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Volume II, Part I

EASY-ACLS DYNAMIC ANALYSIS
Volume II
Component Computer Programs

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This volume contains a detailed description of the component subroutines and of other standard functions/subroutines which are used in the EASY dynamic analysis program. Macro-flow charts and some micro-flowcharts and listings are included. Sample output is included where appropriate.

FOREWORD

This report presents results of work conducted by the Boeing Company, Seattle, Washington, under Air Force Contract F33615-77-C-3054 "Application of the EASY Dynamic Program to the Analysis of Air Cushion Systems on Aircraft" during the period from 15 April 1977 to 1 June 1979. This contract was conducted under the sponsorship of the Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio with Mr. Peters Skele and Lt. D. L. Fischer as project engineers.

This report is comprised of three volumes.

Volume I - Component Mathematical Models
Volume II - Component Computer Programs
(Parts I & II)
Volume III - Description of Simulations

In addition, a User's Manual (Reference 1) has been written to provide a concise reference for day to day usage.

The results presented were developed by the Boeing Aerospace Company. The program managers were A. J. P. Lloyd, H. H. Straub and J. R. Kilner. The principal investigators were M. K. Wahi, G. S. Duleba, J. R. Kilner and P. R. Perkins.

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SECTION I

INTRODUCTION

The EASY-ACLS Model Generation and Analysis Program is documented in three main volumes. Volume I contains the mathematical models for the standard components of the program library. This includes derivation of the dynamic equations of motion for aircraft, trunk-cushion landing systems, an air bag skid system and an arresting gear system, and a discussion of required inputs and outputs for component models. Volume II, this volume, contains a detailed description of all the component subroutines, including macro-flowcharts and detailed listings. In addition, the standard subroutines and functions called by the component subroutines are described, and sample outputs are shown. Volume III contains a description of the development, results and conclusions of EASY computer simulations accomplished during this contract. These consist of landing, takeoff, free flight and drop test simulations. A summary document (Reference 1)* has also been prepared as a User's Manual.

In the EASY program, a user defines the system to be analyzed by specifying the individual components and their interconnections. Each of these components is a subroutine of the main program, and each has input data requirements which must be supplied by the user. In addition to the library of component subroutines, there is also a set of standard subroutines and functions which are called automatically as they are required, and for which the user need not supply any input data. Such standard functions and subroutines are described in Section 3 of this volume. In addition, Section 3 also contains a description of certain linear routines such as first and second order transfer functions, time delays, general controllers, and switches. Subroutines associated with particular ACLS components are described in Section 4.

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*References are located in Volume II, Part II.

For each function or subroutine described in Sections 3 and 4, the theory and data sources are given or the appropriate Section of Volume I is referenced. Macro-flowcharts and some micro-flow charts showing the main decision points and calculation procedures are shown. For all functions and subroutines a listing is given. Included in the listing is a detailed description of the input/output list. The inputs and outputs are divided into the following classifications:

- Output State
- Output Derivative
- Integrator Control
- Output Variable
- Input Variable
- Input Parameter

These terms are discussed fully in Reference 2, but will be reviewed briefly here in order to assist in understanding the subroutines and functions. An Output State is a variable whose derivative (Output Derivative) is calculated within the subroutine. The Integrator Control is an integer whose value is set by the main program. The Output Derivative is calculated within the subroutine unless the integrator is "frozen" by setting the Integrator Control equal to zero. For every Output State there is one Output Derivative and one Integrator Control. Output Variables, as the name implies, are variables which are calculated within a function or subroutine and are then output from that function or subroutine. Similarly, input variables are variables which are input to a function or subroutine. Input Parameters are also input to a function or subroutine, but are generally constant during a simulation. For example, the inlet flow rate or temperature to a component would be an Input Variable, whereas a controller gain or duct length would be an Input Parameter. In general, the program user must supply data inputs for all Input Parameters; however many Input Variables will be automatically satisfied by the interconnections between adjacent components. This is discussed more fully in Reference 2.

The functions and subroutines described in Sections 3 and 4 contain error controls which are of two types, namely for fatal and non-fatal errors. The latter type are by far the more common, and occur when, for example, fluid properties are sought outside the range for which valid data are available. It is desirable that non-fatal error diagnostic messages should not be printed everytime they occur; for example, during the course of finding a steady state solution, it is of no significance if invalid data are used provided the final steady state point is based on valid data. The printout of warning diagnostics is controlled by the parameter IERR (= 1 for printout) which is set by the main program and is communicated through the common block ERMESS. For errors which are of sufficient significance to warrant a program stop, the parameter IFATAL is set equal to 1 within the subroutine or function and is communicated back to the main program through the same common block ERMESS.

Other common blocks which are used in the functions and subroutines are:

CTIME - For time
CIO - For read and write control

SECTION II

SUMMARY

The EASY Model Generation and Analysis program is documented in three main volumes. Volume I contains the mathematical models, Volume II (this volume) the component subroutines, and Volume III the description of various dynamic simulations. A User's Manual (Reference 1) has also been prepared to provide a convenient reference guide.

This volume contains a detailed description of the component subroutines, and of other standard functions and subroutines which are called by the component subroutines. Flowcharts and listings are given, including a full description of the input/output lists. Theory and data sources are given, or the relevant section of Volume I is referenced. Sample output is included where appropriate. The procedures for running single components on the EASY program are briefly reviewed, and guidelines to assist users in writing their own subroutines are described.

SECTION III

STANDARD FUNCTIONS AND SUBROUTINES

3.1 Introduction

The EASY Model Generation and Analysis program contains a number of standard functions and subroutines which have been divided into six categories, namely:

Property functions and subroutines - Section 3.2
Flow functions and subroutines - Section 3.3
Transfer functions and subroutines - Section 3.4
Miscellaneous subroutines - Section 3.5
Table look up functions - Section 3.6
Initial condition functions and subroutines - Section 3.7
Supporting subroutines for Foster-Miller trunk component - Section 3.8

The property, the flow, the table look up, and the inital condition functions and subroutines are all called by component subroutines, and their input data requirements are automatically satisfied by the calling subroutine. The transfer functions are generally used to model part or all of a component, and are therefore included in the library of standard components (see Reference 1). However, as they are general dynamic models and are not associated particularly with any one type of ACLS component, they are included in this section rather than in the component subroutines discussed in Section 4 of this volume. The miscellaneous functions include routines for providing input data to the models in tabular form, and for changing variable or parameter inputs during a simulation. Table 1 lists all the standard functions and subroutines and briefly describes their purpose. A full description of each routine is given in the following sections.

Table 1 STANDARD FUNCTIONS AND SUBROUTINES

SECTION NO.	FUNCTION OR SUBROUTINE NAME	PURPOSE
3.2.1	SHCP	Specific heat of humid air
3.2.2	PROP	Property of fluids
3.2.3	PRND	Prandtl number of fluids
3.3.1	FNFLOW	Flow rate in a duct given pressure and loss factor, using tabular data
3.3.2	FSFLOW	Flow rate in a duct given pressure and loss factor, using tabular data
3.3.3	PERF	Trunk element orifice areas for flow to cushion and atmosphere
3.3.4	PERFB	Air bag element orifice areas for flow to atmosphere
3.3.5	AMACH	Mach number in a duct
3.3.6	RENVX	Reynolds number
3.3.7	HI	Convective heat transfer coefficients for flow in ducts and across cylinder
3.3.8	VLX	Flow across butterfly, gate and globe valves
3.4.1	LA	First order lag (time constant form)
3.4.2	LG	First order lag (pole form)
3.4.3	LL	Lead lag (time constant form)
3.4.4	LE	Lead lag (pole-zero form)
3.4.5	TF	Second order transfer function with first order numerator

Table 1 STANDARD FUNCTIONS AND SUBROUTINES

SECTION NO.	FUNCTION OR SUBROUTINE NAME	PURPOSE
3.4.6	TZ	Second order transfer function with second order numerator
3.4.7	RG	Rate Gyro Dynamics and Saturation
3.4.8	FG	Flight-ground controller
3.4.9	AP	Autopilot pitch controller (Jindivik)
3.4.10	AR	Autopilot roll controller (Jindivik)
3.4.11	IT	Integrator with saturation
3.5.1	SW	Switch control for one variable
3.5.2	SX	Switch control for two variables
3.5.3	SY	Switch control for three variables
3.5.4	SZ	Switch control for four variables
3.5.5	TA	Tabular input routine for two variables
3.5.6	TB	Tabular input routine for four variables
3.5.7	AF	Analytical function generator
3.5.8	MA	Multiply and add
3.5.9	FU	Arbitrary function generator
3.5.10	MC	Multiply and add with three variables
3.5.11	SA	Saturation
3.5.12	SB	Saturation with dead band
3.5.13	MB	Multiply, add and divide
3.5.14	FV	Two dimension function generator

Table 1 STANDARD FUNCTIONS AND SUBROUTINES

SECTION NO.	FUNCTION OR SUBROUTINE NAME	PURPOSE
3.5.15	RA	Random number generator function
3.5.16	RN	Random number generator
3.5.17	S2	Sum forces and moments (2 sets of inputs)
3.5.18	S3	Sum forces and moments (3 sets of inputs)
3.5.19	TG	Transform engine thrust into body axis
3.5.20	TR	Transform vectors body to earth axis
3.5.21	XP	Transform angular rates
3.5.22	XT	Transform torques
3.6.1	TBL1	Linear interpolation (one ind. variable)
3.6.2	TBL2	Linear interpolation (two ind. variables)
3.6.3	TBLU1	Polynomial interpolation (one ind. variable)
3.6.4	TBLU2	Polynomial interpolation (two ind. variables)
3.6.5	TBLU3	Polynomial interpolation (three ind. variables)
3.6.6	ETB2	Linear interpolation (two independent variables) Supports TS
3.6.7	ETB3	Linear interpolation (three independent variables) Supports TS
3.7.1	IC	Initial condition package (trunk)

Table 1 STANDARD FUNCTIONS AND SUBROUTINES

SECTION NO.	FUNCTION OR SUBROUTINE NAME	PURPOSE
3.7.2	ICB	Inital condition package (air bag)
3.7.3	ICFS	Free shape equations (trunk)
3.7.4	ICFSB	Free shape equations (air bag)
3.7.5	ICLS	Loaded shape equations (trunk)
3.7.6	ICLSB	Loaded shape equations (air bag)
3.7.7	KINK	Kink wave angle equations (arresting cable)
3.7.8	RES	Arresting cable strain equations
3.7.9	TERRA	Terrain model
3.7.10	VPRINB	Air bag arrays print control
3.7.11	VPRINT	Trunk arrays print control
3.7.12	ELAS	Initial condition package for elastic trunk TS
3.7.13	ELFX	Incomplete elliptic integral of the 2nd kind
3.7.14	ELKX	Complete elliptic integral of the 2nd kind
3.7.15	ELWR	Prints properties of elastic trunk TS
3.7.16	ENDFS	Equations for elastic trunk-end element-free shape
3.7.17	ENDLS	Equations for elastic trunk-end element-loaded shape
3.7.18	SIDEFS	Equations for elastic trunk-side element-free shape
3.7.19	SIDELS	Equations for elastic trunk-side element-loaded shape
3.7.20	XXPRT	Prints elastic trunk parameters during simulation

Table 1 STANDARD FUNCTIONS AND SUBROUTINES

SECTION NO.	FUNCTION OR SUBROUTINE NAME	PURPOSE
3.8.1	CDVCHP	Updates cushion volume-pressure parameters (FM)*
3.8.2	CLRNCE	Ground clearance for trunk segments (FM)*
3.8.3	COORDN	Ground coordinates of trunk segments (FM)*
3.8.4	DYNFAN	Fan dynamic characteristics (FM)*
3.8.5	FLOW	Dynamic flow in ACLS (FM)*
3.8.6	FMFAN	Fan static characteristics (FM)*
3.8.7	FMWRIT	Prints ACLS input data (FM)*
3.8.8	FORCE	ACLS forces (FM)*
3.8.9	HYCURV	Side trunk height (FM)*
3.8.10	OUTFM	Updates variables during simulation (FM)*
3.8.11	PARAMS	Default values for ACLS parameters (FM)*
3.8.12	PROFILE	Defines ground elevation (FM)*
3.8.13	ROTATE	Vehicle-to-initial vector transformation (FM)*
3.8.14	SEGMNT	Divides trunk into segments (FM)*
3.8.15	SHAPE1	Initial estimates of ACLS areas and volumes (FM)*
3.8.16	SHAPE2	ACLS areas and volumes (FM)*
3.8.17	STATIC	Load maps and static equilibrium conditions (FM)*
3.8.18	STEQU	Defines ACLS state derivatives (FM)*
3.8.19	TRUNK	Trunk cross section parameters (FM)*
3.8.20	VALVE	Relief valve orifice area (FM)*

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*FOSTER-MILLER ACLS MODEL

3.2 Property Functions and Subroutines

3.2.1 Function SHCP

The purpose of function SHCP is to calculate the specific heat of an air-water vapor mixture. The function is called by many of the component subroutines for calculating specific heat, and hence the gas constant and the ratio of specific heats. The method is described in Reference 2, Volume I, Appendix A and uses property data from References 3 and 4. The function is valid for temperatures of 300-1600^{o}R, and a warning diagnostic message is printed if the temperature is outside this range. Table 88 shows a flowchart and Table 214 gives a detailed listing. Required inputs are the temperature (T) and specific humidity (SH).

3.2.2 Function PROP

The purpose of function PROP is to calculate the properties of several fluids. The properties, all of which are assumed to be functions of temperature only, are specific heat, viscosity, thermal conductivity and density. The fluids included in the routine are:

- Dry air
- Water at saturation pressure
- 60%/40% Ethylene Glycol/water
- Heat transport fluid FC-75
- Fuel JP-4 (MIL-F-5624)
- Heat transport fluid DC-331
- Hydraulic fluid (MIL-H-83282)
- Hydraulic fluid (MIL-H-5606)

The function uses polynomial approximations to property data obtained from References 3, 5 and 6. Table 73 shows a flowchart and Table 199 gives a detailed listing. Limitations on the allowable temperature range for each fluid are shown in the listing. A warning diagnostic is printed if temperatures are outside the allowable range. The density calculation for dry air is invalid, and the perfect gas equation should be used instead. Required inputs are integers identifying the fluid and the required property, and the absolute temperature.

3.2.3 Function PRND

The purpose of function PRND is to calculate the Prandtl number of fluids. The function calls PROP (Section 3.2.2) to calculate the specific heat, thermal conductivity and viscosity, with the exception that the specific heat of moist air is obtained from SHCP. As discussed in Reference 2, Volume I, Appendix A values of thermal conductivity and viscosity for dry air can be used in the calculation of Prandtl number of an air/water vapor mixture with a neglible effect on accuracy. No diagnostic messages are included in PRND, but will be called from PROP and SHCP (Section 3.2.1) if the temperature lies outside the valid range for the particular fluid. Table 71 shows a flowchart and Table 197 gives a detailed listing. Input requirements are an integer identifying the fluid (as in PROP), the absolute temperature and the specific humidity. The latter input is used for the case of air only.

3.3 Flow Functions and Subroutines

3.3.1 Subroutine FNFLOW

The purpose of subroutine FNFLOW is to calculate the flow rate and Chester Smith function for flow in a constant area section, given the upstream and downstream pressures, temperature, effective area and K (pressure loss) factor. The method is described in Reference 2, Volume I, Appendix F. The Chester Smith function is stored in a data array as a function of pressure ratio. The subroutine can also be used to calculate the flow across an orifice, in which case the K factor should be set equal to one. The input value of K factor must always be greater than zero. In the event that the input value of downstream pressure exceeds the upstream pressure, the subroutine calculates negative flow rates and Chester Smith functions.

A flowchart for the subroutine is shown as Table 37 and Table 163 gives a detailed listing which includes the full input/output list.

3.3.2 Subroutine FSFLOW

The purpose of subroutine FSFLOW is the same as that of FNFLOW except an additional output parameter "SFN" has been added. Parameter SFN is the slope of compressible flow factor FN with respect to the pressure ratio P1/P2. Subroutine FSFLOW is used exclusively for calculating cushion to atmosphere flow rate in the trunk subroutine TK.

A flowchart for the subroutine is shown as Table 41 and Table 167 gives a detailed listing which includes the full input/output list.

3.3.3 Subroutine PERF

This is a special purpose subroutine called only by the trunk component TK. The purpose of subroutine PERF is to calculate orifice areas for flow to atmosphere and to cushion through the lubrication holes provided on the underside of a trunk. Thirteen combinations of performation arrangements are treated and are functions of free or loaded trunk shape and perforations being on the flattened or free parts of the trunk.

A flowchart for the subroutine is shown as Table 69 and Table 195 gives a detailed listing which includes the full input/output list.

3.3.4 Subroutine PERFB

This is also a special purpose subroutine called only the the Air Bag Component AB. Its purpose is same as that of the subroutine PERF except the perforation arrangements which are limited to six and there is no cushion pressure.

A flowchart for the subroutine is shown as Table 70 and Table 196 gives a detailed listing which includes the full input/output list.

3.3.5 Function AMACH

The purpose of function AMACH is to calculate the Mach number of moist air flowing in an element of known cross-sectional area, given the pressure, temperature, flow rate and specific humidity. The method is described in Reference 2, Volume I, Appendix F. The function f(M) defined in equation F-2 is stored in two data arrays. The first array covers a range of values of f(M) from zero through 0.50 at increments of .02, corresponding to Mach numbers of zero through .632. The second array covers the range .50 through .58 at increments of .01, corresponding to Mach numbers of .632 through 1.0. A warning diagnostic message is printed if the calculated value of f(M) lies outside the range covered by the data arrays.

A flowchart for the function is shown as Table 5 and Table 131 gives a detailed listing which includes the full input/output list.

3.3.6 Function RENVX

The purpose of function RENVX is to calculate the Reynolds number of fluid flowing in a duct of circular cross-section, given the flow rate, temperature and duct diameter. The function calls function PROP (Section 3.2.2) to determine the fluid viscosity at the given temperature. As discussed in Reference 2, Volume I, Appendix A, values of viscosity for dry air can be used for the calculation of Reynolds number of an air/water vapor mixture with negligible effect on accuracy. The function output is the absolute value of Reynolds number, irrespective of the sign of the flow rate.

A flowchart for the function is shown as Table 76 and Table 202 gives a detailed listing which includes the full input/output list.

3.3.7 Function HI

The purpose of function HI is to calculate the convective heat transfer coefficient for fluid flow in ducts and for flow across cylinders. The latter capability is primarily of significance for determining the response rate of temperature sensors. The function uses conventional correlations for Nusselt number against Reynolds number and Prandtl number for transitional and turbulent flow in ducts, and for Nusselt number against Graetz number for laminar flow in ducts. For flow across cylinders, a correlation of Nusselt number against Reynolds number is used for air, and Nusselt number against Reynolds number and Prandtl number for liquids. The complete equations and references are given in Reference 2, Volume I, Appendix F. Fluid properties are obtained from function PROP (Section 3.2.2).

A flowchart for the function is shown as Table 46 and Table 172 gives a detailed listing which includes the full input/output list. Figure 1 shows heat transfer coefficients for air flow in ducts and across cylinders.

3.3.8 Subroutine VLX

The purpose of subroutine VLX is to calculate the weight flow of air across butterfly, gate and globe type valves. For butterfly and globe valves, the geometric flow area is first calculated, and the effective area is then determined assuming discharge coefficients of 0.87 and 0.80, respectively. For gate valves the flow is calculated using a table of K factor versus fractional opening. A full description of the method and equations is given in Reference 2, Volume I, Section 3,7. In the event that the downstream pressure is greater than the upstream value, the calculated value of flow will be negative. For globe valves, the input value of poppet diameter must be greater than or equal to the poppet seat diameter.

The valve opening (degrees or fractional opening) is an input to subroutine VLX. In a system analysis, the valve opening will generally be an output

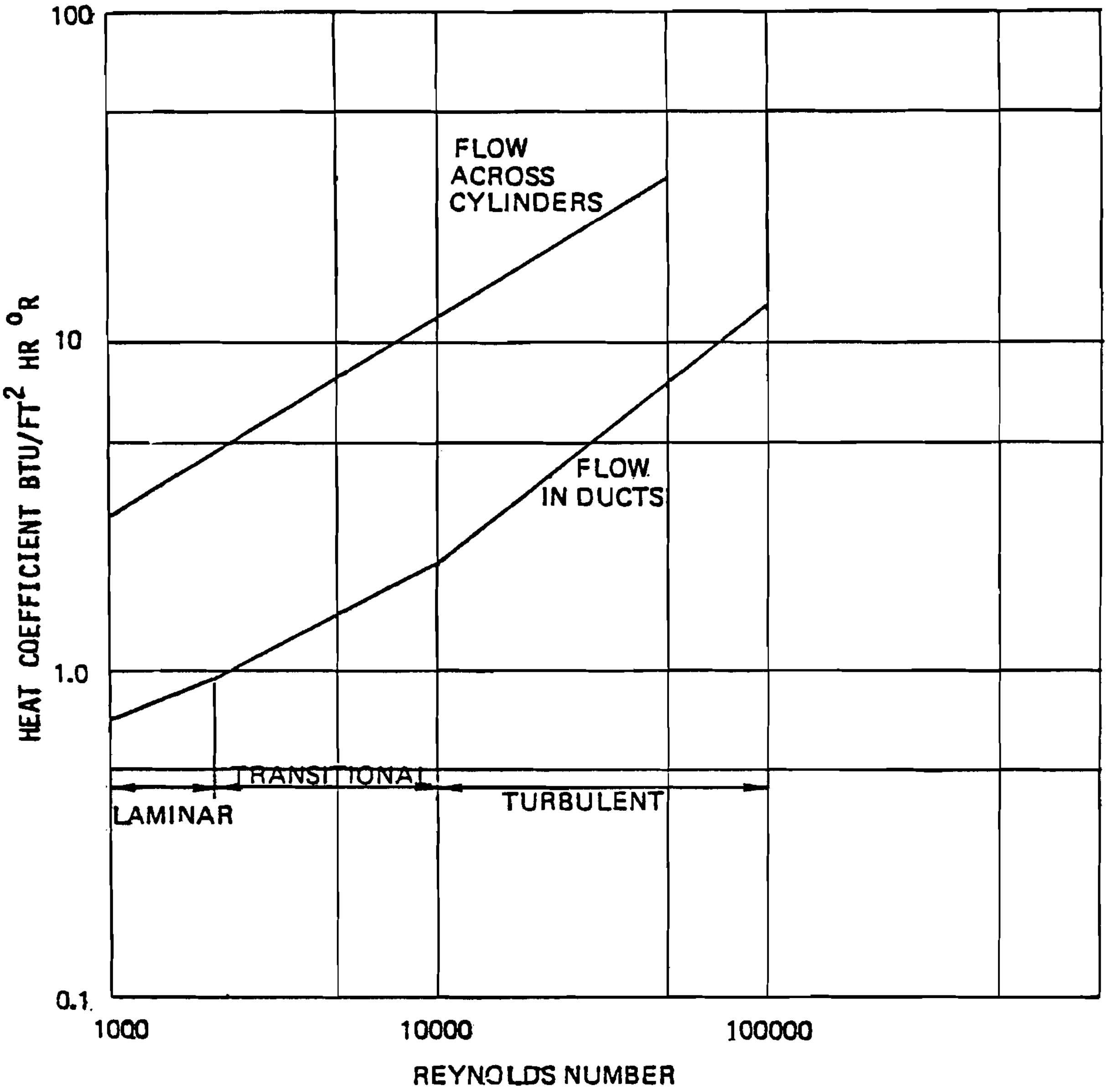


Figure 1 Heat Transfer Coefficients for Flow of Air In Ducts and Across Cylinders

variable from, or calculated within, a control component such as a pressure regulator or temperature controller. During the course of searching for a steady state solution, it is possible that the valve opening will lie outside the normal range. For example, a butterfly valve opening of -10^{o} or 105^{o} might be input to VLX. Although such a value is clearly not a valid in a steady state solution, it is desirable that subroutine VLX calculate reasonable values of flow rate at such values in order to permit convergence to the correct steady state solution. The method incorporated into VLX is illustrated in Figure 2(a) for butterfly valves, and Figure 2(b) for globe and gate valves.

A flowchart for the subroutine is shown as Table 120 and Table 246 gives a detailed listing which includes the full input/output list.

3.4 Transfer Functions and Subroutines

3.4.1 Subroutine LA

The purpose of subroutine LA is to simulate a first order lag defined as:

$$\frac{FO}{FIN} = \frac{Gain}{(1 + TC \times s)} \qquad 3.4\text{-}1$$

where

FO is the output   GAIN is the gain
FIN is the input   TC is the time constant

and s is the Laplace operator

The time constant TC must not equal zero.

Table 56 shows a flowchart for the subroutine and Table 182 gives a detailed listing which includes the full input/output list. Figure 3(a) shows a typical calculated response to a unit step change in input, which agrees with the analytical response given by

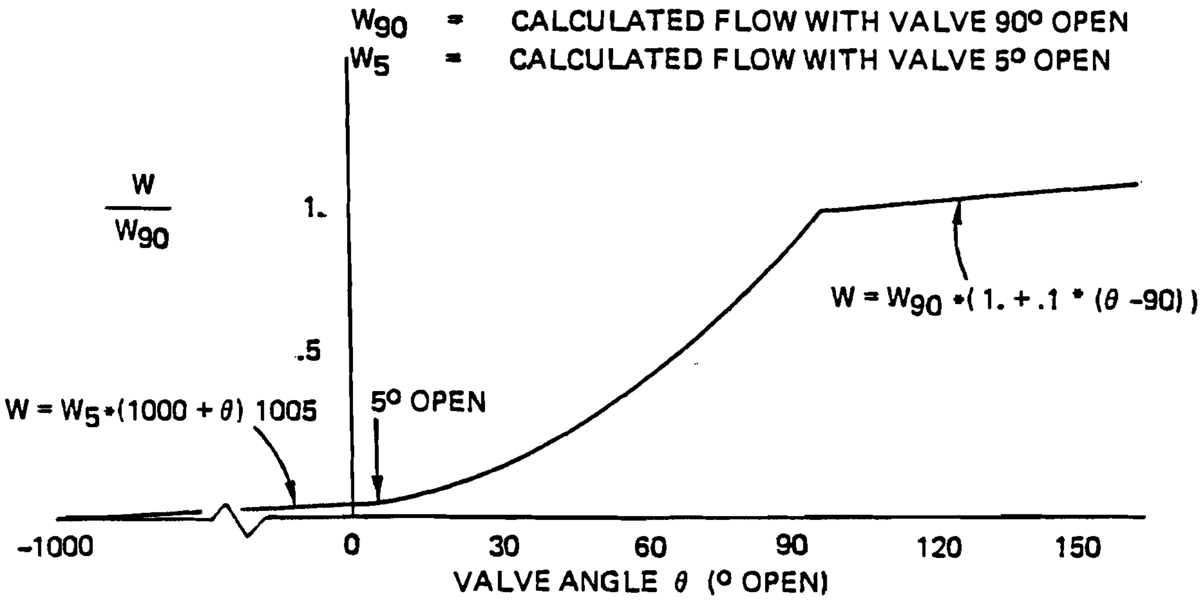


Figure 2 (a) Flow Calculation for Butterfly Valves

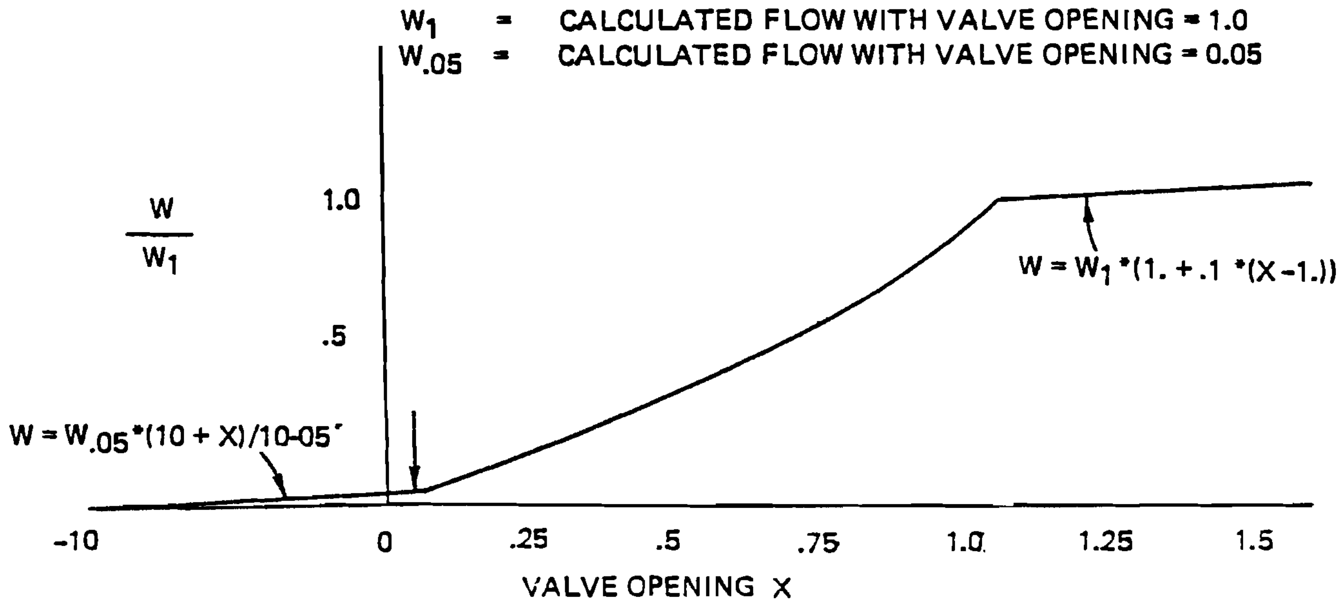


Figure 2 - (b) Flow Calculation for Globe and Gate Valves

Figure 2 Calculation of Flows in Subroutine VLX Outside Normal Valve Angle Limits

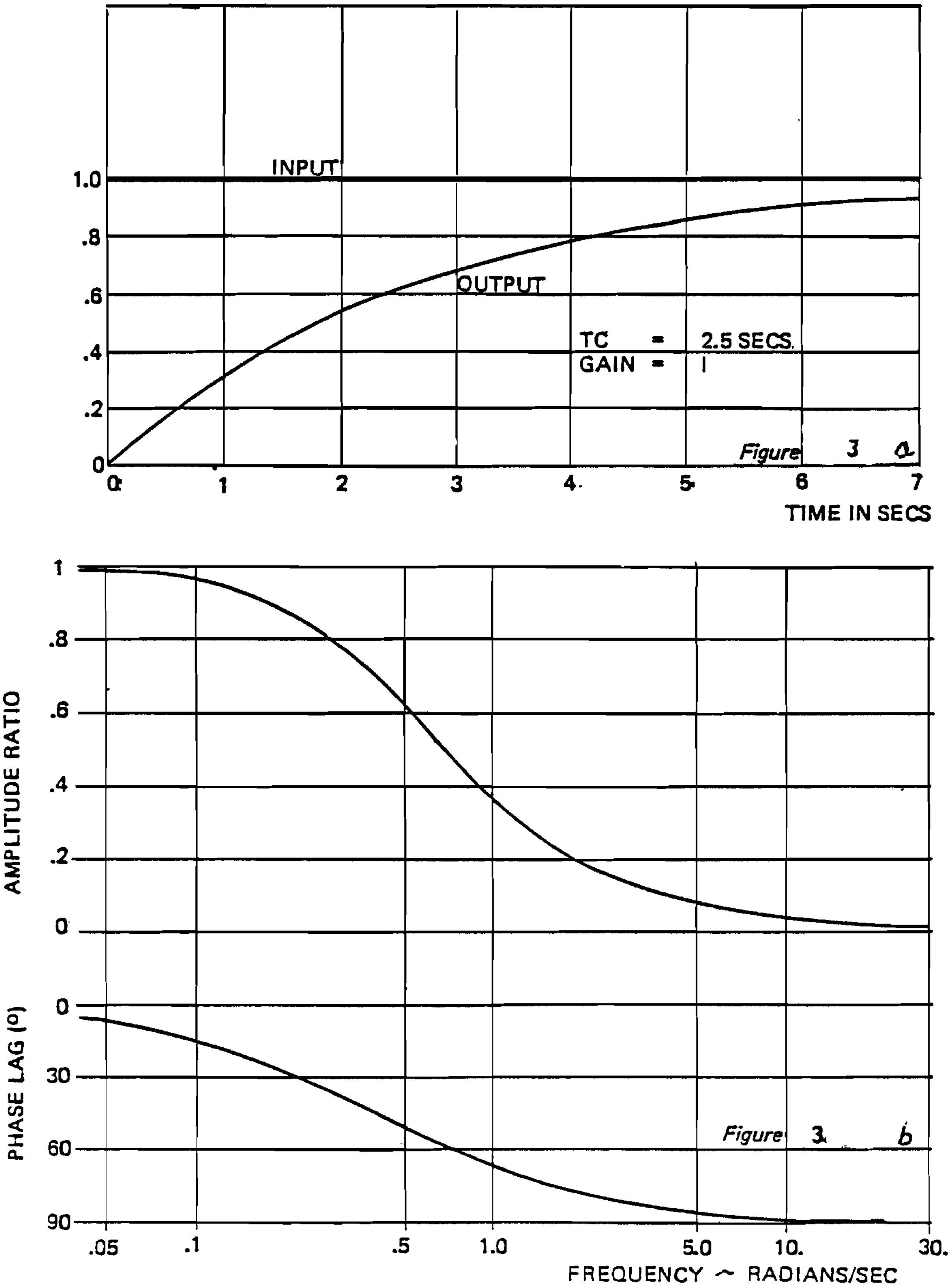


Figure 3 Typical Response for Subroutine LA

$$FO = (1 - e^{-t/TC}) \times GAIN \qquad 3.4\text{-}2$$

where t is time. Figure 3(b) shows the frequency response.

3.4.2 Subroutine LG

The purpose of subroutine LG is to simulate a first order lag defined by:

$$\frac{FO}{FIN} = \frac{ZO}{s+PO} \qquad 3.4.3$$

where

FO is the output   ZO is the zero location
FIN is the input   PO is the pole location

and s is the Laplace operator.

A flowchart for the subroutine is shown as Table 58 and Table 184 gives a detailed listing.

3.4.3 Subroutine LL

The purpose of subroutine LL is to simulate a lead-lag defined by:

$$\frac{FO}{FIN} = GAIN \frac{(1 + TC1 \times s)}{(1 + TC2 \times s)} \qquad 3.4\text{-}4$$

where

FO is the output   GAIN is the gain
FIN is the input   TC1 and TC2 are time constants

and s is the Laplace operator.

The time constant TC2 must not equal zero.

Table 59 shows a flowchart for the subroutine and Table 185 gives a detailed listing which includes the full input/output list. Table 4(a) shows a typical calculated response to a unit step change in input, which agrees with the analytical response given by

$$\frac{FO}{FIN} = (1 + \frac{(TC1 - TC2)}{TC2}\ e^{-t/TC2}) \times GAIN \qquad 3.4\text{-}5$$

where t is time. Figure 4(b) shows the frequency response.

3.4.4 Subroutine LE

The purpose of subroutine LE is to simulate a first order lead-lag defined by:

$$\frac{FO}{FIN} = GAIN\,\frac{s + Z0}{s + P0} \qquad 3.4\text{-}6$$

where

FO	is the output		GAIN	is the gain
FIN	is the input		Z0	is the zero location
s	is the Laplace operator,		P0	is the pole location

A flowchart for the subroutine is shown as Table 57 and Table 183 gives a detailed listing.

3.4.5 Subroutine TF

The purpose of subroutine TF is to simulate a second order transfer function with first order numerator defined by:

$$\frac{FO}{FIN} = \frac{Z1 \times s + Z0}{S^2 + P1 \times s + P0} \qquad 3.4\text{-}7$$

where FO is the output

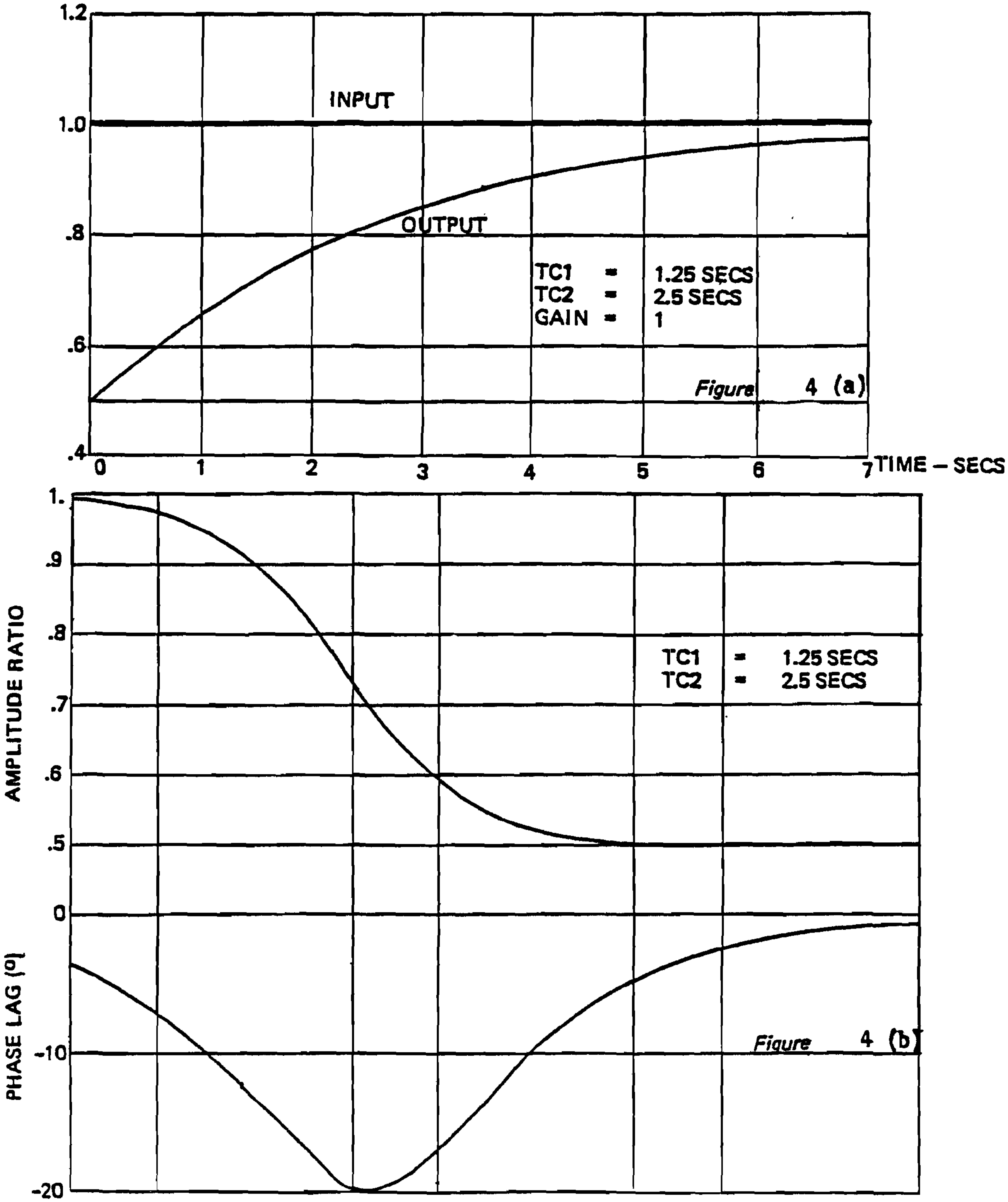


Figure 4 Typical Response for Subroutine LL

FIN is the input

Z0, Z1, P0, and P1 are coefficients

and s is the Laplace operator

Table 109 shows a flowchart for the subroutine and Table 235 gives a detailed listing which includes the full input/output list. Figure 5(a) shows the calculated response to a unit step change in input, which agrees with the analytical response given by

$$FO = Ae^{-\gamma t} \text{Cos}\,\omega t + \left(\frac{B - \gamma A}{\omega}\right) e^{-\gamma t} \text{Sin}\,\omega t - A \qquad 3.4\text{-}8$$

where

$$A = -\frac{Z0}{P0}$$

$$B = Z1 - \frac{Z0 \times P1}{P0}$$

$$\omega^2 = P0 - \left(\frac{P1}{2}\right)2$$

$$\gamma = \frac{P1}{2}$$

and t is the time

Figure 5(b) shows the frequency response.

3.4.6 Subroutine TZ

The purpose of subroutine TZ is to simulate a second order transfer function with second order numerator defined by

$$\frac{FO}{FIN} = \frac{Z2 \times s^2 + Z1 \times s + Z0}{s^2 + P1 \times s + P0} \qquad 3.4\text{-}9$$

where FO is the output

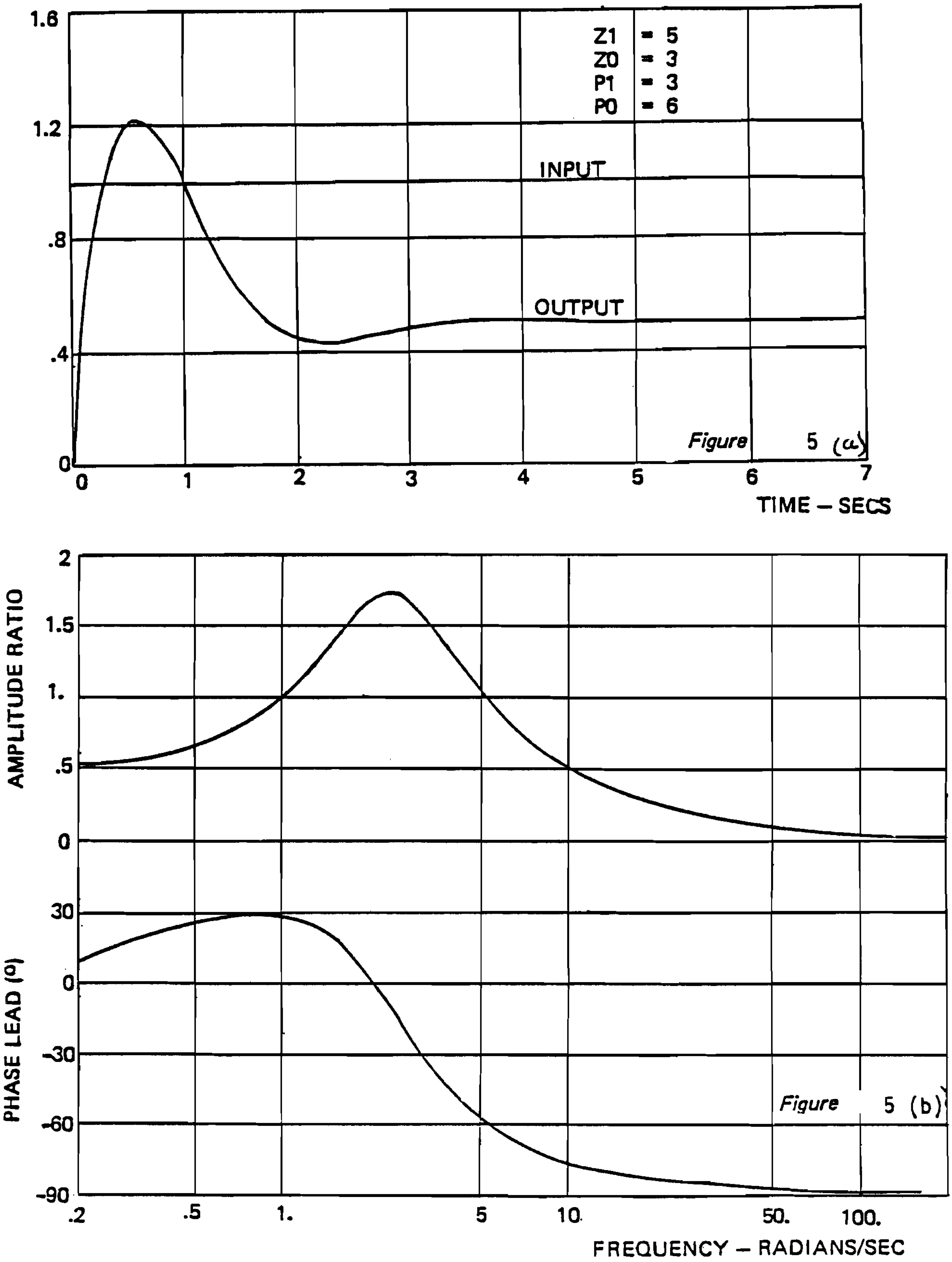


Figure 5 *Typical Response for Subroutine TF*

FIN is the input

Z0, Z1, Z2, P0, and P1 are coefficients

and s is the Laplace operator.

Table 117 shows a flowchart for the subroutine and Table 243 gives a detailed listing which includes the full input/output list. Figure 6(a) shows the calculated response to a unit step change in input, which agrees with the analytical response given by

$$FO = Ae^{-\gamma t} \cos \omega t + \left(\frac{B - \gamma A}{\omega}\right) e^{-\gamma t} \sin \omega t + C \qquad 3.4\text{-}10$$

where

$$A = Z2 - \frac{Z0}{P0}$$

$$B = Z1 - \frac{Z0 \times P1}{P0}$$

$$C = \frac{Z0}{P0}$$

$$\omega^2 = P0 - \left(\frac{P1}{2}\right)^2$$

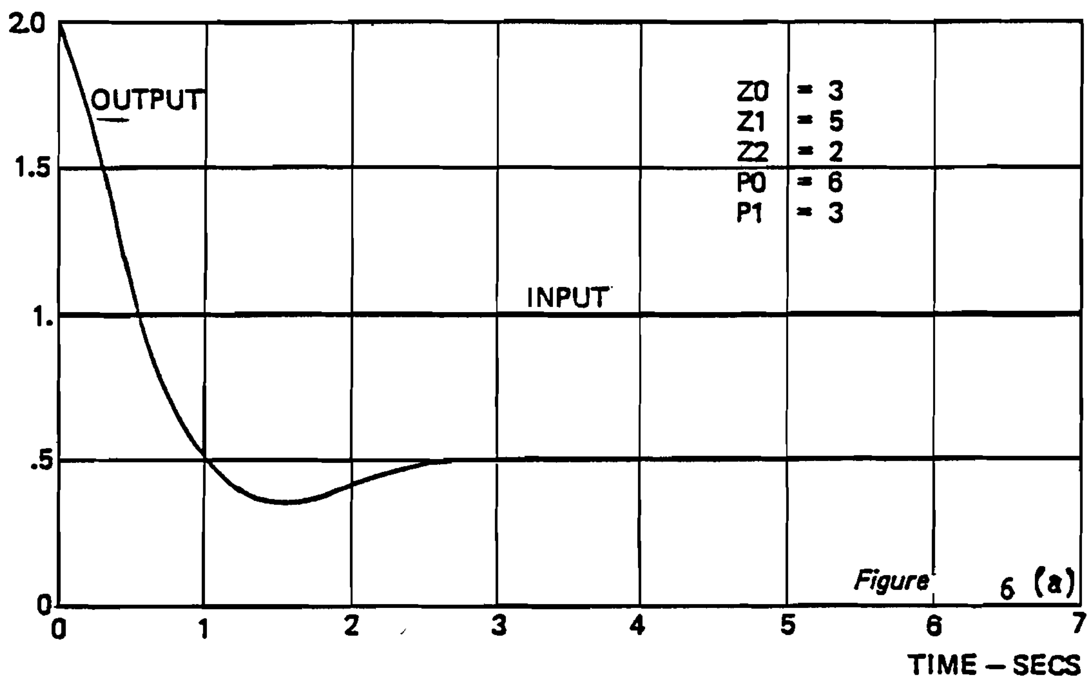
$$\gamma = \frac{P1}{2}$$

and t is the time.

Figure 6(b) shows the frequency response.

3.4.7 Subroutine RG

The purpose of subroutine RG is to simulate dynamics and saturation of three (roll, pitch, yaw) rate gyros. The same 2nd order dynamics and saturation limit is applied to each rate gyro. Saturation is applied by increasing feedback signal around integrators by a factor of 100.



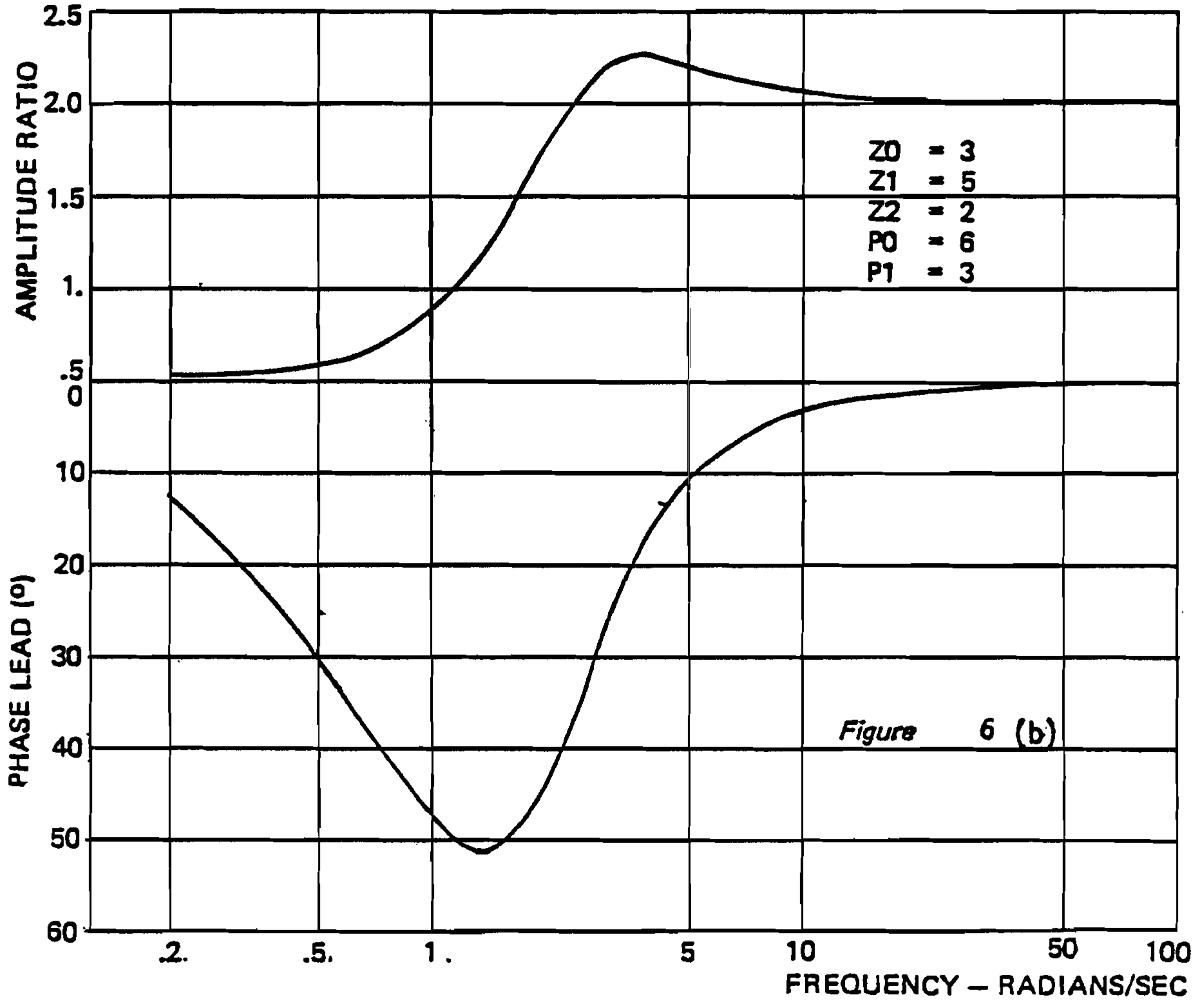
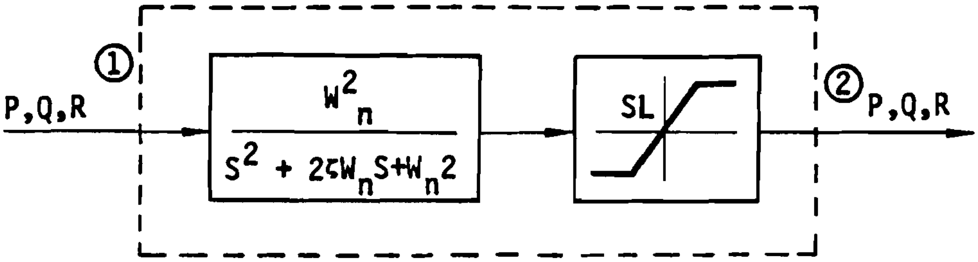


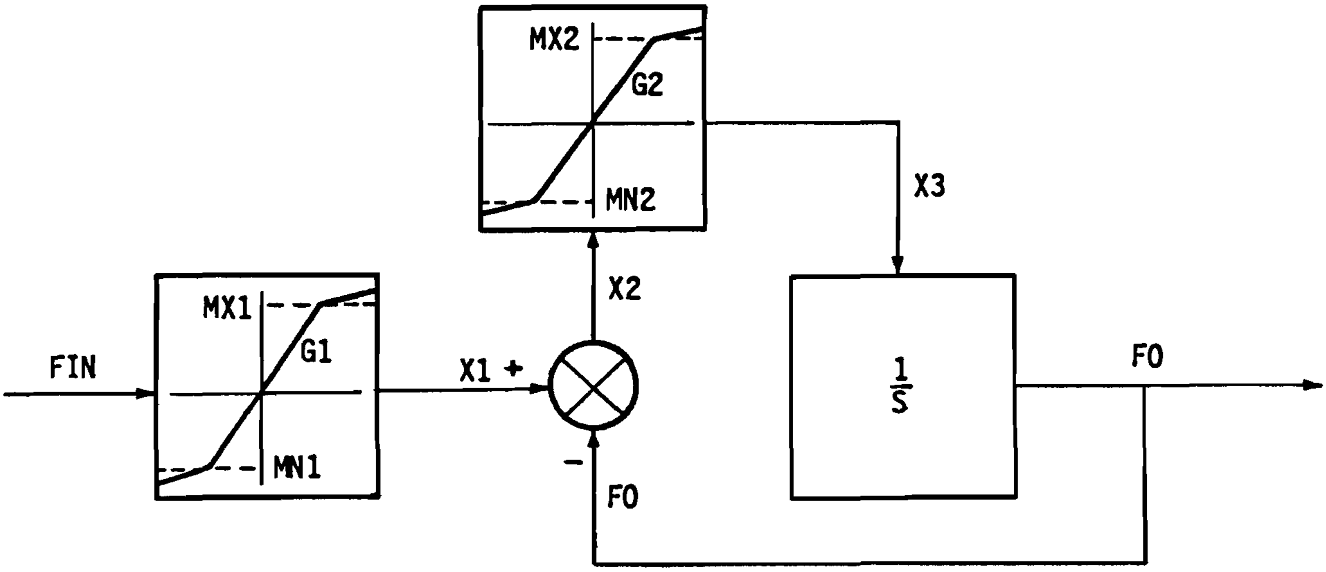
Figure 6 *Typical Response for Subroutine TZ*



A flowchart for the subroutine is shown as Table 78 and Table 204 gives a detailed listing which includes the input/output list.

3.4.8 Subroutine FG

The purpose of subroutine FG is to simulate a simple general purpose flight and ground controller for aircraft.



A flowchart for the subroutine is shown as Table 29 and Table 155 gives a detailed listing.

3.4.9 Subroutine AP

The purpose of subroutine AP is to simulate JINDIVIK autopilot for pitch control and is therefore a special purpose subroutine. The pitch autopilot function is

$$\eta_d = .28\ (\dot{\theta} - \dot{\theta}_d) + .533\ (\theta - \theta_d) \qquad 3.4\text{-}11$$

where η_d = elevator angle
$\dot{\theta}$ = pitch rate
$\dot{\theta}_d$ = pitch reference rate
θ =.pitch angle
θ_d = pitch reference angle

The elevator servo transfer function is

$$\frac{\eta}{\eta_d} = \frac{1 + .32S}{(1+.4S)(1+.11S+.0063\ s^2)} \qquad 3.4\text{-}12$$

where s is the Laplace transform operator.

A flowchart for the subroutine is shown in Table 6 and Table 132 gives a detailed listing.

3.4.10 Subroutine AR

The purpose of subroutine AR is to simulate <u>JINDIVIK</u> autopilot for roll control and is only a special purpose subroutine.

The lateral autopilot function is

$$\begin{aligned}\zeta_d = {} & 0.196\ (\dot{\phi} - \dot{\phi}_d) + .42\ (\phi - \phi_d) + .2R \\ & + K_r \int R dt + .0082 \iint R dt \qquad 3.4\text{-}13\end{aligned}$$

where ζ_d = aileron angle commanded
$\dot{\phi}$ = roll rate
$\dot{\phi}_d$ = roll reference rate (10deg/sec)
ϕ = roll angle
ϕ_d = roll reference angle
R = yaw rate
K_r = 0.35 for flight and approach
K_r = 0 after touchdown (t=0)

$$\frac{\zeta}{\zeta_d} = \frac{1 + .32\ s}{(1+.4S)(1+.11S+.0063\ s^2)} \qquad 3.4\text{-}14$$

where s is the Laplace transform operator.

A flowchart for the subroutine is shown in Table 7 and Table 133 gives a detailed listing.

3.4.11 Subroutine IT

The purpose of subroutine IT is to simulate an integrator with limits on the upper and lower limits of the output. Table 54 shows a flowchart of the subroutine and Table 180 gives a detailed listing which includes the full input/output list. The values of AMA, AMI and GKL can be selected using the same logic described in Reference 2, Volume II, Section 3.4-10.

3.5 Miscellaneous Subroutines

3.5.1 Subroutine SW

The purpose of subroutine SW is to provide the capability to switch the value of a variable during the course of a simulation. The subroutine output (V01) is initially set equal to one or other of the input variables (VA1 and VB1), depending on the initial value of the switch control (SW1). At time TC1 the output variable is switched, and at time TC2 (with TC2 greater than TC1) the output variable is switched back.

The subroutine may be used to provide forcing function inputs such as step changes or impulses, to the boundary conditions of a system, as shown in Figure 7(a) and 7(b). (Arbitrary time dependent inputs can be obtained from subroutines TA and TB described in Sections 3.5.5 and 3.5.6 respectively). The subroutine can also be used to change the value of an input parameter of a component. For example, the K factor of a duct could be changed during a simulation in order to determine the effect of a partial flow blockage; this

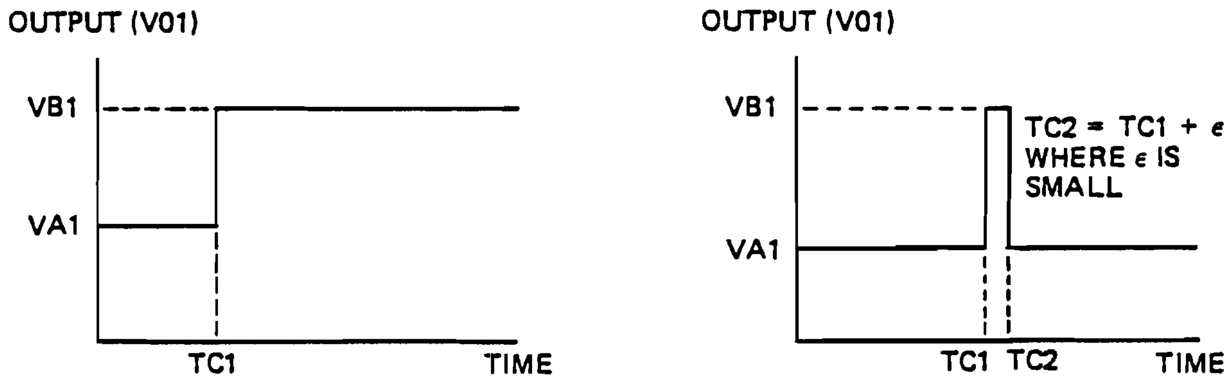


Figure 7 (a) Step Function

Figure 7 (b) Impulse Function

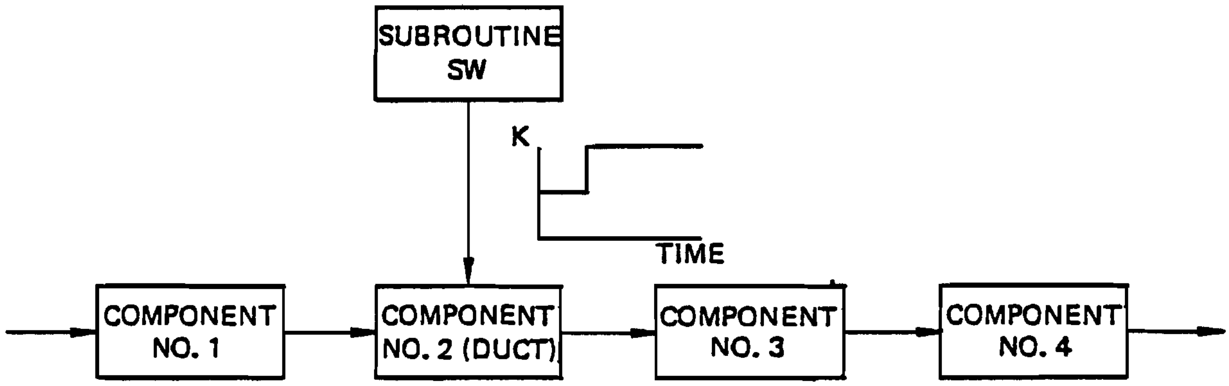


Figure 7 (c) Parameter Changes

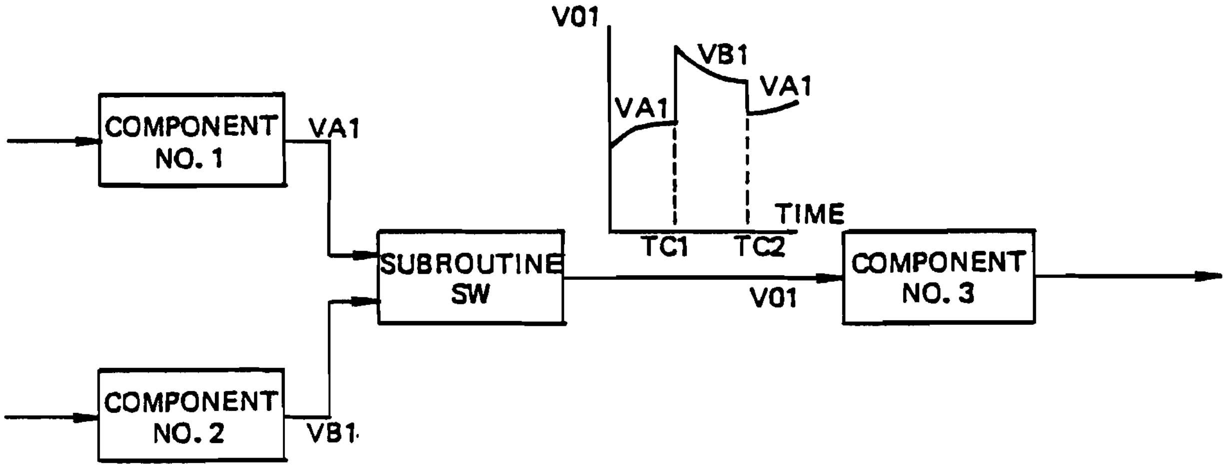


Figure 7 (d) Output Switching

Figure 7 Application of Switch Subroutine SW is illustrated in Figure 7(c). Also the subroutine can be used to switch the output signals from two seperate components as inputs into a single component, (Figure 7(d)).

A flowchart for the subroutine is shown as Table 94 and Table 220 gives a detailed listing which includes the full input/output list.

3.5.2 Subroutine SX

The purpose of subroutine SX is to provide the capability to switch the values of two variables during the course of a simulation. The subroutine is very similar to SW (described in Section 3.5.1) except that there are two outputs (VO1 and VO2), with two inputs for each output (VA1 and VB1 for VO1, VA2 and VB2 for VO2). The outputs are both switched at time TC1 and then switched back at time TC2 (with TC2 greater than TC1). Possible applications of subroutine SX are as discussed in Section 3.5.1 and illustrated in Figure 7.

The flowchart for the subroutine is shown as Table 95 and Table 221 gives a detailed listing which includes the full input/output list.

3.5.3 Subroutine SY

The purpose of subroutine SY is to provide the capability to switch the values of three variables during the course of a simulation. The subroutine is very similar to SW (described in Section 3.5.1), except that there are three outputs (VO1, VO2, and VO3) with two inputs for each output (VA1 and VB1 for VO1, VA2 and VB2 for VO2, and VA3 and VB3 for VO3). The outputs are all switched at time TC1 and then switched back at time TC2 (with TC2 greater than TC1). Possible applications of subroutine SY are discussed in Section 3.5.1 and illustrated in Figure 7.

The flowchart for the subroutine is shown as Table 96 Table 222 gives a detailed listing which includes the full input/output list.

3.5.4 Subroutine SZ

The purpose of subroutine SZ is to provide the capability to switch the values of four variables during the course of a simulation. The subroutine is very similar to the SX (as described in Section 3.5.1) except that there are four outputs (VO1, VO2, VO3, and VO4) with two inputs for each output (VA1 and VB1 for VO1, VA2 and VB2 for VO2, VA3 and VB3 for VO3, and VA4 and VB4 for VO4). The outputs are all switched at time TC1 and then switched back at time TC2 (with TC2 greater than TC1). Possible applications of subroutine SZ are as discussed in Section 3.5.1 and illustrated in Figure 7.

The flowchart for the subroutine is shown as Table 97. Table 223 gives a detailed listing which includes the full input/output list.

3.5.5 Subroutine TA

The purpose of subroutine TA is to provide the capability to input up to four variables as functions of time. Inputs to the subroutine are four one-dimensional tables (A2TAB, B2TAB, C2TAB, and D2TAB) with time as the independent variable. The corresponding outputs are the variables A2, B2, C2, and D2.

The value of time is obtained within the subroutine from the common block CTIME.

A typical application of the subroutine would be to calculate engine bleed and fan air pressures and temperature during a throttle burst or chop. Alternatively it can be used to input other time dependent variables such as electrical heat loads. Step changes or impulses can be input more efficiently using the "switch" subroutines SW, SX, SY and SZ (Sections 3.5.1 through 3.5.4). Subroutine TA should be used where there are four or three time dependent inputs (in the latter instance one table is a dummy); for two or one time dependent inputs, subroutine TB (Section 3.5.6) is more appropriate.

A flowchart for the subroutine is shown as Table 100 and Table 226 gives a detailed listing which includes the full input/output list.

3.5.6 Subroutine TB

The purpose of subroutine TB is to input up to two variables as a function of time. Inputs to the subroutine are two one-dimensional tables (A2TAB and B2TAB) with time as the independent variable. The corresponding outputs are the variable A2 and B2. The value of time is obtained within the subroutine from the common block CTIME.

This subroutine is very similar to TA (Section 3.5.5) except that it is limited to two input tables and corresponding outputs, whereas TA has the capability of up to four input tables. Typical applications of both TA and TB are discussed in Section 3.5.5.

The flowchart for the subroutine is shown as Table 101. Table 227 gives a detailed listing for subroutine TB, including the full input/output list.

3.5.7 Subroutine AF

The purpose of subroutine AF is to generate several analytical functions, with time as the indepedent variable. The output from the subroutine can be used as an input to a system in order to determine the system response to the particular form of excitation. The analytical function is selected by an input code as follows:

COD =	OUTPUT =
1	$C_1 + C_2 \text{ Sin } (C_3 \, t + C_4)$.
2	$C_1 + C_2 \text{ Cos } (C_3 \, t + C_4)$.
3	$C_1 + C_2 \, e^{-C_5 t} \text{ Sin } (C_3 t + C_4)$.
4	$C_1 + C_2 \, e^{-C_5 t} \text{ Cos } (C_3 t + C_4)$.
5	$C_1 + C_2 \, t$
6	$C_1 + C_2 \, e^{-C_3 t}$

3.5-1

where C_1, C_2, C_3, C_4, and C_5 are constants and t is time.

Table 4 shows a flowchart for the subroutine, and Table 130 gives a detailed listing which includes the full input/output list.

3.5.8 Subroutine MA

The purpose of subroutine MA is to reset the value of a variable according to the equation

$$FO = C1 \times FIN + C2 \tag{3.5-2}$$

where FO is the output
FIN is the input
and C1, C2 are input constants

A typical application for subroutine MA would be to simulate a symmetrical flow merge, for example where the flow from two engine bleed systems merge to flow into a single air conditioning pack. For such a case FIN would be the flow from a single engine, FO would be the pack flow, C1 would be set equal to 2 and C2 to zero.

Table 60 shows a flowchart for the subroutine and Table 186 gives a detailed listing which includes the full input/output list.

3.5.9 Subroutine FU

The purpose of subroutine FU is to provide the capability of simulating an arbitrary one-dimensional table $y = f(X)$. The user has the capability of specifying the degree of interpolation and whether or not extrapolation should be permitted.

Table 43 shows a flowchart for the subroutine and Table 169 gives a detailed listing which includes the full input/output list.

3.5.10 Subroutine MC

The purpose of subroutine MC is to reset the value of a variable according to the equations

$$FO = C1 \times FIN + C2 \times FIO + C3 \times FIP + C4 \qquad 3.5\text{-}3$$

where FO is the output

FIN, FIO, FIP are inlet variables

and C1, C2, C3 and C4 are input constants.

A typical application for MC would be to simulate a summation of several variables in a control loop. Table 62 shows a flowchart for the subroutine and Table 188 shows a detailed listing which includes the full input/output list.

3.5.11 Subroutine SA

The purpose of subroutine SA is to simulate a saturation. A typical application would be to limit the output from a controller to within prescribed values. The use of zero slopes in the saturation region should be avoided if possible, since the severe non-linearity will slow down the steady state solver.

Table 82 shows a flowchart for the subroutine and Table 208 gives a detailed listing which includes the full input/output list.

3.5.12 Subroutine SB

The purpose of subroutine SB is to provide the capability of simulating a saturation function with a dead band.

Table 83 shows a flowchart for the subroutine and Table 209 gives a detailed listing which includes the full input/output list.

3.5.13 Subroutine MB

The purpose of subroutine MB is to calculate the value of a variable according the the equation

$$\begin{aligned} FO = {} & C1*FNA+C2*FNB+C3*FNA*FNB \\ & +C4*FNA/FNB+C5 \end{aligned} \tag{3.5-4}$$

where FO is the output,
FNA and FNB are input variables, and
C1, C2, C3, C4, and C5 are input constants.

Table 61 shows a flowchart for the subroutine and Table 187 gives a detailed listing which includes the full input/output list.

3.5.14 Subroutine FV

The purpose of subroutine FV is to provide the capability of simulating an arbitrary two-dimensional table $Z=f(X,Y)$. The user has the capability of specifying the degree of interpolation and whether or not extrapolation should be permitted.

Table 44 shows a flowchart for the subroutine and Table 170 gives a detailed listing which includes the full input/output list.

3.5.15 Subroutine RA

The purpose of subroutine RA is to generate random variables for the gust wind model GW. Discrete random variables with mean zero and variance equal to twice the time increment approximates a unit variance white noise. RA can only be used with the fixed step integrator which is specified by the command: INT MODE = 3. A flowchart of the subroutine is shown as Table 75 and Table 201 gives a detailed listing.

3.5.16 Subroutine RN

The purpose of subroutine RN is to generate a normally distributed random number. This subroutine is called by the subroutine RA.

A flowchart of the subroutine is shown as Table 79 and Table 205 gives a detailed listing.

3.5.17 Subroutine S2

The purpose of subroutine S2 is to sum two sets of 3 axis forces and moments and is thus a summing junction. The two sets of forces must be in the same axis i.e. body, stability, or wind.

A flowchart of the subroutine is shown as Table 98 and Table 224 gives a detailed listing.

3.5.18 Subroutine S3

The purpose of subroutine S3 is to sum three sets of 3 axis forces and moments and is also a summing junction. A flowchart of the subroutine is shown as Table 99 and Table 225 gives a detailed listing.

3.5.19 Subroutine TG

The purpose of subroutine TG is to transform engine thrust into body axis forces and moments (torques) by using user provided direction cosines and moment arms.

A flowchart for the subroutine is shown as Table 110 and Table 236 gives a detailed listing.

3.5.20 Subroutine TR

The purpose of subroutine TR is to transform a set of vector quantities from body axes to earth axes using roll, pitch, yaw angle inputs and direct multiplication method.

A flowchart for the subroutine is shown as Table 113 and Table 239 gives a detailed listing.

3.5.21 Subroutine XP

The purpose of subroutine XP is to perform static transformation on three vector quantities (angular rates) from one coordinate system to another coordinate system using a matrix transformation technique.

A flowchart for the subroutine is shown as Table 124 and Table 250 gives a detailed listing.

3.5.22 Subroutine XT

The purpose of subroutine XT is to perform static transformation on three vector quantities (torques) from one coordinate system to another coordinate system using a matrix transformation technique.

A flowchart for the subroutine is shown as Table 125 and Table 251 gives a detailed listing.

3.6 Table Lookup Functions

3.6.1 Function TBL1

The purpose of function TBL1 is to perform linear interpolation on one independent variable. It is a special purpose function as it is called only by subroutine TK to interpolate the trunk shape parameters.

A flowchart for the function is shown as Table 102 and Table 228 gives a detailed listing.

3.6.2 Function TBL2

The purpose of function TBL2 is to perform curvilinear-to-rectilinear transformation and to linearly interpolate on two independent variables. This is also a special purpose function as it is called only by subroutines TK and AB to interpolate the trunk/bag shape parameters.

A flowchart for the function is shown Table 103 and Table 229 gives a detailed listing.

3.6.3 Function TBLU1

The purpose of function TBLU1 is to perform table search and Lagrangian polynomial interpolation on one independent variable. The function uses a binary search technique to locate the proper position within a table, and then uses a Lagrangian interpolating polynomial of user-defined degree.

A flowchart for the function is shown as Table 104 and Table 230 gives a detailed listing.

3.6.4 Function TBLU2

The purpose of function TBLU2 is to perform table search and Lagrangian polynomial interpolation of user-defined degree on two independent variables.

A flowchart for the function is shown as Table 105 and Table 231 gives a detailed listing.

3.6.5 Function TBLU3

The purpose of function TBLU3 is to perform table search and Lagrangian polynomial interpolation of user-defined degree on three independent variables.

A flowchart for the function is shown as Table 106 and Table 232 gives a detailed listing.

3.6.6 Subroutine ETB2

The purpose of subroutine ETB2 is to provide table look-up for a function of two independent variables $a = f(x,y)$. The subroutine was designed to support the elastic trunk component TS and utilizes equal increment data point spacing and linear interpolation.

A flowchart for the routine is shown as Table 26 and Table 152 gives a detailed listing.

3.6.7 Subroutine ETB3

The purpose of subroutine ETB3 is to provide table look-up for a function of three independent variables $a = f(x,y,z)$. The subroutine was designed to support the elastic trunk component TS and utilizes equal increment data point spacing and linear interpolation.

A flowchart for the routine is shown as Table 27 and Table 153 gives a detailed listing.

3.7 Initial Condition Function and Subroutines

3.7.1 Subroutine IC

The purpose of subroutine IC is to solve for trunk element parametric data for free and loaded ACLS trunk shapes at inital conditions. The concept is based on the so called Digges Parameter Calculations for an inelastic trunk (see AFFDL-TR-71-50, Theory of an ACLS for Aircraft by K. H. Digges, June 1971). It is a special purpose subroutine called only by component TK. The model can generate and store up to six sets of parameter data each representing an element of size and shape specified by the user. Each parameter set can be generated as a membrane model or a frozen model (see Volume I document). The trunk section properties are then evaluated from the stored arrays using table look-up routines (Section 3.6) during the model execution.

A flowchart of the subroutine is shown as Table 48 and Table 174 gives a detailed listing.

3.7.2 Subroutine ICB

The purpose of subroutine ICB is to solve for an air bag element parametric data for free and loaded air bag shapes at inital conditions. The function solves membrane geometry and force-balance equations for even increments of ZO (the vertical distance between aircraft hard structure and bottom of the air bag) and MUT (the bag-runway interface friction) and stores parameter values for table look-up arrays. It is a special purpose subroutine called only by component AB.

A flowchart of the subroutine is shown as Table 49 and Table 175 gives a detailed listing.

3.7.3 Subroutine ICFS

The purpose of subroutine ICFS is to define inital condition free shape Digges model equations for an inelastic trunk. It is a special purpose subroutine and called only by the iterative equation solver routine QNWT in subroutine IC.

A flowchart of the subroutine is shown as Table 50 and Table 176 gives a detailed listing.

3.7.4 Subroutine ICFSB

The purpose of subroutine ICFSB is to evaluate geometry equations for a free shape air bag element. The equations used describe an inelastic membrane subject to uniform internal pressure. This subroutine is called only by QNWT in subroutine ICB.

A flowchart of the subroutine is shown as Table 51 and Table 177 gives a detailed listing.

3.7.5 Subroutine ICLS

The purpose of subroutine ICLS is to define initial condition loaded shape Digges model equations for an inelastic trunk. Like ICFS it is called only by QNWT in subroutine IC.

A flowchart of the subroutine is shown as Table 52 and Table 178 gives a detailed listing.

3.7.6 Subroutine ICLSB

The purpose of subroutine ICLSB is to evaluate element geometry and force balance equations for loaded shape air bag element. Equations describe an inelastic membrane subject to uniform internal pressure and ground reaction forces. Like ICFSB, this subroutine is called only by QNWT in subroutine ICB.

A flowchart of the subroutine is shown as Table 53 and Table 179 gives a detailed listing.

3.7.7 Subroutine KINK

The purpose of subroutine KINK is to calculate the arresting gear cable kink wave angle at landing impact. This is a special purpose subroutine called only by the arresting gear component AS.

A flowchart of the subroutine is shown as Table 55 and Table 181 gives a detailed listing.

3.7.8 Subroutine RES

The purpose of subroutine RES is to evaluate the arresting cable strain. This is also a special purpose subroutine called only by subroutine KINK.

A flowchart of the subroutine is shown as Table 77 and Table 203 gives a detailed listing.

3.7.9 Function TERRA

The purpose of function TERRA is to simulate a rough terrain with random profile or a sinusoidal and (1-cosine) bump profiles. For random profiles the vertical elevation is stored in tabular form as a function of position.

A flowchart of the subroutine is shown as Table 108 and Table 234 gives a detailed listing.

3.7.10 Subroutine VPRINB

The purpose of subroutine VPRINB is to print, as output, the user supplied input data arrays for the air bag element dimensions, perforations etc., the various stored arrays calculated in the initial condition routine ICB, and element geometry and forces calculated during execution/simulation as a function of time.

A flowchart of the subroutine is shown as Table 121 and Table 247 gives a detailed listing.

3.7.11 Subroutine VPRINT

The purpose of subroutine is to print, as output, the user supplied input data arrays for the trunk element dimensions,perforations, scaling factors etc., the various stored arrays calculated in the inital condition routine IC, and element geometry and forces calculated as time-history functions.

A flowchart of the subroutine is shown as Table 122 and Table 248 gives a detailed listing.

3.7.12 Subroutine ELAS

Subroutine ELAS computes the data arrays for elastic trunk component TS. Subroutines ENDFS, ENDLS, SIDEFS and SIDELS are called by QNWT to determine trunk cross-sectional shapes. Data arrays are then filled with computed trunk variables.

A flowchart for the routine is shown as Table 19 and Table 145 gives a detailed listing.

3.7.13 Subroutine ELFX

Subroutine ELFX computes incomplete elliptic integrals of the second kind E (θ,ϕ). The subroutine was designed for use by the elastic trunk component (TS) to compute arc lengths for ellipses. If θ or ϕ are less than zero, the routine will return E = 0.

A flowchart for the routine is shown as Table 20 and Table 146 gives a detailed listing.

3.7.14 Subroutine ELKX

Subroutine ELKX computes complete elliptic integrals of the second kind E $(\theta, \pi/2)$. The subroutine was designed for use by the elastic trunk component (TS) to compute arc lengths for ellipses. If θ is less than zero, the routine will return E = 0.

A flowchart for the routine is shown as Table 21 and Table 147 gives a detailed listing.

3.7.15 Subroutine ELWR

Subroutine ELWR supports the elastic trunk component (TS) to provide printout of the trunk element property arrays.

A flowchart for the routine is shown as Table 22 and Table 148 gives a detailed listing.

3.7.16 Subroutine ENDFS

This subroutine is used by elastic trunk component TS to compute the free shape of a trunk end element. The trunk cross-section is assumed to be elliptical in shape and in point contact with the ground. The shape equations incorporate membrane theory and consider elastic deformation in the trunk hoop and meridian directions.

A flowchart for the routine is shown as Table 23 and Table 149 gives a detailed listing.

3.7.17 Subroutine ENDLS

This subroutine is used by elastic trunk component TS to compute the loaded shape of a trunk end element. The trunk cross-section is assumed to be comprised of elliptical arcs (2), one on each side of a straight section which is in ground contact. As in ENDFS, the shape equations incorporate membrane theory and consider elastic deformation in the hoop and meridian directions.

A flowchart for the routine is shown as Table 24 and Table 150 gives a detailed listing.

3.7.18 Subroutine SIDEFS

This subroutine is used by elastic trunk component TS to compute the free shape of a trunk side element. The trunk cross-section is represented by circular arcs and is assumed to be in point contact with the ground. The shape equations incorporate membrane theory and consider elastic deformation in the meridian direction only.

A flowchart for the routine is shown as Table 89 and Table 215 gives a detailed listing.

3.7.19 Subroutine SIDELS

This subroutine is used by elastic trunk component TS to compute the loaded shape of a trunk side element. The trunk cross-section is represented by two circular arcs, one on each side of a straight section which is in ground contact.

A flowchart for the routine is shown as Table 90 and Table 216 gives a detailed listing.

3.7.20 Subroutine XXPRT

This routine is used by elastic trunk component TS to provide printed output of trunk variables during non-linear simulation.

A flowchart for the routine is shown as Table 126 and Table 252 gives a detailed listing.

3.8 Supporting Subroutines for the Foster-Miller Trunk Component (FM)

Of the twenty subroutines which make up this section, eighteen were written by Foster-Miller Associates Inc., (FMA) as part of their model for an air cushion landing system (ACLS). The remaining two subroutines (FMWRIT and OUTFM) were developed by the Boeing Company to replace FMA input/output routines which were incompatible with the EASY program.

3.8.1 Subroutine CDVCHP

This subroutine calculates the valve of DVCHP which is the ratio of cushion volume change to change in cushion-to-trunk pressure ratio.

A flowchart for the routine is shown as Table 10 and Table 136 gives a detailed listing.

3.8.2 Subroutine CLRNCE

The purpose of this subroutine is to calculate the trunk-ground clearance for each trunk segment.

A flowchart for the subroutine is shown as Table 9 and Table 135 gives a detailed listing.

3.8.3 Subroutine COORDN

This subroutine calculates the X and Z coordinates of the ground point corresponding to each segment, for a particular ACLS orientation.

A flowchart for the routine is shown as Table 11 and Table 137 gives a detailed listing.

3.8.4 Subroutine DYNFAN

This subroutine models the dynamic behavior of the ACLS fan. Fan pressure is calculated from a user defined polynomial function of fan flow.

A flowchart for the routine is shown as Table 16 and Table 142 gives a detailed listing.

3.8.5 Subroutine FLOW

This subroutine calculates the ACLS flow and pressure variables during dynamic simulation.

A flowchart for the routine is shown as Table 32 and Table 158 gives a detailed listing.

3.8.6 Subroutine FMFAN

This subroutine models the static behavior of the ACLS fan. Fan flow is calculated from a user defined polynomial function of fan pressure.

A flowchart for the routine is shown as Table 34 and Table 160 gives a detailed listing.

3.8.7 Subroutine FMWRIT

This subroutine was developed by the Boeing Company to print a list which describes each ACLS input variable and the corresponding value input by the user.

A flowchart for the routine is shown as Table 35 and Table 161 gives a detailed listing.

3.8.8 Subroutine FORCE

This subroutine calculates the forces and torques associated with a particular ACLS orientation.

A flowchart for the routine is shown as Table 38 and Table 164 gives a detailed listing.

3.8.9 Subroutine HYCURV

This subroutine calculates the side trunk height as a function of pressure ratio.

A flowchart for the routine is shown as Table 47 and Table 173 gives a detailed listing.

3.8.10 Subroutine OUTFM

This subroutine was developed by the Boeing Company and replaces FMA routine OUTPUT. The purpose of the routine is to calculate various time dependent variables during ACLS dynamic simulation.

A flowchart for the routine is shown as Table 67 and Table 193 gives a detailed listing.

3.8.11 Subroutine PARAMS

This subroutine provides default values for various ACLS parameters. The user may override these default values by inputing the desired values.

A flowchart for the routine is shown as Table 68 and Table 194 gives a detailed listing.

3.8.12 Subroutine PROFILE

This user-supplied subroutine provides values of ground elevation Yg(i) which correspond to ground coordinates Xg(i) and Zg(i). A default subroutine is included in the ACLS library to simulate a flat ground surface. The user may input a different PROFILE using Fortran statements in the model description data file.

A flowchart for the routine is shown as Table 72 and Table 198 gives a detailed listing.

3.8.13 Subroutine ROTATE

This subroutine transforms vector data from the vehicle frame to the inertial reference frame.

A flowchart for the routine is shown as Table 80 and Table 206 gives a detailed listing.

3.8.14 Subroutine SEGMNT

This subroutine divides the ACLS trunk into a number of segments and assigns initial properties to the segments.

A flowchart for the routine is shown as Table 84 and Table 210 gives a detailed listing.

3.8.15 Subroutine SHAPE1

This subroutine provides an initial assessment of ACLS trunk areas and volumes assuming no ground contact.

A flowchart for the routine is shown as Table 86 and Table 212 gives a detailed listing.

3.8.16 Subroutine SHAPE2

This subroutine calculates current ACLS trunk areas and volumes as a function of vehicle orientation.

A flowchart for the routine is shown as Table 87 and Table 213 gives a detailed listing.

3.8.17 Subroutine STATIC

This subroutine provides static simulation of an ACLS. Equilibrium conditions are calculated and include the position of the aircraft center of gravity; orientation of the aircraft in terms of pitch and roll angles; equilibrium pressure in the trunk, cushion and plenum; equilibrium flows in different parts of the ACLS and the theoretical power required to operate the ACLS.

The static simulation also generates load maps which are useful in evaluating behavior of the ACLS in pure heave (up-down), pitch and roll modes.

A flowchart for the routine is shown as Table 91 and Table 217 gives a detailed listing.

3.8.18 Subroutine STEQU

Subroutine STEQU calculates the time derivatives for the set of ACLS state variables. The routine calls subroutine FLOW and FORCE to update the values of flows, forces and torques associated with the current set of state variables.

A flowchart for the routine is shown as Table 92 and Table 218 gives a detailed listing.

3.8.19 Subroutine TRUNK

This routine calculates the values of variables associated with the ACLS trunk cross section shape.

A flowchart for the routine is shown as Table 114 and Table 240 gives a detailed listing.

3.8.20 Subroutine VALVE

This subroutine calculates the pressure relief valve area as a function of valve displacement.

A flowchart for the routine is shown as Table 119 and Table 245 gives a detailed listing.

SECTION IV

COMPONENT SUBROUTINES

4.1 Ducting Components

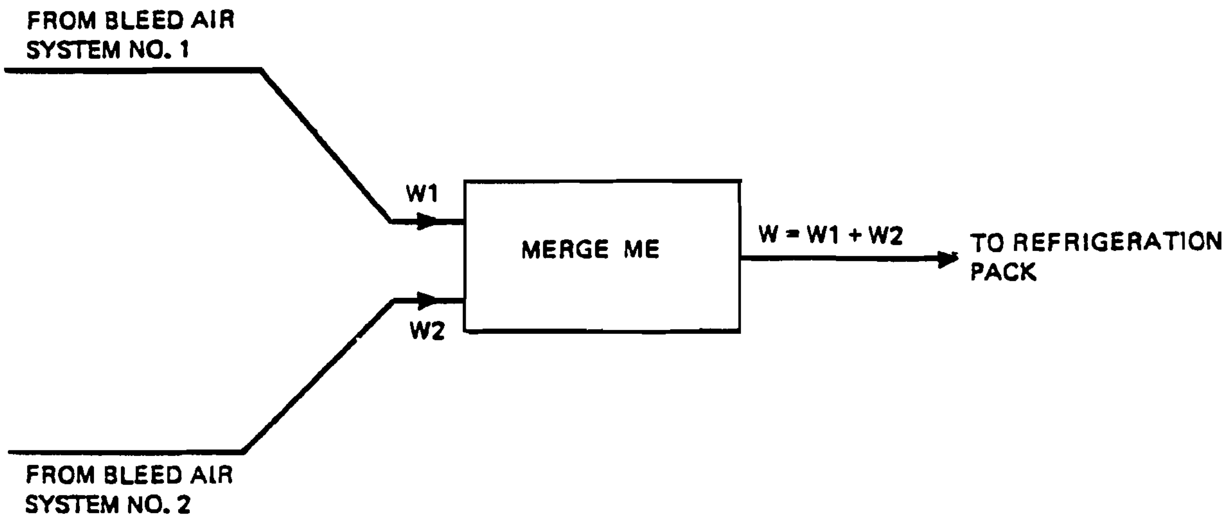
The component subroutines covered in this section include ducts (DU), splits (FS) and merges (MG).

It should be noted that it is possible and often desirable to represent ducting components in other ways. For example, the flow merge between two bleed air systems could be simulated using the merge component MG as shown in Figure 8(a). However if only one of the bleed systems is being modeled in detail, and if the flow from each bleed system is assumed equal, then it would be preferable to use the multiply-and-add standard subroutine MA (see Section 3.5.8) as shown in Figure 8(b). The advantage of using MA in this instance is that less input data is required, and one less state variable would be required. Component MA can of course also be used to simulate a flow split. Ducts can often be omitted, with pressure, temperature, and flow capacitance effects being "lumped-in" with other components.

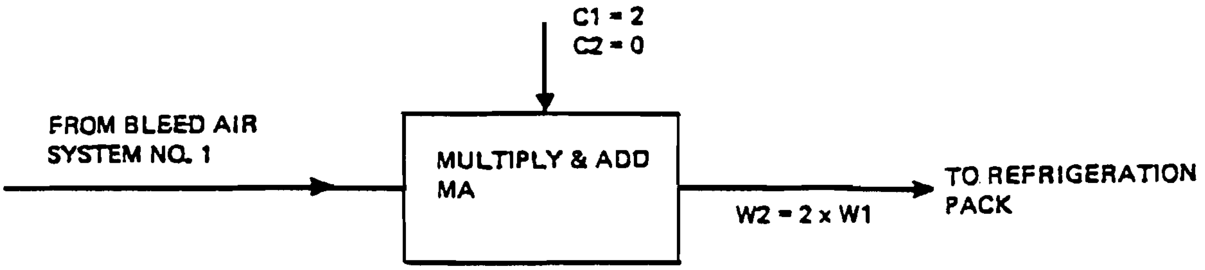
The detailed models for ducts, splits and merges should be used where the high frequency flow dynamics effects are considered significant; otherwise alternates should be used as described above.

4.1.1 Duct DU

The duct component DU is a simple single-state model in which the only dynamic effect simulated is flow capacitance, with pressure being a state variable. The theory for the model is given in Reference 2, Volume I, Section 3.1.1, which also describes the theory for more complex models which can be supplied by the program user if desired.



(a) FLOW MERGE USING COMPONENT ME



(b) FLOW MERGE USING COMPONENT MA

Figure 8 Alternate Representations of Flow Merge

A flowchart for the subroutine is shown as Table 14 and Table 140 gives a detailed listing which includes the full input/output list. A warning message will be printed in the event that the temperature change exceeds 300°F, since in this event a more complex model with temperature nodes in the wall and possibly also in the fluid may be desirable.

4.1.2 Split FS

The split component FS models a flow divide, and has a single inlet port and two outlet ports. The basic approach is very similar to that of the duct component DU. The flow in each outlet leg is calculated based on input values of K factor and effective area for each leg. Heat transfer is calculated based on an input value of hydraulic diameter (for calculation of Reynolds number) and heat transfer area. The theory for the Split model is given in Reference 2, Volume I, Section 3.1.2.

A flowchart for the subroutine is shown as Table 40 and Table 166 gives a detailed listing which includes the full input/output list. A warning diagnostic will be printed in the event that the temperature change exceeds 300°F, since in this event a more complex model with temperature nodes in the wall and possibly also in the fluid may be desirable.

4.1.3 Merge MG

The merge component MG models a flow junction, and has two inlet ports and a single outlet port. The basic approach is very similar to that of the duct component DU. The flow in the outlet leg is calculated based on input values of K factor and effective area for that leg. Heat transfer is calculated based on an input value of hydraulic diameter (for calculation of Reynolds number) and heat transfer area. The theory for the merge model is given in Reference 2, Volume I, Section 3.1.3.

A flowchart for the subroutine is shown as Table 63 and Table 189 gives a detailed listing which includes the full input/output list. A warning diagnostic will be printed in the event that the temperature change exceeds 300°F, since in this event a more complex model with temperature nodes in the wall and possibly also in the fluid may be desirable.

4.1.4 Valve In a Duct DV

The "valve in a duct" component DV simulates a valve (butterfly, gate or globe) in a duct. The basic approach is similar to the duct component DU, except that the flow is calculated by calling the subroutine VLX. Inputs to DV include a parameter defining the type of valve, and the valve opening. The theory for the flow calculation is given in Reference 2, Volume I, Section 3.7.

A flowchart for the subroutine is shown as Table 15 and Table 141 gives a detailed listing which includes the full input/output list. A warning diagnostic will be printed in the event that the temperature change exceeds 300°F, since in this event a more complex model with temperature nodes in the wall and possibly also in the fluid may be desirable.

4.2 Fan and Ejector Components

4.2.1 Ejector EJ

The purpose of the component EJ is to model an air ejector with converging-diverging nozzle and subsonic or choked flow conditions. The subroutine uses a two dimensional input table of flow ratio (total/primary) as a function of the two pressure ratios (total/secondary) and (primary/secondary). For choked throat flow upstream pressure is computed to match flow and for subsonic flow the exit pressure equals secondary supply pressure. A flowchart for the subroutine is shown as Table 18 and Table 144 gives a detailed listing.

4.2.2 Fan with Hysteresis FH

The purpose of the component FH is to model an externally driven axial fan with transition time constant between stall and recovery. It is assumed that transition from normal to stalled operation occurs when the pressure ratio exceeds the stall pressure ratio (user supplied) and that transition from stalled to normal occurs when pressure ratio falls below a reverse pressure ratio (user supplied).

A flowchart for the component is shown as Table 30 and Table 156 gives a detailed listing.

4.2.3 Fan with Surge Analysis FR

The compressor/fan model FR calculates the component performance using steady state maps. Inlet pressure is the one state variable for the model.

The model is capable of reverse flow analysis and can accommodate pressure ratios less than 1. The theory for the model is shown in Reference 2, Volume I, Section 3.2.2.

A flowchart for the subroutine is shown as Table 39 and Table 165 gives a detailed listing which includes the full input/output lists.

4.2.4 ACLS Turbofan FT

The purpose of fan component FT is to simulate a hub or tip driven axial turbofan as used on the Jindivik ACLS vehicle. The subroutine uses input table defining steady state characteristics of tubine and fan. Drive air turbine inlet pressure is a state variable.

A flowchart for the subroutine is shown as Table 42 and Table 168 gives a detailed listing.

4.2.5 Inlet Fan FN

The purpose of this component is to model a fan which is located at the inlet of a duct. It calculates the fan's flow rate, inlet pressure, inlet temperature and outlet temperature. The flow rate is determined from tabular data which is input as a function of pressure ratio (PR) and fan RPM. If this flow rate data has been normalized for $\sqrt{\theta/\delta}$, where θ is the air temperature divided by the air temperature at sea level on a standard day and δ is the air pressure divided by the air pressure at sea level on a standard day. FN will account for this normalization if CORFN is set to any value except 0.0 and .99999. The inlet pressure and temperature are determined by the inlet ram efficiency. The outlet temperature is calcuated from the fan efficiency.

The user has the option of inputing stall line data as a function of pressure ratio. When this data is input, the program will print after each print cycle "The fan is operating in the stall region" whenever the fan is stalled.

A flowchart for the subroutine is shown in Table 36 and Table 162 gives a detailed listing which includes the full input/output lists.

4.3 Aircraft and Aerodynamic Components

4.3.1 Generalized 6DOF Component SG

The six degree of freedom component SG simulates the aircraft rigid body of motion equations. The component receives as input all body axis forces and moments including gravity. Parametric inputs include mass, and moments and cross products of inertia of the aircraft. Outputs from the component include the accelerations and velocities (linear and angular) in the body axis coordinate system, Euler angles and earth axis positions. The differential equations for the twelve states representing the linear and angular velocities and positions are contained in this component. The derivation of equations is described in Section 2.4.1, Volume I. Table 85 shows a flowchart and Table 211 gives a detailed listing.

4.3.2 Six DOF Component DS

This component is same as the component SG except that the X-Z plane is assumed to be a plane of symmetry. Therefore the cross product of inertia terms I_{xy} and I_{yz} and associated terms are taken out simplifying the equations of motion. In addition the airplane positions in X and Y earth axis are not state variables and only rates (velocities) are output. It is recommended that this component be used for inflight models when there are no trunk or ACLS components involved and the optimal controller is being used for finding trim.

A flowchart for the component is shown as Table 13 and Table 139 gives a detailed listing.

4.3.3 4DOF Rigid Body Dynamics FD

The four degree of freedom component consists of the same types of inputs and outputs and uses the same coordinate system as the 6DOF component DS. The degrees of freedom are forward and side velocities and roll and yaw (U,V,P,R) and the model is applicable to ground directional control studies. Table 28 shows a flowchart and Table 154 gives a detailed listing.

4.3.4 3DOF Longitudinal Rigid Body Dynamics TL

This is a simplified version of the six DOF component DS where only longitudinal equations of motion are treated. The degrees of freedom are forward and vertical velocities, and pitch (U,W,Q). The model is applicable to long period longitudinal stability analysis (Phugoid). Table 112 shows a flowchart and Table 238 gives a detailed listing.

4.3.5 3DOF Lateral Rigid Body Dynamics TD

This is also a simplified version of the six DOF component DS where only lateral equations of motion are retained. The degrees of freedom are side velocity, roll and yaw (V,P,R). The model is applicable to lateral stability analysis. Table 107 shows a flowchart and Table 233 gives a detailed listing.

4.3.6 2DOF Longitudinal Rigid Body Dynamics TT

This component is similar to the component TL, above, except that the degrees of freedom are vertical velocity (or heave) and pitch (W,Q). The model is applicable to drop test simulations and for inflight short period longitudinal oscillations. Table 116 shows a flowchart for the subroutine and Table 242 gives a detailed listing.

4.3.7 Aerodynamic Variables Component VA

The model adds total wind perturbation onto the aircraft velocity states, output from 6DOF component, and computes aero variables such as angle-of-attack, sideslip, dynamic pressure, and Mach number. The body to stability axis transformation is achieved wherever applicable. A switch is used to assure compatability with various DOF components. The derivation of equations is described in Section 2.4.7, Volume I. Table 118 shows a flowchart and Table 244 gives a detailed listing.

4.3.8 Longitudinal Forces and Moments Component OL

Inputs to this component include external forces and torques (e.g. due to trunk, engine) and aerostability derivatives for the three longitudinal degrees of freedom. The external forces and moments are combined with the linear aero forces and moments in body axes and output as total force and moment vectors about the aircraft c.g. The module also solves for the linear accelerations U and W in order to compute the implicit aero terms due to $\dot{\alpha}$ and $\dot{\beta}$. The body axis linear accelerations and the torques are then passed to the equations of motion module DS or SG.

The aero derivatives can be specified in either stability axes or in body axes. For more details see Section 5.1 of the User's Manual (Reference 1) and Volume I, Section 2.4.8. A flowchart for the component OL is shown as Table 65 and Table 191 gives a detailed listing.

4.3.9 Lateral Forces and Moments Component DL

This component is identical in design to component OL and computes the lateral set of forces and moments. A flowchart for the component is shown as Table 12 and Table 138 gives a detailed listing.

4.3.10 Aerodynamic Coefficients Table Lookup AC

This component provides for one dimensional table lookup capability for the six basic aerodynamic coefficients; lift, drag, pitch moment, roll moment and yaw moment as functions of angle of attack (α) and the side force coefficient as a function of angle of side slip (β). The user should carefully read the code before using this component or use FORTRAN to input tabular data for the various non-linear aero coefficients. A flowchart for the subroutine is shown as Table 3 and Table 129 gives a detailed listing.

4.4 Engine and Thruster Components

4.4.1 Engine Model (Simple) ES

See 4.4.2 for description.

4.4.2 Engine Model (Complex) EC

Two engine components were developed. Both calculate engine thrust and engine bleed-and-fan-air pressures and temperatures. The model ES is dynamically simple, with all dynamic effects accounted for by a first order lag for the thrust calculation.

In the second, more complex model, EC, the engine pressure ratio (EPR) is computed as a function of the power lever angle. Engine transient conditions are accounted for by introducing a first order lag for engine deceleration and a second order lag for engine acceleration. Net thrust (forward or reverse) is computed as a function of Mach number and the actual engine pressure ratio. The second order function requires user inputs for engine spinup, natural frequency f(EPR) table and damping ratio constant. The first order lag requires only the engine time constant.

The bleed and fan air pressures and temperatures are calculated as functions of corrected engine speed which is a two dimensional table lookup with Mach number and calculated thrust as independent variables. This calculation is common to both components.

A flowchart for the model ES is shown as Table 25 and Table 151 gives the detailed listing. A flowchart for the model EC is shown as Table 17 and Table 143 gives a detailed listing.

4.4.3 Yaw Control Thruster YC

The purpose of component YC is to simulate the effect of an auxiliary yaw thruster used to augment lateral dynamic stability of an ACLS equipped aircraft. The vectored thrust is a function of aircraft yaw angle or an input control signal. The vectored thrust may or may not be dependent on engine thrust i.e. the thruster could be powered independently.

A flowchart for the component YC is shown as Table 127 and Table 253 gives a detailed listing.

4.4.4 Pitch Control Thruster PT

The pitch control thruster provides longitudinal dynamic stability to an ACLS equipped vehicle. The component is identical in design to YC (4.4.3). A flowchart for the component PT is shown as Table 74 and Table 200 gives a detailed listing.

4.4.5 Roll Control Thruster RT

The roll control thruster is also identical in design to the other two thrusters, YC and PT, and provides roll stability. A flowchart for the component is shown as Table 81 and Table 207 gives a detailed listing.

4.5 Wind Components

4.5.1 Gust Wind Model GW

A wind gust model component developed under Contract F33615-76-C-3165 has been adapted for the ACLS library. The model simulates random wind gust components based on Dryden Spectra, in accordance with Section 3.7, MIL-F-8785B. The equations used in the computer code are directly taken from the MIL-F-8785B. Table 45 shows a flow chart, and Table 171 gives a detailed listing.

4.5.2 Steady or Shear Wind Model WS

The purpose of this component is to simulate wind shear or steady wind components. The wind magnitude quoted at control tower altitude of 50 feet is modified by a non-linear shear factor to reflect the change in wind with altitude. The wind vector is assumed parallel to the ground plane. The wind magnitude modified by shear is resolved along the runway coordinates North and East (fwd and side) and transformed into body axis. The derivation of equations is described in Section 2.5.2 Volume I. Table 123 shows a flowchart and Table 249 gives a detailed listing.

4.5.3 Summation of Wind Vectors SV

The total wind components are obtained by the summation of gust and steady/shear wind profiles in the body axis system and the summation is carried out in the component SV. Table 93 shows a flowchart and Table 219 gives a detailed listing.

4.6 Air Cushion System Components

4.6.1 Inelastic Trunk Model TK

The model represents the geometry and pneumatic characteristics of an inelastic trunk enclosing a cushion of air. The trunk is described by a finite number of elements which need not be uniform in cross section, width, or location on the vehicle.

The trunk is composed of three parts: side elements, fore elements and aft elements. The side elements have unconstrained outward movement subject to ground contact or changes in the cushion trunk pressure ratio and are represented with a membrane model. The fore and aft elements experience little or no outward motion due to constraining peripheral stresses and are represented by a frozen model or a constrained membrane model (user option).

The inputs required are related to the trunk geometry such as section properties, attach points, coordinates, perforation arrangements etc., which can be obtained from detailed trunk drawings. The other data inputs needed are trunk damping coefficient as a function of trunk flattened area, relief valve opening as a function of trunk pressure and various flow discharge coefficients. For details see Reference 2, Volume I. A flowchart for the component is shown as Table 111 and Table 237 gives a detailed listing.

4.6.2 Elastic Trunk Model TS

The model represents the geometry and pneumatic characteristics of an elastic trunk enclosing a cushion of air. The trunk is described by a finite number of elements which need not be uniform in cross section, width or location on the vehicle.

The trunk model is comprised of two basic units: side elements and end elements. The end elements take into consideration membrane loads and deformations in both the hoop and meridian directions. For the side elements, the membrane loads and strains are computed for the meridian direction only; deformations in the hoop direction are assumed to be zero. As a user option, each element may be designated as a pillow brake element.

Inputs required include load/deflection characteristics for the membrane as well as inputs related to the trunk geometry such as section properties, membrane attach points, coordinates, perforation arrangements, etc. Other required data are trunk damping coefficient as a function of trunk flattened area, relief valve opening as a function of trunk pressure, pillow brake actuation signal, and various flow discharge coefficients. A flowchart for the component is shown as Table 115 and Table 241 gives a detailed listing.

4.6.3 Foster Miller Inelastic Trunk Model FM and 00

This model was developed by Foster Miller Associates Inc. and adapted by the Boeing Company for inclusion into the EASY program. The model includes the ACLS vehicle body dynamics using two orthogonal coordinate frames of reference; an inertial frame fixed in space and a vehicle frame fixed to the vehicle. The model also represents the geometry and pneumatic characteristics of an inelastic trunk enclosing a cushion of air.

The trunk model is made up of side segments and end segments. Side segments are represented by a simple two-dimensional membrane, and end segments are represented by a frozen model.

Inputs required must describe not only the trunk geometry as with component TK, but also the fan performance (static and dynamic) as polynominal functions, the side membrane height as a polynominal function of pressure ratio, relief valve dimensions, trunk perforation details, etc.

The component FM may be used in the Foster Miller mode (user option) to duplicate all static and dynamic analytical capabilities of the FMA/NASA ACLS program. The component may also be used in the EASY mode (user option) to perform the standard EASY analyses i.e. steady state, linear analysis and simulation.

The component 00 was developed to display variables of interest during program execution, and must be used in conjunction with component FM.

Flowcharts for components FM and 00 are included as Tables 33 and 66 respectively. Subroutine listings are provided as Tables 159 and 192.

4.6.4 Air Bag Model AB

The model represents the geometry and pneumatic characteristics of two parallel inelastic airbags. The bags are described by a finite number of elements which need not be uniform is cross section, width, or location on the vehicle. The air bag elements have unconstrained lateral movement subject to ground friction forces in the Y-axis and are represented by a membrane model. The basic design concepts for the air bag model are identical to those for the trunk model. For derivation of model equations and other details, see Reference 2, Volume I, Section VII.

A flowchart for the model is shown as Table 2 and Table 128 gives a detailed listing.

4.6.5. Arresting Gear Model AS

The model simulates the dynamic response of a Water Twister type of arresting system composed of a steel cable pendant, nylon tape and a water twister energy absorber.

The Water Twister (Registered Trademark) is a simple water brake that converts kinetic energy to heat through turbulence. The brake consists of a fluid filled steel casing, with internal stator vanes, which houses a vaned centrifugal rotor. The rotor is mounted on a shaft which extends out of the top of the casing. A storage reel for a nylon tape purchase element is mounted on and splined to the top end of the rotor shaft. The tape is wrapped on this storage reel, layer on layer, forming a spiral wrap. Pulling the tape off the reel causes the shaft and vaned rotor to revolve within the fluid filled casing, creating turbulence. For derivation of model equations and other details, see Reference 2, Volume I, Section VIII. A flowchart for the model is shown as Table 8 and Table 134 gives a detailed listing.

4.7 Optimal Controller OC

This section pertains to a unique component in the EASY library, the optimal controller OC. User inputs for utilization of this component are described in Reference 2.

A complete description of the calculation methods and theoretical basis for the optimal controller are presented in Reference 2, Section 4.5. Further elaboration is presented in Reference 2, Volume IV. A flowchart for the subroutine is shown as Table 64 and a listing of OC is presented in Table 190.

4.8 Atmospheric Flight Conditions FL

The purpose of model FL is to calculate the ambient data given the airplane's altitude and Mach number. Outputs from the subroutine are the ambient pressure, ambient temperature, ram pressure and ram temperature. The ambient and ram temperatures are calculated by defining the type of day, i.e.:

Day = 1 MIL-STD-210B Operation (1 percent risk) Hot Day
2 MIL-STD-210A Hot Day
3 MIL-STD-210A Tropical Day
4 U.S. Standard Atmosphere (Default)
5 MIL-STD-210A Polar Day
6 MIL-STD-201A Cold Day
7 MIL-STD-210B Operational (1 percent risk) Cold Day

The ram pressure is calculated assuming 100% recovery.

A flowchart for this subroutine is shown in Table 31 and Table 157 gives a detailed listing.

SECTION V

FLOW CHARTS

This section contains all the EASY ACLS subroutine flow charts in alphabetical order by subroutine name.

