be compatible with its neighboring points (i.e., not cause any "bumps").

After the points have been "smoothed" (large errors removed) a requirement that the second derivative and second difference be of the same sign at all data points will guarantee the analytic-spline to have the correct amount as well as correct spacing of inflection points.

The Coordinate Axes

The coordinate system employed is indicated in Fig. 3, below.

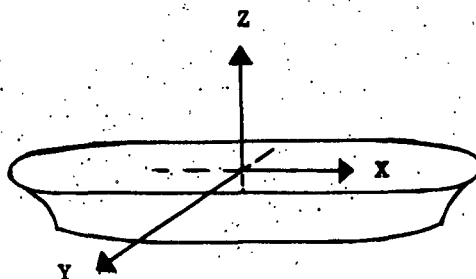


Fig. 3 The Coordinate Axes

* See Page II-2

The equation for the surface of the ship will be a function $Y = F(X, Z)$. The two-dimensional curves obtained by holding Z constant ($Y = f(X)$) will be referred to as waterlines. The two-dimensional curves obtained by holding X constant ($Y = g(Z)$) will be referred to as stations.

Notation

The notation employed offers a means of representing the analytic-spline by a single continuous equation, which has continuous first and second derivatives and a discontinuous third derivative. The discontinuities of the third derivative occur at pre-selected points. In essence, this equation consists of individual cubics between points of discontinuity of the third derivative.

The analytic spline is represented by:

$$(2) \quad Y(X) = A_0 + A_1X + A_2X^2 + A_3X^3 + A_4(X-a_1)_\#^3 + \dots + A_{N+1}(X-a_{N-1})_\#^3 \quad *$$

$a_1 \dots, a_{N-1}$ are the abscissae of the points of discontinuity of the third derivative and should be chosen to coincide with the abscissae of the original data points.

In the above representation

$$(X-a)_\#^3 = \begin{cases} (X-a)^3 & \text{if } X > a \\ 0 & \text{if } X \leq a \end{cases}$$

Or equivalently

$$(X-a)_\#^3 = \frac{1}{2}(X-a)^3 + \frac{1}{2} |(X-a)^3|$$

*This notation was originally introduced by Dr. Feodor Theilheimer

From the above definition it is obvious that $(X-a)_\#^3$ will never be negative

The above notation is very direct.

As an example, consider the following analytic-spline

$$(2') \quad Y(X) = -1 + 3X - 3X^2 + 2X^3 - (X-1)_\#^3$$

For $X \leq 1$ (2') gives the cubic

$$Y_1(X) = -1 + 3X - 3X^2 + 2X^3$$

For $X > 1$ (2') gives the cubic

$$Y_{11}(X) = X^3$$

It can immediately be seen that Y_1 and Y_{11} have equal ordinate values, first derivatives, and second derivatives at $X = 1$, but unequal third derivatives.

B. TWO-DIMENSIONAL FAIRING

As previously stated, a requirement that the second derivative and second difference be of the same sign will guarantee compatibility of inflection points.

This constraint is expressed mathematically as:

Require that

$$(3) \quad r_i \cdot Y''(X_i) \geq 0 \quad i = 1, \dots, N$$

Where

r_i = second difference at i^{th} data point*

$Y''(X_i)$ = second derivative at i^{th} data point

Deviation Requirement

The general analytic-spline $Y(X)$ is given by (2) .

The original offsets (ordinate values of original N points) are denoted by Y_i $i = -1, \dots, N$

The maximum ordinate-deviation between curve and offset is noted by λ (we take maximum to mean largest magnitude and not maximum in an algebraic sense.)

It readily follows that

$$(4) \quad |Y(X_i) - Y_i| \leq \lambda \quad \text{for } i = 1, \dots, N$$

The above expression simply says that the absolute values of the ordinate deviations at the N original points are all less than or equal to λ , (i.e., λ is the maximum deviation).

λ has a distinct value for each specific analytic-spline $Y(X)$.

We now ask the linear programming code to give us the analytic-spline which satisfies fairness constraint (3) and has the smallest value for λ (i.e., minimum-maximum deviation).

*Since the second difference is not defined for the first and last points, the second difference at the second and next to last points will be used for these two points respectively.

Formulation of Deviation and Fairness Constraints as
Linear Programming Problem

The curve fitting problem can now be formulated as a linear programming problem as follows:

Minimize λ subject to the constraints

$$\left. \begin{array}{l} (3) \quad r_1 \cdot Y''(x_1) \geq 0 \\ (4) \quad |Y(x_1) - y_1| \leq \lambda \end{array} \right\} \quad i = 1, \dots, N$$

Since linear programming codes handle linear constraints only, constraint (4) is equivalently expressed by the following pair of linear inequalities:

$$\left. \begin{array}{l} \lambda - Y(x_1) \geq -y_1 \\ \lambda + Y(x_1) \geq y_1 \end{array} \right\} \quad i = 1, \dots, N$$

There are now three linear constraints per point the analytic-spline must satisfy. This problem readily lends itself to linear programming routines. The problem is stated as:

Minimize λ subject to the following linear constraints:

$$\left. \begin{array}{l} \lambda - Y(x_1) \geq -y_1 \\ \lambda + Y(x_1) \geq y_1 \\ r_1 \cdot Y''(x_1) \geq 0 \end{array} \right\} \quad i = 1, \dots, N$$

This formulation requires $N+3$ non-slack variables and $3N$ constraints, (N is the number of original data points).

Actual Presentation

The actual presentation of the problem requires only slight modification. The inequalities are transformed to equalities by the subtraction of a positive quantity (called slack variable) from each inequality. Since present linear programming codes accept positive variables only, the variables (coefficients in equation (2)) are represented by the difference of two non-negative variables, i.e.,

$$A_i = A'_i - A''_i$$

$$A'_i, A''_i \geq 0$$

The formulation of the linear programming problem now becomes:

Minimize λ subject to the following constraints:

$$\begin{aligned} \lambda - (A'_0 - A''_0) - (A'_1 - A''_1)x_1 - (A'_2 - A''_2)x_1^2 - (A'_3 - A''_3)x_1^3 - \dots \\ - (A'_{N+1} - A''_{N+1})(x_1 - a_{N-1})^3 - S_1 = -Y_1 \end{aligned}$$

$$\begin{aligned} \lambda + (A'_0 - A''_0) + (A'_1 - A''_1)x_1 + (A'_2 - A''_2)x_1^2 + (A'_3 - A''_3)x_1^3 + \dots \\ + (A'_{N+1} - A''_{N+1})(x_1 - a_{N-1})^3 - P_1 = Y_1 \end{aligned}$$

$$\begin{aligned} r_1 \cdot \left[2(A'_2 - A''_2) + 6(A'_3 - A''_3)x_1 + \dots + 6(A'_{N+1} - A''_{N+1})(x_1 - a_{N-1})^2 \right] \\ - Q_1 = 0 \end{aligned}$$

$$i = 1, \dots, N$$

* This difficulty can be eliminated, as is shown on Page III-23, Section entitled "Dual Formulation."

In this way an equation of the form:

$$Y(X) = A_0 + A_1 X + A_2 X^2 + A_3 X^3 = A_4 (X-a_1)^3 + \dots + A_{N+1} (X-a_{N-1})^3$$

will be constructed.

The maximum deviation between curve and data points will be given by the value of λ in the final solution.

C. THREE-DIMENSIONAL FAIRING

Extension of Notation to Three-Dimensions

In attempting to fit a surface to a three-dimensional set of points, the same procedure as was used in the two-dimensional case is employed.

Equation (2) is replaced by its three-dimensional extension $Y(X,Z)$:

$$(5) \quad Y(X,Z) = C_0(X) + C_1(X)Z + C_2(X)Z^2 + C_3(X)Z^3 + C_4(X)(Z-b_1)_{\#}^3 \\ + \dots + C_{M+1}(X)(Z-b_{M+1})_{\#}^3$$

Where

$$C_i(X) = c_{i,0} + c_{i,1}X + c_{i,2}X^2 + c_{i,3}X^3 + \dots + c_{i,N+1}(X-a_{N+1})_{\#}^3$$

$$i = 0, \dots, M+1$$

$$a_p = X\text{-Coordinate of } P^{\text{th}} \text{ station}$$

$$b_q = Z\text{-Coordinate of } Q^{\text{th}} \text{ waterline}$$

(5) represents a surface of N stations and M waterlines.

An expansion of Equation (5) gives:

$$\begin{aligned}
Y(X,Z) = & \left[c_{00} + c_{01}X + c_{02}X^2 + c_{03}X^3 + \dots + c_{0,N+1} (X-a_{N-1})_{\#}^3 \right] \\
& + \left[c_{10} + c_{11}X + c_{12}X^2 + c_{13}X^3 + \dots + c_{1,N+1} (X-a_{N-1})_{\#}^3 \right] Z \\
& + \left[c_{20} + c_{21}X + c_{22}X^2 + c_{23}X^3 + \dots + c_{2,N+1} (X-a_{N-1})_{\#}^3 \right] Z^2 \\
& + \left[c_{30} + c_{31}X + c_{32}X^2 + c_{33}X^3 + \dots + c_{3,N+1} (X-a_{N-1})_{\#}^3 \right] Z^3 \\
& + \left[c_{40} + c_{41}X + c_{42}X^2 + c_{43}X^3 + \dots + c_{4,N+1} (X-a_{N-1})_{\#}^3 \right] (Z-b_1)_{\#}^3 \\
& \quad \vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \\
& + \left[c_{M+1,0} + c_{M+1,1}X + c_{M+1,2}X^2 + c_{M+1,3}X^3 \right. \\
& \quad \quad \quad \left. + \dots + c_{M+1,N+1} (X-a_{N-1})_{\#}^3 \right] (Z-b_{M-1})_{\#}^3
\end{aligned}$$

We now have an expression that consists of individual cubics in the coordinate planes between any two stations or waterlines. This surface equation will have (N+2) (M+2) coefficients for N stations and M waterlines.

Requirements

The deviation is again required to be less than or equal to λ

$$\left| Y(X_i, Z_j) - Y_{ij} \right| \leq \lambda \quad \begin{array}{l} i = 1, \dots, N \\ j = 1, \dots, M \end{array}$$

Two second difference constraints are now required in order to guarantee fairness: one in the X-direction and one in the Z-direction.

FORMULATION AS LINEAR PROGRAMMING PROBLEM

The problem is now formulated as a linear programming problem as follows:

Minimize λ subject to the following constraints:

$$\left. \begin{array}{ll} \text{(b)} & \lambda - Y(X_i, Z_j) \geq -Y_{ij} \\ \text{(bb)} & \lambda + Y(X_i, Z_j) \geq Y_{ij} \\ \text{(bbb)} & \hat{r}_{i,j} \cdot Y''(X_i, Z_j)_{zz} \geq 0 \\ \text{(bbbb)} & \hat{r}_{i,j} \cdot Y''(X_i, Z_j)_{xx} \geq 0 \end{array} \right\} \quad \begin{array}{l} i = 1, \dots, N \\ j = 1, \dots, M \end{array}$$

$\hat{r}_{i,j}$ = second difference in Z-direction at j^{th} point on i^{th} station

$\hat{r}_{i,j}$ = second difference in X-direction at i^{th} point on j^{th} waterline

$Y''(X_i, Z_j)_{zz}$ indicates the second derivative of $Y(X, Z)$ with respect to Z (X held constant) at j^{th} point on i^{th} station.

$Y''(X_i, Z_j)_{xx}$ indicates the second derivative of $Y(X, Z)$ with respect to X (Z held constant) at i^{th} point on j^{th} waterline.

This formulation requires $4R$ constraints

% (R = number of original points.)

The maximum deviation will, as in the two-dimensional case, be given by the value of λ in the final solution.

D. DOUBLE SPLINE

On Page III-7 the analytic spline is represented by

$$(i) \quad Y(X) = A_0 + A_1X + A_2X^2 + A_3X^3 + A_4(X-a_1)^3 + \dots + A_{N+1}(X-a_{N-1})^3$$

where $a_1, \dots, a_{N-1}$ are the abscissae of the original input points. With the use of the dual formulation (Page III-23) the number of coefficients in Equation (1) becomes the number of deviation constraints in the dual problem. Since the size of this number is a very critical factor in the length of time it takes to solve the LP problem, we may ask the question, "What effect will the elimination of some of these coefficients have to the final solution." In other words, can we afford to reduce the computer time at the expense of possibly inducing a larger deviation between curve and offsets.

One way of systematically reducing the number of coefficients would be to add an $(X-a_i)^3$ term only at every second data point, (i.e., if $a_1, \dots, a_n$ are the original data points, add $(X-a_i)^3$ terms if, and only if $i = \text{even integer}$. Employing this procedure we would add terms only at $a_2, a_4, \dots, a_{2i}$.

Motivation for this procedure can be extracted from various policies the graphical or manual loft uses. Clearly, the graphical loft does not put a weight, or "duck," at every point and generally agrees the curve with the fewest "ducks" is the most desirable, provided of course that the deviation is reasonable.

It was previously shown that each coefficient A_j for $j \geq 4$ in Equation (i) corresponds to a point where a duck would be used in the graphical loft. By eliminating every second coefficient we have

in effect eliminated every second duck.

In practice, it has been shown that the elimination of these coefficients not only significantly reduces the computing time, but also does not reduce the quality of the curve. In many instances the quality of the curve was increased. A reasonable explanation of this could be that this procedure offers fewer places to have inflection points or zero second derivatives (reverse curvature or flat splots). This procedure of joining three points with a single cubic is referred to as "double splining."

If we were to "double spline," Equation (i) would be replaced with its counterpart:

$$(ii) \quad Y(X) = A_0 + A_1X + A_2X^2 + A_3X^3 + A_4(X-a_1)_\#^3 + A_6(X-a_4)_\#^3 + \dots$$

Where $A_1, \dots, a_n$ are the original input points. The only change to the original formulation, aside from the use of this different curve will be that a second derivative requirement will only be needed at the points where an $(X-a_1)_\#^3$ term is added. Second derivative requirements at the other points would be redundant. As before, a deviation constraint is required at all original points.

E. ALTERNATE REPRESENTATION - SUM OF THE DEVIATIONS

The use of linear programming as a curve fairing tool has suggested an alternate fit to the one just presented. This is the "sum of the deviations" problem. In this formulation, the sum of the absolute values of the deviations between the surface function and the original data are minimized (i.e., minimize $\sum_{i=1}^n |Y(X_i) - Y_i|$). This is made possible by that characteristic of linear programming which requires all variables to be non-negative.

Assume a relationship between the surface equation and the set of original offsets such that the value of the equation at each of the original offsets is less than, or equal to the original offset. That is,

$$Y(X_{i,j}) \leq Y_{i,j} \quad \begin{array}{l} i = 1, \dots, N \\ j = 1, \dots, M \end{array}$$

We can change this inequality to equality by adding a dummy variable as follows (note that the dummy variable must be non-negative):

$$\begin{array}{l} Y(X_{i,j}) + S_{i,j} = Y_{i,j} \\ S_{i,j} \geq 0 \end{array} \quad \begin{array}{l} i = 1, \dots, N \\ j = 1, \dots, M \end{array}$$

In linear programming, inequalities are always changed in this manner to obtain a full set of simultaneous linear equations. The additional variables ($S_{i,j}$) are called slack variables. As previously stated, in any feasible solution in linear programming, all of the variables in the solution must be non-negative. Therefore in any optimal, feasible solution, all of the slacks which remain in the solution will either be at a zero level or positive.. By requiring a very high cost on the slacks when compared to that on the

coefficients, the sum of the slacks (positive deviations) is minimized. This fairing problem is formulated as follows:

$$\left. \begin{array}{l} \text{Minimize } \sum S_{i,j} \text{ subject to the following} \\ Y(X_{i,j}) + S_{i,j} = Y_{i,j} \\ \hat{r}_{i,j} \cdot y''(X_{i,j}) \geq 0 \\ \hat{r}_{i,j} \cdot Y''(X_{i,j})_{xx} \geq 0 \end{array} \right\} \begin{array}{l} i = 1, \dots, N \\ j = 1, \dots, K \end{array}$$

The deviation can be obtained at each offset by reading the value of the slack at that point. If the slack does not enter into the final solution, or enters at a zero level, the surface passes exactly through the offset.

In practice the set of deviation slacks, plus the set of slacks for changing the curvature constraints to equalities, which together form an identity matrix, are used as the first basic feasible solution allowing the optimization phase to begin at once.

A modification of this method has been made utilizing the following formulation (this is done so the deviations will be unrestricted in sign, which in turn should give a closer fit):

$$\left. \begin{array}{l} \text{Minimize } \sum S_{i,j} + Q_{i,j} \text{ subject to the following} \\ Y(X_{i,j}) + S_{i,j} - Q_{i,j} = Y_{i,j} \\ \hat{r}_{i,j} \cdot y''(X_{i,j})_{ff} \geq 0 \\ \hat{r}_{i,j} \cdot Y''(X_{i,j})_{xx} \geq 0 \end{array} \right\} \begin{array}{l} i = 1, \dots, N \\ j = 1, \dots, M \end{array}$$

Here the slacks $S_{i,j}$ and $Q_{i,j}$ are both positive, however, only one of the pair may enter into the solution since they are linearly dependent,* (i.e., will cause a singular matrix)

This formulation allows the surface to pass over some offsets and under others. The first basic feasible solution again consists of the set of slacks $S_{i,j}$ plus those of the curvature constraints.

* $S_{i,j}$ = Positive deviation

$-Q_{i,j}$ = Negative deviation

$S_{i,j} - Q_{i,j}$ = Total deviation, as stated above, in practice,

only one of $S_{i,j}$ or $Q_{i,j}$ will enter into the solution.

F. DUAL FORMULATION

It can be shown* that if we write the primal problem in the form:

$$\begin{aligned} \sum_{j=1}^r d_{i,j} \cdot x_j &= d_i & i = 1, \dots, k \\ \sum_{j=1}^r d_{i,j} \cdot x_j &\geq d_i & i = k+1, \dots, s, \\ x_j &\geq 0 & j = 1, \dots, r \quad \text{MAX } Z = cx \end{aligned}$$

then the dual problem is

$$\begin{aligned} D'w &\geq c', \quad \text{MIN } Z = d'w \\ w_i &\text{ unrestricted} & i = 1, \dots, k \\ w_i &\geq 0 & i = k+1, \dots, s \end{aligned}$$

That is, wherever i^{th} constraint in the primal is an equality, the i^{th} dual variable is unrestricted with regard to sign. This property has considerable importance in our problem, because the coefficients of the surface equation are, by nature, unrestricted. The dual formulation offers a way of eliminating the representation of each coefficient as the difference of two non-negative variables, and this greatly reduces the size of the problem

*Refer to G. Hadley, Linear Programming, p 236 (Addison-Wesley Publishing Co., 1962)

We therefore restate the problem as follows:

Minimize λ subject to the following constraints

$$\left. \begin{aligned} \lambda - Y(X_{i,j}) &= -y_{i,j} \\ \lambda + Y(X_{i,j}) &= y_{i,j} \\ \hat{r}_{i,j} \cdot Y''(X_{i,j})_{ff} &\geq 0 \\ \hat{r}_{i,j} \cdot Y''(X_{i,j})_{xx} &\geq 0 \end{aligned} \right\} \begin{aligned} i &= 1, \dots, N \\ j &= 1, \dots, M \end{aligned}$$

If we present this formulation to the linear program in the dual form, the variables representing the deviation constraints (coefficients of the surface equation) will be unrestricted with regard to sign.

Section IV

FORMULATION OF END CONDITIONS

The previous formulation of the surface fitting problem can handle only rectangular arrays of points, that is, every waterline must have the same number of stations; and conversely, every station must have the same number of waterlines. This condition, unfortunately, does not exist when we consider the bow and stern of a ship. The lower waterlines may have fewer stations than the higher ones. The bow and stern areas also produce other problems which we shall refer to collectively as "end conditions."

If, in the equation for the surface of the ship (i.e., $Y = f(X,Z)$), we replace Y with zero we obtain the expression for the profile of the ship (i.e., $f(x,z) = 0$).

This profile is specified in the original lines drawings of the ship and at times may be very complicated. This profile must also be "fair." The present formulation offers no means for guaranteeing this. In attempting to solve this problem we can be guided by the procedure used in the manual loft.

In manual lofting the profile is "faired" as an independent unit of the ship. The ship is then required to pass through this previously "faired" profile. In this way the ship is guaranteed to have the correct profile, no matter how complicated it may be.

We shall attempt to construct an analogous procedure in the mathematical loft. To begin with, let us show that it is not sufficient to require that the original waterlines pass through the profile, without any

additional restrictions on the surface between the original waterlines.

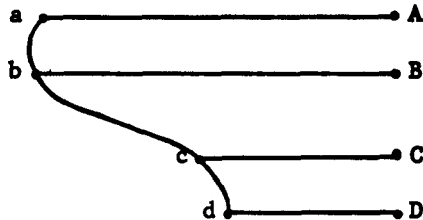


Fig. 1-a

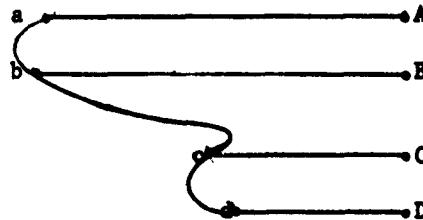


Fig. 1-b

Fig. 1

In Fig. 1, A, B, C, and D are waterlines passing through the profile at Points a, b, c, and d, respectively. The contour of the profile desired is shown in Fig. 1-a; but in the surface fitting problem, a requirement that Waterlines A, B, C, and D pass through Points a, b, c, and d, respectively, without any additional requirements on the profile of the surface, may very possibly result in the Profile shown in Fig. 1-b. At any rate, we cannot guarantee that this will not occur.

Consider the expression for the surface of the ship:

$$Y = f(X, Z)$$

We wish to transform this expression so that Y will be equal to zero at the profile of the ship. Toward this end we construct

$$Y = f(X, Z) \cdot T(X, Z)$$

Where $T(X, Z)$ has the property that it is equal to zero if the point (X, Z) in the $Y = 0$ plane lies on the profile.

$$\text{Let } T(X, Z) = \left[1 - \left[1 + f(Z) - X \right]_+^3 \right]$$

$f(Z)$ is the "faired" spline curve representation of the profile. (Clearly,

since $Y = 0$ at the profile, the profile will be an expression in X and z only). Since $X = f(z)$ is the expression for the profile, for a given waterline - say $Z = Z_0$, $f(Z_0)$ will be the X value corresponding to the intersection of the profile with this waterline.

When $X = f(Z_0)$, i.e., when Point (X, Z_0) lies on the profile

$$T(X, Z_0) = \left[1 - \left[1 + f(Z_0) - f(Z_0) \right]_{\#}^3 \right]_{\#} = 1 - 1 = 0$$

so $Y = f(X, Z_0) T(X, Z_0) = 0$

But, if $X \geq f(Z_0) + 1$ (i.e., X is one unit away or farther from the profile)

$$T(X, Z_0) = \left[1 - \left[1 + f(Z_0) - f(Z_0) - 1 \right]_{\#}^3 \right]_{\#} = 1 - A_{\#}$$

Where $A_{\#} \leq 0$

here we define $A_{\#}$ such that

$$A_{\#} = \begin{cases} 0 & \text{if } A_{\#} \leq 0 \\ A & \text{if } A_{\#} > 0 \end{cases}$$

So

$$T(X, Z_0) = 1 - A_{\#} \text{ with } A_{\#} \leq 0, \text{ becomes}$$

$$T(X, Z_0) = 1 - 0 = 1 \quad \text{for } X \geq f(Z_0) + 1$$

and

$$Y(X, Z) = f(X, Z) T(X, Z) = f(X, Z)$$

This implies that $T(X,Z)$ is effective only between the profile and one unit away from it, also

$$0 \leq T(X,Z) \leq 1 \quad \text{for all } X,Z$$

We raise $[1 + f(Z) - x]$ to the third power so we may have continuous first and second derivatives as well as continuous curve at $X = f(Z) + 1$.

If we consider stations instead of waterlines, we see that similar results will be obtained.

The expression for the surface now becomes

$$Y(X,Z) = f(X,Z) \left[1 - [1 + f(Z) - X]^3 \right]$$

$f(Z)$ = previously faired profile.

If it is desired to have infinite slope where the waterline (station) intersects this profile, we merely replace

$$T(X,Z) = \left[1 - [1 + f(Z) - X]^3 \right]_X$$

with

$$T(X,Z) = \left[1 - [1 + f(Z) - X]^3 \right]_X^P$$

where $0 < P < 1$

The interval in which $T(X,Z)$ is effective does not have to be from the profile to the profile plus 1 unit, but can be from the profile to the

profile plus any arbitrary distance, D , by using

$$T(X,Z) = \left[1 - \left[\frac{D + f(Z) - X}{D} \right]^3 \right]^P$$

$$\text{For } X = f(Z) + D$$

$$T(X,Z) = \left[1 - \left[\frac{D + f(Z) - f(Z) - D}{D} \right]^3 \right]^P$$

$$T(X,Z) = [1]^P = 1$$

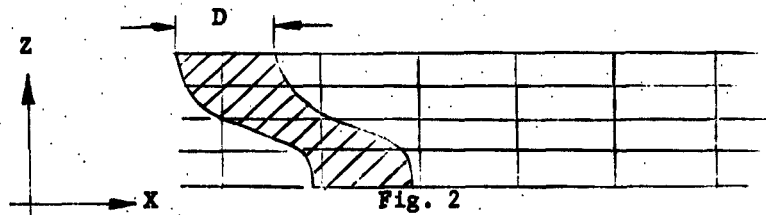
It can very easily be verified that

$$T(X,Z) = 1 \quad \text{if } X \geq f(Z) + D$$

or

$$Y(X,Z) = f(X,Z)$$

$f(X,Z)$ is the spline-surface representation developed in a previous section. $Y(X,Z)$ is now guaranteed to have the correct end profile and becomes a regular spline curve D units away from the profile.



In Fig. 2, the cross-hatched area represents the portion of the surface in which $T(X,Z)$ is effective.

Section V

LOFT INFORMATION

From the mathematical fairing program has come a surface equation which describes the desired hull form. It now becomes necessary to extract from this surface equation the data required for parts definition.

THE FINAL LINES DRAWING

One of the first and more important types of information required from a loft is, of course, a final body plan. The data for the preparation of such body plan is easily obtained from the mathematical ship definition. Substituting any specific frame location X into the hull surface equation $Y = f(X, Z)$, and solving this expression for various values of Z , will provide offsets Y describing the frame of interest. The values for the coordinates of these points may be obtained at any desired scale. If an automatic plotting machine is available, such as the Coordinatograph, the body plan may be scribed quickly and with great accuracy.

Other information for the lines drawing may be obtained in the same manner. Waterlines may be described by substituting a specific value of Z , into the surface equation $Y = f(X, Z)$, and solving the equation at various values of X .

The coordinates of the buttock points are not obtained in such straight-forward fashion. However, using a computer, a technique such as Newton's method may be employed to intersect the hull surface with a plane parallel to the center plane of the ship. Heights of the intersection of the plane and the surface may be

obtained at many points along the length of the ship. Diagonal planes can be handled in the same way, intersecting the surface with a plane at a constant angle to the hull surface.

SHELL PLATE DEVELOPMENT

To develop the flat pattern to which a plate must be cut in order to fit properly in place on the hull when formed, requires several types of information:

- a. Arc lengths along intersections of coordinate planes (station or waterline planes) and the hull surface
- b. Coordinates of points along the sight edges on the hull surface
- c. Arc length along the sight edge on the surface
- d. True angles on the surface between coordinate planes

The mathematics for developing this information is given below.

- a. Finding arc lengths on the hull surface along station or waterline planes:

The general formula for arc length along a station curve, $X = \text{constant}$ is

$$6) \quad S = \int_{Z_0}^{Z_1} \sqrt{1 + f_z^2} dZ$$

When X is constant the hull surface equation becomes

$$7) \quad Y = A + BZ + CZ^2 + DZ^3 + \dots$$

Substituting 7) into 6) gives

$$8) \quad S = \int_{Z_0}^{Z_1} \left[1 + (B + 2CZ + 3DZ^2 + \dots)^2 \right]^{\frac{1}{2}} dZ$$

which can be solved for arc length between any two heights Z .

Similarly, the equation for arc length along the surface in a waterline plane is

$$9) \quad S = \int_{X_0}^{X_1} \left[1 + (B + 2C + 3DX^2 + \dots)^2 \right]^{\frac{1}{2}} dX$$

b. Coordinates of any point along sight edges:

To establish the plate sight edges mathematically from the hull surface equation requires a function $Z = f(X)$ which describes the trace of the sight edge on the $X - Z$ plane. Assume this function is known for the moment.

The equation describing the hull surface is of the form

$$10) \quad Y = f(X, Z)$$

Substituting $Z = f(X)$ into (5)

$$11) \quad Y = f(X)$$

Given any value of X on $Z = f(X)$, Z and Y are determined by equations 6) and 8)

The method for obtaining the function $Z = f(X)$ is to use the preliminary offsets given by the naval architect. These consist of the height above the baseline for each sight edge at each station. The set of heights $(Z_1, \dots, Z_m)$ for each sight edge describes the trace of the sight edge on the centerline plane of the ship.

To establish $Z = f(X)$ two steps are necessary:

1. Since the heights $(Z_1, \dots, Z_m)$ are given only to the accuracy obtained from scaling the drawings, they must be smoothed to prevent unwanted inflections.
2. The smoothed points can then be fitted with a spline curve using the smaller two-dimensional linear programming formulation.

It may be possible to assume that in the equation $Z = f(X)$, Z is a simple function of X such as a parabola. This would require considerable analysis and perhaps revision of the naval architect's method of establishing sight edges.

c. Arc lengths along the sight edges on the surface:

The sight edge has now been defined parametrically

$$\begin{aligned} 12) \quad X &= X \\ Z &= f(X) \\ Y &= f(X) \end{aligned}$$

Substitution into the general formula for arc length and integrating along the X axis gives

$$13) \quad S = \int_{X_0}^{X_1} \left[1 + (f'_Y(X))^2 + f'_Z(X)^2 \right]^{\frac{1}{2}} dX$$

d. The true angle between coordinate planes on the hull surface:

Substitution of the directional cosines of the coordinate planes into the law of cosines gives the angle between these planes as:

$$14) \quad \cos \theta = \frac{f_X f_Z}{\left[(1 + f_X^2) (1 + f_Z^2) \right]^{\frac{1}{2}}}$$

LONGITUDINALS

Many times the position of longitudinals around the hull of the ship is given by the arc length distance from the keel or other longitudinal.

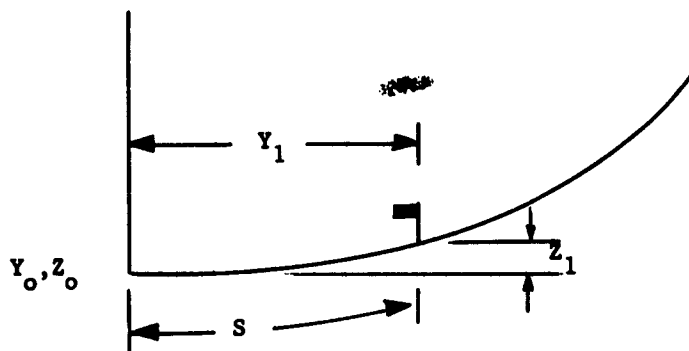


Fig. 4 Establishing the Position of Longitudinals

That is, (Fig. 4) given S and Y_0, Z_0 (which may be the keel line) find Y_1 and Z_1 which are the coordinates of the position of the longitudinal.

The height Z_1 may be found by a trial and error solution of Equation 3) after substituting Z_0 and S . Y_1 can then be found by substituting the station location X , and Z_1 into the surface equation.

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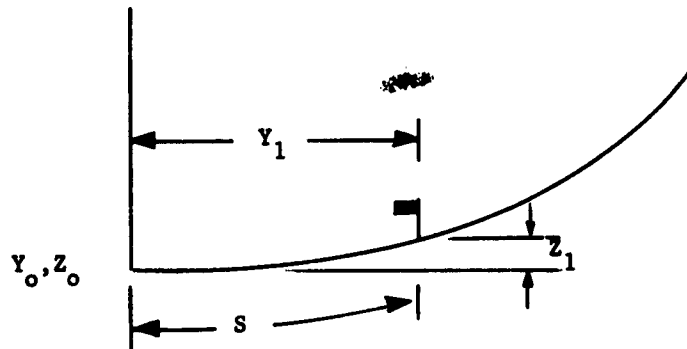


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MATHEMATICAL SHIP LOFTING

PART 2. OPERATING MANUAL

Technical Report 1.0.0-2
Volume 2 of Final Report
Contract NObs-4427

March 1963

TODD SHIPYARDS CORPORATION
LOS ANGELES DIVISION SAN PEDRO CALIFORNIA

FORWARD

This publication is Volume 2 of six volumes of the final report on Mathematical Ship Lofting and Numerical Control of Shipyard Fabricating Equipment. The work reported on herein was performed under Bureau of Ships Contract NObs-4427, Code 770, during the period from April 1961 to March 1963.

The volumes of this final report have the following titles:

- Vol. 1. Project Summary Report (Technical Report 9.0.0)
- Vol. 2. Mathematical Ship Lofting -
 - Part 1. - Theory (Technical Report 1.0.0-1)
 - Part 2. - Operating Manual (Technical Report 1.0.0-2)
- Vol. 3. Mathematical Ship Lofting - Summary Report (Technical Report 1.5.0)
- Vol. 4. Programming System for Numerically Controlled Flame Cutting of Ships Parts - Operating Manual (Technical Report 5.0.0)
- Vol. 5. Development and Testing of Programming System for Numerically Controlled Flame Cutting of Ships' Parts - Summary Report (Technical Report 5.5.0)
- Vol. 6. Numerically Controlled Shipyard Fabricating Equipment - Summary Report (Technical Report 3.0.0)

The work was accomplished by the Research and Development Group of the Los Angeles Division of Todd Shipyards Corporation, San Pedro, Calif. Mr. Thomas G. Smith was Project Manager for the work, and Dr. Henry A. Schade of the University of California, Berkeley, was Principal Consultant.

This report contains the results of work accomplished by the Mathematics Team which consists of:

- D. A. Atkins, Naval Architect - Mathematician (Team Supervisor)
- R. A. Tapia, Mathematician
- J. C. Fassino, Naval Architect - Mathematician
- T. A. Dunaway, Computer Programmer
- S. A. Berger, Mathematician
- W. C. Webster, Naval Architect - Mathematician
- Janice H. Thompson, Secretary

Others of the Todd Staff, whose contributions and participation during the Project were responsible for its successful culmination, consisted of:

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R. W. Feeny, Numerical Control Engineer
H. S. Janssen, European Representative
K. M. Jones, Naval Architect
W. R. Lauper, Mechanical Engineer
M. R. Ward, Jr., Naval Architect

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Section I

INTRODUCTION

The Mathematical Lofting System begins with offsets and data from a naval architect's preliminary lines plan. This data is first checked to be sure it contains no extraneous errors. It is next faired by fitting it with a surface equation which represents the molded surface of the hull and which has certain properties consistent with "fairness." Then data necessary for building the actual ship is extracted from this equation.

Sections II through IX describe the operation of this System. The instructions for the computer programs and program listings are contained in the Appendixes.

The coordinate system used throughout is shown in Fig. I-1. All dimensions used in this system are in feet unless expressly stated otherwise.

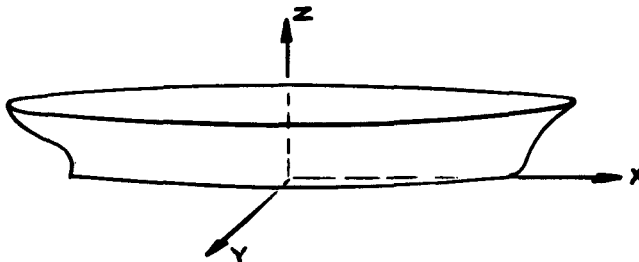


Fig. I-1 Coordinate System

A diagrammatic representation of the Lofting System is shown in Fig. I-2. It is expected that anyone using this System will be familiar with the SPS and FORTRAN programming languages for the IBM-1620 computer. Although the programs included in this report represent a lofting system, it must be remembered the purpose of the programs was primarily to checkout

the development work on the mathematical lofting method.

The organization of this report into Steps follows the numbering of the boxes in Fig. I-2. The flow of data through the System also follows this same order.

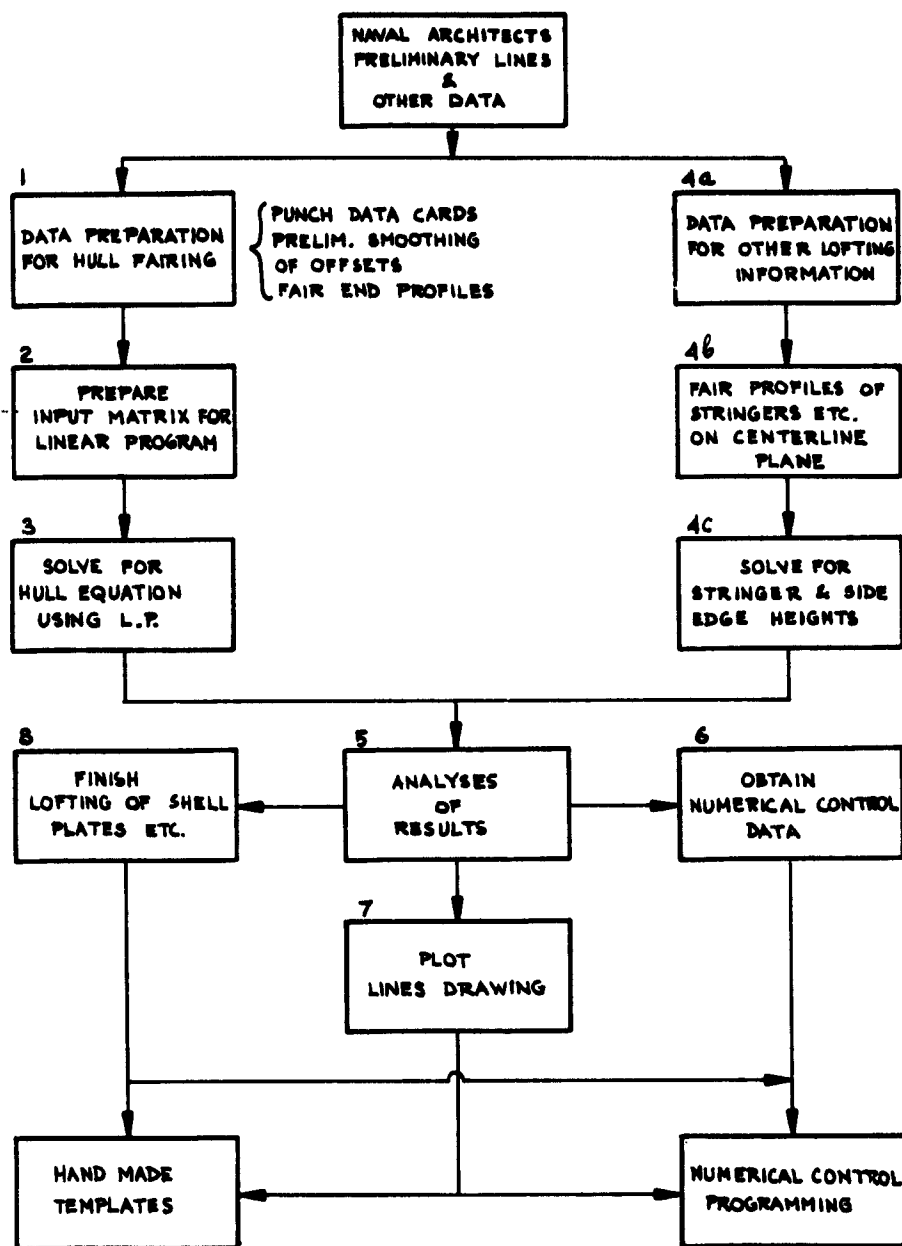


Fig. I-2 Mathematical Lofting System

Section II

PREPARATION OF INPUT DATA (STEP 1)

The flow of data through the preparation stage is shown on Fig. II-1.

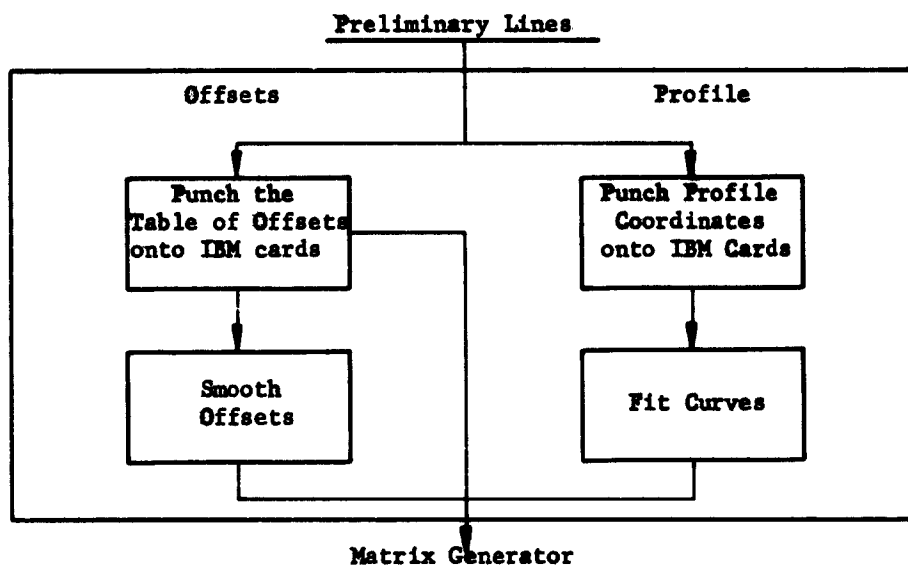


Fig. II-1 Flow Diagram for Data Preparation

A. OFFSETS

The left-hand branch of Fig. II-1 outlines the procedure for preparing the table of offsets for a ship to be lofted. This somewhat expanded table of offsets must include values for every intersection of station and waterline shown in the circumscribing rectangle of Fig. II-2. Although the values of the offsets in the shaded portions are not important and usually are made zero, they are included for

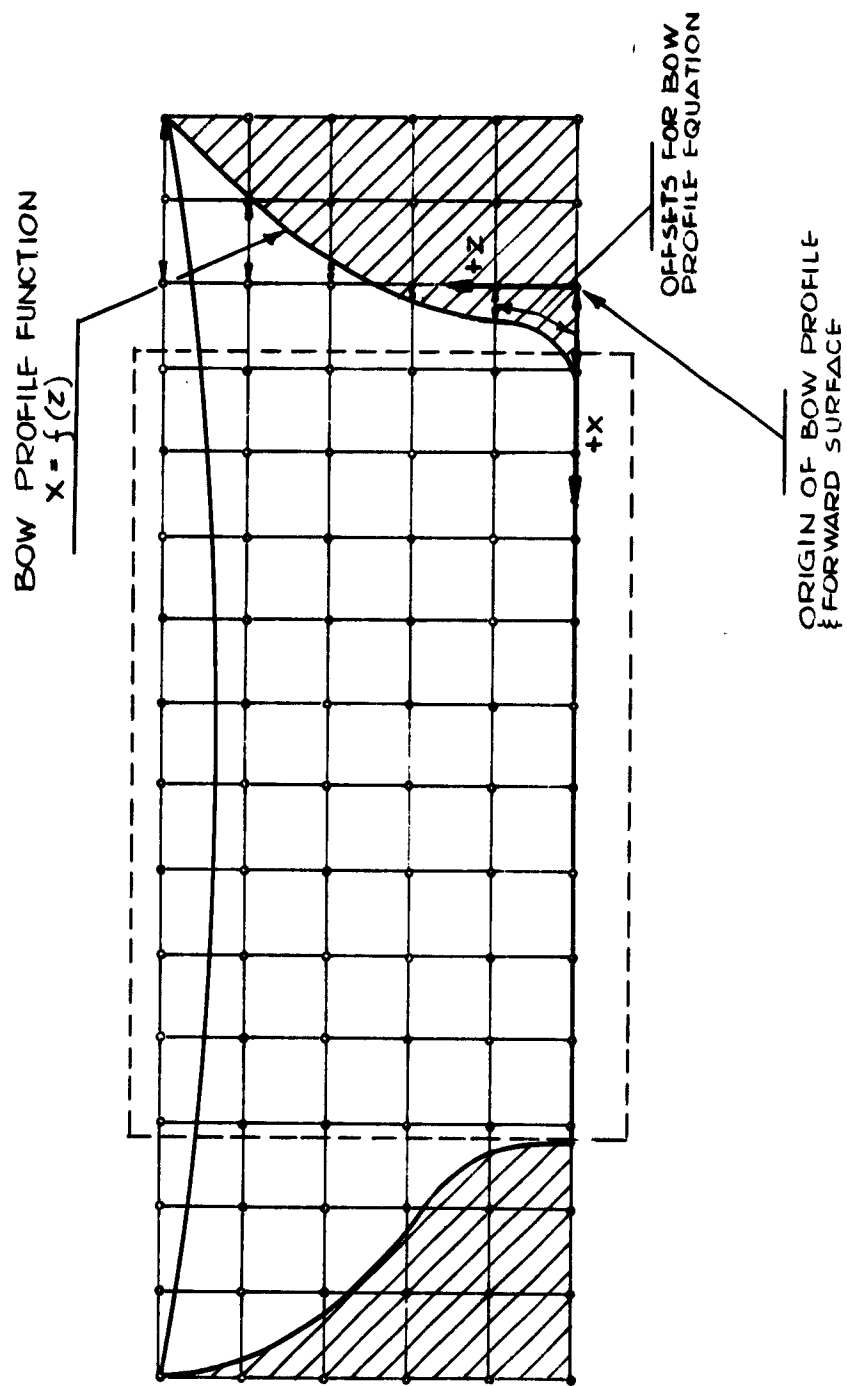


Fig. II-2

mechanical reasons. The offsets above the deck, or knuckle line, must be consistent with the others and faired to a degree such that the second differences calculated using these points will have the proper sign.

The offsets are punched into cards, along with their X and Z locations on the hull. These cards are read by an IBM-1620 computer program which converts them from feet and fractions to feet and decimals, and "smooths" them.* The principle is a necessary part of the lofting system. This procedure essentially points out any offsets which are obviously in error, and substitutes a value which will allow a fair curve to come near it, without causing discrepancies at other points (corrects the second differences). Presently, only the offsets within the dotted rectangle of Fig. II-2 may be smoothed by this routine, since it has not been programmed to accept the end profiles. The remaining points can be examined as noted in Step 2-A. After gaining experience in the fairing procedure, the smoothing program can often be bypassed and the data fed directly into the matrix generating routines. The listing of the signs of the second differences can then be examined for consistency. More information about this can be found in Step 2-A.

The output from this program is directly usable in the second step of the lofting system. Operating instructions, card formats, and a program listing are included in Appendix A.

*The smoothing process is described in Mathematical Ship Lofting - Part 1, Theory, Technical Report 1.0.0-1

B. PROFILES

In addition to the smoothed offsets, functions which describe the fore and aft profiles must be presented to the matrix generating routines of Step 2. This process is represented by the right-hand branch of Fig. II-1. The functions representing the end profiles are obtained from the end profile coordinates using the approach of Step 4.

The function representing the profile is $x = f(z)$ as shown in Fig. II-2. The origin of this equation must be the same as the origin of the surface equation for the hull, and must be scaled the same (see Step 2). The data points for describing the profile must be on the same waterlines as are used for the surface grid.

The coefficients of the equations for the profiles are punched on cards in the format shown in Appendix B to be entered directly into the Step 2 routines.

Section III

GENERATING THE LINEAR PROGRAMMING MATRIX (STEP 2)

The matrix for the linear program is produced by a set of 1620 programs called SMOG (Surface Matrix from Offsets Generator). These routines accept the data assembled in Step 1 and produce the specific matrix required for a particular surface, including the auxiliary information required by the LP program for bookkeeping purposes.

There are four versions of SMOG (Appendix B):

SMOG-1 produces the matrix required for a surface problem, without profile, using the dual formulation and λ fit.

SMOG-2 produces the matrix required for a surface problem, with profile, using the dual formulation and λ fit.

SMOG-3 produces the matrix required for a surface problem, with profile, using the primal formulation and sum of the deviations fit.

SMOG-4 produces a matrix for a 2-dimensional curve using the primal formulation and sum of the deviations fit.

Most surface problems will be run using SMOG-1 or 2. The first three surface versions produce their output in the SHARE Standard LP format, although the output from SMOG-3 must be rearranged as shown in the Appendix.

The general operation of the programs is:

- (1) Read the data and, if necessary, convert the offsets from feet-fractions to feet-in-decimal form
- (2) Calculate and, if required, print the intersections, if any, of each station and waterline with the profile
- (3) Calculate and, if desired, print values and signs of the second differences in both the waterline and station directions

- (4) Calculate and punch the LP matrix, consisting of deviation constraints, curvature constraints, and the peripheral information required by the linear program.

A. MANUAL SMOOTHING

In operation (3) above, the signs of the second differences are found and can be printed. The second differences of the offsets are calculated using a general formula. Therefore, there is no requirement that the stations or waterlines chosen to describe the surface be equally spaced.

If the offsets have not previously been run through the smoothing routine, they may be visually checked at this time. That is, they may be compared against the preliminary lines drawing to see if they actually describe a curve of the same character as shown on the drawing. A second check is to investigate the consistency of the signs of the second differences. For instance, if a single positive second difference turns up in the middle of a string of negative values, the point should be carefully checked for validity and, if necessary, changed a small amount to adjust the sign.

There are also some cases when the correct values for the points will cause the wrong sign to be calculated. This is illustrated in Fig. III-1. The example is taken from Station 14 of the DLG-26 class ships. Using points from the base line, 4' and 8' waterlines, a negative sign will be calculated for the second difference at the 4' waterline, where the character of the curve suggests a positive value. Simply changing the sign within the program before punching the curvature constraints will correct this situation.

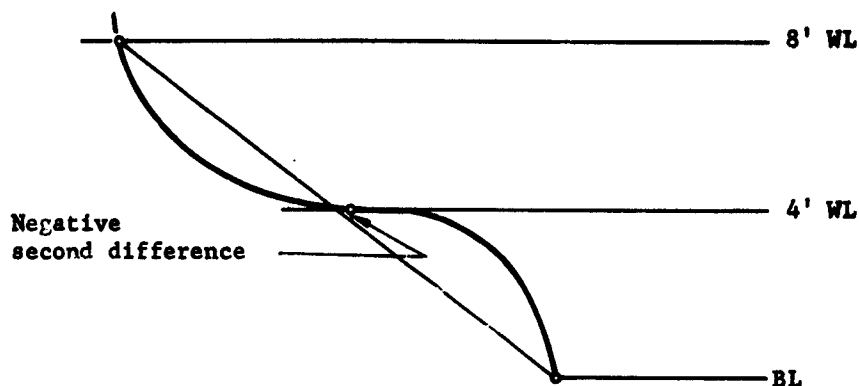


Fig. III-1

B. SCALING

All of the linear programming routines which have been examined have a restriction that the size of a matrix element be less than the absolute value of 10,000. Since some of our matrix elements are the product of two cubes ($X_i^3 \cdot Z_j^3$) their size quickly becomes large. This has necessitated a limitation on the size of the X and Z coordinates. It can be readily seen that this limitation requires the product of the greatest X and Z coordinates to be less than the cube root of 10,000, or 21.53. In practice, the 4 x 5 combination is most common.

The coordinates may be scaled by dividing by some multiple of the station or waterline spacing. A surface five stations across, for example, might have a station spacing of 25' for a total length of 100'. Division by the station spacing gives a scaled value of 4, or, the stations are one unit apart.

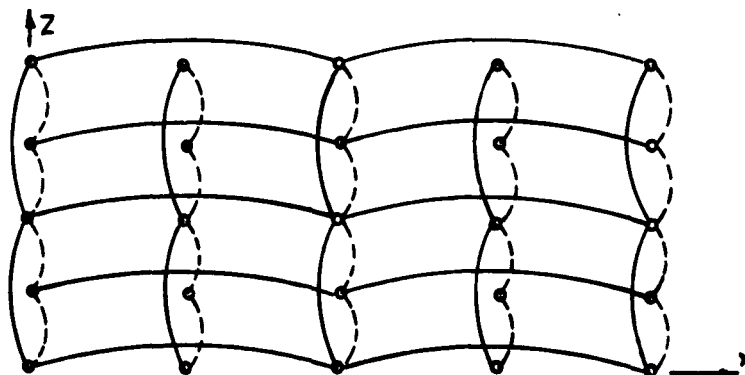
The most it is presently practical to scale is by four times the minimum station or waterline spacing, since this makes the minimum

spacing one-fourth unit. The smallest matrix element then, becomes $(1/4)^3 \times (1/4)^3$ which, if the largest element is greater than 9000, creates an extreme range in the number size. This, of course, causes round-off and other difficulties in solving the matrix. The manner in which scaling is handled by the SMOG routines is noted in Appendix B.

Another important consideration for reducing maximum number size is to require that the first waterline and first station have zero coordinates. The SMOG programs have the ability to translate about the X or Z axis so the origin will occur at 0,0 .

C. SURFACE REPRESENTATION

All three of the surface matrix generators "double spline" the surface in the X direction. That is, they require a cubic to cover two intervals instead of one, as the "single spline" does. The cubic is required to have the proper curvature condition at every other station and is required to come as close as possible to every station. This, as can be seen in Fig. III-2, requires that every surface have an odd number of stations.



Solid lines - Double spline both ways
Combination, solid horizontal, broken vertical - double spline one way only

Fig. III-2 Span of Cubics on Surface

In the Z direction, there is a choice between double spline and single spline. The double spline representation requires a smaller matrix than the single spline representation. The double spline in the Z direction should be used whenever possible. It is, however, sometimes necessary to use single spline in order to gain the necessary flexibility for fitting surfaces with large variations in curvature and slope.

The double spline representation requires the data to contain an odd number of waterlines.

Section IV

USE OF LINEAR PROGRAM (STEP 3)

The linear programming routine which we have used most for fairing, is called LP-90.* It uses the SHARE standard format for input as punched by the SMOG programs. Some information on its use will be found in Appendix C.

Another LP system has been written by Bonner & Moore.** This program is faster than LP-90 for very dense problems, such as the fairing problem. It is, however, somewhat more difficult to use. This system also accepts SHARE standard input through the use of a special loading routine.

The matrix, which was produced by SMOG on the IBM-1620, must be converted to card/magnetic tape off-line on some machine, such as the IBM-1401, before its use with either LP.

The output from LP-90 is a magnetic tape that contains information on the problem written during its solution, and the final solution, which is the set of coefficients for the surface equation. By monitoring the output tape using the printer on the 1401, this final solution may be punched on cards. These cards may then be used as direct input to Step 5.

*LP-90 was written by CEIR Inc., Arlington, Virginia. It can be obtained from SHARE by sending them a magnetic tape on which they will copy the program. It is also available at any service bureau of CEIR.

**Bonner & Moore Associates, Houston, Texas. This system may be purchased from them or used at any Service Bureau Corp, Scientific Computing Center.

Section V

DEFINITION OF LONGITUDINAL STRUCTURAL INTERSECTIONS (STEP 4)

There is one type of intersection with the hull surface that requires additional information. This is the type which is shown in Fig. V-1.

Examples are:

- Shell plate sight edges
- Longitudinal frames and stringers
- Deck edges
- Knuckles

The centerplane projection of these intersections is a fair spline curve.

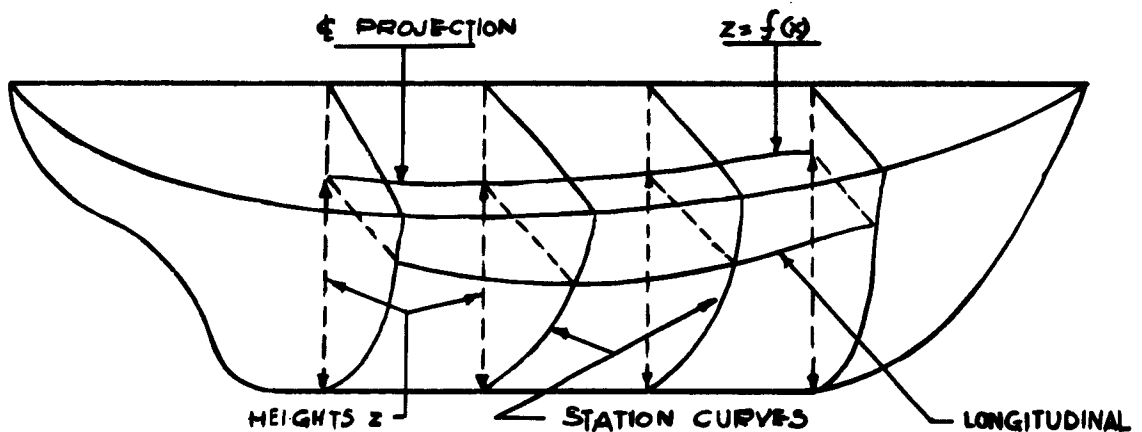


Fig. V-1 Longitudinal Intersections

In order to complete the definition of these curves, an equation for their height at any point along the length of the ship must be found ($z = f(x)$). This function is entered into the routines explained in Step 5, along with the hull equation to determine the height and half-breadth of these intersections on the fair hull. The procedure for

obtaining these functions follows.

A. DATA PREPARATION

The data for each curve generally consists of the height of the curve at each station used to fair the hull surface (Fig. V-1). This data can be entered into the two-dimensional smoothing routine, Appendix A, or directly into the two-dimensional SMOG (SMOG 4) which is described below.

B. GENERATION OF MATRIX

The data from above, plus certain additional information as noted in Appendix B, are entered into SMOG 4. This program scales the data as desired, calculates and prints the second differences, and punches the matrix for the 1620 linear program given below. The matrix is punched in the sum of the deviations formulation. SMOG assumes the curve goes through the first point.

C. USE OF LINEAR PROGRAM

The linear programming code used for two-dimensional curves on the 1620 computer was obtained from the 1620 Users Group. The code^{*} is far from ideal, since it contains many compromises in order to fit on the smallest 1620 available. It is, however, easily obtainable free of charge. There is a proprietary code written by Bonner & Moore Associates, which may be more efficient.

D. USE OF THE EQUATION

The coefficients obtained from the LP may be directly entered into the next phase after punching on cards in the proper format. These, together with the hull equation, enable the height and half-breadths of the intersections to be obtained.

* 1620 Users Group Program 10.0.006

Section VI

CALCULATION OF BASIC DATA OF HULL FORM (STEP 5)

The determination of the basic data necessary to check the surface equation and to construct the ship is accomplished by a FORTRAN II program for the IBM-1620. This program is called GOBACK (the program reverses the fairing procedure and "goes back" to offsets). GOBACK is documented in Appendix D.

The program solves the surface equation for the following kinds of data:

- Offsets along any waterline or station (not necessarily the original waterlines or stations) at any interval desired

- Slopes and curvatures at any given interval along any waterline or station

- Offsets along the intersection of the hull surface and any diagonal plane

- Offsets along any buttock line

- The coefficients of a Thielheimer equation for any waterline or station from the surface equation

- The coefficients for standard cubic equations along any waterline or station

- Offsets along any waterline or station at a variable interval, such that a straight line connecting each succeeding pair of points comes exactly at a given tolerance from the actual curve

- Heights and offsets of the intersection of the hull equation with curves described by equations developed in Step 4, or with any cubic, parabola, or straight line.

The data from this program is directly usable in the programs for developing other loft information which follow it.

Section VII

PREPARATION OF NUMERICAL CONTROL DATA (STEP 6)

In Step 5, one of the output choices from GOBACK was the standard cubic equations for each interval on any waterline or station. With certain alterations, this is the data necessary to describe the hull contours for the numerical control programs.

The necessary alterations are:

The fairing process is carried on entirely in feet and decimals thereof, while numerical control programs use inches. Therefore, the coefficients must be altered so that the independent variable can be entered in inches, and the dependent variable will be in inches.

The results of the fairing process are nearly always scaled in some amount. Numerical control programs work in full scale only. Therefore, the coefficients must be re-scaled.

The origin of the mathematically-lofted surface is often not at the point the numerical control programs require. Therefore, it must be possible to translate from one origin to the other.

A program has been written to make these alterations. This program accepts the output from GOBACK exactly as it is produced. In its present form, it produces data in such a format that it can be inserted directly into AUTOMAP* programs for parts definition. Program details are in Appendix E.

* See Programming System for Numerically Controlled Flame Cutting of Ships Parts - Operating Manual, Technical Report 5.0.0 (Vol. 4 of Final Report under Contract N00s-4427)

Section VIII

PLOTTING THE LINES DRAWINGS (STEP 7)

After obtaining the offsets from GOBACK, it is often desired to make a visual check on the fairness of the surface. For this purpose, a routine was written which uses the 1620 computer and a CalComp* plotter. This routine (Appendix F) accepts the output of GOBACK directly and plots stations, waterlines, or other curves as desired. While this program is written for a specific computer and plotter, the principles of operation would be the same for nearly any other computer-plotter combination.

* California Computer Products, Anaheim, California

Section IX

DETERMINATION OF OTHER LOFT DATA (STEP 8)

A. SHELL PLATE DEVELOPMENT

Using the offsets along sight edges and waterlines furnished by GOBACK, the shell plate development program furnishes the data for the flat plate patterns of the shell plate. This program is explained in Appendix G. The program will do one plate or an entire strake of plating at once. The output can be converted to numerical control input, manually plotted, or plotted by the computer using the plotting routine of Step 7. The data as punched can be entered directly into the plotting program.

When using plating developed by this program intermixed with plating developed manually, allowance must be made for a shift in seam location. This shift is fully explained in Appendix G of this report.

B. STRINGER DEVELOPMENT

Stringer plates differ from shell plates in that they have curvatures in the longitudinal direction only. That is, plates whose cross sections are straight lines but whose longitudinal edges are curves.

These plates are easily handled by the shell plate development program. It is necessary to provide a set of data describing the midline of the plate just as though a shellplate were involved. In the case of the stringer, this information is redundant, but it is needed for mechanical reasons.

C. FRAME AND PLATE BENDING OFFSETS

A program for computing the offsets for frame bending templates is presented in Appendix H. This program is equally applicable to computing offsets of plate bending templates.

The program requires an equation for the molded shape of the frame. It will furnish offsets for any portion of the frame described by the equation at any desired interval. The program accepts the equation in the form of a single standard cubic for each frame segment.

D. INNER HULL OFFSETS

Inner Hull contours of naval combatant ships, such as the DLG class, generally have the same characteristic as the outer hull contours. That is, the surface, or a large part of the surface, must be fair.

That part of the inner hull which has a fairness requirement can be faired by exactly the same methods as are used for the outer hull. Using Steps 1 through 8, the preliminary offsets are put through the same procedure as those for the hull itself.

E. INNER EDGE OF WEB FRAMES

In areas where the inner hull contours have not been faired, many web frames contain inner contours which are related to the outer hull contour. This relation is often a so-called "linear taper." The offset between the two curves is given at the upper and lower ends of the part, and the intermediate offsets are assumed to vary in a linear manner.

A program has been written to produce this taper. It is presented

in Appendix I. The program uses points describing the outer hull contours and the upper and lower offset. It then finds points describing the shape of the inner hull contour.

F. DECK CAMBER OFFSETS

In Appendix J, a program for defining decks is given. This program calculates the vertical offsets from a horizontal plane at a distance equal to the molded depth above the baseline plane, to the deck for several configurations. These are:

Straight line sheer and straight line camber

Straight line sheer and parabolic camber

Parabolic sheer and straight line camber

Parabolic sheer and parabolic camber

Offsets can be obtained at any desired transverse interval at each frame.

Appendix A

SMOOTHING ROUTINES

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Appendix A

SMOOTHING ROUTINES

There are two smoothing programs. One is for two-dimensional curves and the other is for matrices of offsets describing a surface.

The three-dimensional (3-D) smoothing routine is the same as the two-dimensional (2-D) routine with an added iteration routine. The iterating routine smooths the points in one direction (waterlines) making necessary corrections, then smooths the points in the other direction (stations), iterating between the two directions until no further changes are required in the points. Several iterations may be required, of course, since a change in offset while smoothing in one direction may cause bad points in the other direction.

On any given curve, a change in offset will be made if, in the middle of a string of second differences of one sign, a single second difference of the opposite sign is found. If a single second difference of the opposite sign on either end of a curve is found, it will not be changed. Since the character of the curve cannot be examined beyond this point, the sign must be assumed to be legitimate, as indeed it may well be. The conditions just described are illustrated below:

○ Only these points will be changed

```
+ - - - - ⊕ - - - -  
+ + + + ⊖ + + + + -  
+ + + + - - - - + +  
+ + + - - + + + + -  
+ + ⊖ + + + ⊖ +
```

If the program finds a case such as follows

```
+ + + + + - + - + + + + +
```

it will terminate execution. There are several ways to change this set

to obtain a correct set of signs, and it will be possible to detect the correct one only by examining the lines drawing.

3-D SMOOTHING ROUTINE

This program is written in FORTRAN I for an IBM-1620 computer

a. Input Data

Symbols Used in the FORTRAN program:

MA = The number of waterlines contained in the data
NA = The number of stations contained in the data
WL(I) = The vertical distance Z_i from the origin of the data to waterline i
STA(J) = The horizontal distance X_j from the origin of the data to Station j
IASF = The number of feet in the offset ($Y_{i,j}$) when entered in feet, inches, and eighths form
IASI = The number of inches in the offset when entered in feet, inches, and eighths form
IASE = The number of eighth-inch intervals in the offset
ASET (I,J) = The offset ($Y_{i,j}$) when entered in decimal form after conversion from feet, inches and eighths

Header Card:

The data on this card consists of two fixed point numbers.
These numbers must be right justified in the data field.

<u>Variable</u>	<u>Format</u>	<u>Card Columns</u>
MA	2I5	1 - 5
NA		6 - 10

Offset Data Cards:

The remaining data consists of the locations of and values for the offsets. These offsets can, by an appropriate switch setting,

be read by the program in either feet and decimals of a foot form, or in feet, inches and eighths, similar to the preliminary table of offsets. The station and waterline coordinates are always in feet and decimal form.

This data consists of several subsets of data. - one subset for each waterline in the offset matrix. The first card in each subset contains the height of the waterline (Z_j). The remaining cards of the subset each contain a station location (X_i) and the offset at that point ($Y_{i,j}$). The card format, if the offset is entered in feet and decimals, is:

<u>Variable</u>	<u>Format</u>	<u>Card Columns</u>
First card of a subset:		
WL(I)	F10.4	1 - 10
Remaining cards of a subset		
STA(J)	2F10.4	{ 1 - 10 11 - 20
ASET(I,J)		

If the offset is entered in feet, inches, and eighths from the card, formats are:

<u>Variable</u>	<u>Format</u>	<u>Card Columns</u>
First card of a subset:		
WL(I)	F10.4	1 - 10
Remaining cards of a subset:		
STA(J)	F10.4	{ 1 - 10 11 - 15 16 - 20 21 - 25
ISAF		
ISAE	3I5	
ISAE		

b. Output

1. Typewriter messages

If the program successfully completes the smoothing of the points, the message, FAIRING COMPLETE, is typed.

At any time a bad point in the data is detected, the message
BAD POINT, WATERLINE = _____ STATION = _____
LIMITS = _____ to _____, NEW POINT = _____
is typed. The limits denote the boundaries on the value of
the bad offset for the proper sign of second difference. The
new point is the actual offset value chosen.

If the indeterminate case described earlier is found, the
following message is typed:

ADJACENT BAD POINTS

WATERLINE = _____ STATION = _____

2. Punched Cards

There is no output from this program if the input is smooth
without changes. If one or more offsets have been changed,
a complete set of data is punched in exactly the same format
as the decimal form of the input data.

c. Sense Switch Settings

SW 1 - OFF: Offsets are entered in feet and decimal form

SW 1 - ON : Offsets are entered in feet, inches, and eighths form

All other switches are ignored

SAMPLE DATA FOR 3-D SMOOTHING

Feet, Inches, and Eighths Form (Switch 1 ON)*

0 5 10 15 20 25 ← Card Columns

MA NA ISAF IASI IASE

7	5			
0.0	- WL(1)			
25.5	- STA(1)	1	0	0
51.0	- STA(2)	1	0	0
76.5		1	0	0
102.0		1	0	0
127.5		1	0	0
153.0		1	0	0
178.5		1	0	0
2.0	- WL(2)			
25.5	- STA(1)	4	0	3
51.0	- STA(2)	5	6	6
76.5		7	1	3
102.0		8	10	0
127.5		10	8	0
153.0		12	5	1
178.5		13	8	7
4.0				
25.5		5	8	0
51.0		7	10	0
76.5		10	0	3
102.0		12	4	2
127.5		14	7	6
153.0		16	7	1
178.5		18	0	2
8.0				
25.5		7	6	0
51.0		10	3	7
76.5		13	3	5
102.0		16	3	0
127.5		18	10	4
153.0		21	0	0
178.5		22	6	6
12.0				
25.5		8	5	1
51.0		11	9	3
76.5		15	2	0
102.0		18	4	1
127.5		20	0	7
153.0		23	2	7
178.5		24	9	2

Data for 3-D smoothing in decimal form (Switch 1 OFF) is exactly the same as the sample output shown on Pages A-6, A-7.

TYPEWRITER LISTING WHEN PROCESSING SAMPLE DATA

260000200003RS ← Clear Memory Instruction
 ENTER SUBROUTINES; PUSH START
 1620 FORTRAN SUBR. AUTO DIV 9/30/61
 LOAD DATA

BAD POINT, WATERLINE= 12.0000 STATION= 127.5000
 LIMITS- 20.7916 TO 21.5208 NEW POINT= 21.1562

FAIRING COMPLETE
 STOP

OUTPUT OBTAINED FROM PROCESSING SAMPLE DATA

7	5
.0000	
25.5000	1.0000
51.0000	1.0000
76.5000	1.0000
102.0000	1.0000
127.5000	1.0000
153.0000	1.0000
178.5000	1.0000
2.0000	
25.5000	4.0312
51.0000	5.5625
76.5000	7.1145
102.0000	8.8333
127.5000	10.6666
153.0000	12.4270
178.5000	13.7395
4.0000	
25.5000	5.6666
51.0000	7.8333
76.5000	10.0312
102.0000	12.3541
127.5000	14.6458
153.0000	16.5937
178.5000	18.0208
8.0000	
25.5000	7.5000
51.0000	10.3229
76.5000	13.3020

SAMPLE OUTPUT FROM 3-D SMOOTHING ROUTINE CONTINUED:

102.0000	16.2500
127.5000	18.8749
153.0000	21.0000
178.5000	22.5625
12.0000	
25.5000	8.4270
51.0000	11.7812
76.5000	15.1666
102.0000	18.3437
127.5000	21.1562
153.0000	23.2395
178.5000	24.7708

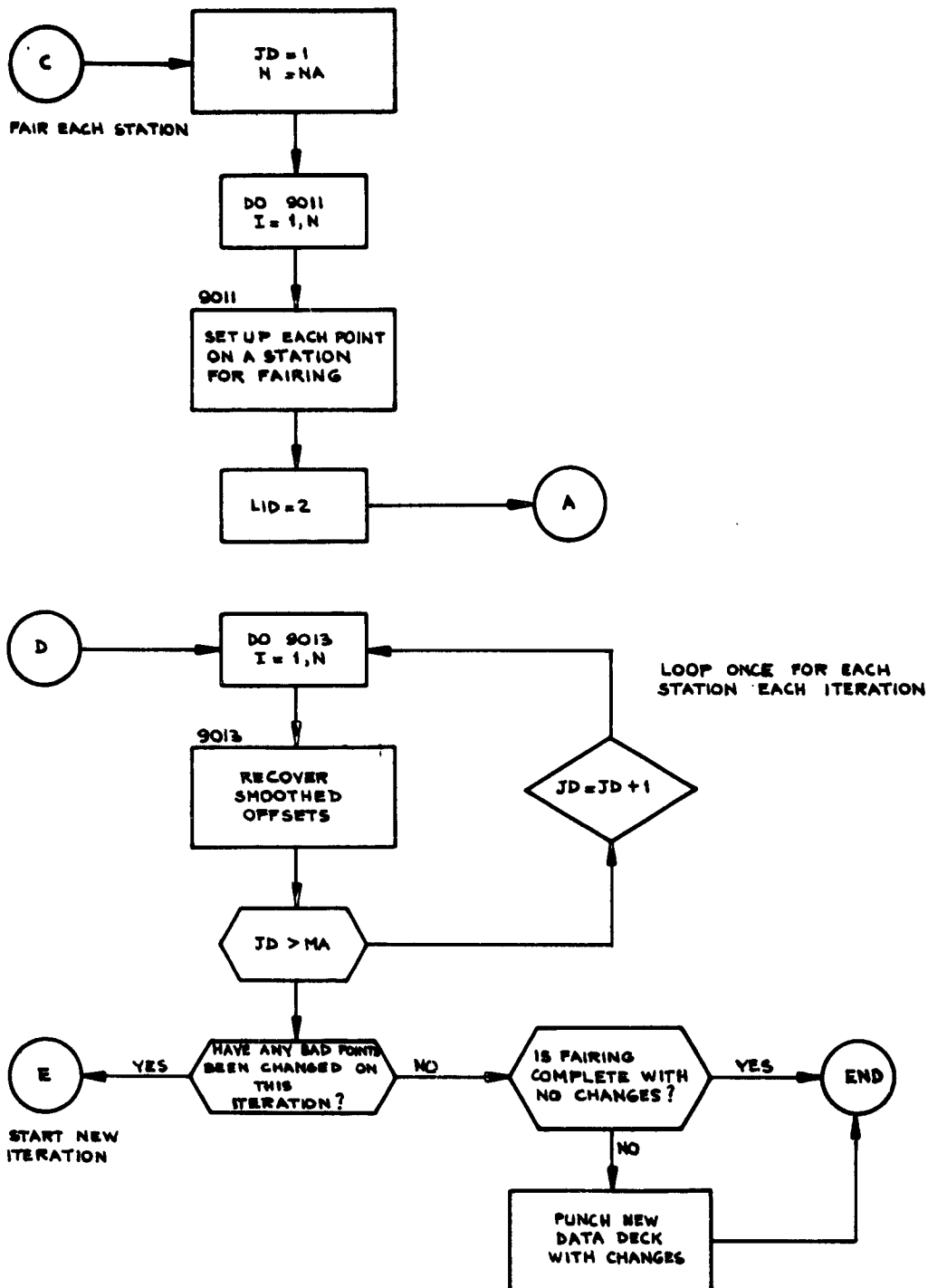
```

graph TD
    IN((IN)) --> READ[READ  
MA, NA]
    READ --> SENSE{IF  
SENSE SW 1}
    SENSE -- ON --> 9200[9200*  
INPUT LOOP  
FOR OFFSETS IN  
FT., IN., EIGHTS]
    SENSE -- OFF --> 9201[9201*  
INPUT LOOP  
FOR OFFSETS IN  
DECIMALS]
    9200 --> 9202[9202*  
CONVERT OFFSETS  
TO  
DECIMALS]
    9201 --> 9202
    9202 --> 9022[9022*  
ID = 1  
N = MA  
LID = 1]
    E((E)) --> 9022
    9022 --> 9008[9008*  
DO 9005  
J = 1, N]
    9008 --> 9005[9005*  
SET UP EACH  
POINT ON A  
WATERLINE FOR  
SMOOTHING]
    9005 --> A((A))
    9005 --> 9006[9006*  
DO 9007  
J = 1, N]
    B((B)) --> 9006
    9006 --> 9007[9007*  
RECOVER  
SMOOTHED  
OFFSETS]
    9007 --> 9008
    9007 --> 9009{ID = ID + 1}
    9009 --> 9008
    9009 --> 9010{ID > NA?}
    9010 -- YES --> C((C))
    9010 -- NO --> 9009
    
```

MA = NO. OF WATERLINES
NA = NO. OF STATIONS

LOOP ONCE FOR EACH WATERLINE ON EACH ITERATION

NUMBERS WITH * REFER TO FORTRAN STATEMENT NUMBERS





FORTRAN LISTING FOR 3-D SMOOTHING ROUTINE

```

C      3-D      POINT FAIRING PROGRAM SURFACE
      DIMENSION ASET(12,25),WL(12),STA(25),AY(30)
      DIMENSION RD(25),FSET(30),DEL(25),D(25)
      LAB=1
      READ 1901,MA,NA
      IF(SENSE SWITCH 1)9200,9110
9200  DO 9201 I=1,NA
      READ 9300,WL(I)
      DO 9201 J=1,MA
      READ 9300,STA(J),IASF,IASI,IASE
      ASF=IASF
      ASI=IASI
      ASE=IASE
9201  ASET(I,J)=ASF+ASI/12.+ASE/96.
      GO TO 9022
9300  FORMAT(F10.4,3I5)
9110  DO 9001 I=1,NA
      READ 1902,WL(I)
      DO 9001 J=1,MA
9001  READ 1902,STA(J),ASET(I,J)
9022  Z=0.
C      FAIR EACH WATERLINE
      ID=1
      LID=1
      N=MA
9008  DO 9005 J=1,N
      FSET(J)=ASET(ID,J)
9005  RD(J)=STA(J)
      ADE=WL(ID)
      GO TO 4000
9006  DO 9007 J=1,N
9007  ASET(ID,J)=FSET(J)
      ID=ID+1
      IF (ID-NA) 9008,9008,9009
9009  LID=LID+1
      Z=Z+ADE
      LAB=LAB+1
C      FAIR EACH STATION
      JD=1
      N=NA
9010  DO 9011 I=1,N
      FSET(I)=ASET(I,JD)
9011  RD(I)=WL(I)
      ADE=STA(JD)
      GO TO 4000
9012  DO 9013 I=1,N
9013  ASET(I,JD)=FSET(I)

```

```

      JD=JD+1
      IF (JD-MA) 9010,9010,9014
9014  IF (Z) 9017,9017,9019
9019  LAB=LAB+1
      GO TO 9022
C     NO CHANGES FO A COMPLETE CYCLE---FAIRING COMPLETE
9017  PRINT 1906
      IF (LAB-2) 9080,9018,9018
9018  PUNCH 1901,MA,NA
      DO 9100 I=1,NA
      PUNCH 1902,WL(I)
      DO 9100 J=1,MA
9100  PUNCH 1902,STA(J),ASET(I,J)
9080  STOP
1901  FORMAT (15,15,F11.6)
1902  FORMAT (2F10.4)
1906  FORMAT (///16HFAIRING COMPLETE)
C     MAIN PROGRAM
4000  R=0.
4001  BA=0.
      DO 4003 I=2,N
4003  D(I)=RD(I)-RD(I-1,
      K=N-1
4004  DO 4005 I=2,K
      DEL(I)=FSET(I)-(FSET(I+1)*D(I)+FSET(I-1)*D(I+1))/(D(I)+D(I+1))
4005  DEL(I)=SGN(DEL(I))
      KK=K-1
      DO 4020 I=3,KK
      IF (ABSF(DEL(I)-DEL(I-1)-DEL(I+1))-2.) 4019,4019,4007
4007  IF (BA) 4080,4008,4009
4008  UPSET=FSET(I)
      FSET(I)=99876.
      BA=1.
      GO TO 4020
4009  SA=(FSET(I+1)*D(I-1)+FSET(I-2)*(D(I+1)+D(I)))/(RD(I+1)-RD(I-2))
      SA=SGN(UPSET-SA)
      SC=(FSET(I+1)*(D(I)+D(I-1))+FSET(I-2)*D(I+1))/(RD(I+1)-RD(I-2))
      SC=SGN(FSET(I)-SC)
      SB=(FSET(I+2)*(D(I+1)+D(I))+UPSET*D(I+2))/(RD(I+2)-RD(I-1))
      SB=SGN(FSET(I+1)-SB)
      SD=(FSET(I)*D(I-2)+FSET(I-3)*(D(I)+D(I-1)))/(RD(I)-RD(I-3))
      SD=SGN(FSET(I-2)-SD)
      TA=DEL(I-2)+SB-SA
      TC=DEL(I+1)+SD-SC

```

```

R=R+1.
IF (ABSF(TA)-2.) 4014,4014,4015
4014 FSET(I-1)=UPSET
      DEL(I)=SB
      DEL(I+1)=SB
      FSET(1)=99876.
      BA=-1.
      GO TO 4020
4015 IF (ABSF(TC)-2.) 4017,4017,4080
4017 BA=-1.
      GO TO 4020
4080 IDD=I-1
      PRINT 1409
      GO TO (3101,3102),LID
3101 PRINT 1408,ADE,RD(I)
      STOP
3102 PRINT 1408,RD(I),ADE
      STOP
1409 FORMAT (/////19HADJACENT BAD POINTS)
1408 FORMAT (10HWATERLINE=,F8.4,10X,8HSTATION=,F9.4)
4019 BA=0.
4020 CONTINUE
      DO 4021 I=3,KK
      IF (FSET(I)-99876.) 4021,4092,4021
4092 SL=(FSET(I+1)*D(I)+FSET(I-1)*D(I+1))/(D(I+1)+D(I))
      SA=(FSET(I-1)*(D(I)+D(I-1))-FSET(I-2)*D(I))/D(I-1)-SL
      SB=(FSET(I+1)*(D(I+1)+D(I+2))-FSET(I+2)*D(I+1))/D(I+2)-SL
      IF (ABSF(SA)-ABSF(SB)) 4120,4120,4119
4119 SA=SB
4120 FSET(I)=SL+0.5*SA
      XUP=SL+SA
      XLOW=SL
      Z=Z+1.
      GO TO (3001,3002),LID
3001 PRINT 1003,ADE,RD(I)
      GO TO 3003
3002 PRINT 1003,RD(I),ADE
3003 CONTINUE
      PRINT 1004,XLOW,XUP,FSET(I)
4021 CONTINUE
      GO TO (9006,9012),LID
1003 FORMAT (/21HBAD POINT, WATERLINE=,F8.4,3X, 8HSTATION=,F9.4)
1004 FORMAT (7HLIMITS=,F12.4,4H TO,F12.4,5X,10HNEW POINT=,F12.4)
      END

```

2-D SMOOTHING ROUTINE

This program is written in FORTRAN I for an IBM-1620 computer. The program is exactly the same as the 3-D Smoothing, without the iterating routine. Thus it is equipped to handle just one curve at a time.

a. Input Data

Symbols Used in the FORTRAN program:

- N = Number of data points to define the curve
- RD(I) = Ordinate of the offset (X_1)
- IFSF = The number of feet in the offset (Y_1) when entered in feet, inches, and eighths form
- IFSI = The number of inches in the offset when entered in feet, inches, and eighths form
- IFSE = The number of eighths inches in the offset when entered in feet, inches, and eighths form
- FSET(I) = The offset (Y_1) when entered in decimal form or after conversion from feet, inches, and eighths

Header Card Format:

<u>Variable</u>	<u>Format</u>	<u>Card Columns</u>
N	I5	1 - 15

Offset Data Card Format:

N cards, the set of which must have one of the following formats:

<u>Variable</u>	<u>Format</u>	<u>Card Columns</u>
Sense Switch 1 ON:		
RD(I)	F10.4	1 - 10
IFSF	3I5	{ 11 - 15 16 - 20 21 - 25
IFSI		
IFSE		
Sense Switch 1 OFF:		
RD(I)	2F10.4	{ 1 - 10 11 - 20
FSET(I)		

b. Output

1. If the points are smooth without change, a halt with a **READER NO FEED** light will occur.
2. If any point needs change its location, the limits of the possible offset values and the selected offset value will be printed.
3. The indeterminate case described in the 3-D Writeup will cause the point numbers of the offending offsets and the word **STOP** to be printed on the typewriter.

c. Sense Switches

Same as 3-D Smoothing Program

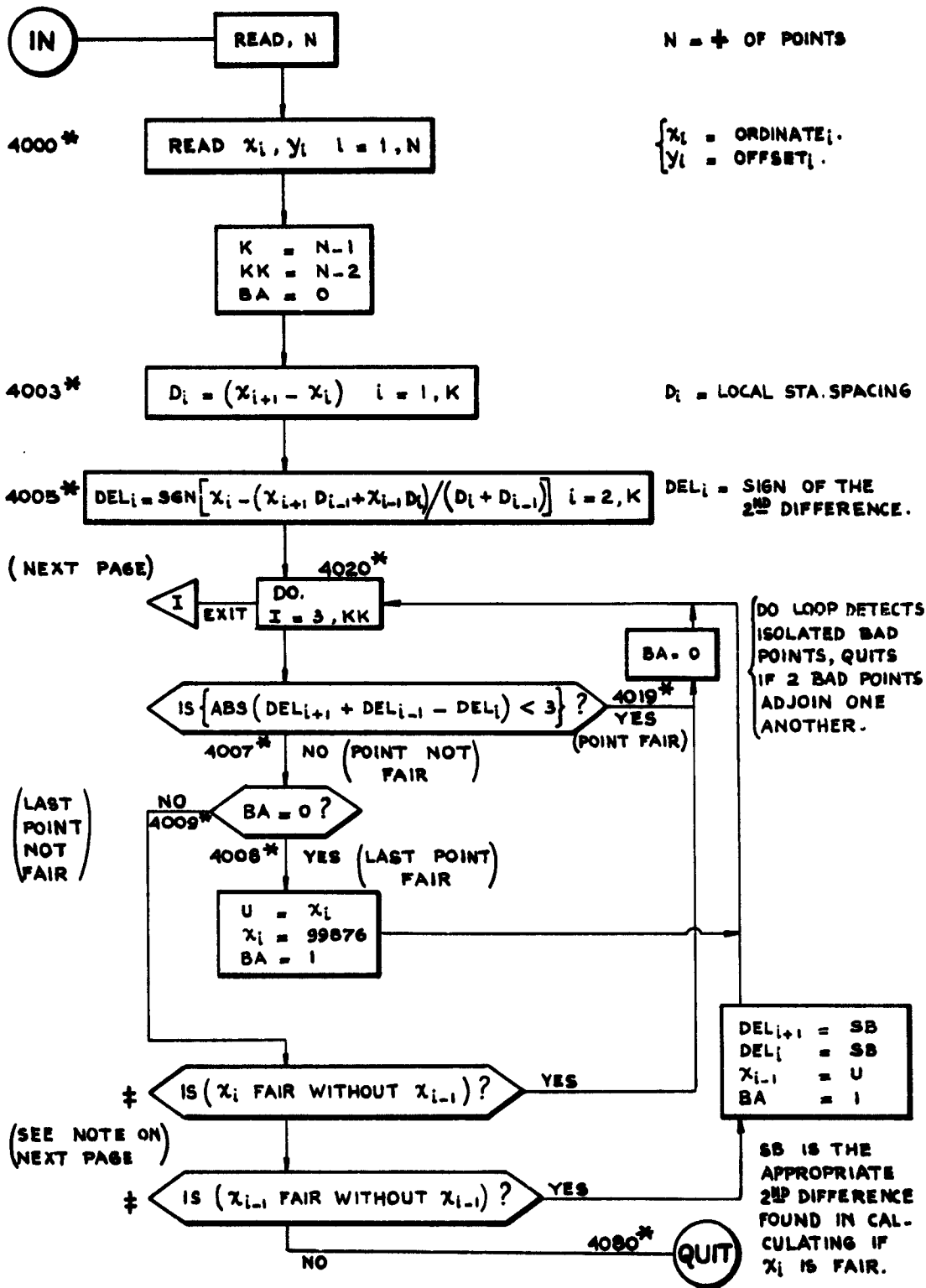
TYPEWRITER LISTING WHEN EXECUTING THE 2-D SMOOTHING PROGRAM

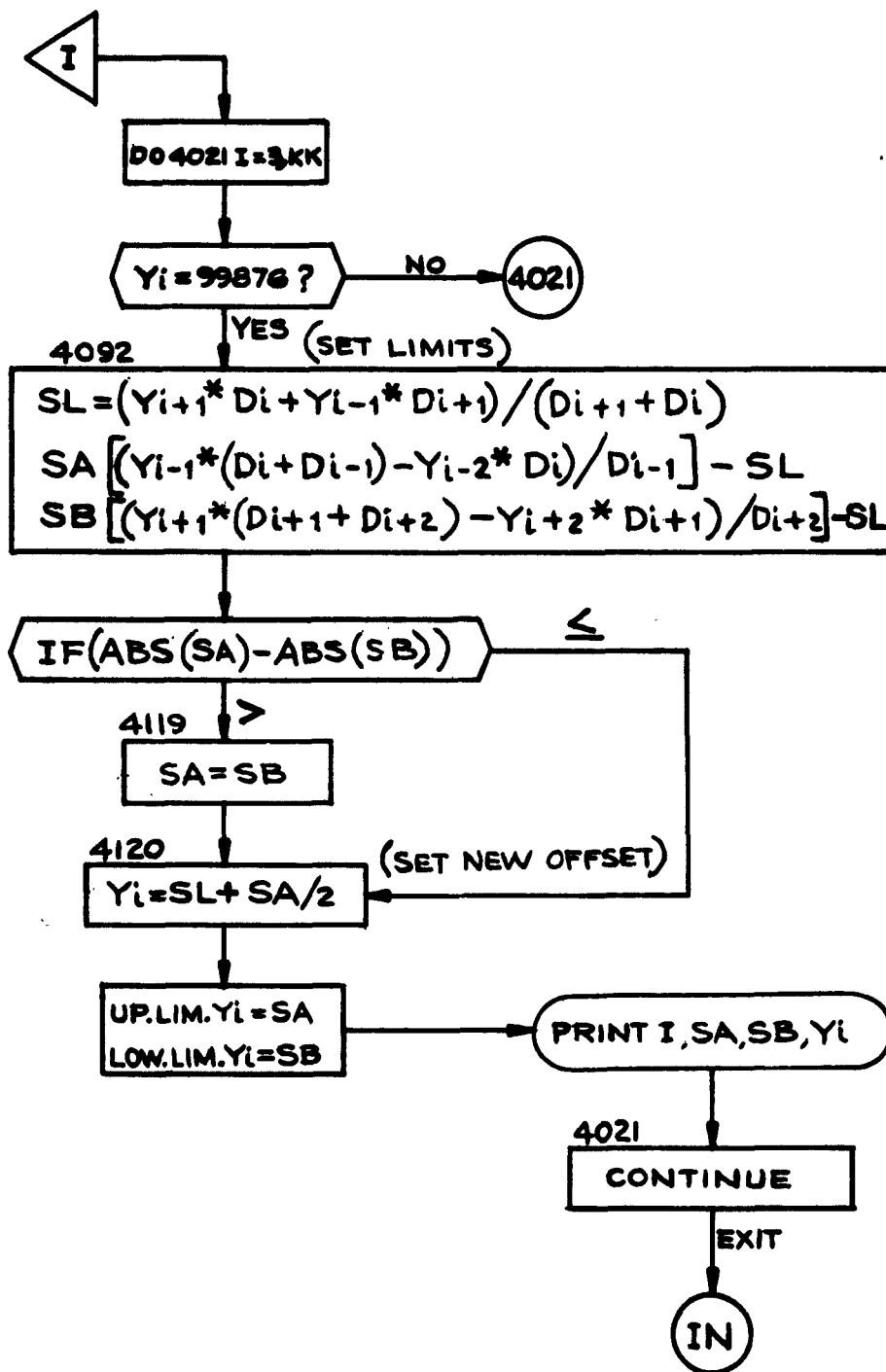
260000200003 ← Instruction for Clearing Memory
LOAD DATA
BAD POINT, STA= 25.5000
LIMITS= 20.7916 TO 21.5208 NEW POINT= 21.1562
STOP

SAMPLE INPUT DATA

7			
5.1	8	5	1
10.2	11	9	3
15.3	15	2	0
20.4	18	4	1
25.5	20	0	7
30.6	23	2	7
35.7	24	9	2

FLOW DIAGRAM FOR 2-D SMOOTHING ROUTINE





FORTAN LISTING FOR 2-D SMOOTHING ROUTINE

```

C   2-D          POINT FAIRING PROGRAM
      DIMENSION RD(20),FSET(20),D(20),DEL(20)
      READ 1001,N
      IF(SENSE SWITCH 1)9100,9000
9100 DO 9101 I=1,N
      READ 1005,RD(I),IFSF,IFSI,IFSE
      FSF=IFSF
      FSI=IFSI
      FSE=IFSE
9101 FSET(I)=FSF+FSI/12.+FSE/96.
      GO TO 4000
1005 FORMAT(F10.4,315)
9000 DO 1 I=1,N
1    READ 1002,RD(I),FSET(I)
4000 R=0.
4001 BA=0.
      DO 4003 I=2,N
4003 D(I)=RD(I)-RD(I-1)
      K=N-1
4004 DO 4005 I=2,K
      DEL(I)=FSET(I)-(FSET(I+1)*D(I)+FSET(I-1)*D(I+1))/(D(I)+D(I+1))
4005 DEL(I)=SGN(DEL(I))
      KK=K-1
      DO 4020 I=3,KK
      IF (ABS(DEL(I)-DEL(I-1)-DEL(I+1))-2.) 4019,4019,4007
4007 IF (BA) 4080,4008,4009
4008 UPSET=FSET(I)
      FSET(I)=99876.
      BA=1.
      GO TO 4020
4009 SA=(FSET(I+1)*D(I-1)+FSET(I-2)*(D(I+1)+D(I)))/(RD(I+1)-RD(I-2))
      SA=SGN(UPSET-SA)
      SC=(FSET(I+1)*(D(I)+D(I-1))+FSET(I-2)*D(I+1))/(RD(I+1)-RD(I-2))
      SC=SGN(FSET(I)-SC)
      SB=(FSET(I+2)*(D(I+1)+D(I))+UPSET*D(I+2))/(RD(I+2)-RD(I-1))
      SB=SGN(FSET(I+1)-SB)
      SD=(FSET(I)*D(I-2)+FSET(I-3)*(D(I)+D(I-1)))/(RD(I)-RD(I-3))
      SD=SGN(FSET(I-2)-SD)
      TA=DEL(I-2)+SB-SA
      TC=DEL(I+1)+SD-SC
      R=R+1.
      IF (ABS(TA)-2.) 4014,4014,4015
4014 FSET(I-1)=UPSET
      DEL(I)=SB
      DEL(I+1)=SD
      FSET(I)=99876.
      BA=-1.
      GO TO 4020
4015 IF (ABS(TC)-2.) 4017,4017,4080
4017 BA=-1.