Table 2: FLOWCHART FOR SUBROUTINE AB

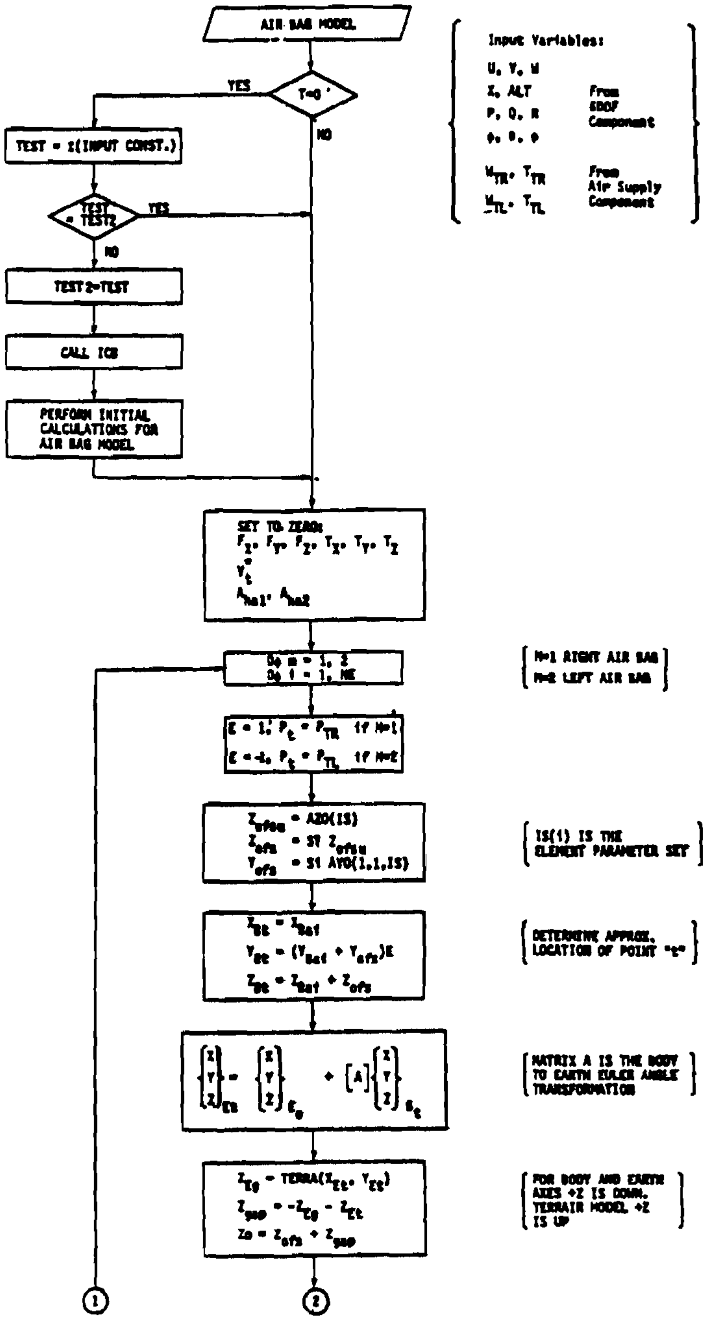


Table 2: FLOWCHART FOR SUBROUTINE AB (CONCLUDED)

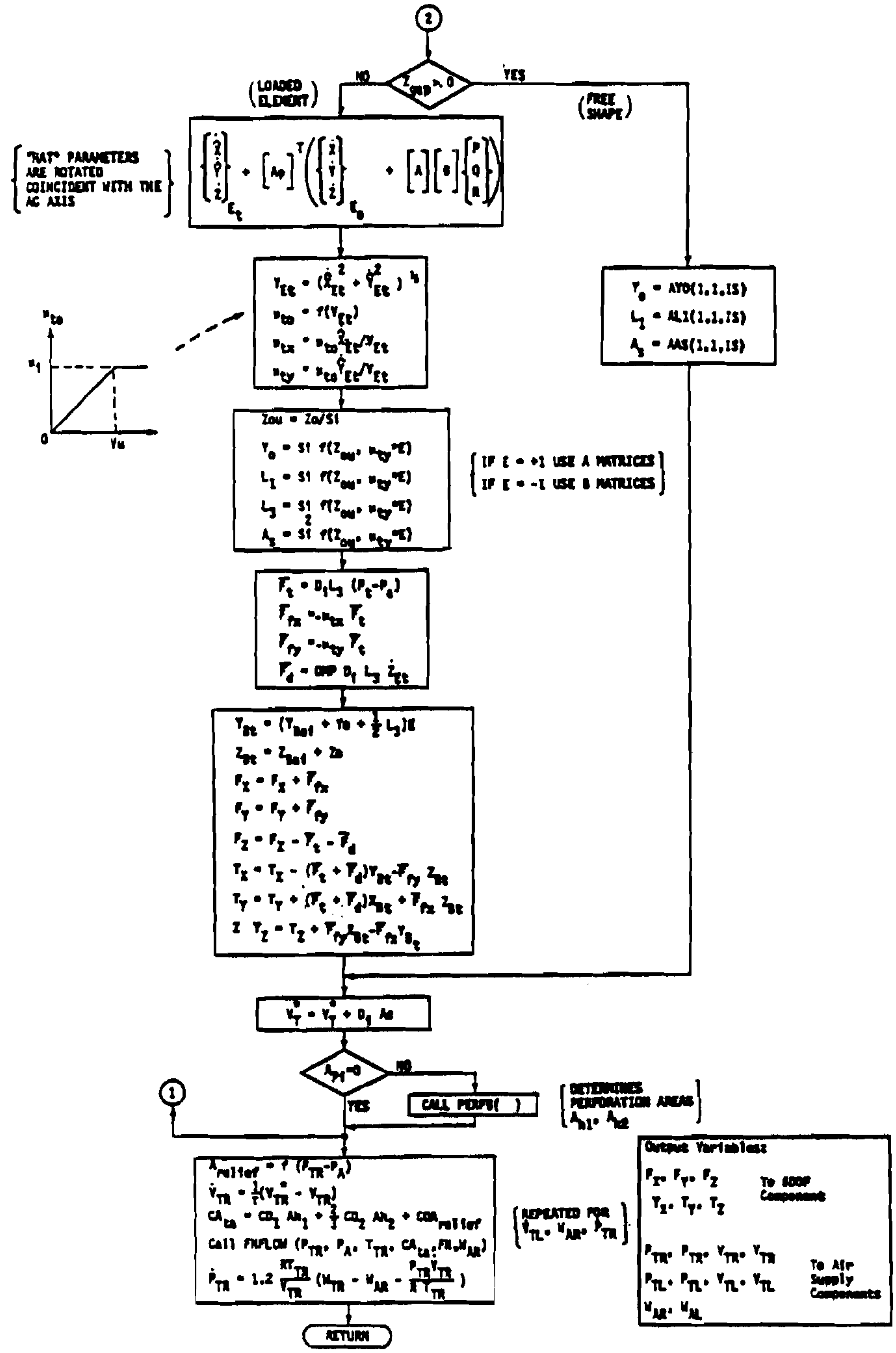
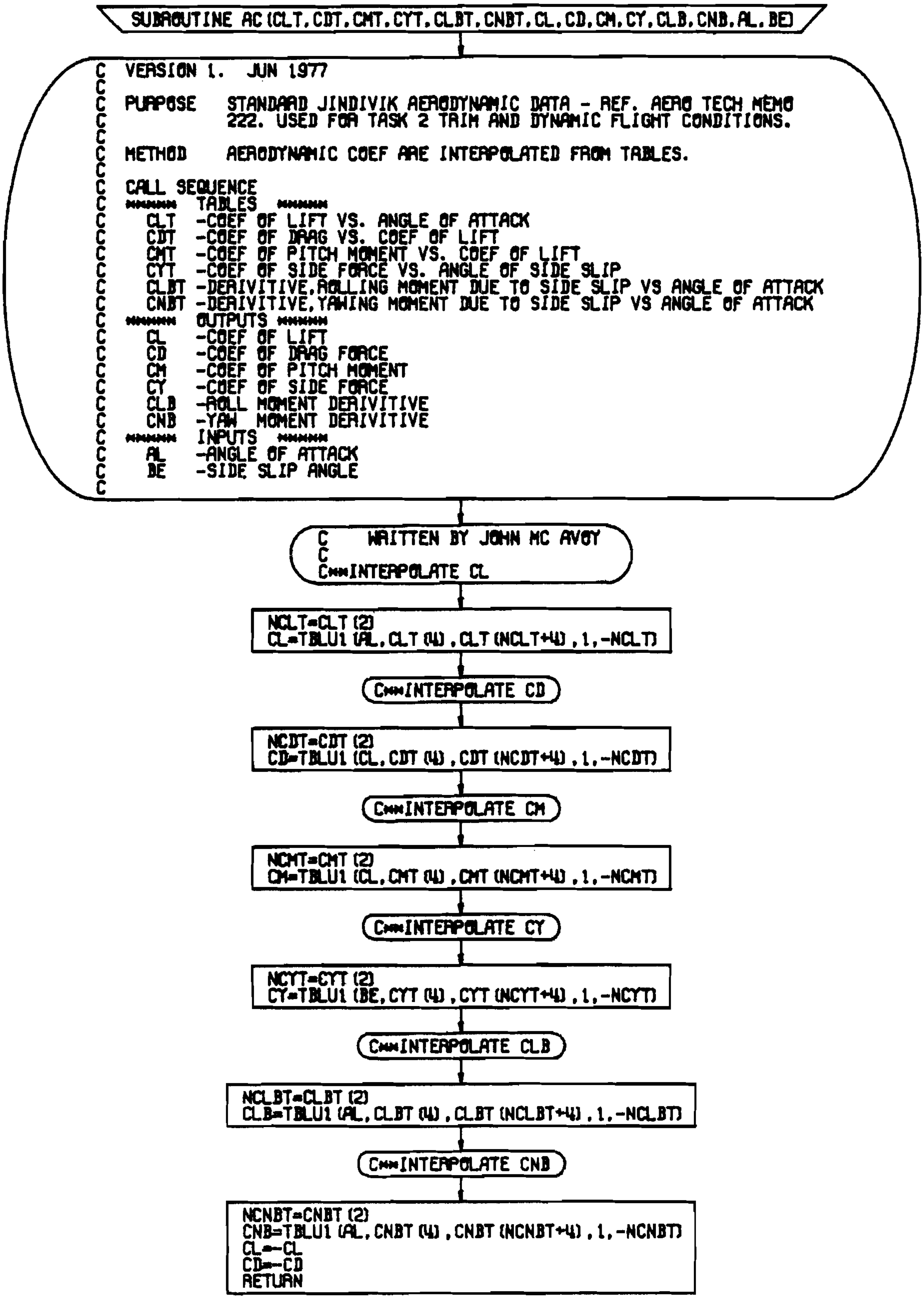


Table 3: FLOWCHART FOR SUBROUTINE AC



```
SUBROUTINE AC (CLT,CDT,CMT,CYT,CLBT,CNBT,CL,CD,CM,CY,CLB,CNB,AL,BE)

C   VERSION 1.  JUN 1977
C
C   PURPOSE   STANDARD JINDIVIK AERODYNAMIC DATA - REF. AERO TECH MEMO
C             222. USED FOR TASK 2 TRIM AND DYNAMIC FLIGHT CONDITIONS.
C
C   METHOD    AERODYNAMIC COEF ARE INTERPOLATED FROM TABLES.
C
C   CALL SEQUENCE
C   ******  TABLES  ******
C     CLT  -COEF OF LIFT VS. ANGLE OF ATTACK
C     CDT  -COEF OF DRAG VS. COEF OF LIFT
C     CMT  -COEF OF PITCH MOMENT VS. COEF OF LIFT
C     CYT  -COEF OF SIDE FORCE VS. ANGLE OF SIDE SLIP
C     CLBT -DERIVITIVE,ROLLING MOMENT DUE TO SIDE SLIP VS ANGLE OF ATTACK
C     CNBT -DERIVITIVE,YAWING MOMENT DUE TO SIDE SLIP VS ANGLE OF ATTACK
C   ******  OUTPUTS ******
C     CL   -COEF OF LIFT
C     CD   -COEF OF DRAG FORCE
C     CM   -COEF OF PITCH MOMENT
C     CY   -COEF OF SIDE FORCE
C     CLB  -ROLL MOMENT DERIVITIVE
C     CNB  -YAW  MOMENT DERIVITIVE
C   ******  INPUTS  ******
C     AL   -ANGLE OF ATTACK
C     BE   -SIDE SLIP ANGLE
C

C     WRITTEN BY JOHN MC AVOY
C
C**INTERPOLATE CL

NCLT=CLT (2)
CL=TBLU1 (AL,CLT (4),CLT (NCLT+4),1,-NCLT)

C**INTERPOLATE CD

NCDT=CDT (2)
CD=TBLU1 (CL,CDT (4),CDT (NCDT+4),1,-NCDT)

C**INTERPOLATE CM

NCMT=CMT (2)
CM=TBLU1 (CL,CMT (4),CMT (NCMT+4),1,-NCMT)

C**INTERPOLATE CY

NCYT=CYT (2)
CY=TBLU1 (BE,CYT (4),CYT (NCYT+4),1,-NCYT)

C**INTERPOLATE CLB

NCLBT=CLBT (2)
CLB=TBLU1 (AL,CLBT (4),CLBT (NCLBT+4),1,-NCLBT)

C**INTERPOLATE CNB

NCNBT=CNBT (2)
CNB=TBLU1 (AL,CNBT (4),CNBT (NCNBT+4),1,-NCNBT)
CL=-CL
CD=-CD
RETURN
```

Table 4: FLOWCHART FOR SUBROUTINE AF

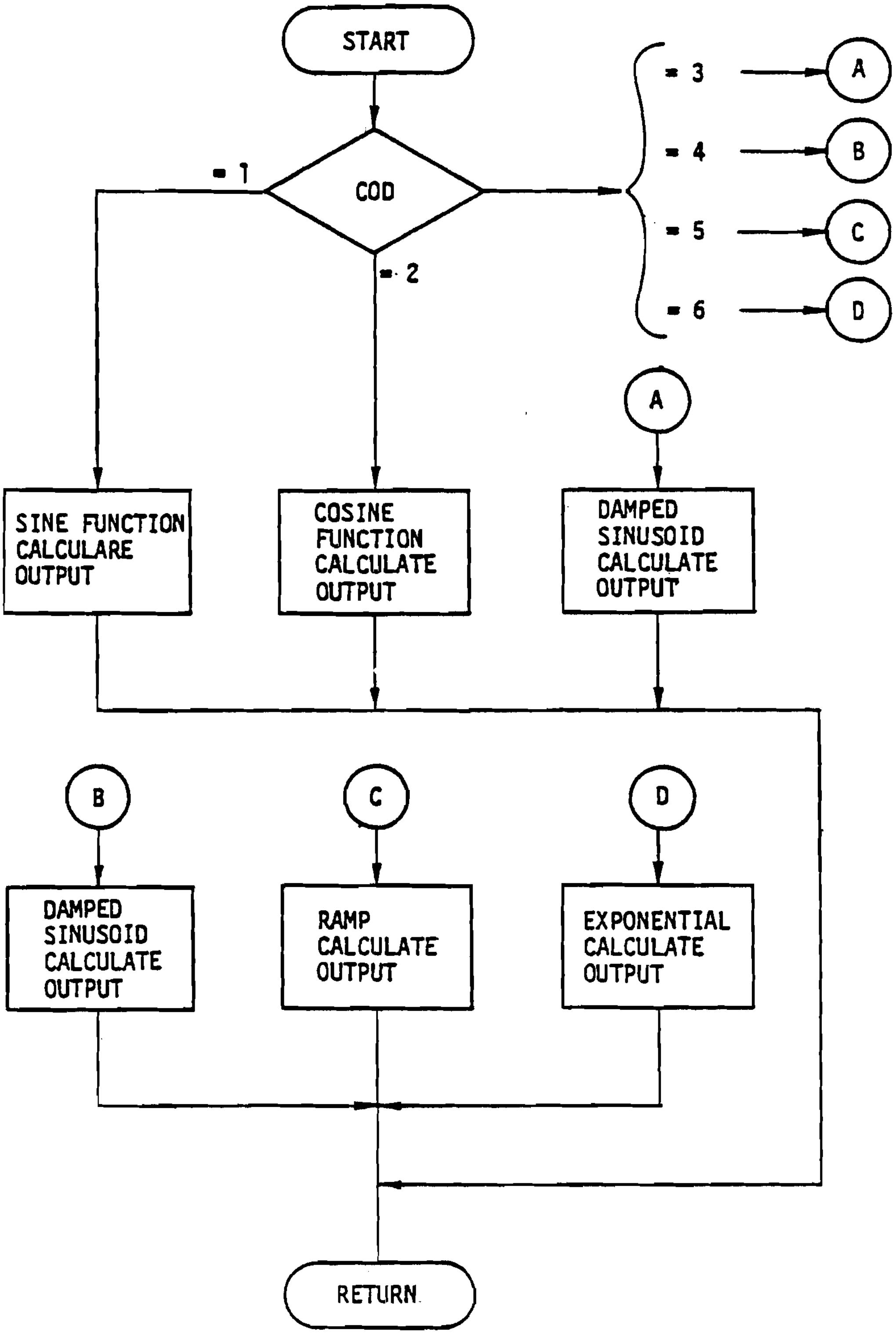


Table 5: FLOWCHART FOR SUBROUTINE AMACH

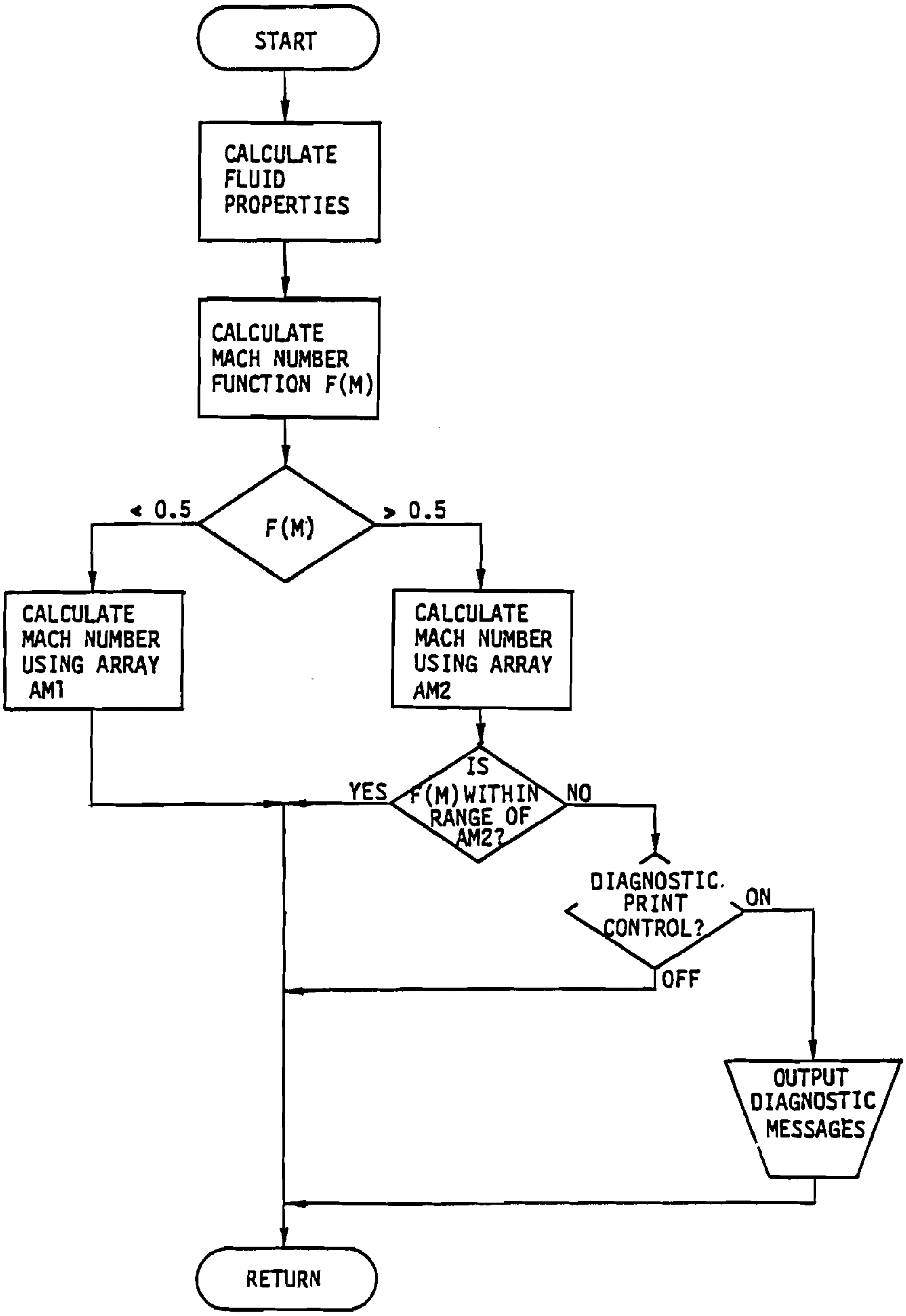
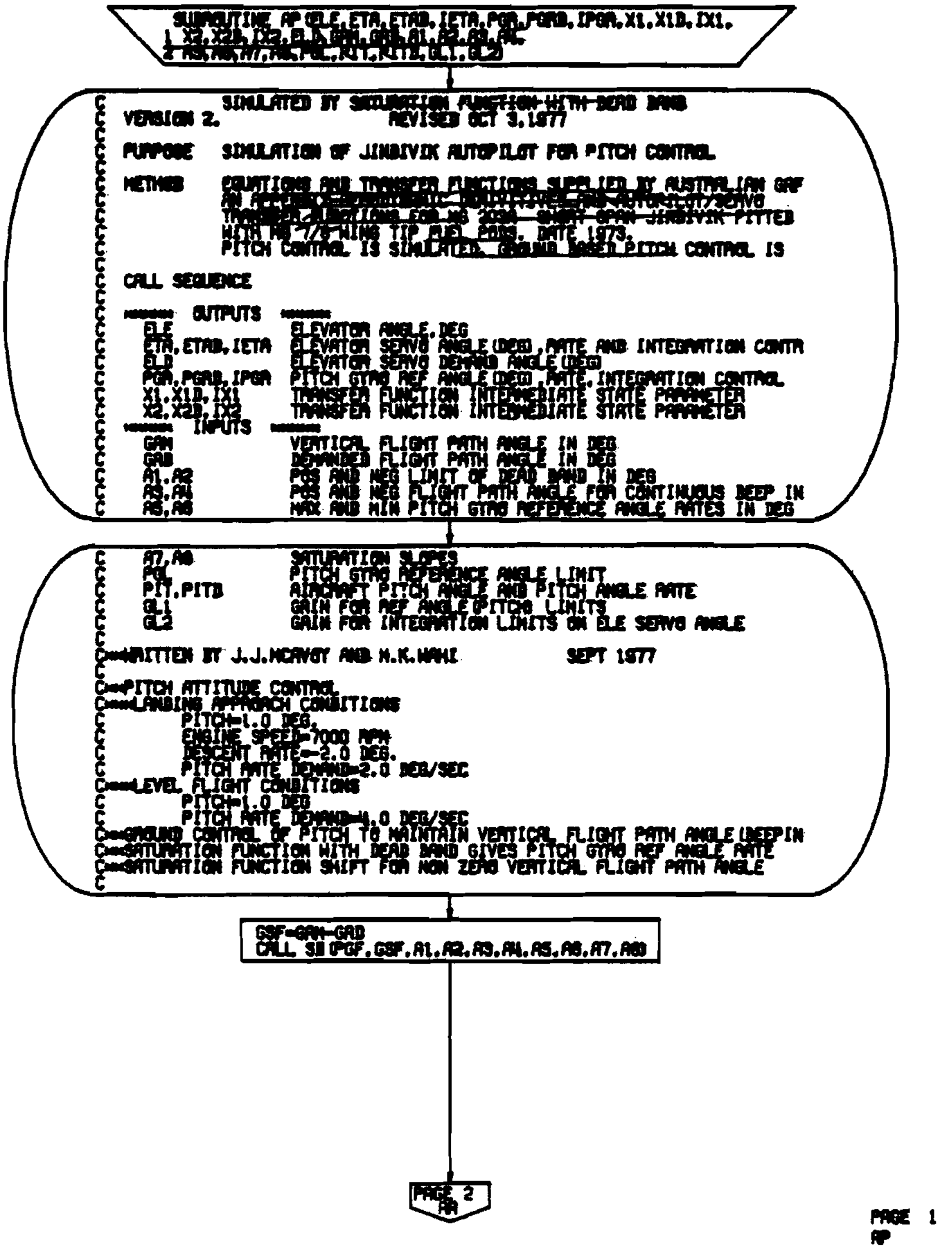


Table 6: FLOWCHART FOR SUBROUTINE AP



```
      SUBROUTINE AP(ELE,ETA,ETAD,IETA,PGA,PGAD,IPGA,X1,X1D,IX1,
     1 X2,X2D,IX2,ELD,GAM,GAD,A1,A2,A3,A4,
     2 A5,A6,A7,A8,PGL,PIT,PITD,GL1,GL2)
C                 SIMULATED BY SATURATION FUNCTION WITH DEAD BAND
C  VERSION 2.                     REVISED OCT 3,1977
C
C  PURPOSE        SIMULATION OF JINDIVIK AUTOPILOT FOR PITCH CONTROL
C
C  METHOD         EQUATIONS AND TRANSFER FUNCTIONS SUPPLIED BY AUSTRALIAN GAF
C                 AN A[illegible] AUTOPILOT/SERVO
C                 TRANSFER FUNCTIONS FOR N6 2030 SHORT SPAN JINDIVIK FITTED
C                 WITH NO 7/8 WING TIP FUEL PODS. DATE 1973.
C                 PITCH CONTROL IS SIMULATED. GROUND BASED PITCH CONTROL IS
C
C  CALL SEQUENCE
C
C  ------  OUTPUTS  ------
C    ELE             ELEVATOR ANGLE,DEG
C    ETA,ETAD,IETA   ELEVATOR SERVO ANGLE(DEG),RATE AND INTEGRATION CONTR
C    ELD             ELEVATOR SERVO DEMAND ANGLE(DEG)
C    PGA,PGAD,IPGA   PITCH GYRO REF ANGLE(DEG),RATE,INTEGRATION CONTROL
C    X1,X1D,IX1      TRANSFER FUNCTION INTERMEDIATE STATE PARAMETER
C    X2,X2D,IX2      TRANSFER FUNCTION INTERMEDIATE STATE PARAMETER
C  ------  INPUTS  ------
C    GAM             VERTICAL FLIGHT PATH ANGLE IN DEG
C    GAD             DEMANDED FLIGHT PATH ANGLE IN DEG
C    A1,A2           POS AND NEG LIMIT OF DEAD BAND IN DEG
C    A3,A4           POS AND NEG FLIGHT PATH ANGLE FOR CONTINUOUS BEEP IN
C    A5,A6           MAX AND MIN PITCH GYRO REFERENCE ANGLE RATES IN DEG
C    A7,A8           SATURATION SLOPES
C    PGL             PITCH GYRO REFERENCE ANGLE LIMIT
C    PIT,PITD        AIRCRAFT PITCH ANGLE AND PITCH ANGLE RATE
C    GL1             GAIN FOR REF ANGLE(PITCH) LIMITS
C    GL2             GAIN FOR INTEGRATION LIMITS ON ELE SERVO ANGLE
C
C==WRITTEN BY J.J.MCAVOY AND M.K.WAHI             SEPT 1977
C
C==PITCH ATTITUDE CONTROL
C===LANDING APPROACH CONDITIONS
C         PITCH=1.0 DEG.
C         ENGINE SPEED=7000 RPM
C         DESCENT RATE=-2.0 DEG.
C         PITCH RATE DEMAND=2.0 DEG/SEC
C===LEVEL FLIGHT CONDITIONS
C         PITCH=1.0 DEG
C         PITCH RATE DEMAND=4.0 DEG/SEC
C==GROUND CONTROL OF PITCH TO MAINTAIN VERTICAL FLIGHT PATH ANGLE(BEEPIN
C==SATURATION FUNCTION WITH DEAD BAND GIVES PITCH GYRO REF ANGLE RATE
C==SATURATION FUNCTION SHIFT FOR NON ZERO VERTICAL FLIGHT PATH ANGLE
C
      GSF=GAM-GAD
      CALL SI(PGF,GSF,A1,A2,A3,A4,A5,A6,A7,A8)
```

Table 6: FLOWCHART FOR SUBROUTINE AP (CONCLUDED)

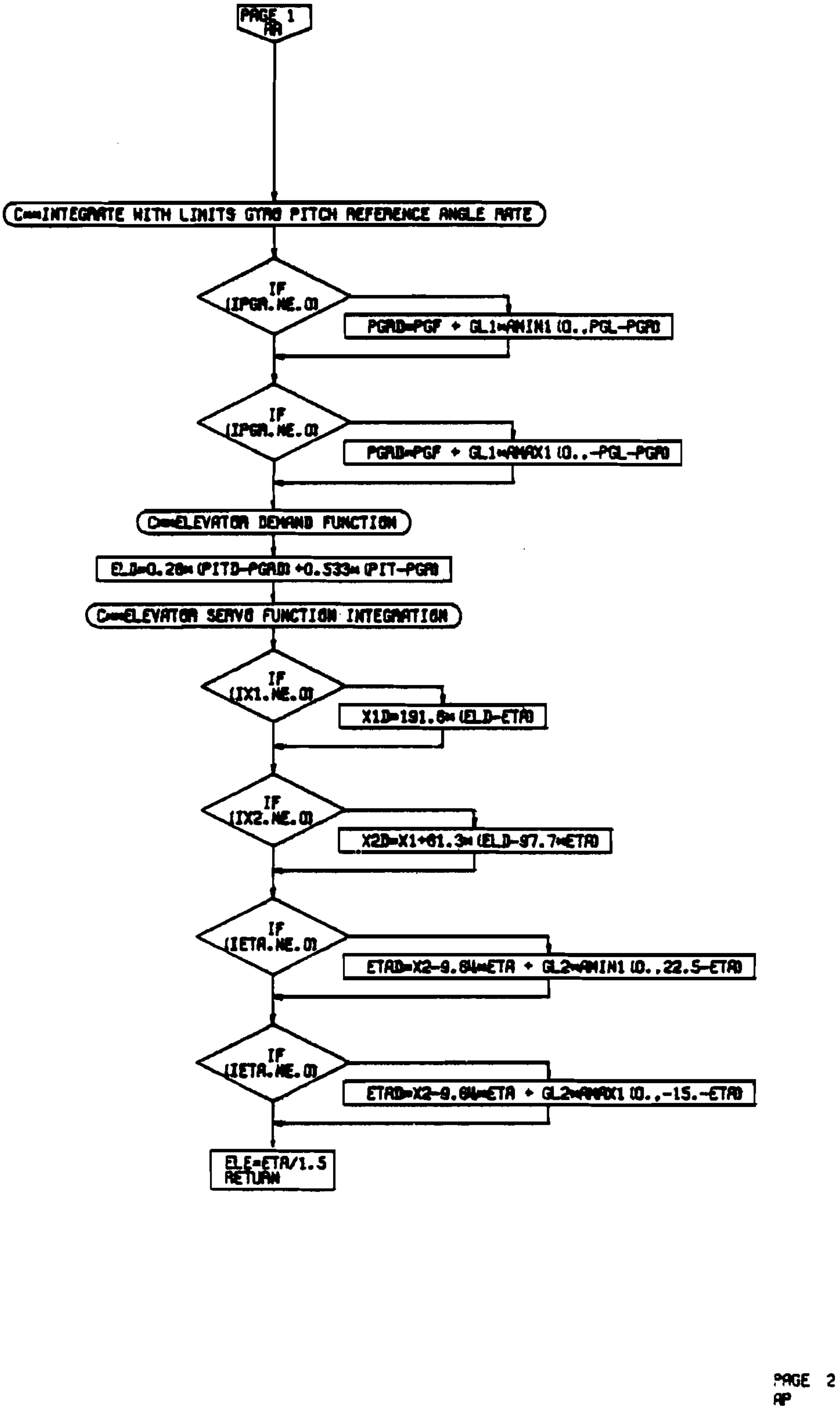
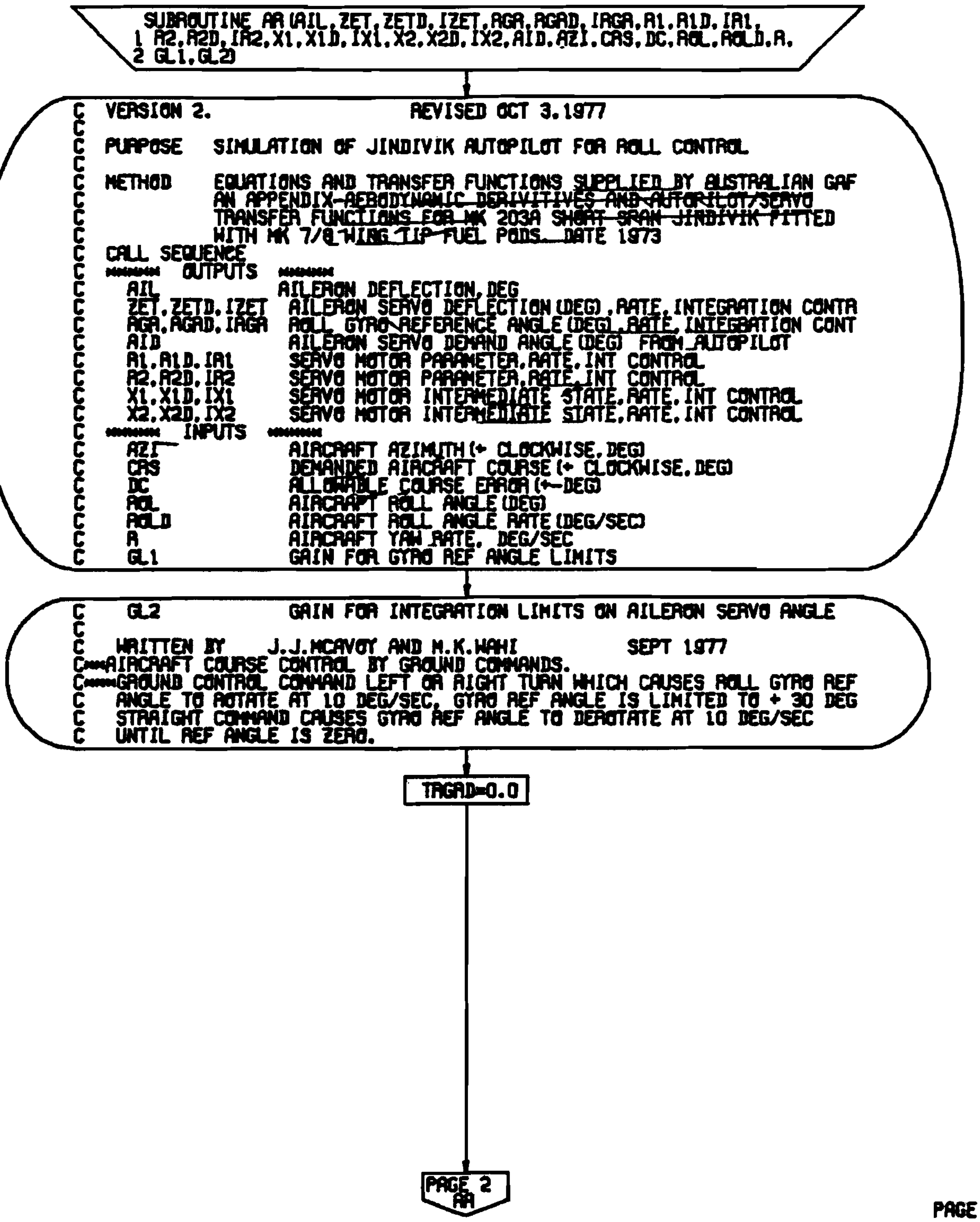


Table 7: FLOWCHART FOR SUBROUTINE AR



```
      SUBROUTINE AR(AIL,ZET,ZETD,IZET,AGA,AGAD,IAGA,A1,A1D,IA1,
     1 A2,A2D,IA2,X1,X1D,IX1,X2,X2D,IX2,AID,AZI,CAS,DC,AOL,AOLD,A,
     2 GL1,GL2)
```

```
C   VERSION 2.                       REVISED OCT 3.1977
C
C   PURPOSE   SIMULATION OF JINDIVIK AUTOPILOT FOR ROLL CONTROL
C
C   METHOD    EQUATIONS AND TRANSFER FUNCTIONS SUPPLIED BY AUSTRALIAN GAF
C             AN APPENDIX-AERODYNAMIC DERIVITIVES AND AUTOPILOT/SERVO
C             TRANSFER FUNCTIONS FOR MK 203A SHORT SPAN JINDIVIK FITTED
C             WITH MK 7/8 WING TIP FUEL PODS  DATE 1973
C   CALL SEQUENCE
C   *******  OUTPUTS  *******
C     AIL              AILERON DEFLECTION,DEG
C     ZET,ZETD,IZET    AILERON SERVO DEFLECTION(DEG),RATE,INTEGRATION CONTR
C     AGA,AGAD,IAGA    ROLL GYRO REFERENCE ANGLE(DEG),RATE,INTEGRATION CONT
C     AID              AILERON SERVO DEMAND ANGLE(DEG) FROM AUTOPILOT
C     A1,A1D,IA1       SERVO MOTOR PARAMETER,RATE,INT CONTROL
C     A2,A2D,IA2       SERVO MOTOR PARAMETER,RATE,INT CONTROL
C     X1,X1D,IX1       SERVO MOTOR INTERMEDIATE STATE,RATE,INT CONTROL
C     X2,X2D,IX2       SERVO MOTOR INTERMEDIATE STATE,RATE,INT CONTROL
C   *******  INPUTS  *******
C     AZI              AIRCRAFT AZIMUTH(+ CLOCKWISE,DEG)
C     CAS              DEMANDED AIRCRAFT COURSE(+ CLOCKWISE,DEG)
C     DC               ALLOWABLE COURSE ERROR(+-DEG)
C     AOL              AIRCRAFT ROLL ANGLE(DEG)
C     AOLD             AIRCRAFT ROLL ANGLE RATE(DEG/SEC)
C     A                AIRCRAFT YAW RATE, DEG/SEC
C     GL1              GAIN FOR GYRO REF ANGLE LIMITS
```

```
C     GL2              GAIN FOR INTEGRATION LIMITS ON AILERON SERVO ANGLE
C
C    WRITTEN BY    J.J.MCAVOY AND M.K.WAHI           SEPT 1977
C***AIRCRAFT COURSE CONTROL BY GROUND COMMANDS.
C****GROUND CONTROL COMMAND LEFT OR RIGHT TURN WHICH CAUSES ROLL GYRO REF
C    ANGLE TO ROTATE AT 10 DEG/SEC, GYRO REF ANGLE IS LIMITED TO + 30 DEG
C    STRAIGHT COMMAND CAUSES GYRO REF ANGLE TO DEROTATE AT 10 DEG/SEC
C    UNTIL REF ANGLE IS ZERO.
```

```
      TAGAD=0.0
```

Table 7: FLOWCHART FOR SUBROUTINE AR (CONTINUED)

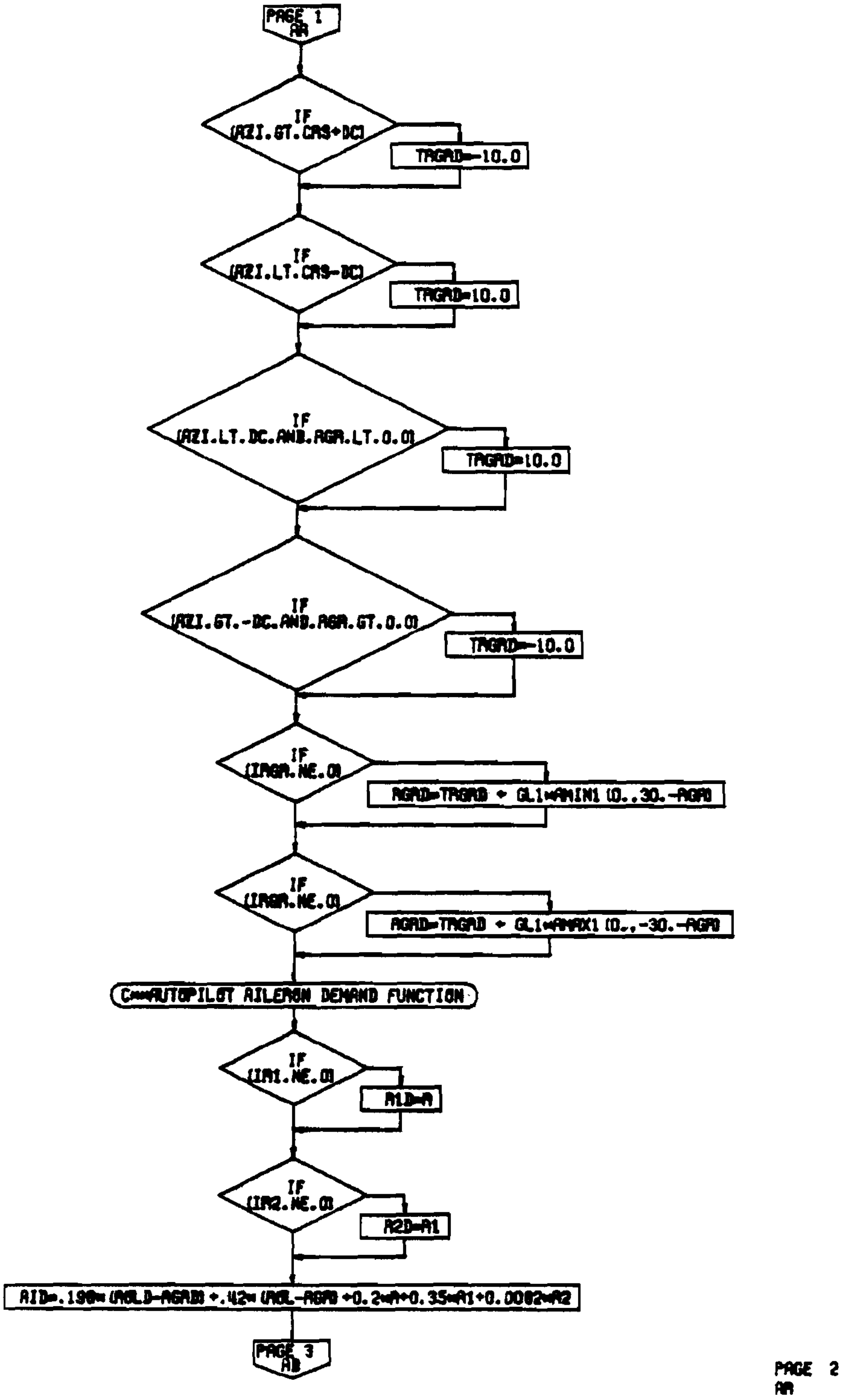


Table 7: FLOWCHART FOR SUBROUTINE AR (CONCLUDED)

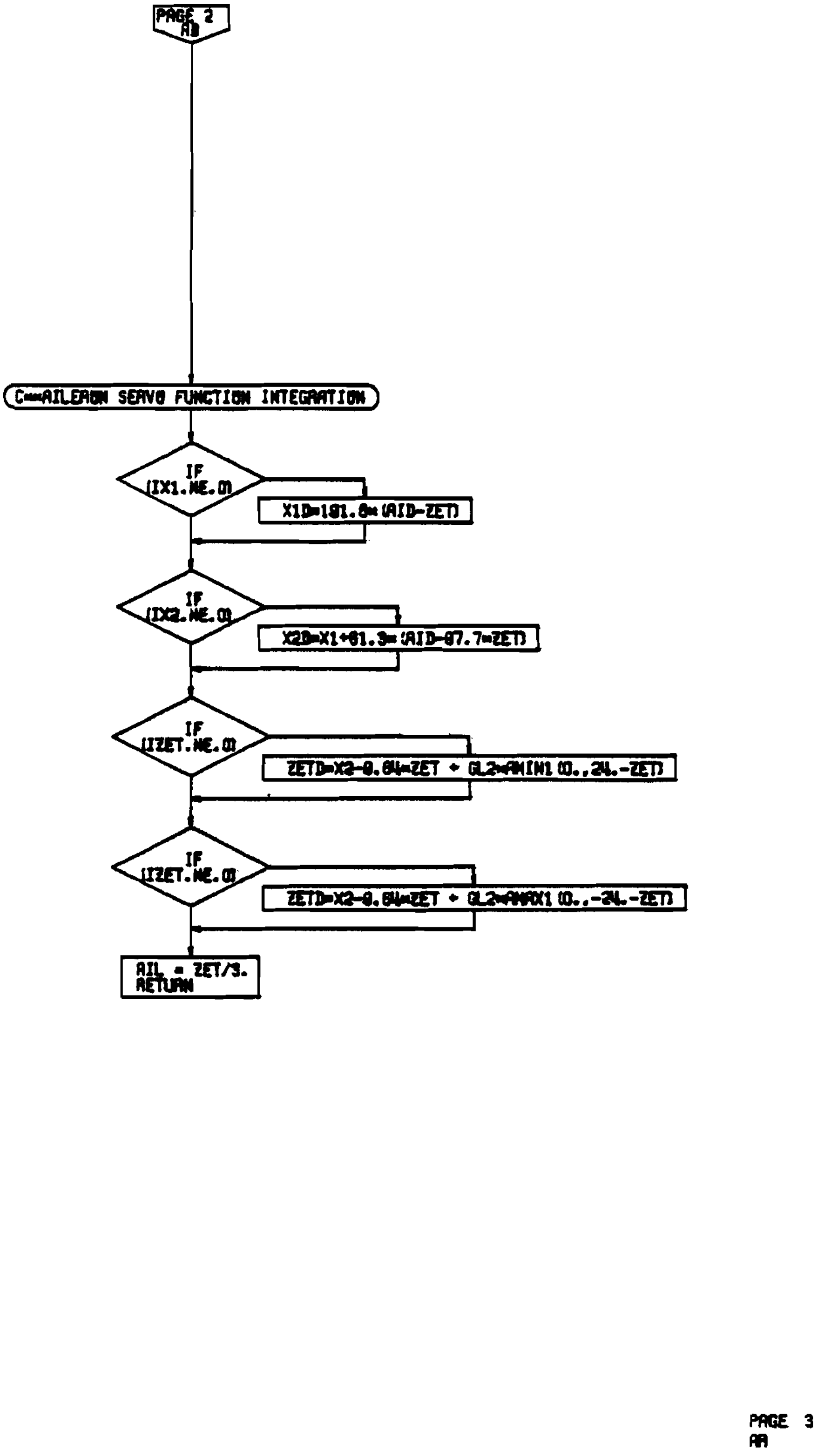


Table 8: FLOWCHART FOR SUBROUTINE AS

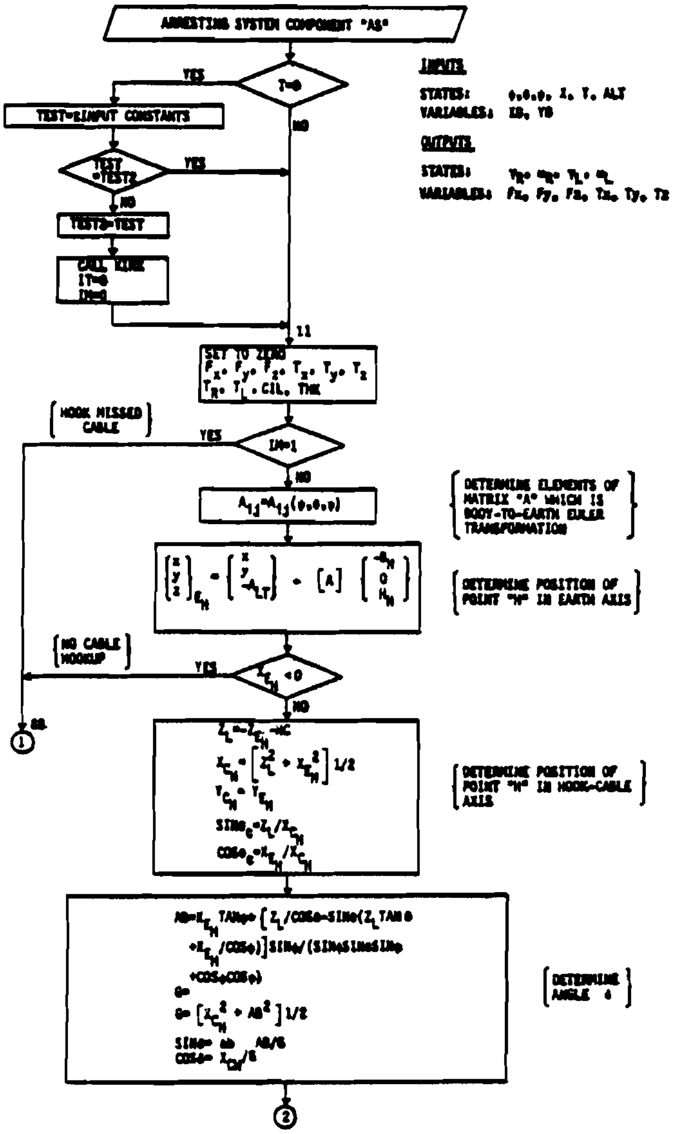


Table 8: FLOWCHART FOR SUBROUTINE AS (CONTINUED)

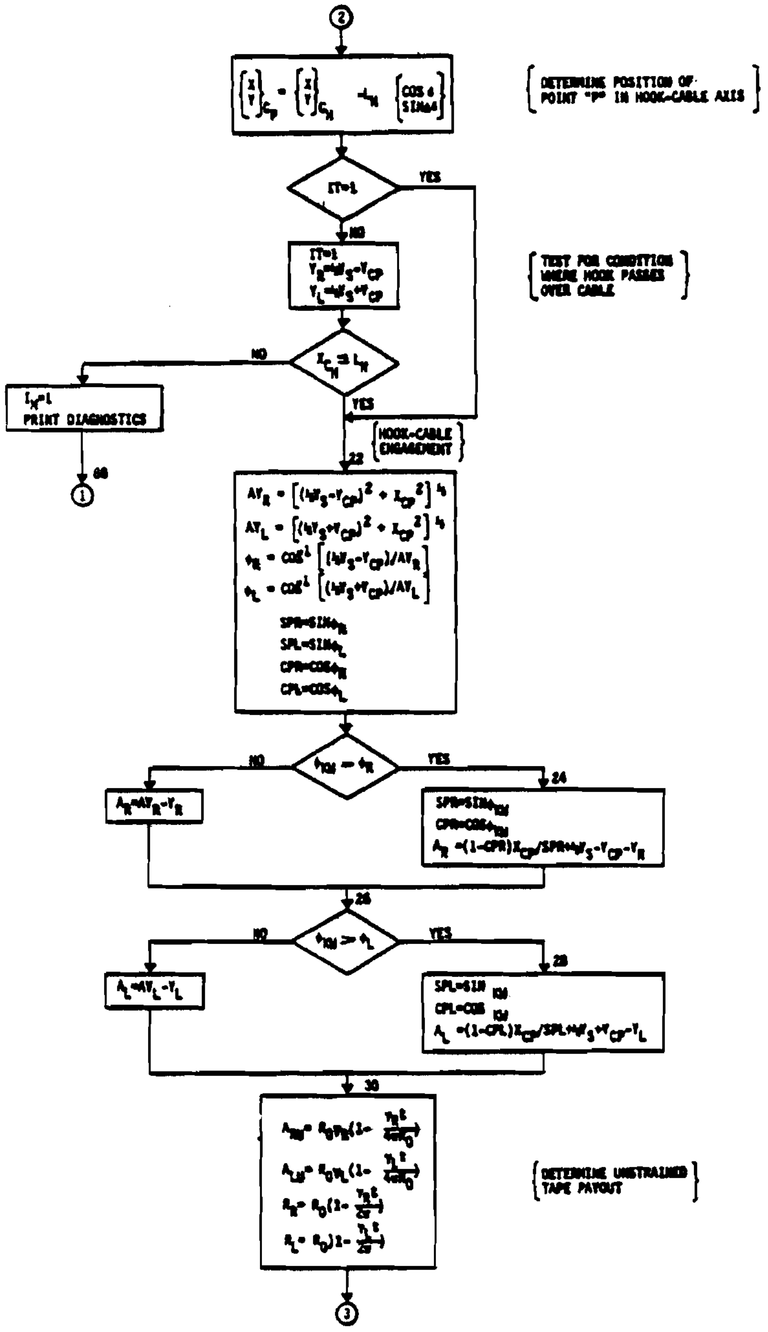


Table 8: FLOWCHART FOR SUBROUTINE AS (CONCLUDED)

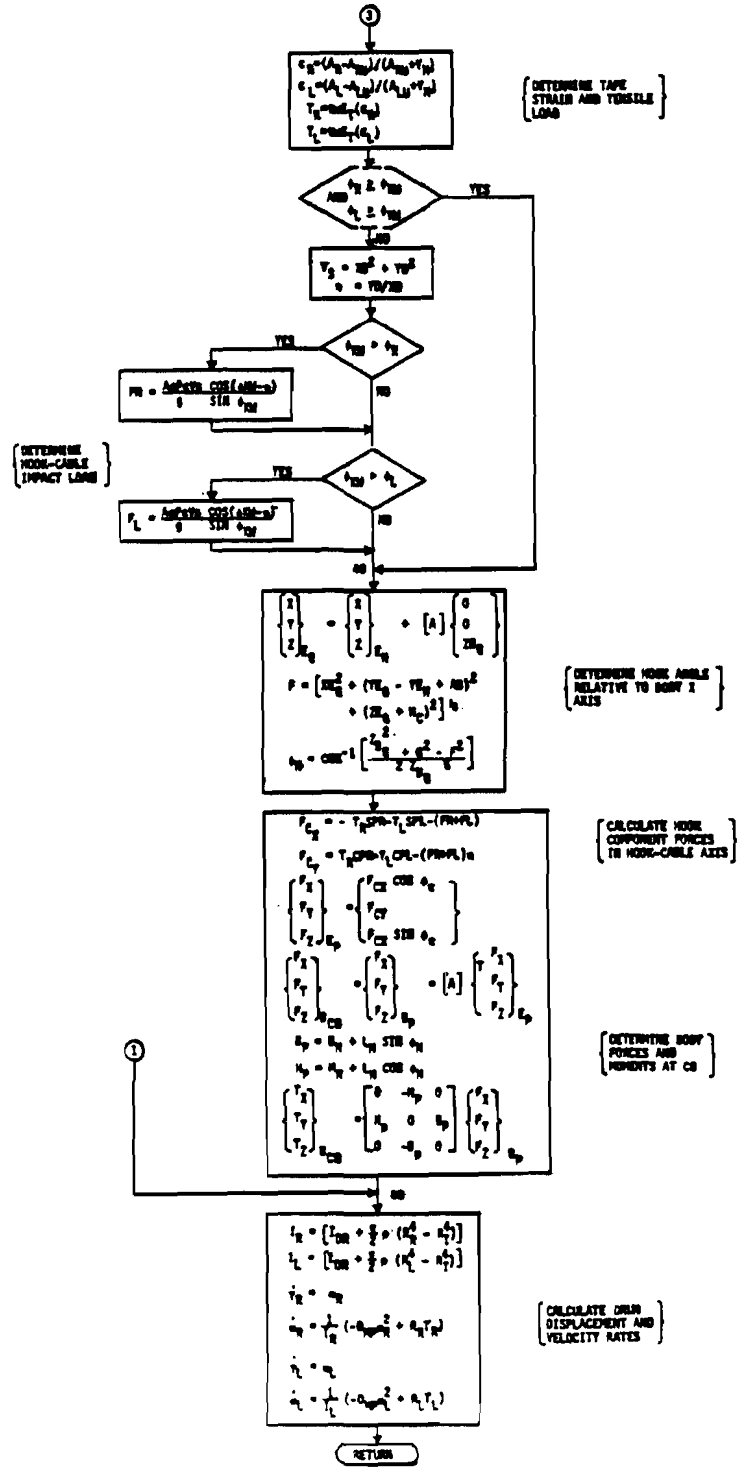
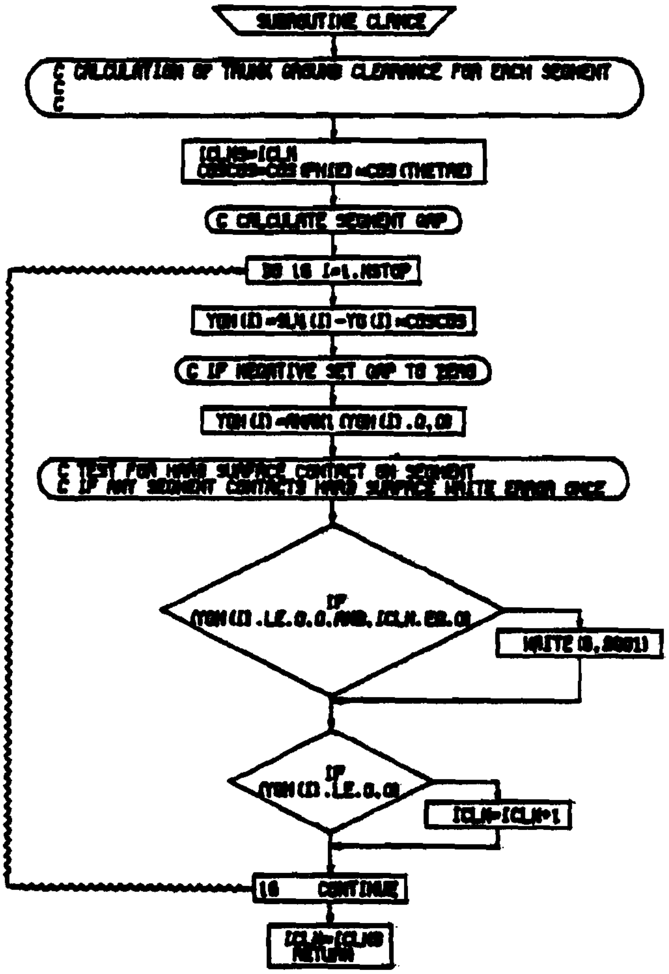
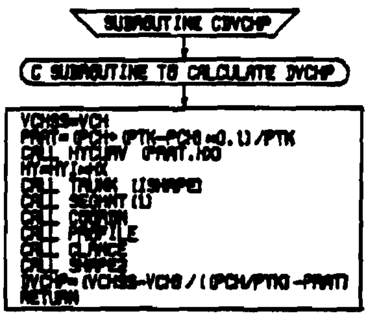


Table 9: FLOWCHART FOR SUBROUTINE CLRNCE



PAGE 1
CLRNCE

Table 10: FLOWCHART FOR SUBROUTINE CDVCHP



```
VCHSS=VCH
PRAT=(PCH+(PTK-PCH)*0.1)/PTK
CALL HYCURV (PRAT,HX)
HY=HY1*HX
CALL TRUNK (ISHAPE)
CALL SEGMNT (1)
CALL COMMON
CALL PROFILE
CALL CLANCE
CALL SHAPE2
DVCHP=(VCHSS-VCH)/((PCH/PTK)-PRAT)
RETURN
```

PAGE 1
CDVCHP

Table 11: FLOWCHART FOR SUBROUTINE COORDN

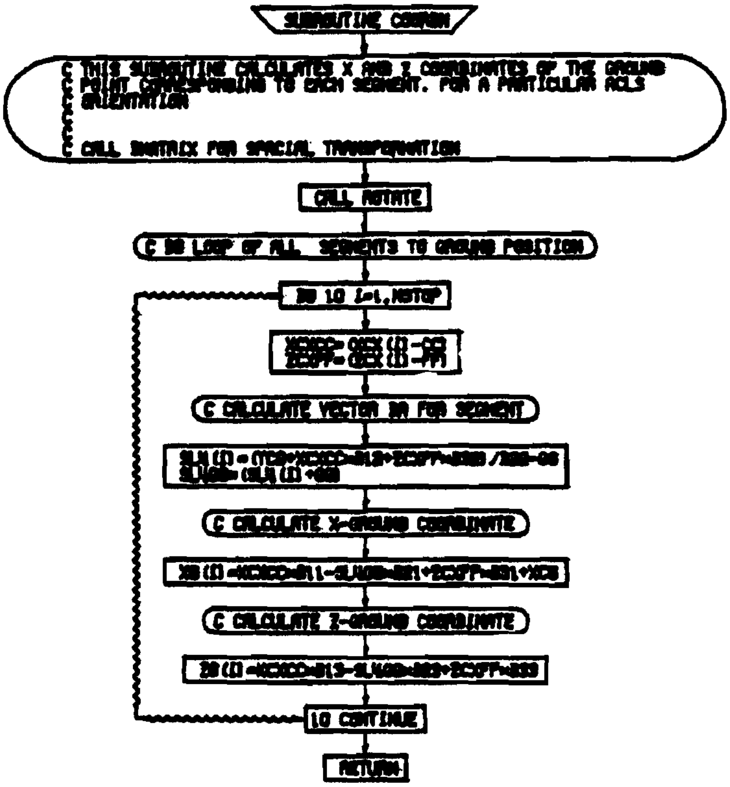


Table 12: FLOWCHART FOR SUBROUTINE DL

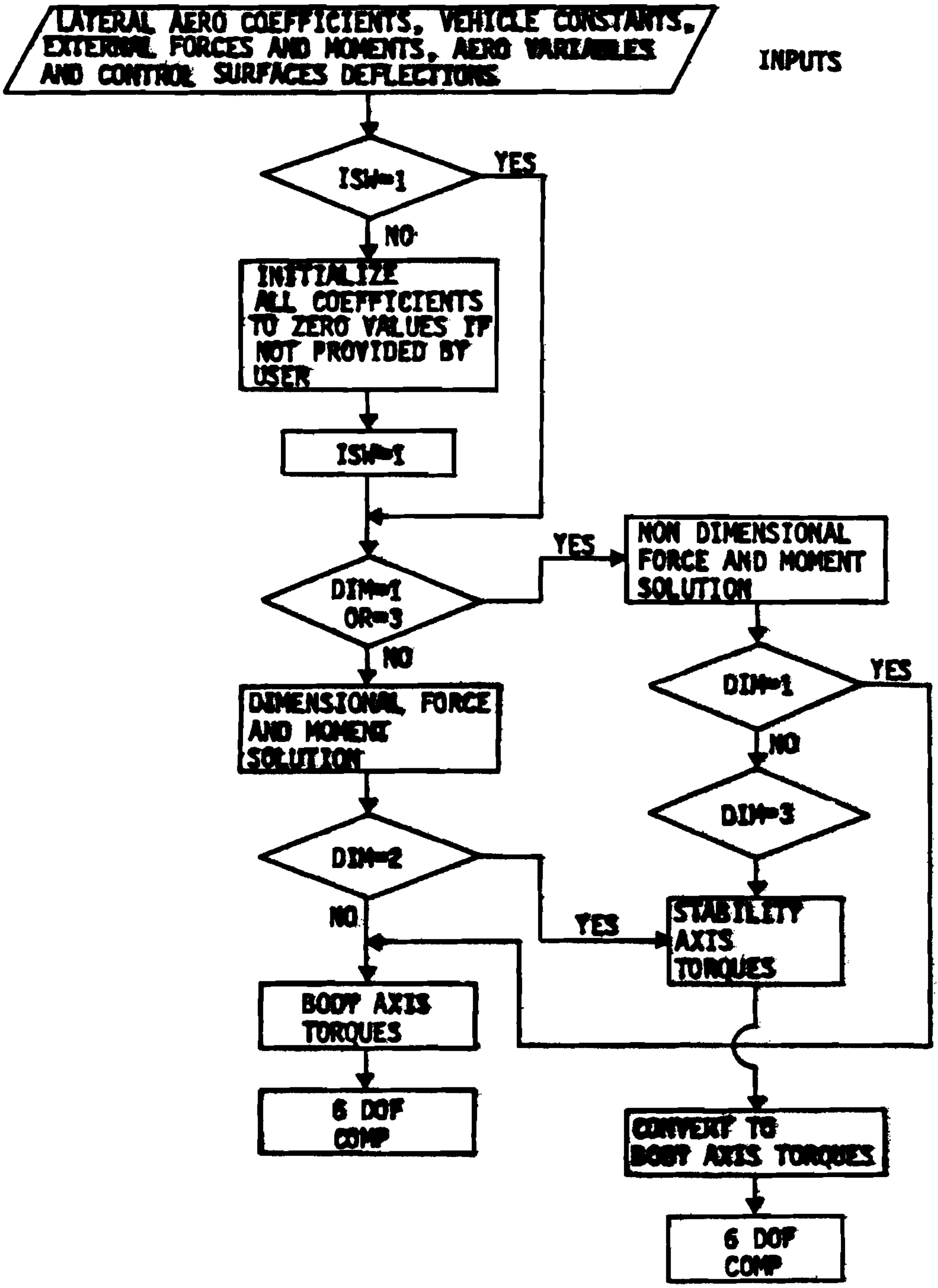


Table 13: FLOWCHART FOR SUBROUTINE DS

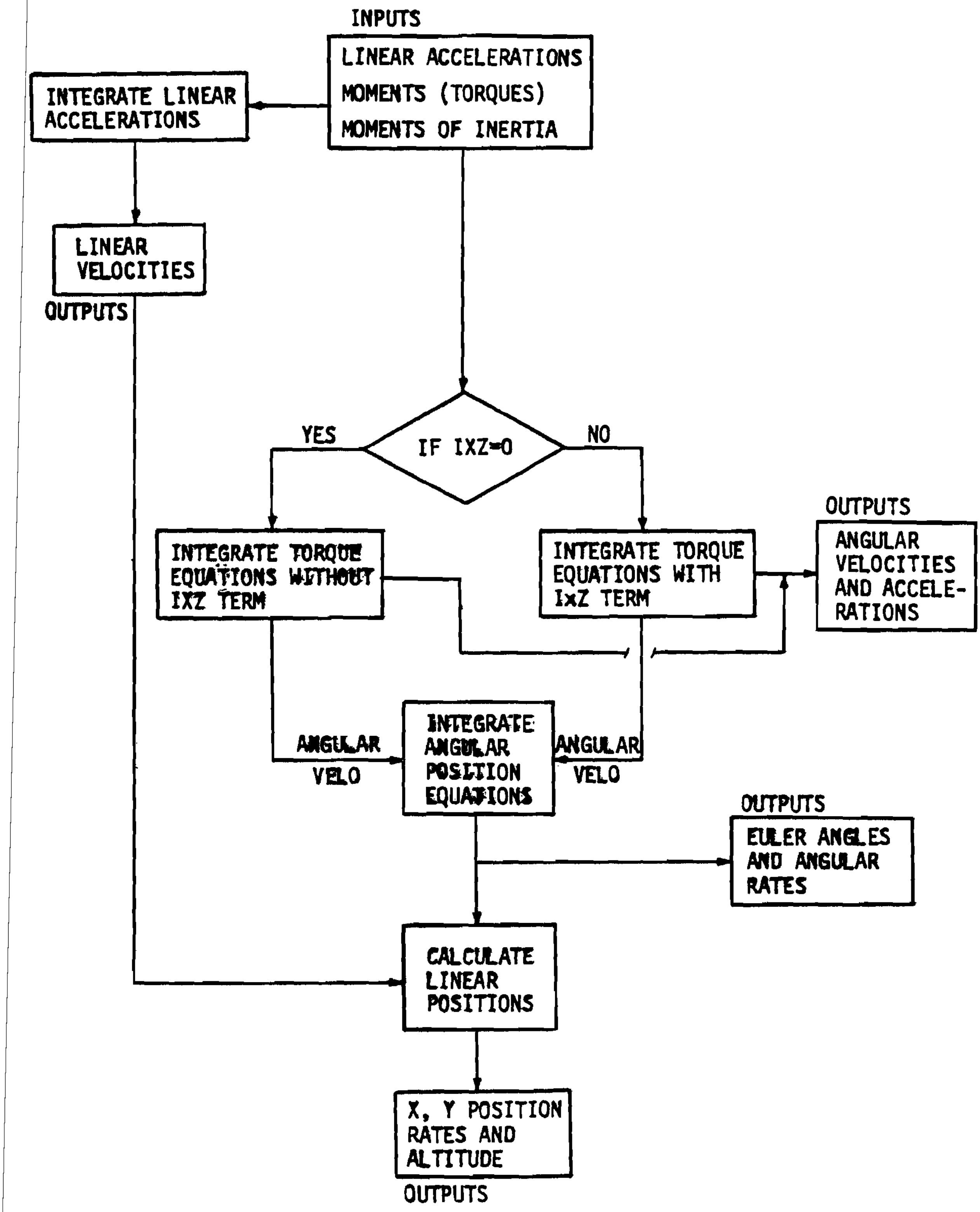


Table 14: FLOWCHART FOR SUBROUTINE DU

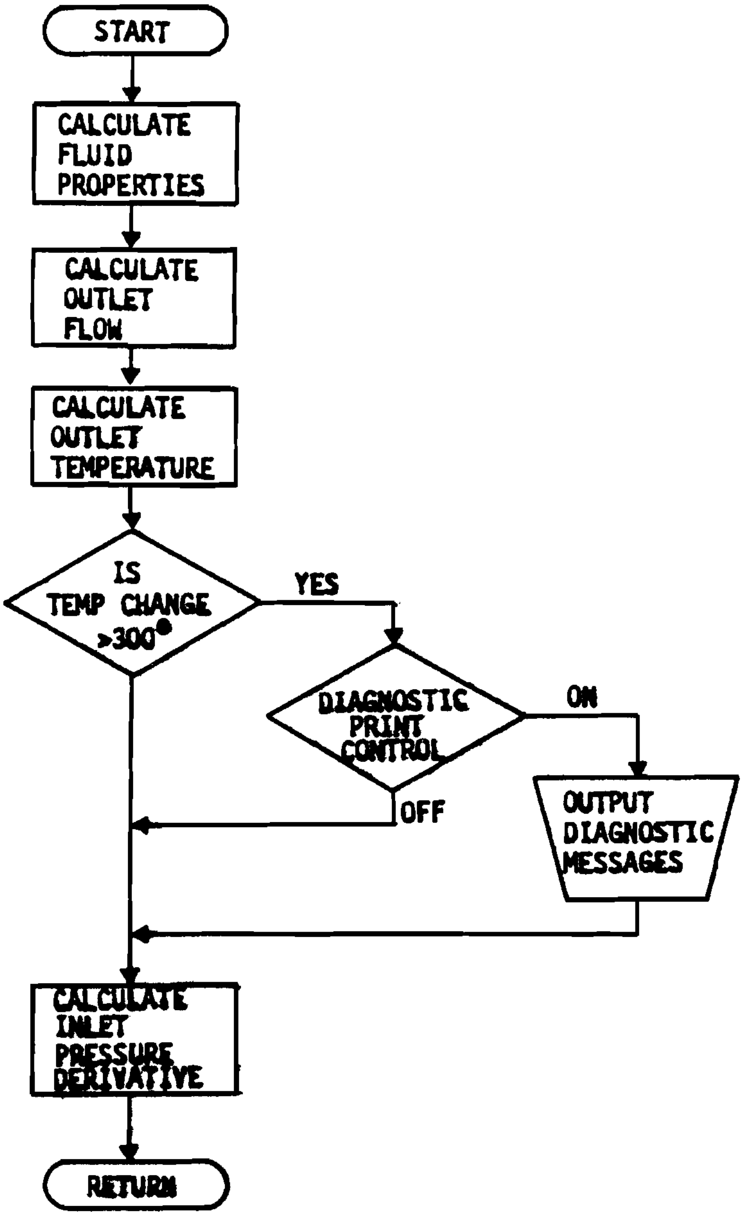


Table 15: FLOWCHART FOR SUBROUTINE DV

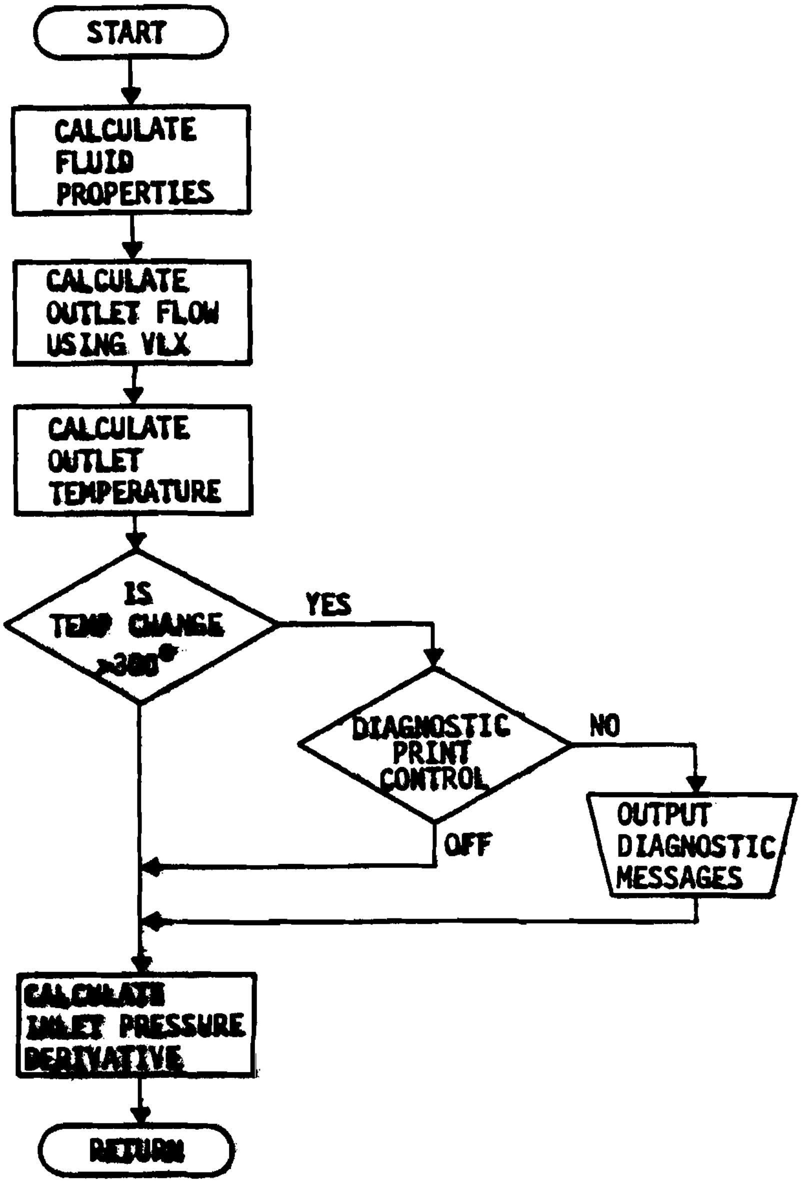
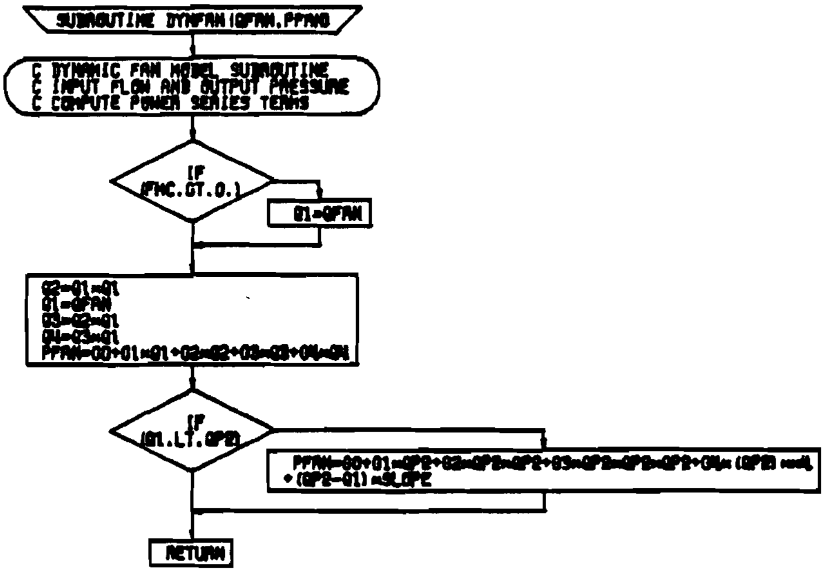


Table 16: FLOWCHART FOR SUBROUTINE DYNFAN



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DYNFAN

Table 17: FLOWCHART FOR SUBROUTINE EC

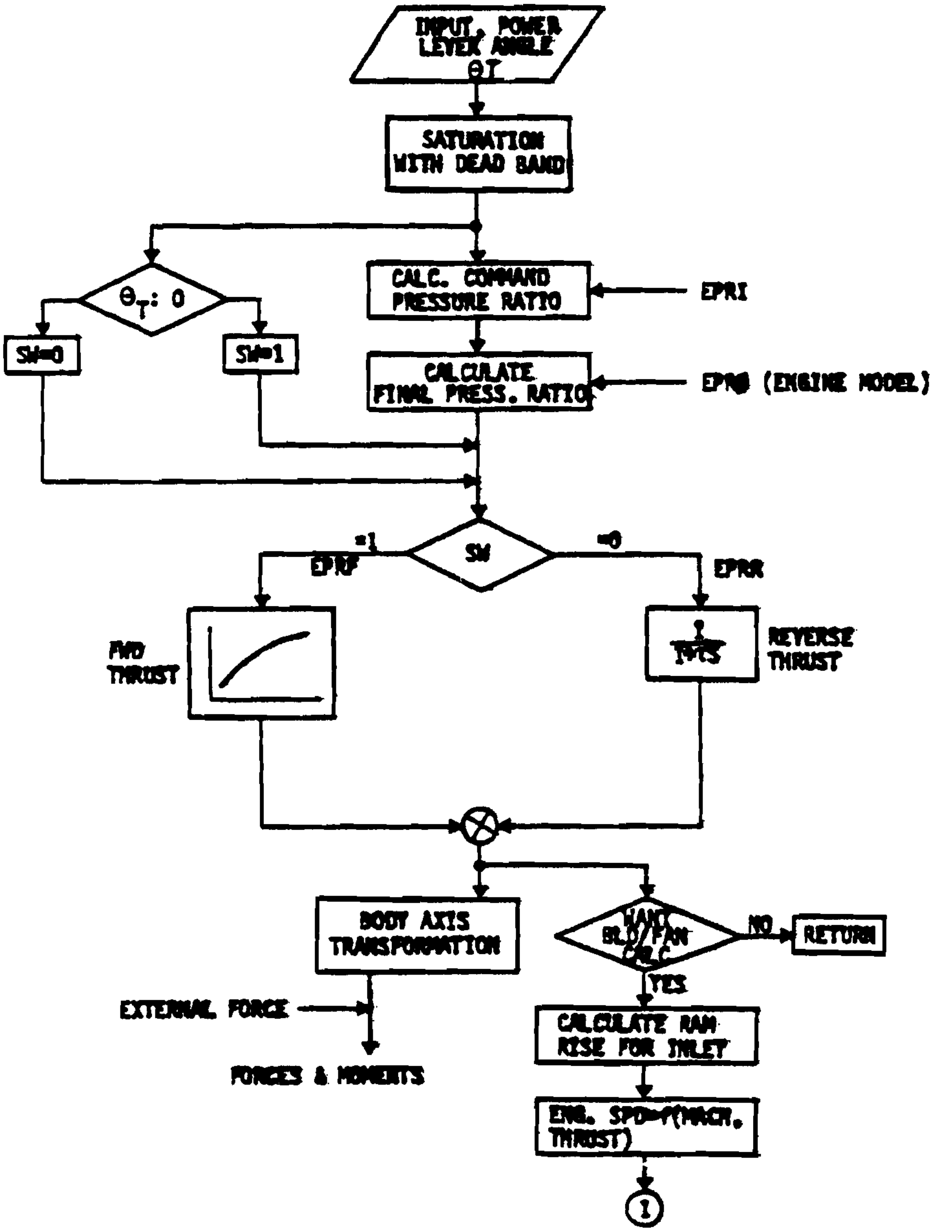


Table 17: FLOWCHART FOR SUBROUTINE EC (CONCLUDED)

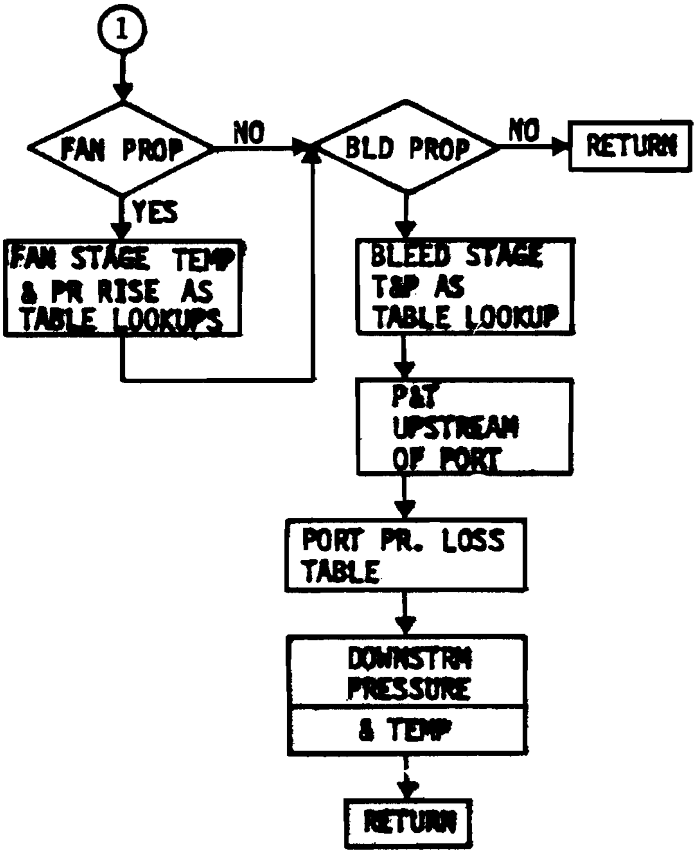
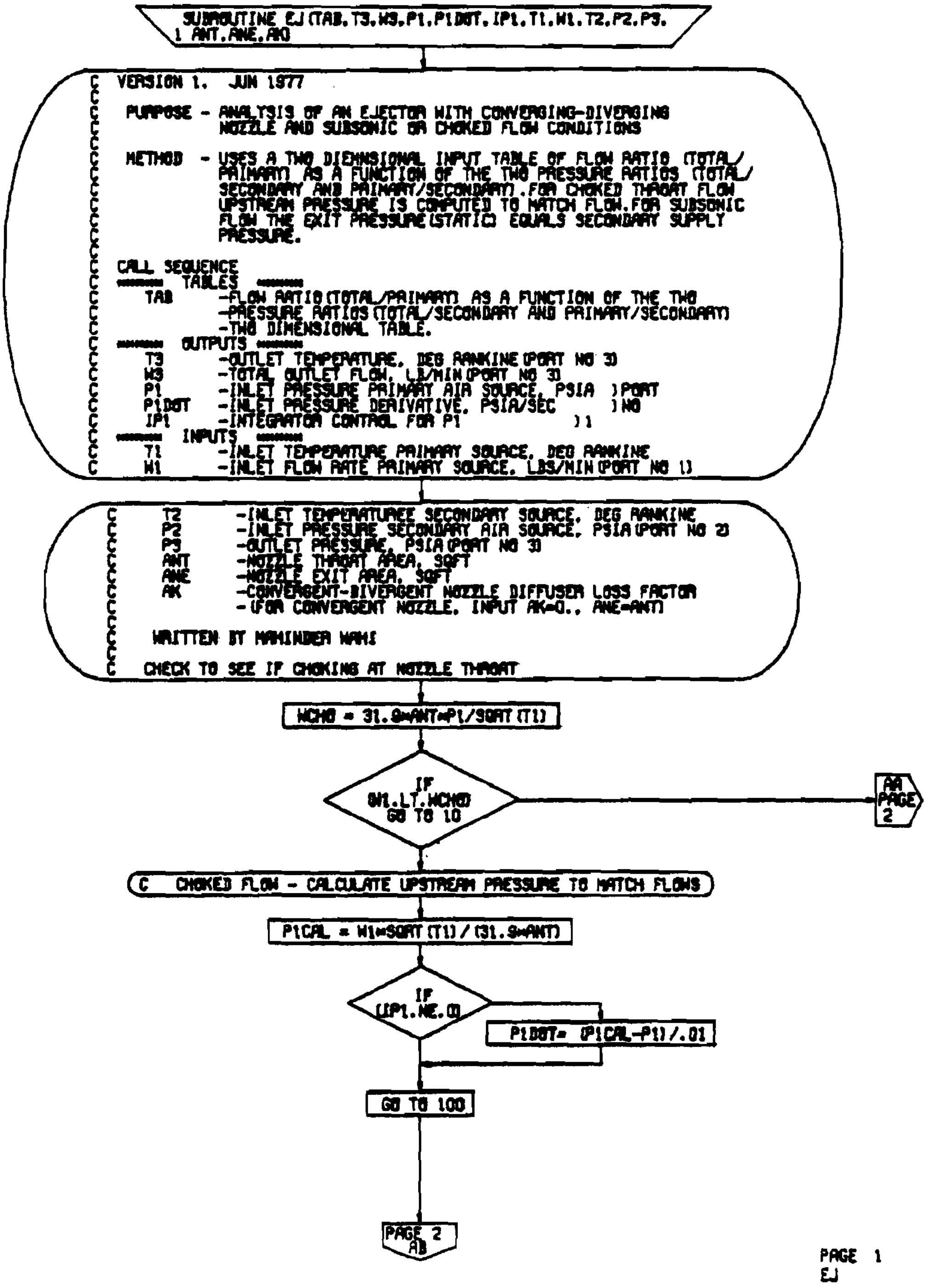
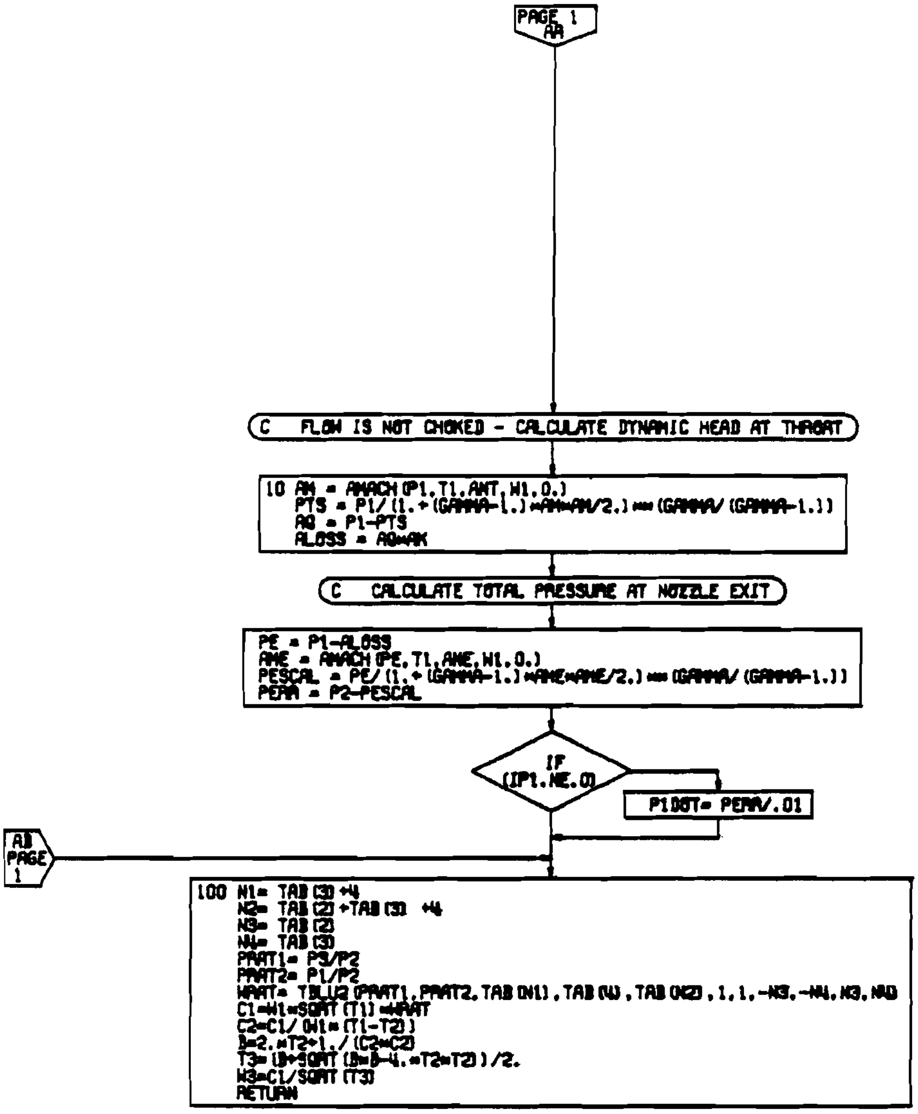


Table 18: FLOWCHART FOR SUBROUTINE EJ



```
      SUBROUTINE EJ(TAB,T3,W3,P1,P1DOT,IP1,T1,W1,T2,P2,P3,
     1 ANT,ANE,AK)
C     VERSION 1.  JUN 1977
C
C      PURPOSE - ANALYSIS OF AN EJECTOR WITH CONVERGING-DIVERGING
C                NOZZLE AND SUBSONIC OR CHOKED FLOW CONDITIONS
C
C      METHOD  - USES A TWO DIEMNSIONAL INPUT TABLE OF FLOW RATIO (TOTAL/
C                PRIMARY) AS A FUNCTION OF THE TWO PRESSURE RATIOS (TOTAL/
C                SECONDARY AND PRIMARY/SECONDARY).FOR CHOKED THROAT FLOW
C                UPSTREAM PRESSURE IS COMPUTED TO MATCH FLOW.FOR SUBSONIC
C                FLOW THE EXIT PRESSURE(STATIC) EQUALS SECONDARY SUPPLY
C                PRESSURE.
C
C     CALL SEQUENCE
C     -------- TABLES --------
C        TAB     -FLOW RATIO(TOTAL/PRIMARY) AS A FUNCTION OF THE TWO
C                -PRESSURE RATIOS(TOTAL/SECONDARY AND PRIMARY/SECONDARY)
C                -TWO DIMENSIONAL TABLE.
C     -------- OUTPUTS --------
C        T3      -OUTLET TEMPERATURE, DEG RANKINE(PORT NO 3)
C        W3      -TOTAL OUTLET FLOW, LB/MIN(PORT NO 3)
C        P1      -INLET PRESSURE PRIMARY AIR SOURCE, PSIA  )PORT
C        P1DOT   -INLET PRESSURE DERIVATIVE, PSIA/SEC      )NO
C        IP1     -INTEGRATOR CONTROL FOR P1                )1
C     -------- INPUTS --------
C        T1      -INLET TEMPERATURE PRIMARY SOURCE, DEG RANKINE
C        W1      -INLET FLOW RATE PRIMARY SOURCE, LBS/MIN(PORT NO 1)
C        T2      -INLET TEMPERATUREE SECONDARY SOURCE, DEG RANKINE
C        P2      -INLET PRESSURE SECONDARY AIR SOURCE, PSIA(PORT NO 2)
C        P3      -OUTLET PRESSURE, PSIA(PORT NO 3)
C        ANT     -NOZZLE THROAT AREA, SQFT
C        ANE     -NOZZLE EXIT AREA, SQFT
C        AK      -CONVERGENT-DIVERGENT NOZZLE DIFFUSER LOSS FACTOR
C                - (FOR CONVERGENT NOZZLE, INPUT AK=0., ANE=ANT)
C
C      WRITTEN BY MAHINDER WAHI
C
C     CHECK TO SEE IF CHOKING AT NOZZLE THROAT
      WCHO = 31.9*ANT*P1/SQRT(T1)
      IF (W1.LT.WCHO) GO TO 10
C     CHOKED FLOW - CALCULATE UPSTREAM PRESSURE TO MATCH FLOWS
      P1CAL = W1*SQRT(T1)/(31.9*ANT)
      IF (IP1.NE.0)
      P1DOT= (P1CAL-P1)/.01
      GO TO 100
```

Table 18: FLOWCHART FOR SUBROUTINE EJ (CONCLUDED)



```
C   FLOW IS NOT CHOKED - CALCULATE DYNAMIC HEAD AT THROAT

10 AM = AMACH(P1,T1,ANT,W1,0.)
   PTS = P1/(1.+(GAMMA-1.)*AM*AM/2.)**(GAMMA/(GAMMA-1.))
   AQ = P1-PTS
   ALOSS = AQ*AK

C   CALCULATE TOTAL PRESSURE AT NOZZLE EXIT

PE = P1-ALOSS
AME = AMACH(PE,T1,AME,W1,0.)
PESCAL = PE/(1.+(GAMMA-1.)*AME*AME/2.)**(GAMMA/(GAMMA-1.))
PERR = P2-PESCAL

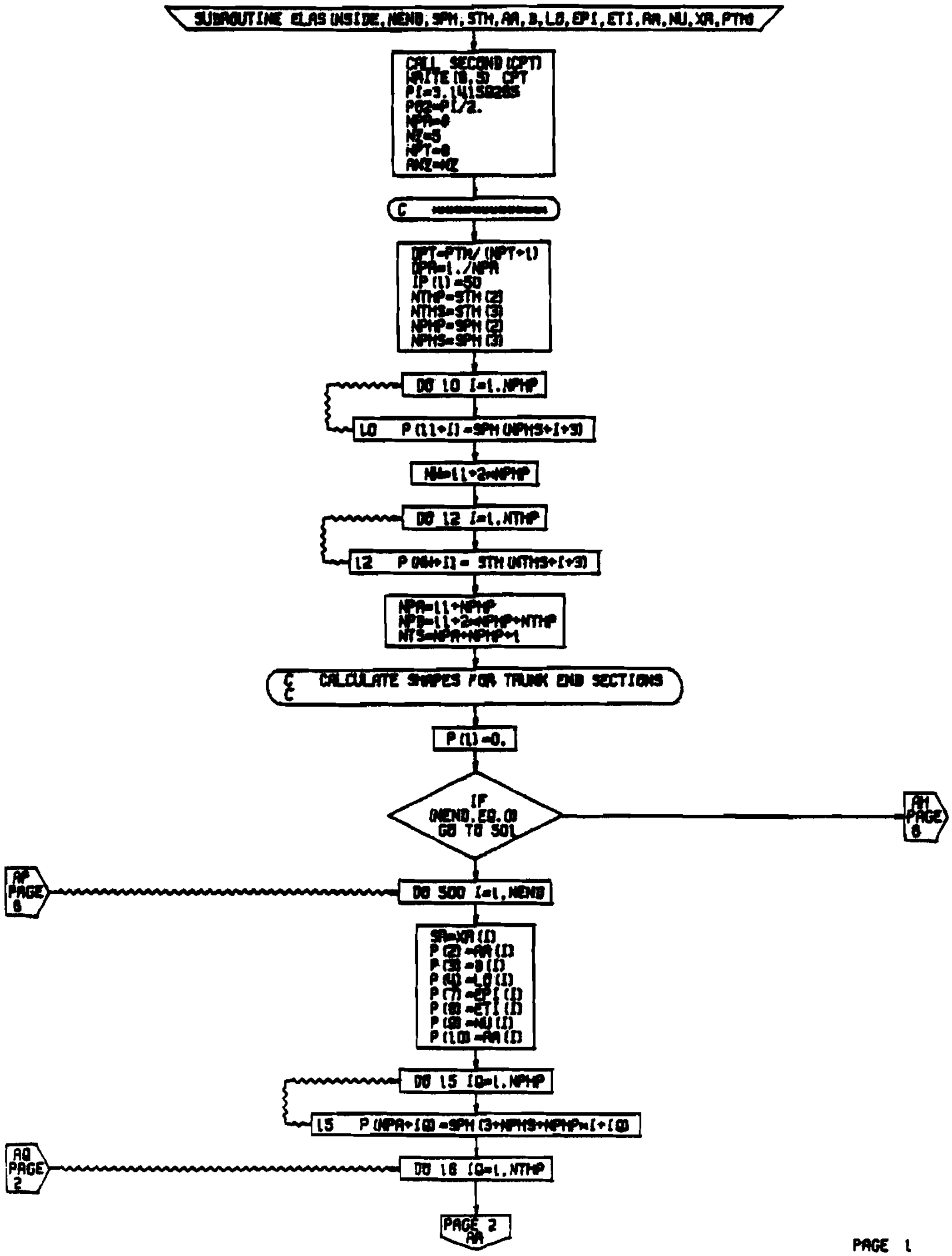
IF (IP1.NE.0)

P1DOT= PERR/.01

100 N1= TAB(3)+4
    N2= TAB(2)+TAB(3) +4
    N3= TAB(2)
    N4= TAB(3)
    PRAT1= P3/P2
    PRAT2= P1/P2
    WRAT= TBLU2(PRAT1,PRAT2,TAB(N1),TAB(4),TAB(N2),1,1,-N3,-N4,N3,N4)
    C1=W1*SQRT(T1)*WRAT
    C2=C1/(W1*(T1-T2))
    B=2.*T2+1./(C2*C2)
    T3=(B+SQRT(B*B-4.*T2*T2))/2.
    W3=C1/SQRT(T3)
    RETURN
```

PAGE 2
EJ

Table 19: FLOWCHART FOR SUBROUTINE ELAS



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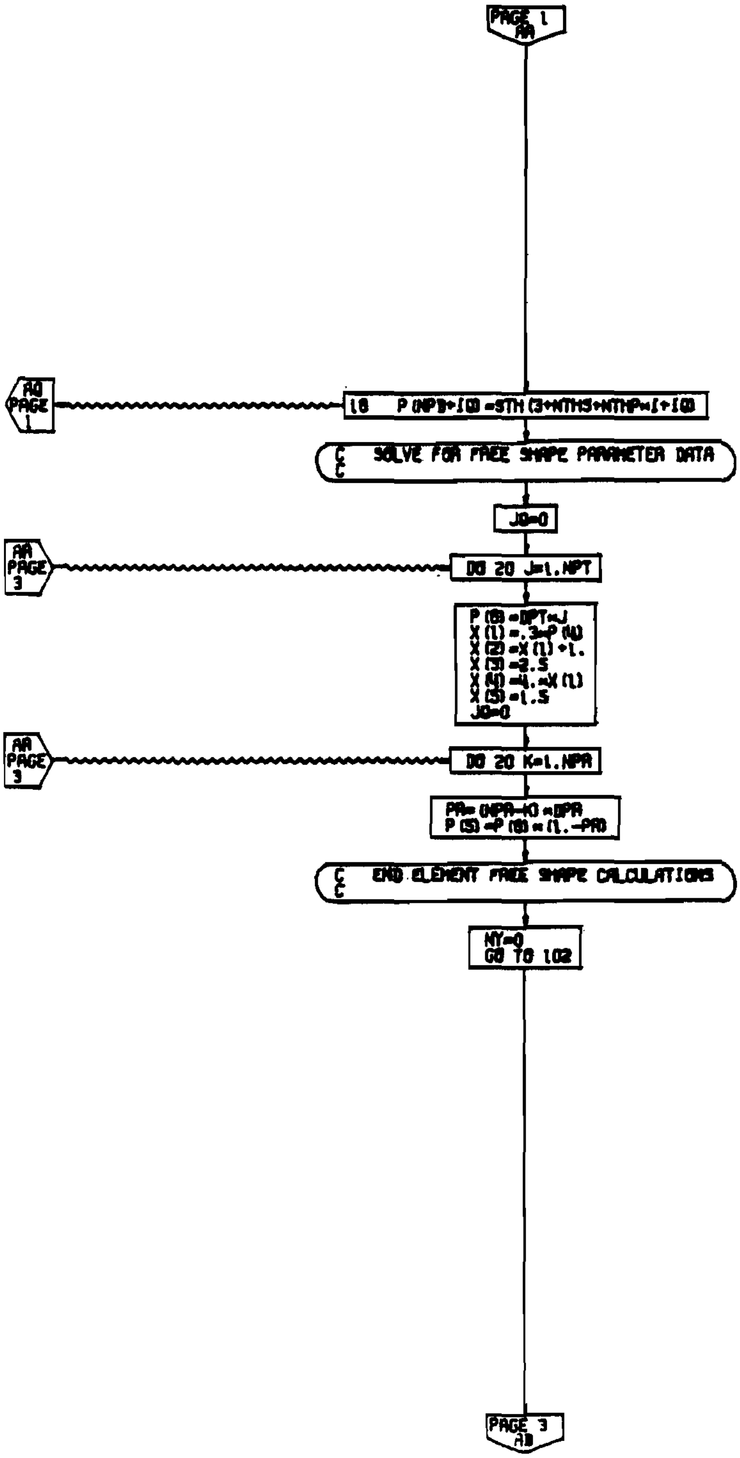
ELAS

Table 19: FLOWCHART FOR SUBROUTINE ELAS (CONTINUED)



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ELAS

Table 19: FLOWCHART FOR SUBROUTINE ELAS (CONTINUED)

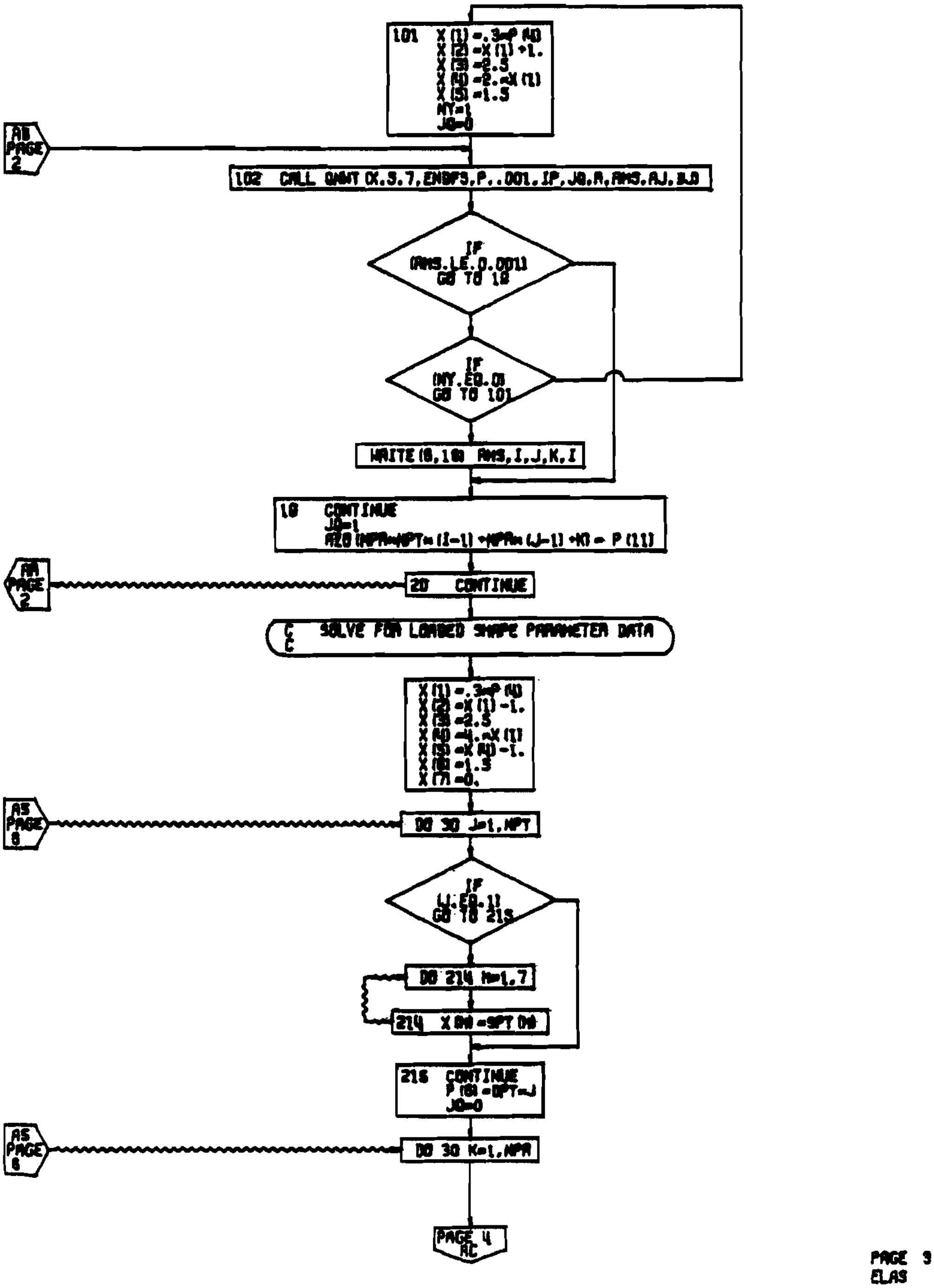


Table 19: FLOWCHART FOR SUBROUTINE ELAS (CONTINUED)

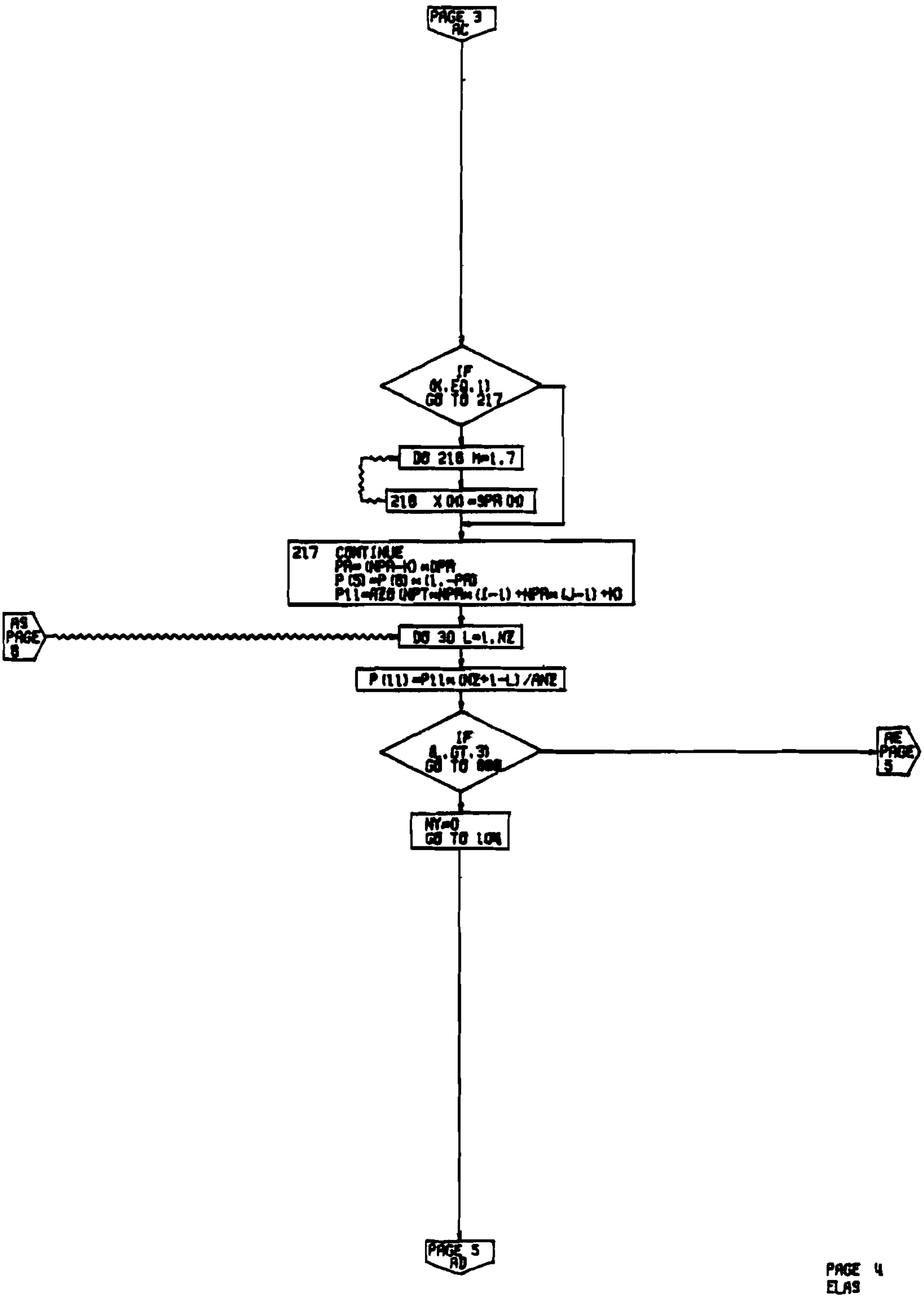


Table 19: FLOWCHART FOR SUBROUTINE ELAS (CONTINUED)

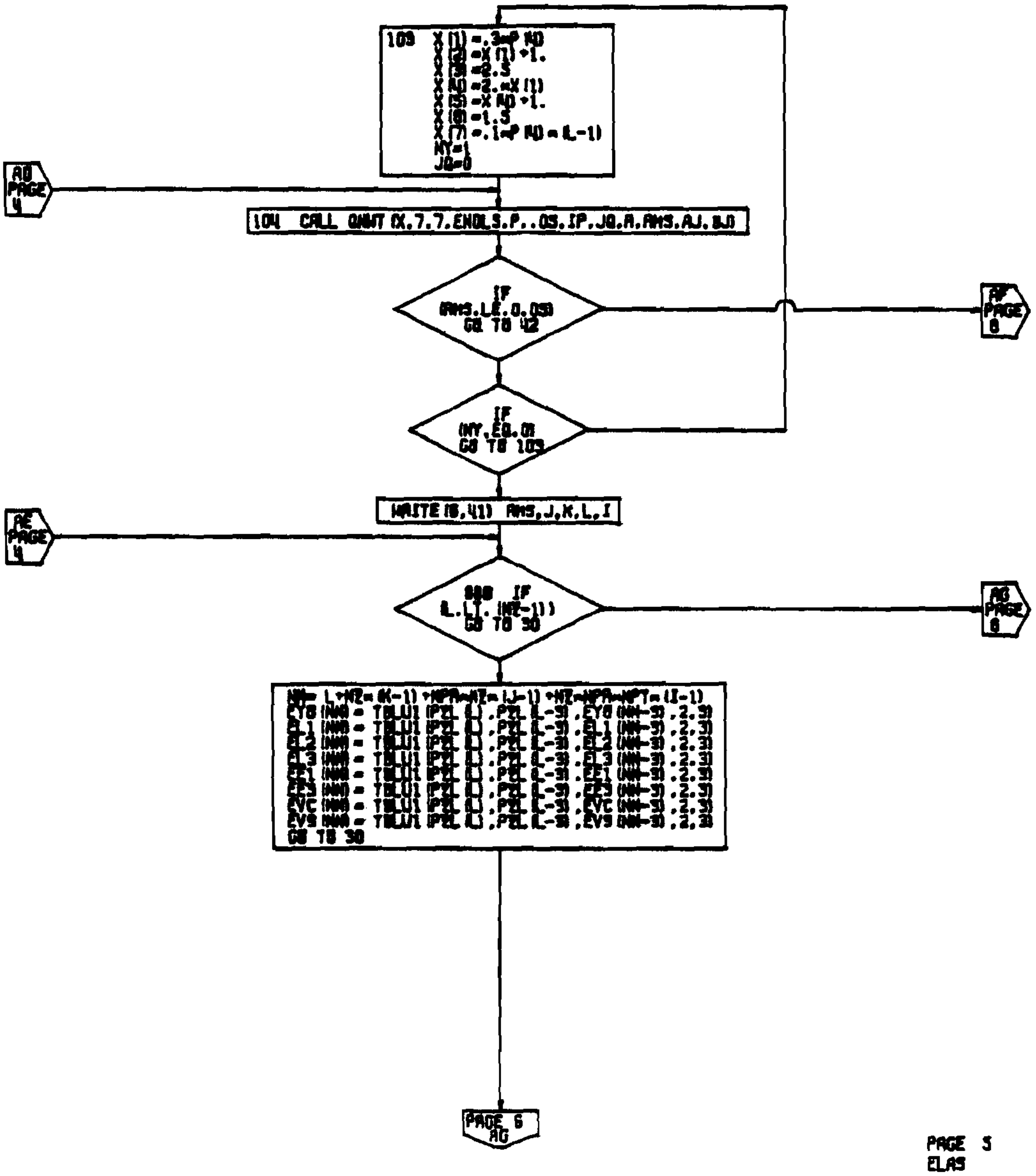
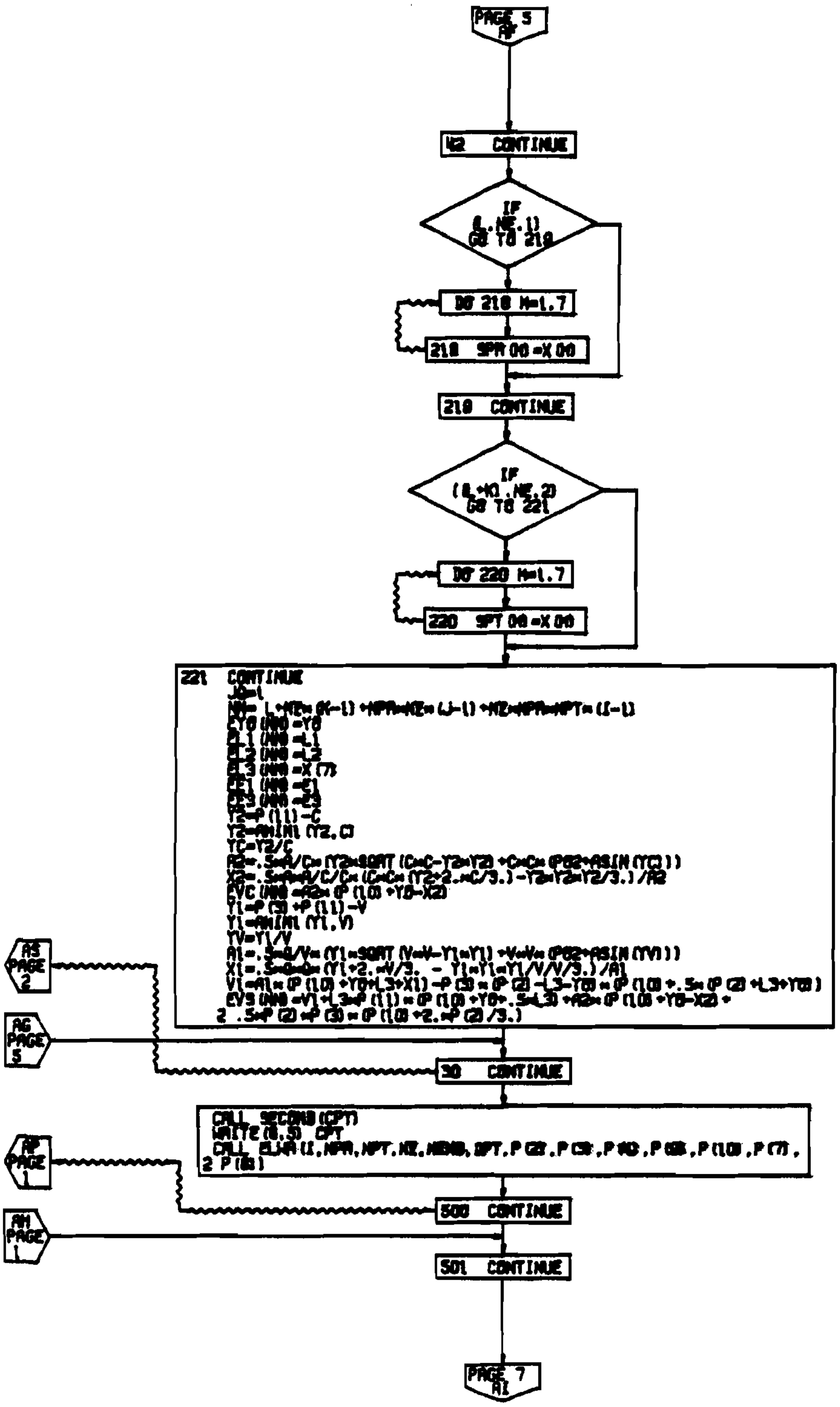


Table 19: FLOWCHART FOR SUBROUTINE ELAS (CONTINUED)



```
221   CONTINUE
      JQ=1
      NN= L+NE*(K-1)+NPR*NE*(J-1)+NE*NPR*NPT*(I-1)
      CY0(NN)=Y0
      EL1(NN)=L1
      EL2(NN)=L2
      EL3(NN)=X(7)
      CE1(NN)=E1
      CE3(NN)=E3
      Y2=P(11)-C
      Y2=AMIN1(Y2,C)
      YC=Y2/C
      A2=.5*A/C*(Y2*SQRT(C*C-Y2*Y2)+C*C*(PIO2+ASIN(YC)))
      X2=.5*A*A/C/C*(C*C*(Y2+2.*C/3.)-Y2*Y2*Y2/3.)/A2
      EVC(NN)=A2*(P(10)+Y0-X2)
      Y1=P(3)+P(11)-V
      Y1=AMIN1(Y1,V)
      YV=Y1/V
      A1=.5*Q/V*(Y1*SQRT(V*V-Y1*Y1)+V*V*(PIO2+ASIN(YV)))
      X1=.5*Q*Q*(Y1+2.*V/3. - Y1*Y1*Y1/V/V/3.)/A1
      V1=A1*(P(10)+Y0+L3+X1)-P(3)*(P(2)-L3-Y0)*(P(10)+.5*(P(2)+L3+Y0))
      EVS(NN)=V1+L3*P(11)*(P(10)+Y0+.5*L3)+A2*(P(10)+Y0-X2)+
     2 .5*P(2)*P(3)*(P(10)+2.*P(2)/3.)
```

```
      CALL SECOND(CPT)
      WRITE(6,5) CPT
      CALL ELWA(I,NPR,NPT,NE,NENB,SPT,P(2),P(3),P(4),P(5),P(10),P(7),
     2 P(8))
```

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ELAS

Table 19: FLOWCHART FOR SUBROUTINE ELAS (CONTINUED)

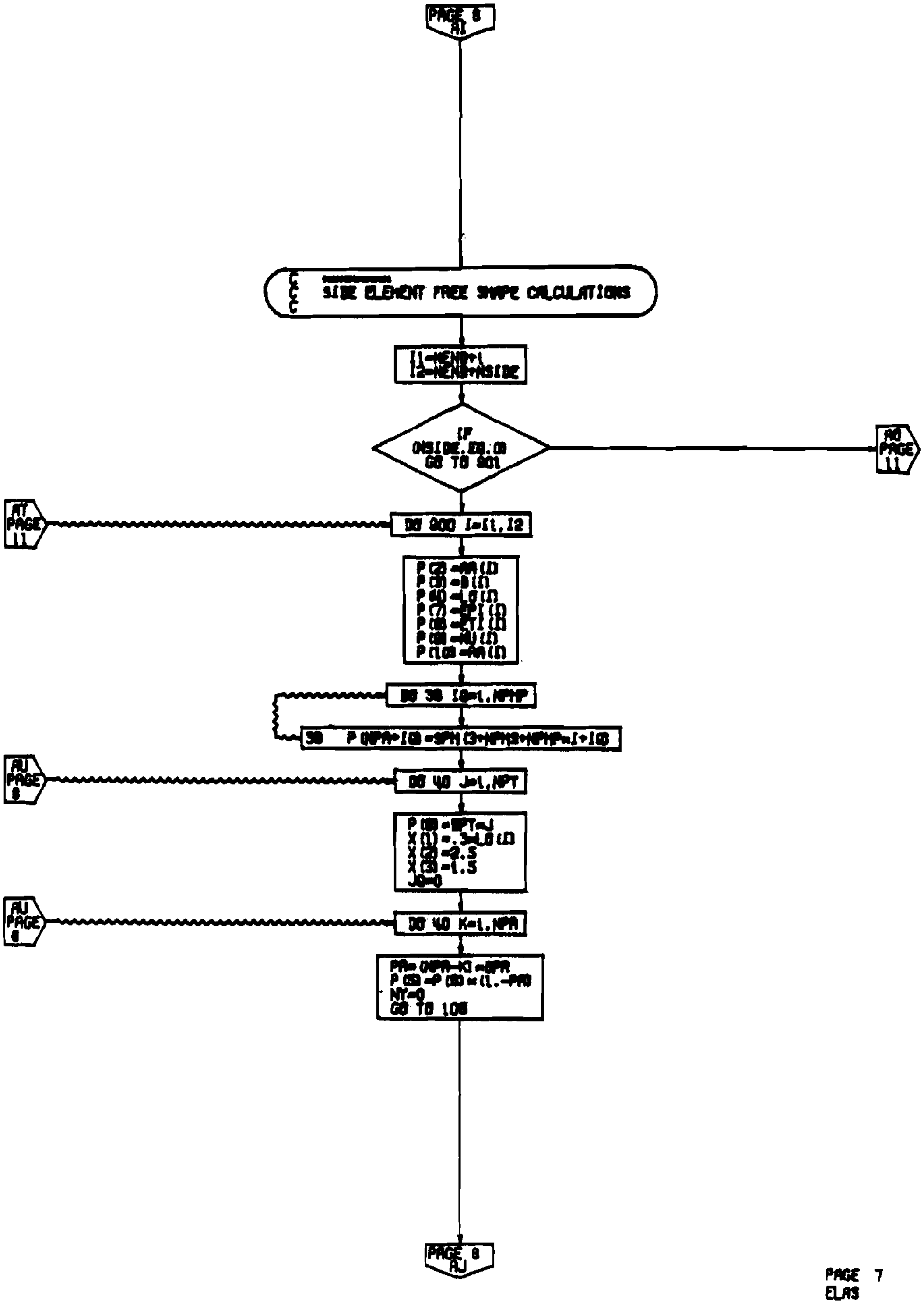


Table 19: FLOWCHART FOR SUBROUTINE ELAS (CONTINUED)

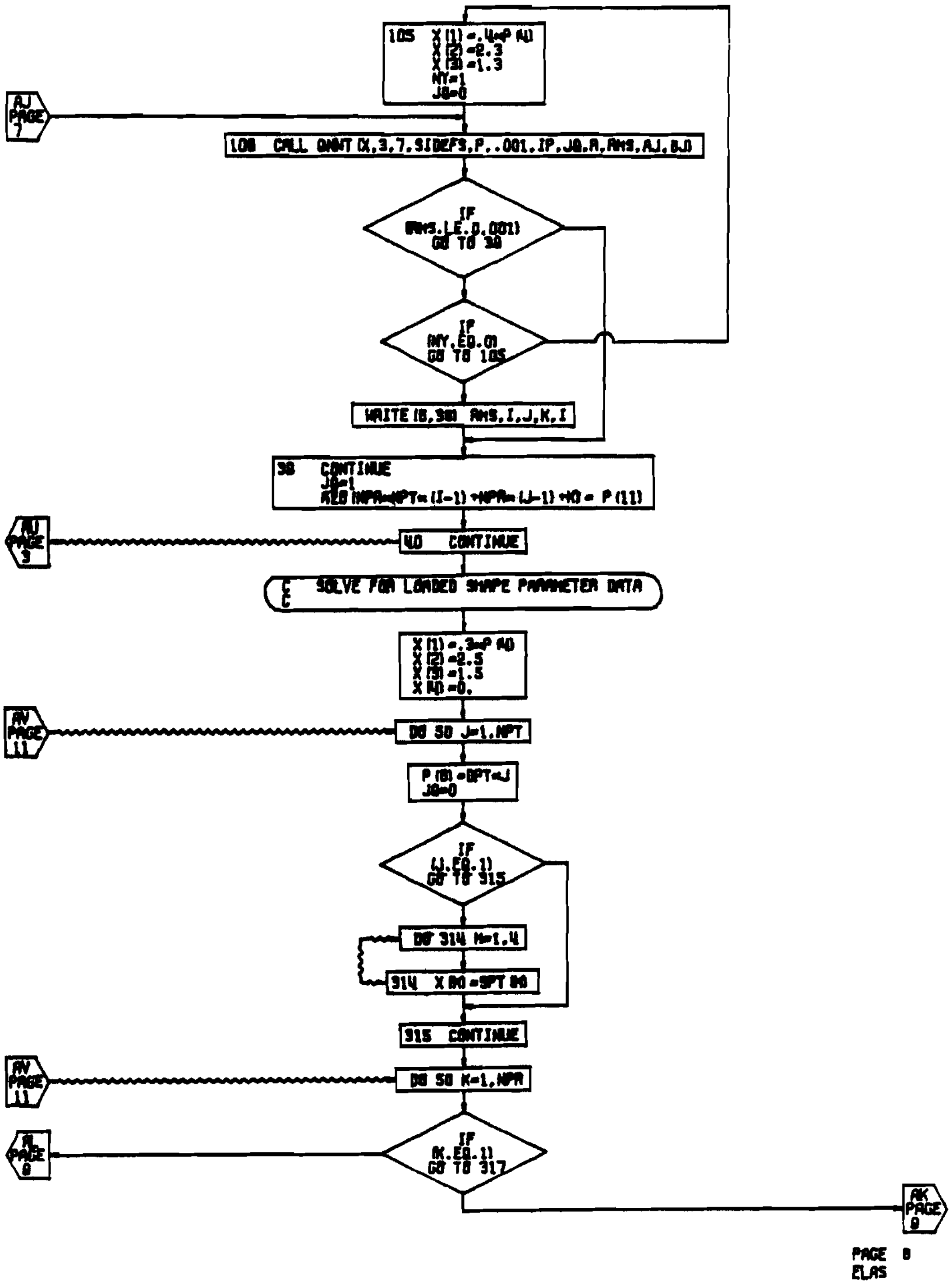


Table 19: FLOWCHART FOR SUBROUTINE ELAS (CONTINUED)

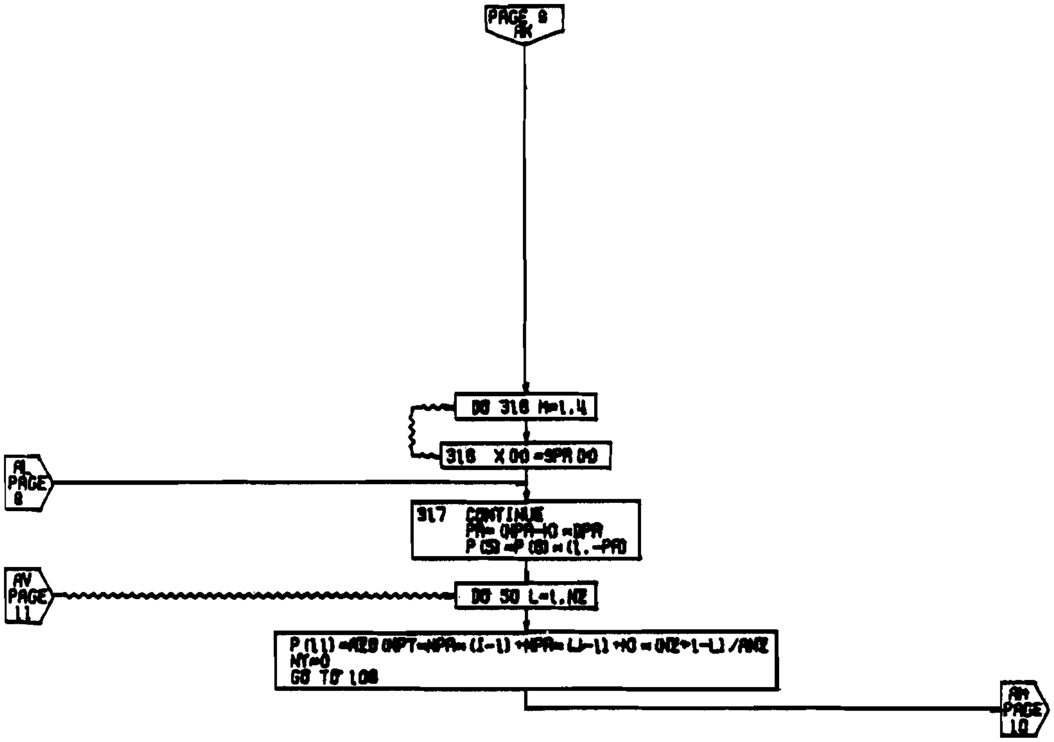


Table 19: FLOWCHART FOR SUBROUTINE ELAS (CONTINUED)

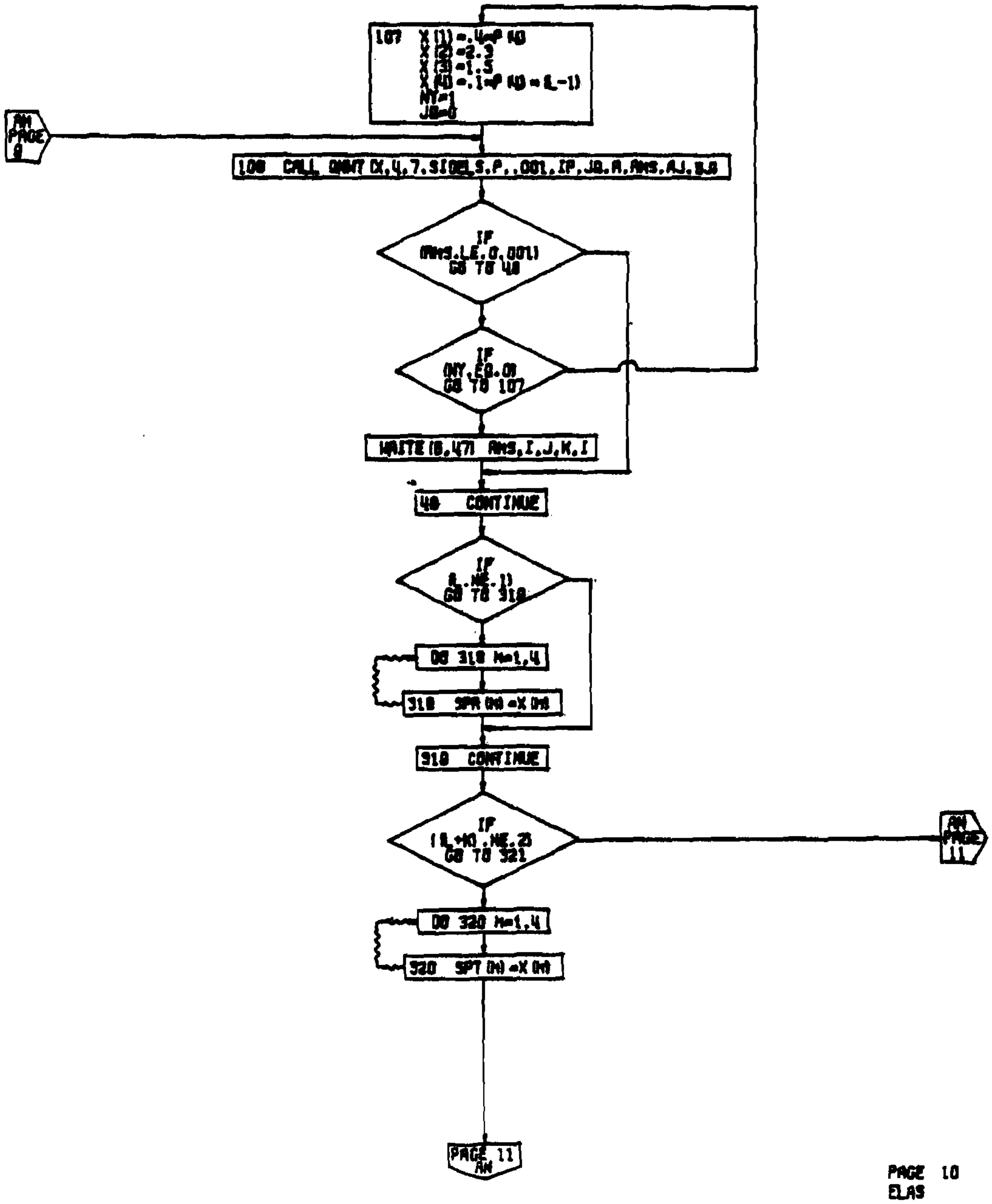
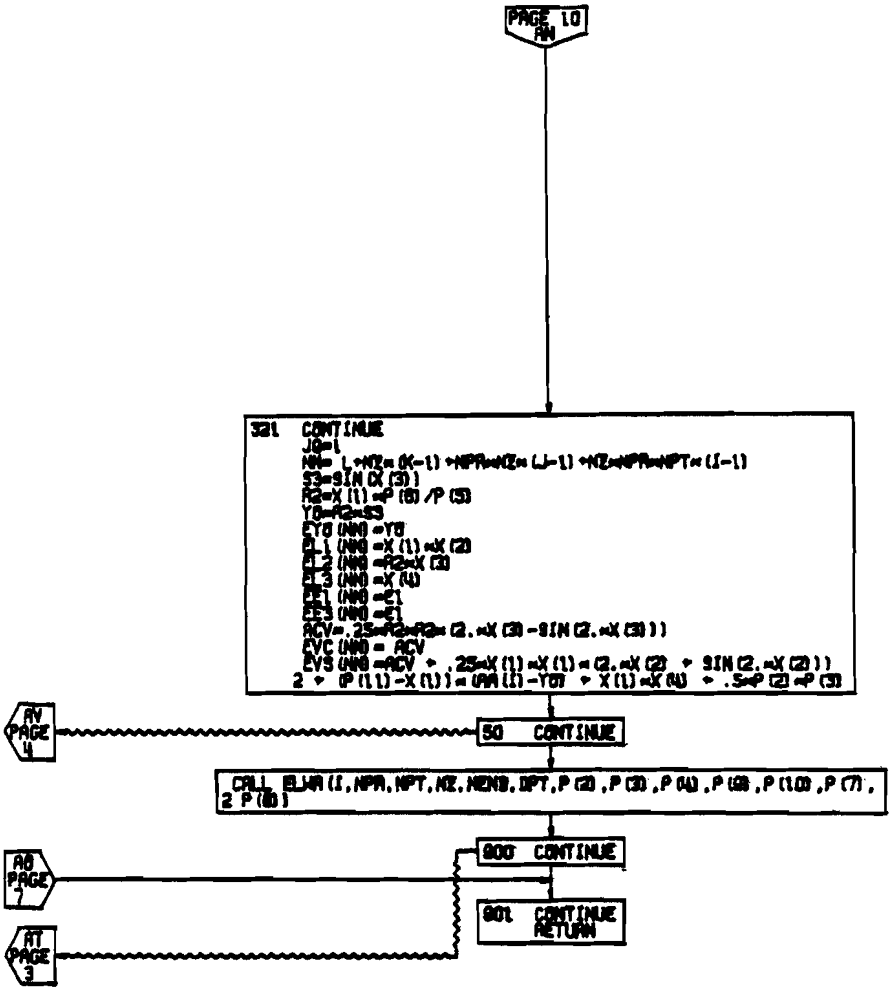


Table 19: FLOWCHART FOR SUBROUTINE ELAS (CONCLUDED)



```
321   CONTINUE
      JQ=1
      NN= L+NZ*(K-1)+NPR*NZ*(J-1)+NZ*NPR*NPT*(I-1)
      S3=SIN(X(3))
      R2=X(1)*P(8)/P(5)
      Y0=R2*S3
      EY0(NN)=Y0
      EL1(NN)=X(1)*X(2)
      EL2(NN)=R2*X(3)
      EL3(NN)=X(4)
      EE1(NN)=E1
      EE3(NN)=E1
      ACV=.25*R2*R2*(2.*X(3)-SIN(2.*X(3)))
      EVC(NN)= ACV
      EVS(NN)=ACV + .25*X(1)*X(1)*(2.*X(2) + SIN(2.*X(2)))
     2 + (P(11)-X(1))*(AA(I)-Y0) + X(1)*X(4) + .5*P(2)*P(3)
```

```
50    CONTINUE
```

```
      CALL ELWA(I,NPR,NPT,NZ,NEND,DPT,P(2),P(3),P(4),P(9),P(10),P(7),
     2 P(8))
```

```
900   CONTINUE
```

```
901   CONTINUE
      RETURN
```

Table 20: FLOWCHART FOR SUBROUTINE ELFX

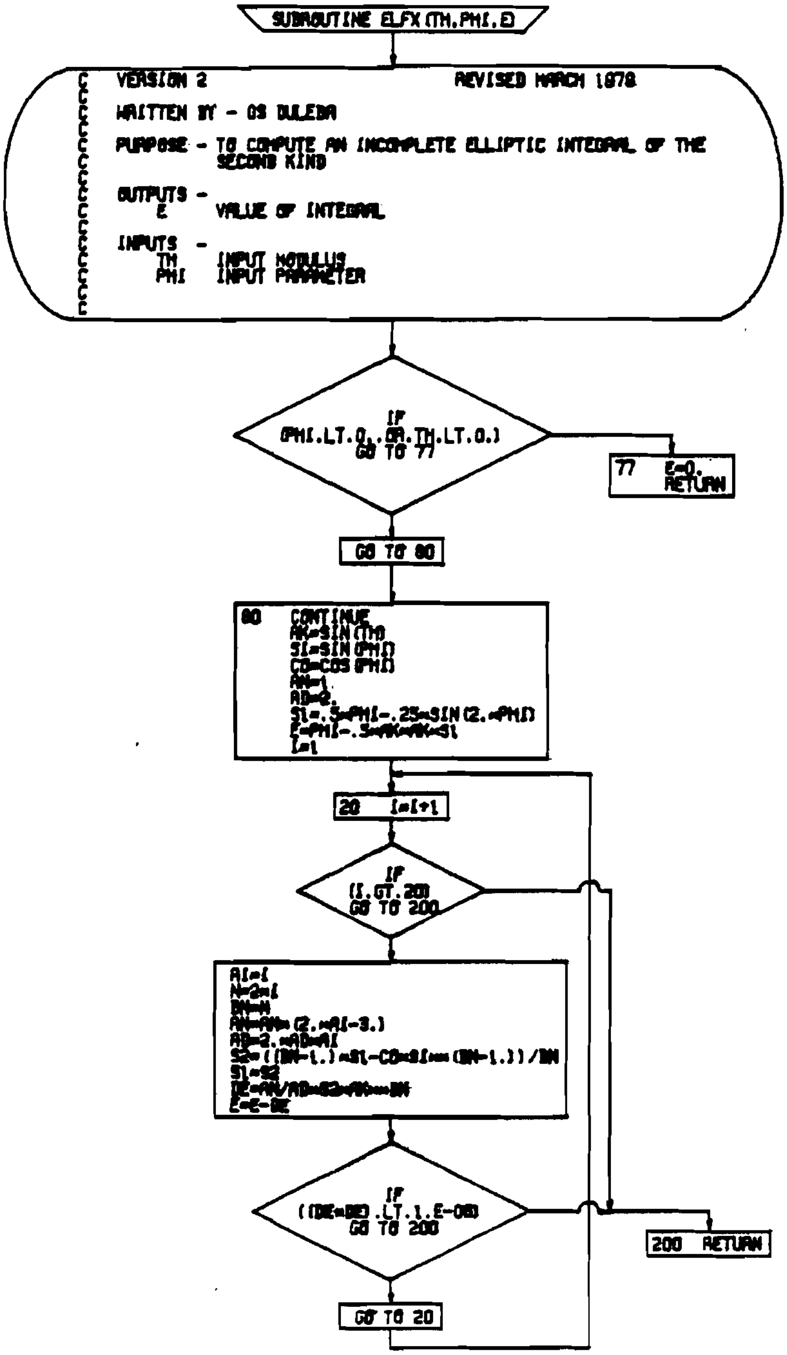


Table 21: FLOWCHART FOR SUBROUTINE ELKX

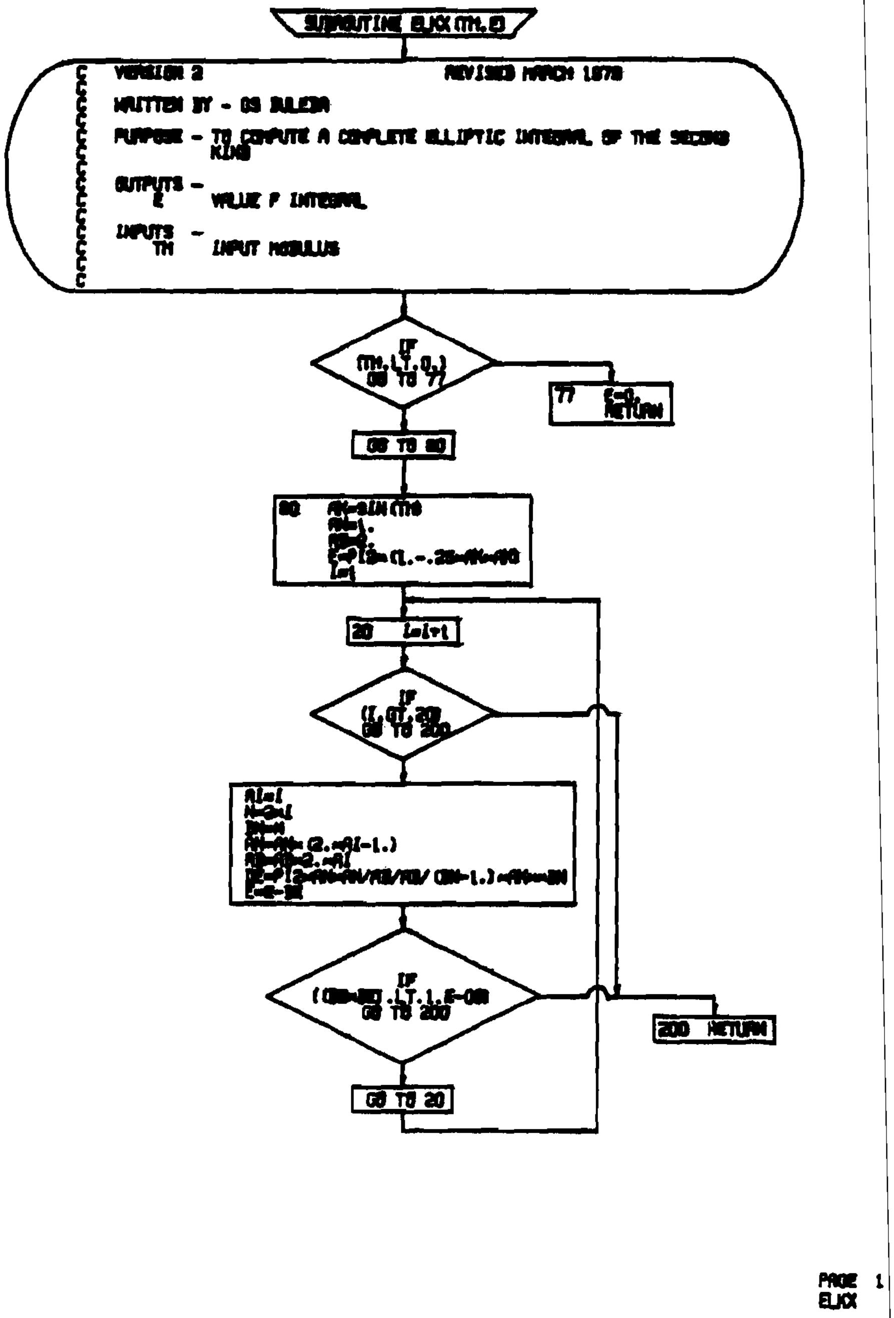


Table 22: FLOWCHART FOR SUBROUTINE ELWR

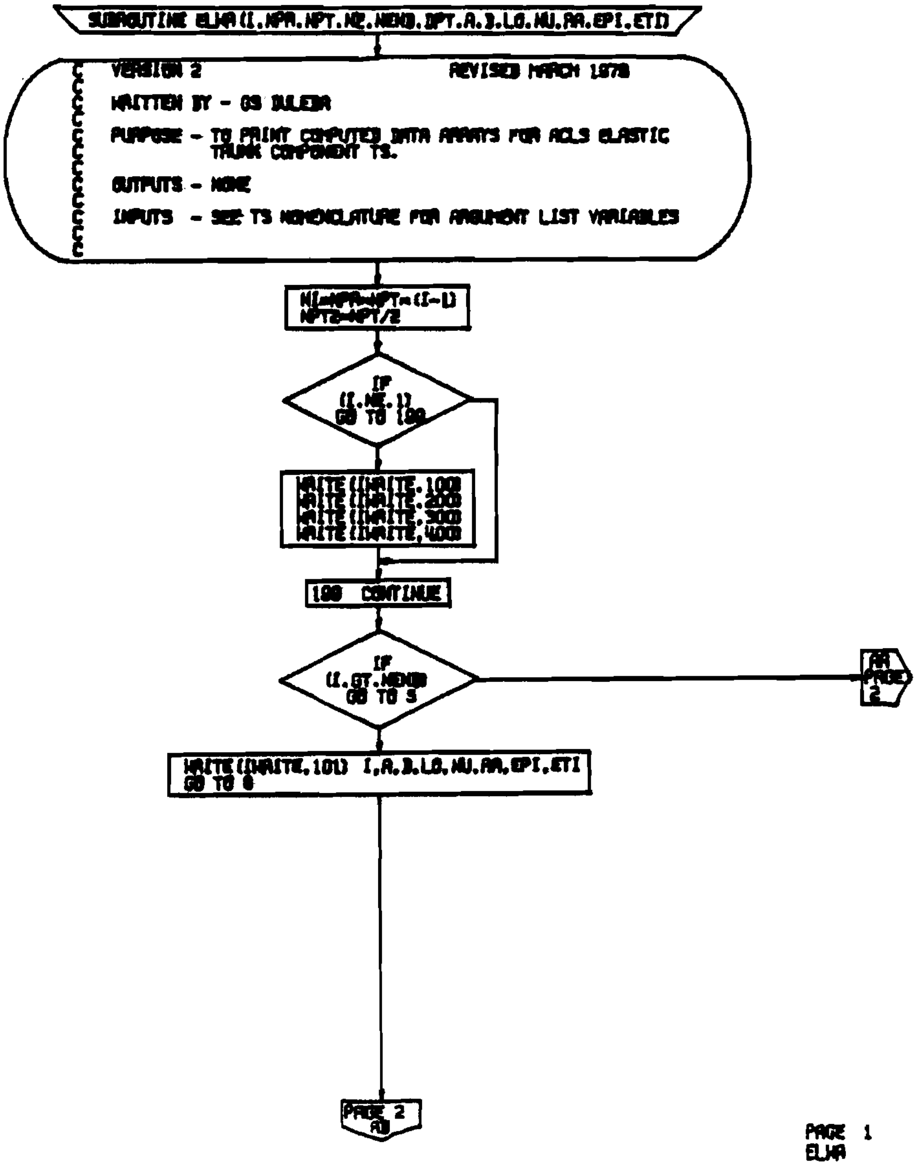
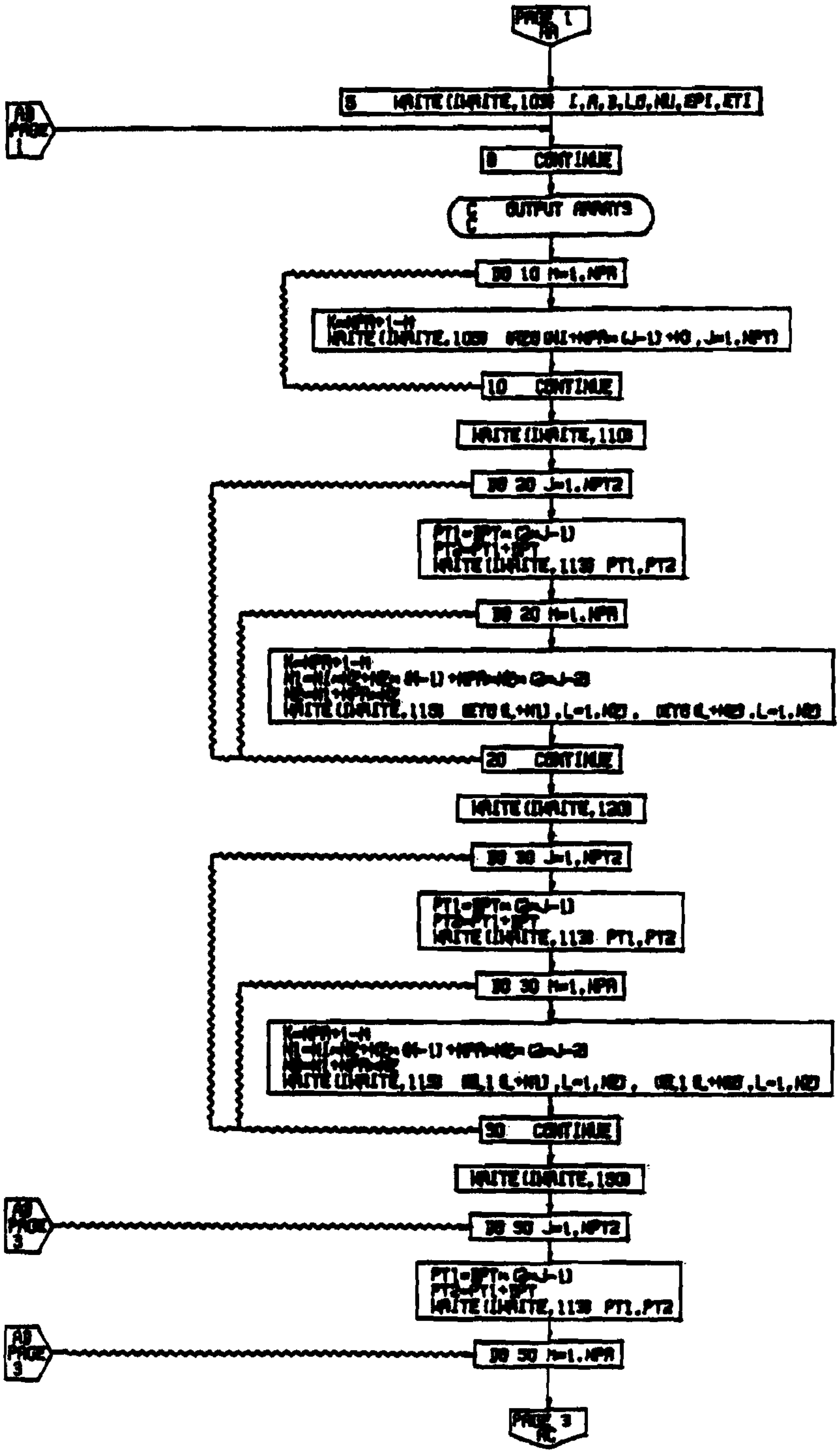
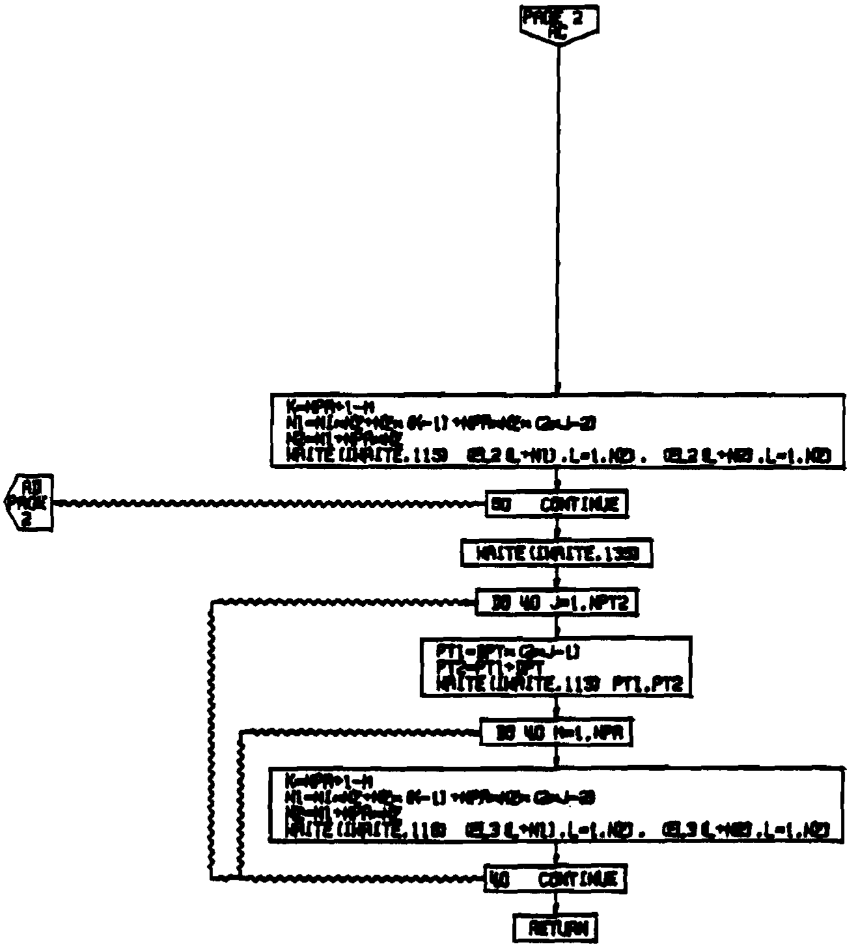


Table 22: FLOWCHART FOR SUBROUTINE ELWR (CONTINUED)



PAGE 2
ELWR

Table 22: FLOWCHART FOR SUBROUTINE ELWR (CONCLUDED)



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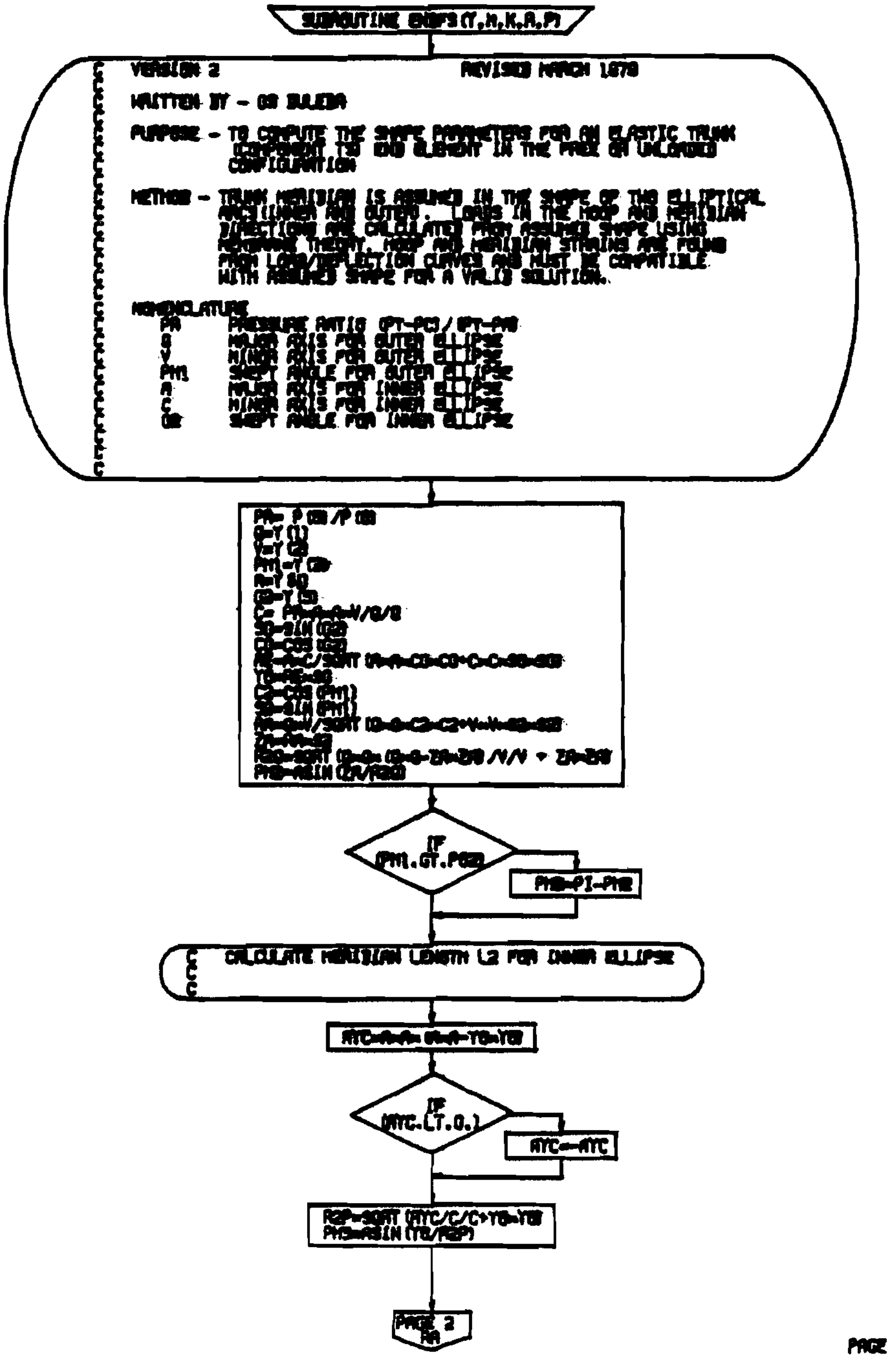
ELWR

Table 23: FLOWCHART FOR SUBROUTINE ENDFS



```
C VERSION 2                                  REVISED MARCH 1978
C
C WRITTEN BY - [illegible]
C
C PURPOSE - TO COMPUTE THE SHAPE PARAMETERS FOR AN ELASTIC TRUNK
C           (COMPONENT TO END ELEMENT IN THE FREE OR UNLOADED
C           CONFIGURATION
C
C METHOD - TRUNK MERIDIAN IS ASSUMED IN THE SHAPE OF TWO ELLIPTICAL
C          ARCS(INNER AND OUTER).  LOADS IN THE HOOP AND MERIDIAN
C          DIRECTIONS ARE CALCULATED FROM ASSUMED SHAPE USING
C          MEMBRANE THEORY.  HOOP AND MERIDIAN STRAINS ARE FOUND
C          FROM LOAD/DEFLECTION CURVES AND MUST BE COMPATIBLE
C          WITH ASSUMED SHAPE FOR A VALID SOLUTION.
C
C NOMENCLATURE
C   PR     PRESSURE RATIO (PT-PC)/(PT-PA)
C   B      MAJOR AXIS FOR OUTER ELLIPSE
C   V      MINOR AXIS FOR OUTER ELLIPSE
C   PH1    SWEPT ANGLE FOR OUTER ELLIPSE
C   A      MAJOR AXIS FOR INNER ELLIPSE
C   C      MINOR AXIS FOR INNER ELLIPSE
C   [illegible]  SWEPT ANGLE FOR INNER ELLIPSE
C
```

```
C
C CALCULATE MERIDIAN LENGTH L2 FOR INNER ELLIPSE
C
```

PAGE 1
ENDFS

Table 23: FLOWCHART FOR SUBROUTINE ENDFS (CONTINUED)

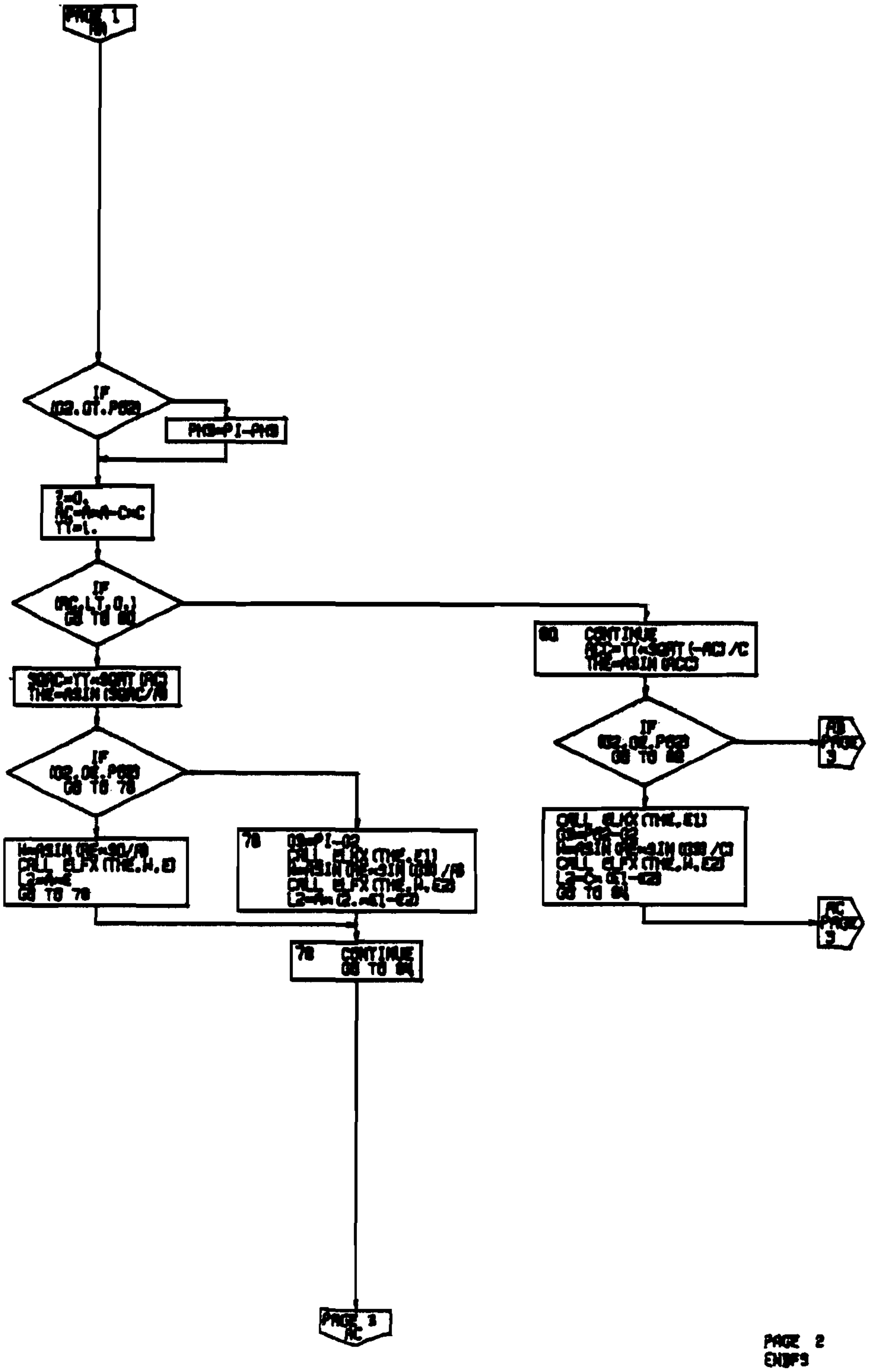


Table 23: FLOWCHART FOR SUBROUTINE ENDFS (CONTINUED)

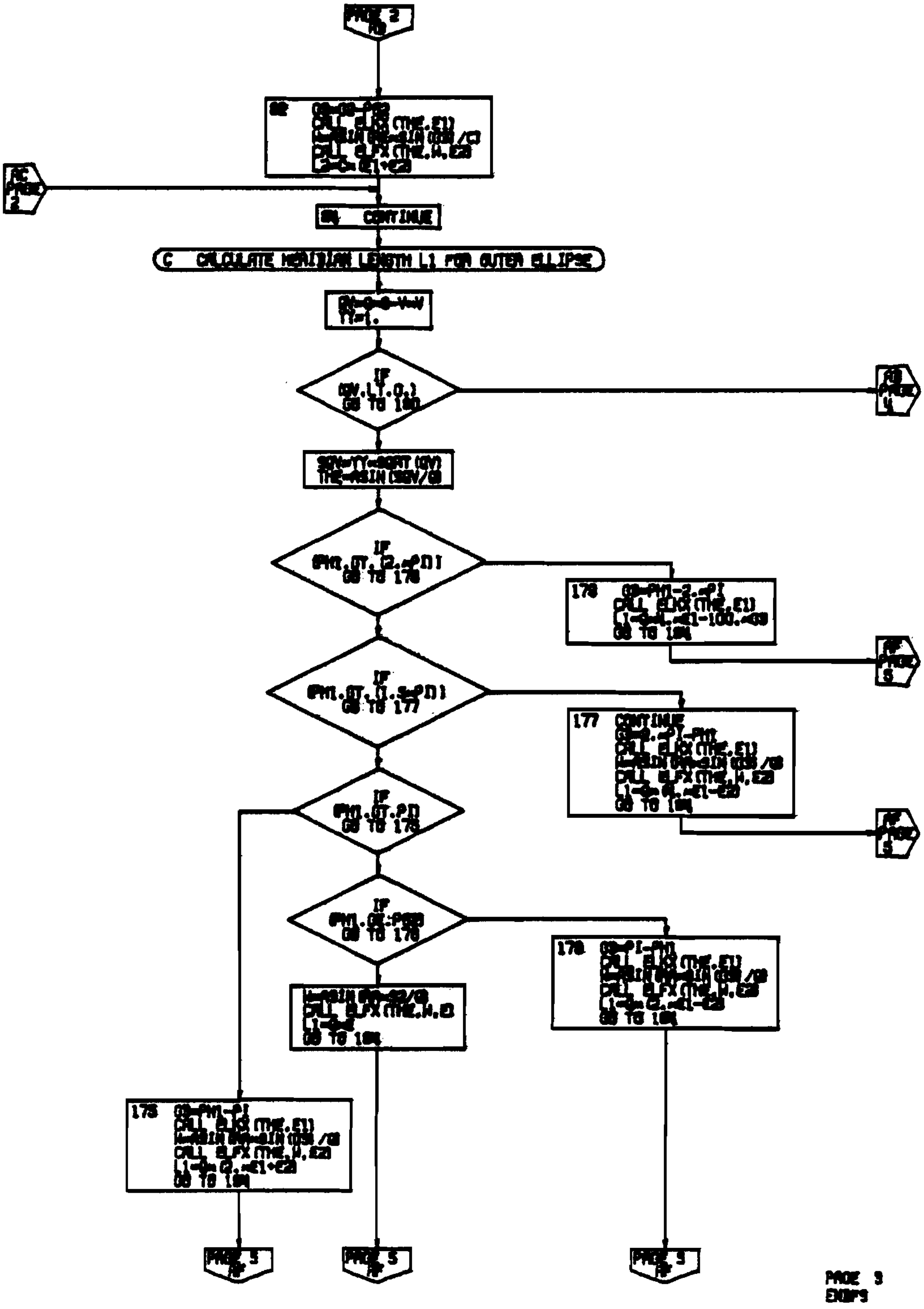


Table 23: FLOWCHART FOR SUBROUTINE ENDFS (CONTINUED)

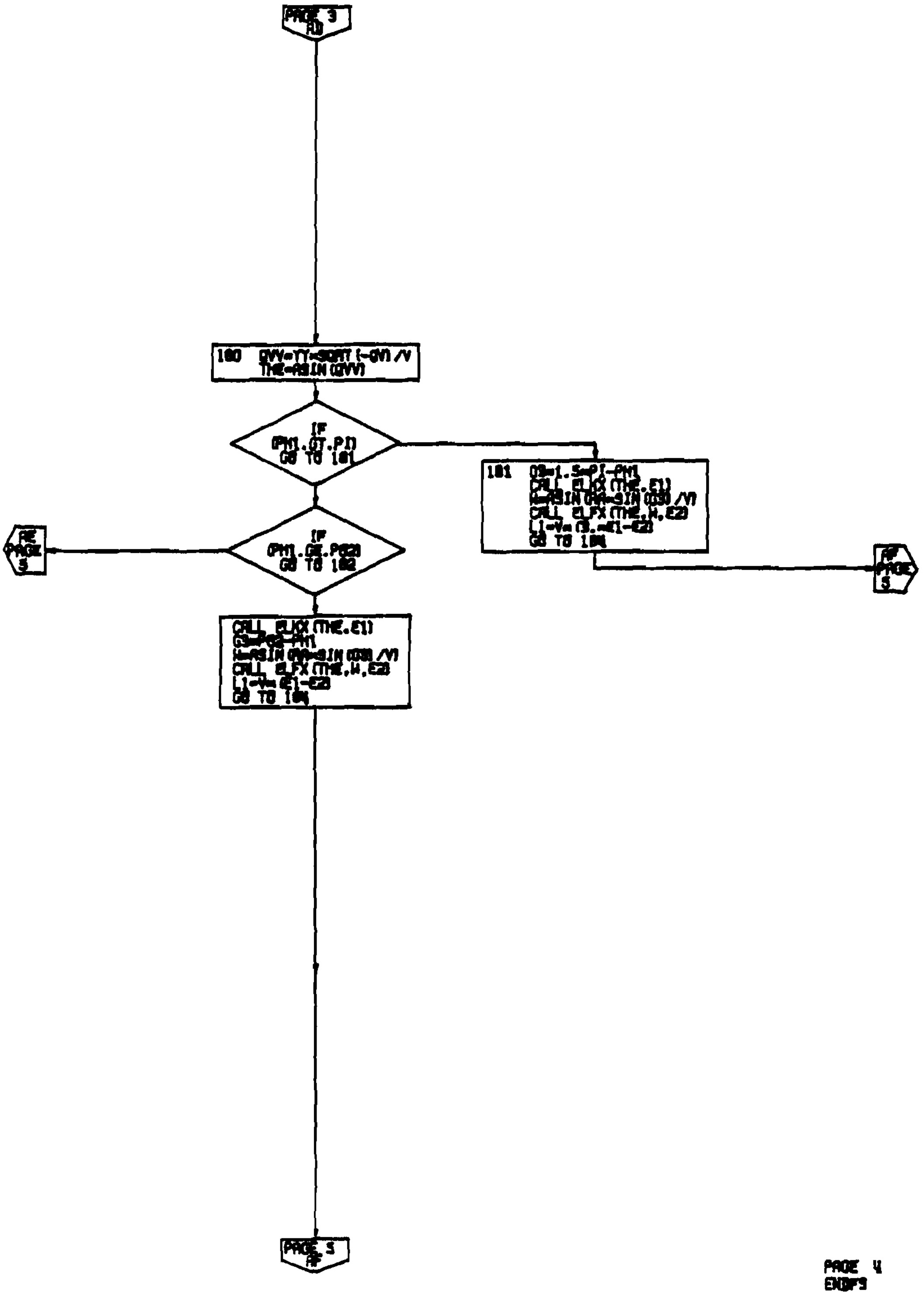
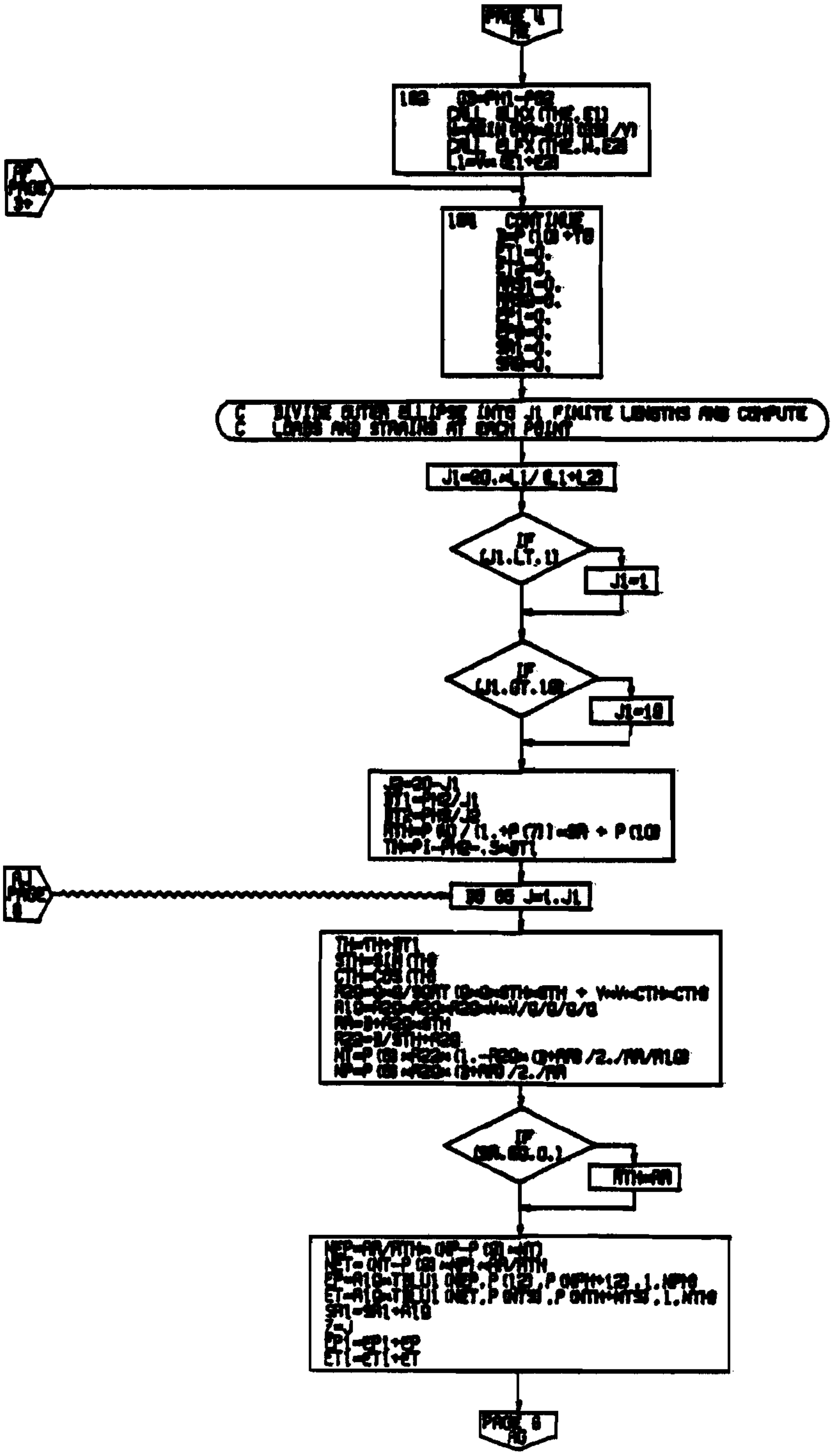


Table 23: FLOWCHART FOR SUBROUTINE ENDFS (CONTINUED)



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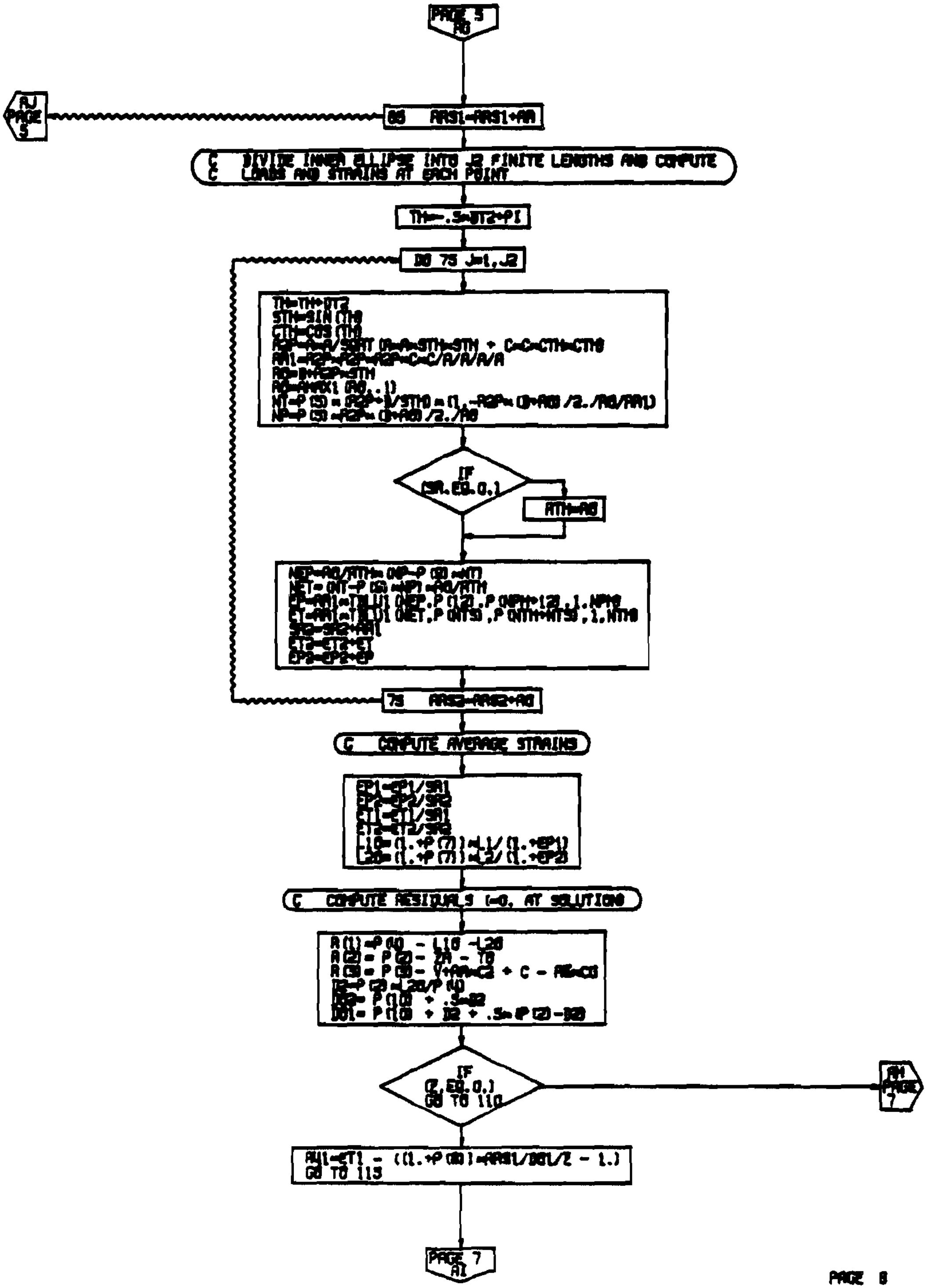
ENDFS

Table 23: FLOWCHART FOR SUBROUTINE ENDFS (CONTINUED)



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ENDFS

Table 23: FLOWCHART FOR SUBROUTINE ENDFS (CONCLUDED)

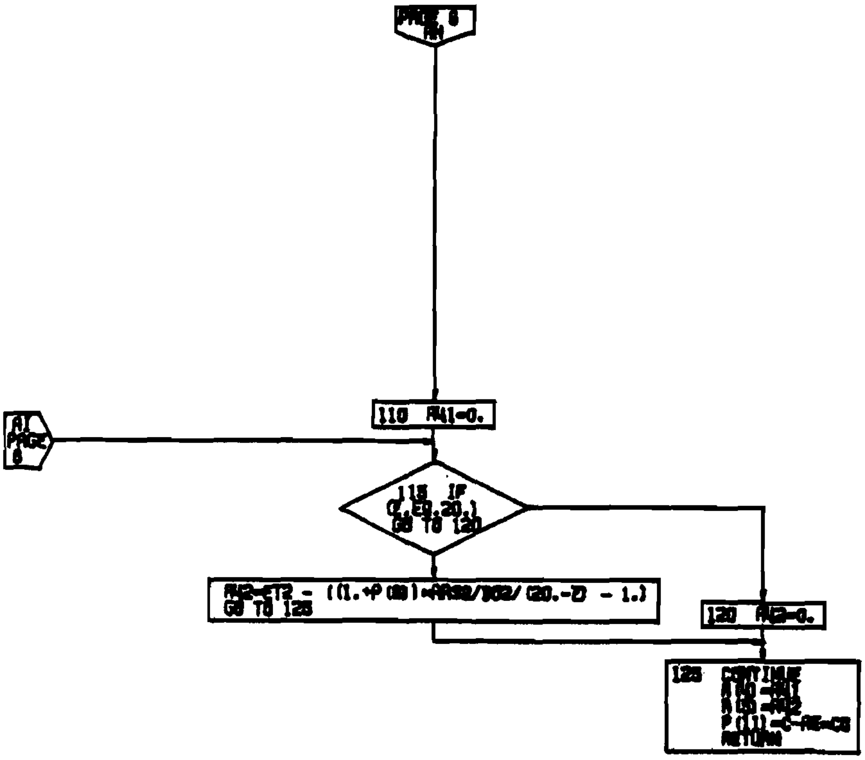
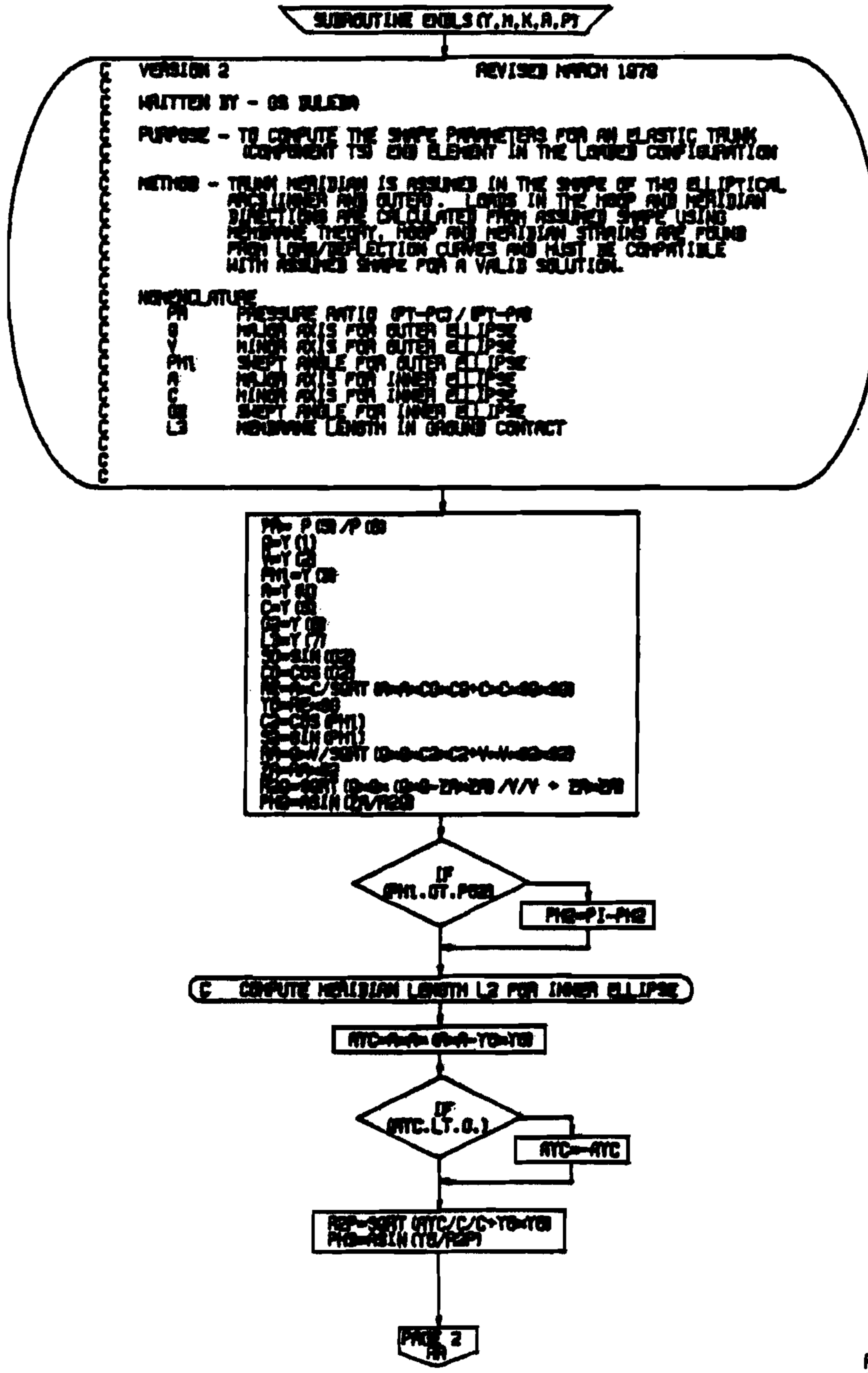


Table 24: FLOWCHART FOR SUBROUTINE ENDLS



```
SUBROUTINE ENDLS(Y,M,K,A,P)

C   VERSION 2                                REVISED MARCH 1978
C
C   WRITTEN BY - GS BULEJA
C
C   PURPOSE - TO COMPUTE THE SHAPE PARAMETERS FOR AN ELASTIC TRUNK
C             (COMPONENT TS) END ELEMENT IN THE LOADED CONFIGURATION
C
C   METHOD - TRUNK MERIDIAN IS ASSUMED IN THE SHAPE OF TWO ELLIPTICAL
C            ARCS(INNER AND OUTER).  LOADS IN THE HOOP AND MERIDIAN
C            DIRECTIONS ARE CALCULATED FROM ASSUMED SHAPE USING
C            MEMBRANE THEORY. HOOP AND MERIDIAN STRAINS ARE FOUND
C            FROM LOAD/DEFLECTION CURVES AND MUST BE COMPATIBLE
C            WITH ASSUMED SHAPE FOR A VALID SOLUTION.
C
C   NOMENCLATURE
C     PR     PRESSURE RATIO (PT-PC)/(PT-PA)
C     B      MAJOR AXIS FOR OUTER ELLIPSE
C     V      MINOR AXIS FOR OUTER ELLIPSE
C     PH1    SWEPT ANGLE FOR OUTER ELLIPSE
C     A      MAJOR AXIS FOR INNER ELLIPSE
C     C      MINOR AXIS FOR INNER ELLIPSE
C     Q2     SWEPT ANGLE FOR INNER ELLIPSE
C     L3     MEMBRANE LENGTH IN GROUND CONTACT
C
C

PR= P(5)/P(6)
B=Y(1)
V=Y(2)
PH1=Y(3)
A=Y(4)
C=Y(5)
Q2=Y(6)
L3=Y(7)
S0=SIN(Q2)
C0=COS(Q2)
R0=A*C/SQRT(A*A*C0*C0+C*C*S0*S0)
Y0=R0*S0
C2=COS(PH1)
S2=SIN(PH1)
R2=B*V/SQRT(B*B*C2*C2+V*V*S2*S2)
Z2=R2*S2
R2Q=SQRT(B*B*(B*B-Z2*Z2)/V/V + Z2*Z2)
PH2=ASIN(Z2/R2Q)

IF (PH1.GT.PIO2)
    PH2=PI-PH2

C   COMPUTE MERIDIAN LENGTH L2 FOR INNER ELLIPSE

ATC=A*A*(A*A-Y0*Y0)

IF (ATC.LT.0.)
    ATC=-ATC

R2P=SQRT(ATC/C/C+Y0*Y0)
PH3=ASIN(Y0/R2P)

PAGE 2
AA
```

PAGE 1
ENDLS

Table 24: FLOWCHART FOR SUBROUTINE ENDLS (CONTINUED)

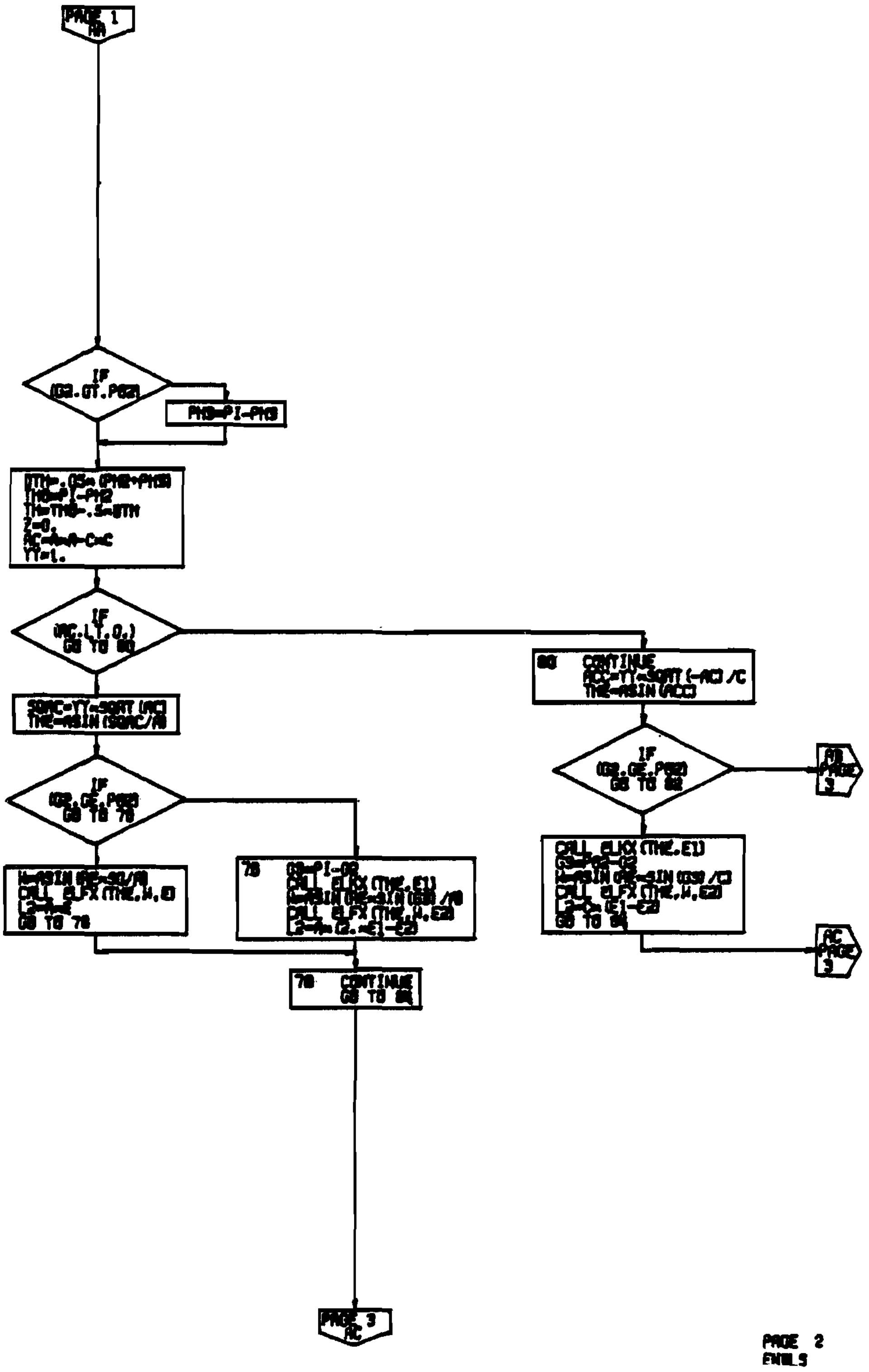


Table 24: FLOWCHART FOR SUBROUTINE ENDLS (CONTINUED)

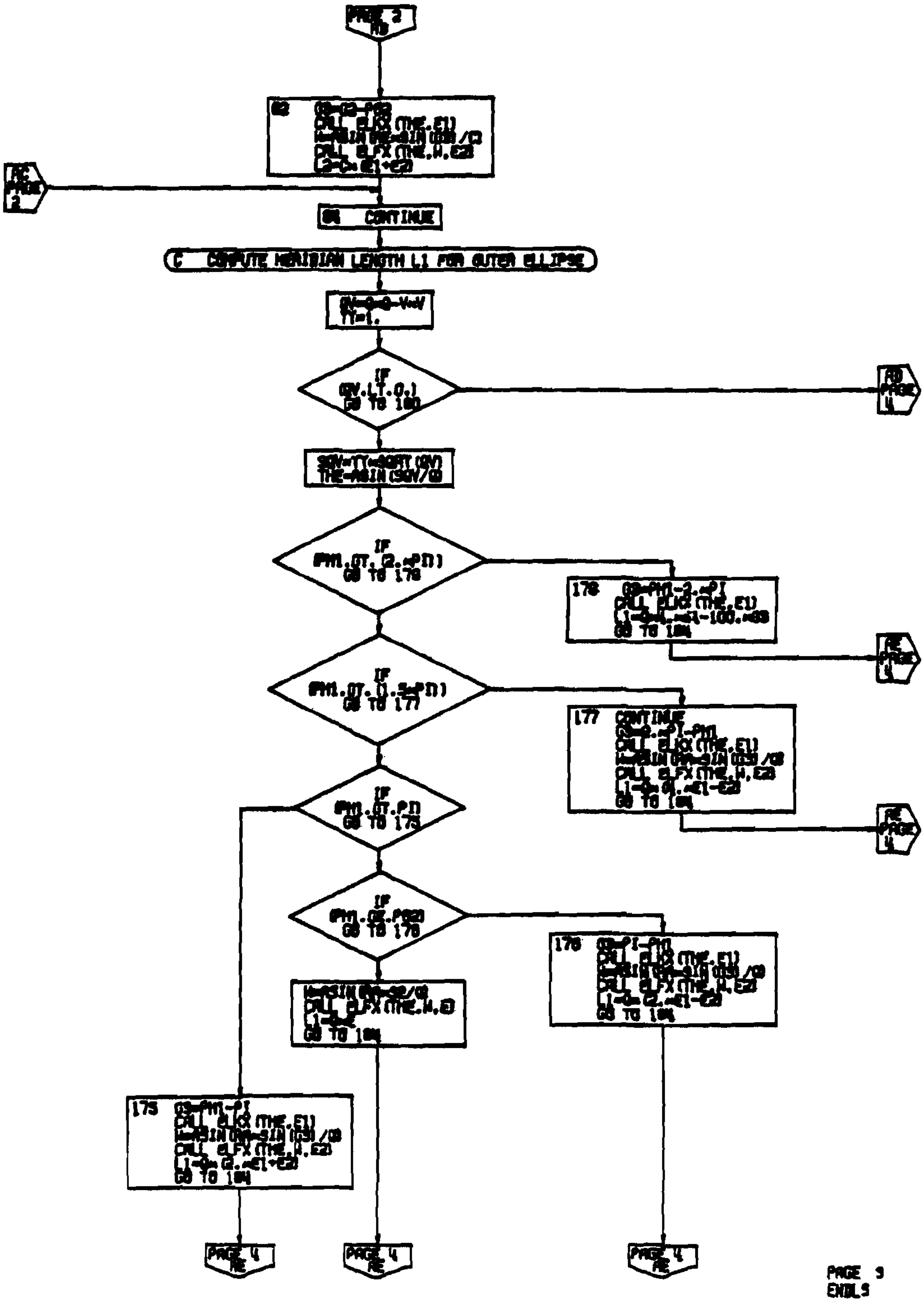


Table 24: FLOWCHART FOR SUBROUTINE ENDLS (CONTINUED)

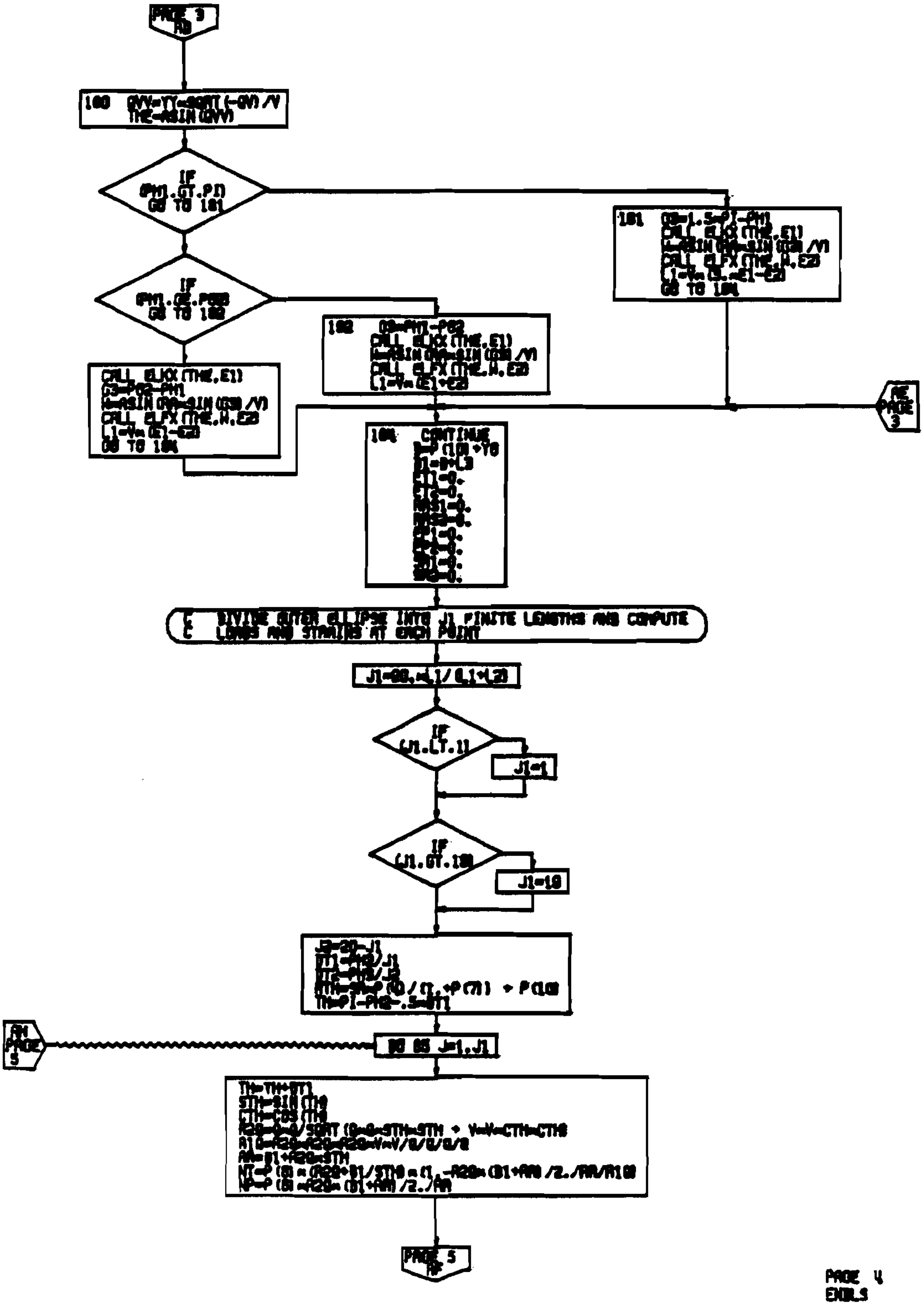


Table 24: FLOWCHART FOR SUBROUTINE ENDLS (CONTINUED)

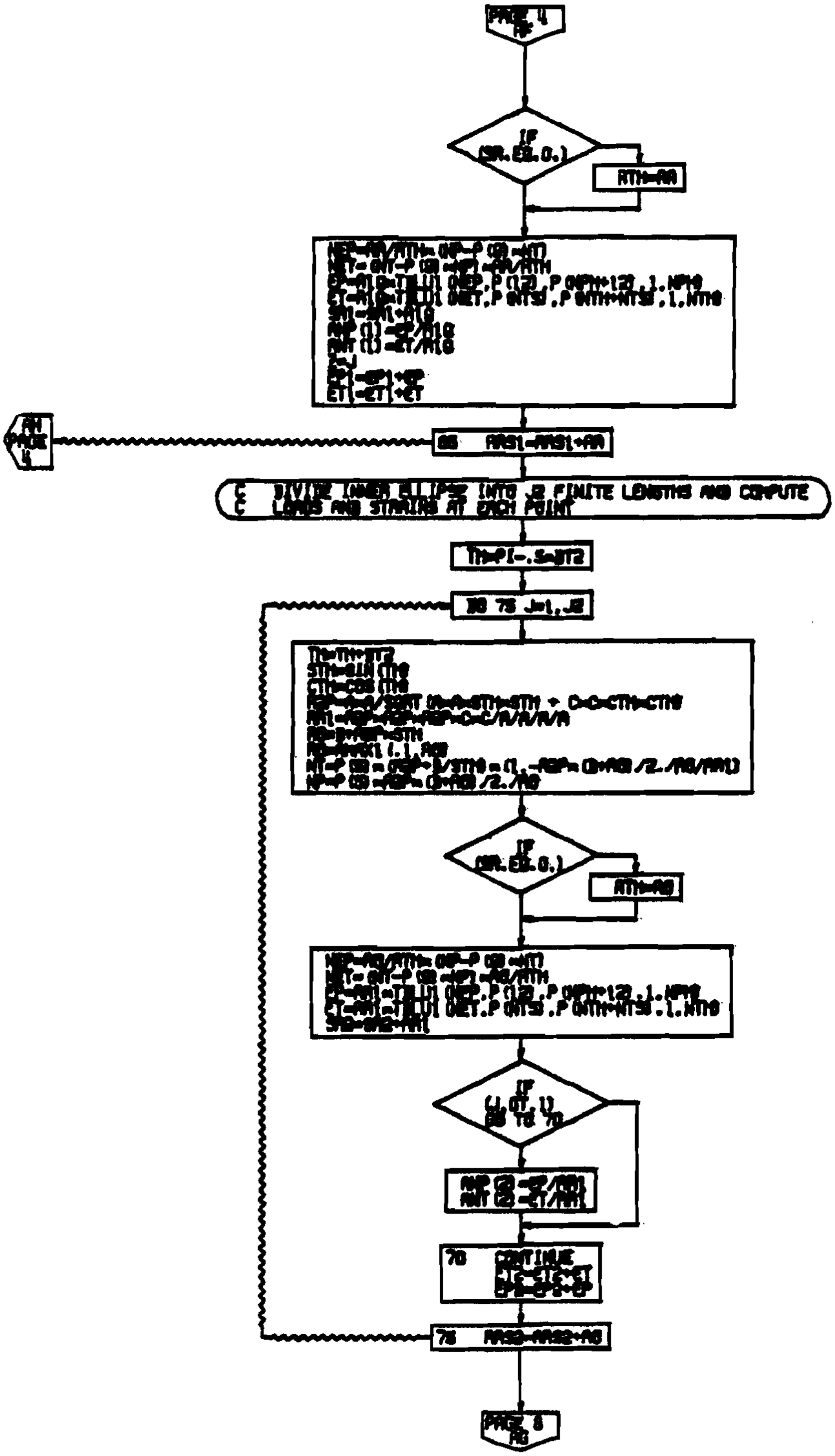
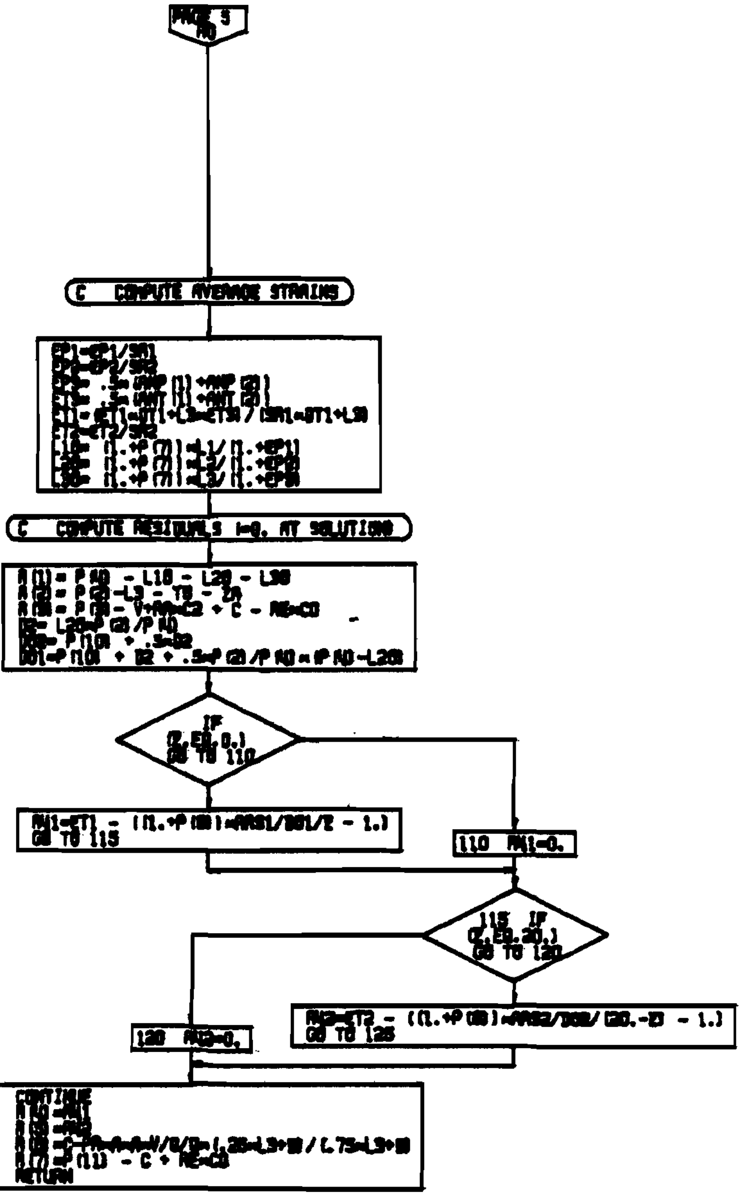


Table 24: FLOWCHART FOR SUBROUTINE ENDLS (CONCLUDED)



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ENDLS

Table 25: FLOWCHART FOR SUBROUTINE ES

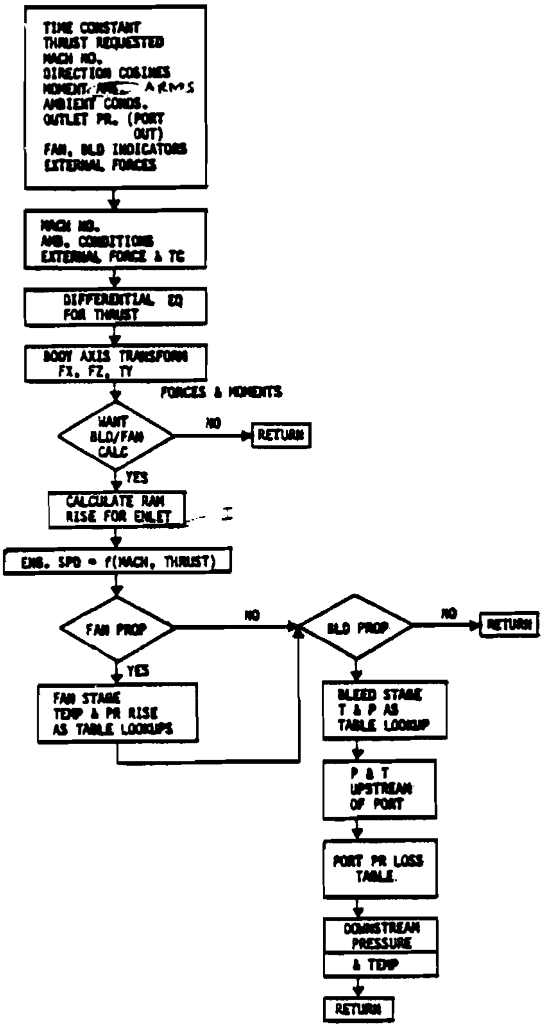
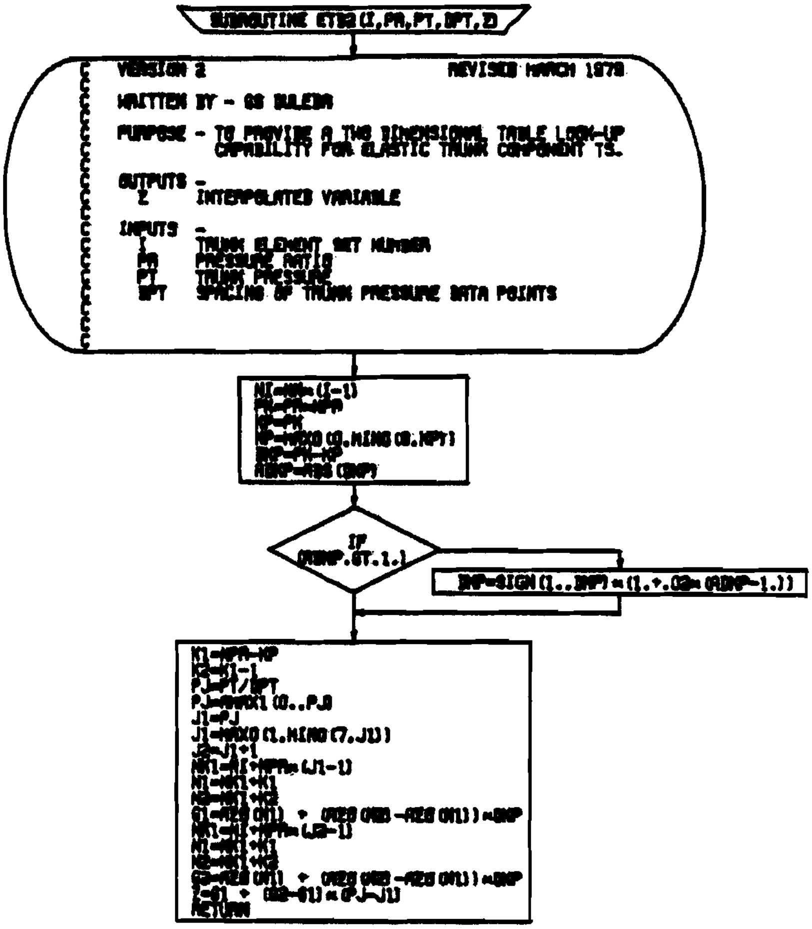
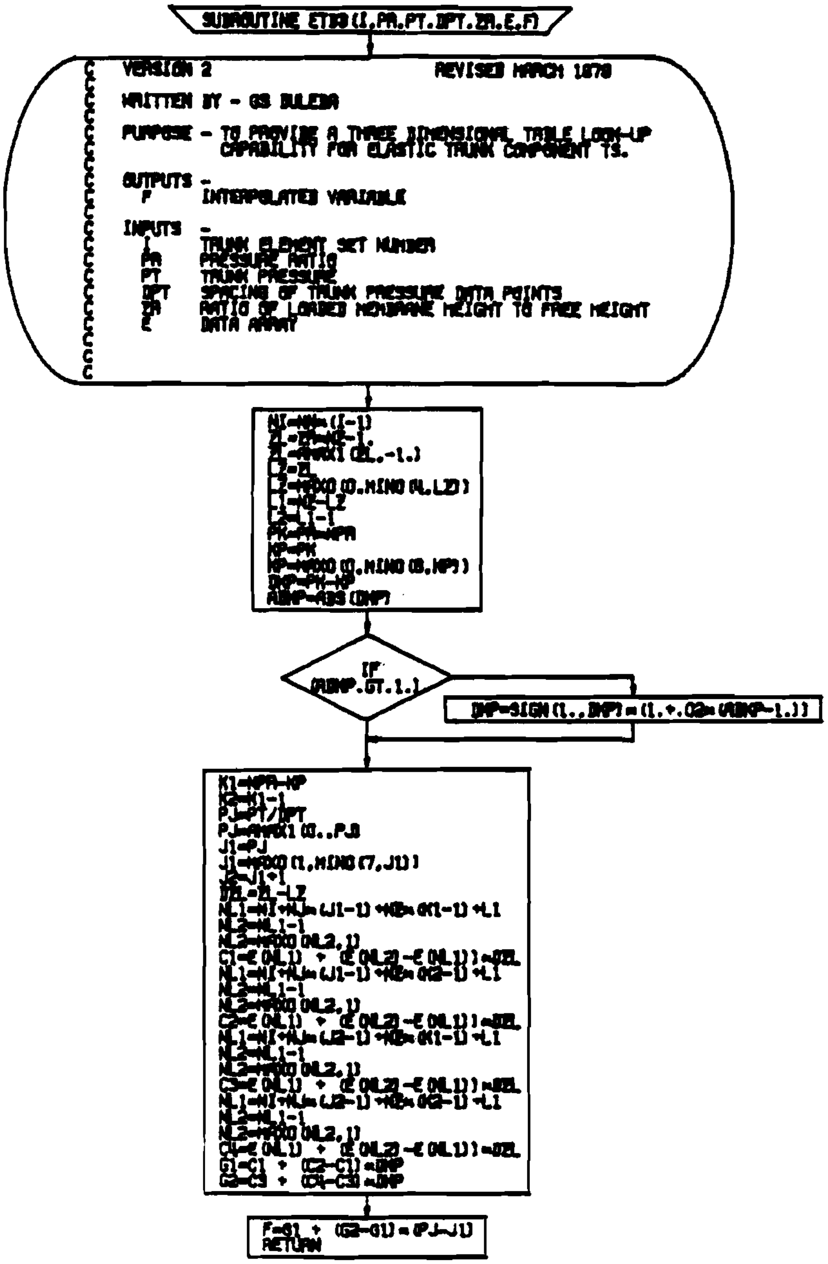


Table 26: FLOWCHART FOR SUBROUTINE ETB2



PAGE 1
ETB2

Table 27: FLOWCHART FOR SUBROUTINE ETB3



```
SUBROUTINE ETB3(I,PR,PT,DPT,ZR,E,F)
C     VERSION 2                              REVISED MARCH 1978
C
C     WRITTEN BY - GS BULEZA
C
C     PURPOSE - TO PROVIDE A THREE DIMENSIONAL TABLE LOOK-UP
C                 CAPABILITY FOR ELASTIC TRUNK COMPONENT TS.
C
C     OUTPUTS -
C       F      INTERPOLATED VARIABLE
C
C     INPUTS  -
C       I      TRUNK ELEMENT SET NUMBER
C       PR     PRESSURE RATIO
C       PT     TRUNK PRESSURE
C       DPT    SPACING OF TRUNK PRESSURE DATA POINTS
C       ZR     RATIO OF LOADED MEMBRANE HEIGHT TO FREE HEIGHT
C       E      DATA ARRAY
C
C

NI=NN*(I-1)
ZL=ZR*NZ-1.
ZL=AMAX1(ZL,-1.)
LZ=ZL
LZ=MAX0(0,MIN0(NL,LZ))
L1=NZ-LZ
L2=L1-1
PK=PR*NPR
KP=PK
KP=MAX0(0,MIN0(8,KP))
DKP=PK-KP
ADKP=ABS(DKP)

IF
(ADKP.GT.1.)

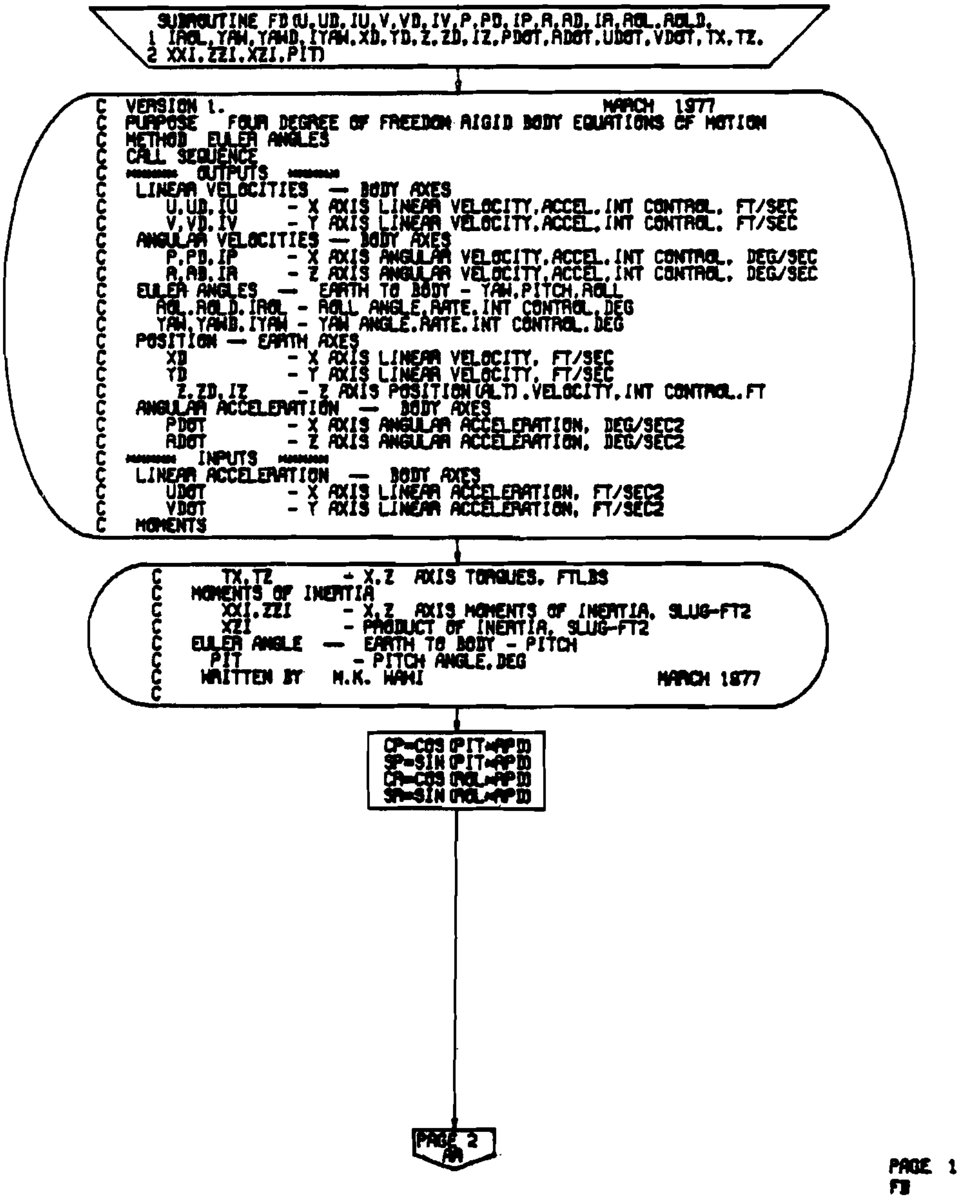
DKP=SIGN(1.,DKP)*(1.+.02*(ADKP-1.))

K1=NPR-KP
K2=K1-1
PJ=PT/DPT
PJ=AMAX1(0.,PJ)
J1=PJ
J1=MAX0(1,MIN0(7,J1))
J2=J1+1
DZL=ZL-LZ
NL1=NI+NJ*(J1-1)+NK*(K1-1)+L1
NL2=NL1-1
NL2=MAX0(NL2,1)
C1=E(NL1) + (E(NL2)-E(NL1))*DZL
NL1=NI+NJ*(J1-1)+NK*(K2-1)+L1
NL2=NL1-1
NL2=MAX0(NL2,1)
C2=E(NL1) + (E(NL2)-E(NL1))*DZL
NL1=NI+NJ*(J2-1)+NK*(K1-1)+L1
NL2=NL1-1
NL2=MAX0(NL2,1)
C3=E(NL1) + (E(NL2)-E(NL1))*DZL
NL1=NI+NJ*(J2-1)+NK*(K2-1)+L1
NL2=NL1-1
NL2=MAX0(NL2,1)
C4=E(NL1) + (E(NL2)-E(NL1))*DZL
G1=C1 + (C2-C1)*DKP
G2=C3 + (C4-C3)*DKP

F=G1 + (G2-G1)*(PJ-J1)
RETURN
```

PAGE 1
ETB3

Table 28: FLOWCHART FOR SUBROUTINE FD



```
      SUBROUTINE FD(U,UD,IU,V,VD,IV,P,PD,IP,R,RD,IR,ROL,ROLD,
     1 IROL,YAW,YAWD,IYAW,XD,YD,Z,ZD,IZ,PDOT,RDOT,UDOT,VDOT,TX,TZ,
     2 XXI,ZZI,XZI,PIT)
```

```
C   VERSION 1.                                       MARCH  1977
C   PURPOSE   FOUR DEGREE OF FREEDOM RIGID BODY EQUATIONS OF MOTION
C   METHOD  EULER ANGLES
C   CALL SEQUENCE
C   *******  OUTPUTS  *******
C    LINEAR VELOCITIES  -- BODY AXES
C       U,UD,IU      - X AXIS LINEAR VELOCITY,ACCEL,INT CONTROL, FT/SEC
C       V,VD,IV      - Y AXIS LINEAR VELOCITY,ACCEL,INT CONTROL, FT/SEC
C    ANGULAR VELOCITIES -- BODY AXES
C       P,PD,IP      - X AXIS ANGULAR VELOCITY,ACCEL,INT CONTROL, DEG/SEC
C       R,RD,IR      - Z AXIS ANGULAR VELOCITY,ACCEL,INT CONTROL, DEG/SEC
C    EULER ANGLES  --  EARTH TO BODY - YAW,PITCH,ROLL
C      ROL,ROLD,IROL - ROLL ANGLE,RATE,INT CONTROL,DEG
C      YAW,YAWD,IYAW - YAW ANGLE,RATE,INT CONTROL,DEG
C    POSITION -- EARTH AXES
C       XD           - X AXIS LINEAR VELOCITY, FT/SEC
C       YD           - Y AXIS LINEAR VELOCITY, FT/SEC
C         Z,ZD,IZ    - Z AXIS POSITION(ALT).VELOCITY,INT CONTROL.FT
C    ANGULAR ACCELERATION  --   BODY AXES
C       PDOT         - X AXIS ANGULAR ACCELERATION, DEG/SEC2
C       RDOT         - Z AXIS ANGULAR ACCELERATION, DEG/SEC2
C   *******  INPUTS  *******
C    LINEAR ACCELERATION  --  BODY AXES
C       UDOT         - X AXIS LINEAR ACCELERATION, FT/SEC2
C       VDOT         - Y AXIS LINEAR ACCELERATION, FT/SEC2
C    MOMENTS
```

```
C       TX,TZ        - X,Z  AXIS TORQUES, FTLBS
C    MOMENTS OF INERTIA
C       XXI,ZZI      - X,Z  AXIS MOMENTS OF INERTIA, SLUG-FT2
C       XZI          - PRODUCT OF INERTIA, SLUG-FT2
C    EULER ANGLE  --  EARTH TO BODY - PITCH
C      PIT           - PITCH ANGLE,DEG
C     WRITTEN BY   M.K. WAHI                            MARCH 1977
C
```

```
      CP=COS(PIT*RPD)
      SP=SIN(PIT*RPD)
      CR=COS(ROL*RPD)
      SR=SIN(ROL*RPD)
```

Table 28: FLOWCHART FOR SUBROUTINE FD (CONTINUED)

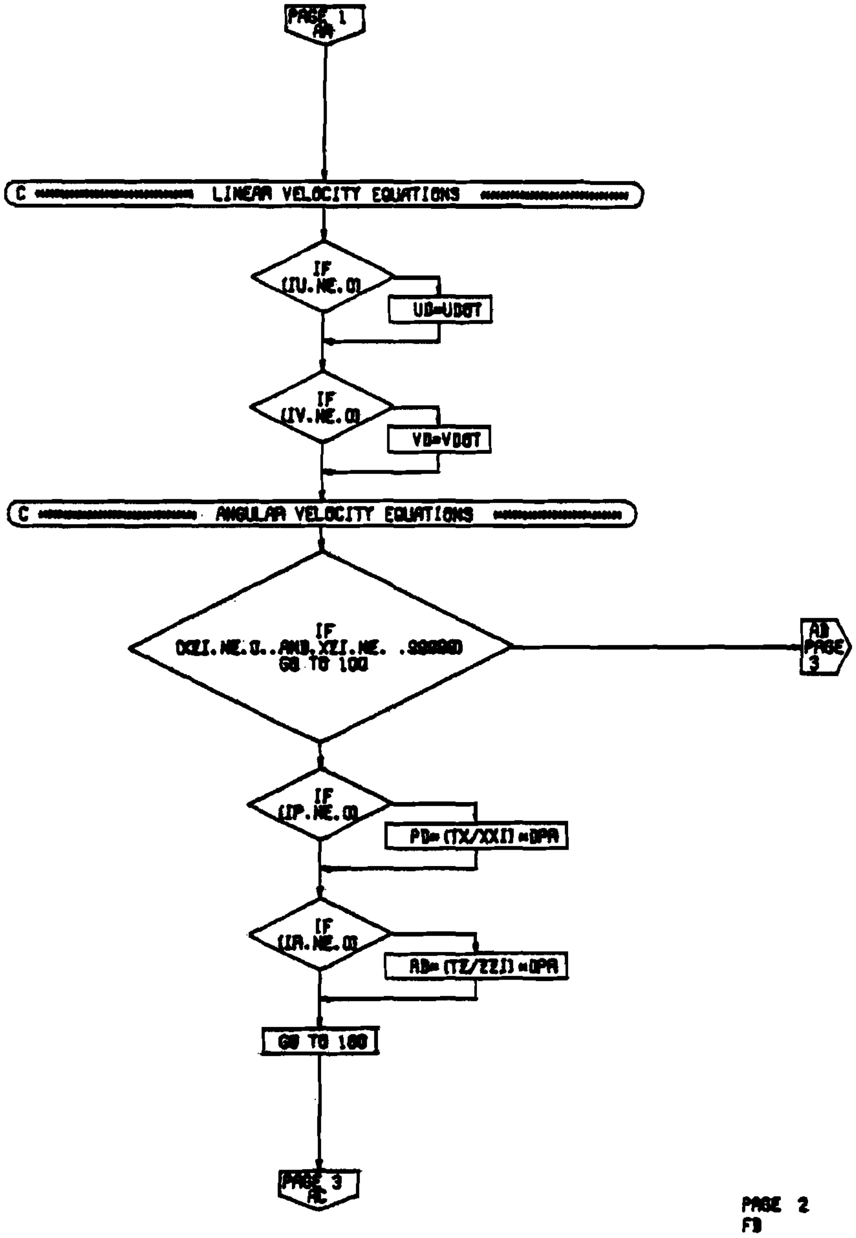


Table 28: FLOWCHART FOR SUBROUTINE FD (CONTINUED)

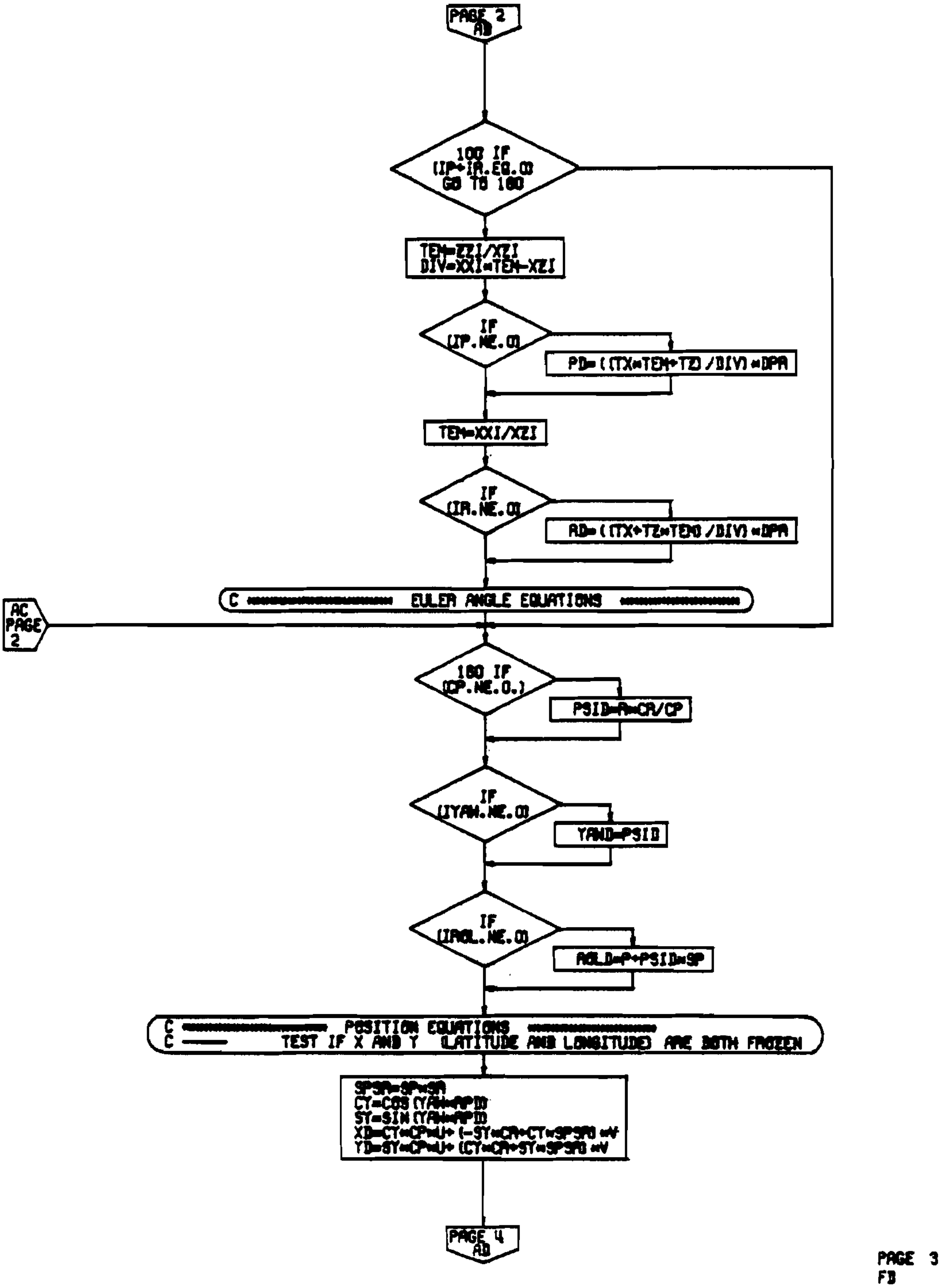


Table 28: FLOWCHART FOR SUBROUTINE FD (CONCLUDED)

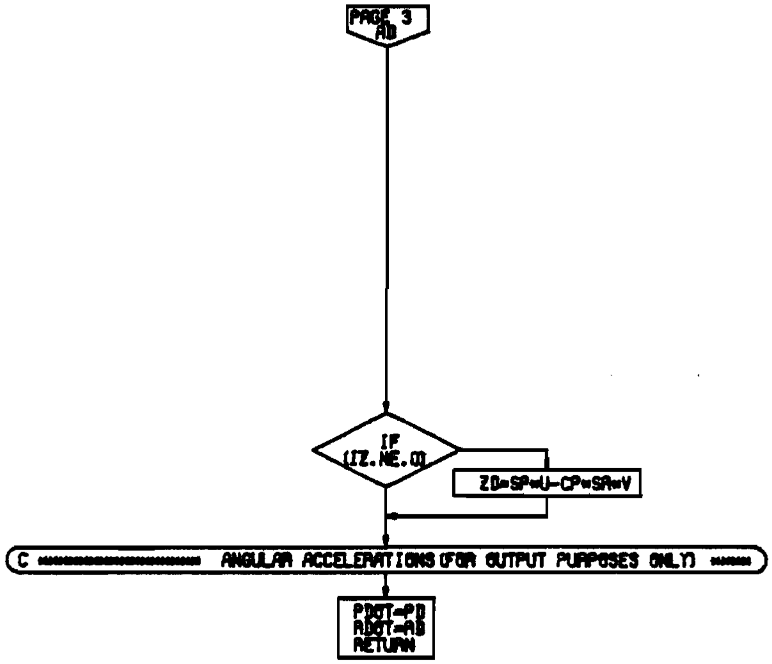
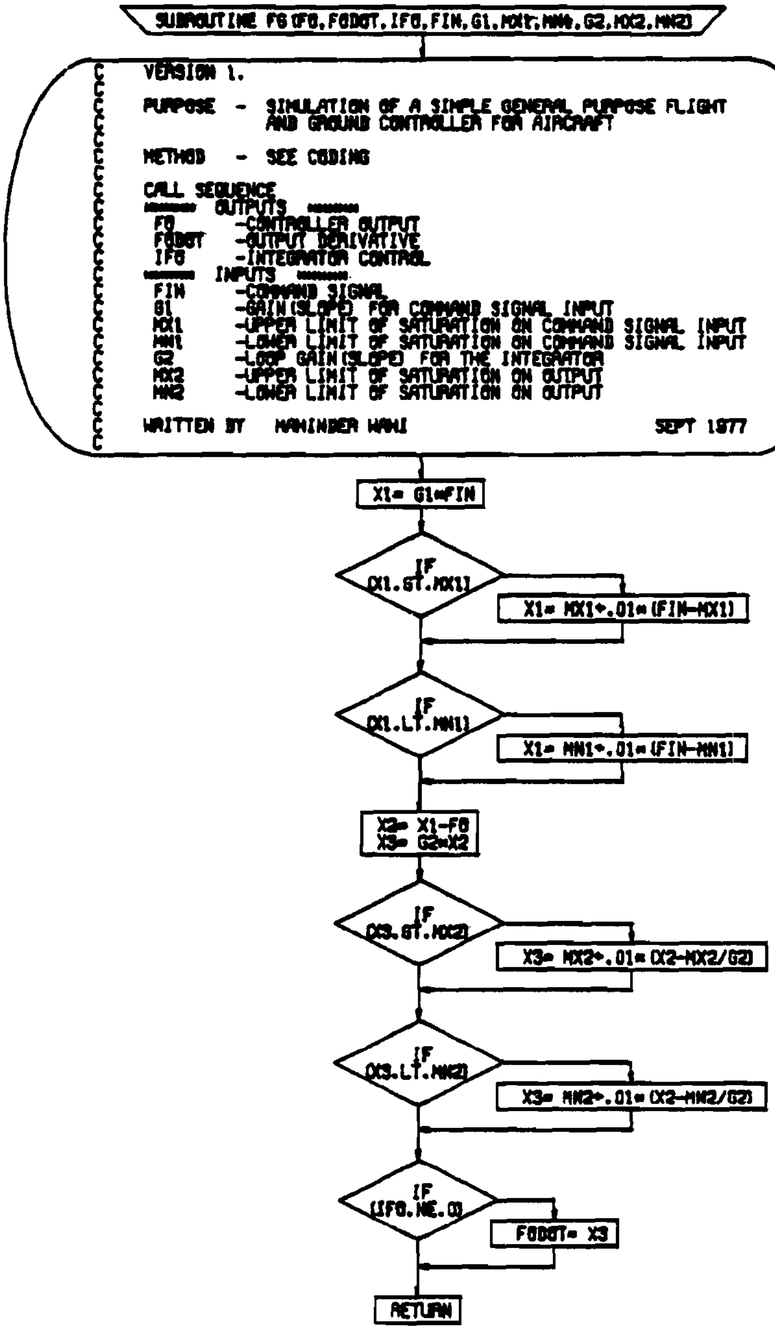


Table 29: FLOWCHART FOR SUBROUTINE FG



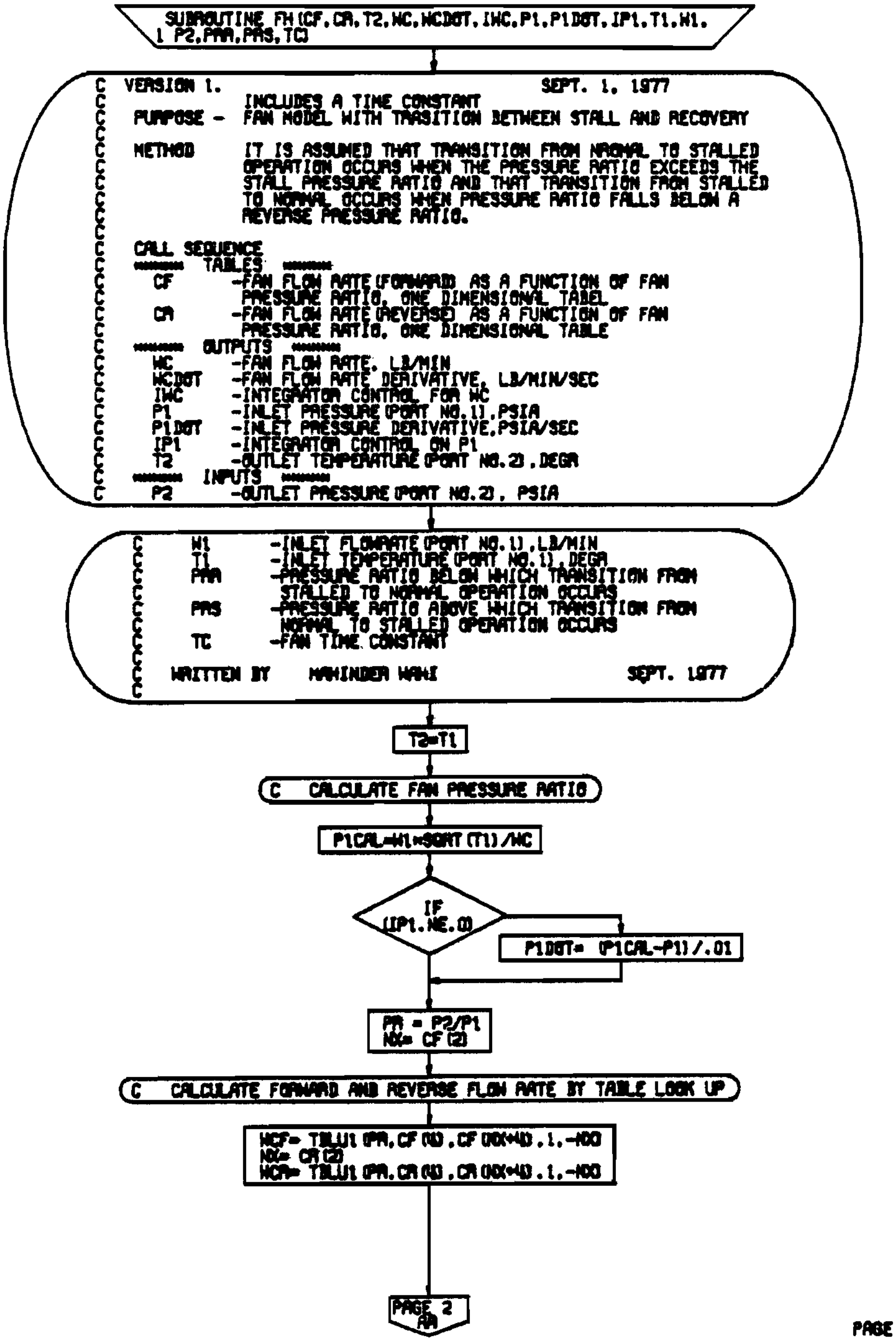
```
SUBROUTINE FG(FG,FGDOT,IFG,FIN,G1,MX1,MN1,G2,MX2,MN2)

C     VERSION 1.
C
C     PURPOSE  -  SIMULATION OF A SIMPLE GENERAL PURPOSE FLIGHT
C                 AND GROUND CONTROLLER FOR AIRCRAFT
C
C     METHOD   -  SEE CODING
C
C     CALL SEQUENCE
C     ------  OUTPUTS  ------
C      FG       -CONTROLLER OUTPUT
C      FGDOT    -OUTPUT DERIVATIVE
C      IFG      -INTEGRATOR CONTROL
C     ------  INPUTS  ------
C      FIN      -COMMAND SIGNAL
C      G1       -GAIN(SLOPE) FOR COMMAND SIGNAL INPUT
C      MX1      -UPPER LIMIT OF SATURATION ON COMMAND SIGNAL INPUT
C      MN1      -LOWER LIMIT OF SATURATION ON COMMAND SIGNAL INPUT
C      G2       -LOOP GAIN(SLOPE) FOR THE INTEGRATOR
C      MX2      -UPPER LIMIT OF SATURATION ON OUTPUT
C      MN2      -LOWER LIMIT OF SATURATION ON OUTPUT
C
C     WRITTEN BY   MAHINDER WAHI                         SEPT 1977
C

X1= G1*FIN
IF (X1.GT.MX1)
X1= MX1+.01*(FIN-MX1)
IF (X1.LT.MN1)
X1= MN1+.01*(FIN-MN1)
X2= X1-FG
X3= G2*X2
IF (X3.GT.MX2)
X3= MX2+.01*(X2-MX2/G2)
IF (X3.LT.MN2)
X3= MN2+.01*(X2-MN2/G2)
IF (IFG.NE.0)
FGDOT= X3
RETURN
```

PAGE 1
FG

Table 30: FLOWCHART FOR SUBROUTINE FH



```
      SUBROUTINE FH(CF,CR,T2,WC,WCDOT,IWC,P1,P1DOT,IP1,T1,W1,
     1 P2,PRR,PRS,TC)

C  VERSION 1.                                   SEPT. 1, 1977
C                 INCLUDES A TIME CONSTANT
C   PURPOSE -     FAN MODEL WITH TRASITION BETWEEN STALL AND RECOVERY
C
C   METHOD        IT IS ASSUMED THAT TRANSITION FROM NRONAL TO STALLED
C                 OPERATION OCCURS WHEN THE PRESSURE RATIO EXCEEDS THE
C                 STALL PRESSURE RATIO AND THAT TRANSITION FROM STALLED
C                 TO NORMAL OCCURS WHEN PRESSURE RATIO FALLS BELOW A
C                 REVERSE PRESSURE RATIO.
C
C   CALL SEQUENCE
C   *******  TABLES  *******
C     CF        -FAN FLOW RATE(FORWARD) AS A FUNCTION OF FAN
C                PRESSURE RATIO, ONE DIMENSIONAL TABEL
C     CR        -FAN FLOW RATE(REVERSE) AS A FUNCTION OF FAN
C                PRESSURE RATIO, ONE DIMENSIONAL TABLE
C   *******  OUTPUTS  *******
C     WC        -FAN FLOW RATE, LB/MIN
C     WCDOT     -FAN FLOW RATE DERIVATIVE, LB/MIN/SEC
C     IWC       -INTEGRATOR CONTROL FOR WC
C     P1        -INLET PRESSURE(PORT NO.1),PSIA
C     P1DOT     -INLET PRESSURE DERIVATIVE,PSIA/SEC
C     IP1       -INTEGRATOR CONTROL ON P1
C     T2        -OUTLET TEMPERATURE(PORT NO.2),DEGR
C   *******  INPUTS  *******
C     P2        -OUTLET PRESSURE(PORT NO.2), PSIA

C       W1        -INLET FLOWRATE(PORT NO.1),LB/MIN
C       T1        -INLET TEMPERATURE(PORT NO.1),DEGR
C       PRR       -PRESSURE RATIO BELOW WHICH TRANSITION FROM
C                  STALLED TO NORMAL OPERATION OCCURS
C       PRS       -PRESSURE RATIO ABOVE WHICH TRANSITION FROM
C                  NORMAL TO STALLED OPERATION OCCURS
C       TC        -FAN TIME CONSTANT
C
C    WRITTEN BY    MAHINDER WAHI                        SEPT. 1977
C

T2=T1

C   CALCULATE FAN PRESSURE RATIO

P1CAL=W1*SQRT(T1)/WC

IF
(IP1.NE.0)

P1DOT= (P1CAL-P1)/.01

PR = P2/P1
NX= CF(2)

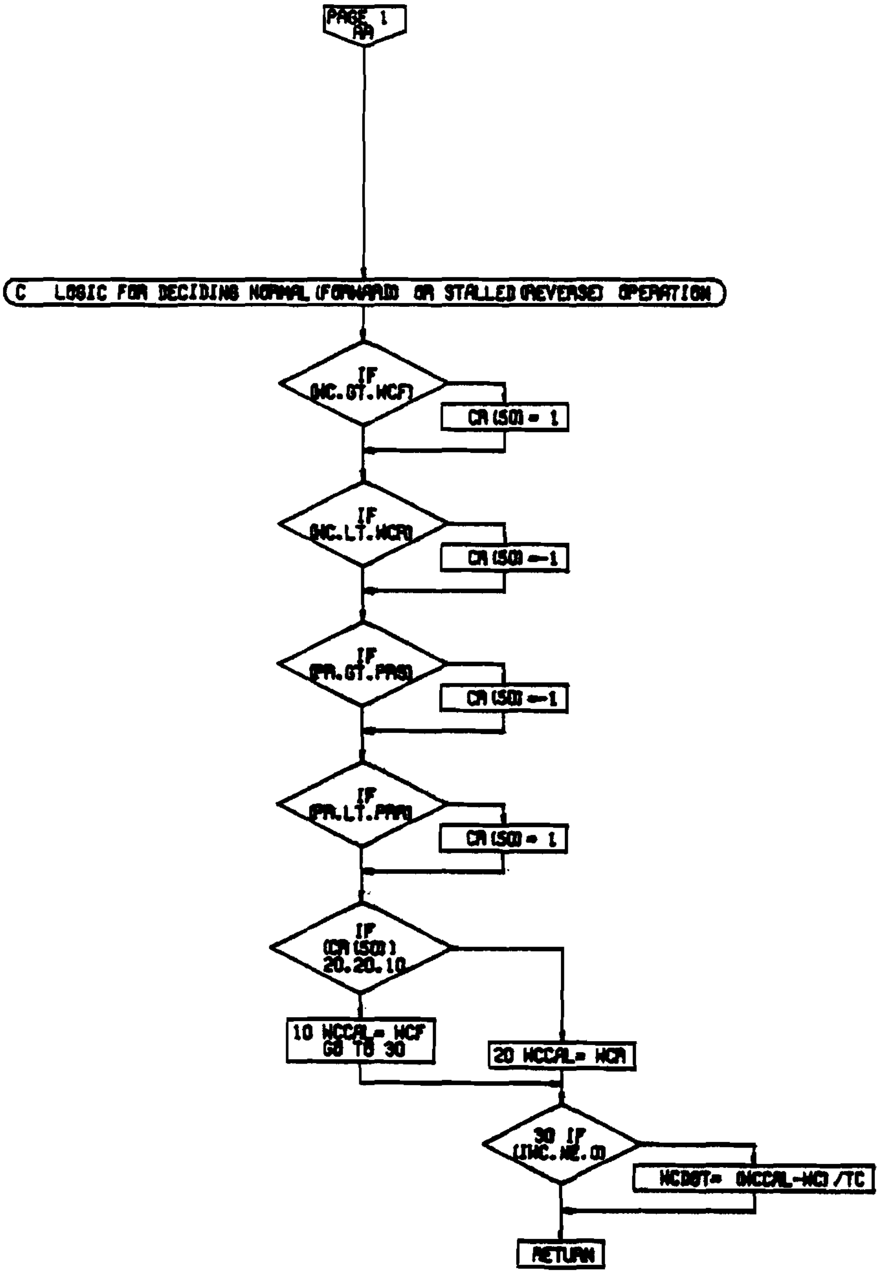
C   CALCULATE FORWARD AND REVERSE FLOW RATE BY TABLE LOOK UP

WCF= TBLU1(PR,CF(4),CF(NX+4),1,-NX)
NX= CR(2)
WCR= TBLU1(PR,CR(4),CR(NX+4),1,-NX)

PAGE 2
 AA
```

PAGE 1
FH

Table 30: FLOWCHART FOR SUBROUTINE FH (CONCLUDED)