```

```

GO TO 4020
4080 1DD=1-1
      PRINT 1408,1DD,1
1408 FORMAT (12,12)
      STOP
4019 BA=0.
4020 CONTINUE
      DO 4021 I=3, KK
      IF (FSET(I)-99876.) 4021,4092,4021
4092 SL=(FSET(I+1)*D(I)+FSET(I-1)*D(I+1))/(D(I+1)+D(I))
      SA=(FSET(I-1)*(D(I)+D(I-1))-FSET(I-2)*D(I))/D(I-1)-SL
      SB=(FSET(I+1)*(D(I+1)+D(I+2))-FSET(I+2)*D(I+1))/D(I+2)-SL
      IF (ABS(SA)-ABS(SB)) 4120,4120,4119
4119 SA=SB
4120 FSET(I)=SL+0.5*SA
      XUP=SL+SA
      XLOW=SL
      PRINT 1003, RD(I)
      PRINT 1004, XLOW, XUP, FSET(I)
4021 CONTINUE
1001 FORMAT (15)
1002 FORMAT (2F10.4)
1003 FORMAT (15HBAD POINT, STA=,F10.4)
1004 FORMAT (7HLIMITS=,F12.4,4H TO,F12.4,5X,10HNEW POINT=,F12.4)
      STOP
      END

```

Appendix B

SMOG

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Section I

INTRODUCTION

The purpose of the SMOG programs is to generate the matrices necessary for input to the linear programming routine.

The specific use of each program presented in this Appendix is listed below.

SMOG 1 - A one pass program which generates a matrix for a surface without profile in the dual formulation and λ fit.

SMOG 2 - A two pass program which generates a matrix for a surface with profile in the dual formulation and λ fit. Pass 1 generates the deviation constraints; Pass 2 generates the curvature constraints.

SMOG 3 - A two pass program which generates a matrix for a surface with profile in the primal formulation and sum of the deviations fit. Pass 1 generates the deviation constraints; Pass 2 generates the curvature constraints.

SMOG 4 - A single pass program which generates a matrix for fairing a two-dimensional line with the primal formulation and λ fit, using the 1620 linear program

There is no requirement that the waterlines or stations used by this program be equally spaced. It is desirable because of the variation in size of the matrix elements produced, however, to have them as equally spaced as possible

SECOND DIFFERENCE EQUATIONS

The equation which is used to calculate the second differences is given below. The normalized values of the coordinates are used in finding these second differences.

For waterlines, the equation is:

$$SD_{i,j} = \frac{2}{(x_{j+1} - x_{j-1})} \left[\frac{y_{i,j+1} - y_{i,j}}{x_{j+1} - x_j} - \frac{y_{i,j} - y_{i,j-1}}{x_j - x_{j-1}} \right]$$

For stations, the equation is:

$$SD_{j,i} = \frac{2}{(z_{i+1} - z_{i-1})} \left[\frac{y_{j,i+1} - y_{j,i}}{z_{i+1} - z_i} - \frac{y_{j,i} - y_{j,i-1}}{z_i - z_{i-1}} \right]$$

NORMALIZING

The procedure for normalizing the x and z coordinates is given below. If the program establishes the normalizing and translating factors for the coordinates, these are found as follows:

$$S_x = x_1 - x_0 \quad T_x = x_0$$

$$S_z = z_1 - z_0 \quad T_z = z_0$$

Each x and z coordinate is then altered as follows:

$$x_j = \frac{x_j - T_x}{S_x}$$

$$z_i = \frac{z_i - T_z}{S_z}$$

If it is desired to scale and translate different amounts than this, the values S_x , T_x , S_z , and T_z may be read in.

OUTPUT DATA

The output data from each of the programs except SMOG 4 is in standard SHARE format. This is the accepted linear programming format established by the IBM 704, 7090 Users Group. Examples of each of the data cards punched by these programs is shown in Fig. B-1. Figure B-2 shows the organization of the data deck when ready for use with the linear program.

Column Number									
1	7	23	29	35	36	37	38	39	40
* PROBLEM HEADING HERE									
ROW ID									
OFFSET									
R 1									
BASIS									
C 1.0.0 R 1									
C 1.0.1 R 2									
MATRIX									
C 1 OFFSET - .X.X .X.X.X									
C 1 R 1 .X.X .X.X.X									
C 1 R 2 .X.X .X.X.X									
FIRST B									
R 1 .X.X .X.X									
R 2 .X.X .X.X									
E.O.F.									

Fig. B-1 LP/90 Card Formats
(SHARE Standard Format)

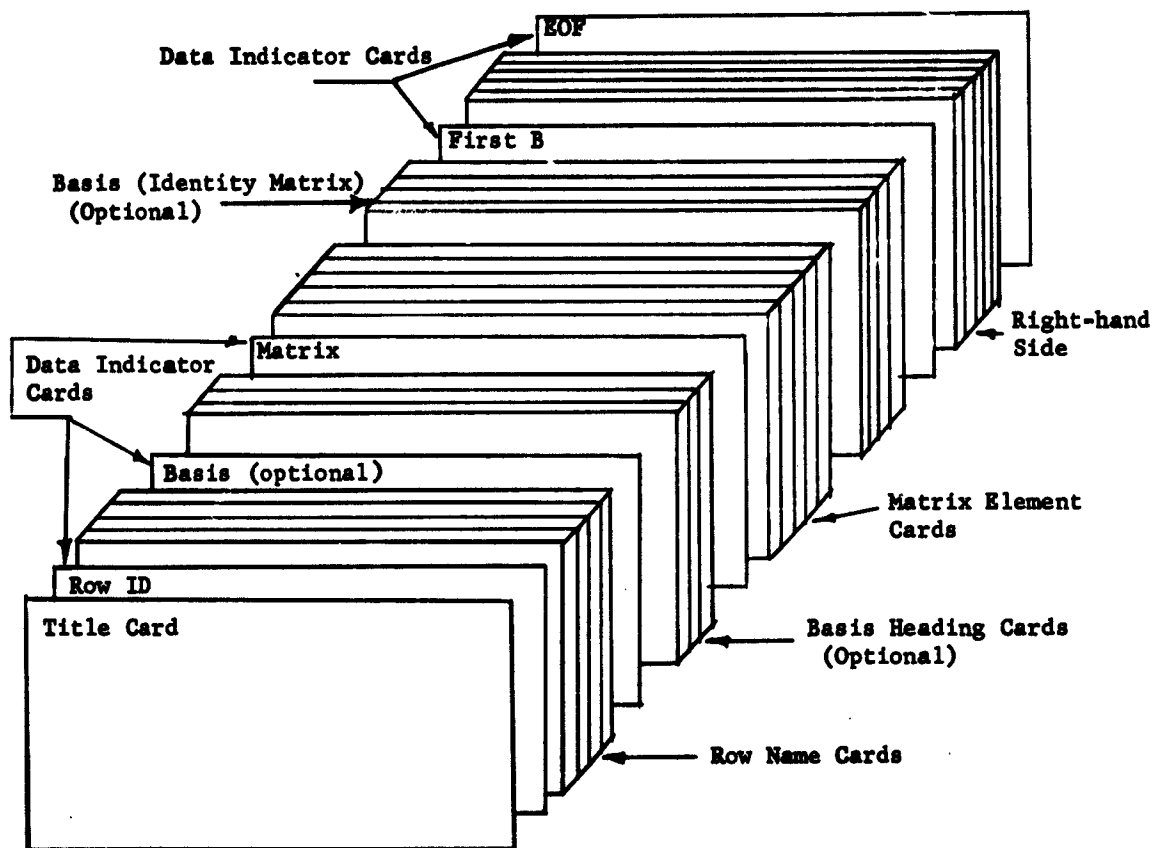


Fig. B-2 Input Card Order

Section II

SMOG 1 AND 2

The purpose of the programs, SMOG 1 and SMOG 2, is to generate the matrices required for surfaces with the following characteristics:

- (1) Dual formulation
- (2) λ (minimax fit)
- (3) Double splined in x direction
- (4) Single or double splined in the z direction

In addition, SMOG 2 produces a matrix with the modifications necessary for end profiles. The organization of each program is given in Fig. B-3.

The surface equation

Figure B-4 shows a five-station by five-waterline surface and the equation representing this surface. When producing a matrix to describe this problem to the linear program we must generate a requirement that the surface come close to each offset on the grid. The requirement is of the form

$$\left. \begin{array}{l} \text{(a)} \quad \lambda - Y(x_i, z_j) = -Y_{i,j} \\ \text{(b)} \quad \lambda + Y(x_i, z_j) = Y_{i,j} \end{array} \right\} \begin{array}{l} i = 1, \dots, N \\ j = 1, \dots, M \end{array}$$

One (a) and one (b) column (constraints are columns in the dual) are generated for each offset. For instance, offset (1,3) Fig. B-4, would have the requirements

$$\begin{array}{l} \text{(a)} \quad \lambda - A_{01}x_3 - A_{02}x_3^2 - A_{03}x_3^3 = -Y_{1,3} \\ \text{(b)} \quad \lambda + A_{01}x_3 + A_{02}x_3^2 + A_{03}x_3^3 = Y_{1,3} \end{array}$$

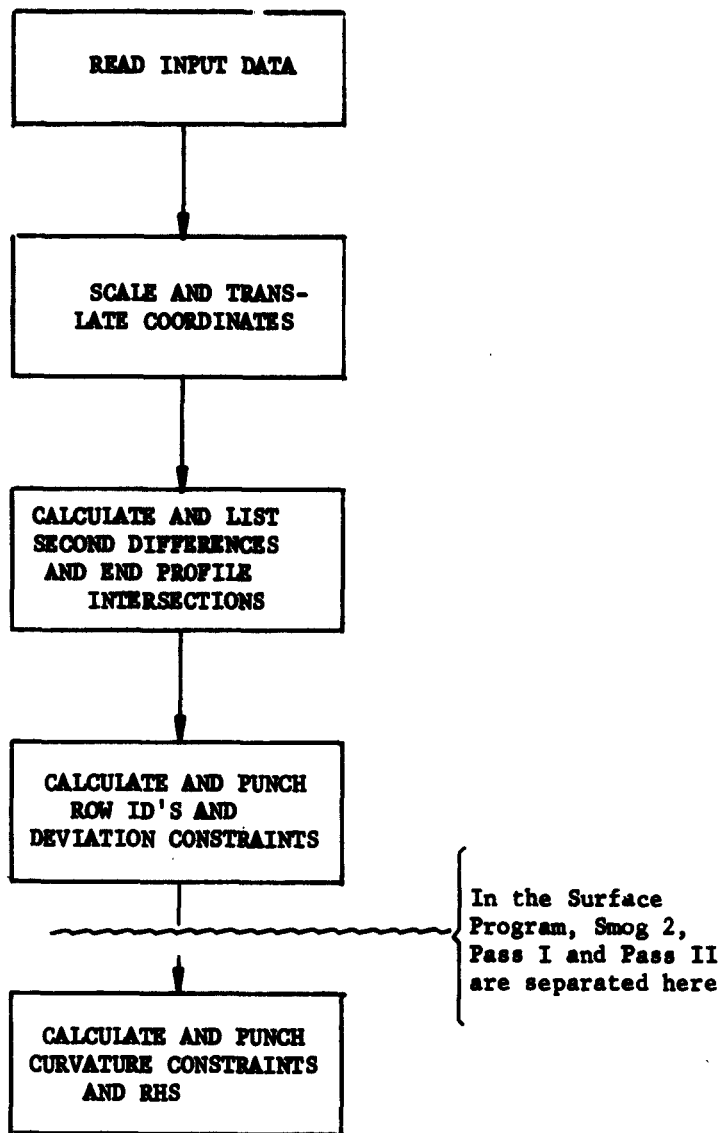
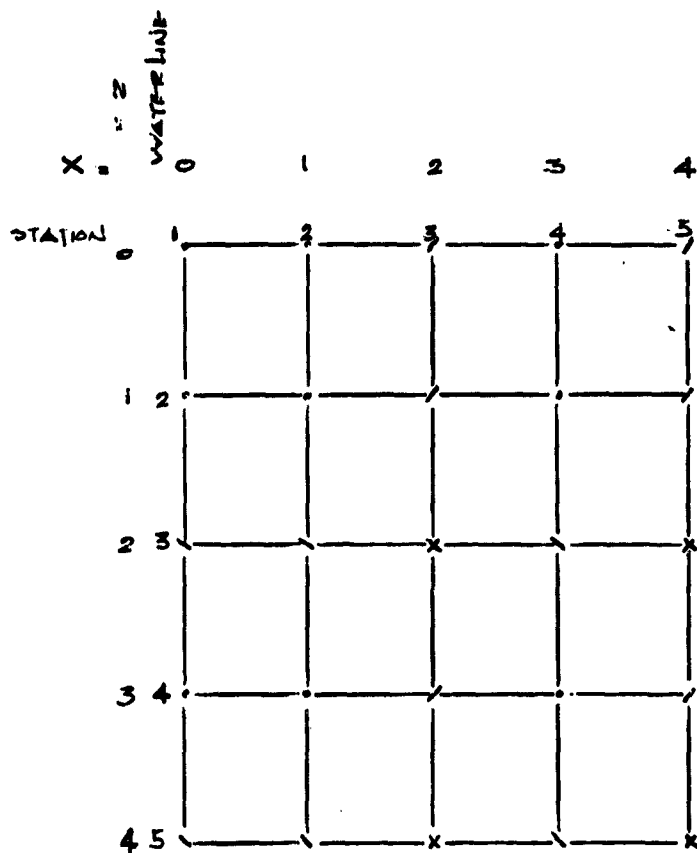


Fig. B-3 Organization of SMOG 1 and SMOG 2



$$\begin{aligned}
 Y = & A_{00} + A_{01}x + A_{02}x^2 + A_{03}x^3 + A_{04}(x-x_3)_{\#}^3 \\
 & + \left(A_{11}x + A_{12}x^2 + A_{13}x^3 + A_{14}(x-x_3)_{\#}^3 \right) z \\
 & + \left(A_{21}x + A_{22}x^2 + A_{23}x^3 + A_{24}(x-x_3)_{\#}^3 \right) z^2 \\
 & + \left(A_{31}x + A_{32}x^2 + A_{33}x^3 + A_{34}(x-x_3)_{\#}^3 \right) z^3 \\
 & + \left(A_{41}x + A_{42}x^2 + A_{43}x^3 + A_{44}(x-x_3)_{\#}^3 \right) (z-z_3)_{\#}^3
 \end{aligned}$$

- ✓ Points where the sign of the x curvature is enforced
- \ Points where the sign of the z curvature is enforced

Fig. B-4

The constant coefficient A_{00} is given the value of the offset (x_1, z_1) and is not included in the matrix. (The surface always goes through this offset, therefore A_{00} is known).

Similarly, the constraints for Point (3,3) are:

$$(a) \quad \lambda - \left[A_{01}x_3 + A_{02}x_3^2 + A_{03}x_3^3 \right] \\ - \left[A_{11}x_3 + A_{12}x_3^2 + A_{13}x_3^3 \right] z_3 \\ - \left[A_{21}x_3 + A_{22}x_3^2 + A_{23}x_3^3 \right] z_3^2 \\ - \left[A_{31}x_3 + A_{32}x_3^2 + A_{33}x_3^3 \right] z_3^3 = -Y(3,3)$$

$$(b) \quad \lambda + \left[A_{01}x_3 + A_{02}x_3^2 + A_{03}x_3^3 \right] \\ + \left[A_{11}x_3 + A_{12}x_3^2 + A_{13}x_3^3 \right] z_3 \\ + \left[A_{21}x_3 + A_{22}x_3^2 + A_{23}x_3^3 \right] z_3^2 \\ + \left[A_{31}x_3 + A_{32}x_3^2 + A_{33}x_3^3 \right] z_3^3 = Y(3,3)$$

There are also constraints on the sign of the curvature at certain of the offsets. These constraints have the following form where $\hat{r}_{i,j}$ and $\hat{\hat{r}}_{i,j}$ are the signs of the second differences found in Section I of this Appendix

$$(c) \quad \hat{r}_{i,j} \cdot Y''(x_i, z_j)_{zz} \geq 0$$

$$(d) \quad \hat{\hat{r}}_{i,j} \cdot Y''(x_i, z_j)_{xx} \geq 0$$

At Offset (1,3) there is a curvature constraint in the x direction only, as shown in Fig. B-4 .

$$(c) \quad \hat{r}_{1,j} (A_{02} - 3A_{03}x_3) \geq 0$$

There are x and z constraints both at offset (3,3) as follows:

$$(c) \quad \hat{r}_{1,j} \left[-A_{02} - 3A_{03}x_3 - (A_{02} + 3A_{03}x_3) z_3 - (A_{02} + 3A_{03}x_3) z_x^2 - (A_{02} + 3A_{03}x_3) z_3^3 \right] \geq 0$$

$$(d) \quad \hat{r}_{1,j} \left[- (A_{21}x_3 + A_{22}x_3^2 + A_{23}x_3^3) - (A_{21}x_3 + A_{22}x_3^2 + A_{23}x_3^3) 3z_3 \right] \geq 0$$

PROVIDING A BASIC FEASIBLE SOLUTION

It is often desirable, when fairing a surface in the dual, to provide the linear program with a basic feasible solution. This consists of an identity matrix of slacks as shown in Fig. B-5.

This identity matrix is produced by the program given in Appendix K. The program is furnished with the number of the last non-basis column and the number of rows in the non-basis matrix. It will then produce a set of basis headings and the identity matrix.

The set of basis headings are inserted in the dual matrix immediately following the row identifications. The identity matrix is placed just ahead of the first B card. This matrix can be produced by SMOG 1, and the actual listing of the matrix for a surface is included in Section III of this Appendix.

	$y_{1,2} - y_{1,2}$	$y_{1,3} - y_{1,3}$	$y_{1,3} - y_{1,3}$	...	0	...	0	...	0	
A_{01}	λ	λ	λ	λ	λ	λ	λ	λ	λ	C_{01}
A_{02}	$-x_1$	x_1	$-x_2$	$-x_2$	x_2	$-x_2$	x_2	$-x_2$	x_2	.
A_{03}	$-x_1^2$	x_1^2	$-x_2^2$	$-x_2^2$	x_2^2	$-x_2^2$	x_2^2	$-x_2^2$	x_2^2	.
A_{04}	$-x_1^3$	x_1^3	$-x_2^3$	$-x_2^3$	x_2^3	$-x_2^3$	x_2^3	$-x_2^3$	x_2^3	.
.	Deviation constraints (columns) Curvature constraints (columns) Identity Matrix (First Feasible Solution - Optional)									Cost Column
.										
.										

Fig. B-5 Matrix Tableau

Fig. B-5

SURFACE EQUATION WITH END PROFILE

In order to allow for end profiles on the surfaces, the surface equation $y = f(x,z)$ has been modified by multiplying it by a function T so that $y = f(x,z) \cdot T(x,z)$

where

$$(e) \quad T(x,z) = \left[1 - \left(\frac{D + G(z) - x}{D} \right)^r \right]^P$$

$G(z)$ is the two-dimensional Theilheimer equation of the profile mentioned in Section II-B of the report. The equation $G(x)$ must have the same origin and be scaled the same as the surface equation. D is the fraction of the station spacing over which the function is effective, and P determines if the slope of the surface at the bow is finite or infinite. The usual value for P is 1 for finite slope, 1/3 for infinite slope. The value of r is normally 3.

For any given value of x and z , when generating a matrix for a given surface $T(x,z)$ reduces to a number. Therefore, the deviation constraints can be modified in the following manner.

$$(a) \quad \lambda - Y(x_i, z_j) = \frac{Y_{1,1}}{T(x_i, z_j)}$$

$$(b) \quad \lambda + Y(x_i, z_j) = \frac{Y_{1,1}}{T(x_i, z_j)}$$

So the only modification necessary for producing deviation constraints is to divide the offset by the value of T . T is given the value one if the actual value is less than a given indicator.

The second derivative constraints modifications are more involved. The constraints are:

(1) for the x direction

$$\hat{r}_{1,j} \left[\frac{d^2}{dx^2} \left(f(x_1, z_j) \cdot T(x_1, z_j) \right) \right] \geq 0$$

(2) for the y direction

$$\hat{r}_{1,j} \left[\frac{d^2}{dz^2} \left(f(x_1, z_j) \cdot T(x_1, z_j) \right) \right] \geq 0$$

Using the rule for differentiating the product of two terms twice, these become:

$$(1) \quad \hat{r}_{1,j} \left[f(x_1, z_j) \cdot T''(x_1, z_j)_{xx} + 2 \left(T'(x_1, z_j)_x \cdot f'(x_1, z_j)_x \right) + T(x_1, z_j) \cdot f''(x_1, z_j)_{xx} \right] \geq 0$$

$$(2) \quad \hat{r}_{1,j} \left[f(x_1, z_j) \cdot T''(x_1, z_j)_{zz} + 2 \left(T'(x_1, z_j)_z \cdot f'(x_1, z_j)_z \right) + T(x_1, z_j) \cdot f''(x_1, z_j)_{zz} \right] \geq 0$$

These constraints are produced for the linear programming matrix by SMOG 2.

A. SMOG 1

OPERATING INSTRUCTIONS

This program produces a surface matrix without profile conditions in the dual formulation and λ fit. The surface will be double splined in the x direction and may be either single or double splined in the z direction. The program is written in FORTRAN II for an IBM-1620 computer.

Fortran Symbol Definitions

M	-	Total number of waterlines in the surface to be faired. This will be an odd number if the surface is double splined in the z direction.
N	-	Total number of stations in the surface. This will always be an odd number.
X(J)	-	Distance along the x axis from the origin of the surface to Station j .
Z(I)	-	Distance along the z axis from the origin of the surface to waterline i .
Y(I,J)	-	Offset of the surface at waterline i , station j , in feet and decimals
IAY	-	Number of feet in the offset if read in feet, inches and eighths.
IBY	-	Number of inches corresponding to IAY
ICY	-	Number of eighths corresponding to IAY
NAA	-	Program indicator If NAA = -1 scale factors for normalizing and translating X(J) and Z(I) are read in. If NAA = +1 scaling and translating are done by the program as given in Section I of this Appendix.
SX	-	Scale factor for X(J) when these are read in
TX	-	Translation factor for X(J) when these are read in
SZ	-	Scale factor for Z(I) when these are read in

- TZ - Translation factor for Z(I) when these are read in
- RHS - Right hand side - In the dual this is really the cost on the equation coefficients. The ideal value for RHS would be zero; however, this makes the solution susceptible to cycling so that a value of .0001 is usually used.
- CURV - Value of the requirement vector for the curvature constraints, this value actually goes in the cost row in the dual and is always made zero.
- NAB - Program indicator
- If NAB = -1 , the surface will be double splined in the z direction and M must be an odd number.
- If NAB = +1 , the surface will be single splined in the z direction and M is unrestricted.

Input

The input data cards are described below. There are certain input variables on which there are restrictions on the value which can be entered. These restrictions follow.

<u>Variable</u>	<u>Minimum No.</u>	<u>Maximum No.</u>
N	3	15
M	3	11

In describing the various data cards, the actual FORTRAN format field is used in most cases. These fields come consecutively across the card with no gaps or blank columns between, except where indicated. The field descriptions are the FORTRAN F field, which uses the FORTRAN fixed point decimal number, and the I field that uses the FORTRAN integer number, which is always right justified. The card numbers are not punched on the data cards.

<u>Contents of Card</u>					<u>Card No.</u>
Card Columns	1	2-12	13-53		1
Contents	*	Blank	Any alphameric problem heading (This heading will be used for identifying the problem on the LP output)		
Format Variable	I5 NAA	I5 NAB			2
Format Variable	I5 M	I5 N	F11.6 CURV	F11.6 RHS	3
Format Variable	F10.4 Z(I)				} N Cards per Group } Next M Groups
Alternate Cards:					
Format Variable	F10.4 X(J)	F10.4 Y(I,J)			
or:					
Format Variable	F10.4 X(J)	I5 IAY	I5 IBY	I5 ICY	

This arrangement can be stated as follows:

The first card of each set gives the height z of the waterline. The following cards each give a station coordinate and the offset at the intersection of the given waterline and station. There is one set of cards for each waterline in the surface.

Format Variable	F10.4 SX	F10.4 SZ	F10.4 TX	F10.4 TZ	Last card

(This card only used if $NAA = -1$)

Output

The output from this program is designed to be read directly by the LP-90 program after card to magnetic tape conversion.

The first card punched contains the Heading Read in the first input

card. The next set of cards are the row identification cards. These identify each row of the matrix to be used in this solution. For this matrix all of the rows are always used and identified, including the cost row which has the name "OFFSET."

After these comes a card punched "MATRIX," and then the input matrix to the linear program. The matrix is in column form with the rows in order within the column. Zero values are not punched.

The card formats are given in Fig. B-1. The order of the output data is shown graphically in Fig. B-2. The sample problem output shows exactly what the output data consists of.

Sense Switch Settings

Sense Switch 1 - Not used

Sense Switch 2 - ON The values of the x and z second differences and the resulting signs are printed

Sense Switch 2 - OFF The above is not printed

Sense Switch 3 - ON The offsets are read in as feet, inches and eighths

Sense Switch 3 - OFF The offsets are read in as feet and decimals

SAMPLE PROBLEM

The sample problem is a five-station by five-waterline set of offsets taken from the AG-88 class icebreaker. The stations used are Stations 13, 30, 32, 34, and 36 foot levels. The matrix is for an equation double splined in both the x and z directions.

SAMPLE PROBLEM FOR SMOG 1

INPUT

* 5X5 Z DOUBLE SPLINED AG-88 ICE BREAKER

1 -1

5 5 .000000 .0001

28.0000			
137.5000	30	3	0
150.0000	29	2	2
162.5000	27	6	4
175.0000	25	2	4
187.5	21	10	6
30.0000			
137.5000	30	7	5
150.0000	29	7	7
162.5000	28	2	5
175.0000	26	2	4
187.5000	23	3	5
32.0000			
137.5000	30	8	5
150.0000	29	10	4
162.5000	28	7	5
175.0000	26	10	4
187.5000	24	4	3
34.0000			
137.5000	30	8	3
150.0000	29	11	2
162.5000	28	10	5
175.0000	27	3	5
187.5000	25	1	7
36.0000			
137.5000	30	5	5
150.0000	29	10	4
162.5000	28	11	5
175.0000	27	6	6
187.5000	25	7	3

TYPEWRITER LISTING OF SECOND DIFFERENCES
(Sense Switch 2 ON)

Switch 2 OUTPUT

*

SX5 Z DOUBLE SPLINED AG-88 ICE BREAKER
2ND DIFF - WLINES

WL	STA	ACT VALUE	SIGN
1	2	-.003732	1.00
1	3	-.004400	1.00
1	4	-.006266	1.00
1	5	-.006266	1.00
2	2	-.002933	1.00
2	3	-.003666	1.00
2	4	-.005733	1.00
2	5	-.005733	1.00
3	2	-.002532	1.00
3	3	-.003334	1.00
3	4	-.004799	1.00
3	5	-.004799	1.00
4	2	-.001865	1.00
4	3	-.003400	1.00
4	4	-.003599	1.00
4	5	-.003599	1.00
5	2	-.001999	1.00
5	3	-.003200	1.00
5	4	-.003467	1.00
5	5	-.003467	1.00

2ND DIFF-STATIONS

STA	WL	ACT VALUE	SIGN
1	2	-.075525	1.00
1	3	-.026025	1.00
1	4	-.052100	1.00
1	5	-.052100	1.00
2	2	-.062525	1.00
2	3	-.039050	1.00
2	4	-.031250	1.00
2	5	-.031250	1.00
3	2	-.065100	1.00
3	3	-.041675	1.00
3	4	-.041675	1.00
3	5	-.041675	1.00
4	2	-.083350	1.00
4	3	-.059875	1.00
4	4	-.041650	1.00
4	5	-.041650	1.00
5	2	-.085925	1.00
5	3	-.067700	1.00
5	4	-.083350	1.00
5	5	-.083350	1.00

* SMDG 1
ROW ID

SX5 Z DOUBLE SPLINED AG-88 ICE BREAKER

OFSET
R 1
R 2
R 3
R 4
R 5
R 6
R 7
R 8
R 9
R 10
R 11
R 12
R 13
R 14
R 15
R 16
R 17
R 18
R 19
R 20
R 21
R 22
R 23
R 24
R 25

MATRIX

C	1	OFSET-	1.06260
C	1	R 1	1.0
C	1	R 2-	1.00000
C	1	R 3-	1.00000
C	1	R 4-	1.00000
C	2	OFSET	1.06260
C	2	R 1	1.0
C	2	R 2	1.00000
C	2	R 3	1.00000
C	2	R 4	1.00000
C	3	OFSET-	2.70840
C	3	R 1	1.0

1.0.0-2

B-21

1.0.0-2

C	3	R	2-	2.00000
C	3	R	3-	4.00000
C	3	R	4-	8.00000
C	4	OFSET		2.70840
C	4	R	1	1.0
C	4	R	2	2.00000
C	4	R	3	4.00000
C	4	R	4	8.00000
C	5	OFSET-		5.04170
C	5	R	1	1.0
C	5	R	2-	3.00000
C	5	R	3-	9.00000
C	5	R	4-	27.00000
C	5	R	5-	1.00000
C	6	OFSET		5.04170
C	6	R	1	1.0
C	6	R	2	3.00000
C	6	R	3	9.00000
C	6	R	4	27.00000
C	6	R	5	1.00000
C	7	OFSET-		8.35420
C	7	R	1	1.0
C	7	R	2-	4.00000
C	7	R	3-	16.00000
C	7	R	4-	64.00000
C	7	R	5-	8.00000
C	8	OFSET		8.35420
C	8	R	1	1.0
C	8	R	2	4.00000
C	8	R	3	16.00000
C	8	R	4	64.00000
C	8	R	5	8.00000
C	9	OFSET		.38540
C	9	R	1	1.0
C	9	R	6-	1.00000
C	9	R	11-	1.00000
C	9	R	16-	1.0 00
C	10	OFSET-		.38540
C	10	R	1	1.0
C	10	R	6	1.00000
C	10	R	11	1.00000

B-22

1.0.0-2

B-23

C	10	R	16	1.00000
C	11	OFFSET-		.59380
C	11	R	1	1.0
C	11	R	2-	1.00000
C	11	R	3-	1.00000
C	11	R	4-	1.00000
C	11	R	6-	1.00000
C	11	R	7-	1.00000
C	11	R	8-	1.00000
C	11	R	9-	1.00000
C	11	R	11-	1.00000
C	11	R	12-	1.00000
C	11	R	13-	1.00000
C	11	R	14-	1.00000
C	11	R	16-	1.00000
C	11	R	17-	1.00000
C	11	R	18-	1.00000
C	11	R	19-	1.00000
C	12	OFFSET		.59380
C	12	R	1	1.0
C	12	R	2	1.00000
C	12	R	3	1.00000
C	12	R	4	1.00000
C	12	R	6	1.00000
C	12	R	7	1.00000
C	12	R	8	1.00000
C	12	R	9	1.00000
C	12	R	11	1.00000
C	12	R	12	1.00000
C	12	R	13	1.00000
C	12	R	14	1.00000
C	12	R	16	1.00000
C	12	R	17	1.00000
C	12	R	18	1.00000
C	12	R	19	1.00000
C	13	OFFSET-		2.03130
C	13	R	1	1.0
C	13	R	2-	2.00000
C	13	R	3-	4.00000
C	13	R	4-	8.00000
C	13	R	6-	1.00000

1.0.0-2

13.24

C	13	R	7-	2.00000
C	13	R	8-	4.00000
C	13	R	9-	8.00000
C	13	R	11-	1.00000
C	13	R	12-	2.00000
C	13	R	13-	4.00000
C	13	R	14-	8.00000
C	13	R	16-	1.00000
C	13	R	17-	2.00000
C	13	R	18-	4.00000
C	13	R	19-	8.00000
C	14	OFFSET		2.03130
C	14	R	1	1.0
C	14	R	2	2.00000
C	14	R	3	4.00000
C	14	R	4	8.00000
C	14	R	6	1.00000
C	14	R	7	2.00000
C	14	R	8	4.00000
C	14	R	9	8.00000
C	14	R	11	1.00000
C	14	R	12	2.00000
C	14	R	13	4.00000
C	14	R	14	8.00000
C	14	R	15	1.00000
C	14	R	17	2.00000
C	14	R	18	4.00000
C	14	R	19	8.00000
C	15	OFFSET-		4.04170
C	15	R	1	1.0
C	15	R	2-	3.00000
C	15	R	3-	9.00000
C	15	R	4-	27.00000
C	15	R	5-	1.00000
C	15	R	6-	1.00000
C	15	R	7-	3.00000
C	15	R	8-	9.00000
C	15	R	9-	27.00000
C	15	R	10-	1.00000
C	15	R	11-	1.00000
C	15	R	12-	3.00000

1.0.0-2

C	15 R	13-	9.00000
C	15 R	14-	27.00000
C	15 R	15-	1.00000
C	15 R	16-	1.00000
C	15 R	17-	3.00000
C	15 R	18-	9.00000
C	15 R	19-	27.00000
C	15 R	20-	1.00000
C	16 OFFSET		4.04170
C	16 R	1	1.0
C	16 R	2	3.00000
C	16 R	3	9.00000
C	16 R	4	27.00000
C	16 R	5	1.00000
C	16 R	6	1.00000
C	16 R	7	3.00000
C	16 R	8	9.00000
C	16 R	9	27.00000
C	16 R	10	1.00000
C	16 R	11	1.00000
C	16 R	12	3.00000
C	16 R	13	9.00000
C	16 R	14	27.00000
C	16 R	15	1.00000
C	16 R	16	1.00000
C	16 R	17	3.00000
C	16 R	18	9.00000
C	16 R	19	27.00000
C	16 R	20	1.00000
C	17 OFFSET-		6.94800
C	17 R	1	1.0
C	17 R	2-	4.00000
C	17 R	3-	16.00000
C	17 R	4-	64.00000
C	17 R	5-	8.00000
C	17 R	6-	1.00000
C	17 R	7-	4.00000
C	17 R	8-	16.00000
C	17 R	9-	64.00000
C	17 R	10-	8.00000
C	17 R	11-	1.00000

B-25

1.0.0-2

B-26

C	17	R	12-	4.00000
C	17	R	13-	16.00000
C	17	R	14-	64.00000
C	17	R	15-	8.00000
C	17	R	16-	1.00000
C	17	R	17-	4.00000
C	17	R	18-	16.00000
C	17	R	19-	64.00000
C	17	R	20-	8.00000
C	18	OFFSET		6.94800
C	18	R	1	1.0
C	18	R	2	4.00000
C	18	R	3	16.00000
C	18	R	4	64.00000
C	18	R	5	8.00000
C	18	R	6	1.00000
C	18	R	7	4.00000
C	18	R	8	16.00000
C	18	R	9	64.00000
C	18	R	10	8.00000
C	18	R	11	1.00000
C	18	R	12	4.00000
C	18	R	13	16.00000
C	18	R	14	64.00000
C	18	R	15	8.00000
C	18	R	16	1.00000
C	18	R	17	4.00000
C	18	R	18	16.00000
C	18	R	19	64.00000
C	18	R	20	8.00000
C	19	OFFSET		.46870
C	19	R	1	1.0
C	19	R	6-	2.00000
C	19	R	11-	4.00000
C	19	R	16-	8.00000
C	20	OFFSET		.46870
C	20	R	1	1.0
C	20	R	6	2.00000
C	20	R	11	4.00000
C	20	R	16	8.00000
C	21	OFFSET		.37510

C	21	R	1	1.0
C	21	R	2-	1.00000
C	21	R	3-	1.00000
C	21	R	4-	1.00000
C	21	R	6-	2.00000
C	21	R	7-	2.00000
C	21	R	8-	2.00000
C	21	R	9-	2.00000
C	21	R	11-	4.00000
C	21	R	12-	4.00000
C	21	R	13-	4.00000
C	21	R	14-	4.00000
C	21	R	16-	8.00000
C	21	R	17-	8.00000
C	21	R	18-	8.00000
C	21	R	19-	8.00000
C	22	OFFSET		.37510
C	22	R	1	1.0
C	22	R	2	1.00000
C	22	R	3	1.00000
C	22	R	4	1.00000
C	22	R	6	2.00000
C	22	R	7	2.00000
C	22	R	8	2.00000
C	22	R	9	2.00000
C	22	R	11	4.00000
C	22	R	12	4.00000
C	22	R	13	4.00000
C	22	R	14	4.00000
C	22	R	16	8.00000
C	22	R	17	8.00000
C	22	R	18	8.00000
C	22	R	19	8.00000
C	23	OFFSET-		1.61460
C	23	R	1	1.0
C	23	R	2-	2.00000
C	23	R	3-	4.00000
C	23	R	4-	8.00000
C	23	R	6-	2.00000
C	23	R	7-	4.00000
C	23	R	8-	8.00000

1.0.0.7

B.27

1.0.0.2

B.28

C	23	R	9-	16.00000
C	23	R	11-	4.00000
C	23	R	12-	8.00000
C	23	R	13-	16.00000
C	23	R	14-	32.00000
C	23	R	16-	8.00000
C	23	R	17-	16.00000
C	23	R	18-	32.00000
C	23	R	19-	64.00000
C	24	OFFSET		1.61460
C	24	R	1	1.0
C	24	R	2	2.00000
C	24	R	3	4.00000
C	24	R	4	8.00000
C	24	R	6	2.00000
C	24	R	7	4.00000
C	24	R	8	8.00000
C	24	R	9	16.00000
C	24	R	11	4.00000
C	24	R	12	8.00000
C	24	R	13	16.00000
C	24	R	14	32.00000
C	24	R	16	8.00000
C	24	R	17	16.00000
C	24	R	18	32.00000
C	24	R	19	64.00000
C	25	OFFSET-		3.37510
C	25	R	1	1.0
C	25	R	2-	3.00000
C	25	R	3-	9.00000
C	25	R	4-	27.00000
C	25	R	5-	1.00000
C	25	R	6-	2.00000
C	25	R	7-	6.00000
C	25	R	8-	18.00000
C	25	R	9-	54.00000
C	25	R	10-	2.00000
C	25	R	11-	4.00000
C	25	R	12-	12.00000
C	25	R	13-	36.00000
C	25	R	14-	108.00000

C	25	R	15-	4.00000
C	25	R	16-	8.00000
C	25	R	17-	24.00000
C	25	R	18-	72.00000
C	25	R	19-	216.00000
C	25	R	20-	8.00000
C	26	OFFSET		3.37510
C	26	R	1	1.0
C	26	R	2	3.00000
C	26	R	3	9.00000
C	26	R	4	27.00000
C	26	R	5	1.00000
C	26	R	6	2.00000
C	26	R	7	6.00000
C	26	R	8	18.00000
C	26	R	9	54.00000
C	26	R	10	2.00000
C	26	R	11	4.00000
C	26	R	12	12.00000
C	26	R	13	36.00000
C	26	R	14	108.00000
C	26	R	15	4.00000
C	26	R	16	8.00000
C	26	R	17	24.00000
C	26	R	18	72.00000
C	26	R	19	216.00000
C	26	R	20	8.00000
C	27	OFFSET--		5.88550
C	27	R	1	1.0
C	27	R	2-	4.00000
C	27	R	3-	16.00000
C	27	R	4-	64.00000
C	27	R	5-	8.00000
C	27	R	6-	2.00000
C	27	R	7-	8.00000
C	27	R	8-	32.00000
C	27	R	9-	128.00000
C	27	R	10-	16.00000
C	27	R	11-	4.00000
C	27	R	12-	16.00000
C	27	R	13-	64.00000

1.0.0-2

B-29

C	27	R	14-	256.00000
C	27	R	15-	32.00000
C	27	R	16-	8.00000
C	27	R	17-	32.00000
C	27	R	18-	128.00000
C	27	R	19-	512.00000
C	27	R	20-	64.00000
C	28	OFSET		5.88550
C	28	R	1	1.0
C	28	R	2	4.00000
C	28	R	3	16.00000
C	28	R	4	64.00000
C	28	R	5	8.00000
C	28	R	6	2.00000
C	28	R	7	8.00000
C	28	R	8	32.00000
C	28	R	9	128.00000
C	28	R	10	16.00000
C	28	R	11	4.00000
C	28	R	12	16.00000
C	28	R	13	64.00000
C	28	R	14	256.00000
C	28	R	15	32.00000
C	28	R	16	8.00000
C	28	R	17	32.00000
C	28	R	18	128.00000
C	28	R	19	512.00000
C	28	R	20	64.00000
C	29	OFSET		.44790
C	29	R	1	1.0
C	29	R	6-	3.00000
C	29	R	11-	9.00000
C	29	R	16-	27.00000
C	29	R	21-	1.00000
C	30	OFSET		.44790
C	30	R	1	1.0
C	30	R	6	3.00000
C	30	R	11	9.00000
C	30	R	16	27.00000
C	30	R	21	1.00000
C	31	OFSET		.31260

1.0.0-2

B-80

C	31 R	1	1.0
C	31 R	2-	1.00000
C	31 R	3-	1.00000
C	31 R	4-	1.00000
C	31 R	6-	3.00000
C	31 R	7-	3.00000
C	31 R	8-	3.00000
C	31 R	9-	3.00000
C	31 R	11-	9.00000
C	31 R	12-	9.00000
C	31 R	13-	9.00000
C	31 R	14-	9.00000
C	31 R	16-	27.00000
C	31 R	17-	27.00000
C	31 R	18-	27.00000
C	31 R	19-	27.00000
C	31 R	21-	1.00000
C	31 R	22-	1.00000
C	31 R	23-	1.00000
C	31 R	24-	1.00000
C	32 OFFSET		.31260
C	32 R	1	1.0
C	32 R	2	1.00000
C	32 R	3	1.00000
C	32 R	4	1.00000
C	32 R	6	3.00000
C	32 R	7	3.00000
C	32 R	8	3.00000
C	32 R	9	3.00000
C	32 R	11	9.00000
C	32 R	12	9.00000
C	32 R	13	9.00000
C	32 R	14	9.00000
C	32 R	16	27.00000
C	32 R	17	27.00000
C	32 R	18	27.00000
C	32 R	19	27.00000
C	32 R	21	1.00000
C	32 R	22	1.00000
C	32 R	23	1.00000
C	32 R	24	1.00000

C	33	OFSET-	1.36460
C	33	R 1	1.0
C	33	R 2-	2.00000
C	33	R 3-	4.00000
C	33	R 4-	8.00000
C	33	R 6-	3.00000
C	33	R 7-	6.00000
C	33	R 8-	12.00000
C	33	R 9-	24.00000
C	33	R 11-	9.00000
C	33	R 12-	18.00000
C	33	R 13-	36.00000
C	33	R 14-	72.00000
C	33	R 16-	27.00000
C	33	R 17-	54.00000
C	33	R 18-	108.00000
C	33	R 19-	216.00000
C	33	R 21-	1.00000
C	33	R 22-	2.00000
C	33	R 23-	4.00000
C	33	R 24-	8.00000
C	34	OFSET	1.36460
C	34	R 1	1.0
C	34	R 2	2.00000
C	34	R 3	4.00000
C	34	R 4	8.00000
C	34	R 6	3.00000
C	34	R 7	6.00000
C	34	R 8	12.00000
C	34	R 9	24.00000
C	34	R 11	9.00000
C	34	R 12	18.00000
C	34	R 13	36.00000
C	34	R 14	72.00000
C	34	R 16	27.00000
C	34	R 17	54.00000
C	34	R 18	108.00000
C	34	R 19	216.00000
C	34	R 21	1.00000
C	34	R 22	2.00000
C	34	R 23	4.00000

C	34	R	24	8.00000
C	35	OFFSET-		2.94800
C	35	R	1	1.0
C	35	R	2-	3.00000
C	35	R	3-	9.00000
C	35	R	4-	27.00000
C	35	R	5-	1.00000
C	35	R	6-	3.00000
C	35	R	7-	9.00000
C	35	R	8-	27.00000
C	35	R	9-	81.00000
C	35	R	10-	3.00000
C	35	R	11-	9.00000
C	35	R	12-	27.00000
C	35	R	13-	81.00000
C	35	R	14-	243.00000
C	35	R	15-	9.00000
C	35	R	16-	27.00000
C	35	R	17-	81.00000
C	35	R	18-	243.00000
C	35	R	19-	729.00000
C	35	R	20-	27.00000
C	35	R	21-	1.00000
C	35	R	22-	3.00000
C	35	R	23-	9.00000
C	35	R	24-	27.00000
C	35	R	25-	1.00000
C	36	OFFSET		2.94800
C	36	R	1	1.0
C	36	R	2	3.00000
C	36	R	3	9.00000
C	36	R	4	27.00000
C	36	R	5	1.00000
C	36	R	6	3.00000
C	36	R	7	9.00000
C	36	R	8	27.00000
C	36	R	9	81.00000
C	36	R	10	3.00000
C	36	R	11	9.00000
C	36	R	12	27.00000
C	36	R	13	81.00000

C	36 R	14	243.00000
C	36 R	15	9.00000
C	36 R	16	27.00000
C	36 R	17	81.00000
C	36 R	18	243.00000
C	36 R	19	729.00000
C	36 R	20	27.00000
C	36 R	21	1.00000
C	36 R	22	3.00000
C	36 R	23	9.00000
C	36 R	24	27.00000
C	36 R	25	1.00000
C	37 OFFSET-		5.09380
C	37 R	1	1.0
C	37 R	2-	4.00000
C	37 R	3-	16.00000
C	37 R	4-	64.00000
C	37 R	5-	8.00000
C	37 R	6-	3.00000
C	37 R	7-	12.00000
C	37 R	8-	48.00000
C	37 R	9-	192.00000
C	37 R	10-	24.00000
C	37 R	11-	9.00000
C	37 R	12-	36.00000
C	37 R	13-	144.00000
C	37 R	14-	576.00000
C	37 R	15-	72.00000
C	37 R	16-	27.00000
C	37 R	17-	108.00000
C	37 R	18-	432.00000
C	37 R	19-	1728.00000
C	37 R	20-	216.00000
C	37 R	21-	1.00000
C	37 R	22-	4.00000
C	37 R	23-	16.00000
C	37 R	24-	64.00000
C	37 R	25-	8.00000
C	38 OFFSET		5.09380
C	38 R	1	1.0
C	38 R	2	4.00000

1.0.0-2

B-34

C	38 R	3	16.00000
C	38 R	4	64.00000
C	38 R	5	8.00000
C	38 R	6	3.00000
C	38 R	7	12.00000
C	38 R	8	48.00000
C	38 R	9	192.00000
C	38 R	10	24.00000
C	38 R	11	9.00000
C	38 R	12	36.00000
C	38 R	13	144.00000
C	38 R	14	576.00000
C	38 R	15	72.00000
C	38 R	16	27.00000
C	38 R	17	108.00000
C	38 R	18	432.00000
C	38 R	19	1728.00000
C	38 R	20	216.00000
C	38 R	21	1.00000
C	38 R	22	4.00000
C	38 R	23	16.00000
C	38 R	24	64.00000
C	38 R	25	8.00000
C	39 OFFSET		.21870
C	39 R	1	1.0
C	39 R	6-	4.00000
C	39 R	11-	16.00000
C	39 R	16-	64.00000
C	39 R	21-	8.00000
C	40 OFFSET-		.21870
C	40 R	1	1.0
C	40 R	6	4.00000
C	40 R	11	16.00000
C	40 R	16	64.00000
C	40 R	21	8.00000
C	41 OFFSET-		.37510
C	41 R	1	1.0
C	41 R	2-	1.00000
C	41 R	3-	1.00000
C	41 R	4-	1.00000
C	41 R	6-	4.00000

1.0.0-2

C	41	R	7-	4.00000
C	41	R	8-	4.00000
C	41	R	9-	4.00000
C	41	R	11-	16.00000
C	41	R	12-	16.00000
C	41	R	13-	16.00000
C	41	R	14-	16.00000
C	41	R	16-	64.00000
C	41	R	17-	64.00000
C	41	R	18-	64.00000
C	41	R	19-	64.00000
C	41	R	21-	8.00000
C	41	R	22-	8.00000
C	41	R	23-	8.00000
C	41	R	24-	8.00000
C	42	OFFSET	-37510	
C	42	R	1	1.0
C	42	R	2	1.00000
C	42	R	3	1.00000
C	42	R	4	1.00000
C	42	R	6	4.00000
C	42	R	7	4.00000
C	42	R	8	4.00000
C	42	R	9	4.00000
C	42	R	11	16.00000
C	42	R	12	16.00000
C	42	R	13	16.00000
C	42	R	14	16.00000
C	42	R	16	64.00000
C	42	R	17	64.00000
C	42	R	18	64.00000
C	42	R	19	64.00000
C	42	R	21	8.00000
C	42	R	22	8.00000
C	42	R	23	8.00000
C	42	R	24	8.00000
C	43	OFFSET	-1.28130	
C	43	R	1	1.0
C	43	R	2-	2.00000
C	43	R	3-	4.00000
C	43	R	4-	8.00000

B-36

C	43 R	6-	4.00000
C	43 R	7-	8.00000
C	43 R	8-	16.00000
C	43 R	9-	32.00000
C	43 R	11-	16.00000
C	43 R	12-	32.00000
C	43 R	13-	64.00000
C	43 R	14-	128.00000
C	43 R	16-	64.00000
C	43 R	17-	128.00000
C	43 R	18-	256.00000
C	43 R	19-	512.00000
C	43 R	21-	8.00000
C	43 R	22-	16.00000
C	43 R	23-	32.00000
C	43 R	24-	64.00000
C	44 OFFSET		1.28130
C	44 R	1	1.0
C	44 R	2	2.00000
C	44 R	3	4.00000
C	44 R	4	8.00000
C	44 R	6	4.00000
C	44 R	7	8.00000
C	44 R	8	16.00000
C	44 R	9	32.00000
C	44 R	11	16.00000
C	44 R	12	32.00000
C	44 R	13	64.00000
C	44 R	14	128.00000
C	44 R	16	64.00000
C	44 R	17	128.00000
C	44 R	18	256.00000
C	44 R	19	512.00000
C	44 R	21	8.00000
C	44 R	22	16.00000
C	44 R	23	32.00000
C	44 R	24	64.00000
C	45 OFFSET-		2.68750
C	45 R	1	1.0
C	45 R	2-	3.00000
C	45 R	3-	9.00000

C	45	R	4-	27.00000
C	45	R	5-	1.00000
C	45	R	6-	4.00000
C	45	R	7-	12.00000
C	45	R	8-	36.00000
C	45	R	9-	108.00000
C	45	R	10-	4.00000
C	45	R	11-	16.00000
C	45	R	12-	48.00000
C	45	R	13-	144.00000
C	45	R	14-	432.00000
C	45	R	15-	16.00000
C	45	R	16-	64.00000
C	45	R	17-	192.00000
C	45	R	18-	576.00000
C	45	R	19-	1728.00000
C	45	R	20-	64.00000
C	45	R	21-	8.00000
C	45	R	22-	24.00000
C	45	R	23-	72.00000
C	45	R	24-	216.00000
C	45	R	25-	8.00000
C	46	OFSET		2.68750
C	46	R	1	1.0
C	46	R	2	3.00000
C	46	R	3	9.00000
C	46	R	4	27.00000
C	46	R	5	1.00000
C	46	R	6	4.00000
C	46	R	7	12.00000
C	46	R	8	36.00000
C	46	R	9	108.00000
C	46	R	10	4.00000
C	46	R	11	16.00000
C	46	R	12	48.00000
C	46	R	13	144.00000
C	46	R	14	432.00000
C	46	R	15	16.00000
C	46	R	16	64.00000
C	46	R	17	192.00000
C	46	R	18	576.00000

C	46 R	19	1728.00000
C	46 R	20	64.00000
C	46 R	21	8.00000
C	46 R	22	24.00000
C	46 R	23	72.00000
C	46 R	24	216.00000
C	46 R	25	8.00000
C	47 OFSET-		4.63550
C	47 R	1	1.0
C	47 R	2-	4.00000
C	47 R	3-	16.00000
C	47 R	4-	64.00000
C	47 R	5-	8.00000
C	47 R	6-	4.00000
C	47 R	7-	16.00000
C	47 R	8-	64.00000
C	47 R	9-	256.00000
C	47 R	10-	32.00000
C	47 R	11-	16.00000
C	47 R	12-	64.00000
C	47 R	13-	256.00000
C	47 R	14-	1024.00000
C	47 R	15-	128.00000
C	47 R	16-	64.00000
C	47 R	17-	256.00000
C	47 R	18-	1024.00000
C	47 R	19-	4096.00000
C	47 R	20-	512.00000
C	47 R	21-	8.00000
C	47 R	22-	32.00000
C	47 R	23-	128.00000
C	47 R	24-	512.00000
C	47 R	25-	64.00000
C	48 OFSET		4.63550
C	48 R	1	1.0
C	48 R	2	4.00000
C	48 R	3	16.00000
C	48 R	4	64.00000
C	48 R	5	8.00000
C	48 R	6	4.00000
C	48 R	7	16.00000

1.0.0-2

B-89

C	48 R	8	64.00000
C	48 R	9	256.00000
C	48 R	10	32.00000
C	48 R	11	16.00000
C	48 R	12	64.00000
C	48 R	13	256.00000
C	48 R	14	1024.00000
C	48 R	15	128.00000
C	48 R	16	64.00000
C	48 R	17	256.00000
C	48 R	18	1024.00000
C	48 R	19	4096.00000
C	48 R	20	512.00000
C	48 R	21	8.00000
C	48 R	22	32.00000
C	48 R	23	128.00000
C	48 R	24	512.00000
C	48 R	25	64.00000
C	49 OFSET		0.00000
C	49 R	3-	1.00000
C	49 R	4-	6.00000
C	50 OFSET		0.00000
C	50 R	3-	1.00000
C	50 R	4-	12.00000
C	50 R	5-	6.00000
C	51 OFSET		0.00000
C	51 R	3-	1.00000
C	51 R	4-	6.00000
C	51 R	8-	1.00000
C	51 R	9-	6.00000
C	51 R	13-	1.00000
C	51 R	14-	6.00000
C	51 R	18-	1.00000
C	51 R	19-	6.00000
C	52 OFSET		0.00000
C	52 R	3-	1.00000
C	52 R	4-	12.00000
C	52 R	5-	6.00000
C	52 R	8-	1.00000
C	52 R	9-	12.00000
C	52 R	10-	6.00000

1.0.0-2

B-40

C	52 R	13-	1.00000
C	52 R	14-	12.00000
C	52 R	15-	6.00000
C	52 R	18-	1.00000
C	52 R	19-	12.00000
C	52 R	20-	6.00000
C	53	OFFSET	0.00000
C	53 R	3-	1.00000
C	53 R	4-	6.00000
C	53 R	8-	2.00000
C	53 R	9-	12.00000
C	53 R	13-	4.00000
C	53 R	14-	24.00000
C	53 R	18-	8.00000
C	53 R	19-	48.00000
C	54	OFFSET	0.00000
C	54 R	3-	1.00000
C	54 R	4-	12.00000
C	54 R	5-	6.00000
C	54 R	8-	2.00000
C	54 R	9-	24.00000
C	54 R	10-	12.00000
C	54 R	13-	4.00000
C	54 R	14-	48.00000
C	54 R	15-	24.00000
C	54 R	18-	8.00000
C	54 R	19-	96.00000
C	54 R	20-	48.00000
C	55	OFFSET	0.00000
C	55 R	3-	1.00000
C	55 R	4-	6.00000
C	55 R	8-	3.00000
C	55 R	9-	18.00000
C	55 R	13-	9.00000
C	55 R	14-	54.00000
C	55 R	18-	27.00000
C	55 R	19-	162.00000
C	55 R	23-	1.00000
C	55 R	24-	6.00000
C	56	OFFSET	0.00000
C	56 R	3-	1.00000

1.0.0-2

B-41

1.0.0-2

C	56 R	4-	12.00000
C	56 R	5-	6.00000
C	56 R	8-	3.00000
C	56 R	9-	36.00000
C	56 R	10-	18.00000
C	56 R	13-	9.00000
C	56 R	14-	108.00000
C	56 R	15-	54.00000
C	56 R	18-	27.00000
C	56 R	19-	324.00000
C	56 R	20-	162.00000
C	56 R	23-	1.00000
C	56 R	24-	12.00000
C	56 R	25-	6.00000
C	57 OFSET		0.00000
C	57 R	3-	1.00000
C	57 R	4-	6.00000
C	57 R	8-	4.00000
C	57 R	9-	24.00000
C	57 R	13-	16.00000
C	57 R	14-	96.00000
C	57 R	18-	64.00000
C	57 R	19-	384.00000
C	57 R	23-	8.00000
C	57 R	24-	48.00000
C	58 OFSET		0.00000
C	58 R	3-	1.00000
C	58 R	4-	12.00000
C	58 R	5-	6.00000
C	58 R	8-	4.00000
C	58 R	9-	48.00000
C	58 R	10-	24.00000
C	58 R	13-	16.00000
C	58 R	14-	192.00000
C	58 R	15-	96.00000
C	58 R	18-	64.00000
C	58 R	19-	768.00000
C	58 R	20-	384.00000
C	58 R	23-	8.00000
C	58 R	24-	96.00000
C	58 R	25-	48.00000

B-42

C	59	OFSET	0.00000
C	59	R 11-	1.00000
C	59	R 16-	6.00000
C	60	OFSET	0.00000
C	60	R 11-	1.00000
C	60	R 12-	1.00000
C	60	R 13-	1.00000
C	60	R 14-	1.00000
C	60	R 16-	6.00000
C	60	R 17-	6.00000
C	60	R 18-	6.00000
C	60	R 19-	6.00000
C	61	OFSET	0.00000
C	61	R 11-	1.00000
C	61	R 12-	2.00000
C	61	R 13-	4.00000
C	61	R 14-	8.00000
C	61	R 16-	6.00000
C	61	R 17-	12.00000
C	61	R 18-	24.00000
C	61	R 19-	48.00000
C	62	OFSET	0.00000
C	62	R 11-	1.00000
C	62	R 12-	3.00000
C	62	R 13-	9.00000
C	62	R 14-	27.00000
C	62	R 15-	1.00000
C	62	R 16-	6.00000
C	62	R 17-	18.00000
C	62	R 18-	54.00000
C	62	R 19-	162.00000
C	62	R 20-	6.00000
C	63	OFSET	0.00000
C	63	R 11-	1.00000
C	63	R 12-	4.00000
C	63	R 13-	16.00000
C	63	R 14-	64.00000
C	63	R 15-	8.00000
C	63	R 16-	6.00000
C	63	R 17-	24.00000
C	63	R 18-	96.00000

1.0.0-2

B-43

C	63	R	19-	384.00000
C	63	R	20-	48.00000
C	64	OFSET		0.00000
C	64	R	11-	1.00000
C	64	R	16-	12.00000
C	64	R	21-	6.00000
C	65	OFSET		0.00000
C	65	R	11-	1.00000
C	65	R	12-	1.00000
C	65	R	13-	1.00000
C	65	R	14-	1.00000
C	65	R	16-	12.00000
C	65	R	17-	12.00000
C	65	R	18-	12.00000
C	65	R	19-	12.00000
C	65	R	21-	6.00000
C	65	R	22-	6.00000
C	65	R	23-	6.00000
C	65	R	24-	6.00000
C	66	OFSET		0.00000
C	66	R	11-	1.00000
C	66	R	12-	2.00000
C	66	R	13-	4.00000
C	66	R	14-	8.00000
C	66	R	16-	12.00000
C	66	R	17-	24.00000
C	66	R	18-	48.00000
C	66	R	19-	96.00000
C	66	R	21-	6.00000
C	66	R	22-	12.00000
C	66	R	23-	24.00000
C	66	R	24-	48.00000
C	67	OFSET		0.00000
C	67	R	11-	1.00000
C	67	R	12-	3.00000
C	67	R	13-	9.00000
C	67	R	14-	27.00000
C	67	R	15-	1.00000
C	67	R	16-	12.00000
C	67	R	17-	36.00000
C	67	R	18-	108.00000

1.0.0.2

B-44

C 67 R 19- 324.00000
 C 67 R 20- 12.00000
 C 67 R 21- 6.00000
 C 67 R 22- 18.00000
 C 67 R 23- 54.00000
 C 67 R 24- 162.00000
 C 67 R 25- 6.00000
 C 68 OFFSET 0.00000
 C 68 R 11- 1.00000
 C 68 R 12- 4.00000
 C 68 R 13- 16.00000
 C 68 R 14- 64.00000
 C 68 R 15- 8.00000
 C 68 R 16- 12.00000
 C 68 R 17- 48.00000
 C 68 R 18- 192.00000
 C 68 R 19- 768.00000
 C 68 R 20- 96.00000
 C 68 R 21- 6.00000
 C 68 R 22- 24.00000
 C 68 R 23- 96.00000
 C 68 R 24- 384.00000
 C 68 R 25- 48.00000

FIRST B

R	1	2.0
R	2	.00010
R	3	.00010
R	4	.00010
R	5	.00010
R	6	.00010
R	7	.00010
R	8	.00010
R	9	.00010
R	10	.00010
R	11	.00010
R	12	.00010
R	13	.00010
R	14	.00010
R	15	.00010
R	16	.00010
R	17	.00010

1.0.0.2

B-45

.00010
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.00010
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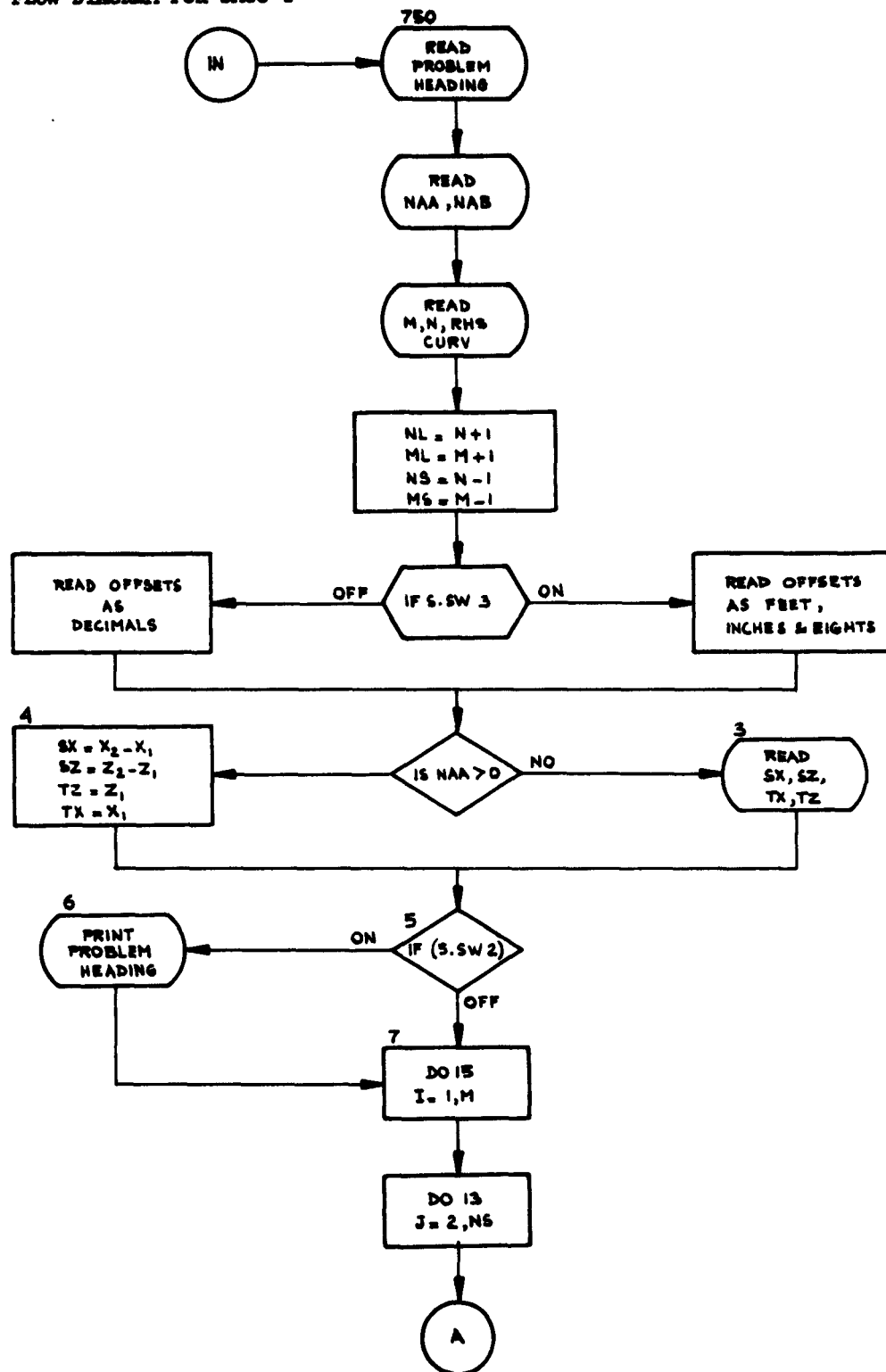
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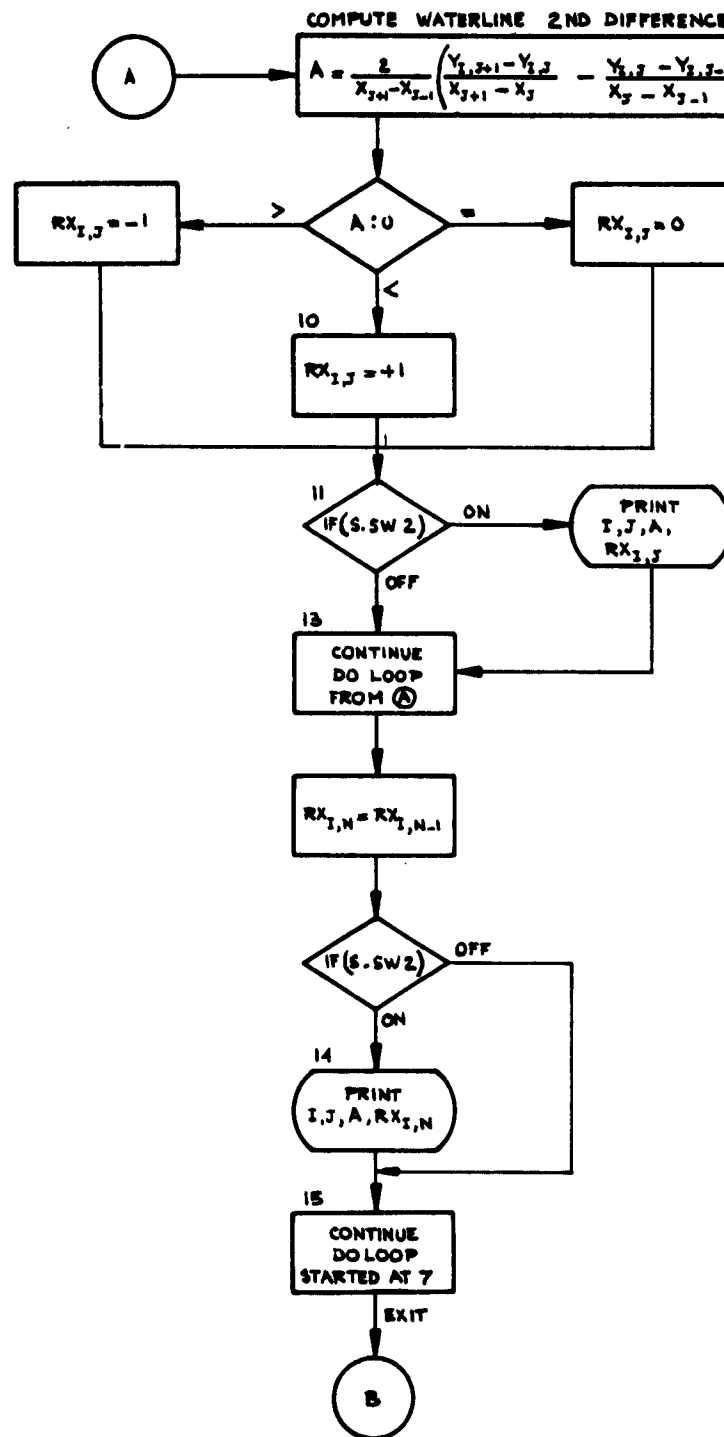
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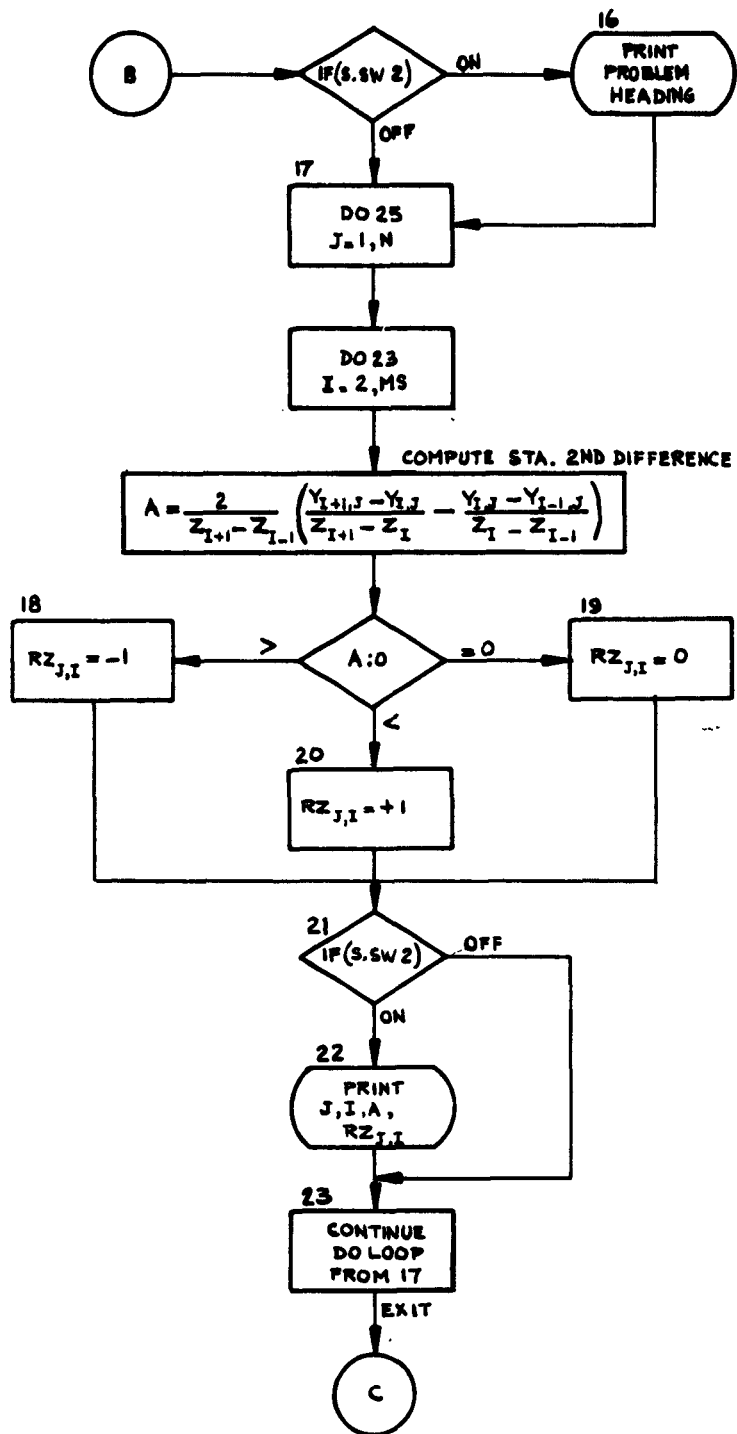
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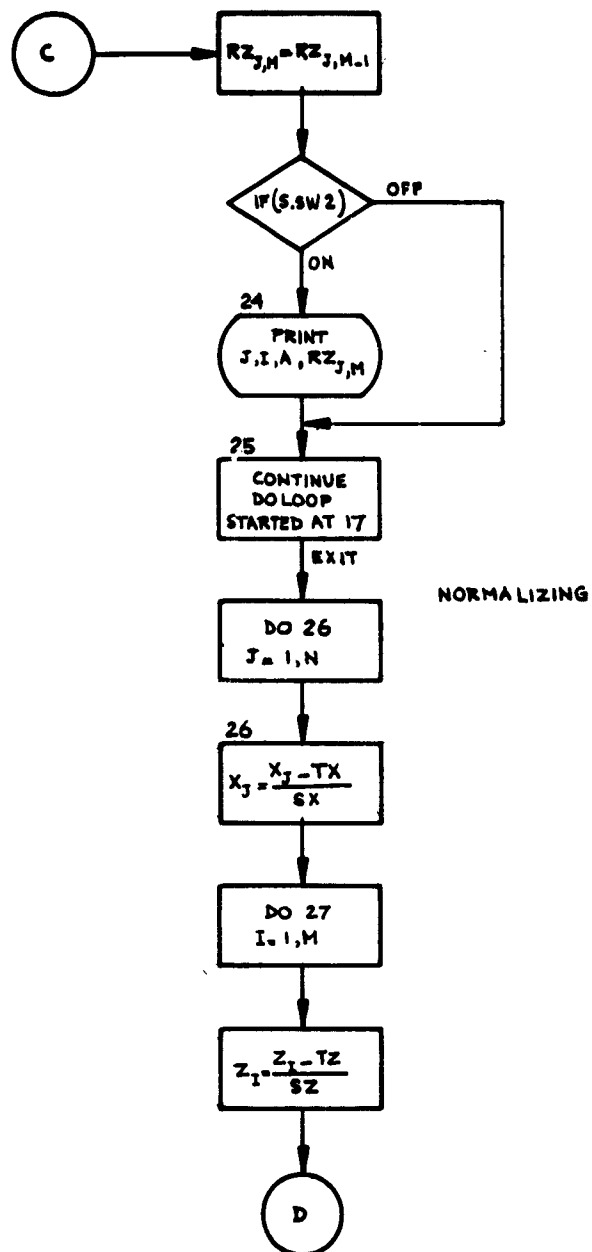
B.46

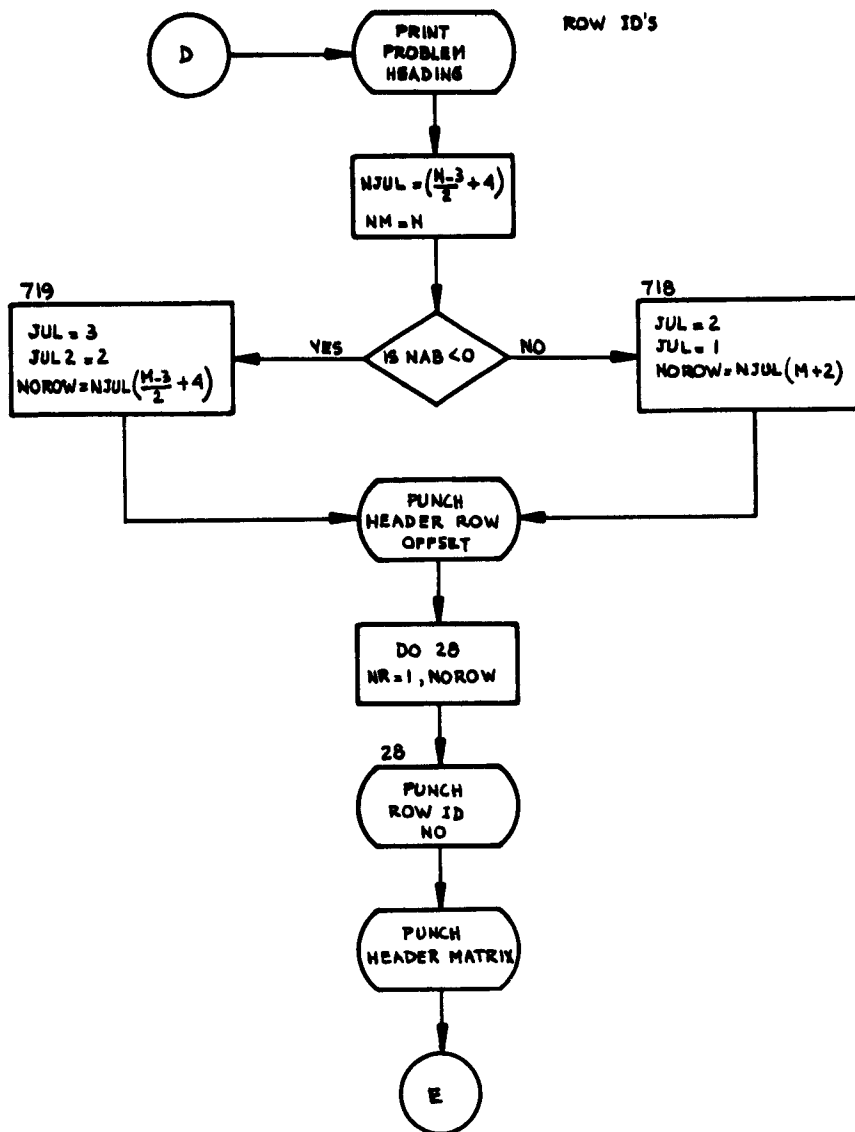
FLOW DIAGRAM FOR SMOG 1

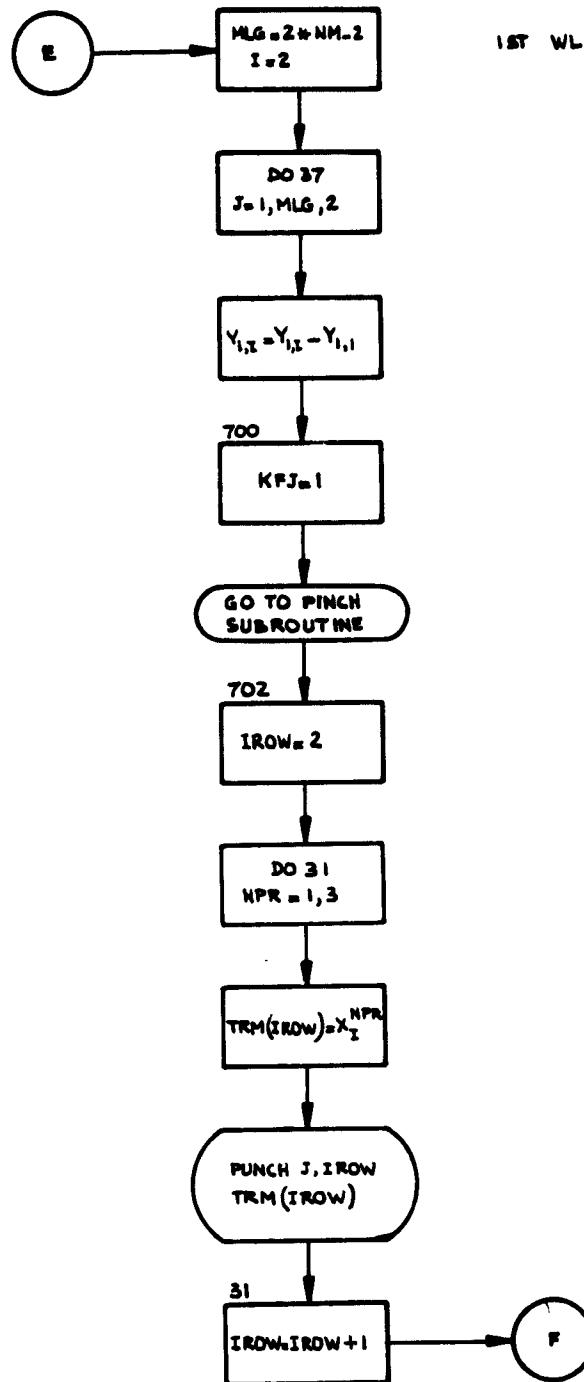


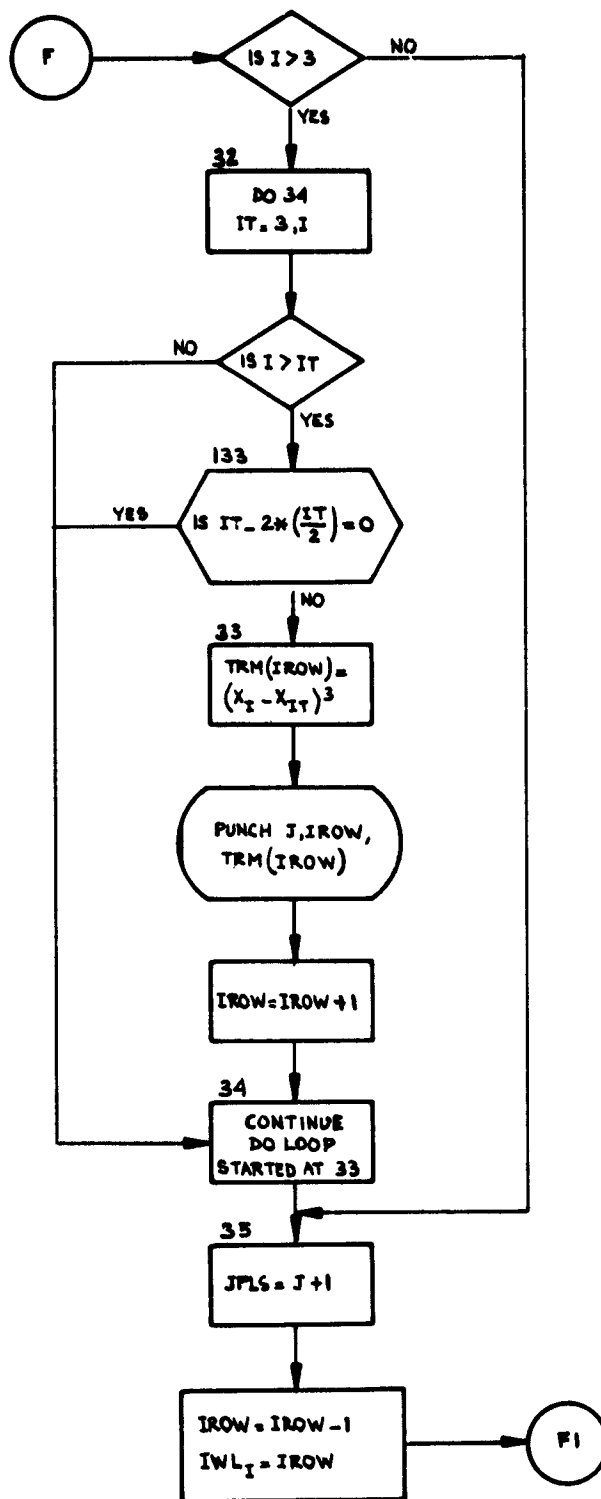


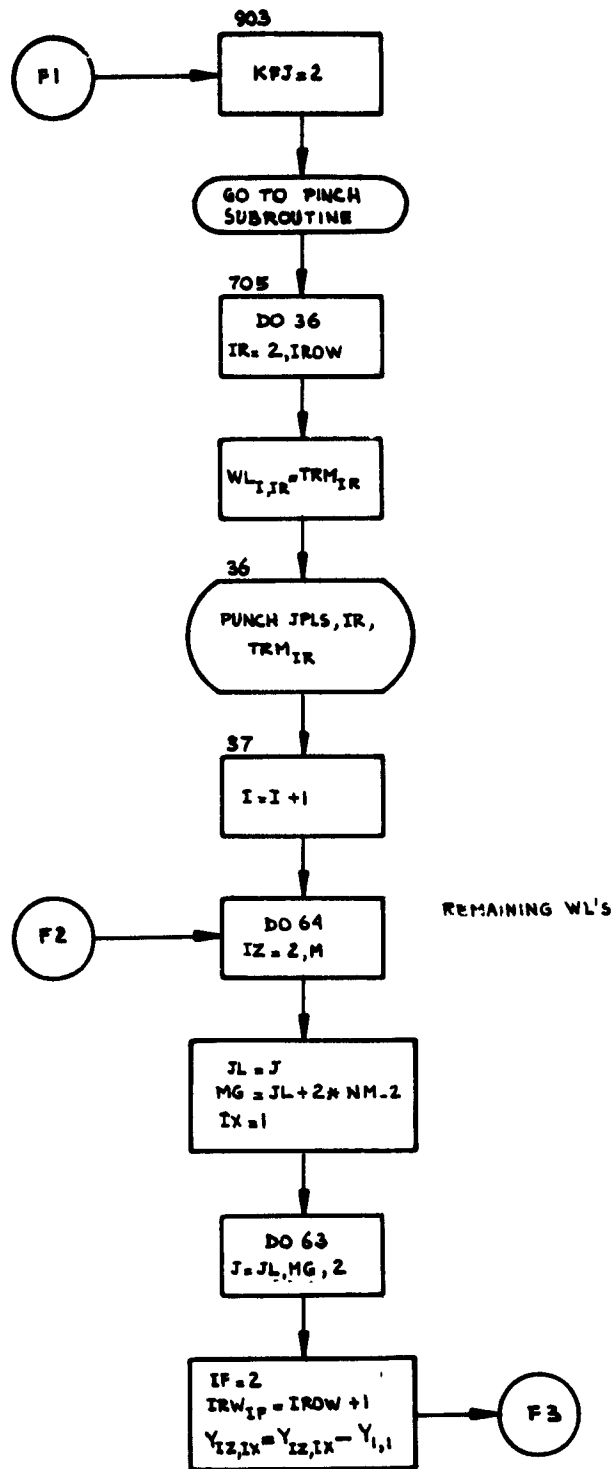


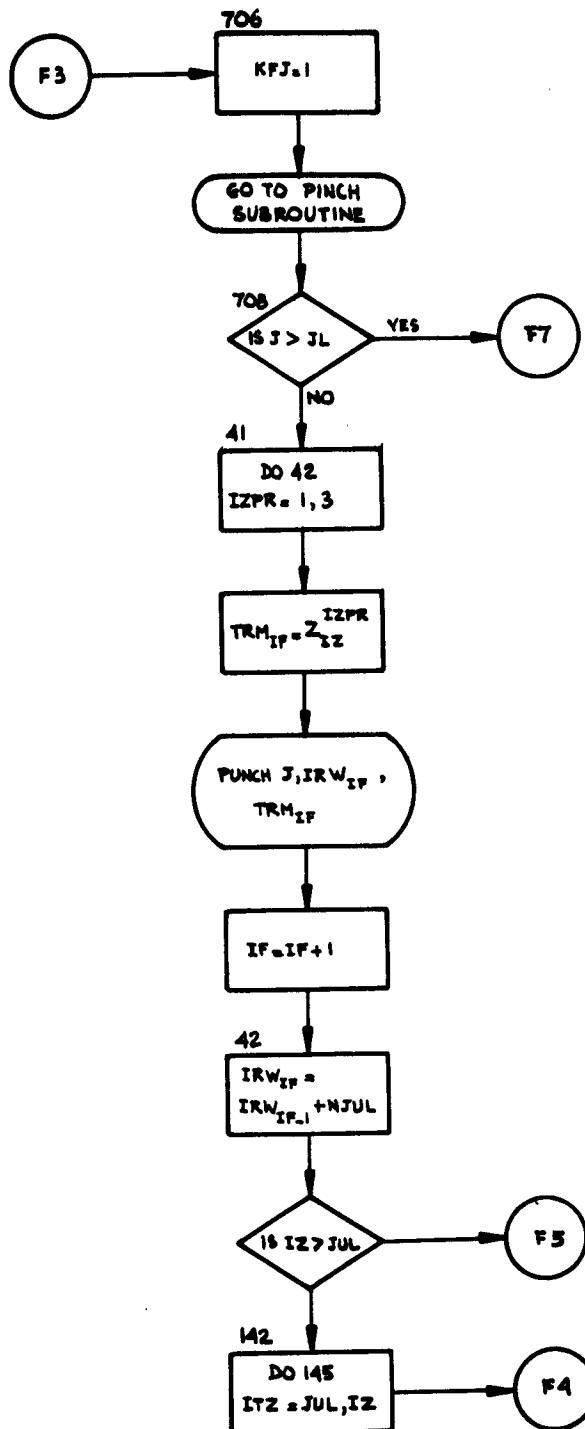


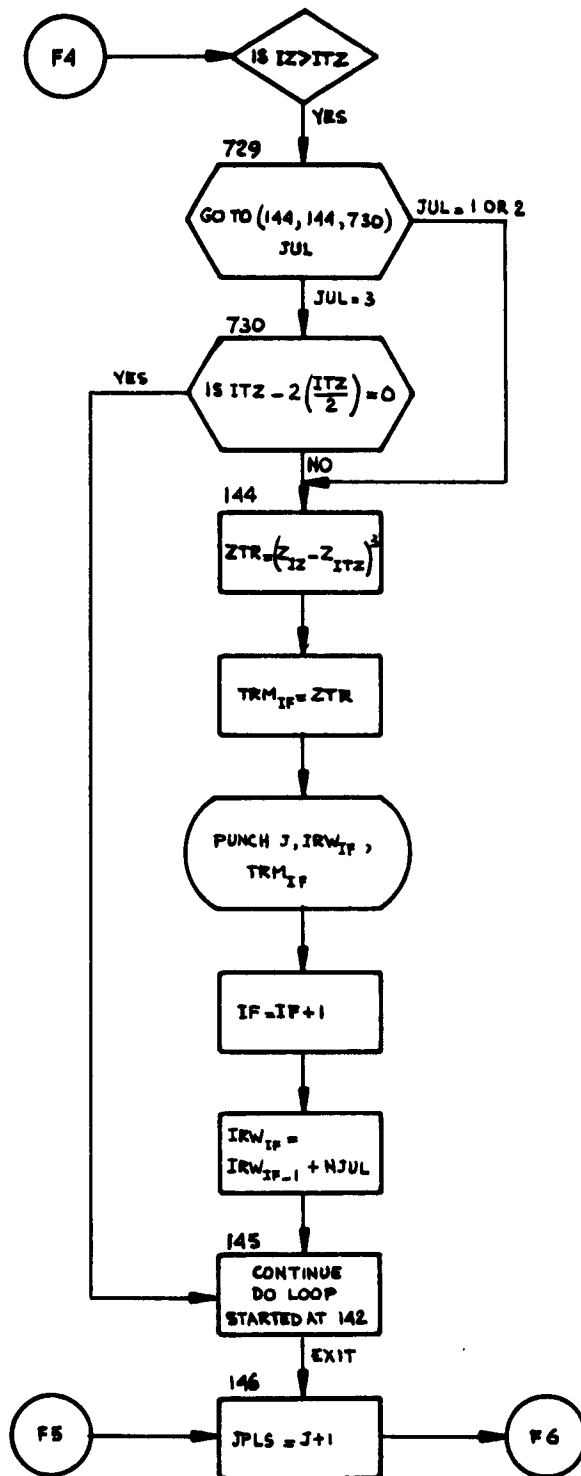


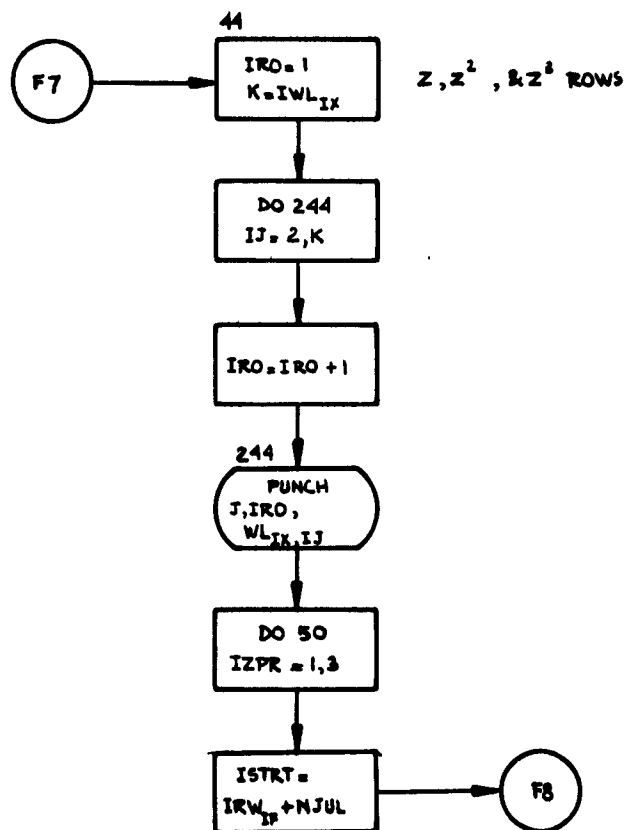
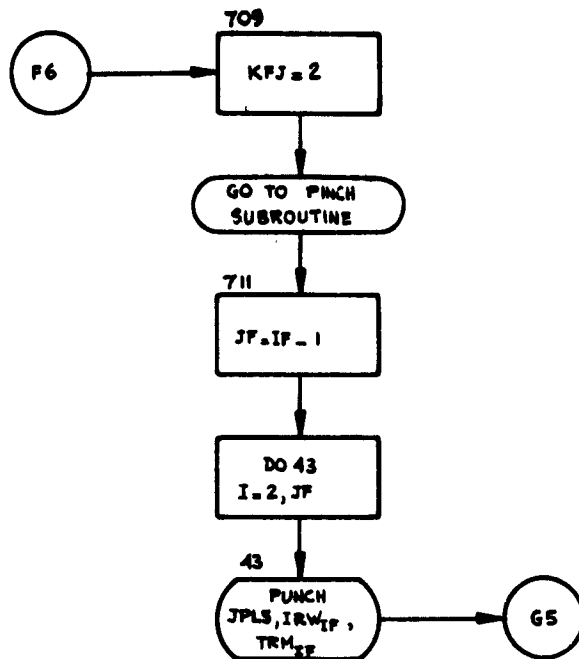


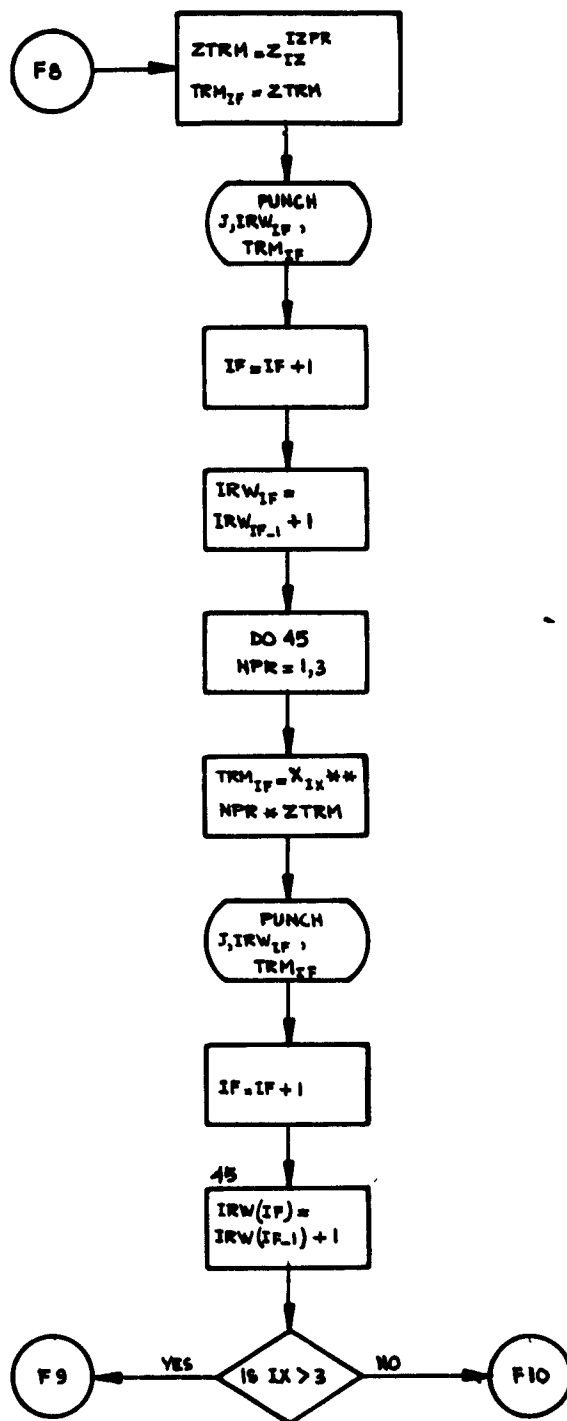


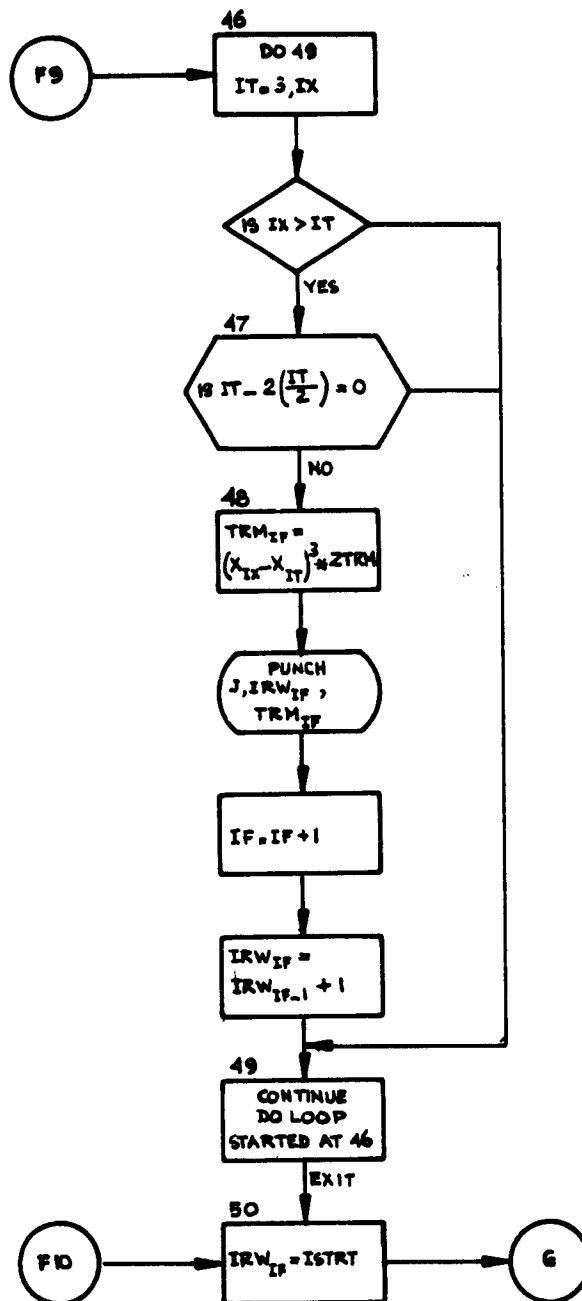


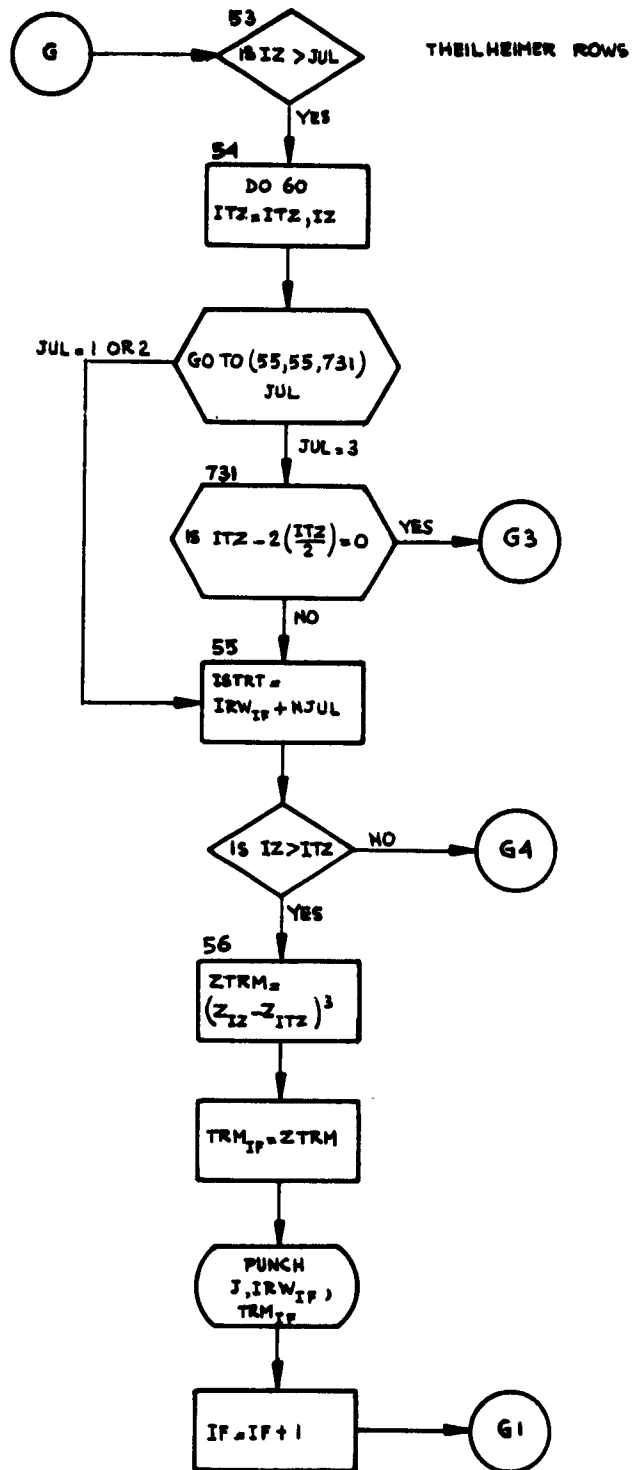


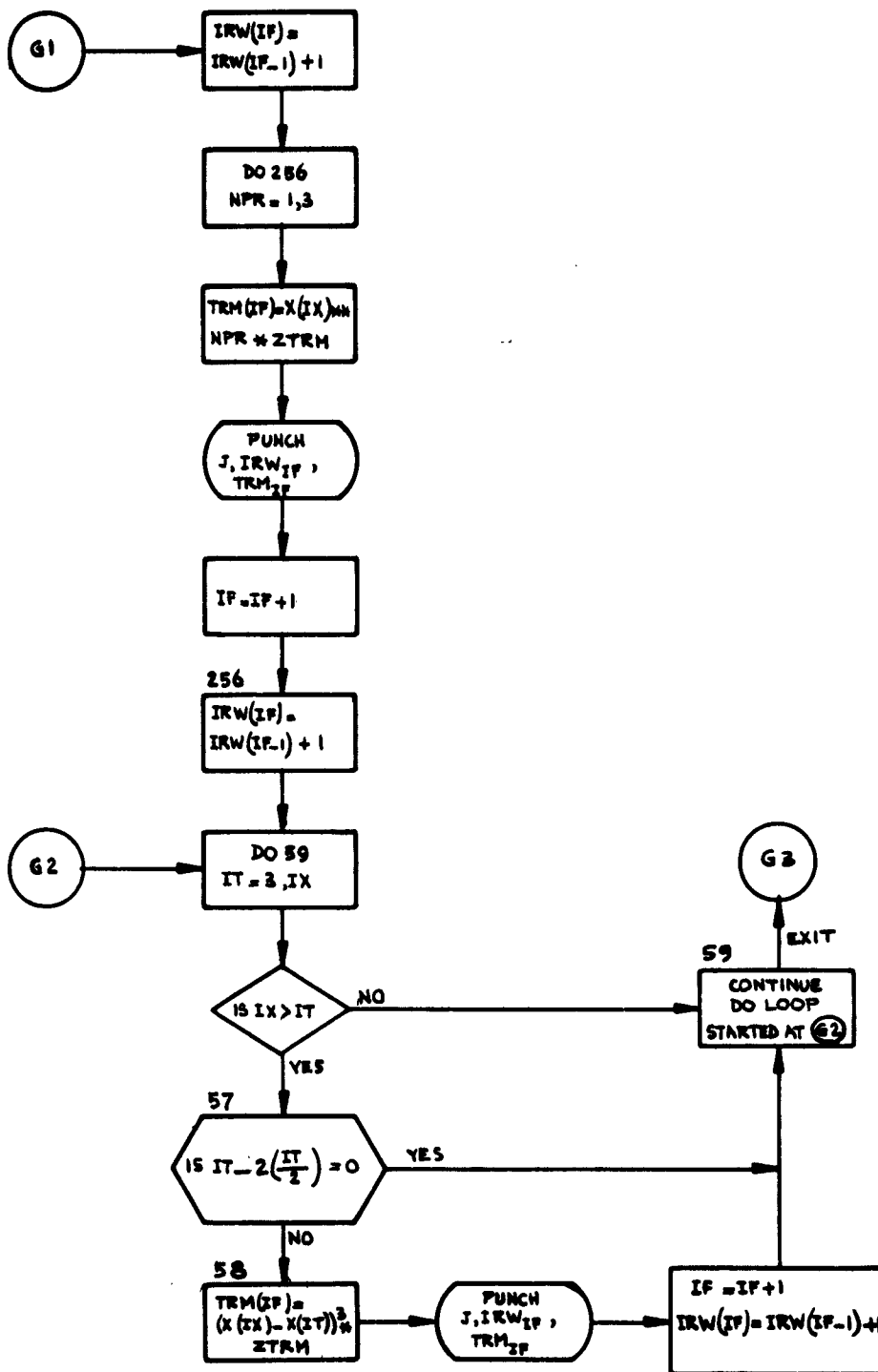


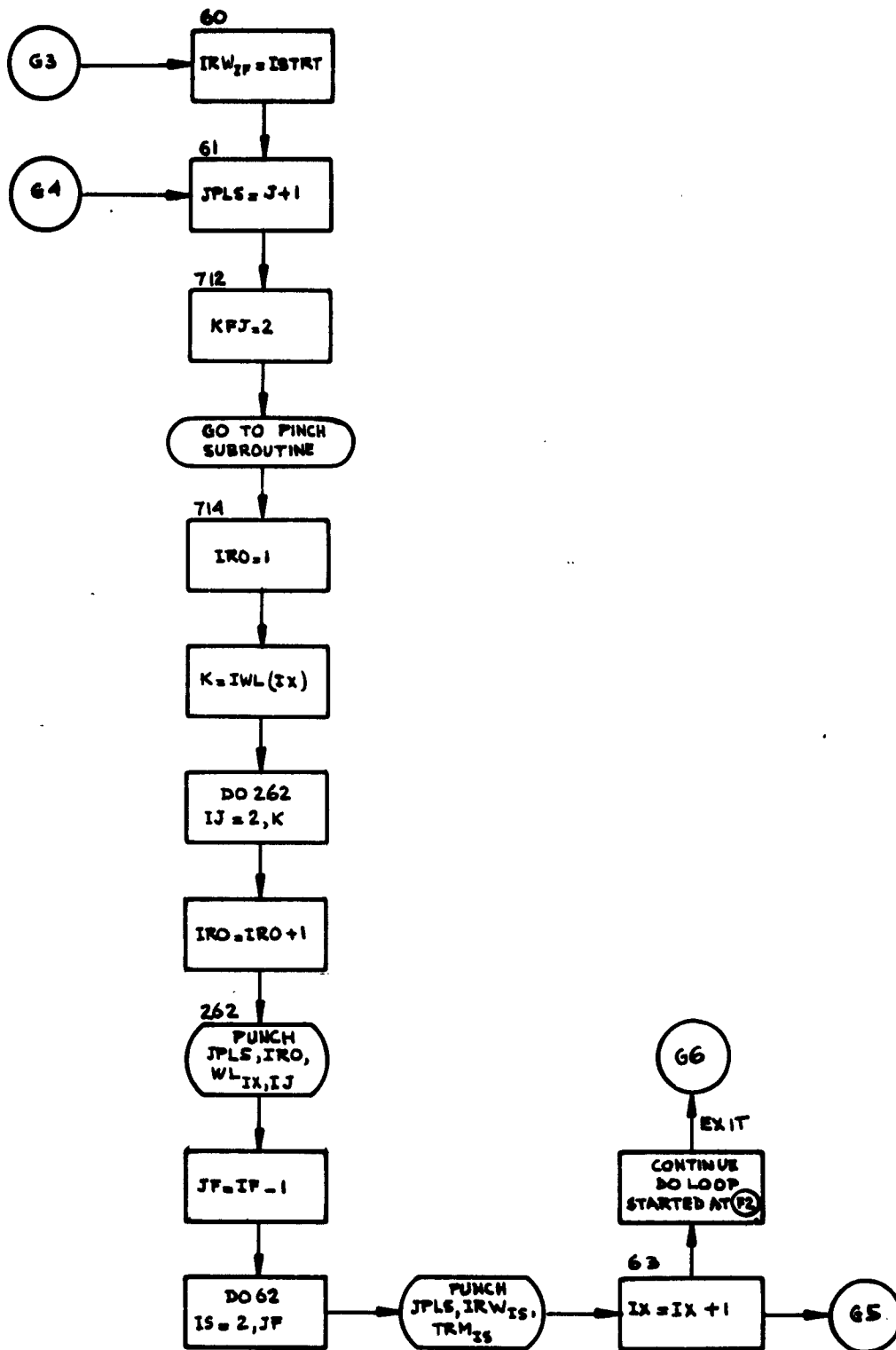


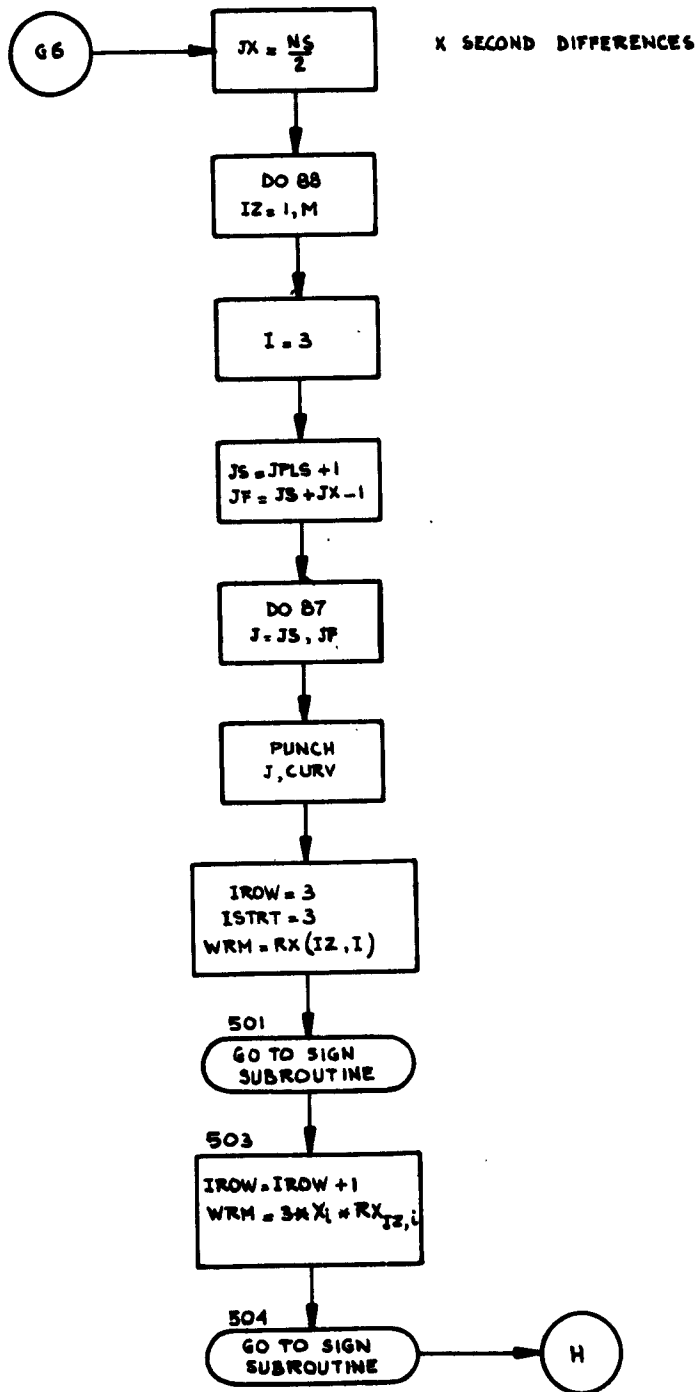


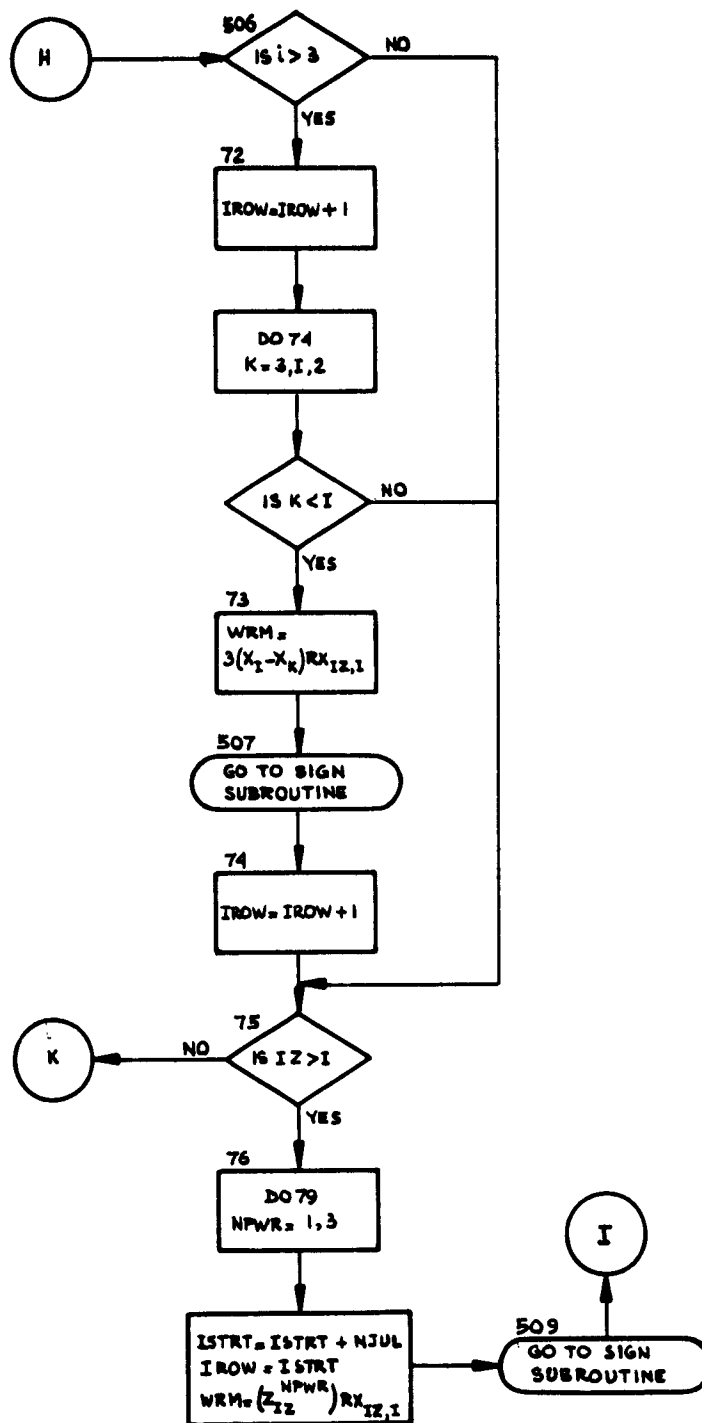


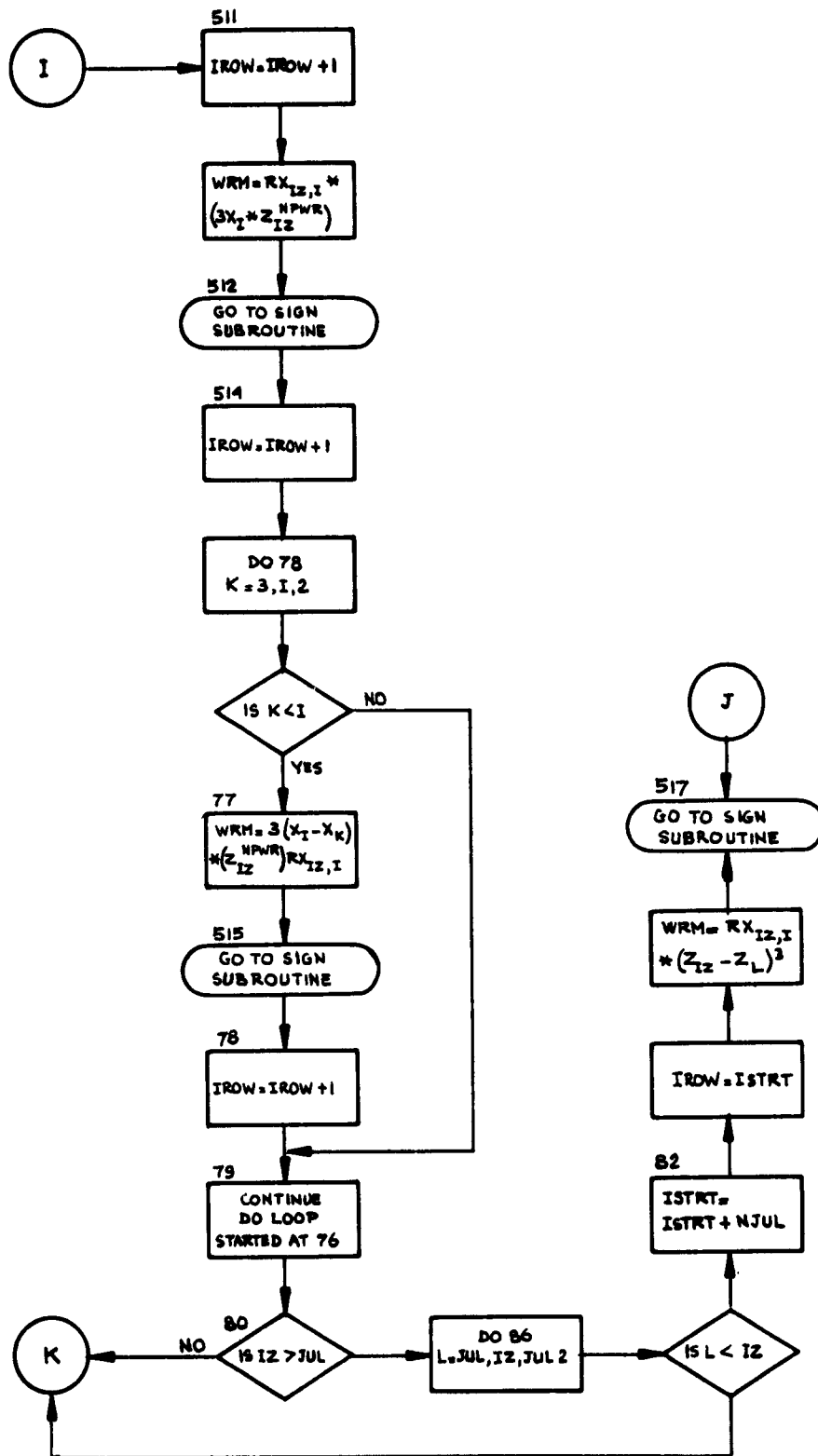


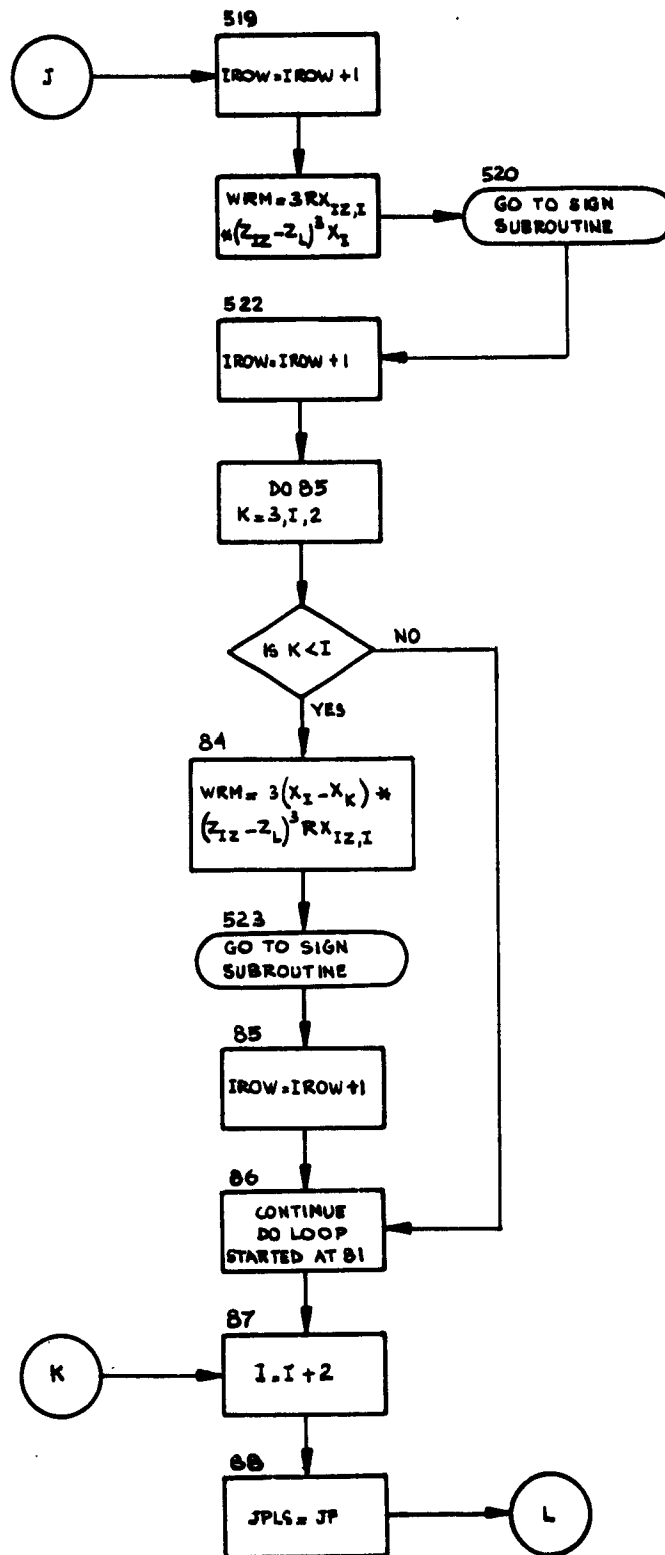




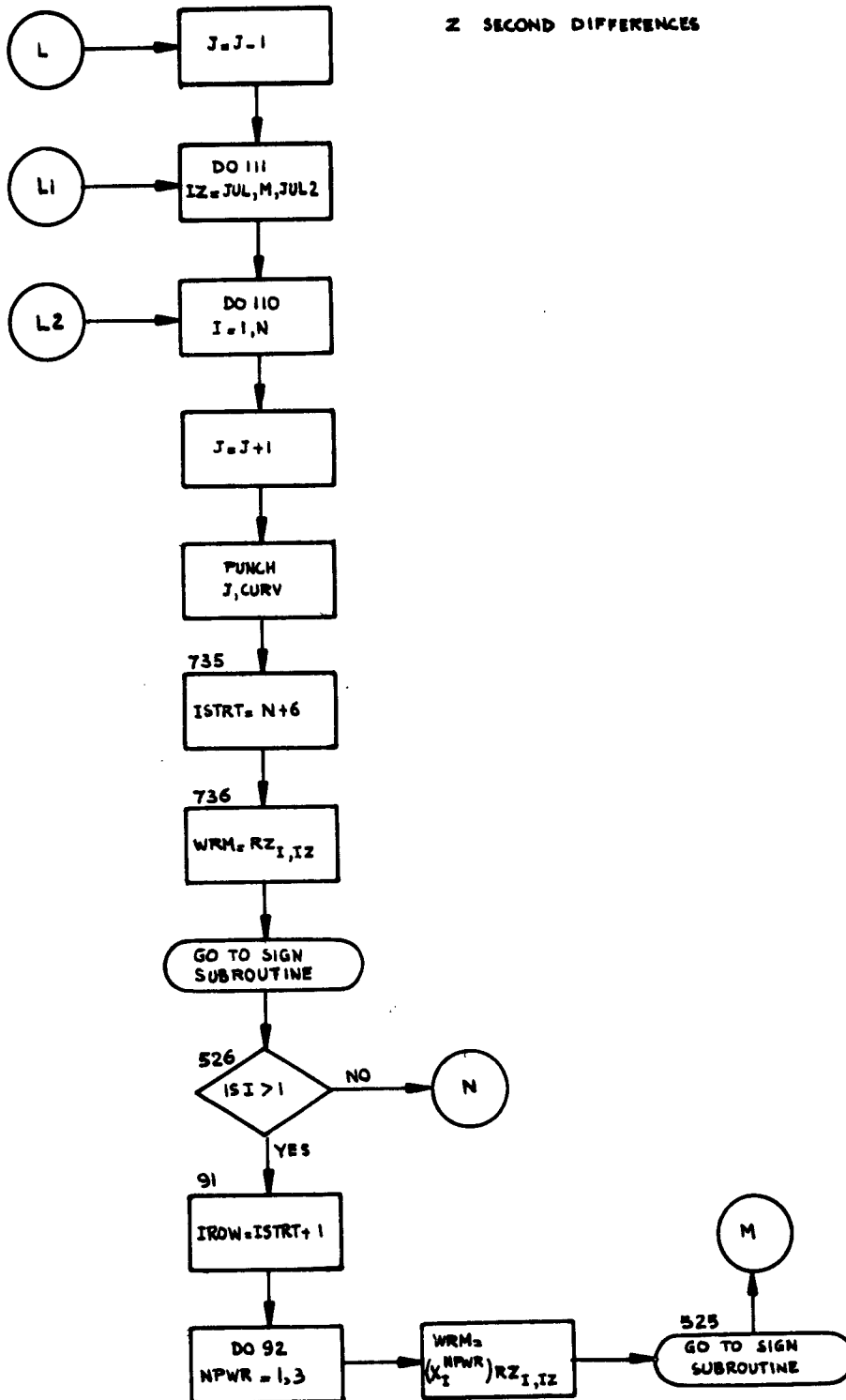


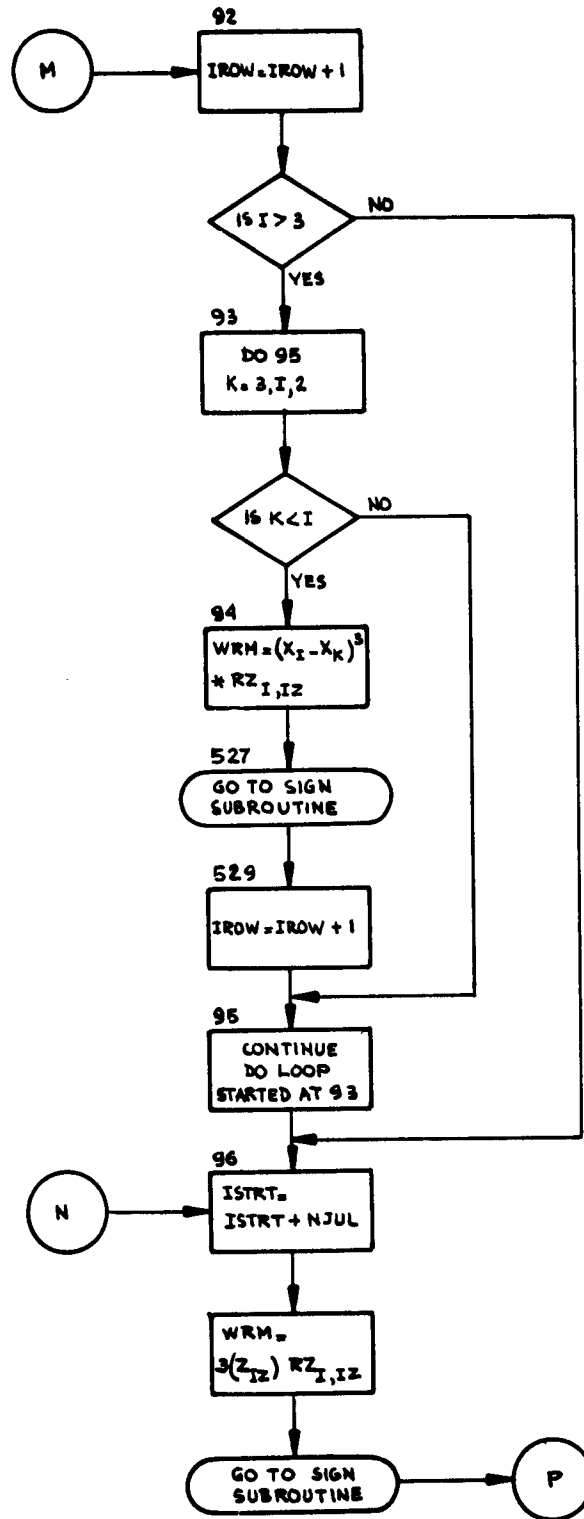


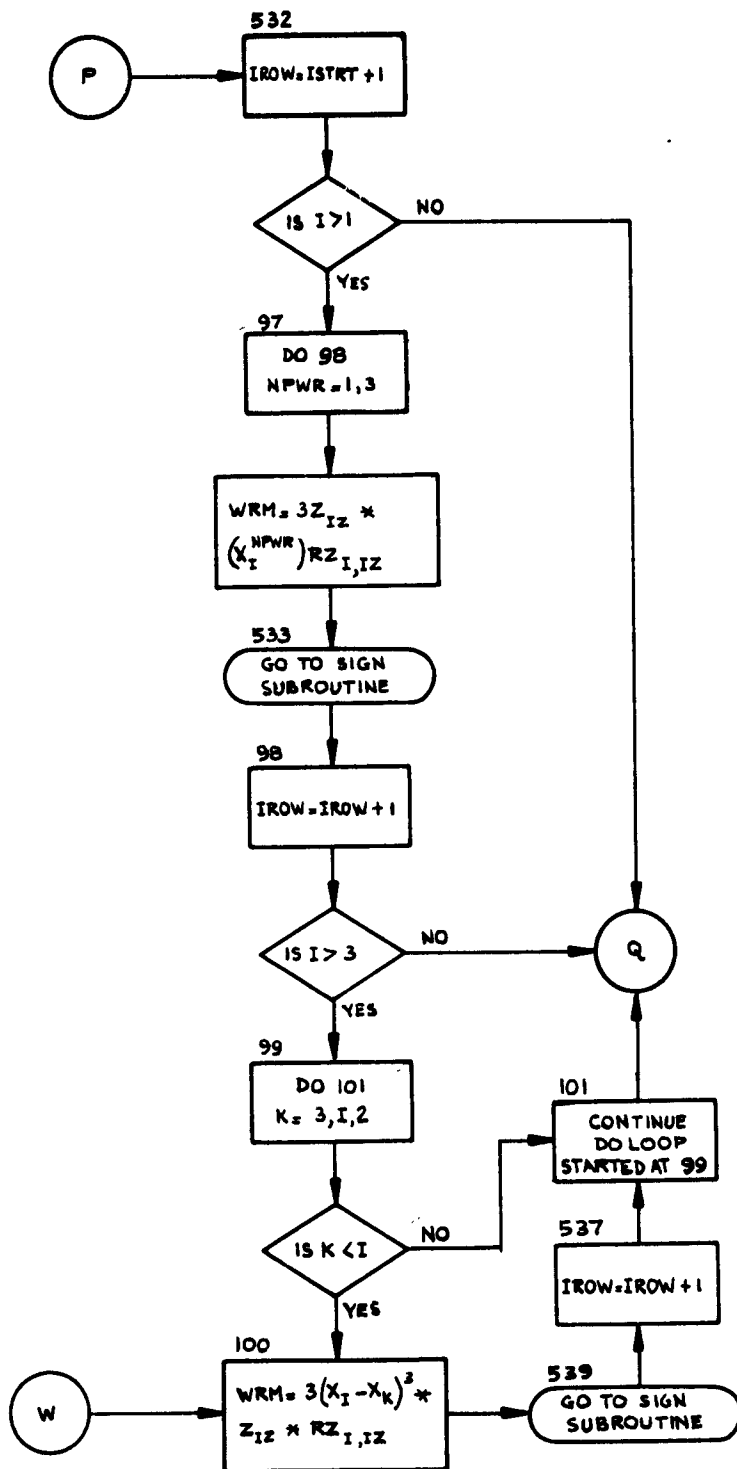


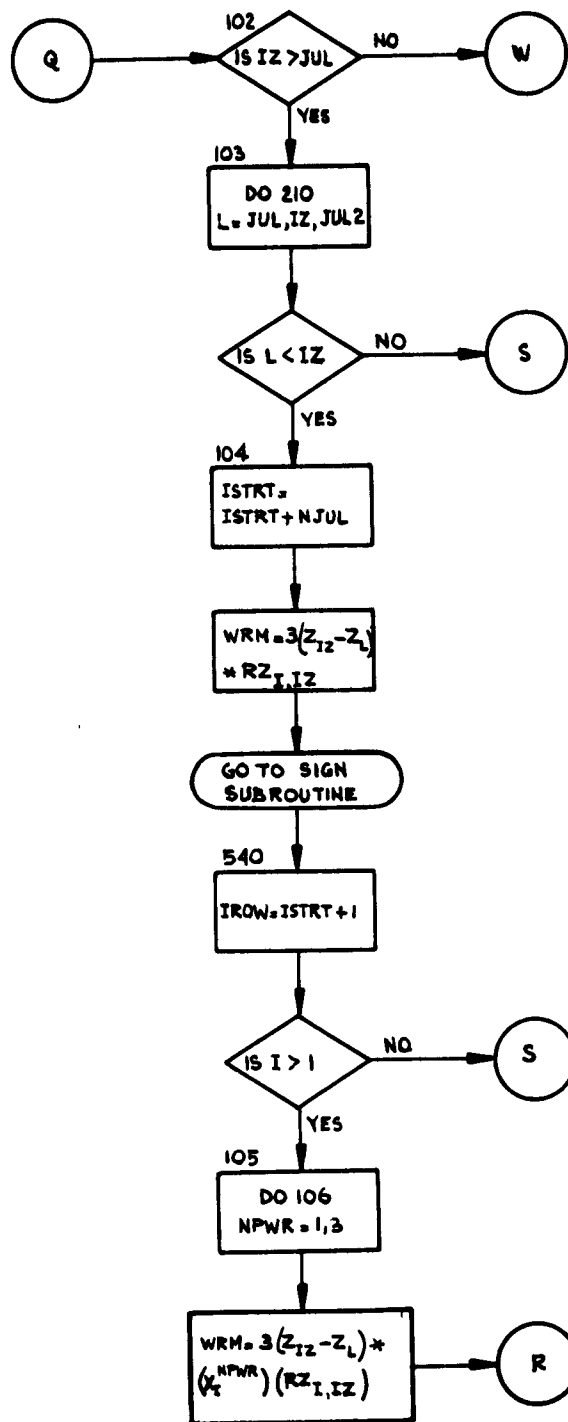


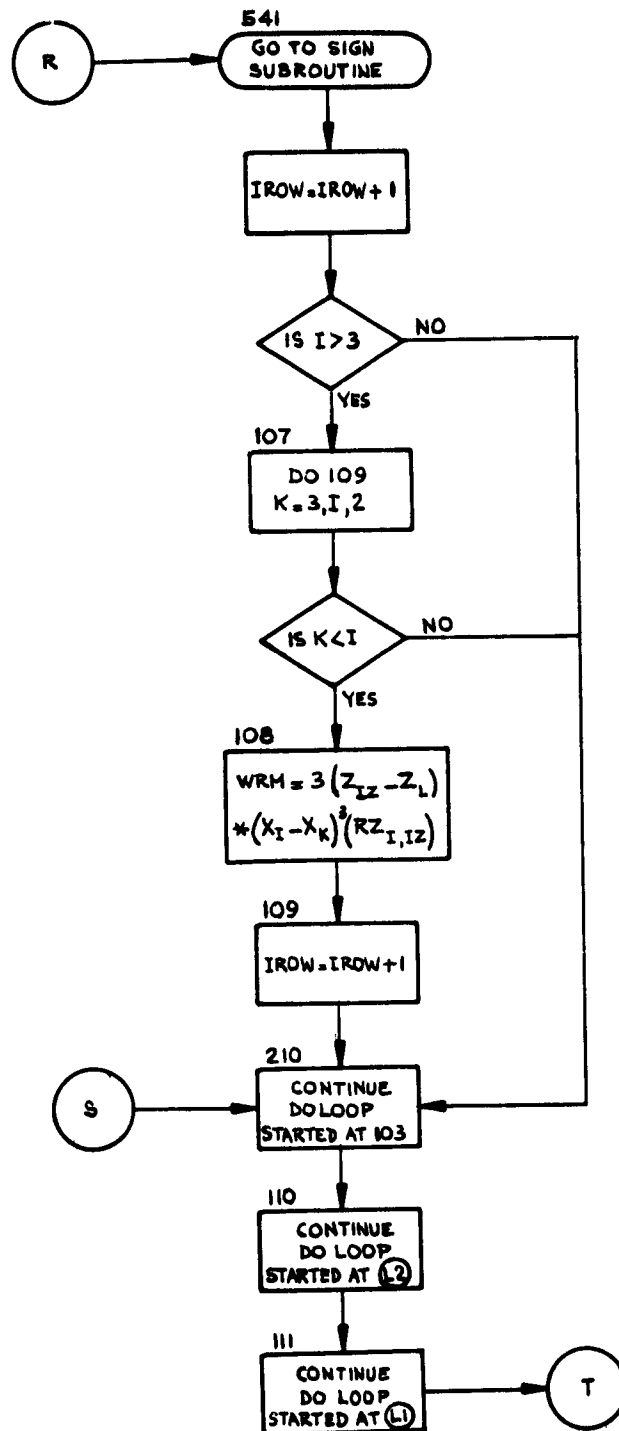
Z SECOND DIFFERENCES

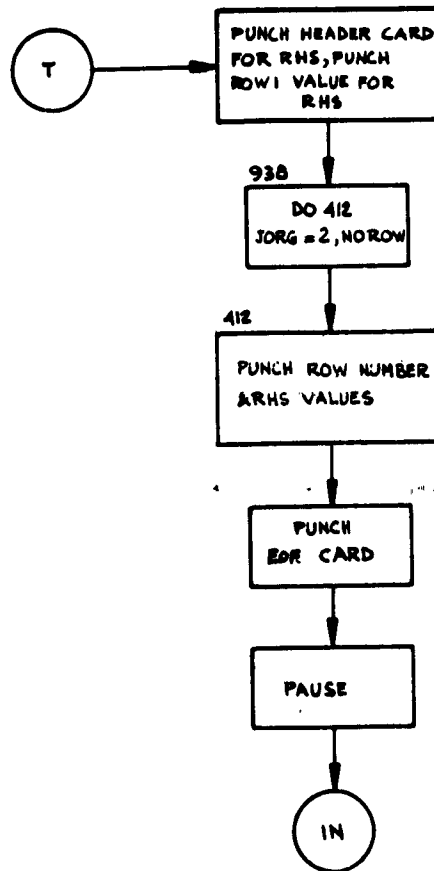




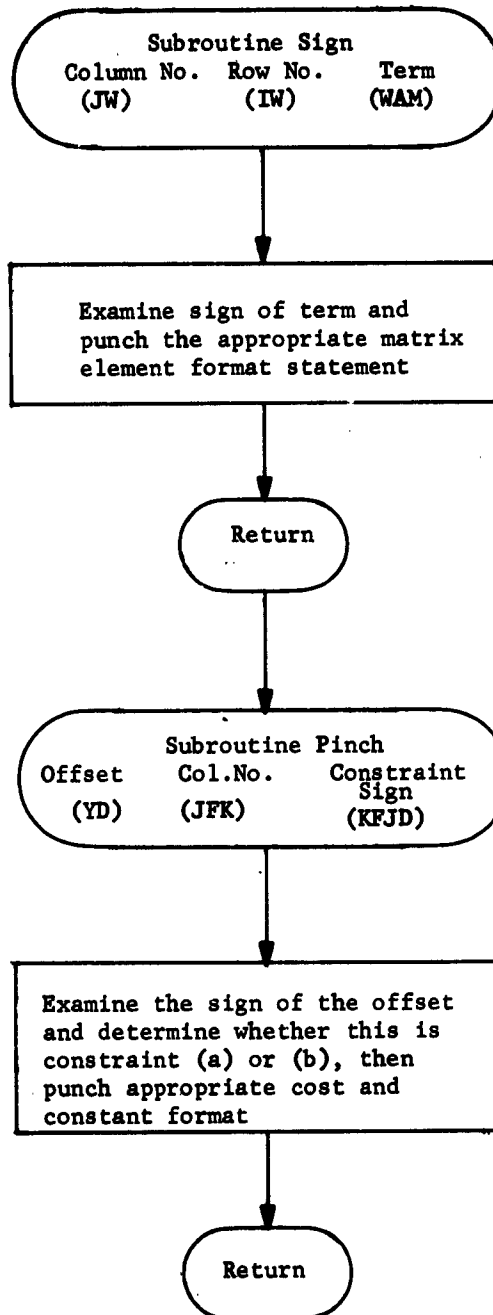








SUBROUTINES



FORTRAN LISTING FOR SMOG 1

```

C      SMOG1    DUAL  X OR X AND Z DBL SPL  NO PROFILE
      DIMENSION RX(11,15),RZ(15,11),TRM(150), IRW(250)
      DIMENSION X(15),Z(11),Y(11,15),WL(15,11),IWL(15)
C      *      *      INPUT      *      *
750 READ 173
      READ 172,NAA,NAB
      READ 150,M,N,CURV,RHS
      NL=N+1
      ML=M+1
      NS=N-1
      MS=M-1
      DO 2 I=1,M
      READ 154,Z(I)
      DO 2 J=1,N
      IF(SENSE SWITCH 3)802,803
802 READ 183,X(J),IAY,IBY,ICY
      AAY=IAY
      BBY=IBY
      CCY=ICY
      Y(I,J)=AAY+(BBY+(CCY/8.))/12.
      GO TO 2
803 READ 154,X(J),Y(I,J)
      2 CONTINUE
      IF(NAA)3,3,4
      3 READ 154,SX,SZ,TX,TZ
      GO TO 5
      4 SX=X(2)-X(1)
      SZ=Z(2)-Z(1)
      TZ=Z(1)
      TX=X(1)
C      *      *      WATERLINE 2ND DIFFERENCES      *      *
      5 IF(SENSE SWITCH 2)6,7
      6 PRINT 173
      PRINT 157
      7 DO 15 I=1,M
      DO 13 J=2,NS
      A=2./((X(J+1)-X(J-1)))
      ZA=Y(I,J+1)-Y(I,J)
      A=A*(ZA/(X(J+1)-X(J))-(Y(I,J)-Y(I,J-1))/(X(J)-X(J-1)))
      IF(A)10,9,8
      8 RX(I,J)=1.
      GO TO 11
      9 RX(I,J)=0.
      GO TO 11
      10 RX(I,J)=1.

```

```

11 IF(SENSE SWITCH 2)12,13
12 PRINT 158,I,J,A,RX(I,J)
13 CONTINUE
   RX(I,N)=RX(I,NS)
   IF(SENSE SWITCH 2)14,15
14 PRINT 158,I,J,A,RX(I,N)
15 CONTINUE
C   *   *   STATION 2ND DIFFERENCES   *   *
   IF(SENSE SWITCH 2)16,17
16 PRINT 159
17 DO 25 J=1,N
   DO 23 I=2,MS
   A=2./(Z(I+1)-Z(I-1))
   ZAA=Y(I+1,J)-Y(I,J)
   A=A*(ZAA/(Z(I+1)-Z(I))-(Y(I,J)-Y(I-1,J))/(Z(I)-Z(I-1)))
   IF(A)20,19,18
18 RZ(J,I)=-1.
   GO TO 21
19 RZ(J,I)=0.
   GO TO 21
20 RZ(J,I)=1.
21 IF(SENSE SWITCH 2)22,23
22 PRINT 158,J,I,A,RZ(J,I)
23 CONTINUE
   RZ(J,M)=RZ(J,MS)
   IF(SENSE SWITCH 2)24,25
24 PRINT 158,J,I,A,RZ(J,M)
25 CONTINUE
C   *   *   NORMALIZING   *   *
   DO 26 J=1,N
26 X(J)=(X(J)-TX)/SX
   DO 27 I=1,M
27 Z(I)=(Z(I)-TZ)/SZ
C   *   *   ROW ID   *   *
   PUNCH 173
   NJUL=((N-3)/2)+4
   NM=N
   IF(NAB)719,718,718
719 JUL=3
   JUL2=2
   NOROW=NJUL*((M-3)/2+4)
   GO TO 720
718 JUL=2
   JUL2=1
   NOROW=(M+2)*NJUL

```

```

720 PUNCH 160
    DO 28 NR=1,NOROW
28 PUNCH 162,NR
C      *      *      MATRIX      *      *
      PUNCH 164
C      *      *      FIRST WATERLINE      *

      MLG=(2*NM)-2
      I=2
      DO 37 J=1,MLG,2
      Y(1,I)=Y(1,I)-Y(1,1)
700 KFJ=1
      CALL PINCH (Y(1,I),J,KFJ)
702 IROW=2
      DO 31 NPR=1,3
      TRM(IROW)=X(1)**NPR
      PUNCH 167,J,IROW,TRM(IROW)
31 IROW=IROW+1
      IF(I-3)35,35,32
32 DO 34 IT=3,1
      IF(I-IT)34,34,133
133 IF(IT-2*(IT/2))33,34,33
33 TRM(IROW)=(X(1)-X(IT))**3
      PUNCH 167,J,IROW,TRM(IROW)
      IROW=IROW+1
34 CONTINUE
35 JPLS=J+1
      IROW=IROW-1
      IWL(1)=IROW
703 KFJ=2
      CALL PINCH (Y(1,I),JPLS,KFJ)
705 DO 36 IR=2,IROW
      WL(1,IR)=TRM(IR)
36 PUNCH 169,JPLS,IR,TRM(IR)
37 I=I+1
C      *      *      REMAINING WL      *      *
      DO 64 IZ=2,M
      JL=J
      MG=JL+(2*NM)-2
      IX=1
      DO 63 J=JL,MG,2
      IF=2
      IRW(IF)=IROW+1
      Y(IZ,IX)=Y(IZ,IX)-Y(1,1)
706 KFJ=1
      CALL PINCH (Y(IZ,IX),J,KFJ)

```

```

708 IF(J-JL)41,41,44
41 DO 42 IZPR=1,3
   TRM(1F)=Z(IZ)**IZPR
   PUNCH 167,J,IRW(1F),TRM(1F)
   1F=1F+1
42 IRW(1F)=IRW(1F-1)+NJUL
   IF(IZ-JUL)146,146,142
142 DO 145 ITZ=JUL,IZ
   IF(IZ-ITZ)146,146,729
729 GO TO (144,144,730),JUL
730 IF(ITZ-2*(ITZ/2))144,145,144
144 ZTR=(Z(IZ)-Z(ITZ))**3
   TRM(1F)=ZTR
   PUNCH 167,J,IRW(1F),TRM(1F)
   1F=1F+1
   IRW(1F)=IRW(1F-1)+NJUL
145 CONTINUE
146 JPLS=J+1
709 KFJ=2
   CALL PINCH (Y(IZ,IX),JPLS,KFJ)
711 JF=1F-1
   DO 43 1F=2,JF
43 PUNCH 169,JPLS,IRW(1F),TRM(1F)
   GO TO 63
C  * * Z , Z SQR , Z CUBE ROWS * *
44 IRO =1
   K=IWL(IX)
   DO 244 1J=2,K
   IRO =IRO +1
244 PUNCH 167,J,IRO,WL(IX,1J)
   DO 50 IZPR=1,3
   ISTRT=IRW(1F)+NJUL
   ZTRM=Z(IZ)**IZPR
   TRM(1F)=ZTRM
   PUNCH 167,J,IRW(1F),TRM(1F)
   1F=1F+1
   IRW(1F)=IRW(1F-1)+1
   DO 45 NPR=1,3
   TRM(1F)=(X(IX)**NPR)*ZTRM
   PUNCH 167,J,IRW(1F),TRM(1F)
   1F=1F+1
45 IRW(1F)=IRW(1F-1)+1
   IF(IX-3)50,50,46
46 DO 49 1T=3,IX
   IF(IX-1T)49,49,47

```

```

47 IF(IT-2*(IT/2))48,49,48
48 TRM(IF)=((X(IX)-X(IT))**3)*ZTRM
PUNCH 167,J,IRW(IF),TRM(IF)
IF=IF+1
IRW(IF)=IRW(IF-1)+1
49 CONTINUE
50 IRW(IF)=ISTR
C      *      *      THEILHEIMER ROWS      *      *
53 IF(IZ-JUL)61,61,54
54 DO 60 ITZ=JUL,IZ
GO TO (55,55,731),JUL
731 IF(ITZ-2*(ITZ/2))55,60,55
55 ISTR=IRW(IF)+NJUL
IF(IZ-ITZ)61,61,56
56 ZTRM=(Z(IZ)-Z(ITZ))**3
TRM(IF)=ZTRM
PUNCH 167,J,IRW(IF),TRM(IF)
IF=IF+1
IRW(IF)=IRW(IF-1)+1
DO 256 NPR=1,3
TRM(IF)=(X(IX)**NPR)*ZTRM
PUNCH 167,J,IRW(IF),TRM(IF)
IF=IF+1
256 IRW(IF)=IRW(IF-1)+1
DO 59 IT=3,IX
IF(IX-IT)59,59,57
57 IF(IT-2*(IT/2))58,59,58
58 TRM(IF)=((X(IX)-X(IT))**3)*ZTRM
PUNCH 167,J,IRW(IF),TRM(IF)
IF=IF+1
IRW(IF)=IRW(IF-1)+1
59 CONTINUE
60 IRW(IF)=ISTR
61 JPLS=J+1
712 KFJ=2
CALL PINCH (Y(IZ,IX),JPLS,KFJ)
714 IRO =1
K=IWL(IX)
DO 262 IJ=2,K
IRO =IRO +1
262 PUNCH 169,JPLS,IRO ,WL(IX,IJ)
JF=IF-1
DO 62 IS=2,JF
62 PUNCH 169,JPLS,IRW(IS),TRM(IS)
63 IX=IX+1

```

```

C 64 CONTINUE
      *      *      X SEC DIFFERENCES      *      *
      JX=NS/2
      DO 88 IZ=1,M
      I=3
      JS=JPLS+1
      JF=JS+JX-1
      DO 87 J=JS,JF
      PUNCH 171,J,CURV
      IROW=3
      ISTRT=3
      WRM=RX(IZ,I)
501 CALL SIGN(J,IROW,WRM)
503 IROW=IROW+1
      WRM=3.*X(I)*RX(IZ,I)
504 CALL SIGN(J,IROW,WRM)
506 IF(I-3)75,75,72
      72 IROW=IROW+1
      DO 74 K=3,1,2
      IF(K-1)73,75,75
      73 WRM=3.*(X(I)-X(K))*RX(IZ,I)
507 CALL SIGN(J,IROW,WRM)
      74 IROW=IROW+1
      75 IF(IZ-1)87,87,76
      76 DO 79 NPWR=1,3
      ISTRT=ISTRT+NJUL
      IROW=ISTRT
      WRM=(Z(IZ)**NPWR)*RX(IZ,I)
509 CALL SIGN(J,IROW,WRM)
511 IROW=IROW+1
      WRM=(3.*X(I)*(Z(IZ)**NPWR))*RX(IZ,I)
512 CALL SIGN(J,IROW,WRM)
514 IROW=IROW+1
      DO 78 K=3,1,2
      IF(K-1)77,79,79
      77 WRM=3.*(X(I)-X(K))*(Z(IZ)**NPWR)*RX(IZ,I)
515 CALL SIGN(J,IROW,WRM)
      78 IROW=IROW+1
      79 CONTINUE
      80 IF(IZ-JUL)87,87,81
      81 DO 86 L=JUL,IZ,JUL2
      IF(L-IZ)82,87,87
      82 ISTRT=ISTRT+NJUL
      IROW=ISTRT
      WRM=RX(IZ,I)*((Z(IZ)-Z(L))**3)

```

```

517 CALL SIGN(J,IROW,WRM)
519 IROW=IROW+1
      WRM=3.*X(1)*((Z(IZ)-Z(L))**3)*RX(IZ,1)
520 CALL SIGN(J,IROW,WRM)
522 IROW=IROW+1
      DO 85 K=3,1,2
        IF(K-1)84,86,86
      84 WRM=(3.*(X(1)-X(K))*((Z(IZ)-Z(L))**3))*RX(IZ,1)
523 CALL SIGN(J,IROW,WRM)
      85 IROW=IROW+1
      86 CONTINUE
      87 I=I+2
      88 JPLS=JF
C      Z SEC DIFFERENCES      *      *
      J=J-1
      DO 111 IZ=JUL,M,JUL2
      DO 110 I=1,N
      J=J+1
      PUNCH 171,J,CURV
735 ISTRT=N+6
736 WRM=RZ(1,IZ)
      CALL SIGN(J,ISTRT,WRM)
562 IF(I-1)96,96,91
      91 IROW=ISTRT+1
      DO 92 NPWR=1,3
        WRM=(X(1)**NPWR)*RZ(1,IZ)
525 CALL SIGN(J,IROW,WRM)
      92 IROW=IROW+1
        IF(I-3)96,96,93
      93 DO 95 K=3,1,2
        IF(K-1)94,95,95
      94 WRM=((X(1)-X(K))**3)*RZ(1,IZ)
527 CALL SIGN(J,IROW,WRM)
529 IROW=IROW+1
      95 CONTINUE
      96 ISTRT=ISTRT+NJUL
        WRM=3.*Z(IZ)*RZ(1,IZ)
        CALL SIGN(J,ISTRT,WRM)
532 IROW=ISTRT+1
        IF(I-1)102,102,97
      97 DO 98 NPWR=1,3
        WRM=(X(1)**NPWR)*Z(IZ)*3.*RZ(1,IZ)
533 CALL SIGN(J,IROW,WRM)
      98 IROW=IROW+1
        IF(I-3)102,102,99

```

```

99 DO 101 K=3,1,2
   IF(K-1)100,101,101
100 WRM=((X(1)-X(K))**3)*Z(1Z)*3.*RZ(1,1Z)
535 CALL SIGN(J,IROW,WRM)
537 IROW=IROW+1
101 CONTINUE
102 IF(1Z-JUL)110,110,103
103 DO 210 L=JUL,1Z,JUL2
   IF(L-1Z)104,210,210
104 ISTRT=ISTRT+NJUL
   WRM=(Z(1Z)-Z(L))*RZ(1,1Z)*3.
   CALL SIGN(J,ISTRT,WRM)
540 IROW=ISTRT+1
   IF(1-1)210,210,105
105 DO 106 NPWR=1,3
   WRM=(Z(1Z)-Z(L))*(X(1)**NPWR)*3.*RZ(1,1Z)
541 CALL SIGN(J,IROW,WRM)
106 IROW=IROW+1
   IF(1-3)210,210,107
107 DO 109 K=3,1,2
   IF(K-1)108,210,210
108 WRM=(Z(1Z)-Z(L))*((X(1)-X(K))**3)*3.*RZ(1,1Z)
543 CALL SIGN(J,IROW,WRM)
109 IROW=IROW+1
210 CONTINUE
110 CONTINUE
111 CONTINUE
   PUNCH 174
   PUNCH 175
738 DO 412 JORG=2,NOROW
412 PUNCH 177,JORG,RHS
737 PUNCH 176
   PRINT 178
   PAUSE 751
   GO TO 750
150 FORMAT(215,F11.6,F11.6)
154 FORMAT(4F10.4)
157 FORMAT(10X,17H2ND DIFF - W/LINES//
C30H WL STA ACT VALUE SIGN/)
158 FORMAT(215,F12.6,F8.2)
159 FORMAT(//10X,17H2ND DIFF-STATIONS//
C30H STA WL ACT VALUE SIGN/)
160 FORMAT(6HROW ID/12X,6H OFFSET)
162 FORMAT(12X,2H R,14)

```



```
164 FORMAT(6HMATRIX)
167 FORMAT(6X,2H C,14,2H R,14,1H-,F11.5)
169 FORMAT(6X,2H C,14,2H R,14,F12.5)
171 FORMAT(6X,2H C,14,6H OFFSET,F12.5)
172 FORMAT(2I5)
173 FORMAT(1H*,5X,47H
174 FORMAT(7HFIRST B)
175 FORMAT(12X,14H R 1 2.0)
176 FORMAT(3HEOF)
177 FORMAT(12X,2H R,14,1H ,F11.5)
178 FORMAT(28HENTER NEW DATA - PRESS START)
183 FORMAT(F10.4,3I5)
END
```

)

```

SUBROUTINE PINCH (YD,JFK,KFJD)
IF(YD) 706,707,707
706 YD=YD
GO TO (752,753),KFJD
752 PUNCH 168,JFK,YD,JFK
GO TO 754
753 PUNCH 166,JFK,YD,JFK
754 YD=YD
RETURN
707 GO TO (755,756),KFJD
755 PUNCH 166,JFK,YD,JFK
RETURN
756 PUNCH 168,JFK,YD,JFK
RETURN
166 FORMAT(6X,2H C,14,6H OFFSET,F12.5/6X,2H C,14,6H R 1,8H 1
.0)
168 FORMAT(6X,2H C,14,7H OFFSET-,F11.5/6X,2H C,14,6H R 1,8H
1.0)
183 FORMAT(F10.5,3I5)
END

```

```
      SUBROUTINE SIGN (JW,IW,WAM)
      IF(WAM)370,373,371
370  WAM=-WAM
      PUNCH 169,JW,IW,WAM
      RETURN
371  PUNCH 167,JW,IW,WAM
373  RETURN
169  FORMAT(6X,2H C,14,2H R,14,F12.5)
167  FORMAT(6X,2H C,14,2H R,14,1H-,F11.5)
      END
```

B. SMOG 2

This program produces a surface matrix without profile conditions in the dual formulation and λ fit. The surface will be double splined in the x direction and may be either single or double splined in the z direction. The program is written in FORTRAN II for an IBM-1620 computer.

Organization

SMOG 2 consists of two passes as shown in Fig. B-1. The input data shown below is read into Pass 1. At the termination of the execution of Pass 1 the data necessary for Pass 2 is punched. This data can be read directly into Pass 2. If it becomes necessary to change the sign of a second difference as mentioned in Step 2, this may be done by altering the Pass 2 data. More information on this data is found in the description of the Pass 2 input.

B. SMOG 2

PASS 1

OPERATING INSTRUCTIONS

Pass 1 of SMOG 2 calculates the second differences of the offsets and the intersections of the profile with the waterlines and stations. It then punches the row identifications, deviation constraints and data for Pass II. The program is written in FORTRAN II for the IBM-1620 computer.

Fortran Symbol Definition

- M - Total number of waterlines in the surface to be faired. This will be an odd number if the surface is double splined in the z direction.
- N - Total number of stations in the surface. This will always be an odd number.
- X(J) - Distance along the x axis from the origin of the surface to Station j .
- Z(I) - Distance along the z axis from the origin of the surface to waterline i .
- Y(I,J) - Offset of the surface at Waterline i , Station j , in feet and decimals
- IAY - Number of feet in the offset if read in feet, inches and eighths.
- IBY - Number of inches corresponding to IAY
- ICY - Number of eighths corresponding to IAY
- NAA - Program indicator
 - If NAA = -1, scale factors for normalizing and translating X(J) and Z(I) are read in.
 - If NAA = +1, scaling and translating are done by the program as given in Section I of this Appendix.

SX - Scale factor for X(J) when these are read in
 TX - Translation factor for X(J) when these are read in
 SZ - Scale factor for Z(I) when these are read in
 TZ - Translation factor for Z(I) when these are read in
 RHS - Right hand side - In the dual, this is really the cost on the equation coefficients. The ideal value for RHS would be zero; however, this makes the solution susceptible to cycling so that a value of .0001 is usually used.
 CURV - Value of the requirement vector for the curvature constraints, this value actually goes in the cost row in the dual and is always made zero.
 NAB - Program indicator
 If NAB = -1 , the surface will be double splined in the z direction and M must be an odd number.
 If NAB = +1 , the surface will be single splined in the z direction and M is unrestricted.
 COST - The penalty assigned to λ . This will appear in Row 1 of the right-hand side. The value is normally made 20 .
 EXP 1 - The value of p in the profile function, usually made .3333 .
 EXP 2 - The value of r in the profile function, usually 3.0 .
 POINT - The value of D in the profile function. This number is the length of the fraction of the station spacing over which the profile function is effective in terms of the full-scale surface (the value will be translated and normalized exactly like the x values are).
 C(I) - Coefficients of the Theilheimer equation describing the profile. There must be (M+2) coefficients. Straight lines or other curves may be used by making all except the desired coefficients zero.

Input

The input data cards are described below. There are certain input variables on which there are restrictions on the value which can be entered. These restrictions follow.

<u>Variable</u>	<u>Minimum No.</u>	<u>Maximum No.</u>
N	3	15
M	3	11

In describing the various data cards, the actual FORTRAN format field is used in most cases. These fields come consecutively across the card with no gaps or blank columns between, except where indicated. The field descriptions are the FORTRAN F field, which uses the FORTRAN fixed point decimal number, and the I field that uses the FORTRAN integer number, which is always right justified. The card numbers are not punched on the data cards.

<u>Contents of Card</u>					<u>Card No.</u>	
Card Columns	1	2-12	13-53			1
Contents	*	Blank	Any alphameric problem heading (This heading will be used for identifying the problem on the LP output)			
Format	I5	I5	F11.6	F11.6		2
Variable	NAA	NAB	POINT	COST		
Format	I5	I5	F11.6	F11.6	F11.6	F11.6 3
Variable	M	N	CURV	RHS	EXP1	EXP2
Format	F10.4					Next
Variable	C(I)					M+2 cards

Format	F10.4
Variable	Z(I)

Alternate Cards:

Format	F10.4	F10.4
Variable	X(J)	Y(I,J)

or:

Format	F10.4	15	15	15
Variable	X(J)	IAY	IBY	ICY

N Cards
per Group

Next
M
Groups

This arrangement can be stated as follows:

The first card of each set gives the height z of the waterline. The following cards each give a station coordinate and the offset at the intersection of the given waterline and station. There is one set of cards for each waterline in the surface.

Format	F10.4	F10.4	F10.4	F10.4	Last card
Variable	SX	SZ	TX	TZ	

(This card is entered only if NAA = -1

Output

The output from this program is designed to be read directly by the LP-90 program after card to magnetic tape conversion.

The first card punched contains the Loading Read in the first input card. The next set of cards are the row identification coordinates. These identify each row of the matrix to be used in this solution. For this matrix all of the rows are always used and identified, including the cost row which has the name "OFFSET."

Next, a card punched "MATRIX" is produced, followed by the deviation constraint portion of the matrix. Finally the input data for Pass 2 is punched.

The output formats are shown in Fig. B-1 , and the order of the output deck in Fig B-2 . The actual output from PASS 1 is shown in the sample problem.

Sense Switch Settings

Sense Switch 1	-	Not used	
Sense Switch 2	-	ON	The values of the x and z second differences and the resulting signs are printed.
Sense Switch 2	-	OFF	The above is not printed
Sense Switch 3	-	ON	The offsets are read in as feet, inches, and eighths
Sense Switch 3	-	OFF	The offsets are read in as feet and decimals

SAMPLE PROBLEM

The following sample problem is a five-station by five-waterline set of offsets taken from the DLG-26 class ships. The stations are Numbers 0 , $1/2$, 1 , $1-1/2$, and 2 , and the waterlines are 12, 16, 24, and 28 .

The surface contains the bow profile of the DLG. The matrix is double splined in the z direction. Only the output from Pass 1 is listed here; the output from Pass 2 is included with the instructions from that program.

SAMPLE PROBLEM - SMOG 2, PASS 1

* * S A M P L E I N P U T * *

```

*      TODD  DLG  5X5  END  PROF I  LE  X-Z  DBL  SPL-
      1      -1    1.      20.
      5      5    0.      .001      3.      .33333333
      1.52935
      - .5873
      0.
      0.
      0.
      0.
      0.
      0.
      .0000
      .0000
      12.7500  1.041666
      25.5000  2.458333
      38.2500  3.874999
      51.0000  5.333333
      1.0000
      .0000
      12.7500  1.239583
      25.5000  2.697916
      38.2500  4.197916
      51.0000  5.812500
      2.0000
      .0000
      12.7500  1.479166
      25.5000  2.979166
      38.2500  4.583333
      51.0000  6.333333
      3.0000
      .0000
      12.7500  1.791666
      25.5000  3.447916
      38.2500  5.250000
      51.0000  7.166666
      4.0000
      .0000
      12.7500  2.416666
      25.5000  4.322916
      38.2500  6.416666
      51.0000  8.583333
  
```

End Profile Coefficients

Surface Offsets

TYPEWRITER LISTING OF INTERSECTIONS AND SECOND DIFFERENCES

(Switch 2 ON) OUTPUT

* TODD DLG 5X5 END PROFILE X-Z DBL SPL-

END PROFILE INTERSECTIONS

WLINES

1	1.529350
-.5873	0.0000
2	.942050
-.5873	0.0000
3	.354750
-.5873	0.0000
4	-.232550
-.5873	0.0000
5	-.819850
-.5873	0.0000

STATIONS

1	2.604003
2	.901367
3	0.000000
4	0.000000
5	0.000000

2ND DIFF - WLINES

WL	STA	NORM VALUE	SIGN
1	1	OUT OF SURFACE	
1	2	OUT OF SURFACE	
1	3	-5.176766	1.00
1	4	.041668	-1.00
1	5	.041668	-1.00
2	1	OUT OF SURFACE	
2	2	-37.680848	1.00
2	3	.041667	-1.00
2	4	.114584	-1.00
2	5	.114584	-1.00
3	1	OUT OF SURFACE	
3	2	-.963248	1.00
3	3	.104167	-1.00
3	4	.145833	-1.00
3	5	.145833	-1.00
4	1	-.049093	1.00
4	2	.208333	-1.00
4	3	.145834	-1.00
4	4	.114582	-1.00
4	5	.114582	-1.00

5	1	.927938	-1.00
5	2	.197917	-1.00
5	3	.187500	-1.00
5	4	.072917	-1.00
5	5	.072917	-1.00

2ND DIFF-STATIONS

STA	WL	NORM VALUE	SIGN
1	2	OUT OF SURFACE	
1	3	OUT OF SURFACE	
1	4	-.439121	1.00
1	5	-.439121	1.00
2	2	-3.216759	1.00
2	3	.072917	-1.00
2	4	.312500	-1.00
2	5	.312500	-1.00
3	2	.041667	-1.00
3	3	.187500	-1.00
3	4	.406250	-1.00
3	5	.406250	-1.00
4	2	.062500	-1.00
4	3	.281250	-1.00
4	4	.499999	-1.00
4	5	.499999	-1.00
5	2	.041666	-1.00
5	3	.312500	-1.00
5	4	.583334	-1.00
5	5	.583334	-1.00

1.0.0-2

SMOG 2 - PASS 1 * * SAMPLE OUTPUT * *
* TODD DLG 5X5 END PROFILE X-Z DBL SPL-12/3/62
ROW ID

OFSET
R 1
R 2
R 3
R 4
R 5
R 6
R 7
R 8
R 9
R 10
R 11
R 12
R 13
R 14
R 15
R 16
R 17
R 18
R 19
R 20
R 21
R 22
R 23
R 24
R 25
R 26

MATRIX C 5 OFSET 2.45833
C 5 R 1 1.0
C 5 R 2- 1.0
C 5 R 3- 2.00000
C 5 R 4- 4.00000
C 5 R 5- 8.00000
C 6 OFSET- 2.45833
C 6 R 1 1.0

B-95

1.0.0.2

C	6 R	2	1.0
C	6 R	3	2.00000
C	6 R	4	4.00000
C	6 R	5	8.00000
C	7 OFFSET		3.87499
C	7 R	1	1.0
C	7 R	2-	1.0
C	7 R	3-	3.00000
C	7 R	4-	9.00000
C	7 R	5-	27.00000
C	7 R	6-	1.00000
C	8 OFFSET-		3.87499
C	8 R	1	1.0
C	8 R	2	1.0
C	8 R	3	3.00000
C	8 R	4	9.00000
C	8 R	5	27.00000
C	8 R	6	1.00000
C	9 OFFSET		5.33333
C	9 R	1	1.0
C	9 R	2-	1.0
C	9 R	3-	4.00000
C	9 R	4-	16.00000
C	9 R	5-	64.00000
C	9 R	6-	8.00000
C	10 OFFSET-		5.33333
C	10 R	1	1.0
C	10 R	2	1.0
C	10 R	3	4.00000
C	10 R	4	16.00000
C	10 R	5	64.00000
C	10 R	6	8.00000
C	13 OFFSET		1.24702
C	13 R	1	1.0
C	13 R	2-	1.0
C	13 R	3-	1.00000
C	13 R	4-	1.00000
C	13 R	5-	1.00000
C	13 R	7-	1.00000
C	13 R	8-	1.00000
C	13 R	9-	1.00000

C	13 R	10-	1.00000
C	13 R	12-	1.00000
C	13 R	13-	1.00000
C	13 R	14-	1.00000
C	13 R	15-	1.00000
C	13 R	17-	1.00000
C	13 R	18-	1.00000
C	13 R	19-	1.00000
C	13 R	20-	1.00000
C	14 OFFSET-	1.24702	
C	14 R	1	1.0
C	14 R	2	1.0
C	14 R	3	1.00000
C	14 R	4	1.00000
C	14 R	5	1.00000
C	14 R	7	1.00000
C	14 R	8	1.00000
C	14 R	9	1.00000
C	14 R	10	1.00000
C	14 R	12	1.00000
C	14 R	13	1.00000
C	14 R	14	1.00000
C	14 R	15	1.00000
C	14 R	17	1.00000
C	14 R	18	1.00000
C	14 R	19	1.00000
C	14 R	20	1.00000
C	15 OFFSET	2.69791	
C	15 R	1	1.0
C	15 R	2-	1.0
C	15 R	3-	2.00000
C	15 R	4-	4.00000
C	15 R	5-	8.00000
C	15 R	7-	1.00000
C	15 R	8-	2.00000
C	15 R	9-	4.00000
C	15 R	10-	8.00000
C	15 R	12-	1.00000
C	15 R	13-	2.00000
C	15 R	14-	4.00000
C	15 R	15-	8.00000

1.0.0-2

B-97

C	15 R	17-	1.00000
C	15 R	18-	2.00000
C	15 R	19-	4.00000
C	15 R	20-	8.00000
C	16	OFFSET-	2.69791
C	16 R	1	1.0
C	16 R	2	1.0
C	16 R	3	2.00000
C	16 R	4	4.00000
C	16 R	5	8.00000
C	16 R	7	1.00000
C	16 R	8	2.00000
C	16 R	9	4.00000
C	16 R	10	8.00000
C	16 R	12	1.00000
C	16 R	13	2.00000
C	16 R	14	4.00000
C	16 R	15	8.00000
C	16 R	17	1.00000
C	16 R	18	2.00000
C	16 R	19	4.00000
C	16 R	20	8.00000
C	17	OFFSET	4.19791
C	17 R	1	1.0
C	17 R	2-	1.0
C	17 R	3-	3.00000
C	17 R	4-	9.00000
C	17 R	5-	27.00000
C	17 R	6-	1.00000
C	17 R	7-	1.00000
C	17 R	8-	3.00000
C	17 R	9-	9.00000
C	17 R	10-	27.00000
C	17 R	11-	1.00000
C	17 R	12-	1.00000
C	17 R	13-	3.00000
C	17 R	14-	9.00000
C	17 R	15-	27.00000
C	17 R	16-	1.00000
C	17 R	17-	1.00000
C	17 R	18-	3.00000

1.0.0.2

C	17 R	19-	9.00000
C	17 R	20-	27.00000
C	17 R	21-	1.00000
C	18 OFFSET-		4.19791
C	18 R	1	1.0
C	18 R	2	1.0
C	18 R	3	3.00000
C	18 R	4	9.00000
C	18 R	5	27.00000
C	18 R	6	1.00000
C	18 R	7	1.00000
C	18 R	8	3.00000
C	18 R	9	9.00000
C	18 R	10	27.00000
C	18 R	11	1.00000
C	18 R	12	1.00000
C	18 R	13	3.00000
C	18 R	14	9.00000
C	18 R	15	27.00000
C	18 R	16	1.00000
C	18 R	17	1.00000
C	18 R	18	3.00000
C	18 R	19	9.00000
C	18 R	20	27.00000
C	18 R	21	1.00000
C	19 OFFSET		5.81250
C	19 R	1	1.0
C	19 R	2-	1.0
C	19 R	3-	4.00000
C	19 R	4-	16.00000
C	19 R	5-	64.00000
C	19 R	6-	8.00000
C	19 R	7-	1.00000
C	19 R	8-	4.00000
C	19 R	9-	16.00000
C	19 R	10-	64.00000
C	19 R	11-	8.00000
C	19 R	12-	1.00000
C	19 R	13-	4.00000
C	19 R	14-	16.00000
C	19 R	15-	64.00000

B-99

1.0.0-2

C	19 R	16-	8.00000
C	19 R	17-	1.00000
C	19 R	18-	4.00000
C	19 R	19-	16.00000
C	19 R	20-	64.00000
C	19 R	21-	8.00000
C	20 OFFSET-		5.81250
C	20 R	1	1.0
C	20 R	2	1.0
C	20 R	3	4.00000
C	20 R	4	16.00000
C	20 R	5	64.00000
C	20 R	6	8.00000
C	20 R	7	1.00000
C	20 R	8	4.00000
C	20 R	9	16.00000
C	20 R	10	64.00000
C	20 R	11	8.00000
C	20 R	12	1.00000
C	20 R	13	4.00000
C	20 R	14	16.00000
C	20 R	15	64.00000
C	20 R	16	8.00000
C	20 R	17	1.00000
C	20 R	18	4.00000
C	20 R	19	16.00000
C	20 R	20	64.00000
C	20 R	21	8.00000
C	23 OFFSET		1.47916
C	23 R	1	1.0
C	23 R	2-	1.0
C	23 R	3-	1.00000
C	23 R	4-	1.00000
C	23 R	5-	1.00000
C	23 R	7-	2.00000
C	23 R	8-	2.00000
C	23 R	9-	2.00000
C	23 R	10-	2.00000
C	23 R	12-	4.00000
C	23 R	13-	4.00000
C	23 R	14-	4.00000

B-100

1.0.0-2

C	23	R	15-	4.00000
C	23	R	17-	8.00000
C	23	R	18-	8.00000
C	23	R	19-	8.00000
C	23	R	20-	8.00000
C	24	OFSET-		1.47916
C	24	R	1	1.0
C	24	R	2	1.0
C	24	R	3	1.00000
C	24	R	4	1.00000
C	24	R	5	1.00000
C	24	R	7	2.00000
C	24	R	8	2.00000
C	24	R	9	2.00000
C	24	R	10	2.00000
C	24	R	12	4.00000
C	24	R	13	4.00000
C	24	R	14	4.00000
C	24	R	15	4.00000
C	24	R	17	8.00000
C	24	R	18	8.00000
C	24	R	19	8.00000
C	24	R	20	8.00000
C	25	OFSET		2.97916
C	25	R	1	1.0
C	25	R	2-	1.0
C	25	R	3-	2.00000
C	25	R	4-	4.00000
C	25	R	5-	8.00000
C	25	R	7-	2.00000
C	25	R	8-	4.00000
C	25	R	9-	8.00000
C	25	R	10-	16.00000
C	25	R	12-	4.00000
C	25	R	13-	8.00000
C	25	R	14-	16.00000
C	25	R	15-	32.00000
C	25	R	17-	8.00000
C	25	R	18-	16.00000
C	25	R	19-	32.00000
C	25	R	20-	64.00000

B-101

C	26	OFSET-	2.97916
C	26	R 1	1.0
C	26	R 2	1.0
C	26	R 3	2.00000
C	26	R 4	4.00000
C	26	R 5	8.00000
C	26	R 7	2.00000
C	26	R 8	4.00000
C	26	R 9	8.00000
C	26	R 10	16.00000
C	26	R 12	4.00000
C	26	R 13	8.00000
C	26	R 14	16.00000
C	26	R 15	32.00000
C	26	R 17	8.00000
C	26	R 18	16.00000
C	26	R 19	32.00000
C	26	R 20	64.00000
C	27	OFSET	4.58333
C	27	R 1	1.0
C	27	R 2-	1.0
C	27	R 3-	3.00000
C	27	R 4-	9.00000
C	27	R 5-	27.00000
C	27	R 6-	1.00000
C	27	R 7-	2.00000
C	27	R 8-	6.00000
C	27	R 9-	18.00000
C	27	R 10-	54.00000
C	27	R 11-	2.00000
C	27	R 12-	4.00000
C	27	R 13-	12.00000
C	27	R 14-	36.00000
C	27	R 15-	108.00000
C	27	R 16-	4.00000
C	27	R 17-	8.00000
C	27	R 18-	24.00000
C	27	R 19-	72.00000
C	27	R 20-	216.00000
C	27	R 21-	8.00000
C	28	OFSET-	4.58333

1.0.0.2

B-102

C	28	R	1	1.0
C	28	R	2	1.0
C	28	R	3	3.00000
C	28	R	4	9.00000
C	28	R	5	27.00000
C	28	R	6	1.00000
C	28	R	7	2.00000
C	28	R	8	6.00000
C	28	R	9	18.00000
C	28	R	10	54.00000
C	28	R	11	2.00000
C	28	R	12	4.00000
C	28	R	13	12.00000
C	28	R	14	36.00000
C	28	R	15	108.00000
C	28	R	16	4.00000
C	28	R	17	8.00000
C	28	R	18	24.00000
C	28	R	19	72.00000
C	28	R	20	216.00000
C	28	R	21	8.00000
C	29	OFFSET	6.33333	
C	29	R	1	1.0
C	29	R	2-	1.0
C	29	R	3-	4.00000
C	29	R	4-	16.00000
C	29	R	5-	64.00000
C	29	R	6-	8.00000
C	29	R	7-	2.00000
C	29	R	8-	8.00000
C	29	R	9-	32.00000
C	29	R	10-	128.00000
C	29	R	11-	16.00000
C	29	R	12-	4.00000
C	29	R	13-	16.00000
C	29	R	14-	64.00000
C	29	R	15-	256.00000
C	29	R	16-	32.00000
C	29	R	17-	8.00000
C	29	R	18-	32.00000
C	29	R	19-	128.00000

1.0.0.2

B.103

1.0.0-2

C	29	R	20-	512.00000
C	29	R	21-	64.00000
C	30	OFSET-	6.33333	
C	30	R	1	1.0
C	30	R	2	1.0
C	30	R	3	4.00000
C	30	R	4	16.00000
C	30	R	5	64.00000
C	30	R	6	8.00000
C	30	R	7	2.00000
C	30	R	8	8.00000
C	30	R	9	32.00000
C	30	R	10	128.00000
C	30	R	11	16.00000
C	30	R	12	4.00000
C	30	R	13	16.00000
C	30	R	14	64.00000
C	30	R	15	256.00000
C	30	R	16	32.00000
C	30	R	17	8.00000
C	30	R	18	32.00000
C	30	R	19	128.00000
C	30	R	20	512.00000
C	30	R	21	64.00000
C	31	OFSET-	.34374	
C	31	R	1	1.0
C	31	R	2-	1.0
C	31	R	7-	3.00000
C	31	R	12-	9.00000
C	31	R	17-	27.00000
C	31	R	22-	1.00000
C	32	OFSET-	.34374	
C	32	R	1	1.0
C	32	R	2	1.0
C	32	R	7	3.00000
C	32	R	12	9.00000
C	32	R	17	27.00000
C	32	R	22	1.00000
C	33	OFSET	1.79166	
C	33	R	1	1.0
C	33	R	2-	1.0

B-104

1.0.0-2

C	33	R	3-	1.00000
C	33	R	4-	1.00000
C	33	R	5-	1.00000
C	33	R	7-	3.00000
C	33	R	8-	3.00000
C	33	R	9-	3.00000
C	33	R	10-	3.00000
C	33	R	12-	9.00000
C	33	R	13-	9.00000
C	33	R	14-	9.00000
C	33	R	15-	9.00000
C	33	R	17-	27.00000
C	33	R	18-	27.00000
C	33	R	19-	27.00000
C	33	R	20-	27.00000
C	33	R	22-	1.00000
C	33	R	23-	1.00000
C	33	R	24-	1.00000
C	33	R	25-	1.00000
C	34	OFFSET-		1.79166
C	34	R	1	1.0
C	34	R	2	1.0
C	34	R	3	1.00000
C	34	R	4	1.00000
C	34	R	5	1.00000
C	34	R	7	3.00000
C	34	R	8	3.00000
C	34	R	9	3.00000
C	34	R	10	3.00000
C	34	R	12	9.00000
C	34	R	13	9.00000
C	34	R	14	9.00000
C	34	R	15	9.00000
C	34	R	17	27.00000
C	34	R	18	27.00000
C	34	R	19	27.00000
C	34	R	20	27.00000
C	34	R	22	1.00000
C	34	R	23	1.00000
C	34	R	24	1.00000
C	34	R	25	1.00000

B-105

1.0.0.2

C	35	OFFSET	3.44791
C	35	R 1	1.0
C	35	R 2-	1.0
C	35	R 3-	2.00000
C	35	R 4-	4.00000
C	35	R 5-	8.00000
C	35	R 7-	3.00000
C	35	R 8-	6.00000
C	35	R 9-	12.00000
C	35	R 10-	24.00000
C	35	R 12-	9.00000
C	35	R 13-	18.00000
C	35	R 14-	36.00000
C	35	R 15-	72.00000
C	35	R 17-	27.00000
C	35	R 18-	54.00000
C	35	R 19-	108.00000
C	35	R 20-	216.00000
C	35	R 22-	1.00000
C	35	R 23-	2.00000
C	35	R 24-	4.00000
C	35	R 25-	8.00000
C	36	OFFSET-	3.44791
C	36	R 1	1.0
C	36	R 2	1.0
C	36	R 3	2.00000
C	36	R 4	4.00000
C	36	R 5	8.00000
C	36	R 7	3.00000
C	36	R 8	6.00000
C	36	R 9	12.00000
C	36	R 10	24.00000
C	36	R 12	9.00000
C	36	R 13	18.00000
C	36	R 14	36.00000
C	36	R 15	72.00000
C	36	R 17	27.00000
C	36	R 18	54.00000
C	36	R 19	108.00000
C	36	R 20	216.00000
C	36	R 22	1.00000

B-106

1.0.0.2

C	36 R	23	2.00000
C	36 R	24	4.00000
C	36 R	25	8.00000
C	37 OFFSET		5.25000
C	37 R	1	1.0
C	37 R	2-	1.0
C	37 R	3-	3.00000
C	37 R	4-	9.00000
C	37 R	5-	27.00000
C	37 R	6-	1.00000
C	37 R	7-	3.00000
C	37 R	8-	9.00000
C	37 R	9-	27.00000
C	37 R	10-	81.00000
C	37 R	11-	3.00000
C	37 R	12-	9.00000
C	37 R	13-	27.00000
C	37 R	14-	81.00000
C	37 R	15-	243.00000
C	37 R	16-	9.00000
C	37 R	17-	27.00000
C	37 R	18-	81.00000
C	37 R	19-	243.00000
C	37 R	20-	729.00000
C	37 R	21-	27.00000
C	37 R	22-	1.00000
C	37 R	23-	3.00000
C	37 R	24-	9.00000
C	37 R	25-	27.00000
C	37 R	26-	1.00000
C	38 OFFSET-		5.25000
C	38 R	1	1.0
C	38 R	2	1.0
C	38 R	3	3.00000
C	38 R	4	9.00000
C	38 R	5	27.00000
C	38 R	6	1.00000
C	38 R	7	3.00000
C	38 R	8	9.00000
C	38 R	9	27.00000
C	38 R	10	81.00000

B:07

1.0.0.2

C	38 R	11	3.00000
C	38 R	12	9.00000
C	38 R	13	27.00000
C	38 R	14	81.00000
C	38 R	15	243.00000
C	38 R	16	9.00000
C	38 R	17	27.00000
C	38 R	18	81.00000
C	38 R	19	243.00000
C	38 R	20	729.00000
C	38 R	21	27.00000
C	38 R	22	1.00000
C	38 R	23	3.00000
C	38 R	24	9.00000
C	38 R	25	27.00000
C	38 R	26	1.00000
C	39 OFFSET		7.16666
C	39 R	1	1.0
C	39 R	2-	1.0
C	39 R	3-	4.00000
C	39 R	4-	16.00000
C	39 R	5-	64.00000
C	39 R	6-	8.00000
C	39 R	7-	3.00000
C	39 R	8-	12.00000
C	39 R	9-	48.00000
C	39 R	10-	192.00000
C	39 R	11-	24.00000
C	39 R	12-	9.00000
C	39 R	13-	36.00000
C	39 R	14-	144.00000
C	39 R	15-	576.00000
C	39 R	16-	72.00000
C	39 R	17-	27.00000
C	39 R	18-	108.00000
C	39 R	19-	432.00000
C	39 R	20-	1728.00000
C	39 R	21-	216.00000
C	39 R	22-	1.00000
C	39 R	23-	4.00000
C	39 R	24-	16.00000

B-108

C	39	R	25-	64.00000
C	39	R	26-	8.00000
C	40	OFSET-		7.16666
C	40	R	1	1.0
C	40	R	2	1.0
C	40	R	3	4.00000
C	40	R	4	16.00000
C	40	R	5	64.00000
C	40	R	6	8.00000
C	40	R	7	3.00000
C	40	R	8	12.00000
C	40	R	9	48.00000
C	40	R	10	192.00000
C	40	R	11	24.00000
C	40	R	12	9.00000
C	40	R	13	36.00000
C	40	R	14	144.00000
C	40	R	15	576.00000
C	40	R	16	72.00000
C	40	R	17	27.00000
C	40	R	18	108.00000
C	40	R	19	432.00000
C	40	R	20	1728.00000
C	40	R	21	216.00000
C	40	R	22	1.00000
C	40	R	23	4.00000
C	40	R	24	16.00000
C	40	R	25	64.00000
C	40	R	26	8.00000
C	41	OFSET		.70833
C	41	R	1	1.0
C	41	R	2-	1.0
C	41	R	7-	4.00000
C	41	R	12-	16.00000
C	41	R	17-	64.00000
C	41	R	22-	8.00000
C	42	OFSET-		.70833
C	42	R	1	1.0
C	42	R	2	1.0
C	42	R	7	4.00000
C	42	R	12	16.00000