PAGE 2
FH

Table 31: FLOWCHART FOR SUBROUTINE FL

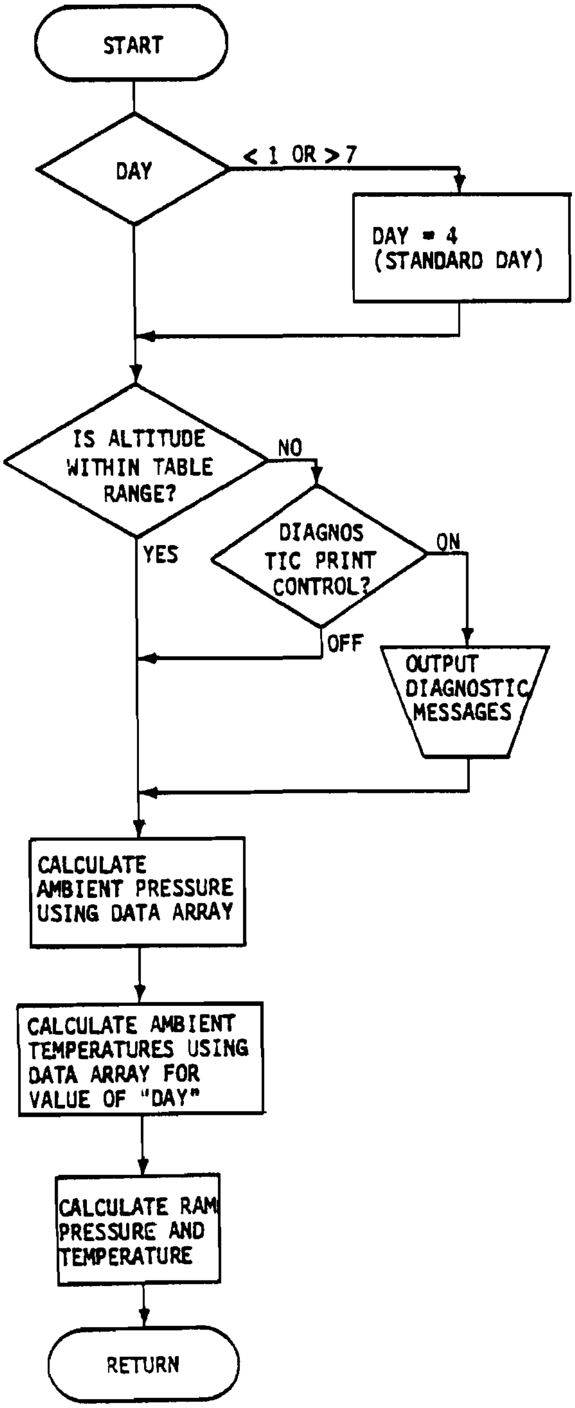


Table 32: FLOWCHART FOR SUBROUTINE FLOW

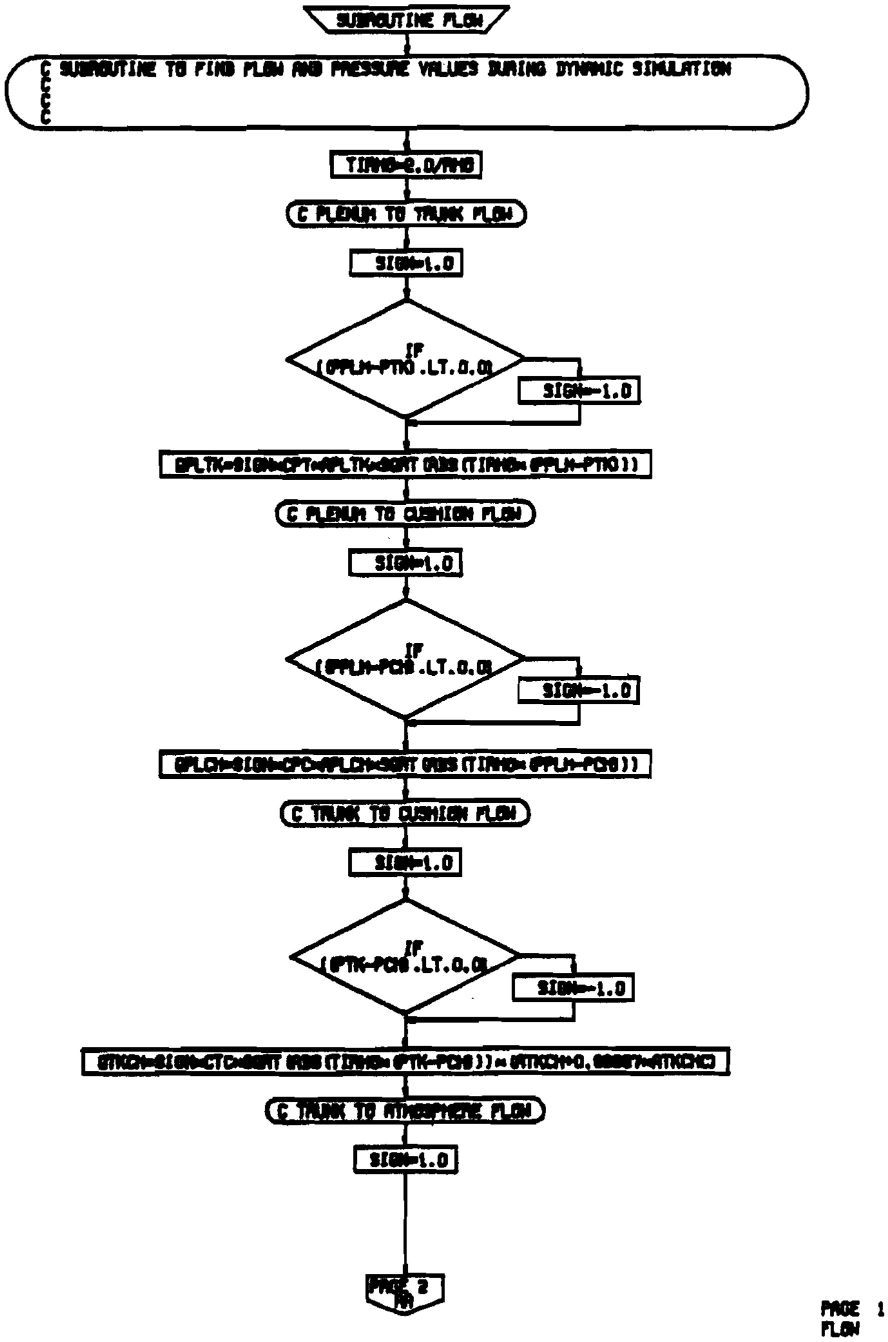


Table 32: FLOWCHART FOR SUBROUTINE FLOW (CONTINUED)

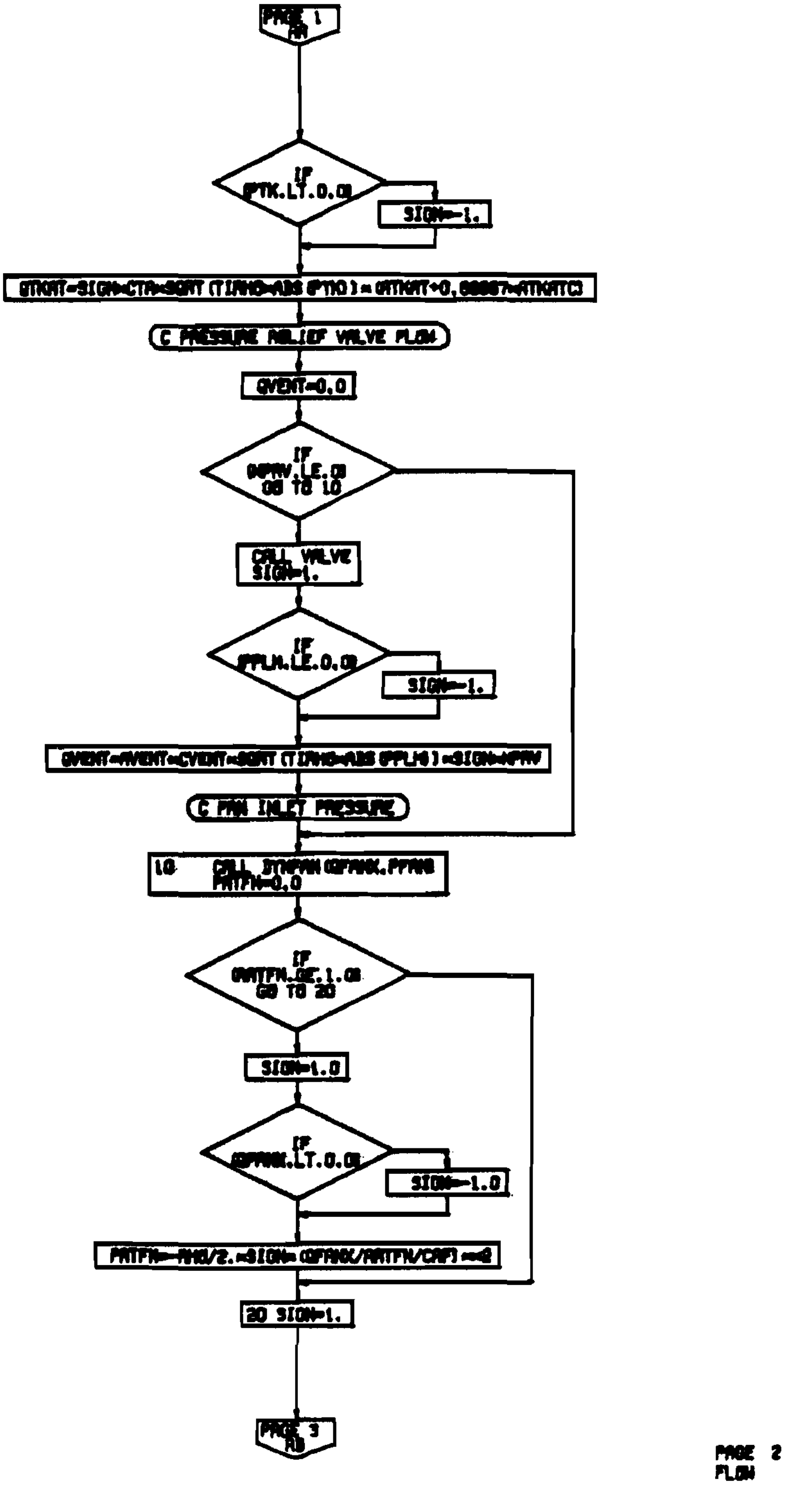


Table 32: FLOWCHART FOR SUBROUTINE FLOW (CONCLUDED)

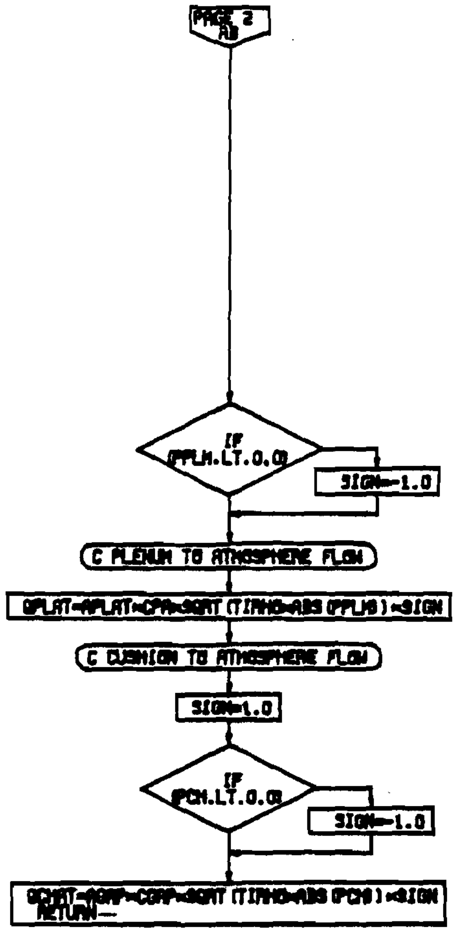


Table 33: FLOWCHART FOR SUBROUTINE FM

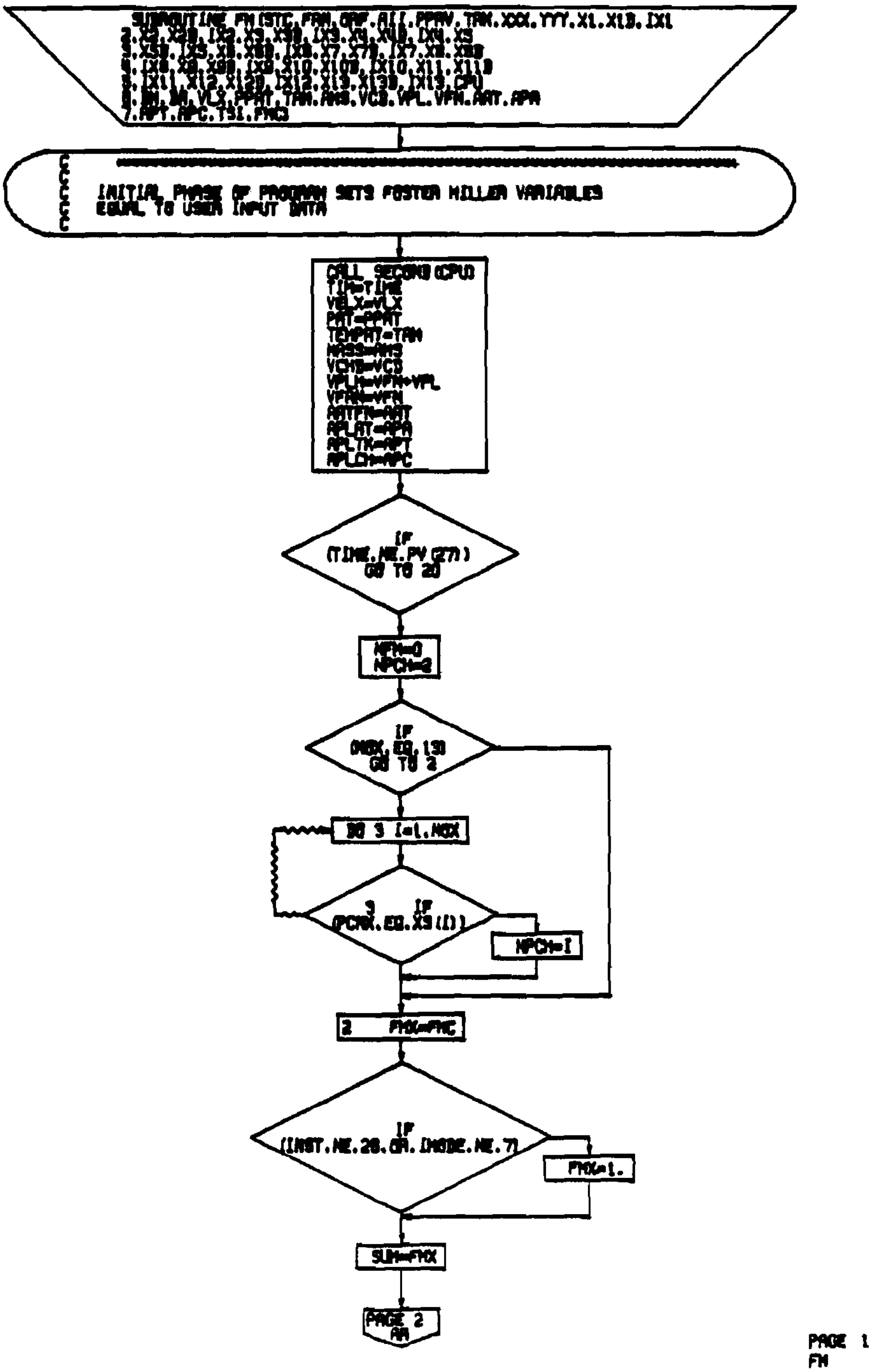


Table 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)

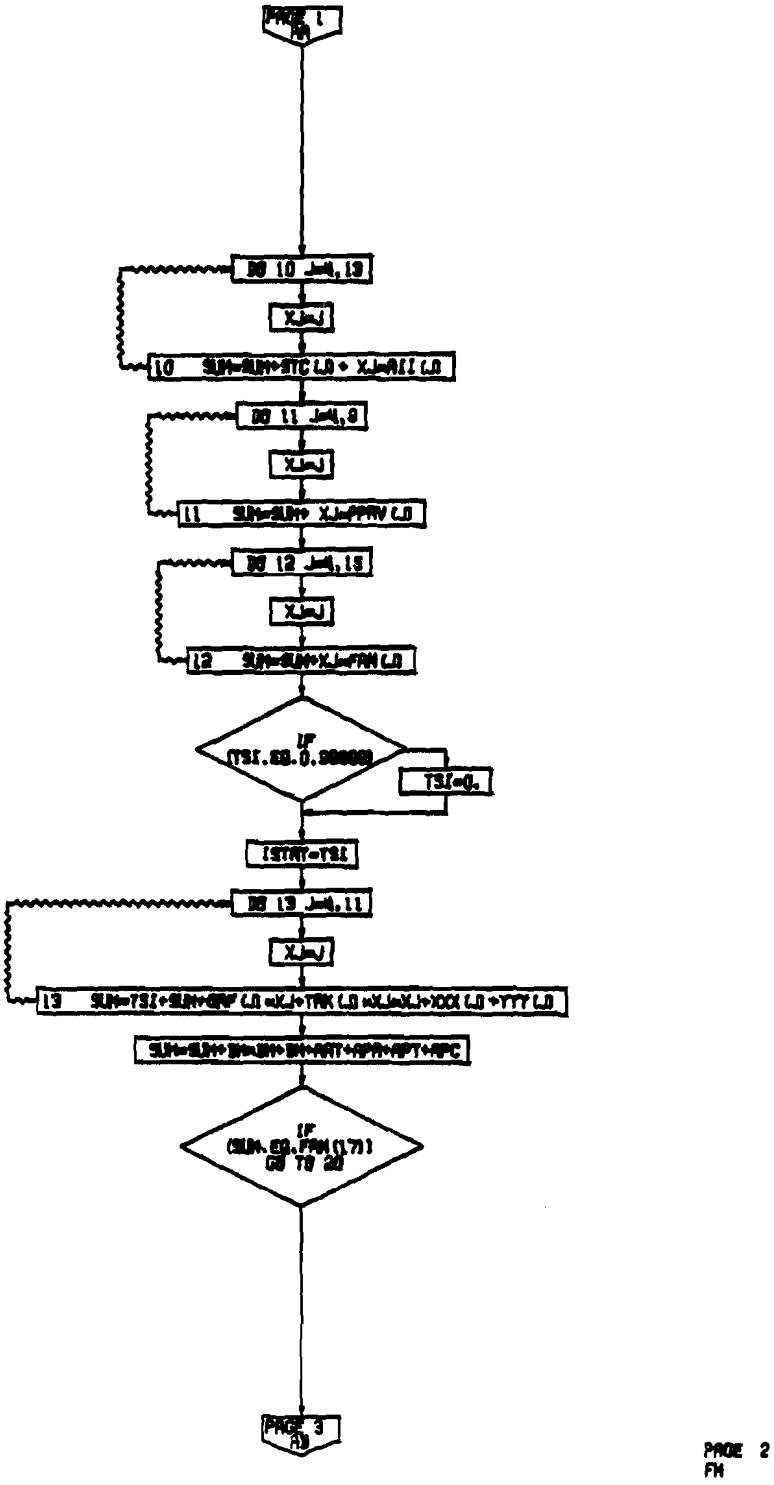


Table 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)

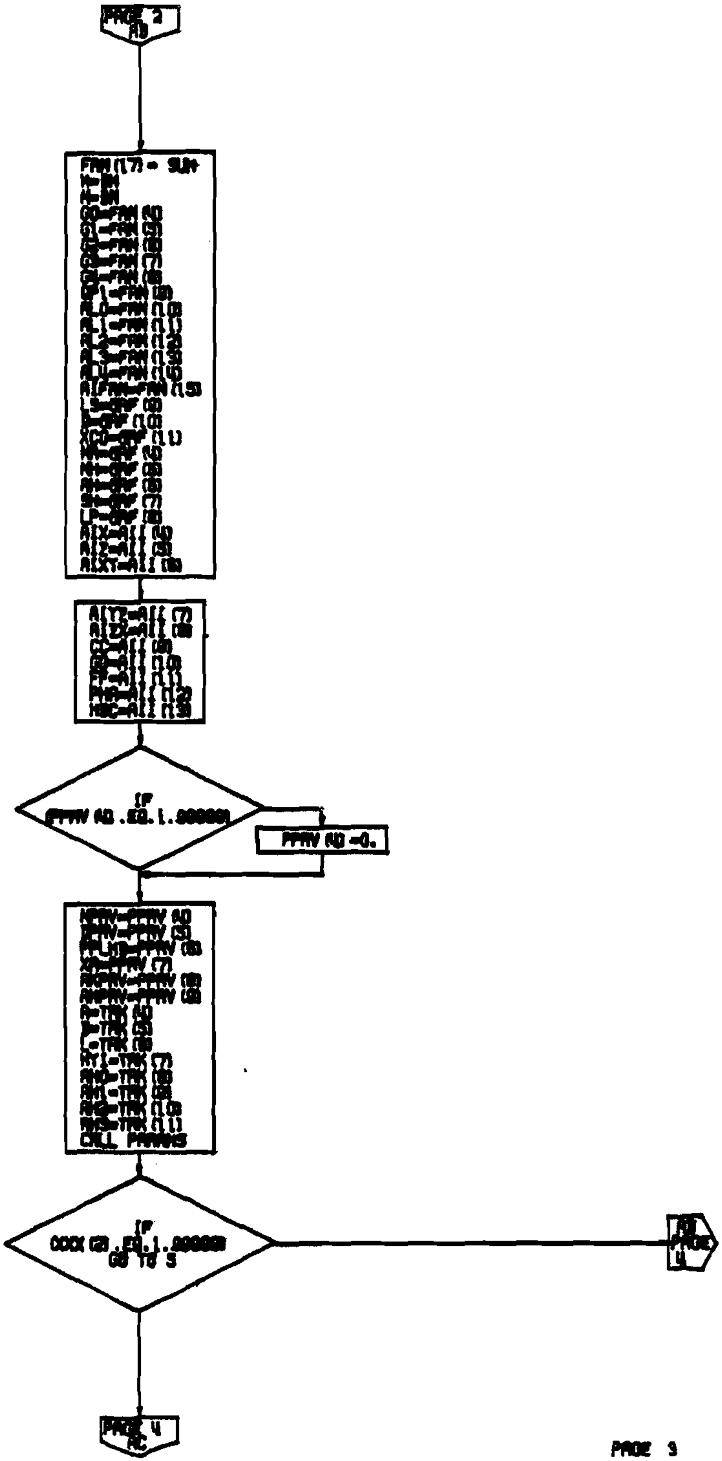


Table 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)

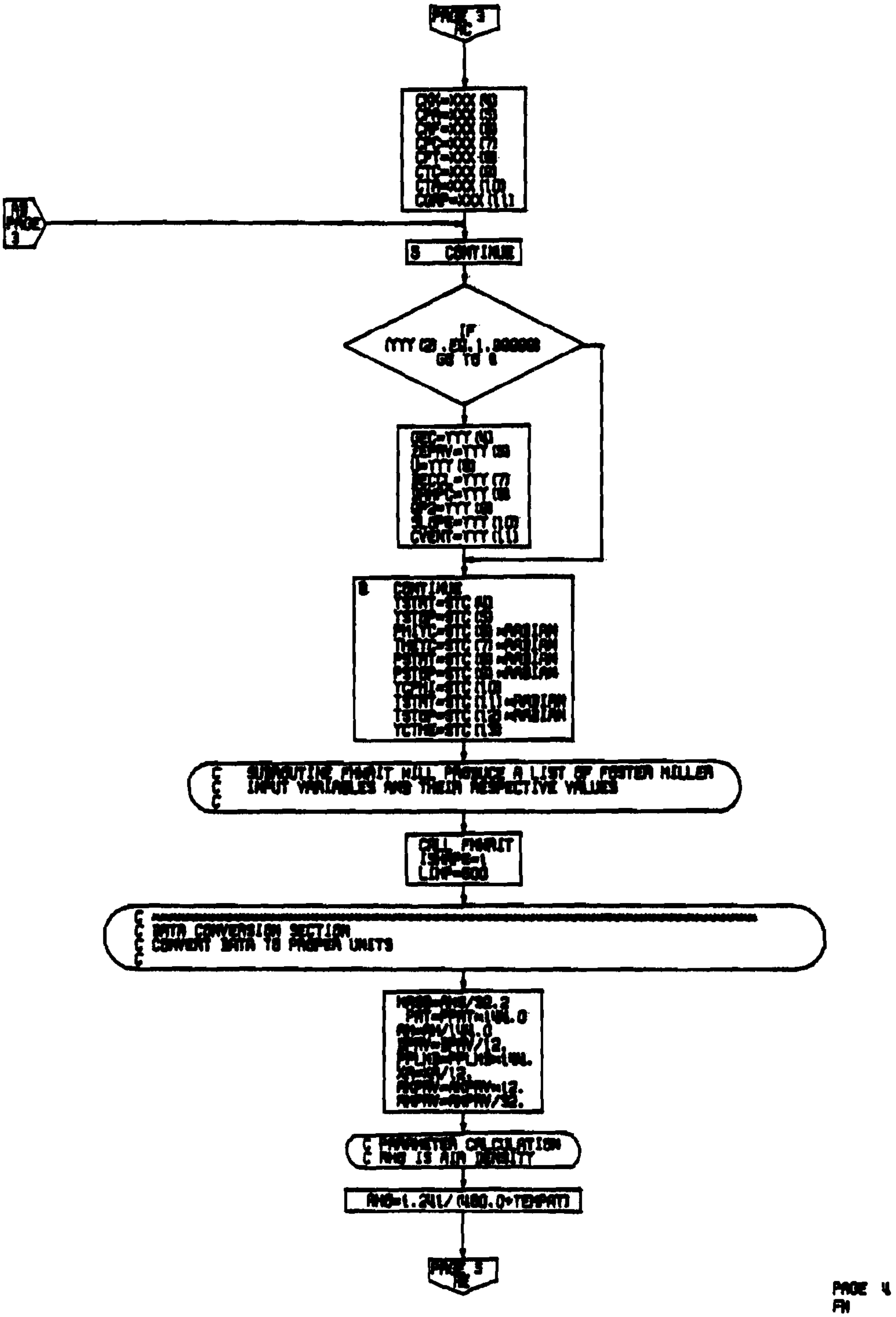


Table 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)

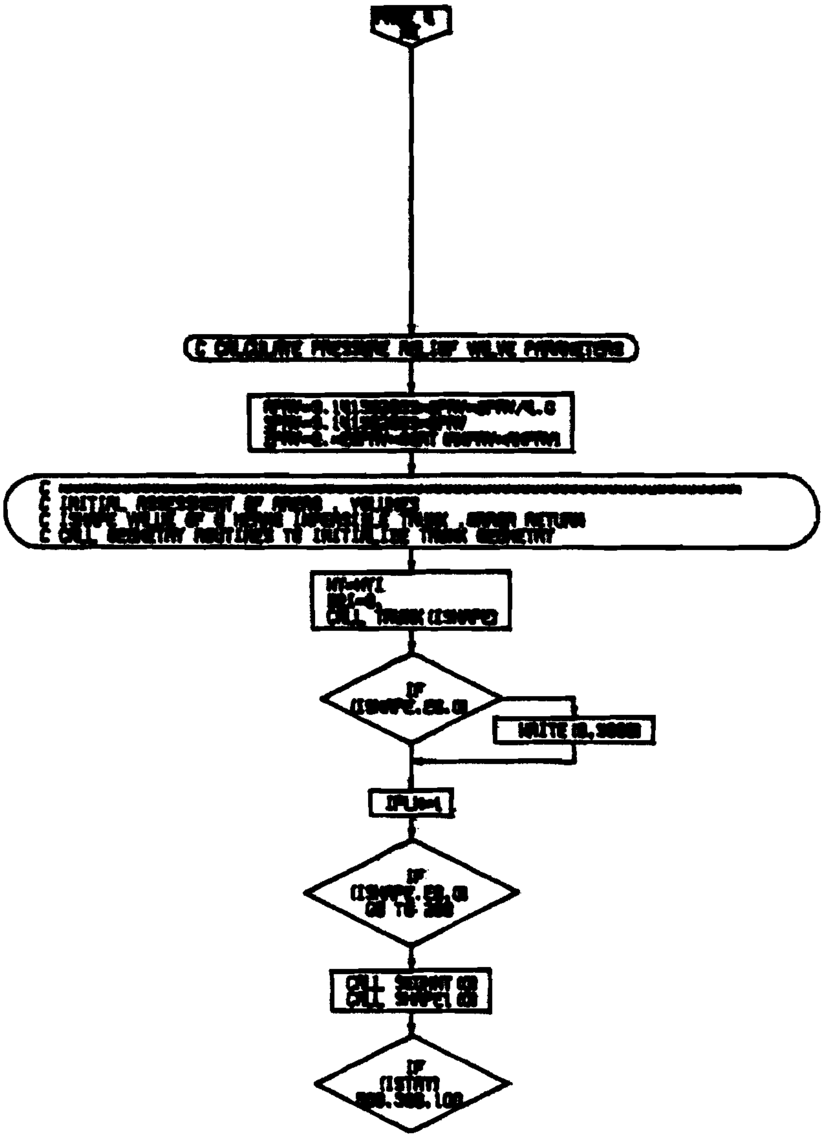


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Table 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)

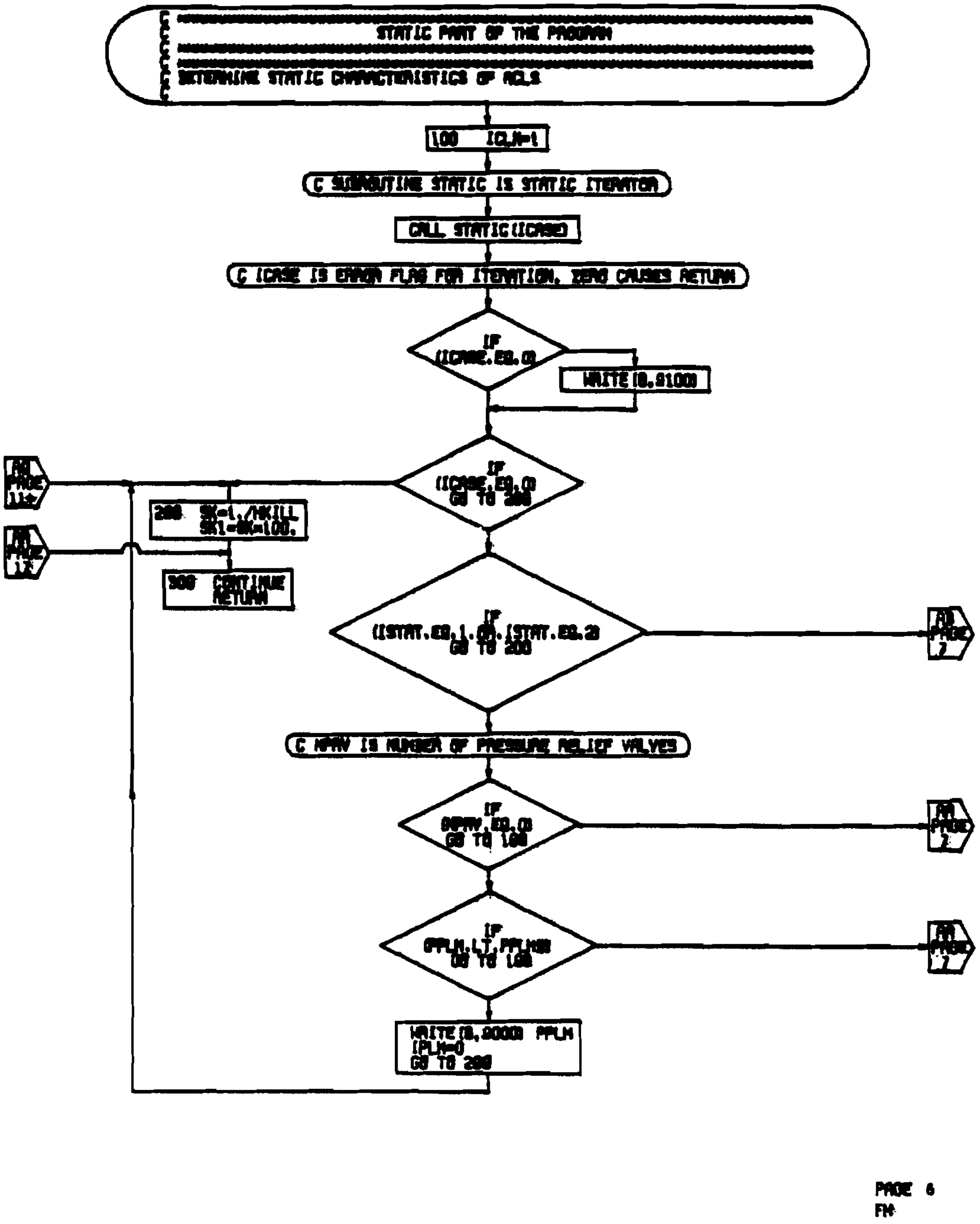


Table 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)

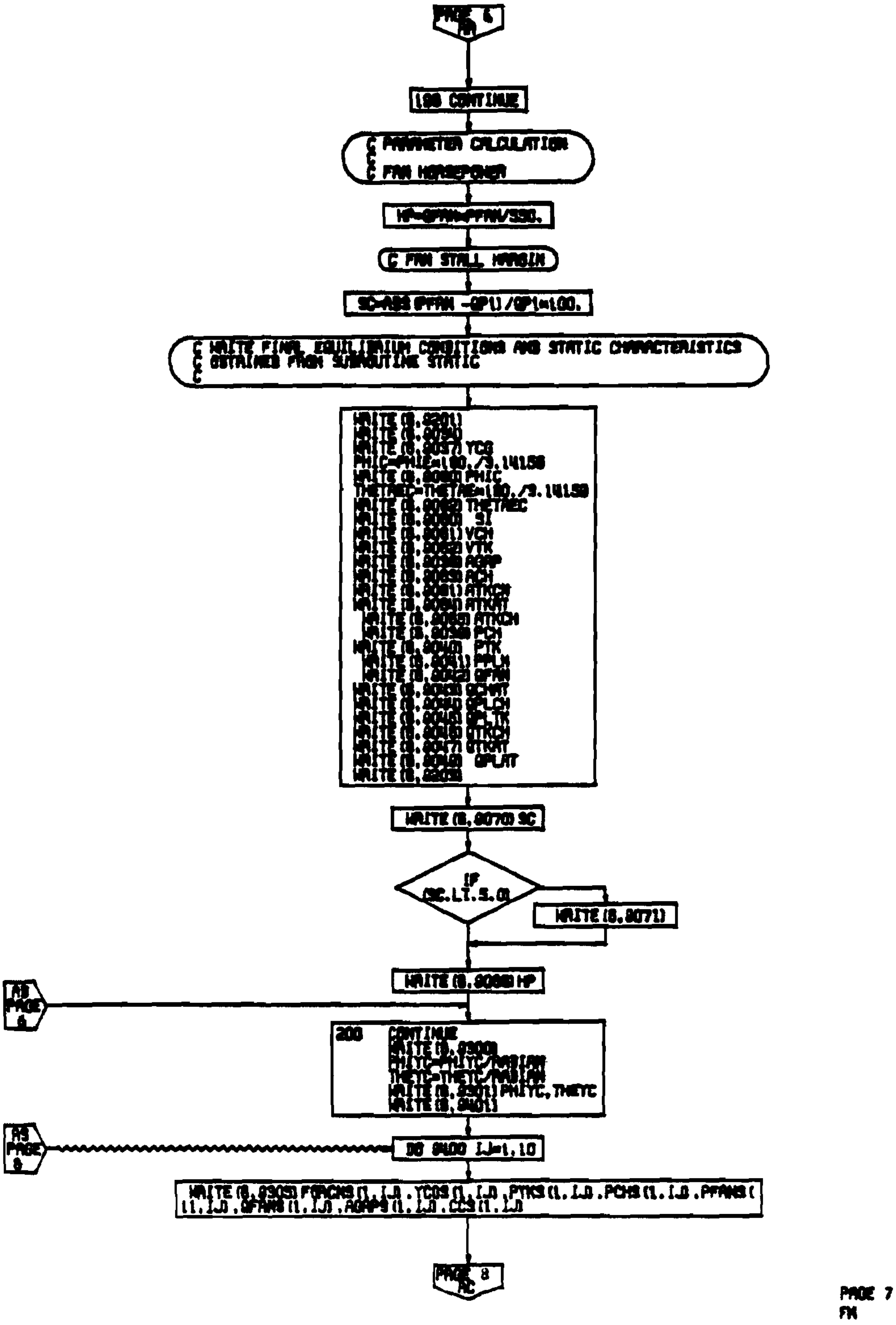


Table 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)

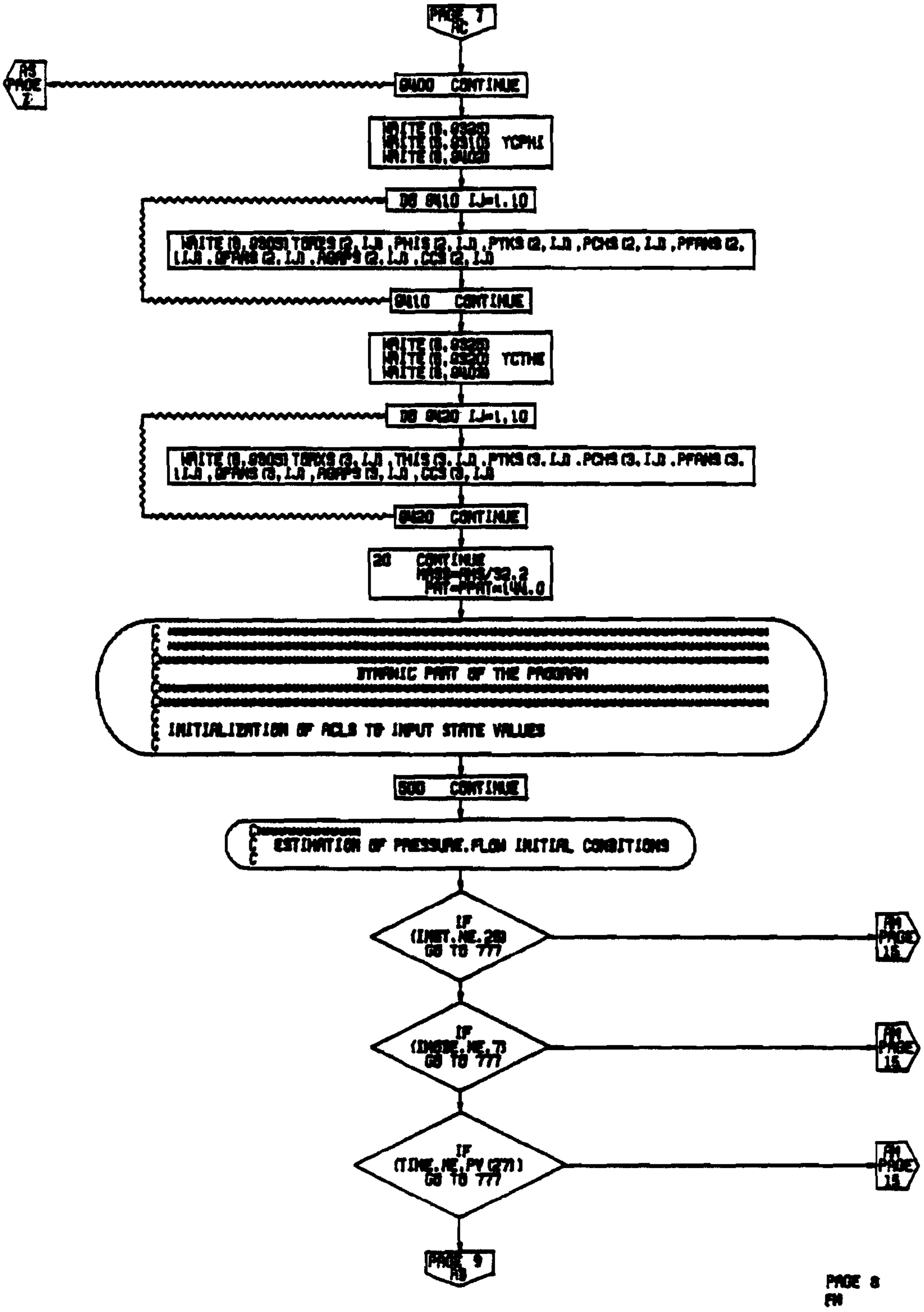


Table 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)

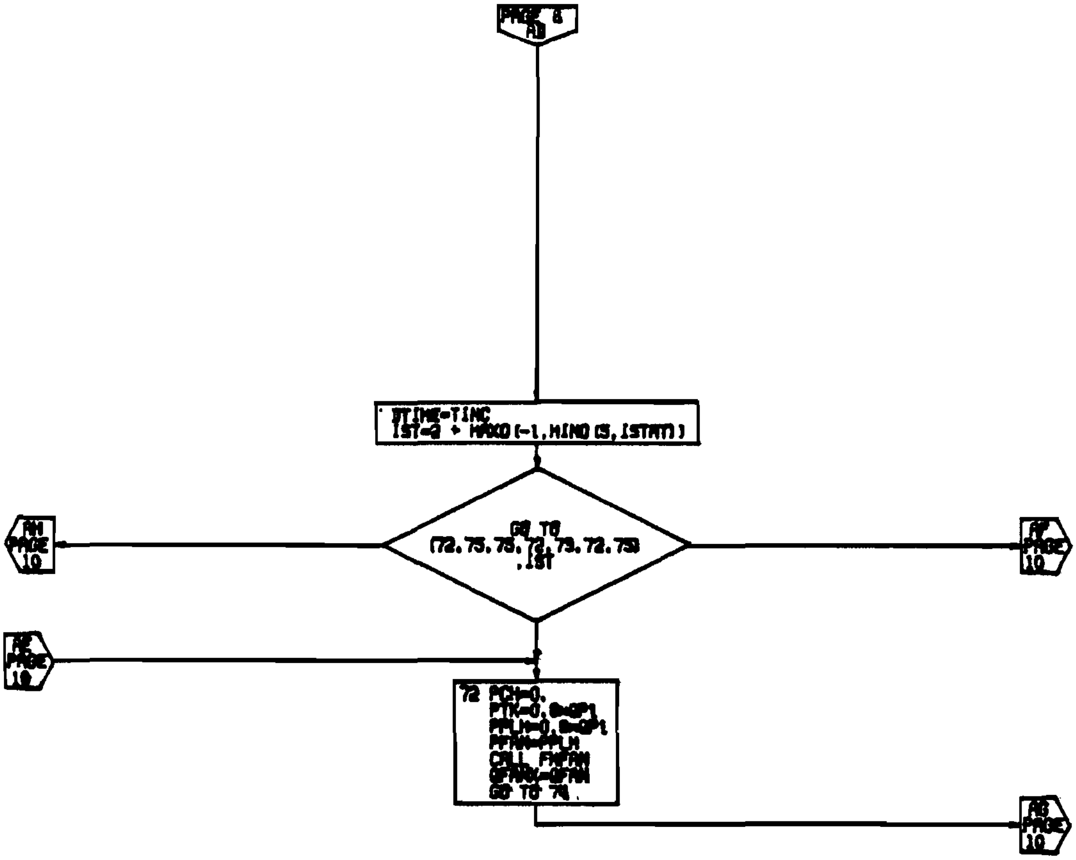


Table 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)

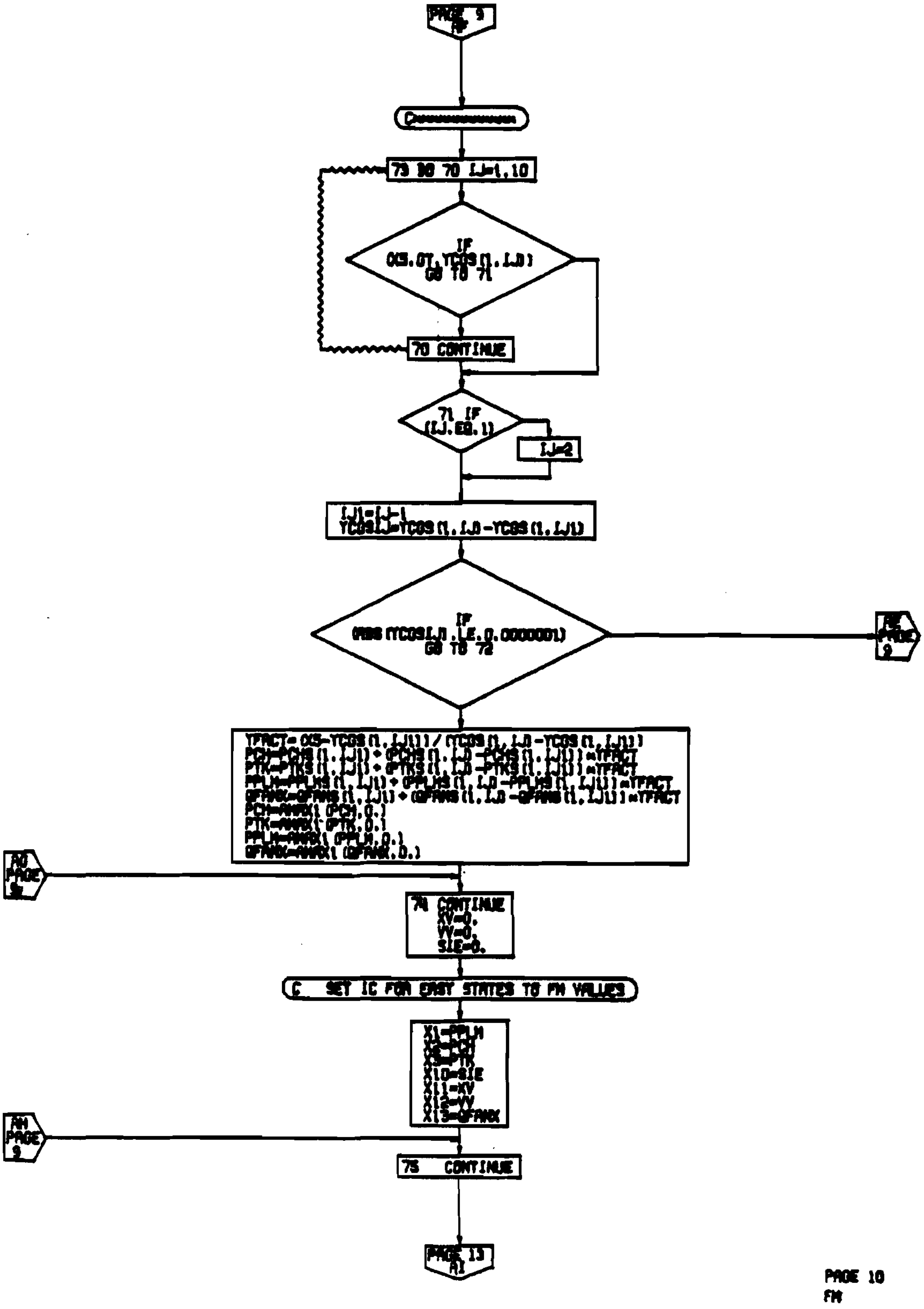


Table 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)

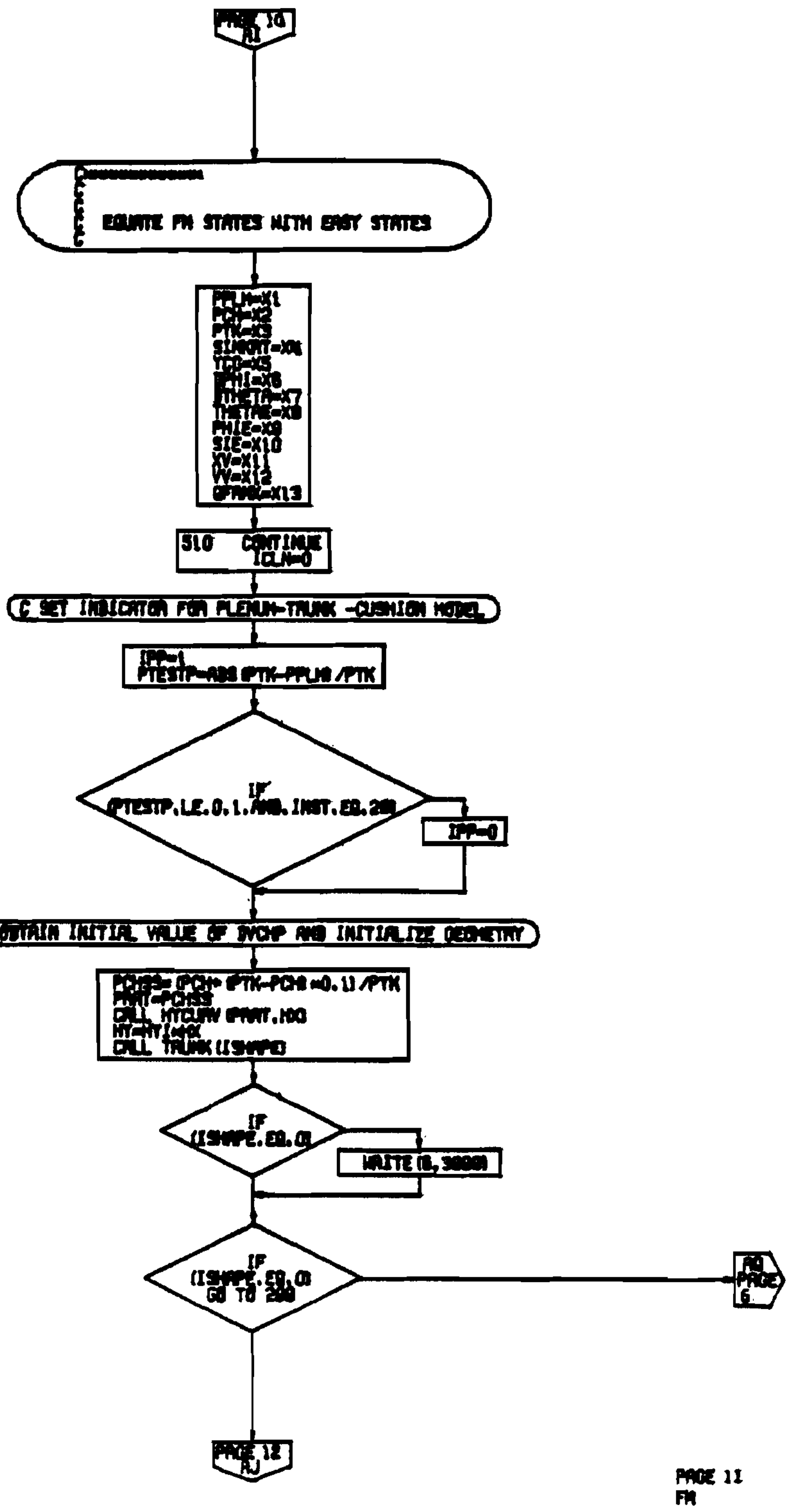
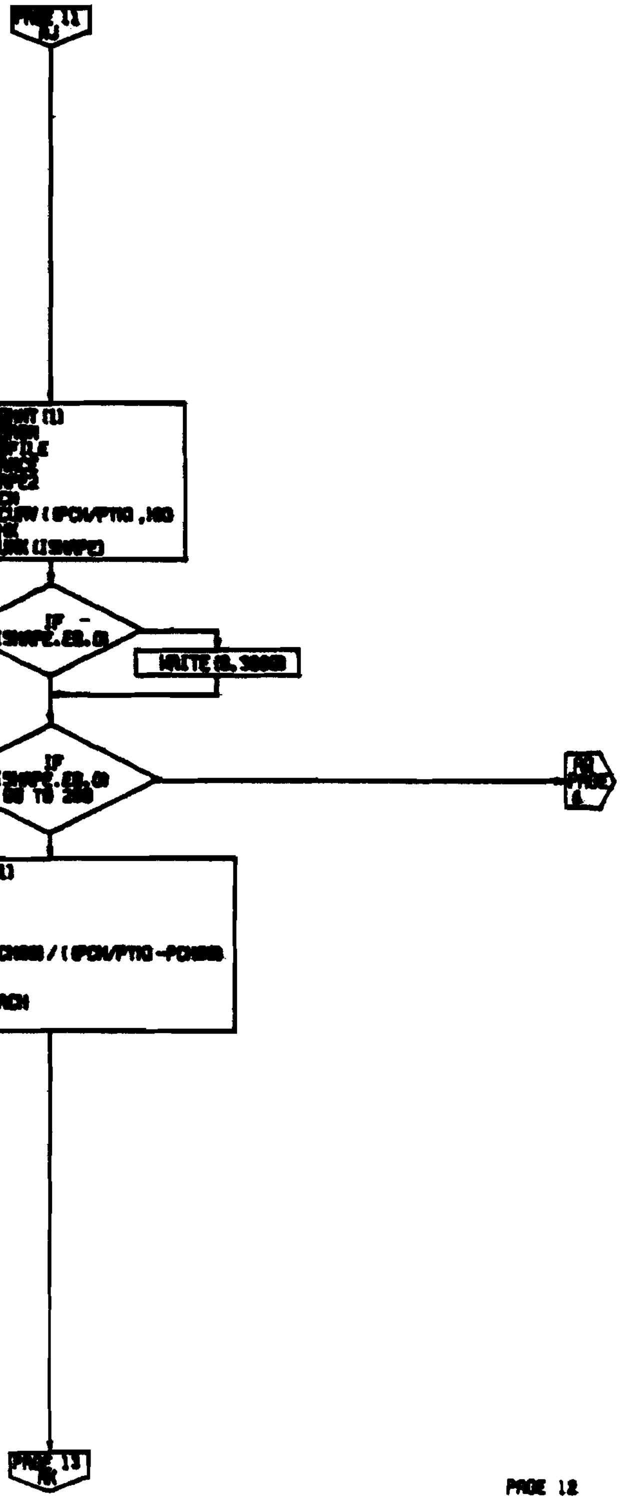


Table 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)



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Tabel 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)

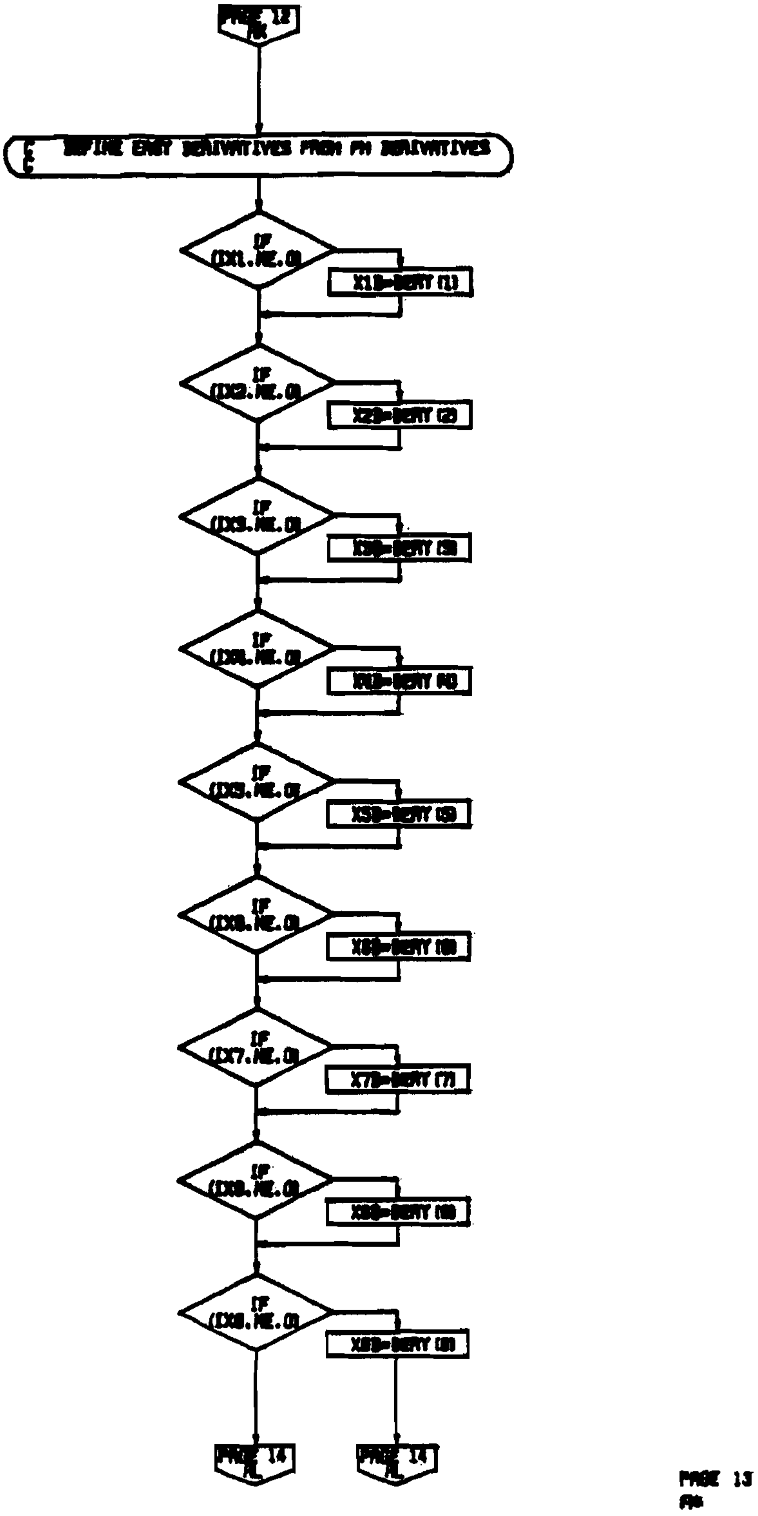


Table 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)

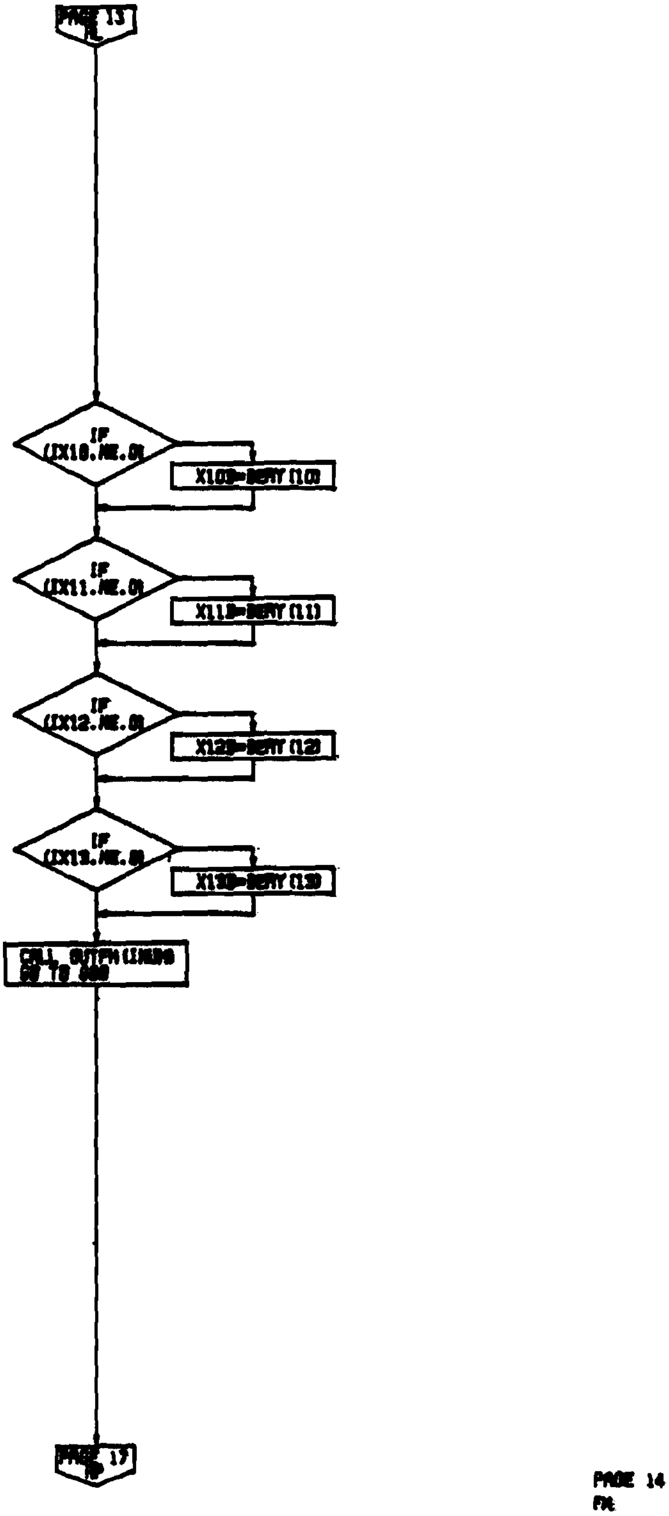
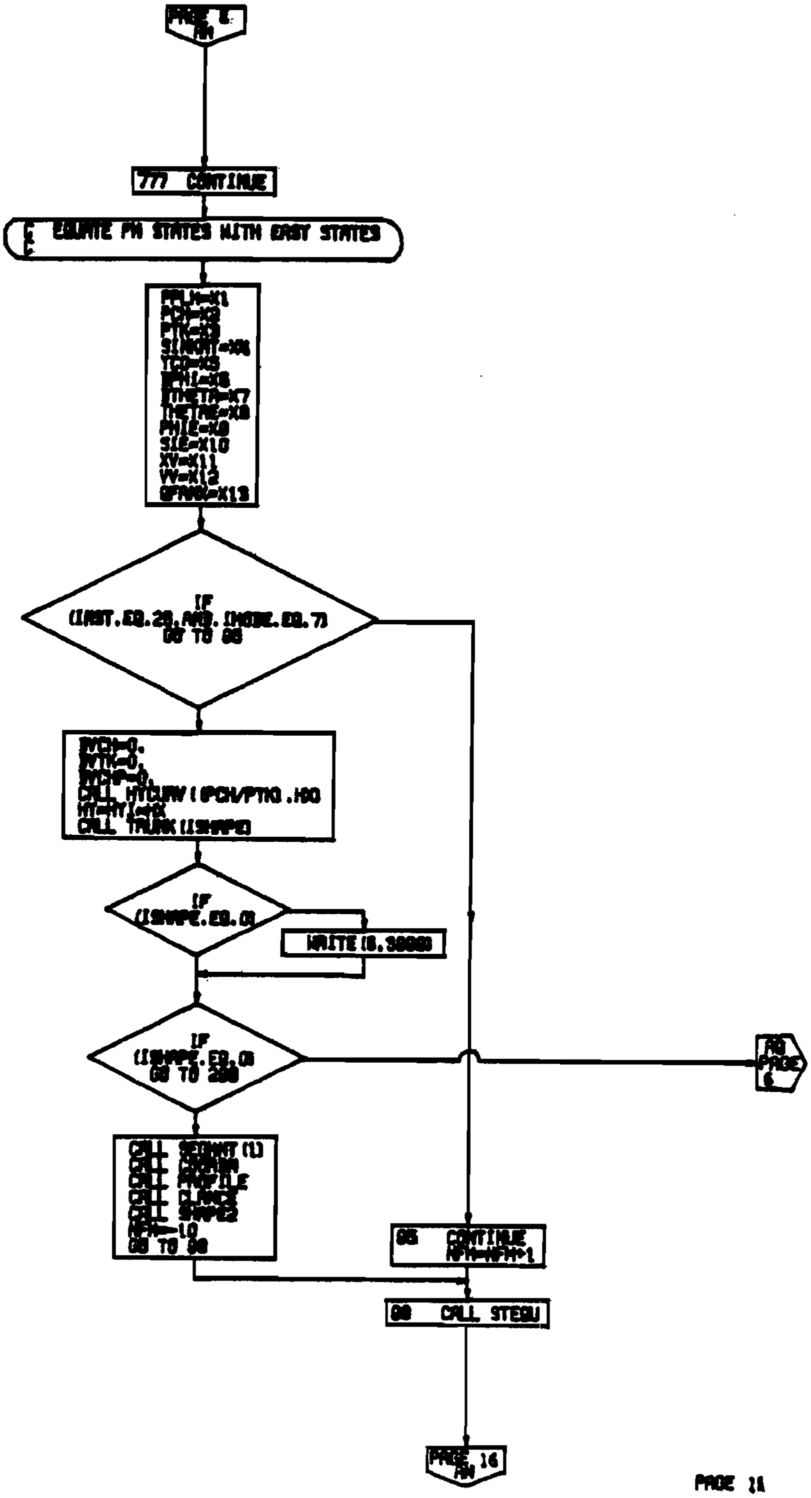


Table 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)



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FM

Table 33: FLOWCHART FOR SUBROUTINE FM (CONTINUED)

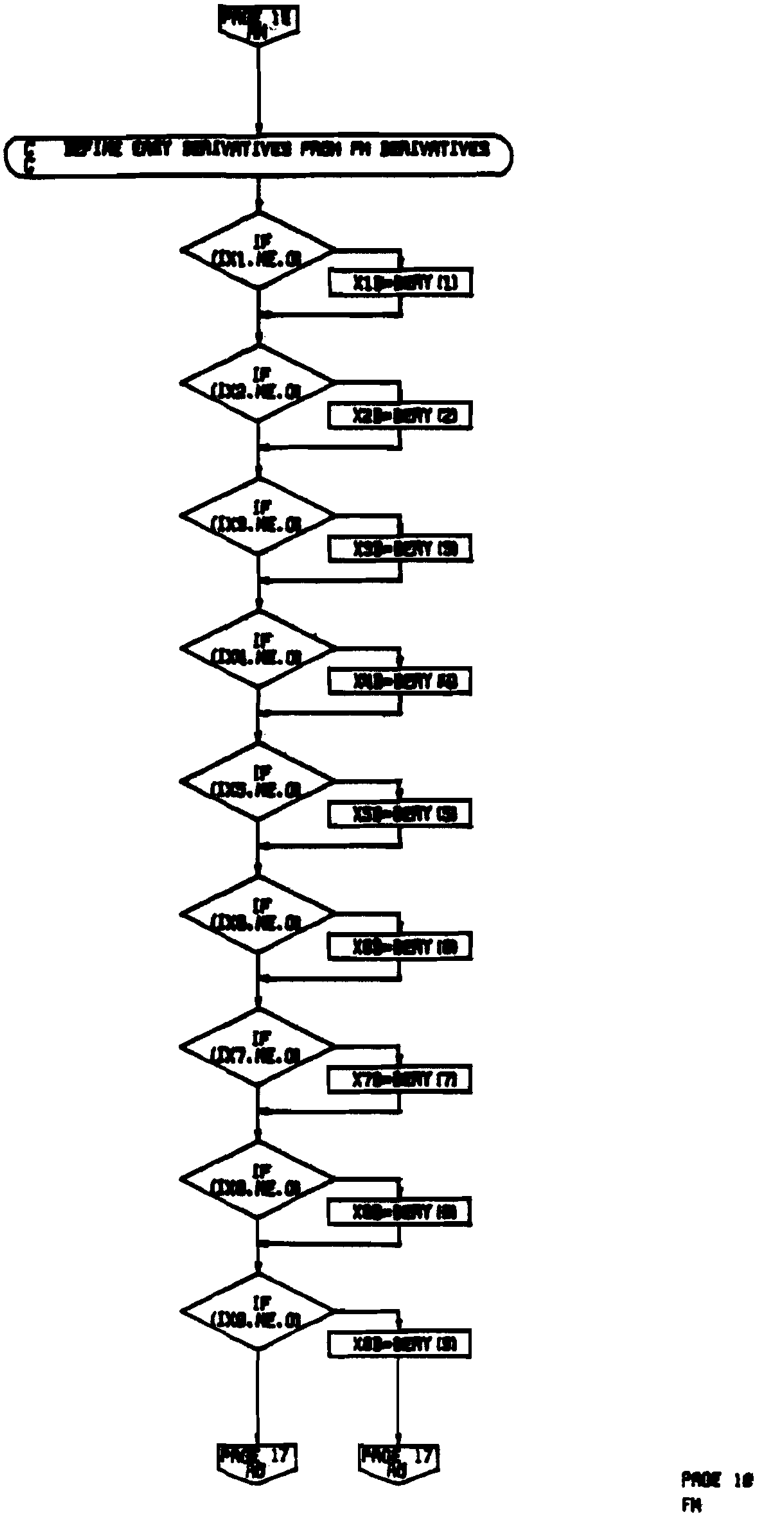

Table 33: FLOWCHART FOR SUBROUTINE FM (CONCLUDED)

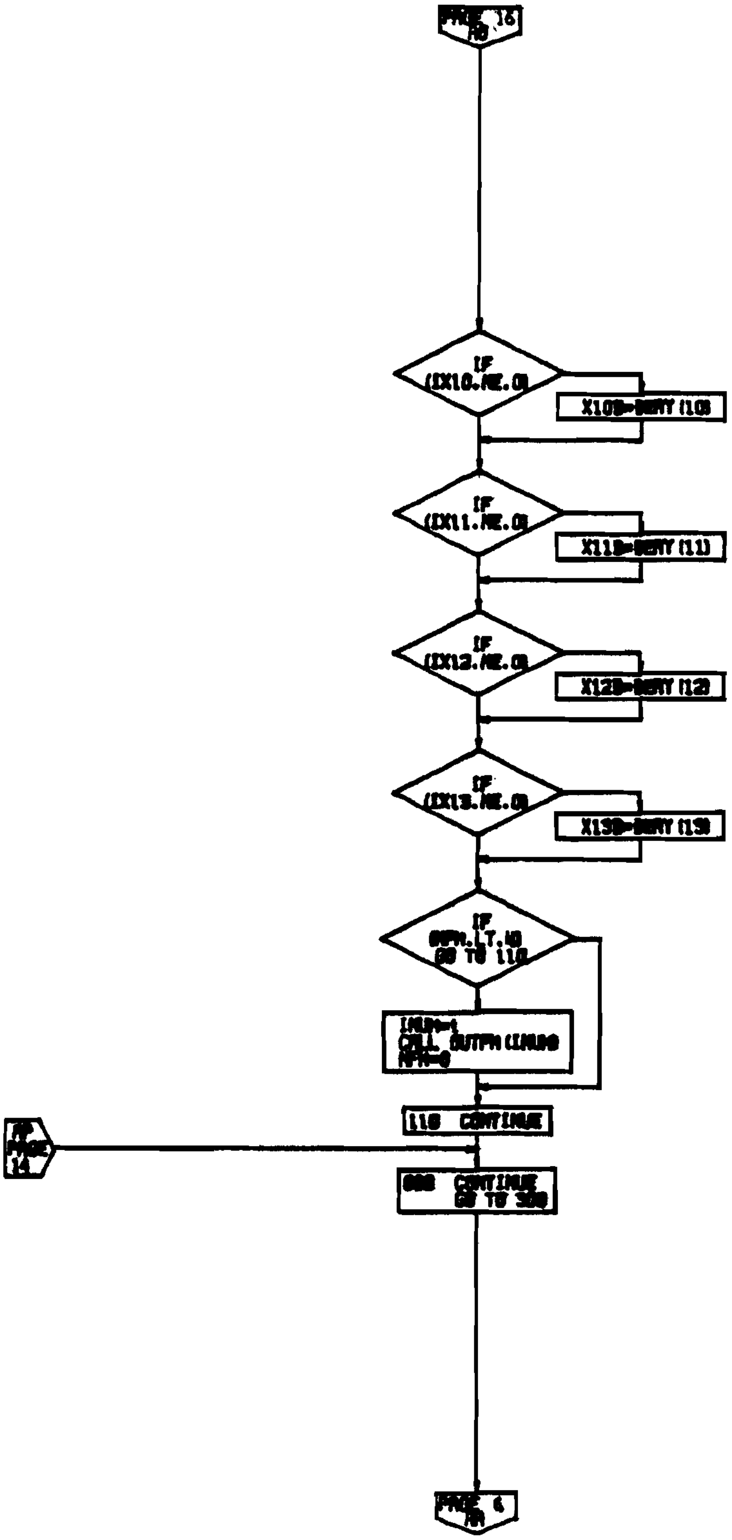

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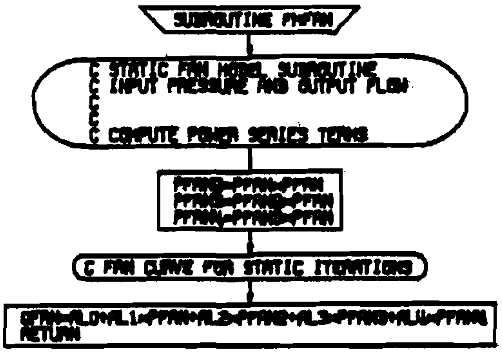
Table 34: FLOWCHART FOR SUBROUTINE FMFAN



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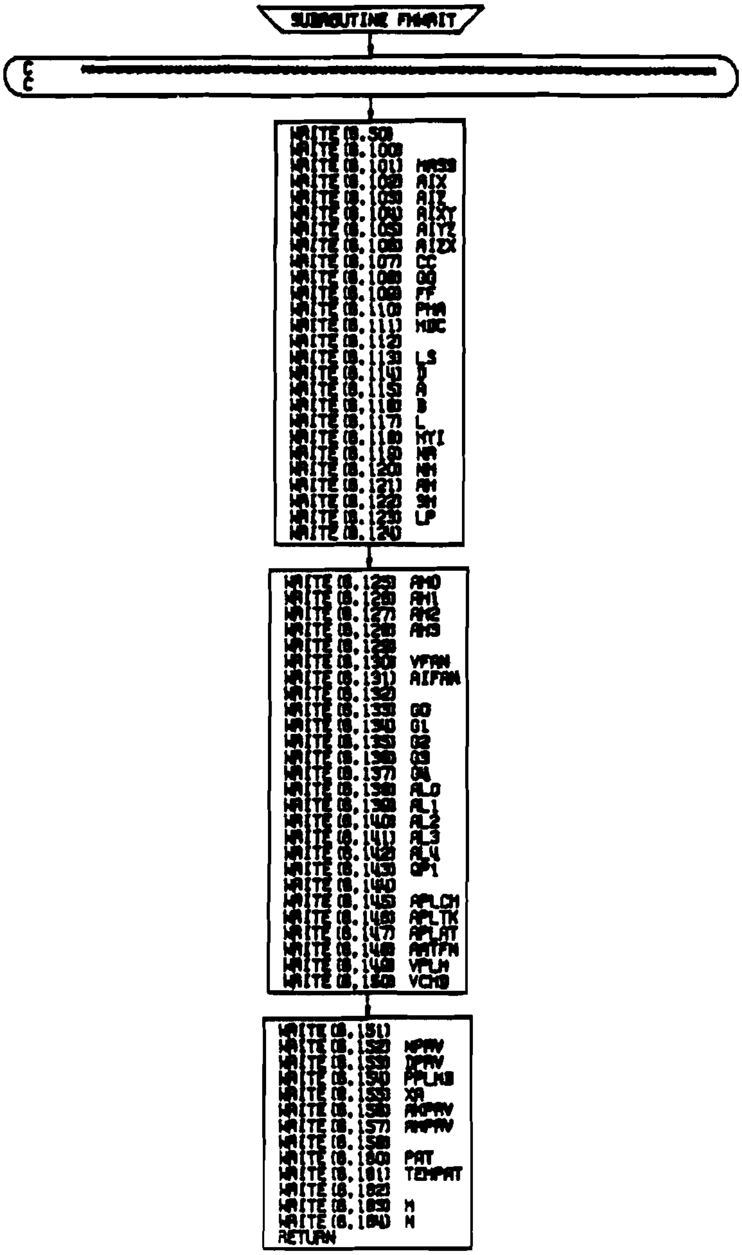
FMFAN

Table 35: FLOWCHART FOR SUBROUTINE FMWRIT



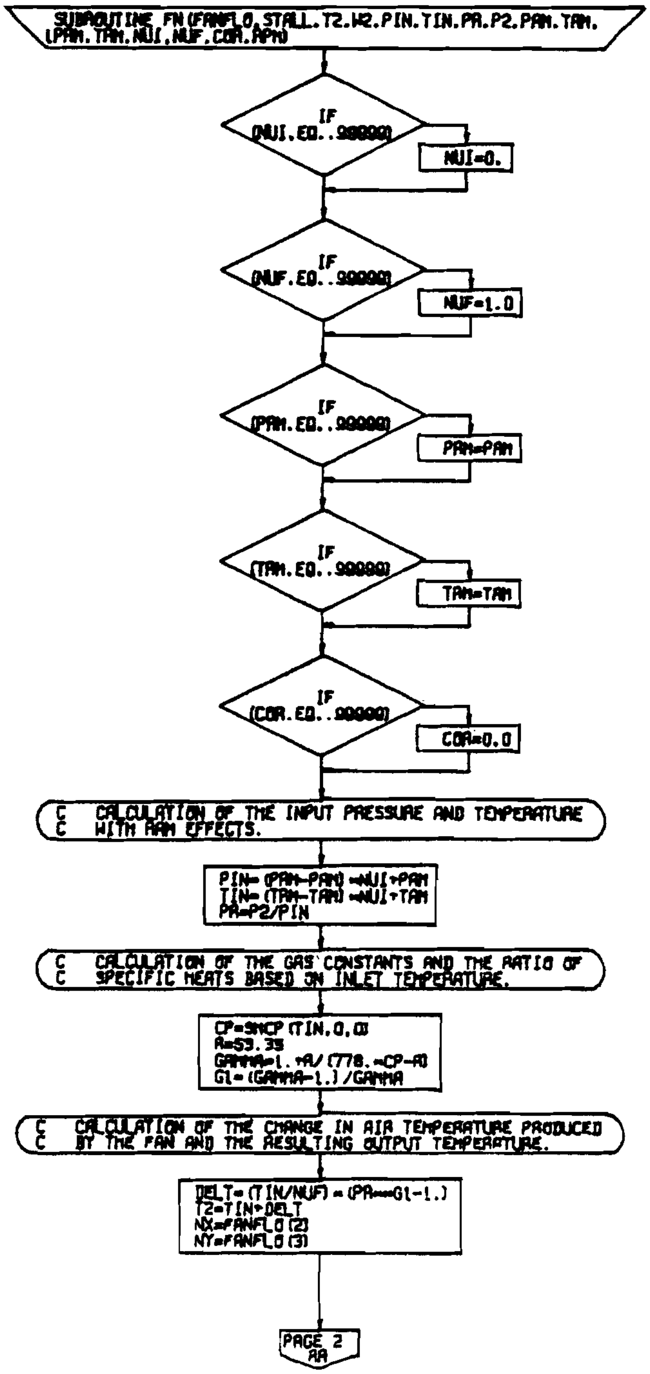
```
SUBROUTINE FMWRIT
C
C  ----------------------------------------------------------------
WRITE (6,50)
WRITE (6,100)
WRITE (6,101) MASS
WRITE (6,102) AIX
WRITE (6,103) AIZ
WRITE (6,104) AIXY
WRITE (6,105) AIYZ
WRITE (6,106) AIZX
WRITE (6,107) CC
WRITE (6,108) GG
WRITE (6,109) FF
WRITE (6,110) PHA
WRITE (6,111) MBC
WRITE (6,112)
WRITE (6,113) LS
WRITE (6,114) D
WRITE (6,115) A
WRITE (6,116) B
WRITE (6,117) L
WRITE (6,118) MTI
WRITE (6,119) NR
WRITE (6,120) NM
WRITE (6,121) AM
WRITE (6,122) SM
WRITE (6,123) LP
WRITE (6,124)

WRITE (6,125) AM0
WRITE (6,126) AM1
WRITE (6,127) AM2
WRITE (6,128) AM3
WRITE (6,129)
WRITE (6,130) VFAN
WRITE (6,131) AIFAN
WRITE (6,132)
WRITE (6,133) G0
WRITE (6,134) G1
WRITE (6,135) G2
WRITE (6,136) G3
WRITE (6,137) G4
WRITE (6,138) AL0
WRITE (6,139) AL1
WRITE (6,140) AL2
WRITE (6,141) AL3
WRITE (6,142) AL4
WRITE (6,143) QP1
WRITE (6,144)
WRITE (6,145) APLCH
WRITE (6,146) APLTK
WRITE (6,147) APLAT
WRITE (6,148) AATFN
WRITE (6,149) VPLM
WRITE (6,150) VCHG

WRITE (6,151)
WRITE (6,152) NPAV
WRITE (6,153) DPAV
WRITE (6,154) PPLKG
WRITE (6,155) XA
WRITE (6,156) AKPAV
WRITE (6,157) ANPAV
WRITE (6,158)
WRITE (6,160) PAT
WRITE (6,161) TEMPAT
WRITE (6,162)
WRITE (6,163) M
WRITE (6,164) N
RETURN
```

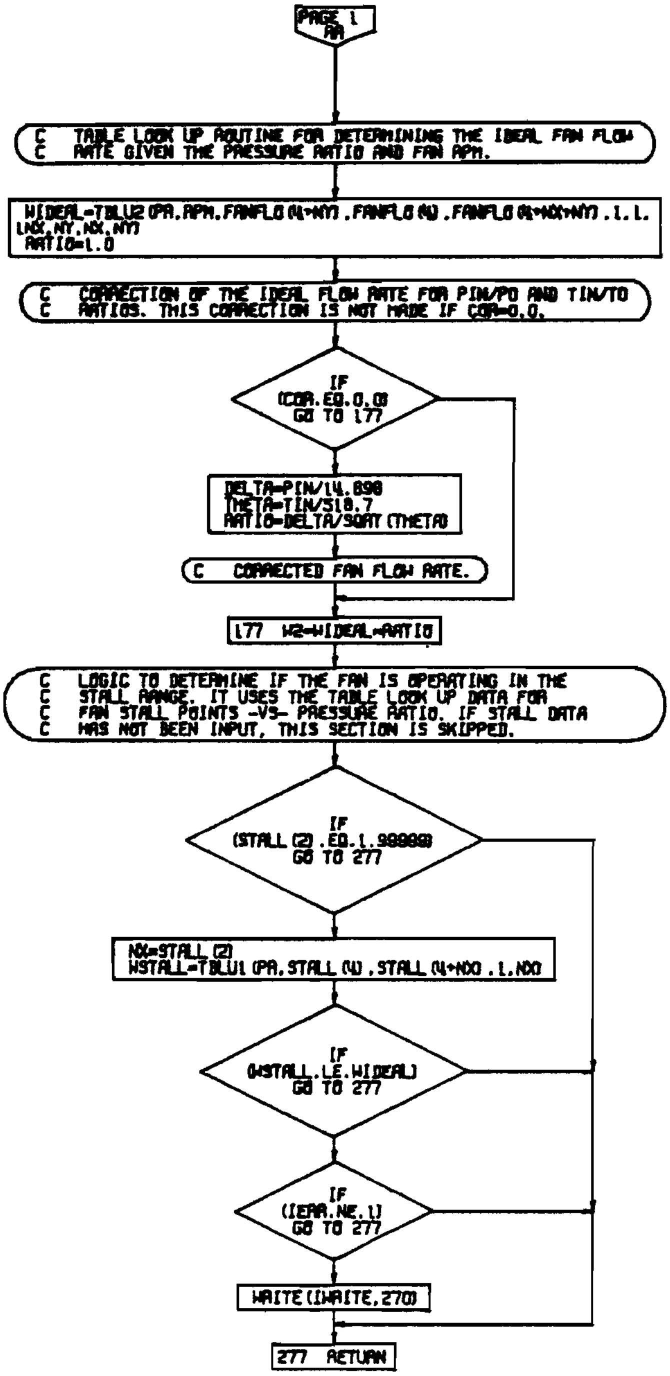
PAGE 1
FMWRIT

Table 36: FLOWCHART FOR SUBROUTINE FN



PAGE
FN

Table 36: FLOWCHART FOR SUBROUTINE FN (CONCLUDED)



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FN

Table 37: FLOWCHART FOR SUBROUTINE FNFLOW

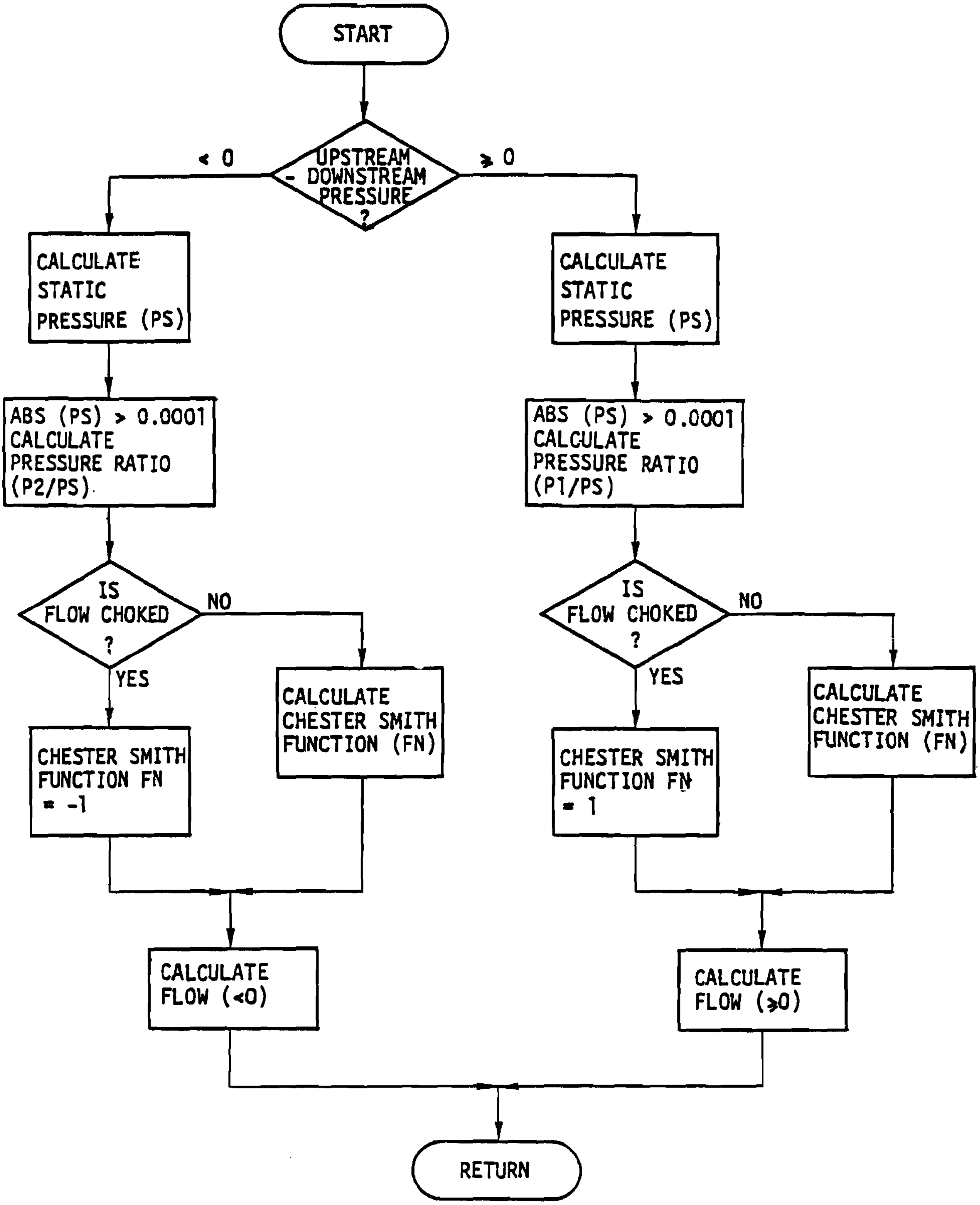


Table 38: FLOWCHART FOR SUBROUTINE FORCE

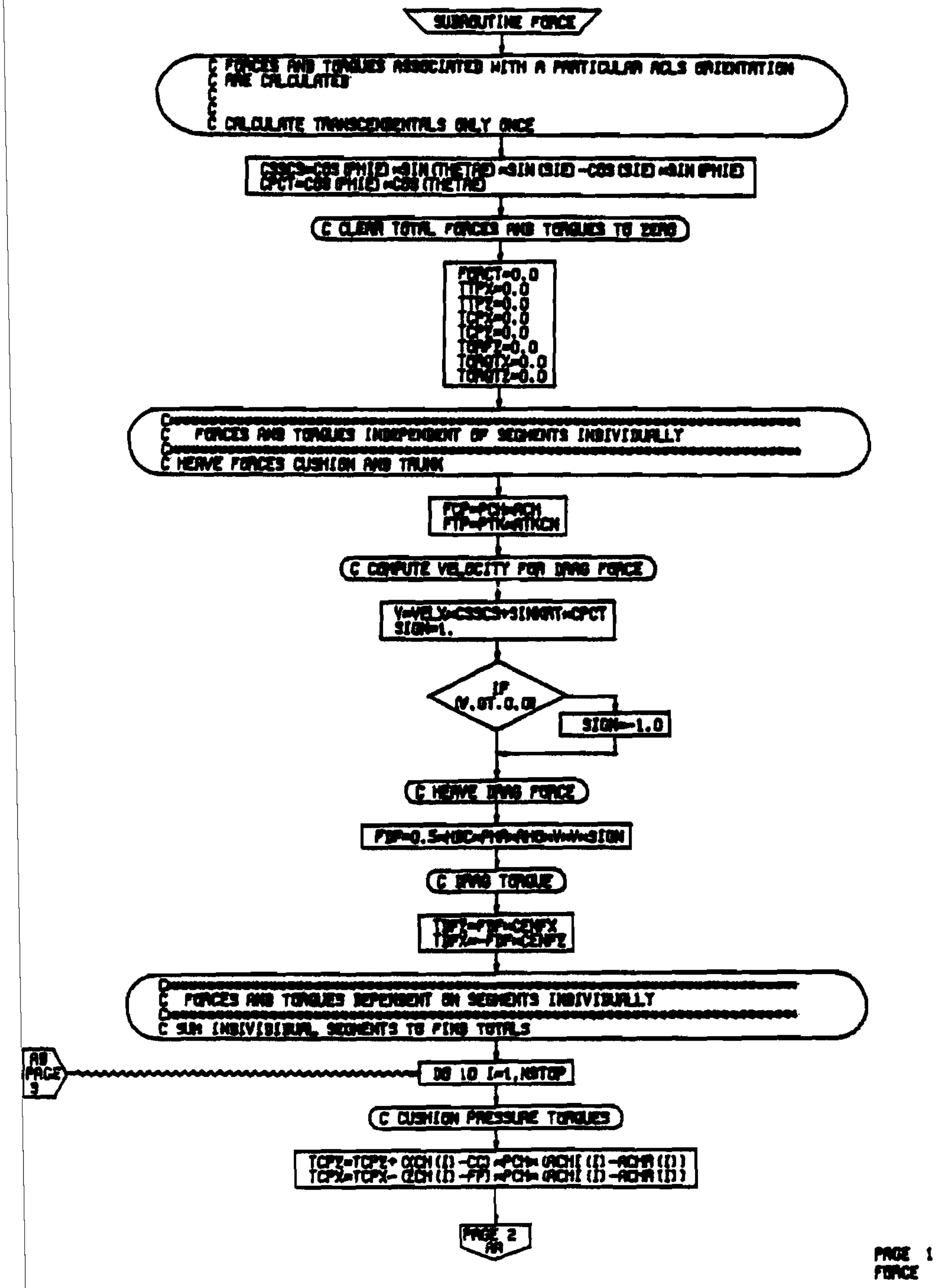


Table 38: FLOWCHART FOR SUBROUTINE FORCE (CONTINUED)

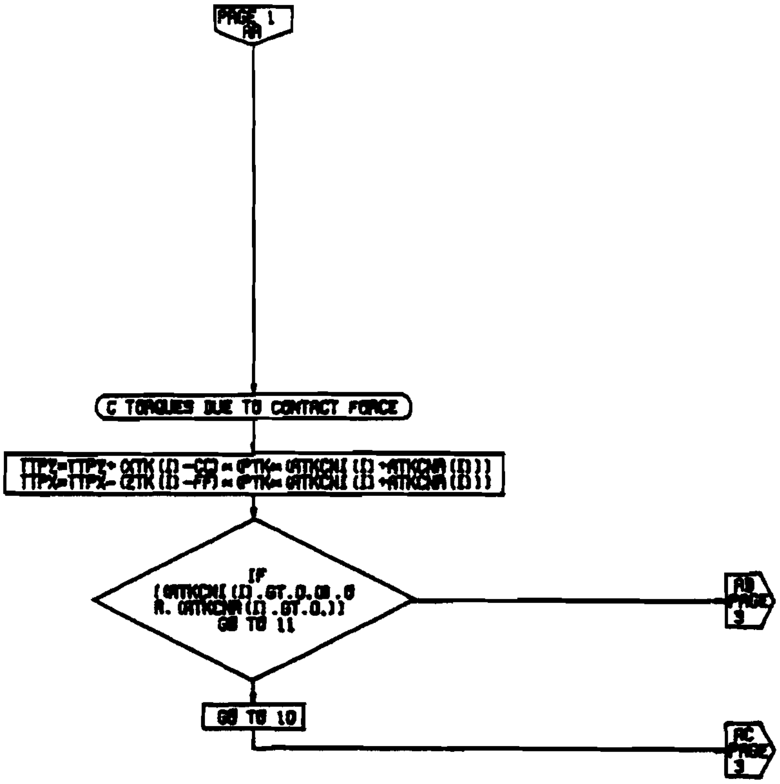
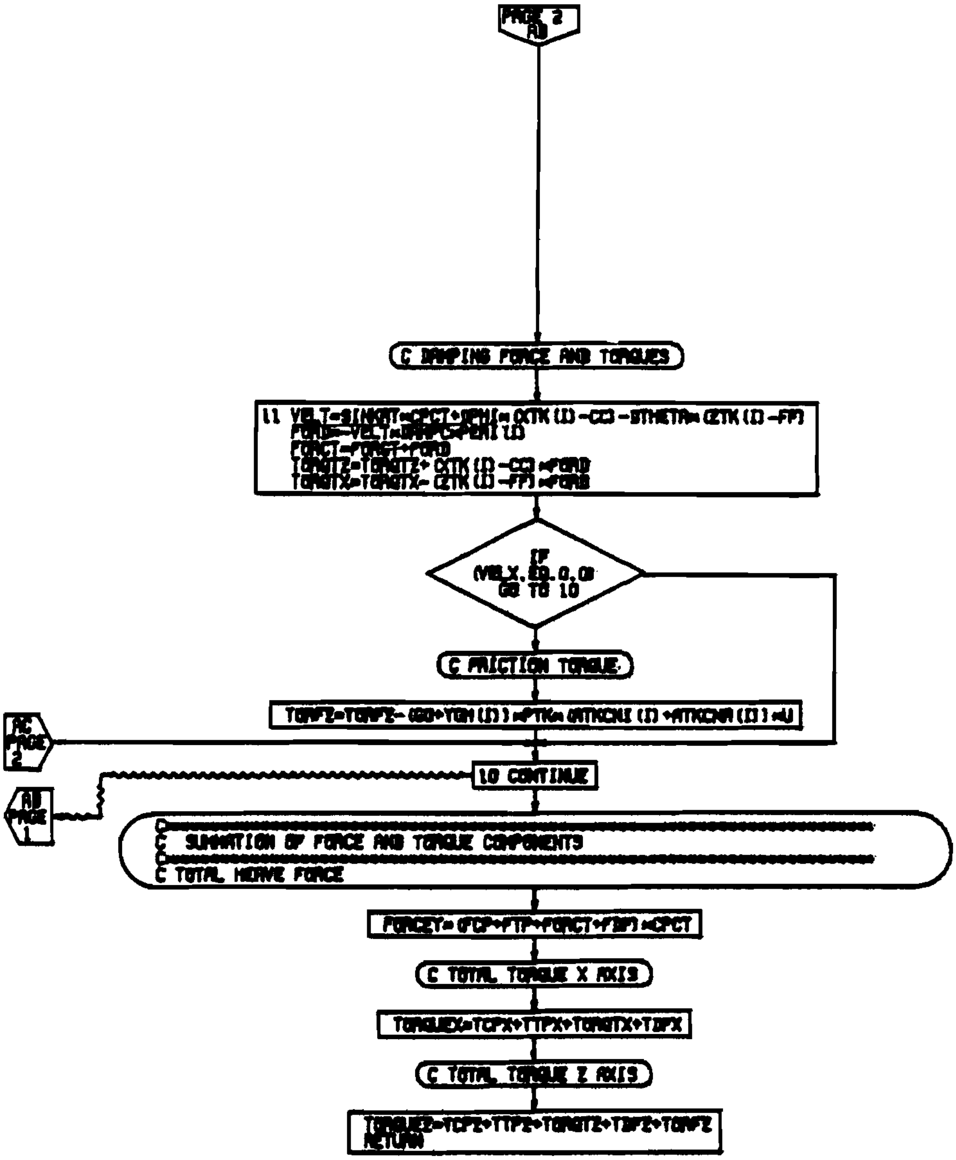


Table 38: FLOWCHART FOR SUBROUTINE FORCE (CONCLUDED)



PAGE 3
FORCE

Table 39: FLOWCHART FOR SUBROUTINE FR

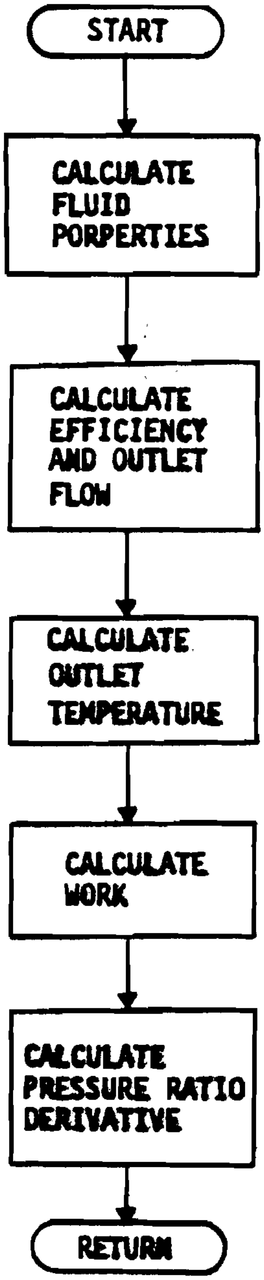


Table 40: FLOWCHART FOR SUBROUTINE FS

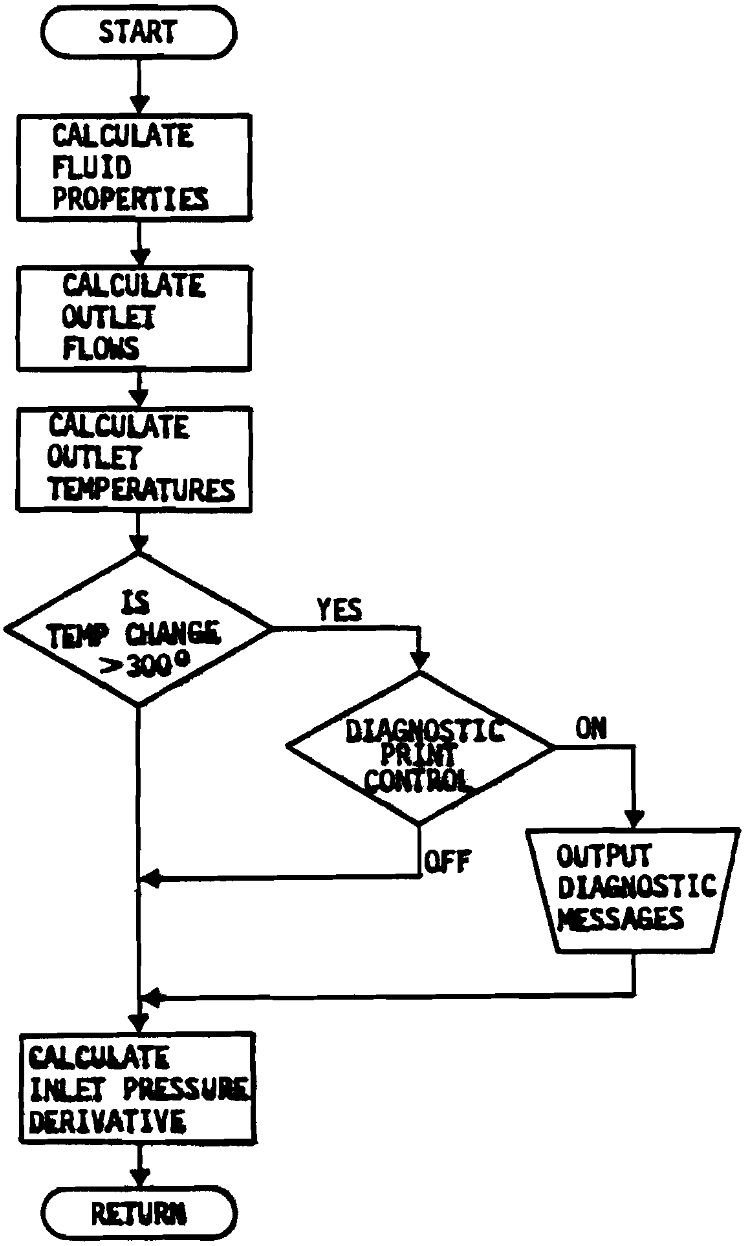
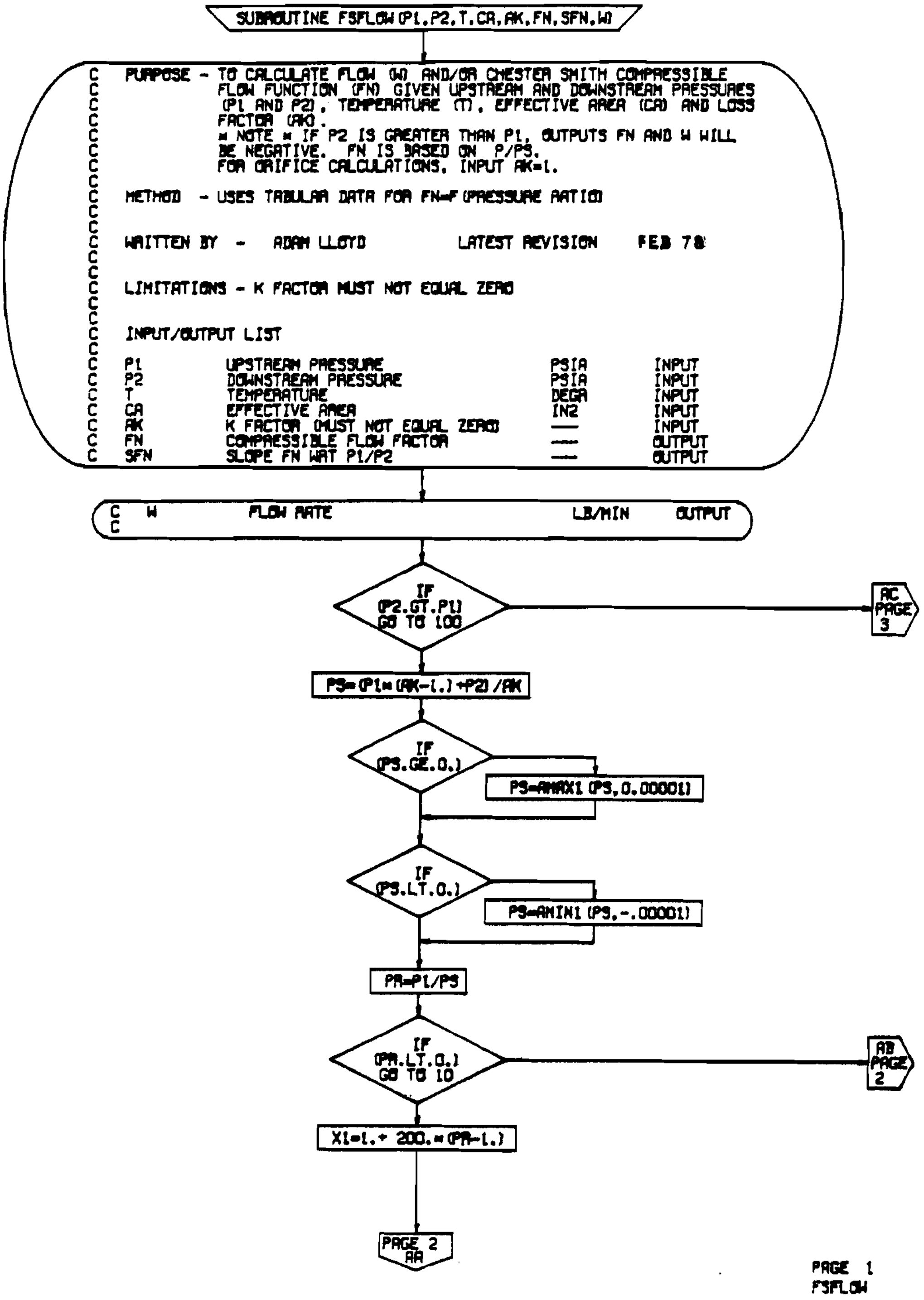


Table 41: FLOWCHART FOR SUBROUTINE FSFLOW



```
      SUBROUTINE FSFLOW(P1,P2,T,CA,AK,FN,SFN,W)
C     PURPOSE - TO CALCULATE FLOW (W) AND/OR CHESTER SMITH COMPRESSIBLE
C               FLOW FUNCTION (FN) GIVEN UPSTREAM AND DOWNSTREAM PRESSURES
C               (P1 AND P2), TEMPERATURE (T), EFFECTIVE AREA (CA) AND LOSS
C               FACTOR (AK).
C               * NOTE * IF P2 IS GREATER THAN P1, OUTPUTS FN AND W WILL
C               BE NEGATIVE.  FN IS BASED ON  P/PS.
C               FOR ORIFICE CALCULATIONS, INPUT AK=1.
C
C     METHOD  - USES TABULAR DATA FOR FN=F(PRESSURE RATIO)
C
C
C     WRITTEN BY -   ADAM LLOYD            LATEST REVISION    FEB 78
C
C
C     LIMITATIONS - K FACTOR MUST NOT EQUAL ZERO
C
C
C     INPUT/OUTPUT LIST
C
C     P1          UPSTREAM PRESSURE                    PSIA      INPUT
C     P2          DOWNSTREAM PRESSURE                  PSIA      INPUT
C     T           TEMPERATURE                          DEGR      INPUT
C     CA          EFFECTIVE AREA                       IN2       INPUT
C     AK          K FACTOR (MUST NOT EQUAL ZERO)       ----      INPUT
C     FN          COMPRESSIBLE FLOW FACTOR             ----      OUTPUT
C     SFN         SLOPE FN WRT P1/P2                   ----      OUTPUT
C     W           FLOW RATE                            LB/MIN    OUTPUT
C
```

Table 41: FLOWCHART FOR SUBROUTINE FSFLOW (CONTINUED)

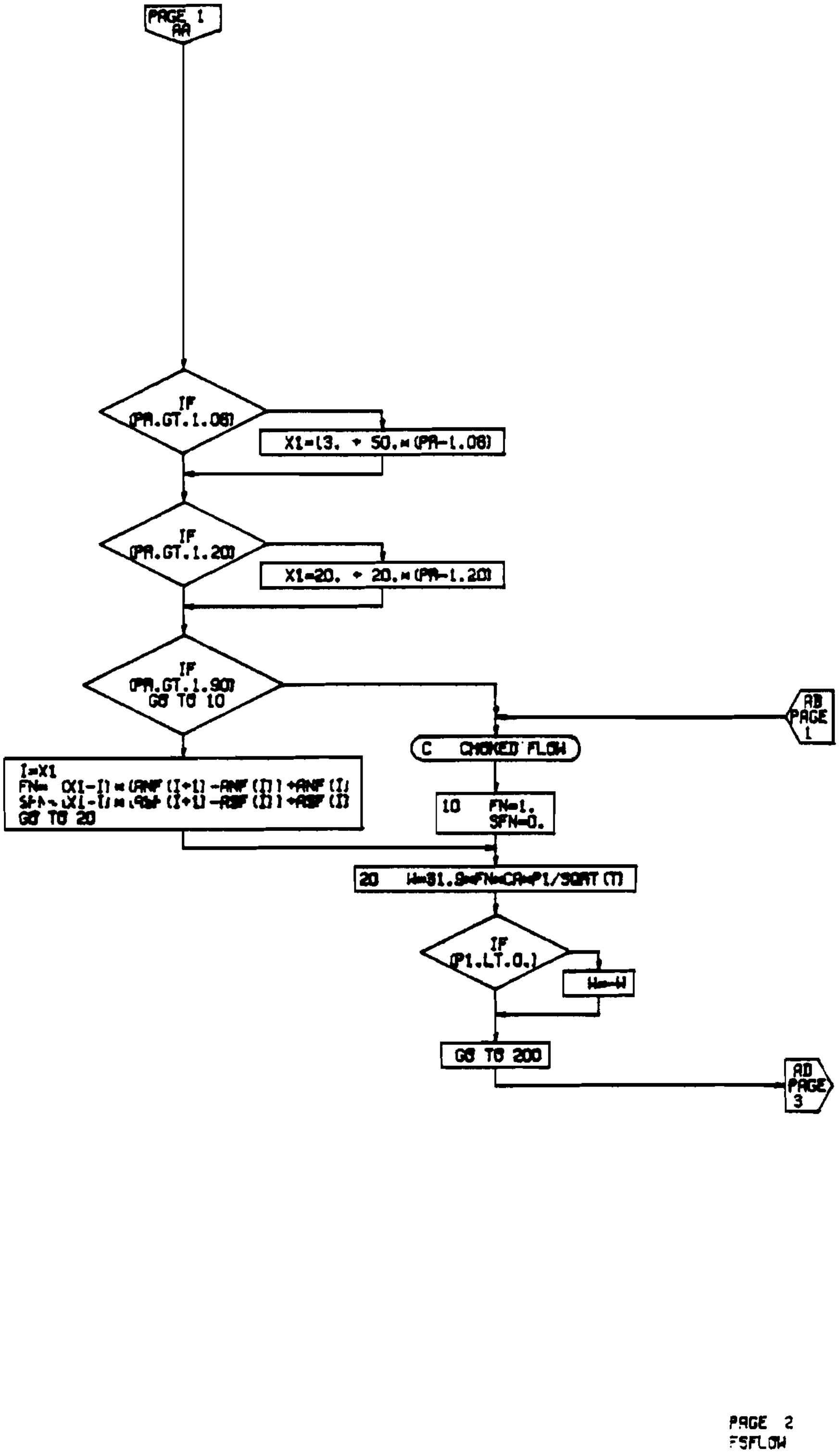
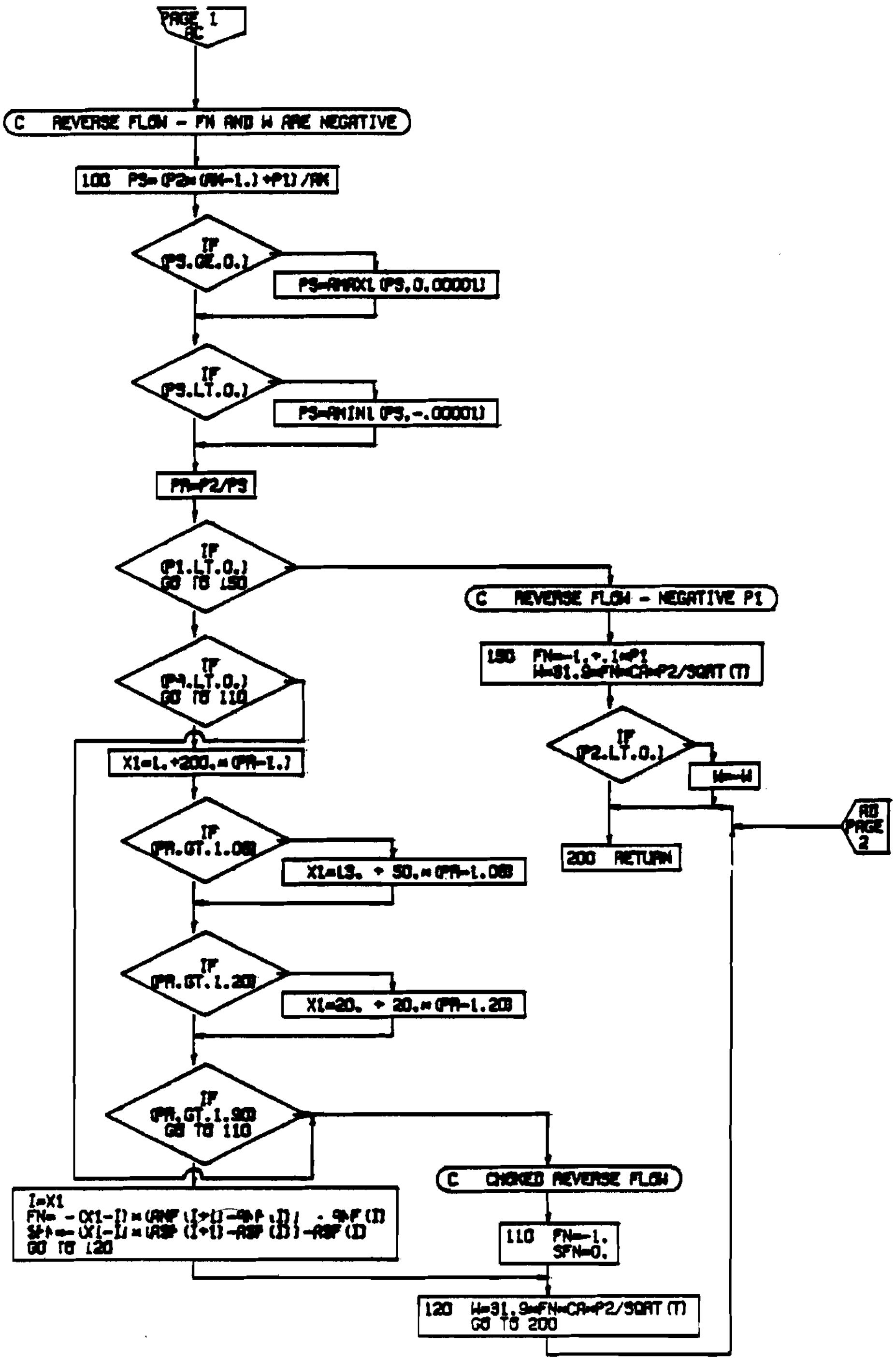


Table 41: FLOWCHART FOR SUBROUTINE FSFLOW (CONCLUDED)



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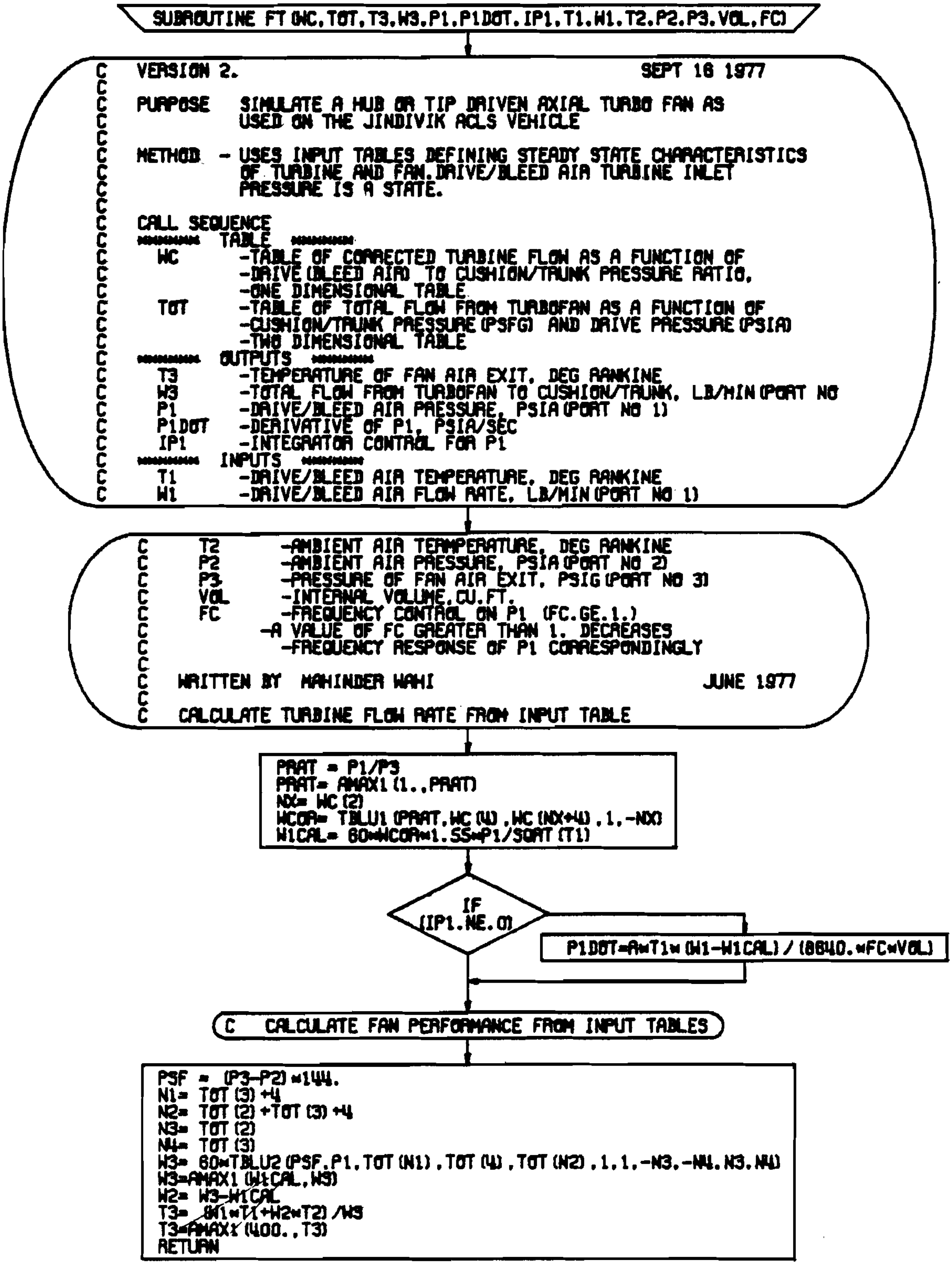
FSFLOW

Table 42: FLOWCHART FOR SUBROUTINE FT



```
SUBROUTINE FT(WC,TOT,T3.W3.P1.P1DOT.IP1.T1.W1.T2.P2.P3.VOL,FC)
```

```
C     VERSION 2.                                        SEPT 16 1977
C
C     PURPOSE   SIMULATE A HUB OR TIP DRIVEN AXIAL TURBO FAN AS
C               USED ON THE JINDIVIK ACLS VEHICLE
C
C     METHOD  - USES INPUT TABLES DEFINING STEADY STATE CHARACTERISTICS
C               OF TURBINE AND FAN.DRIVE/BLEED AIR TURBINE INLET
C               PRESSURE IS A STATE.
C
C     CALL SEQUENCE
C     ********  TABLE  ********
C       WC      -TABLE OF CORRECTED TURBINE FLOW AS A FUNCTION OF
C               -DRIVE(BLEED AIR) TO CUSHION/TRUNK PRESSURE RATIO,
C               -ONE DIMENSIONAL TABLE
C       TOT     -TABLE OF TOTAL FLOW FROM TURBOFAN AS A FUNCTION OF
C               -CUSHION/TRUNK PRESSURE(PSFG) AND DRIVE PRESSURE(PSIA)
C               -TWO DIMENSIONAL TABLE
C     ********  OUTPUTS  ********
C       T3      -TEMPERATURE OF FAN AIR EXIT, DEG RANKINE
C       W3      -TOTAL FLOW FROM TURBOFAN TO CUSHION/TRUNK, LB/MIN(PORT NO
C       P1      -DRIVE/BLEED AIR PRESSURE, PSIA(PORT NO 1)
C       P1DOT   -DERIVATIVE OF P1, PSIA/SEC
C       IP1     -INTEGRATOR CONTROL FOR P1
C     ********  INPUTS  ********
C       T1      -DRIVE/BLEED AIR TEMPERATURE, DEG RANKINE
C       W1      -DRIVE/BLEED AIR FLOW RATE, LB/MIN(PORT NO 1)
```

```
C      T2      -AMBIENT AIR TERMPERATURE, DEG RANKINE
C      P2      -AMBIENT AIR PRESSURE, PSIA(PORT NO 2)
C      P3      -PRESSURE OF FAN AIR EXIT, PSIG(PORT NO 3)
C      VOL     -INTERNAL VOLUME,CU.FT.
C      FC      -FREQUENCY CONTROL ON P1 (FC.GE.1.)
C             -A VALUE OF FC GREATER THAN 1. DECREASES
C              -FREQUENCY RESPONSE OF P1 CORRESPONDINGLY
C
C   WRITTEN BY  MAHINDER WAHI                              JUNE 1977
C
C   CALCULATE TURBINE FLOW RATE FROM INPUT TABLE
```

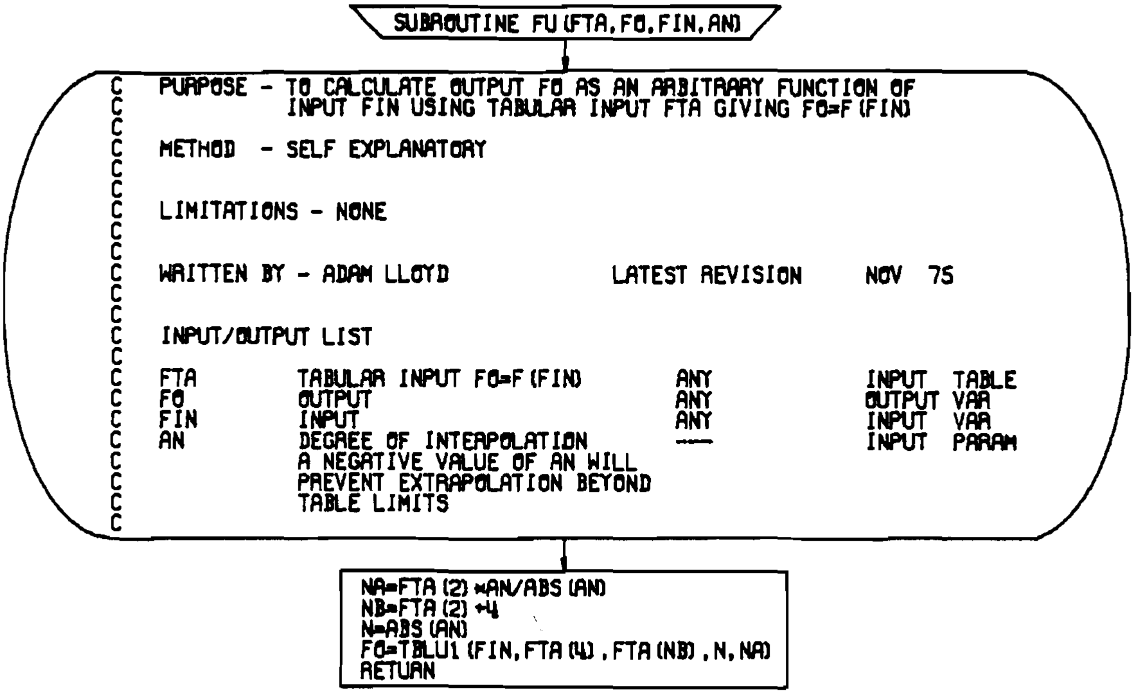
```
PRAT = P1/P3
PRAT= AMAX1(1.,PRAT)
NX= WC(2)
WCOR= TBLU1(PRAT,WC(4),WC(NX+4),1,-NX)
W1CAL= 60*WCOR*1.55*P1/SQRT(T1)
```

```
P1DOT=A*T1*(W1-W1CAL)/(8640.*FC*VOL)
```

```
C   CALCULATE FAN PERFORMANCE FROM INPUT TABLES
```

```
PSF = (P3-P2)*144.
N1= TOT(3)+4
N2= TOT(2)+TOT(3)+4
N3= TOT(2)
N4= TOT(3)
W3= 60*TBLU2(PSF,P1,TOT(N1),TOT(4),TOT(N2),1,1,-N3,-N4,N3,N4)
W3=AMAX1(W1CAL,W3)
W2= W3-W1CAL
T3= (W1*T1+W2*T2)/W3
T3=AMAX1(400.,T3)
RETURN
```