1.0.0-2

C	42	R	17	64.00000
C	42	R	22	8.00000
C	43	OFFSET		2.41666
C	43	R	1	1.0
C	43	R	2-	1.0
C	43	R	3-	1.00000
C	43	R	4-	1.00000
C	43	R	5-	1.00000
C	43	R	7-	4.00000
C	43	R	8-	4.00000
C	43	R	9-	4.00000
C	43	R	10-	4.00000
C	43	R	12-	16.00000
C	43	R	13-	16.00000
C	43	R	14-	16.00000
C	43	R	15-	16.00000
C	43	R	17-	64.00000
C	43	R	18-	64.00000
C	43	R	19-	64.00000
C	43	R	20-	64.00000
C	43	R	22-	8.00000
C	43	R	23-	8.00000
C	43	R	24-	8.00000
C	43	R	25-	8.00000
C	44	OFFSET-		2.41666
C	44	R	1	1.0
C	44	R	2	1.0
C	44	R	3	1.00000
C	44	R	4	1.00000
C	44	R	5	1.00000
C	44	R	7	4.00000
C	44	R	8	4.00000
C	44	R	9	4.00000
C	44	R	10	4.00000
C	44	R	12	16.00000
C	44	R	13	16.00000
C	44	R	14	16.00000
C	44	R	15	16.00000
C	44	R	17	64.00000
C	44	R	18	64.00000
C	44	R	19	64.00000

B-110

C	44	R	20	64.00000
C	44	R	22	8.00000
C	44	R	23	8.00000
C	44	R	24	8.00000
C	44	R	25	8.00000
C	45	OFSET		4.32291
C	45	R	1	1.0
C	45	R	2-	1.0
C	45	R	3-	2.00000
C	45	R	4-	4.00000
C	45	R	5-	8.00000
C	45	R	7-	4.00000
C	45	R	8-	8.00000
C	45	R	9-	16.00000
C	45	R	10-	32.00000
C	45	R	12-	16.00000
C	45	R	13-	32.00000
C	45	R	14-	64.00000
C	45	R	15-	128.00000
C	45	R	17-	64.00000
C	45	R	18-	128.00000
C	45	R	19-	256.00000
C	45	R	20-	512.00000
C	45	R	22-	8.00000
C	45	R	23-	16.00000
C	45	R	24-	32.00000
C	45	R	25-	64.00000
C	46	OFSET		4.32291
C	46	R	1	1.0
C	46	R	2	1.0
C	46	R	3	2.00000
C	46	R	4	4.00000
C	46	R	5	8.00000
C	46	R	7	4.00000
C	46	R	8	8.00000
C	46	R	9	16.00000
C	46	R	10	32.00000
C	46	R	12	16.00000
C	46	R	13	32.00000
C	46	R	14	64.00000
C	46	R	15	128.00000

1.0.0-2

B-111

C	46	R	17	64.00000
C	46	R	18	128.00000
C	46	R	19	256.00000
C	46	R	20	512.00000
C	46	R	22	8.00000
C	46	R	23	16.00000
C	46	R	24	32.00000
C	46	R	25	64.00000
C	47	OFFSET		6.41666
C	47	R	1	1.0
C	47	R	2-	1.0
C	47	R	3-	3.00000
C	47	R	4-	9.00000
C	47	R	5-	27.00000
C	47	R	6-	1.00000
C	47	R	7-	4.00000
C	47	R	8-	12.00000
C	47	R	9-	36.00000
C	47	R	10-	108.00000
C	47	R	11-	4.00000
C	47	R	12-	16.00000
C	47	R	13-	48.00000
C	47	R	14-	144.00000
C	47	R	15-	432.00000
C	47	R	16-	16.00000
C	47	R	17-	64.00000
C	47	R	18-	192.00000
C	47	R	19-	576.00000
C	47	R	20-	1728.00000
C	47	R	21-	64.00000
C	47	R	22-	8.00000
C	47	R	23-	24.00000
C	47	R	24-	72.00000
C	47	R	25-	216.00000
C	47	R	26-	8.00000
C	48	OFFSET-		6.41666
C	48	R	1	1.0
C	48	R	2	1.0
C	48	R	3	3.00000
C	48	R	4	9.00000
C	48	R	5	27.00000

1.0.0-2

B-112

C	48 R	6	1.00000
C	48 R	7	4.00000
C	48 R	8	12.00000
C	48 R	9	36.00000
C	48 R	10	108.00000
C	48 R	11	4.00000
C	48 R	12	16.00000
C	48 R	13	48.00000
C	48 R	14	144.00000
C	48 R	15	432.00000
C	48 R	16	16.00000
C	48 R	17	64.00000
C	48 R	18	192.00000
C	48 R	19	576.00000
C	48 R	20	1728.00000
C	48 R	21	64.00000
C	48 R	22	8.00000
C	48 R	23	24.00000
C	48 R	24	72.00000
C	48 R	25	216.00000
C	48 R	26	8.00000
C	49 OFSET		8.58333
C	49 R	1	1.0
C	49 R	2-	1.0
C	49 R	3-	4.00000
C	49 R	4-	16.00000
C	49 R	5-	64.00000
C	49 R	6-	8.00000
C	49 R	7-	4.00000
C	49 R	8-	16.00000
C	49 R	9-	64.00000
C	49 R	10-	256.00000
C	49 R	11-	32.00000
C	49 R	12-	16.00000
C	49 R	13-	64.00000
C	49 R	14-	256.00000
C	49 R	15-	1024.00000
C	49 R	16-	128.00000
C	49 R	17-	64.00000
C	49 R	18-	256.00000
C	49 R	19-	1024.00000

1.0.0.2

C	49	R	20-	4096.00000
C	49	R	21-	512.00000
C	49	R	22-	8.00000
C	49	R	23-	32.00000
C	49	R	24-	128.00000
C	49	R	25-	512.00000
C	49	R	26-	64.00000
C	50	OFFSET-		8.58333
C	50	R	1	1.0
C	50	R	2	1.0
C	50	R	3	4.00000
C	50	R	4	16.00000
C	50	R	5	64.00000
C	50	R	6	8.00000
C	50	R	7	4.00000
C	50	R	8	16.00000
C	50	R	9	64.00000
C	50	R	10	256.00000
C	50	R	11	32.00000
C	50	R	12	16.00000
C	50	R	13	64.00000
C	50	R	14	256.00000
C	50	R	15	1024.00000
C	50	R	16	128.00000
C	50	R	17	64.00000
C	50	R	18	256.00000
C	50	R	19	1024.00000
C	50	R	20	4096.00000
C	50	R	21	512.00000
C	50	R	22	8.00000
C	50	R	23	32.00000
C	50	R	24	128.00000
C	50	R	25	512.00000
C	50	R	26	64.00000
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	20.00000000			
	1.00000000			
	1.00000000			

4	4	26	1	0.00000000	.00100000
		.07843137	3.00000000		

1.0.0-2

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-1.00000000			
-1.00000000			
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-1.00000000			
-1.00000000			
-1.00000000			
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-1.00000000			
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-1.00000000			
-1.00000000			
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-1.00000000			

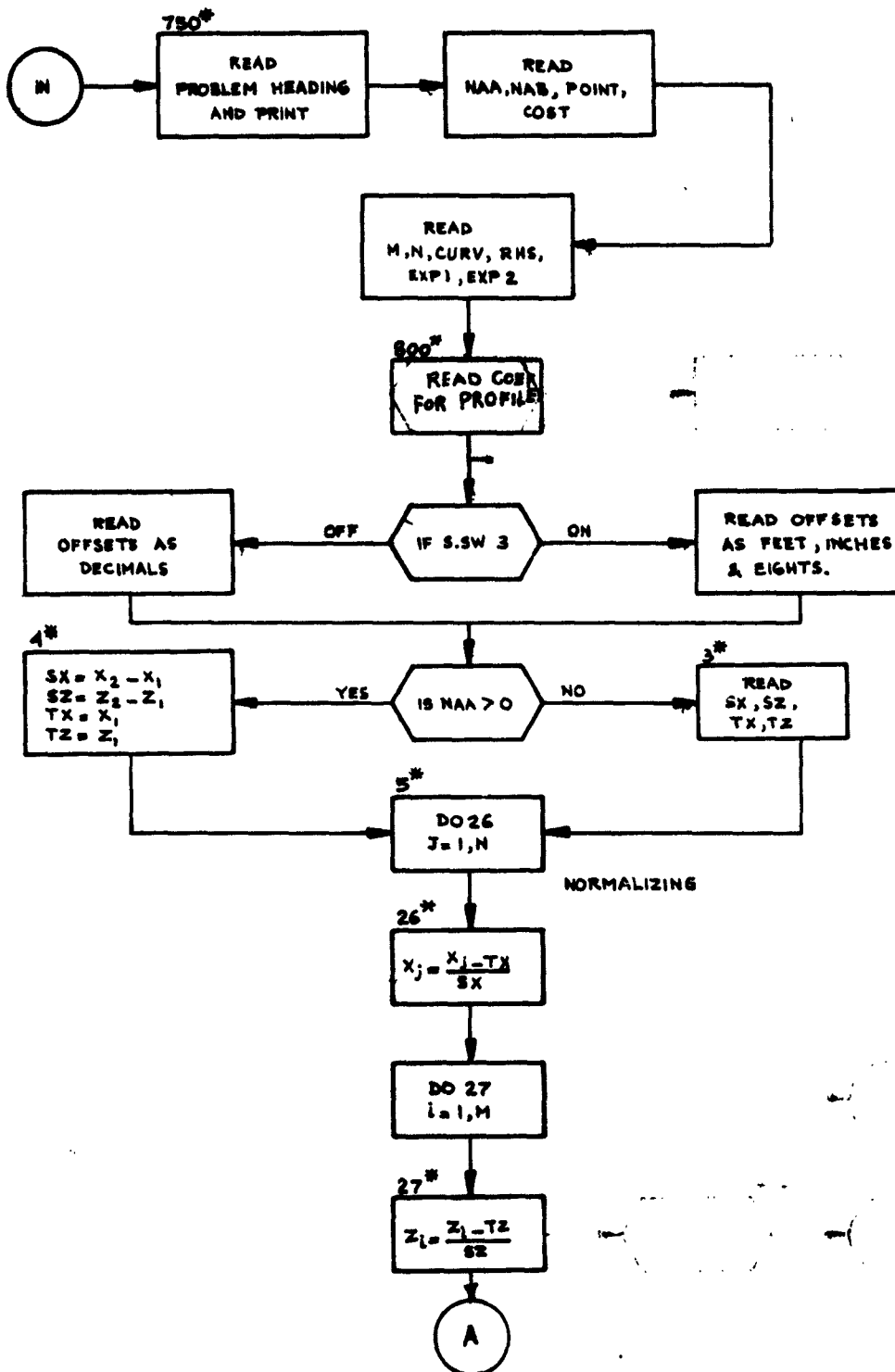
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-.58730000
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0.00000000

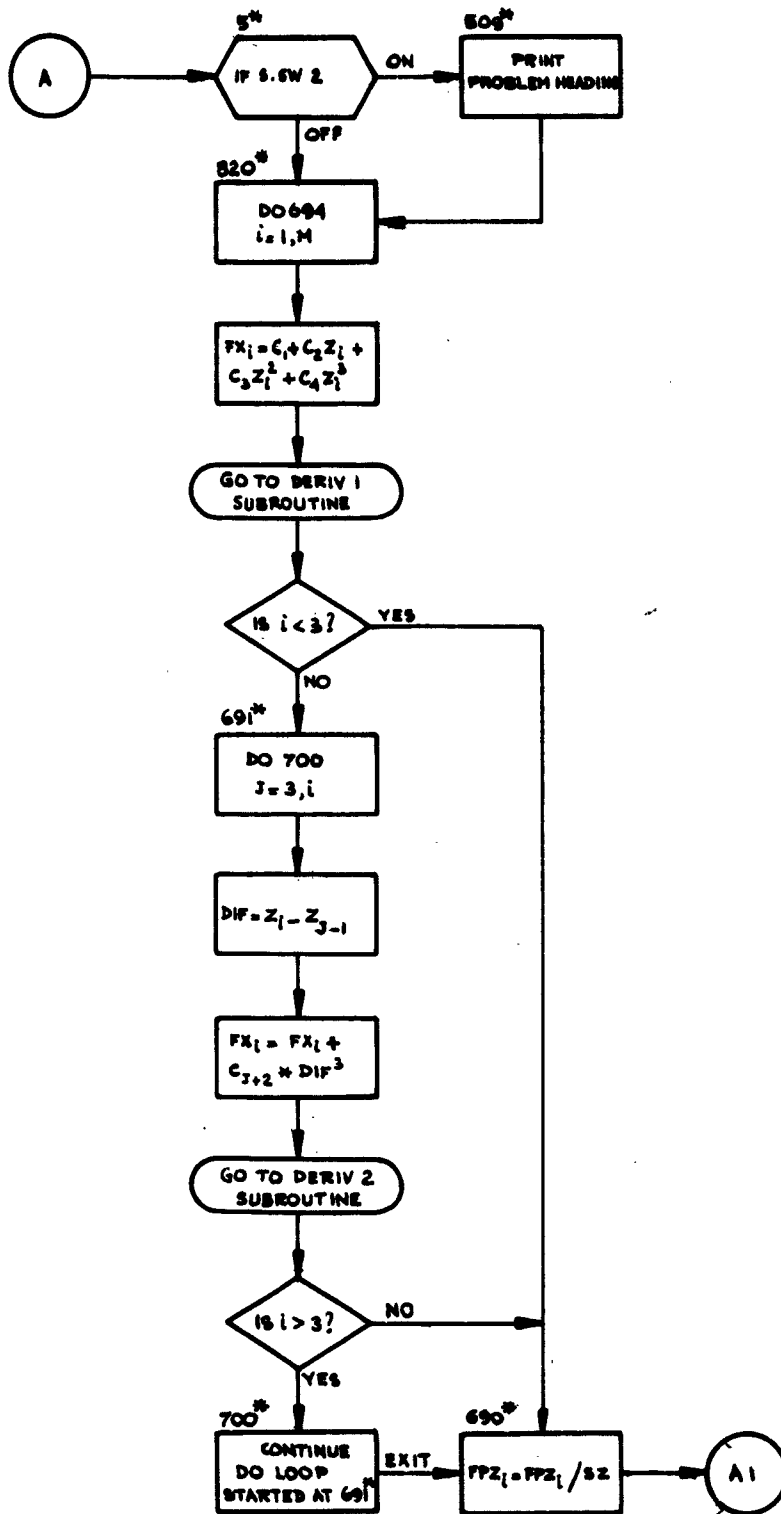
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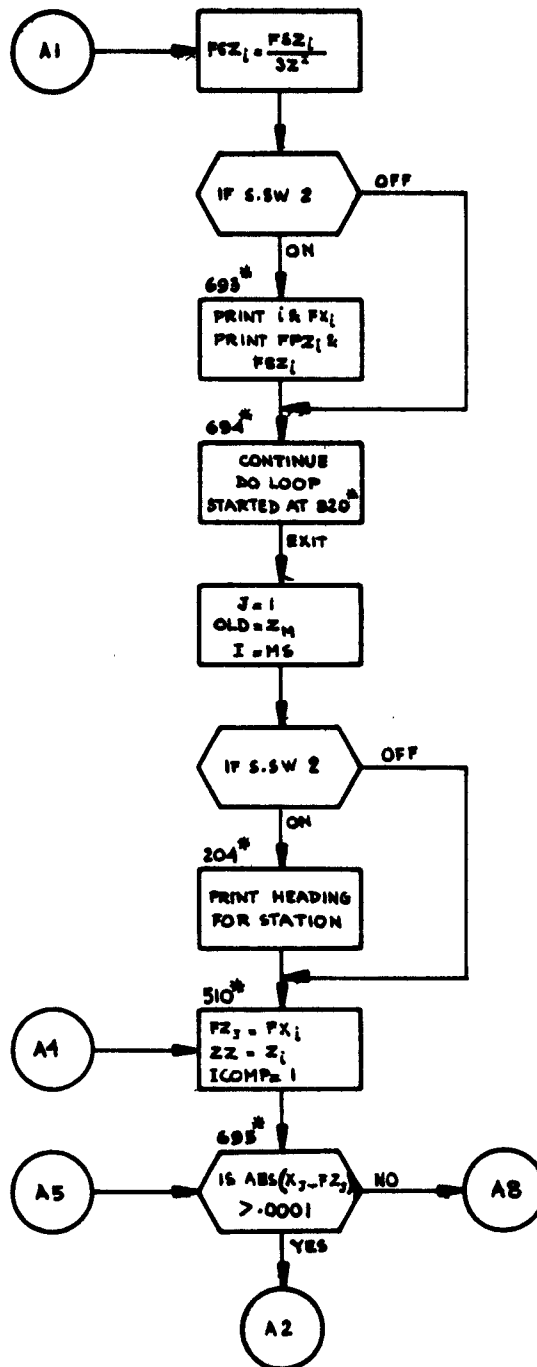
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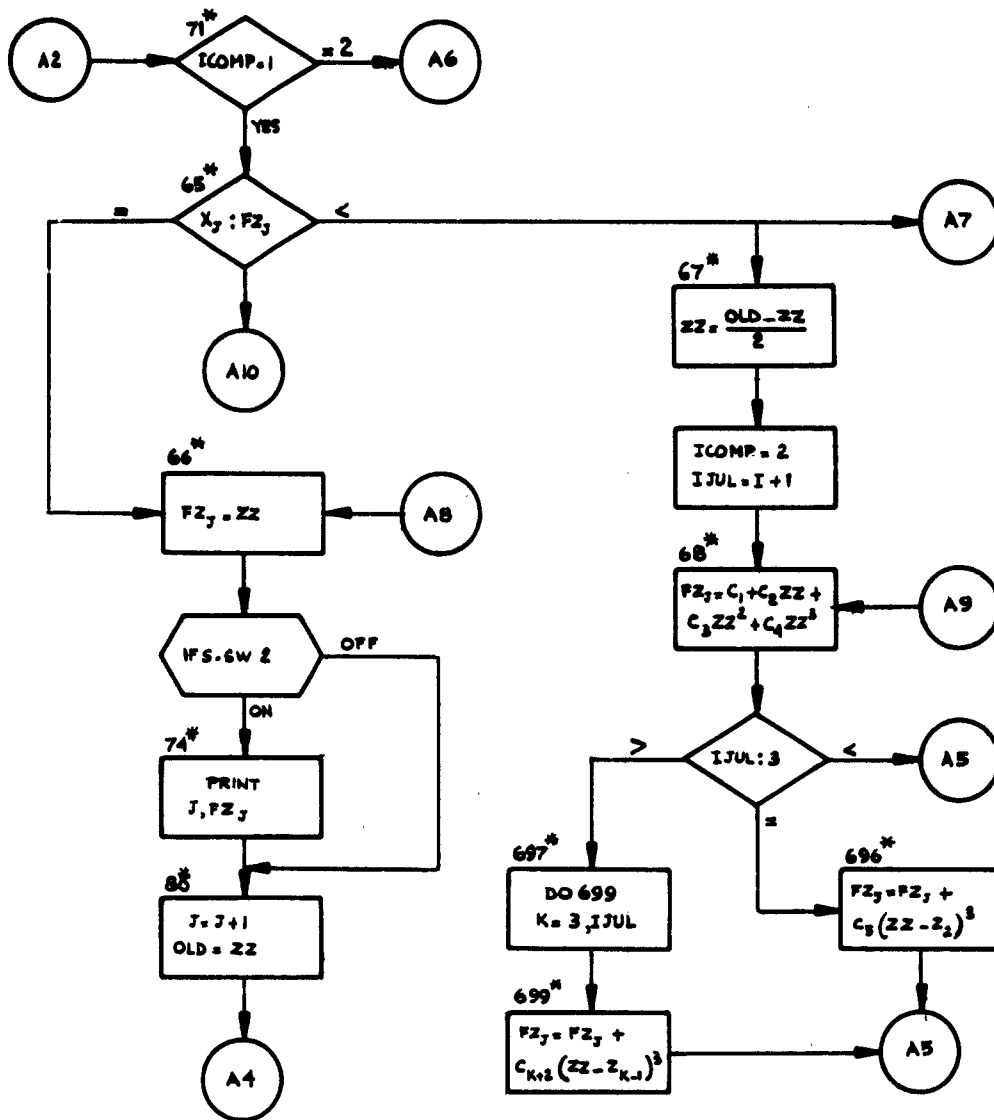
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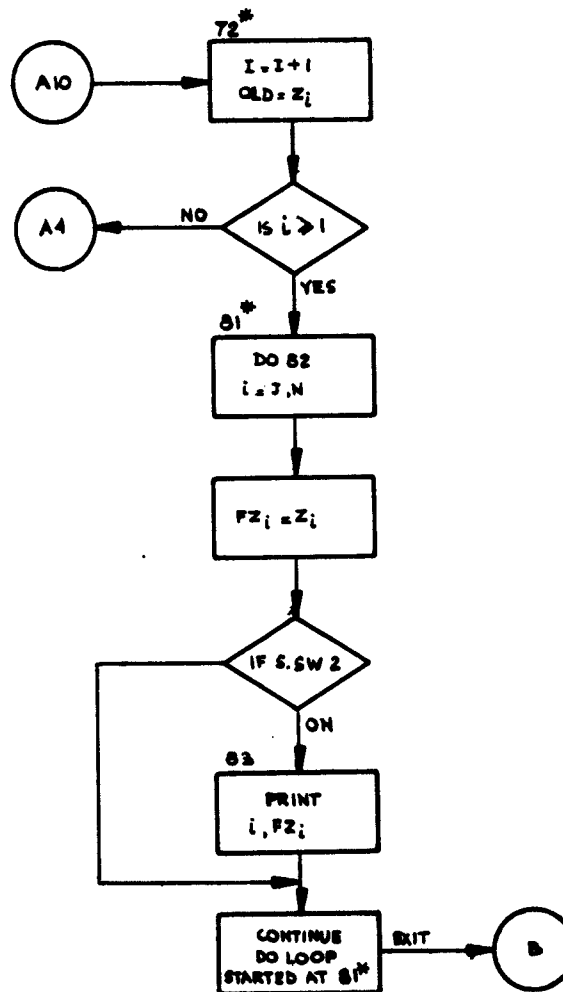
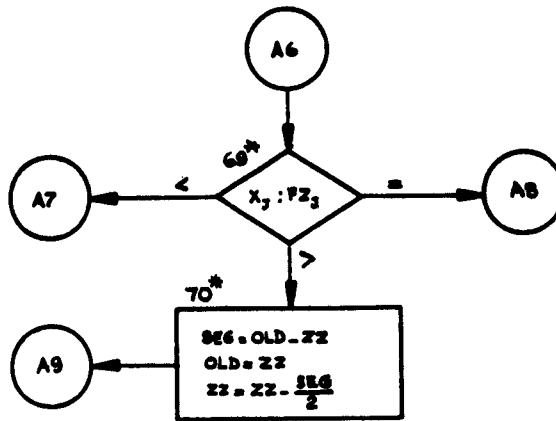
FLOW DIAGRAM - SMOG 2, PASS 1

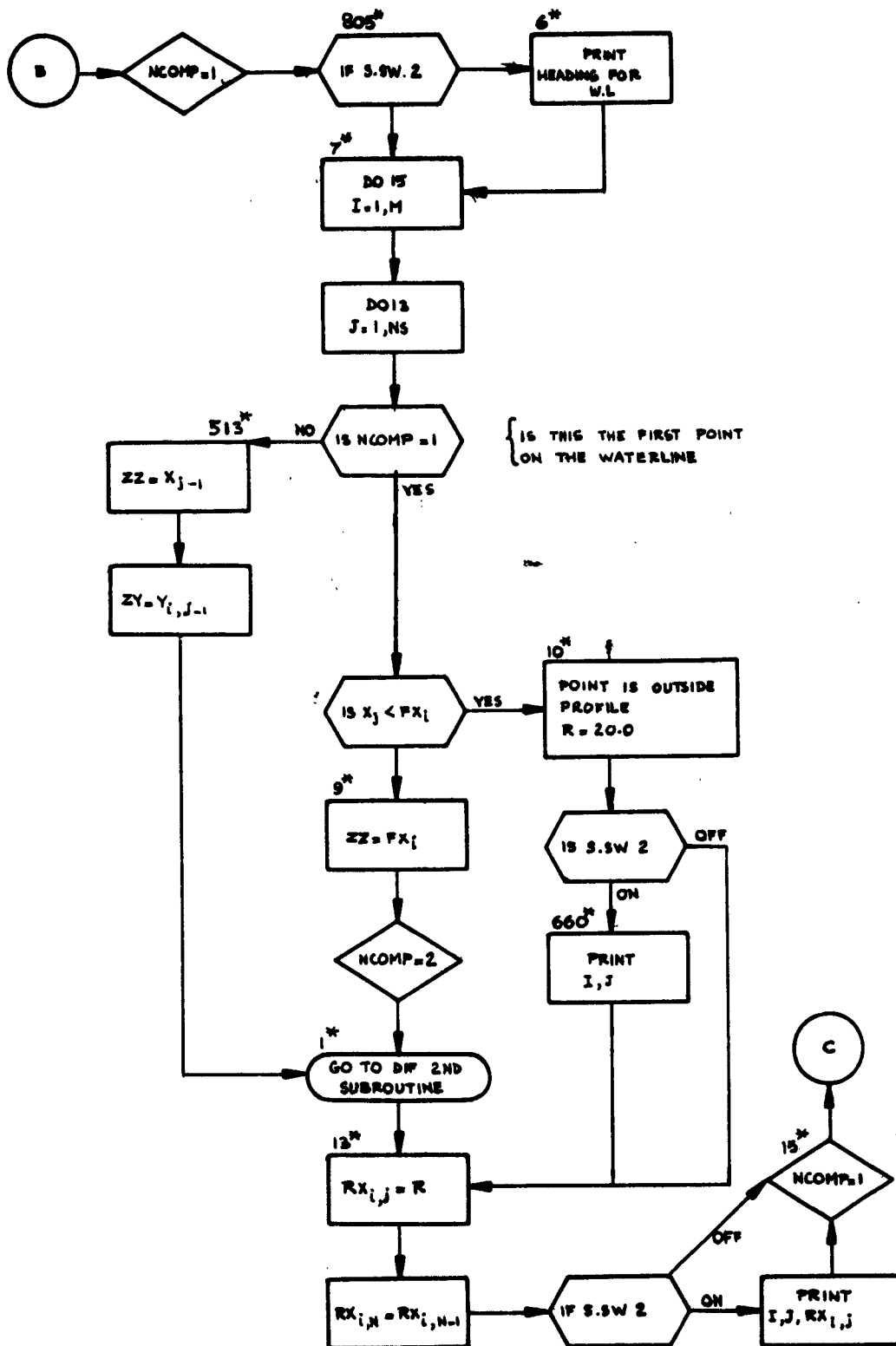


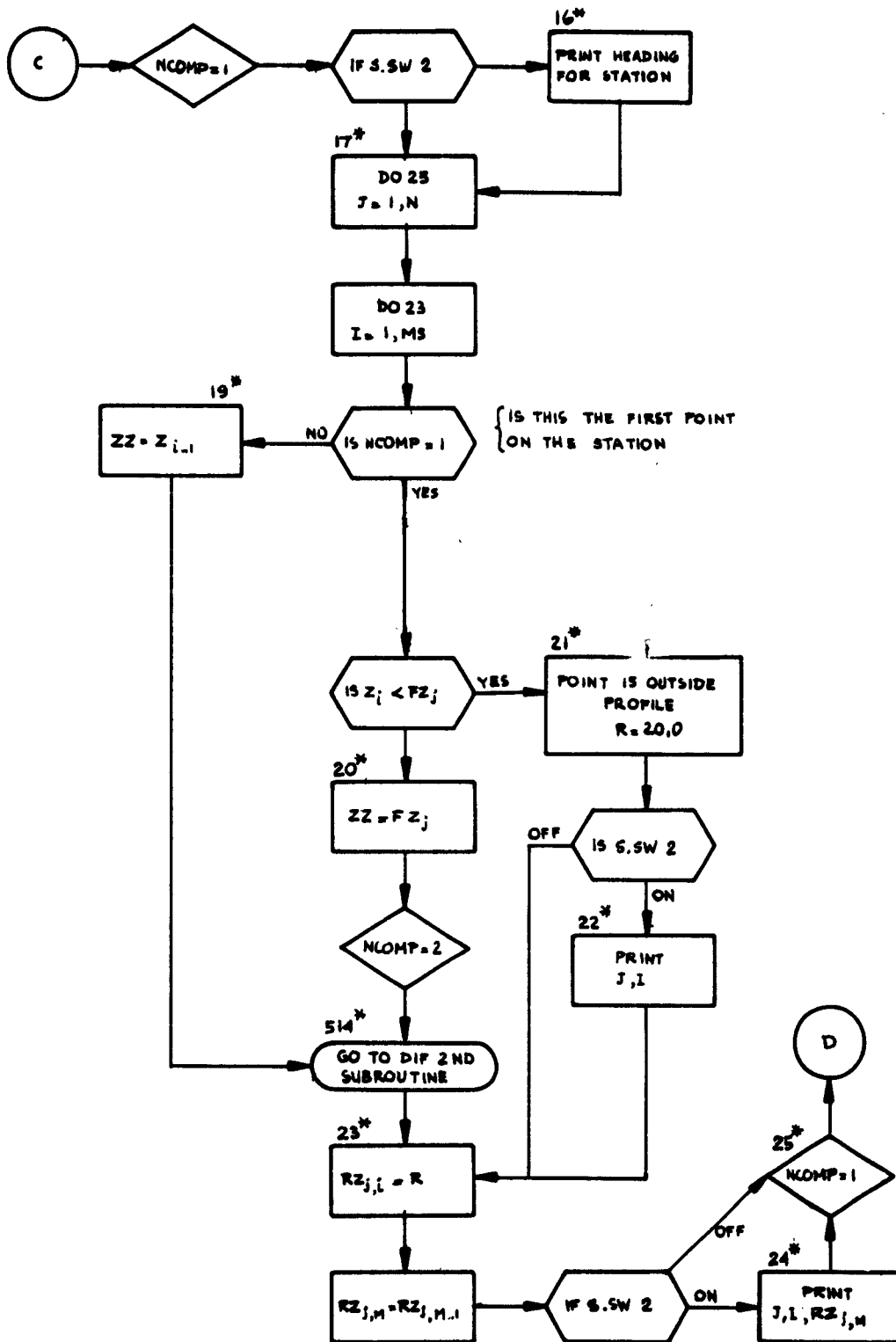


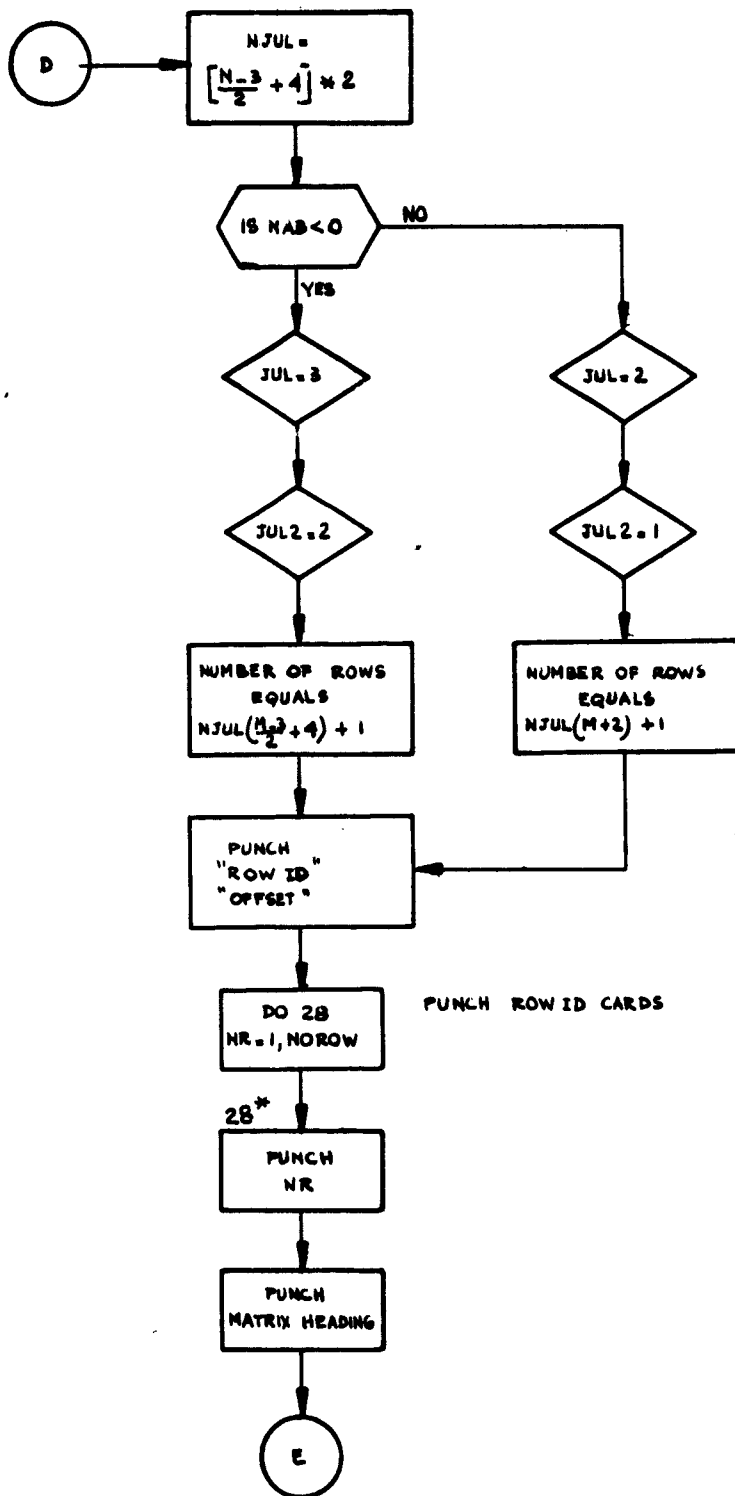


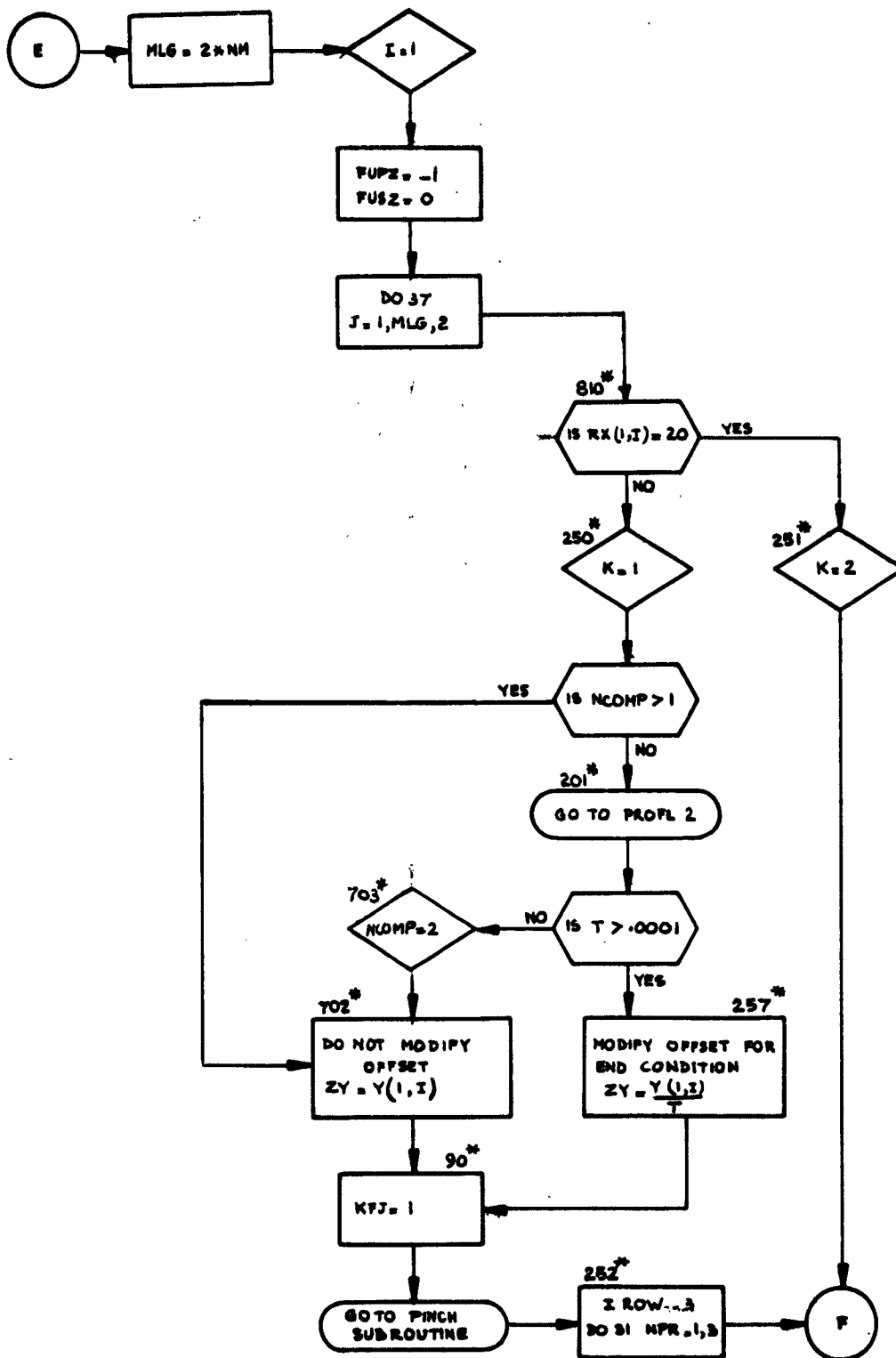


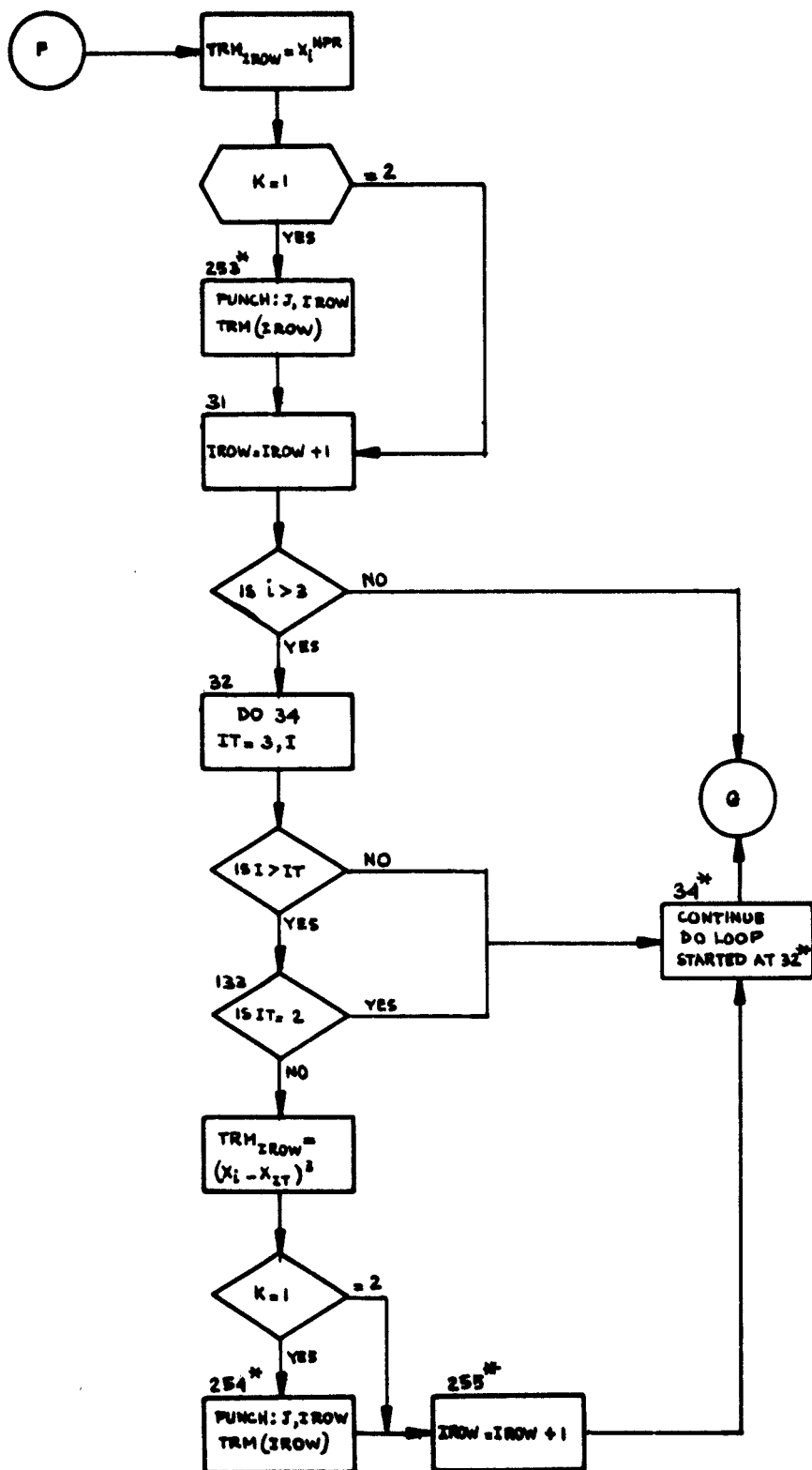


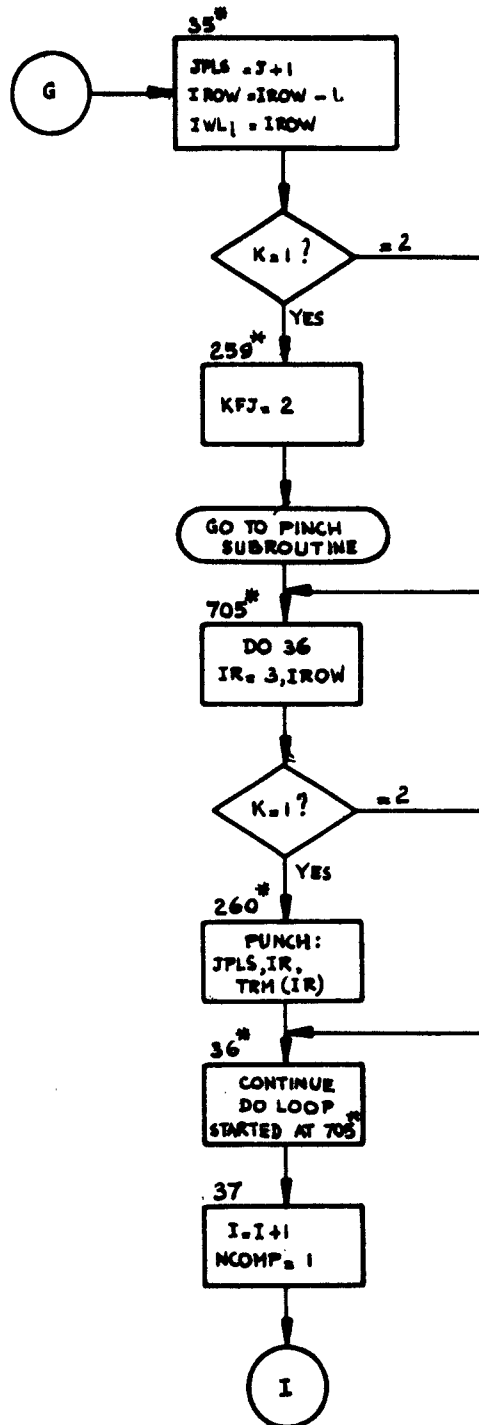


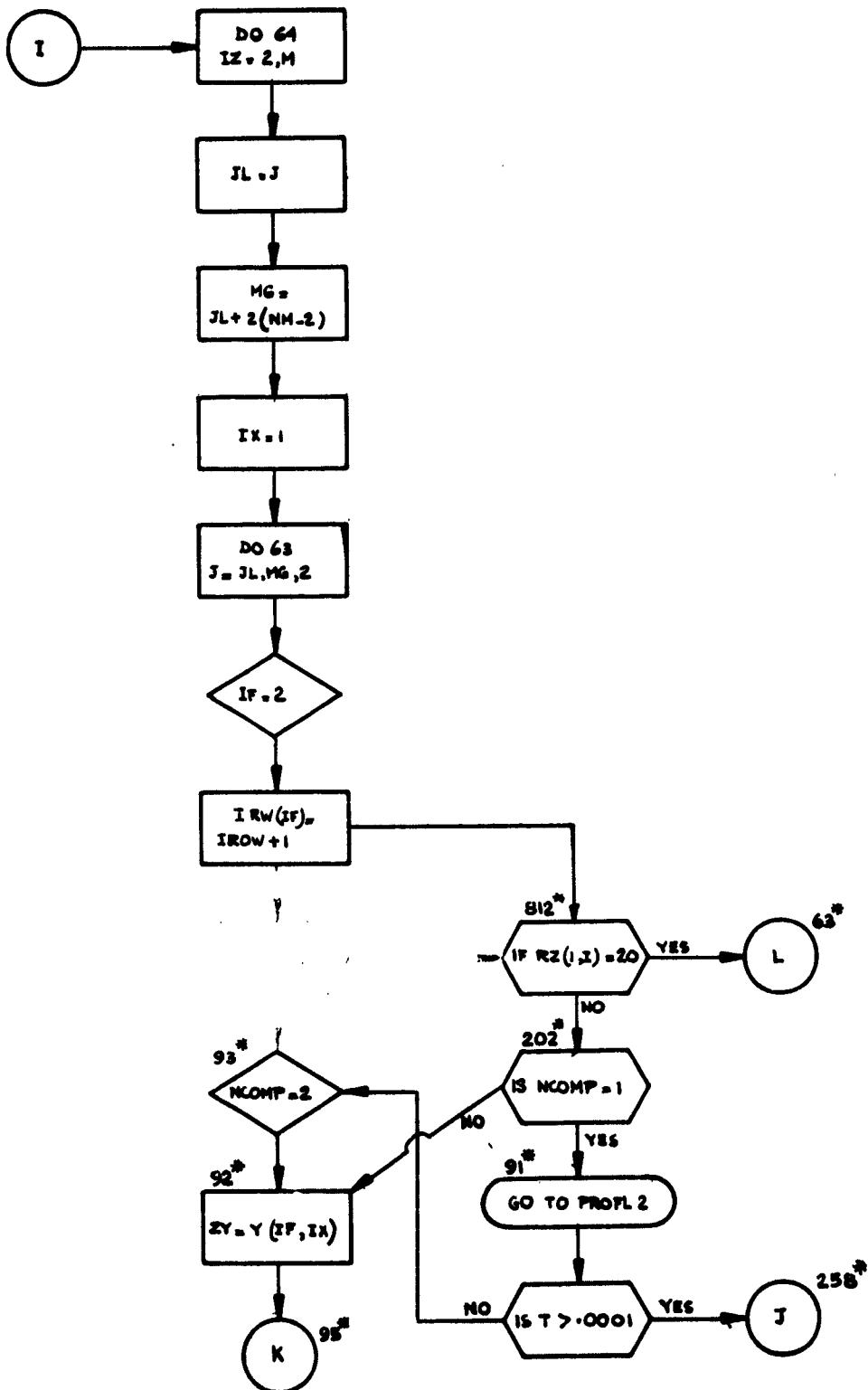


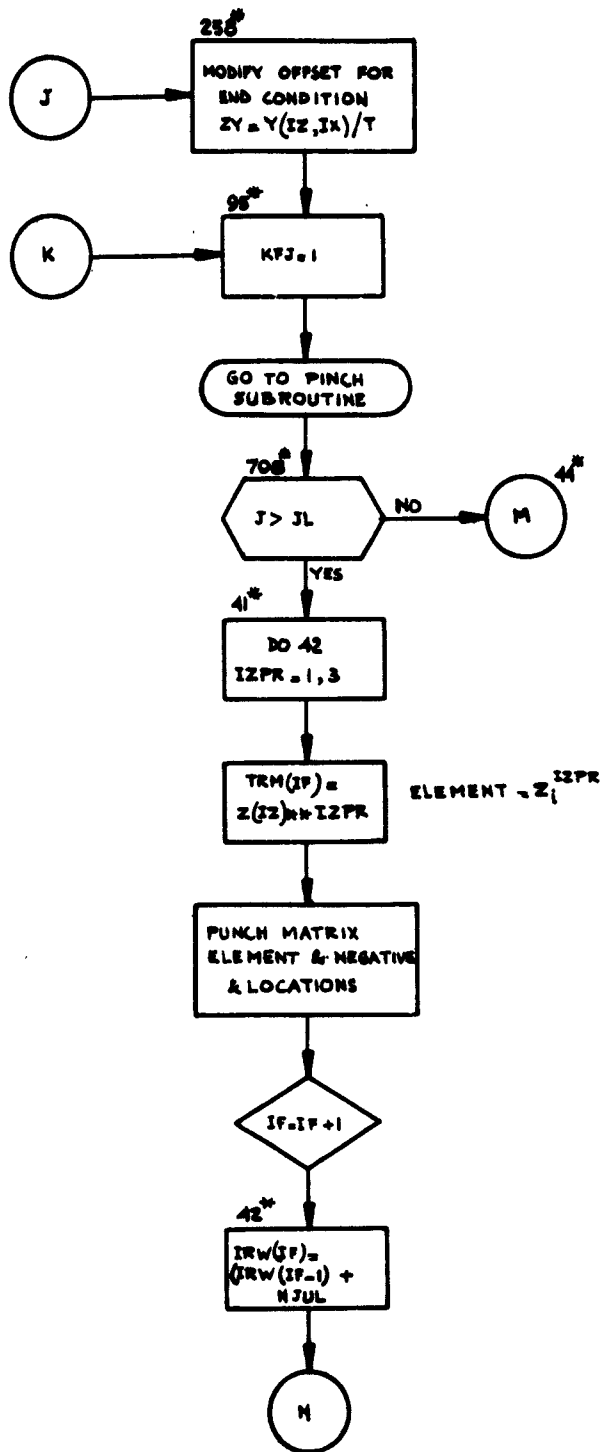


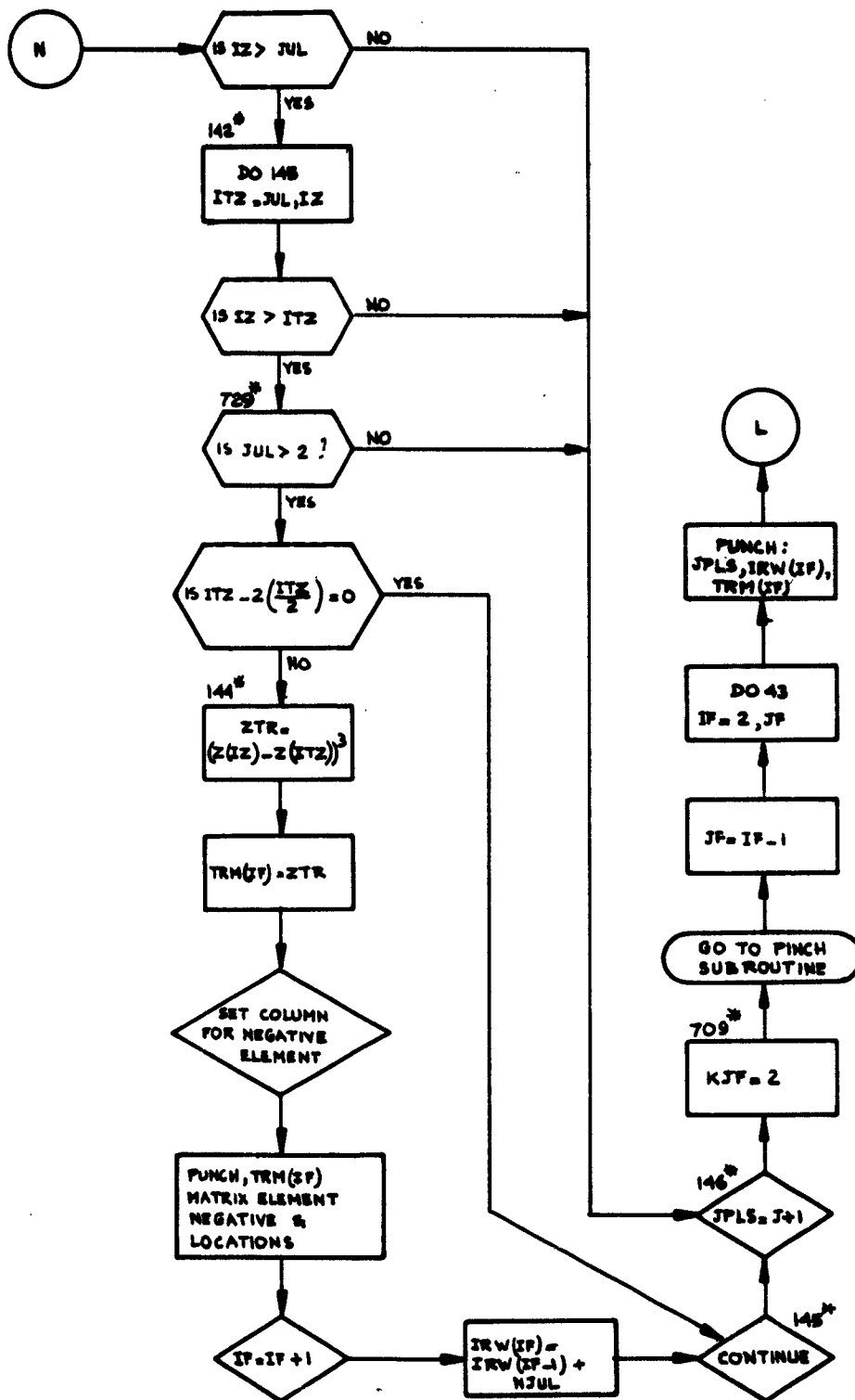


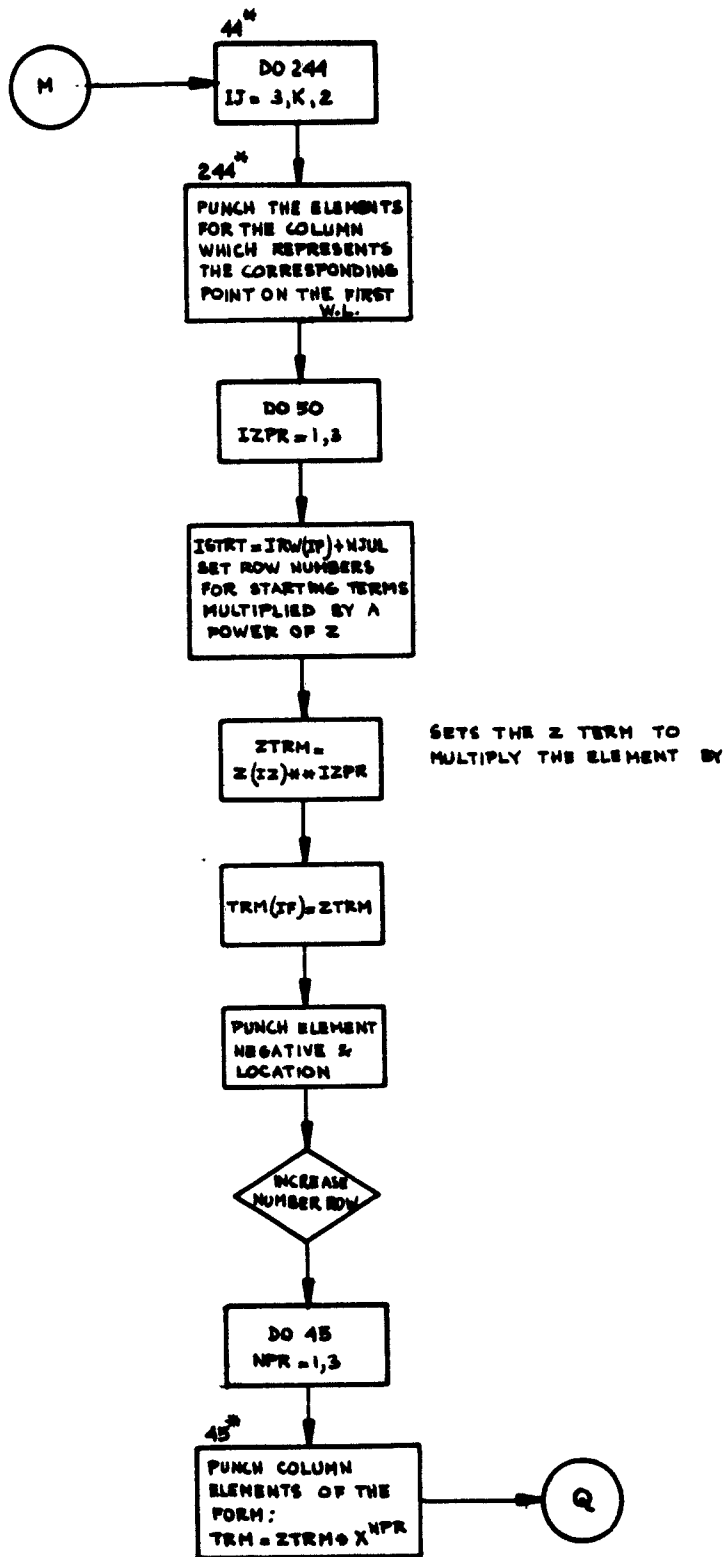


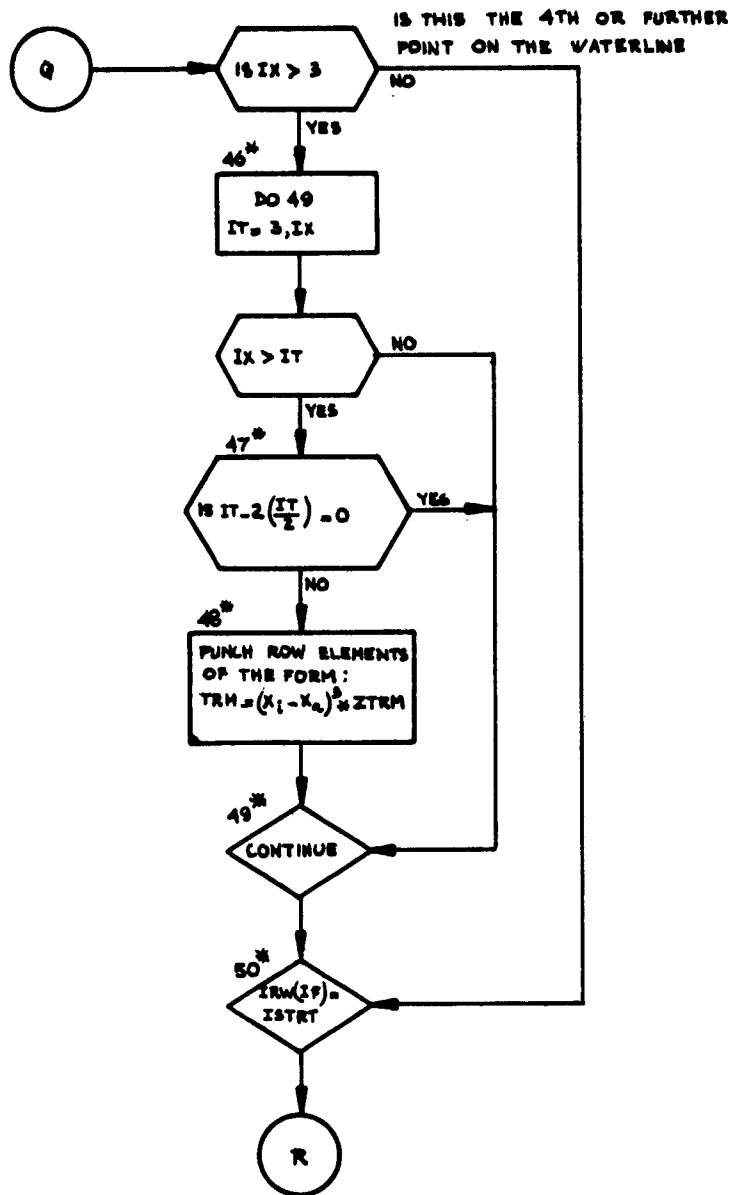


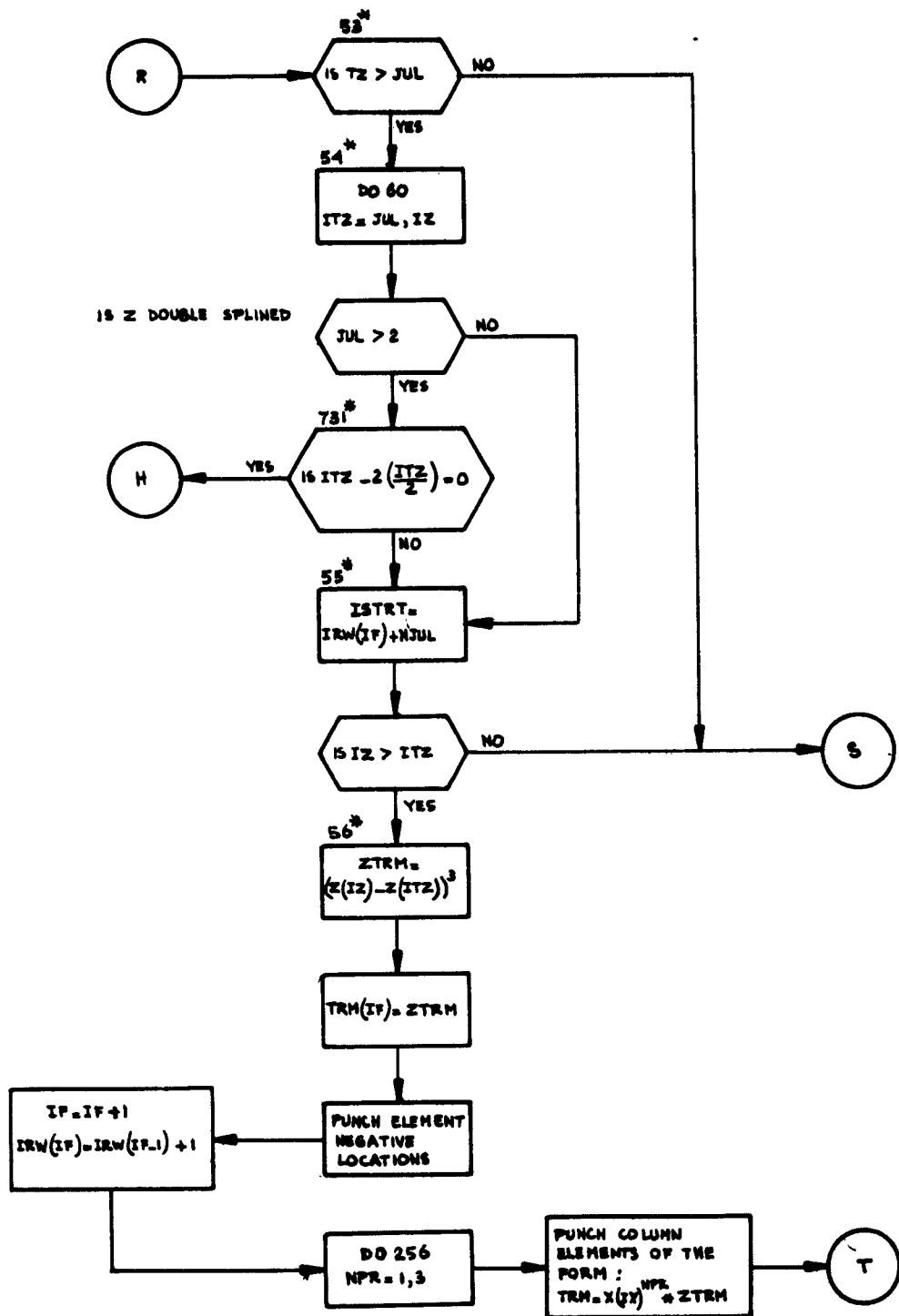


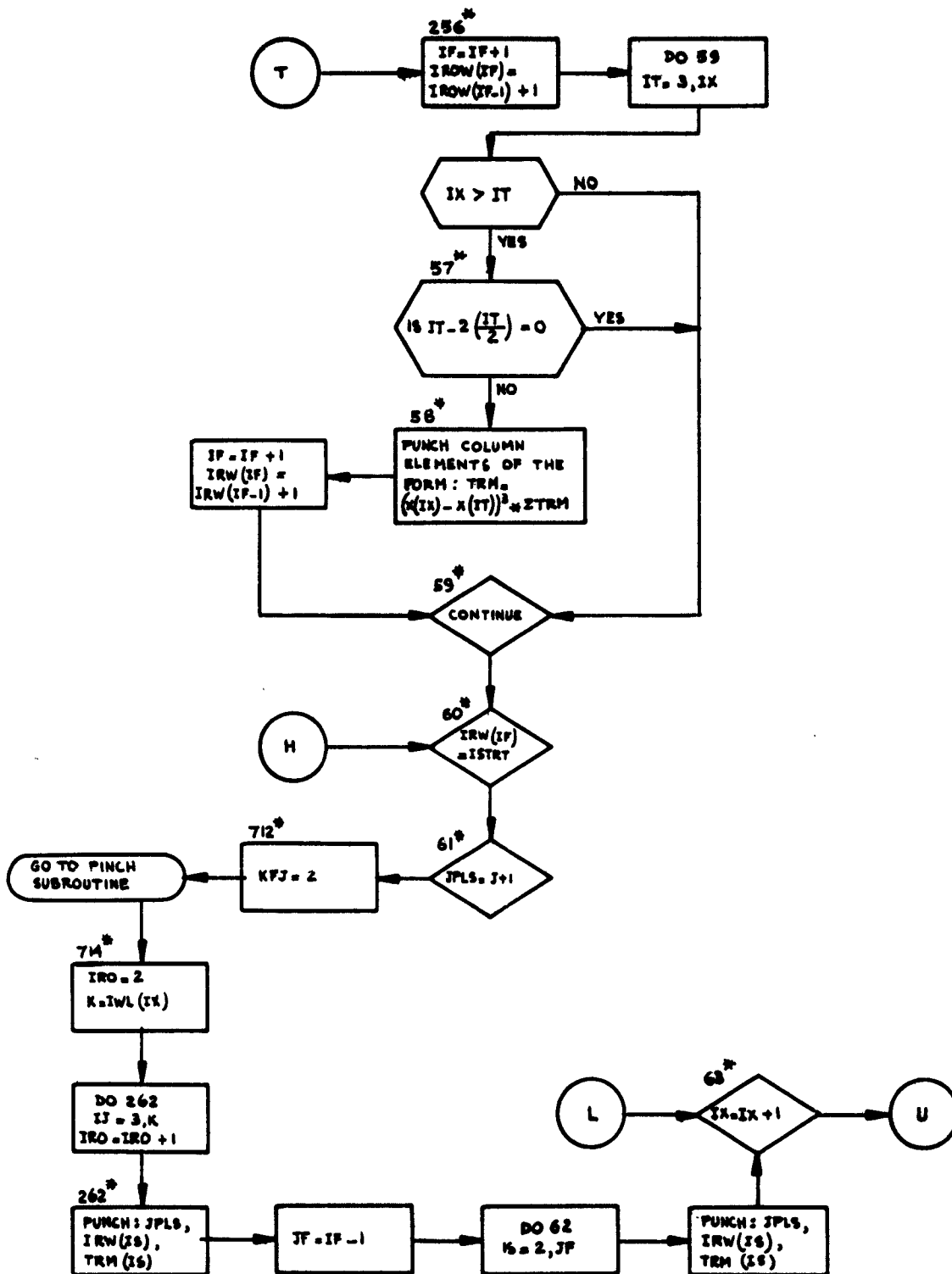


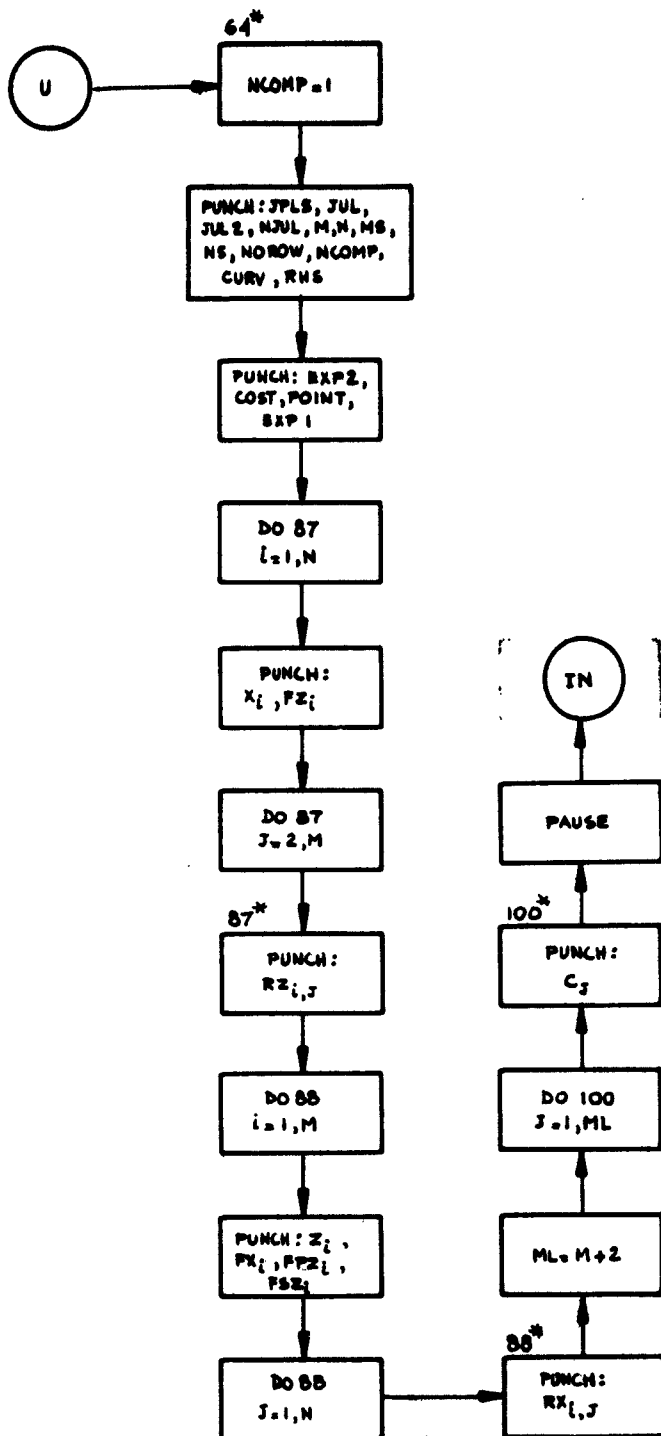




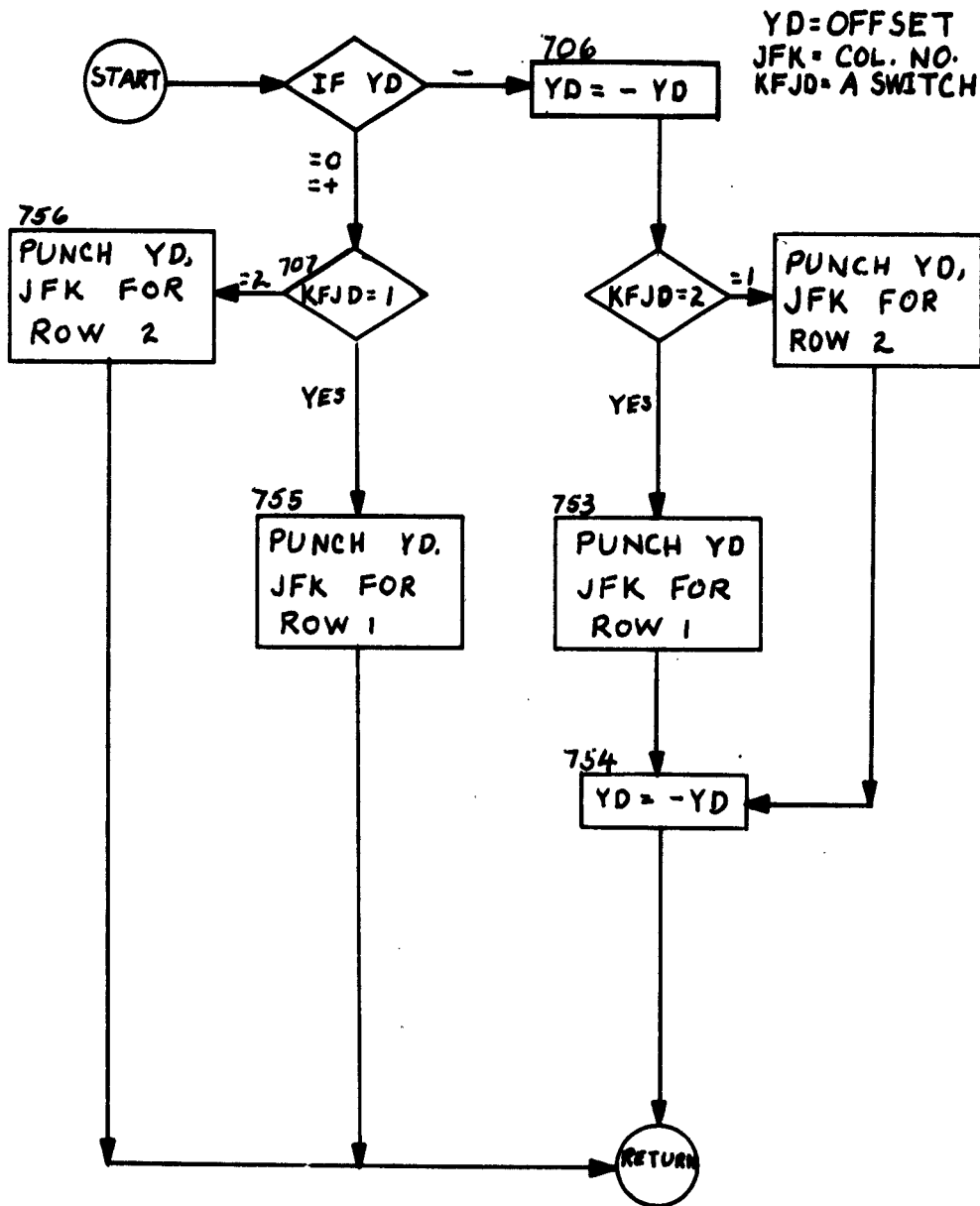








SUBROUTINE PINCH (YD, JFK, KFJD)

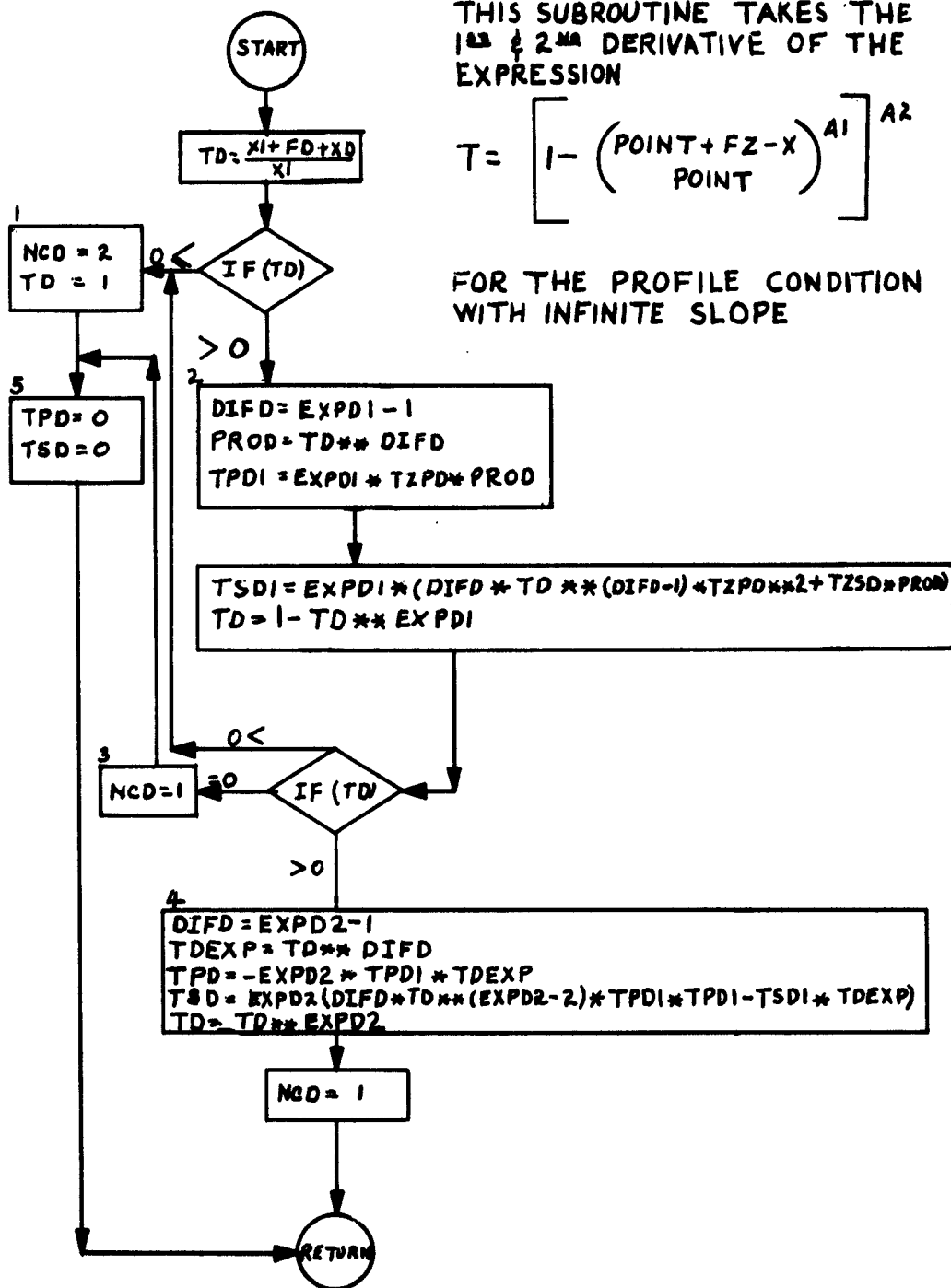


SUBROUTINE PROFL 2 XD,FD,EXPDI,TZPD,TZSD,EXPD2,XI,TD,
TPD, TSD, NCD

THIS SUBROUTINE TAKES THE
1st & 2nd DERIVATIVE OF THE
EXPRESSION

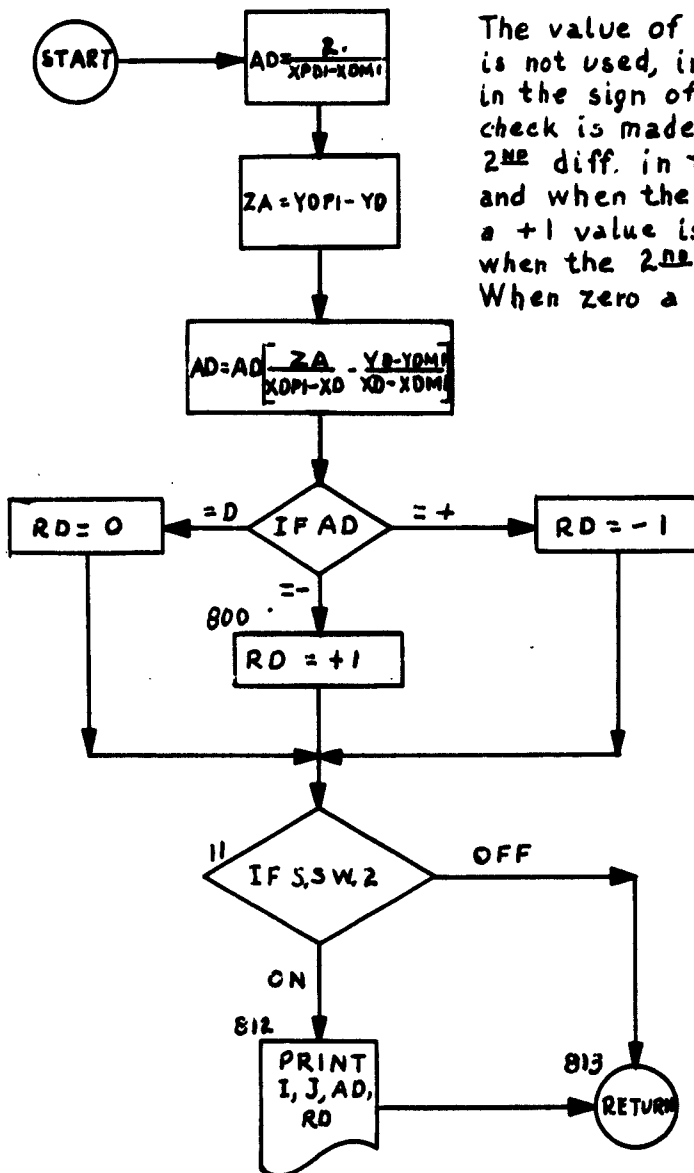
$$T = \left[1 - \left(\frac{\text{POINT} + \text{FZ} - \text{X}}{\text{POINT}} \right)^{A1} \right]^{A2}$$

FOR THE PROFILE CONDITION
WITH INFINITE SLOPE



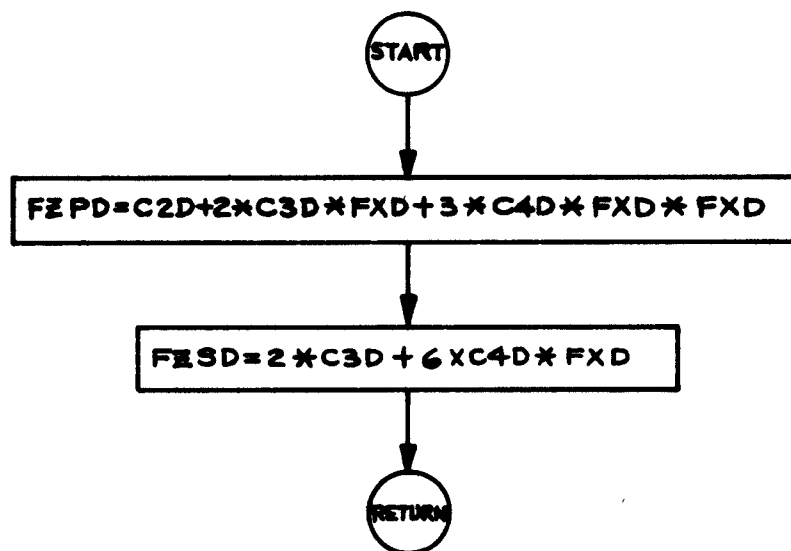
SUBROUTINE DIF2ND COMPUTES THE DIFFERENCE
OF A POINT $X_{i,j}, Y_{i,j}$ BY:

$$R = \frac{2}{X_{i+1} - X_{i-1}} \left(\frac{Y_{i+1} - Y_i}{X_{i+1} - X_i} - \frac{Y_i - Y_{i-1}}{X_i - X_{i-1}} \right)$$



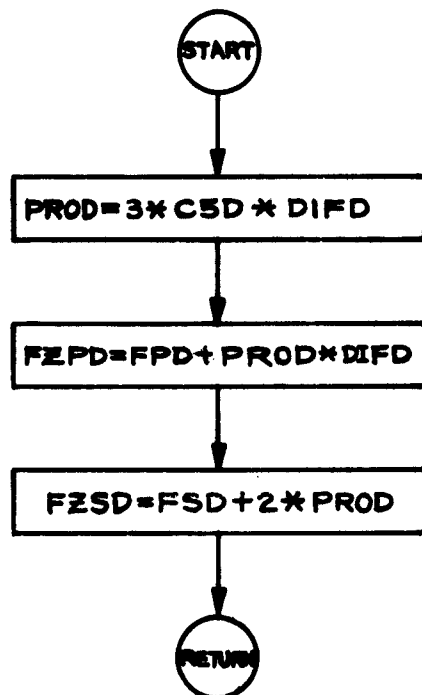
The value of the 2nd Diff. is not used, interest is only in the sign of same $\therefore$ a check is made on the sign of 2nd diff. in this subroutine and when the sign is minus a +1 value is output and -1 when the 2nd diff. is positive. When zero a zero is output.

SUBROUTINE DERIV1 (C2D, C3D, C4D, FXD, FZPD, FZSD)



THIS SUBROUTINE TAKES THE 1ST & 2ND DERIVATIVE
OF THE STANDARD CUBIC

SUBROUTINE DERIV2 (C5D,DIFD,FPD,FSD,FZPD,FZSD)



**THIS SUBROUTINE TAKES THE 1ST & 2ND
DERIVATIVE OF THE THEILHEIMER TERMS
AND ADDS THEM TO THE STANDARD CUBIC
1ST & 2ND DERIVATIVES**

FORTRAN LISTING

```

C      SMOG2 PASS 1  DUAL  X OR X AND Z DBL SPL  WITH PROFILE
      DIMENSION RX(11,15),RZ(15,11),TRM(150), IRW(250),FZ(11),FX(15
)
      DIMENSION X(15),Z(11),Y(11,15),WL(15,11),IWL(15),C(13),FPZ(11
),
      CFSZ(11)
C      *      *      INPUT      *      *
750 READ 173
      PRINT 173
      READ 150,NAA,NAB,POINT,COST
      READ 150,M,N,CURV,RHS,EXP1,EXP2
      ML=M+2
      DO 751 I=1,ML
751  READ 154,C(I)
      NCOMP=1
      NL=N+1
      ML=M+1
      NS=N-1
      MS=M-1
      DO 2 I=1,M
      READ 154,Z(I)
      DO 2 J=1,N
      IF(SENSE SWITCH 3)802,803
802  READ 183,X(J),IAY,IBY,ICY
      AAY=IAY
      BBY=IBY
      CCY=ICY
      Y(I,J)=AAY+(BBY+(CCY/8.))/12.
      GO TO 2
803  READ 154,X(J),Y(I,J)
      2 CONTINUE
      IF(NAA)3,3,4
      3 READ 154,SX,SZ,TX,TZ
      GO TO 5
      4 SX=X(2)-X(1)
      SZ=Z(2)-Z(1)
      TZ=Z(1)
      TX=X(1)
      5 IF(SENSE SWITCH 2)509,508
509  PRINT 165
C      *      *      NORMALIZING      *      *
508 DO 26 J=1,N
      26 X(J)=(X(J)-TX)/SX
      DO 27 I=1,M
      27 Z(I)=(Z(I)-TZ)/SZ

```

```

C      POINT=(POINT-TX)/SX
      * * * END PROFILE INTERSECTIONS * *
DO 694 I=1,M
FX(I)=C(1)+C(2)*Z(I)+C(3)*Z(I)*Z(I)+C(4)*Z(I)**3
CALL DERIV1 (C(2),C(3),C(4),Z(I),FPZ(I),FSZ(I))
IF(I-3)690,691,691
691 DO 700 J=3,I
DIF=Z(I)-Z(J-1)
FX(I)=FX(I)+C(J+2)*DIF**3
CALL DERIV2 (C(J+2),DIF,FPZ(I),FSZ(I),FPZ(I),FSZ(I))
IF(I-3)690,690,700
700 CONTINUE
690 FPZ(I)=FPZ(I)/SZ
FSZ(I)=FSZ(I)/(SZ*SZ)
IF(SENSE SWITCH 2)693,694
693 PRINT 170,I,FX(I)
PRINT 154,FPZ(I),FSZ(I)
694 CONTINUE
J=1
OLD =Z(M)
I=MS
IF(SENSE SWITCH 2)204,510
204 PRINT 179
510 FZ(J)=FX(I)
ZZ=Z(I)
ICOMP=1
695 IF(ABSF(X(J)-FZ(J))-0.0001) 66,66,71
71 GO TO (65,69),ICOMP
65 IF(X(J)-FZ(J)) 67,66,72
66 FZ(J)=ZZ
IF(SENSE SWITCH 2) 74,80
74 PRINT 170,J,FZ(J)
80 J=J+1
OLD=ZZ
GO TO 510
67 ZZ=ZZ+(OLD-ZZ)/2.
ICOMP=2
IJUL=I+1
68 FZ(J)=C(1)+C(2)*ZZ+C(3)*ZZ*ZZ+C(4)*ZZ**3
IF(IJUL-3) 695,696,697
696 FZ(J)=FZ(J)+C(5)*(ZZ-Z(2))**3
GO TO 695
697 DO 699 K=3,IJUL
699 FZ(J)=FZ(J)+C(K+2)*(ZZ-Z(K-1))**3

```

```

        GO TO 695
69  IF(X(J)-FZ(J)) 67,66,70
70  SEG=OLD-ZZ
    OLD=ZZ
    ZZ=ZZ-SEG/2.
    GO TO 68
72  OLD=Z(I)
    I=I-1
    IF(I-1)81,510,510
81  DO 82 I=J,N
    FZ(I)=Z(I)
    IF(SENSE SWITCH 2)83,82
83  PRINT 170,I,FZ(I)
82  CONTINUE
C      *      *      WATERLINE  2ND  DIFFERENCES      *      *
    IF(SENSE SWITCH 2)6,7
6  PRINT 157
7  DO 15 I=1,M
    DO 13 J=1,NS
    GO TO (8,513),NCOMP
8  ZY=0.
    IF(X(J)-FX(I))10,10,9
10  R=20.
    IF(SENSE SWITCH 2)660,13
660 PRINT 151,I,J
    GO TO 13
9  ZZ=FX(I)
    NCOMP=2
    GO TO 1
513 ZZ=X(J-1)
    ZY=Y(I,J-1)
1  CALL DIF2ND (X(J),X(J+1),ZZ,Y(I,J),Y(I,J+1),ZY,I,J,R,A)
13  RX(I,J)=R
    RX(I,N)=RX(I,NS)
    IF(SENSE SWITCH 2)14,15
14  PRINT 158,I,J,A,RX(I,N)
15  NCOMP=1
C      *      *      STATION  2ND  DIFFERENCES      *      *
    IF(SENSE SWITCH 2)16,17
16  PRINT 159
17  DO 25 J=1,N
    DO 23 I=2,MS
    GO TO (18,19),NCOMP
18  IF(Z(I)-FZ(J))21,21,20
21  R=20.

```

```

      IF(SENSE SWITCH 2)22,23
22  PRINT 151,J,I
      GO TO 23
20  ZZ=FZ(J)
      NCOMP=2
      GO TO 514
19  ZZ=Z(I-1)
514 CALL DIF2ND (Z(I),Z(I+1),ZZ,Y(I,J),Y(I+1,J),Y(I-1,J),J,I,R,A)
23  RZ(J,I)=R
      RZ(J,M)=RZ(J,MS)
      IF(SENSE SWITCH 2)24,25
24  PRINT 158,J,I,A,RZ(J,M)
25  NCOMP=1
C          *      *      ROW ID          *      *
      PUNCH 173
      NJUL=((M-3)/2)+4
      NM=N
      IF(NAB)719,718,718
719  JUL=3
      JUL2=2
      NOROW=NJUL*((M-3)/2+4)+1
      GO TO 720
718  JUL=2
      JUL2=1
      NOROW=(M+2)*NJUL+1
720  PUNCH 160
      DO 28 NR=1,NOROW
28  PUNCH 162,NR
C          *      *      MATRIX          *      *
      PUNCH 164
C          *      *      FIRST WATERLINE          *
      MLG=(2*NM)
      I=1
      FUPZ=-1.
      FUSZ=0.
      DO 37 J=1,MLG,2
      IF(RX(1,I)-20.)250,251,250
251 K=2
      GO TO 252
250 K=1
200 GO TO (201,702),NCOMP
201 CALL PROFL2(X(I),FX(1),EXP1,FUPZ,FUSZ,EXP2,POINT,T,TP,TS,
NCOMP)
      IF(T-.0001)703,703,257
257 ZY=Y(1,I)/T

```

```

      GO TO 90
703 NCOMP=2
702 ZY=Y(1,1)
90 KFJ=1
      CALL PINCH (ZY,J,KFJ)
252 IROW=3
      DO 31 NPR=1,3
      TRM(IROW)=X(1)**NPR
      GO TO (253,31),K
253 PUNCH 167,J,IROW,TRM(IROW)
31 IROW=IROW+1
      IF(1-3)35,35,32
32 DO 34 IT=3,1
      IF(1-IT)34,34,133
133 IF(IT-2*(IT/2))33,34,33
33 TRM(IROW)=(X(1)-X(IT))**3
      GO TO (254,255),K
254 PUNCH 167,J,IROW,TRM(IROW)
255 IROW=IROW+1
34 CONTINUE
35 JPLS=J+1
      IROW=IROW-1
      IWL(1)=IROW
      GO TO (259,705),K
259 KFJ=2
      CALL PINCH (ZY,JPLS,KFJ)
705 DO 36 IR=3,IROW
      WL(1,IR)=TRM(IR)
      GO TO (260,36),K
260 PUNCH 169,JPLS,IR,TRM(IR)
36 CONTINUE
37 I=I+1
      NCOMP=1
C      *      *      REMAINING WL      *      *
      DO 64 IZ=2,M
      JL=J
      MG=JL+(2*NM)-2
      IX=1
      DO 63 J=JL,MG,2
      IF=2
      IRW(IF)=IROW+1
      IF(RX(IZ,IX)-20.)202,63,202
202 GO TO (91,92),NCOMP
91 CALL PROFL2(X(IX),FX(IZ),EXP1,FUPZ,FUSZ,EXP2,POINT,T,TP,TS,NCO
MP)

```

```

      IF(T-.0001)93,93,258
258 ZY=Y(IZ,IX)/T
      GO TO 95
      93 NCOMP=2
      92 ZY=Y(IZ,IX)
      95 KFJ=1
      CALL PINCH (ZY,J,KFJ)
708 IF(J-JL)41,41,44
      41 DO 42 IZPR=1,3
      TRM(IF)=Z(IZ)**IZPR
      PUNCH 167,J,IRW(IF),TRM(IF)
      IF=IF+1
      42 IRW(IF)=IRW(IF-1)+NJUL
      IF(IZ-JUL)146,146,142
142 DO 145 ITZ=JUL,IZ
      IF(IZ-ITZ)146,146,729
729 GO TO (144,144,730),JUL
730 IF(ITZ-2*(ITZ/2))144,145,144
144 ZTR=(Z(IZ)-Z(ITZ))**3
      TRM(IF)=ZTR
      PUNCH 167,J,IRW(IF),TRM(IF)
      IF=IF+1
      IRW(IF)=IRW(IF-1)+NJUL
145 CONTINUE
146 JPLS=J+1
709 KFJ=2
      CALL PINCH (ZY,JPLS,KFJ)
711 JF=IF-1
      DO 43 IF=2,JF
      43 PUNCH 169,JPLS,IRW(IF),TRM(IF)
      GO TO 63
C      * * Z , Z SQR , Z CUBE ROWS * *
      44 IRO =2
      K=IWL(IX)
      DO 244 IJ=3,K
      IRO =IRO +1
244 PUNCH 167,J,IRO,WL(IX,IJ)
      DO 50 IZPR=1,3
      ISTRT=IRW(IF)+NJUL
      ZTRM=Z(IZ)**IZPR
      TRM(IF)=ZTRM
      PUNCH 167,J,IRW(IF),TRM(IF)
      IF=IF+1
      IRW(IF)=IRW(IF-1)+1

```



```

DO 45 NPR=1,3
TRM(IF)=(X(IX)**NPR)*ZTRM
PUNCH 167,J,IRW(IF),TRM(IF)
IF=IF+1
45 IRW(IF)=IRW(IF-1)+1
IF(IX-3)50,50,46
46 DO 49 IT=3,IX
IF(IX-IT)49,49,47
47 IF(IT-2*(IT/2))48,49,48
48 TRM(IF)=((X(IX)-X(IT))**3)*ZTRM
PUNCH 167,J,IRW(IF),TRM(IF)
IF=IF+1
IRW(IF)=IRW(IF-1)+1
49 CONTINUE
50 IRW(IF)=ISTR
C      *      *      THEILHEIMER ROWS      *      *
53 IF(IZ-JUL)61,61,54
54 DO 60 ITZ=JUL,IZ
GO TO (55,55,731),JUL
731 IF(ITZ-2*(ITZ/2))55,60,55
55 ISTR=IRW(IF)+NJUL
IF(IZ-ITZ)61,61,56
56 ZTRM=(Z(IZ)-Z(ITZ))**3
TRM(IF)=ZTRM
PUNCH 167,J,IRW(IF),TRM(IF)
IF=IF+1
IRW(IF)=IRW(IF-1)+1
DO 256 NPR=1,3
TRM(IF)=(X(IX)**NPR)*ZTRM
PUNCH 167,J,IRW(IF),TRM(IF)
IF=IF+1
256 IRW(IF)=IRW(IF-1)+1
DO 59 IT=3,IX
IF(IX-IT)59,59,57
57 IF(IT-2*(IT/2))58,59,58
58 TRM(IF)=((X(IX)-X(IT))**3)*ZTRM
PUNCH 167,J,IRW(IF),TRM(IF)
IF=IF+1
IRW(IF)=IRW(IF-1)+1
59 CONTINUE
60 IRW(IF)=ISTR
61 JPLS=J+1
712 KFJ=2
CALL PINCH (ZY,JPLS,KFJ)

```

```

714 IRO =2
    K=IWL(IX)
    DO 262 IJ=3,K
        IRO =IRO +1
262 PUNCH 169,JPLS,IRO ,WL(IX,IJ)
    JF=IF-1
    DO 62 IS=2,JF
62 PUNCH 169,JPLS,IRW(IS),TRM(IS)
63 IX=IX+1
64 NCOMP=1
    PUNCH 180,JPLS,JUL,JUL2,NJUL,M,N,MS,NS,NOROW,NCOMP,CURV,RHS
    PUNCH 181,EXP2,COST,POINT,EXP1
    DO 87 I=1,M
        PUNCH 181,X(I),FZ(I)
    DO 87 J=2,M
87 PUNCH 181,RZ(I,J)
    DO 88 I=1,M
        PUNCH 181,Z(I),FX(I),FPZ(I),FSZ(I)
    DO 88 J=1,N
88 PUNCH 181,RX(I,J)
    ML=M+2
    DO 100 J=1,ML
100 PUNCH 181,C(J)
    PRINT 178
    PAUSE 751
    GO TO 750
150 FORMAT(2I5,4F11.6)
151 FORMAT(2I5,17H OUT OF SURFACE)
154 FORMAT(4F10.4)
157 FORMAT(/10X,17H2ND DIFF - W LINES//
    C30H WL STA NORM VALUE SIGN/)
158 FORMAT(2I5,F12.6,F8.2)
159 FORMAT(/10X,17H2ND DIFF-STATIONS//
    C30H STA WL NORM VALUE SIGN/)
160 FORMAT(6HROW ID/12X,6H OFSET)
162 FORMAT(12X,2H R,14)
164 FORMAT(6HMATRIX)
165 FORMAT(/6X,25HEND PROFILE INTERSECTIONS//15X,6HMLINES/)
167 FORMAT(6X,2H C,14,2H R,14,1H-,F11.5)
169 FORMAT(6X,2H C,14,2H R,14,F12.5)
170 FORMAT(5X,15,F12.6)
171 FORMAT(6X,2H C,14,6H OFSET,F12.5)
172 FORMAT(2I5)
173 FORMAT(1H*,5X,47H
)

```

(
178 FORMAT(28HENTER NEW DATA - PRESS START)
179 FORMAT (/14X,8HSTATIONS/)
180 FORMAT (10I5,2F15.9)
181 FORMAT (4F15.9)
183 FORMAT(F10.5,3I5)
END

```

SUBROUTINE PINCH (YD,JFK,KFJD)
  IF(YD) 706,707,707
706 YD=-YD
  GO TO (752,753),KFJD
752 PUNCH 168,JFK,YD,JFK,JFK
  GO TO 754
753 PUNCH 166,JFK,YD,JFK,JFK
754 YD=-YD
  RETURN
707 GO TO (755,756),KFJD
755 PUNCH 166,JFK,YD,JFK,JFK
  RETURN
756 PUNCH 168,JFK,YD,JFK,JFK
  RETURN
166 FORMAT(6X,2H C,14,6H OFFSET,F12.5/6X,2H C,14,6H R 1,8H 1.0/
C6X,2H C,14,6H R 2,8H 1.0)
168 FORMAT(6X,2H C,14,7H OFFSET-,F11.5/6X,2H C,14,6H R 1,8H 1.0/
C6X,2H C,14,6H R 2,8H 1.0)
END

```

```

SUBROUTINE PROFL2(XD,FD,EXPD1,TZPD,TZSD,EXPD2,X1,TD,TPD,TSD,NCD)
  TD=(X1+FD-XD)/X1
  IF(TD-.00001)1,1,2
2 DIFD=EXPD1-1.
  PROD=TD**DIFD
  TPD1=EXPD1*TZPD*PROD
  TSD1=EXPD1*(DIFD*TD**(DIFD-1.))*TZPD**2+TZSD*PROD
  TD=1.-TD**EXPD1
  IF(TD-.00001)7,7,4
4 DIFD=EXPD2-1.
  TDEXP=TD**DIFD
  TPD=-EXPD2*TPD1*TDEXP
  TSD=EXPD2*(DIFD*TD**(EXPD2-2.))*TPD1*TPD1-TSD1*TDEXP
  TD=TD**EXPD2
  IF(TD-.00001)7,7,6
7 TD=0.
  GO TO 3
6 NCD=1
  RETURN
1 NCD=2
  TD=1.
5 TPD=0.
  TSD=0.
  RETURN
3 NCD=1
  GO TO 5
END

```

```

SUBROUTINE DIF2ND(XD,XDP1,XDM1,YD,YDP1,YDM1,ID,JD,RD,AD)
AD=2./(XDP1-XDM1)
ZA=YDP1-YD
AD=AD*(ZA/(XDP1-XD)-(YD-YDM1)/(XD-XDM1))
IF(AD)800,809,808
808 RD=-1.
GO TO 11
809 RD=0.
GO TO 11
800 RD=1.
11 IF(SENSE SWITCH 2)812,813
812 PRINT 158,ID,JD,AD,RD
158 FORMAT(2I5,F12.6,F8.2)
813 RETURN
END

```

```

SUBROUTINE DERIV1 (C2D,C3D,C4D,FXD,FZPD,FZSD)
FZPD=C2D+2.*C3D*FXD+3.*C4D*FXD*FXD
FZSD=2.*C3D+6.*C4D*FXD
RETURN
END

```

```

SUBROUTINE DERIV2 (C5D,DIFD,FPD,FSD,FZPD,FZSD)
PROD=3.*C5D*DIFD
FZPD=FPD+PROD*DIFD
FZSD=FSD+2.*PROD
RETURN
END

```

PASS 2

OPERATING INSTRUCTIONS

Pass 2 of the program accepts the data punched in Pass 1. It produces the curvature constraints of the matrix and then the right-hand side, which for the dual, consists of the costs on the variables.

Fortran Input Symbols

- JPLS - The number of the last column produced in Pass 1
- JUL - Program indicator
 JUL = 3 if the surface is double splined in the z direction
 JUL = 2 if the surface is single splined in the z direction
 This value is equal to the subscript of the first z value of a point of discontinuity
- JUL2 - Program indicator
 JUL2 = 2 if the z direction is double splined
 JUL2 = 1 if the z direction is single splined
 This value is equal to the number of waterline intervals between points of discontinuity
- NJUL - This value $\left(\frac{N-3}{2} + 4\right)$ is equal to the maximum number of rows necessary to store the x terms, each of which is multiplied by a specific z term
- M - Total number of waterlines in the surface
- MS - M-1
- N - Total number of stations in the surface
- NS - N-1
- NOROW - Total number of rows in the matrix
 For z double spline
$$\text{NOROW} = \left[\left(\frac{M-3}{2} \right) + 4 \text{ NJUL} \right] + 1$$

 For z single spline
$$\text{NOROW} = \left[(M+2) \text{ NJUL} \right]$$

NCOMP - Program indicator

COST - The penalty assigned to λ . This will appear in Row 1 of the right-hand side. The value is normally made 20.

EXP1 - The value of p in the profile function usually made .3333 .

EXP2 - The value of r in the profile function, usually 3.0 .

POINT - The value of D in the profile function. This number is the length of fraction of the station spacing over which the profile function is effective in terms of the full scale surface (the value has been translated and normalized exactly like the x values are).

C(I) - Coefficients of the Theilheimer equation describing the profile. There must be $(M+2)$ coefficients. Straight lines or other curves may be used by making all except the desired coefficients zero.

RHS - Right-hand side - In the dual this is really the cost on the equation coefficients. The ideal value for RHS would be zero; however, this makes the solution susceptible to cycling so that a value of .0001 is usually used.

CURV - Value of the requirement vector for the curvature constraints. This value actually goes in the cost row in the dual and is always made zero.

X(J) - Distance along the x axis from the origin of the surface to Station j .

Z(I) - Distance along the z axis from the origin of the surface to Waterline i .

FX(I) - The x coordinate of the intersection of Waterline i with the profile

FZ(J) - The z coordinate of the intersection of Station j with the profile

FPZ(I) - The first derivative, with respect to z , of the profile equation at Waterline i .

FSZ(I) - The second derivative with respect to z of the profile equation at Waterline i .

- RZ(I,J) - The sign of the second difference of the Station Curve j at Waterline i . This will have the opposite sign from the actual second difference.
- RX(I,J) - The sign of the second difference of Waterline Curve i at Station j . This will be the opposite of the actual sign.

Input Data

The following input formats are listed as a matter of record in case modifications of the data cards are to be made. Normally this data will be obtained from executing Pass 1 in a form which can be entered directly into Pass 2.

<u>Contents of Card</u>									<u>Card No.</u>	
Format	I5	I5	I5	I5	I5	I5	I5	I5	1	
Variable	JPLS	JUL	JUL2	NJUL	M	N	MS	NS		
Format (continuation of Card 1)										
Variable			I5 MOROW	I5 NCOMP	F15.5 CURV	F15.5 RHS				
Format	F15.9	F15.9	F15.9	F15.9						2
Variable	EXP2	COST	POINT	EXP1						
Format	F15.9	F15.9					1st card/set		} Next N Sets	
Variable	X(I)	FZ(I)								
Format	F15.9					M Cards/set				
Variable	RZ(I,J)									
Format	F15.9	F15.9	F15.9	F15.9						} Next M Sets
Variable	Z(I)	FX(I)	FPZ(I)	FSZ(I)	1st card/set					
Format	F15.9					N Cards/set				
Variable	RX(I,J)									
Format	F15.9								} Next M+2 Cards	
Variable	C(J)									

Output

The curvature constraint elements are produced first. These are punched with the formats listed in Fig. B- , as are the following cards. The elements are punched in column order with the rows ordered within the columns. Next, a card punched "FIRST B" is produced. Afterwards, the right-hand side is punched in row order. Finally, the last card in the deck is punched "EOF."

After the input data for Pass 2 is removed from the Pass 1 output, the Pass 2 output is placed directly behind the Pass 1 output. The deck is now complete and ready for input to LP-90 .

Sense Switches

No sense switches are used.

SAMPLE PROBLEM - Pass 2 Input Punched by Pass 1

			* * SAMPLE INPUT * *							
50	3	2	5	5	5	4	4	26	1	0.00000000
	.00100000									
	.33333333		20.00000000			.07843137			3.00000000	
	0.00000000		2.60400380							
	20.00000000									
	20.00000000									
	1.00000000									
	1.00000000									
	1.00000000		.90136719							
	1.00000000									
	-1.00000000									
	-1.00000000									
	-1.00000000									
	2.00000000		0.00000000							
	-1.00000000									
	-1.00000000									
	-1.00000000									
	-1.00000000									
	3.00000000		0.00000000							
	-1.00000000									
	-1.00000000									
	-1.00000000									
	-1.00000000									
	4.00000000		0.00000000							
	-1.00000000									
	-1.00000000									
	-1.00000000									
	-1.00000000									
	0.00000000		1.52935000			-.58730000			0.00000000	
	20.00000000									
	20.00000000									
	1.00000000									
	-1.00000000									
	-1.00000000									
	1.00000000		.94205000			-.58730000			0.00000000	
	20.00000000									
	1.00000000									
	-1.00000000									
	-1.00000000									
	-1.00000000									
	2.00000000		.35475000			-.58730000			0.00000000	
	20.00000000									
	1.00000000									
	-1.00000000									
	-1.00000000									
	-1.00000000									
	3.00000000		-.23255000			-.58730000			0.00000000	

1.00000000			
-1.00000000			
-1.00000000			
-1.00000000			
-1.00000000			
4.00000000	- .81985000	- .58730000	0.00000000
-1.00000000			
-1.00000000			
-1.00000000			
-1.00000000			
-1.00000000			
1.52935000			
- .58730000			
0.00000000			
0.00000000			
0.00000000			
0.00000000			
0.00000000			

*** SAMPLE OUTPUT ***

SDG 2 - PASS 2

C 52	OFSET	0.00000
C 52 R 4-		1.00000
C 52 R 5-		6.00000
C 53	OFSET	0.00000
C 53 R 4		1.00000
C 53 R 5		12.00000
C 53 R 6		6.00000
C 55	OFSET	0.00000
C 55 R 4		1.00000
C 55 R 5		6.00000
C 55 R 9		1.00000
C 55 R 10		6.00000
C 55 R 14		1.00000
C 55 R 15		6.00000
C 55 R 19		1.00000
C 55 R 20		6.00000
C 56	OFSET	0.00000
C 56 R 4		1.00000
C 56 R 5		12.00000
C 56 R 6		6.00000
C 56 R 9		1.00000
C 56 R 10		12.00000
C 56 R 11		6.00000
C 56 R 14		1.00000
C 56 R 15		12.00000
C 56 R 16		6.00000
C 56 R 19		1.00000
C 56 R 20		12.00000
C 56 R 21		6.00000
C 58	OFSET	0.00000
C 58 R 4		1.00000
C 58 R 5		6.00000
C 58 R 9		2.00000
C 58 R 10		12.00000
C 58 R 14		4.00000
C 58 R 15		24.00000
C 58 R 19		8.00000
C 58 R 20		48.00000

1.0.0-2

C	59	OFSET	0.00000
C	59	R 4	1.00000
C	59	R 5	12.00000
C	59	R 6	6.00000
C	59	R 9	2.00000
C	59	R 10	24.00000
C	59	R 11	12.00000
C	59	R 14	4.00000
C	59	R 15	48.00000
C	59	R 16	24.00000
C	59	R 19	8.00000
C	59	R 20	96.00000
C	59	R 21	48.00000
C	60	OFSET	0.00000
C	60	R 4-	1.00000
C	60	R 9-	3.00000
C	60	R 14-	9.00000
C	60	R 19-	27.00000
C	60	R 24-	1.00000
C	61	OFSET	0.00000
C	61	R 4	1.00000
C	61	R 5	6.00000
C	61	R 9	3.00000
C	61	R 10	18.00000
C	61	R 14	9.00000
C	61	R 15	54.00000
C	61	R 19	27.00000
C	61	R 20	162.00000
C	61	R 24	1.00000
C	61	R 25	6.00000
C	62	OFSET	0.00000
C	62	R 4	1.00000
C	62	R 5	12.00000
C	62	R 6	6.00000
C	62	R 9	3.00000
C	62	R 10	36.00000
C	62	R 11	18.00000
C	62	R 14	9.00000
C	62	R 15	108.00000
C	62	R 16	54.00000
C	62	R 19	27.00000

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1.0.0.2

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C	62 R	20	324.00000
C	62 R	21	162.00000
C	62 R	24	1.00000
C	62 R	25	12.00000
C	62 R	26	6.00000
C	63 OFFSET		0.00000
C	63 R	4	1.00000
C	63 R	9	4.00000
C	63 R	14	16.00000
C	63 R	19	64.00000
C	63 R	24	8.00000
C	64 OFFSET		0.00000
C	64 R	4	1.00000
C	64 R	5	6.00000
C	64 R	9	4.00000
C	64 R	10	24.00000
C	64 R	14	16.00000
C	64 R	15	96.00000
C	64 R	19	64.00000
C	64 R	20	384.00000
C	64 R	24	8.00000
C	64 R	25	48.00000
C	65 OFFSET		0.00000
C	65 R	4	1.00000
C	65 R	5	12.00000
C	65 R	6	6.00000
C	65 R	9	4.00000
C	65 R	10	48.00000
C	65 R	11	24.00000
C	65 R	14	16.00000
C	65 R	15	192.00000
C	65 R	16	96.00000
C	65 R	19	64.00000
C	65 R	20	768.00000
C	65 R	21	384.00000
C	65 R	24	8.00000
C	65 R	25	96.00000
C	65 R	26	48.00000
C	67 OFFSET		0.00000
C	67 R	12-	1.00000
C	67 R	17-	12.00000

C	67	R	22-	6.00000
C	68	OFSET		0.00000
C	68	R	12	1.00000
C	68	R	13	1.00000
C	68	R	14	1.00000
C	68	R	15	1.00000
C	68	R	17	6.00000
C	68	R	18	6.00000
C	68	R	19	6.00000
C	68	R	20	6.00000
C	69	OFSET		0.00000
C	69	R	12	1.00000
C	69	R	13	1.00000
C	69	R	14	1.00000
C	69	R	15	1.00000
C	69	R	17	12.00000
C	69	R	18	12.00000
C	69	R	19	12.00000
C	69	R	20	12.00000
C	69	R	22	6.00000
C	69	R	23	6.00000
C	69	R	24	6.00000
C	69	R	25	6.00000
C	70	OFSET		0.00000
C	70	R	12	1.00000
C	70	R	13	2.00000
C	70	R	14	4.00000
C	70	R	15	8.00000
C	70	R	17	6.00000
C	70	R	18	12.00000
C	70	R	19	24.00000
C	70	R	20	48.00000
C	71	OFSET		0.00000
C	71	R	12	1.00000
C	71	R	13	2.00000
C	71	R	14	4.00000
C	71	R	15	8.00000
C	71	R	17	12.00000
C	71	R	18	24.00000
C	71	R	19	48.00000
C	71	R	20	96.00000

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C	71	R	22	6.00000
C	71	R	23	12.00000
C	71	R	24	24.00000
C	71	R	25	48.00000
C	72	OFFSET		0.00000
C	72	R	12	1.00000
C	72	R	13	3.00000
C	72	R	14	9.00000
C	72	R	15	27.00000
C	72	R	16	1.00000
C	72	R	17	6.00000
C	72	R	18	18.00000
C	72	R	19	54.00000
C	72	R	20	162.00000
C	72	R	21	6.00000
C	73	OFFSET		0.00000
C	73	R	12	1.00000
C	73	R	13	3.00000
C	73	R	14	9.00000
C	73	R	15	27.00000
C	73	R	16	1.00000
C	73	R	17	12.00000
C	73	R	18	36.00000
C	73	R	19	108.00000
C	73	R	20	324.00000
C	73	R	21	12.00000
C	73	R	22	6.00000
C	73	R	23	18.00000
C	73	R	24	54.00000
C	73	R	25	162.00000
C	73	R	26	6.00000
C	74	OFFSET		0.00000
C	74	R	12	1.00000
C	74	R	13	4.00000
C	74	R	14	16.00000
C	74	R	15	64.00000
C	74	R	16	8.00000
C	74	R	17	6.00000
C	74	R	18	24.00000
C	74	R	19	96.00000
C	74	R	20	384.00000

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1.0.0-2

C	74	R	21	48.00000
C	75	OFSET		0.00000
C	75	R	12	1.00000
C	75	R	13	4.00000
C	75	R	14	16.00000
C	75	R	15	64.00000
C	75	R	16	8.00000
C	75	R	17	12.00000
C	75	R	18	48.00000
C	75	R	19	192.00000
C	75	R	20	768.00000
C	75	R	21	96.00000
C	75	R	22	6.00000
C	75	R	23	24.00000
C	75	R	24	96.00000
C	75	R	25	384.00000
C	75	R	26	48.00000
FIRST B				
		R	1	20.00000
		R	2	.00100
		R	3	.00100
		R	4	.00100
		R	5	.00100
		R	6	.00100
		R	7	.00100
		R	8	.00100
		R	9	.00100
		R	10	.00100
		R	11	.00100
		R	12	.00100
		R	13	.00100
		R	14	.00100
		R	15	.00100
		R	16	.00100
		R	17	.00100
		R	18	.00100
		R	19	.00100
		R	20	.00100
		R	21	.00100
		R	22	.00100
		R	23	.00100

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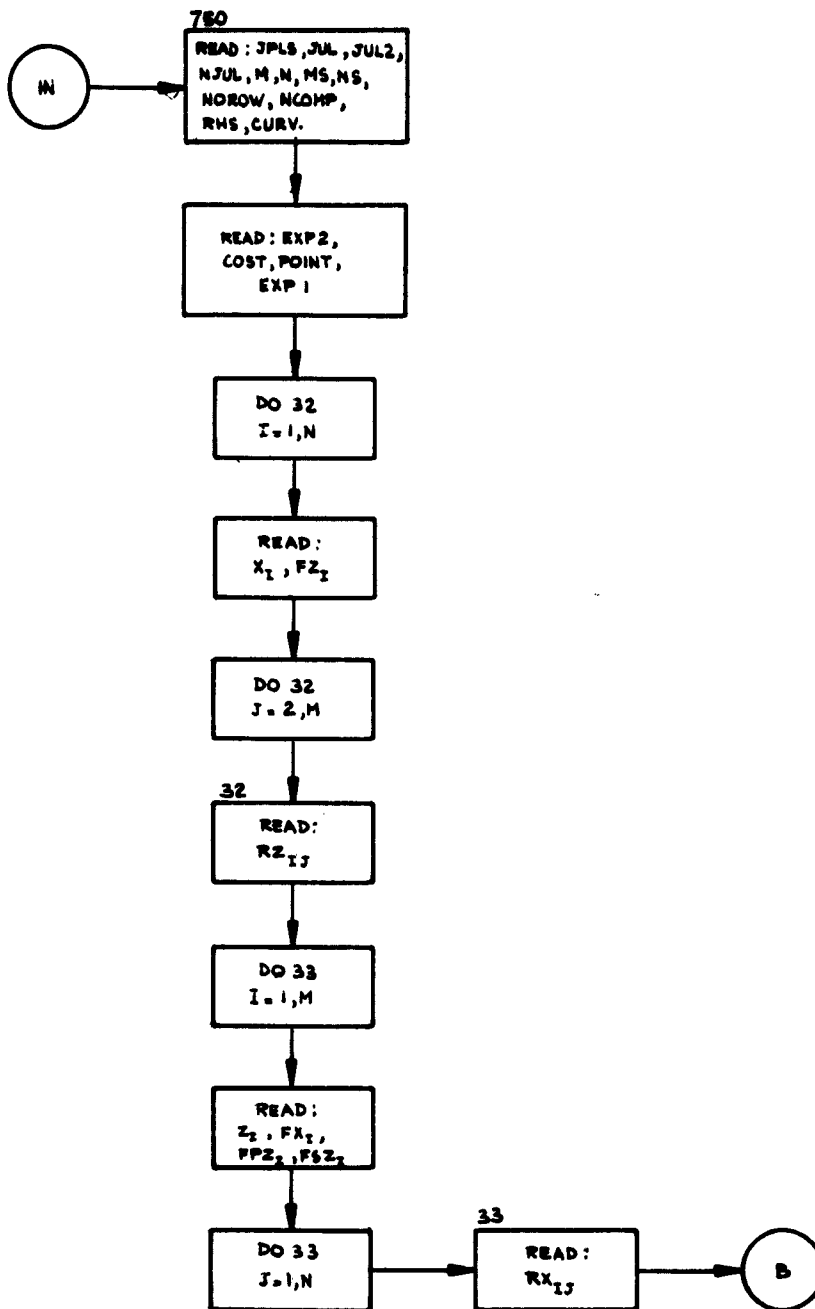
.00100
.00100
.00100

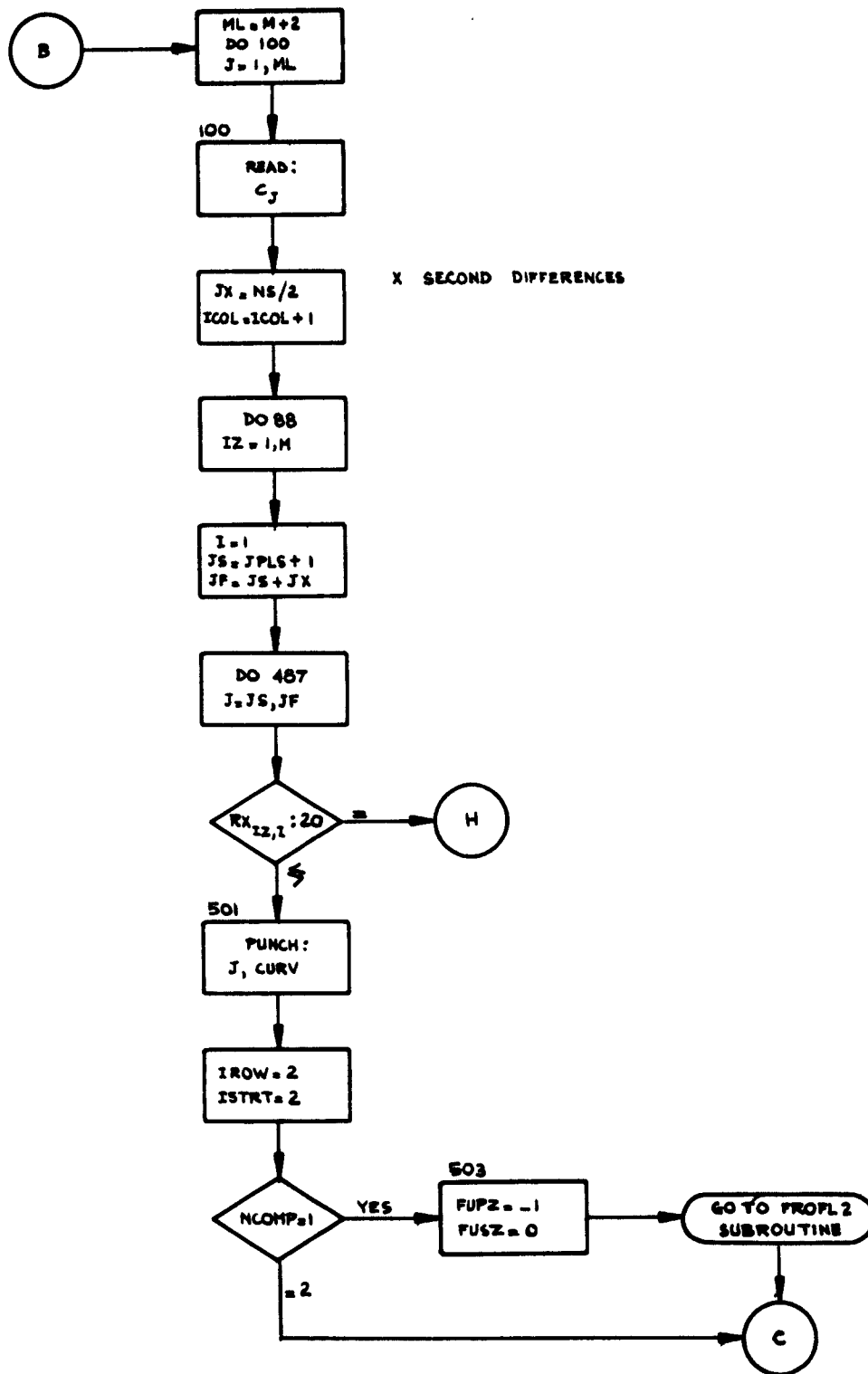
R 24
R 25
R 26

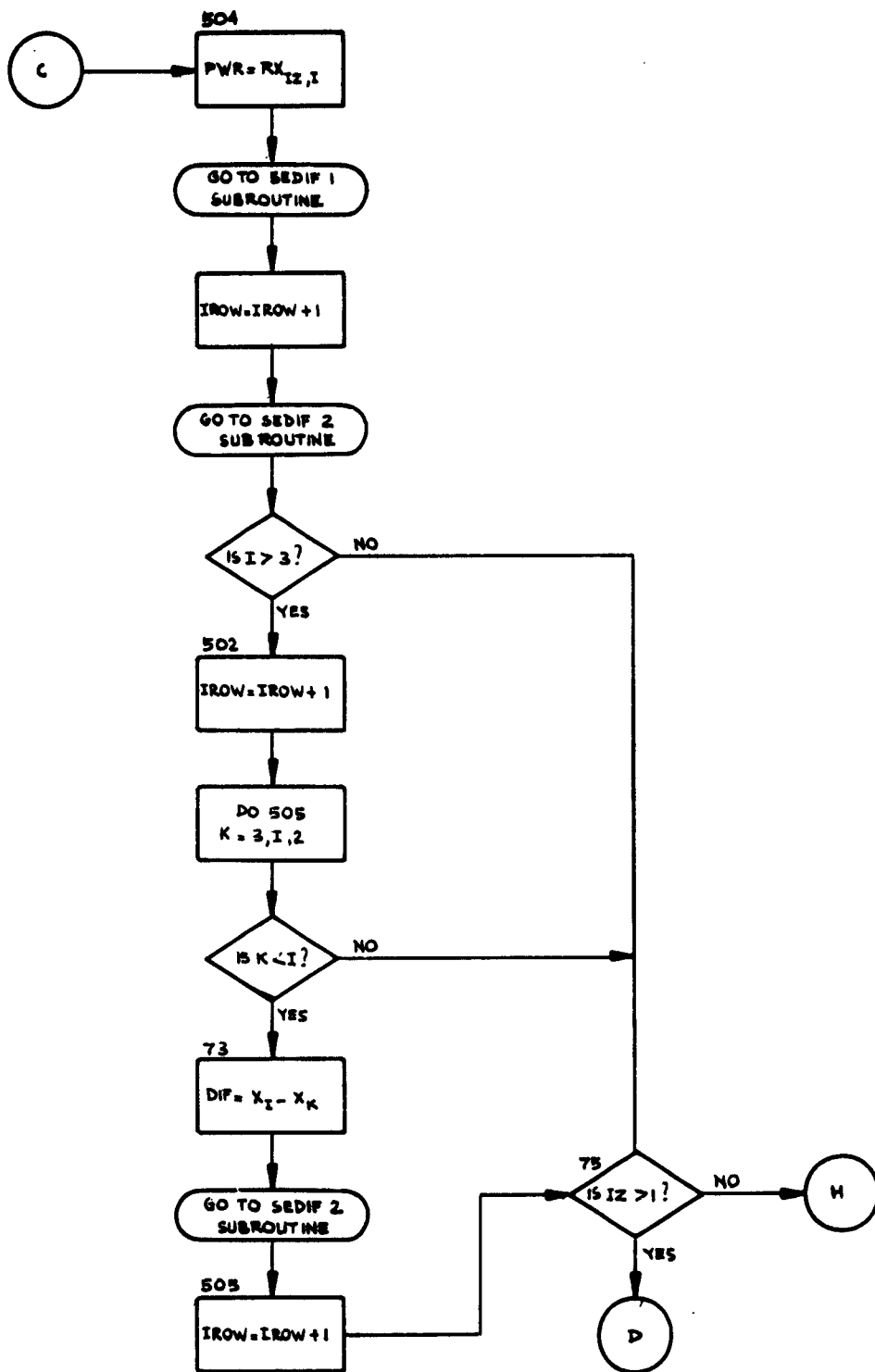
EOF

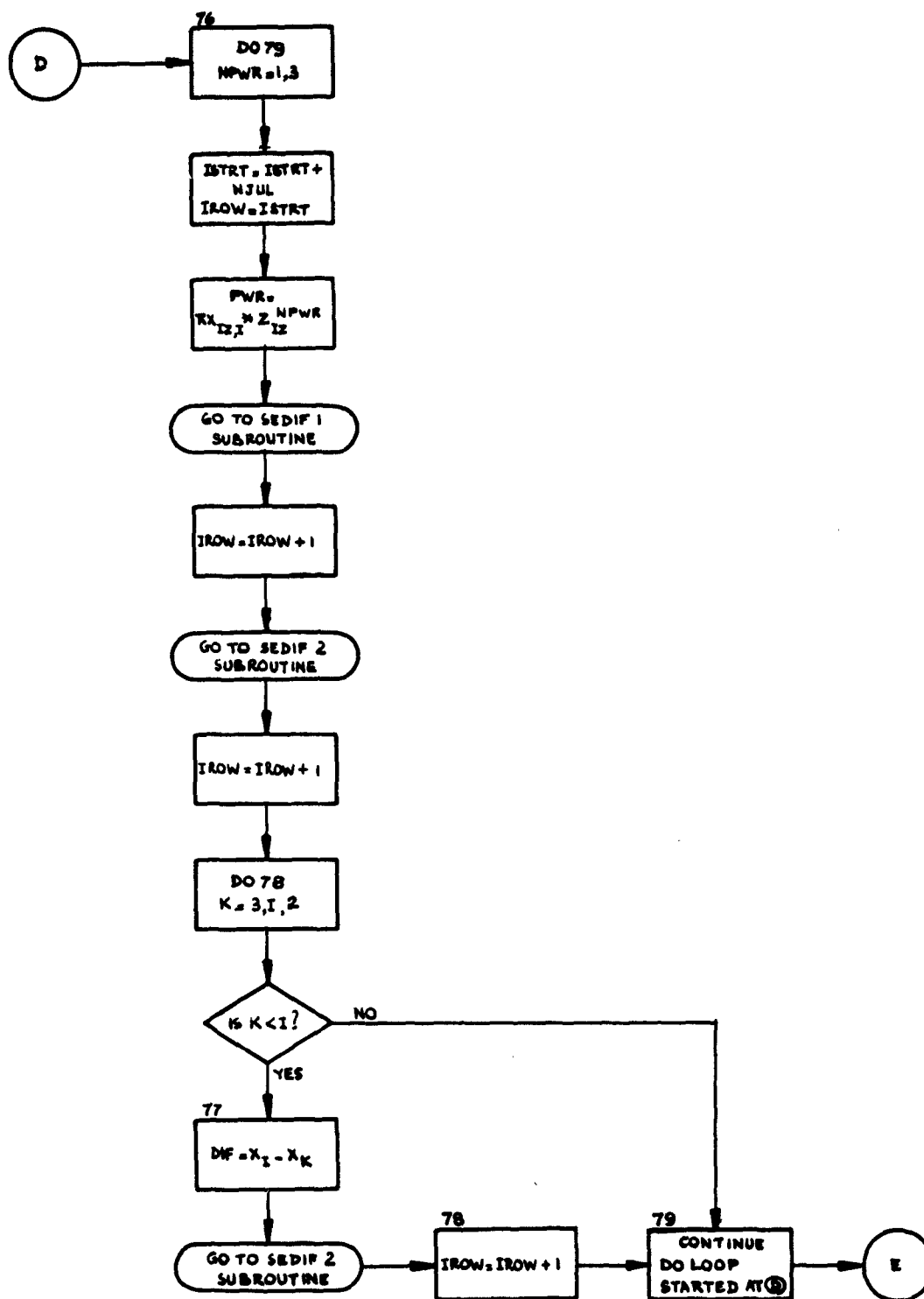
B-165

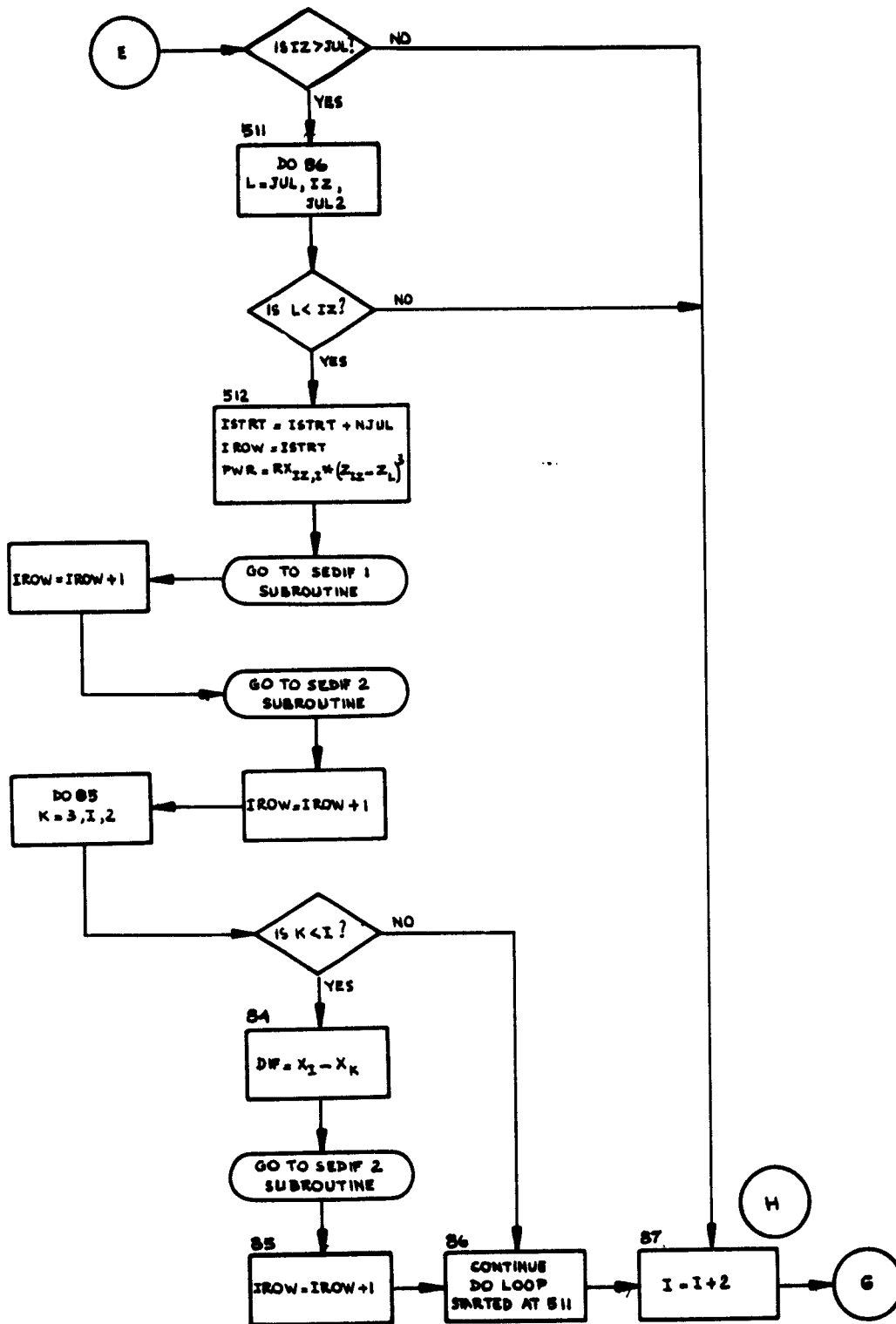
FLOW DIAGRAM - SMOG 2 - PASS II

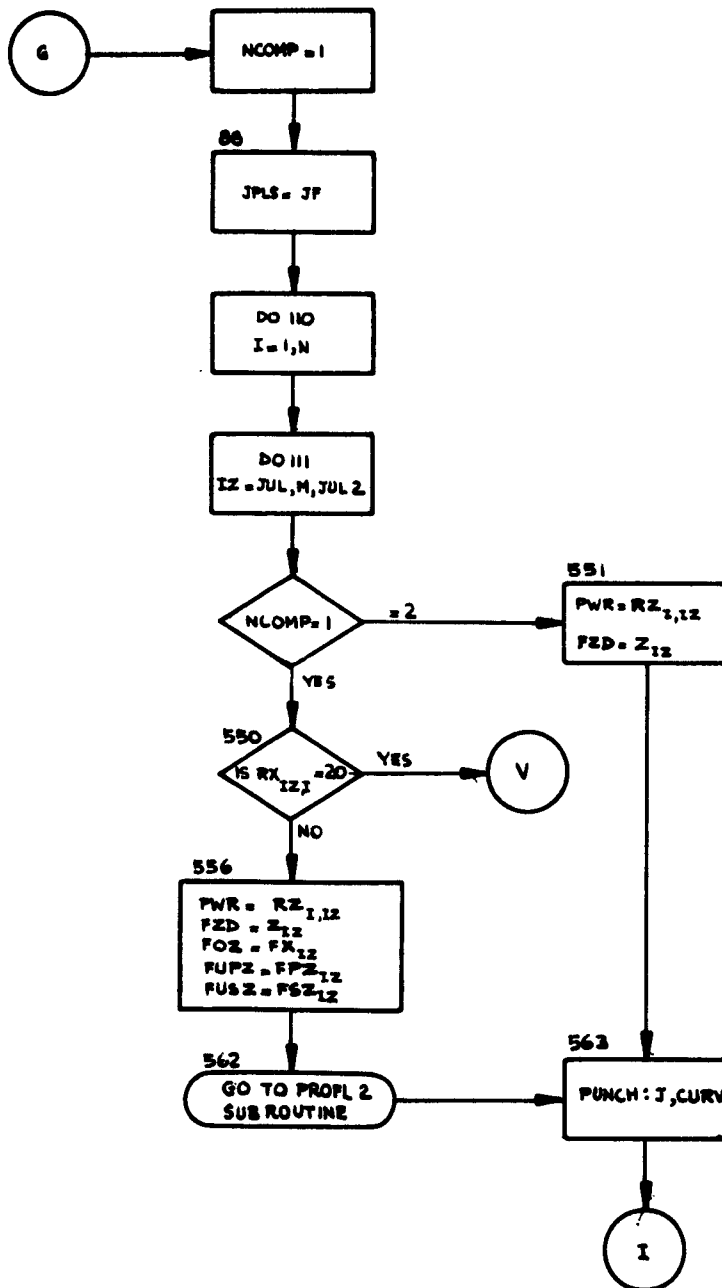


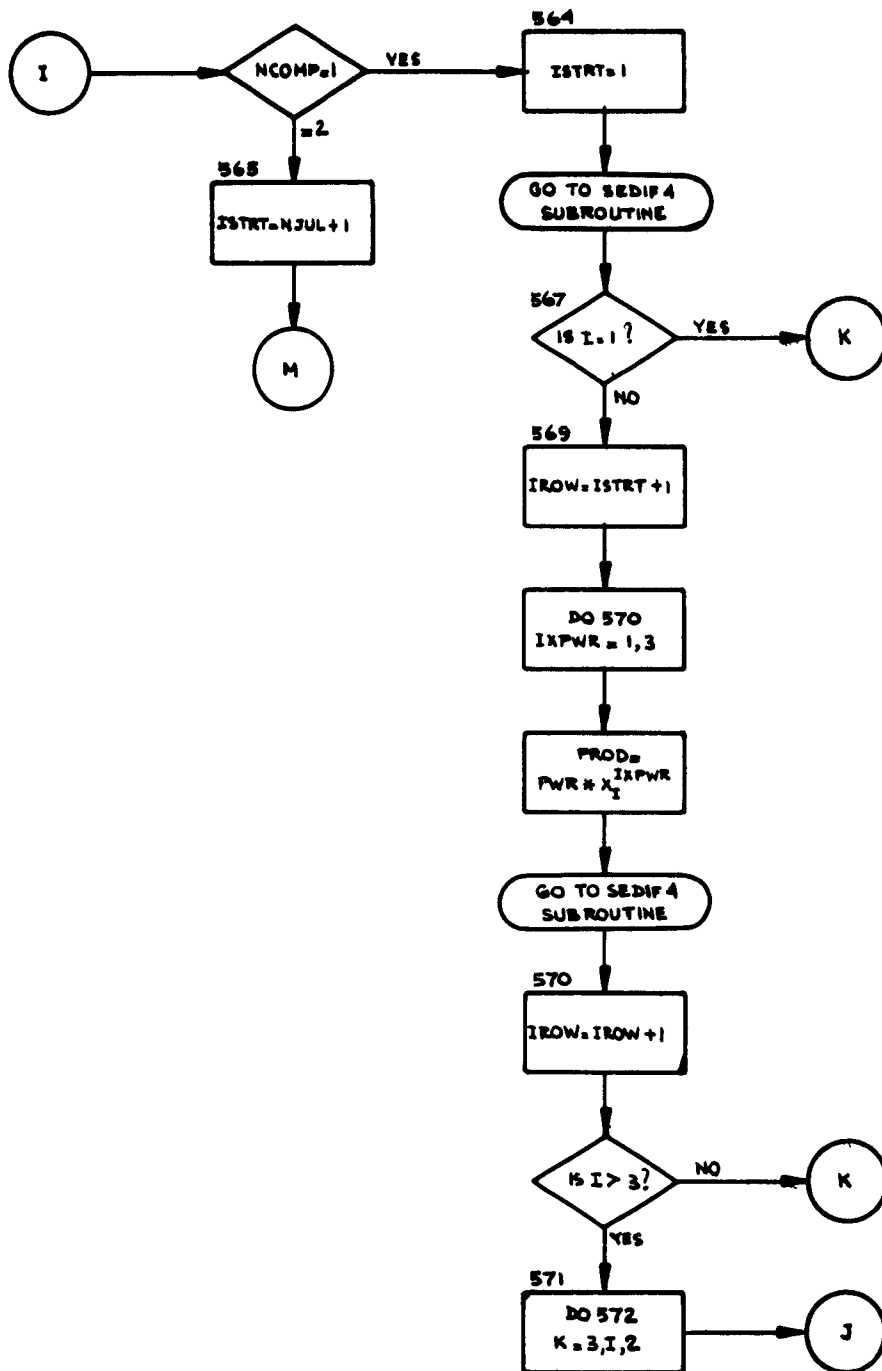


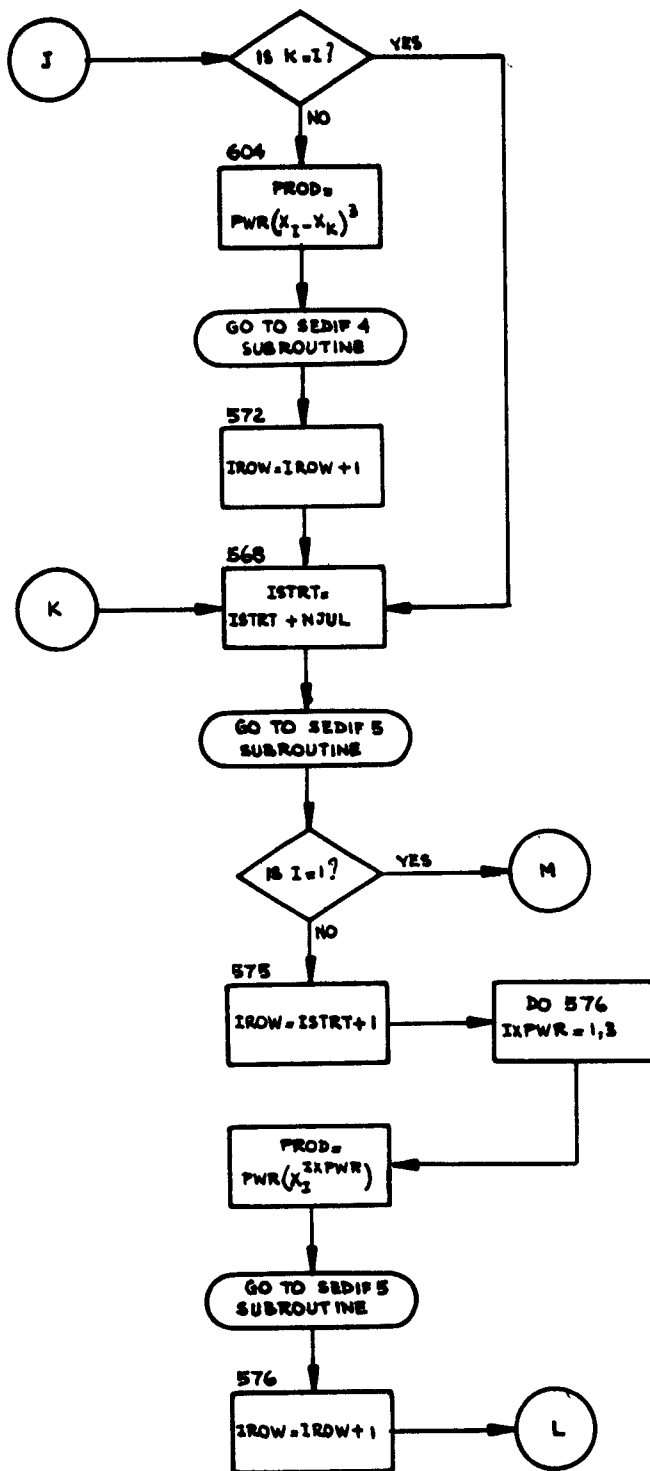


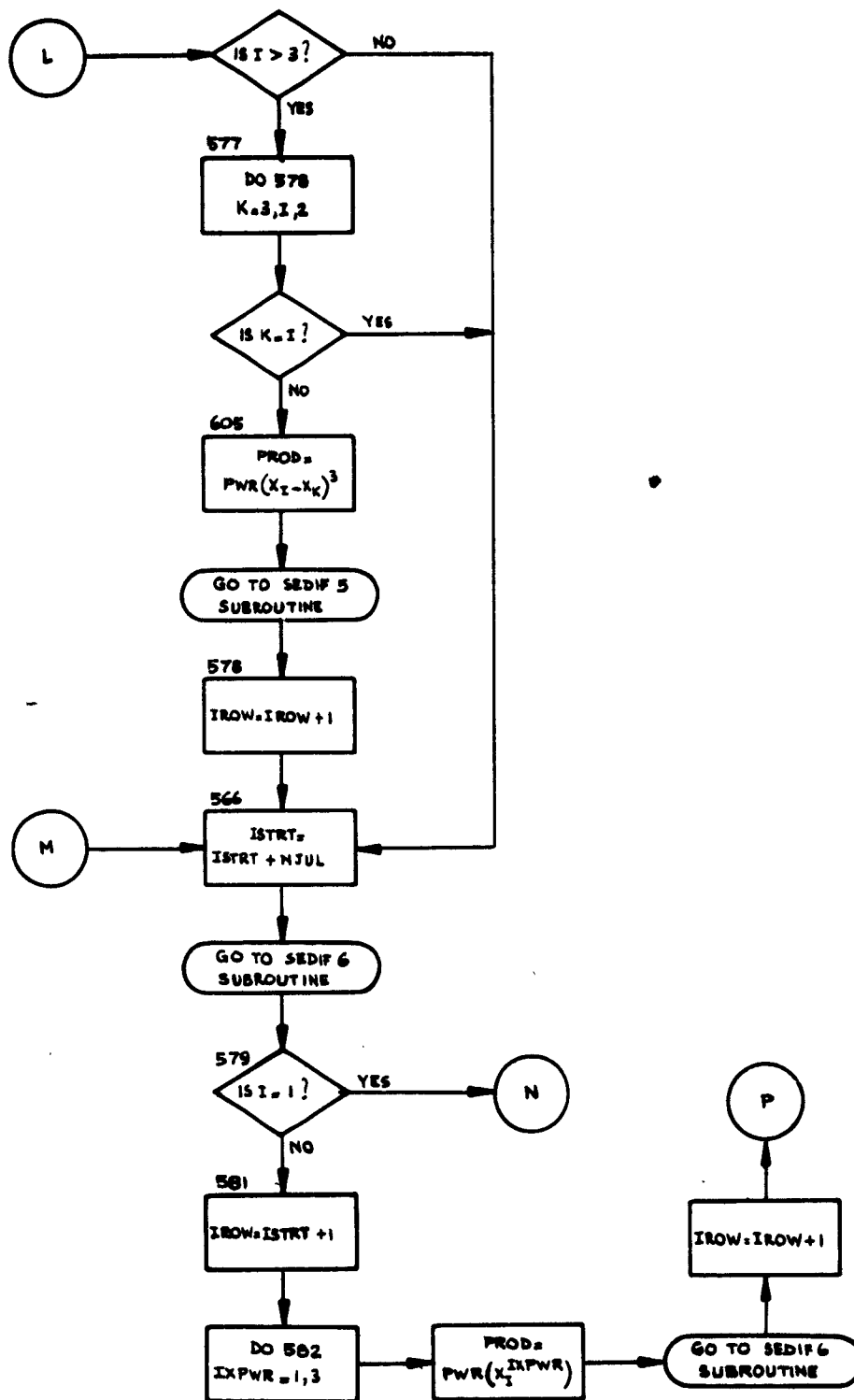


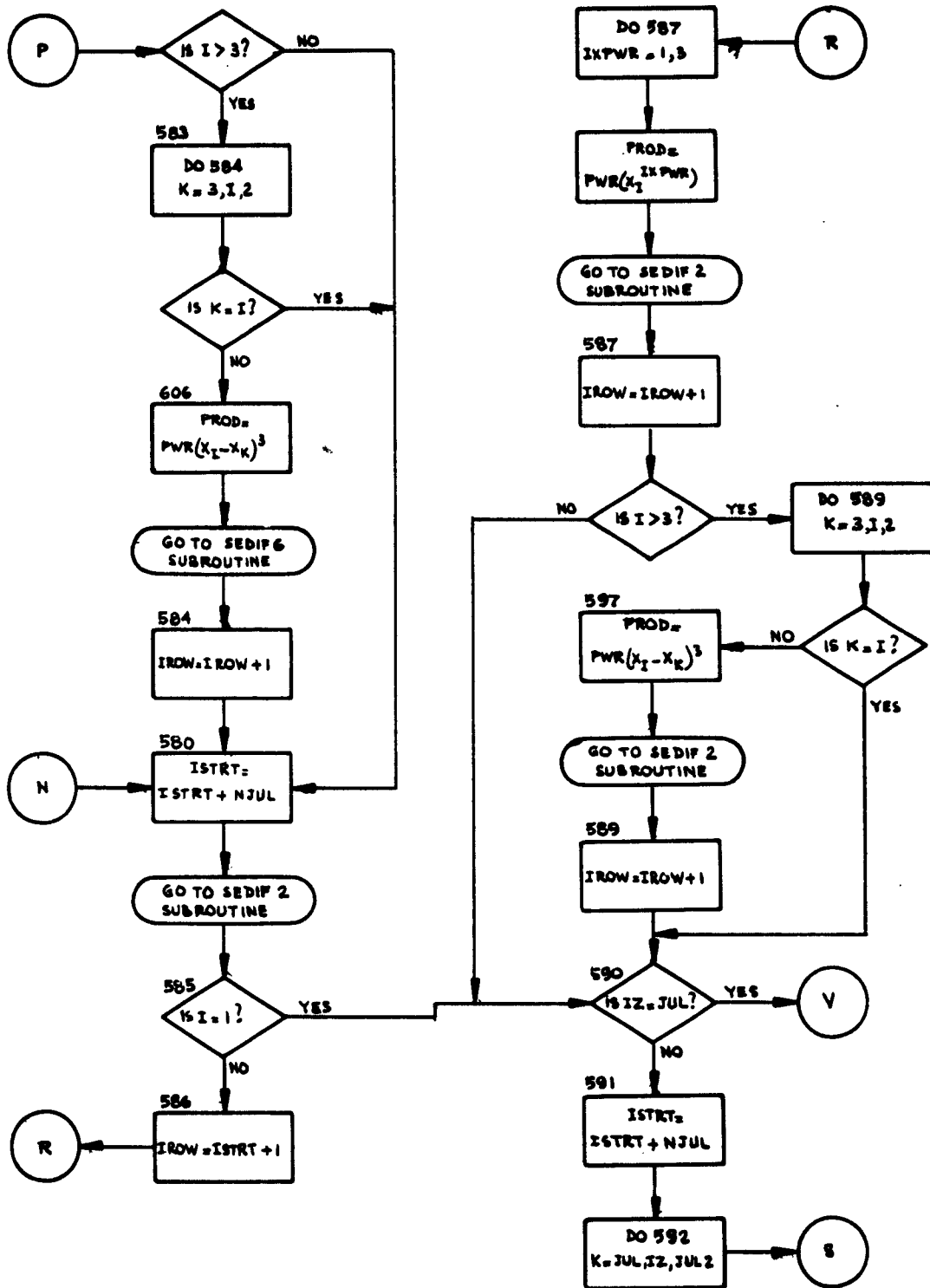


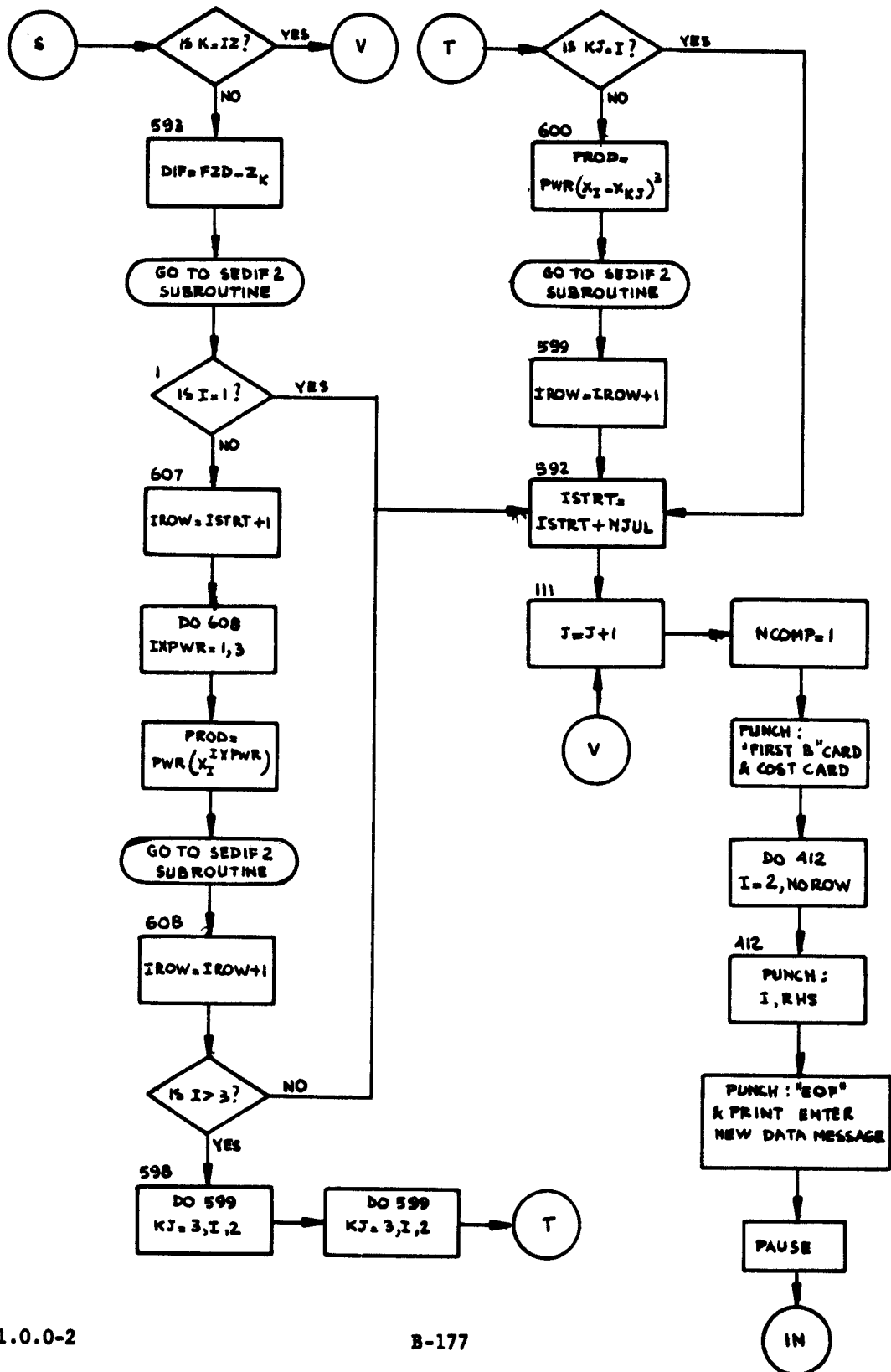






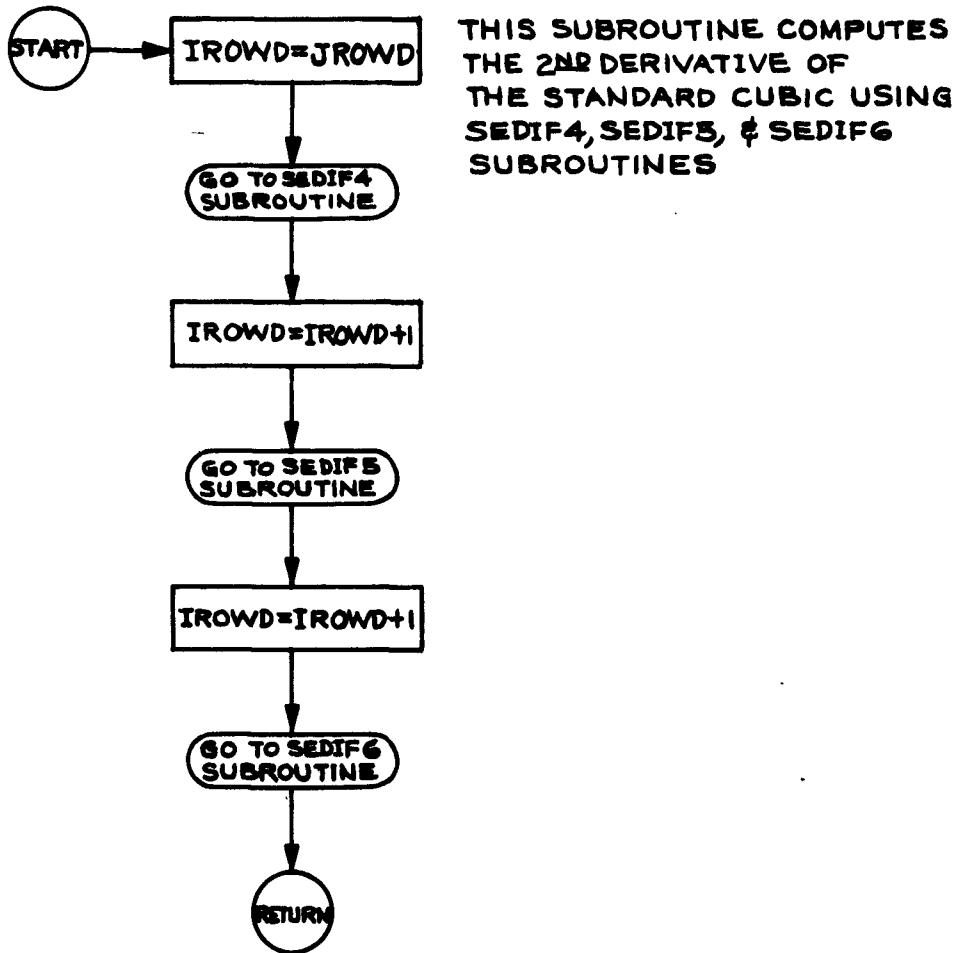




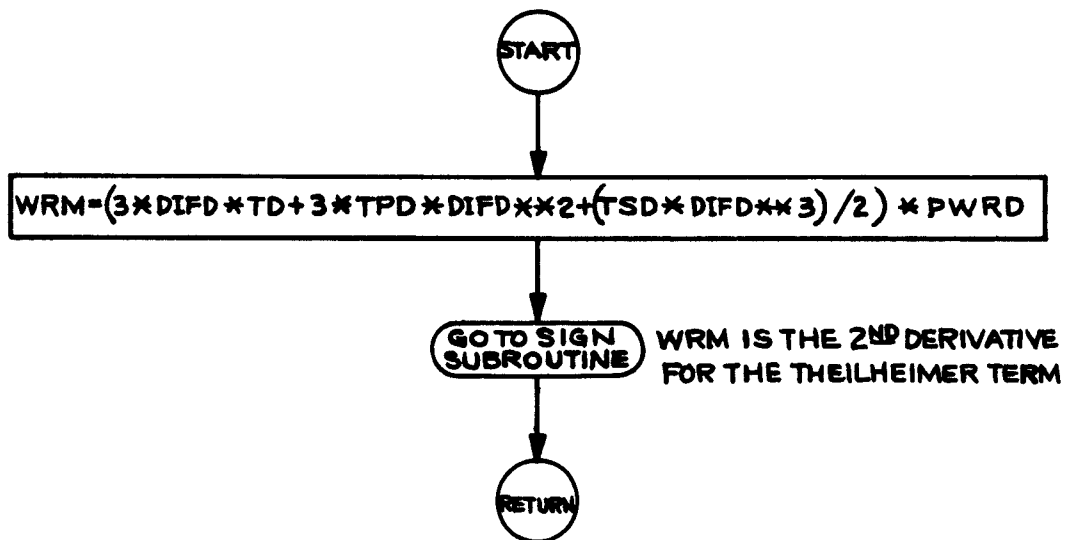


For Flow Diagram of Profile 2 Subroutine, See SMOG 2, Pass 1

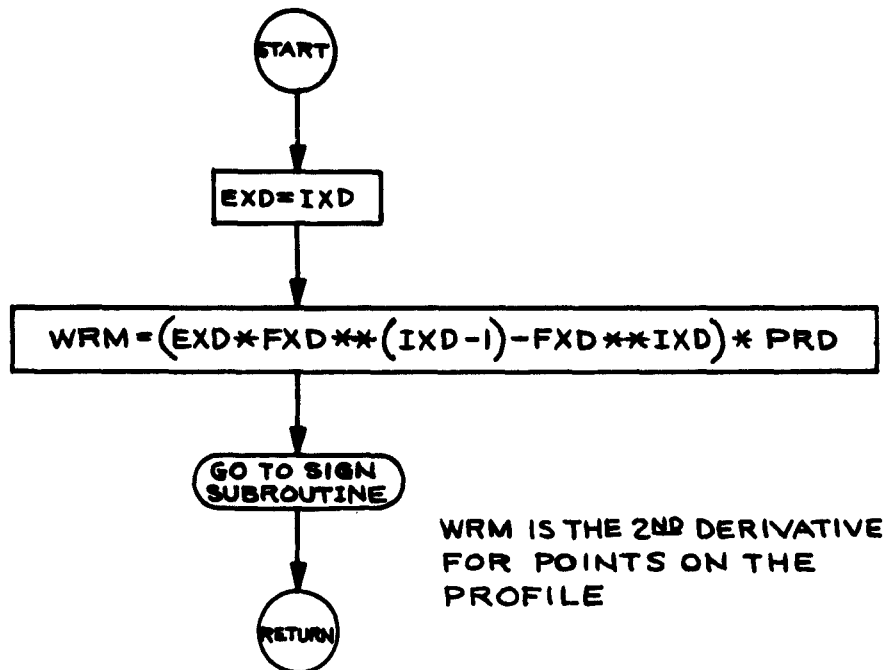
SUBROUTINE SEDIF1(TD,TPD,TSD,XD,JROWD,JD,PWRD,IROWD)



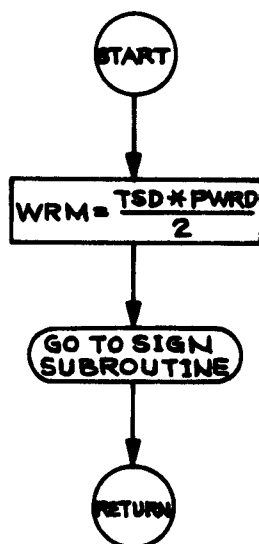
SUBROUTINE SEDIF2(DIFD,TD,TPD,TSD,PWRD,IROWD,JD)



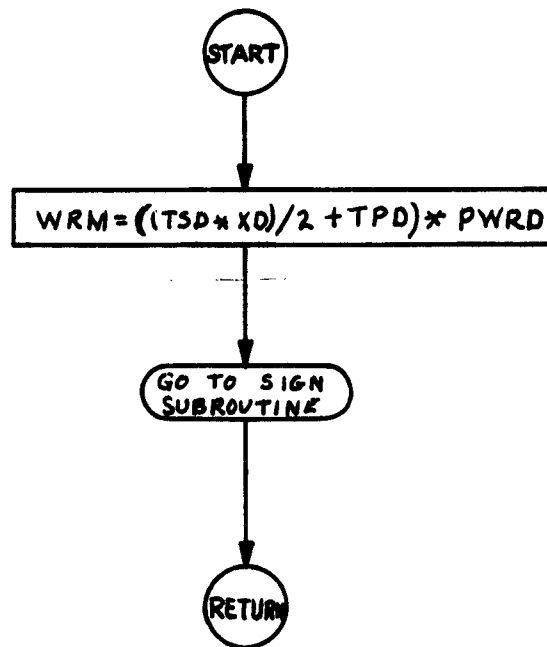
SUBROUTINE SEDIF3(IXD,FXD,PRD,IROWD,JSD)



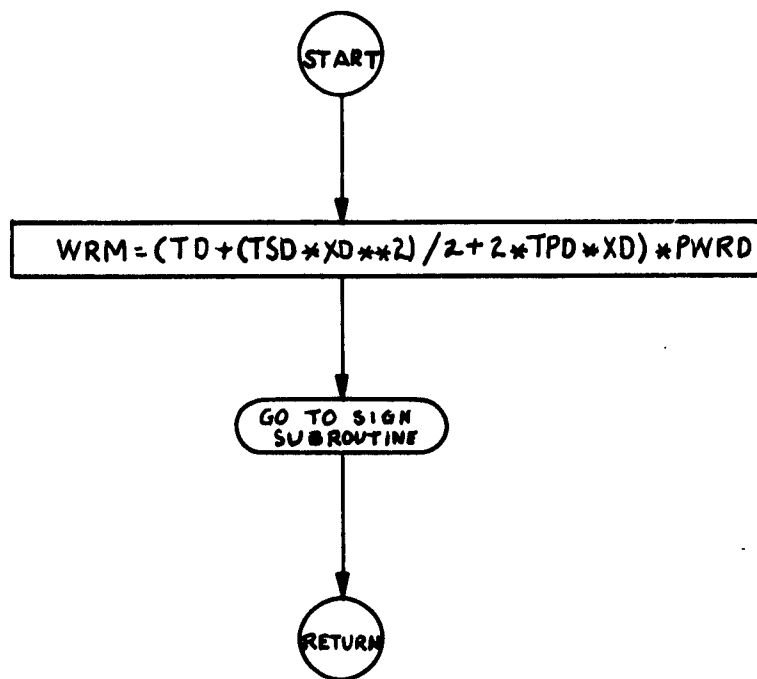
SUBROUTINE SEDIF4(TSD,PWRD,JD,IROWD)



SUBROUTINE SEDIF5 (TPD, TSD, XD, PWRD, JD, IROWD)

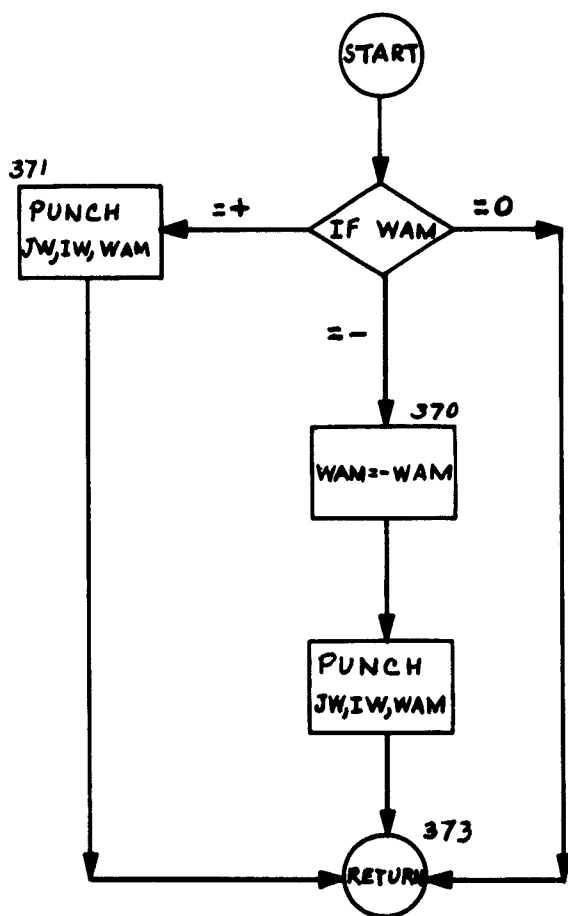


SUBROUTINE SEDIF6 (TD,TPD,TSD,XD, JD, PWRD,IROW D)



SUBROUTINE SIGN (JW, IW, WAM)

THIS SUBROUTINE PUNCHES
THE 2ND DERIVATIVE FROM
THE SEDIF SUBROUTINES,
ALONG WITH THE IDENTIFYING
SUBSCRIPT NO'S I & J, IN
PROPER FORMAT



FORTRAN LISTING

```

C      SMOG2 PASS 2  DUAL X OR X AND Z DBL SPL WITH PROFILE
      DIMENSION RX(11,15),RZ(15,11),FZ(11),FX(15),X(15),Z(11),Y(11,
15)
      DIMENSION FPZ(11),FSZ(11),C(13)
750  READ 180,JPLS,JUL,JUL2,NJUL,M,N,MS,NS,NOROW,NCOMP,CURV,RHS
      READ 181,EXP2,COST,POINT,EXP1
      DO 32 I=1,N
      READ 181,X(I),FZ(I)
      DO 32 J=2,M
32  READ 181,RZ(I,J)
      DO 33 I=1,M
      READ 181,Z(I),FX(I),FPZ(I),FSZ(I)
      DO 33 J=1,N
33  READ 181,RX(I,J)
      ML=M+2
      DO 100 J=1,ML
100  READ 181,C(J)
C      *      *      X SEC DIFFERENCES      *      *
      JX=NS/2
      DO 88 IZ=1,M
      I=1
      JS=JPLS+1
      JF=JS+JX
      DO 87 J=JS,JF
      IF(RX(IZ,I)-20.)501,87,501
501  PUNCH 171,J,CURV
      IROW=2
      ISTRT=2
      GO TO (503,504),NCOMP
503  FUPZ=-1.
      FUSZ=0.
      CALL PROFL2 (X(I),FX(IZ),EXP1,FUPZ,FUSZ,EXP2,POINT,T,TP,TS
,NCOMP)
504  PWR=RX(IZ,I)
      CALL SEDIF1 (T,TP,TS,X(I),IROW,J,PWR,IROW)
      IROW=IROW+1
      CALL SEDIF2 (X(I),T,TP,TS,PWR,IROW,J)
      IF(I-3)75,75,502
502  IROW=IROW+1
      DO 505 K=3,1,2
      IF(K-1)73,75,75
73  DIF=X(I)-X(K)
      CALL SEDIF2 (DIF,T,TP,TS,PWR,IROW,J)
505  IROW=IROW+1
75  IF(IZ-1)87,87,76

```

```

76 DO 79 NPWR=1,3
   ISTRT=ISTRT+NJUL
   IROW=ISTRT
   PWR=RX(IZ,1)*Z(IZ)**NPWR
   CALL SEDIF1 (T,TP,TS,X(1),IROW,J,PWR,IROW)
   IROW=IROW+1
   CALL SEDIF2 (X(1),T,TP,TS,PWR,IROW,J)
   IROW=IROW+1
   DO 78 K=3,1,2
   IF(K-1)77,79,79
77 DIF=X(1)-X(K)
   CALL SEDIF2 (DIF,T,TP,TS,PWR,IROW,J)
78 IROW=IROW+1
79 CONTINUE
   IF(IZ-JUL)87,87,511
511 DO 86 L=JUL,IZ,JUL2
   IF(L-IZ)512,87,87
512 ISTRT=ISTRT+NJUL
   IROW=ISTRT
   PWR=RX(IZ,1)*(Z(IZ)-Z(L))**3
   CALL SEDIF1 (T,TP,TS,X(1),IROW,J,PWR,IROW)
   IROW=IROW+1
   CALL SEDIF2 (X(1),T,TP,TS,PWR,IROW,J)
   IROW=IROW+1
   DO 85 K=3,1,2
   IF(K-1)84,86,86
84 DIF=X(1)-X(K)
   CALL SEDIF2 (DIF,T,TP,TS,PWR,IROW,J)
85 IROW=IROW+1
86 CONTINUE
87 I=I+2
   NCOMP=1
88 JPLS=JF
C      Z SEC DIFFERENCES      *      *
   DO 110 I=1,N
   DO 111 IZ=JUL,M,JUL2
   GO TO (550,551),NCOMP
550 IF(RX(IZ,1)-20.)556,111,556
556 PWR=RZ(1,IZ)
   FZD=Z(IZ)
   FOZ=FX(IZ)
   FUPZ=FPZ(IZ)
   FUSZ=FSZ(IZ)
562 CALL PROFL2(X(1),FOZ,EXP1,FUPZ,FUSZ,EXP2,POINT,T,TP,TS,
NCOMP)

```

```

GO TO 563
551 PWR=RZ(1,1Z)
    FZD=Z(1Z)
563 PUNCH 171,J,CURV
    GO TO (564,565),NCOMP
565 ISTRT=2+NJUL
    GO TO 566
564 ISTRT=2
    CALL SEDIF4 (TS,PWR,J,ISTRT)
567 IF(1-1)569,568,569
569 IROW=ISTRT+1
    DO 570 IXPWR=1,3
    PROD=PWR*X(1)**IXPWR
    CALL SEDIF4(TS,PROD,J,IROW)
570 IROW=IROW+1
    IF(1-3)568,568,571
571 DO 572 K=3,1,2
    IF(K-1)604,568,604
604 PROD=PWR*(X(1)-X(K))**3
    CALL SEDIF4(TS,PROD,J,IROW)
572 IROW=IROW+1
568 ISTRT=ISTRT+NJUL
    CALL SEDIF5(TP,TS,FZD,PWR,J,ISTRT)
573 IF(1-1)575,566,575
575 IROW=ISTRT+1
    DO 576 IXPWR=1,3
    PROD=PWR*X(1)**IXPWR
    CALL SEDIF5 (TP,TS,FZD,PROD,J,IROW)
576 IROW=IROW+1
    IF(1-3)566,566,577
577 DO 578 K=3,1,2
    IF(K-1)605,566,605
605 PROD=PWR*(X(1)-X(K))**3
    CALL SEDIF5 (TP,TS,FZD,PROD,J,IROW)
578 IROW=IROW+1
566 ISTRT=ISTRT+NJUL
    CALL SEDIF6 (T,TP,TS,FZD,J,PWR,ISTRT)
579 IF(1-1)581,580,581
581 IROW=ISTRT+1
    DO 582 IXPWR=1,3
    PROD=PWR*X(1)**IXPWR
    CALL SEDIF6 (T,TP,TS,FZD,J,PROD,IROW)
582 IROW=IROW+1
    IF(1-3)580,580,583
583 DO 584 K=3,1,2
    IF(K-1)606,580,606

```

```

606 PROD=PWR*(X(1)-X(K))**3
   CALL SEDIF6 (T,TP,TS,FZD,J,PROD,IROW)
584 IROW=IROW+1
580 ISTRT=ISTRT+NJUL
   CALL SEDIF2 (FZD,T,TP,TS,PWR,ISTRT,J)
585 IF(1-1)586,590,586
586 IROW=ISTRT+1
   DO 587 IXPWR=1,3
   PROD=PWR*X(1)**IXPWR
   CALL SEDIF2 (FZD,T,TP,TS,PROD,IROW,J)
587 IROW=IROW+1
   IF(1-3)590,590,588
588 DO 589 K=3,1,2
   IF(K-1)597,590,597
597 PROD=PWR*(X(1)-X(K))**3
   CALL SEDIF2 (FZD,T,TP,TS,PROD,IROW,J)
589 IROW=IROW+1
590 IF(1Z-JUL)591,111,591
591 ISTRT=ISTRT+NJUL
   DO 592 K=JUL,1Z,JUL2
   IF(K-1Z)593,111,593
593 DIF=FZD-Z(K)
   CALL SEDIF2 (DIF,T,TP,TS,PWR,ISTRT,J)
   1 IF(1-1)607,592,607
607 IROW=ISTRT+1
   DO 608 IXPWR=1,3
   PROD=PWR*X(1)**IXPWR
   CALL SEDIF2 (DIF,T,TP,TS,PROD,IROW,J)
608 IROW=IROW+1
   IF(1-3)592,592,598
598 DO 599 KJ=3,1,2
   IF(KJ-1)600,592,600
600 PROD=PWR*(X(1)-X(KJ))**3
   CALL SEDIF2 (DIF,T,TP,TS,PROD,IROW,J)
599 IROW=IROW+1
592 ISTRT=ISTRT+NJUL
111 J=J+1
110 NCOMP=1
   PUNCH 174
   PUNCH 175,COST
   DO 412 I=2,NOROW
412 PUNCH 177,1,RHS
   PUNCH 176
   PRINT 178
   PAUSE 751

```


GO TO 750
171 FORMAT(6X,2H C,14,6H OFFSET,F12.5)
173 FORMAT(1H*,5X,47H
)
174 FORMAT(7H FIRST B)
175 FORMAT(12X, 6H R 1,F12.5)
176 FORMAT(3HEOF)
177 FORMAT(12X,2H R,14,1H ,F11.5)
178 FORMAT(28H ENTER NEW DATA - PRESS START)
180 FORMAT (10I5,2F15.9)
181 FORMAT (4F15.9)
END

```

SUBROUTINE PROFL2(XD,FD,EXPD1,TZPD,TZSD,EXPD2,X1,TD,TPD,TSD,NCD)
  TD=(X1+FD-XD)/X1
  IF(TD-.00001)1,1,2
2  DIFD=EXPD1-1.
  PROD=TD**DIFD
  TPD1=EXPD1*TZPD*PROD
  TSD1=EXPD1*(DIFD*TD**(DIFD-1.)*TZPD**2+TZSD*PROD)
  TD=1.-TD**EXPD1
  IF(TD-.00001)7,7,4
4  DIFD=EXPD2-1.
  TDEXP=TD**DIFD
  TPD=-EXPD2*TPD1*TDEXP
  TSD=EXPD2*(DIFD*TD**(EXPD2-2.)*TPD1*TPD1-TSD1*TDEXP)
  TD=TD**EXPD2
  IF(TD-.00001)7,7,6
7  TD=0.
  GO TO 3
6  NCD=1
  RETURN
1  NCD=2
  TD=1.
5  TPD=0.
  TSD=0.
  RETURN
3  NCD=1
  GO TO 5
END

```

```

SUBROUTINE SEDIF1 (TD,TPD,TSD,XD,JROWD,JD,PWRD,IROWD)
  IROWD=JROWD
  CALL SEDIF4 (TSD,PWRD,JD,IROWD)
  IROWD=IROWD+1
  CALL SEDIF5 (TPD,TSD,XD,PWRD,JD,IROWD)
  IROWD=IROWD+1
  CALL SEDIF6 (TD,TPD,TSD,XD,JD,PWRD,IROWD)
  RETURN
END

```

```

SUBROUTINE SEDIF2 (DIFD,TD,TPD,TSD,PWRD,IROWD,JD)
  WRM=(3.*DIFD*TD+3.*TPD*DIFD**2+(TSD*DIFD**3)/2.)*PWRD
  CALL SIGN (JD,IROWD,WRM)
  RETURN
END

```

```

SUBROUTINE SEDIF3 (IXD,FXD,PRD,IROWD,JSD)
EXD=IXD
WRM=(EXD*FXD**(IXD-1)-FXD**IXD)*PRD
CALL SIGN (JSD,IROWD,WRM)
RETURN
END

```

```

SUBROUTINE SEDIF4 (TSD,PWRD,JD,IROWD)
WRM=(TSD*PWRD)/2.
CALL SIGN (JD,IROWD,WRM)
RETURN
END

```

```

SUBROUTINE SEDIF5 (TPD,TSD,XD,PWRD,JD,IROWD)
WRM=((TSD*XD)/2.+TPD)*PWRD
CALL SIGN (JD,IROWD,WRM)
RETURN
END

```

```

SUBROUTINE SEDIF6 (TD,TPD,TSD,XD,JD,PWRD,IROWD)
WRM=TD
WRM=WRM+(TSD*XD**2)/2.
WRM=WRM+2.*TPD*XD
WRM=WRM*PWRD
CALL SIGN (JD,IROWD,WRM)
RETURN
END

```

```

SUBROUTINE SIGN (JW,IW,WAM)
IF(WAM)370,373,371
370 WAM=-WAM
PUNCH 169,JW,IW,WAM
RETURN
371 PUNCH 167,JW,IW,WAM
373 RETURN
167 FORMAT(6X,2H C,14,2H R,14,1H-,F11.5)
169 FORMAT(6X,2H C,14,2H R,14,F12.5)
END

```

Section III

SMOG 3

The purpose of the program named SMOG 3 is to generate a matrix with the following characteristics:

- (1) Primal formulation
- (2) Sum of the deviations fit
- (3) Double splined in the x direction
- (4) Single or double splined in the z direction
- (5) Containing profile conditions

Figure B-4 (Section II of this Appendix) shows a five-station by five-waterline surface and an equation representing this surface. The matrix which represents this equation consists of two parts. The first part consists of the deviation constraints. The second part is the curvature constraints.

The deviation constraints have the form:

$$(a) \quad Y(x_i, z_j) + S_{i,j} - Q_{i,j} = Y_{i,j}$$

thus offset (1,3) Fig. B-4 would have the constraint:

$$(a) \quad (a_{01} - b_{01})x_3 + (a_{02} - b_{02})x_3^2 \\ + (a_{03} - b_{03})x_3^3 + S_{1,3} - Q_{1,3} = Y_{1,3}$$

$$\text{where} \quad a_{01} - b_{01} = A_{01}$$

$$a_{02} - b_{02} = A_{02}$$

$$a_{03} - b_{03} = A_{03}$$

The curvature constraints are the same as those of SMOG 1 and SMOG 2

$$(b) \quad \hat{r}_{i,j} \cdot f''(x_i, z_j)_{xx} \geq 0$$

$$(c) \quad \hat{r}_{i,j} \cdot f''(x_i, z_j)_{zz} \geq 0$$

A tableau of the matrix is given in Fig. B-6. The positive identity matrix corresponding to $S_{i,j}$ is always used to provide a basic feasible solution, and SMOG 3 provides the basis headings for this purpose.

Data Assembly Instructions

Before the data punched by Passes 1 and 2 of SMOG 3 can be used, it must be rearranged according to the instructions which follow:

Pass 1

- (1) Be sure Pass 2 input data has been removed from behind the output deck
- (2) Remove the first four cards from the front of the output deck. These are punched with the heading, ROW ID, OFFSET, MATRIX.
- (3) Sort the output deck on Column 16 with the edit off. The output deck will fall in the reject hopper and the cost row cards will fall in the Column 2 hopper.
Set the cost row elements aside.

Pass 2

- (1) Remove the last two cards from the output deck. These are punched FIRST B and EOF
- (2) Place the Pass 2 output deck directly behind the Pass 1 output deck.

Pass 1 and 2

- (1) Sort the combined deck on Column 8 with the edit off. The right-hand side cards and row identification will fall in the reject hopper. Set these aside.
- (2) Sort the combined deck on Column 25 with the edit off. The basis heading cards will fall in the reject hopper.
- (3) Keypunch a card with BASIS in Columns 1-5 and place in front of the basis heading deck.

.001	.001	...	1000.	1000.	...	0.0.	...	1000.	1000.	...	
Deviation Constraints (Rows)			Identity Matrix (Deviation and Curvature Rows)							Negative Identity Matrix (Deviation Rows Only)	C_{01} $y_{1,1}$ $y_{1,2}$ $\vdots$
Curvature Constraints (Rows)			(First Feasible Solution)							Requirement Vector 0.0 0.0 $\vdots$	
A_{01}	A_{02}	...								=	

Fig. B-6 Matrix Tableau

- (4) Sort the row identification - right-hand side deck on Column 25 with the edit off. The row identification cards will fall in the reject hopper.
- (5) Place the following cards in the front of a card box in the following order:
- Heading card
 - Row ID
 - OFFSET
 - The row identification deck
 - The basis heading deck
 - MATRIX
- (6) Sort the combined output decks on Columns 12, 11, 10. This will place them in Column order. Put the resulting deck behind the MATRIX card.
- (7) Put the First B card ahead of the right-hand side deck and the EOF card behind it. Then put this deck behind the combined output decks.

A fully assembled output deck combining the sample problem of Pass 1 and Pass 2 is given immediately following the Pass 2 sample output listing.

SMOG 3 PASS 1

OPERATING INSTRUCTIONS

Pass 1 of SMOG 3 calculates the second differences of the offsets and the intersections of the profile with the waterlines and stations. It then punches the deviation constraints for the matrix. The program is written in FORTRAN II for the IBM-1620 computer.

Fortran Symbol Definitions

- M - Total number of waterlines in the surface to be faired. This will be an odd number if the surface is double splined in the z direction.
- N - Total number of stations in the surface. This will always be an odd number.
- X(J) - Distance along the x axis from the origin of the surface to station j .
- Z(I) - Distance along the z axis from the origin of the surface to Waterline i .
- Y(I,J) - Offset of the surface at waterline i , station j , in feet and decimals
- IAY - Number of feet in the offset if read in feet, inches and eighths.
- IBY - Number of inches corresponding to IAY
- ICY - Number of eighths corresponding to IAY
- NAA - Program indicator
 - If NAA = -1, scale factors for normalizing and translating x(J) and z(I) are read in
 - If NAA = +1, scaling and translating are done by the program as given in Section II .
- SX - Scale factor for X(J) when these are read in
- TX - Translation factor for X(J) when these are read in
- SZ - Scale factor for Z(I) when these are read in
- TZ - Translation factor for Z(I) when these are read in

- RHS - The cost on the slack variables associated with the deviation constraints. Usually made equal to 1000 .
- CURV - The cost on the non-slack variables. Usually made .001 .
- NAB - Program Indicator
- If NAB = -1 , the surface will be double splined in the z direction, and M must be an odd number
- If NAB = +1 , the surface will be single splined in the z direction and M is unrestricted
- COST - Used in Pass 2. A zero value must be given
- EXP1 - The value of p in the profile function, usually made .3333
- EXP2 - The value of r in the profile function, usually 3.0 .
- POINT - The value of D in the profile function. This number is the length of the fraction of the station spacing over which the profile function is effective in terms of the full-scale surface (the value will be translated and normalized exactly like the x values are).
- C(I) - Coefficients of the Theilheimer equation describing the profile. There must be (M+2) coefficients. Straight lines or other curves may be used by making all except the desired coefficients zero.

Input

The input data cards are described below. There are certain input variables on which there are restrictions on the value which can be entered. These restrictions follow.

<u>Variable</u>	<u>Minimum</u>	<u>Maximum</u>
N	3	15
M	3	11

In describing the various data cards, the actual FORTRAN format field description is used in most cases. These fields come consecutively across the card with no gaps or blank columns between,

except where indicated. The field descriptions are the FORTRAN F field, which uses the FORTRAN fixed point decimal number, and the I field that uses the FORTRAN integer number, which is always right justified. The card numbers are not punched on the data cards.

<u>Contents of Card</u>							<u>Card No.</u>
Card Columns	1	2-12	13-53				1
Contents	*	Blank	Any alphameric problem heading (This heading will be used for identifying the problem on the LP output)				
Format	I5	I5	F11.6	F11.6			2
Variable	NAA	NAB	POINT	COST			
Format	I5	I5	F11.6	F11.6	F11.6	F11.6	3
Variable	M	N	CURV	RHS	EXP1	EXP2	
Format	F10.4						Next
Variable	C(I)						M+2 cards
Format	F10.4						N cards per group
Variable	Z(I)						
Alternate Cards:							
Format	F10.4	F10.4					
Variable	X(J)	Y(I,J)					
	or						
Format	F10.4	I5	I5	I5			Next
Variable	X(J)	IAY	IBY	ICY			M Groups

This arrangement can be stated as follows: The first card of each set gives the height z of the waterline. The following cards each give a station coordinate and the offset at the intersection of the given waterline and station. There is one set of cards for each waterline in the surface.

Format	F10.4	F10.4	F10.4	F10.4	Last Card
Variable	SX	SZ	TK	TZ	

(This card is entered only if NAA = -1)

Output

All of the data necessary for the deviation constraints in the matrix are punched by this program. The first cards punched contain the heading, "ROW ID," "OFFSET" (this is the identification of the cost row) and "MATRIX."