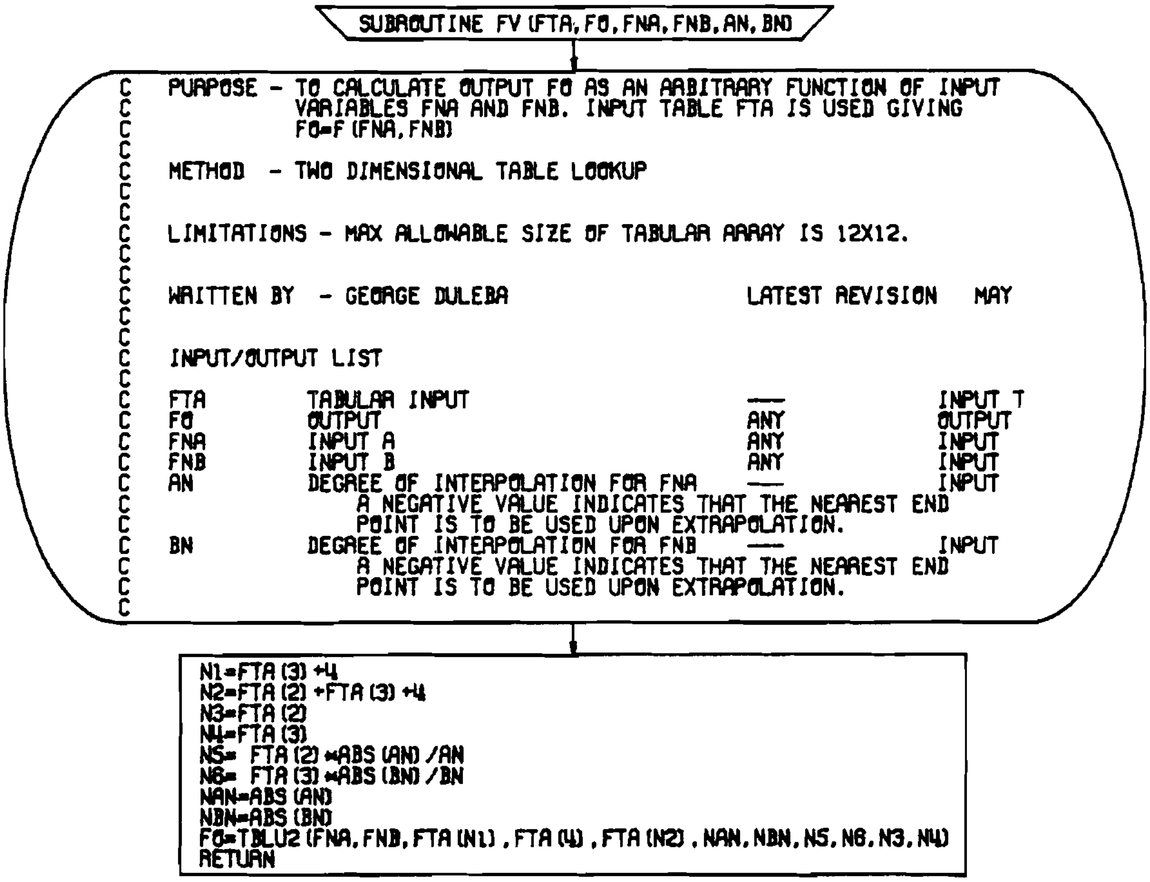
Table 43: FLOWCHART FOR SUBROUTINE FU



```
SUBROUTINE FU(FTA,FO,FIN,AN)
C   PURPOSE - TO CALCULATE OUTPUT FO AS AN ARBITRARY FUNCTION OF
C             INPUT FIN USING TABULAR INPUT FTA GIVING FO=F(FIN)
C
C   METHOD  - SELF EXPLANATORY
C
C
C   LIMITATIONS - NONE
C
C
C   WRITTEN BY - ADAM LLOYD            LATEST REVISION     NOV  75
C
C
C   INPUT/OUTPUT LIST
C
C   FTA        TABULAR INPUT FO=F(FIN)       ANY           INPUT  TABLE
C   FO         OUTPUT                        ANY           OUTPUT VAR
C   FIN        INPUT                         ANY           INPUT  VAR
C   AN         DEGREE OF INTERPOLATION       ----          INPUT  PARAM
C              A NEGATIVE VALUE OF AN WILL
C              PREVENT EXTRAPOLATION BEYOND
C              TABLE LIMITS
C
```

```
NA=FTA(2)*AN/ABS(AN)
NB=FTA(2)+4
N=ABS(AN)
FO=TBLU1(FIN,FTA(4),FTA(NB),N,NA)
RETURN
```

Table 44: FLOWCHART FOR SUBROUTINE FV

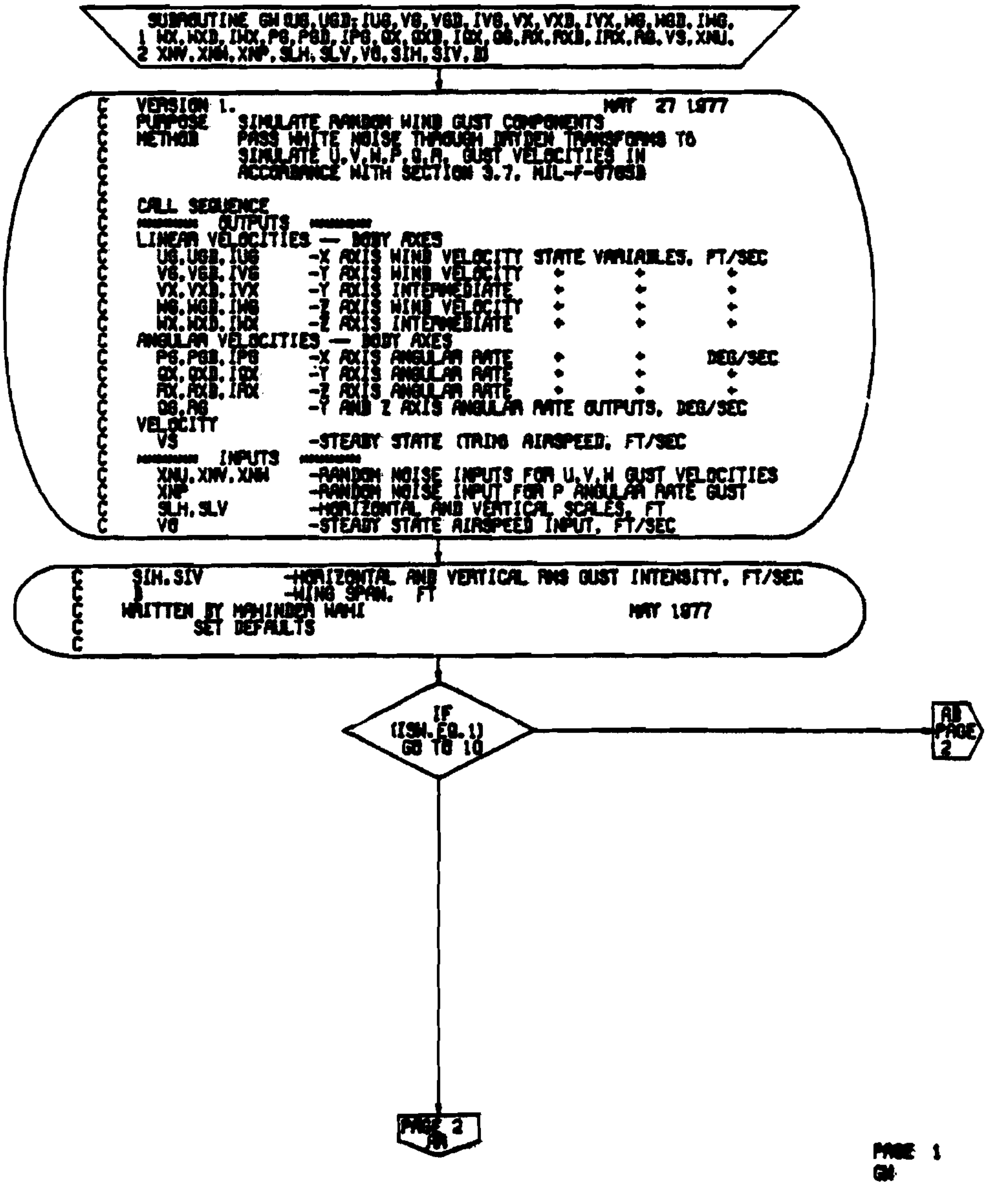


```
SUBROUTINE FV (FTA,FO,FNA,FNB,AN,BN)
```

```
C     PURPOSE - TO CALCULATE OUTPUT FO AS AN ARBITRARY FUNCTION OF INPUT
C               VARIABLES FNA AND FNB. INPUT TABLE FTA IS USED GIVING
C               FO=F (FNA,FNB)
C
C     METHOD  - TWO DIMENSIONAL TABLE LOOKUP
C
C
C     LIMITATIONS - MAX ALLOWABLE SIZE OF TABULAR ARRAY IS 12X12.
C
C
C     WRITTEN BY  - GEORGE DULEBA                    LATEST REVISION   MAY
C
C
C     INPUT/OUTPUT LIST
C
C     FTA          TABULAR INPUT                        ---             INPUT T
C     FO           OUTPUT                               ANY             OUTPUT
C     FNA          INPUT A                              ANY             INPUT
C     FNB          INPUT B                              ANY             INPUT
C     AN           DEGREE OF INTERPOLATION FOR FNA      ---             INPUT
C                       A NEGATIVE VALUE INDICATES THAT THE NEAREST END
C                       POINT IS TO BE USED UPON EXTRAPOLATION.
C     BN           DEGREE OF INTERPOLATION FOR FNB      ---             INPUT
C                       A NEGATIVE VALUE INDICATES THAT THE NEAREST END
C                       POINT IS TO BE USED UPON EXTRAPOLATION.
C
```

```
N1=FTA (3) +4
N2=FTA (2) +FTA (3) +4
N3=FTA (2)
N4=FTA (3)
N5= FTA (2) *ABS (AN) /AN
N6= FTA (3) *ABS (BN) /BN
NAN=ABS (AN)
NBN=ABS (BN)
FO=TBLU2 (FNA,FNB,FTA (N1) ,FTA (4) ,FTA (N2) ,NAN,NBN,N5,N6,N3,N4)
RETURN
```

Table 45: FLOWCHART FOR SUBROUTINE GW



```
      SUBROUTINE GW(UG,UGD,IUG,VG,VGD,IVG,VX,VXD,IVX,WG,WGD,IWG,
     1 WX,WXD,IWX,PG,PGD,IPG,QX,QXD,IQX,QG,RX,RXD,IRX,RG,VS,XNU,
     2 XNV,XNW,XNP,SLH,SLV,V0,SIH,SIV,B)
```

```
C     VERSION 1.                                    MAY  27 1977
C     PURPOSE   SIMULATE RANDOM WIND GUST COMPONENTS
C     METHOD    PASS WHITE NOISE THROUGH DRYDEN TRANSFORMS TO
C               SIMULATE U,V,W,P,Q,R, GUST VELOCITIES IN
C               ACCORDANCE WITH SECTION 3.7, MIL-F-8785B
C
C     CALL SEQUENCE
C     -------  OUTPUTS  -------
C     LINEAR VELOCITIES -- BODY AXES
C       UG,UGD,IUG      -X AXIS WIND VELOCITY STATE VARIABLES, FT/SEC
C       VG,VGD,IVG      -Y AXIS WIND VELOCITY    *       *        *
C       VX,VXD,IVX      -Y AXIS INTERMEDIATE     *       *        *
C       WG,WGD,IWG      -Z AXIS WIND VELOCITY    *       *        *
C       WX,WXD,IWX      -Z AXIS INTERMEDIATE     *       *        *
C     ANGULAR VELOCITIES -- BODY AXES
C       PG,PGD,IPG      -X AXIS ANGULAR RATE     *       *     DEG/SEC
C       QX,QXD,IQX      -Y AXIS ANGULAR RATE     *       *        *
C       RX,RXD,IRX      -Z AXIS ANGULAR RATE     *       *        *
C       QG,RG           -Y AND Z AXIS ANGULAR RATE OUTPUTS, DEG/SEC
C     VELOCITY
C       VS              -STEADY STATE (TRIM) AIRSPEED, FT/SEC
C     -------  INPUTS  -------
C       XNU,XNV,XNW     -RANDOM NOISE INPUTS FOR U,V,W GUST VELOCITIES
C       XNP             -RANDOM NOISE INPUT FOR P ANGULAR RATE GUST
C       SLH,SLV         -HORIZONTAL AND VERTICAL SCALES, FT
C       V0              -STEADY STATE AIRSPEED INPUT, FT/SEC
```

```
C       SIH,SIV         -HORIZONTAL AND VERTICAL RMS GUST INTENSITY, FT/SEC
C       B               -WING SPAN,  FT
C     WRITTEN BY MAHINDER WAHI                           MAY 1977
C            SET DEFAULTS
C
```

Table 45: FLOWCHART FOR SUBROUTINE GW (CONTINUED)

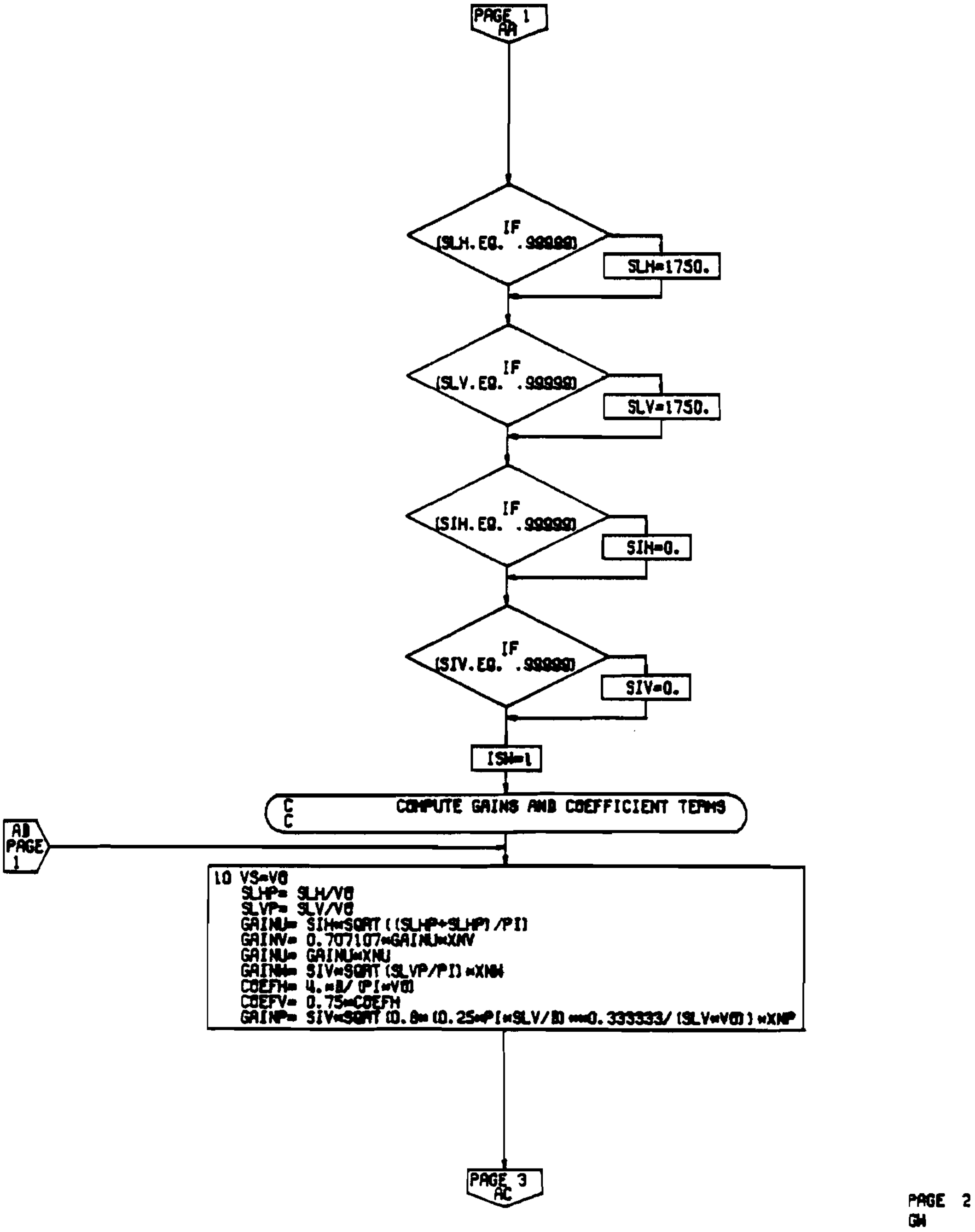
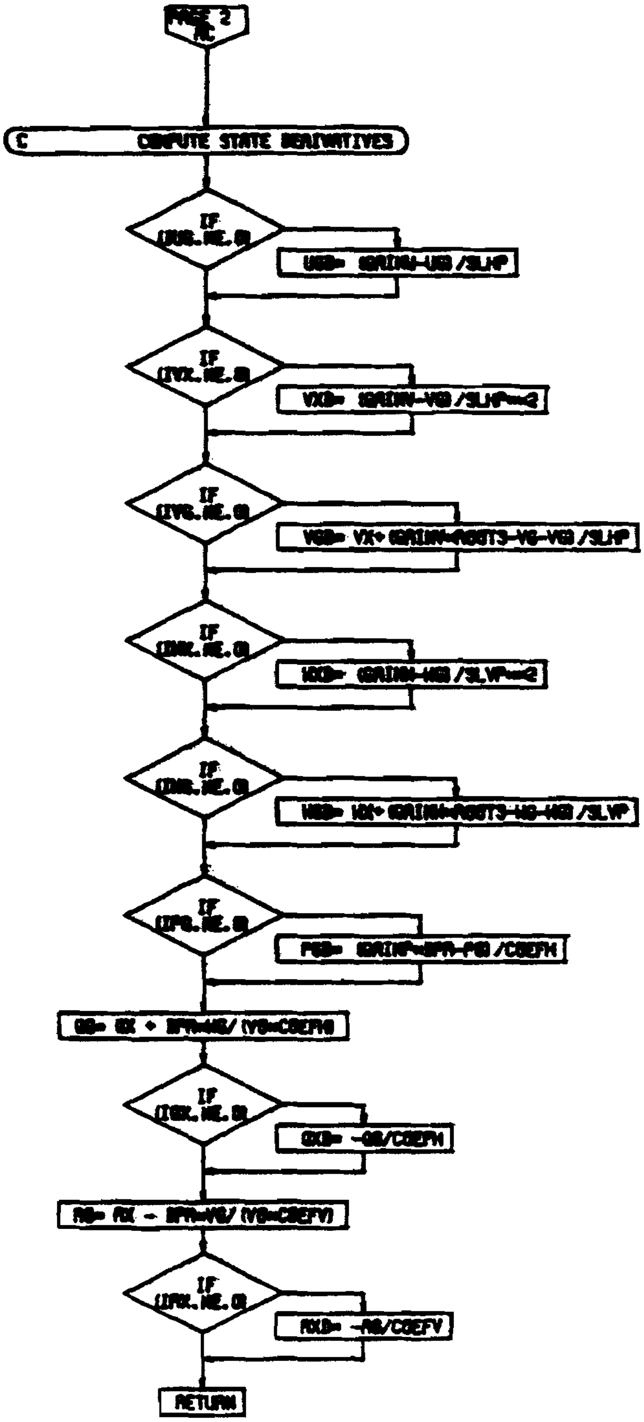


Table 45: FLOWCHART FOR SUBROUTINE GW (CONCLUDED)



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GW

Table 46: FLOWCHART FOR SUBROUTINE HI

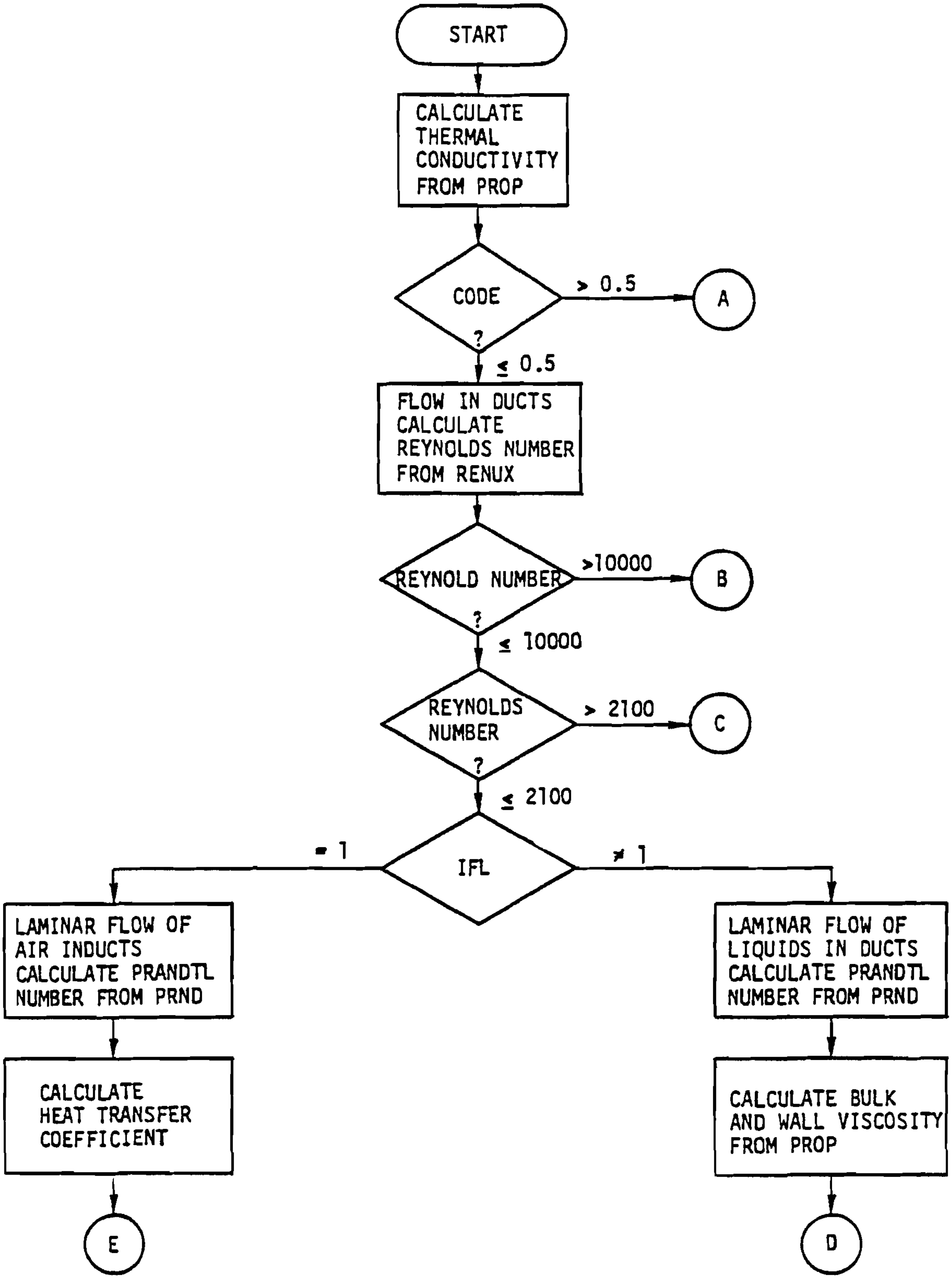


Table 46: FLOWCHART FOR SUBROUTINE HI (CONTINUED)

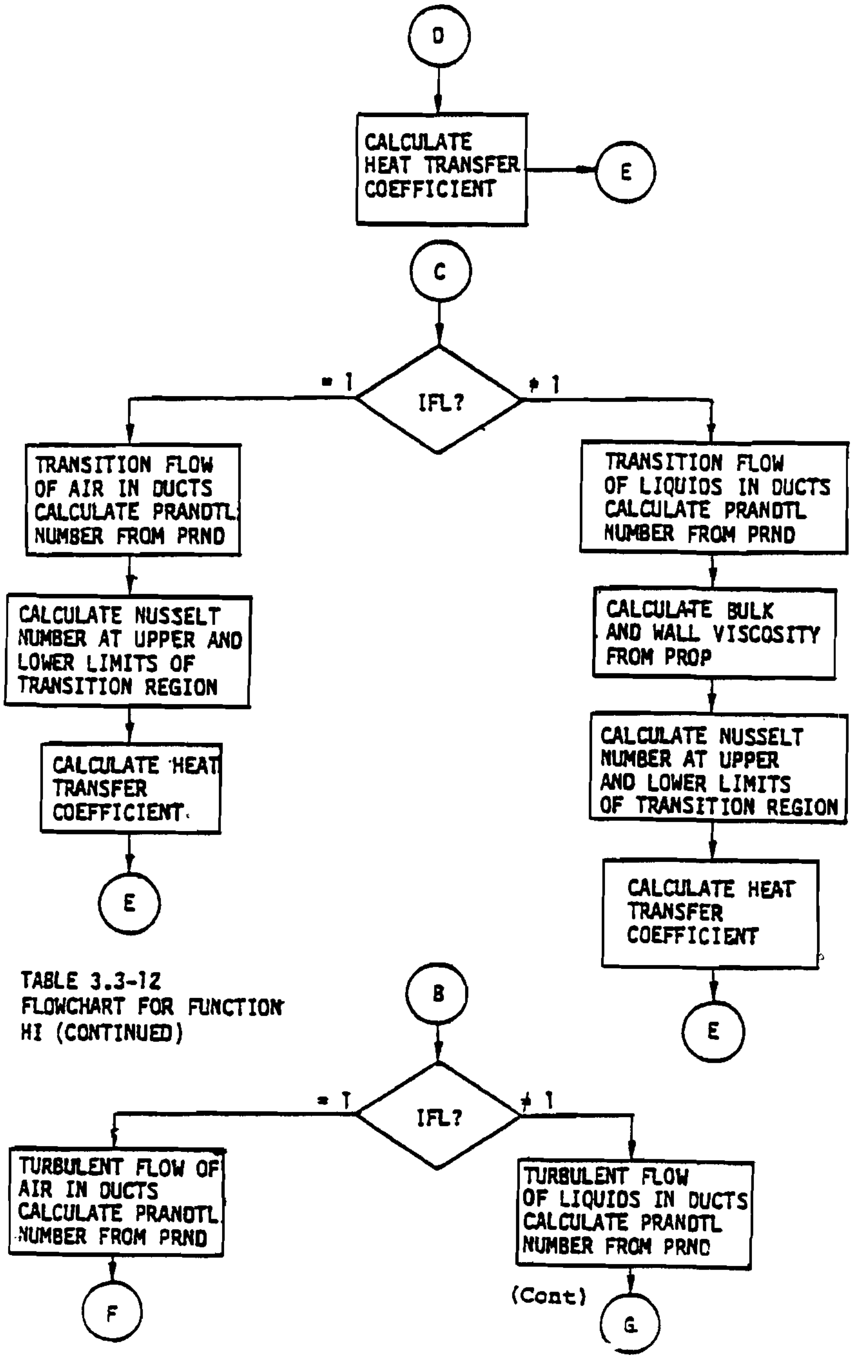


Table 46: FLOWCHART FOR SUBROUTINE HI (CONCLUDED)

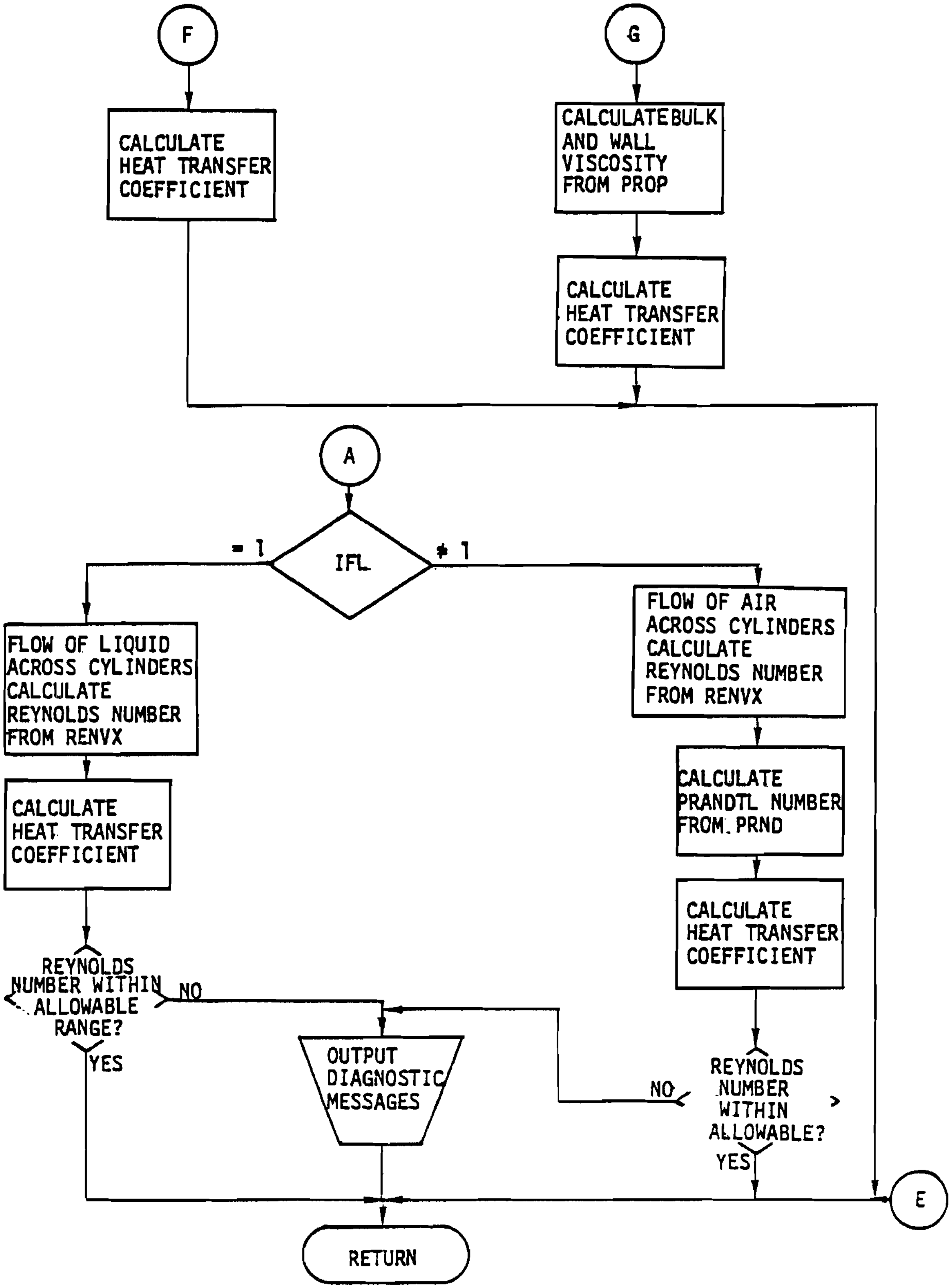
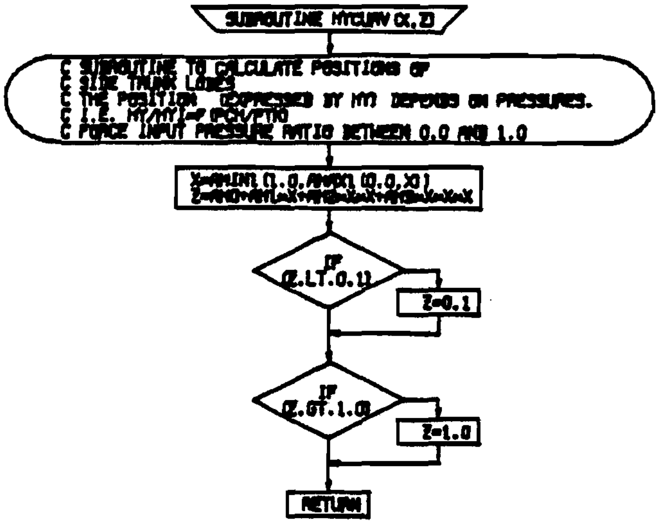


Table 47: FLOWCHART FOR SUBROUTINE HYCURV



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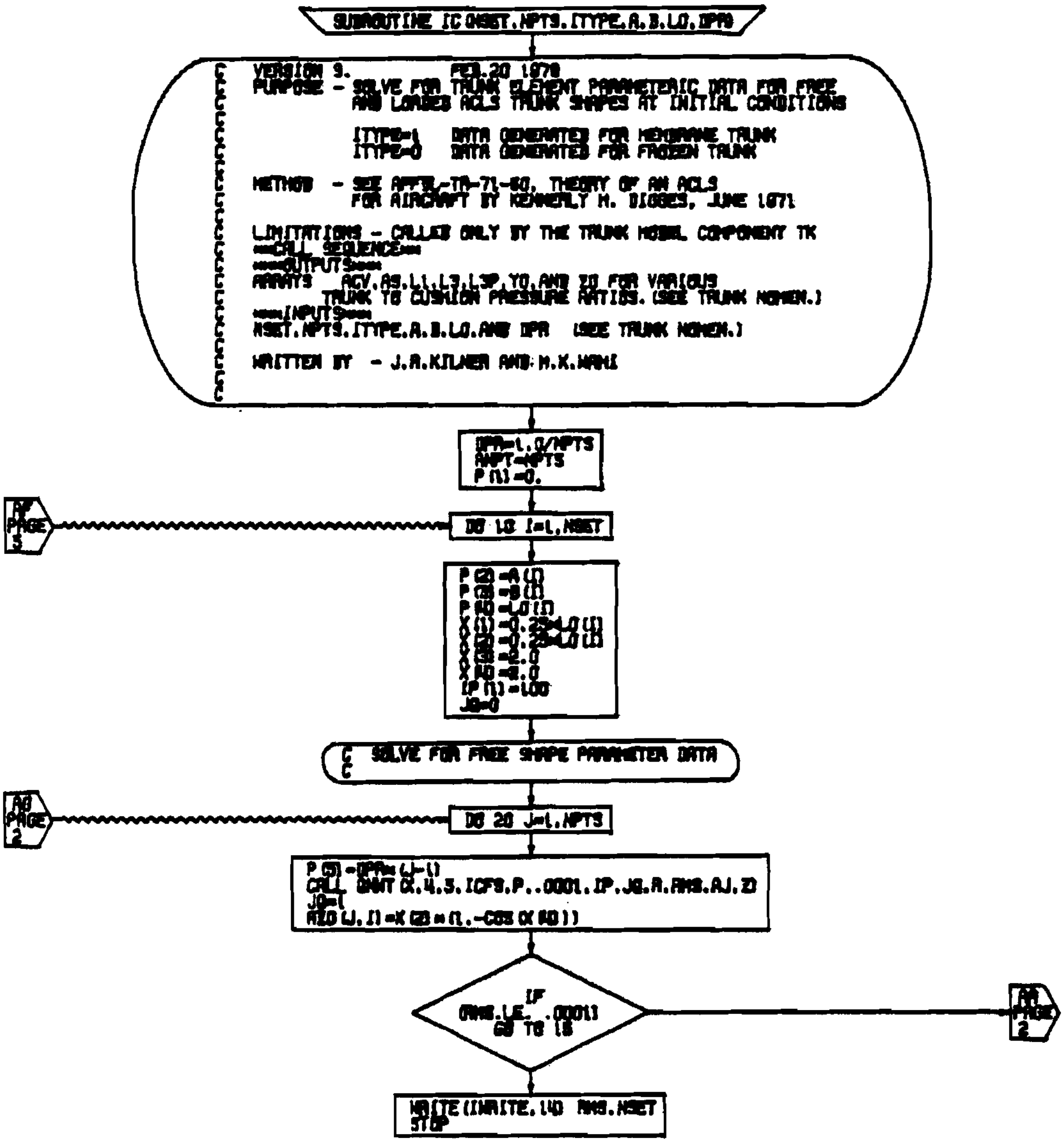
HYCURV

Table 48: FLOWCHART FOR SUBROUTINE IC



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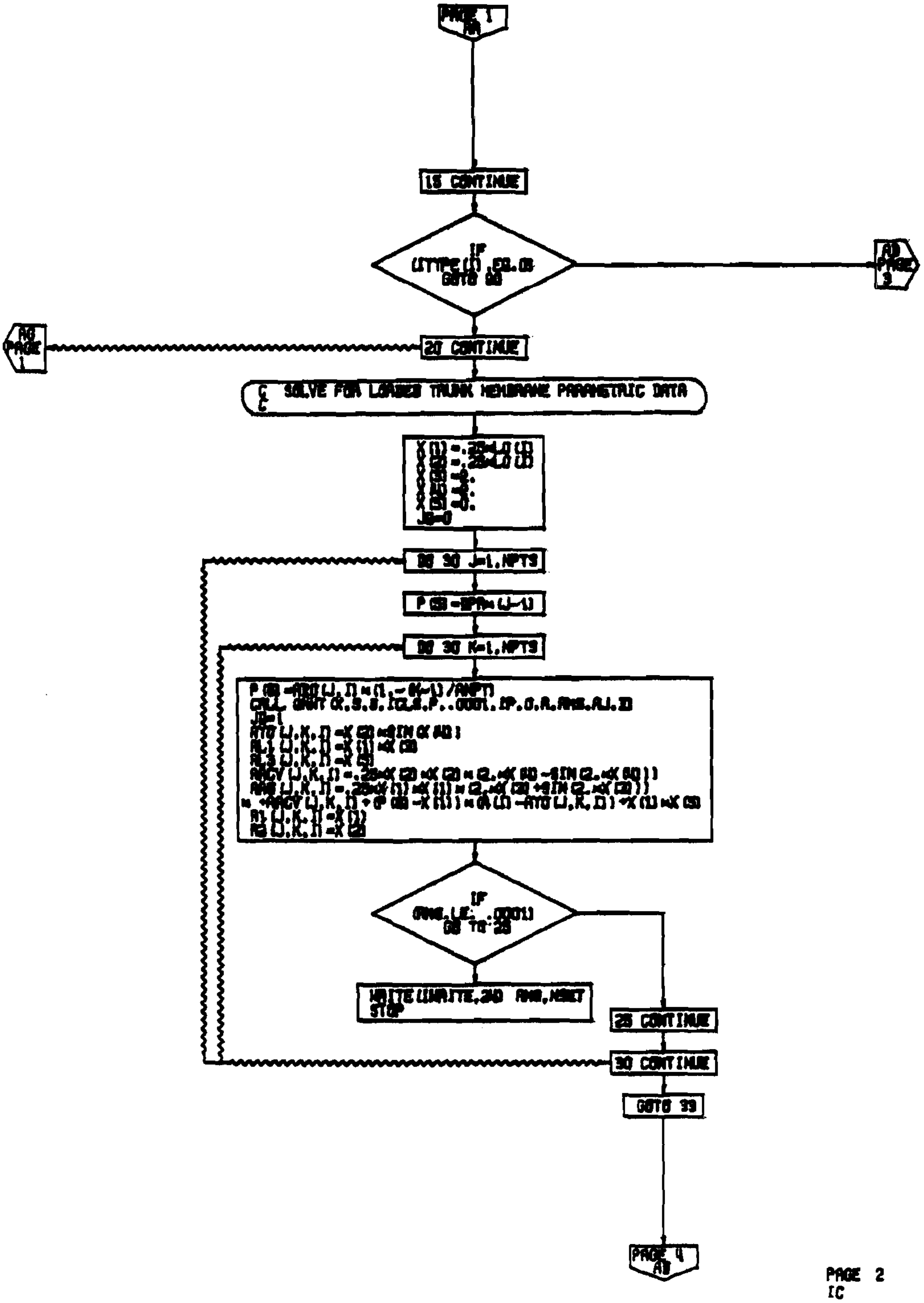
IC

Table 48: FLOWCHART FOR SUBROUTINE IC (CONTINUED)



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IC

Table 48: FLOWCHART FOR SUBROUTINE IC (CONTINUED)

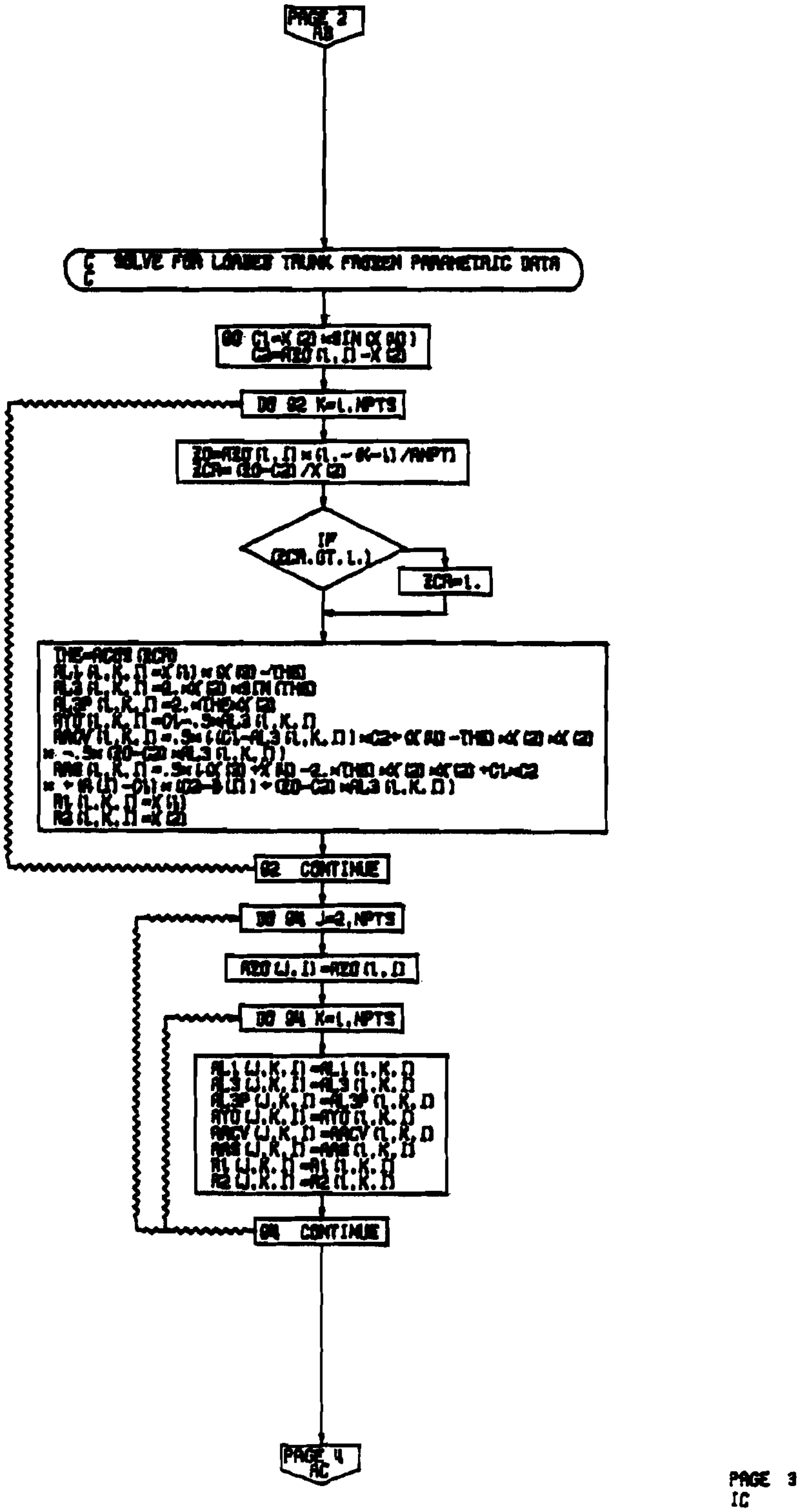
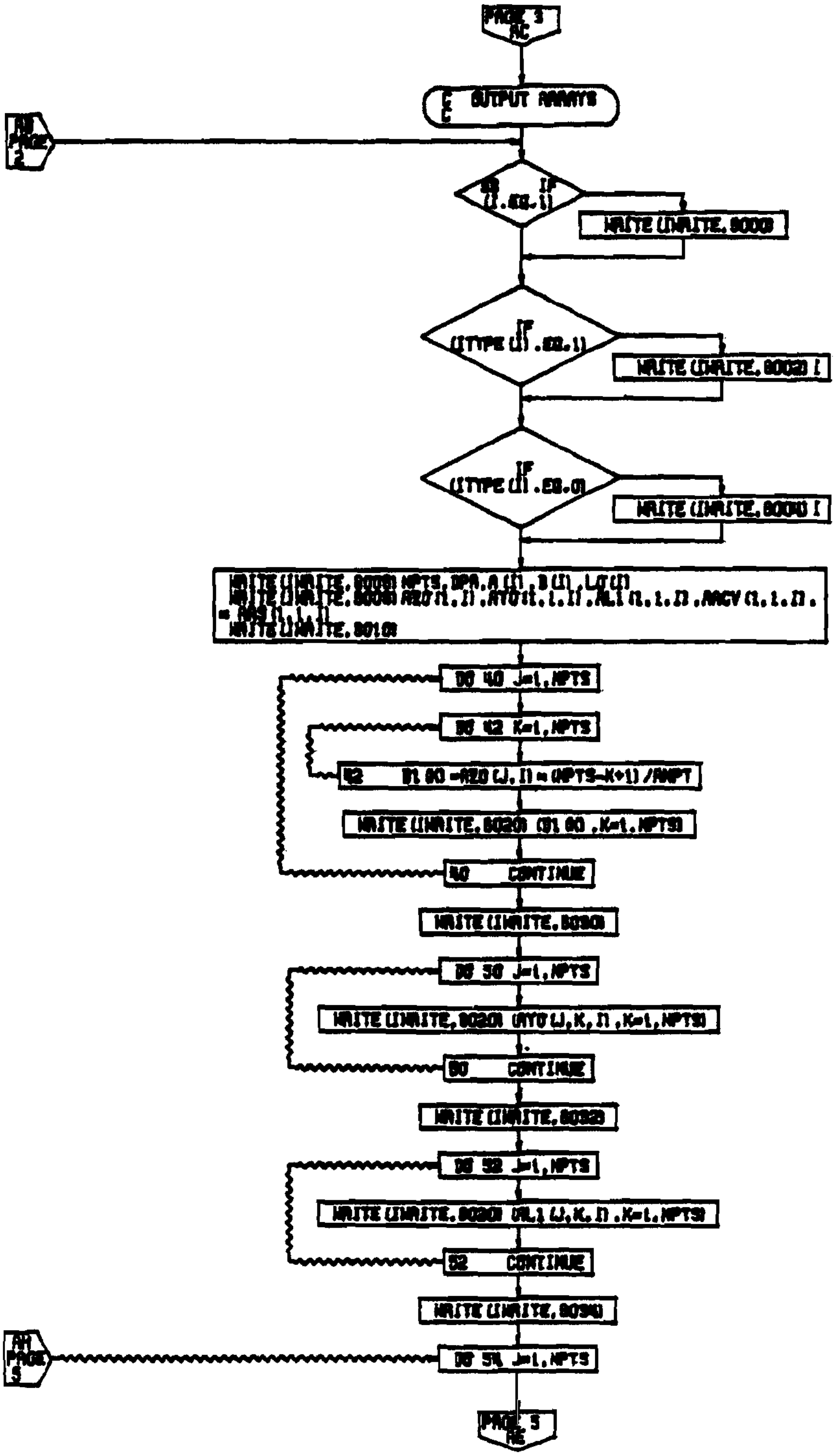


Table 48: FLOWCHART FOR SUBROUTINE IC (CONTINUED)



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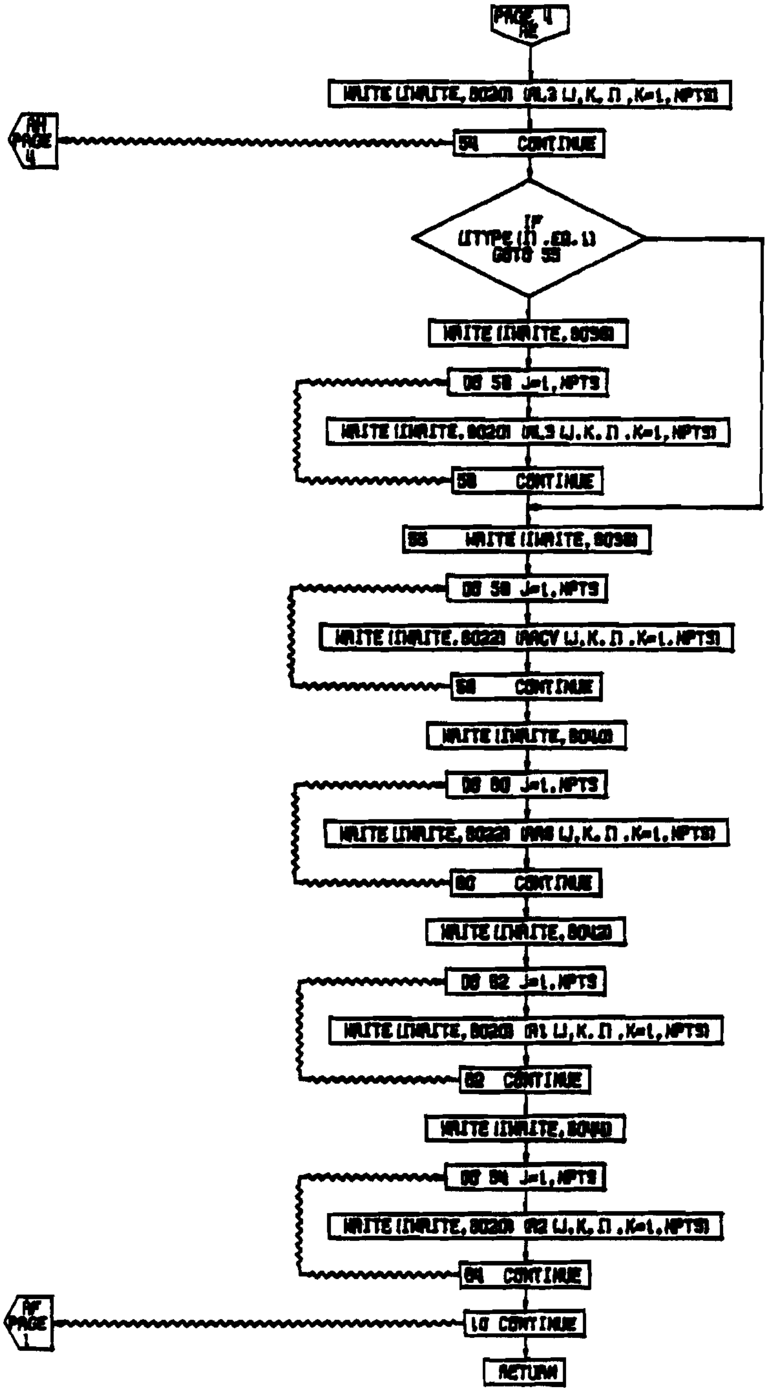
IC

Table 48: FLOWCHART FOR SUBROUTINE IC (CONCLUDED)



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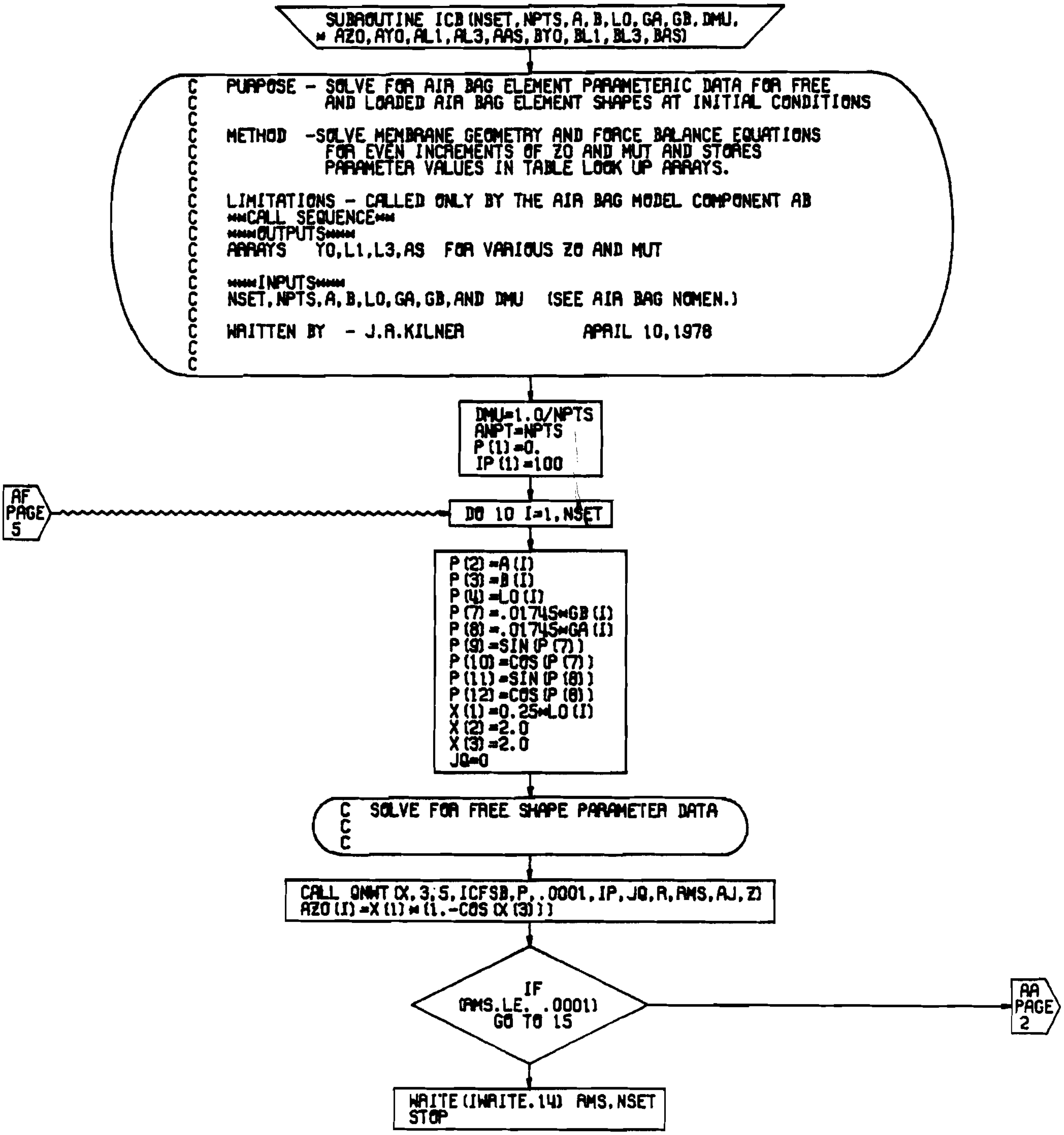
IC

Table 49: FLOWCHART FOR SUBROUTINE ICB



```
      SUBROUTINE ICB(NSET,NPTS,A,B,LO,GA,GB,DMU,
     * AZO,AYO,AL1,AL3,AAS,BYO,BL1,BL3,BAS)
C     PURPOSE - SOLVE FOR AIR BAG ELEMENT PARAMETERIC DATA FOR FREE
C               AND LOADED AIR BAG ELEMENT SHAPES AT INITIAL CONDITIONS
C
C     METHOD  -SOLVE MEMBRANE GEOMETRY AND FORCE BALANCE EQUATIONS
C               FOR EVEN INCREMENTS OF ZO AND MUT AND STORES
C               PARAMETER VALUES IN TABLE LOOK UP ARRAYS.
C
C     LIMITATIONS - CALLED ONLY BY THE AIR BAG MODEL COMPONENT AB
C     **CALL SEQUENCE**
C     ****OUTPUTS****
C     ARRAYS   YO,L1,L3,AS   FOR VARIOUS ZO AND MUT
C
C     ****INPUTS****
C     NSET,NPTS,A,B,LO,GA,GB,AND DMU   (SEE AIR BAG NOMEN.)
C
C     WRITTEN BY   - J.A.KILNER              APRIL 10,1978
C
C

      DMU=1.0/NPTS
      ANPT=NPTS
      P(1)=0.
      IP(1)=100

      DO 10 I=1,NSET

      P(2)=A(I)
      P(3)=B(I)
      P(4)=LO(I)
      P(7)=.01745*GB(I)
      P(8)=.01745*GA(I)
      P(9)=SIN(P(7))
      P(10)=COS(P(7))
      P(11)=SIN(P(8))
      P(12)=COS(P(8))
      X(1)=0.25*LO(I)
      X(2)=2.0
      X(3)=2.0
      JQ=0

C     SOLVE FOR FREE SHAPE PARAMETER DATA
C
C

      CALL QNWT(X,3,5,ICFSB,P,.0001,IP,JQ,R,RMS,AJ,Z)
      AZO(I)=X(1)*(1.-COS(X(3)))

      IF
      (RMS.LE. .0001)
      GO TO 15

      WRITE(IWRITE,14) RMS,NSET
      STOP
```

Table 49: FLOWCHART FOR SUBROUTINE ICB (CONTINUED)

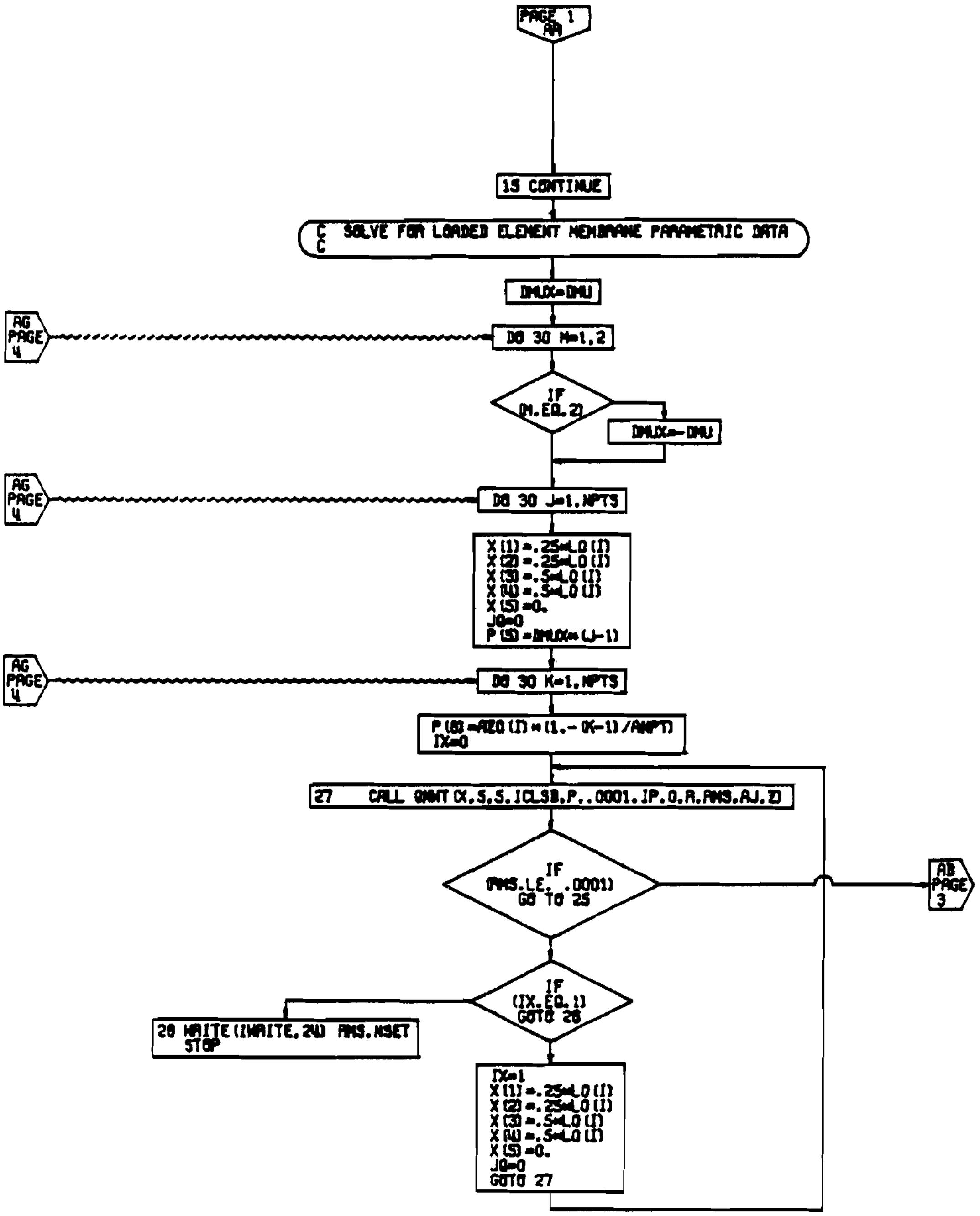
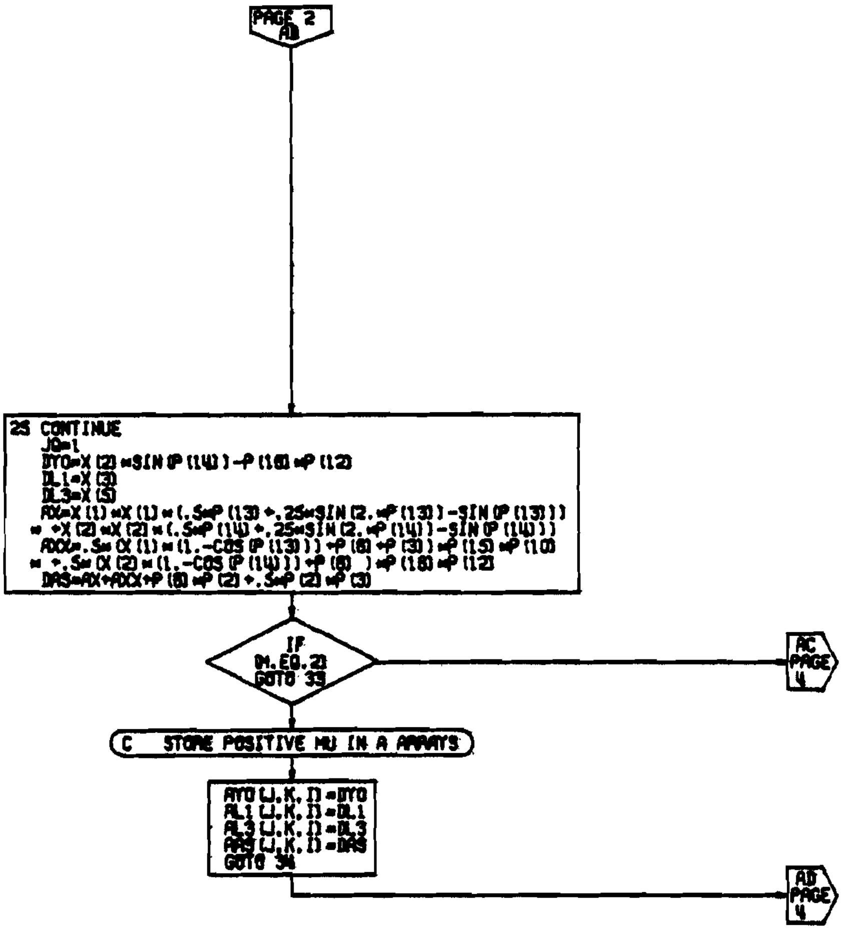


Table 49: FLOWCHART FOR SUBROUTINE ICB (CONTINUED)



```
25 CONTINUE
   JQ=1
   DYO=X(2)*SIN(P(14))-P(16)*P(12)
   DL1=X(3)
   DL3=X(5)
   AX=X(1)*X(1)*(.5*P(13)+.25*SIN(2.*P(13))-SIN(P(13)))
 *  +X(2)*X(2)*(.5*P(14)+.25*SIN(2.*P(14))-SIN(P(14)))
   AXX=.5*(X(1)*(1.-COS(P(13)))+P(6)+P(3))*P(15)*P(10)
 *  +.5*(X(2)*(1.-COS(P(14)))+P(6) )*P(16)*P(12)
   DAS=AX+AXX+P(6)*P(2)+.5*P(2)*P(3)
```

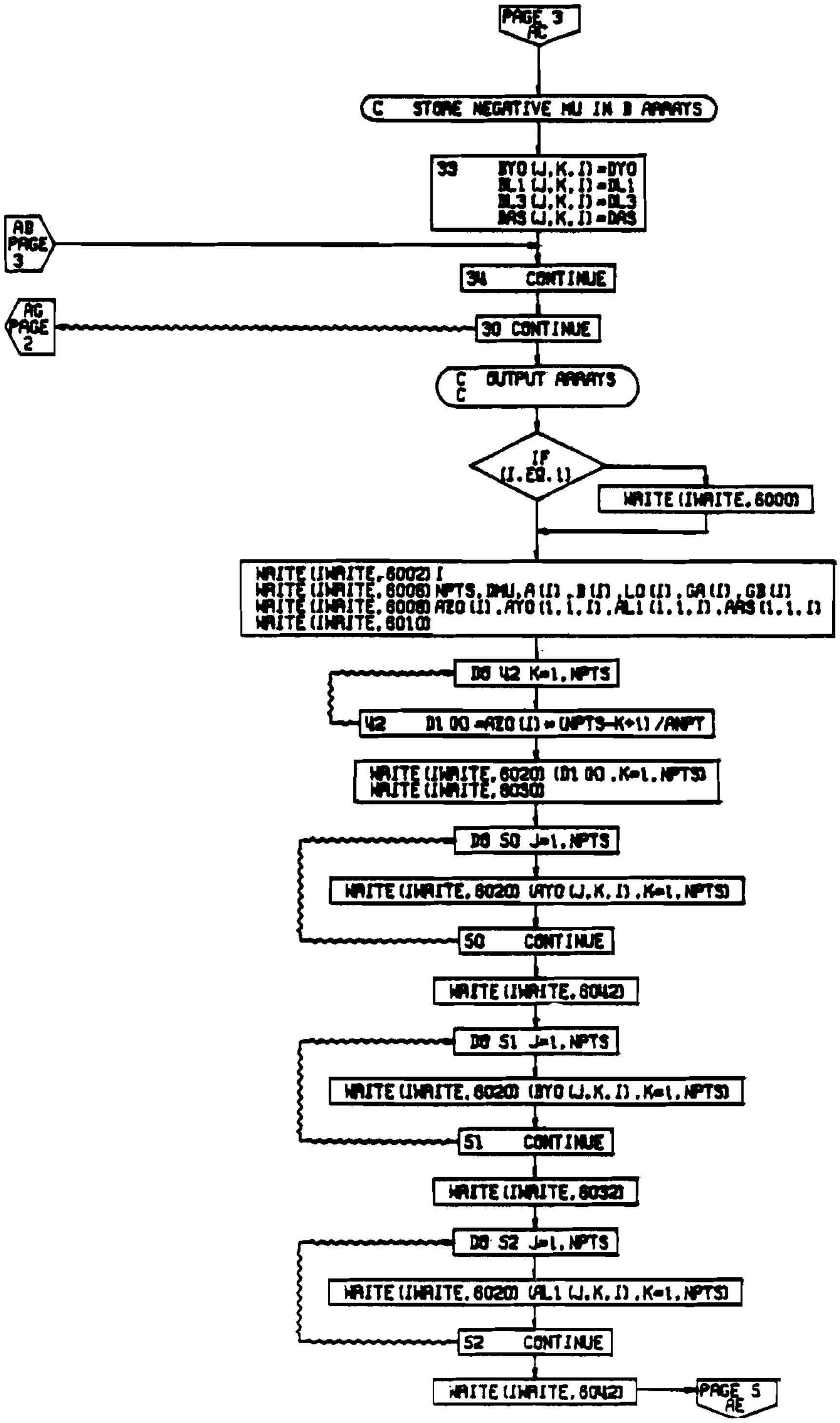
```
IF
(M.EQ.2)
GOTO 33
```

```
C     STORE POSITIVE MU IN A ARRAYS
```

```
AYO(J,K,I)=DYO
AL1(J,K,I)=DL1
AL3(J,K,I)=DL3
AAS(J,K,I)=DAS
GOTO 34
```

PAGE 3
ICB

Table 49: FLOWCHART FOR SUBROUTINE ICB (CONTINUED)



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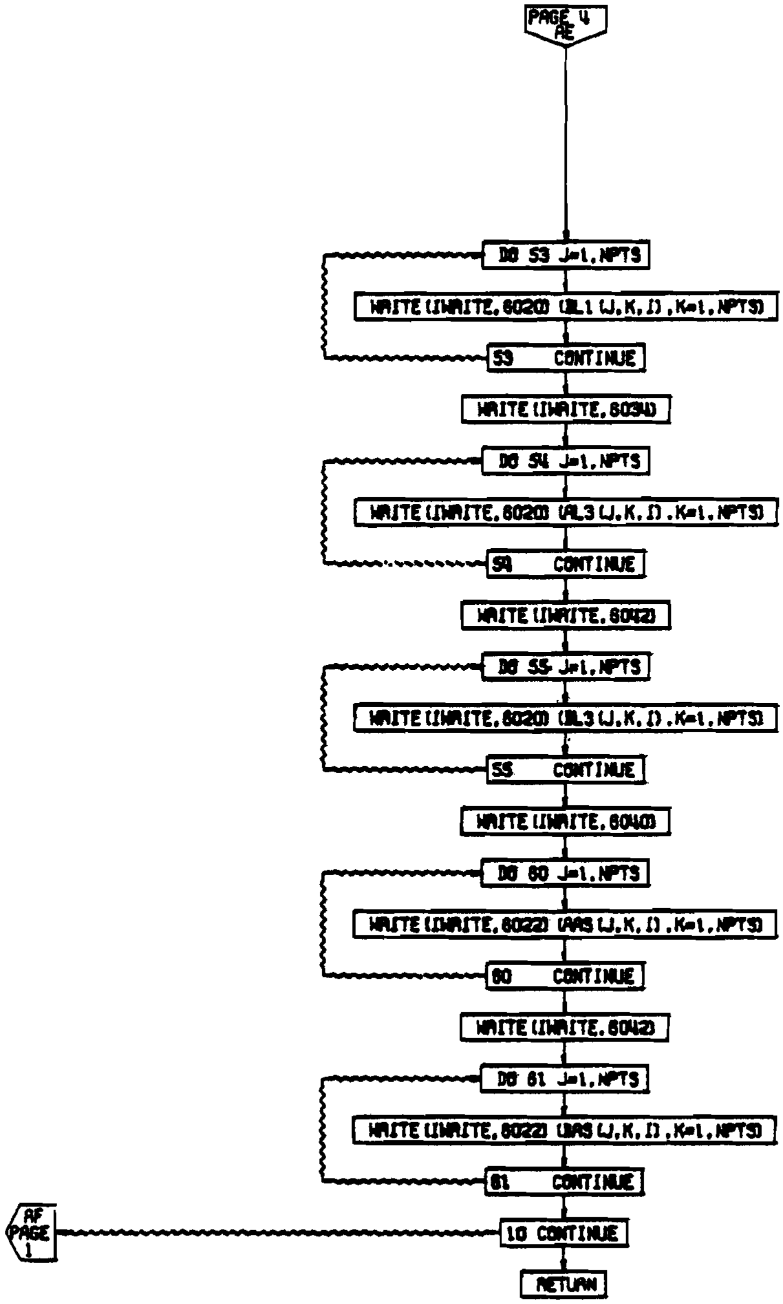
ICB

Table 49: FLOWCHART FOR SUBROUTINE ICB (CONCLUDED)



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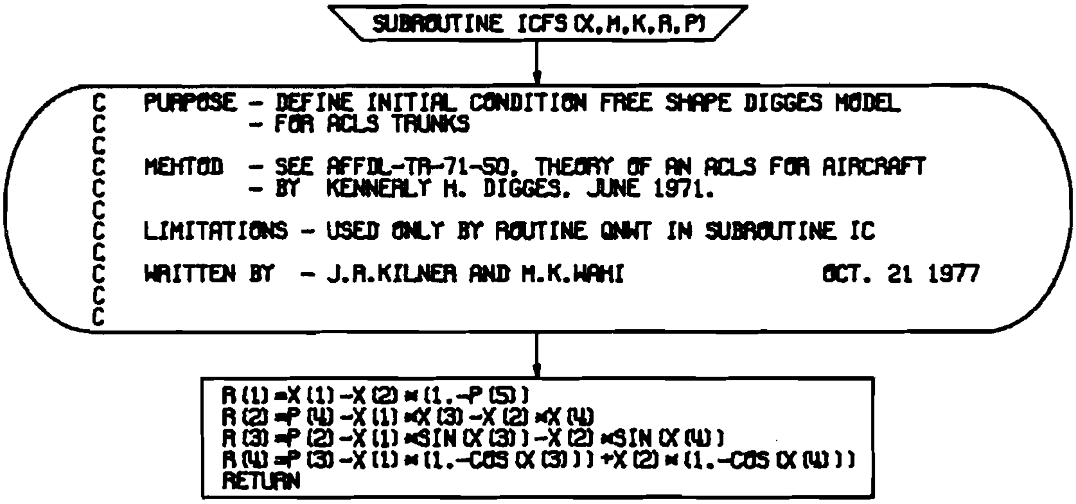
ICB

Table 50: FLOWCHART FOR SUBROUTINE ICFS

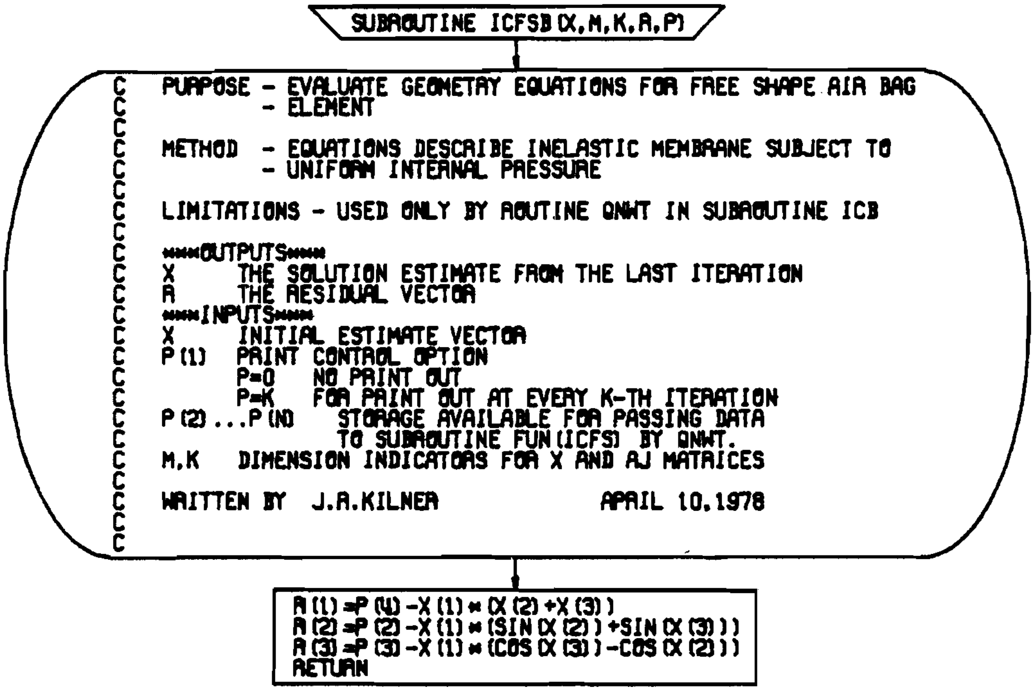


```
SUBROUTINE ICFS(X,M,K,A,P)

C   PURPOSE - DEFINE INITIAL CONDITION FREE SHAPE DIGGES MODEL
C           - FOR ACLS TRUNKS
C
C   MEHTOD  - SEE AFFDL-TR-71-50, THEORY OF AN ACLS FOR AIRCRAFT
C           - BY  KENNERLY H. DIGGES, JUNE 1971.
C
C   LIMITATIONS - USED ONLY BY ROUTINE QNWT IN SUBROUTINE IC
C
C   WRITTEN BY  - J.A.KILNER AND M.K.WAHI               OCT. 21 1977
C
C

A(1)=X(1)-X(2)*(1.-P(5))
A(2)=P(4)-X(1)*X(3)-X(2)*X(4)
A(3)=P(2)-X(1)*SIN(X(3))-X(2)*SIN(X(4))
A(4)=P(3)-X(1)*(1.-COS(X(3)))+X(2)*(1.-COS(X(4)))
RETURN
```

Table 51: FLOWCHART FOR SUBROUTINE ICFSB

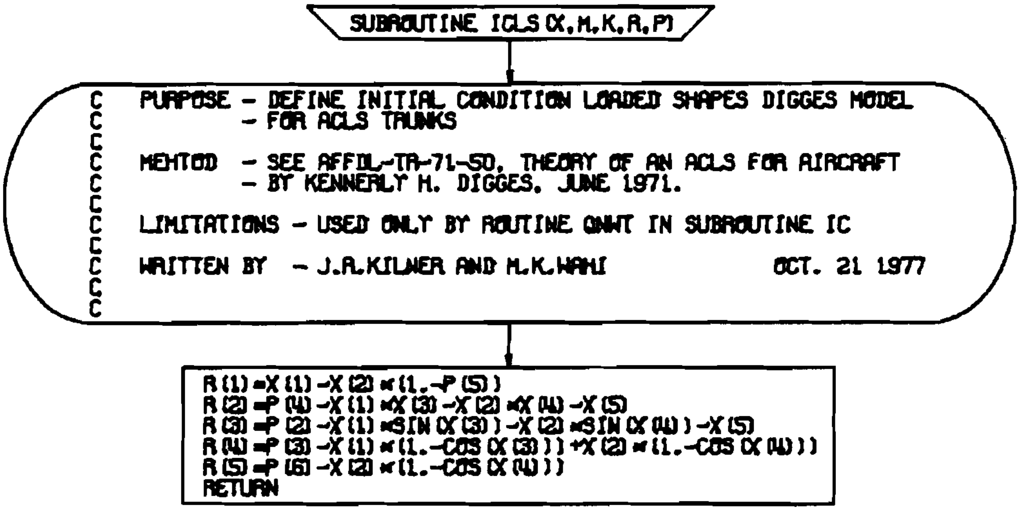


```
SUBROUTINE ICFSB(X,M,K,R,P)

C     PURPOSE - EVALUATE GEOMETRY EQUATIONS FOR FREE SHAPE AIR BAG
C             - ELEMENT
C
C     METHOD  - EQUATIONS DESCRIBE INELASTIC MEMBRANE SUBJECT TO
C             - UNIFORM INTERNAL PRESSURE
C
C     LIMITATIONS - USED ONLY BY ROUTINE QNWT IN SUBROUTINE ICB
C
C     *****OUTPUTS*****
C     X      THE SOLUTION ESTIMATE FROM THE LAST ITERATION
C     R      THE RESIDUAL VECTOR
C     *****INPUTS*****
C     X      INITIAL ESTIMATE VECTOR
C     P(1)   PRINT CONTROL OPTION
C            P=0   NO PRINT OUT
C            P=K   FOR PRINT OUT AT EVERY K-TH ITERATION
C     P(2)...P(N)    STORAGE AVAILABLE FOR PASSING DATA
C                    TO SUBROUTINE FUN(ICFS) BY QNWT.
C     M,K    DIMENSION INDICATORS FOR X AND AJ MATRICES
C
C     WRITTEN BY  J.R.KILNER             APRIL 10,1978
C
C

R(1)=P(1)-X(1)*(X(2)+X(3))
R(2)=P(2)-X(1)*(SIN(X(2))+SIN(X(3)))
R(3)=P(3)-X(1)*(COS(X(3))-COS(X(2)))
RETURN
```

Table 52: FLOWCHART FOR SUBROUTINE ICLS

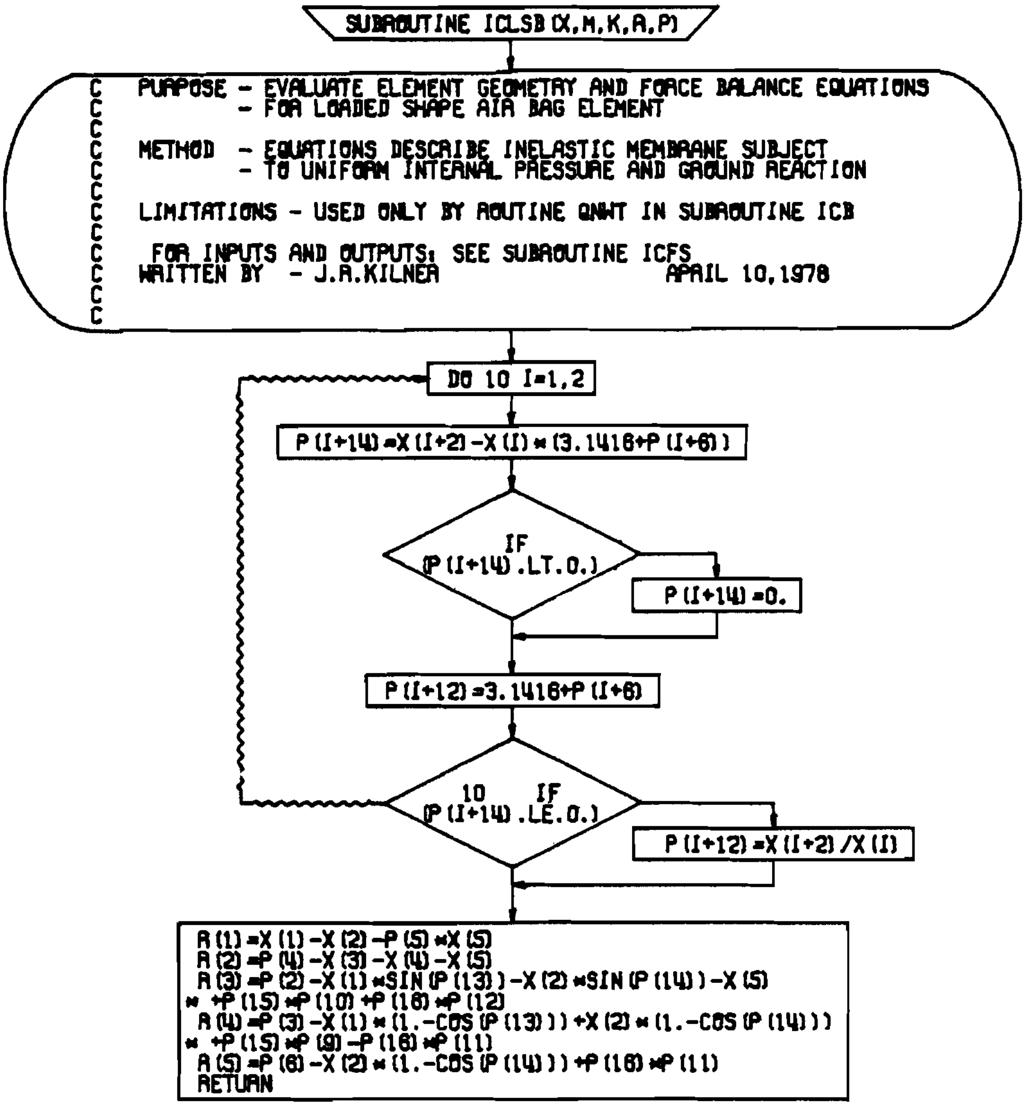


```
SUBROUTINE ICLS(X,M,K,R,P)

C   PURPOSE - DEFINE INITIAL CONDITION LOADED SHAPES DIGGES MODEL
C           - FOR ACLS TRUNKS
C
C   MEHTOD  - SEE AFFDL-TR-71-50, THEORY OF AN ACLS FOR AIRCRAFT
C           - BY KENNERLY H. DIGGES, JUNE 1971.
C
C   LIMITATIONS - USED ONLY BY ROUTINE QNWT IN SUBROUTINE IC
C
C   WRITTEN BY  - J.A.KILNER AND M.K.WAHI              OCT. 21 1977
C
C

R(1)=X(1)-X(2)*(1.-P(5))
R(2)=P(4)-X(1)*X(3)-X(2)*X(4)-X(5)
R(3)=P(2)-X(1)*SIN(X(3))-X(2)*SIN(X(4))-X(5)
R(4)=P(3)-X(1)*(1.-COS(X(3)))+X(2)*(1.-COS(X(4)))
R(5)=P(6)-X(2)*(1.-COS(X(4)))
RETURN
```

Table 53: FLOWCHART FOR SUBROUTINE ICLSB



```
SUBROUTINE ICLSB (X,M,K,A,P)

C     PURPOSE - EVALUATE ELEMENT GEOMETRY AND FORCE BALANCE EQUATIONS
C             - FOR LOADED SHAPE AIR BAG ELEMENT
C
C     METHOD  - EQUATIONS DESCRIBE INELASTIC MEMBRANE SUBJECT
C             - TO UNIFORM INTERNAL PRESSURE AND GROUND REACTION
C
C     LIMITATIONS - USED ONLY BY ROUTINE QNWT IN SUBROUTINE ICB
C
C      FOR INPUTS AND OUTPUTS: SEE SUBROUTINE ICFS
C     WRITTEN BY  - J.R.KILNER                    APRIL 10,1978
C
C

DO 10 I=1,2

P (I+14) =X (I+2) -X (I) * (3.1416+P (I+6) )

IF
(P (I+14) .LT.0.)

P (I+14) =0.

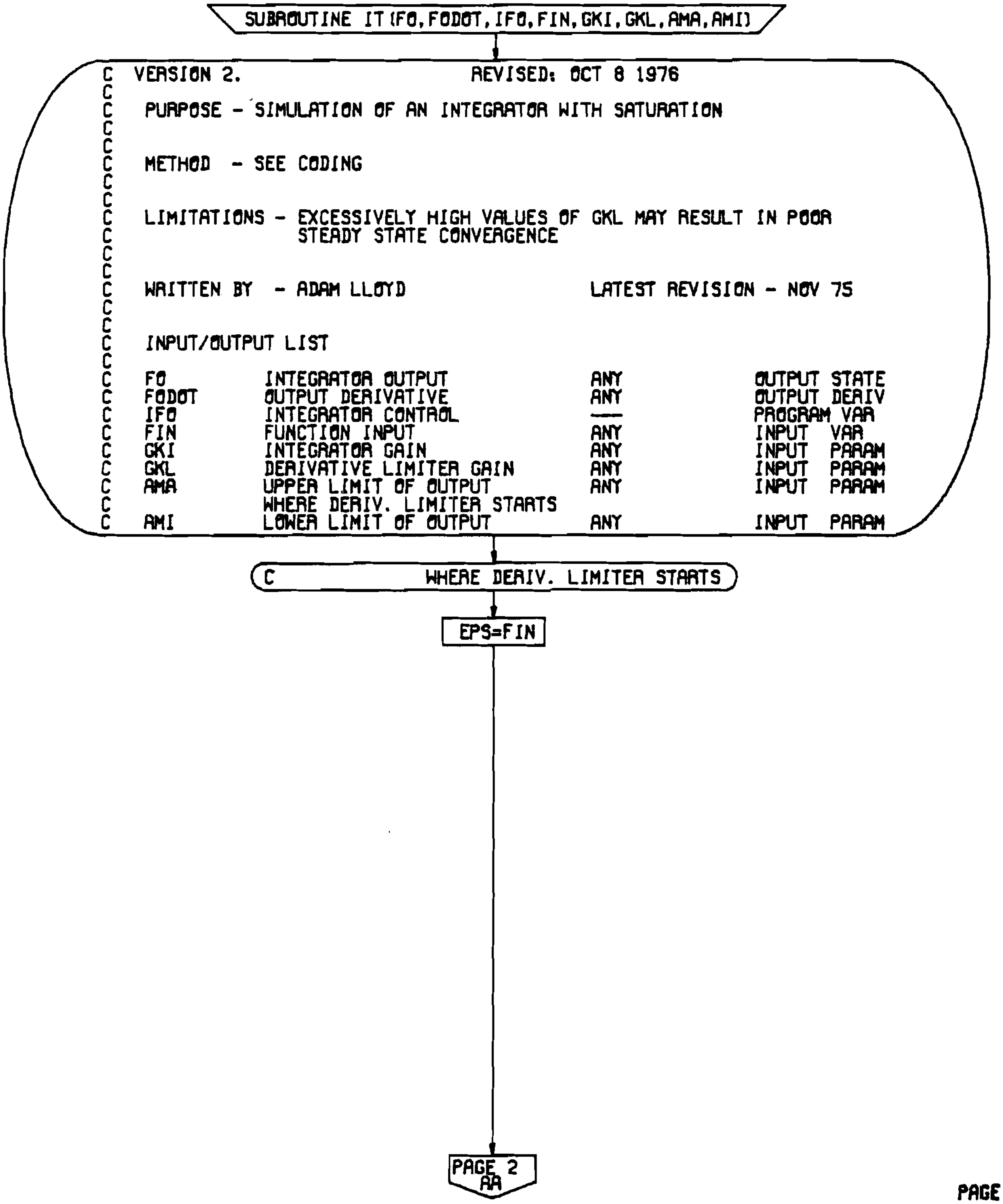
P (I+12) =3.1416+P (I+6)

10    IF
(P (I+14) .LE.0.)

P (I+12) =X (I+2) /X (I)

 A (1) =X (1) -X (2) -P (5) *X (5)
 A (2) =P (4) -X (3) -X (4) -X (5)
 A (3) =P (2) -X (1) *SIN (P (13) ) -X (2) *SIN (P (14) ) -X (5)
*  +P (15) *P (10) +P (16) *P (12)
 A (4) =P (3) -X (1) * (1.-COS (P (13) ) ) +X (2) * (1.-COS (P (14) ) )
*  +P (15) *P (9) -P (16) *P (11)
 A (5) =P (6) -X (2) * (1.-COS (P (14) ) ) +P (16) *P (11)
 RETURN
```

Table 54: FLOWCHART FOR SUBROUTINE IT



```
SUBROUTINE IT(F0,F0DOT,IF0,FIN,GKI,GKL,AMA,AMI)

C  VERSION 2.                            REVISED: OCT 8 1976
C
C   PURPOSE - SIMULATION OF AN INTEGRATOR WITH SATURATION
C
C
C   METHOD  - SEE CODING
C
C
C   LIMITATIONS - EXCESSIVELY HIGH VALUES OF GKL MAY RESULT IN POOR
C                 STEADY STATE CONVERGENCE
C
C
C   WRITTEN BY  - ADAM LLOYD                 LATEST REVISION - NOV 75
C
C
C   INPUT/OUTPUT LIST
C
C   F0         INTEGRATOR OUTPUT             ANY           OUTPUT STATE
C   F0DOT      OUTPUT DERIVATIVE             ANY           OUTPUT DERIV
C   IF0        INTEGRATOR CONTROL            ---           PROGRAM VAR
C   FIN        FUNCTION INPUT                ANY           INPUT  VAR
C   GKI        INTEGRATOR GAIN               ANY           INPUT  PARAM
C   GKL        DERIVATIVE LIMITER GAIN       ANY           INPUT  PARAM
C   AMA        UPPER LIMIT OF OUTPUT         ANY           INPUT  PARAM
C              WHERE DERIV. LIMITER STARTS
C   AMI        LOWER LIMIT OF OUTPUT         ANY           INPUT  PARAM

C                   WHERE DERIV. LIMITER STARTS

EPS=FIN
```

Table 54: FLOWCHART FOR SUBROUTINE IT (CONCLUDED)

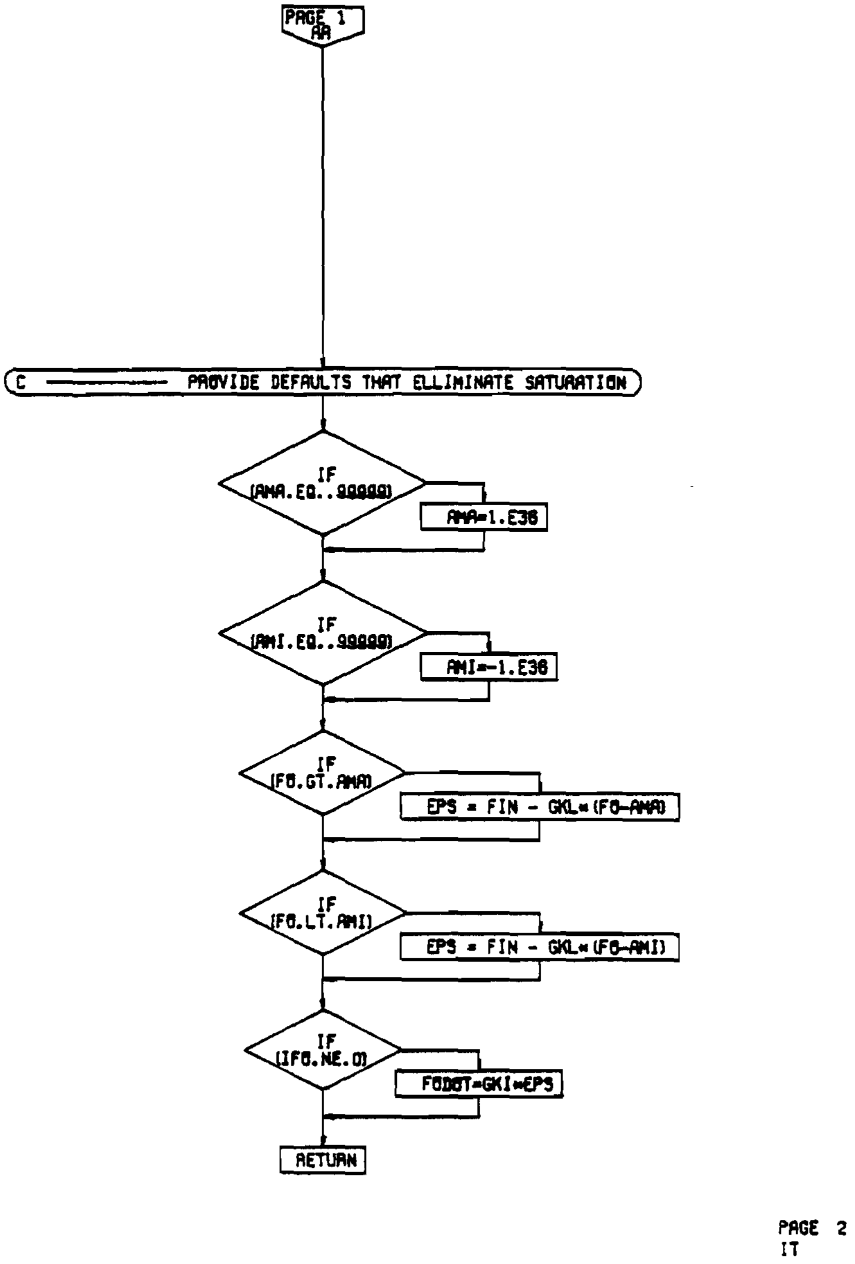
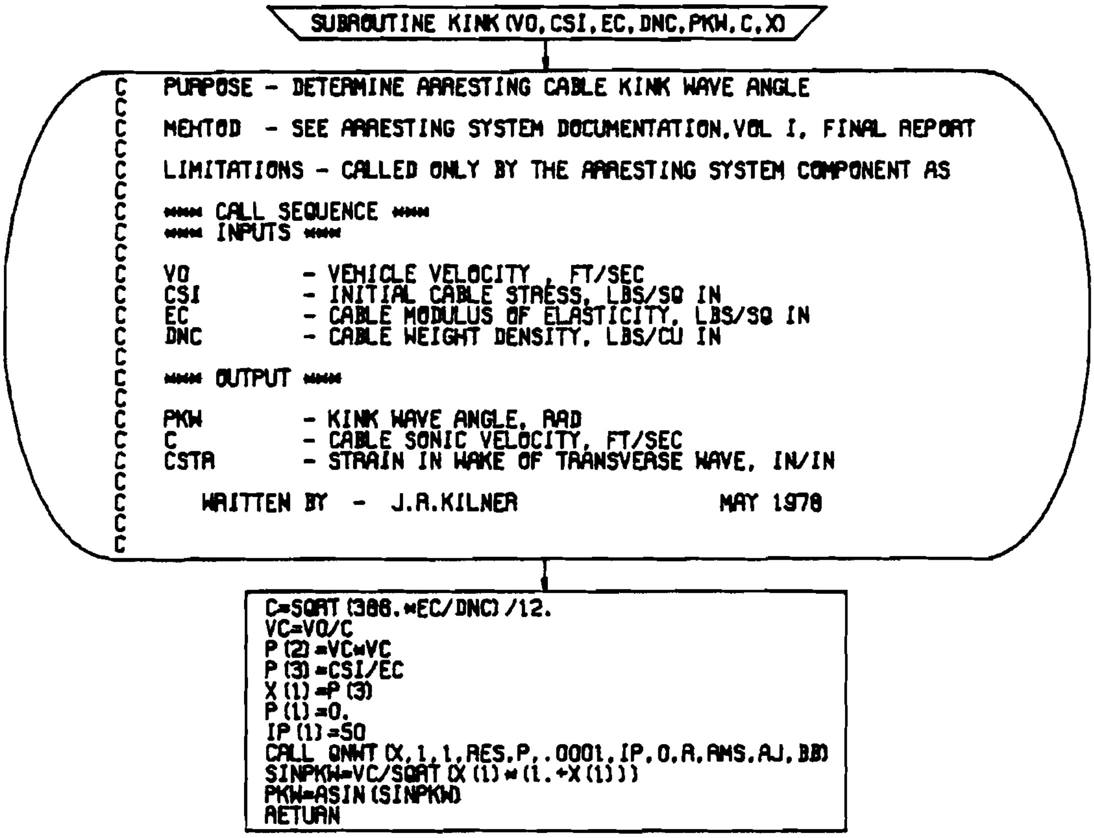


Table 55: FLOWCHART FOR SUBROUTINE KINK

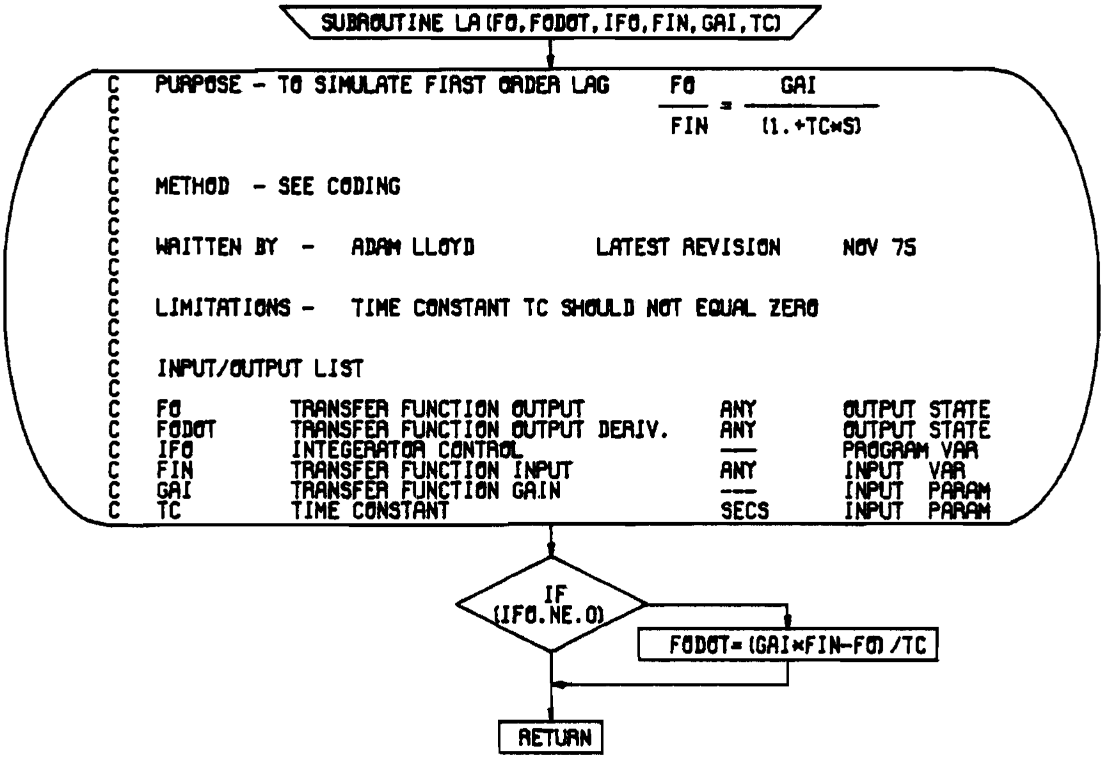


```
SUBROUTINE KINK(VO,CSI,EC,DNC,PKW,C,X)
```

```
C     PURPOSE - DETERMINE ARRESTING CABLE KINK WAVE ANGLE
C
C     MEHTOD  - SEE ARRESTING SYSTEM DOCUMENTATION,VOL I, FINAL REPORT
C
C     LIMITATIONS - CALLED ONLY BY THE ARRESTING SYSTEM COMPONENT AS
C
C     **** CALL SEQUENCE ****
C     **** INPUTS ****
C
C     VO          - VEHICLE VELOCITY  , FT/SEC
C     CSI         - INITIAL CABLE STRESS, LBS/SQ IN
C     EC          - CABLE MODULUS OF ELASTICITY, LBS/SQ IN
C     DNC         - CABLE WEIGHT DENSITY, LBS/CU IN
C
C     **** OUTPUT ****
C
C     PKW         - KINK WAVE ANGLE, RAD
C     C           - CABLE SONIC VELOCITY, FT/SEC
C     CSTR        - STRAIN IN WAKE OF TRANSVERSE WAVE, IN/IN
C
C        WRITTEN BY  -  J.R.KILNER               MAY 1978
C
C
```

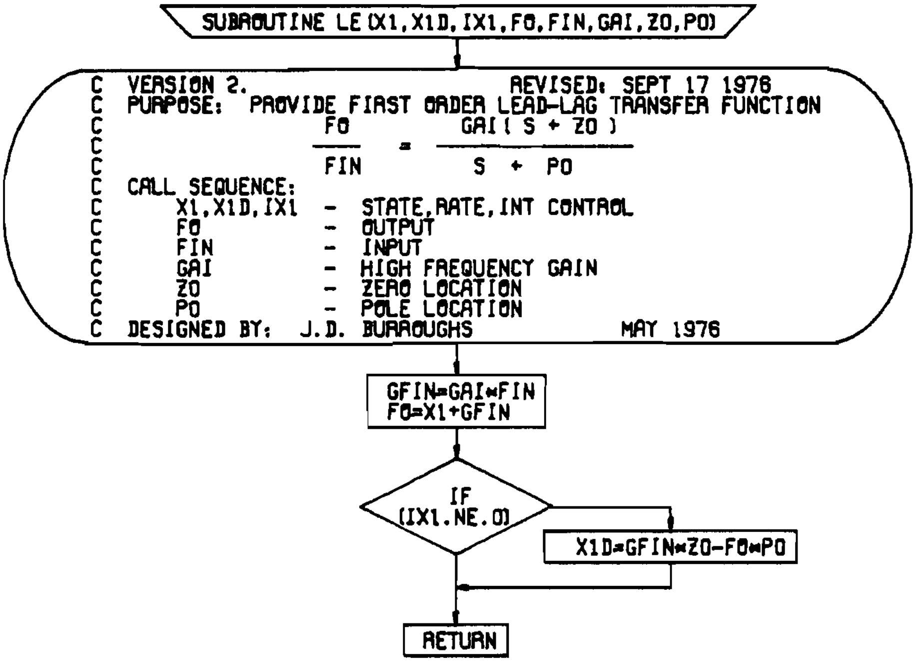
```
C=SQRT(386.*EC/DNC)/12.
VC=VO/C
P(2)=VC*VC
P(3)=CSI/EC
X(1)=P(3)
P(1)=0.
IP(1)=50
CALL  QNWT(X,1,1,RES,P,.0001,IP,0,R,RMS,AJ,BB)
SINPKW=VC/SQRT(X(1)*(1.+X(1)))
PKW=ASIN(SINPKW)
RETURN
```

Table 56: FLOWCHART FOR SUBROUTINE LA



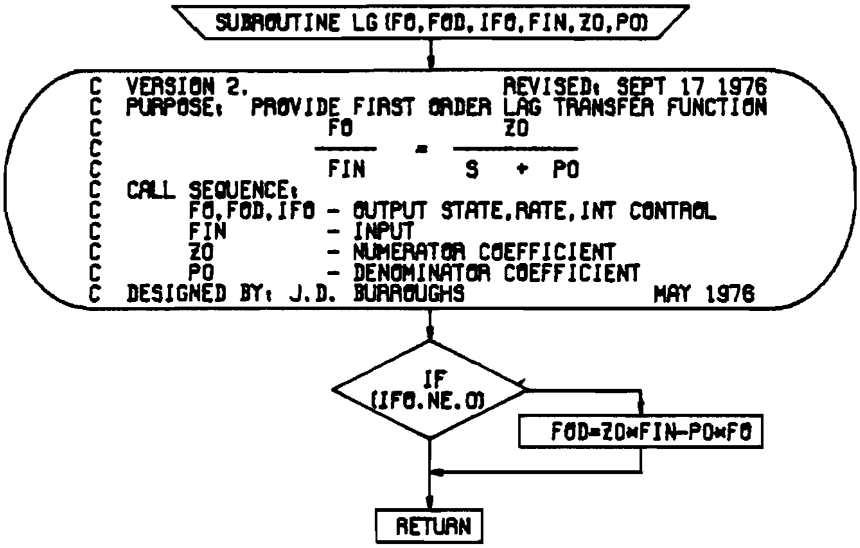
```
C    PURPOSE - TO SIMULATE FIRST ORDER LAG       FO        GAI
C                                               ---- = ----------
C                                               FIN     (1.+TC*S)
C
C
C    METHOD  - SEE CODING
C
C
C    WRITTEN BY  -   ADAM LLOYD          LATEST REVISION     NOV 75
C
C
C    LIMITATIONS -   TIME CONSTANT TC SHOULD NOT EQUAL ZERO
C
C
C    INPUT/OUTPUT LIST
C
C    FO         TRANSFER FUNCTION OUTPUT           ANY       OUTPUT STATE
C    FODOT      TRANSFER FUNCTION OUTPUT DERIV.    ANY       OUTPUT STATE
C    IFO        INTEGERATOR CONTROL                ---       PROGRAM VAR
C    FIN        TRANSFER FUNCTION INPUT            ANY       INPUT   VAR
C    GAI        TRANSFER FUNCTION GAIN             ---       INPUT   PARAM
C    TC         TIME CONSTANT                      SECS      INPUT   PARAM
```

Table 57: FLOWCHART FOR SUBROUTINE LE



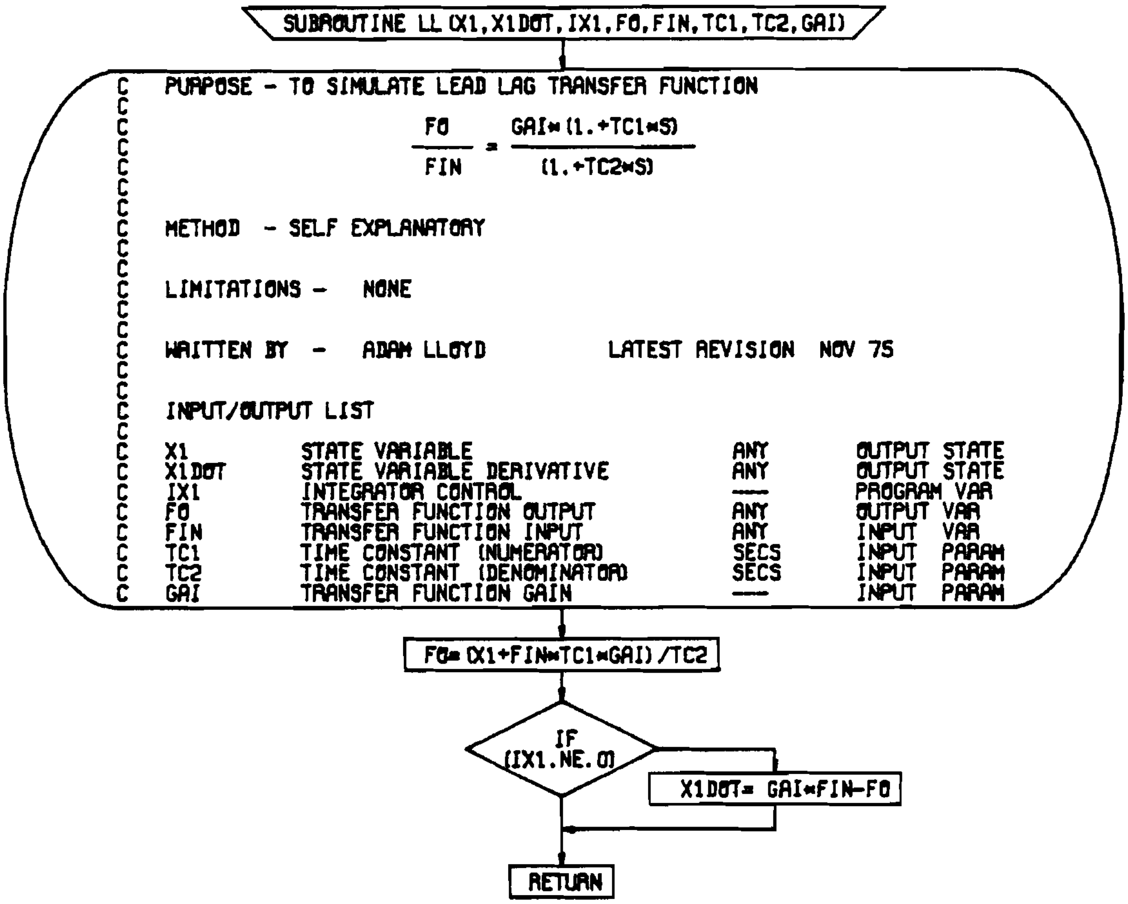
```
C  VERSION 2.                            REVISED: SEPT 17 1976
C  PURPOSE:  PROVIDE FIRST ORDER LEAD-LAG TRANSFER FUNCTION
C                    FO            GAI( S + ZO )
C                   ----    =     ---------------
C                    FIN            S  +  PO
C  CALL SEQUENCE:
C       X1,X1D,IX1   -  STATE,RATE,INT CONTROL
C       FO           -  OUTPUT
C       FIN          -  INPUT
C       GAI          -  HIGH FREQUENCY GAIN
C       ZO           -  ZERO LOCATION
C       PO           -  POLE LOCATION
C  DESIGNED BY:  J.D. BURROUGHS           MAY 1976
```

Table 58: FLOWCHART FOR SUBROUTINE LG



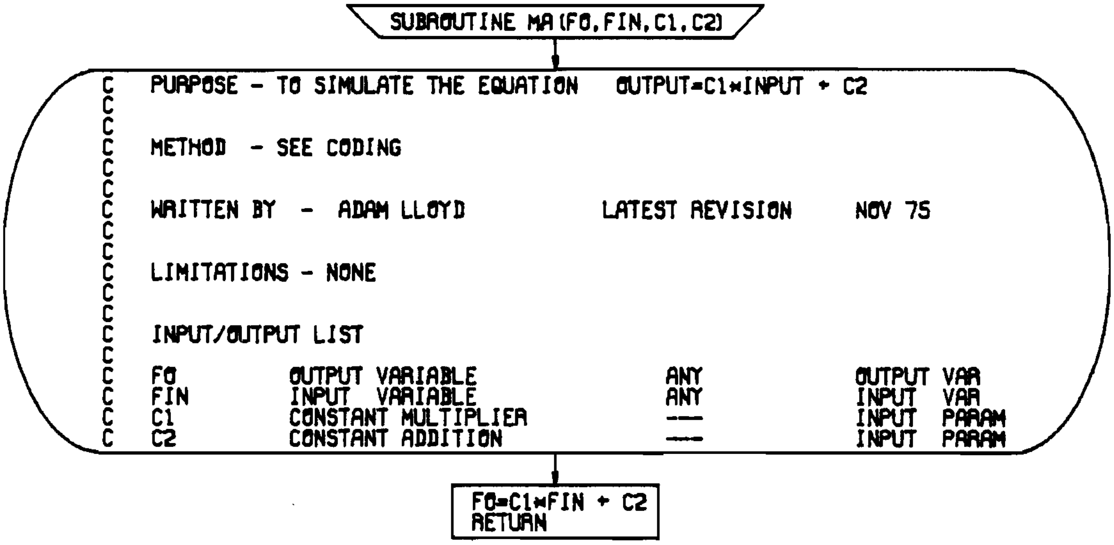
```
SUBROUTINE LG(FO,FOD,IFO,FIN,ZO,PO)
C  VERSION 2.                         REVISED: SEPT 17 1976
C  PURPOSE:  PROVIDE FIRST ORDER LAG TRANSFER FUNCTION
C                 FO               ZO
C               -----    =     ----------
C                FIN           S   +  PO
C  CALL SEQUENCE:
C         FO,FOD,IFO - OUTPUT STATE,RATE,INT CONTROL
C         FIN        - INPUT
C         ZO         - NUMERATOR COEFFICIENT
C         PO         - DENOMINATOR COEFFICIENT
C  DESIGNED BY: J.D. BURROUGHS                  MAY 1976
```

Table 59: FLOWCHART FOR SUBROUTINE LL



```
C    PURPOSE - TO SIMULATE LEAD LAG TRANSFER FUNCTION
C
C                          FO      GAI* (1.+TC1*S)
C                         ----  =  ---------------
C                         FIN        (1.+TC2*S)
C
C
C    METHOD  - SELF EXPLANATORY
C
C
C    LIMITATIONS -   NONE
C
C
C    WRITTEN BY  -   ADAM LLOYD          LATEST REVISION  NOV 75
C
C
C    INPUT/OUTPUT LIST
C
C    X1        STATE VARIABLE                        ANY       OUTPUT STATE
C    X1DOT     STATE VARIABLE DERIVATIVE             ANY       OUTPUT STATE
C    IX1       INTEGRATOR CONTROL                    ---       PROGRAM VAR
C    FO        TRANSFER FUNCTION OUTPUT              ANY       OUTPUT VAR
C    FIN       TRANSFER FUNCTION INPUT               ANY       INPUT  VAR
C    TC1       TIME CONSTANT  (NUMERATOR)            SECS      INPUT  PARAM
C    TC2       TIME CONSTANT  (DENOMINATOR)          SECS      INPUT  PARAM
C    GAI       TRANSFER FUNCTION GAIN                ---       INPUT  PARAM
```

Table 60: FLOWCHART FOR SUBROUTINE MA

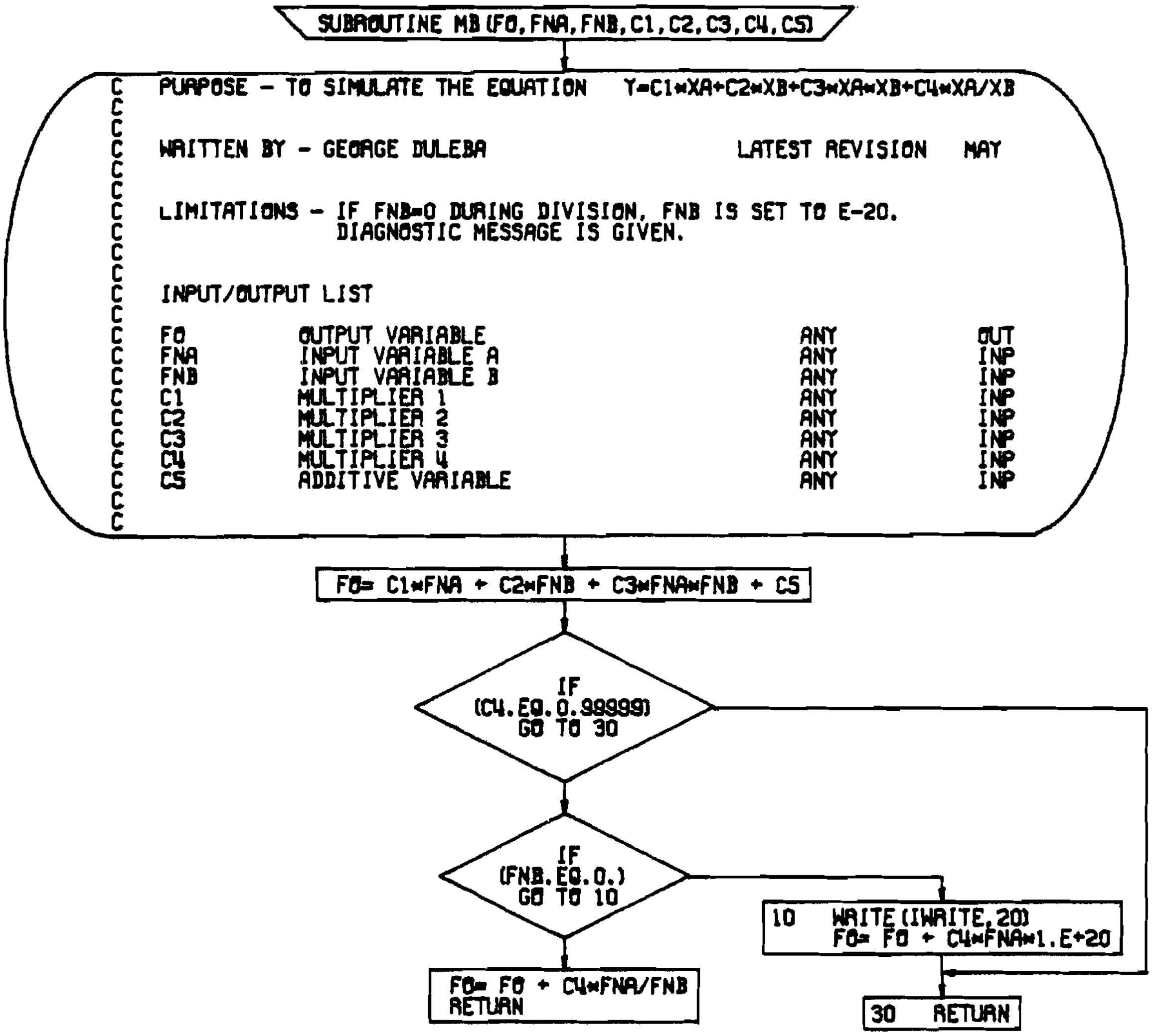


```
SUBROUTINE MA(FO,FIN,C1,C2)

C     PURPOSE - TO SIMULATE THE EQUATION   OUTPUT=C1*INPUT + C2
C
C
C     METHOD  - SEE CODING
C
C
C     WRITTEN BY  -  ADAM LLOYD          LATEST REVISION     NOV 75
C
C
C     LIMITATIONS - NONE
C
C
C     INPUT/OUTPUT LIST
C
C     FO          OUTPUT VARIABLE          ANY          OUTPUT VAR
C     FIN         INPUT  VARIABLE          ANY          INPUT  VAR
C     C1          CONSTANT MULTIPLIER      ---          INPUT  PARAM
C     C2          CONSTANT ADDITION        ---          INPUT  PARAM

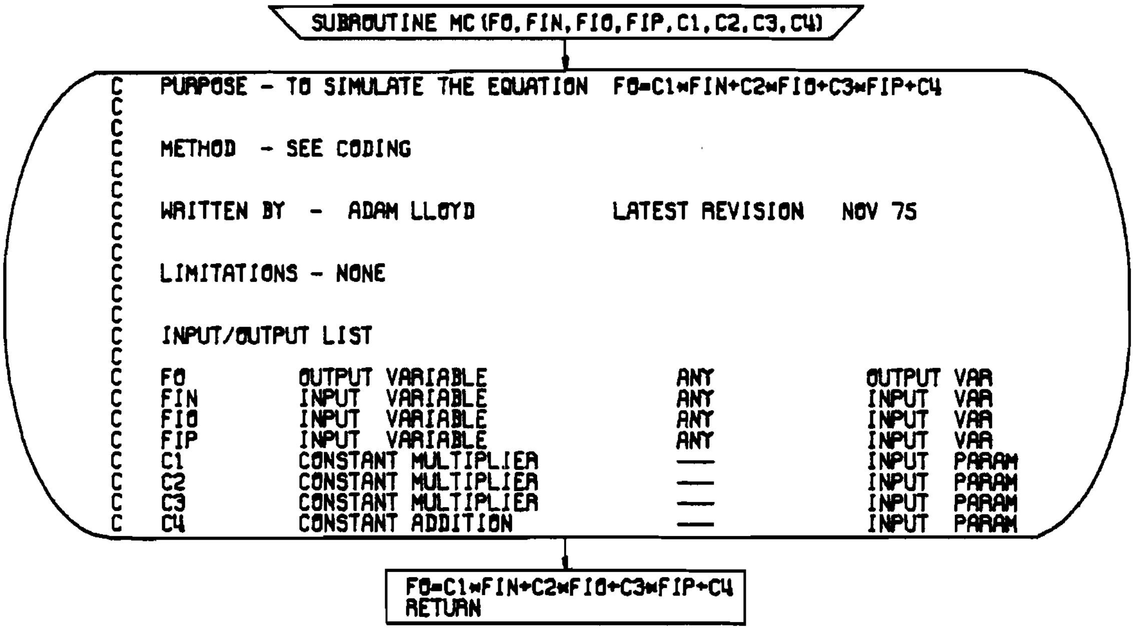
FO=C1*FIN + C2
RETURN
```

Table 61: FLOWCHART FOR SUBROUTINE MB



```
C     PURPOSE - TO SIMULATE THE EQUATION    Y=C1*XA+C2*XB+C3*XA*XB+C4*XA/XB
C
C
C     WRITTEN BY - GEORGE DULEBA                    LATEST REVISION    MAY
C
C
C     LIMITATIONS - IF FNB=0 DURING DIVISION, FNB IS SET TO E-20.
C                   DIAGNOSTIC MESSAGE IS GIVEN.
C
C
C     INPUT/OUTPUT LIST
C
C     F0         OUTPUT VARIABLE                         ANY           OUT
C     FNA        INPUT VARIABLE A                        ANY           INP
C     FNB        INPUT VARIABLE B                        ANY           INP
C     C1         MULTIPLIER 1                            ANY           INP
C     C2         MULTIPLIER 2                            ANY           INP
C     C3         MULTIPLIER 3                            ANY           INP
C     C4         MULTIPLIER 4                            ANY           INP
C     C5         ADDITIVE VARIABLE                       ANY           INP
C
C
```

Table 62: FLOWCHART FOR SUBROUTINE MC



```
SUBROUTINE MC(F0,FIN,FI0,FIP,C1,C2,C3,C4)

C     PURPOSE - TO SIMULATE THE EQUATION  F0=C1*FIN+C2*FI0+C3*FIP+C4
C
C
C     METHOD  - SEE CODING
C
C
C     WRITTEN BY  -  ADAM LLOYD          LATEST REVISION   NOV 75
C
C
C     LIMITATIONS - NONE
C
C
C     INPUT/OUTPUT LIST
C
C     F0         OUTPUT VARIABLE                 ANY             OUTPUT VAR
C     FIN        INPUT  VARIABLE                 ANY             INPUT  VAR
C     FI0        INPUT  VARIABLE                 ANY             INPUT  VAR
C     FIP        INPUT  VARIABLE                 ANY             INPUT  VAR
C     C1         CONSTANT MULTIPLIER             ---             INPUT  PARAM
C     C2         CONSTANT MULTIPLIER             ---             INPUT  PARAM
C     C3         CONSTANT MULTIPLIER             ---             INPUT  PARAM
C     C4         CONSTANT ADDITION               ---             INPUT  PARAM

F0=C1*FIN+C2*FI0+C3*FIP+C4
RETURN
```

Table 63: FLOWCHART FOR SUBROUTINE MG

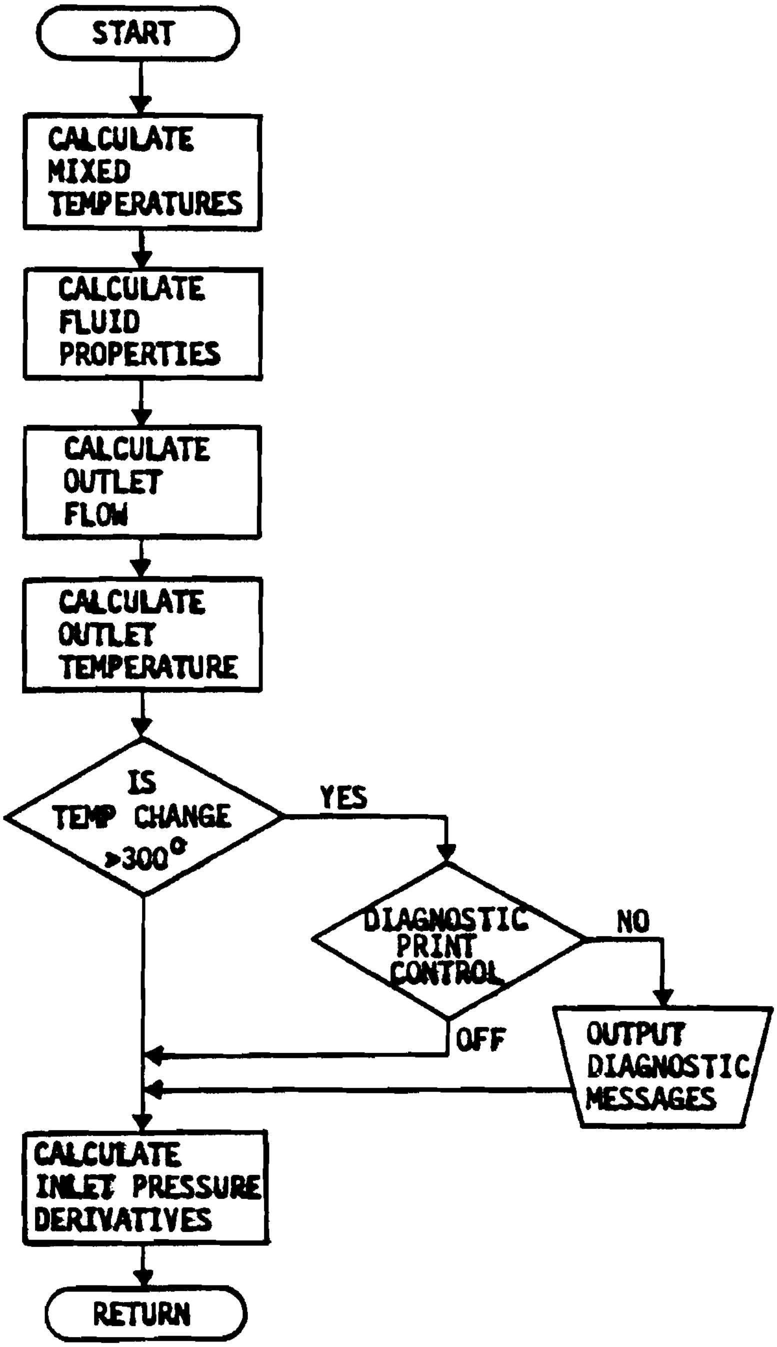
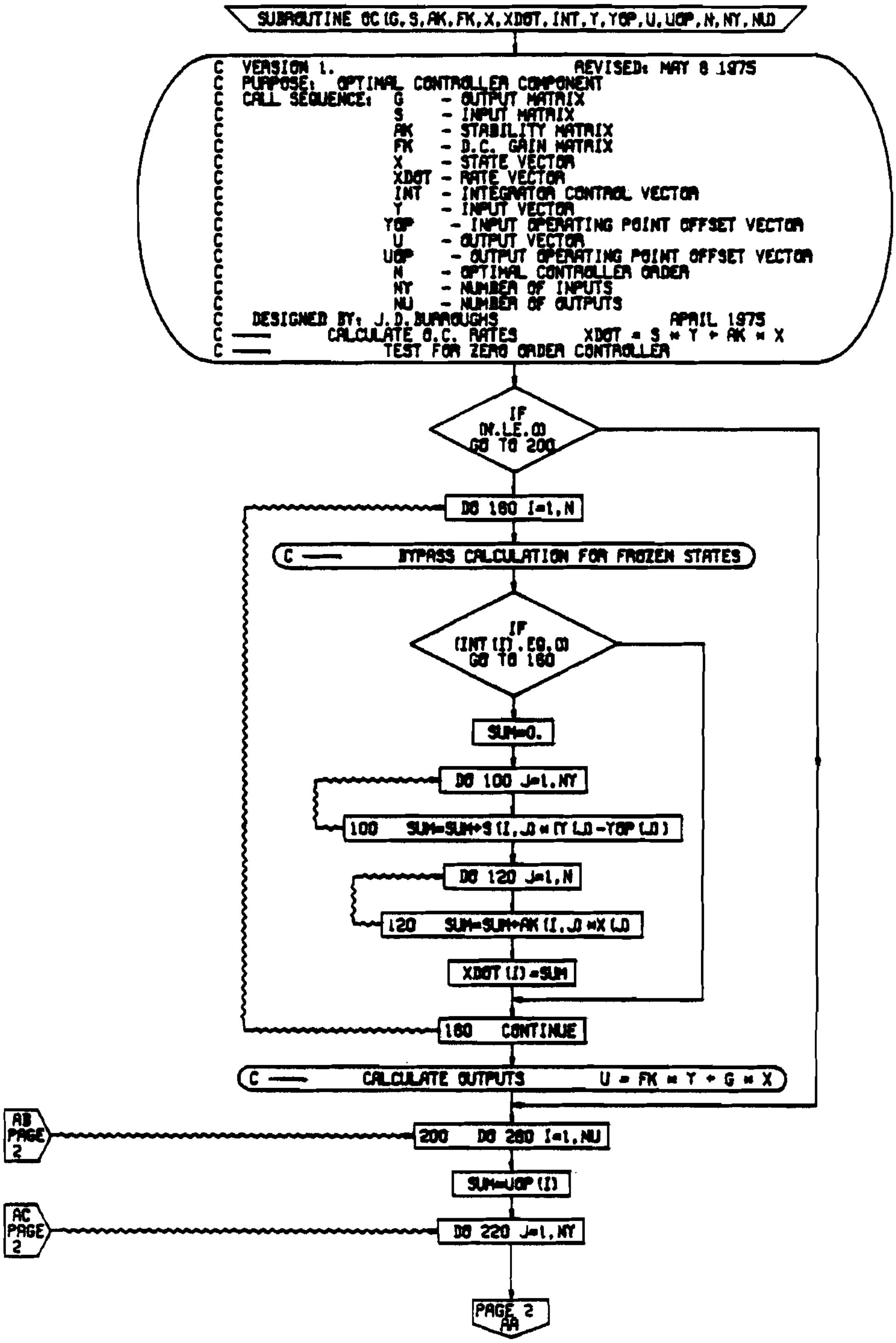


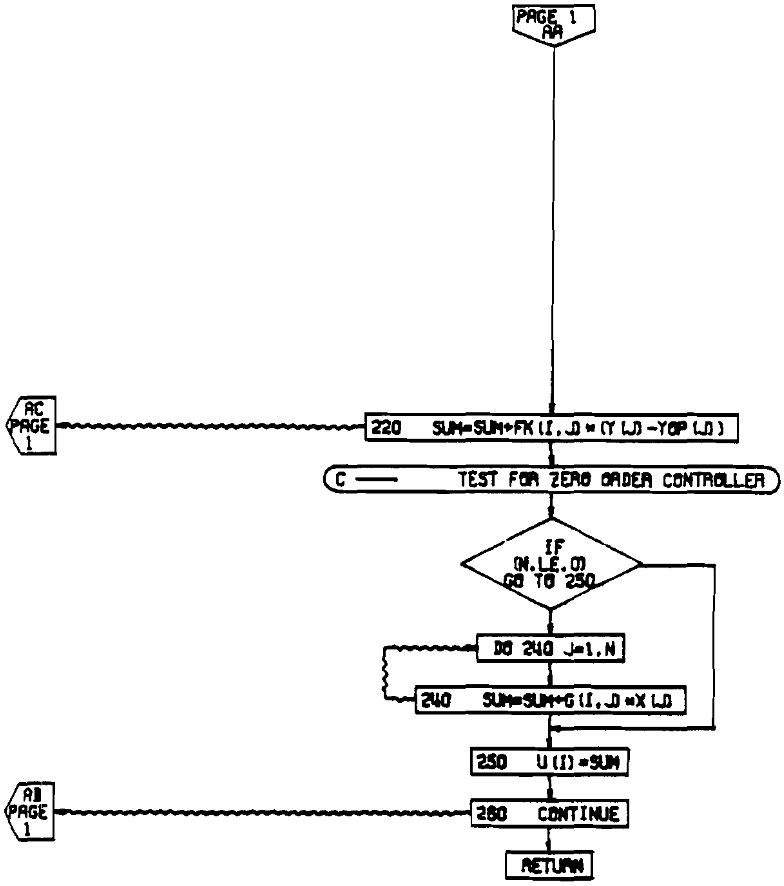
Table 64: FLOWCHART FOR SUBROUTINE OC



```
C   VERSION 1.                                REVISED: MAY 8 1975
C   PURPOSE:  OPTIMAL CONTROLLER COMPONENT
C   CALL SEQUENCE:  G     - OUTPUT MATRIX
C                   S     - INPUT MATRIX
C                   AK    - STABILITY MATRIX
C                   FK    - D.C. GAIN MATRIX
C                   X     - STATE VECTOR
C                   XDOT  - RATE VECTOR
C                   INT   - INTEGRATOR CONTROL VECTOR
C                   Y     - INPUT VECTOR
C                  YOP     - INPUT OPERATING POINT OFFSET VECTOR
C                   U     - OUTPUT VECTOR
C                  UOP     - OUTPUT OPERATING POINT OFFSET VECTOR
C                   N     - OPTIMAL CONTROLLER ORDER
C                   NY    - NUMBER OF INPUTS
C                   NU    - NUMBER OF OUTPUTS
C    DESIGNED BY: J.D.BURROUGHS                          APRIL 1975
C ——        CALCULATE O.C. RATES        XDOT = S * Y + AK * X
C ——                TEST FOR ZERO ORDER CONTROLLER
```

PAGE 1
OC

Table 64: FLOWCHART FOR SUBROUTINE OC (CONCLUDED)



PAGE 2
OC

Table 65: FLOWCHART FOR SUBROUTINE OL

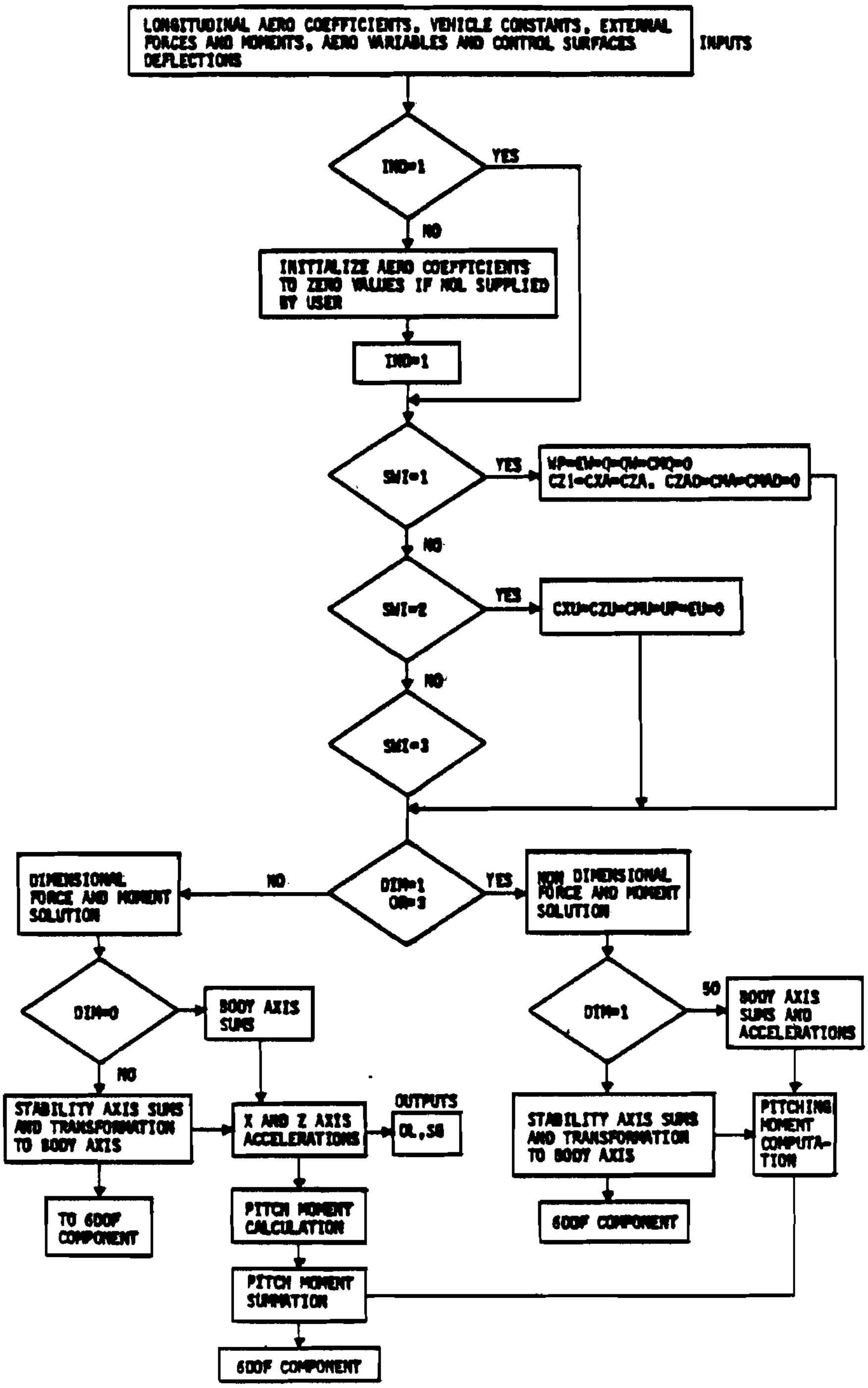
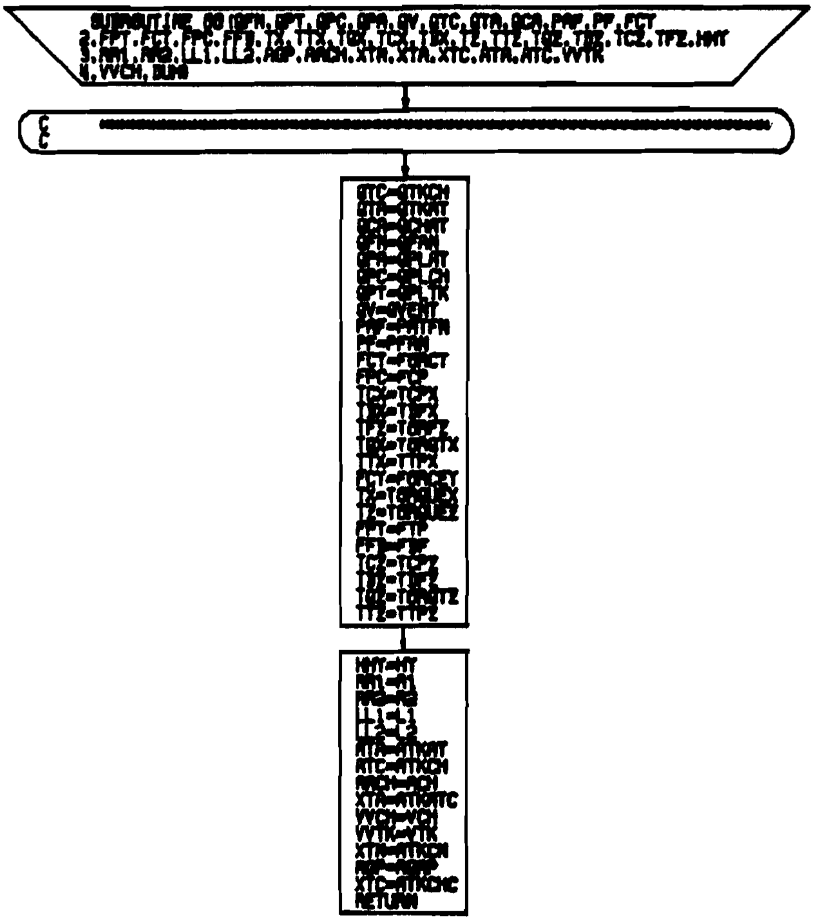


Table 66: FLOWCHART FOR SUBROUTINE OO



PAGE 1
OO

Table 67: FLOWCHART FOR SUBROUTINE OUTFM

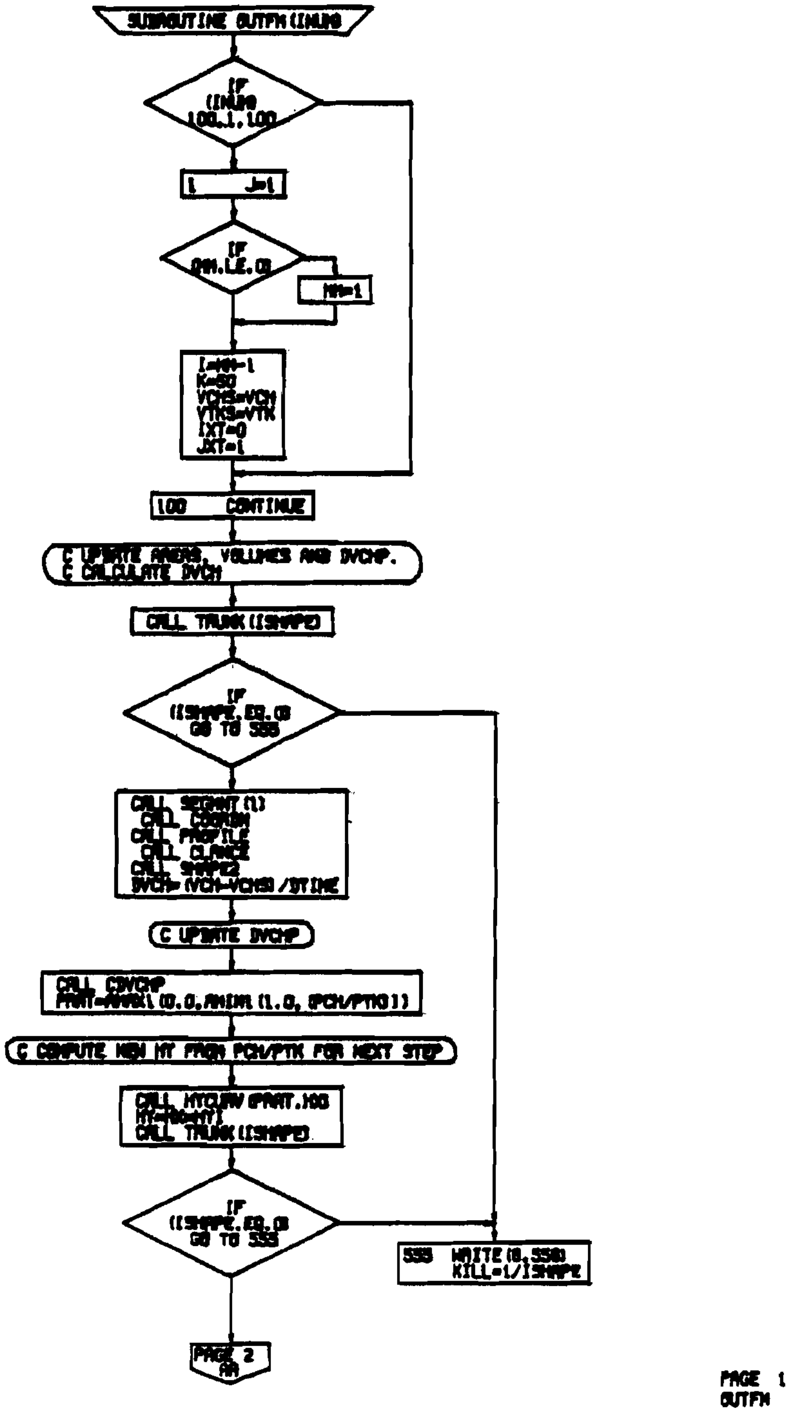


Table 67: FLOWCHART FOR SUBROUTINE OUTFM (CONTINUED)

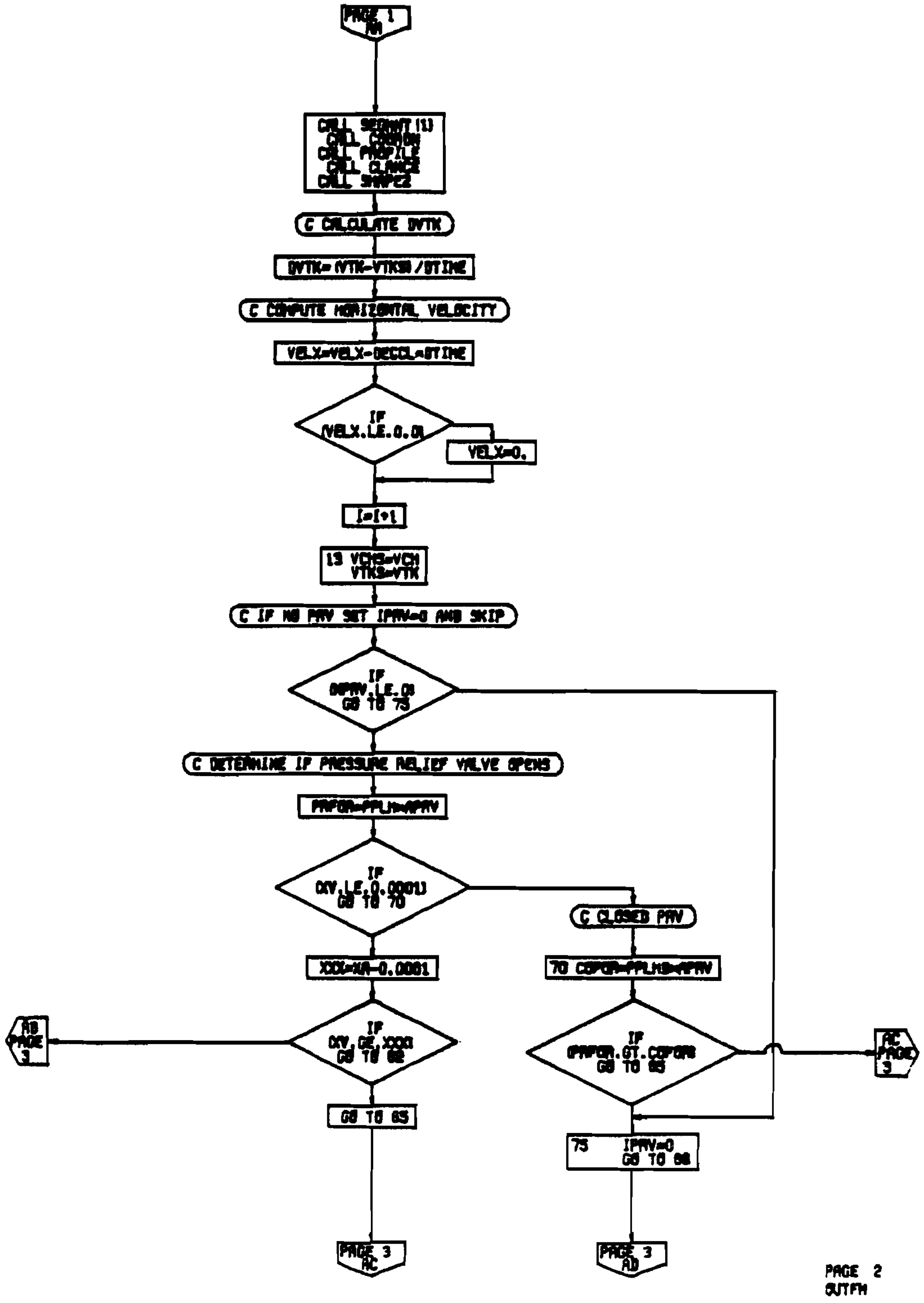


Table 67: FLOWCHART FOR SUBROUTINE OUTFM (CONCLUDED)

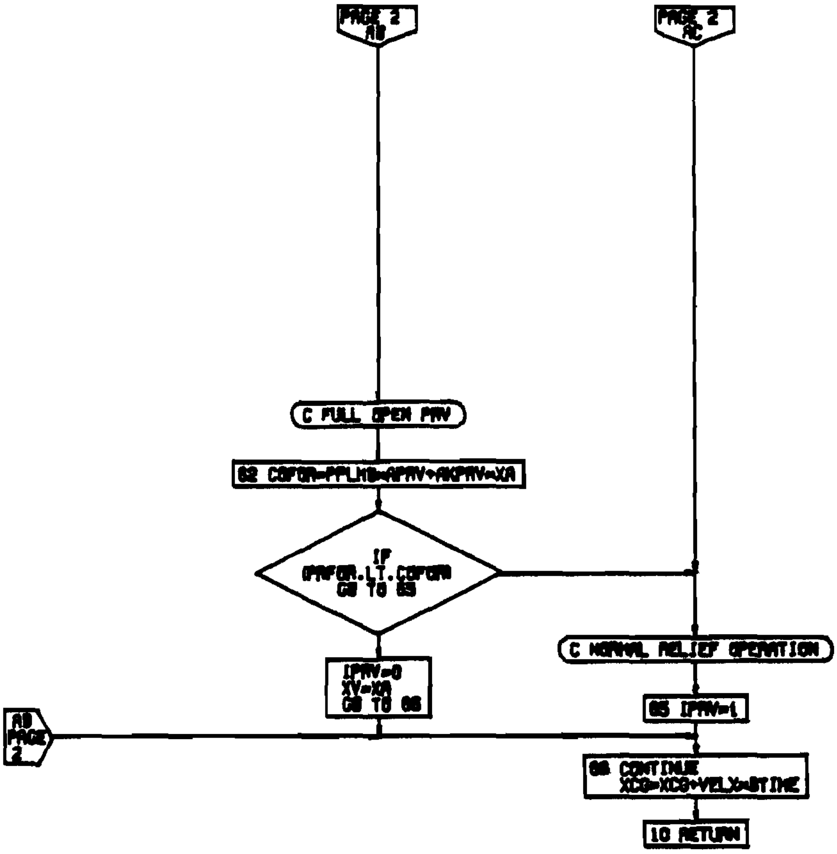
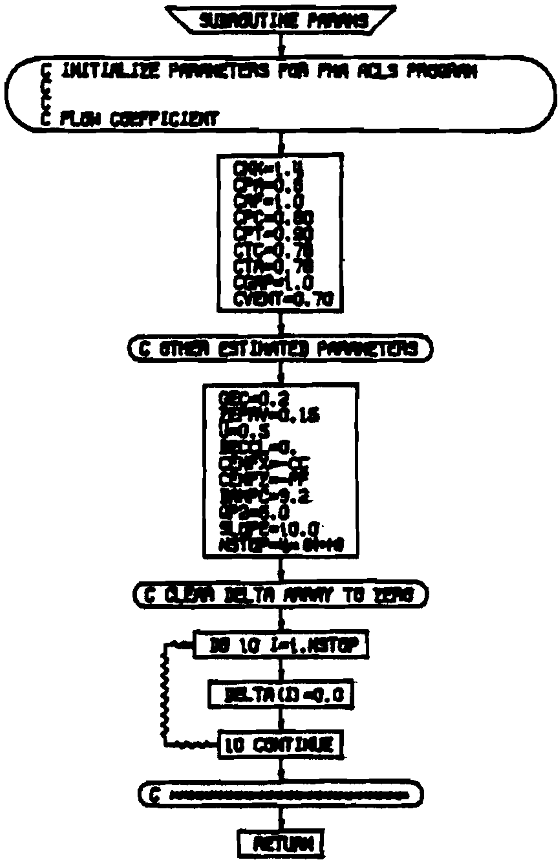


Table 68: FLOWCHART FOR SUBROUTINE PARAMS



PAGE 1
PARAMS

Table 69: FLOWCHART FOR SUBROUTINE PERF

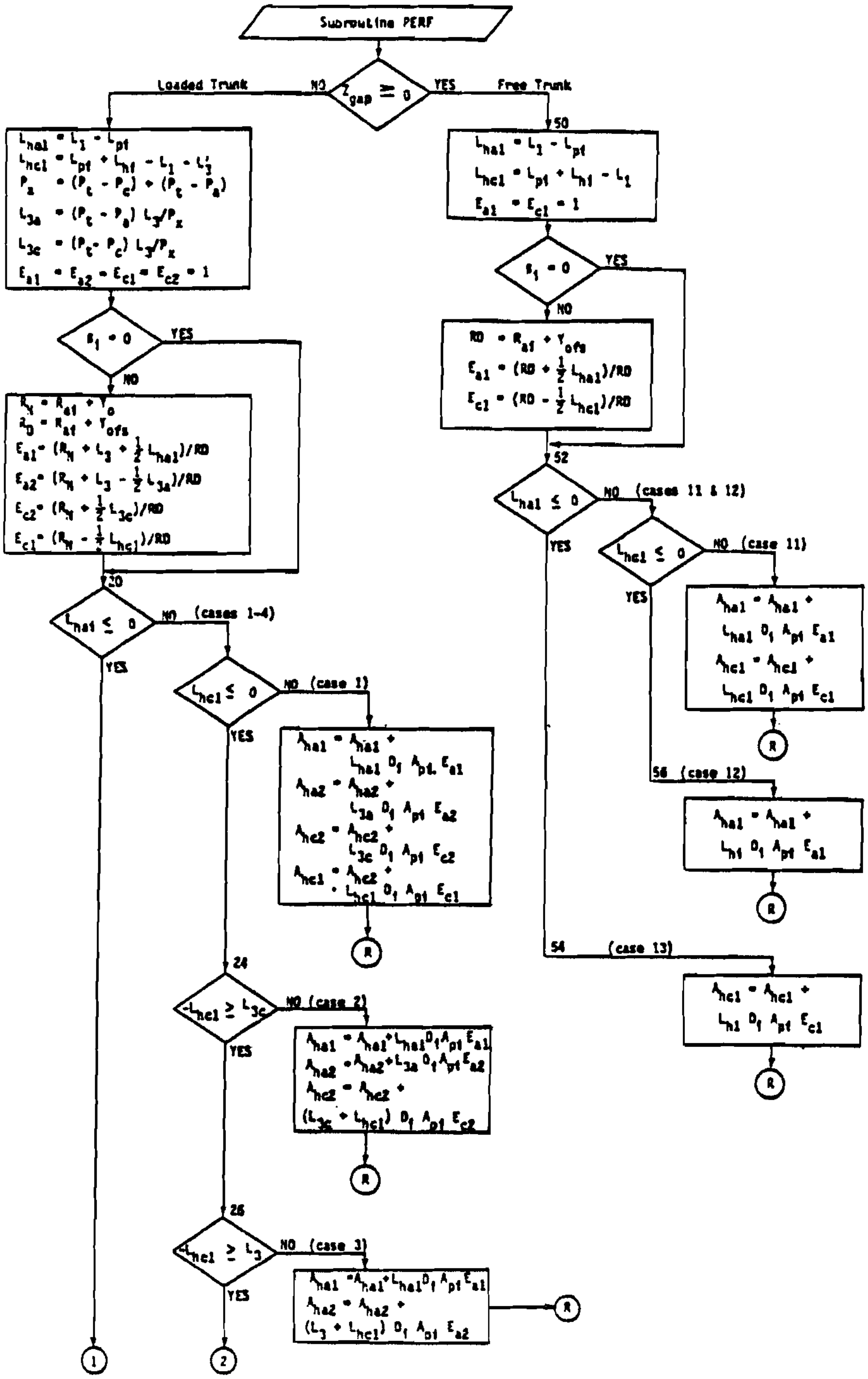


Table 69: FLOWCHART FOR SUBROUTINE PERF (CONCLUDED)

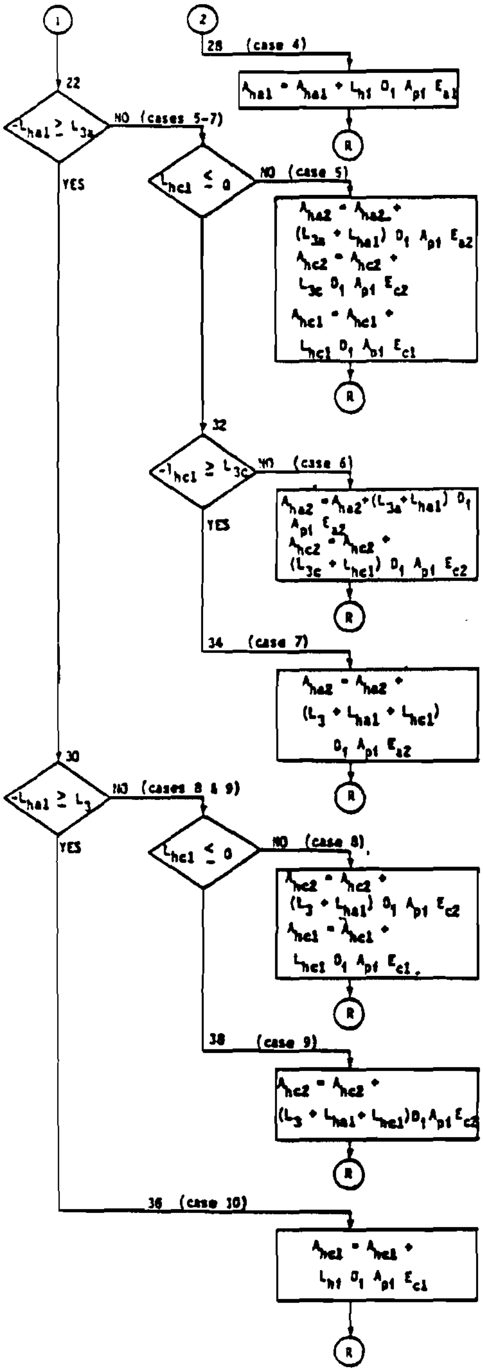


Table 70: FLOWCHART FOR SUBROUTINE PERFB

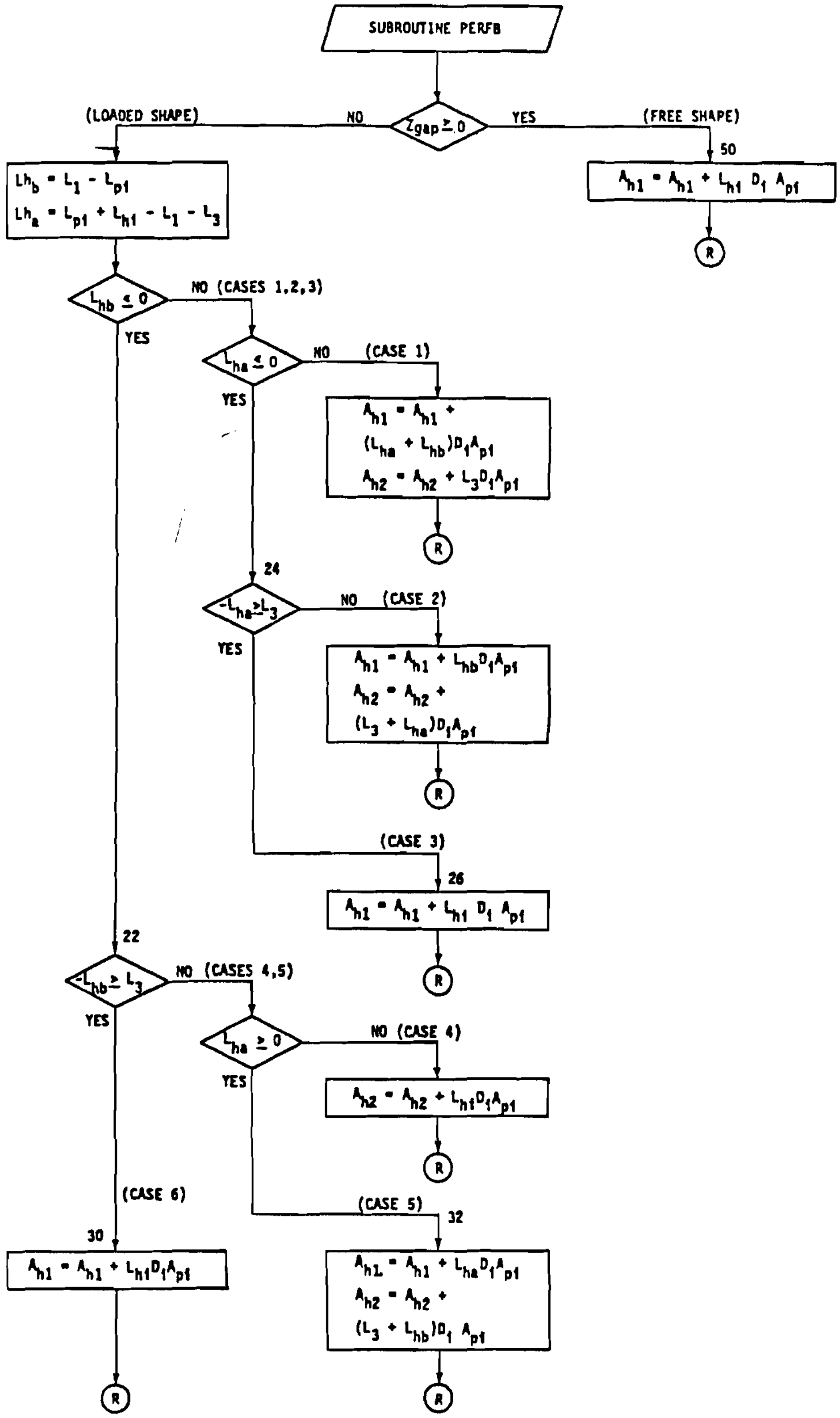


Table 71: FLOWCHART FOR SUBROUTINE PRND

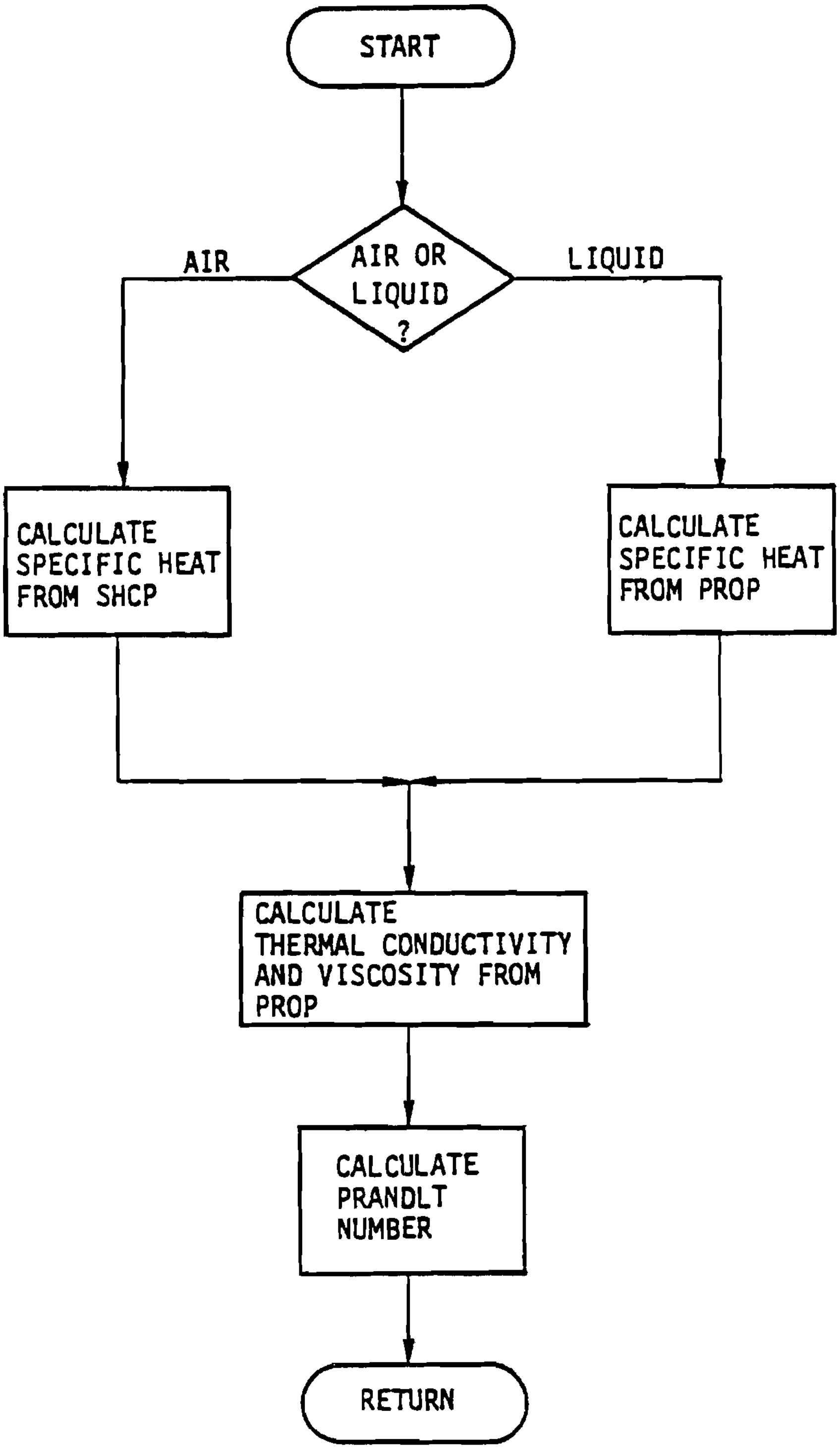


Table 72: FLOWCHART FOR SUBROUTINE PROFILE

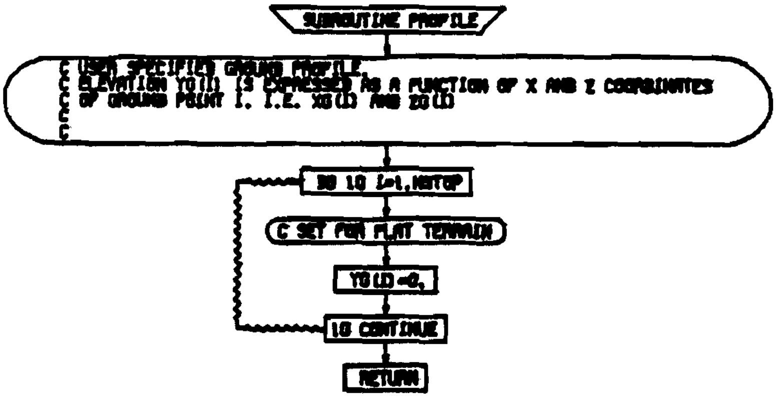


Table 73: FLOWCHART FOR SUBROUTINE PROP

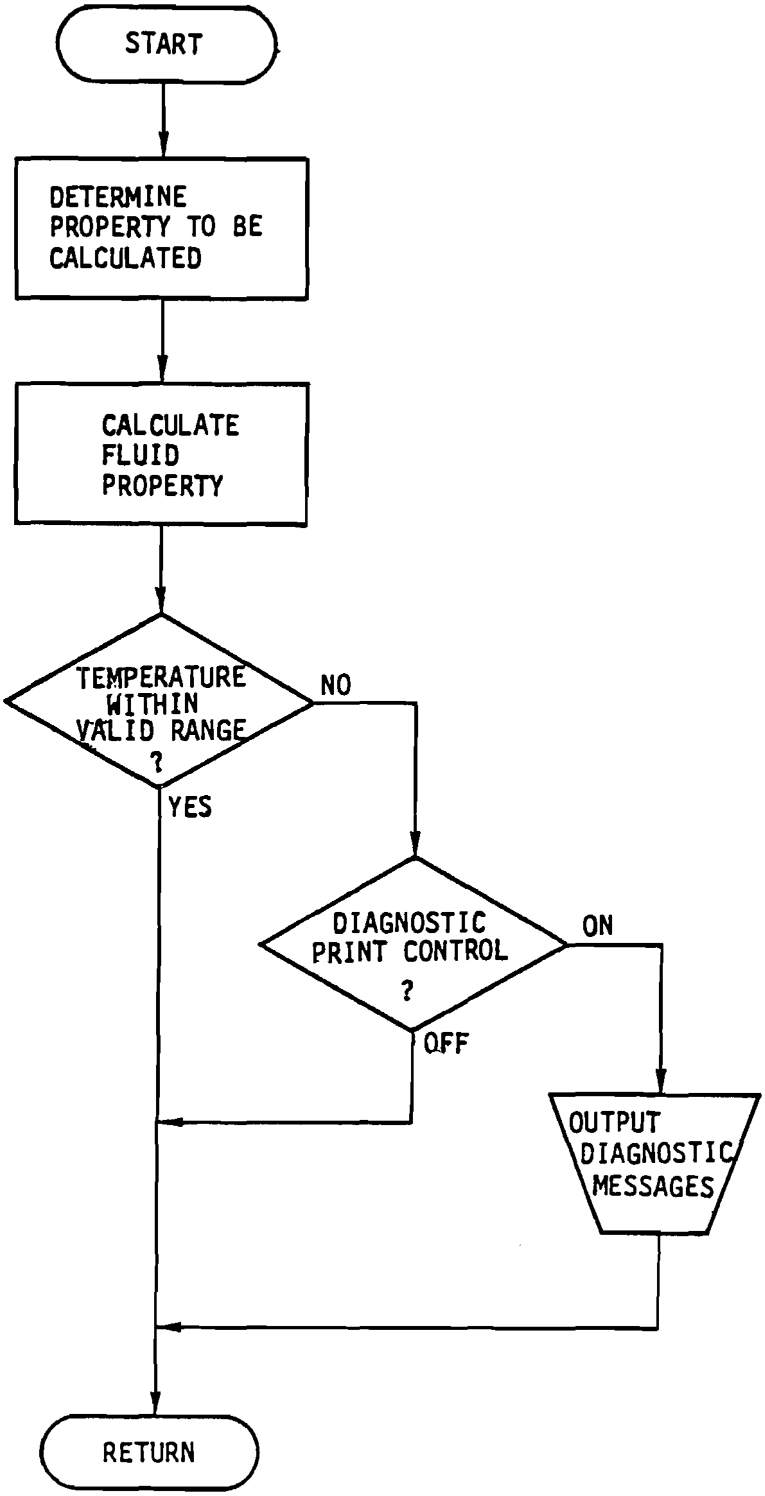
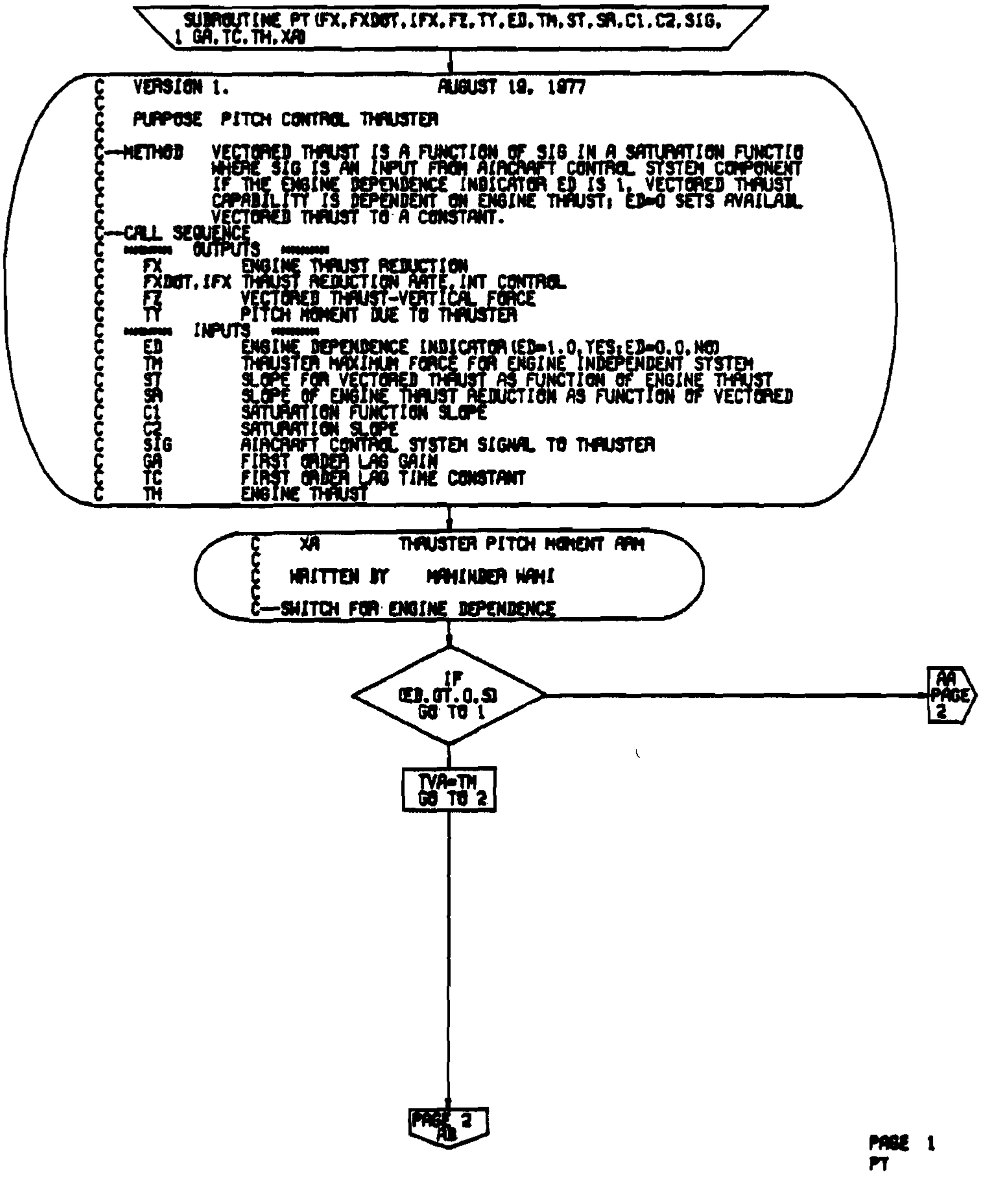


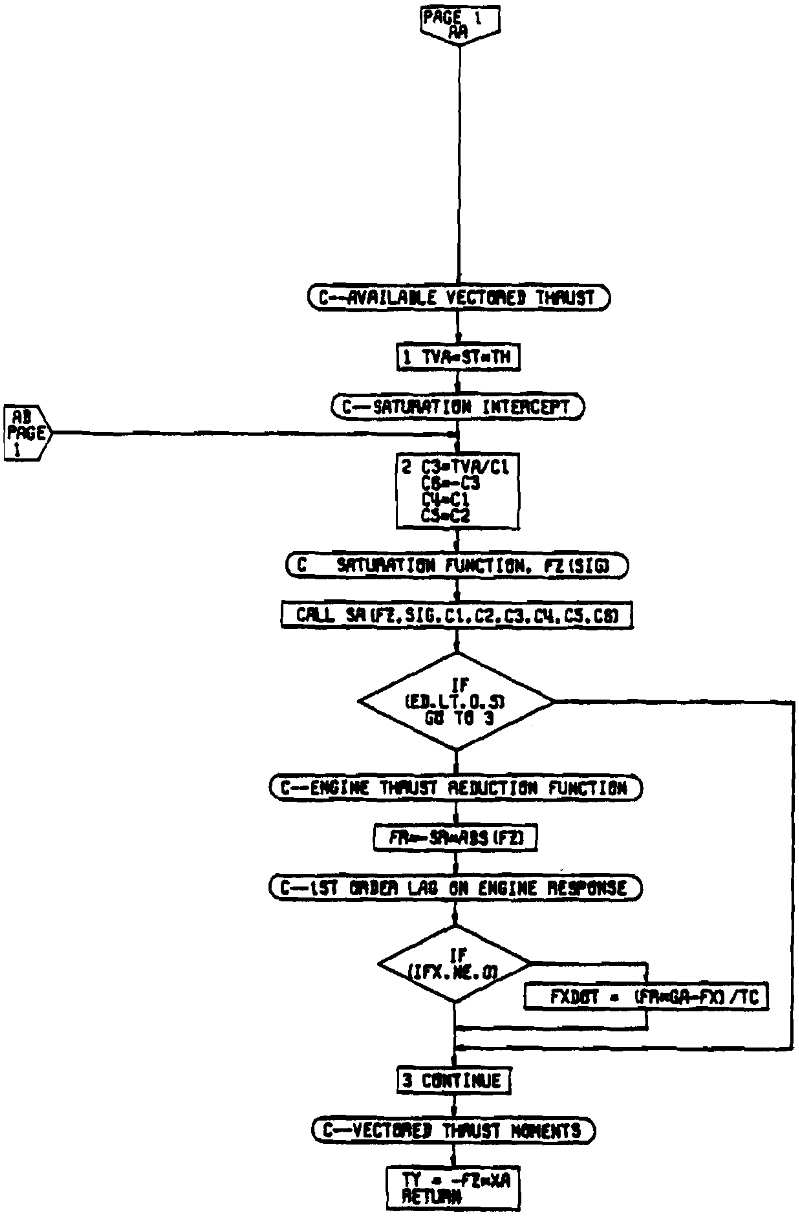
Table 74: FLOWCHART FOR SUBROUTINE PT



```
      SUBROUTINE PT(FX,FXDOT,IFX,FZ,TY,ED,TM,ST,SA,C1,C2,SIG,
     1 GA,TC,TH,XA)
C   VERSION 1.                    AUGUST 19, 1977
C
C   PURPOSE  PITCH CONTROL THRUSTER
C
C--METHOD   VECTORED THRUST IS A FUNCTION OF SIG IN A SATURATION FUNCTIO
C           WHERE SIG IS AN INPUT FROM AIRCRAFT CONTROL SYSTEM COMPONENT
C           IF THE ENGINE DEPENDENCE INDICATOR ED IS 1, VECTORED THRUST
C           CAPABILITY IS DEPENDENT ON ENGINE THRUST; ED=0 SETS AVAILABL
C           VECTORED THRUST TO A CONSTANT.
C--CALL SEQUENCE
C  ------  OUTPUTS  ------
C    FX         ENGINE THRUST REDUCTION
C    FXDOT,IFX THRUST REDUCTION RATE,INT CONTROL
C    FZ         VECTORED THRUST-VERTICAL FORCE
C    TY         PITCH MOMENT DUE TO THRUSTER
C  ------  INPUTS  ------
C    ED         ENGINE DEPENDENCE INDICATOR(ED=1.0,YES;ED=0.0,NO)
C    TM         THRUSTER MAXIMUM FORCE FOR ENGINE INDEPENDENT SYSTEM
C    ST         SLOPE FOR VECTORED THRUST AS FUNCTION OF ENGINE THRUST
C    SA         SLOPE OF ENGINE THRUST REDUCTION AS FUNCTION OF VECTORED
C    C1         SATURATION FUNCTION SLOPE
C    C2         SATURATION SLOPE
C    SIG        AIRCRAFT CONTROL SYSTEM SIGNAL TO THRUSTER
C    GA         FIRST ORDER LAG GAIN
C    TC         FIRST ORDER LAG TIME CONSTANT
C    TH         ENGINE THRUST
C    XA         THRUSTER PITCH MOMENT ARM
C
C   WRITTEN BY    MAHINDER WAHI
C
C--SWITCH FOR ENGINE DEPENDENCE
      IF (ED.GT.0.5) GO TO 1
      TVA=TM
      GO TO 2
```

PAGE 1
PT

Table 74: FLOWCHART FOR SUBROUTINE PT (CONCLUDED)



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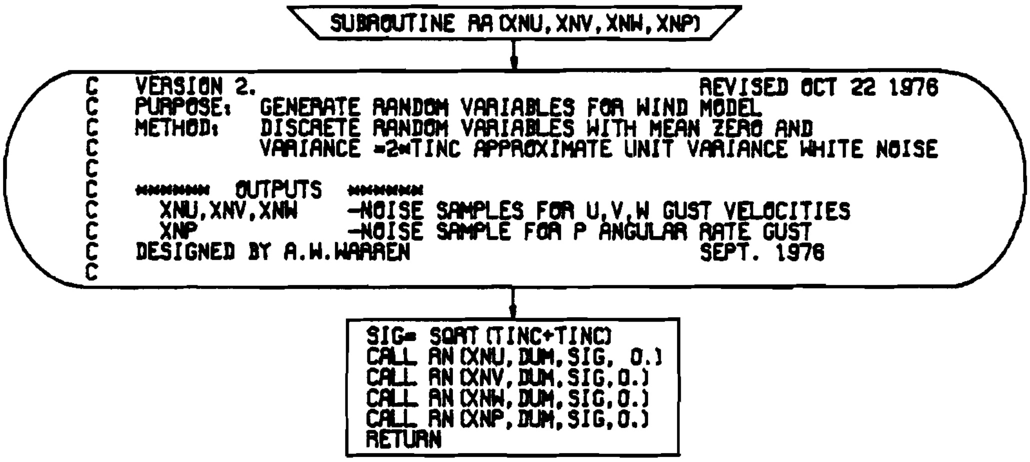
PT

Table 75: FLOWCHART FOR SUBROUTINE RA



```
SUBROUTINE RA (XNU,XNV,XNW,XNP)
```

```
C     VERSION 2.                                    REVISED OCT 22 1976
C     PURPOSE:  GENERATE RANDOM VARIABLES FOR WIND MODEL
C     METHOD:   DISCRETE RANDOM VARIABLES WITH MEAN ZERO AND
C               VARIANCE =2*TINC APPROXIMATE UNIT VARIANCE WHITE NOISE
C
C     ******** OUTPUTS  ********
C       XNU,XNV,XNW     -NOISE SAMPLES FOR U,V,W GUST VELOCITIES
C       XNP             -NOISE SAMPLE FOR P ANGULAR RATE GUST
C     DESIGNED BY A.W.WARREN                        SEPT. 1976
C
```

```
SIG= SQRT (TINC+TINC)
CALL RN (XNU,DUM,SIG, 0.)
CALL RN (XNV,DUM,SIG,0.)
CALL RN (XNW,DUM,SIG,0.)
CALL RN (XNP,DUM,SIG,0.)
RETURN
```

Table 76: FLOWCHART FOR SUBROUTINE RENVX

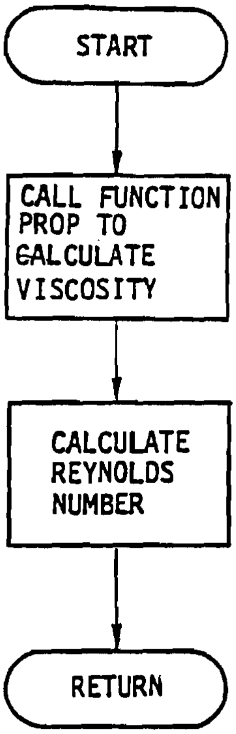
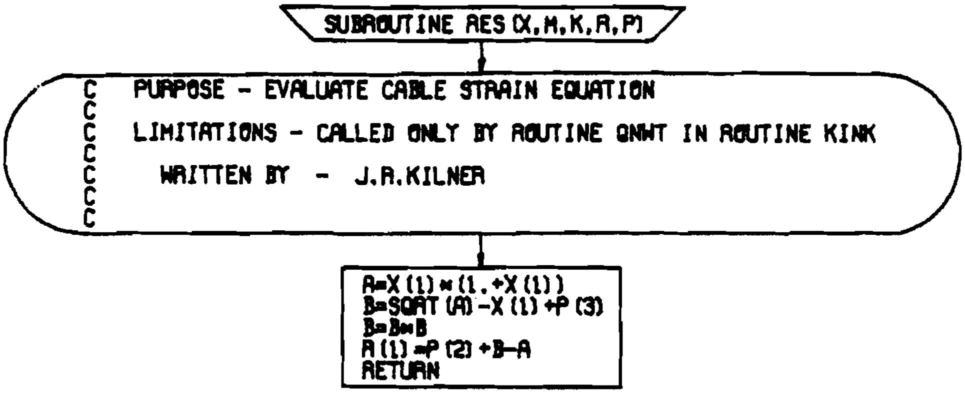
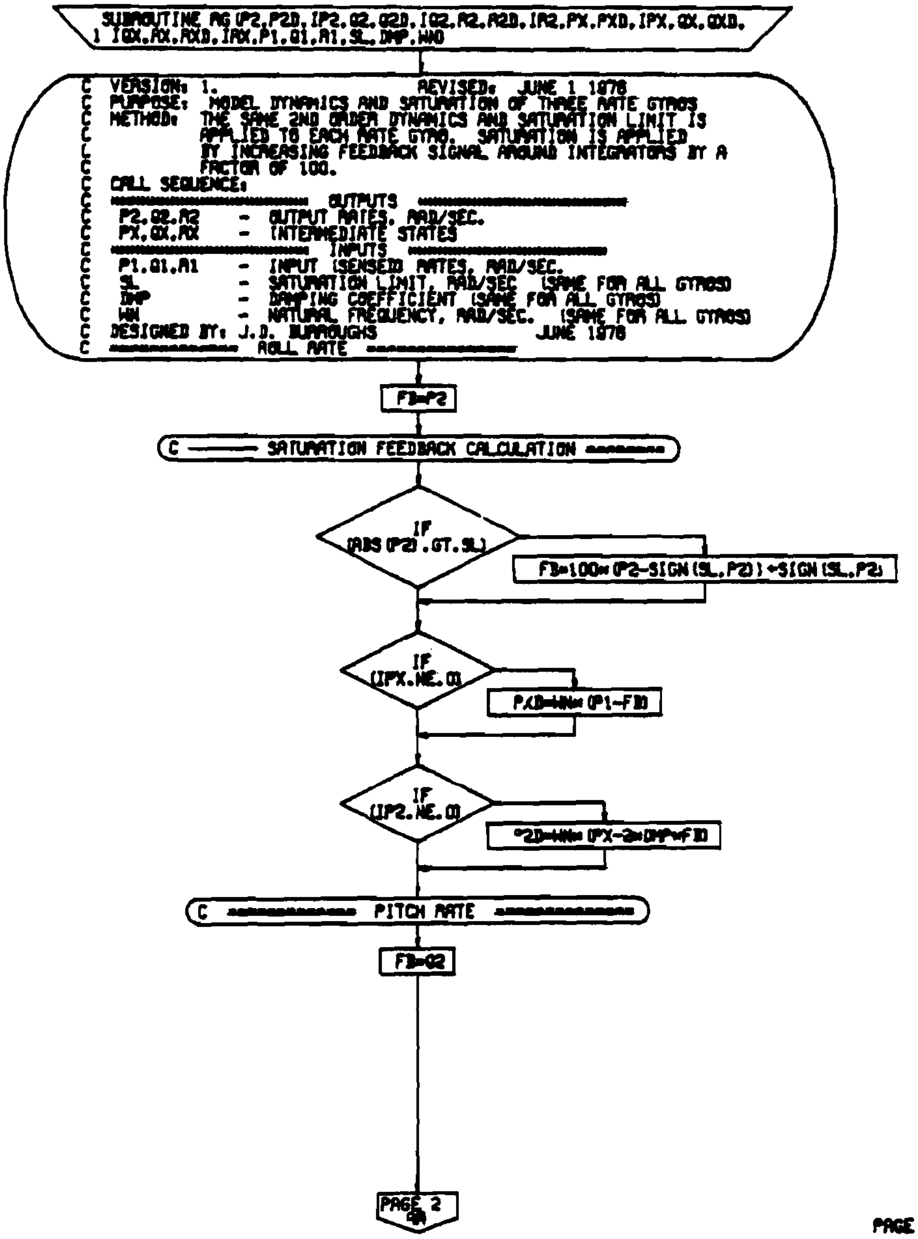


Table 77: FLOWCHART FOR SUBROUTINE RES



```
SUBROUTINE RES (X,M,K,R,P)
C   PURPOSE - EVALUATE CABLE STRAIN EQUATION
C
C   LIMITATIONS - CALLED ONLY BY ROUTINE QNWT IN ROUTINE KINK
C
C     WRITTEN BY  -  J.R.KILNER
C
C
A=X(1)*(1.+X(1))
B=SQRT(A)-X(1)+P(3)
B=B*B
R(1)=P(2)+B-A
RETURN
```

Table 78: FLOWCHART FOR SUBROUTINE RG



```
      SUBROUTINE RG(P2,P2D,IP2,Q2,Q2D,IQ2,R2,R2D,IR2,PX,PXD,IPX,QX,QXD,
     1 IQX,RX,RXD,IRX,P1,Q1,R1,SL,DMP,WN)
C  VERSION: 1.                        REVISED: JUNE 1 1978
C  PURPOSE:  MODEL DYNAMICS AND SATURATION OF THREE RATE GYROS
C  METHOD:  THE SAME 2ND ORDER DYNAMICS AND SATURATION LIMIT IS
C           APPLIED TO EACH RATE GYRO.  SATURATION IS APPLIED
C           BY INCREASING FEEDBACK SIGNAL AROUND INTEGRATORS BY A
C           FACTOR OF 100.
C  CALL SEQUENCE:
C  ========================== OUTPUTS ==============================
C   P2,Q2,R2      -  OUTPUT RATES, RAD/SEC.
C   PX,QX,RX      -  INTERMEDIATE STATES
C  ========================== INPUTS ===============================
C   P1,Q1,R1      -  INPUT (SENSED) RATES, RAD/SEC.
C   SL            -  SATURATION LIMIT, RAD/SEC  (SAME FOR ALL GYROS)
C   DMP           -  DAMPING COEFFICIENT (SAME FOR ALL GYROS)
C   WN            -  NATURAL FREQUENCY, RAD/SEC.  (SAME FOR ALL GYROS)
C  DESIGNED BY: J.D. BURROUGHS                    JUNE 1978
C  ============== ROLL RATE ==================

FB=P2

C ------ SATURATION FEEDBACK CALCULATION ======

IF (ABS(P2).GT.SL)
    FB=100*(P2-SIGN(SL,P2))+SIGN(SL,P2)

IF (IPX.NE.0)
    PXD=WN*(P1-FB)

IF (IP2.NE.0)
    P2D=WN*(PX-2*DMP*FB)

C ============== PITCH RATE ==============

FB=Q2
```

PAGE 1
RG

Table 78: FLOWCHART FOR SUBROUTINE RG (CONCLUDED)

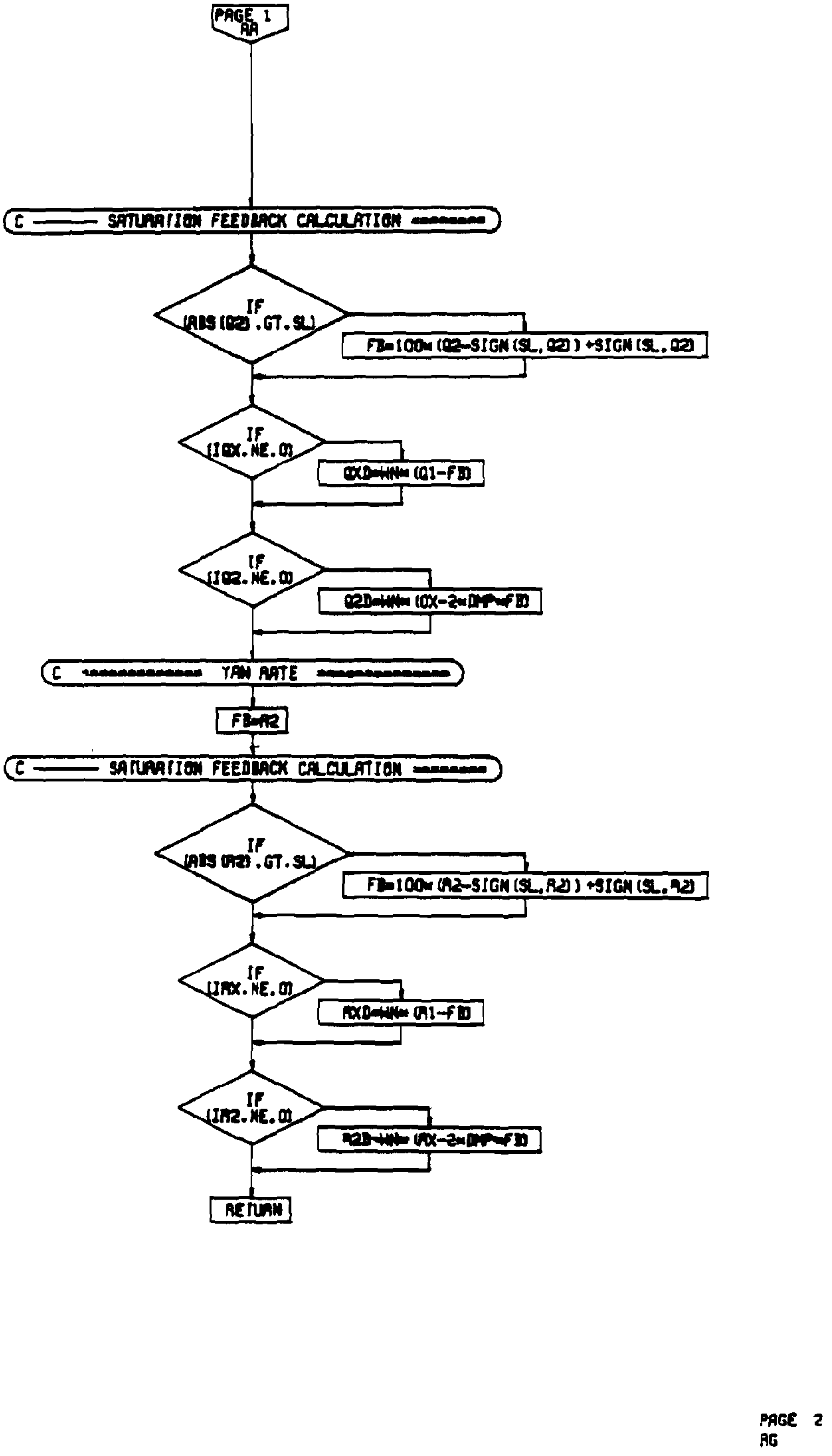
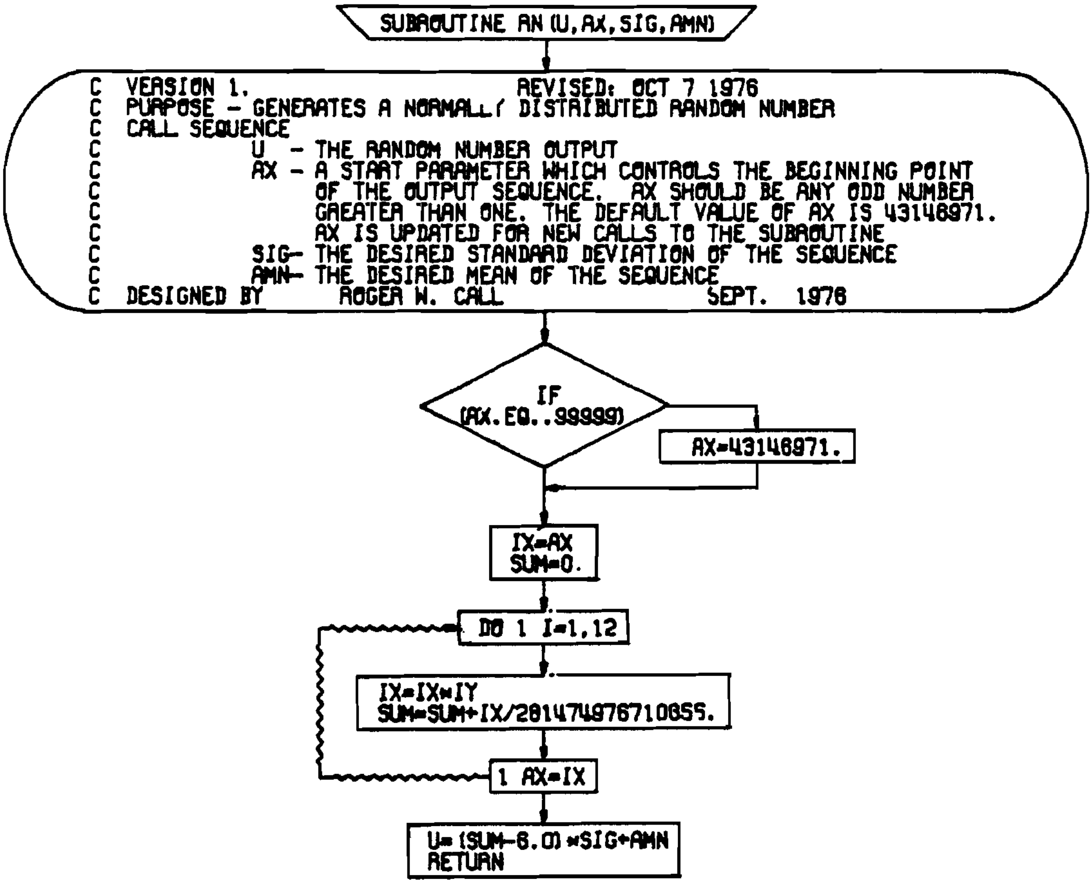
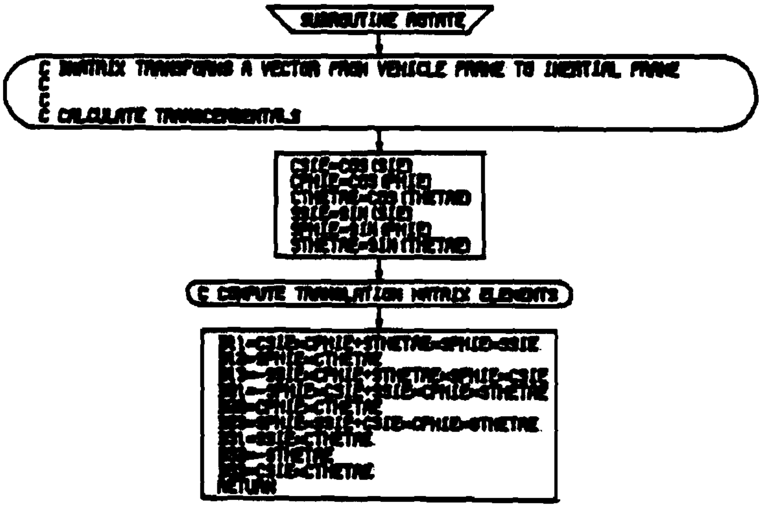


Table 79: FLOWCHART FOR SUBROUTINE RN



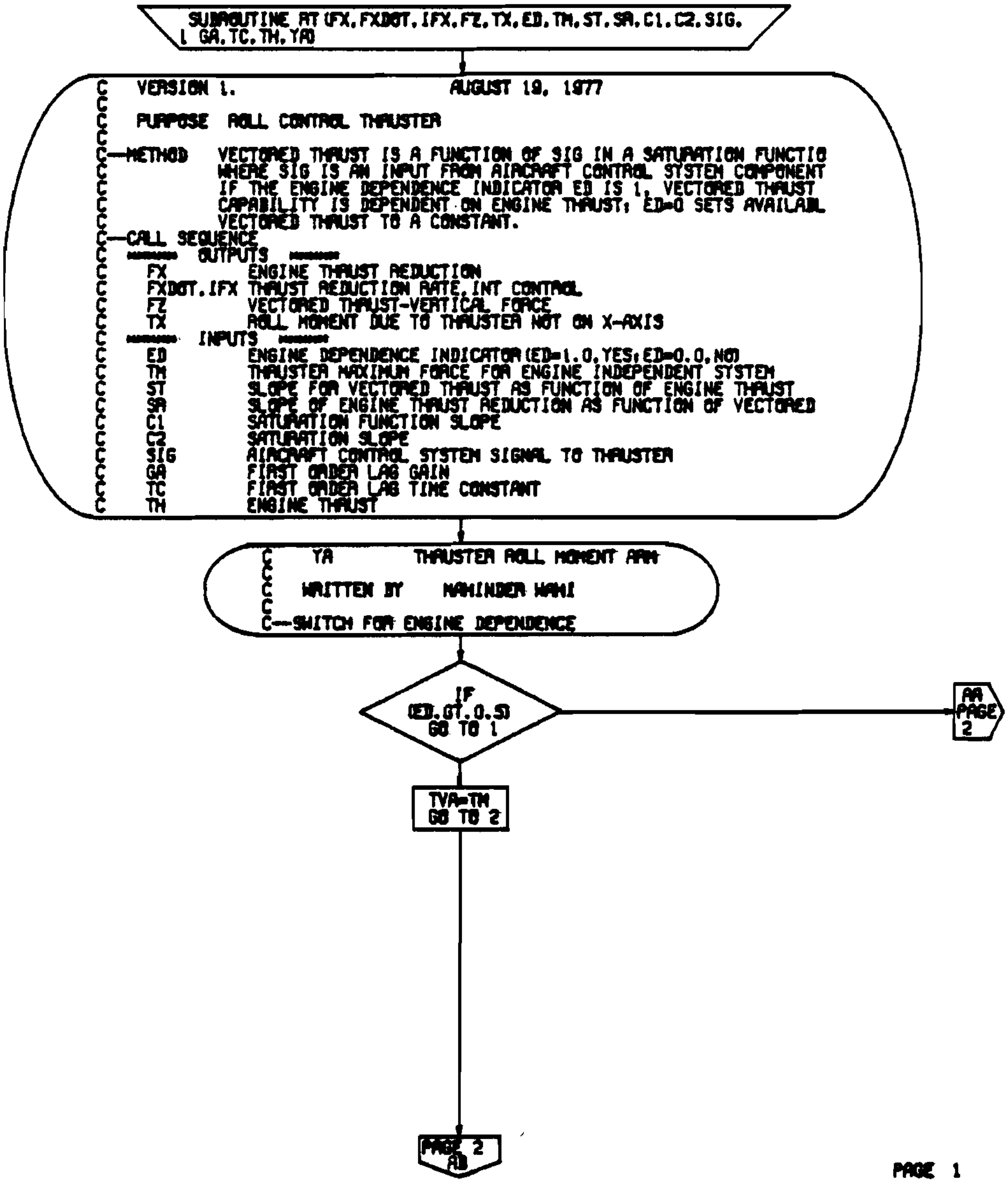
```
C  VERSION 1.                              REVISED: OCT 7 1976
C  PURPOSE - GENERATES A NORMALLY DISTRIBUTED RANDOM NUMBER
C  CALL SEQUENCE
C              U  - THE RANDOM NUMBER OUTPUT
C              AX - A START PARAMETER WHICH CONTROLS THE BEGINNING POINT
C                   OF THE OUTPUT SEQUENCE.  AX SHOULD BE ANY ODD NUMBER
C                   GREATER THAN ONE. THE DEFAULT VALUE OF AX IS 43146971.
C                   AX IS UPDATED FOR NEW CALLS TO THE SUBROUTINE
C              SIG- THE DESIRED STANDARD DEVIATION OF THE SEQUENCE
C              AMN- THE DESIRED MEAN OF THE SEQUENCE
C  DESIGNED BY      ROGER W. CALL                      SEPT.  1976
```

Table 80: FLOWCHART FOR SUBROUTINE ROTATE



PAGE 1
ROTATE

Table 81: FLOWCHART FOR SUBROUTINE RT



```
      SUBROUTINE RT(FX,FXDOT,IFX,FZ,TX,ED,TM,ST,SR,C1,C2,SIG,
     1 GA,TC,TH,YA)
C    VERSION 1.                    AUGUST 19, 1977
C
C    PURPOSE  ROLL CONTROL THRUSTER
C
C--METHOD    VECTORED THRUST IS A FUNCTION OF SIG IN A SATURATION FUNCTIO
C            WHERE SIG IS AN INPUT FROM AIRCRAFT CONTROL SYSTEM COMPONENT
C            IF THE ENGINE DEPENDENCE INDICATOR ED IS 1, VECTORED THRUST
C            CAPABILITY IS DEPENDENT ON ENGINE THRUST; ED=0 SETS AVAILABL
C            VECTORED THRUST TO A CONSTANT.
C--CALL SEQUENCE
C  ------  OUTPUTS  ------
C     FX         ENGINE THRUST REDUCTION
C     FXDOT,IFX  THRUST REDUCTION RATE,INT CONTROL
C     FZ         VECTORED THRUST-VERTICAL FORCE
C     TX         ROLL MOMENT DUE TO THRUSTER NOT ON X-AXIS
C  ------  INPUTS  ------
C     ED         ENGINE DEPENDENCE INDICATOR(ED=1.0,YES;ED=0.0,NO)
C     TM         THRUSTER MAXIMUM FORCE FOR ENGINE INDEPENDENT SYSTEM
C     ST         SLOPE FOR VECTORED THRUST AS FUNCTION OF ENGINE THRUST
C     SR         SLOPE OF ENGINE THRUST REDUCTION AS FUNCTION OF VECTORED
C     C1         SATURATION FUNCTION SLOPE
C     C2         SATURATION SLOPE
C     SIG        AIRCRAFT CONTROL SYSTEM SIGNAL TO THRUSTER
C     GA         FIRST ORDER LAG GAIN
C     TC         FIRST ORDER LAG TIME CONSTANT
C     TH         ENGINE THRUST
C     YA         THRUSTER ROLL MOMENT ARM
C
C     WRITTEN BY    MAHINDER WAHI
C
C--SWITCH FOR ENGINE DEPENDENCE
      IF (ED.GT.0.5) GO TO 1
      TVA=TM
      GO TO 2
```

PAGE 1
RT

Table 81: FLOWCHART FOR SUBROUTINE RT (CONCLUDED)

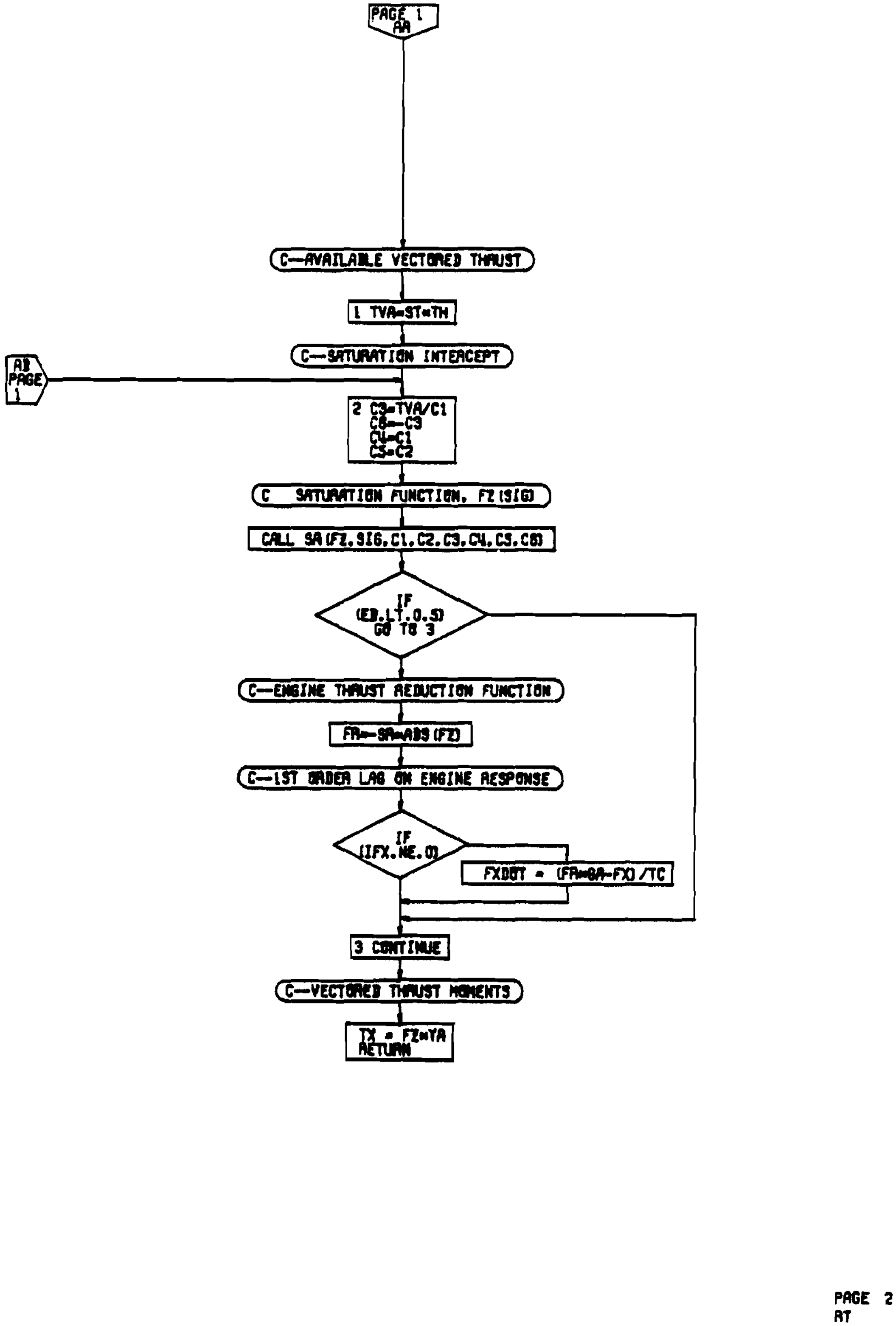
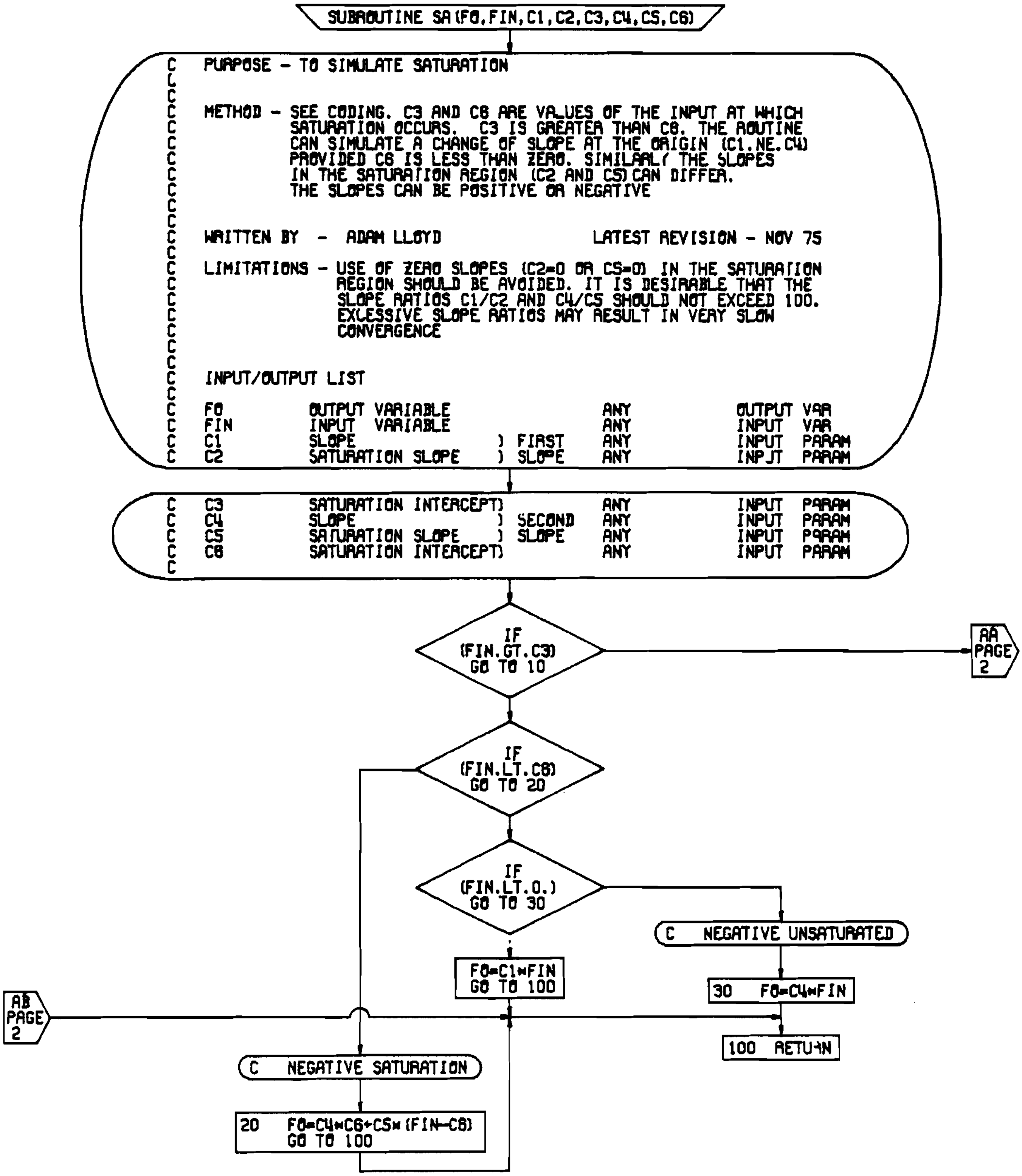


Table 82: FLOWCHART FOR SUBROUTINE SA



```
SUBROUTINE SA(FO,FIN,C1,C2,C3,C4,C5,C6)
C     PURPOSE - TO SIMULATE SATURATION
C
C
C     METHOD - SEE CODING. C3 AND C6 ARE VALUES OF THE INPUT AT WHICH
C              SATURATION OCCURS.  C3 IS GREATER THAN C6. THE ROUTINE
C              CAN SIMULATE A CHANGE OF SLOPE AT THE ORIGIN (C1.NE.C4)
C              PROVIDED C6 IS LESS THAN ZERO. SIMILARLY THE SLOPES
C              IN THE SATURATION REGION (C2 AND C5) CAN DIFFER.
C              THE SLOPES CAN BE POSITIVE OR NEGATIVE
C
C
C     WRITTEN BY  -  ADAM LLOYD                 LATEST REVISION - NOV 75
C
C     LIMITATIONS - USE OF ZERO SLOPES (C2=0 OR C5=0) IN THE SATURATION
C                   REGION SHOULD BE AVOIDED. IT IS DESIRABLE THAT THE
C                   SLOPE RATIOS C1/C2 AND C4/C5 SHOULD NOT EXCEED 100.
C                   EXCESSIVE SLOPE RATIOS MAY RESULT IN VERY SLOW
C                   CONVERGENCE
C
C
C     INPUT/OUTPUT LIST
C
C     FO          OUTPUT VARIABLE                  ANY          OUTPUT VAR
C     FIN         INPUT  VARIABLE                  ANY          INPUT  VAR
C     C1          SLOPE               ) FIRST      ANY          INPUT  PARAM
C     C2          SATURATION SLOPE    ) SLOPE      ANY          INPUT  PARAM
C     C3          SATURATION INTERCEPT)            ANY          INPUT  PARAM
C     C4          SLOPE               ) SECOND     ANY          INPUT  PARAM
C     C5          SATURATION SLOPE    ) SLOPE      ANY          INPUT  PARAM
C     C6          SATURATION INTERCEPT)            ANY          INPUT  PARAM
C
```

Table 82: FLOWCHART FOR SUBROUTINE SA (CONCLUDED)

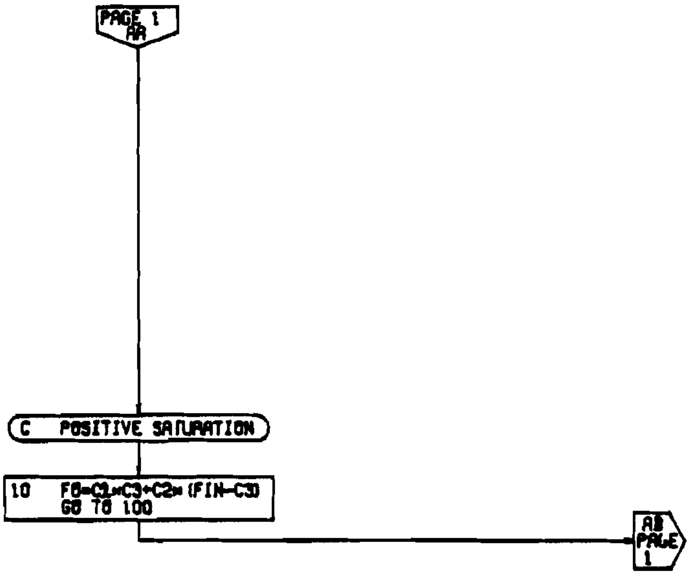
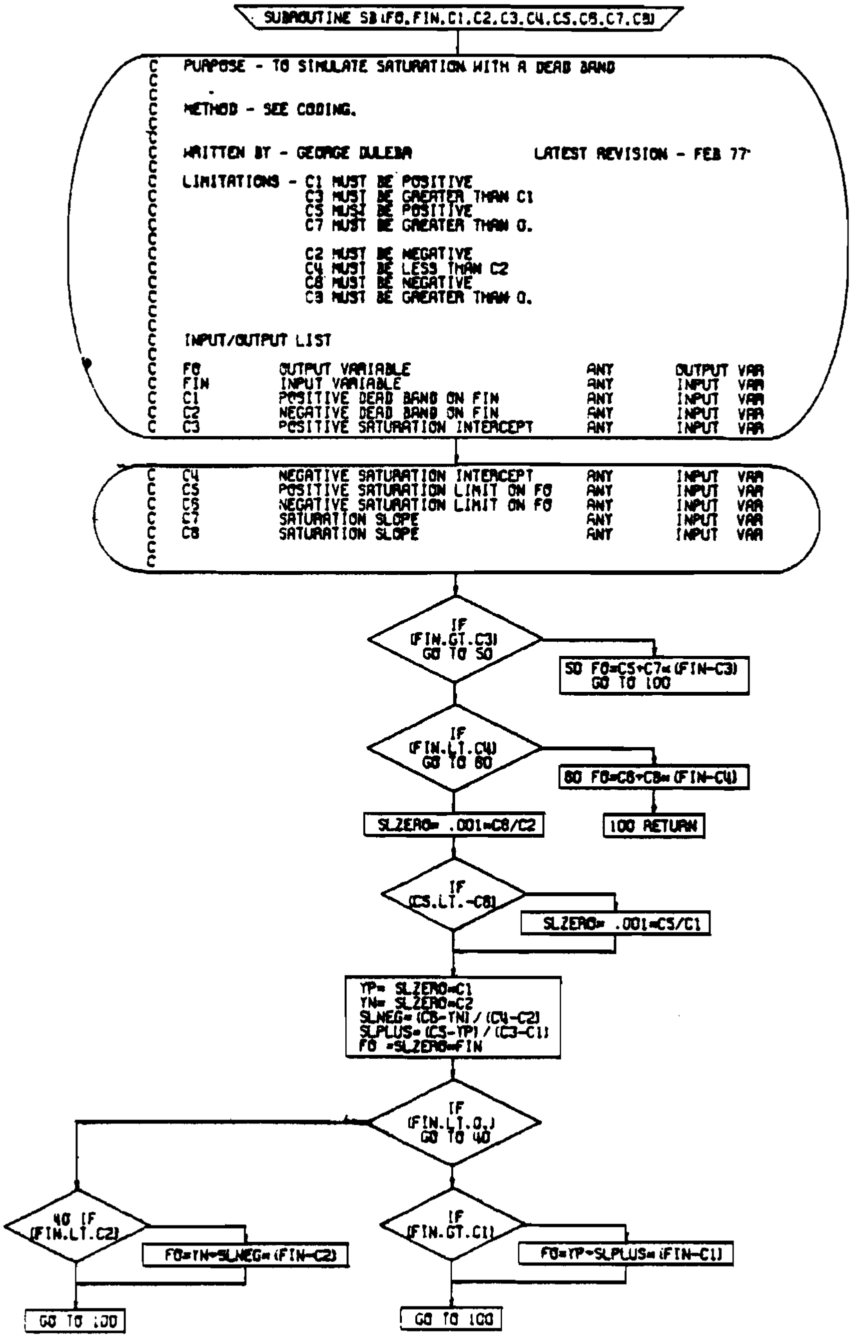


Table 83: FLOWCHART FOR SUBROUTINE SB



```
SUBROUTINE SB(FO,FIN,C1,C2,C3,C4,C5,C6,C7,C8)
C     PURPOSE - TO SIMULATE SATURATION WITH A DEAD BAND
C
C
C     METHOD - SEE CODING.
C
C
C     WRITTEN BY - GEORGE DULEBA                   LATEST REVISION - FEB 77
C
C     LIMITATIONS - C1 MUST BE POSITIVE
C                   C3 MUST BE GREATER THAN C1
C                   C5 MUST BE POSITIVE
C                   C7 MUST BE GREATER THAN 0.
C
C                   C2 MUST BE NEGATIVE
C                   C4 MUST BE LESS THAN C2
C                   C6 MUST BE NEGATIVE
C                   C8 MUST BE GREATER THAN 0.
C
C
C     INPUT/OUTPUT LIST
C
C     FO          OUTPUT VARIABLE                     ANY        OUTPUT VAR
C     FIN         INPUT VARIABLE                      ANY        INPUT  VAR
C     C1          POSITIVE DEAD BAND ON FIN           ANY        INPUT  VAR
C     C2          NEGATIVE DEAD BAND ON FIN           ANY        INPUT  VAR
C     C3          POSITIVE SATURATION INTERCEPT       ANY        INPUT  VAR
C     C4          NEGATIVE SATURATION INTERCEPT       ANY        INPUT  VAR
C     C5          POSITIVE SATURATION LIMIT ON FO     ANY        INPUT  VAR
C     C6          NEGATIVE SATURATION LIMIT ON FO     ANY        INPUT  VAR
C     C7          SATURATION SLOPE                    ANY        INPUT  VAR
C     C8          SATURATION SLOPE                    ANY        INPUT  VAR
C
C
```

Table 84: FLOWCHART FOR SUBROUTINE SEGMNT

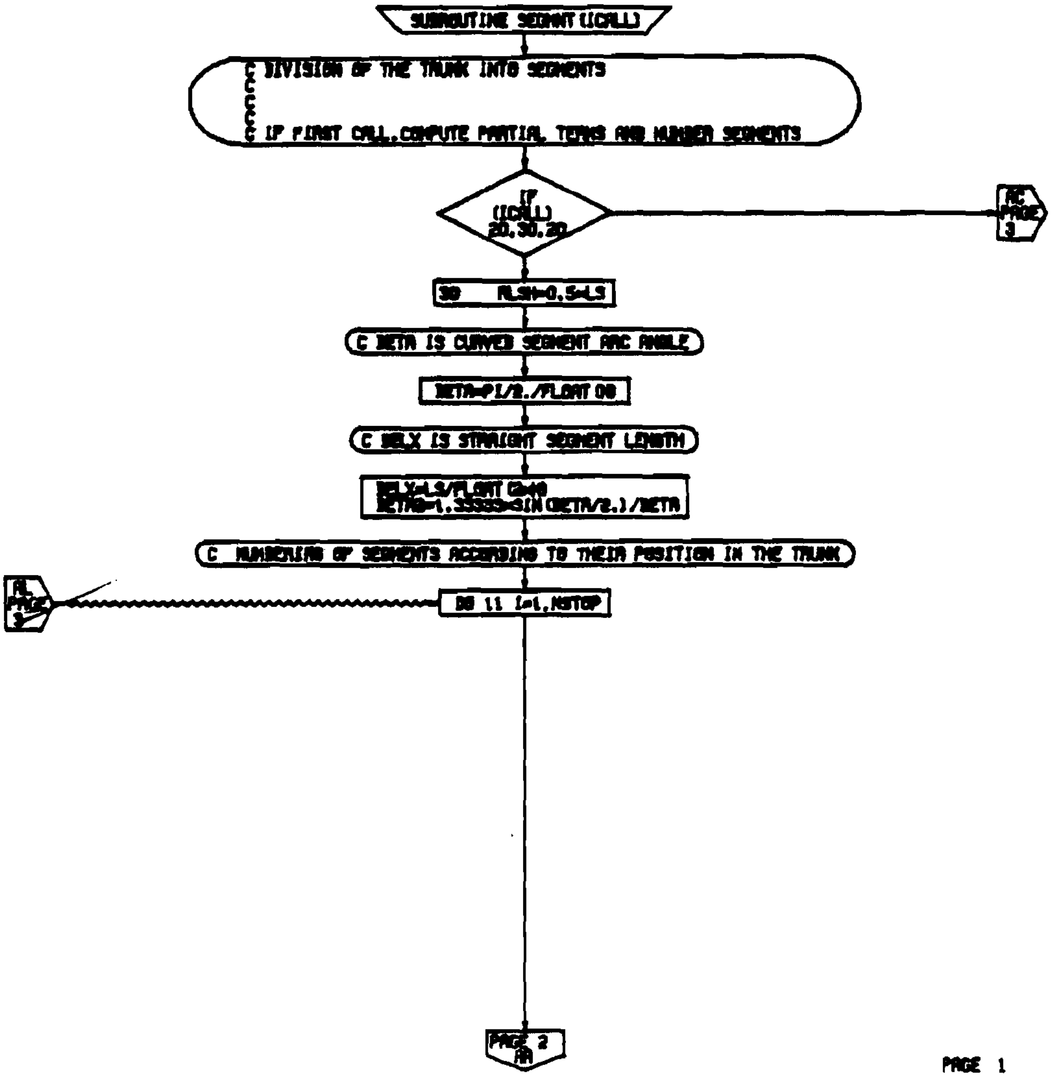


Table 84: FLOWCHART FOR SUBROUTINE SEGMNT (CONTINUED)

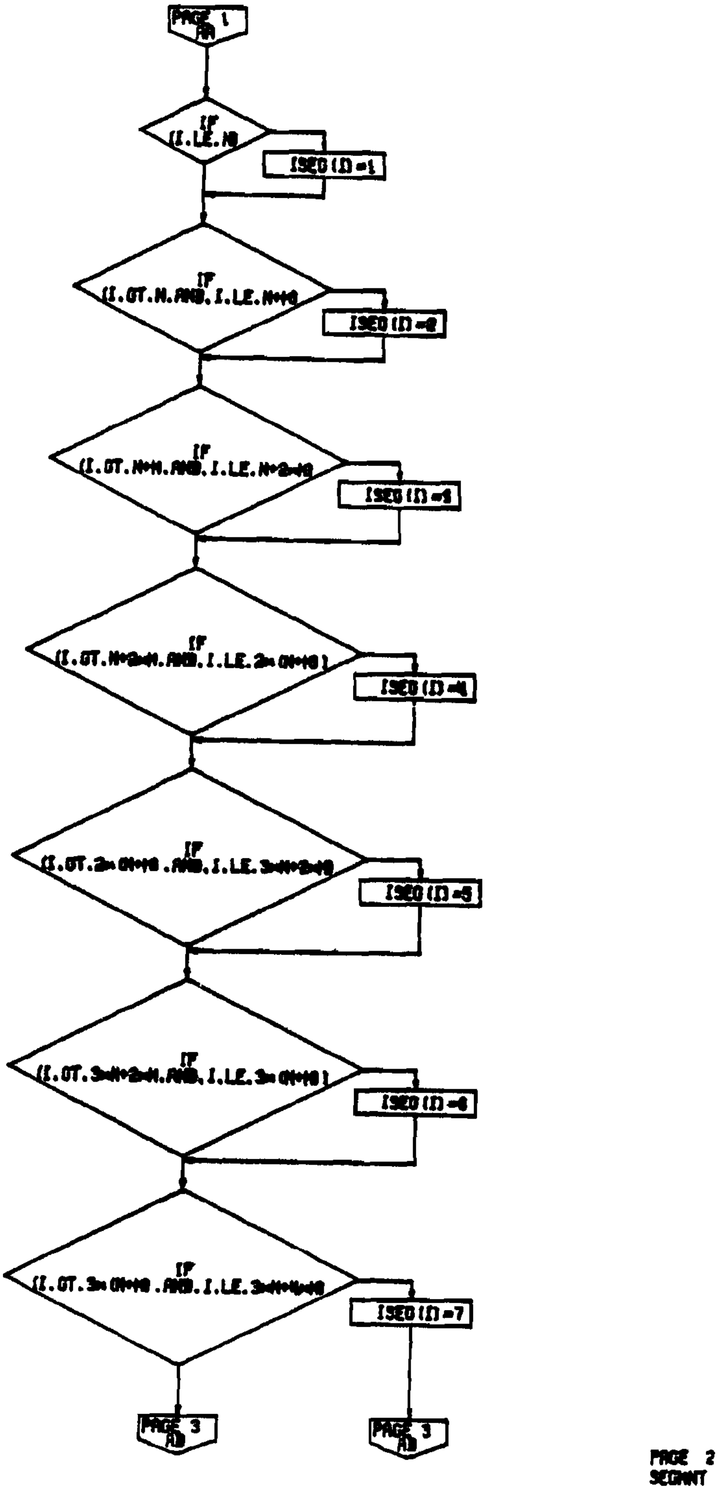


Table 84: FLOWCHART FOR SUBROUTINE SEGMNT (CONTINUED)

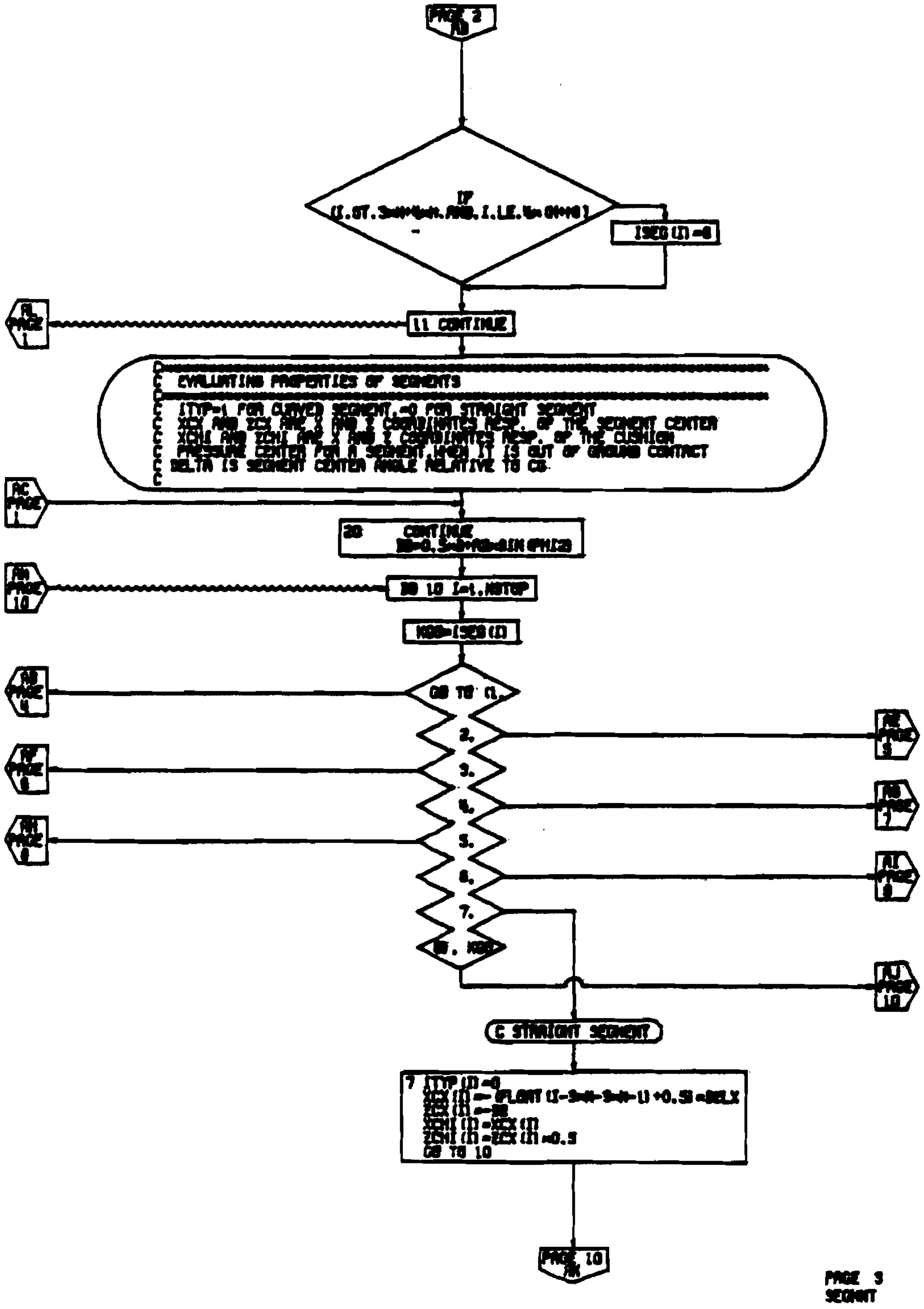
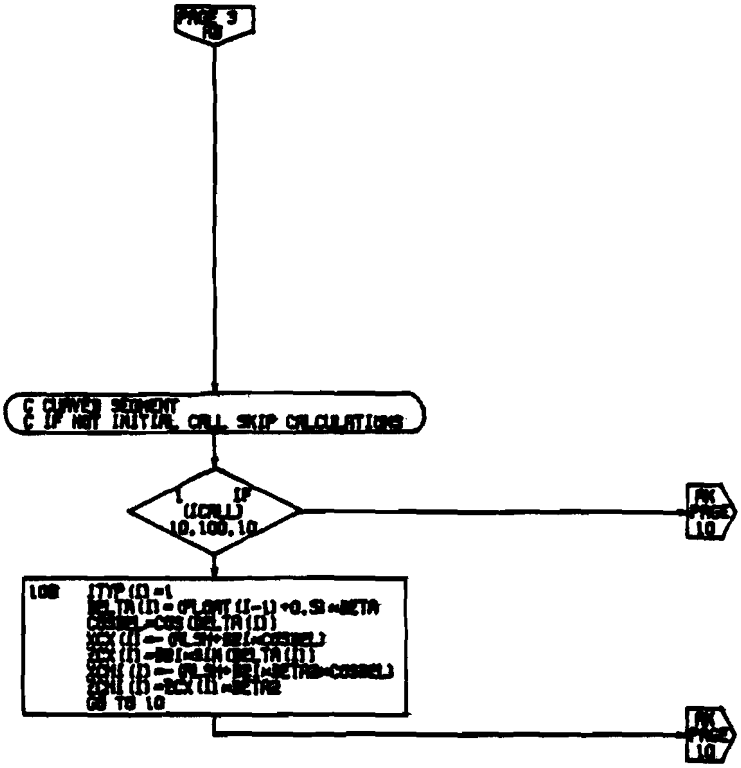


Table 84: FLOWCHART FOR SUBROUTINE SEGMNT (CONTINUED)



PAGE 4
SEGMNT

Table 84: FLOWCHART FOR SUBROUTINE SEGMNT (CONTINUED)

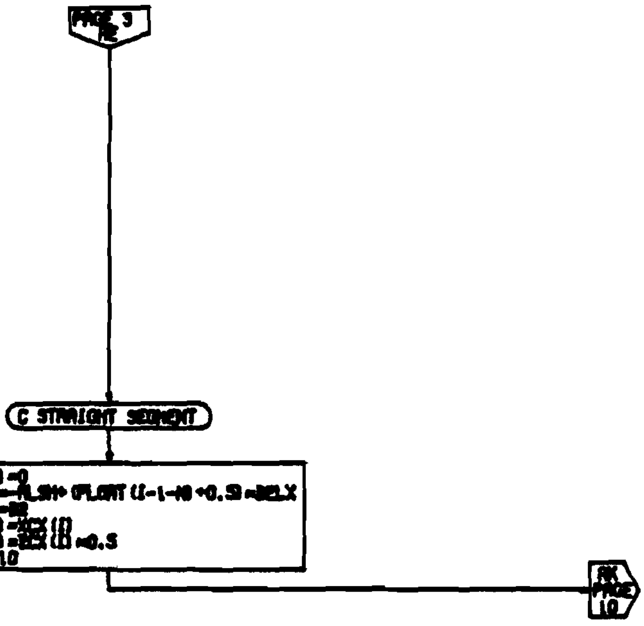


Table 84: FLOWCHART FOR SUBROUTINE SEGMNT (CONTINUED)

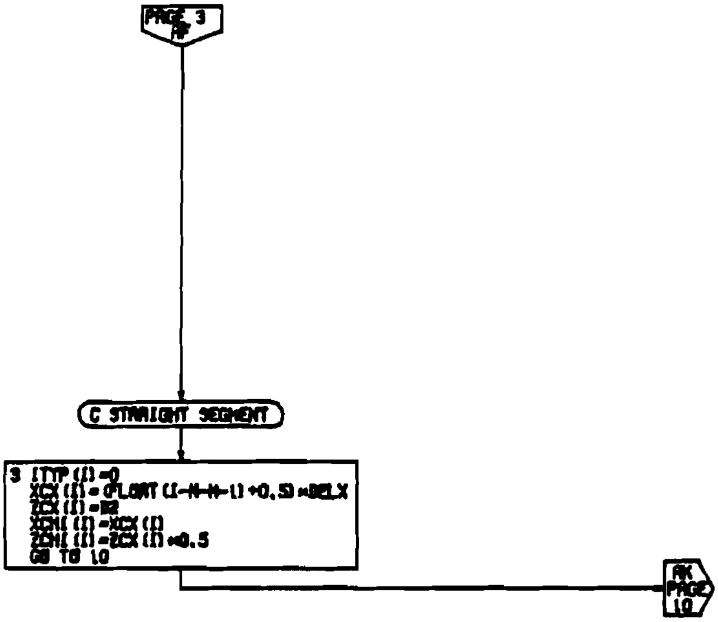


Table 84: FLOWCHART FOR SUBROUTINE SEGMNT (CONTINUED)