The matrix elements are punched in row order with the columns in order within the rows. Each row also contains in order of appearance:

- (1) The row identification for that row
- (2) The right-hand side element for that row
- (3) The costs of the two slack columns associated with the row
- (4) The slack elements
- (5) The basis heading card

This output must be sorted, together with the output from Pass 2, before being used with LP-90. The sorting instructions are in the section called "Output Assembly."

Sense Switch Settings

Sense Switch 1 - Not Used

Sense Switch 2 - ON The values of the x and z second differences and the resulting signs are printed

Sense Switch 2 - OFF The above is not printed

Sense Switch 3 - ON The offsets are read in as feet, inches and eighths

Sense Switch 3 - OFF The offsets are read in as feet and decimals

Sense Switch 4 - ON The data for Pass 2 is punched

Sense Switch 4 - OFF The data for Pass 2 is not punched but remains in storage for later use with Pass 2.

SAMPLE PROBLEM

The following sample problem is a five-station by five-waterline set of offsets taken from the DLG-26 class ships. The stations are Numbers 0 , 1/2 , 1 , 1-1/2 , 2, and the waterlines are 12, 16, 20, 24, and 28. The surface contains the bow profile of the DLG. The matrix is double splined in the z direction. Only the output from Pass 1 in the order in which it was punched is listed here. The output from Pass 2 is included with the instructions from that program. The sorted, assembled, and combined outputs of Pass 1 and 2 is listed after the Pass 2 output.

SAMPLE PROBLEM FOR SMOG 3, PASS 1

* * SAMPLE INPUT * *

```

*   TODD  DLG  5X5  END PROFILE X-Z DBL SPL-12/3/62
    1   -1   1.   0.
    5   5   0.001 1000.   3.   .33333333
1.52935
- .5873
0.
0.
0.
0.
0.
.0000
.0000 .000000
12.7500 1.041666
25.5000 2.458333
38.2500 3.874999
51.0000 5.333333
1.0000
.0000 .000000
12.7500 1.239583
25.5000 2.697916
38.2500 4.197916
51.0000 5.812500
2.0000
.0000 .078
12.7500 1.479166
25.5000 2.979166
38.2500 4.583333
51.0000 6.333333
3.0000
.0000 .343749
12.7500 1.791666
25.5000 3.447916
38.2500 5.250000
51.0000 7.166666
4.0000
.0000 .708333
12.7500 2.416666
25.5000 4.322916
38.2500 6.416666
51.0000 8.583333

```

* TODD DLG 5X5 END PROFILE X-Z DBL SPL-12/3/62

END PROFILE INTERSECTIONS

W LINES

1	1.529350
-.5873	0.0000
2	.942050
-.5873	0.0000
3	.354750
-.5873	0.0000
4	-.232550
-.5873	0.0000
5	-.819850
-.5873	0.0000

STATIONS

1	2.604003
2	.901367
3	0.000000
4	0.000000
5	0.000000

2ND DIFF - W LINES

WL	STA	NORM VALUE	SIGN
1	1	OUT OF SURFACE	
1	2	OUT OF SURFACE	
1	3	-5.176766	1.00
1	4	.041668	-1.00
1	5	.041668	-1.00
2	1	OUT OF SURFACE	
2	2	-37.680848	1.00
2	3	.041667	-1.00
2	4	.114584	-1.00
2	5	.114584	-1.00
3	1	OUT OF SURFACE	
3	2	-.963248	1.00
3	3	.104167	-1.00
3	4	.145833	-1.00
3	5	.145833	-1.00
4	1	-.049093	1.00
4	2	.208333	-1.00
4	3	.145834	-1.00
4	4	.114582	-1.00
4	5	.114582	-1.00

5	1	.927938	-1.00
5	2	.197917	-1.00
5	3	.187500	-1.00
5	4	.072917	-1.00
5	5	.072917	-1.00

2ND DIFF-STATIONS

STA	WL	NORM VALUE	SIGN
1	2	OUT OF SURFACE	
1	3	OUT OF SURFACE	
1	4	-.439121	1.00
1	5	-.439121	1.00
2	2	-3.216759	1.00
2	3	.072917	-1.00
2	4	.312500	-1.00
2	5	.312500	-1.00
3	2	.041667	-1.00
3	3	.187500	-1.00
3	4	.406250	-1.00
3	5	.406250	-1.00
4	2	.062500	-1.00
4	3	.281250	-1.00
4	4	.499999	-1.00
4	5	.499999	-1.00
5	2	.041666	-1.00
5	3	.312500	-1.00
5	4	.583334	-1.00
5	5	.583334	-1.00

SMOG 3, PASS 1

* TODD DLG 5X5 END PROFILE X-2 DBL SPL-12/3/62

10.0-2

ROW ID	MATRIX	OFSET
C	R	3
C	R	3
C	1 R	3-
C	2 R	3
C	3 R	3-
C	4 R	3
C	5 R	3-
C	6 R	3
C	7 R	3-
C	8 R	3
C	51 OFSET	1000.00000
C	52 OFSET	1000.00000
C	51 R	3
C	52 R	3-
C	51/R	3
C	R	4
C	R	4
C	1 R	4-
C	2 R	4
C	3 R	4-
C	4 R	4
C	5 R	4-
C	6 R	4
C	7 R	4-
C	8 R	4
C	9 R	4-
C	10 R	4
C	53 OFSET	1000.00000
C	54 OFSET	1000.00000
C	53 R	4
C	54 R	4-
C	53 R	4
C	R	5
C	R	5
C	1 R	5-
C	2 R	5
C	3 R	5-

B-205

C	4	R	5	4.00000
C	5	R	5-	16.00000
C	6	R	5	16.00000
C	7	R	5-	64.00000
C	8	R	5	64.00000
C	9	R	5-	8.00000
C	10	R	5	8.00000
C	55	OFSET		1000.00000
C	56	OFSET		1000.00000
C	55	R	5	1.0
C	56	R	5-	1.0
C	55	R	5	
		R	7	
		R	7	1.24702
C	1	R	7-	1.0
C	2	R	7	1.0
C	3	R	7-	1.00000
C	4	R	7	1.00000
C	5	R	7-	1.00000
C	6	R	7	1.00000
C	7	R	7-	1.00000
C	8	R	7	1.00000
C	11	R	7-	1.00000
C	12	R	7	1.00000
C	13	R	7-	1.00000
C	14	R	7	1.00000
C	15	R	7-	1.00000
C	16	R	7	1.00000
C	17	R	7-	1.00000
C	18	R	7	1.00000
C	21	R	7-	1.00000
C	22	R	7	1.00000
C	23	R	7-	1.00000
C	24	R	7	1.00000
C	25	R	7-	1.00000
C	26	R	7	1.00000
C	27	R	7-	1.00000
C	28	R	7	1.00000
C	31	R	7-	1.00000
C	32	R	7	1.00000
C	33	R	7-	1.00000

1.0.0-2

B-205

C	34	R	7	1.00000
C	35	R	7-	1.00000
C	36	R	7	1.00000
C	37	R	7-	1.00000
C	38	R	7	1.00000
C	57	OFSET	1000.00000	
C	58	OFSET	1000.00000	
C	57	R	7	1.0
C	58	R	7-	1.0
C	57	R	7	
		K	8	2.69791
		R	8	1.0
C	1	R	8-	1.0
C	2	R	8	2.00000
C	3	R	8-	2.00000
C	4	R	8	4.00000
C	5	R	8-	4.00000
C	6	R	8	8.00000
C	7	R	8-	8.00000
C	8	R	8	1.00000
C	11	R	8-	1.00000
C	12	R	8	2.00000
C	13	R	8-	2.00000
C	14	R	8	4.00000
C	15	R	8-	4.00000
C	16	R	8	8.00000
C	17	R	8-	8.00000
C	18	R	8	1.00000
C	21	R	8-	1.00000
C	22	R	8	2.00000
C	23	R	8-	2.00000
C	24	R	8	4.00000
C	25	R	8-	4.00000
C	26	R	8	8.00000
C	27	R	8-	8.00000
C	28	R	8	1.00000
C	31	R	8-	1.00000
C	32	R	8	2.00000
C	33	R	8-	2.00000
C	34	R	8	4.00000
C	35	R	8-	

1.0.0-2

B-206

1.0.0.2

C	36	R	8	4.00000
C	37	R	8-	8.00000
C	38	R	8	8.00000
C	59	OFSET		1000.00000
C	60	OFSET		1000.00000
C	59	R	8	1.0
C	60	R	8-	1.0
C	59	R	8	
		R	9	4.19791
C	1	R	9-	1.0
C	2	R	9	1.0
C	3	R	9-	3.00000
C	4	R	9	3.00000
C	5	R	9-	9.00000
C	6	R	9	9.00000
C	7	R	9-	27.00000
C	8	R	9	27.00000
C	9	R	9-	1.00000
C	10	R	9	1.00000
C	11	R	9-	1.00000
C	12	R	9	1.00000
C	13	R	9-	3.00000
C	14	R	9	3.00000
C	15	R	9-	9.00000
C	16	R	9	9.00000
C	17	R	9-	27.00000
C	18	R	9	27.00000
C	19	R	9-	1.00000
C	20	R	9	1.00000
C	21	R	9-	1.00000
C	22	R	9	1.00000
C	23	R	9-	3.00000
C	24	R	9	3.00000
C	25	R	9-	9.00000
C	26	R	9	9.00000
C	27	R	9-	27.00000
C	28	R	9	27.00000
C	29	R	9-	1.00000
C	30	R	9	1.00000
C	31	R	9-	1.00000

B.207

1.0.0-2

B-2.0

C	32	R	9	1.00000
C	33	R	9-	3.00000
C	34	R	9	3.00000
C	35	R	9-	9.00000
C	36	R	9	9.00000
C	37	R	9-	27.00000
C	38	R	9	27.00000
C	39	R	9-	1.00000
C	40	R	9	1.00000
C	61	OFSET	1000.00000	
C	62	OFSET	1000.00000	
C	61	R	9	1.0
C	62	R	9-	1.0
C	61	R	9	
		R	10	
		R	10	5.81250
C	1	R	10-	1.0
C	2	R	10	1.0
C	3	R	10-	4.00000
C	4	R	10	4.00000
C	5	R	10-	16.00000
C	6	R	10	16.00000
C	7	R	10-	64.00000
C	8	R	10	64.00000
C	9	R	10-	8.00000
C	10	R	10	8.00000
C	11	R	10-	1.00000
C	12	R	10	1.00000
C	13	R	10-	4.00000
C	14	R	10	4.00000
C	15	R	10-	16.00000
C	16	R	10	16.00000
C	17	R	10-	64.00000
C	18	R	10	64.00000
C	19	R	10-	8.00000
C	20	R	10	8.00000
C	21	R	10-	1.00000
C	22	R	10	1.00000
C	23	R	10-	4.00000
C	24	R	10	4.00000
C	25	R	10-	16.00000

C	26	R	10	16.00000
C	27	R	10-	64.00000
C	28	R	10	64.00000
C	29	R	10-	8.00000
C	30	R	10	8.00000
C	31	R	10-	1.00000
C	32	R	10	1.00000
C	33	R	10-	4.00000
C	34	R	10	4.00000
C	35	R	10-	16.00000
C	36	R	10	16.00000
C	37	R	10-	64.00000
C	38	R	10	64.00000
C	39	R	10-	8.00000
C	40	R	10	8.00000
C	63	OFSET	1000.00000	
C	64	OFSET	1000.00000	
C	63	R	10	1.0
C	64	R	10-	1.0
C	63	R	10	
		R	12	1.47916
C	1	R	12-	1.0
C	2	R	12	1.0
C	3	R	12-	1.00000
C	4	R	12	1.00000
C	5	R	12-	1.00000
C	6	R	12	1.00000
C	7	R	12-	1.00000
C	8	R	12	1.00000
C	11	R	12-	2.00000
C	12	R	12	2.00000
C	13	R	12-	2.00000
C	14	R	12	2.00000
C	15	R	12-	2.00000
C	16	R	12	2.00000
C	17	R	12-	2.00000
C	18	R	12	2.00000
C	21	R	12-	4.00000
C	22	R	12	4.00000
C	23	R	12-	4.00000

1.0.0.2

C	24	R	12	4.00000
C	25	R	12-	4.00000
C	26	R	12	4.00000
C	27	R	12-	4.00000
C	28	R	12	4.00000
C	31	R	12-	8.00000
C	32	R	12	8.00000
C	33	R	12-	8.00000
C	34	R	12	8.00000
C	35	R	12-	8.00000
C	36	R	12	8.00000
C	37	R	12-	8.00000
C	38	R	12	8.00000
C	65	OFSET		1000.00000
C	66	OFSET		1000.00000
C	65	R	12	1.0
C	66	R	12-	1.0
C	65	R	13	
C		R	13	2.97916
C	1	R	13-	1.0
C	2	R	13	1.0
C	3	R	13-	2.00000
C	4	R	13	2.00000
C	5	R	13-	4.00000
C	6	R	13	4.00000
C	7	R	13-	8.00000
C	8	R	13	8.00000
C	11	R	13-	2.00000
C	12	R	13	2.00000
C	13	R	13-	4.00000
C	14	R	13	4.00000
C	15	R	13-	8.00000
C	16	R	13	8.00000
C	17	R	13-	16.00000
C	18	R	13	16.00000
C	21	R	13-	4.00000
C	22	R	13	4.00000
C	23	R	13-	8.00000
C	24	R	13	8.00000
C	25	R	13-	16.00000

13.210

C	26	R	13	16.00000
C	27	R	13-	32.00000
C	28	R	13	32.00000
C	31	R	13-	8.00000
C	32	R	13	8.00000
C	33	R	13-	16.00000
C	34	R	13	16.00000
C	35	R	13-	32.00000
C	36	R	13	32.00000
C	37	R	13-	64.00000
C	38	R	13	64.00000
C	67	OFSET		1000.00000
C	68	OFSET		1000.00000
C	67	R	13	1.0
C	68	R	13-	1.0
C	67	R	13	
		R	14	4.58333
		R	14	1.0
C	1	R	14-	1.0
C	2	R	14	3.00000
C	3	R	14-	3.00000
C	4	R	14	9.00000
C	5	R	14-	9.00000
C	6	R	14	27.00000
C	7	R	14-	27.00000
C	8	R	14	1.00000
C	9	R	14-	1.00000
C	10	R	14	2.00000
C	11	R	14-	2.00000
C	12	R	14	6.00000
C	13	R	14-	6.00000
C	14	R	14	18.00000
C	15	R	14-	18.00000
C	16	R	14	54.00000
C	17	R	14-	54.00000
C	18	R	14	2.00000
C	19	R	14-	2.00000
C	20	R	14	4.00000
C	21	R	14-	4.00000
C	22	R	14	12.00000
C	23	R	14-	

1.0.0.2

B-211

C	24	R	14	12.00000
C	25	R	14-	36.00000
C	26	R	14	36.00000
C	27	R	14-	108.00000
C	28	R	14	108.00000
C	29	R	14-	4.00000
C	30	R	14	4.00000
C	31	R	14-	8.00000
C	32	R	14	8.00000
C	33	R	14-	24.00000
C	34	R	14	24.00000
C	35	R	14-	72.00000
C	36	R	14	72.00000
C	37	R	14-	216.00000
C	38	R	14	216.00000
C	39	R	14-	8.00000
C	40	R	14	8.00000
C	69	OFSET		1000.00000
C	70	OFSET		1000.00000
C	69	R	14	1.0
C	70	R	14-	1.0
C	69	R	14	
		R	15	6.33333
C		R	15	1.0
C	1	R	15-	1.0
C	2	R	15	4.00000
C	3	R	15-	4.00000
C	4	R	15	16.00000
C	5	R	15-	16.00000
C	6	R	15	64.00000
C	7	R	15-	64.00000
C	8	R	15	8.00000
C	9	R	15-	8.00000
C	10	R	15	8.00000
C	11	R	15-	2.00000
C	12	R	15	2.00000
C	13	R	15-	8.00000
C	14	R	15	8.00000
C	15	R	15-	32.00000
C	16	R	15	32.00000
C	17	R	15-	128.00000

C	18 R	15	128.00000
C	19 R	15-	16.00000
C	20 R	15	16.00000
C	21 R	15-	4.00000
C	22 R	15	4.00000
C	23 R	15-	16.00000
C	24 R	15	16.00000
C	25 R	15-	64.00000
C	26 R	15	64.00000
C	27 R	15-	256.00000
C	28 R	15	256.00000
C	29 R	15-	32.00000
C	30 R	15	32.00000
C	31 R	15-	8.00000
C	32 R	15	8.00000
C	33 R	15-	32.00000
C	34 R	15	32.00000
C	35 R	15-	128.00000
C	36 R	15	128.00000
C	37 R	15-	512.00000
C	38 R	15	512.00000
C	39 R	15-	64.00000
C	40 R	15	64.00000
C	71	OFFSET	1000.00000
C	72	OFFSET	1000.00000
C	71 R	15	1.0
C	72 R	15-	1.0
C	71 R	15	
	R	16	
	R	16	.34374
C	1 R	16-	1.0
C	2 R	16	1.0
C	11 R	16-	3.00000
C	12 R	16	3.00000
C	21 R	16-	9.00000
C	22 R	16	9.00000
C	31 R	16-	27.00000
C	32 R	16	27.00000
C	41 R	16-	1.00000
C	42 R	16	1.00000
C	73	OFFSET	1000.00000

1.0.0.~

B-213

	74	OFSET	1000.00000
C	73 R	16	1.0
C	74 R	16-	1.0
C	73 R	16	
C	73 R	17	
			1.79166
C	1 R	17-	1.0
C	2 R	17	1.0
C	3 R	17-	1.00000
C	4 R	17	1.00000
C	5 R	17-	1.00000
C	6 R	17	1.00000
C	7 R	17-	1.00000
C	8 R	17	1.00000
C	11 R	17-	3.00000
C	12 R	17	3.00000
C	13 R	17-	3.00000
C	14 R	17	3.00000
C	15 R	17-	3.00000
C	16 R	17	3.00000
C	17 R	17-	3.00000
C	18 R	17	3.00000
C	21 R	17-	9.00000
C	22 R	17	9.00000
C	23 R	17-	9.00000
C	24 R	17	9.00000
C	25 R	17-	9.00000
C	26 R	17	9.00000
C	27 R	17-	9.00000
C	28 R	17	9.00000
C	31 R	17-	27.00000
C	32 R	17	27.00000
C	33 R	17-	27.00000
C	34 R	17	27.00000
C	35 R	17-	27.00000
C	36 R	17	27.00000
C	37 R	17-	27.00000
C	38 R	17	27.00000
C	41 R	17-	1.00000
C	42 R	17	1.00000
C	43 R	17-	1.00000

1.0.0-2

B-214

C	44	R	17	1.00000
C	45	R	17-	1.00000
C	46	R	17	1.00000
C	47	R	17-	1.00000
C	48	R	17	1.00000
C	75	OFSET	1000.00000	
C	76	OFSET	1000.00000	
C	75	R	17	1.0
C	76	R	17-	1.0
C	75	R	17	
		R	18	
		R	18	3.44791
C	1	R	18-	1.0
C	2	R	18	1.0
C	3	R	18-	2.00000
C	4	R	18	2.00000
C	5	R	18-	4.00000
C	6	R	18	4.00000
C	7	R	18-	8.00000
C	8	R	18	8.00000
C	11	R	18-	3.00000
C	12	R	18	3.00000
C	13	R	18-	6.00000
C	14	R	18	6.00000
C	15	R	18-	12.00000
C	16	R	18	12.00000
C	17	R	18-	24.00000
C	18	R	18	24.00000
C	21	R	18-	9.00000
C	22	R	18	9.00000
C	23	R	18-	18.00000
C	24	R	18	18.00000
C	25	R	18-	36.00000
C	26	R	18	36.00000
C	27	R	18-	72.00000
C	28	R	18	72.00000
C	31	R	18-	27.00000
C	32	R	18	27.00000
C	33	R	18-	54.00000
C	34	R	18	54.00000
C	35	R	18-	108.00000

1.0.6.2

B-2.15

C	24 R	19	27.00000
C	25 R	19-	81.00000
C	26 R	19	81.00000
C	27 R	19-	243.00000
C	28 R	19	243.00000
C	29 R	19-	9.00000
C	30 R	19	9.00000
C	31 R	19-	27.00000
C	32 R	19	27.00000
C	33 R	19-	81.00000
C	34 R	19	81.00000
C	35 R	19-	243.00000
C	36 R	19	243.00000
C	37 R	19-	729.00000
C	38 R	19	729.00000
C	39 R	19-	27.00000
C	40 R	19	27.00000
C	41 R	19-	1.00000
C	42 R	19	1.00000
C	43 R	19-	3.00000
C	44 R	19	3.00000
C	45 R	19-	9.00000
C	46 R	19	9.00000
C	47 R	19-	27.00000
C	48 R	19	27.00000
C	49 R	19-	1.00000
C	50 R	19	1.00000
C	79 OFSET		1000.00000
C	80 OFSET		1000.00000
C	79 R	19	1.0
C	80 R	19-	1.0
C	79 R	19	
	R	20	7.16666
	R	20	1.0
C	1 R	20-	1.0
C	2 R	20	4.00000
C	3 R	20-	4.00000
C	4 R	20	16.00000
C	5 R	20-	16.00000
C	6 R	20	64.00000
C	7 R	20-	

1.0.0.~

B-27

C	36 R	18	108.00000
C	37 R	18-	216.00000
C	38 R	18	216.00000
C	41 R	18-	1.00000
C	42 R	18	1.00000
C	43 R	18-	2.00000
C	44 R	18	2.00000
C	45 R	18-	4.00000
C	46 R	18	4.00000
C	47 R	18-	8.00000
C	48 R	18	8.00000
C	77 OFSET		1000.00000
C	78 OFSET		1000.00000
C	77 R	18	1.0
C	78 R	18-	1.0
C	77 R	18	
	R	19	
	R	19	5.25000
C	1 R	19-	1.0
C	2 R	19	1.0
C	3 R	19-	3.00000
C	4 R	19	3.00000
C	5 R	19-	9.00000
C	6 R	19	9.00000
C	7 R	19-	27.00000
C	8 R	19	27.00000
C	9 R	19-	1.00000
C	10 R	19	1.00000
C	11 R	19-	3.00000
C	12 R	19	3.00000
C	13 R	19-	9.00000
C	14 R	19	9.00000
C	15 R	19-	27.00000
C	16 R	19	27.00000
C	17 R	19-	81.00000
C	18 R	19	81.00000
C	19 R	19-	3.00000
C	20 R	19	3.00000
C	21 R	19-	9.00000
C	22 R	19	9.00000
C	23 R	19-	27.00000

1.0.0.2

B-216

C	8	R	20	64.00000
C	9	R	20-	8.00000
C	10	R	20	8.00000
C	11	R	20-	3.00000
C	12	R	20	3.00000
C	13	R	20-	12.00000
C	14	R	20	12.00000
C	15	R	20-	48.00000
C	16	R	20	48.00000
C	17	R	20-	192.00000
C	18	R	20	192.00000
C	19	R	20-	24.00000
C	20	R	20	24.00000
C	21	R	20-	9.00000
C	22	R	20	9.00000
C	23	R	20-	36.00000
C	24	R	20	36.00000
C	25	R	20-	144.00000
C	26	R	20	144.00000
C	27	R	20-	576.00000
C	28	R	20	576.00000
C	29	R	20-	72.00000
C	30	R	20	72.00000
C	31	R	20-	27.00000
C	32	R	20	27.00000
C	33	R	20-	108.00000
C	34	R	20	108.00000
C	35	R	20-	432.00000
C	36	R	20	432.00000
C	37	R	20-	1728.00000
C	38	R	20	1728.00000
C	39	R	20-	216.00000
C	40	R	20	216.00000
C	41	R	20-	1.00000
C	42	R	20	1.00000
C	43	R	20-	4.00000
C	44	R	20	4.00000
C	45	R	20-	16.00000
C	46	R	20	16.00000
C	47	R	20-	64.00000
C	48	R	20	64.00000

1.0.0-2

B-2/8

C	49	R	20-	8.00000
C	50	R	20	8.00000
C	81	OFSET	1000.00000	
C	82	OFSET	1000.00000	
C	81	R	20	1.0
C	82	R	20-	1.0
C	81	R	20	
		R	21	.70833
C	1	R	21-	1.0
C	2	R	21-	1.0
C	11	R	21-	4.00000
C	12	R	21	4.00000
C	21	R	21-	16.00000
C	22	R	21	16.00000
C	31	R	21-	64.00000
C	32	R	21	64.00000
C	41	R	21-	8.00000
C	42	R	21	8.00000
C	83	OFSET	1000.00000	
C	84	OFSET	1000.00000	
C	83	R	21	1.0
C	84	R	21-	1.0
C	83	R	21	
		R	22	2.41666
C	1	R	22-	1.0
C	2	R	22	1.0
C	3	R	22-	1.00000
C	4	R	22	1.00000
C	5	R	22-	1.00000
C	6	R	22	1.00000
C	7	R	22-	1.00000
C	8	R	22	1.00000
C	11	R	22-	4.00000
C	12	R	22	4.00000
C	13	R	22-	4.00000
C	14	R	22	4.00000
C	15	R	22-	4.00000
C	16	R	22	4.00000
C	17	R	22-	4.00000

1.0.0-2

B-219

C	18	R	22	4.00000
C	21	R	22-	16.00000
C	22	R	22	16.00000
C	23	R	22-	16.00000
C	24	R	22	16.00000
C	25	R	22-	16.00000
C	26	R	22	16.00000
C	27	R	22-	16.00000
C	28	R	22	16.00000
C	31	R	22-	64.00000
C	32	R	22	64.00000
C	33	R	22-	64.00000
C	34	R	22	64.00000
C	35	R	22-	64.00000
C	36	R	22	64.00000
C	37	R	22-	64.00000
C	38	R	22	64.00000
C	41	R	22-	8.00000
C	42	R	22	8.00000
C	43	R	22-	8.00000
C	44	R	22	8.00000
C	45	R	22-	8.00000
C	46	R	22	8.00000
C	47	R	22-	8.00000
C	48	R	22	8.00000
C	85	OFSET	1000.00000	1000.00000
C	86	OFSET	1000.00000	1000.00000
C	85	R	22	1.0
C	86	R	22-	1.0
C	85	R	22	
		R	23	
		R	23	4.32291
C	1	R	23-	1.0
C	2	R	23	1.0
C	3	R	23-	2.00000
C	4	R	23	2.00000
C	5	R	23-	4.00000
C	6	R	23	4.00000
C	7	R	23-	8.00000
C	8	R	23	8.00000
C	11	R	23-	4.00000

1.0.0.2

B-220

1.0.0-2

C	12	R	23	4.00000
C	13	R	23-	8.00000
C	14	R	23	8.00000
C	15	R	23-	16.00000
C	16	R	23	16.00000
C	17	R	23-	32.00000
C	18	R	23	32.00000
C	21	R	23-	16.00000
C	22	R	23	16.00000
C	23	R	23-	32.00000
C	24	R	23	32.00000
C	25	R	23-	64.00000
C	26	R	23	64.00000
C	27	R	23-	128.00000
C	28	R	23	128.00000
C	31	R	23-	64.00000
C	32	R	23	64.00000
C	33	R	23-	128.00000
C	34	R	23	128.00000
C	35	R	23-	256.00000
C	36	R	23	256.00000
C	37	R	23-	512.00000
C	38	R	23	512.00000
C	41	R	23-	8.00000
C	42	R	23	8.00000
C	43	R	23-	16.00000
C	44	R	23	16.00000
C	45	R	23-	32.00000
C	46	R	23	32.00000
C	47	R	23-	64.00000
C	48	R	23	64.00000
C	87	OFSET		1000.00000
C	88	OFSET		1000.00000
C	87	R	23	1.0
C	88	R	23-	1.0
C	87	R	23	
		R	24	
		R	24	6.41666
C	1	R	24-	1.0
C	2	R	24	1.0
C	3	R	24-	3.00000

B-221

C	4	R	24	3.00000
C	5	R	24-	9.00000
C	6	R	24	9.00000
C	7	R	24-	27.00000
C	8	R	24	27.00000
C	9	R	24-	1.00000
C	10	R	24	1.00000
C	11	R	24-	4.00000
C	12	R	24	4.00000
C	13	R	24-	12.00000
C	14	R	24	12.00000
C	15	R	24-	36.00000
C	16	R	24	36.00000
C	17	R	24-	108.00000
C	18	R	24	108.00000
C	19	R	24-	4.00000
C	20	R	24	4.00000
C	21	R	24-	16.00000
C	22	R	24	16.00000
C	23	R	24-	48.00000
C	24	R	24	48.00000
C	25	R	24-	144.00000
C	26	R	24	144.00000
C	27	R	24-	432.00000
C	28	R	24	432.00000
C	29	R	24-	16.00000
C	30	R	24	16.00000
C	31	R	24-	64.00000
C	32	R	24	64.00000
C	33	R	24-	192.00000
C	34	R	24	192.00000
C	35	R	24-	576.00000
C	36	R	24	576.00000
C	37	R	24-	1728.00000
C	38	R	24	1728.00000
C	39	R	24-	64.00000
C	40	R	24	64.00000
C	41	R	24-	8.00000
C	42	R	24	8.00000
C	43	R	24-	24.00000
C	44	R	24	24.00000

1.0.0.2

B.222

1.0.0.2

C	45	R	24-	72.00000
C	46	R	24	72.00000
C	47	R	24-	216.00000
C	48	R	24	216.00000
C	49	R	24-	8.00000
C	50	R	24	8.00000
C	89	OFFSET		1000.00000
C	90	OFFSET		1000.00000
C	89	R	24	1.0
C	90	R	24-	1.0
C	89	R	24	
	R	25		8.58333
	R	25		1.0
C	1	R	25-	1.0
C	2	R	25	4.00000
C	3	R	25-	4.00000
C	4	R	25	16.00000
C	5	R	25-	16.00000
C	6	R	25	64.00000
C	7	R	25-	64.00000
C	8	R	25	8.00000
C	9	R	25-	8.00000
C	10	R	25	4.00000
C	11	R	25-	4.00000
C	12	R	25	16.00000
C	13	R	25-	16.00000
C	14	R	25	64.00000
C	15	R	25-	64.00000
C	16	R	25	256.00000
C	17	R	25-	256.00000
C	18	R	25	32.00000
C	19	R	25-	32.00000
C	20	R	25	16.00000
C	21	R	25-	16.00000
C	22	R	25	64.00000
C	23	R	25-	64.00000
C	24	R	25	256.00000
C	25	R	25-	256.00000
C	26	R	25	1024.00000
C	27	R	25-	1024.00000
C	28	R	25	

B-228

1.0.0.2

C	29	R	25-	128.00000
C	30	R	25	128.00000
C	31	R	25-	64.00000
C	32	R	25	64.00000
C	33	R	25-	256.00000
C	34	R	25	256.00000
C	35	R	25-	1024.00000
C	36	R	25	1024.00000
C	37	R	25-	4096.00000
C	38	R	25	4096.00000
C	39	R	25-	512.00000
C	40	R	25	512.00000
C	41	R	25-	8.00000
C	42	R	25	8.00000
C	43	R	25-	32.00000
C	44	R	25	32.00000
C	45	R	25-	128.00000
C	46	R	25	128.00000
C	47	R	25-	512.00000
C	48	R	25	512.00000
C	49	R	25-	64.00000
C	50	R	25	64.00000
C	91	OFSET	1000.00000	1000.00000
C	92	OFSET	1.0	1.0
C	91	R	25	1.0
C	92	R	25-	0.00100
C	91	R	25	0.00100
C	1	OFSET		0.00100
C	2	OFSET		0.00100
C	3	OFSET		0.00100
C	4	OFSET		0.00100
C	5	OFSET		0.00100
C	6	OFSET		0.00100
C	7	OFSET		0.00100
C	8	OFSET		0.00100
C	9	OFSET		0.00100
C	10	OFSET		0.00100
C	11	OFSET		0.00100
C	12	OFSET		0.00100
C	13	OFSET		0.00100
C	14	OFSET		0.00100

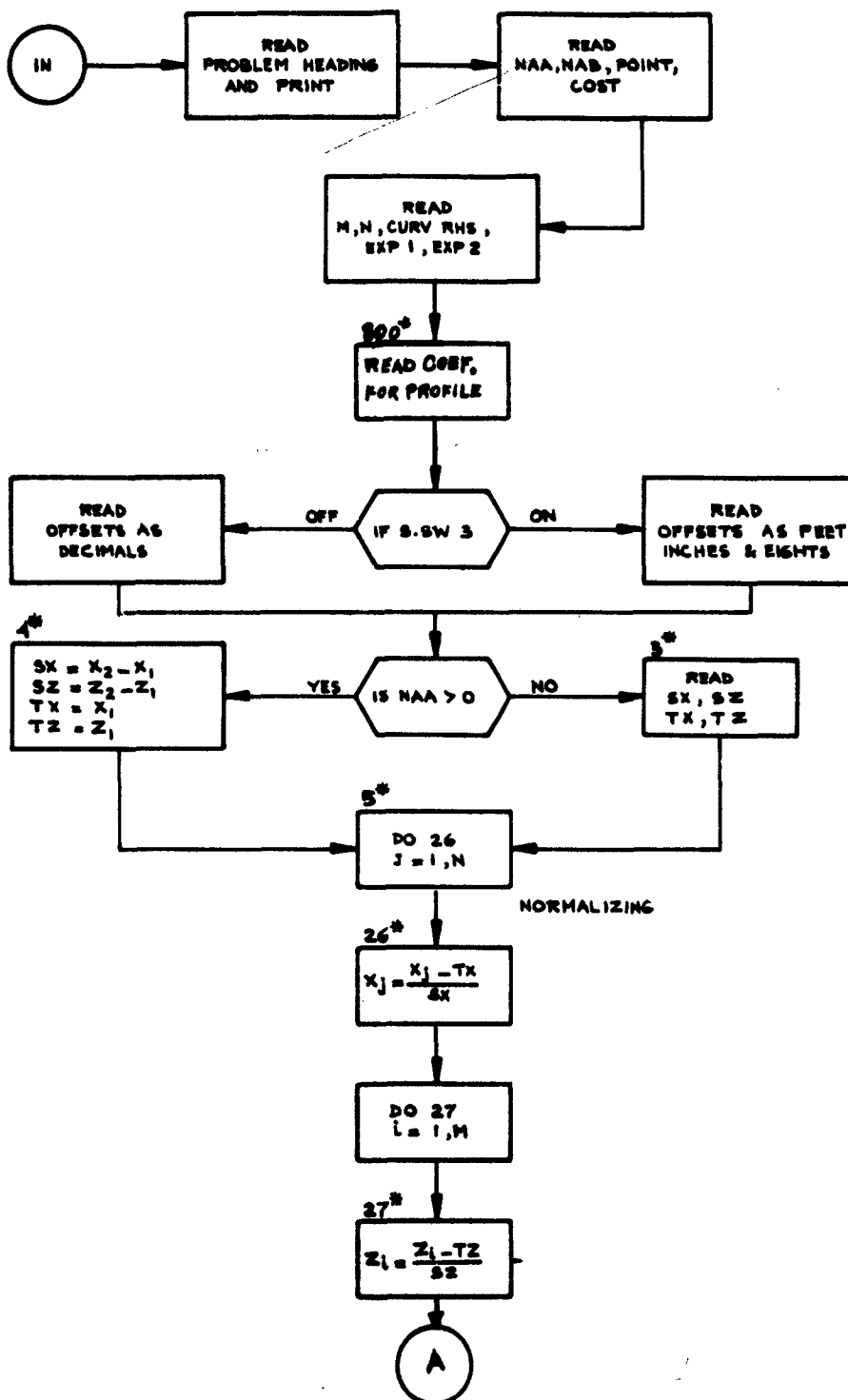
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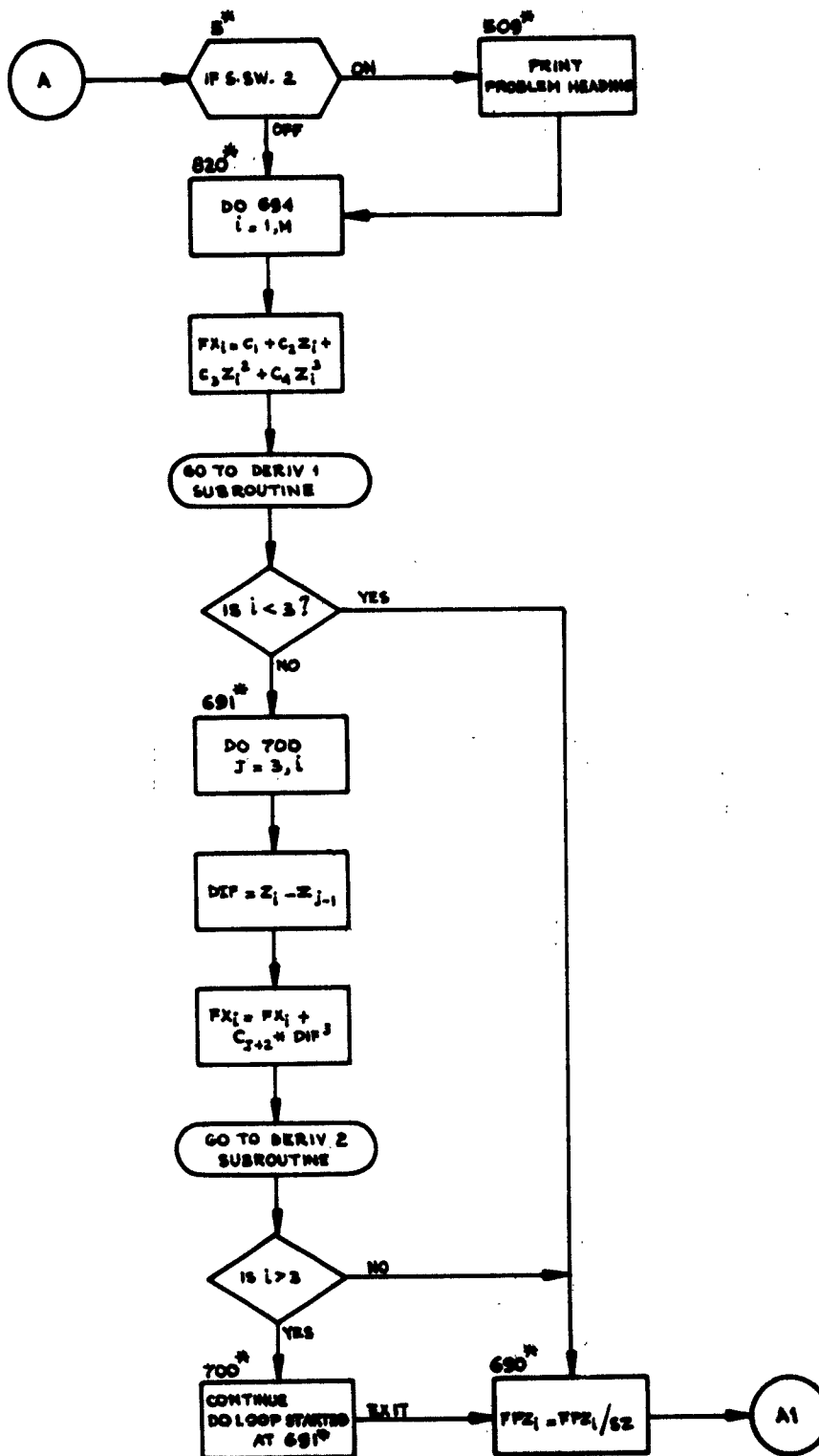
B-225

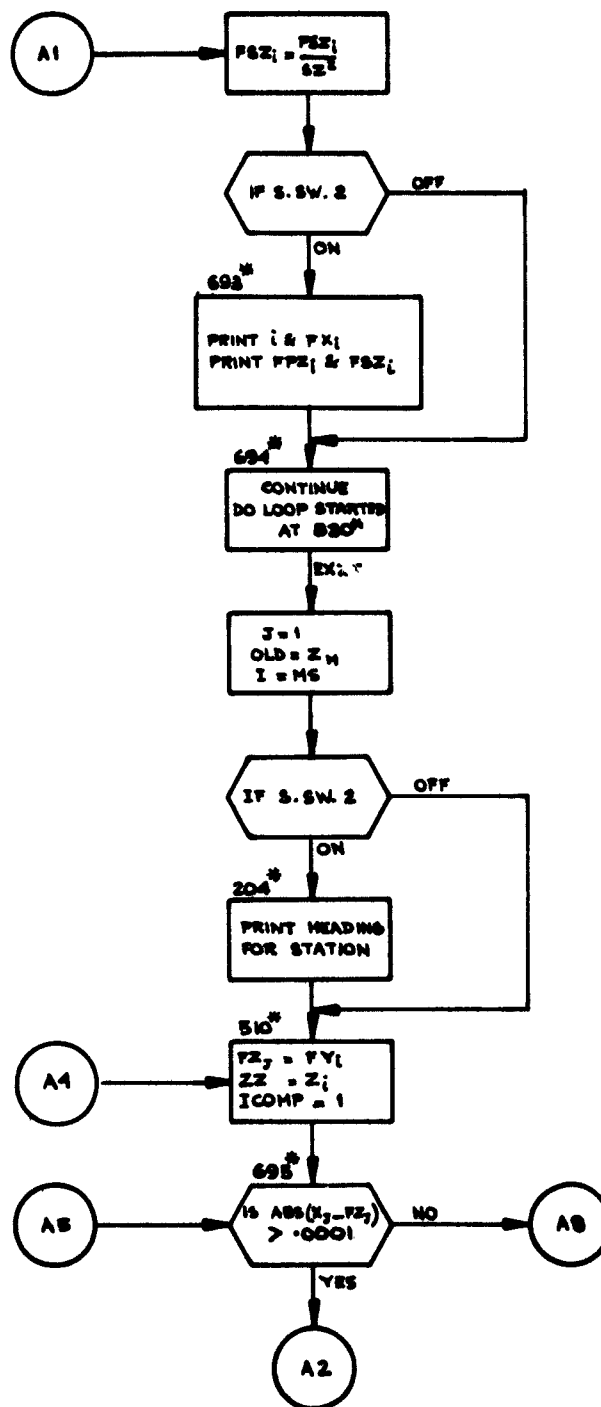
C	15	OFSET	0.00100
C	16	OFSET	0.00100
C	17	OFSET	0.00100
C	18	OFSET	0.00100
C	19	OFSET	0.00100
C	20	OFSET	0.00100
C	21	OFSET	0.00100
C	22	OFSET	0.00100
C	23	OFSET	0.00100
C	24	OFSET	0.00100
C	25	OFSET	0.00100
C	26	OFSET	0.00100
C	27	OFSET	0.00100
C	28	OFSET	0.00100
C	29	OFSET	0.00100
C	30	OFSET	0.00100
C	31	OFSET	0.00100
C	32	OFSET	0.00100
C	33	OFSET	0.00100
C	34	OFSET	0.00100
C	35	OFSET	0.00100
C	36	OFSET	0.00100
C	37	OFSET	0.00100
C	38	OFSET	0.00100
C	39	OFSET	0.00100
C	40	OFSET	0.00100
C	41	OFSET	0.00100
C	42	OFSET	0.00100
C	43	OFSET	0.00100
C	44	OFSET	0.00100
C	45	OFSET	0.00100
C	46	OFSET	0.00100
C	47	OFSET	0.00100
C	48	OFSET	0.00100
C	49	OFSET	0.00100
C	50	OFSET	0.00100

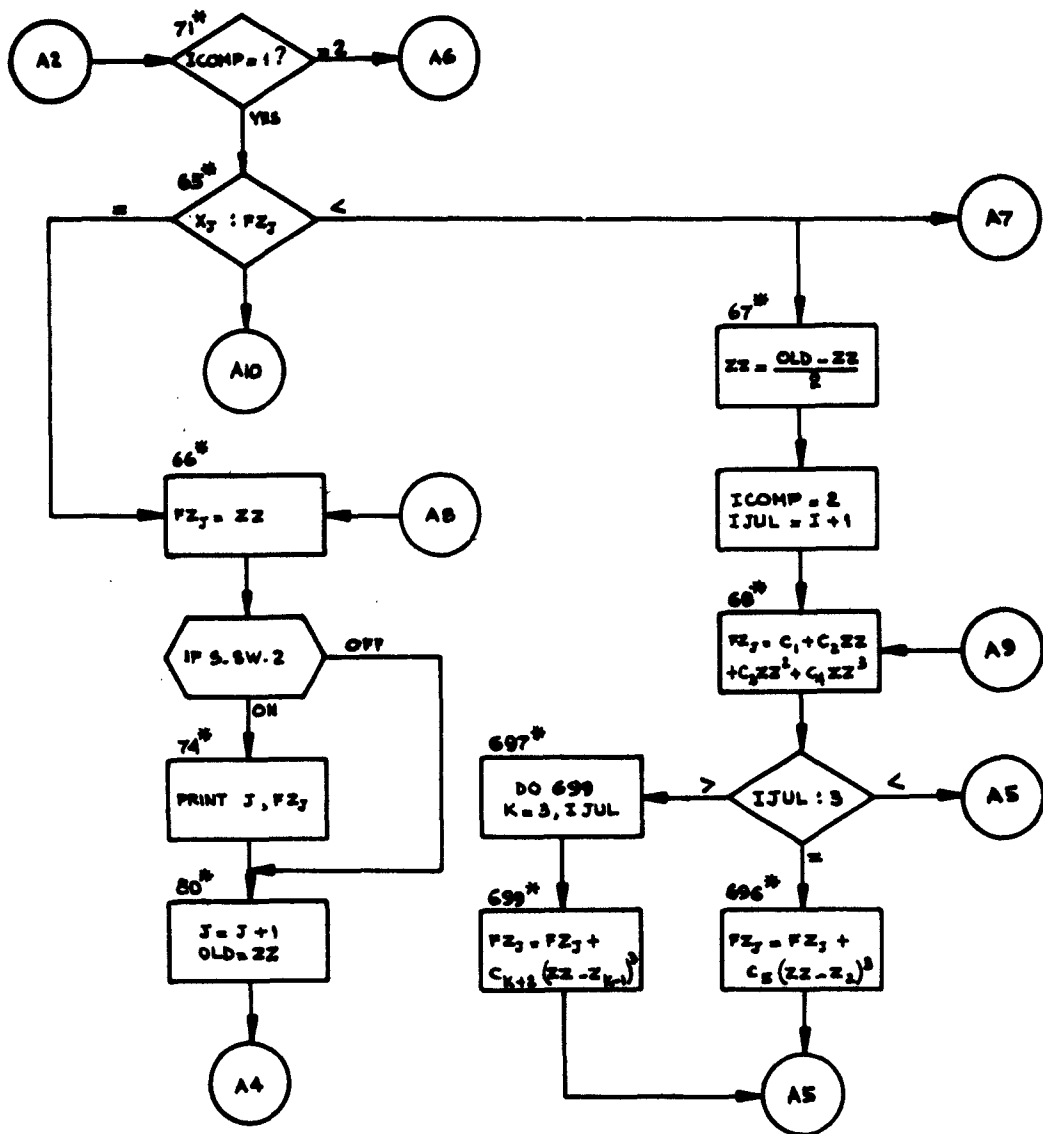
FLOW DIAGRAM - SMOG 3, PASS 1

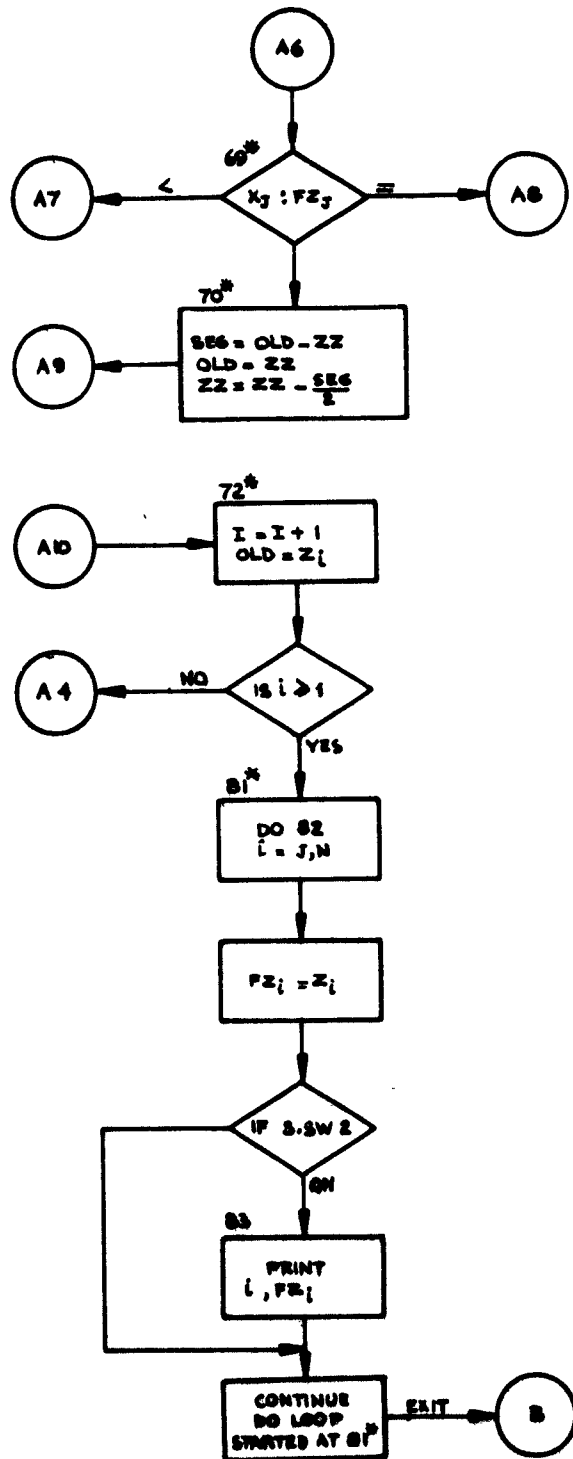
(See SMOG 2, Pass 1 for flow diagrams of the subroutines)

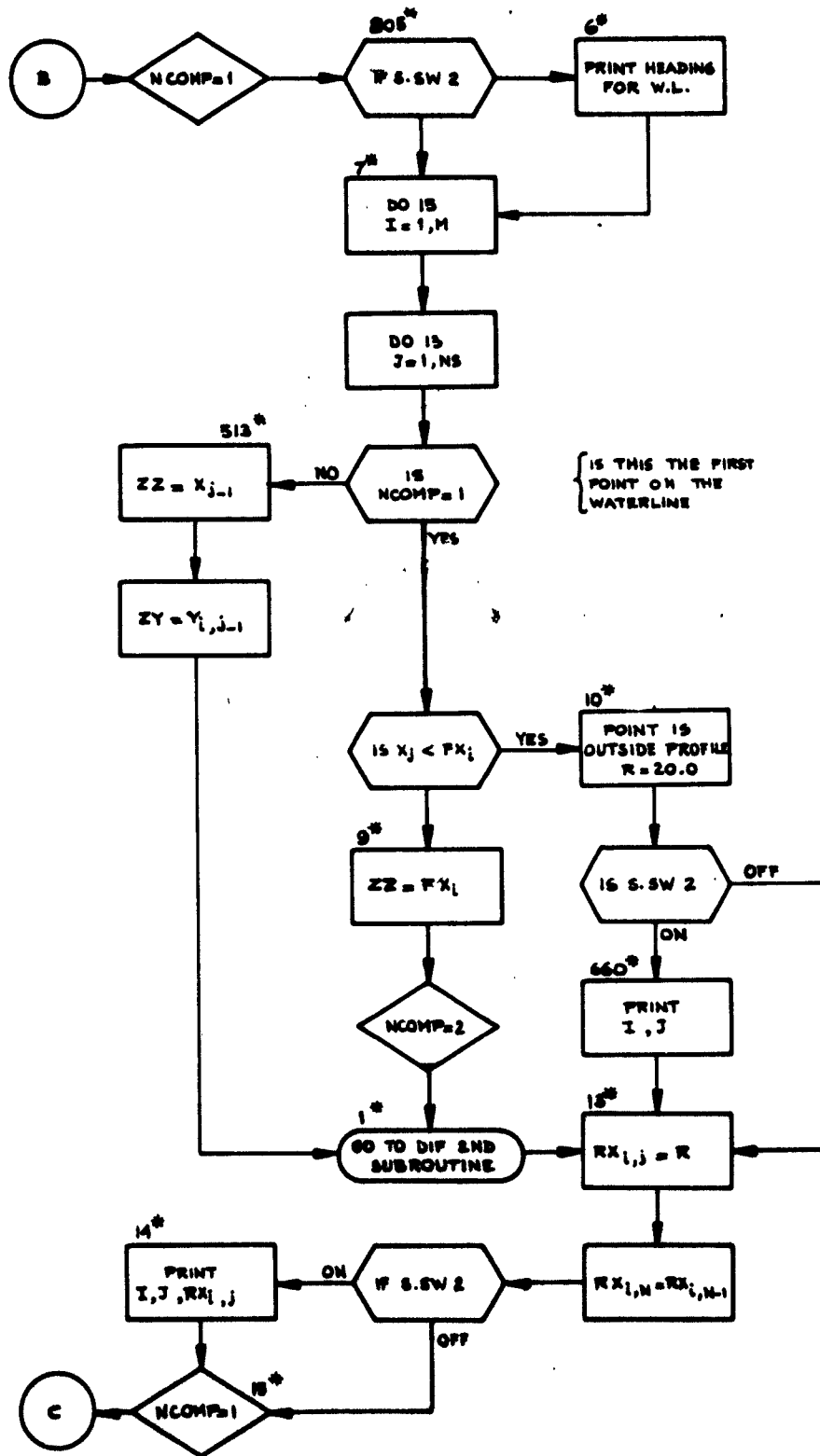


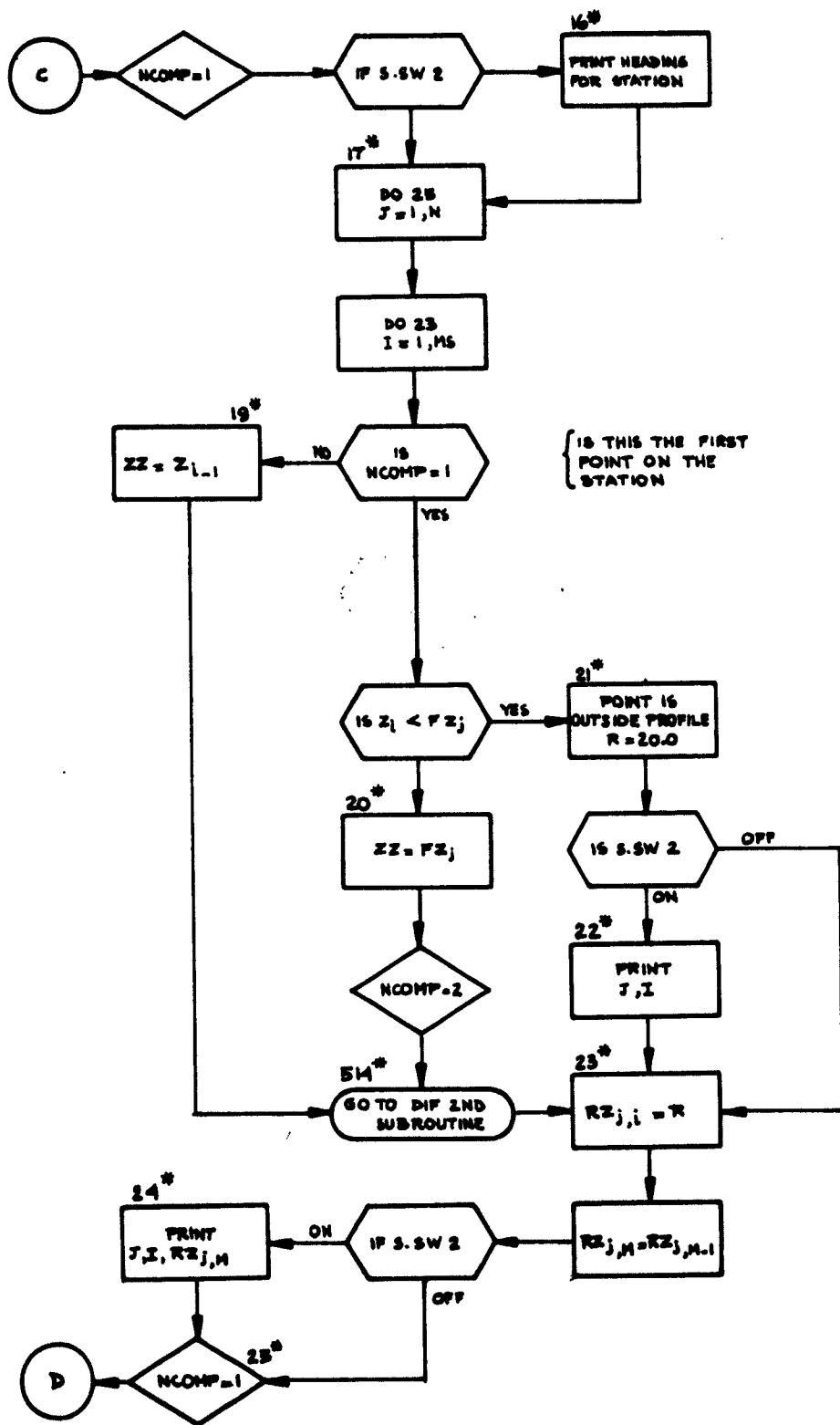


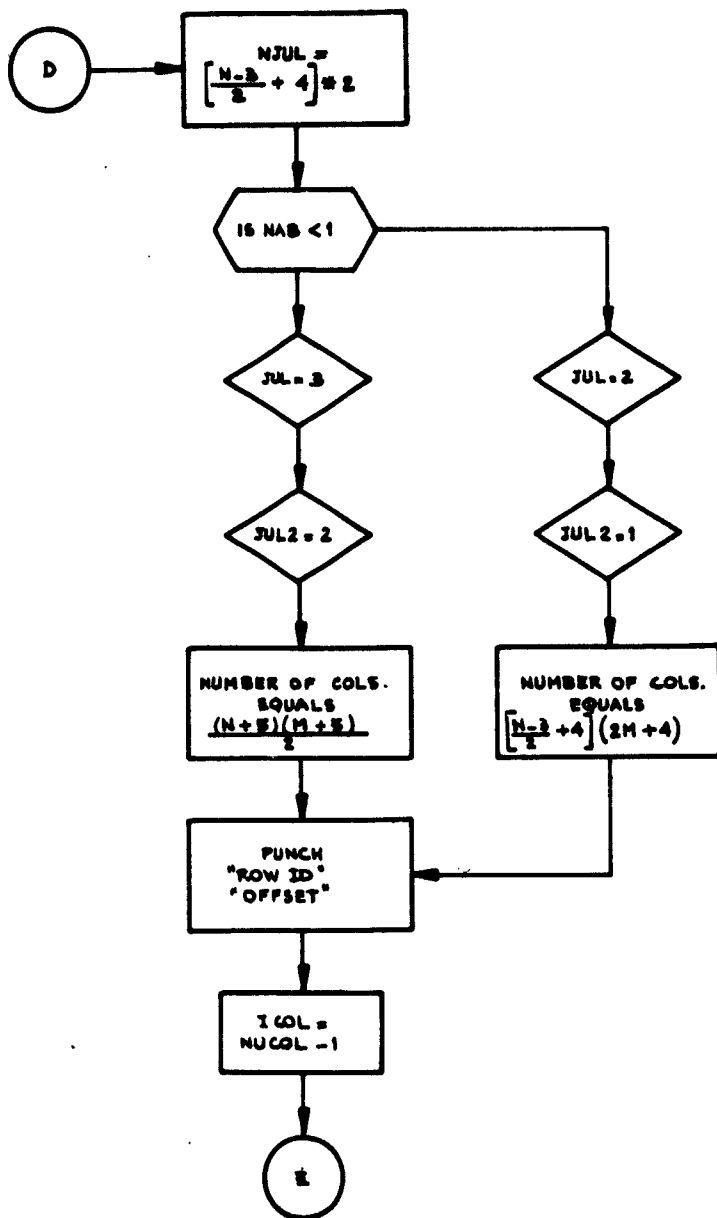


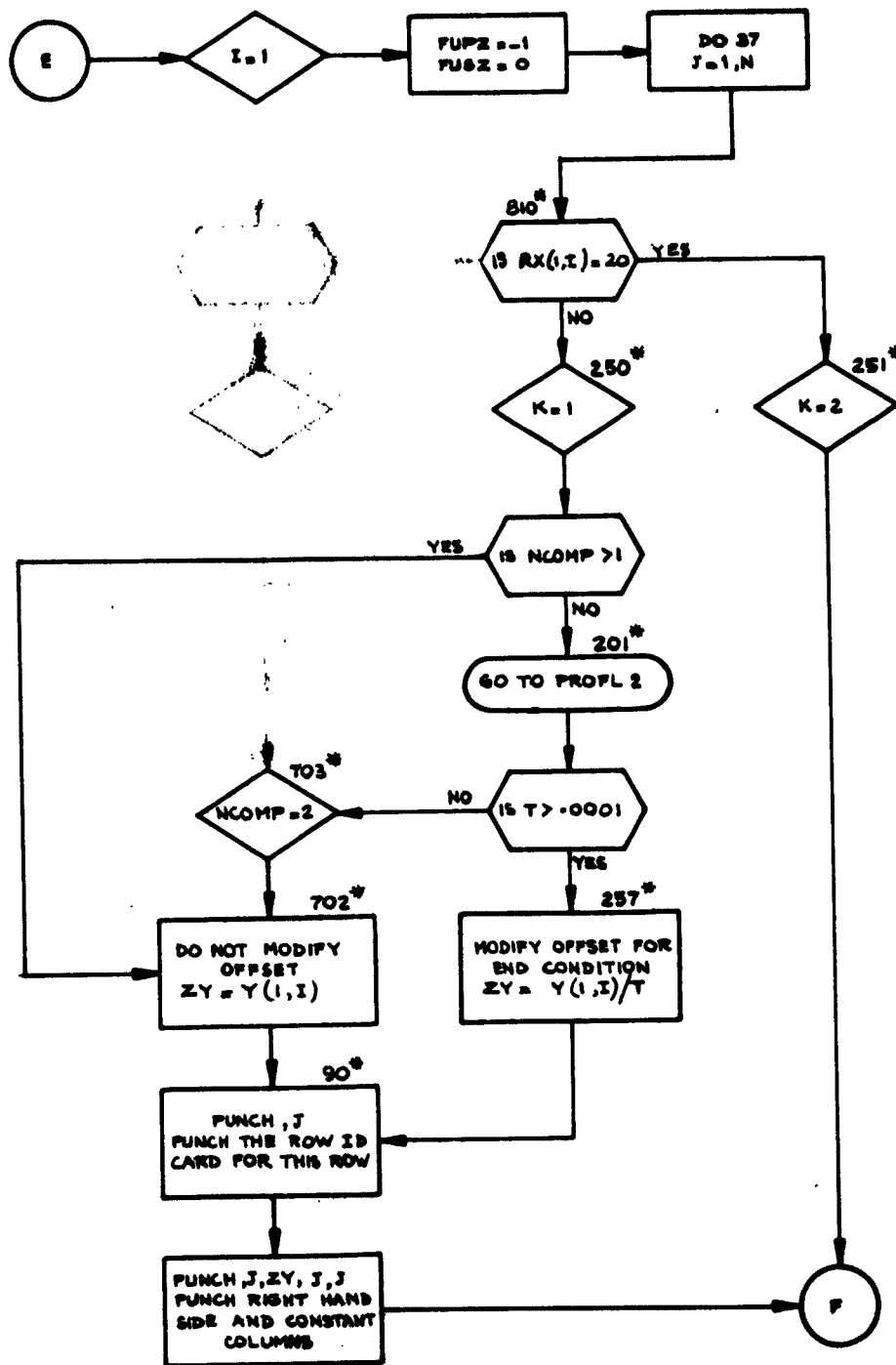




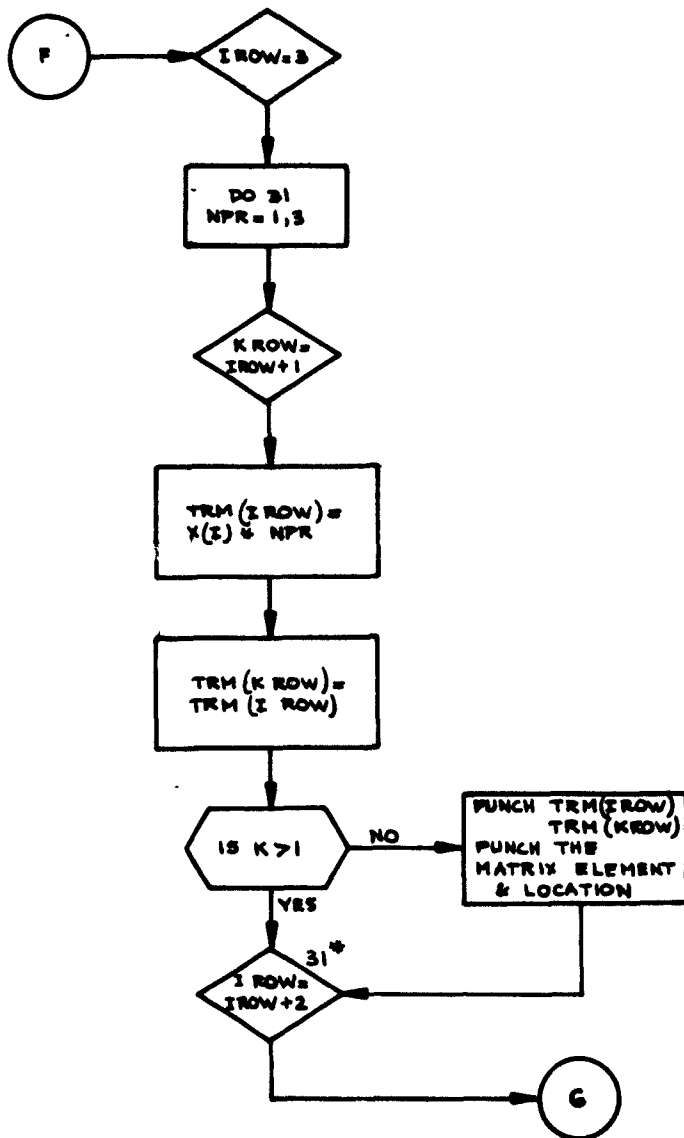


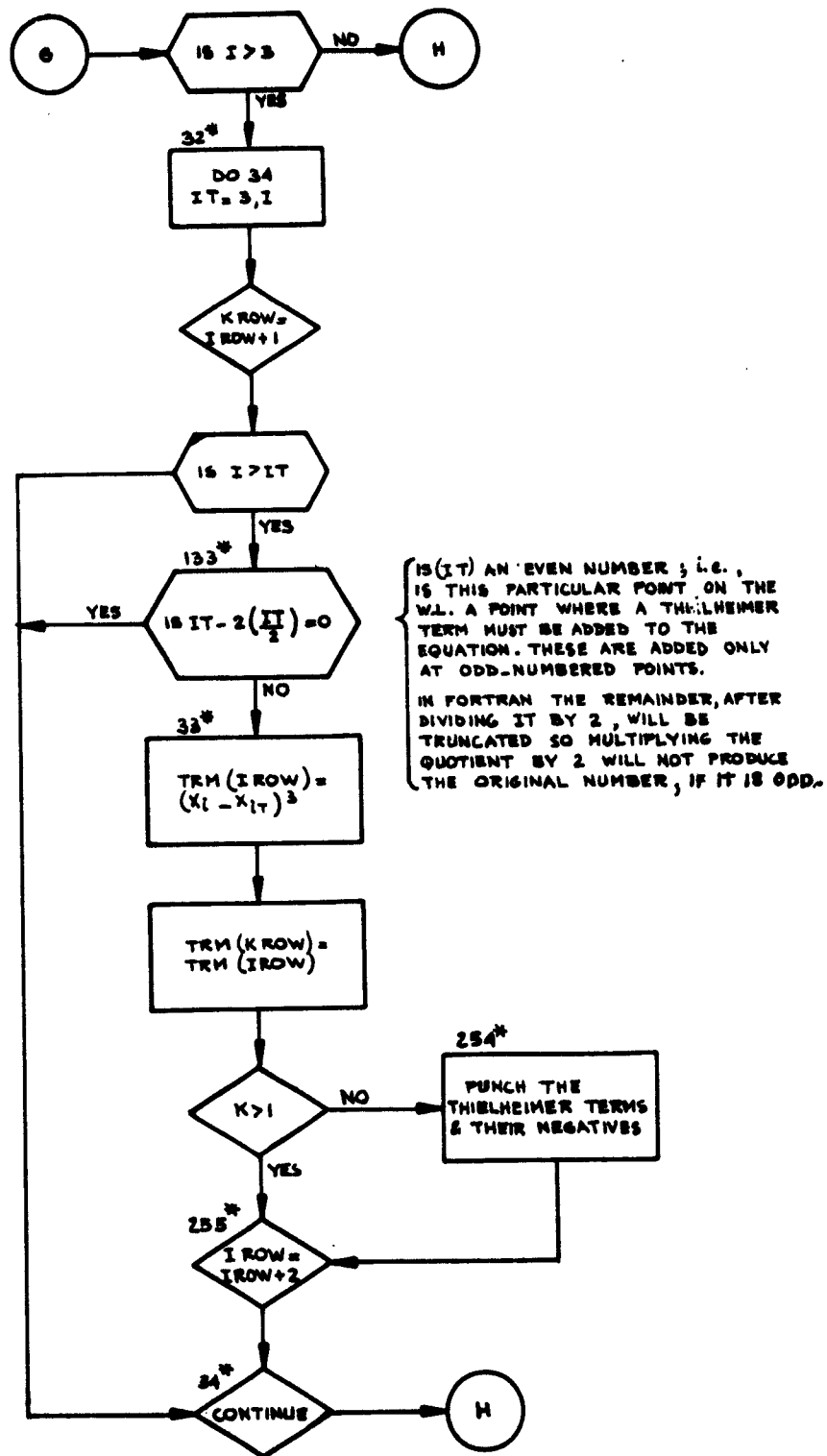


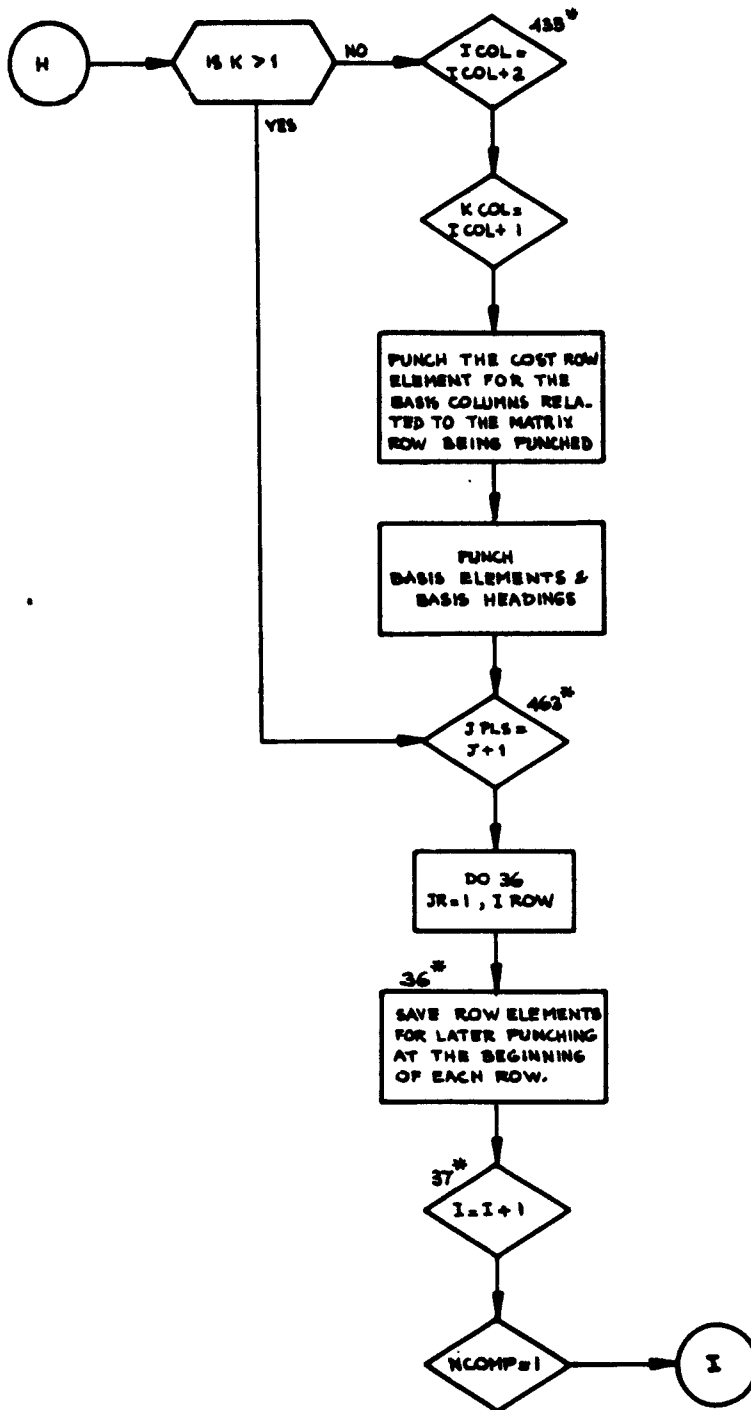


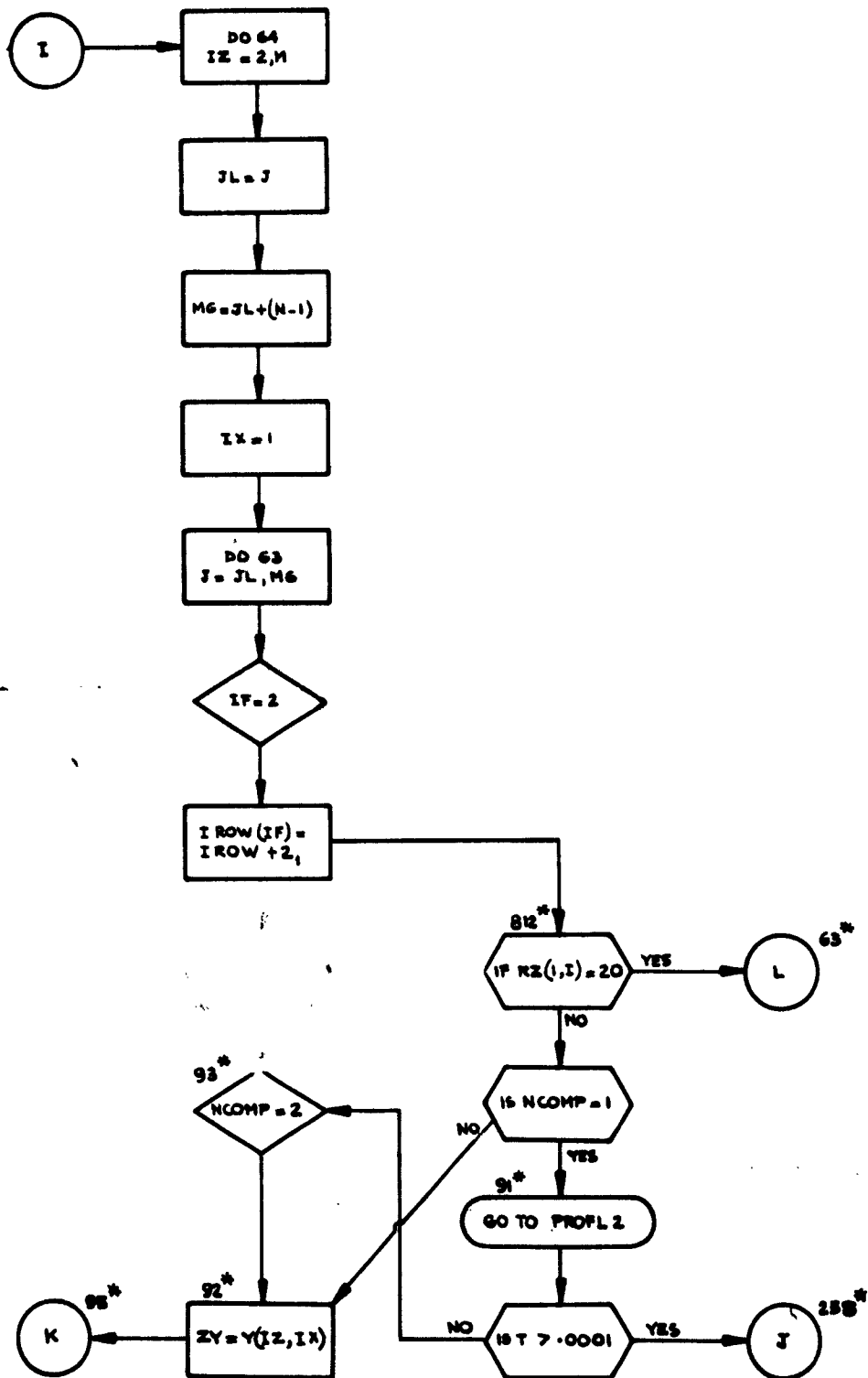


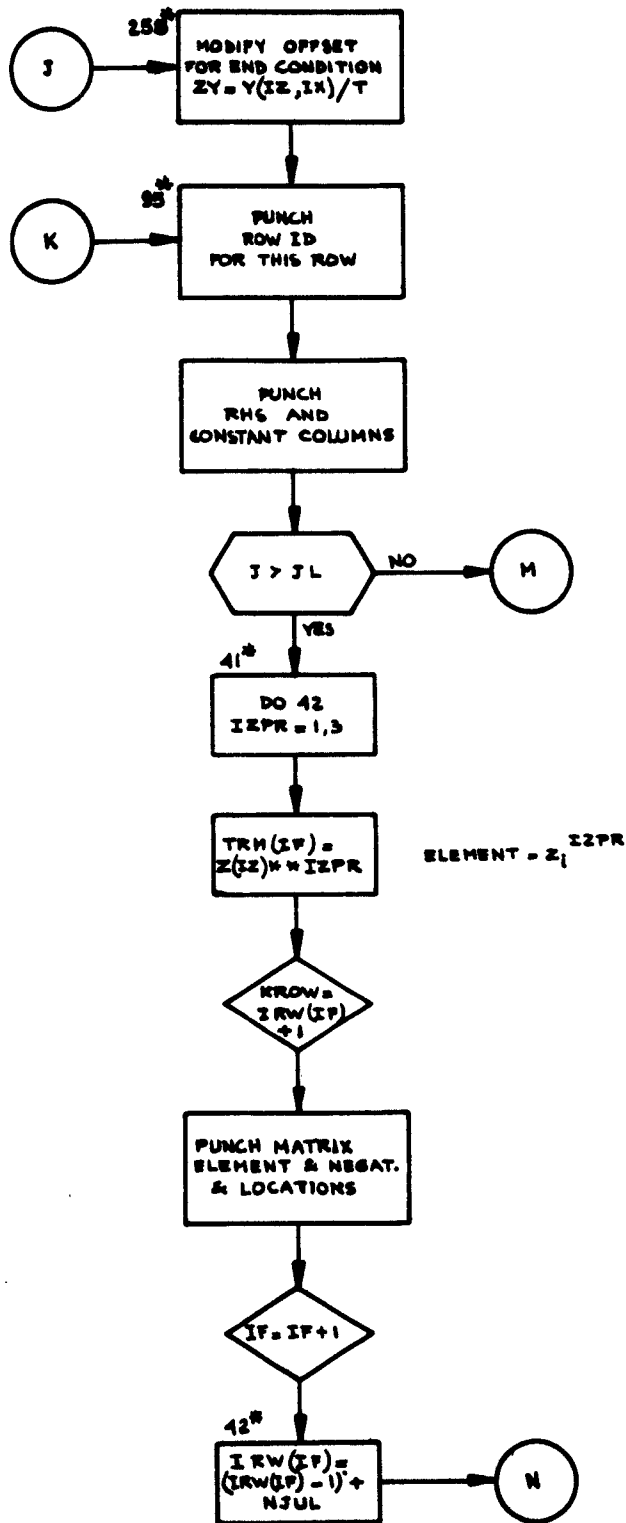
THIS LOOP CALCULATES THE FIRST THREE NON-CONSTANT TERMS OF THE EQUATION & THEIR NEGATIVE COUNTERPARTS FOR EACH POINT ON THE WATERLINE $[x_i, -x_i, x_i^2, -x_i^2, x_i^3, -x_i^3]$.