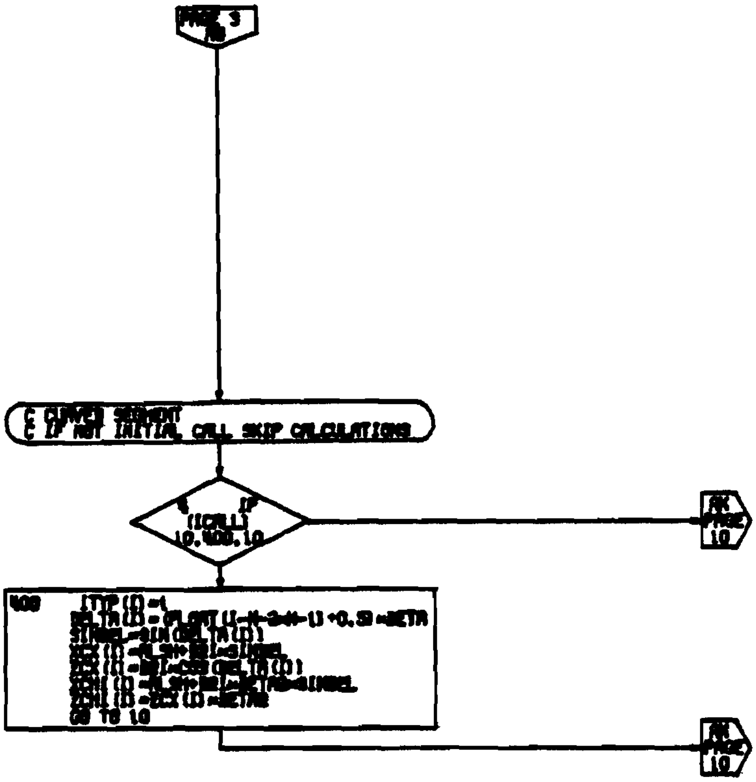


Table 84: FLOWCHART FOR SUBROUTINE SEGMNT (CONTINUED)

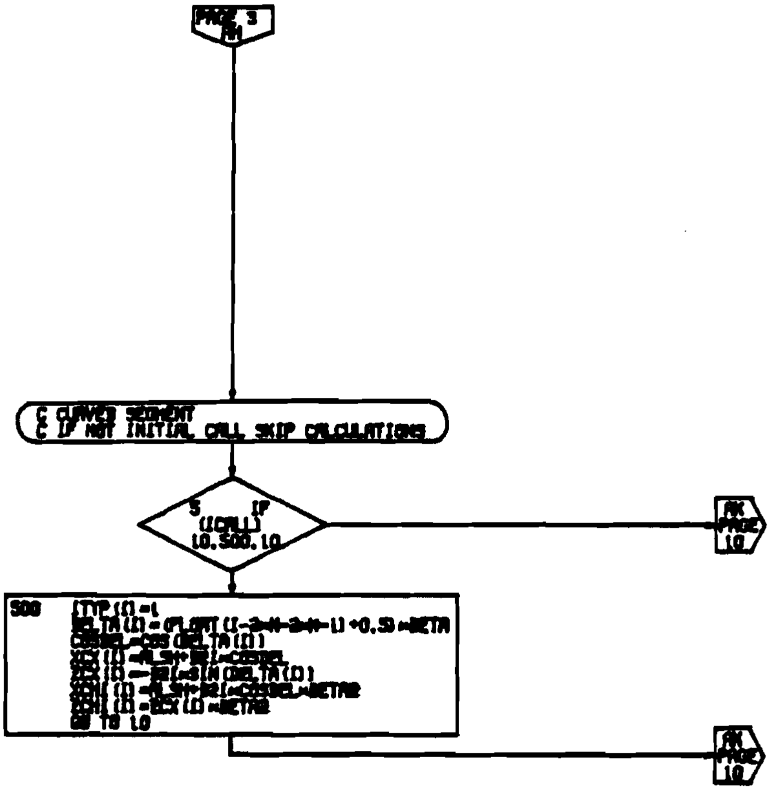


Table 84: FLOWCHART FOR SUBROUTINE SEGMNT (CONTINUED)

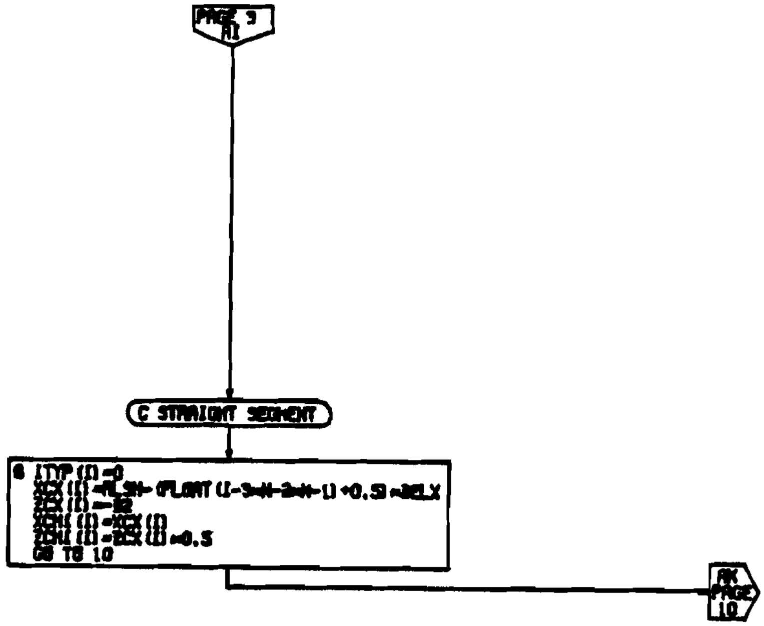
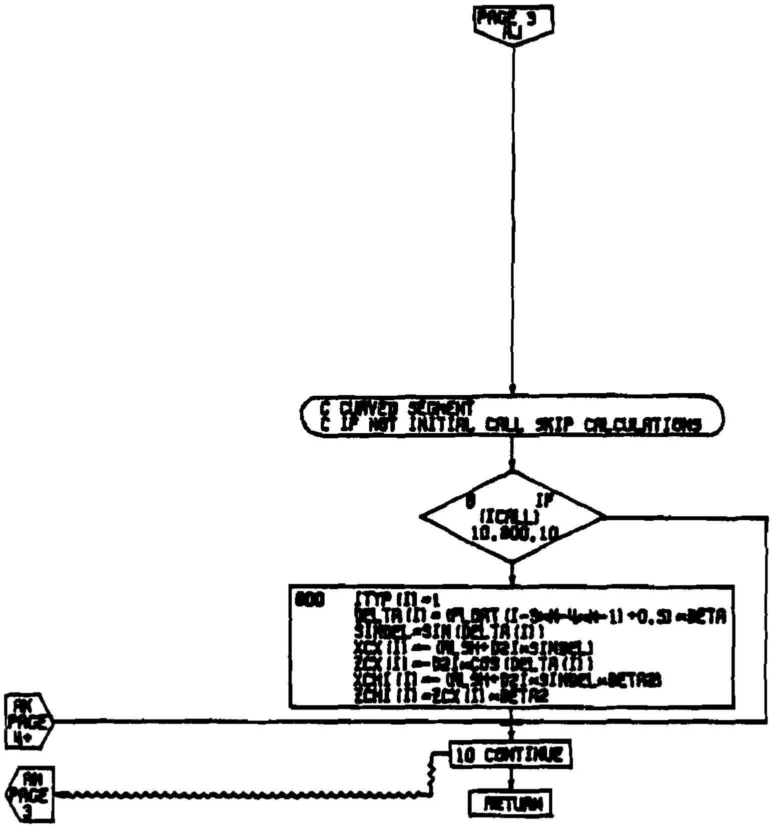


Table 84: FLOWCHART FOR SUBROUTINE SEGMNT (CONCLUDED)



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SEGMNT

Table 85: FLOWCHART FOR SUBROUTINE SG

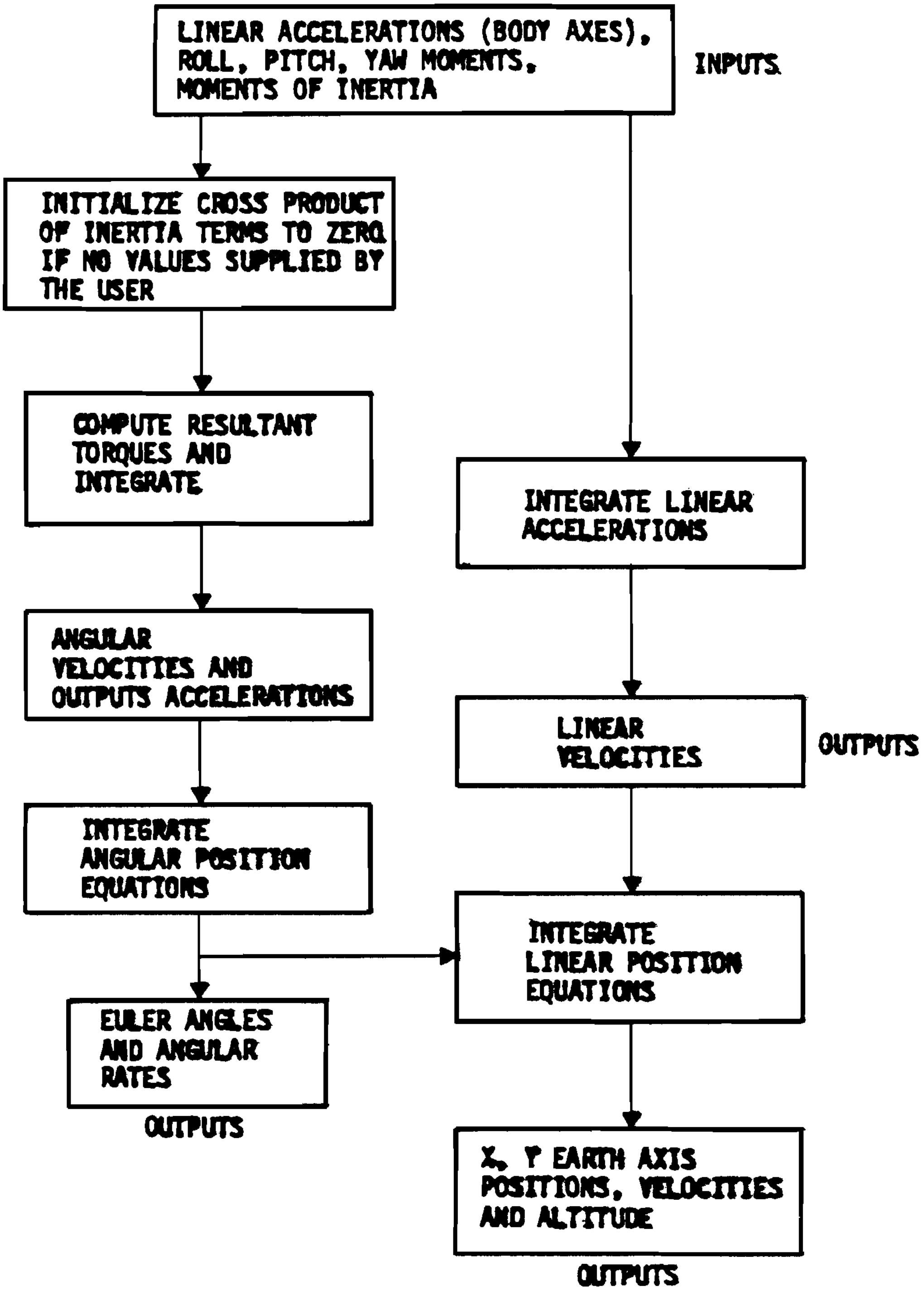
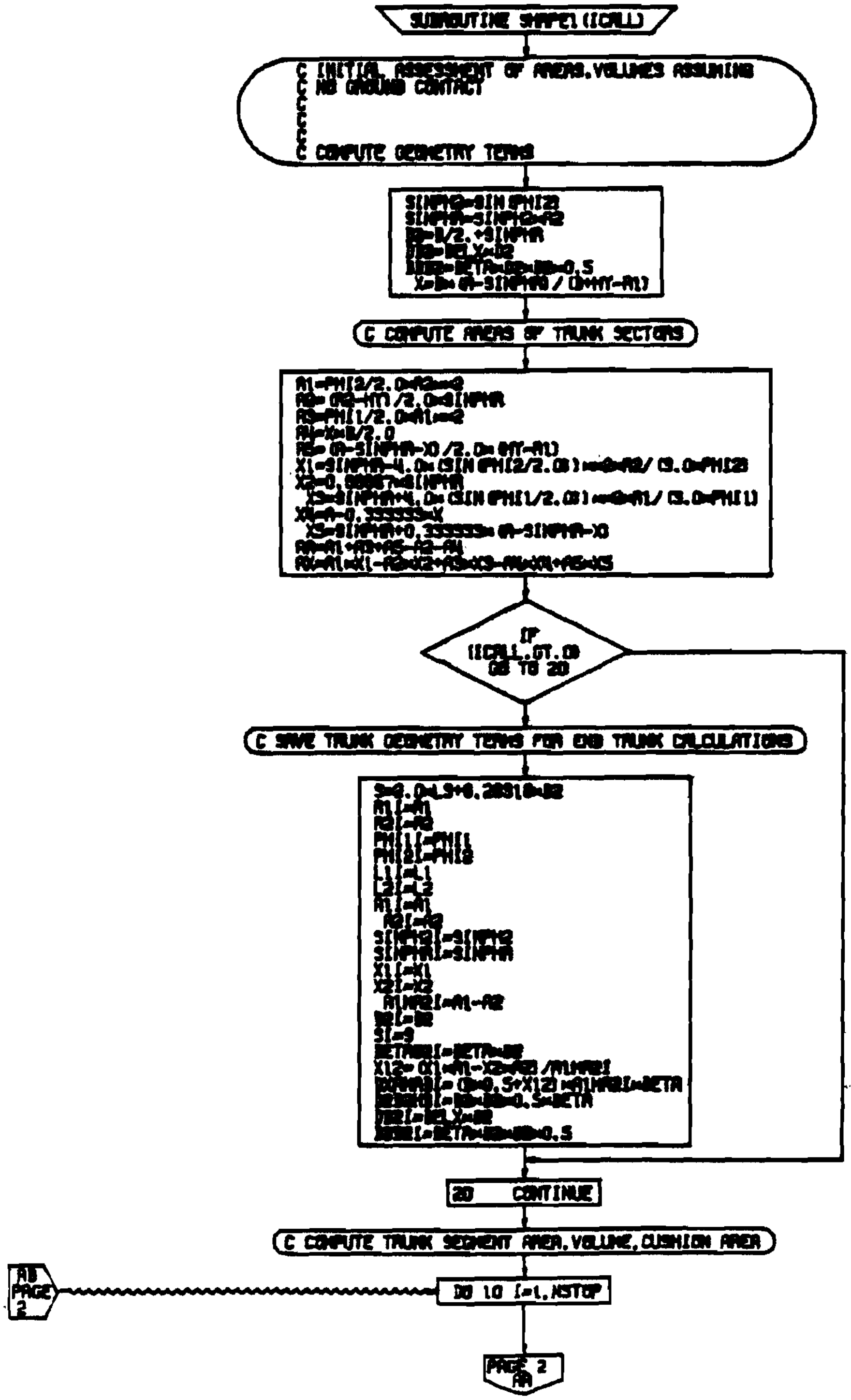


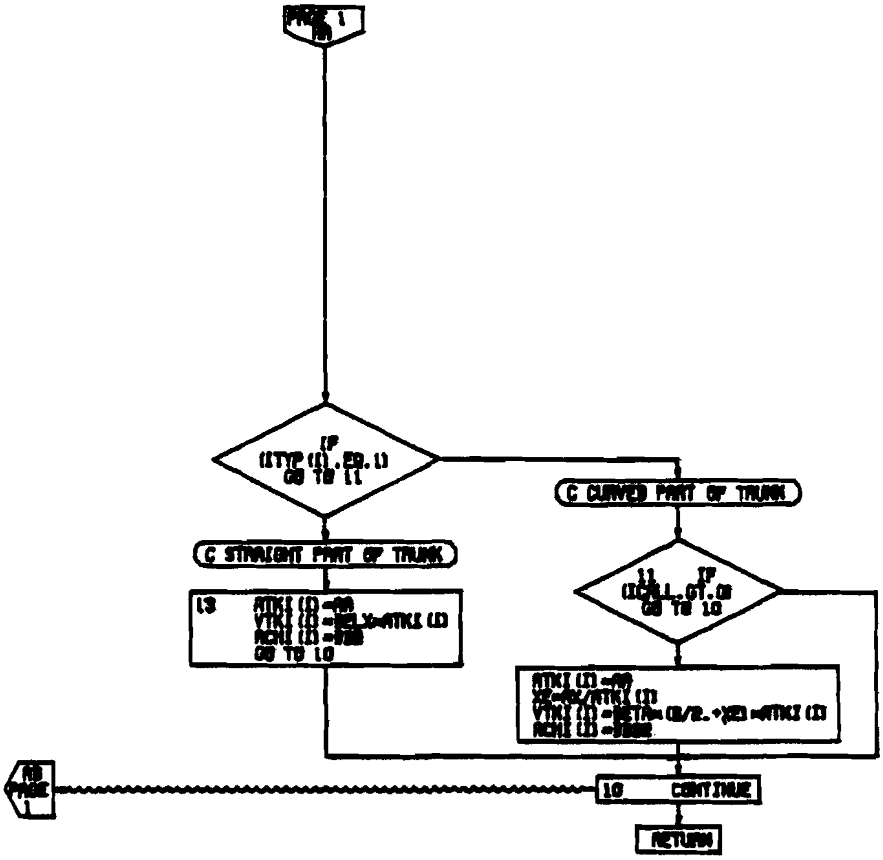
Table 86: FLOWCHART FOR SUBROUTINE SHAPE1



```
SUBROUTINE SHAPE1(ICALL)
C INITIAL ASSESSMENT OF AREAS,VOLUMES ASSUMING
C NO GROUND CONTACT
C
C
C
C
C COMPUTE GEOMETRY TERMS
SINPH2=SIN(PHI2)
SINPHR=SINPH2*R2
B2=B/2.+SINPHR
VB2=DELX*B2
XIB2=BETA*B2*B2*0.5
 X=B*(A-SINPHR)/(B+HT-R1)
C COMPUTE AREAS OF TRUNK SECTORS
A1=PHI2/2.0*R2**2
A2=(R2-HT)/2.0*SINPHR
A3=PHI1/2.0*R1**2
A4=X*B/2.0
A5=(A-SINPHR-X)/2.0*(HT-R1)
X1=SINPHR-4.0*(SIN(PHI2/2.0))**3*R2/(3.0*PHI2)
X2=0.666667*SINPHR
 X3=SINPHR+4.0*(SIN(PHI1/2.0))**3*R1/(3.0*PHI1)
X4=A-0.333333*X
 X5=SINPHR+0.333333*(A-SINPHR-X)
AA=A1+A3+A5-A2-A4
AV=A1*X1-A2*X2+A3*X3-A4*X4+A5*X5
IF
(ICALL.GT.0)
GO TO 20
C SAVE TRUNK GEOMETRY TERMS FOR END TRUNK CALCULATIONS
S=2.0*L3+6.28318*B2
R1I=R1
R2I=R2
PHI1I=PHI1
PHI2I=PHI2
L1I=L1
L2I=L2
A1I=A1
 A2I=A2
SINPH2I=SINPH2
SINPHRI=SINPHR
X1I=X1
X2I=X2
 A1MA2I=A1-A2
B2I=B2
SI=S
BETAB2I=BETA*B2
X12=(X1*A1-X2*A2)/A1MA2I
[illegible]I=(B*0.5+X12)*A1MA2I*BETA
[illegible]I=B2*B2*0.5*BETA
VB2I=DELX*B2
XIB2I=BETA*B2*B2*0.5
20    CONTINUE
C COMPUTE TRUNK SEGMENT AREA,VOLUME,CUSHION AREA
DO 10 I=1,NSTOP
```

PAGE 1
SHAPE1

Table 86: FLOWCHART FOR SUBROUTINE SHAPE1 (CONCLUDED)



PAGE 2
SHAPE1

Table 87: FLOWCHART FOR SUBROUTINE SHAPE 2

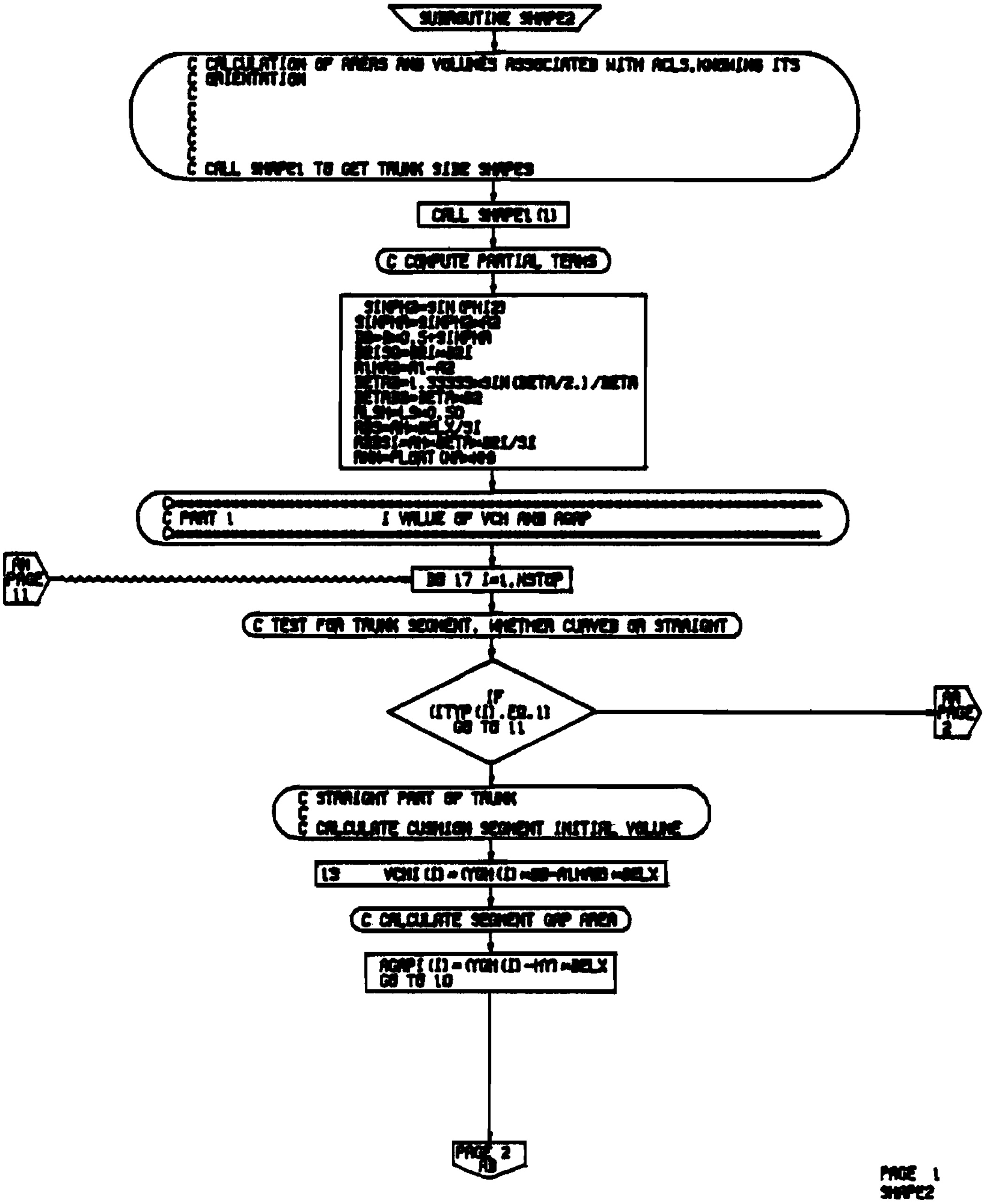


Table 87: FLOWCHART FOR SUBROUTINE SHAPE 2 (CONTINUED)

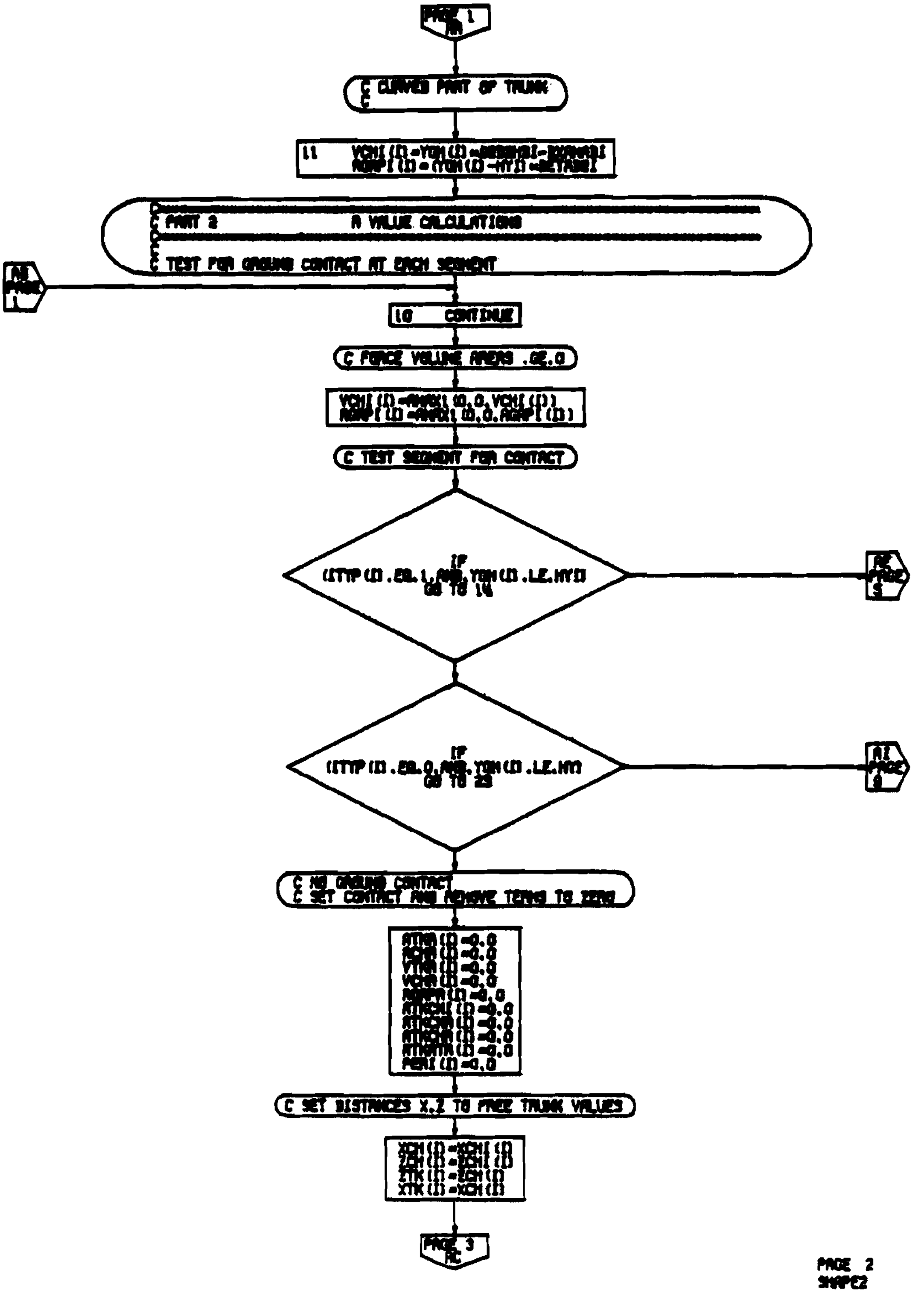
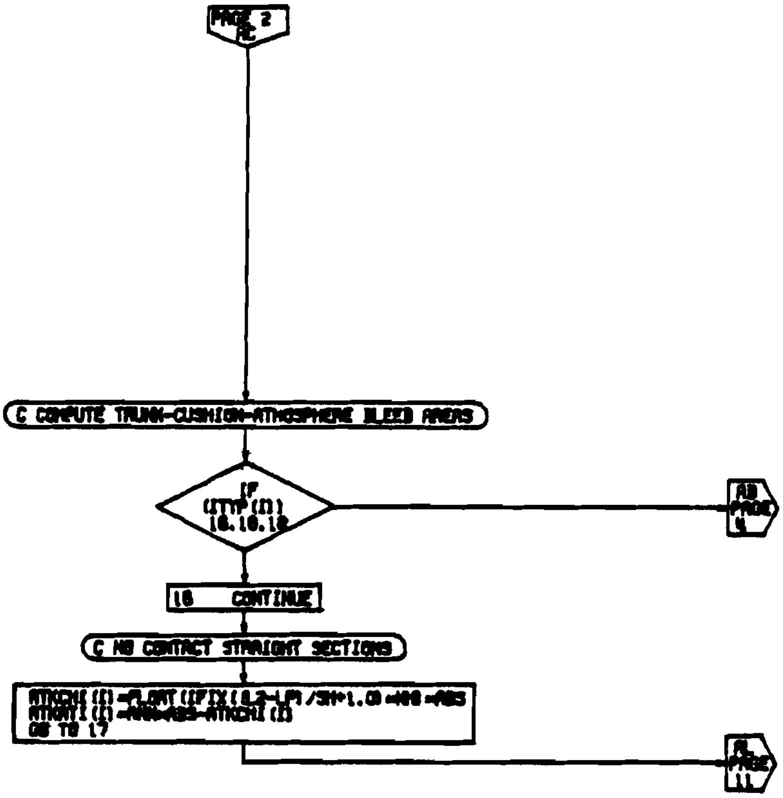
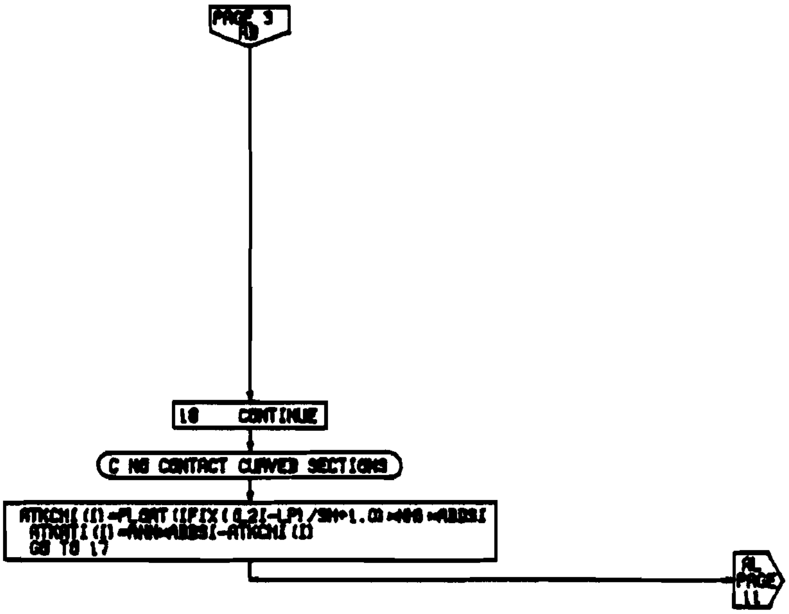


Table 87: FLOWCHART FOR SUBROUTINE SHAPE 2 (CONTINUED)



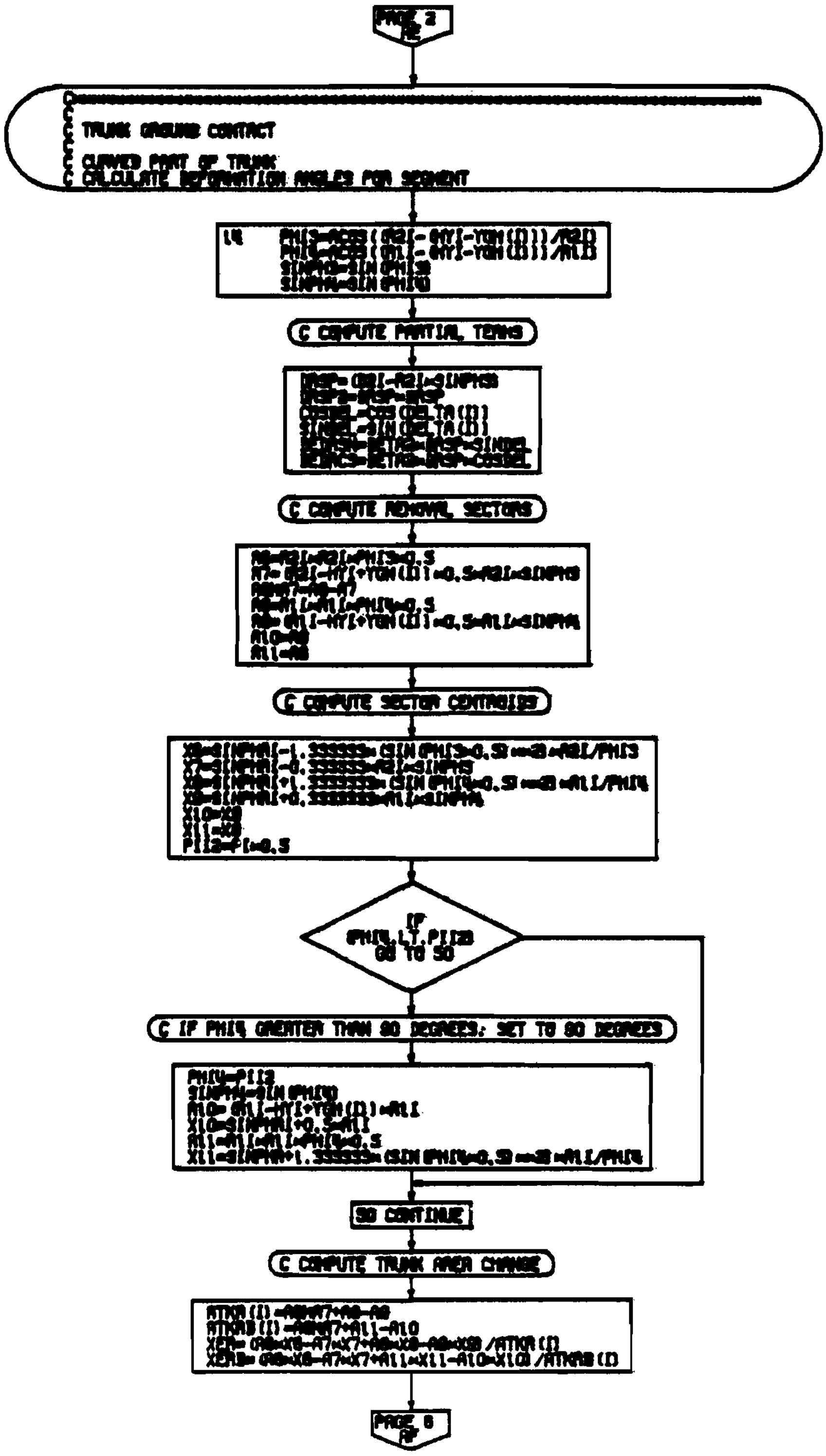
PAGE 3
SHAPE2

Table 87: FLOWCHART FOR SUBROUTINE SHAPE 2 (CONTINUED)



PAGE 4
SHAPE2

Table 87: FLOWCHART FOR SUBROUTINE SHAPE 2 (CONTINUED)



PAGE 5
SHAPE2

Table 87: FLOWCHART FOR SUBROUTINE SHAPE 2 (CONTINUED)

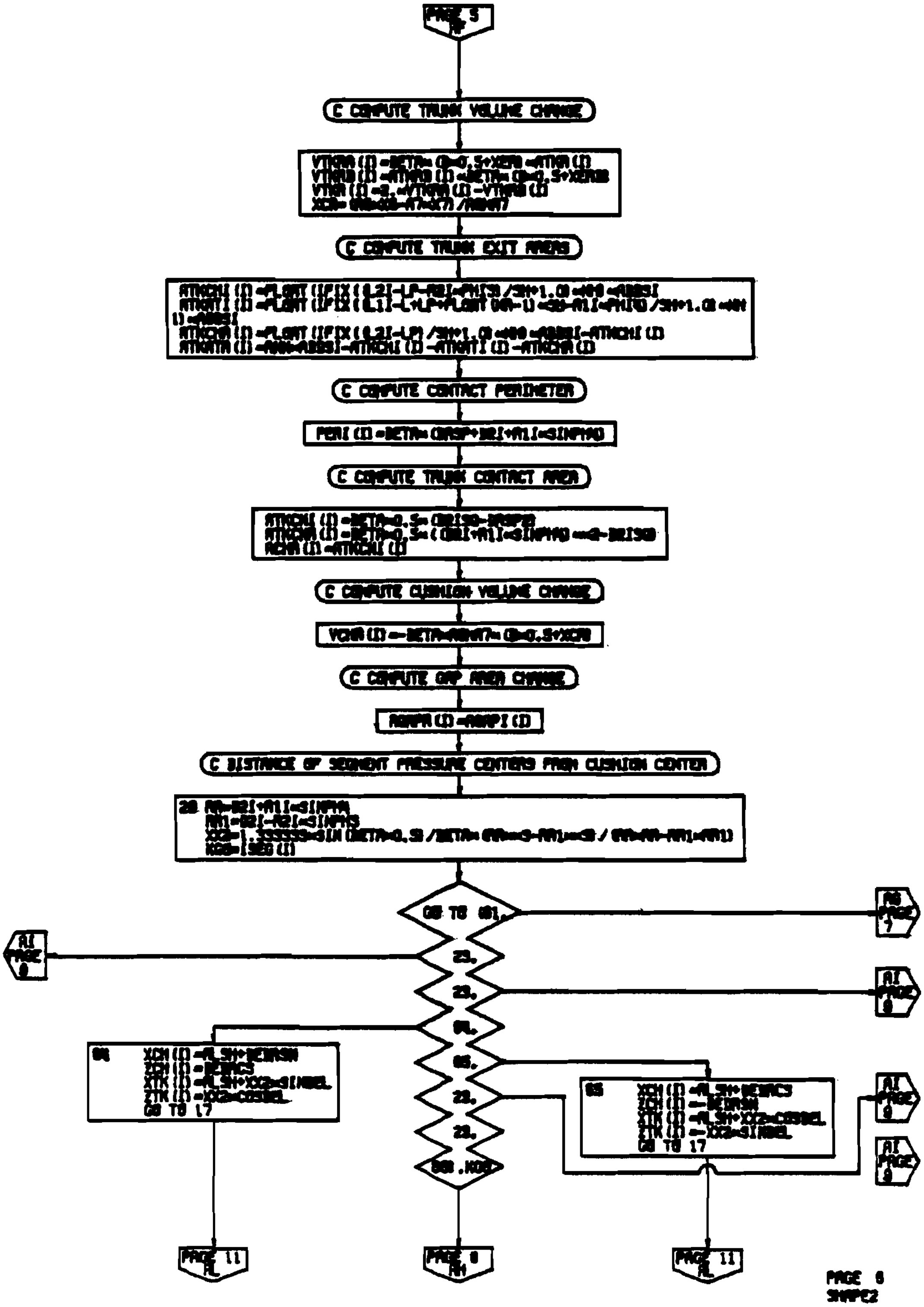
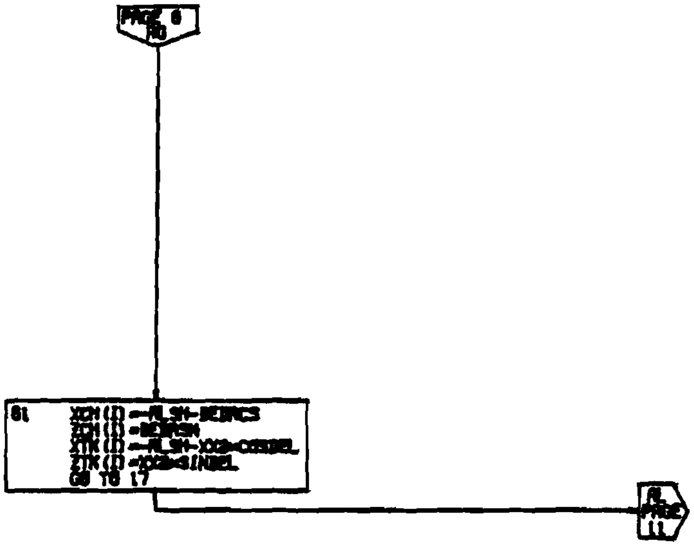


Table 87: FLOWCHART FOR SUBROUTINE SHAPE 2 (CONTINUED)



PAGE 7
SHAPE2

Table 87: FLOWCHART FOR SUBROUTINE SHAPE 2 (CONTINUED)

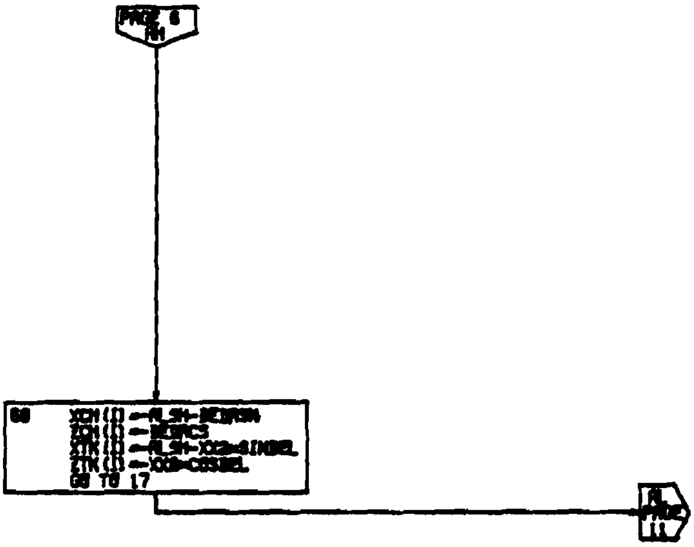
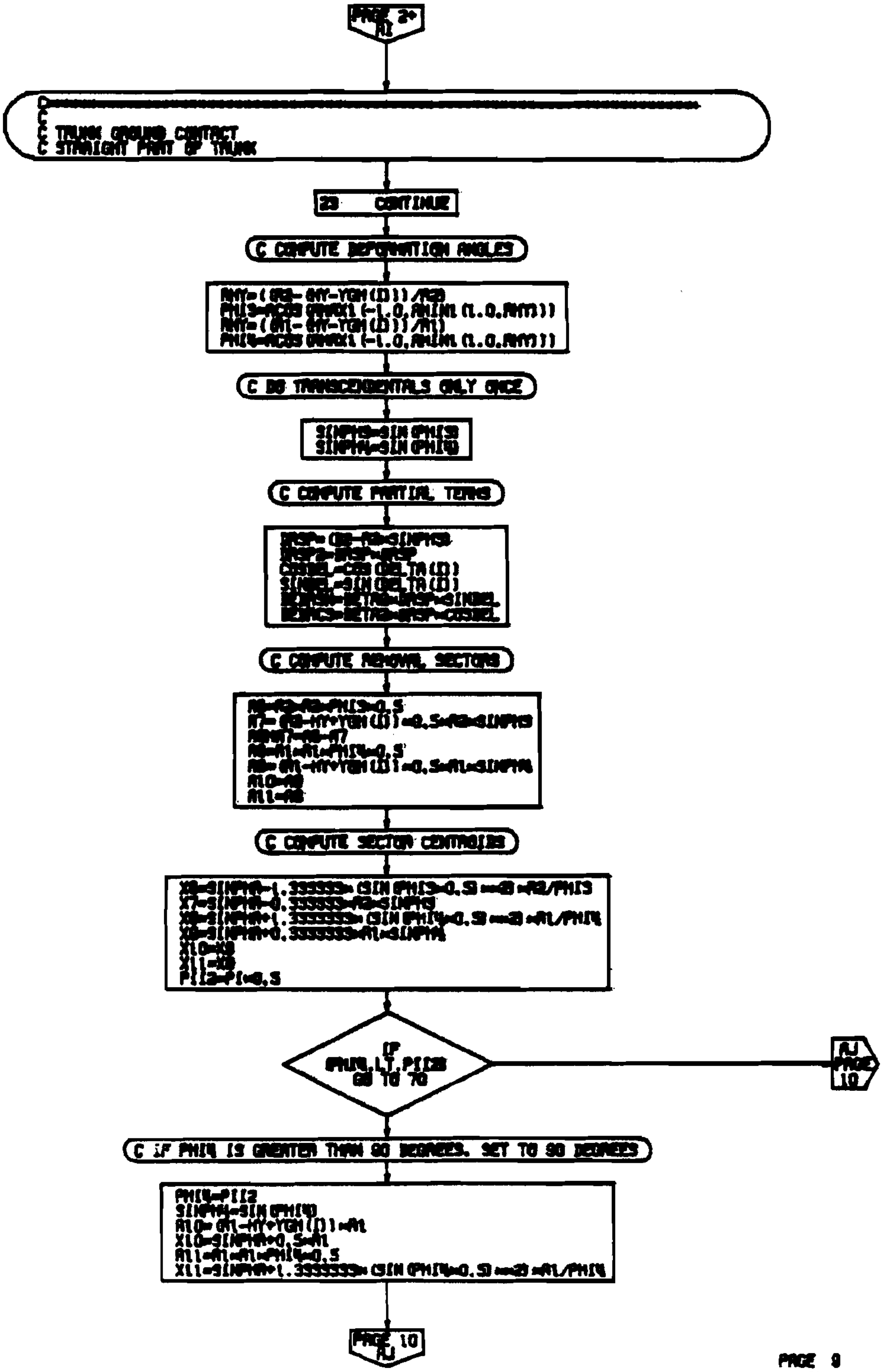


Table 87: FLOWCHART FOR SUBROUTINE SHAPE 2 (CONTINUED)



PAGE 9
SHAPE2

Table 87: FLOWCHART FOR SUBROUTINE SHAPE 2 (CONTINUED)

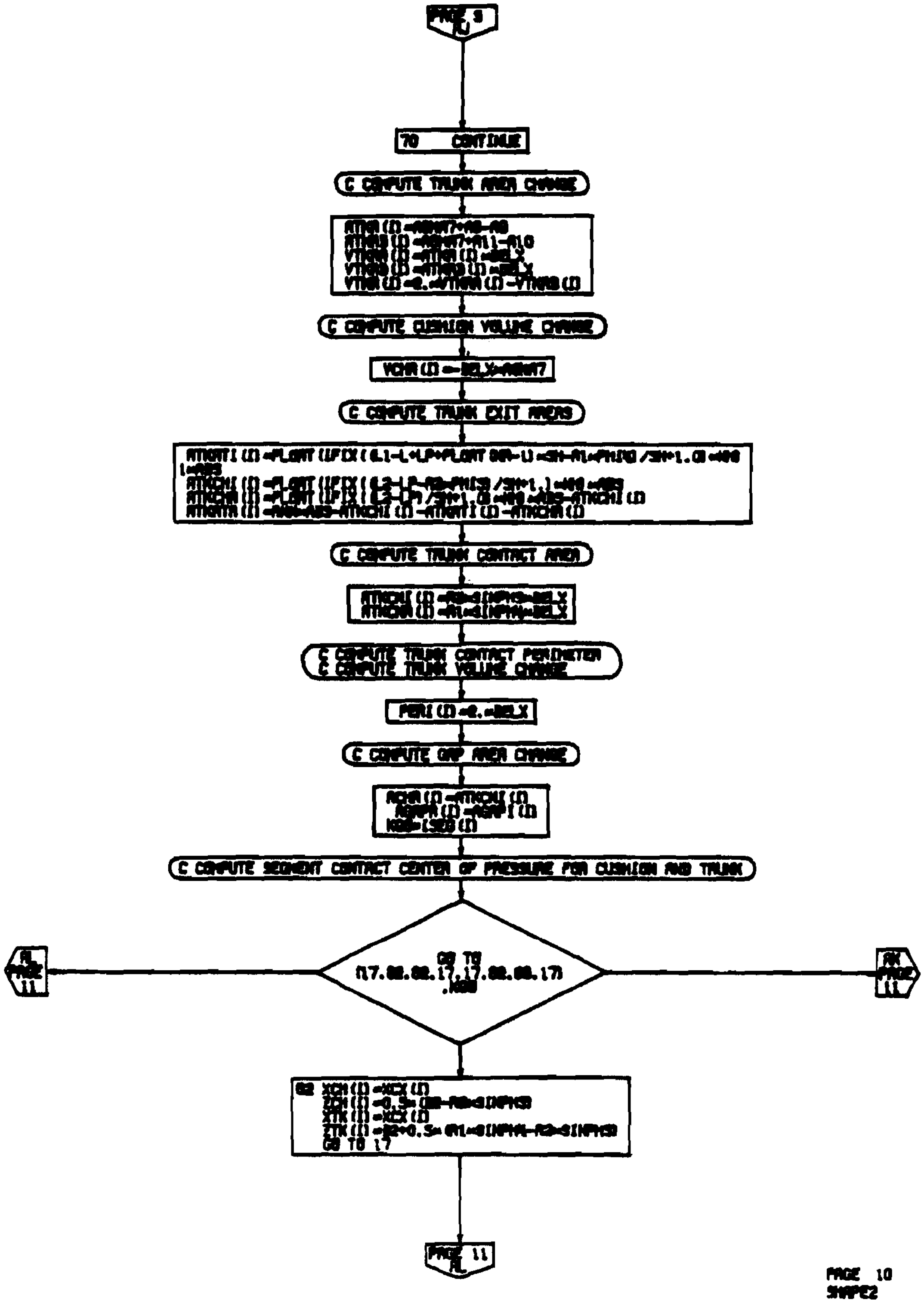


Table 87: FLOWCHART FOR SUBROUTINE SHAPE 2 (CONTINUED)

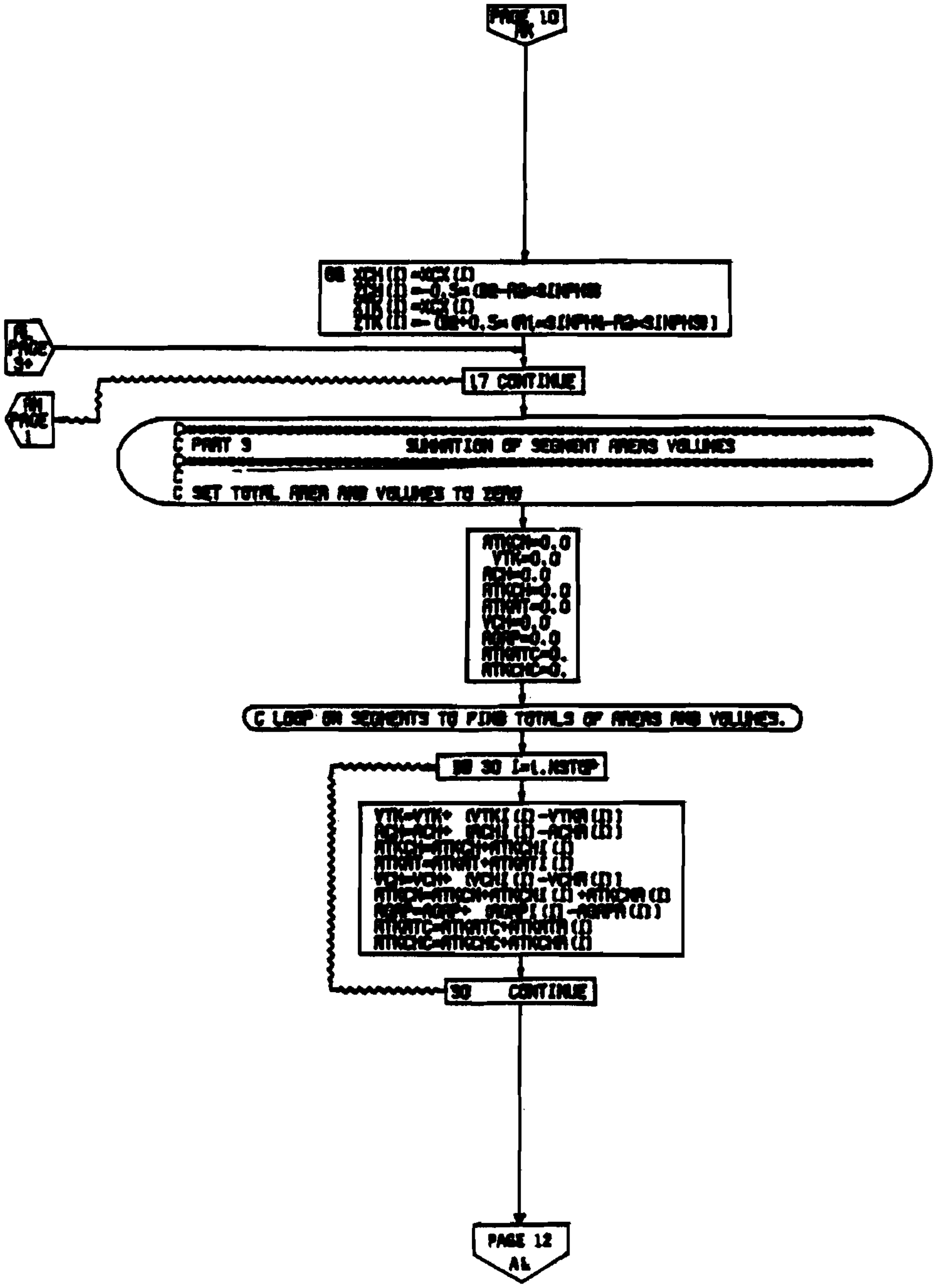
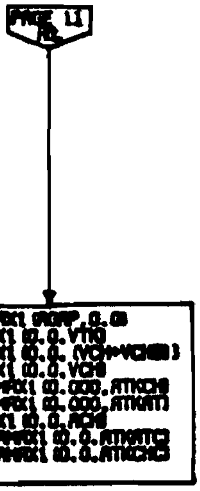


Table 87: FLOWCHART FOR SUBROUTINE SHAPE 2 (CONCLUDED)



PAGE 12
SHAPE2

Table 88 FLOWCHART FOR SUBROUTINE SHCP

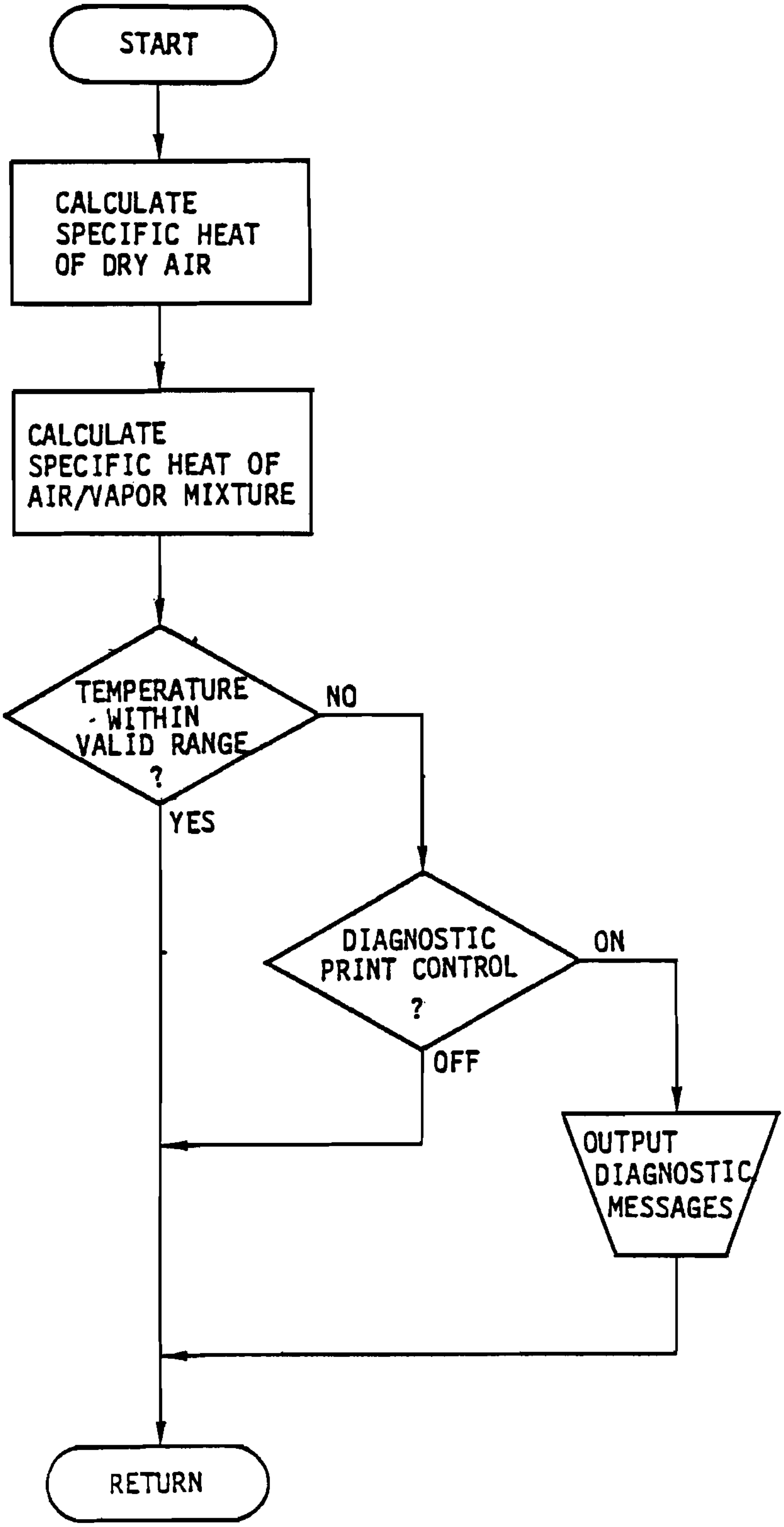
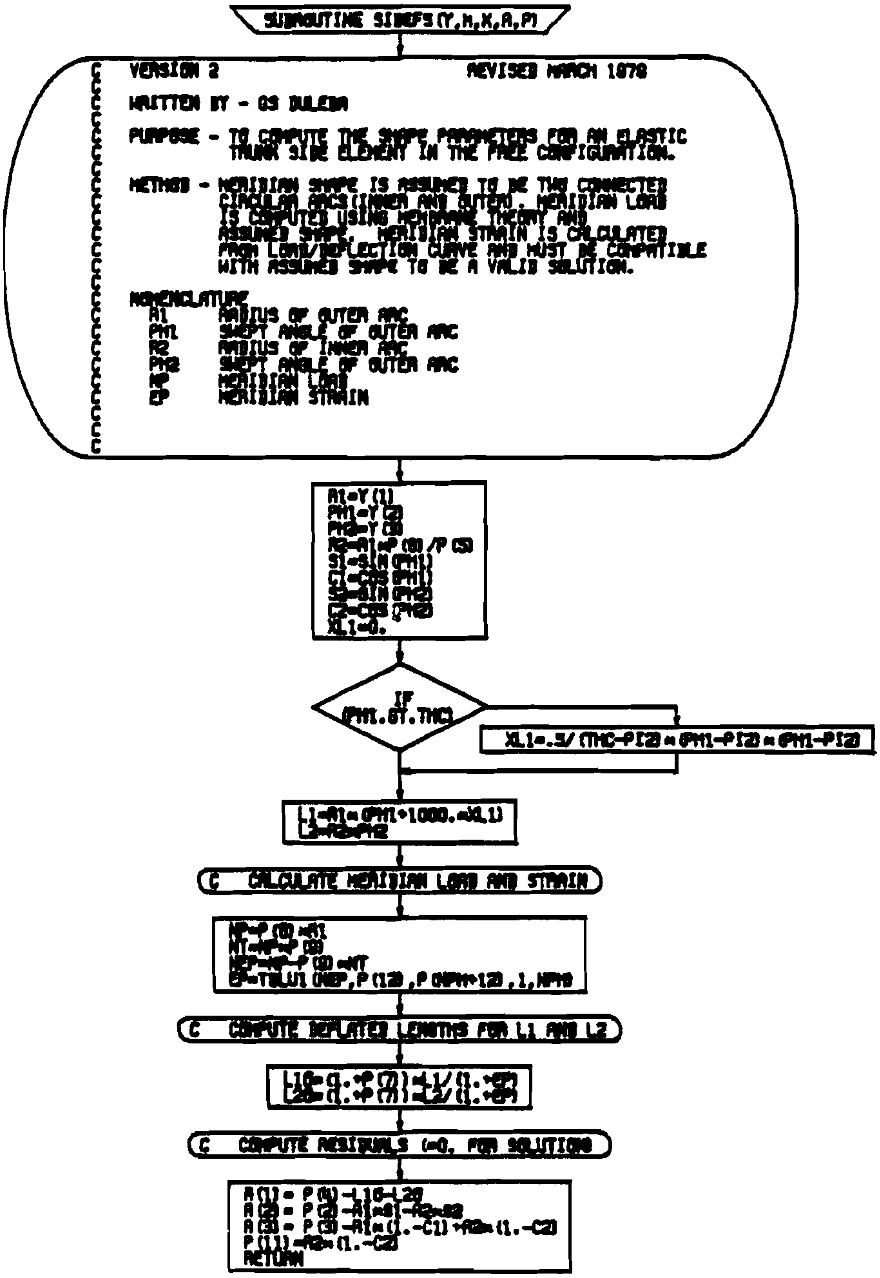


Table 89: FLOWCHART FOR SUBROUTINE SIDEFS



```
SUBROUTINE SIDEFS(Y,N,X,R,P)

C   VERSION 2                                    REVISED MARCH 1978
C
C   WRITTEN BY - GS DULEBA
C
C   PURPOSE - TO COMPUTE THE SHAPE PARAMETERS FOR AN ELASTIC
C             TRUNK SIDE ELEMENT IN THE FREE CONFIGURATION.
C
C   METHOD - MERIDIAN SHAPE IS ASSUMED TO BE TWO CONNECTED
C            CIRCULAR ARCS(INNER AND OUTER). MERIDIAN LOAD
C            IS COMPUTED USING MEMBRANE THEORY AND
C            ASSUMED SHAPE.  MERIDIAN STRAIN IS CALCULATED
C            FROM LOAD/DEFLECTION CURVE AND MUST BE COMPATIBLE
C            WITH ASSUMED SHAPE TO BE A VALID SOLUTION.
C
C   NOMENCLATURE
C     R1     RADIUS OF OUTER ARC
C     PM1    SWEPT ANGLE OF OUTER ARC
C     R2     RADIUS OF INNER ARC
C     PM2    SWEPT ANGLE OF OUTER ARC
C     NP     MERIDIAN LOAD
C     EP     MERIDIAN STRAIN
C
C

R1=Y(1)
PM1=Y(2)
PM2=Y(3)
R2=R1*P(6)/P(5)
S1=SIN(PM1)
C1=COS(PM1)
S2=SIN(PM2)
C2=COS(PM2)
XL1=0.

IF
(PM1.GT.THC)
XL1=.5/(THC-PI2)*(PM1-PI2)*(PM1-PI2)

L1=R1*(PM1+1000.*XL1)
L2=R2*PM2

C   CALCULATE MERIDIAN LOAD AND STRAIN

NP=P(6)*R1
NT=NP*P(3)
NEP=NP-P(9)*NT
EP=TBLU1(NEP,P(12),P(NPM+12),1,NPM)

C   COMPUTE DEFLATED LENGTHS FOR L1 AND L2

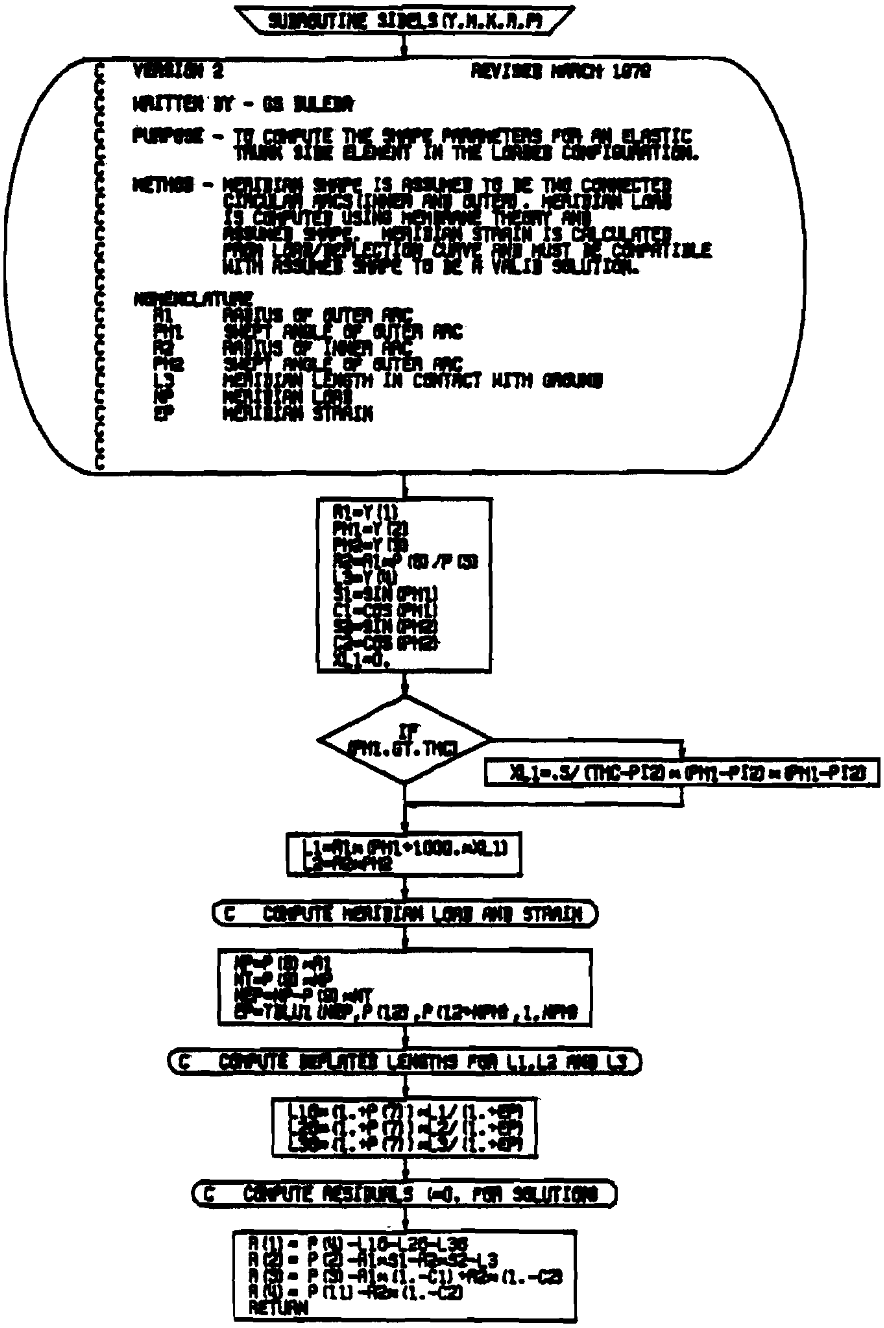
L10=(1.+P(7))*L1/(1.+EP)
L20=(1.+P(7))*L2/(1.+EP)

C   COMPUTE RESIDUALS (=0. FOR SOLUTION)

R(1)= P(4)-L10-L20
R(2)= P(2)-R1*S1-R2*S2
R(3)= P(3)-R1*(1.-C1)+R2*(1.-C2)
P(11)=R2*(1.-C2)
RETURN
```

PAGE 1
SIDEFS

Table 90: FLOWCHART FOR SUBROUTINE SIDELS



```
SUBROUTINE SIDELS(Y,N,K,R,P)

C    VERSION 2                            REVISED MARCH 1978
C
C    WRITTEN BY - GS BULEDA
C
C    PURPOSE - TO COMPUTE THE SHAPE PARAMETERS FOR AN ELASTIC
C              TRUNK SIDE ELEMENT IN THE LOADED CONFIGURATION.
C
C    METHOD - MERIDIAN SHAPE IS ASSUMED TO BE TWO CONNECTED
C             CIRCULAR ARCS(INNER AND OUTER). MERIDIAN LOAD
C             IS COMPUTED USING MEMBRANE THEORY AND
C             ASSUMED SHAPE.  MERIDIAN STRAIN IS CALCULATED
C             FROM LOAD/DEFLECTION CURVE AND MUST BE COMPATIBLE
C             WITH ASSUMED SHAPE TO BE A VALID SOLUTION.
C
C    NOMENCLATURE
C      R1     RADIUS OF OUTER ARC
C      PH1    SWEPT ANGLE OF OUTER ARC
C      R2     RADIUS OF INNER ARC
C      PH2    SWEPT ANGLE OF OUTER ARC
C      L3     MERIDIAN LENGTH IN CONTACT WITH GROUND
C      NP     MERIDIAN LOAD
C      EP     MERIDIAN STRAIN
C
C

R1=Y(1)
PH1=Y(2)
PH2=Y(3)
R2=R1*P(6)/P(5)
L3=Y(4)
S1=SIN(PH1)
C1=COS(PH1)
S2=SIN(PH2)
C2=COS(PH2)
XL1=0.

IF
(PH1.GT.THC)
        XL1=.5/(THC-PI2)*(PH1-PI2)*(PH1-PI2)

L1=R1*(PH1+1000.*XL1)
L2=R2*PH2

C   COMPUTE MERIDIAN LOAD AND STRAIN

NP=P(8)*R1
NT=P(9)*NP
NEP=NP-P(9)*NT
EP=TBLU1(NEP,P(12),P(12+NPTS),1,NPTS)

C   COMPUTE DEFLATED LENGTHS FOR L1,L2 AND L3

L10=(1.+P(7))*L1/(1.+EP)
L20=(1.+P(7))*L2/(1.+EP)
L30=(1.+P(7))*L3/(1.+EP)

C   COMPUTE RESIDUALS (=0. FOR SOLUTION)

R(1) = P(4)-L10-L20-L30
R(2) = P(2)-R1*S1-R2*S2-L3
R(3) = P(3)-R1*(1.-C1)+R2*(1.-C2)
R(4) = P(11)-R2*(1.-C2)
RETURN
```

Table 91: FLOWCHART FOR SUBROUTINE STATIC

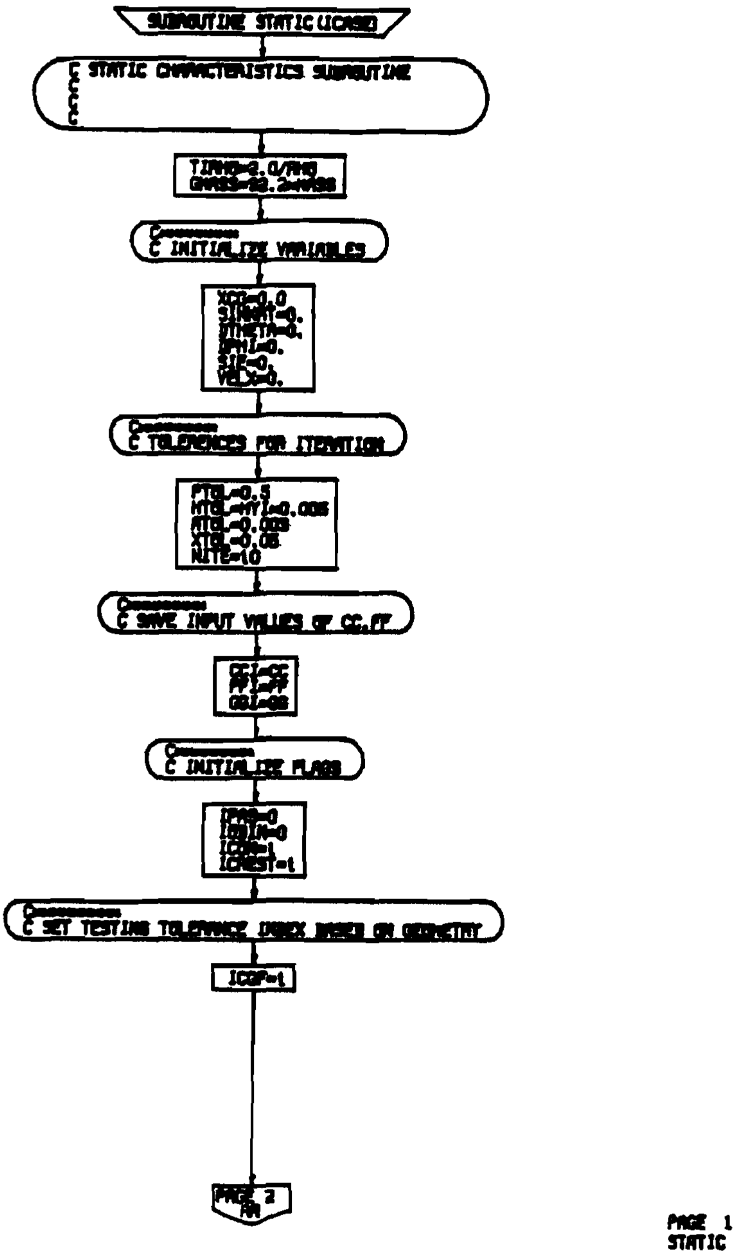


Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

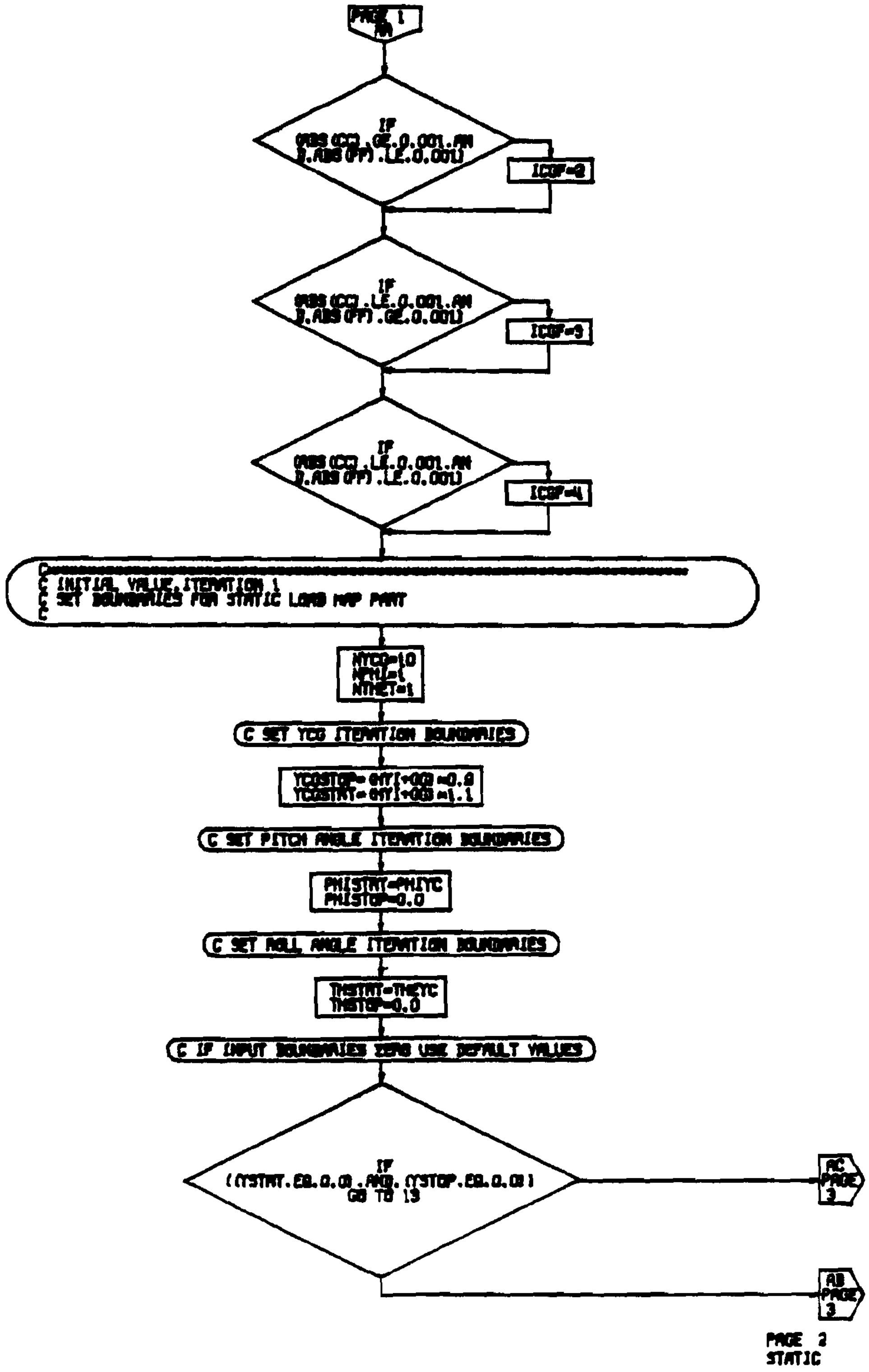


Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

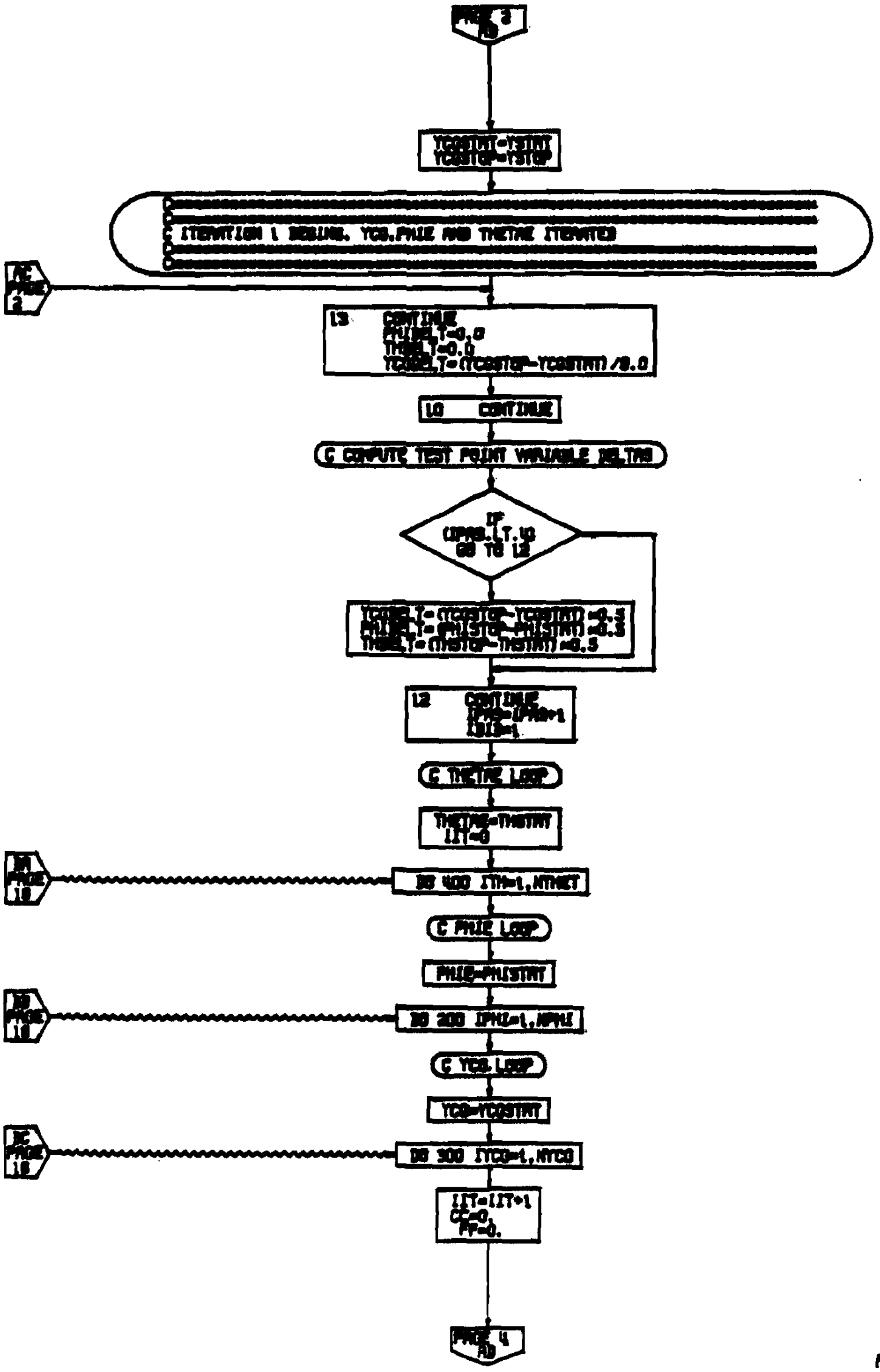


Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

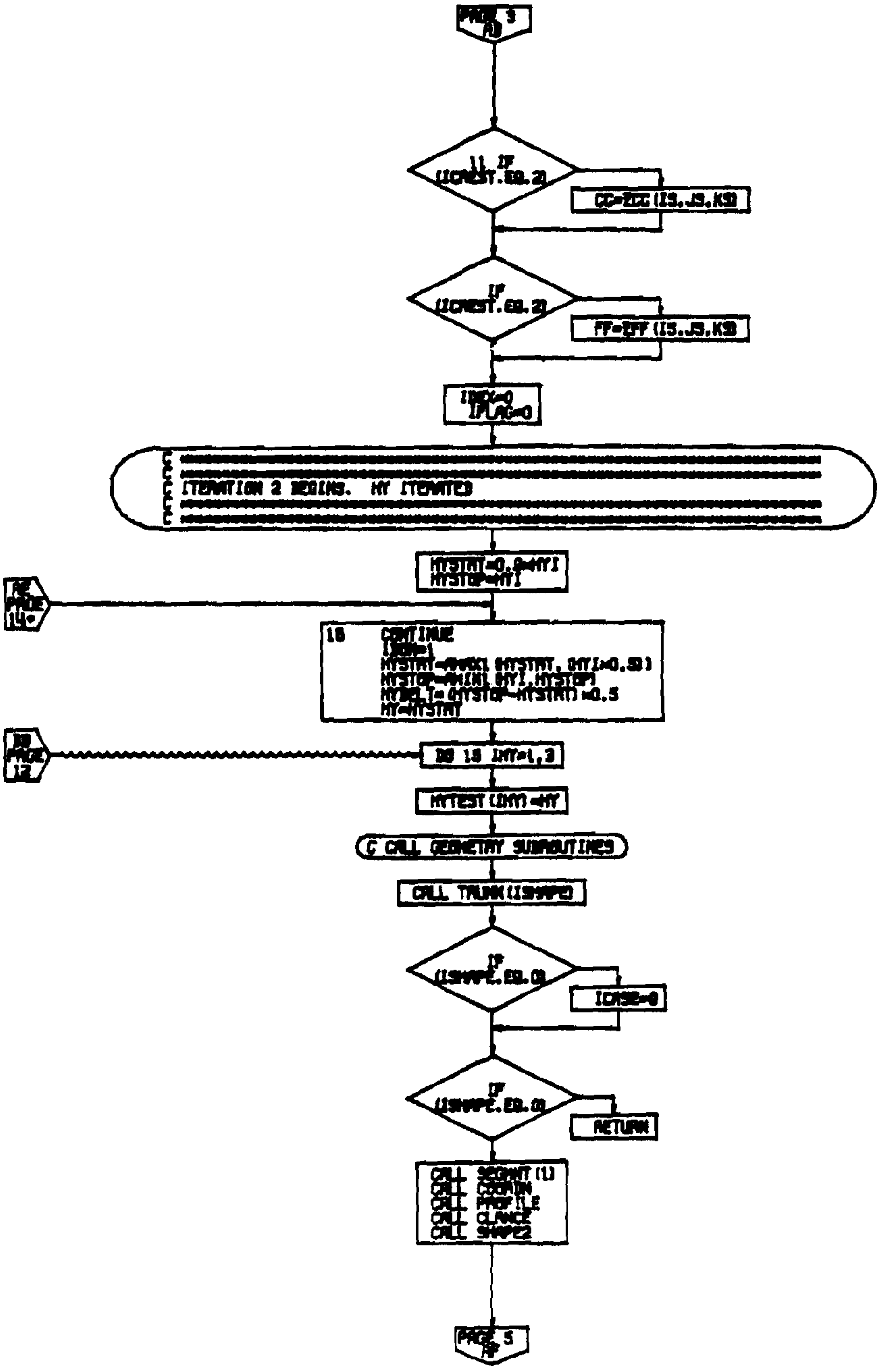


Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

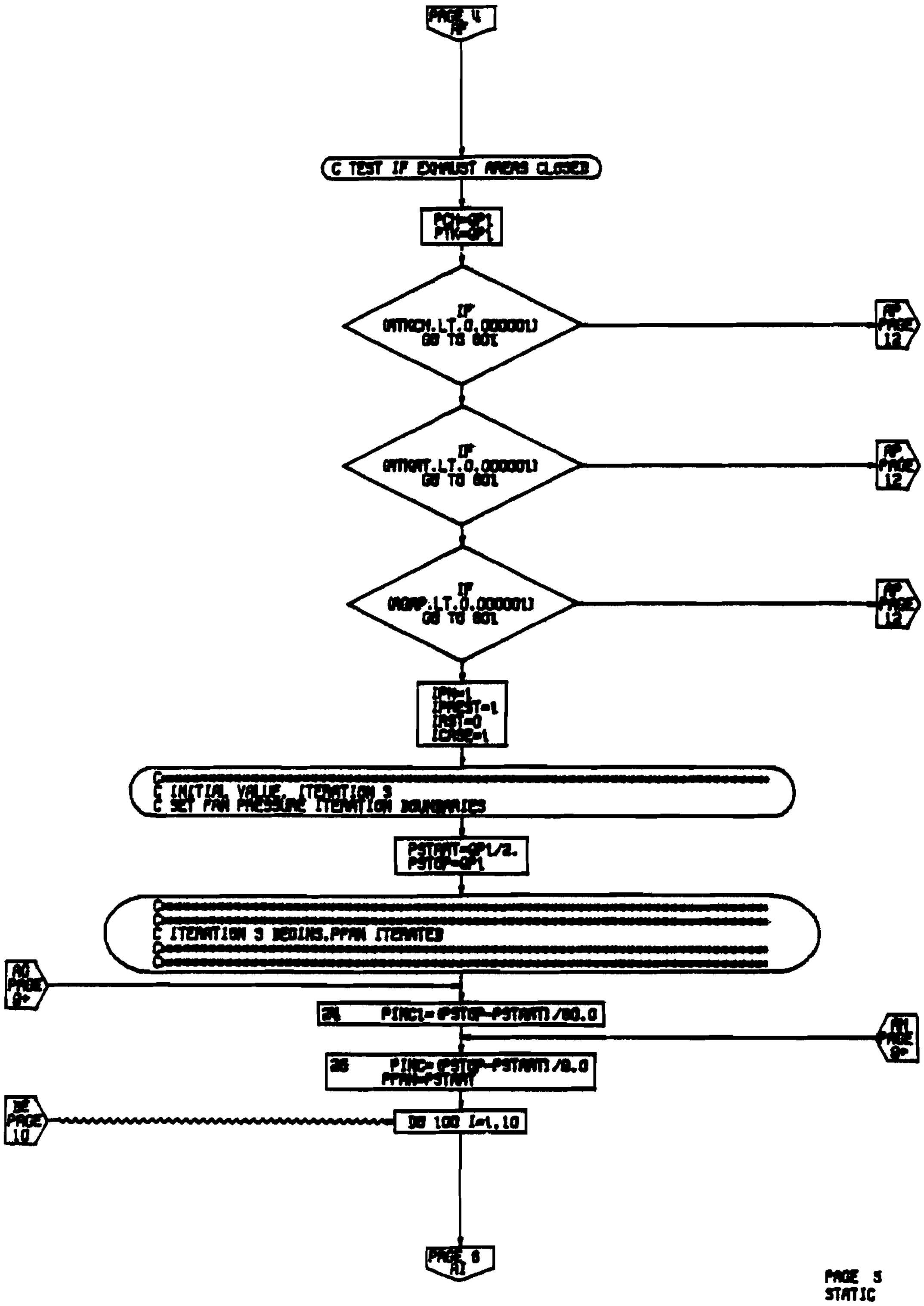


Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

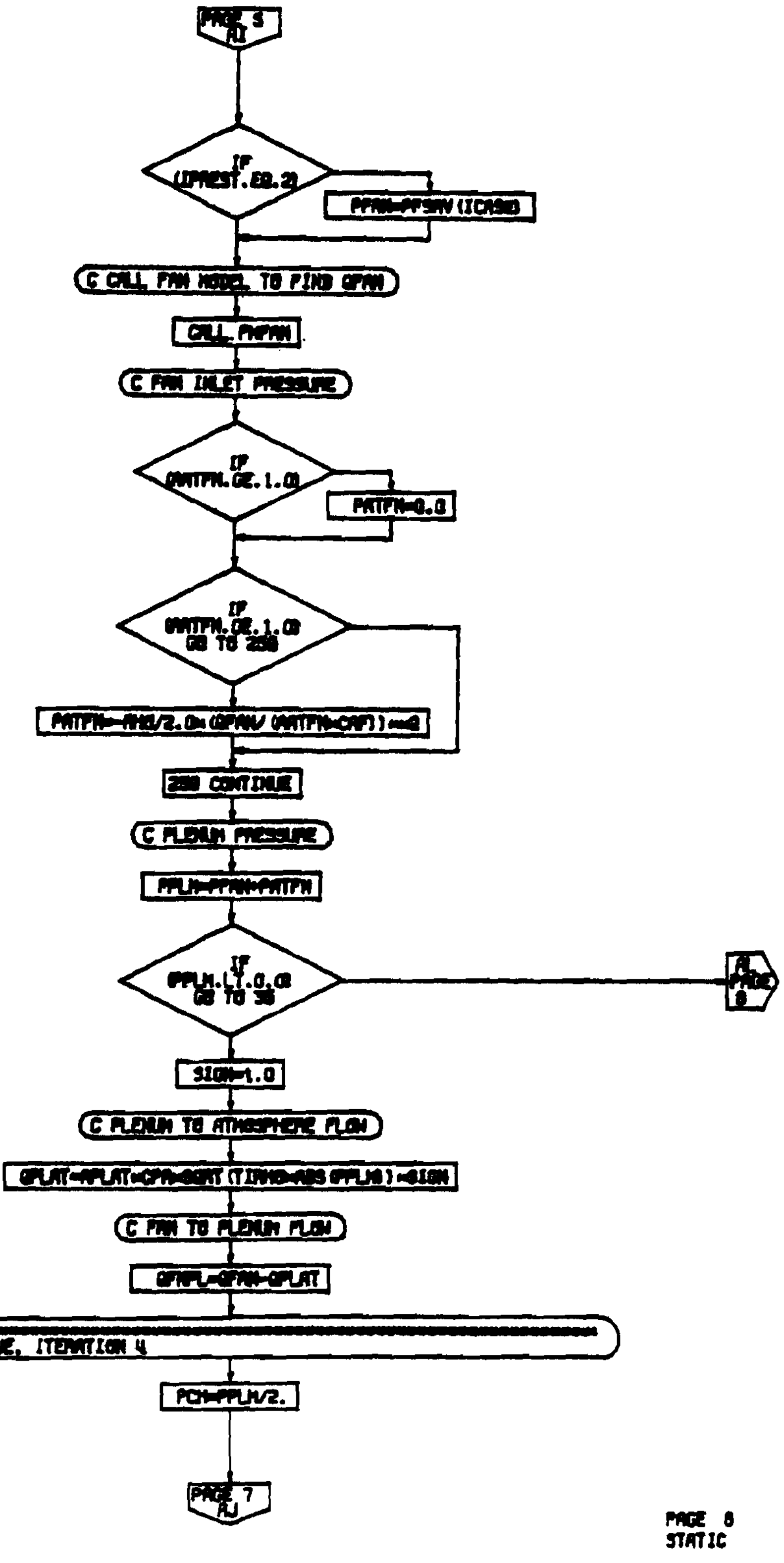


Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

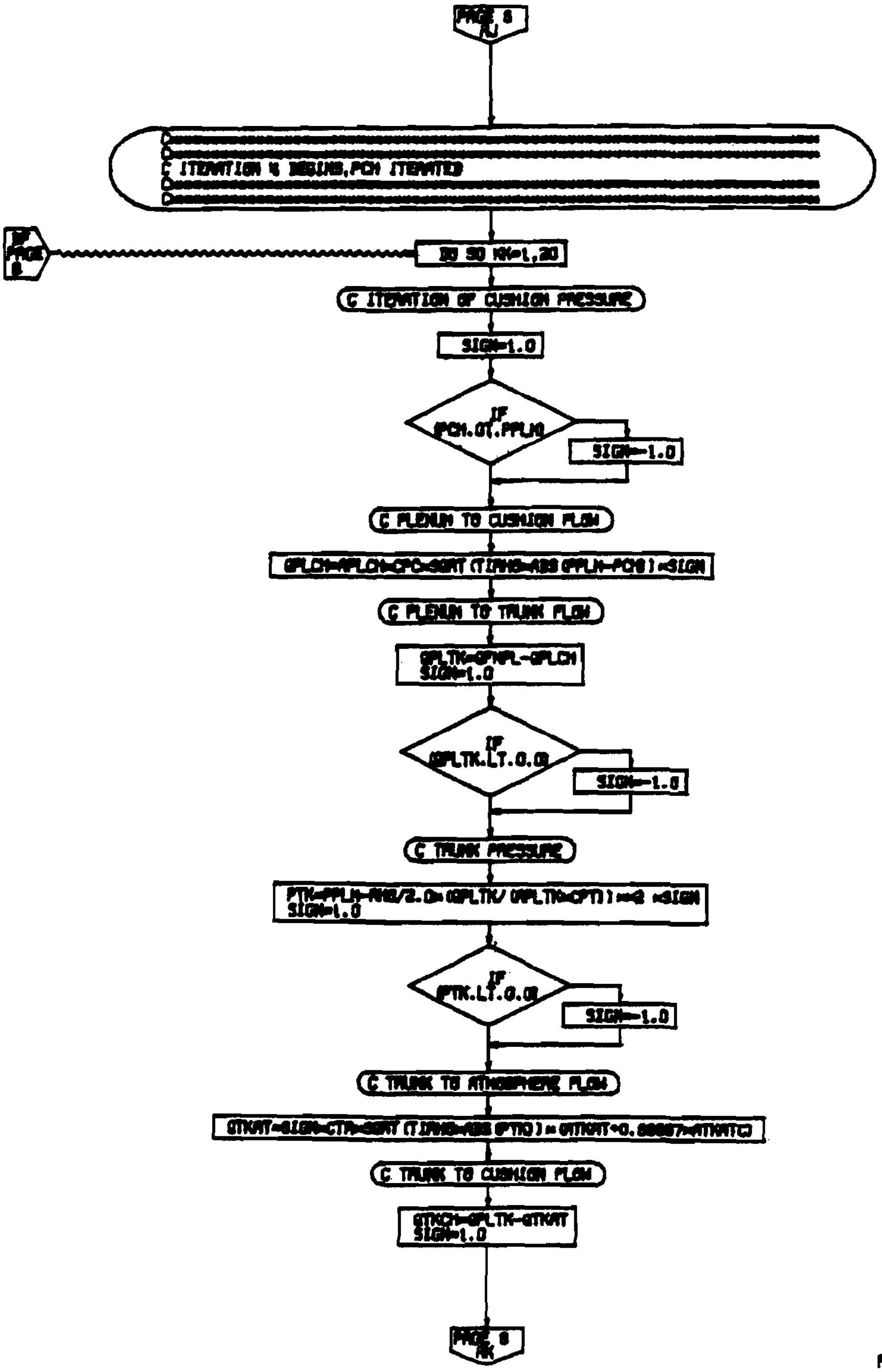


Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

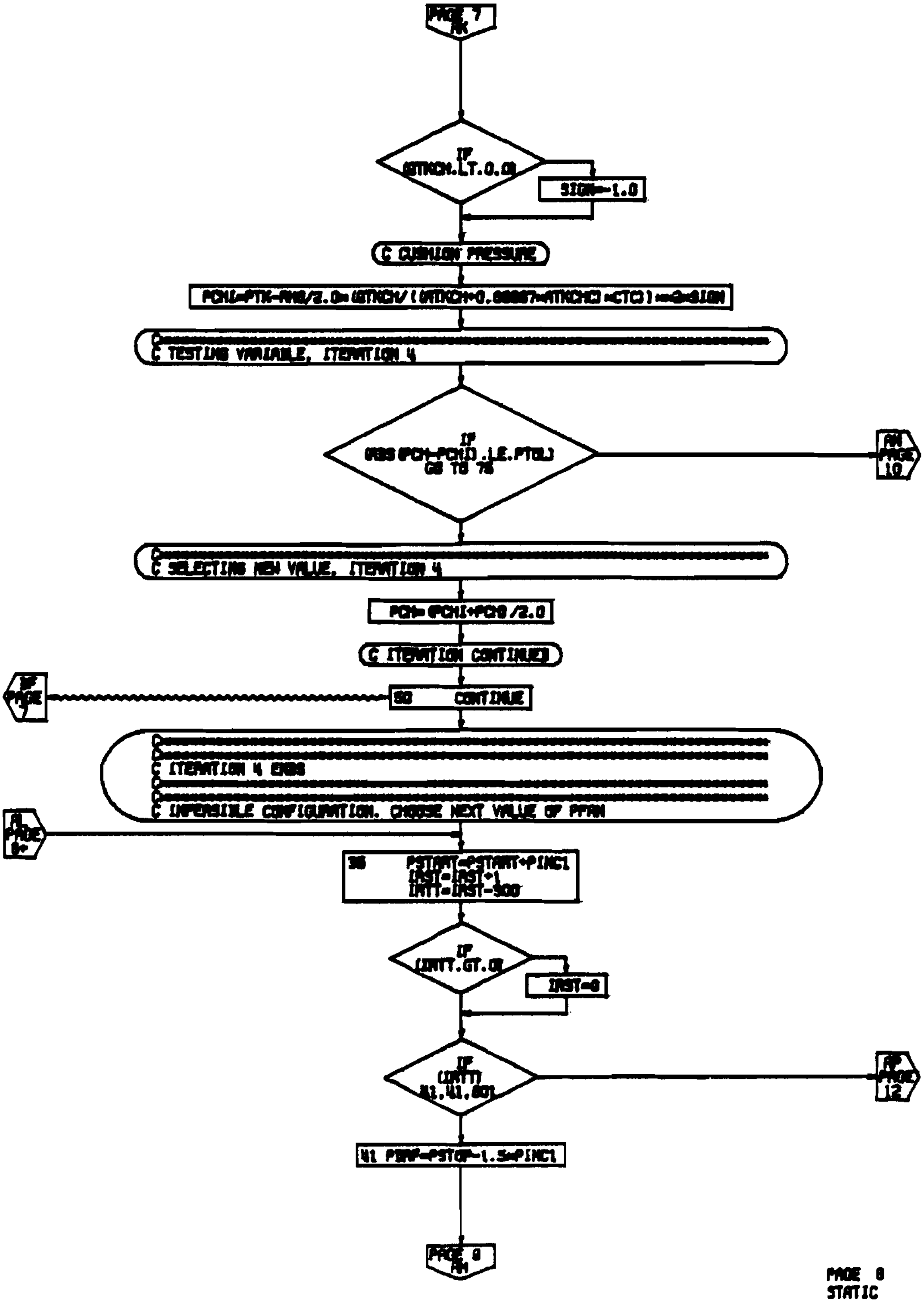


Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

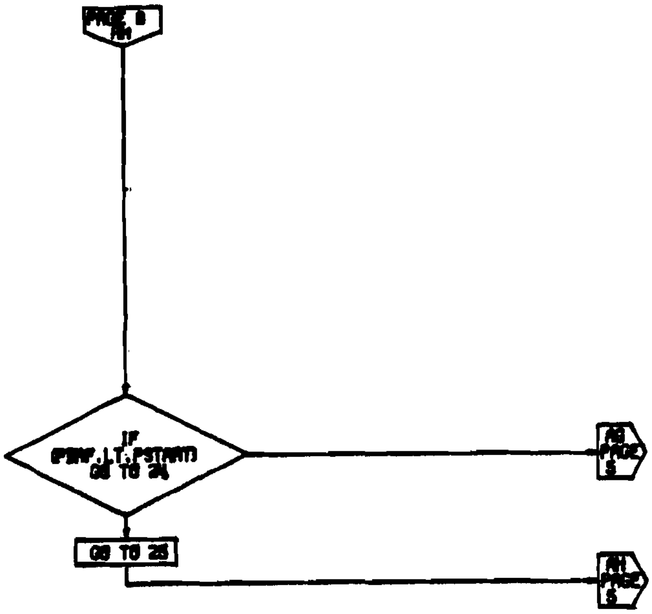


Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

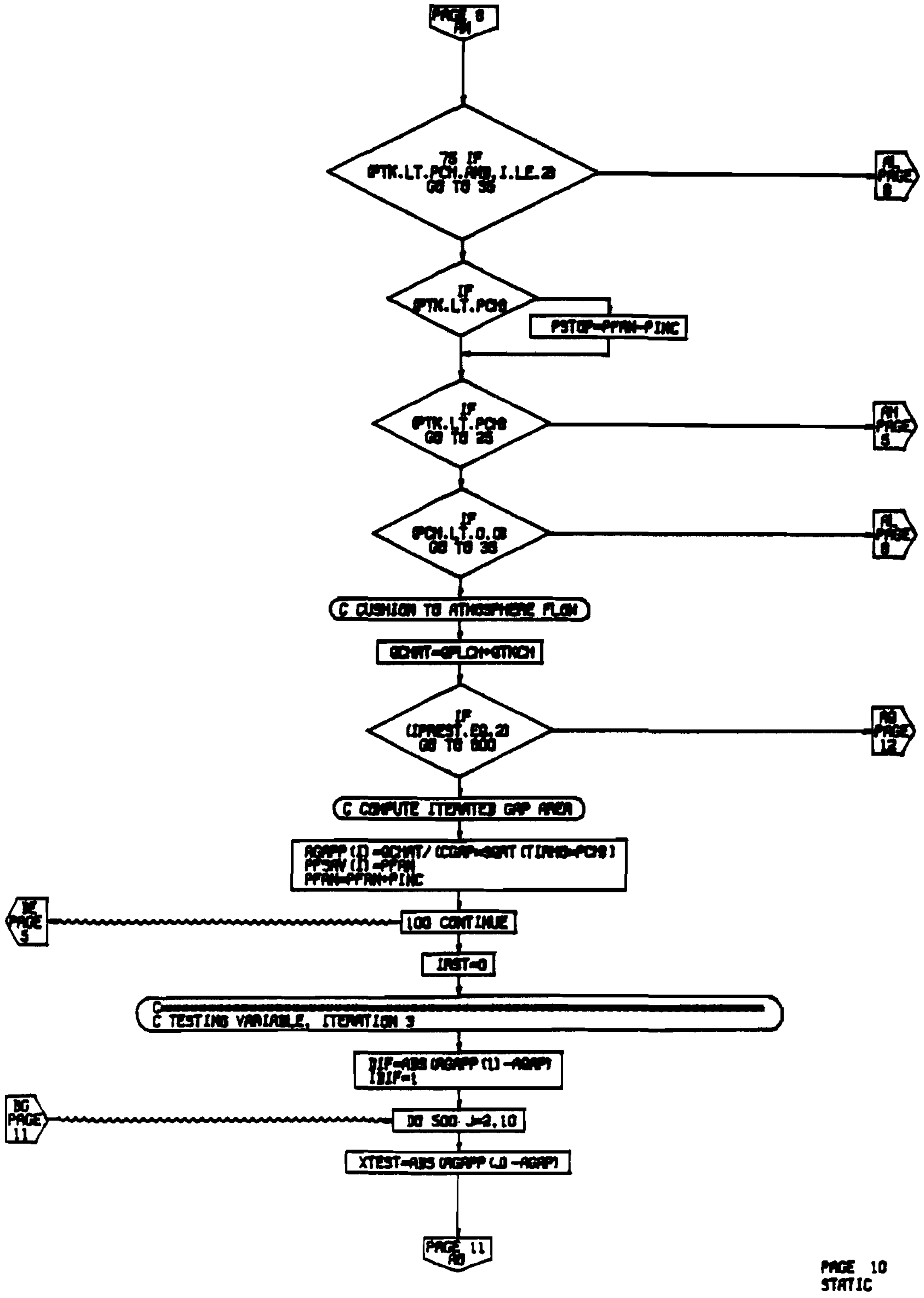


Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

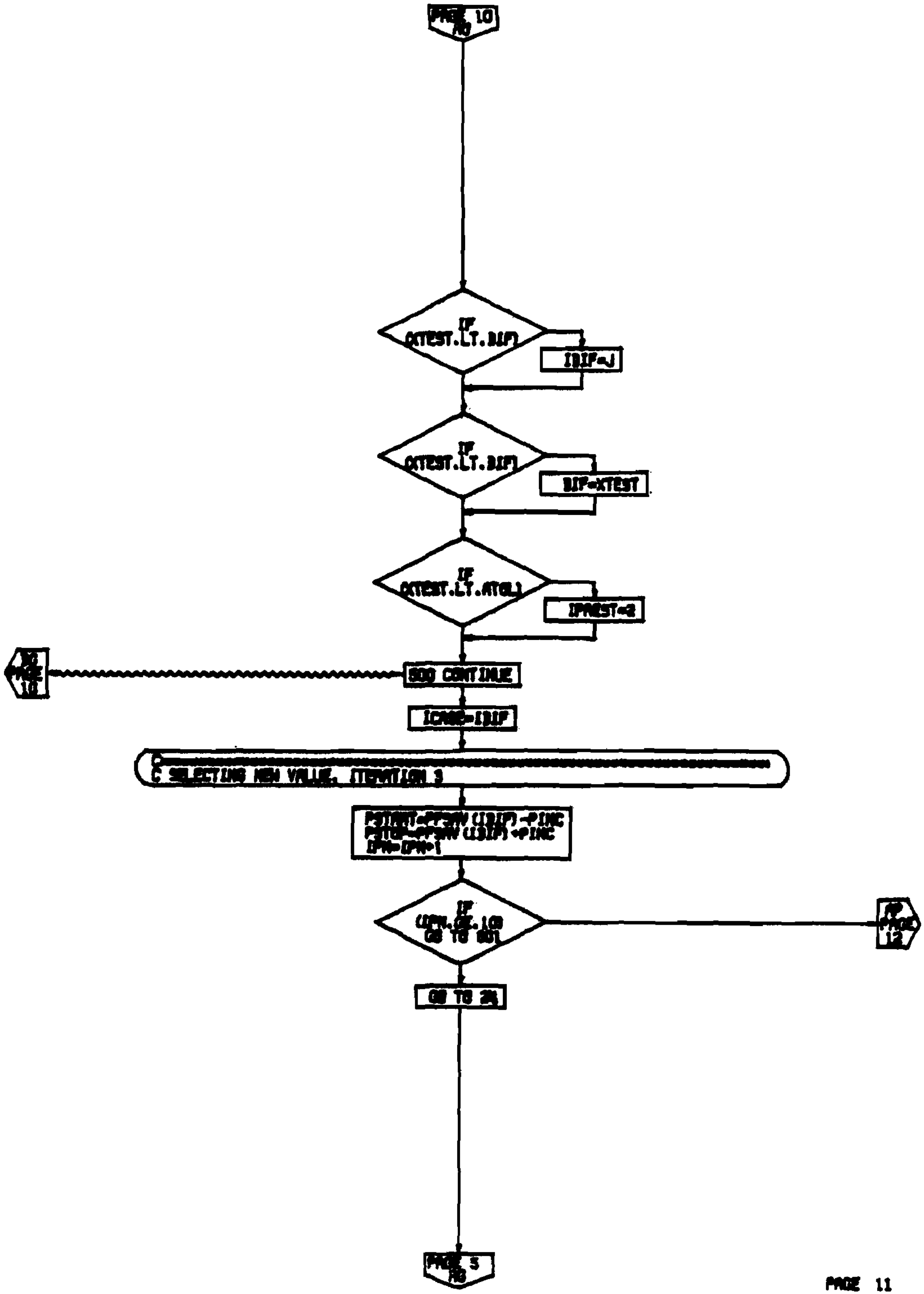


Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

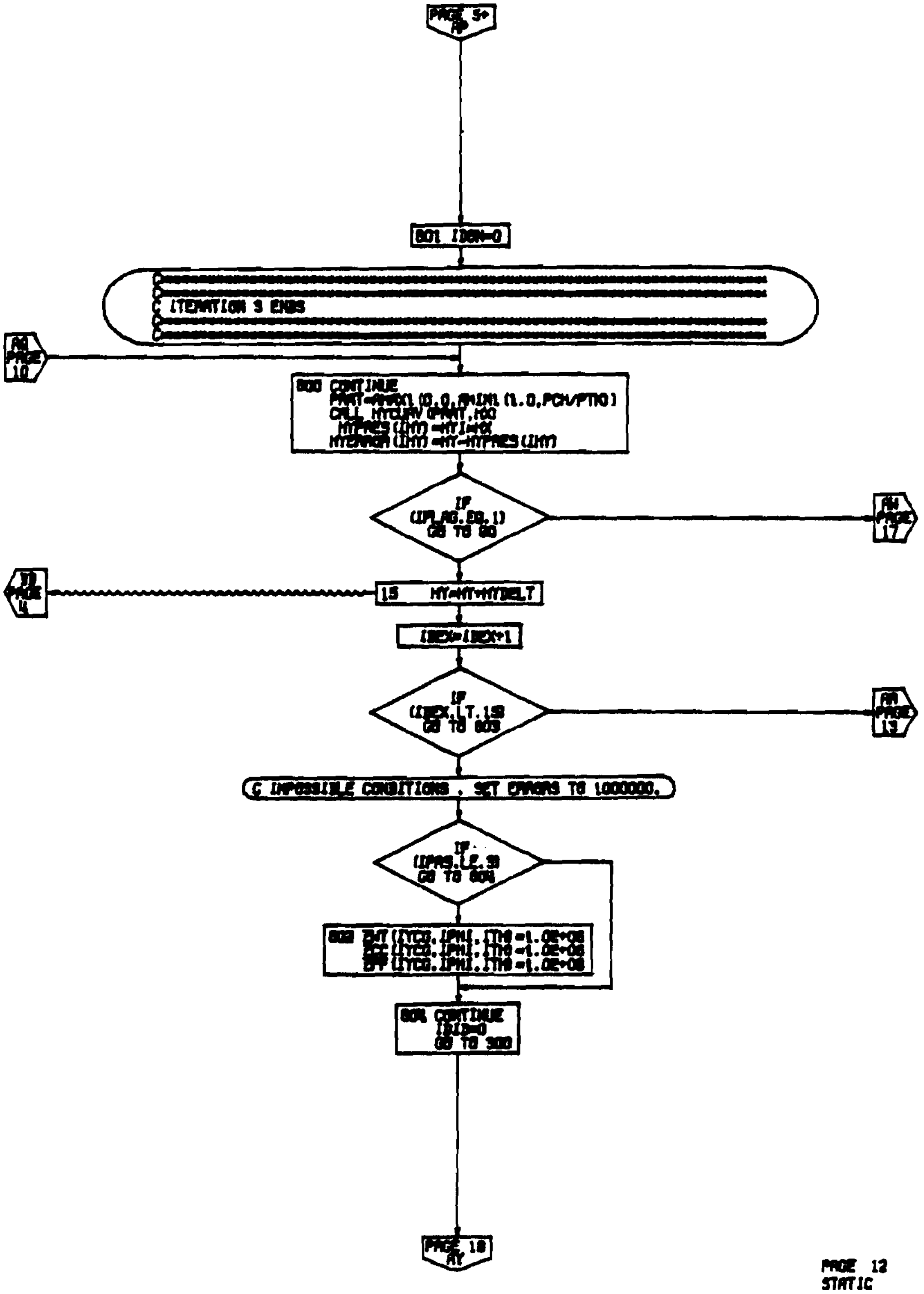


Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

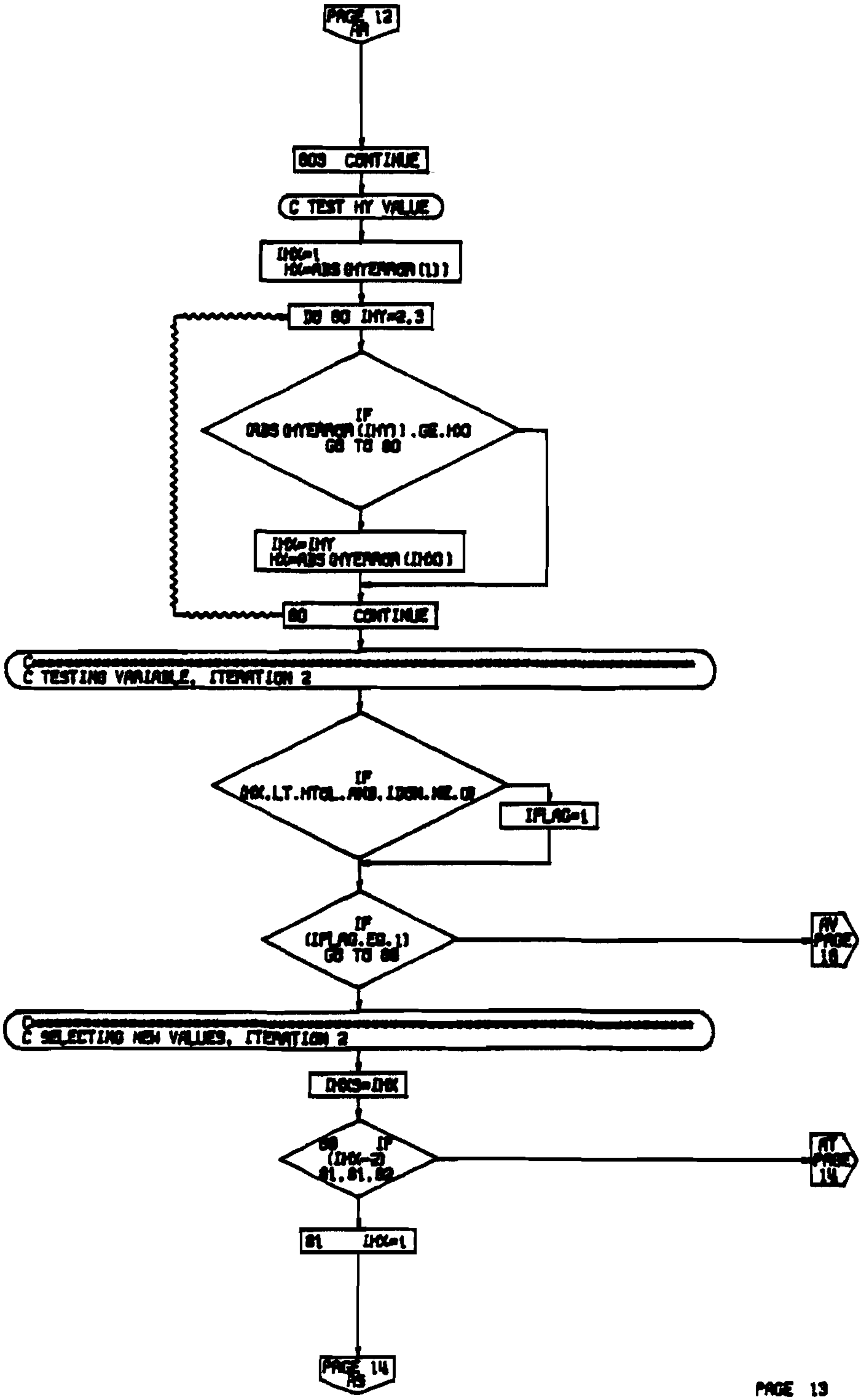


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Table 91: FLOWCHART FOR SBUROUTINE STATIC (CONTINUED)