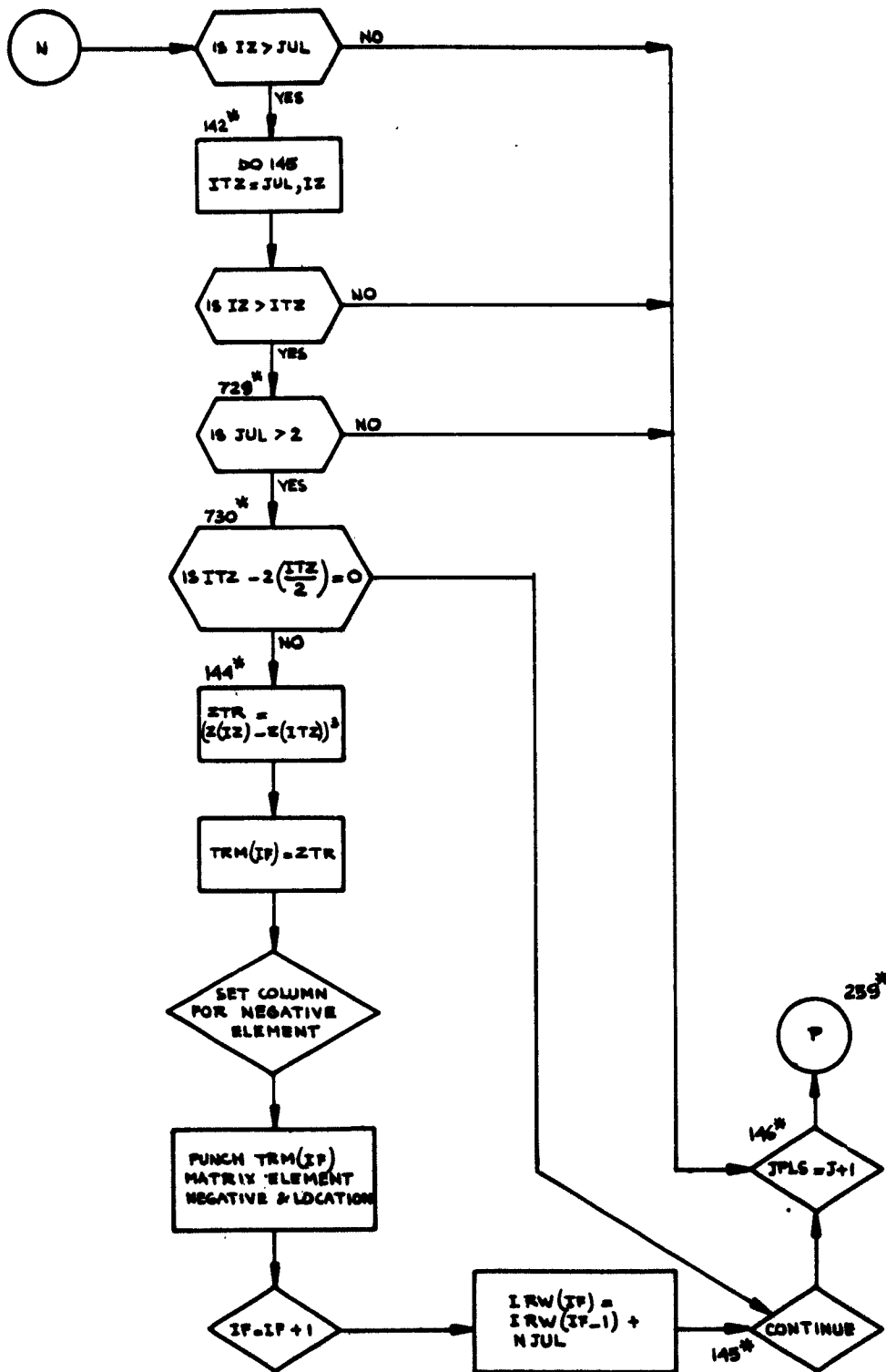


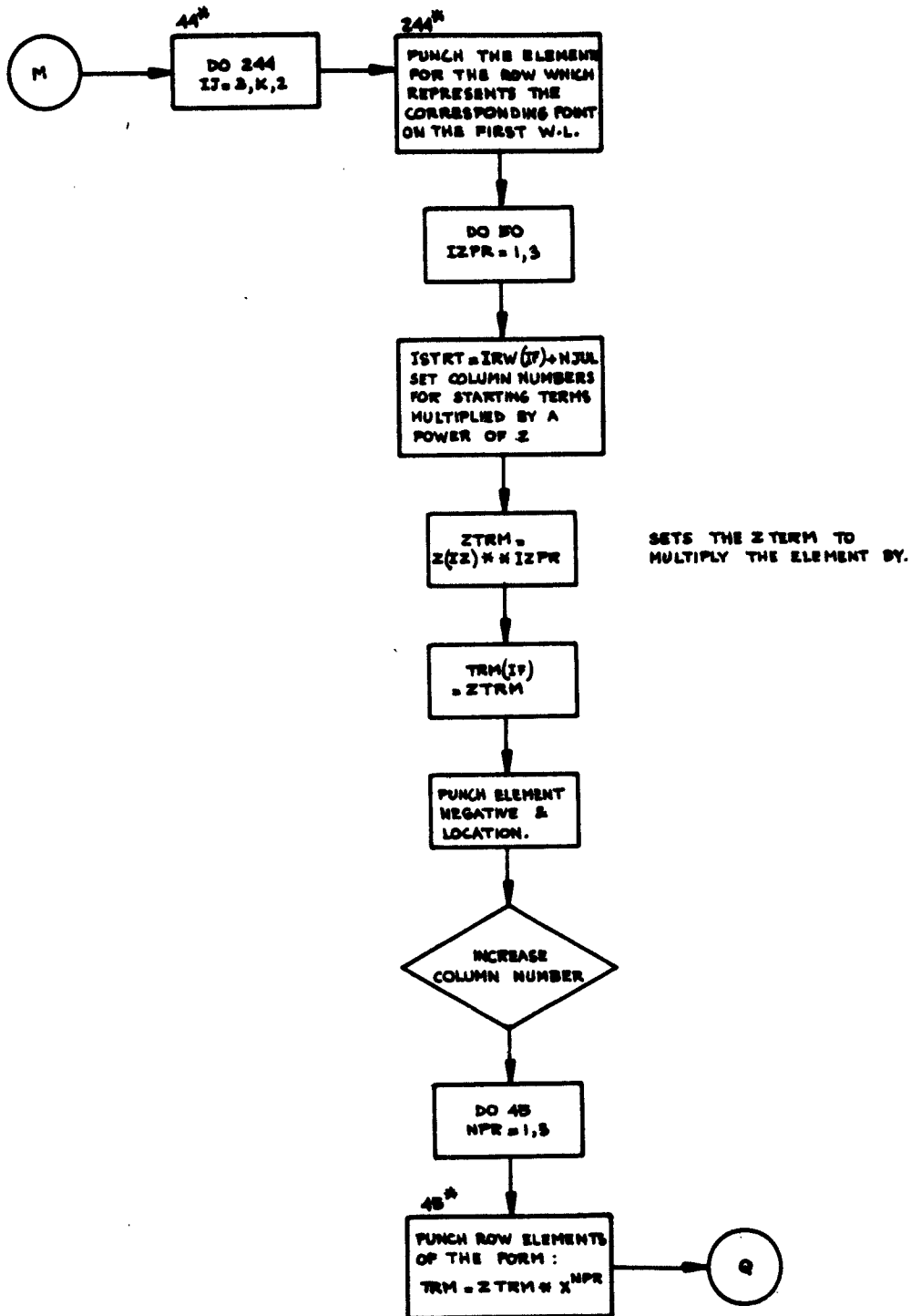


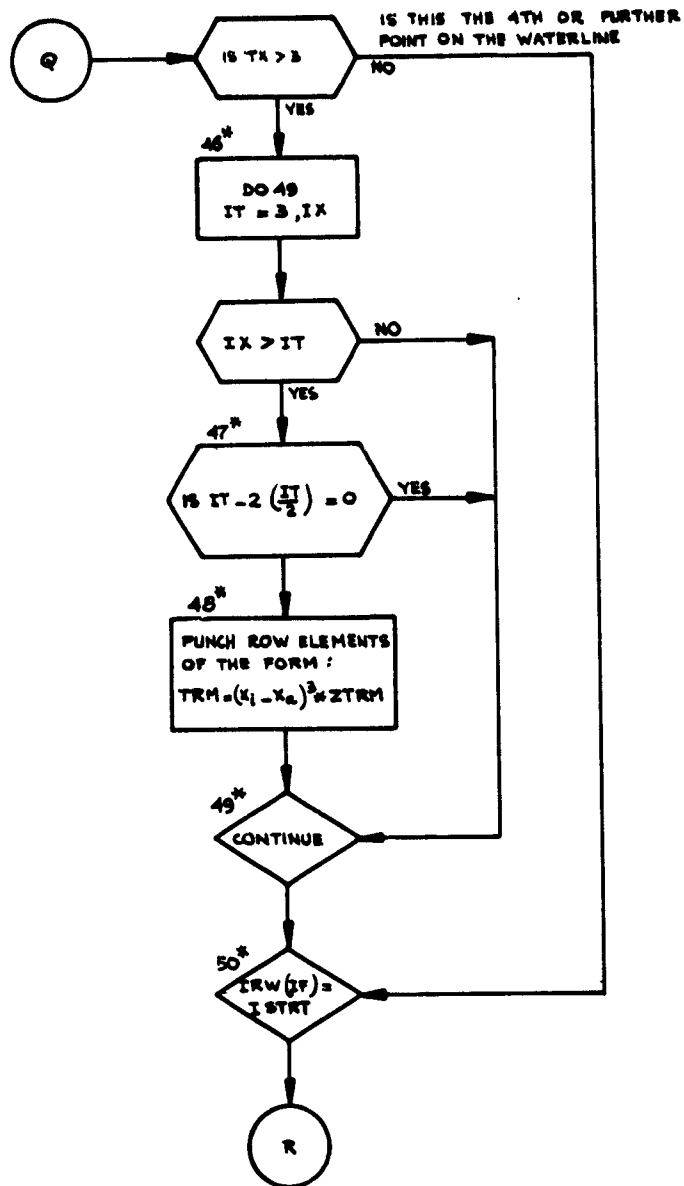


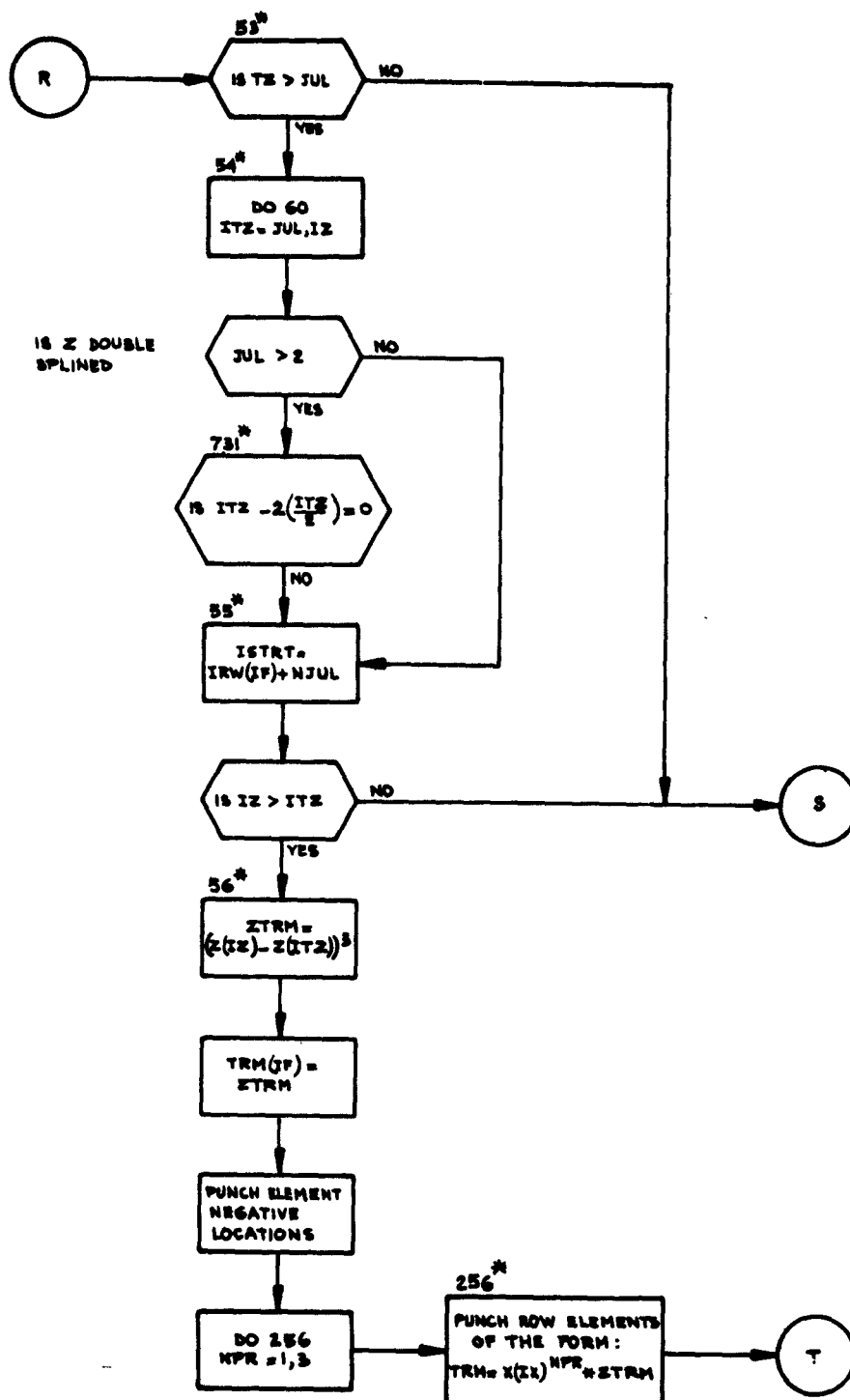


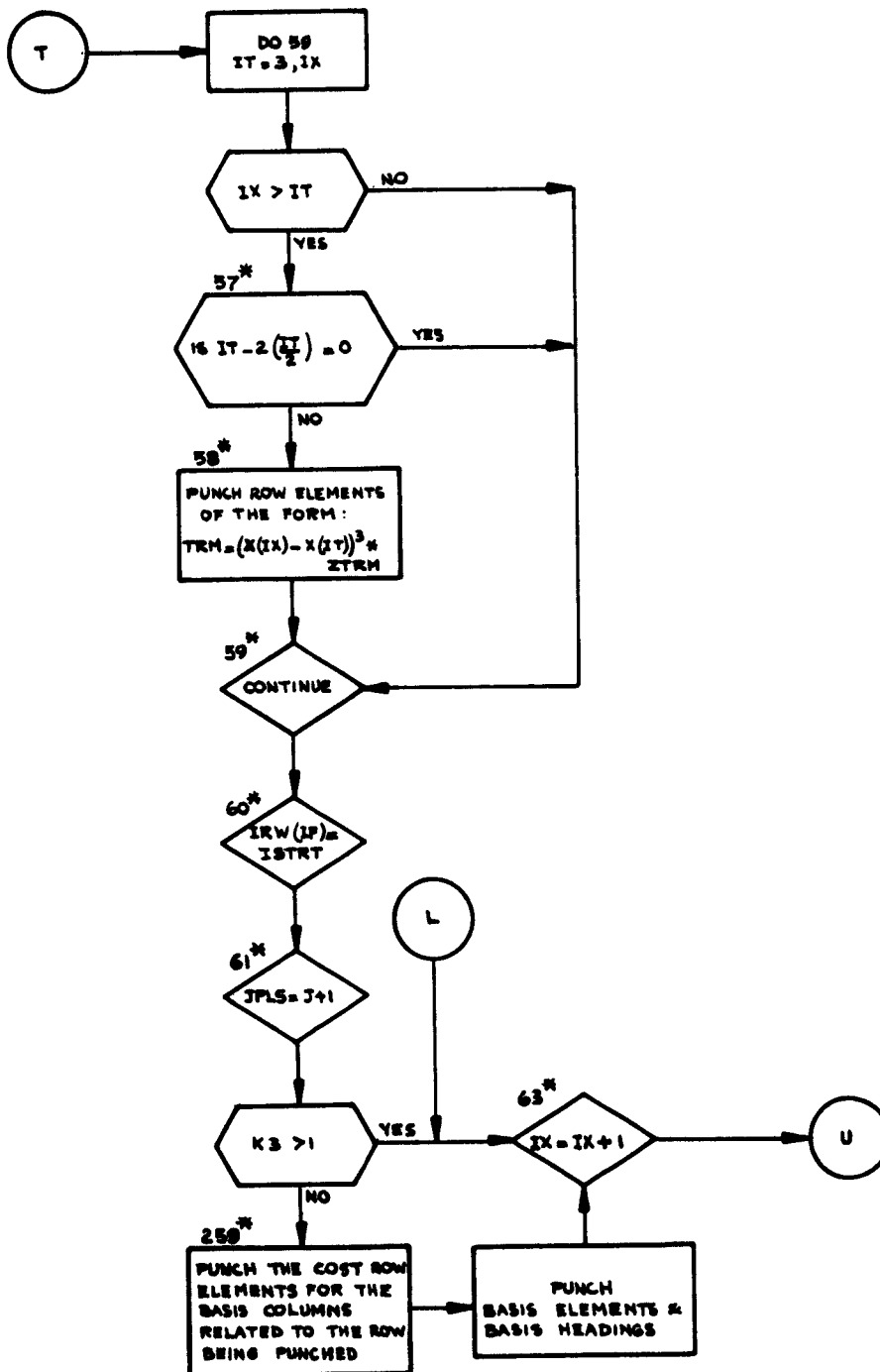


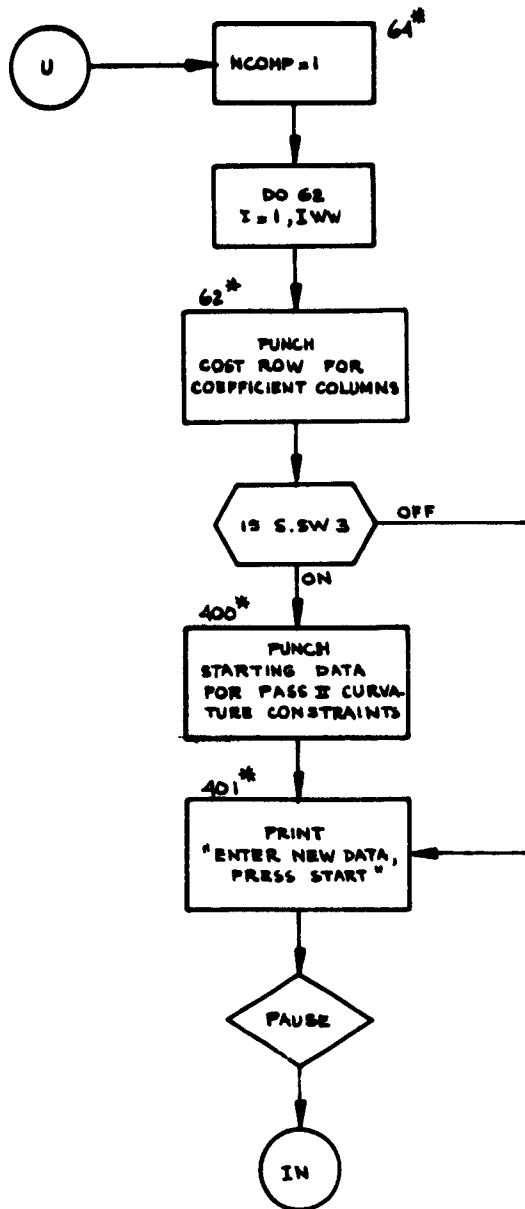












FORTRAN LISTING - SMOG 3, PASS 1

```

C      SMOG3 PASS 1 PRIMAL SUM OF DEV X OR X AND Z DBL SPL WI PRFL
      )      DIMENSION RX(11,15),RZ(15,11),TRM(150), IRW(250),FZ(11),FX(15
      )      DIMENSION X(15),Z(11),Y(11,15),WL(15,11),IWL(15),C(13),FPZ(11
      ),      CFSZ(11)
      COMMON JPLS,JUL,JUL2,NJUL,M,N,MS,NS, NUCOL,NCOMP,CURV,COST
      COMMON EXP2,COST,POINT,EXP1,IWW,ICOL
      COMMON X,FZ,RZ,Z,FX,FPZ,FSZ,RX,C
C      *      *      INPUT      *      *
750 READ 173
      PRINT 173
      READ 150,NAA,NAB,POINT,COST
      READ 150,M,N,CURV,RHS,EXP1,EXP2
      ML=M+2
      DO 751 I=1,ML
751 READ 154,C(I)
      NCOMP=1
      NL=N+1
      ML=M+1
      NS=N-1
      MS=M-1
      DO 2 I=1,M
      READ 154,Z(I)
      DO 2 J=1,N
      IF(SENSE SWITCH 3)802,803
802 READ 183,X(J),IAY,IBY,ICY
      AAY=IAY
      BBY=IBY
      CCY=ICY
      Y(I,J)=AAY+(BBY+(CCY/8.))/12.
      GO TO 2
803 READ 154,X(J),Y(I,J)
      2 CONTINUE
      IF(NAA)3,3,4
      3 READ 154,SX,SZ,TX,TZ
      GO TO 508
      4 SX=X(2)-X(1)
      SZ=Z(2)-Z(1)
      TZ=Z(1)
      TX=X(1)
C      *      *      NORMALIZING      *      *
508 DO 26 J=1,N
      26 X(J)=(X(J)-TX)/SX
      DO 27 I=1,M
      27 Z(I)=(Z(I)-TZ)/SZ

```

```

POINT=(POINT-TX)/SX
C      * * END PROFILE INTERSECTIONS * *
5 IF(SENSE SWITCH 2)509,820
509 PRINT 165
820 DO 694 I=1,M
    FX(I)=C(1)+C(2)*Z(I)+C(3)*Z(I)*Z(I)+C(4)*Z(I)**3
    CALL DERIV1 (C(2),C(3),C(4),Z(I),FPZ(I),FSZ(I))
    IF(I-3)690,691,691
691 DO 700 J=3,I
    DIF=Z(I)-Z(J-1)
    FX(I)=FX(I)+C(J+2)*DIF**3
    CALL DERIV2 (C(J+2),DIF,FPZ(I),FSZ(I),FPZ(I),FSZ(I))
    IF(I-3)690,690,700
700 CONTINUE
690 FPZ(I)=FPZ(I)/SZ
    FSZ(I)=FSZ(I)/(SZ*SZ)
    IF(SENSE SWITCH 2)693,694
693 PRINT 170,I,FX(I)
    PRINT 154,FPZ(I),FSZ(I)
694 CONTINUE
    J=1
    OLD =Z(M)
    I=MS
    IF(SENSE SWITCH 2)204,510
204 PRINT 179
510 FZ(J)=FX(I)
    ZZ=Z(I)
    ICOMP=1
695 IF(ABS(FX(J)-FZ(J))-0.0001) 66,66,71
71 GO TO (65,69),ICOMP
65 IF(X(J)-FZ(J)) 67,66,72
66 FZ(J)=ZZ
    IF(SENSE SWITCH 2) 74,80
74 PRINT 170,J,FZ(J)
80 J=J+1
    OLD=ZZ
    GO TO 510
67 ZZ=ZZ+(OLD-ZZ)/2.
    ICOMP=2
    IJUL=I+1
68 FZ(J)=C(1)+C(2)*ZZ+C(3)*ZZ*ZZ+C(4)*ZZ**3
    IF(IJUL-3) 695,696,697
696 FZ(J)=FZ(J)+C(5)*(ZZ-Z(2))**3
    GO TO 695
697 DO 699 K=3,IJUL

```

```

699 FZ(J)=FZ(J)+C(K+2)*(ZZ-Z(K-1))**3
    GO TO 695
69 IF(X(J)-FZ(J)) 67,66,70
70 SEG=OLD-ZZ
    OLD=ZZ
    ZZ=ZZ-SEG/2.
    GO TO 68
72 OLD=Z(I)
    I=I-1
    IF(I-1)81,510,510
81 DO 82 I=J,N
    FZ(I)=Z(I)
    IF(SENSE SWITCH 2)83,82
83 PRINT 170,I,FZ(I)
82 CONTINUE
C      *      *      WATERLINE  2ND  DIFFERENCES      *      *
805 IF(SENSE SWITCH 2)6,7
6 PRINT 157
7 DO 15 I=1,M
    DO 13 J=1,NS
    GO TO (8,513),NCOMP
8 ZY=0.
    IF(X(J)-FX(I))10,10,9
10 R=20.
    IF(SENSE SWITCH 2)660,13
660 PRINT 151,I,J
    GO TO 13
9 ZZ=FX(I)
    NCOMP=2
    GO TO 1
513 ZZ=X(J-1)
    ZY=Y(I,J-1)
1 CALL DIF2ND (X(J),X(J+1),ZZ,Y(I,J),Y(I,J+1),ZY,I,J,R,A)
13 RX(I,J)=R
    RX(I,N)=RX(I,NS)
    IF(SENSE SWITCH 2)14,15
14 PRINT 158,I,J,A,RX(I,N)
15 NCOMP=1
C      *      *      STATION  2ND  DIFFERENCES      *      *
    IF(SENSE SWITCH 2)16,17
16 PRINT 159
17 DO 25 J=1,N
    DO 23 I=2,NS
    GO TO (18,19),NCOMP
18 IF(Z(I)-FZ(J))21,21,20

```

```

21 R=20.
   IF(SENSE SWITCH 2)22,23
22 PRINT 151,J,I
   GO TO 23
20 ZZ=FZ(J)
   NCOMP=2
   GO TO 514
19 ZZ=Z(I-1)
514 CALL DIF2ND (Z(I),Z(I+1),ZZ,Y(I,J),Y(I+1,J),Y(I-1,J),J,I,R,A)
23 RZ(J,I)=R
   RZ(J,M)=RZ(J,MS)
   IF(SENSE SWITCH 2)24,25
24 PRINT 158,J,I,A,RZ(J,M)
25 NCOMP=1
C      *      *      ROW ID      *      *
   PUNCH 173
   NJUL=(((N-3)/2)+4)*2
   NM=N
   IF(NAB)719,718,718
719 JUL=3
   JUL2=2
   NUCOL=((N+5)*(M+5))/2
   GO TO 720
718 JUL=2
   JUL2=1
   NUCOL=2*(M+2)*(((N-3)/2)+4)
720 PUNCH 160
   ICOL=NUCOL-1
C      *      *      MATRIX      *      *
   PUNCH 164
C      *      *      FIRST WATERLINE      *
*
   MLG=NM
   I=1
   FUPZ=-1.
   FUSZ=0.
   DO 37 J=1,MLG
810 IF(RX(I,I)-20.)250,251,250
251 K=2
   GO TO 252
250 K=1
200 GO TO (201,702),NCOMP
201 CALL PROFL2(X(I),FX(I),EXP1,FUPZ,FUSZ,EXP2,POINT,T,TP,TS
,NCOMP)

```

```

      IF(T=.0001) 703, 703, 257
257  ZY=Y(1,1)/T
      GO TO 90
703  NCOMP=2
702  ZY=Y(1,1)
90   PUNCH 162,J
      PUNCH 177,J,ZY,J,J
252  IROW=3
      DO 31 NPR=1,3
      KROW=IROW+1
      TRM(IROW)=X(1)**NPR
      TRM(KROW)=TRM(IROW)
      GO TO (253,31),K
253  PUNCH 167,IROW,J,TRM(IROW),KROW,J,TRM(IROW)
31   IROW=IROW+2
      IF(1-3)35,35,32
32   DO 34 IT=3,1
      KROW=IROW+1
      IF(1-IT)34,34,133
133  IF(IT-2*(IT/2))33,34,33
33   TRM(IROW)=(X(1)-X(IT))**3
      TRM(KROW)=TRM(IROW)
      GO TO (254,255),K
254  PUNCH 167,IROW,J,TRM(IROW),KROW,J,TRM(IROW)
255  IROW=IROW+2
34   CONTINUE
35   GO TO(435,463),K
435  ICOL=ICOL+2
      KCOL=ICOL+1
      PUNCH 171,ICOL,RHS,KCOL,RHS
      PUNCH 152,ICOL,J,KCOL,J,ICOL,J
463  JPLS=J+1
      IROW=IROW-1
      IWL(1)=IROW
      DO 36 JR=3,IROW
36   WL(1,JR)=TRM(JR)
37   I=I+1
      NCOMP=1
      K3=1
C      *      *      REMAINING WL      *      *
      DO 64 IZ=2,M
      JL=J
      MG=JL+NM-1
      IX=1
      DO 63 J=JL,MG

```

```

      IF=2
      IRW(IF)=IROW+1
812 IF(RX(IZ,IX)-20.)202, 63,202
202 GO TO (91,92),NCOMP
      91 CALL PROFL2(X(IX),FX(IZ),EXP1,FUPZ,FUSZ,EXP2,POINT,T,TP,TS
,NCOMP)
      IF(T-.0001)93,93,258
258 ZY=Y(IZ,IX)/T
      GO TO 95
      93 NCOMP=2
      92 ZY=Y(IZ,IX)
      95 PUNCH 162,J
      PUNCH 177,J,ZY,J,J
708 IF(J-JL)41,41,44
      41 DO 42 IZPR=1,3
      TRM(IF)=Z(IZ)**IZPR
      KROW=IRW(IF)+1
      PUNCH 167,IRW(IF),J,TRM(IF),KROW,J,TRM(IF)
      IF=IF+1
      42 IRW(IF)=IRW(IF-1)+NJUL
      IF(IZ-JUL)146,146,142
142 DO 145 ITZ=JUL,IZ
      IF(IZ-ITZ)146,146,729
729 GO TO (144,144,730),JUL
730 IF(ITZ-2*(ITZ/2))144,145,144
144 ZTR=(Z(IZ)-Z(ITZ))**3
      TRM(IF)=ZTR
      KROW=IRW(IF)+1
      PUNCH 167,IRW(IF),J,TRM(IF),KROW,J,TRM(IF)
      IF=IF+1
      IRW(IF)=IRW(IF-1)+NJUL
145 CONTINUE
146 JPLS=J+1
      GO TO 259
C      * * Z , Z SQR , Z CUBE ROWS * *
      44 IRO=1
      K=IWL(IX)
      DO 244 IJ=3,K,2
      IRO=IRO+2
      KROW=IRO+1
244 PUNCH 167,IRO,J,WL(IX,IJ),KROW,J,WL(IX,IJ)
      DO 50 IZPR=1,3
      ISTRT=IRW(IF)+NJUL
      ZTRM=Z(IZ)**IZPR
      TRM(IF)=ZTRM

```

```

KROW=IRW(IF)+1
PUNCH 167,IRW(IF),J,TRM(IF),KROW,J,TRM(IF)
IF=IF+1
IRW(IF)=IRW(IF-1)+2
DO 45 NPR=1,3
TRM(IF)=(X(IX)**NPR)*ZTRM
KROW=IRW(IF)+1
PUNCH 167,IRW(IF),J,TRM(IF),KROW,J,TRM(IF)
IF=IF+1
45 IRW(IF)=IRW(IF-1)+2
IF(IX-3)50,50,46
46 DO 49 IT=3,IX
IF(IX-IT)49,49,47
47 IF(IT-2*(IT/2))48,49,48
48 TRM(IF)=((X(IX)-X(IT))**3)*ZTRM
KROW=IRW(IF)+1
PUNCH 167,IRW(IF),J,TRM(IF),KROW,J,TRM(IF)
IF=IF+1
IRW(IF)=IRW(IF-1)+2
49 CONTINUE
50 IRW(IF)=ISTR
C      *      *      THEILHEIMER ROWS      *      *
53 IF(IZ-JUL)61,61,54
54 DO 60 ITZ=JUL,IZ
GO TO (55,55,731),JUL
731 IF(ITZ-2*(ITZ/2))55,60,55
55 ISTR=IRW(IF)+NJUL
IF(IZ-ITZ)61,61,56
56 ZTRM=(Z(IZ)-Z(ITZ))**3
TRM(IF)=ZTRM
KROW=IRW(IF)+1
PUNCH 167,IRW(IF),J,TRM(IF),KROW,J,TRM(IF)
IF=IF+1
IRW(IF)=IRW(IF-1)+2
DO 256 NPR=1,3
TRM(IF)=(X(IX)**NPR)*ZTRM
KROW=IRW(IF)+1
PUNCH 167,IRW(IF),J,TRM(IF),KROW,J,TRM(IF)
IF=IF+1
256 IRW(IF)=IRW(IF-1)+2
DO 59 IT=3,IX
IF(IX-IT)59,59,57
57 IF(IT-2*(IT/2))58,59,58
58 TRM(IF)=((X(IX)-X(IT))**3)*ZTRM
KROW=IRW(IF)+1
PUNCH 167,IRW(IF),J,TRM(IF),KROW,J,TRM(IF)

```



```

      IF=IF+1
      IRW(IF)=IRW(IF-1)+2
59  CONTINUE
      IWW=KROW
60  IRW(IF)=ISTRT
61  JPLS=J+1
      GO TO (259,63),K3
259  ICOL=ICOL+2
      KCOL=ICOL+1
      PUNCH 171,ICOL,RHS,KCOL,RHS
      PUNCH 152,ICOL,J,KCOL,J,ICOL,J
63  IX=IX+1
64  NCOMP=1
      DO 62 I=1,IWW
62  PUNCH 171,I,CURV
      IF(SENSE SWITCH 3)400,401
400  CONTINUE
      PUNCH 180,JPLS,JUL,JUL2,NJUL,M,N,MS,NS,NUCOL,NCOMP,COST,COST
      PUNCH 181,EXP2,COST,POINT,EXP1,IWW,ICOL
      DO 87 I=1,N
      PUNCH 181,X(I),FZ(I)
      DO 87 J=2,M
87  PUNCH 181,RZ(I,J)
      DO 88 I=1,M
      PUNCH 181,Z(I),FX(I),FPZ(I),FSZ(I)
      DO 88 J=1,N
88  PUNCH 181,RX(I,J)
      ML=M+2
      DO 100 J=1,ML
100  PUNCH 181,C(J)
401  PRINT 178
      PAUSE 751
      GO TO 750
150  FORMAT(2I5,4F11.6)
151  FORMAT(2I5,17H OUT OF SURFACE)
152  FORMAT(7X,1HC,14,2H R,14,8H 1.0/7X,1HC,14,2H R,14,8H-
1.0/
      C 7X,1HC,14,2H R,14)
154  FORMAT(4F10.4)
157  FORMAT(//10X,17H2ND DIFF - W/LINES//
      C30H WL STA NORM VALUE SIGN/)
158  FORMAT(2I5,F12.6,F8.2)
159  FORMAT(//10X,17H2ND DIFF-STATIONS//
      C30H STA WL NORM VALUE SIGN/)
160  FORMAT(6HROW ID/12X,6H OFFSET)

```

```

162 FORMAT(12X,2H R,14)
164 FORMAT(6HMATRIX)
165 FORMAT(//6X,25HEND PROFILE INTERSECTIONS//15X,6HMLINES/)
167 FORMAT(6X,2H C,14,2H R,14,1H-,F11.5/6X,2H C,14,2H R,14,F12.5)
169 FORMAT(6X,2H C,14,2H R,14,F12.5)
170 FORMAT(5X,15,F12.6)
171 FORMAT(6X,2H C,14,6H OFFSET,1H ,F11.5)
172 FORMAT(215)
173 FORMAT(1H*,5X,47H
)
177 FORMAT(12X,2H R,14,1H ,F11.5/7X,6HC 1 ,1HR,14,1H-,4X,3H1.0/
C 7X,6HC 2 ,1HR,14,5X,3H1.0)
178 FORMAT(28HENTER NEW DATA - PRESS START)
179 FORMAT (/14X,8HSTATIONS/)
180 FORMAT (1015;2F15.9)
181 FORMAT (4F15.9,14,14)
182 FORMAT(6X,2H C,14,6H OFFSET,1H ,F11.5/6X,2H C,14,6H OFFSET,1H F
11.5)
183 FORMAT(F10.5,315)
END

```

Note: See SMOG 2, PASS 1 for listings of the subroutines

SMOG 3 PASS 2

OPERATING INSTRUCTIONS

Pass 2 of the program accepts the data punched in Pass 1. It produces the curvature constraints for the matrix.

Fortran Input Symbols

JPLS	-	The number of the last column produced in Pass 1.
JUL	-	Program indicator JUL = 3 if the surface is double splined in the z direction JUL = 2 if the surface is single splined in the z direction This value is equal to the subscript of the first z value of the point of discontinuity.
JUL2	-	Program indicator JUL2 = 2 if the z direction is double splined JUL2 = 1 if the z direction is single splined. This value is equal to the number of waterline intervals between points of discontinuity.
NJUL	-	This value $2(\frac{N-3}{2} + 4)$ is equal to the maximum number of rows necessary to store the x terms, each of which is multiplied by a specific z term
M	-	Total number of waterlines in the surface
MS	-	M-1
N	-	Total number of stations in the surface
NS	-	N-1
NUCOL	-	Total number of columns in the non-slack matrix For z double spline, $NUCOL = \frac{(N+5)(M+5)}{2}$ For z single spline, $NUCOL = 2(M+2)NJUL$
NCOMP	-	Program indicator
COST	-	Becomes equal to curvature. Not used (See RHS and CURV)

EXP1 - The value of p in the profile functions, usually made .3333

EXP2 - The value of r in the profile function, usually made 3.0 .

POINT - The value of D in the profile function. This number is the length of the fraction of the station spacing over which the profile function is effective in terms of the full-scale surface (the value has been translated and normalized exactly like the x values are).

C(I) - Coefficients of the Theilheimer equation describing the profile. There must be $(M+2)$ coefficients. Straight lines or other curves may be used by making all except the desired coefficients zero.

CURV - Is equal to the value of COST in Pass 1. This is the value of the cost on the slacks corresponding to the curvature constraints. Usually equal to zero.

RHS - Equal to the value of COST from Pass 1 . This is the value of the right-hand side for the curvature constraints.

X(J) - Distance along the x axis from the origin of the surface to Station j .

Z(I) - Distance along the z axis from the origin of the surface to Waterline i .

FX(I) - The x coordinate of the intersection of Waterline i with the profile.

FZ(J) - The z coordinate of the intersection of Station j with the profile

FPZ(I) - The first derivative with respect to z of the profile equation at Waterline i .

FSZ(I) - The second derivative with respect to z of the profile equation at Waterline i .

RZ(I,J) - The sign of the second difference of the Station Curve j at Waterline i . This will have the opposite sign from the actual second difference.

KX(I,J) - The sign of the second difference of Waterline Curve i at Station j . This will be the opposite of the actual sign

ICOL - The column number of the first curvature slack.

IWW - Not used in Pass 2 .

Input

The following input formats are listed as a matter of record in case modifications of the data cards are to be made. Normally, this data will be obtained from executing Pass 1 in a form which can be entered directly into Pass 2.

<u>Contents of Card</u>								<u>Card NO.</u>
Format	I5	I5	I5	I5	I5	I5	I5	
Variable	JPLS	JUL	JUL2	NJUL	M	N	MS	NS
Format (Continuation of Card 1)				I5	I5	F15.5	F15.5	1
Variable				NUCOL	NCOMP	RHS	CURV	
Format	F15.9	F15.9	F15.9	F15.9	I4	I4		2
Variable	EXP2	COST	POINT	EXP1	IWW	ICOL		
Format	F15.9	F15.9						
Variable	X(I)	FZ(I)					1st card/set	Next N Sets
Format	F15.9							
Variable	RZ(I,J)						M-1 Cards/Set	
Format	F15.9	F15.9	F15.9	F15.9				
Variable	Z(I)	FX(I)	FPZ(I)	FSZ(I)			1st Card/Set	Next M Sets
Format	F15.9							
Variable	RX(I,J)						N-1 Cards/Set	
Format	F15.9							
Variable	C(J)							Next M+2 Cards

Output

This program produces the curvature constraints in row order with the columns ordered within the rows. It also produces the row identifications, slack cost entries, slack elements, basis headings, and right-hand side entries for these rows. The output must be sorted together with the output from Pass 1 before use.

Sense Switches:

Sense Switch 3 ON - The data punched in Pass 1 is read

Sense Switch 3 OFF- The data is picked up from the common storage locations.

SAMPLE PROBLEM - SMOG 3, PASS 2

* * SAMPLE INPUT * *									
26	3	2	10	5	5	4	4	1	0.00000000
1000.00000000									
.33333333			0.00000000			.07843137		3.00000000	50
91			2.60400380						
0.00000000									
20.00000000									
20.00000000									
1.00000000									
1.00000000									
1.00000000			.90136719						
1.00000000									
-1.00000000									
-1.00000000									
-1.00000000									
2.00000000			0.00000000						
-1.00000000									
-1.00000000									
-1.00000000									
-1.00000000									
3.00000000			0.00000000						
-1.00000000									
-1.00000000									
-1.00000000									
-1.00000000									
4.00000000			0.00000000						
-1.00000000									
-1.00000000									
-1.00000000									
-1.00000000									
0.00000000			1.52935000			-.58730000		0.00000000	
20.00000000									
20.00000000									
1.00000000									
-1.00000000									
-1.00000000									
1.00000000			.94205000			-.58730000		0.00000000	
20.00000000									
1.00000000									
-1.00000000									
-1.00000000									
-1.00000000									
2.00000000			.35475000			-.58730000		0.00000000	
20.00000000									
1.00000000									
-1.00000000									
-1.00000000									
-1.00000000									

3.00000000	-.23255000	-.58730000	0.00000000
1.00000000			
-1.00000000			
-1.00000000			
-1.00000000			
-1.00000000			
4.00000000	-.81985000	-.58730000	0.00000000
-1.00000000			
-1.00000000			
-1.00000000			
-1.00000000			
-1.00000000			
1.52935000			
-.58730000			
0.00000000			
0.00000000			
0.00000000			
0.00000000			
0.00000000			

* * SAMPLE OUTPUT * *

R	27	0.00000
R	27	1.00000
5 R	27-	1.00000
6 R	27-	6.00000
7 R	27-	6.00000
8 R	27	000.00000
93	OFFSET	
C	93 R	27
C	93 R	27
C	93 R	28
R	28	0.00000
R	28	1.00000
5 R	28-	1.00000
6 R	28-	12.00000
7 R	28	12.00000
8 R	28-	6.00000
9 R	28	6.00000
10 R	28-	000.00000
94	OFFSET	
C	94 R	28
C	94 R	28
C	94 R	30
R	30	0.00000
R	30	1.00000
5 R	30-	1.00000
6 R	30-	6.00000
7 R	30	6.00000
8 R	30-	1.00000
15 R	30	1.00000
16 R	30-	6.00000
17 R	30	6.00000
18 R	30-	1.00000
25 R	30	1.00000
26 R	30-	1.00000
27 R	30	6.00000
28 R	30-	6.00000
35 R	30	1.00000
36 R	30-	1.00000
37 R	30	6.00000
38 R	30-	6.00000
95	OFFSET	
C	95 R	30

1.0.0-2

C	95	R	30	1.0
		R	31	0.00000
C	5	R	31	1.00000
C	6	R	31-	1.00000
C	7	R	31	12.00000
C	8	R	31-	12.00000
C	9	R	31	6.00000
C	10	R	31-	6.00000
C	15	R	31	1.00000
C	16	R	31-	1.00000
C	17	R	31	12.00000
C	18	R	31-	12.00000
C	19	R	31	6.00000
C	20	R	31-	6.00000
C	25	R	31	1.00000
C	26	R	31-	1.00000
C	27	R	31	12.00000
C	28	R	31-	12.00000
C	29	R	31	6.00000
C	30	R	31-	6.00000
C	35	R	31	1.00000
C	36	R	31-	1.00000
C	37	R	31	12.00000
C	38	R	31-	12.00000
C	39	R	31	6.00000
C	40	R	31-	6.00000
C	96	OFFSET		000.00000
C	96	R	31	
C	96	R	31	1.0
		R	33	0.00000
		R	33	1.00000
C	5	R	33	1.00000
C	6	R	33-	1.00000
C	7	R	33	6.00000
C	8	R	33-	6.00000
C	15	R	33	2.00000
C	16	R	33-	2.00000
C	17	R	33	12.00000
C	18	R	33-	12.00000
C	25	R	33	4.00000

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C	26	R	33-	4.00000
C	27	R	33	24.00000
C	28	R	33-	24.00000
C	35	R	33	8.00000
C	36	R	33-	8.00000
C	37	R	33	48.00000
C	38	R	33-	48.00000
C	97	OFFSET		000.00000
C	97	R	33	
C	97	R	33	1.0
		R	34	
		R	34	0.00000
C	5	R	34	1.00000
C	6	R	34-	1.00000
C	7	R	34	12.00000
C	8	R	34-	12.00000
C	9	R	34	6.00000
C	10	R	34-	6.00000
C	15	R	34	2.00000
C	16	R	34-	2.00000
C	17	R	34	24.00000
C	18	R	34-	24.00000
C	19	R	34	12.00000
C	20	R	34-	12.00000
C	25	R	34	4.00000
C	26	R	34-	4.00000
C	27	R	34	48.00000
C	28	R	34-	48.00000
C	29	R	34	24.00000
C	30	R	34-	24.00000
C	35	R	34	8.00000
C	36	R	34-	8.00000
C	37	R	34	96.00000
C	38	R	34-	96.00000
C	39	R	34	48.00000
C	40	R	34-	48.00000
C	98	OFFSET		000.00000
C	98	R	34	
C	98	R	34	1.0
		R	35	
		R	35	0.00000

C	5 R	35-	1.00000
C	6 R	35	1.00000
C	15 R	35-	3.00000
C	16 R	35	3.00000
C	25 R	35-	9.00000
C	26 R	35	9.00000
C	35 R	35-	27.00000
C	36 R	35	27.00000
C	45 R	35-	1.00000
C	46 R	35	1.00000
C	99	OFFSET	000.00000
C	99 R	35	
C	99 R	35	1.0
		R 36	0.00000
C	5 R	36	1.00000
C	6 R	36-	1.00000
C	7 R	36	6.00000
C	8 R	36-	6.00000
C	15 R	36	3.00000
C	16 R	36-	3.00000
C	17 R	36	18.00000
C	18 R	36-	18.00000
C	25 R	36	9.00000
C	26 R	36-	9.00000
C	27 R	36	54.00000
C	28 R	36-	54.00000
C	35 R	36	27.00000
C	36 R	36-	27.00000
C	37 R	36	162.00000
C	38 R	36-	162.00000
C	45 R	36	1.00000
C	46 R	36	1.00000
C	47 R	36	6.00000
C	48 R	36-	6.00000
C	100	OFFSET	000.00000
C	100 R	36	
C	100 R	36	1.0
		R 37	
		R 37	0.00000
C	5 R	37	1.00000

C	6 R	37-	1.00000
C	7 R	37	12.00000
C	8 R	37-	12.00000
C	9 R	37	6.00000
C	10 R	37-	6.00000
C	15 R	37	5.00000
C	16 R	37-	3.00000
C	17 R	37	36.00000
C	18 R	37-	36.00000
C	19 R	37	18.00000
C	20 R	37-	18.00000
C	25 R	37	9.00000
C	26 R	37-	9.00000
C	27 R	37	108.00000
C	28 R	37-	108.00000
C	29 R	37	54.00000
C	30 R	37-	54.00000
C	35 R	37	27.00000
C	36 R	37-	27.00000
C	37 R	37	324.00000
C	38 R	37-	324.00000
C	39 R	37	162.00000
C	40 R	37-	162.00000
C	45 R	37	1.00000
C	46 R	37-	1.00000
C	47 R	37	12.00000
C	48 R	37-	12.00000
C	49 R	37	6.00000
C	50 R	37-	6.00000
C	101 OFFSET		000.00000
C	101 R	37	
C	101 R	37	1.0
	R	38	
	R	38	0.00000
C	5 R	38	1.00000
C	6 R	38-	1.00000
C	15 R	38	4.00000
C	16 R	38-	4.00000
C	25 R	38	16.00000
C	26 R	38-	16.00000
C	35 R	38	64.00000

C	36 R	38-	64.00000
C	45 R	38	8.00000
C	46 R	38-	8.00000
C	102	OFFSET	000.00000
C	102 R	38	
C	102 R	38	1.0
	R	39	
	R	39	0.00000
C	5 R	39	1.00000
C	6 R	39-	1.00000
C	7 R	39	6.00000
C	8 R	39-	6.00000
C	15 R	39	4.00000
C	16 R	39-	4.00000
C	17 R	39	24.00000
C	18 R	39-	24.00000
C	25 R	39	16.00000
C	26 R	39-	16.00000
C	27 R	39	96.00000
C	28 R	39-	96.00000
C	35 R	39	64.00000
C	36 R	39-	64.00000
C	37 R	39	384.00000
C	38 R	39-	384.00000
C	45 R	39	8.00000
C	46 R	39-	8.00000
C	47 R	39	48.00000
C	48 R	39-	48.00000
C	103	OFFSET	000.00000
C	103 R	39	
C	103 R	39	1.0
	R	40	
	R	40	0.00000
C	5 R	40	1.00000
C	6 R	40-	1.00000
C	7 R	40	12.00000
C	8 R	40-	12.00000
C	9 R	40	6.00000
C	10 R	40-	6.00000
C	15 R	40	4.00000
C	16 R	40-	4.00000

C	17	R	40	48.00000
C	18	R	40-	48.00000
C	19	R	40	24.00000
C	20	R	40-	24.00000
C	25	R	40	16.00000
C	26	R	40-	16.00000
C	27	R	40	192.00000
C	28	R	40-	192.00000
C	29	R	40	96.00000
C	30	R	40-	96.00000
C	35	R	40	64.00000
C	36	R	40-	64.00000
C	37	R	40	768.00000
C	38	R	40-	768.00000
C	39	R	40	384.00000
C	40	R	40-	384.00000
C	45	R	40	8.00000
C	46	R	40-	8.00000
C	47	R	40	96.00000
C	48	R	40-	96.00000
C	49	R	40	48.00000
C	50	R	40-	48.00000
C	104	OFFSET		000.00000
C	104	R	40	
C	104	R	40	1.0
		R	42	
		R	42	000.00000
C	21	R	42-	1.00000
C	22	R	42	1.00000
C	31	R	42-	12.00000
C	32	R	42	12.00000
C	41	R	42-	6.00000
C	42	R	42	6.00000
C	105	OFFSET		000.00000
C	105	R	42	
C	105	R	42	1.0
		R	43	
		R	43	000.00000
C	21	R	43	1.00000
C	22	R	43-	1.00000
C	23	R	43	1.00000

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C	24	R	43-	1.00000
C	25	R	43	1.00000
C	26	R	43-	1.00000
C	27	R	43	1.00000
C	28	R	43-	1.00000
C	31	R	43	6.00000
C	32	R	43-	6.00000
C	33	R	43	6.00000
C	34	R	43-	6.00000
C	35	R	43	6.00000
C	36	R	43-	6.00000
C	37	R	43	6.00000
C	38	R	43-	6.00000
C	106	OFFSET		000.00000
C	106	R	43	
C	106	R	43	1.0
		R	44	
		R	44	000.00000
C	21	R	44	1.00000
C	22	R	44-	1.00000
C	23	R	44	1.00000
C	24	R	44-	1.00000
C	25	R	44	1.00000
C	26	R	44-	1.00000
C	27	R	44	1.00000
C	28	R	44-	1.00000
C	31	R	44	12.00000
C	32	R	44-	12.00000
C	33	R	44	12.00000
C	34	R	44-	12.00000
C	35	R	44	12.00000
C	36	R	44-	12.00000
C	37	R	44	12.00000
C	38	R	44-	12.00000
C	41	R	44	6.00000
C	42	R	44-	6.00000
C	43	R	44	6.00000
C	44	R	44-	6.00000
C	45	R	44	6.00000
C	46	R	44-	6.00000
C	47	R	44	6.00000

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C	48	R	44-	6.00000
C	107	OFFSET		000.00000
C	107	R	44	
C	107	R	44	1.0
		R	45	
		R	45	000.00000
C	21	R	45	1.00000
C	22	R	45-	1.00000
C	23	R	45	2.00000
C	24	R	45-	2.00000
C	25	R	45	4.00000
C	26	R	45-	4.00000
C	27	R	45	8.00000
C	28	R	45-	8.00000
C	31	R	45	6.00000
C	32	R	45-	6.00000
C	33	R	45	12.00000
C	34	R	45-	12.00000
C	35	R	45	24.00000
C	36	R	45-	24.00000
C	37	R	45	48.00000
C	38	R	45-	48.00000
C	108	OFFSET		000.00000
C	108	R	45	
C	108	R	45	1.0
		R	46	
		R	46	000.00000
C	21	R	46	1.00000
C	22	R	46-	1.00000
C	23	R	46	2.00000
C	24	R	46-	2.00000
C	25	R	46	4.00000
C	26	R	46-	4.00000
C	27	R	46	8.00000
C	28	R	46-	8.00000
C	31	R	46	12.00000
C	32	R	46-	12.00000
C	33	R	46	24.00000
C	34	R	46-	24.00000
C	35	R	46	48.00000
C	36	R	46-	48.00000

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C	37	R	46	96.00000
C	38	R	46-	96.00000
C	41	R	46	6.00000
C	42	R	46-	6.00000
C	43	R	46	12.00000
C	44	R	46-	12.00000
C	45	R	46	24.00000
C	46	R	46-	24.00000
C	47	R	46	48.00000
C	48	R	46-	48.00000
C	109	OFFSET		000.00000
C	109	R	46	
C	109	R	46	1.0
		R	47	
		R	47	000.00000
C	21	R	47	1.00000
C	22	R	47-	1.00000
C	23	R	47	3.00000
C	24	R	47-	3.00000
C	25	R	47	9.00000
C	26	R	47-	9.00000
C	27	R	47	27.00000
C	28	R	47-	27.00000
C	29	R	47	1.00000
C	30	R	47-	1.00000
C	31	R	47	6.00000
C	32	R	47-	6.00000
C	33	R	47	18.00000
C	34	R	47-	18.00000
C	35	R	47	54.00000
C	36	R	47-	54.00000
C	37	R	47	162.00000
C	38	R	47-	162.00000
C	39	R	47	6.00000
C	40	R	47-	6.00000
C	110	OFFSET		000.00000
C	110	R	47	
C	110	R	47	1.0
		R	48	
		R	48	000.00000
C	21	R	48	1.00000

C	22	R	48-	1.00000
C	23	R	48	3.00000
C	24	R	48-	3.00000
C	25	R	48	9.00000
C	26	R	48-	9.00000
C	27	R	48	27.00000
C	28	R	48-	27.00000
C	29	R	48	1.00000
C	30	R	48-	1.00000
C	31	R	48	12.00000
C	32	R	48-	12.00000
C	33	R	48	36.00000
C	34	R	48-	36.00000
C	35	R	48	108.00000
C	36	R	48-	108.00000
C	37	R	48	324.00000
C	38	R	48-	324.00000
C	39	R	48	12.00000
C	40	R	48-	12.00000
C	41	R	48	6.00000
C	42	R	48-	6.00000
C	43	R	48	18.00000
C	44	R	48-	18.00000
C	45	R	48	54.00000
C	46	R	48-	54.00000
C	47	R	48	162.00000
C	48	R	48-	162.00000
C	49	R	48	6.00000
C	50	R	48-	6.00000
C	111	OFSET		000.00000
C	111	R	48	
C	111	R	48	1.0
		R	49	
		R	49	000.00000
C	21	R	49	1.00000
C	22	R	49-	1.00000
C	23	R	49	4.00000
C	24	R	49-	4.00000
C	25	R	49	16.00000
C	26	R	49-	16.00000
C	27	R	49	64.00000

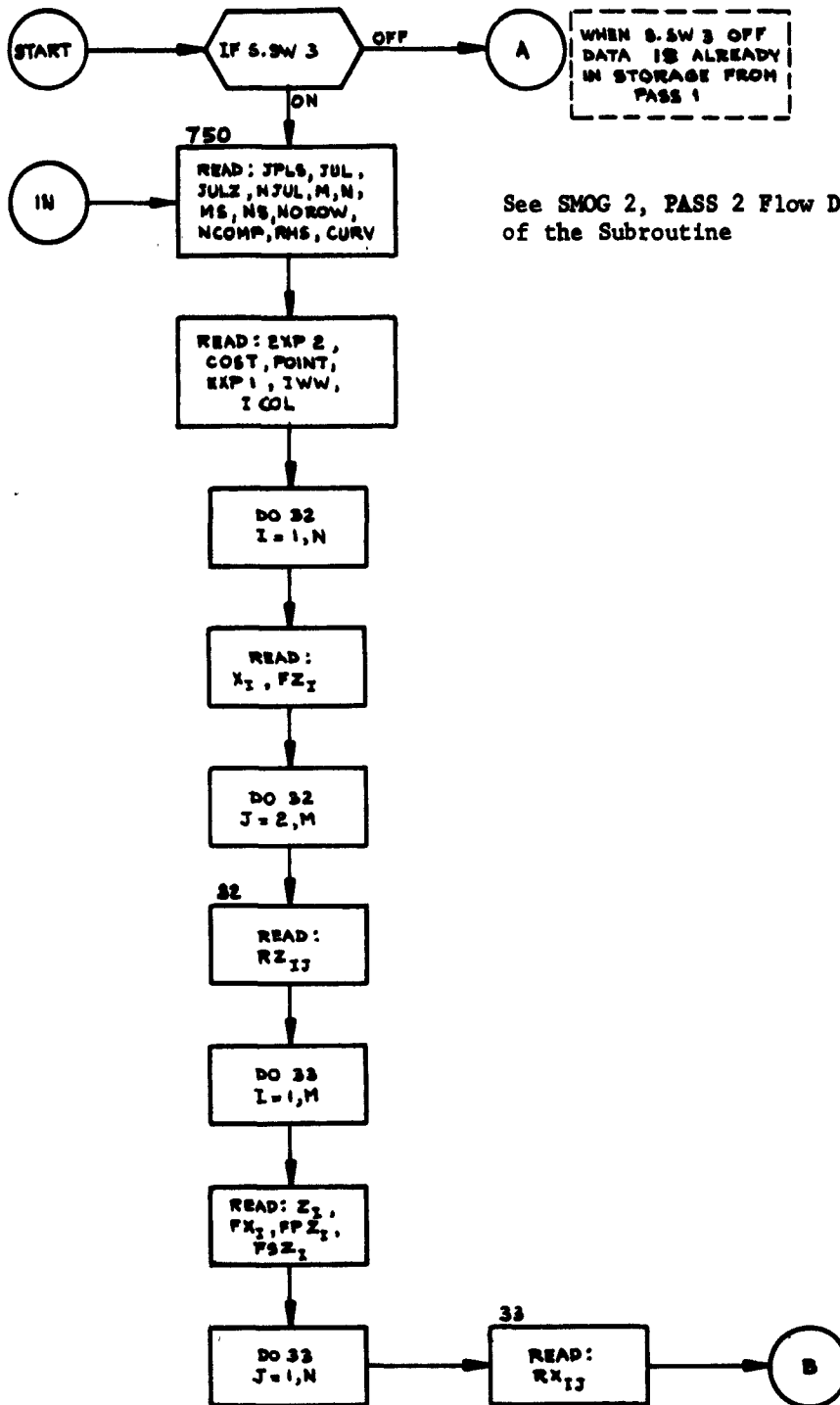
1.0.0.~

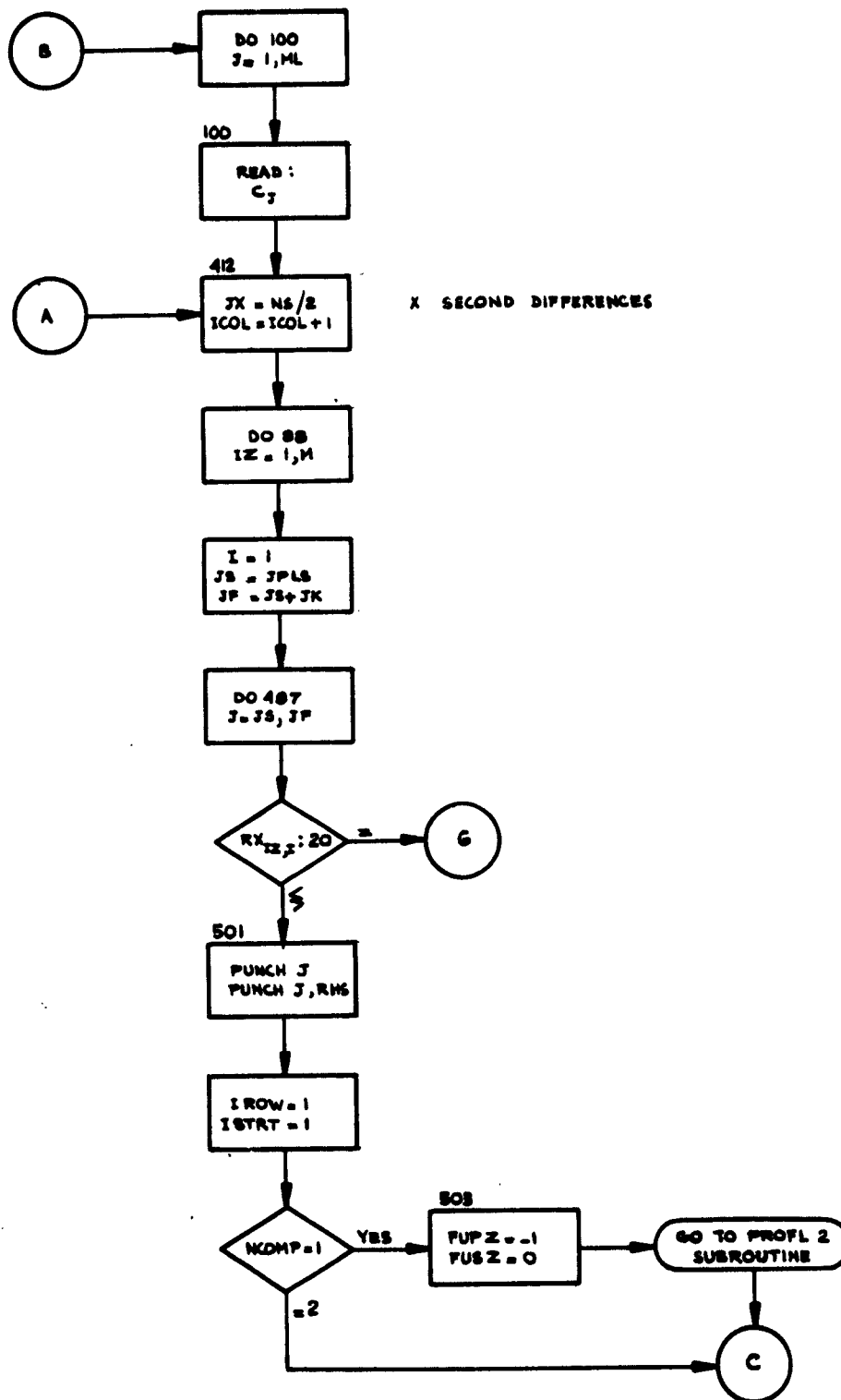
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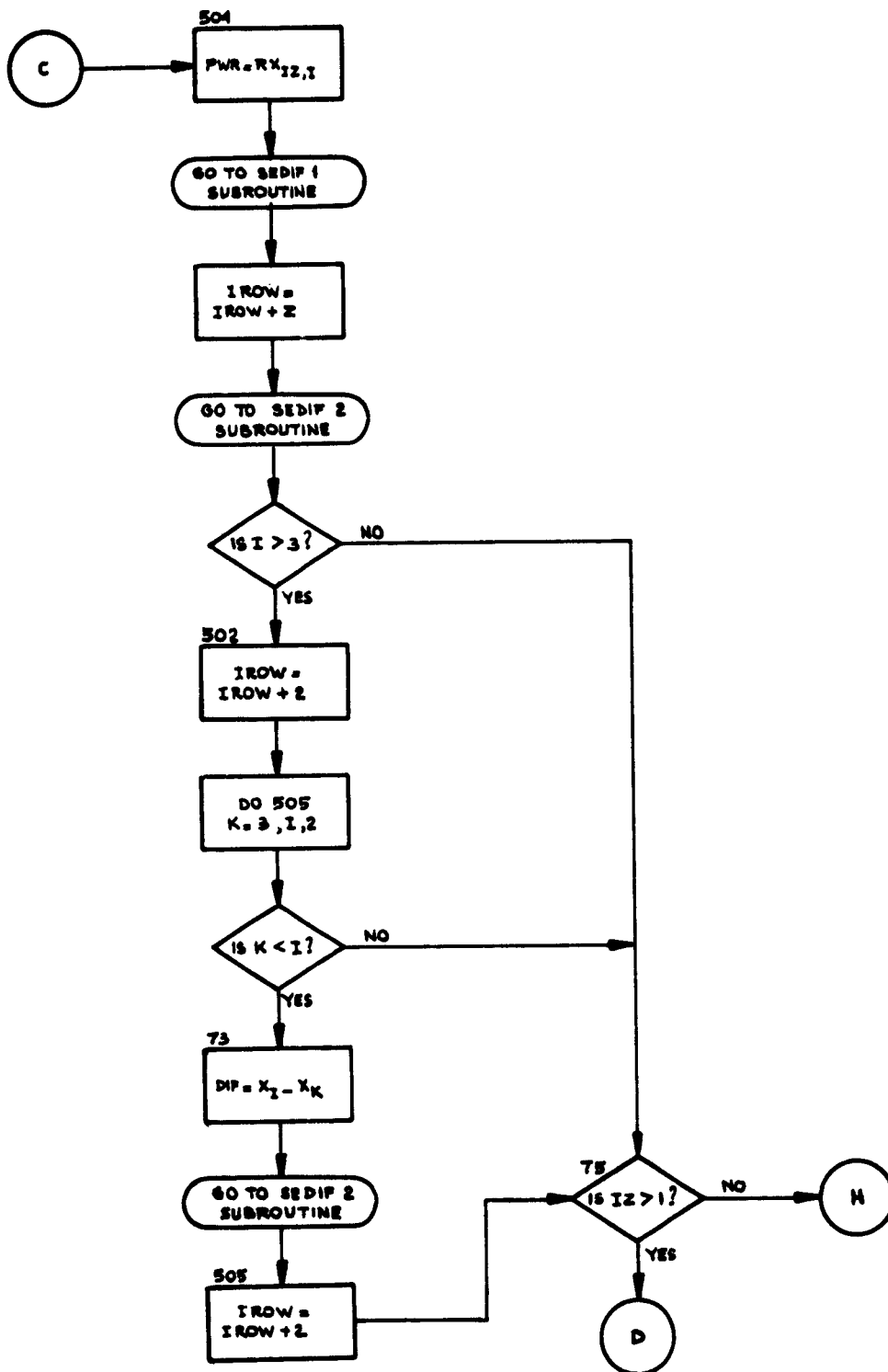
C 44 R 50-	24.00000
C 45 R 50	96.00000
C 46 R 50-	96.00000
C 47 R 50	384.00000
C 48 R 50-	384.00000
C 49 R 50	48.00000
C 50 R 50-	48.00000
C 113 OFSET	000.00000
C 113 R 50	
C 113 R 50	1.0

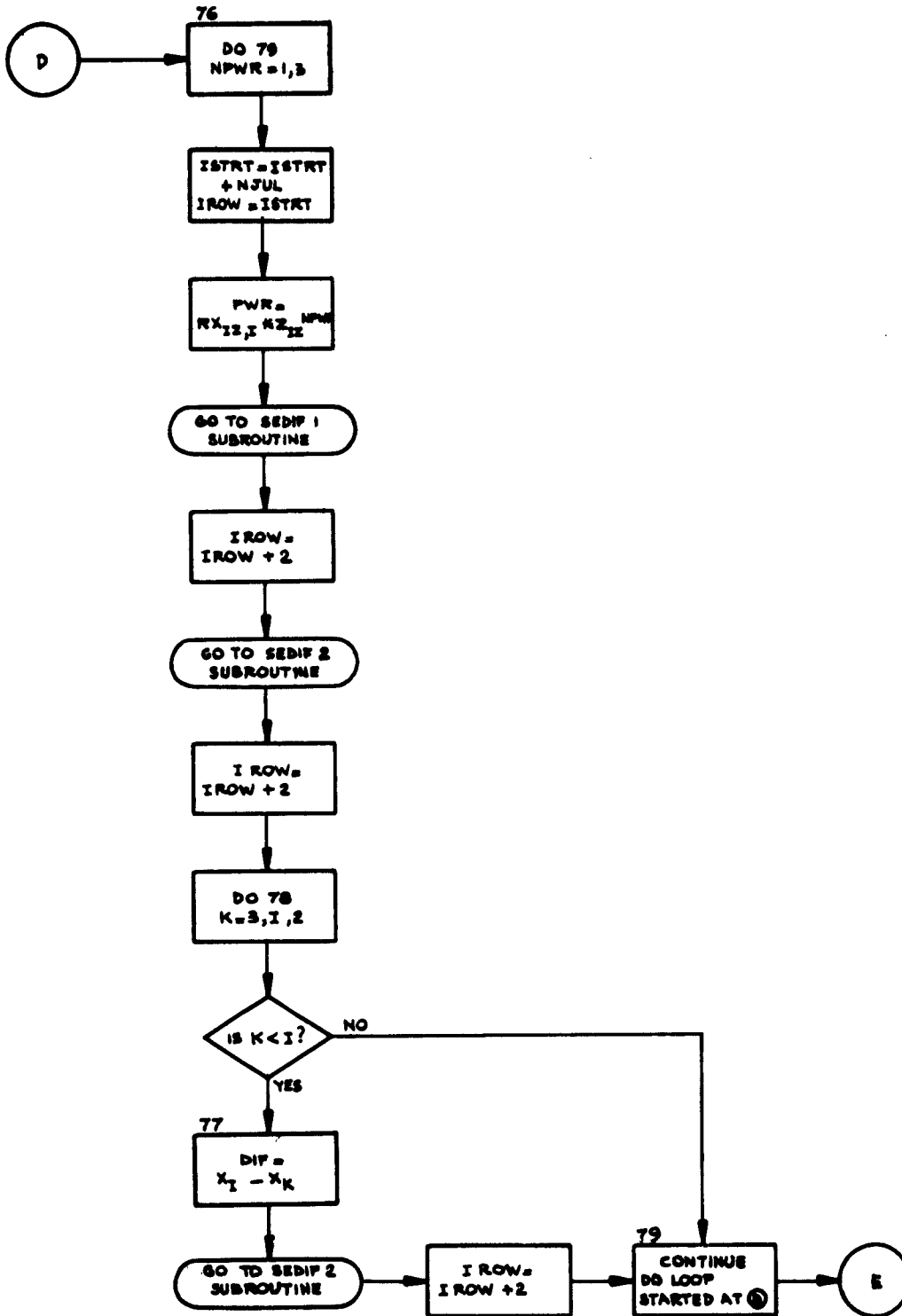
1.0

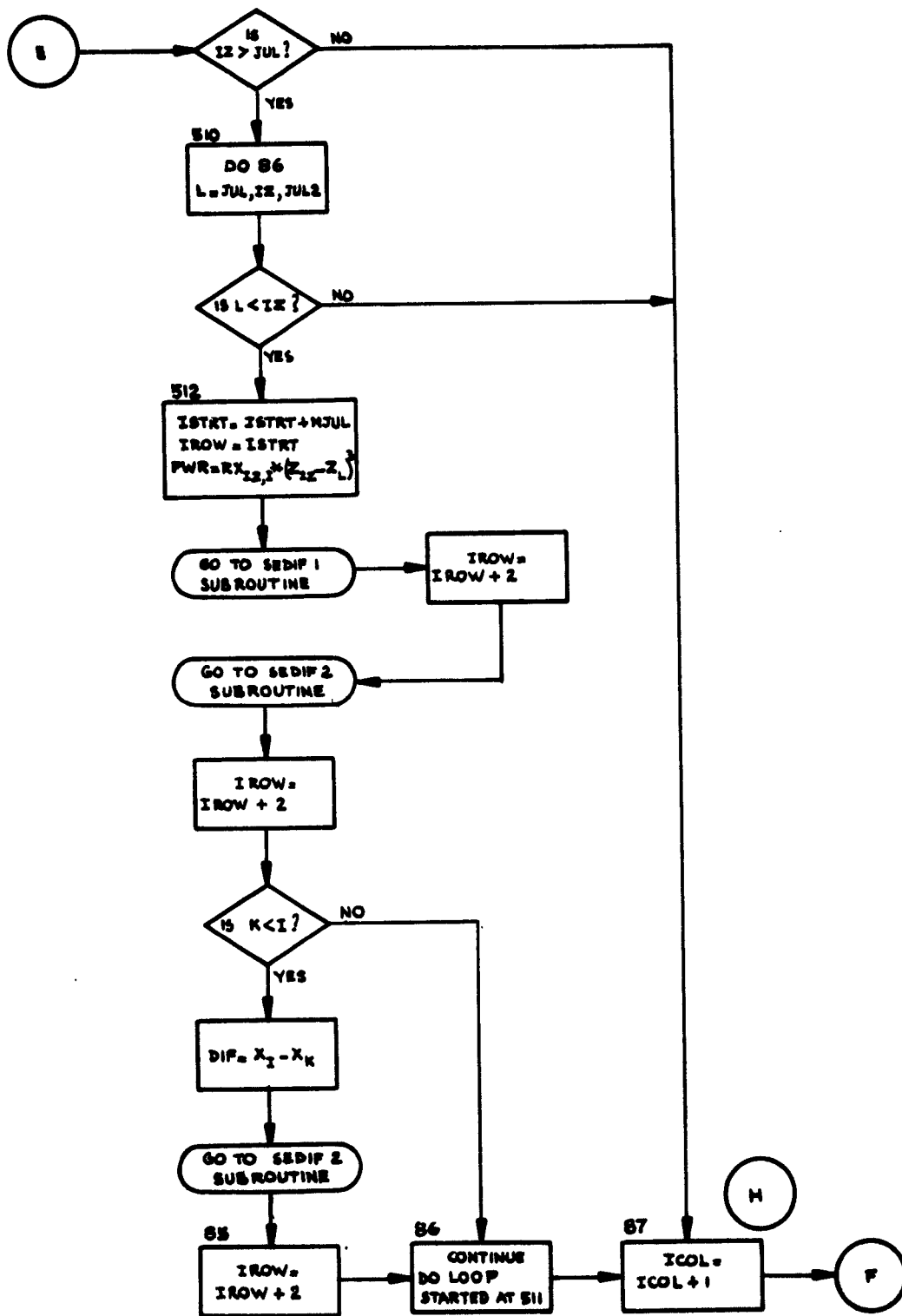
FLOW DIAGRAM - SMOG 3, PASS 2

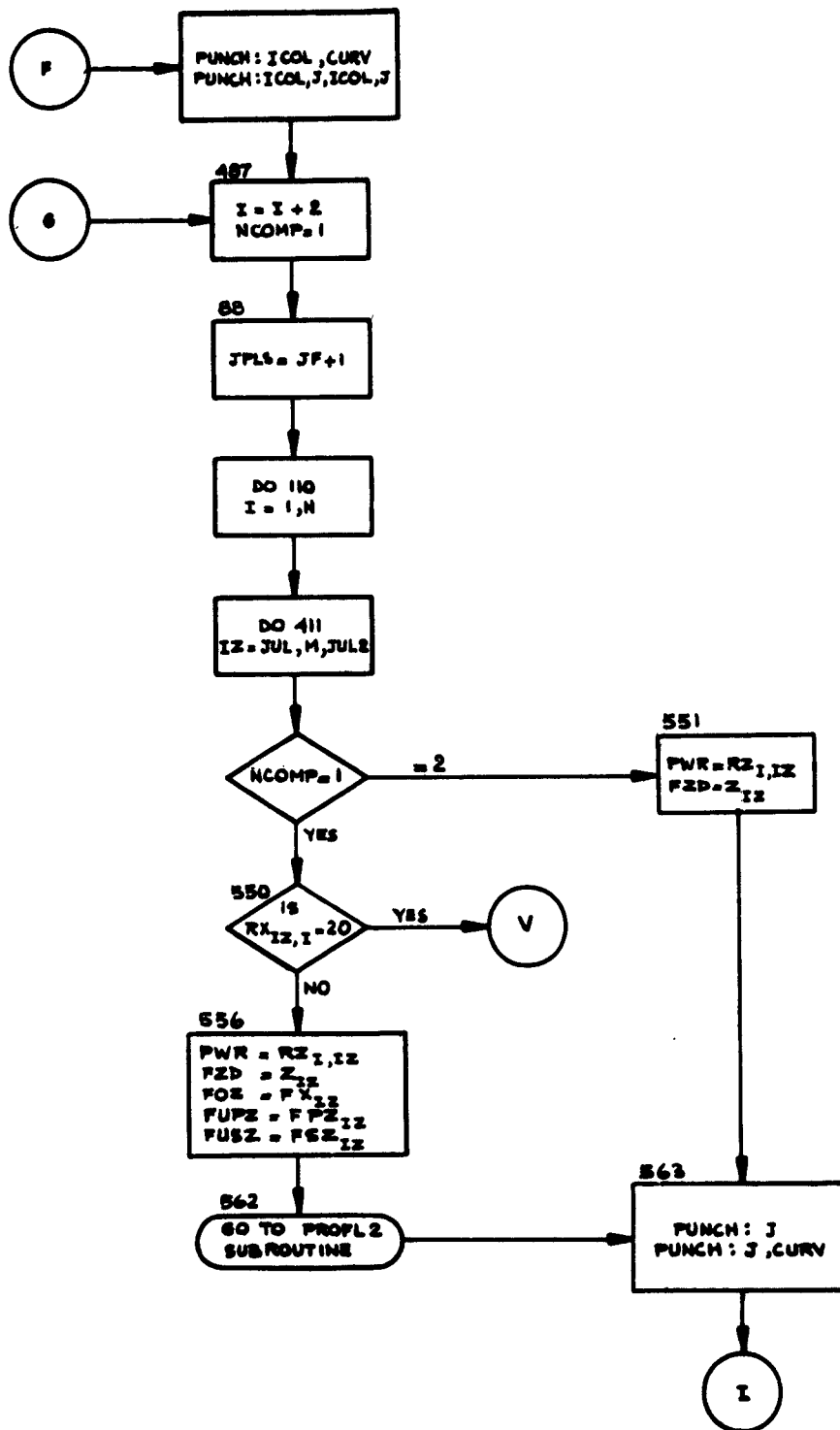


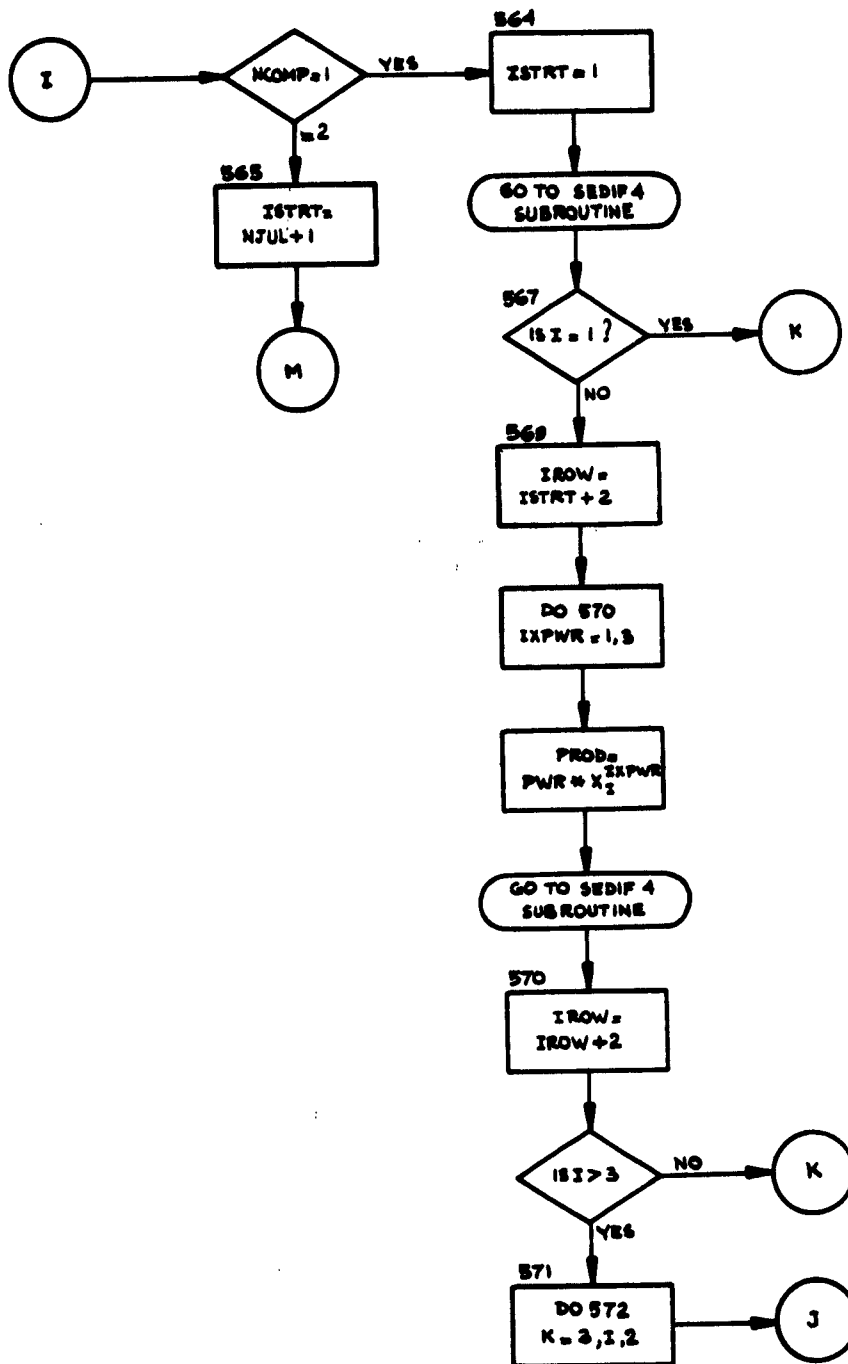


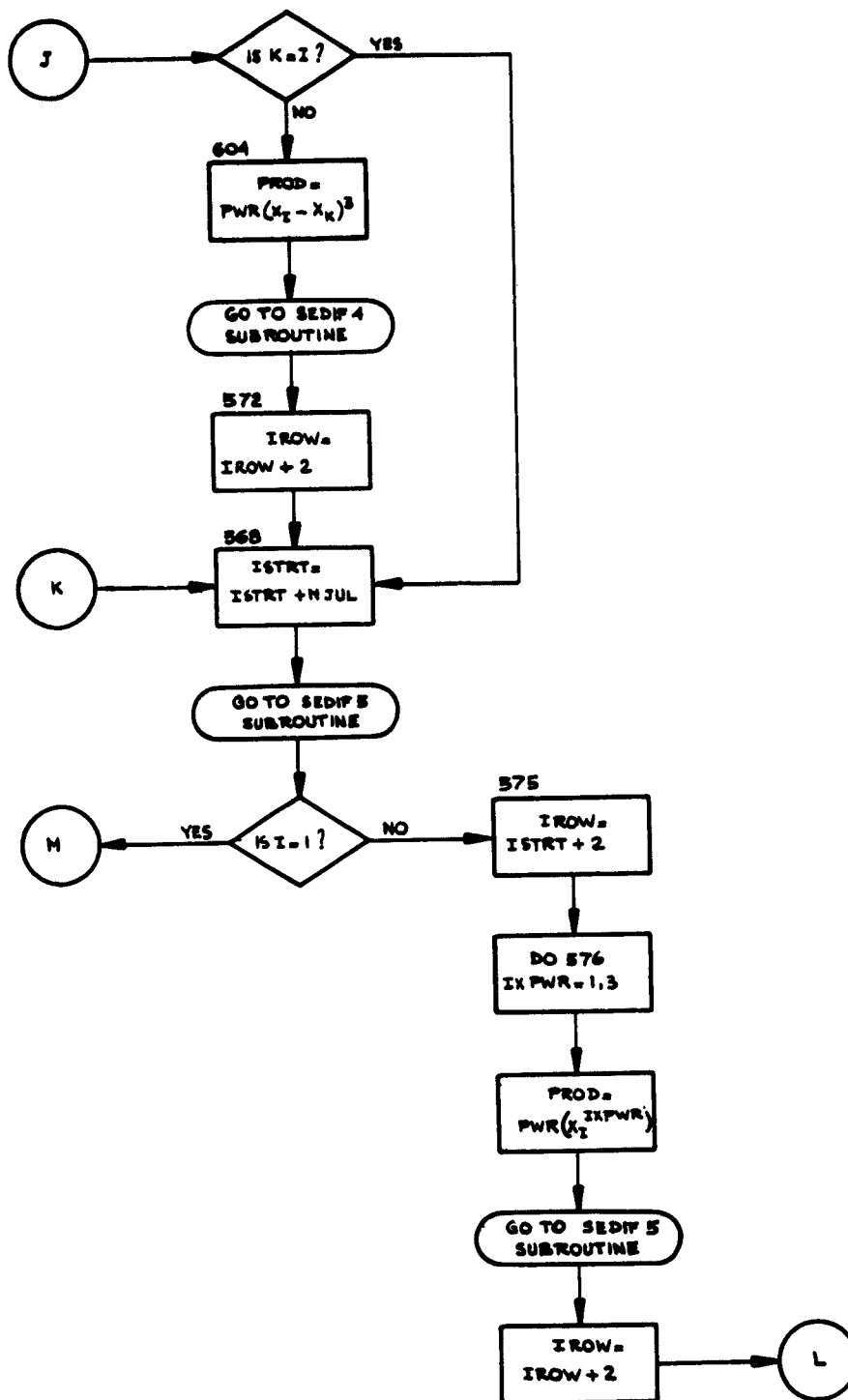


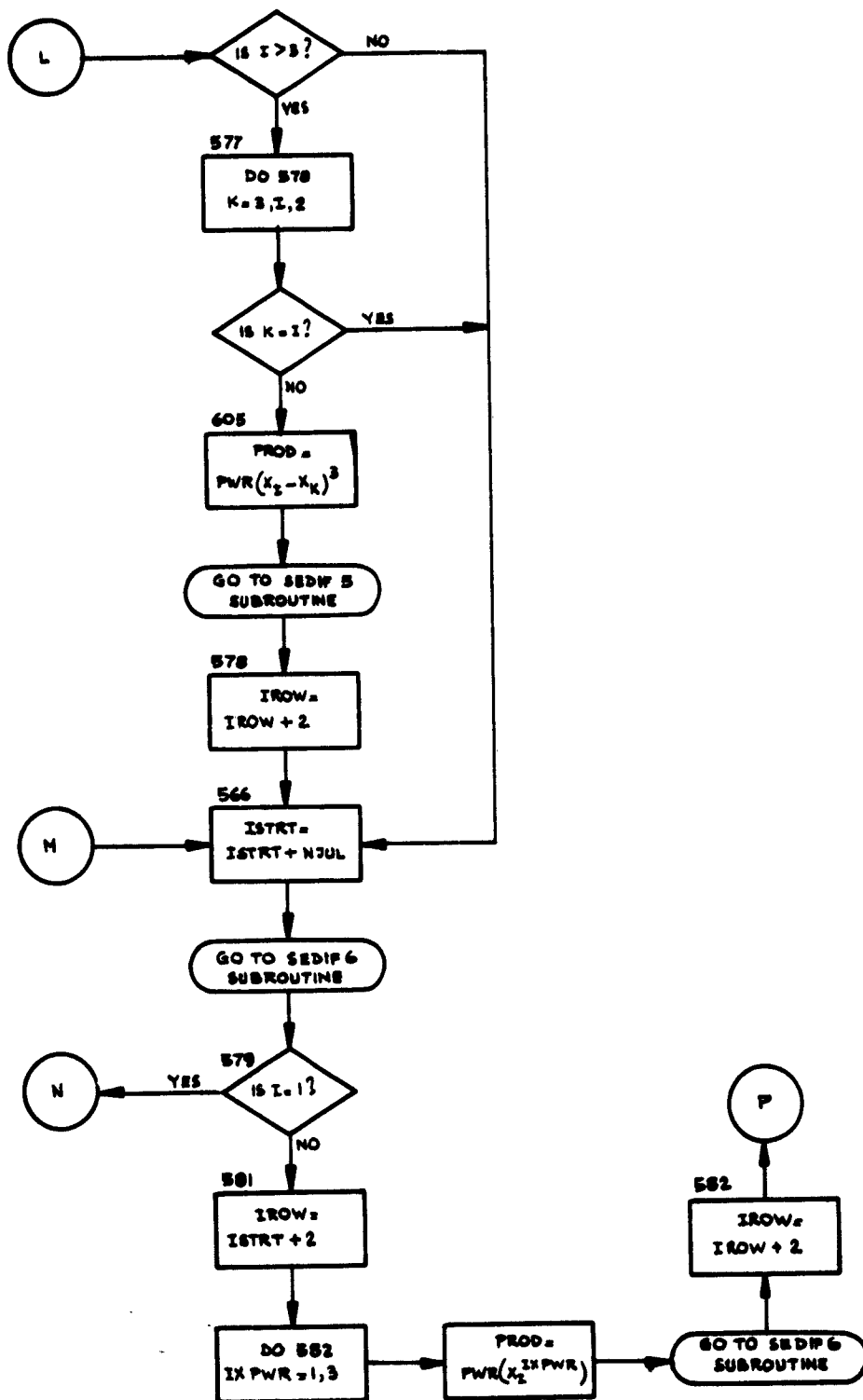


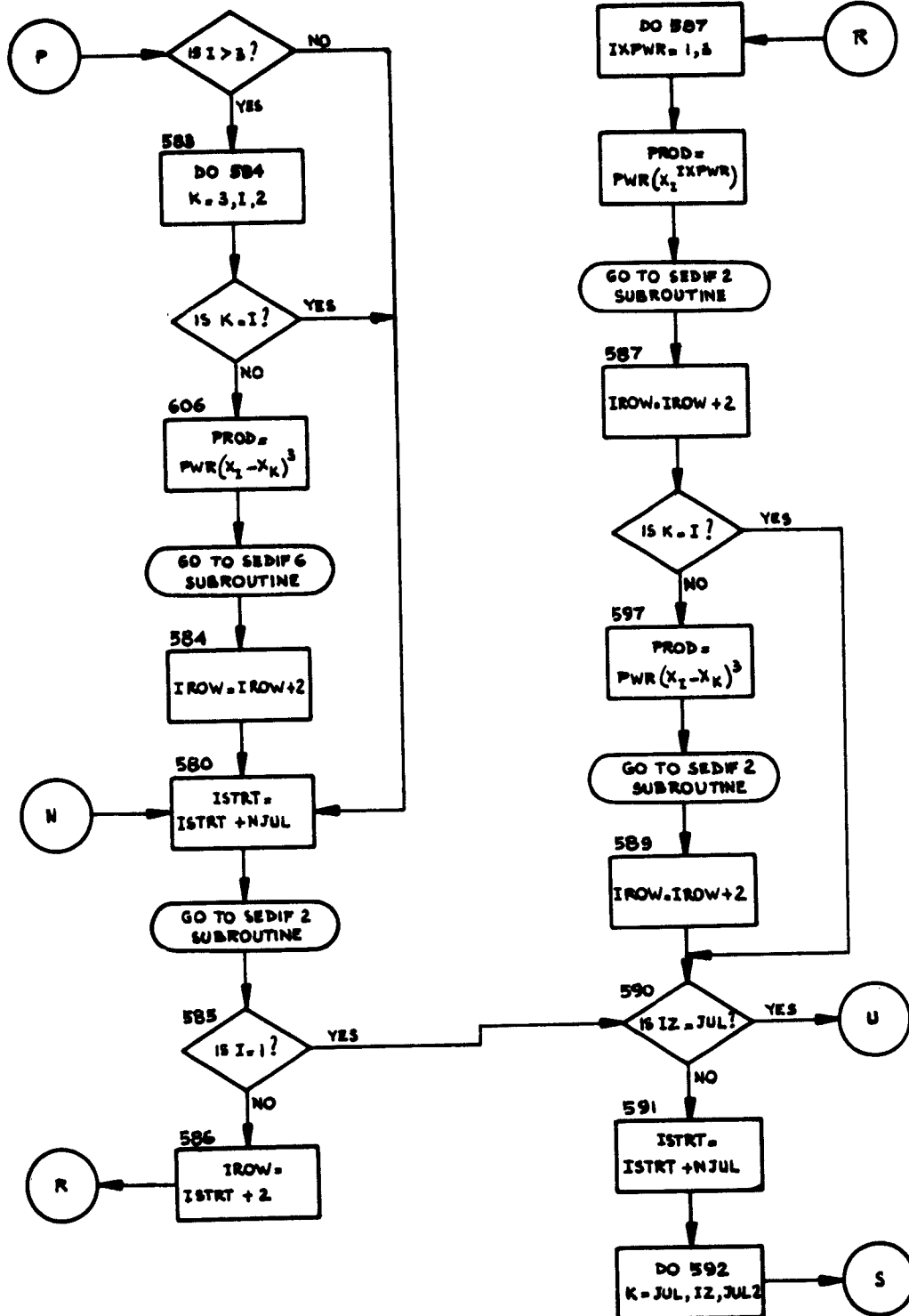


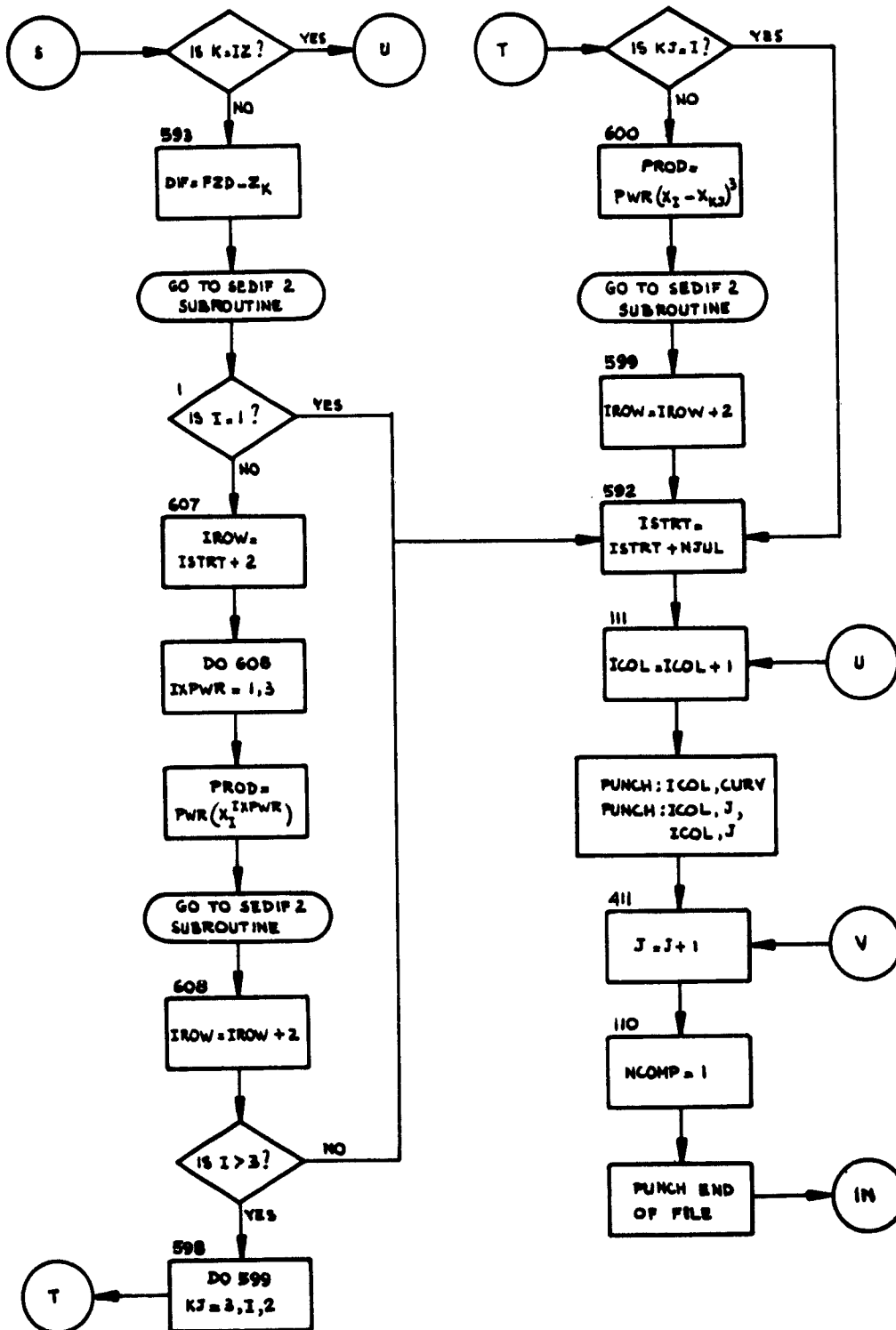












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C      SMOG3 PASS 2 PRIMAL SUM OF DEV  X OR X AND Z DBL SPL WI PRFL
15)    DIMENSION RX(11,15),RZ(15,11),FZ(11),FX(15),X(15),Z(11),Y(11,
      DIMENSION FPZ(11),FSZ(11),C(13)
      COMMON JPLS,JUL,JUL2,NJUL,M,N,MS,NS,NOROW,NCOMP,RHS,COST
      COMMON EXP2,CURV,POINT,EXP1,IWW,ICOL
      COMMON X,FZ,RZ,Z,FX,FPZ,FSZ,RX,C
      IF(SENSE SWITCH 3)750,412
750    READ 180,JPLS,JUL,JUL2,NJUL,M,N,MS,NS,NOROW,NCOMP,RHS,CURV
      READ 181,EXP2,COST,POINT,EXP1,IWW,ICOL
      DO 32 I=1,N
      READ 181,X(I),FZ(I)
      DO 32 J=2,M
32    READ 181,RZ(I,J)
      DO 33 I=1,M
      READ 181,Z(I),FX(I),FPZ(I),FSZ(I)
      DO 33 J=1,N
33    READ 181,RX(I,J)
      ML=M+2
      DO 100 J=1,ML
100    READ 181,C(J)
C      *      *      X SEC DIFFERENCES      *      *
412    JX=NS/2
      ICOL=ICOL+1
      DO 88 IZ=1,M
      I=1
      JS=JPLS
      JF=JS+JX
      DO 487 J=JS,JF
      IF(RX(IZ,I)-20.)501,487,501
501    PUNCH 162,J
      PUNCH 177,J,RHS
      IROW=1
      ISTRT=1
      GO TO (503,504),NCOMP
503    FUPZ=-1.
      FUSZ=0.
      CALL PROFL2 (X(I),FX(IZ),EXP1,FUPZ,FUSZ,EXP2,POINT,T,TP,TS
,NCOMP)
504    PWR=RX(IZ,I)
      CALL SEDIF1 (T,TP,TS,X(I),J,IROW,PWR)
      IROW=IROW+2
      CALL SEDIF2 (X(I),T,TP,TS,PWR,J,IROW)
      IF(I-3)75,75,502
502    IROW=IROW+2

```

```

      DO 505 K=3,1,2
      IF(K-1)73,75,75
73  DIF=X(1)-X(K)
      CALL SEDIF2 (DIF,T,TP,TS,PWR,J,IROW)
505  IROW=IROW+2
75  IF(IZ-1)87,87,76
76  DO 79 NPWR=1,3
      ISTRT=ISTRT+NJUL
      IROW=ISTRT
      PWR=RX(IZ,1)*Z(IZ)**NPWR
      CALL SEDIF1 (T,TP,TS,X(1),J,IROW,PWR)
      IROW=IROW+2
      CALL SEDIF2 (X(1),T,TP,TS,PWR,J,IROW)
      IROW=IROW+2
      DO 78 K=3,1,2
      IF(K-1)77,79,79
77  DIF=X(1)-X(K)
      CALL SEDIF2 (DIF,T,TP,TS,PWR,J,IROW)
78  IROW=IROW+2
79  CONTINUE
      IF(IZ-JUL)87,87,511
511  DO 86 L=JUL,IZ,JUL2
      IF(L-IZ)512,87,87
512  ISTRT=ISTRT+NJUL
      IROW=ISTRT
      PWR=RX(IZ,1)*(Z(IZ)-Z(L))**3
      CALL SEDIF1 (T,TP,TS,X(1),J,IROW,PWR)
      IROW=IROW+2
      CALL SEDIF2 (X(1),T,TP,TS,PWR,J,IROW)
      IROW=IROW+2
      DO 85 K=3,1,2
      IF(K-1)84,86,86
84  DIF=X(1)-X(K)
      CALL SEDIF2 (DIF,T,TP,TS,PWR,J,IROW)
85  IROW=IROW+2
86  CONTINUE
87  ICOL=ICOL+1
      PUNCH 171,ICOL,CURV
      PUNCH 152,ICOL,J,ICOL,J
487  I=I+2
      NCOMP=1
88  JPLS=JF+1
C    Z SEC DIFFERENCES      *      *
      DO 110 I=1,M
      DO 411 IZ=JUL,M,JUL2

```



```

GO TO (550,551),NCOMP
550 IF(RX(IZ,1)-20.)556,411,556
556 PWR=RZ(1,IZ)
    FZD=Z(IZ)
    FOZ=FX(IZ)
    FUPZ=FPZ(IZ)
    FUSZ=FSZ(IZ)
562 CALL PROFL2(X(1),FOZ,EXP1,FUPZ,FUSZ,EXP2,POINT,T,TP,TS,
NCOMP)
    GO TO 563
551 PWR=RZ(1,IZ)
    FZD=Z(IZ)
563 PUNCH 162,J
    PUNCH 177,J,CURV
    GO TO (564,565),NCOMP
565 ISTRT=1+NJUL
    GO TO 566
564 ISTRT=1
    CALL SEDIF4 (TS,PWR,J,ISTRT)
567 IF(1-1)569,568,569
569 IROW=ISTRT+2
    DO 570 IXPWR=1,3
    PROD=PWR*X(1)**IXPWR
    CALL SEDIF4(TS,PROD,J,IROW)
570 IROW=IROW+2
    IF(1-3)568,568,571
571 DO 572 K=3,1,2
    IF(K-1)604,568,604
604 PROD=PWR*(X(1)-X(K))**3
    CALL SEDIF4(TS,PROD,J,IROW)
572 IROW=IROW+2
568 ISTRT=ISTRT+NJUL
    CALL SEDIF5(TP,TS,FZD,PWR,J,ISTRT)
573 IF(1-1)575,566,575
575 IROW=ISTRT+2
    DO 576 IXPWR=1,3
    PROD=PWR*X(1)**IXPWR
    CALL SEDIF5 (TP,TS,FZD,PROD,J,IROW)
576 IROW=IROW+2
    IF(1-3)566,566,577
577 DO 578 K=3,1,2
    IF(K-1)605,566,605
605 PROD=PWR*(X(1)-X(K))**3
    CALL SEDIF5 (TP,TS,FZD,PROD,J,IROW)
578 IROW=IROW+2

```

```

566 ISTRT=ISTRT+NJUL
    CALL SEDIF6 (T,TP,TS,FZD,J,PWR,ISTRT)
579 IF(1-1)581,580,581
581 IROW=ISTRT+2
    DO 582 IXPWR=1,3
        PROD=PWR*X(1)**IXPWR
        CALL SEDIF6 (T,TP,TS,FZD,J,PROD,IROW)
582 IROW=IROW+2
    IF(1-3)580,580,583
583 DO 584 K=3,1,2
    IF(K-1)606,580,606
606 PROD=PWR*(X(1)-X(K))**3
    CALL SEDIF6 (T,TP,TS,FZD,J,PROD,IROW)
584 IROW=IROW+2
580 ISTRT=ISTRT+NJUL
    CALL SEDIF2 (FZD,T,TP,TS,PWR,J,ISTRT)
585 IF(1-1)586,590,586
586 IROW=ISTRT+2
    DO 587 IXPWR=1,3
        PROD=PWR*X(1)**IXPWR
        CALL SEDIF2 (FZD,T,TP,TS,PROD,J,IROW)
587 IROW=IROW+2
    IF(1-3)590,590,588
588 DO 589 K=3,1,2
    IF(K-1)597,590,597
597 PROD=PWR*(X(1)-X(K))**3
    CALL SEDIF2 (FZD,T,TP,TS,PROD,J,IROW)
589 IROW=IROW+2
590 IF(1Z-JUL)591,111,591
591 ISTRT=ISTRT+NJUL
    DO 592 K=JUL,1Z,JUL2
    IF(K-1Z)593,111,593
593 DIF=FZD-Z(K)
    CALL SEDIF2 (DIF,T,TP,TS,PWR,J,ISTRT)
    1 IF(1-1)607,592,607
607 IROW=ISTRT+2
    DO 608 IXPWR=1,3
        PROD=PWR*X(1)**IXPWR
        CALL SEDIF2 (DIF,T,TP,TS,PROD,J,IROW)
608 IROW=IROW+2
    IF(1-3)592,592,598
598 DO 599 KJ=3,1,2
    IF(KJ-1)600,592,600
600 PROD=PWR*(X(1)-X(KJ))**3
    CALL SEDIF2 (DIF,T,TP,TS,PROD,J,IROW)

```

```

599 IROW=IROW+2
592 ISTRT=ISTRT+NJUL
111 ICOL=ICOL+1
    PUNCH 171,ICOL,CURV
    PUNCH 152,ICOL,J,ICOL,J
411 J=J+1
110 NCOMP=1
    PUNCH 174
    PUNCH 176
    PRINT 178
    PAUSE 751
    GO TO 750
152 FORMAT(7X,1HC,14,2H R,14/7X,1HC,14,2H R,14,8H      1.0)
171 FORMAT(6X,2H C,14,6H OFFSET,F12.5)
173 FORMAT(1H*,5X,47H
)
174 FORMAT(7HFIRST B)
175 FORMAT(12X, 6H R    1,F12.5)
176 FORMAT(3HEOF)
177 FORMAT(12X,2H R,14,1H ,F11.5)
178 FORMAT(28HENTER NEW DATA - PRESS START)
180 FORMAT (10I5,2F15.9)
162 FORMAT(12X,2H R,14)
181 FORMAT (4F15.9,14,14)
    END

```

```

SUBROUTINE SEDIF1 (TD,TPD,TSD,XD,JD,IROWD,PWRD)
CALL SEDIF4 (TSD,PWRD,JD,IROWD)
IROWD=IROWD+2
CALL SEDIF5 (TPD,TSD,XD,PWRD,JD,IROWD)
IROWD=IROWD+2
CALL SEDIF6 (TD,TPD,TSD,XD,JD,PWRD,IROWD)
RETURN
END

```

```

SUBROUTINE SEDIF2 (DIFD,TD,TPD,TSD,PWRD,JD,IROWD)
WRM=(3.*DIFD*TD+3.*TPD*DIFD**2+(TSD*DIFD**3)/2.)*PWRD
CALL SIGN (JD,IROWD,WRM)
RETURN
END

```

```

SUBROUTINE SEDIF3 (IXD,FXD,PRD,JSD,IROWD)
EXD=IXD
WRM=(EXD*FXD**2+(IXD-1)*FXD**2)*PRD
CALL SIGN (JSD,IROWD,WRM)
RETURN
END

```

```

SUBROUTINE SEDIF4 (TSD,PWRD,JD,IROWD)
WRM=(TSD*PWRD)/2.
CALL SIGN (JD,IROWD,WRM)
RETURN
END

```

```

SUBROUTINE SEDIF5 (TPD,TSD,XD,PWRD,JD,IROWD)
WRM=((TSD*XD)/2.+TPD)*PWRD
CALL SIGN (JD,IROWD,WRM)
RETURN
END

```

```

SUBROUTINE SEDIF6 (TD,TPD,TSD,XD,JD,PWRD,IROWD)
WRM=TD
WRM=WRM+(TSD*XD**2)/2.
WRM=WRM+2.*TPD*XD
WRM=WRM*PWRD
CALL SIGN (JD,IROWD,WRM)
RETURN
END

```

```

SUBROUTINE SIGN (IW,JW,WAM)
JWPL=JW+1
IF(WAM)370,373,371
370 WAM=-WAM
PUNCH 169,JW,IW,WAM,JWPL,IW,WAM
RETURN
371 PUNCH 167,JW,IW,WAM,JWPL,IW,WAM
373 RETURN
167 FORMAT(6X,2H C,14,2H R,14,1H-,F11.5/6X,2H C,14,2H R,14,F12.5)
169 FORMAT(6X,2H C,14,2H R,14,F12.5/6X,2H C,14,2H R,14,1H-,F11.5)
END

```

* TODD DLG 5X5 FND PROFILE X-Z DBL SPL-12/3/62

ROW ID

OFSET
R 3
R 4
R 5
R 7
R 8
R 9
R 10
R 12
R 13
R 14
R 15
R 16
R 17
R 18
R 19
R 20
R 21
R 22
R 23
R 24
R 25
R 27
R 28
R 30
R 31
R 33
R 34
R 35
R 36
R 37
R 38
R 39
R 40
R 42
R 43
R 44
R 45
R 46

1.0.0.2

B-293

1.0.0 - 2

B-294

47	3	51	C
48	4	53	C
49	5	55	C
50	7	57	C
	8	59	C
	9	61	C
	10	63	C
	12	65	C
	13	67	C
	14	69	C
	15	71	C
	16	73	C
	17	75	C
	18	77	C
	19	79	C
	20	81	C
	21	83	C
	22	85	C
	23	87	C
	24	89	C
	25	91	C
	27	93	C
	28	94	C
	30	95	C
	31	96	C
	33	97	C
	34	98	C
	35	99	C
	36	100	C
	37	101	C
	38	102	C
	39	103	C
	40	104	C
	42	105	C
	43	106	C
	44	107	C

BASIS

C	108 R	45
C	109 R	46
C	110 R	47
C	111 R	48
C	112 R	49
C	113 R	50

C	I	OFSET	0.00100
C	1 R	3-	1.0
C	1 R	4-	1.0
C	1 R	5-	1.0
C	1 R	7-	1.0
C	1 R	8-	1.0
C	1 R	9-	1.0
C	1 R	10-	1.0
C	1 R	12-	1.0
C	1 R	13-	1.0
C	1 R	14-	1.0
C	1 R	15-	1.0
C	1 R	16-	1.0
C	1 R	17-	1.0
C	1 R	18-	1.0
C	1 R	19-	1.0
C	1 R	20-	1.0
C	1 R	21-	1.0
C	1 R	22-	1.0
C	1 R	23-	1.0
C	1 R	24-	1.0
C	1 R	25-	1.0
C	2 OFSET		0.00100
C	2 R	3	1.0
C	2 R	4	1.0
C	2 R	5	1.0
C	2 R	7	1.0
C	2 R	8	1.0
C	2 R	9	1.0
C	2 R	10	1.0
C	2 R	12	1.0
C	2 R	13	1.0
C	2 R	14	1.0
C	2 R	15	1.0

B-295

1.0.0-2

C	2	R	16	1.0
C	2	R	17	1.0
C	2	R	18	1.0
C	2	R	19	1.0
C	2	R	20	1.0
C	2	R	21	1.0
C	2	R	22	1.0
C	2	R	23	1.0
C	2	R	24	1.0
C	2	R	25	1.0
C	3	OFSET		0.00100
C	3	R	3-	2.00000
C	3	R	4-	3.00000
C	3	R	5-	4.00000
C	3	R	7-	1.00000
C	3	R	8-	2.00000
C	3	R	9-	3.00000
C	3	R	10-	4.00000
C	3	R	12-	1.00000
C	3	R	13-	2.00000
C	3	R	14-	3.00000
C	3	R	15-	4.00000
C	3	R	17-	1.00000
C	3	R	18-	2.00000
C	3	R	19-	3.00000
C	3	R	20-	4.00000
C	3	R	22-	1.00000
C	3	R	23-	2.00000
C	3	R	24-	3.00000
C	3	R	25-	4.00000
C	4	OFSET		0.00100
C	4	R	3	2.00000
C	4	R	4	3.00000
C	4	R	5	4.00000
C	4	R	7	1.00000
C	4	R	8	2.00000
C	4	R	9	3.00000
C	4	R	10	4.00000
C	4	R	12	1.00000
C	4	R	13	2.00000
C	4	R	14	3.00000

B-296

C	4 R	15	4.00000
C	4 R	17	1.00000
C	4 R	18	2.00000
C	4 R	19	3.00000
C	4 R	20	4.00000
C	4 R	22	1.00000
C	4 R	23	2.00000
C	4 R	24	3.00000
C	4 R	25	4.00000
C	5 OFFSET	0.00100	
C	5 R	3-	4.00000
C	5 R	4-	9.00000
C	5 R	5-	16.00000
C	5 R	7-	1.00000
C	5 R	8-	4.00000
C	5 R	9-	9.00000
C	5 R	10-	16.00000
C	5 R	12-	1.00000
C	5 R	13-	4.00000
C	5 R	14-	9.00000
C	5 R	15-	16.00000
C	5 R	17-	1.00000
C	5 R	18-	4.00000
C	5 R	19-	9.00000
C	5 R	20-	16.00000
C	5 R	22-	1.00000
C	5 R	23-	4.00000
C	5 R	24-	9.00000
C	5 R	25-	16.00000
C	5 R	27-	1.00000
C	5 R	28	1.00000
C	5 R	30	1.00000
C	5 R	31	1.00000
C	5 R	33	1.00000
C	5 R	34	1.00000
C	5 R	35-	1.00000
C	5 R	36	1.00000
C	5 R	37	1.00000
C	5 R	38	1.00000
C	5 R	39	1.00000
C	5 R	40	1.00000

C	6	OFSET	0.00100
C	6	R 3	4.00000
C	6	R 4	9.00000
C	6	R 5	16.00000
C	6	R 7	1.00000
C	6	R 8	4.00000
C	6	R 9	9.00000
C	6	R 10	16.00000
C	6	R 12	1.00000
C	6	R 13	4.00000
C	6	R 14	9.00000
C	6	R 15	16.00000
C	6	R 17	1.00000
C	6	R 18	4.00000
C	6	R 19	9.00000
C	6	R 20	16.00000
C	6	R 22	1.00000
C	6	R 23	4.00000
C	6	R 24	9.00000
C	6	R 25	16.00000
C	6	R 27	1.00000
C	6	R 28-	1.00000
C	6	R 30-	1.00000
C	6	R 31-	1.00000
C	6	R 33-	1.00000
C	6	R 34-	1.00000
C	6	R 35	1.00000
C	6	R 36-	1.00000
C	6	R 37-	1.00000
C	6	R 38-	1.00000
C	6	R 39-	1.00000
C	6	R 40-	1.00000
C	7	OFSET	0.00100
C	7	R 3-	8.00000
C	7	R 4-	27.00000
C	7	R 5-	64.00000
C	7	R 7-	1.00000
C	7	R 8-	8.00000
C	7	R 9-	27.00000
C	7	R 10-	64.00000
C	7	R 12-	1.00000

C	7 R	13-	8.00000
C	7 R	14-	27.00000
C	7 R	15-	64.00000
C	7 R	16-	1.00000
C	7 R	17-	8.00000
C	7 R	18-	27.00000
C	7 R	19-	64.00000
C	7 R	20-	1.00000
C	7 R	21-	8.00000
C	7 R	22-	27.00000
C	7 R	23-	64.00000
C	7 R	24-	1.00000
C	7 R	25-	8.00000
C	7 R	26-	27.00000
C	7 R	27-	64.00000
C	7 R	28	12.00000
C	7 R	29	6.00000
C	7 R	30	12.00000
C	7 R	31	6.00000
C	7 R	32	12.00000
C	7 R	33	6.00000
C	7 R	34	12.00000
C	7 R	35	6.00000
C	7 R	36	12.00000
C	7 R	37	6.00000
C	7 R	38	12.00000
C	7 R	39	6.00000
C	7 R	40	12.00000
C	8	OFFSET	0.00100
C	8 R	3	8.00000
C	8 R	4	27.00000
C	8 R	5	64.00000
C	8 R	6	1.00000
C	8 R	7	8.00000
C	8 R	8	27.00000
C	8 R	9	64.00000
C	8 R	10	1.00000
C	8 R	11	8.00000
C	8 R	12	27.00000
C	8 R	13	64.00000
C	8 R	14	1.00000
C	8 R	15	8.00000
C	8 R	16	27.00000
C	8 R	17	64.00000
C	8 R	18	1.00000
C	8 R	19	8.00000
C	8 R	20	27.00000
C	8 R	21	64.00000
C	8 R	22	1.00000
C	8 R	23	8.00000
C	8 R	24	27.00000
C	8 R	25	64.00000

C	8 R	27	6.00000
C	8 R	28-	12.00000
C	8 R	30-	6.00000
C	8 R	31-	12.00000
C	8 R	33-	6.00000
C	8 R	34-	12.00000
C	8 R	36-	6.00000
C	8 R	37-	12.00000
C	8 R	39-	6.00000
C	8 R	40-	12.00000
C	9 OFFSET		0.00100
C	9 R	4-	1.00000
C	9 R	5-	8.00000
C	9 R	9-	1.00000
C	9 R	10-	8.00000
C	9 R	14-	1.00000
C	9 R	15-	8.00000
C	9 R	19-	1.00000
C	9 R	20-	8.00000
C	9 R	24-	1.00000
C	9 R	25-	8.00000
C	9 R	28	6.00000
C	9 R	31	6.00000
C	9 R	34	6.00000
C	9 R	37	6.00000
C	9 R	40	6.00000
C	10 OFFSET		0.00100
C	10 R	4	1.00000
C	10 R	5	8.00000
C	10 R	9	1.00000
C	10 R	10	8.00000
C	10 R	14	1.00000
C	10 R	15	8.00000
C	10 R	19	1.00000
C	10 R	20	8.00000
C	10 R	24	1.00000
C	10 R	25	8.00000
C	10 R	28-	6.00000
C	10 R	31-	6.00000
C	10 R	34-	6.00000
C	10 R	37-	6.00000

C	10 R	40-	6.00000
C	11	OFFSET	0.00100
C	11 R	7-	1.00000
C	11 R	8-	1.00000
C	11 R	9-	1.00000
C	11 R	10-	1.00000
C	11 R	12-	2.00000
C	11 R	13-	2.00000
C	11 R	14-	2.00000
C	11 R	15-	2.00000
C	11 R	16-	3.00000
C	11 R	17-	3.00000
C	11 R	18-	3.00000
C	11 R	19-	3.00000
C	11 R	20-	3.00000
C	11 R	21-	4.00000
C	11 R	22-	4.00000
C	11 R	23-	4.00000
C	11 R	24-	4.00000
C	11 R	25-	4.00000
C	12	OFFSET	0.00100
C	12 R	7	1.00000
C	12 R	8	1.00000
C	12 R	9	1.00000
C	12 R	10	1.00000
C	12 R	12	2.00000
C	12 R	13	2.00000
C	12 R	14	2.00000
C	12 R	15	2.00000
C	12 R	16	3.00000
C	12 R	17	3.00000
C	12 R	18	3.00000
C	12 R	19	3.00000
C	12 R	20	3.00000
C	12 R	21	4.00000
C	12 R	22	4.00000
C	12 R	23	4.00000
C	12 R	24	4.00000
C	12 R	25	4.00000
C	13	OFFSET	0.00100
C	13 R	7-	1.00000

C	13 R	8-	2.00000
C	13 R	9-	3.00000
C	13 R	10-	4.00000
C	13 R	12-	2.00000
C	13 R	13-	4.00000
C	13 R	14-	6.00000
C	13 R	15-	8.00000
C	13 R	17-	3.00000
C	13 R	18-	6.00000
C	13 R	19-	9.00000
C	13 R	20-	12.00000
C	13 R	22-	4.00000
C	13 R	23-	8.00000
C	13 R	24-	12.00000
C	13 R	25-	16.00000
C	14 OFFSET		0.00100
C	14 R	7	1.00000
C	14 R	8	2.00000
C	14 R	9	3.00000
C	14 R	10	4.00000
C	14 R	12	2.00000
C	14 R	13	4.00000
C	14 R	14	6.00000
C	14 R	15	8.00000
C	14 R	17	3.00000
C	14 R	18	6.00000
C	14 R	19	9.00000
C	14 R	20	12.00000
C	14 R	22	4.00000
C	14 R	23	8.00000
C	14 R	24	12.00000
C	14 R	25	16.00000
C	15 OFFSET		0.00100
C	15 R	7-	1.00000
C	15 R	8-	4.00000
C	15 R	9-	9.00000
C	15 R	10-	16.00000
C	15 R	12-	2.00000
C	15 R	13-	8.00000
C	15 R	14-	18.00000
C	15 R	15-	32.00000

C	15 R	17-	3.00000
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C	15 R	20-	48.00000
C	15 R	22-	4.00000
C	15 R	23-	16.00000
C	15 R	24-	36.00000
C	15 R	25-	64.00000
C	15 R	30	1.00000
C	15 R	31	1.00000
C	15 R	33	2.00000
C	15 R	34	2.00000
C	15 R	35-	3.00000
C	15 R	36	3.00000
C	15 R	37	3.00000
C	15 R	38	4.00000
C	15 R	39	4.00000
C	15 R	40	4.00000
C	16	OFFSET	0.00100
C	16 R	7	1.00000
C	16 R	8	4.00000
C	16 R	9	9.00000
C	16 R	10	16.00000
C	16 R	12	2.00000
C	16 R	13	8.00000
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C	16 R	23	16.00000
C	16 R	24	36.00000
C	16 R	25	64.00000
C	16 R	30-	1.00000
C	16 R	31-	1.00000
C	16 R	33-	2.00000
C	16 R	34-	2.00000
C	16 R	35	3.00000
C	16 R	36-	3.00000

C	16 R	37-	3.00000
C	16 R	38-	4.00000
C	16 R	39-	4.00000
C	16 R	40-	4.00000
C	17	OFFSET	0.00100
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C	17 R	8-	8.00000
C	17 R	9-	27.00000
C	17 R	10-	64.00000
C	17 R	12-	2.00000
C	17 R	13-	16.00000
C	17 R	14-	54.00000
C	17 R	15-	128.00000
C	17 R	17-	3.00000
C	17 R	18-	24.00000
C	17 R	19-	81.00000
C	17 R	20-	192.00000
C	17 R	22-	4.00000
C	17 R	23-	32.00000
C	17 R	24-	108.00000
C	17 R	25-	256.00000
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C	17 R	36	18.00000
C	17 R	37	36.00000
C	17 R	39	24.00000
C	17 R	40	48.00000
C	18	OFFSET	0.00100
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C	18 R	10	64.00000
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C	18 R	13	16.00000
C	18 R	14	54.00000
C	18 R	15	128.00000
C	18 R	17	3.00000
C	18 R	18	24.00000
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C	18 R	24	108.00000
C	18 R	25	256.00000
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C	18 R	36-	18.00000
C	18 R	37-	36.00000
C	18 R	39-	24.00000
C	18 R	40-	48.00000
C	19	OFFSET	0.00100
C	19 R	9-	1.00000
C	19 R	10-	8.00000
C	19 R	14-	2.00000
C	19 R	15-	16.00000
C	19 R	19-	3.00000
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C	19 R	31	6.00000
C	19 R	34	12.00000
C	19 R	37	18.00000
C	19 R	40	24.00000
C	20	OFFSET	0.00100
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C	20 R	10	8.00000
C	20 R	14	2.00000
C	20 R	15	16.00000
C	20 R	19	3.00000
C	20 R	20	24.00000
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C	20 R	31-	6.00000
C	20 R	34-	12.00000
C	20 R	37-	18.00000
C	20 R	40-	24.00000
C	21	OFFSET	0.00100
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C	21 R	9-	1.00000
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C	21 R	22-	16.00000
C	21 R	23-	16.00000
C	21 R	24-	16.00000
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C	21 R	42-	1.00000
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C	21 R	49	1.00000
C	21 R	50	1.00000
C	22 OFFSET		0.00100
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C	22 R	10	1.00000
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C	22 R	13	4.00000
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C	22 R	21	16.00000

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C	22	R	49-	1.00000
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C	23	R	24-	32.00000
C	23	R	25-	48.00000
C	23	R	43	64.00000
C	23	R	44	1.00000
C	23	R	45	1.00000
C	23	R	46	2.00000
C	23	R	47	2.00000
C	23	R	48	3.00000
C	23	R	49	3.00000
C	23	R	50	4.00000
C	24	OFSET	7	4.00000
C	24	R	7	0.00100
C	24	R	8	1.00000
C	24	R	8	2.00000

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C	24	R	23	32.00000
C	24	R	24	48.00000
C	24	R	25	64.00000
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C	24	R	48-	3.00000
C	24	R	49-	4.00000
C	24	R	50-	4.00000
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C	25	R	14-	36.00000
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C	25	R	18-	36.00000
C	25	R	19-	81.00000
C	25	R	20-	144.00000
C	25	R	22-	16.00000
C	25	R	23-	64.00000
C	25	R	24-	144.00000
C	25	R	25-	256.00000
C	25	R	30	1.00000
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C	26	R	13	16.00000
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C	26	R	17	9.00000
C	26	R	18	36.00000
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C	26	R	20	144.00000
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C	26	R	33-	4.00000
C	26	R	34-	4.00000
C	26	R	35	9.00000
C	26	R	36-	9.00000
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C	26	R	38-	16.00000

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C	26	R	40-	16.00000
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C	26	R	45-	4.00000
C	26	R	46-	4.00000
C	26	R	47-	9.00000
C	26	R	48-	9.00000
C	26	R	49-	16.00000
C	26	R	50-	16.00000
C	27	OFSET		0.00100
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C	27	R	8-	8.00000
C	27	R	9-	27.00000
C	27	R	10-	64.00000
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C	27	R	24-	432.00000
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C	27	R	47	27.00000
C	27	R	48	27.00000

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C	28	R	43-	1.00000
C	28	R	44-	1.00000
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C	28	R	47-	27.00000
C	28	R	48-	27.00000
C	28	R	49-	64.00000
C	28	R	50-	64.00000
C	29	OFSET		0.00100
C	29	R	9-	1.00000
C	29	R	10-	8.00000
C	29	R	14-	4.00000
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C	29 R	34	24.00000
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C	29 R	40	96.00000
C	29 R	47	1.00000
C	29 R	48	1.00000
C	29 R	49	8.00000
C	29 R	50	8.00000
C	30 OFFSET		0.00100
C	30 R	9	1.00000
C	30 R	10	8.00000
C	30 R	14	4.00000
C	30 R	15	32.00000
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C	30 R	37-	54.00000
C	30 R	40-	96.00000
C	30 R	47-	1.00000
C	30 R	48-	1.00000
C	30 R	49-	8.00000
C	30 R	50-	8.00000
C	31 OFFSET		0.00100
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C	31 R	8-	1.00000
C	31 R	9-	1.00000
C	31 R	10-	1.00000
C	31 R	12-	8.00000
C	31 R	13-	8.00000
C	31 R	14-	8.00000
C	31 R	15-	8.00000
C	31 R	16-	27.00000
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C	31 R	18-	27.00000
C	31 R	19-	27.00000

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C	31 R	22-	64.00000
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C	31 R	42-	12.00000
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C	31 R	47	6.00000
C	31 R	48	12.00000
C	31 R	49	6.00000
C	31 R	50	12.00000
C	32 OFFSET		0.00100
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C	32 R	9	1.00000
C	32 R	10	1.00000
C	32 R	12	8.00000
C	32 R	13	8.00000
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C	32 R	25	64.00000
C	32 R	42	12.00000
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C	32 R	44-	12.00000
C	32 R	45-	6.00000
C	32 R	46-	12.00000
C	32 R	47-	6.00000
C	32 R	48-	12.00000

C	32	R	49-	6.00000
C	32	R	50-	12.00000
C	33	OFSET		0.00100
C	33	R	7-	1.00000
C	33	R	8-	2.00000
C	33	R	9-	3.00000
C	33	R	10-	4.00000
C	33	R	12-	8.00000
C	33	R	13-	16.00000
C	33	R	14-	24.00000
C	33	R	15-	32.00000
C	33	R	17-	27.00000
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C	33	R	23-	128.00000
C	33	R	24-	192.00000
C	33	R	25-	256.00000
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C	33	R	44	12.00000
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C	33	R	47	18.00000
C	33	R	48	36.00000
C	33	R	49	24.00000
C	33	R	50	48.00000
C	34	OFSET		0.00100
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C	34	R	8	2.00000
C	34	R	9	3.00000
C	34	R	10	4.00000
C	34	R	12	8.00000
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C	34	R	17	27.00000
C	34	R	18	54.00000
C	34	R	19	81.00000
C	34	R	20	108.00000
C	34	R	22	64.00000

C	34	R	23	128.00000
C	34	R	24	192.00000
C	34	R	25	256.00000
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C	34	R	44-	12.00000
C	34	R	45-	12.00000
C	34	R	46-	24.00000
C	34	R	47-	18.00000
C	34	R	48-	36.00000
C	34	R	49-	24.00000
C	34	R	50-	48.00000
C	35	OFFSET		0.00100
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C	35	R	8-	4.00000
C	35	R	9-	9.00000
C	35	R	10-	16.00000
C	35	R	12-	8.00000
C	35	R	13-	32.00000
C	35	R	14-	72.00000
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C	35	R	17-	27.00000
C	35	R	18-	108.00000
C	35	R	19-	243.00000
C	35	R	20-	432.00000
C	35	R	22-	64.00000
C	35	R	23-	256.00000
C	35	R	24-	576.00000
C	35	R	25-	1024.00000
C	35	R	30	1.00000
C	35	R	31	1.00000
C	35	R	33	8.00000
C	35	R	34	8.00000
C	35	R	35-	27.00000
C	35	R	36	27.00000
C	35	R	37	27.00000
C	35	R	38	64.00000
C	35	R	39	64.00000
C	35	R	40	64.00000
C	35	R	43	6.00000
C	35	R	44	12.00000
C	35	R	45	24.00000

C	35 R	46	48.00000
C	35 R	47	54.00000
C	35 R	48	108.00000
C	35 R	49	96.00000
C	35 R	50	192.00000
C	36	OFFSET	0.00100
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C	36 R	8	4.00000
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C	36 R	10	16.00000
C	36 R	12	8.00000
C	36 R	13	32.00000
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C	36 R	22	64.00000
C	36 R	23	256.00000
C	36 R	24	576.00000
C	36 R	25	1024.00000
C	36 R	30-	1.00000
C	36 R	31-	1.00000
C	36 R	33-	8.00000
C	36 R	34-	8.00000
C	36 R	35	27.00000
C	36 R	36-	27.00000
C	36 R	37-	27.00000
C	36 R	38-	64.00000
C	36 R	39-	64.00000
C	36 R	40-	64.00000
C	36 R	43-	6.00000
C	36 R	44-	12.00000
C	36 R	45-	24.00000
C	36 R	46-	48.00000
C	36 R	47-	54.00000
C	36 R	48-	108.00000
C	36 R	49-	96.00000
C	36 R	50-	192.00000
C	37	OFFSET	0.00100

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C	37 R	9-	27.00000
C	37 R	10-	64.00000
C	37 R	12-	8.00000
C	37 R	13-	64.00000
C	37 R	14-	216.00000
C	37 R	15-	512.00000
C	37 R	17-	27.00000
C	37 R	18-	216.00000
C	37 R	19-	729.00000
C	37 R	20-	1728.00000
C	37 R	22-	64.00000
C	37 R	23-	512.00000
C	37 R	24-	1728.00000
C	37 R	25-	4096.00000
C	37 R	30	6.00000
C	37 R	31	12.00000
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C	37 R	34	96.00000
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C	37 R	37	324.00000
C	37 R	39	384.00000
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C	37 R	46	96.00000
C	37 R	47	162.00000
C	37 R	48	324.00000
C	37 R	49	384.00000
C	37 R	50	768.00000
C	38 OFFSET		0.00100
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C	38 R	9	27.00000
C	38 R	10	64.00000
C	38 R	12	8.00000
C	38 R	13	64.00000
C	38 R	14	216.00000
C	38 R	15	512.00000

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C	38 R	17	27.00000
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C	38 R	22	64.00000
C	38 R	23	512.00000
C	38 R	24	1728.00000
C	38 R	25	4096.00000
C	38 R	30-	6.00000
C	38 R	31-	12.00000
C	38 R	33-	48.00000
C	38 R	34-	96.00000
C	38 R	36-	162.00000
C	38 R	37-	324.00000
C	38 R	39-	384.00000
C	38 R	40-	768.00000
C	38 R	43-	6.00000
C	38 R	44-	12.00000
C	38 R	45-	48.00000
C	38 R	46-	96.00000
C	38 R	47-	162.00000
C	38 R	48-	324.00000
C	38 R	49-	384.00000
C	38 R	50-	768.00000
C	39 OFFSET		0.00100
C	39 R	9-	1.00000
C	39 R	10-	8.00000
C	39 R	14-	8.00000
C	39 R	15-	64.00000
C	39 R	19-	27.00000
C	39 R	20-	216.00000
C	39 R	24-	64.00000
C	39 R	25-	512.00000
C	39 R	31	6.00000
C	39 R	34	48.00000
C	39 R	37	162.00000
C	39 R	40	384.00000
C	39 R	47	6.00000
C	39 R	48	12.00000
C	39 R	49	48.00000
C	39 R	50	96.00000

C	40	OFSET	0.00100
C	40	R 9	1.00000
C	40	R 10	8.00000
C	40	R 14	8.00000
C	40	R 15	64.00000
C	40	R 19	27.00000
C	40	R 20	216.00000
C	40	R 24	64.00000
C	40	R 25	512.00000
C	40	R 31-	6.00000
C	40	R 34-	48.00000
C	40	R 37-	162.00000
C	40	R 40-	384.00000
C	40	R 47-	6.00000
C	40	R 48-	12.00000
C	40	R 49-	48.00000
C	40	R 50-	96.00000
C	41	OFSET	0.00100
C	41	R 16-	1.00000
C	41	R 17-	1.00000
C	41	R 18-	1.00000
C	41	R 19-	1.00000
C	41	R 20-	1.00000
C	41	R 21-	8.00000
C	41	R 22-	8.00000
C	41	R 23-	8.00000
C	41	R 24-	8.00000
C	41	R 25-	8.00000
C	41	R 42-	6.00000
C	41	R 44	6.00000
C	41	R 46	6.00000
C	41	R 48	6.00000
C	41	R 50	6.00000
C	42	OFSET	0.00100
C	42	R 16	1.00000
C	42	R 17	1.00000
C	42	R 18	1.00000
C	42	R 19	1.00000
C	42	R 20	1.00000
C	42	R 21	8.00000
C	42	R 22	8.00000

C	42	R	23	8.00000
C	42	R	24	8.00000
C	42	R	25	8.00000
C	42	R	42	6.00000
C	42	R	44-	6.00000
C	42	R	46-	6.00000
C	42	R	48-	6.00000
C	42	R	50-	6.00000
C	43	OFFSET		0.00100
C	43	R	17-	1.00000
C	43	R	18-	2.00000
C	43	R	19-	3.00000
C	43	R	20-	4.00000
C	43	R	22-	8.00000
C	43	R	23-	16.00000
C	43	R	24-	24.00000
C	43	R	25-	32.00000
C	43	R	44	6.00000
C	43	R	46	12.00000
C	43	R	48	18.00000
C	43	R	50	24.00000
C	44	OFFSET		0.00100
C	44	R	17	1.00000
C	44	R	18	2.00000
C	44	R	19	3.00000
C	44	R	20	4.00000
C	44	R	22	8.00000
C	44	R	23	16.00000
C	44	R	24	24.00000
C	44	R	25	32.00000
C	44	R	44-	6.00000
C	44	R	46-	12.00000
C	44	R	48-	18.00000
C	44	R	50-	24.00000
C	45	OFFSET		0.00100
C	45	R	17-	1.00000
C	45	R	18-	4.00000
C	45	R	19-	9.00000
C	45	R	20-	16.00000
C	45	R	22-	8.00000
C	45	R	23-	32.00000

C	45	R	24-	72.00000
C	45	R	25-	128.00000
C	45	R	35-	1.00000
C	45	R	36	1.00000
C	45	R	37	1.00000
C	45	R	38	8.00000
C	45	R	39	8.00000
C	45	R	40	8.00000
C	45	R	44	6.00000
C	45	R	46	24.00000
C	45	R	48	54.00000
C	45	R	50	96.00000
C	46	OFFSET		0.00100
C	46	R	17	1.00000
C	46	R	18	4.00000
C	46	R	19	9.00000
C	46	R	20	16.00000
C	46	R	22	8.00000
C	46	R	23	32.00000
C	46	R	24	72.00000
C	46	R	25	128.00000
C	46	R	35	1.00000
C	46	R	36-	1.00000
C	46	R	37-	1.00000
C	46	R	38-	8.00000
C	46	R	39-	8.00000
C	46	R	40-	8.00000
C	46	R	44-	6.00000
C	46	R	46-	24.00000
C	46	R	48-	54.00000
C	46	R	50-	96.00000
C	47	OFFSET		0.00100
C	47	R	17-	1.00000
C	47	R	18-	8.00000
C	47	R	19-	27.00000
C	47	R	20-	64.00000
C	47	R	22-	8.00000
C	47	R	23-	64.00000
C	47	R	24-	216.00000
C	47	R	25-	512.00000
C	47	R	36	6.00000

C	47 R	37	12.00000
C	47 R	39	48.00000
C	47 R	40	96.00000
C	47 R	44	6.00000
C	47 R	46	48.00000
C	47 R	48	162.00000
C	47 R	50	384.00000
C	48 OFFSET		0.00100
C	48 R	17	1.00000
C	48 R	18	8.00000
C	48 R	19	27.00000
C	48 R	20	64.00000
C	48 R	22	8.00000
C	48 R	23	64.00000
C	48 R	24	216.00000
C	48 R	25	512.00000
C	48 R	36-	6.00000
C	48 R	37-	12.00000
C	48 R	39-	48.00000
C	48 R	40-	96.00000
C	48 R	44-	6.00000
C	48 R	46-	48.00000
C	48 R	48-	162.00000
C	48 R	50-	384.00000
C	49 OFFSET		0.00100
C	49 R	19-	1.00000
C	49 R	20-	8.00000
C	49 R	24-	8.00000
C	49 R	25-	64.00000
C	49 R	37	6.00000
C	49 R	40	48.00000
C	49 R	48	6.00000
C	49 R	50	48.00000
C	50 OFFSET		0.00100
C	50 R	19	1.00000
C	50 R	20	8.00000
C	50 R	24	8.00000
C	50 R	25	64.00000
C	50 R	37-	6.00000
C	50 R	40-	48.00000
C	50 R	48-	6.00000

C	50	R	50-	48.00000
C	51	OFSET		1000.00000
C	51	R	3	1.0
C	52	OFSET		1000.00000
C	52	R	3-	1.0
C	53	OFSET		1000.00000
C	53	R	4	1.0
C	54	OFSET		1000.00000
C	54	R	4-	1.0
C	55	OFSET		1000.00000
C	55	R	5	1.0
C	56	OFSET		1000.00000
C	56	R	5-	1.0
C	57	OFSET		1000.00000
C	57	R	7	1.0
C	58	OFSET		1000.00000
C	58	R	7-	1.0
C	59	OFSET		1000.00000
C	59	R	8	1.0
C	60	OFSET		1000.00000
C	60	R	8-	1.0
C	61	OFSET		1000.00000
C	61	R	9	1.0
C	62	OFSET		1000.00000
C	62	R	9-	1.0
C	63	OFSET		1000.00000
C	63	R	10	1.0
C	64	OFSET		1000.00000
C	64	R	10-	1.0
C	65	OFSET		1000.00000
C	65	R	12	1.0
C	66	OFSET		1000.00000
C	66	R	12-	1.0
C	67	OFSET		1000.00000
C	67	R	13	1.0
C	68	OFSET		1000.00000
C	68	R	13-	1.0
C	69	OFSET		1000.00000
C	69	R	14	1.0
C	70	OFSET		1000.00000
C	70	R	14-	1.0

C	71	OFSET	1000.00000
C	71	R 15	1.0
C	72	OFSET	1000.00000
C	72	R 15-	1.0
C	73	OFSET	1000.00000
C	73	R 16	1.0
C	74	OFSET	1000.00000
C	74	R 16-	1.0
C	75	OFSET	1000.00000
C	75	R 17	1.0
C	76	OFSET	1000.00000
C	76	R 17-	1.0
C	77	OFSET	1000.00000
C	77	R 18	1.0
C	78	OFSET	1000.00000
C	78	R 18-	1.0
C	79	OFSET	1000.00000
C	79	R 19	1.0
C	80	OFSET	1000.00000
C	80	R 19-	1.0
C	81	OFSET	1000.00000
C	81	R 20	1.0
C	82	OFSET	1000.00000
C	82	R 20-	1.0
C	83	OFSET	1000.00000
C	83	R 21	1.0
C	84	OFSET	1000.00000
C	84	R 21-	1.0
C	85	OFSET	1000.00000
C	85	R 22	1.0
C	86	OFSET	1000.00000
C	86	R 22-	1.0
C	87	OFSET	1000.00000
C	87	R 23	1.0
C	88	OFSET	1000.00000
C	88	R 23-	1.0
C	89	OFSET	1000.00000
C	89	R 24	1.0
C	90	OFSET	1000.00000
C	90	R 24-	1.0
C	91	OFSET	1000.00000

C 91 R 25	1.0
C 92 OFSET	1000.00000
C 92 R 25-	1.0
C 93 OFSET	000.00000
C 93 R 27	1.0
C 94 OFSET	000.00000
C 94 R 28	1.0
C 95 OFSET	000.00000
C 95 R 30	1.0
C 96 OFSET	000.00000
C 96 R 31	1.0
C 97 OFSET	000.00000
C 97 R 33	1.0
C 98 OFSET	000.00000
C 98 R 34	1.0
C 99 OFSET	000.00000
C 99 R 35	1.0
C 100 OFSET	000.00000
C 100 R 36	1.0
C 101 OFSET	000.00000
C 101 R 37	1.0
C 102 OFSET	000.00000
C 102 R 38	1.0
C 103 OFSET	000.00000
C 103 R 39	1.0
C 104 OFSET	000.00000
C 104 R 40	1.0
C 105 OFSET	000.00000
C 105 R 42	1.0
C 106 OFSET	000.00000
C 106 R 43	1.0
C 107 OFSET	000.00000
C 107 R 44	1.0
C 108 OFSET	000.00000
C 108 R 45	1.0
C 109 OFSET	000.00000
C 109 R 46	1.0
C 110 OFSET	000.00000
C 110 R 47	1.0
C 111 OFSET	000.00000
C 111 R 48	1.0

C 112	OFSET	000.00000
C 112 R 49		1.0
C 113	OFSET	000.00000
C 113 R 50		1.0
FIRST B		
R	3	2.45833
R	4	3.87499
R	5	5.33333
R	7	1.24702
R	8	2.69791
R	9	4.19791
R	10	5.81250
R	12	1.47916
R	13	2.97916
R	14	4.58333
R	15	6.33333
R	16	.34374
R	17	1.79166
R	18	3.44791
R	19	5.25000
R	20	7.16666
R	21	.70833
R	22	2.41666
R	23	4.32291
R	24	6.41666
R	25	8.58333
R	27	0.00000
R	28	0.00000
R	30	0.00000
R	31	0.00000
R	33	0.00000
R	34	0.00000
R	35	0.00000
R	36	0.00000
R	37	0.00000
R	38	0.00000
R	39	0.00000
R	40	0.00000
R	42	000.00000
R	43	000.00000
R	44	000.00000

EOF

R 45	000.00000
R 46	000.00000
R 47	000.00000
R 48	000.00000
R 49	000.00000
R 50	000.00000

Section IV

SMDG 4

The SMDG 4 program produces a matrix for fairing a two-dimensional curve, either double or single splined, with the primal formulation and sum of the deviations fit. The program is written in FORTRAN II for the IBM-1620 computer.

Fortran Symbol Definitions

N	-	The number of data offsets along the curve
COSTB	-	The cost associated with slacks
COSTN	-	The cost on the non-slack variables
X(I)	-	The x coordinate of the offset
Y(I)	-	The y coordinate of the offset if read in feet and decimals.
AA	-	The number of feet in the offset if read in feet, inches, and eighths
BB	-	The number of inches in the offset if read in feet, inches, and eighths
CC	-	The number of eighths in the offset if read in feet, inches, and eighths
SX	-	Scaling factor for normalizing the x coordinates. It equals $x_1 - x_0$ if set by the program.
TX	-	Translation factor for the x coordinates. It equals x_0 if set by the program.

Input Card Formats

The card formats are arranged as follows:

<u>Contents</u>					<u>Card No.</u>
Column	1-5				1
Contains any alphameric heading					
Format	I5	F10.4	F10.4		2
Variable	N	COSTB	COSTN		
Alternate Cards:					
Format	F10.4	F5.1	F5.1	F5.1	} Next N Cards
Variable	X(I)	$\pm$ AA	$\pm$ BB	$\pm$ CC	
or					
Format	F10.4	F10.4			} Last Card
Variable	X(I)	Y(I)			
Format	F10.4	F10.4			
Variable	SX	TX			

Output

The output is in a form suitable for the 1620 Users Group, Linear Programming Routine No. 10.0.006.

Sense Switches

- Switch 1 ON - The curve will be double splined
- Switch 1 OFF - The curve will be single splined
- Switch 2 ON - The scaling factors will be read from the card reader
- Switch 2 OFF - The program will set the scaling factors
- Switch 3 ON - The second differences will be printed
- Switch 3 OFF - The second differences will not be printed

SMDG 4

TYPEWRITER LISTING OF SECOND DIFFERENCES OF SAMPLE DATA

2ND DIFF - W LINES

STA	ACT VALUE	SIGN
2	.000169	-1.00
3	.000238	-1.00
4	.000068	-1.00
5	.000068	-1.00

* * SAMPLE INPUT * *

D1037
 5 999.9999 .001
 87.500000 30.5729
 105.000000 30.307300
 122.500000 30.09375
 140.000000 29.953120
 157.500000 29.833330

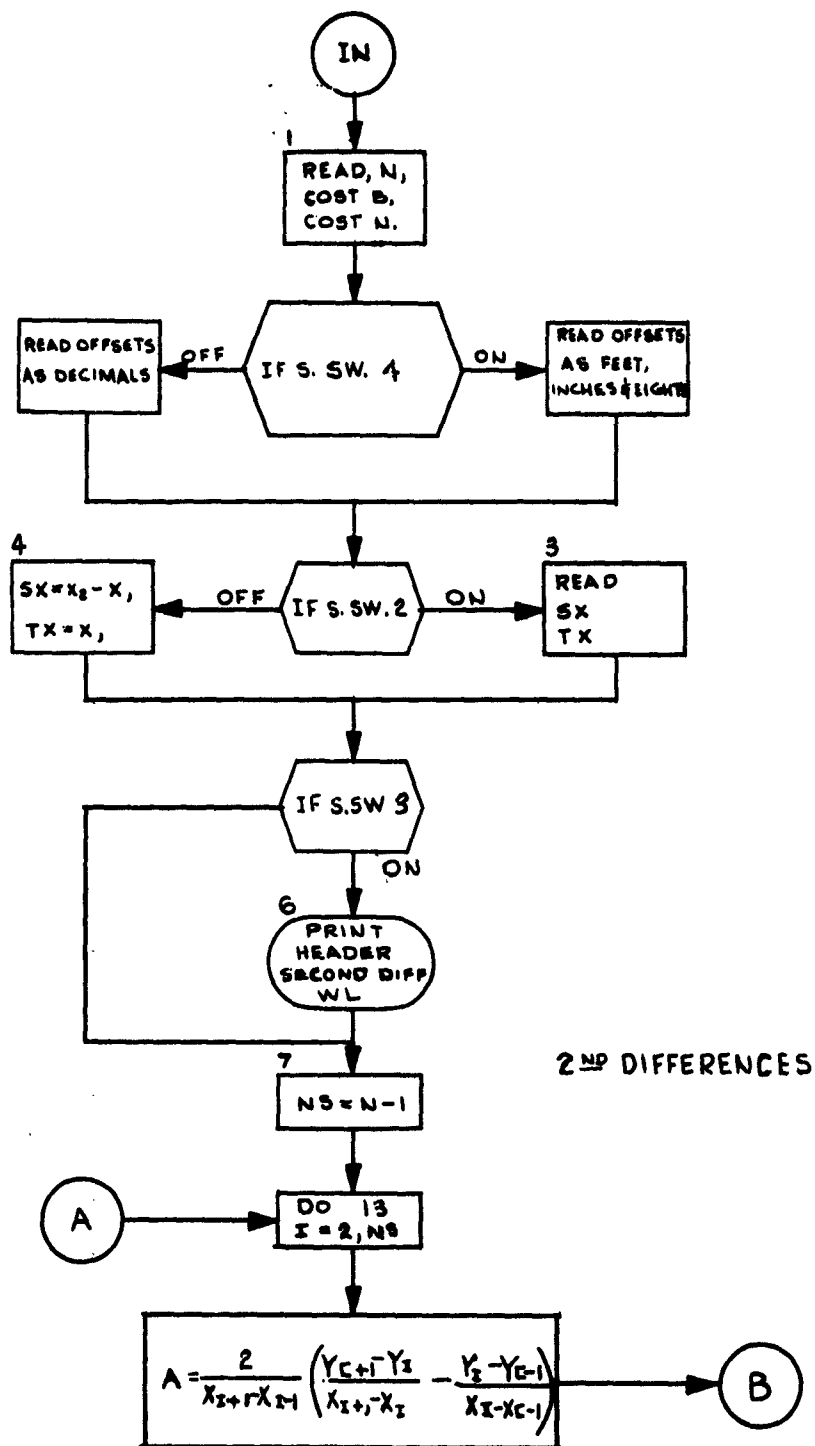
OUTPUT MATRIX FROM SAMPLE DATA

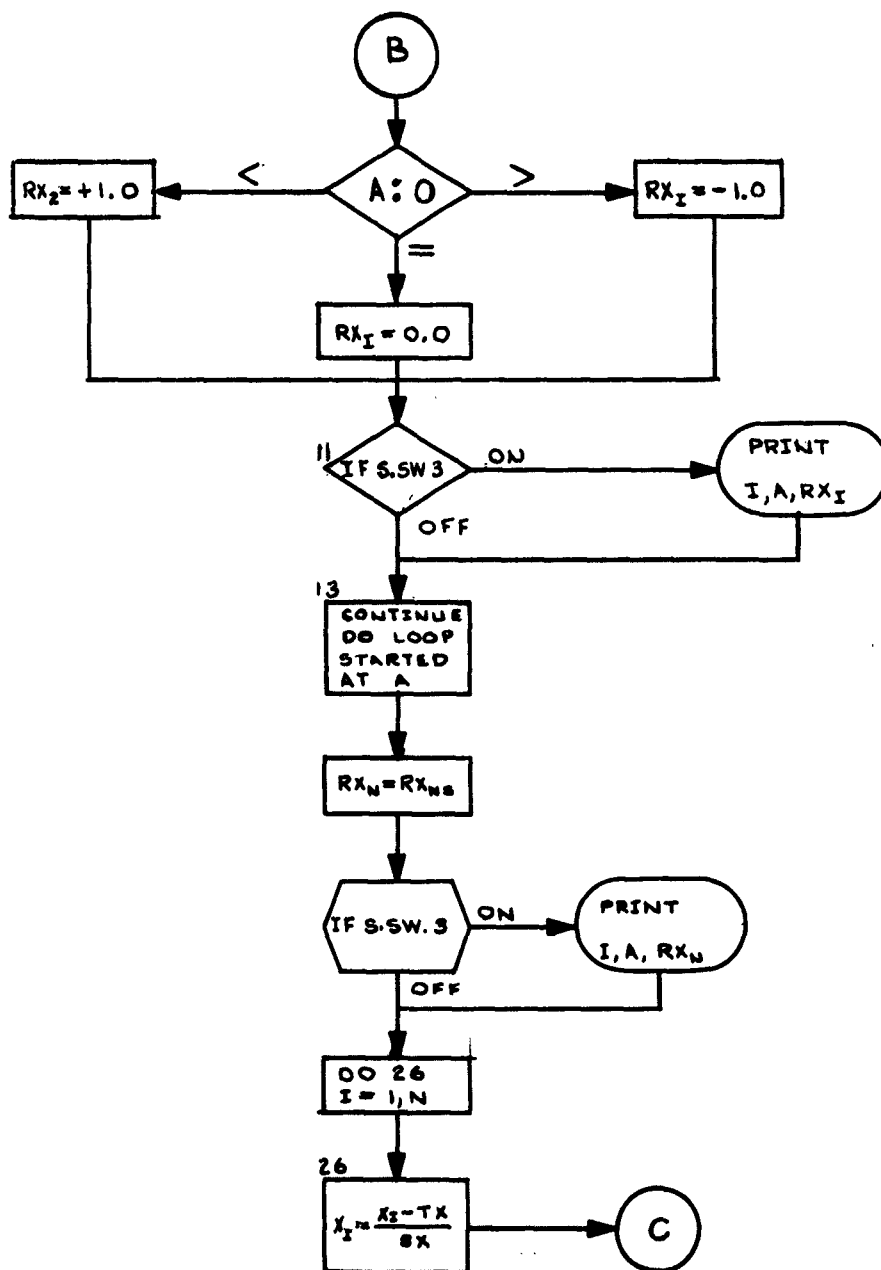
* * SAMPLE OUTPUT * *

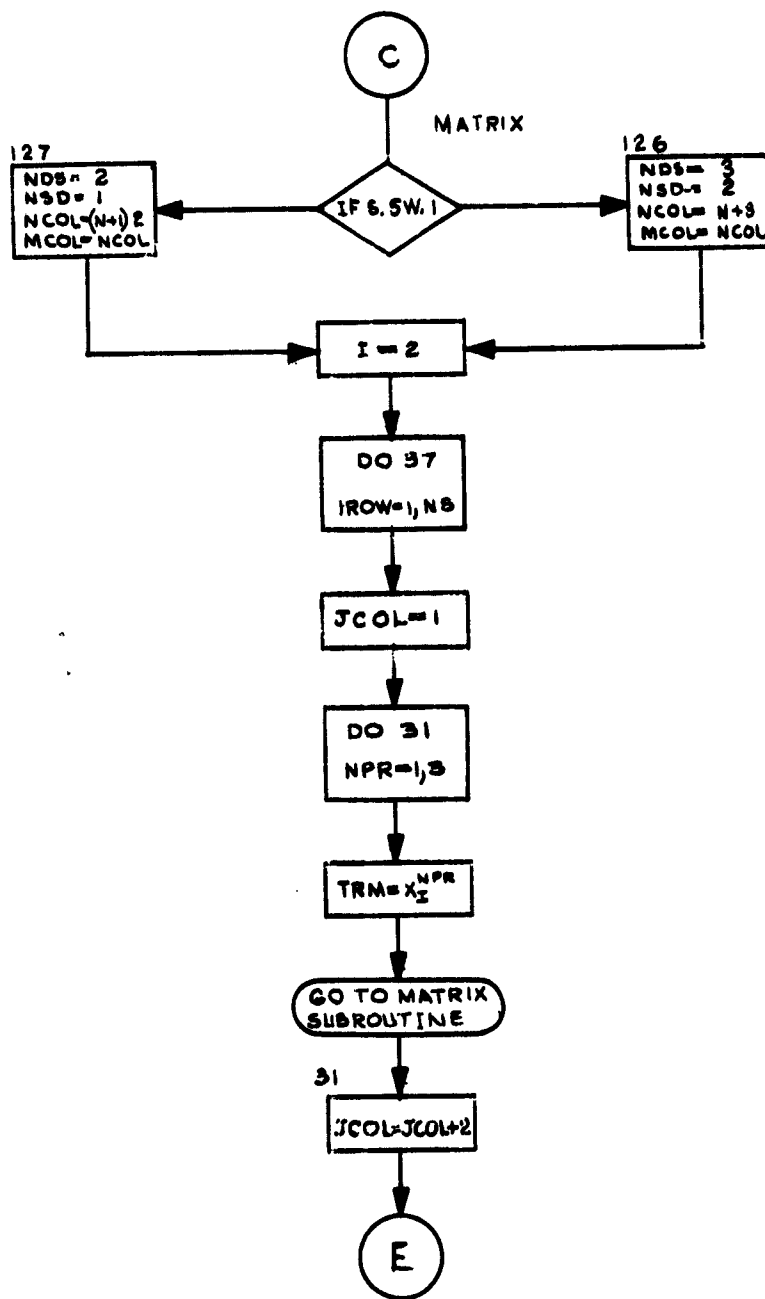
D1037
 006 008 1
 001 001 1.0000
 001 002 - 1.0000
 001 003 1.0000
 001 004 - 1.0000
 001 005 1.0000
 001 006 - 1.0000
 001 009 1.0000
 002 001 2.0000
 002 002 - 2.0000
 002 003 4.0000
 002 004 - 4.0000
 002 005 8.0000
 002 006 - 8.0000
 002 010 1.0000
 003 001 3.0000
 003 002 - 3.0000
 003 003 9.0000
 003 004 - 9.0000
 003 005 27.0000
 003 006 - 27.0000
 003 007 1.0000
 003 008 - 1.0000
 003 011 1.0000
 004 001 4.0000
 004 002 - 4.0000
 004 003 16.0000
 004 004 - 16.0000
 004 005 64.0000
 004 006 - 64.0000
 004 007 8.0000

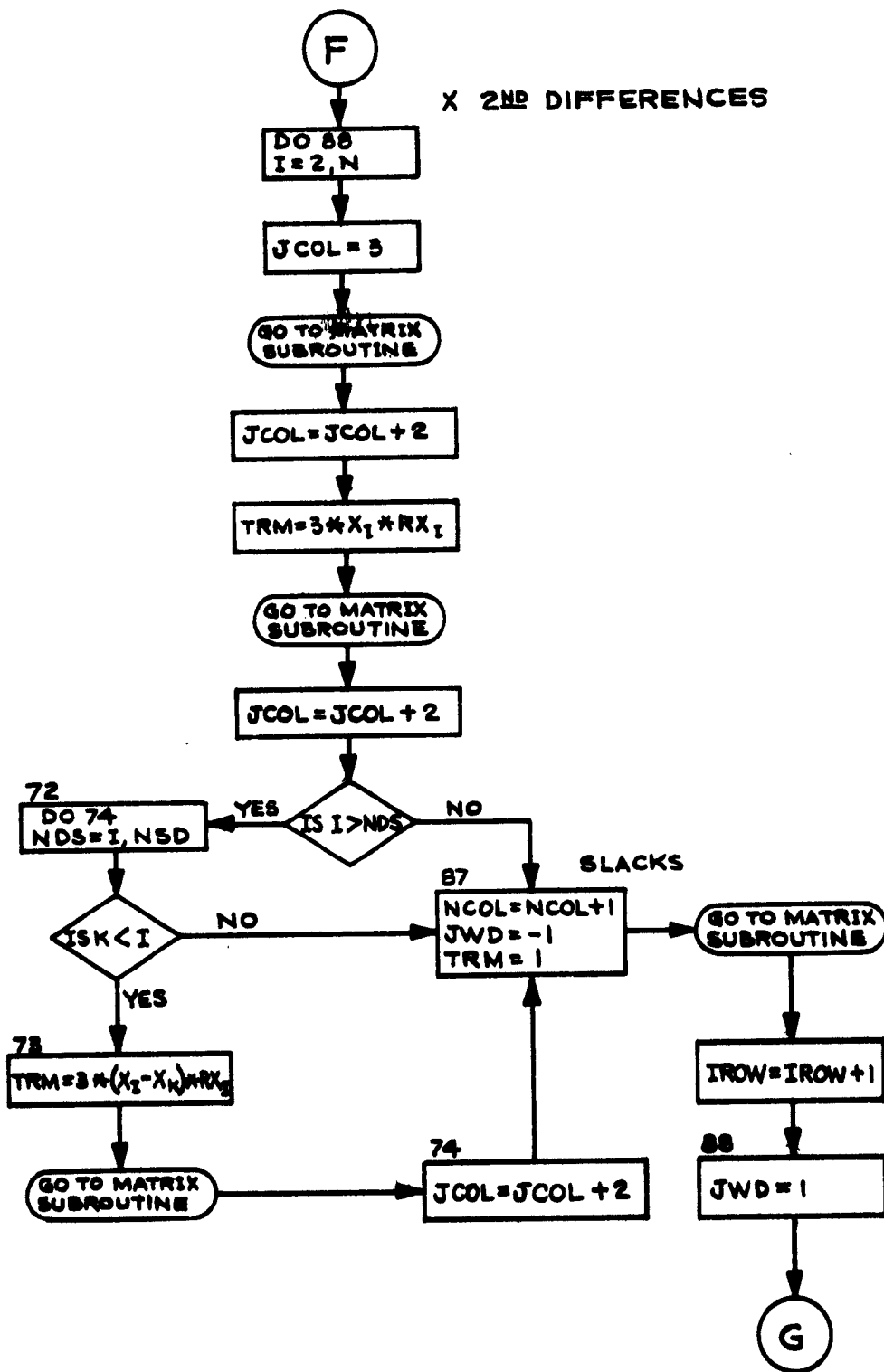
004	008	-	8.0000
004	012		1.0000
005	003	-	1.0000
005	004		1.0000
005	005	-	6.0000
005	006		6.0000
005	013		1.0000
006	003	-	1.0000
006	004		1.0000
006	005	-	12.0000
006	006		12.0000
006	007	-	6.0000
006	008		6.0000
006	014		1.0000
00J	001	101	100000J
00J	002	102	100000J
00J	003	103	100000J
00J	004	104	100000J
00J	005	105	100000J
00J	006	106	100000J
00J	007	107	100000J
00J	008	108	100000J
00J	009	109	199999R
00J	010	110	199999R
00J	011	111	199999R
00J	012	112	199999R
00J	013	113	199999R
00J	014	114	199999R
001	00J	101	299999R
002	00J	102	299999R
003	00J	103	299999R
004	00J	104	299999R
005	00J	105	200000-
006	00J	106	200000-
001	000	-	.2656
002	000	-	.4791
003	000	-	.6197
004	000	-	.7395
000			

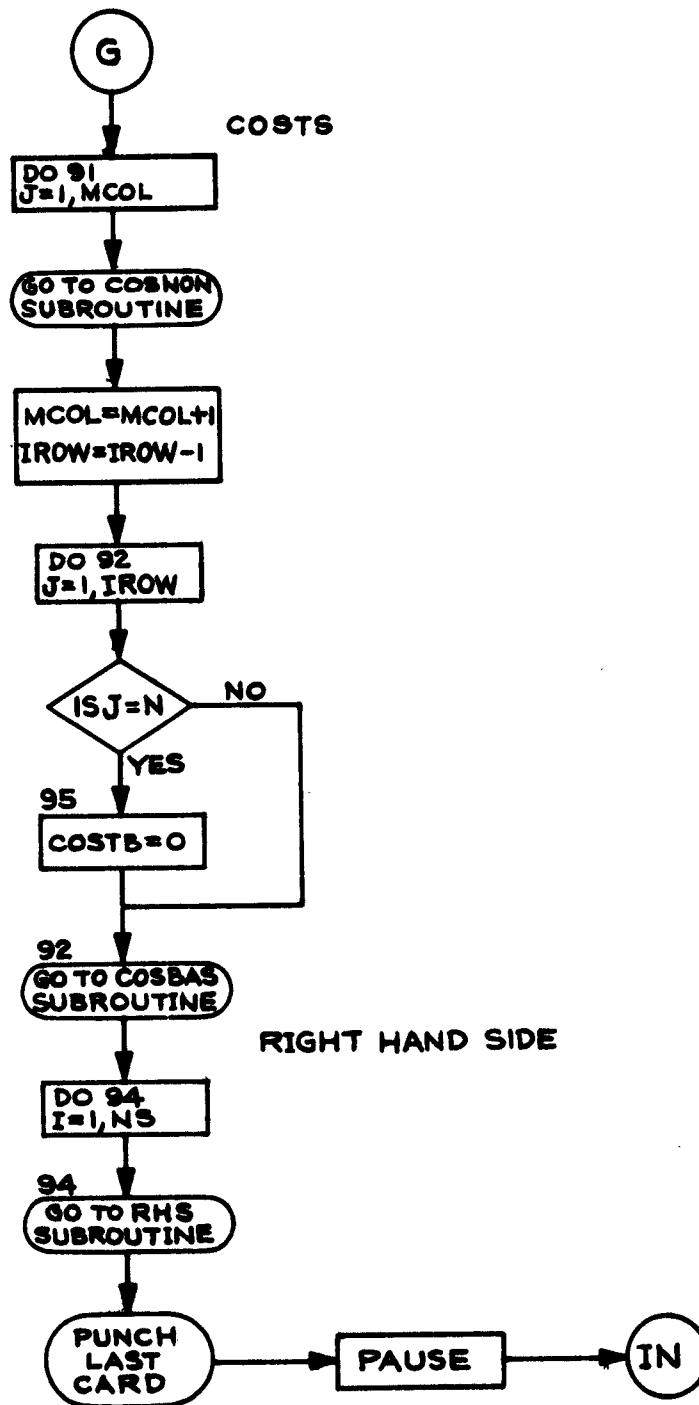
FLOW DIAGRAM - SMOG 4

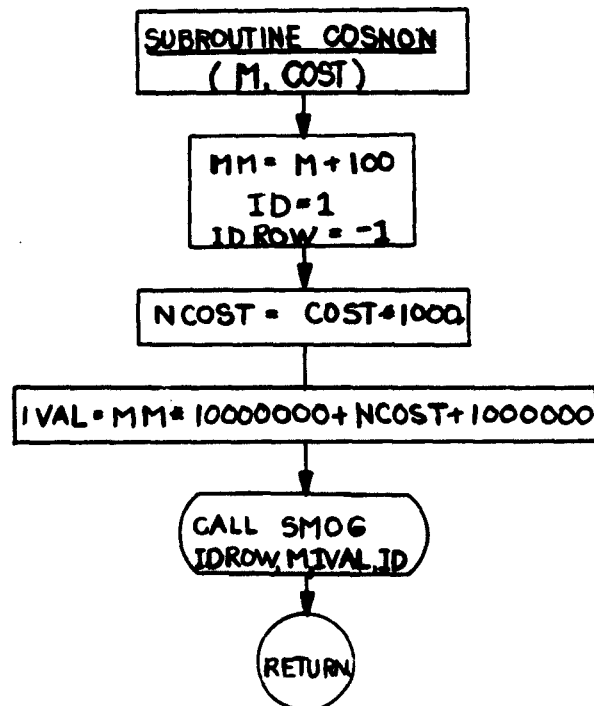
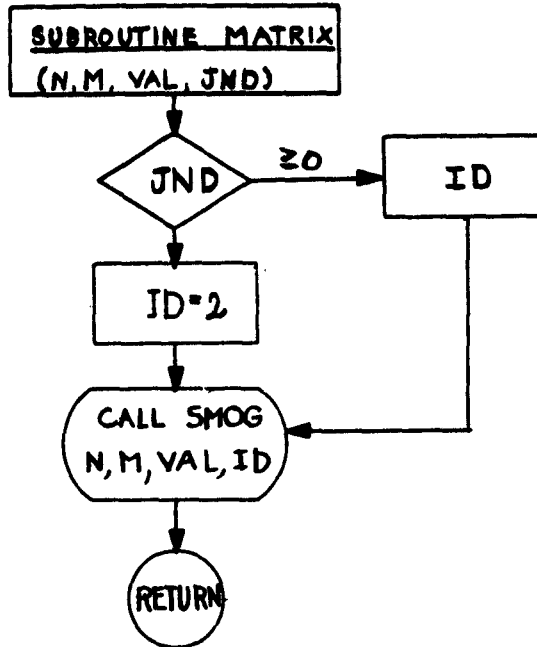


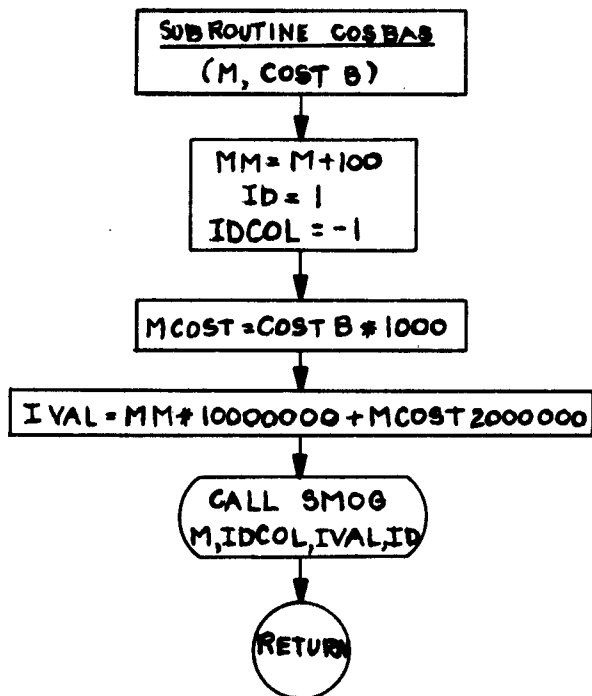
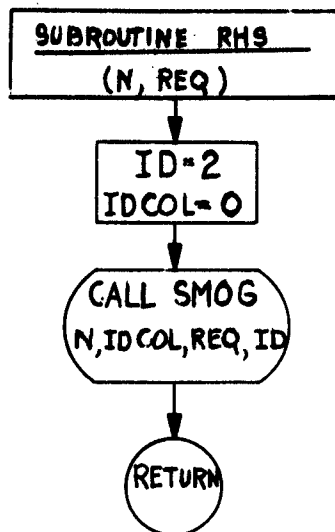


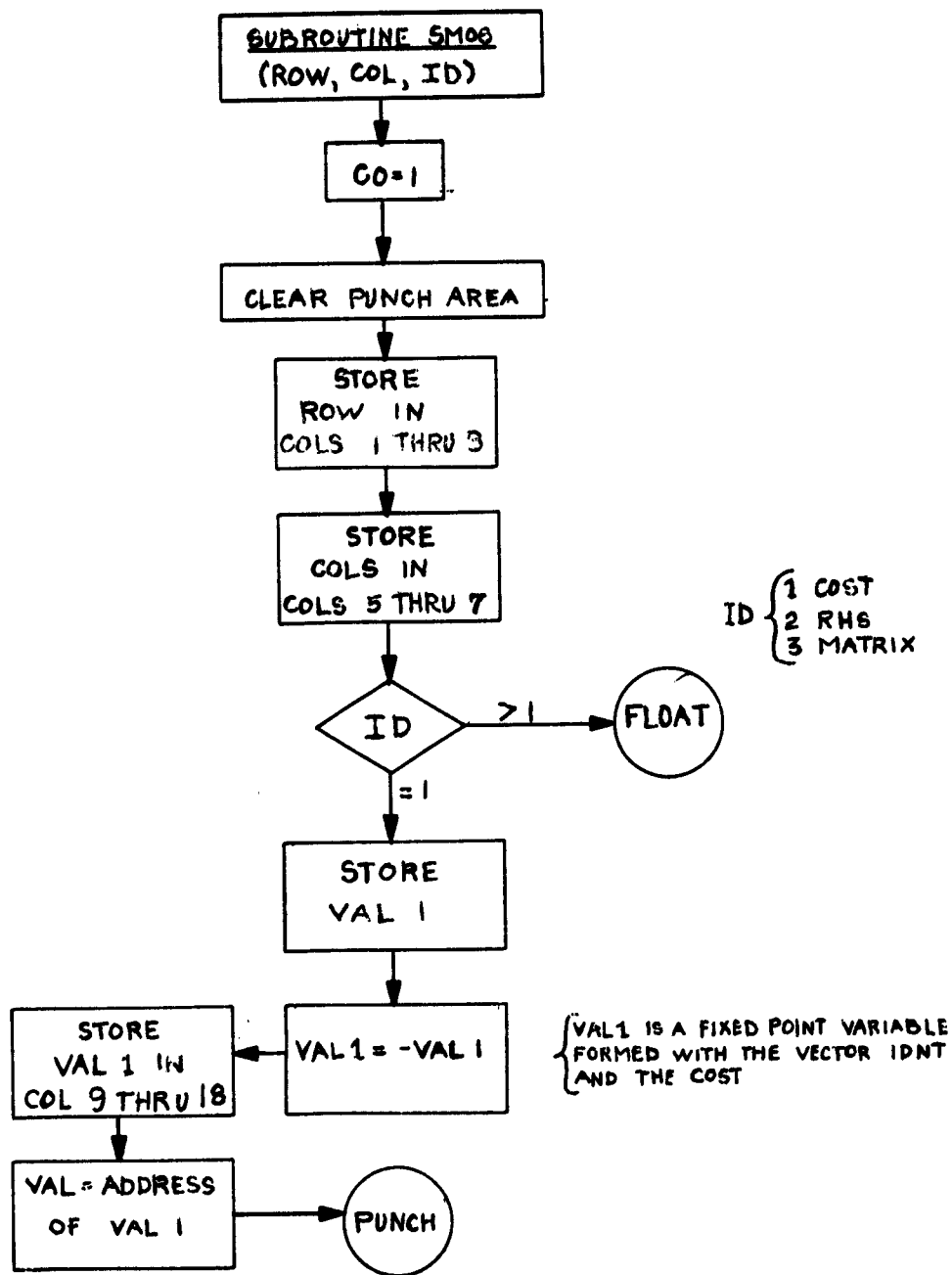


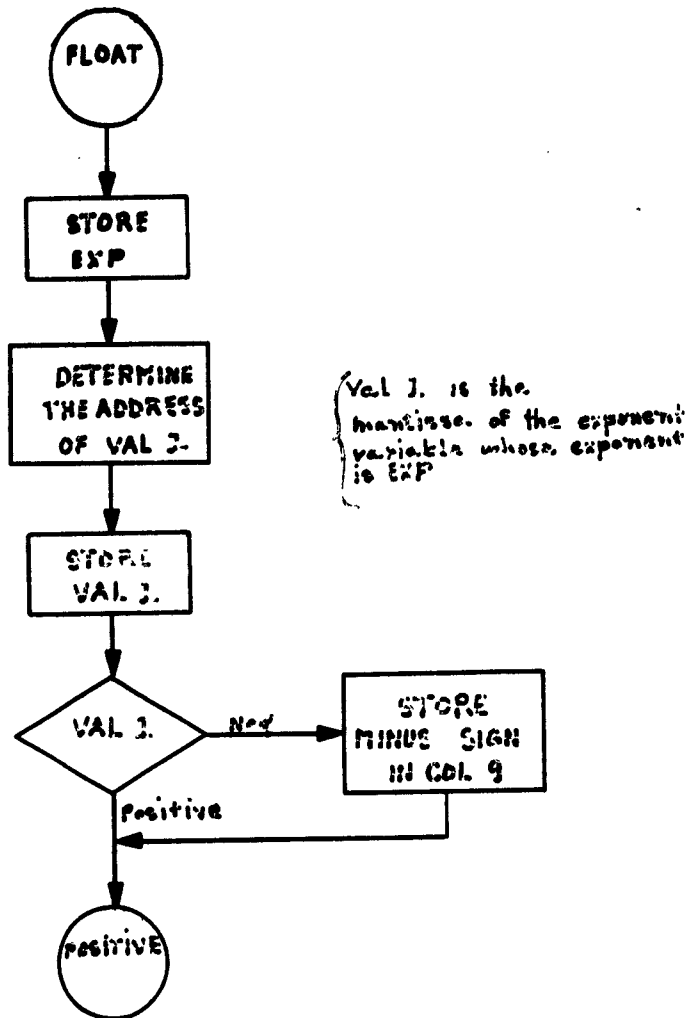


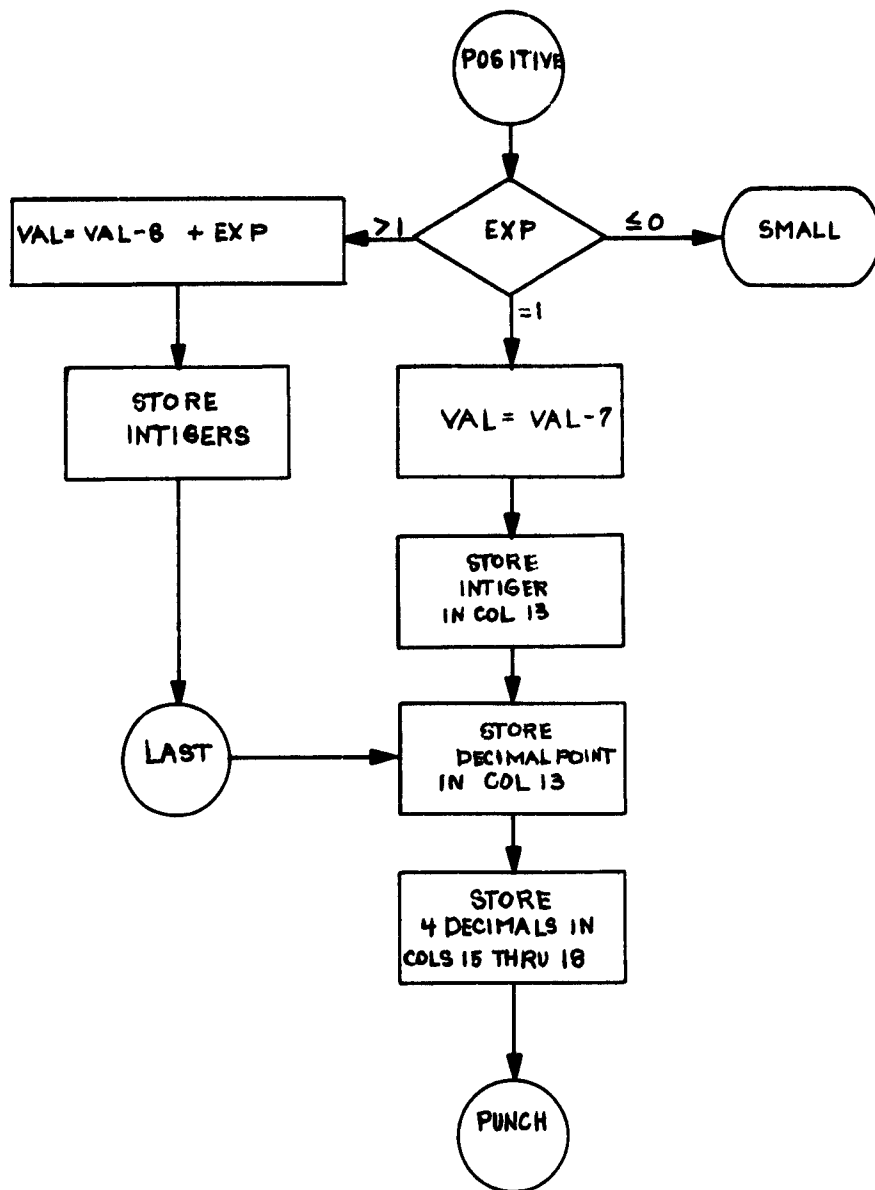


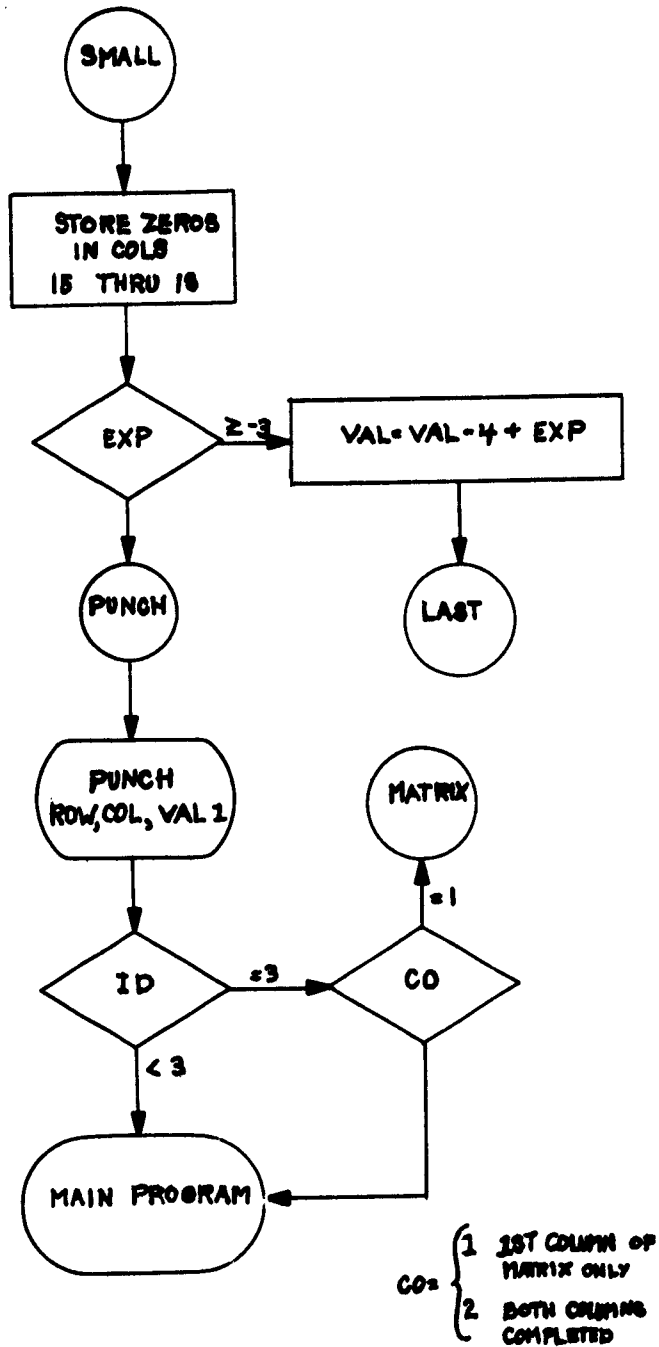


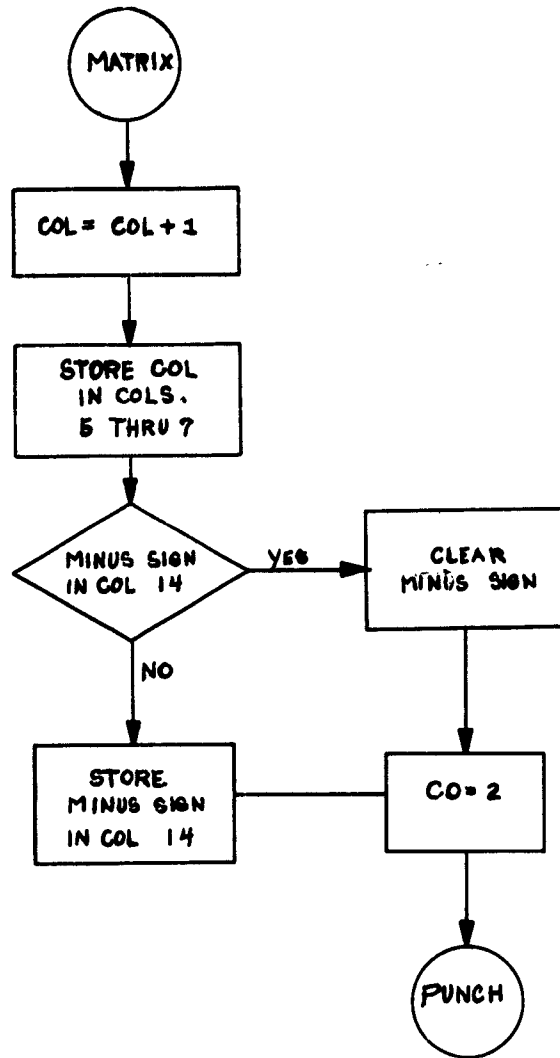


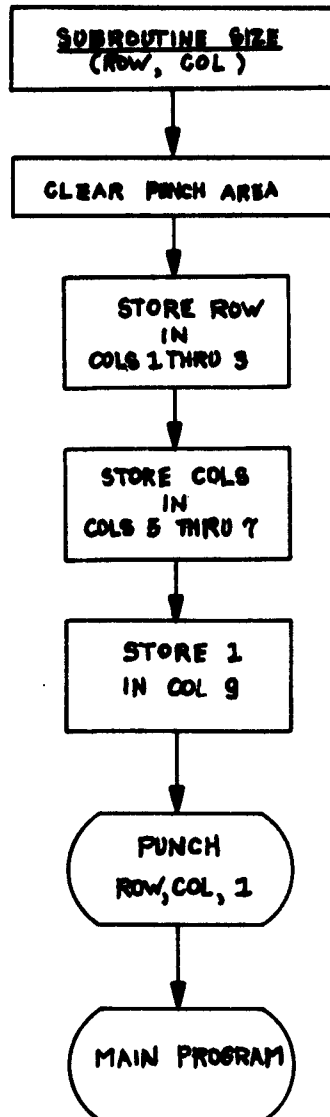












FORTRAN LISTING - SMOG 4

```

*0810
C   SMOG FOR 1620 LP 4/2/63
    DIMENSION X(30),Y(30),RX(30)
    1 READ 600
      PUNCH 600
      READ 150,N,COSTB,COSTN
      JWD=1
      NL=N+1
      DO 2 I=1,N
        IF(SENSE SWITCH 4)201,202
201  READ 160,X(I),AA,BB,CC
      Y(I)=AA+(BB+(CC/8.))/12.
      GO TO 2
202  READ 152,X(I),Y(I)
    2 CONTINUE
      IF(SENSE SWITCH 2)3,4
    3 READ 152,SX,TX
      GO TO 5
    4 SX=X(2)-X(1)
      TX=X(1)
    5 IF(SENSE SWITCH 3)6,7
    6 PRINT 157
      * * SECOND DIFFERENCES * *
    7 NS=N-1
      DO 13 I=2,NS
        A=2./((X(I+1)-X(I-1)))
        ZA=Y(I+1)-Y(I)
        A=A*(ZA/(X(I+1)-X(I))-(Y(I)-Y(I-1))/(X(I)-X(I-1)))
        IF(A)10,9,8
    8 RX(I)=-1.
      GO TO 11
    9 RX(I)=0.
      GO TO 11
   10 RX(I)=1.
   11 IF(SENSE SWITCH 3)12,13
   12 PRINT 158,I,A,RX(I)
   13 CONTINUE
      RX(N)=RX(NS)
      IF(SENSE SWITCH 3)14,15
   14 PRINT 158,I,A,RX(N)
      * * NORMALIZING * *
   15 DO 26 I=1,N
   26 X(I)=(X(I)-TX)/SX
      * * MATRIX * *
      IF(SENSE SWITCH 1)126,127
126  NDS=3
      NSD=2
      NCOL=3+N

```

```

        NROW=N-1+(N-1)/2
        GO TO 128
127 NDS=2
    NSD=1
    NCOL=(N+1)*2
    NROW=2*(N-1)
128 MCOL=NCOL
    I=2
    CALL SIZE (NROW,MCOL)
    DO 37 IROW=1,NS
        JCOL=1
        DO 31 NPR=1,3
            TRM=X(I)**NPR
            CALL MATRIX(IROW,JCOL,TRM,JWD)
31 JCOL=JCOL+2
        IF(I-NDS)137,137,32
32 DO 34 IT=NDS,I
        IF(I-IT)34,34,133
133 IF(SENSE SWITCH 1)134,33
134 IF(IT-2*(IT/2))33,34,33
33 TRM=(X(I)-X(IT))**3
    CALL MATRIX(IROW,JCOL,TRM,JWD)
    JCOL=JCOL+2
34 CONTINUE
137 NCOL=NCOL+1
    JWD=-1
    TRM=1.
    CALL MATRIX(IROW,NCOL,TRM,JWD)
    JWD=1
37 I=I+1
C      *      *      X SECOND DIFFERENCES      *      *
    DO 88 I=NDS,N,NSD
        JCOL=3
        CALL MATRIX(IROW,JCOL,RX(I),JWD)
        JCOL=JCOL+2
        TRM=3.*X(I)*RX(I)
        CALL MATRIX(IROW,JCOL,TRM,JWD)
        JCOL=JCOL+2
        IF(I-NDS)75,75,72
72 DO 74 K=NDS,I,NSD
        IF(K-1)73,75,75
73 TRM=3.*(X(I)-X(K))*RX(I)
        CALL MATRIX(IROW,JCOL,TRM,JWD)
74 JCOL=JCOL+2
75 CONTINUE
C      *      *      SLACKS      *      *
87 NCOL=NCOL+1
    JWD=-1

```

```

      TRM=1.
      CALL MATRIX(IROW,NCOL,TRM,JWD)
      IROW=IROW+1
88 JWD=1
C      *      *      COSTS      *      *
      DO 91 J=1,MCOL
91 CALL COSNON(J,COSTN)
      IROW=IROW-1
      MCOL=MCOL+IROW
      DO 300 I=J,MCOL
300 CALL COSNON(I,COSTB)
      DO 92 J=1,IROW
      IF(J-N)92,95,92
95 COSTB=0.
92 CALL COSBAS(J,COSTB)
C      *      *      R H S      *      *
      DO 94 I=1,NS
      Y(I+1)=Y(I+1)-Y(1)
94 CALL RHS(I,Y(I+1))
      PUNCH 161
      PAUSE
      GO TO 1
150 FORMAT(15,2F10.6)
152 FORMAT(2F10.4)
157 FORMAT(10X,17H2ND DIFF - W/LINES//
C      8X,22HSTA ACT VALUE SIGN/)
158 FORMAT(5X,15,F12.6,F8.2)
160 FORMAT(F10.5,3F5.1)
161 FORMAT(3H000)
600 FORMAT(5H )
601 FORMAT(19X,14,14,2H 1)
      END
*0810
      SUBROUTINE COSBAS(M,COSTB)
      MM=M+100
      ID=1
      IDCOL=-1
      MCOST=COSTB*1000.
      IVAL=MM*10000000+MCOST+2000000
      CALL SMOG (M,IDCOL,IVAL,ID)
      RETURN
      END
*0810
      SUBROUTINE COSNON(M,COST)
      MM=M+100
      ID=1
      IDROW=-1
      NCOST=COST *1000.

```

IVAL=MM*10000000+NCOST+1000000
CALL SMOG (IDROW,M,IVAL,ID)
RETURN
END

*0810 SUBROUTINE RHS(N,REQ)
ID=2
IDCOL=0
CALL SMOG (N,IDCOL,REQ,ID)
RETURN
END

*0810 SUBROUTINE MATRIX(N,M,VAL,JND)
IF(JND)509,508,508
508 ID=3
CALL SMOG (N,M,VAL,ID)
RETURN
509 ID=2
CALL SMOG (N,M,VAL,ID)
RETURN
END

I-ADD OP	P/L LABEL	UP	OPERANDS
56000720050036002010050040001200275260005900274250001100000260009000269 -			
260009509264310000000200260014002742500000000011490001200000 -			
			* * SMOG SUBROUTINE - 4/2/63 * *
12006		DORG	12006*
12006 L2 12005 00000	SMOG	SF	SMOG-1,0*
12012 J2 12005 000-5		SM	SMOG-1,5,C10*
12030 K0 12669 1200N		TF	ROW,SMOG-1,0111,
12042 J2 12005 000-5		SM	SMOG-1,5,010*
12054 K0 12659 1200N		TF	COL,SMOG-1,0111,
12066 J2 12005 000J0		SM	SMOG-1,10,010*
12078 K0 12644 1200N		TF	ID,SMOG-1,0111,
12090 J0 12649 J2677		TFM	VAL,VAL1,017,
12102 J6 12686 000-1		TFM	CC,1,010,
12114 L5 12837 00000		CF	ZERO-9,0*
12126 L5 12787 00000		CF	ZERO-59,0*
12138 L5 12737 00000		CF	ZERO-109,0*
12150 K0 12634 12846		TF	STORE-7,ERO,01,
12162 L2 12667 00000		SF	ROW-2,0*
12174 PL 12479 12669		TNF	STORE-155,ROW,01,
12186 L2 12657 00000		SF	COL-2,0*
12198 PL 12487 12659		TNF	STORE-147,COL,01,
12210 J1 12005 000-5		AM	SMOG-1,5,010*
			1041 FOR COST IDENTIFICATION *FIXED POINT VAR.*
			1042 FOR RHS. *FLOATING POINT VAR.*
			1043 FOR MATRIX VALUES *FLOAT,POINT VAR.*
			CHECK FOR FIXED VALUE*
1222 J4 12644 000-1		CM	1L,1,010,
12234 M6 12856 01100		CP	FLOAT,0*
12246 K0 12677 1200N	FIXED	TF	VAL1,SMOG-1,0111,
12258 L2 12677 00000		SF	VAL1,0,
12270 PL 12507 12677		TNF	STORE-125,VAL1,01,
12282 L9 12475 00400	PUNCH	WACD	STORE-159,0*
12294 J4 12644 000-5		CM	1L,5,010,
12306 M7 12342 01200		TNE	EXIT,0*
12318 J4 12686 000-2		CM	CO,2,010,
12330 M7 12362 01200		CNE	MATRIX,0*
12342 J2 12005 000J2	EXIT	SM	SMOG-1,12,010*
12354 M9 1200N 00000		B	SMOG-1,06*
12362		DORG	*-5*
			CHECK FOR LAST PASS OF MATRIX LOOP*
			CHECK FOR MATRIX VALUES*
			SET FLAG ON THE LAST DIGIT*
			STORE COST IN COLS. 9 THRU 18*
			STORE COST AND VECTOR IDENTIFICATION*
			CLEAR PUNCH AREA*
			STORE ROW NUMBER IN COLS. 1 THRU 3*
			STORE COLUMN NUMBER IN COLS. 5 THRU 7*
			STORE ID VALUE*
			SAVE ADDRESS OF VAL1*
			ASSIGN CO EQUAL 1*
			STORE COLUMN VALU1*
			STORE ROW VALUE*

[illegible]

I-ADD OP	P/L LABEL	OP	OPERANDS
12916 M9 12880 00000		B	LOOP,,0*
12924		DORG	*-3*
12924 J2 12684 000-2	ADDRESS	SM	LOCAT,2,010, ADDRESS OF THE MANTISA*
12936 K0 12677 1268M		TF	VAL1,LOCAT,0111, STORE MANTISA IN VAL1*
12948 M4 12984 1264R		BNF	POSIT,VAL,0111, CHECK FOR NEGATIVE VALUE*
12960 L3 1264R 00000		CF	VAL,,06*
12972 J6 12491 000K0		TFM	STORE-143,20,010, STORE MINUS SIGN IN COL. 9*
12984 J4 12679 000-1	POSIT	CM	EXP,1,010*
12996 M7 1316A 01300		BN	SMALL,,0, CHCK FOR EXP LESS OR EQUAL THAN 0*
13008 M6 130. 01100		BP	PLUS1,,0, CHECK FOR EXP GREATER THAN 1*
	*		AREA FOR EXP#1*
13020 J2 12649 000-7		SM	VAL,7,010*
13032 KN 12499 1264R		TD	STORE-135,VAL,0111,STORE INTEGER IN COL. 13*
13044 J5 12498 00007		TDM	STORE-136,7,0*
13056 M9 13100 00000		B	DECIM,,0*
13064		DORG	*-3*
	*		ADDRESS OF THE UNITS POSITION # VAL - 8 & EXP*
13064 J2 12649 000-8	PLUS1	SM	VAL,8,010*
13076 KJ 12649 12679		A	VAL,EXP,01*
13088 PL 12499 1264R		TNF	STORE-135,VAL,0111,STORE INTEGERS*
13100 J1 12649 000-1	DECIM	AM	VAL,1,010*
13112 L2 1264R 00000		SF	VAL,,06*
13124 J1 12649 000-3		AM	VAL,3,010*
13136 PL 12509 1264R		TNF	STORE-125,VAL,0111,STORE 4 DECIMALS IN COLS. 15 THRU 18*
13148 J6 12501 000-3	LAST	TFM	STORE-133,3,010, STORE DECIMAL POINT IN COL. 14*
13160 M9 12282 00000		B	PUNCH,,0*
13168		DORG	*-3*
13168 K0 12509 12854	SMALL	TF	STORE-125,ZER04,01*
13180 J4 12679 000-1		CM	EXP,3,01011, CHECK FOR EXP LESS THAN -3*
13192 M7 12282 01300		BN	PUNCH,,0*
	*		ADDRESS OF THE 1/10000 POSITION # VAL - 4 & EXP*
13204 J2 12649 000-4		SM	VAL,4,010*
13216 KJ 12649 12679		A	VAL,EXP,01*
13228 M9 13136 00000		B	LAST,,0*
13236		DORG	*-3*
12006		DEND	12006*
00000 L600000005004900000*			
3600100005003600172005003600244005003600316005003600000000500			-8-0096-0115-

I-ADD OP P/L LABEL OP OPERANDS

0000000000102030400020406080003060902100408021610050015102006021814200# -
70411282008061422300908172630000000005060708090012141618151811242720242# -
822363520353045403632484455324946536048465462754453627180123456789123456# -
789-23456789-JK456789-JKL56789-JKLM6789-JKLMN789-JKLMN089-JKLMN# -
M8000000000049J20060P9-JKLMNOPQ# L10038800019M90000000000M90003600000 -

[illegible]

1.0.0.2

I-ADD OP	P/L LABEL	OP	OPERANDS
00000000000	1020304000204060800003060902100408021610050015102006021814200#	-	-
704112820080614223009081726300000000005060708090012141618151811242720242#		-	-
822363520353045403632484455324946536048465462754453627180123456789123456#		-	-
789-23456789-J3456789-JK456789-JKL56789-JKLM6789-JKLMN789-JKLMN089-JKLMN#		-	-
M800000000049J20060P9-JKLMNOPQ#	L10038800019M900000000000M90003600000	-	-

Appendix C

OPERATING TECHNIQUES FOR LINEAR PROGRAMMING

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Appendix C

OPERATING PROCEDURES FOR LINEAR PROGRAMMING

There are several considerations in the fairing of a surface using linear programming which may have a bearing on the final result attained. The following is a short discussion of these.

SENSE OF COORDINATE SYSTEM

The coordinate system employed in the fairing procedure is very general. The origin of each surface faired is at the intersection of the first waterline and the first station in the surface. Thus it may be at any one of the four corners of the surface, depending on which station and which waterline is chosen as "first."

For surfaces without profiles it is generally more convenient to choose the origin to be at the corner with the least value for the offset. Since this offset becomes the constant for the equation and is subtracted from the other offsets, this allows the remaining portion of the other offsets to be positive. On most ships the origin then becomes the lowest waterline on the surface and the station furthest forward if the surface is forward on the ship, or aft if the surface is aft on the ship.

For surfaces with profiles, the origin of the surface must be the same as the origin of the profile equation. Therefore, for the bow the origin of both the surface and profile is usually made the intersection of the forward perpendicular and the baseline; aft, the origin is the intersection of the aft perpendicular and the baseline.

The positive sense of the coordinates is always along the surface. If

the origin is at the lower-right corner, for instance, the positive x direction is to the left, and the positive z direction is up.

BASIC FEASIBLE SOLUTION

Most linear programming codes, such as LP-90 and the code for the IBM-1620, have two modes of operation. That is, when they first start to solve a problem the Phase I Algorithm is used to find a first feasible solution, without regard to optimality; and after finding this, Phase II is used to find an optimum solution.

In larger problems the search for the first basic feasible solution is time consuming and, due to the increase in the number of calculations, encourages the buildup of round-off error. It has been found advantageous then, in these larger problems, to provide the program with a basic feasible solution so the optimization can begin at once.

This is done by producing in the matrix an identity matrix of rank equal to the number of rows in the matrix. The identity matrix is identified to the program for use as the first basic feasible solution.

Each of the SMOG programs has a routine for generating this basis and identifying it to the linear program. In SMOG 3 and SMOG 4, this routine is self-contained. For SMOG 1 and SMOG 2, the routine of Appendix K is used.

INVERSION

During the solution of a linear programming problem, difficulties may arise from three sources: first, from the increase in number of non-zero elements in the matrix, which causes the iteration times to become greater.

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INVERSION

During the solution of a linear programming problem, difficulties may arise from three sources: first, from the increase in number of non-zero elements in the matrix, which causes the iteration times to become greater.

Second, because of a buildup of round-off error, some of the numbers may lose significance. Third, from the buildup of the number of transformations in the product form of the inversion, the time per iteration increases.

Most linear programming routines which are meant to handle large problems, such as LP-90, have provision for inverting the basis matrix. This inversion, carried out at intervals during the solution of the problem, will be extremely helpful in reducing all of the difficulties mentioned above.

The best method for choosing the inversion interval seems to be that of simply keeping a running check on the time per iteration. The iteration time will be found to increase slowly for several iterations, then to increase more rapidly. At this point it is time to invert. On surfaces of eighty to one-hundred offsets this usually occurs at about every thirty iterations. It is not efficient to invert in any case at intervals of less than twenty to twenty-five iterations, because the inversion time cancels any savings in iteration time.