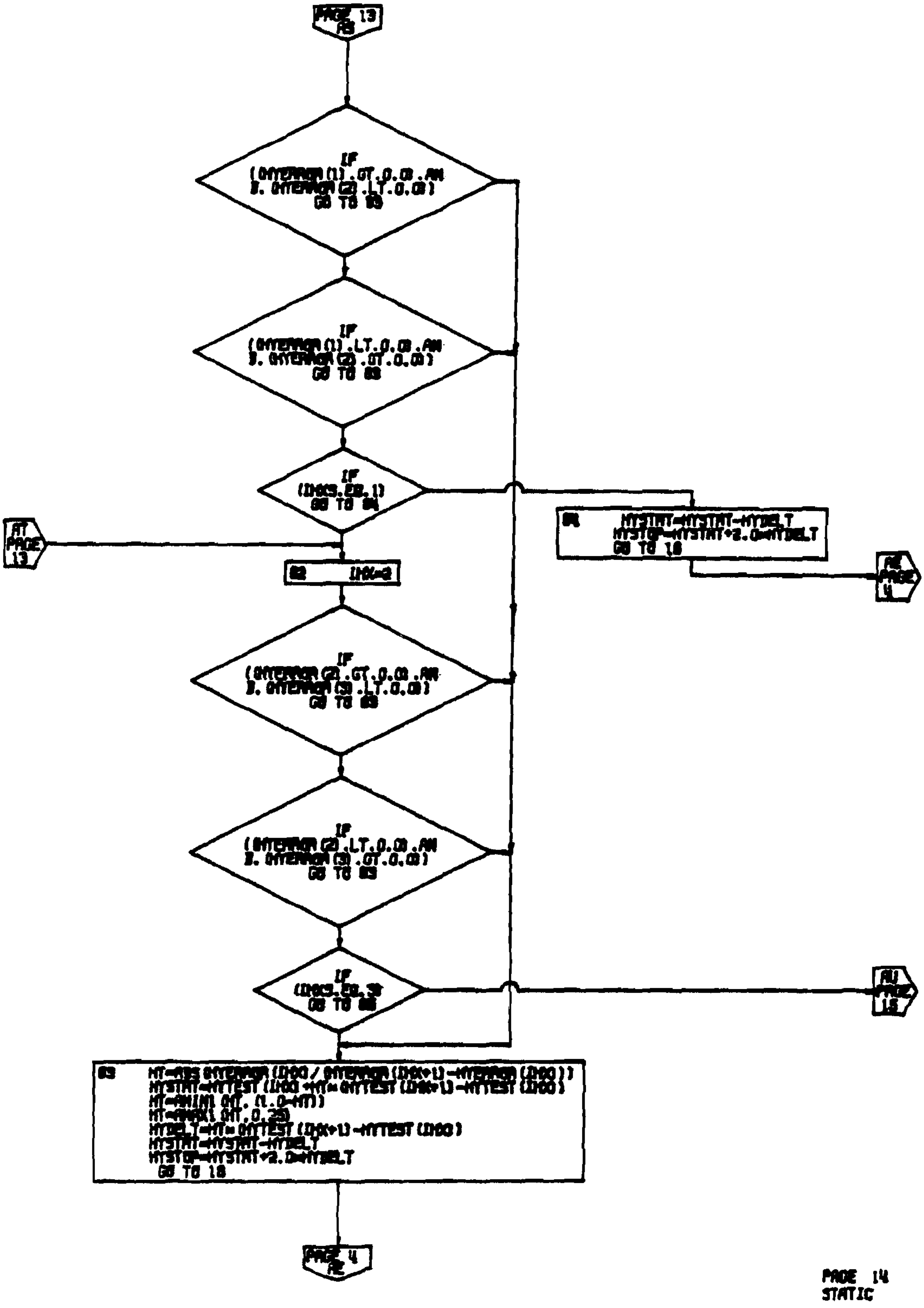

Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

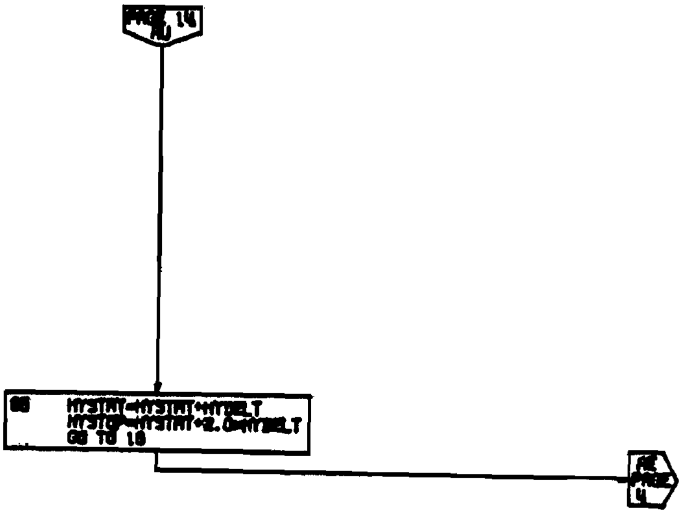

Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

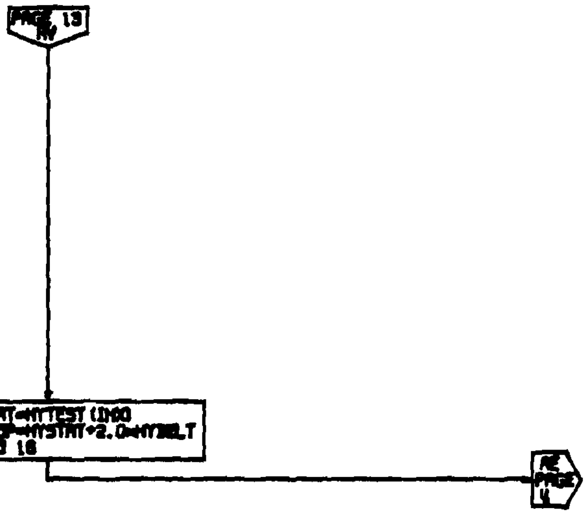

Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

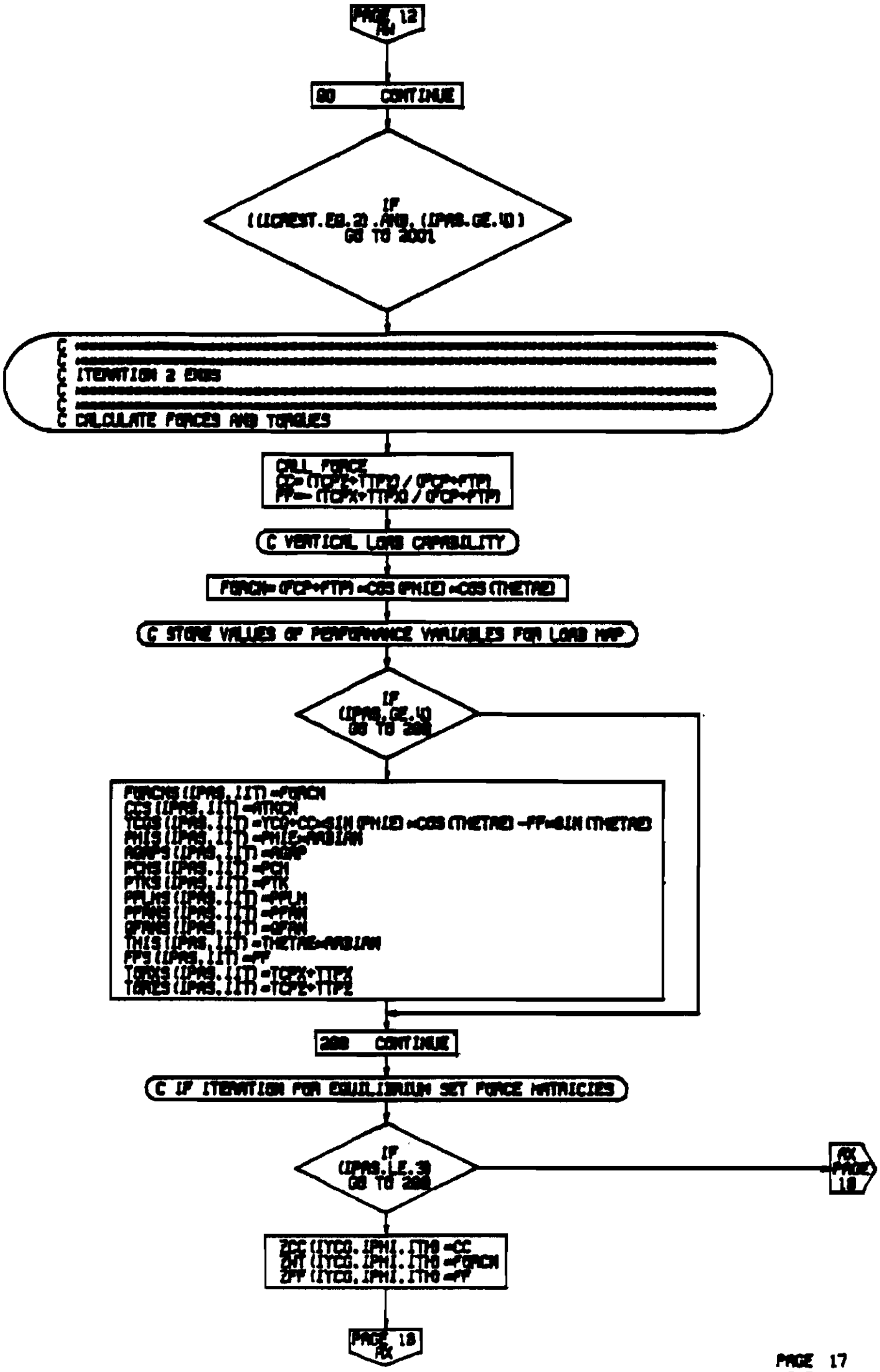

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Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

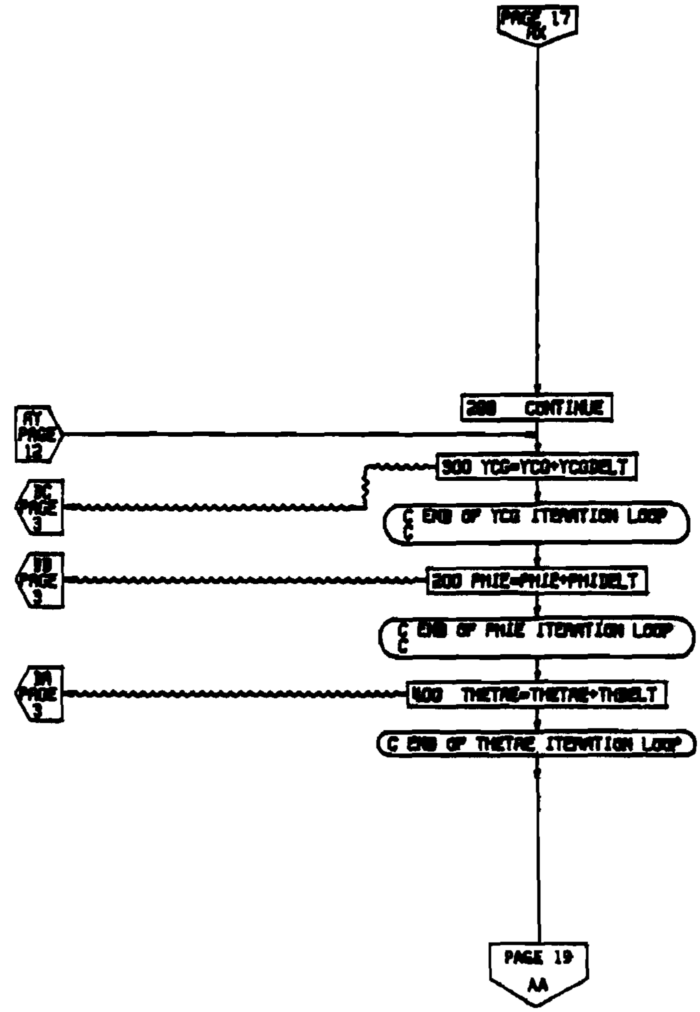

Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

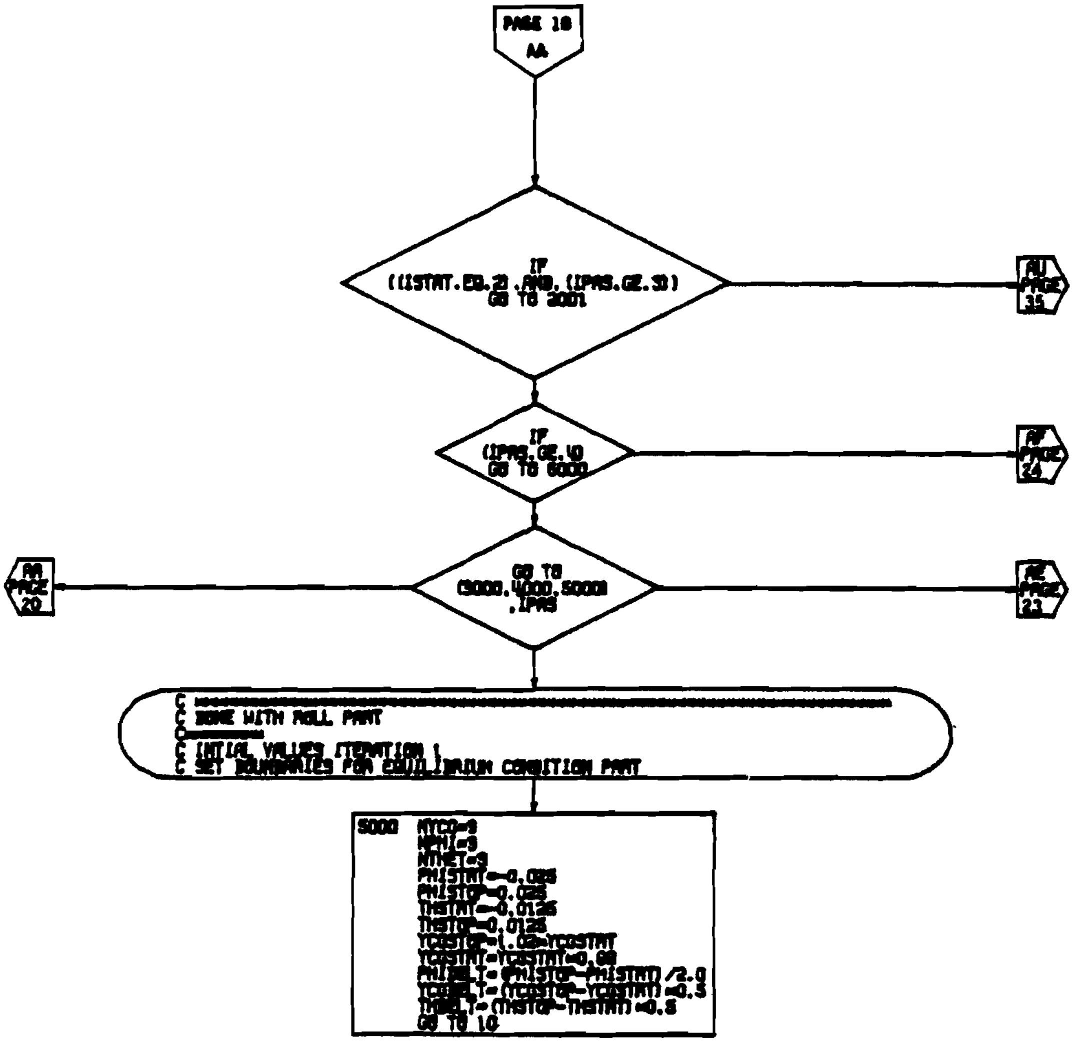

Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

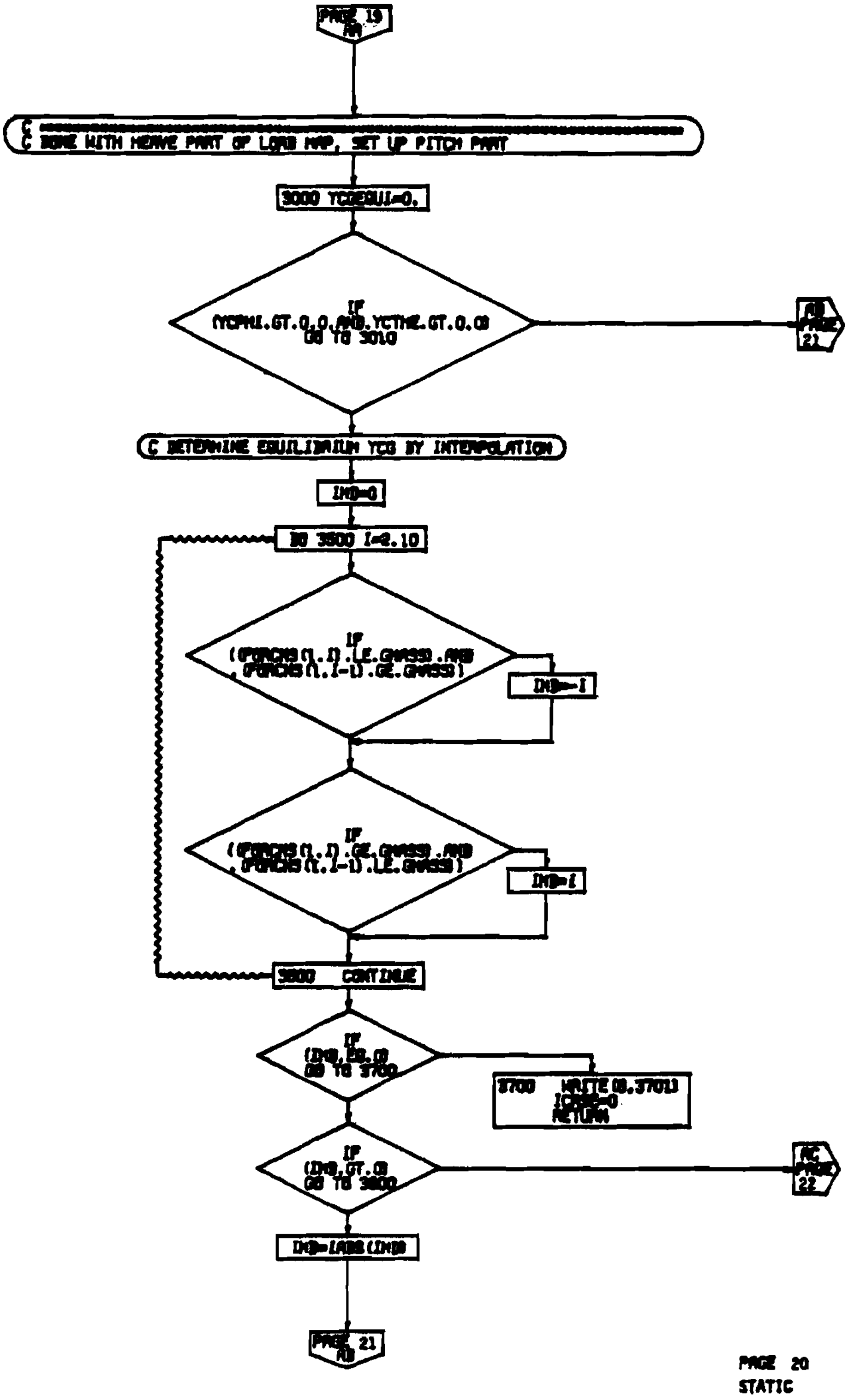

Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

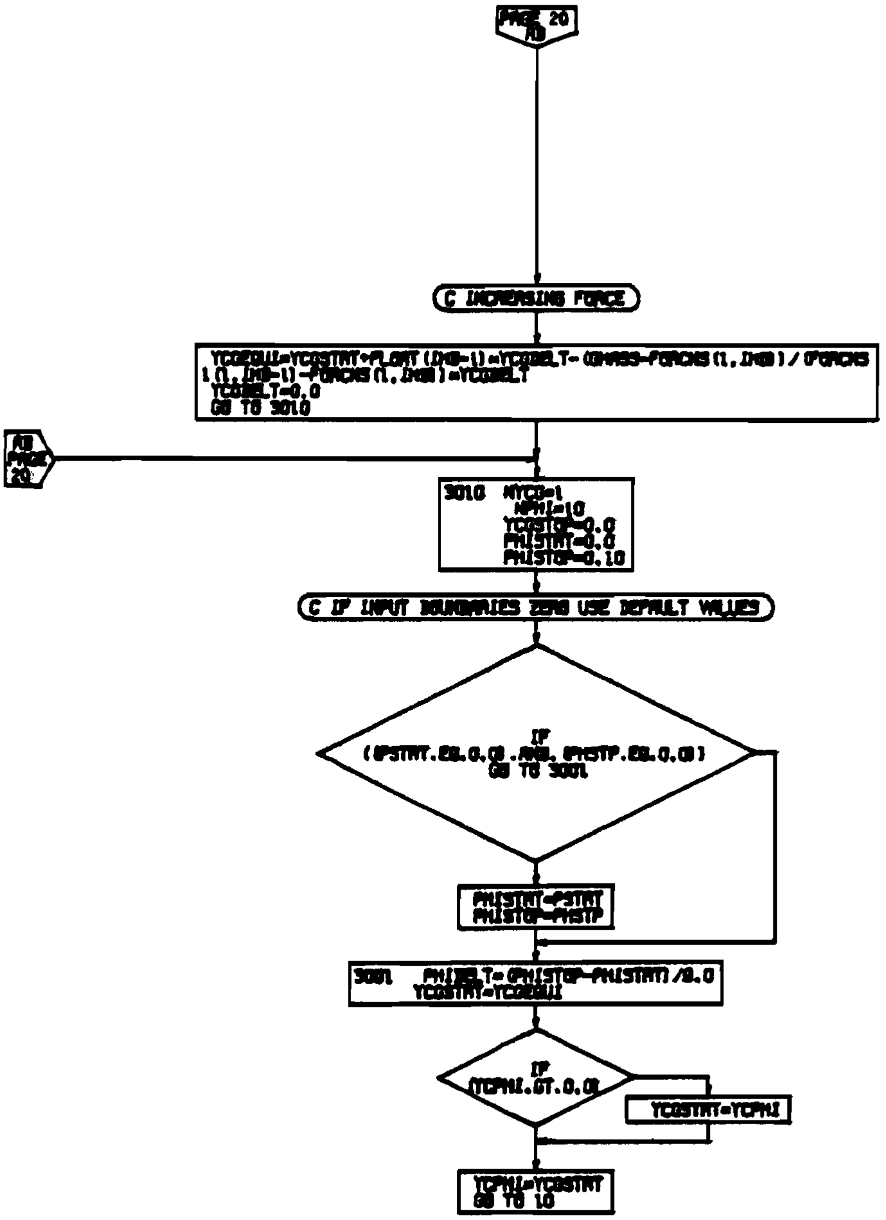

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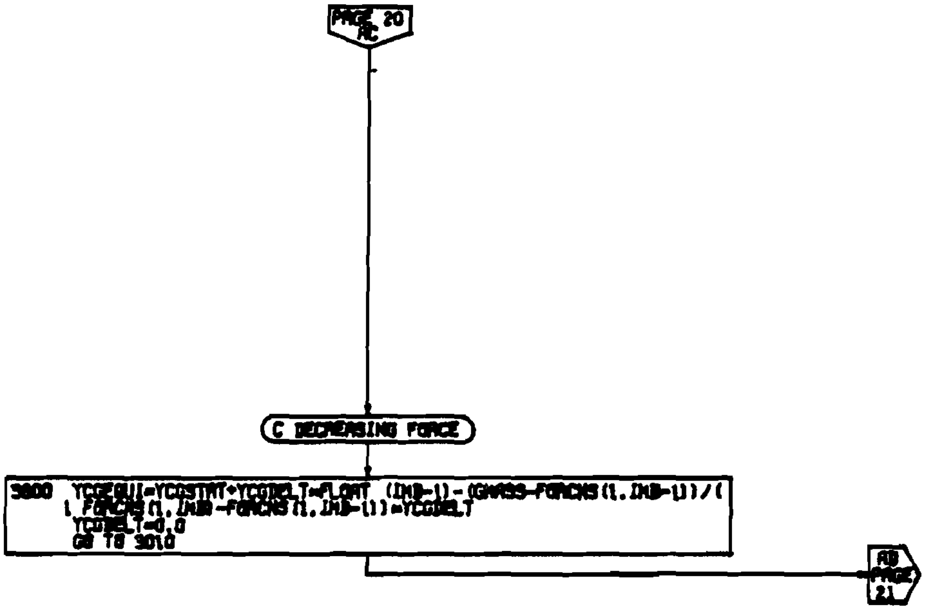
Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)



```
3000  YCGEQUI=YCGSTRT+YCGDELT*FLOAT (IMB-1)-(GMASS-FORCNS(1,IMB-1))/(
     1 FORCNS(1,IMB)-FORCNS(1,IMB-1))*YCGDELT
      YCGDELT=0.0
      GO TO 3010
```

Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

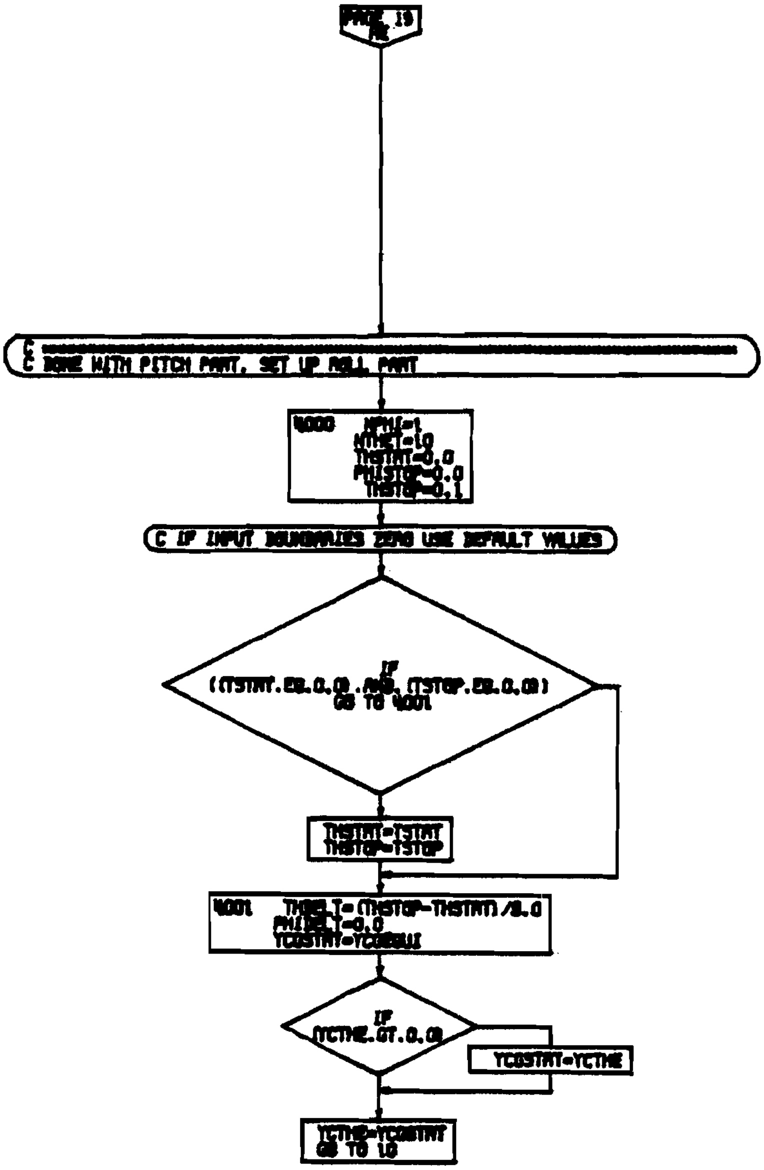


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Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

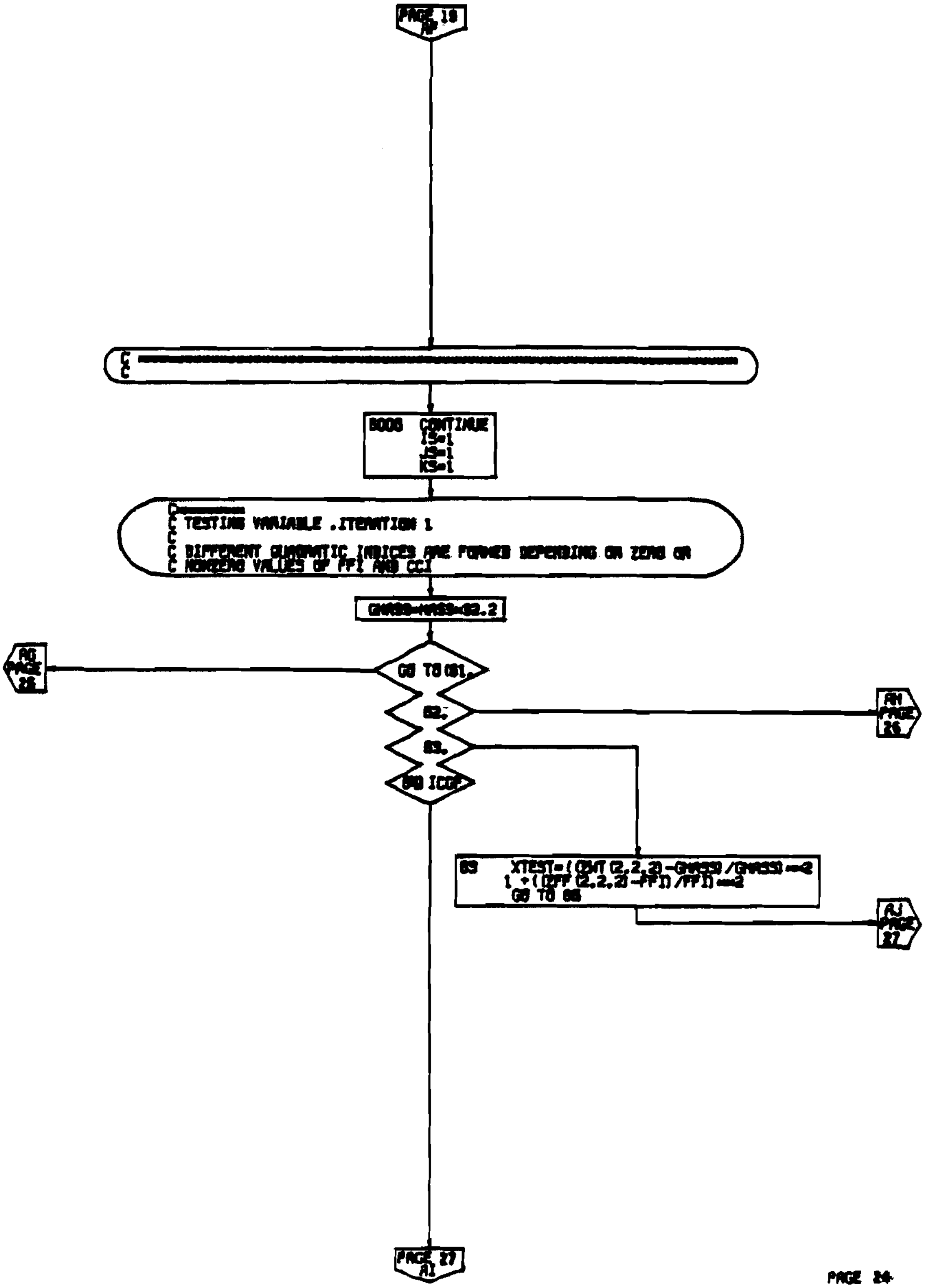

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Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

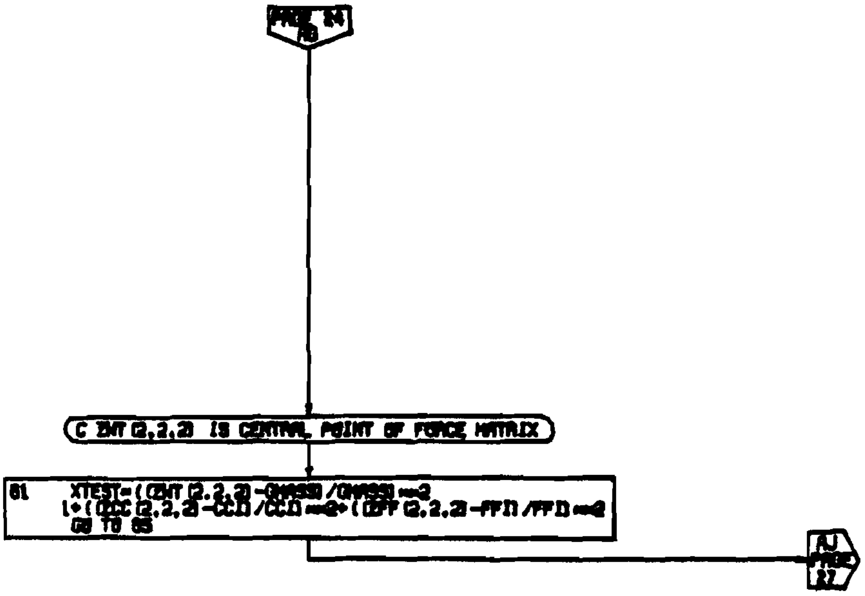

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Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

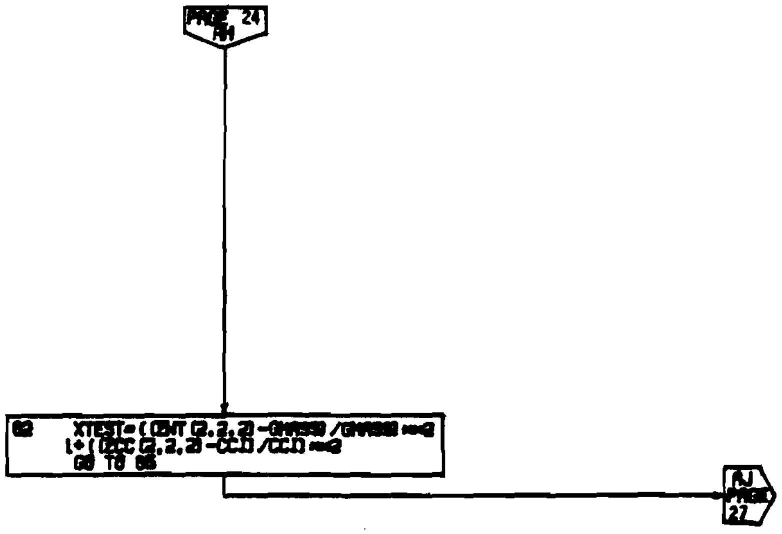

Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

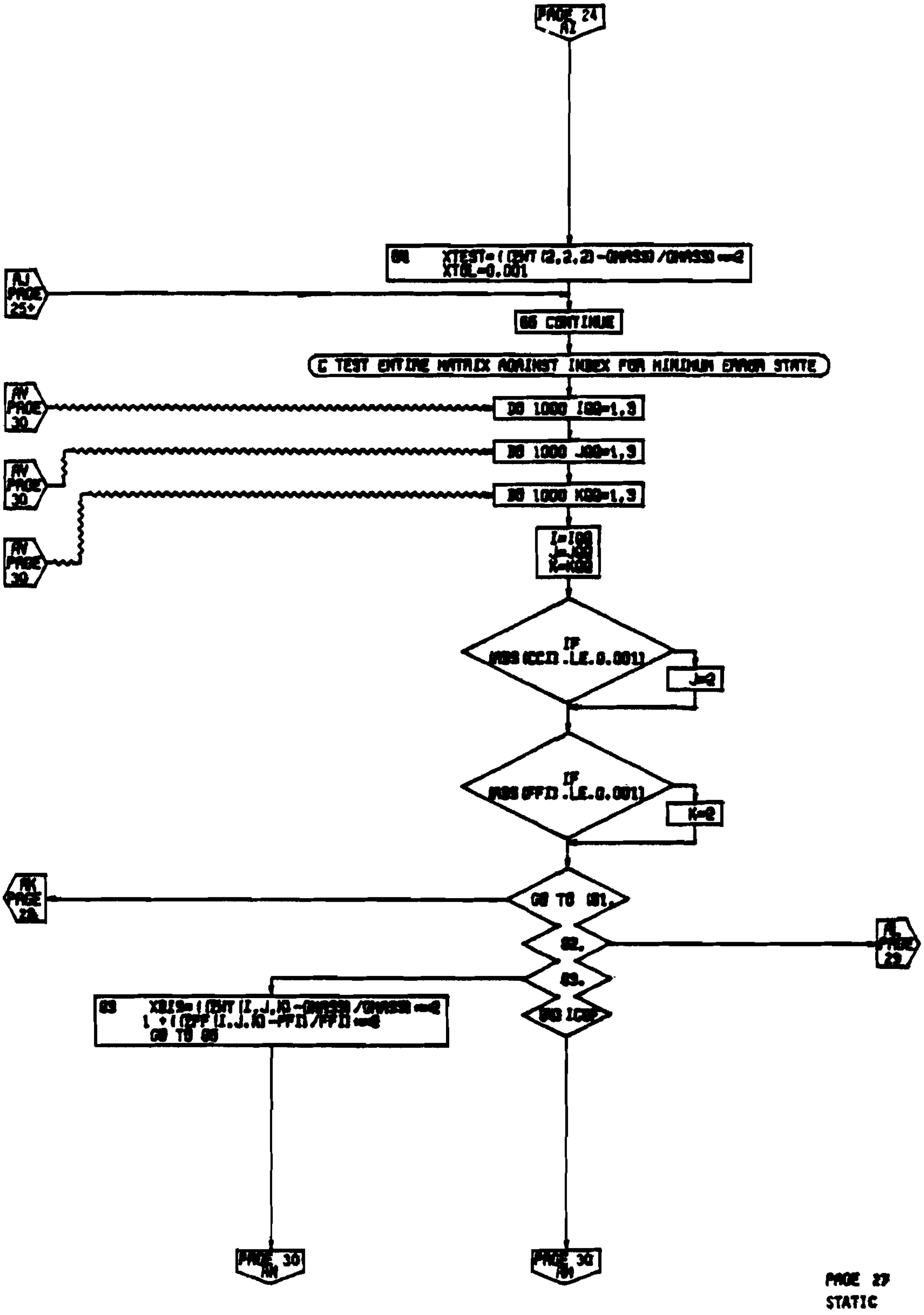

Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

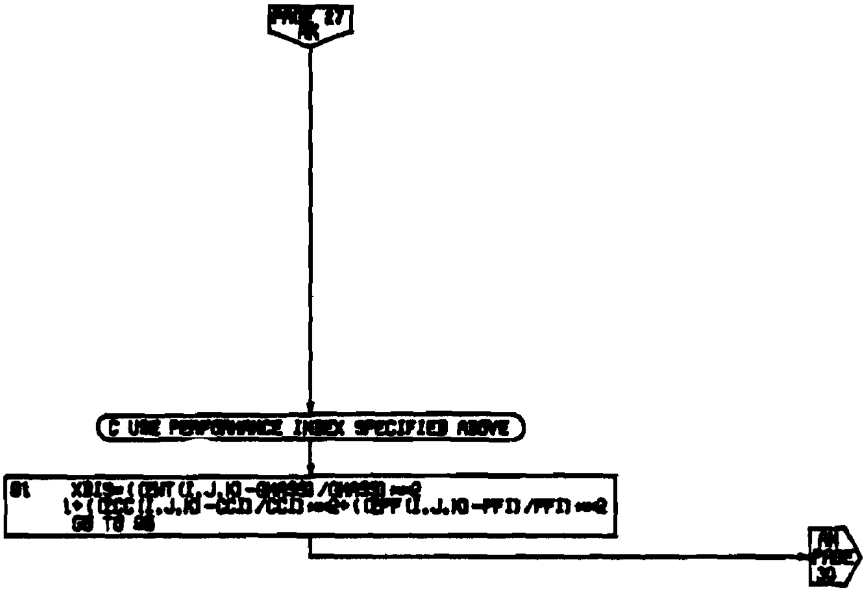

Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

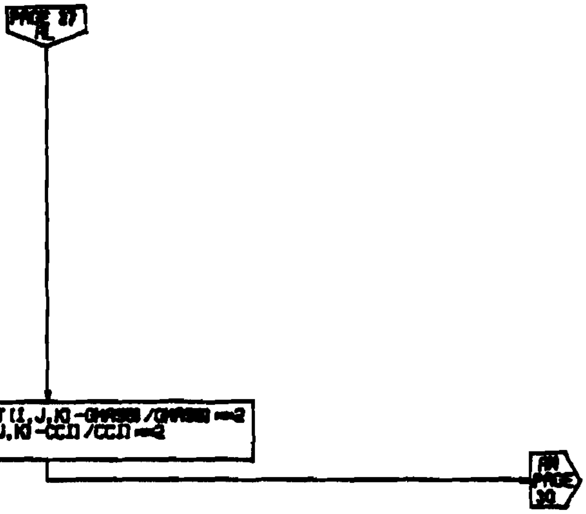

Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

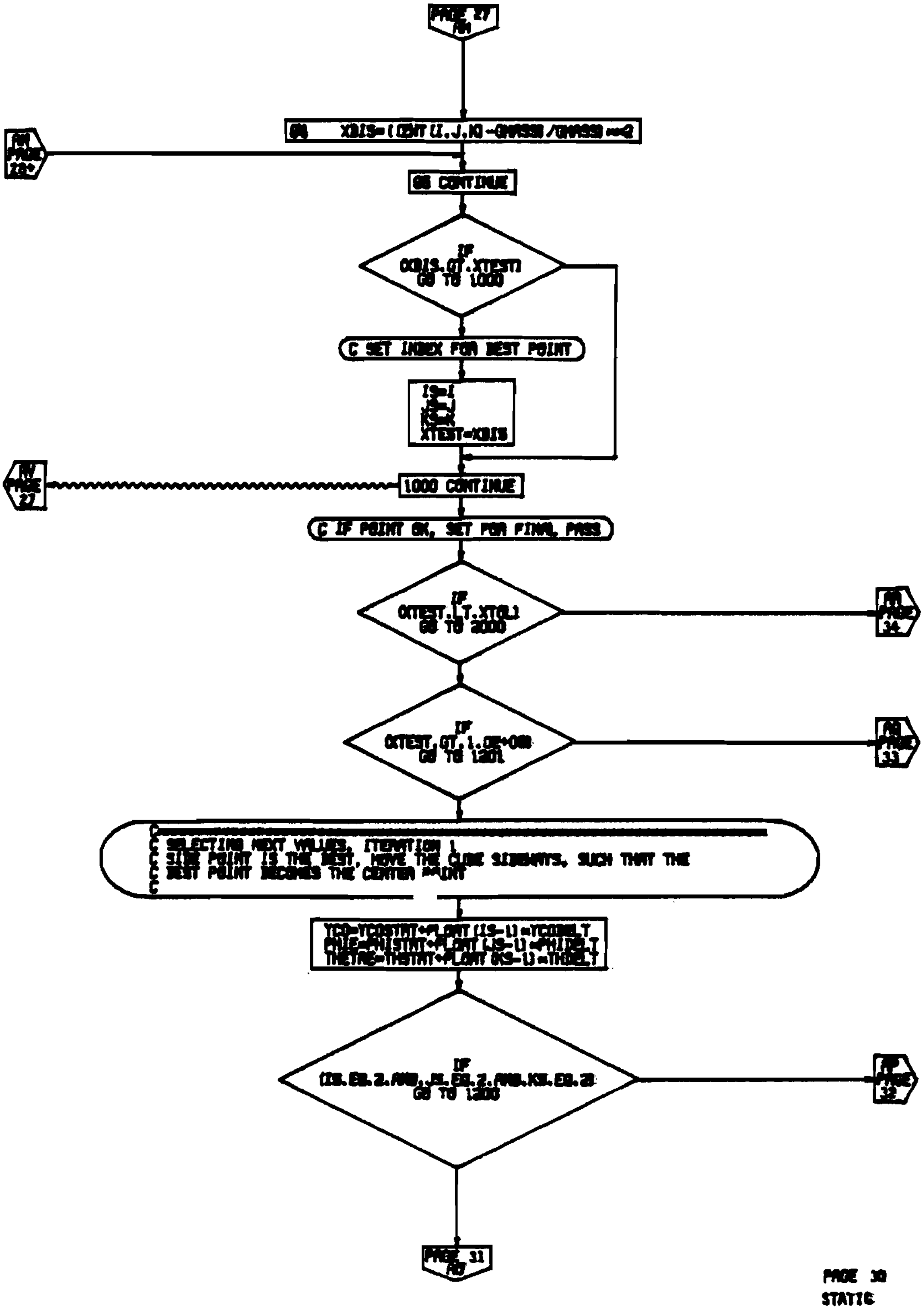

Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

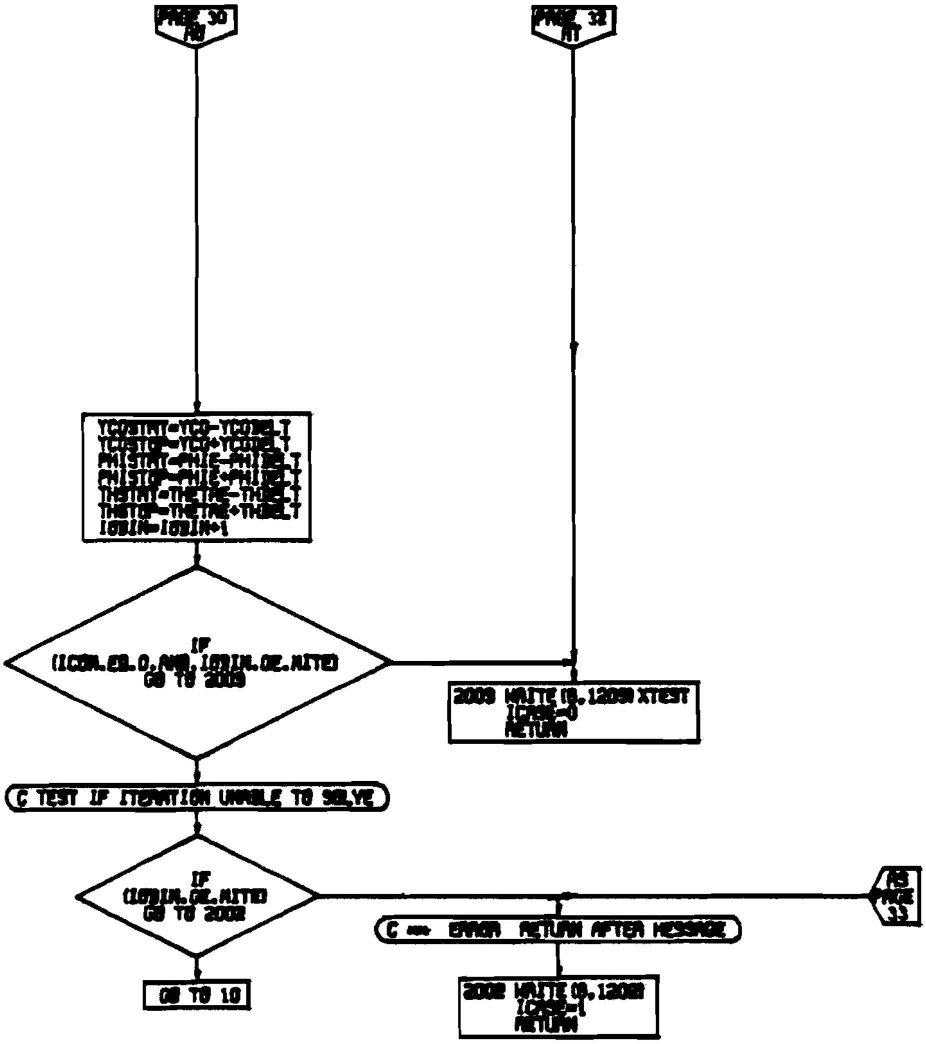

Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

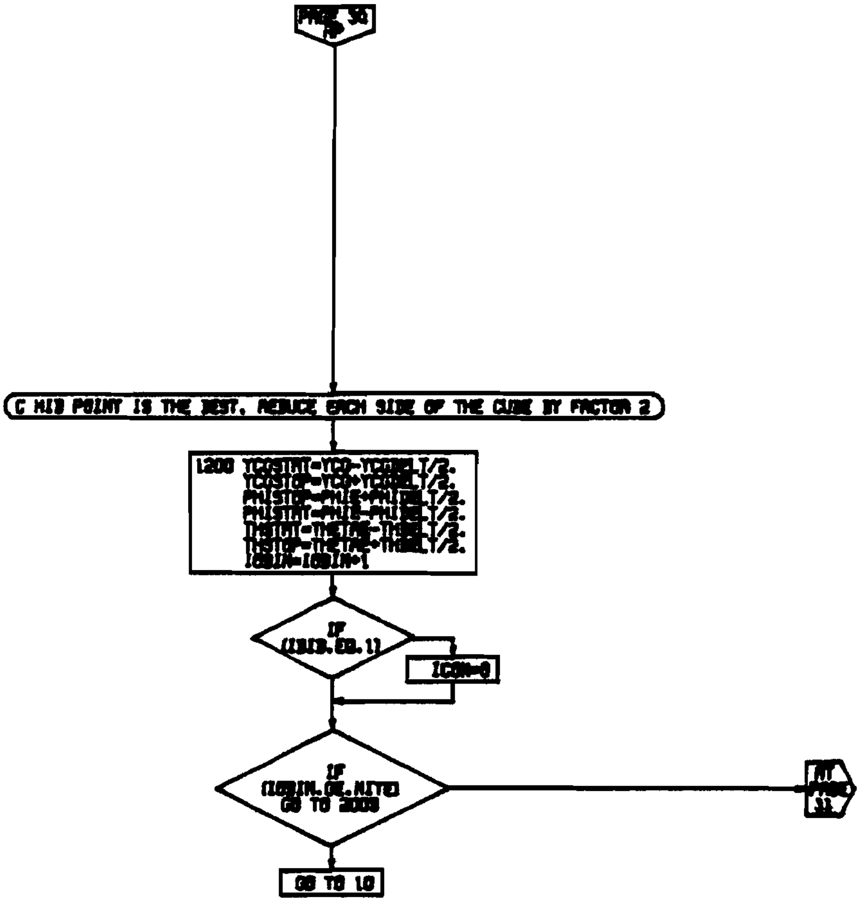

Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)

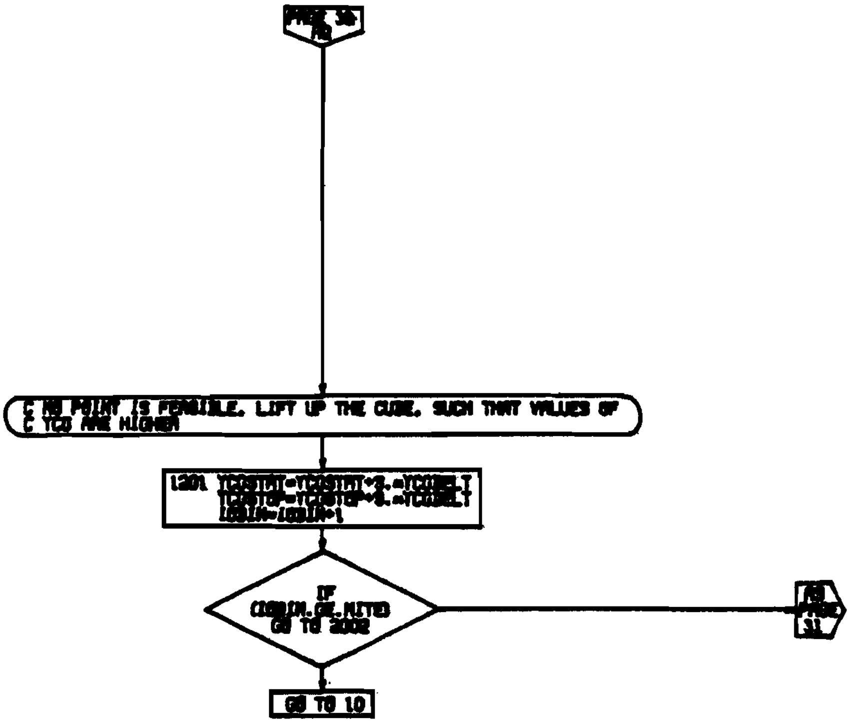

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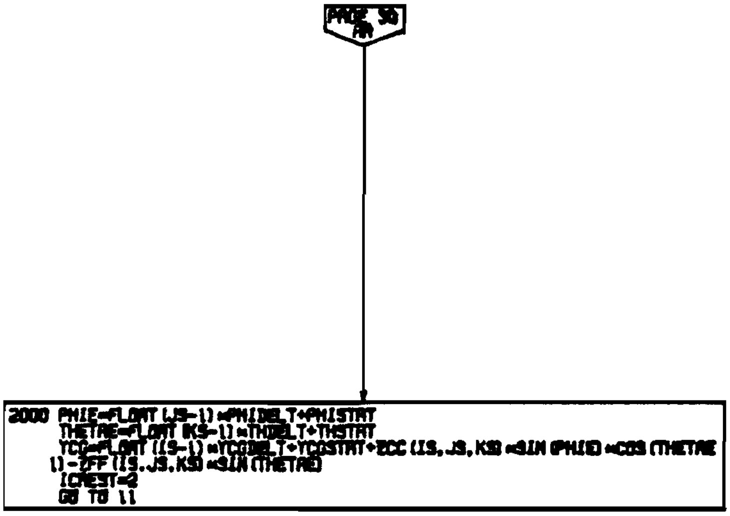
Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONTINUED)



```
2000 PHIE=FLOAT(JS-1)*PHIDELT+PHISTAT
     THETAE=FLOAT(KS-1)*THDELT+THSTAT
     YCC=FLOAT(IS-1)*YCCDELT+YCCSTAT+ZCC(IS,JS,KS)*SIN(PHIE)*COS(THETAE
    1)-ZFF(IS,JS,KS)*SIN(THETAE)
     ICREST=2
     GO TO 11
```

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Table 91: FLOWCHART FOR SUBROUTINE STATIC (CONCLUDED)

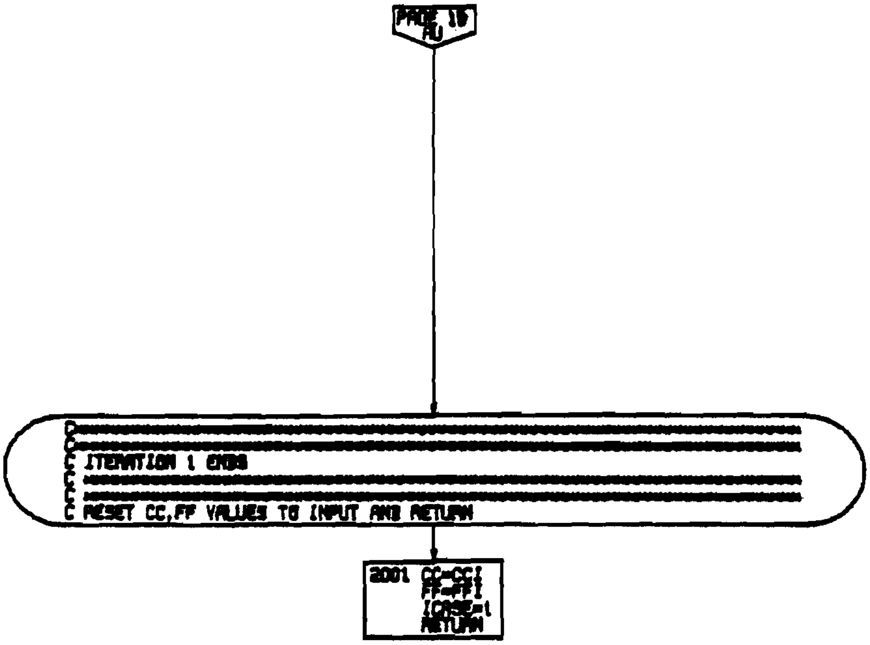
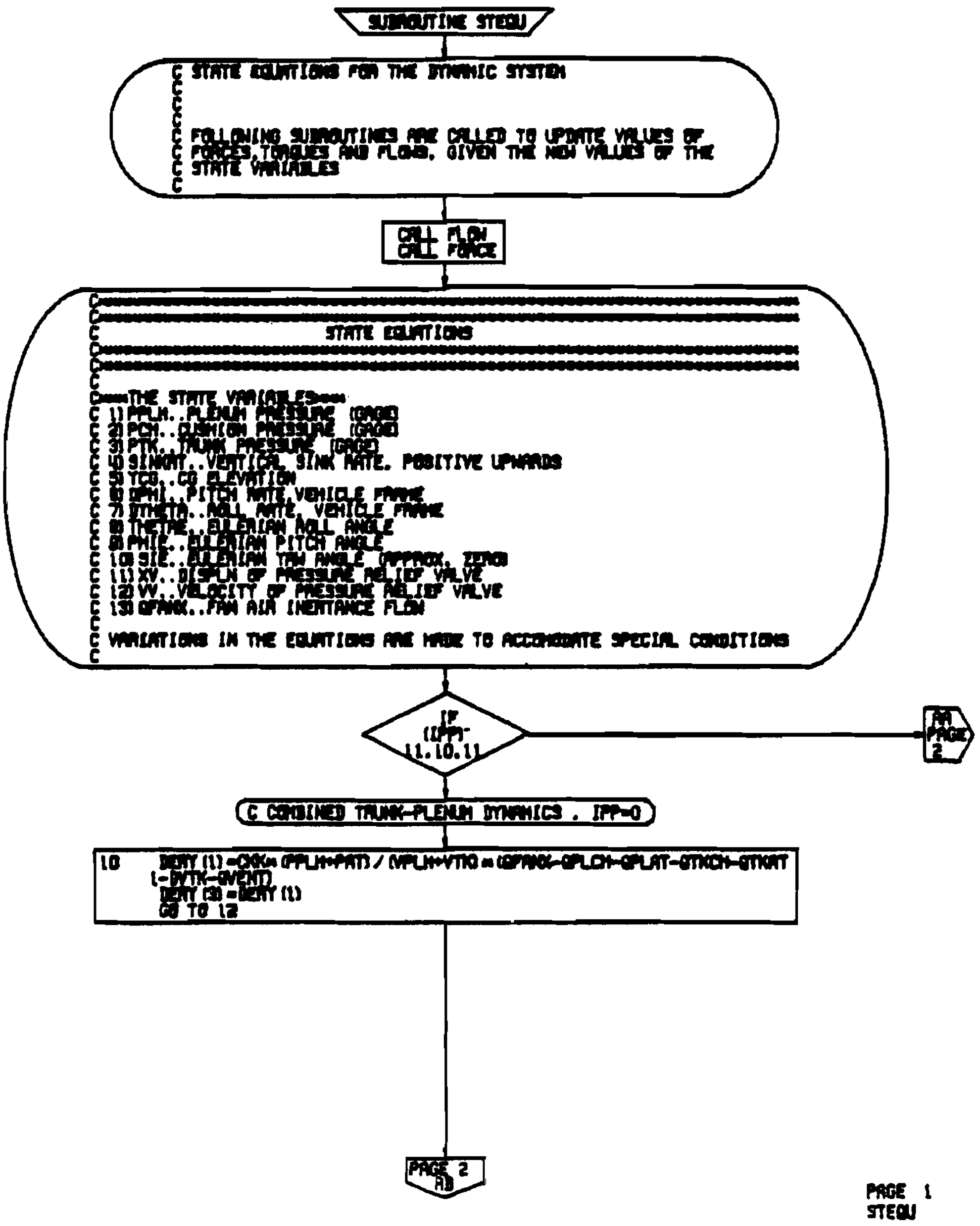


Table 92: FLOWCHART FOR SUBROUTINE STEQU



```
SUBROUTINE STEQU
C STATE EQUATIONS FOR THE DYNAMIC SYSTEM
C
C
C
C
C FOLLOWING SUBROUTINES ARE CALLED TO UPDATE VALUES OF
C FORCES,TORQUES AND FLOWS, GIVEN THE NEW VALUES OF THE
C STATE VARIABLES
C
      CALL FLOW
      CALL FORCE
C************************************************************************
C************************************************************************
C                           STATE EQUATIONS
C************************************************************************
C************************************************************************
C
C****THE STATE VARIABLES****
C 1)PPLM..PLENUM PRESSURE (GAGE)
C 2)PCM..CUSHION PRESSURE (GAGE)
C 3)PTK..TRUNK PRESSURE (GAGE)
C 4)SINKRT..VERTICAL SINK RATE. POSITIVE UPWARDS
C 5)YCG..CG ELEVATION
C 6)DPHI..PITCH RATE,VEHICLE FRAME
C 7)DTHETA..ROLL RATE, VEHICLE FRAME
C 8)THETAE..EULERIAN ROLL ANGLE
C 9)PHIE..EULERIAN PITCH ANGLE
C 10)SIE..EULERIAN YAW ANGLE (APPROX. ZERO)
C 11)XV..DISPLN OF PRESSURE RELIEF VALVE
C 12)VV..VELOCITY OF PRESSURE RELIEF VALVE
C 13)QFANX..FAN AIR INERTANCE FLOW
C
C VARIATIONS IN THE EQUATIONS ARE MADE TO ACCOMODATE SPECIAL CONDITIONS
C
      IF (IPP) 11,10,11
C COMBINED TRUNK-PLENUM DYNAMICS . IPP=0
10    DERY(1)=CKK*(PPLM+PAT)/(VPLM+VTK)*(QFANX-QPLCM-QPLAT-QTKCM-QTKAT
     1-DVTK-QVENT)
      DERY(3)=DERY(1)
      GO TO 12
```

Table 92: FLOWCHART FOR SUBROUTINE STEQU (CONTINUED)

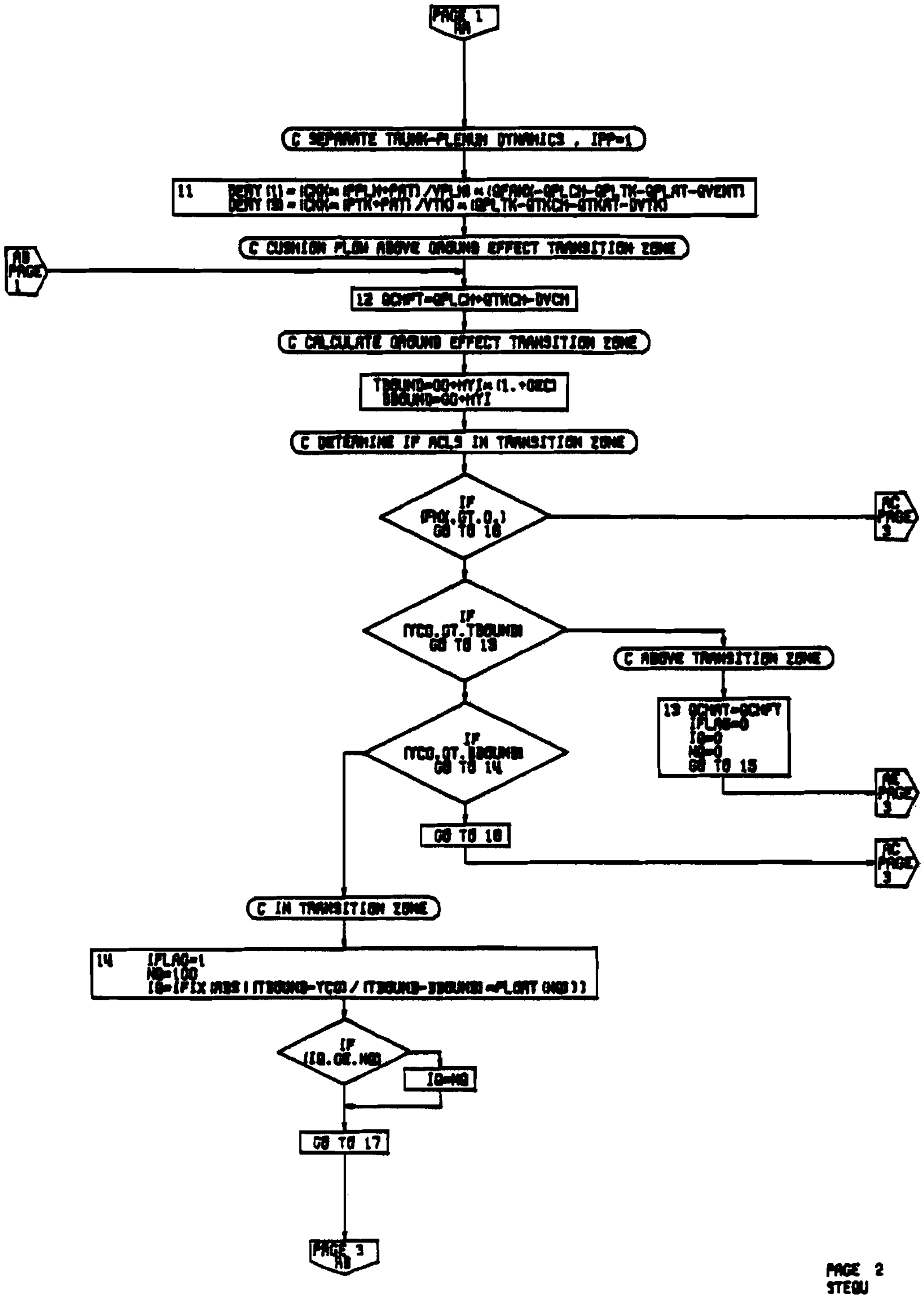
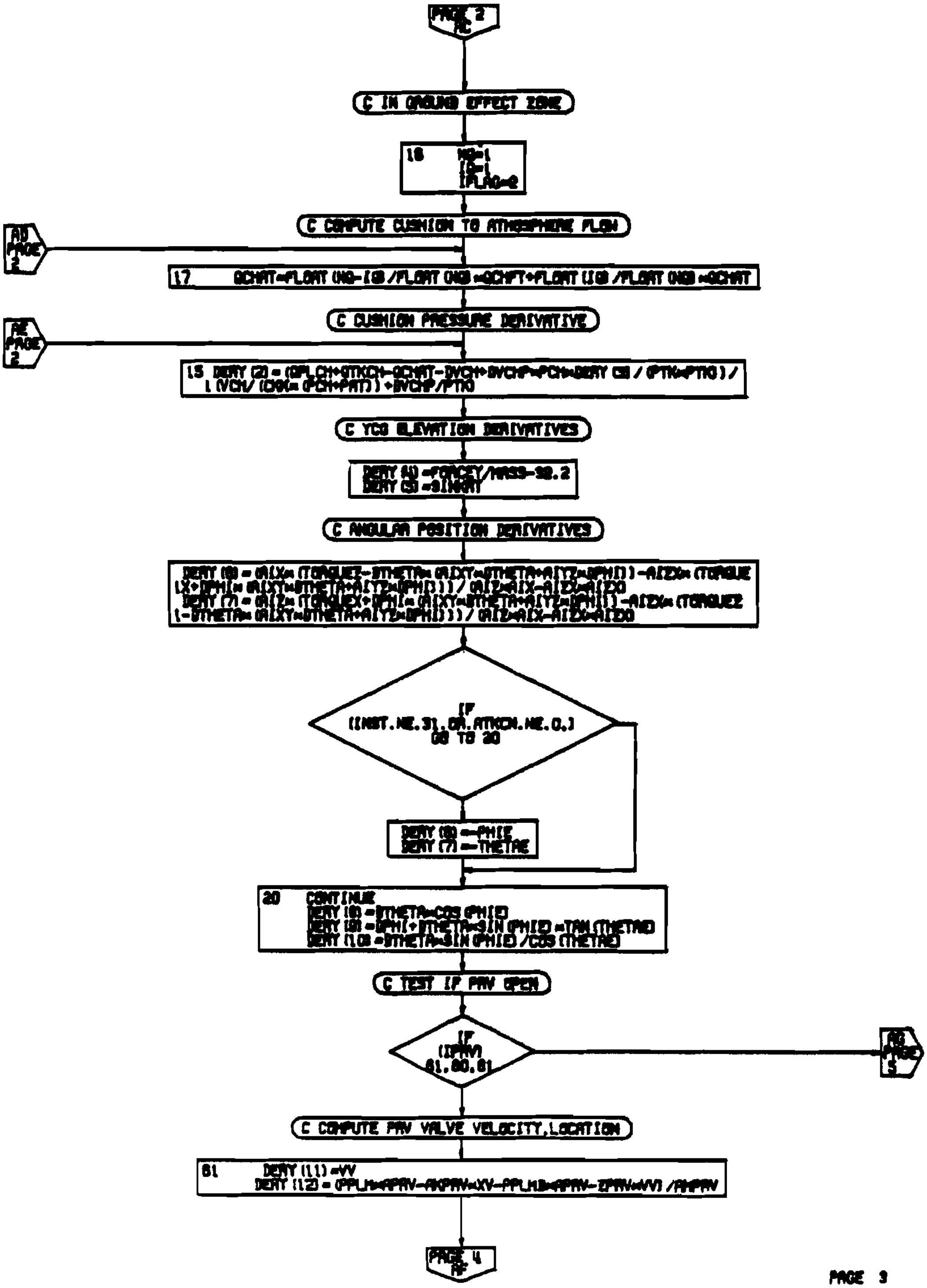


Table 92: FLOWCHART FOR SUBROUTINE STEQU (CONTINUED)



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STEQU

Table 92: FLOWCHART FOR SUBROUTINE STEQU (CONTINUED)

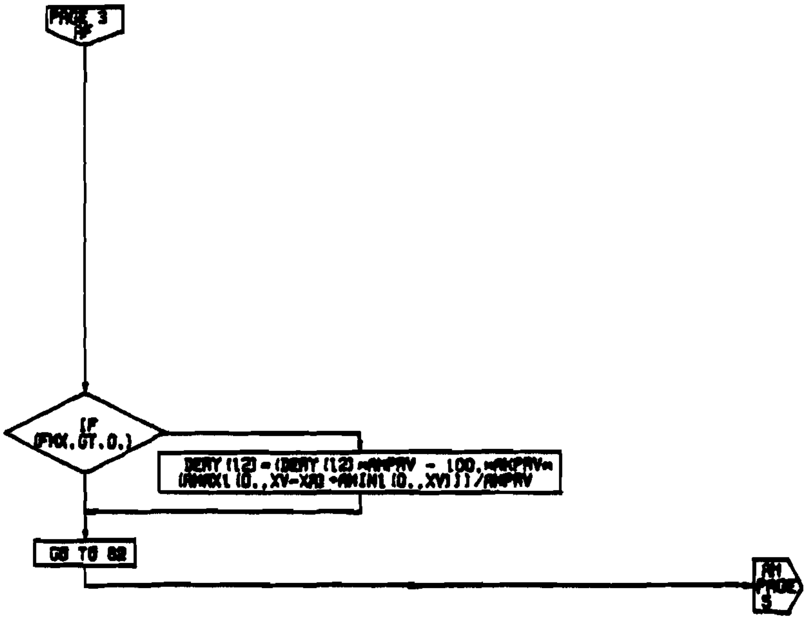

Table 92: FLOWCHART FOR SUBROUTINE STEQU (CONCLUDED)

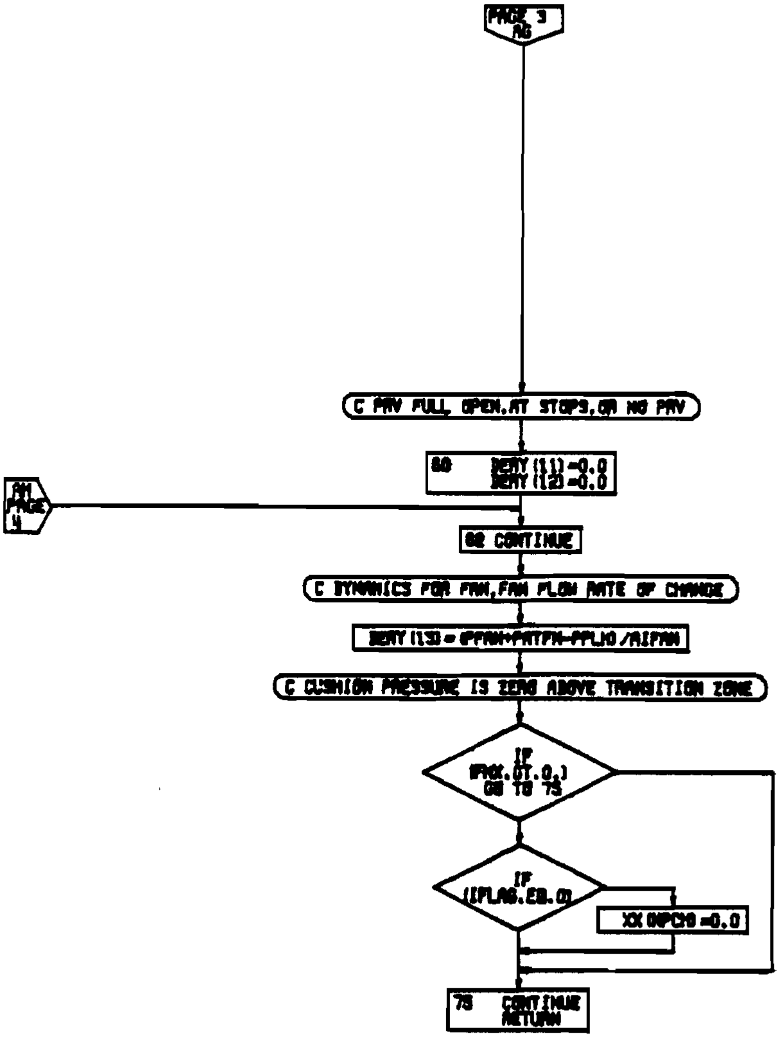

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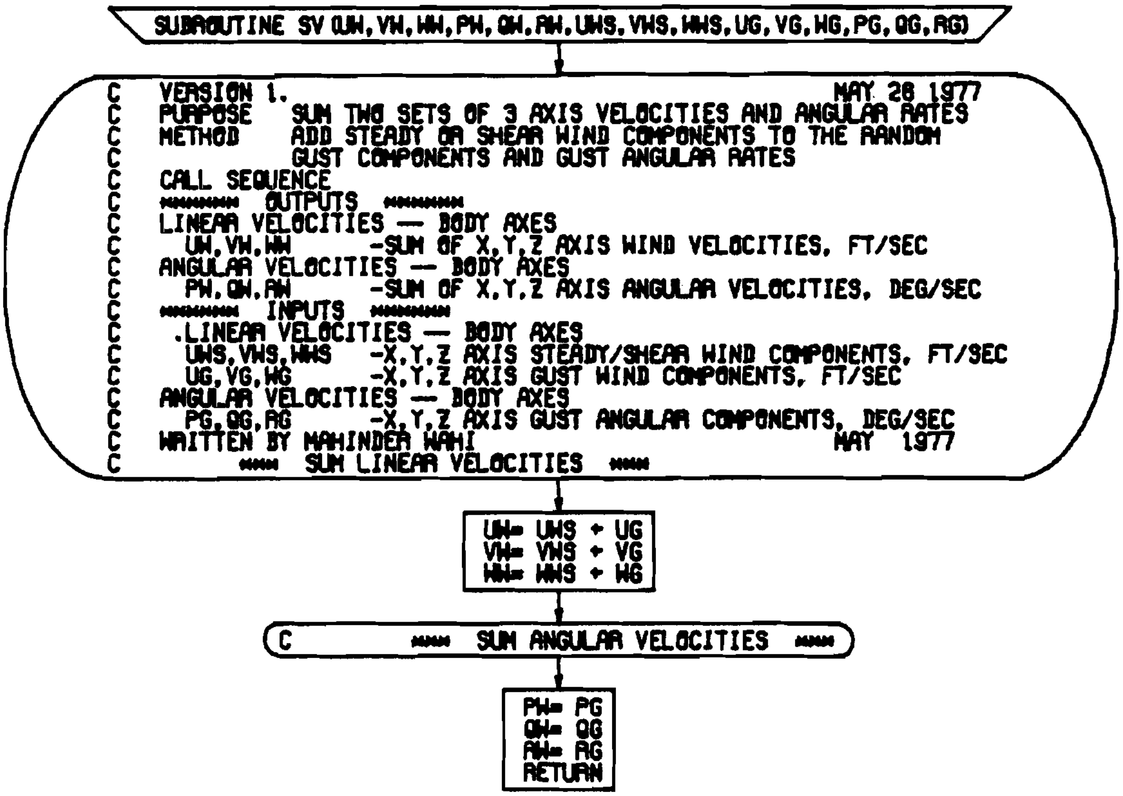
Table 93: FLOWCHART FOR SUBROUTINE SV



```
SUBROUTINE SV (UW,VW,WW,PW,QW,RW,UWS,VWS,WWS,UG,VG,WG,PG,QG,RG)
C    VERSION 1.                                              MAY 28 1977
C    PURPOSE    SUM TWO SETS OF 3 AXIS VELOCITIES AND ANGULAR RATES
C    METHOD     ADD STEADY OR SHEAR WIND COMPONENTS TO THE RANDOM
C               GUST COMPONENTS AND GUST ANGULAR RATES
C    CALL SEQUENCE
C    ********  OUTPUTS  ********
C    LINEAR VELOCITIES -- BODY AXES
C      UW,VW,WW       -SUM OF X,Y,Z AXIS WIND VELOCITIES, FT/SEC
C    ANGULAR VELOCITIES -- BODY AXES
C      PW,QW,RW       -SUM OF X,Y,Z AXIS ANGULAR VELOCITIES, DEG/SEC
C    ********  INPUTS  ********
C     .LINEAR VELOCITIES -- BODY AXES
C      UWS,VWS,WWS    -X,Y,Z AXIS STEADY/SHEAR WIND COMPONENTS, FT/SEC
C      UG,VG,WG       -X,Y,Z AXIS GUST WIND COMPONENTS, FT/SEC
C    ANGULAR VELOCITIES -- BODY AXES
C      PG,QG,RG       -X,Y,Z AXIS GUST ANGULAR COMPONENTS, DEG/SEC
C    WRITTEN BY MAHINDER WAHI                                MAY  1977
C          ****  SUM LINEAR VELOCITIES  ****

UW= UWS + UG
VW= VWS + VG
WW= WWS + WG

C          ****  SUM ANGULAR VELOCITIES  ****

PW= PG
QW= QG
RW= RG
RETURN
```

Table 94: FLOWCHART FOR SUBROUTINE SW

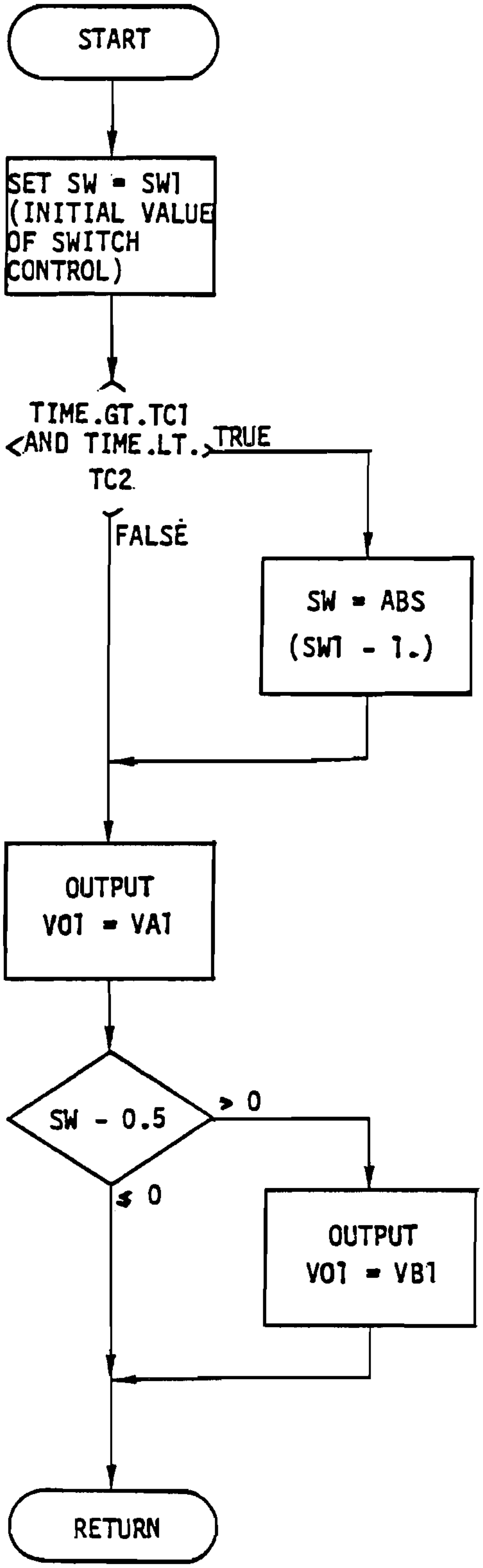
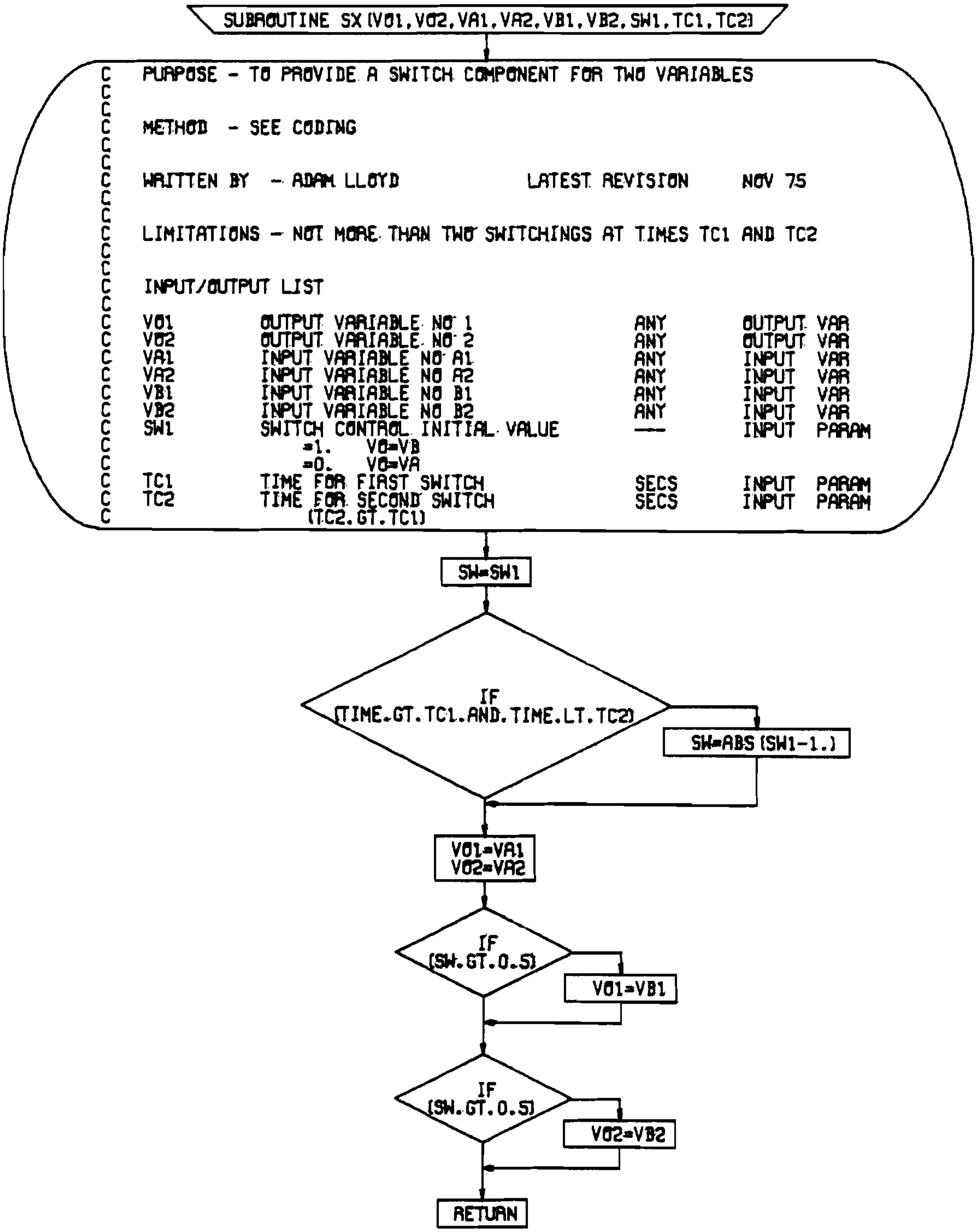
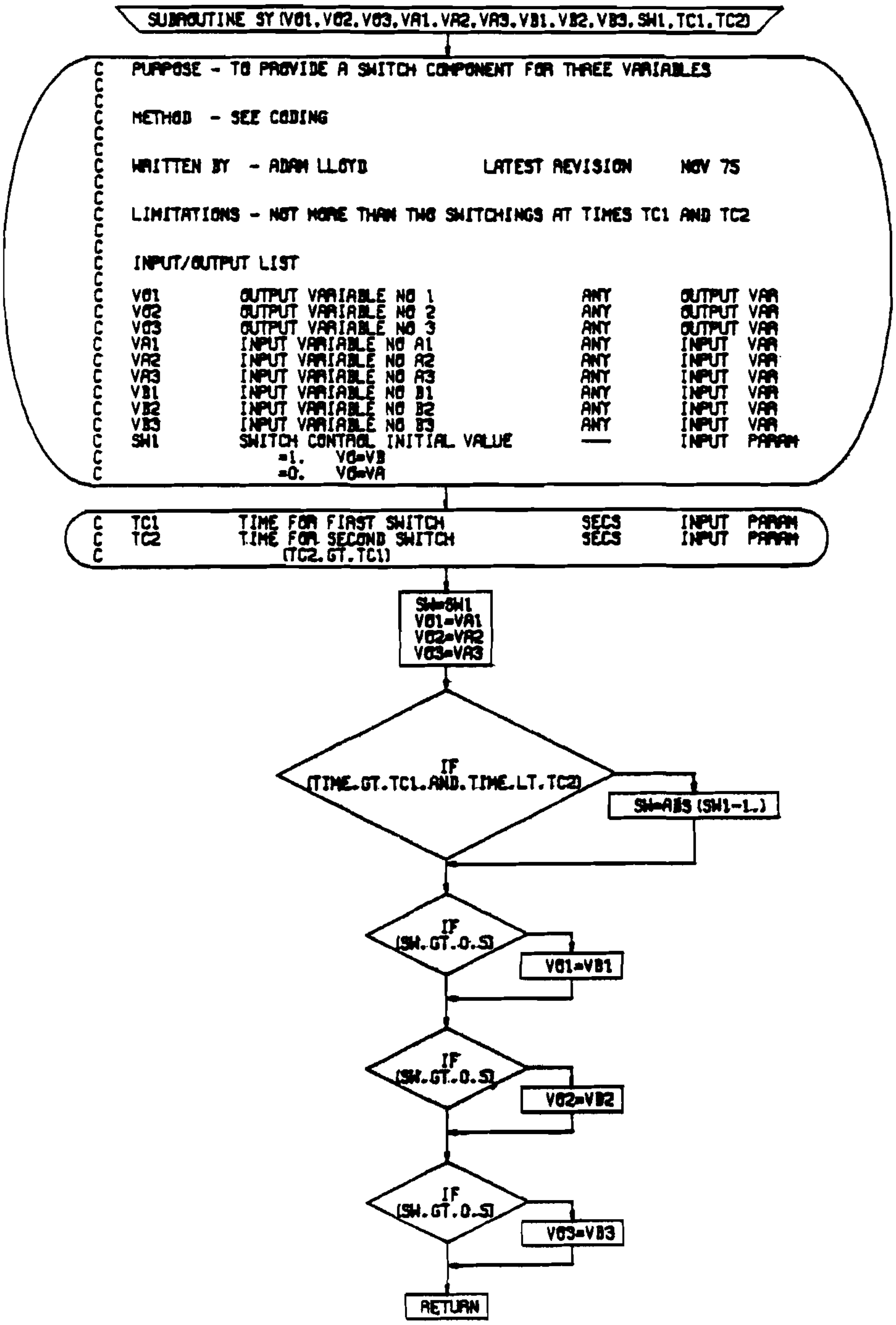


Table 95: FLOWCHART FOR SUBROUTINE SX



```
C     PURPOSE - TO PROVIDE A SWITCH COMPONENT FOR TWO VARIABLES
C
C
C     METHOD  - SEE CODING
C
C
C     WRITTEN BY  - ADAM LLOYD            LATEST REVISION     NOV 75
C
C
C     LIMITATIONS - NOT MORE THAN TWO SWITCHINGS AT TIMES TC1 AND TC2
C
C
C     INPUT/OUTPUT LIST
C
C     VO1        OUTPUT VARIABLE NO 1                 ANY       OUTPUT VAR
C     VO2        OUTPUT VARIABLE NO 2                 ANY       OUTPUT VAR
C     VA1        INPUT VARIABLE NO A1                 ANY       INPUT  VAR
C     VA2        INPUT VARIABLE NO A2                 ANY       INPUT  VAR
C     VB1        INPUT VARIABLE NO B1                 ANY       INPUT  VAR
C     VB2        INPUT VARIABLE NO B2                 ANY       INPUT  VAR
C     SW1        SWITCH CONTROL INITIAL VALUE         ---       INPUT  PARAM
C                     =1.    VO=VB
C                     =0.    VO=VA
C     TC1        TIME FOR FIRST SWITCH                SECS      INPUT  PARAM
C     TC2        TIME FOR SECOND SWITCH               SECS      INPUT  PARAM
C                     (TC2.GT.TC1)
```

Table 96: FLOWCHART FOR SUBROUTINE SY



```
      SUBROUTINE SY (V01,V02,V03,VA1,VA2,VA3,VB1,VB2,VB3,SH1,TC1,TC2)
C     PURPOSE - TO PROVIDE A SWITCH COMPONENT FOR THREE VARIABLES
C
C
C     METHOD  - SEE CODING
C
C
C     WRITTEN BY  - ADAM LLOYD            LATEST REVISION     NOV 75
C
C
C     LIMITATIONS - NOT MORE THAN TWO SWITCHINGS AT TIMES TC1 AND TC2
C
C
C     INPUT/OUTPUT LIST
C
C     V01         OUTPUT VARIABLE NO 1                ANY       OUTPUT VAR
C     V02         OUTPUT VARIABLE NO 2                ANY       OUTPUT VAR
C     V03         OUTPUT VARIABLE NO 3                ANY       OUTPUT VAR
C     VA1         INPUT VARIABLE NO A1                ANY       INPUT  VAR
C     VA2         INPUT VARIABLE NO A2                ANY       INPUT  VAR
C     VA3         INPUT VARIABLE NO A3                ANY       INPUT  VAR
C     VB1         INPUT VARIABLE NO B1                ANY       INPUT  VAR
C     VB2         INPUT VARIABLE NO B2                ANY       INPUT  VAR
C     VB3         INPUT VARIABLE NO B3                ANY       INPUT  VAR
C     SH1         SWITCH CONTROL INITIAL VALUE        ----      INPUT  PARAM
C                     =1.    V0=VB
C                     =0.    V0=VA
C     TC1         TIME FOR FIRST SWITCH               SECS      INPUT  PARAM
C     TC2         TIME FOR SECOND SWITCH              SECS      INPUT  PARAM
C                     (TC2.GT.TC1)
```

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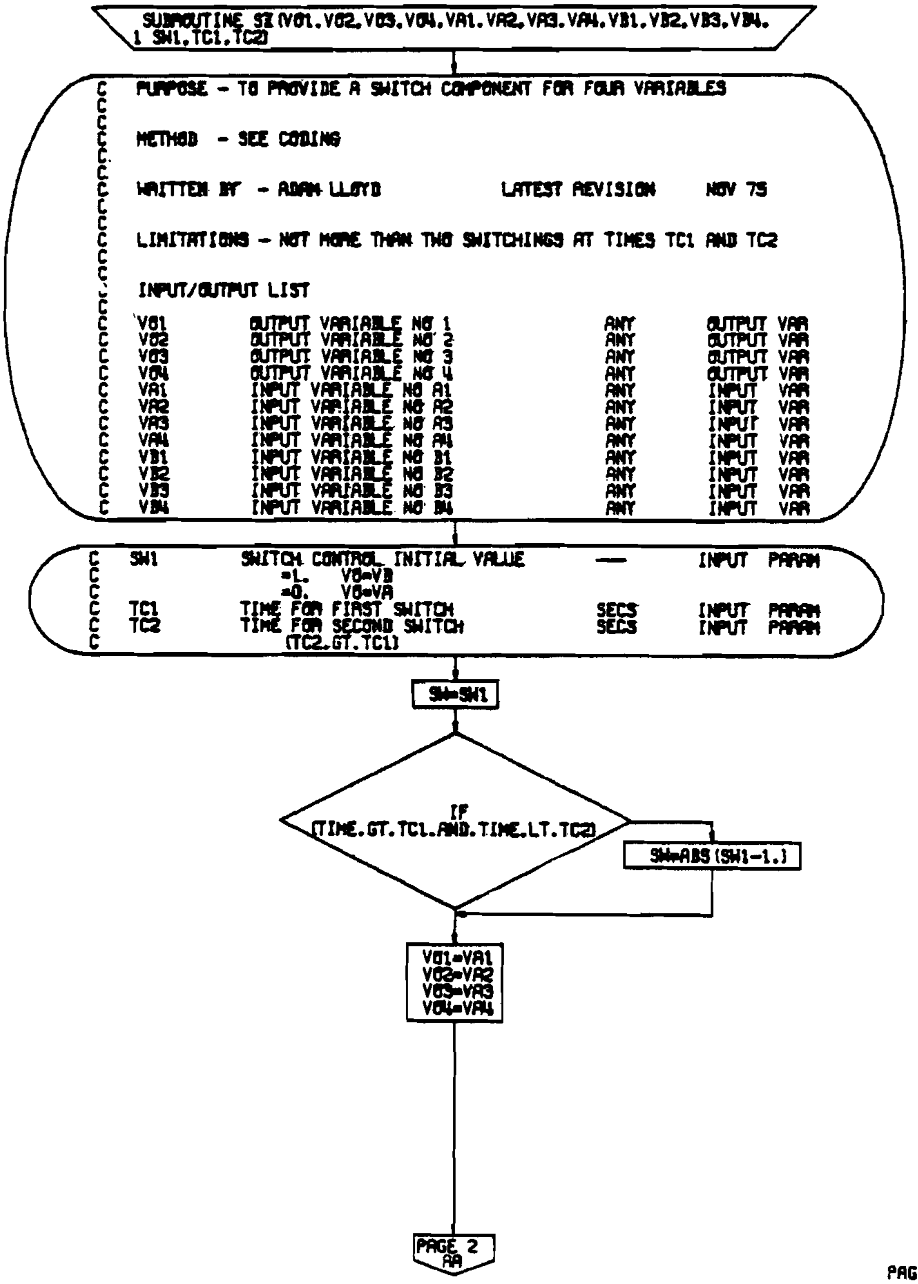
SY

Table 97: FLOWCHART FOR SUBROUTINE SZ



```
      SUBROUTINE SZ(V01.V02.V03.V04.VA1.VA2.VA3.VA4.VB1.VB2.VB3.VB4.
     1 SW1.TC1.TC2)
C     PURPOSE - TO PROVIDE A SWITCH COMPONENT FOR FOUR VARIABLES
C
C
C     METHOD  - SEE CODING
C
C
C     WRITTEN BY  - ADAM LLOYD             LATEST REVISION     NOV 75
C
C
C     LIMITATIONS - NOT MORE THAN TWO SWITCHINGS AT TIMES TC1 AND TC2
C
C
C     INPUT/OUTPUT LIST
C
C     V01        OUTPUT VARIABLE NO 1               ANY       OUTPUT VAR
C     V02        OUTPUT VARIABLE NO 2               ANY       OUTPUT VAR
C     V03        OUTPUT VARIABLE NO 3               ANY       OUTPUT VAR
C     V04        OUTPUT VARIABLE NO 4               ANY       OUTPUT VAR
C     VA1        INPUT VARIABLE NO A1               ANY       INPUT  VAR
C     VA2        INPUT VARIABLE NO A2               ANY       INPUT  VAR
C     VA3        INPUT VARIABLE NO A3               ANY       INPUT  VAR
C     VA4        INPUT VARIABLE NO A4               ANY       INPUT  VAR
C     VB1        INPUT VARIABLE NO B1               ANY       INPUT  VAR
C     VB2        INPUT VARIABLE NO B2               ANY       INPUT  VAR
C     VB3        INPUT VARIABLE NO B3               ANY       INPUT  VAR
C     VB4        INPUT VARIABLE NO B4               ANY       INPUT  VAR
C     SW1        SWITCH CONTROL INITIAL VALUE       ---       INPUT  PARAM
C                     =1.    VO=VB
C                     =0.    VO=VA
C     TC1        TIME FOR FIRST SWITCH              SECS      INPUT  PARAM
C     TC2        TIME FOR SECOND SWITCH             SECS      INPUT  PARAM
C                     (TC2.GT.TC1)
```

```
SW=SW1
IF (TIME.GT.TC1.AND.TIME.LT.TC2)
SW=ABS(SW1-1.)
V01=VA1
V02=VA2
V03=VA3
V04=VA4
```

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SZ

Table 97: FLOWCHART FOR SUBROUTINE SZ (CONCLUDED)

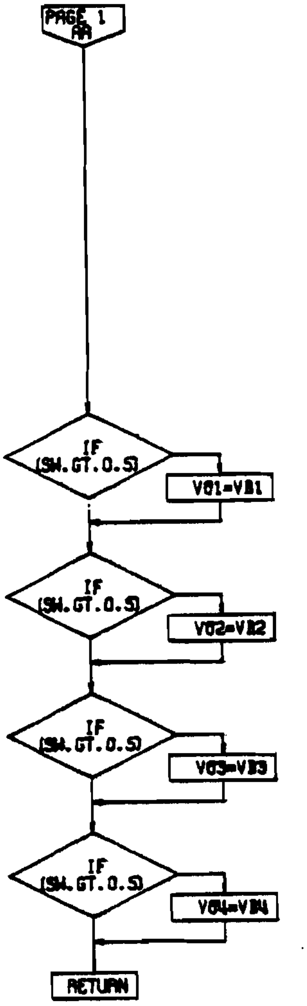

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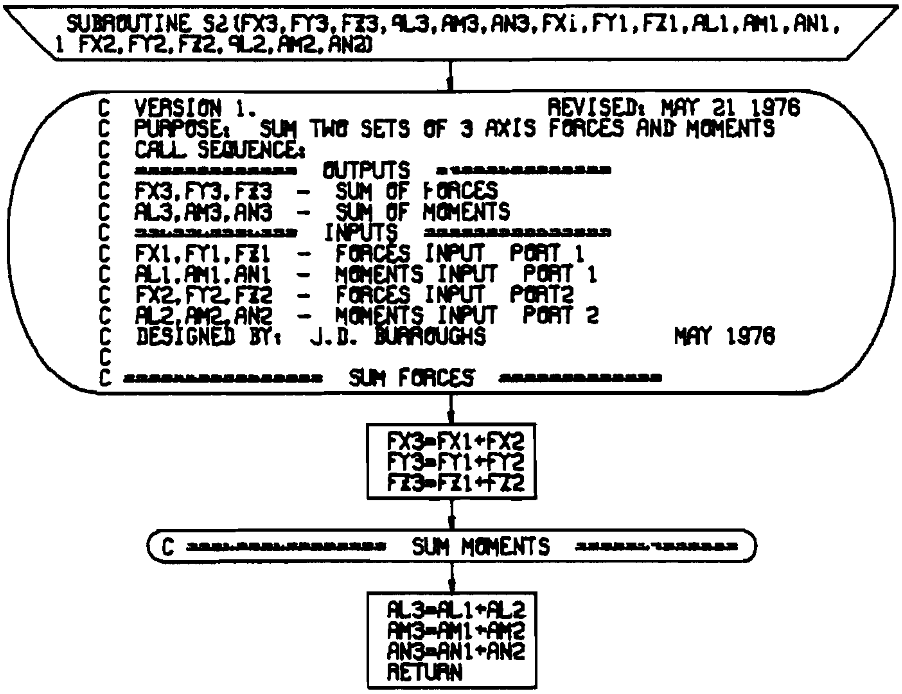
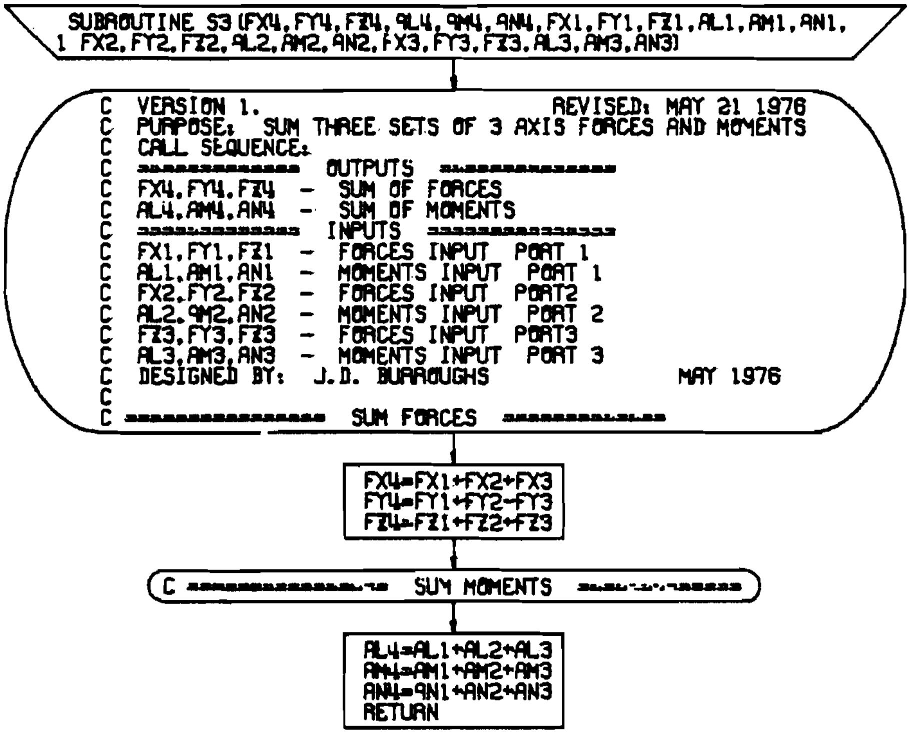
Table 98: FLOWCHART FOR SUBROUTINE S2



```
      SUBROUTINE S2(FX3,FY3,FZ3,AL3,AM3,AN3,FX1,FY1,FZ1,AL1,AM1,AN1,
     1 FX2,FY2,FZ2,AL2,AM2,AN2)
C  VERSION 1.                         REVISED: MAY 21 1976
C  PURPOSE:  SUM TWO SETS OF 3 AXIS FORCES AND MOMENTS
C  CALL SEQUENCE:
C  ============  OUTPUTS  ============
C  FX3,FY3,FZ3  -  SUM OF FORCES
C  AL3,AM3,AN3  -  SUM OF MOMENTS
C  ============  INPUTS  ==============
C  FX1,FY1,FZ1  -  FORCES INPUT  PORT 1
C  AL1,AM1,AN1  -  MOMENTS INPUT  PORT 1
C  FX2,FY2,FZ2  -  FORCES INPUT  PORT2
C  AL2,AM2,AN2  -  MOMENTS INPUT  PORT 2
C  DESIGNED BY:  J.D. BURROUGHS               MAY 1976
C
C ===============  SUM FORCES  ============
      FX3=FX1+FX2
      FY3=FY1+FY2
      FZ3=FZ1+FZ2
C ===============  SUM MOMENTS  ============
      AL3=AL1+AL2
      AM3=AM1+AM2
      AN3=AN1+AN2
      RETURN
```

Table 99: FLOWCHART FOR SUBROUTINE S3



```
      SUBROUTINE S3(FX4,FY4,FZ4,AL4,AM4,AN4,FX1,FY1,FZ1,AL1,AM1,AN1,
     1 FX2,FY2,FZ2,AL2,AM2,AN2,FX3,FY3,FZ3,AL3,AM3,AN3)
C   VERSION 1.                                    REVISED: MAY 21 1976
C   PURPOSE:  SUM THREE SETS OF 3 AXIS FORCES AND MOMENTS
C   CALL SEQUENCE:
C   =============  OUTPUTS  =============
C   FX4,FY4,FZ4   -  SUM OF FORCES
C   AL4,AM4,AN4   -  SUM OF MOMENTS
C   =============  INPUTS  ==============
C   FX1,FY1,FZ1   -  FORCES INPUT  PORT 1
C   AL1,AM1,AN1   -  MOMENTS INPUT  PORT 1
C   FX2,FY2,FZ2   -  FORCES INPUT  PORT2
C   AL2,AM2,AN2   -  MOMENTS INPUT  PORT 2
C   FZ3,FY3,FZ3   -  FORCES INPUT  PORT3
C   AL3,AM3,AN3   -  MOMENTS INPUT  PORT 3
C   DESIGNED BY:  J.D. BURROUGHS                        MAY 1976
C
C ================  SUM FORCES  ============
      FX4=FX1+FX2+FX3
      FY4=FY1+FY2+FY3
      FZ4=FZ1+FZ2+FZ3
C ==============  SUM MOMENTS  ==========
      AL4=AL1+AL2+AL3
      AM4=AM1+AM2+AM3
      AN4=AN1+AN2+AN3
      RETURN
```

Table 100: FLOWCHART FOR SUBROUTINE TA

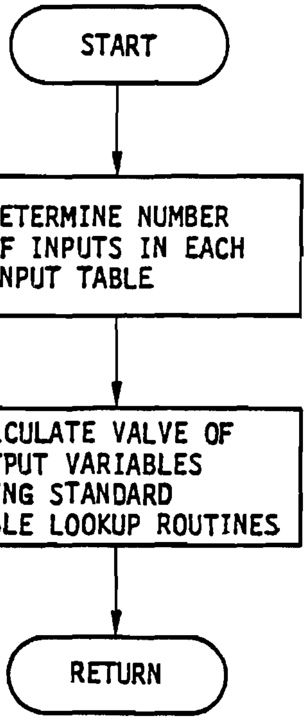
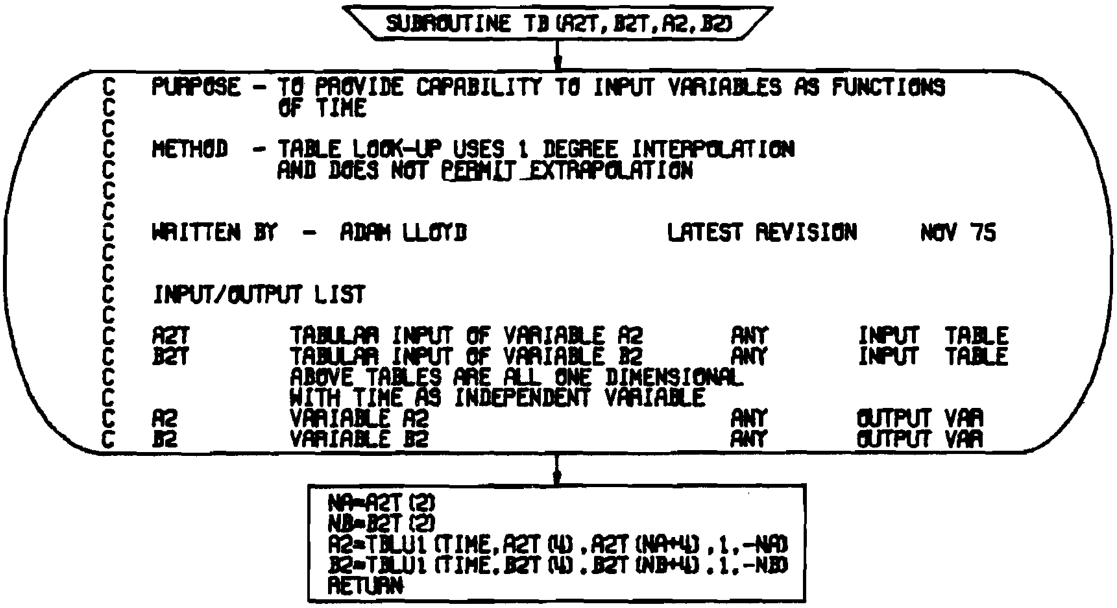


Table 101: FLOWCHART FOR SUBROUTINE TB



```
SUBROUTINE TB (A2T,B2T,A2,B2)

C    PURPOSE - TO PROVIDE CAPABILITY TO INPUT VARIABLES AS FUNCTIONS
C              OF TIME
C
C    METHOD  - TABLE LOOK-UP USES 1 DEGREE INTERPOLATION
C              AND DOES NOT PERMIT EXTRAPOLATION
C
C
C    WRITTEN BY  -  ADAM LLOYD                 LATEST REVISION     NOV 75
C
C
C    INPUT/OUTPUT LIST
C
C    A2T          TABULAR INPUT OF VARIABLE A2        ANY        INPUT  TABLE
C    B2T          TABULAR INPUT OF VARIABLE B2        ANY        INPUT  TABLE
C                 ABOVE TABLES ARE ALL ONE DIMENSIONAL
C                 WITH TIME AS INDEPENDENT VARIABLE
C    A2           VARIABLE A2                         ANY        OUTPUT VAR
C    B2           VARIABLE B2                         ANY        OUTPUT VAR

NA=A2T (2)
NB=B2T (2)
A2=TBLU1 (TIME,A2T (4) ,A2T (NA+4) ,1.,-NA)
B2=TBLU1 (TIME.B2T (4) .B2T (NB+4) .1.-NB)
RETURN
```

Table 102: FLOWCHART FOR SUBROUTINE TBL1

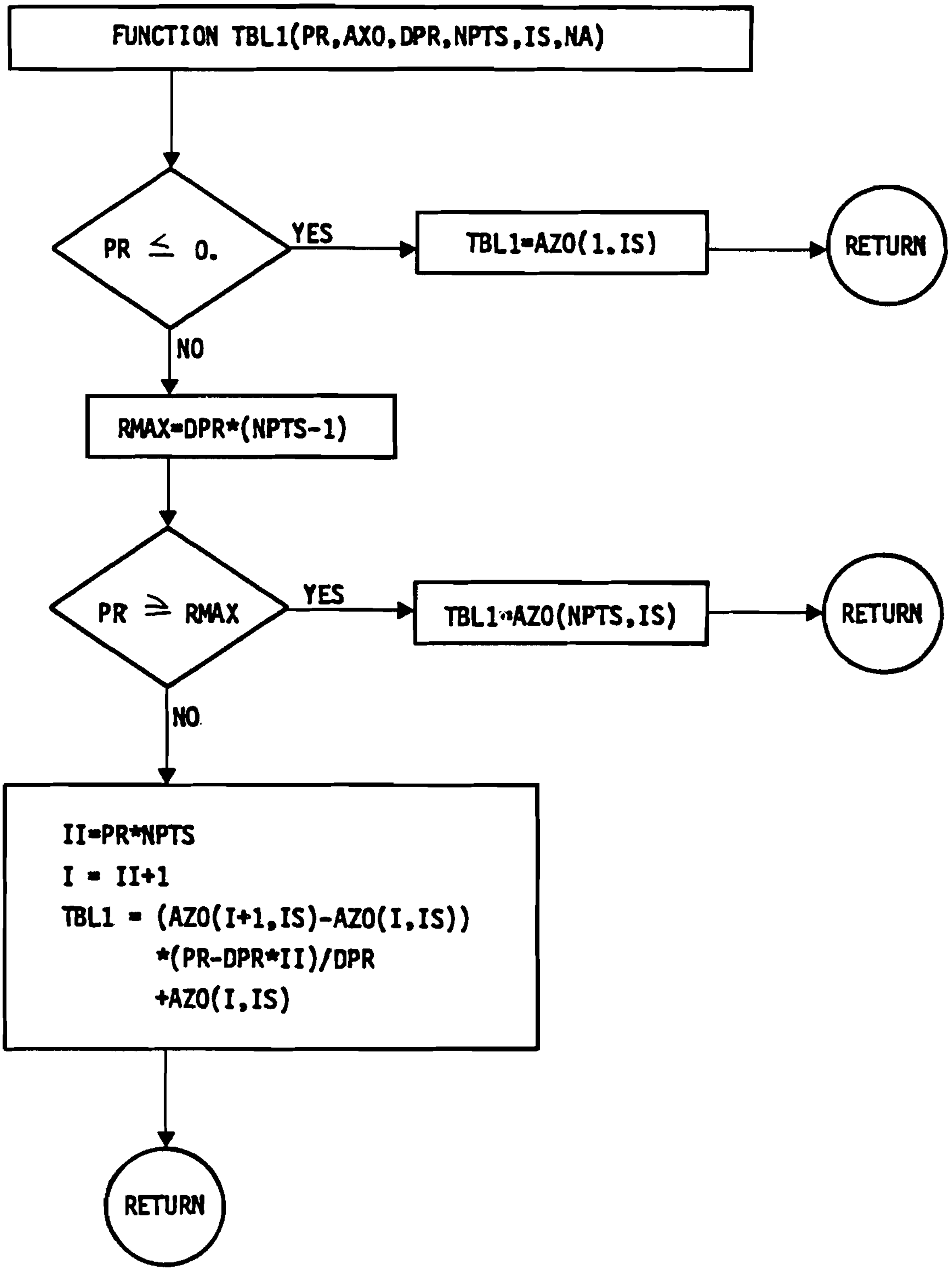


Table 103: FLOWCHART FOR SUBROUTINE TBL2

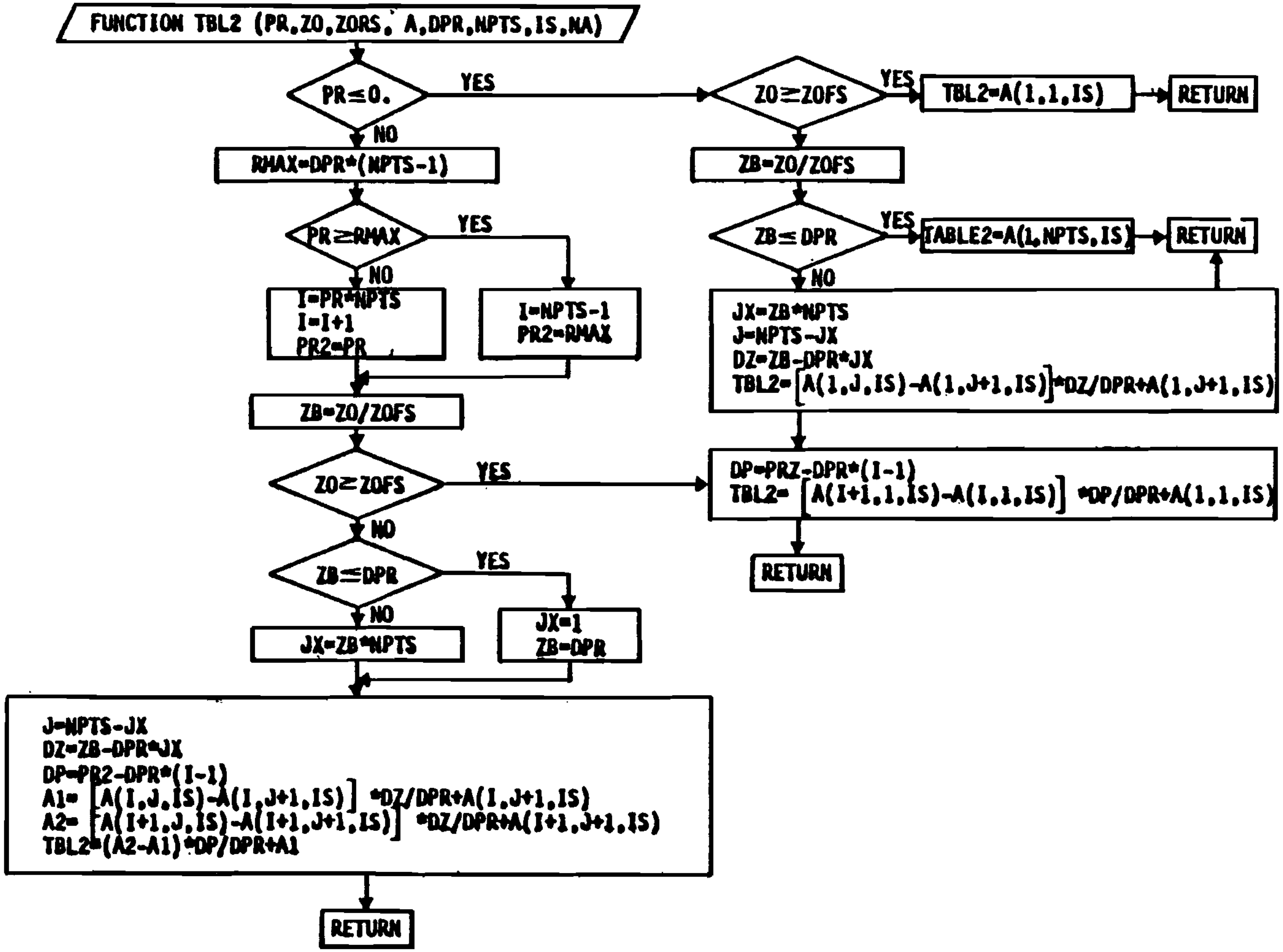
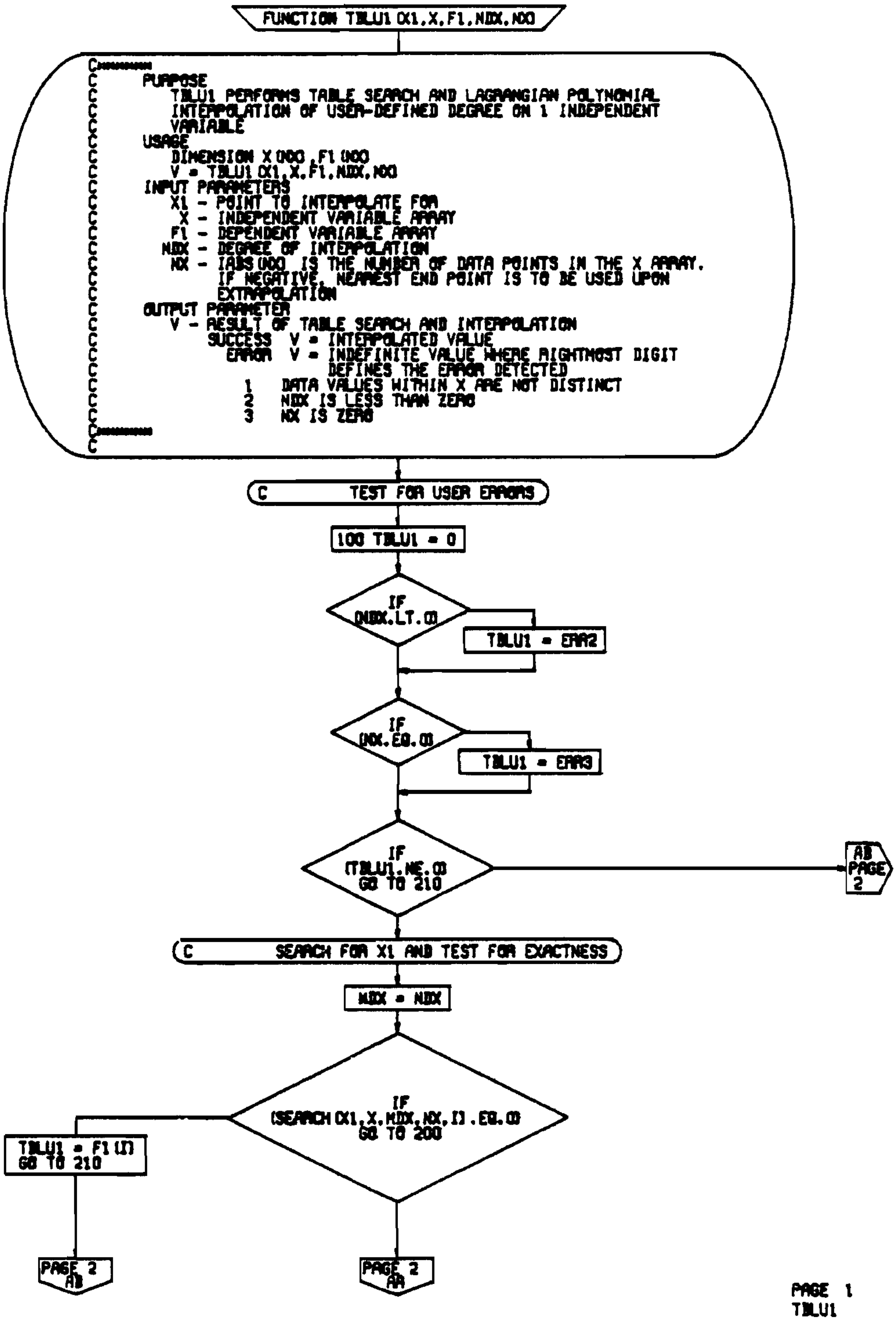


Table 104: FLOWCHART FOR SUBROUTINE TBLU1



```
C*********
C      PURPOSE
C         TBLU1 PERFORMS TABLE SEARCH AND LAGRANGIAN POLYNOMIAL
C         INTERPOLATION OF USER-DEFINED DEGREE ON 1 INDEPENDENT
C         VARIABLE
C      USAGE
C         DIMENSION X(NX),F1(NX)
C         V = TBLU1(X1,X,F1,NDX,NX)
C      INPUT PARAMETERS
C         X1 - POINT TO INTERPOLATE FOR
C          X - INDEPENDENT VARIABLE ARRAY
C         F1 - DEPENDENT VARIABLE ARRAY
C        NDX - DEGREE OF INTERPOLATION
C         NX - IABS(NX) IS THE NUMBER OF DATA POINTS IN THE X ARRAY.
C              IF NEGATIVE, NEAREST END POINT IS TO BE USED UPON
C              EXTRAPOLATION
C      OUTPUT PARAMETER
C         V - RESULT OF TABLE SEARCH AND INTERPOLATION
C              SUCCESS  V = INTERPOLATED VALUE
C                ERROR  V = INDEFINITE VALUE WHERE RIGHTMOST DIGIT
C                           DEFINES THE ERROR DETECTED
C                 1   DATA VALUES WITHIN X ARE NOT DISTINCT
C                 2   NDX IS LESS THAN ZERO
C                 3   NX IS ZERO
C*********
C
```

Table 104: FLOWCHART FOR SUBROUTINE TBLU1 (CONCLUDED)

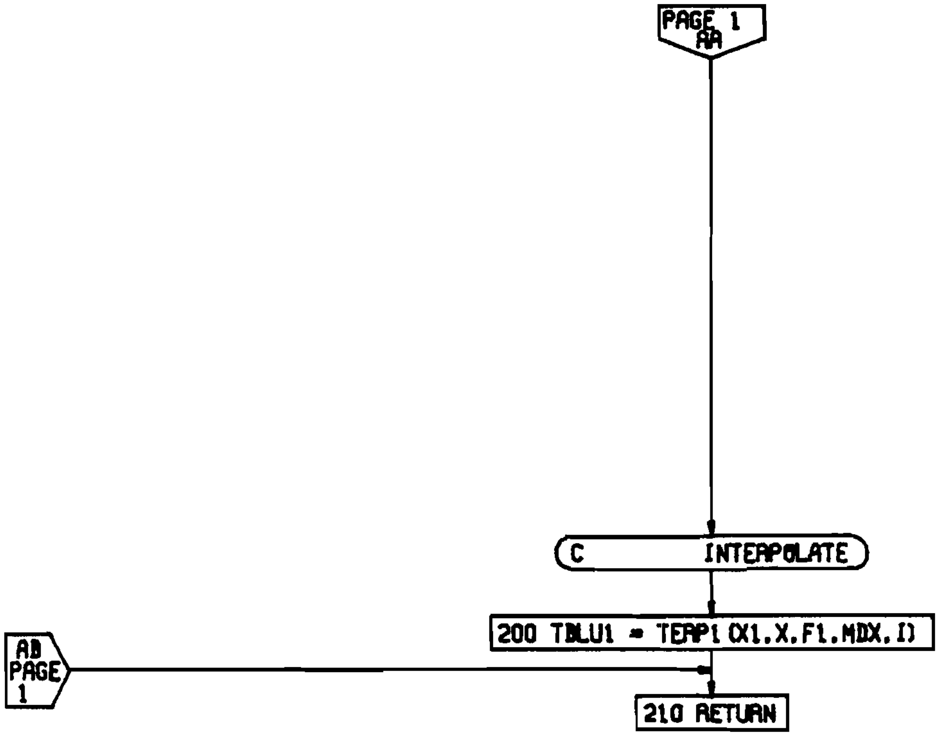
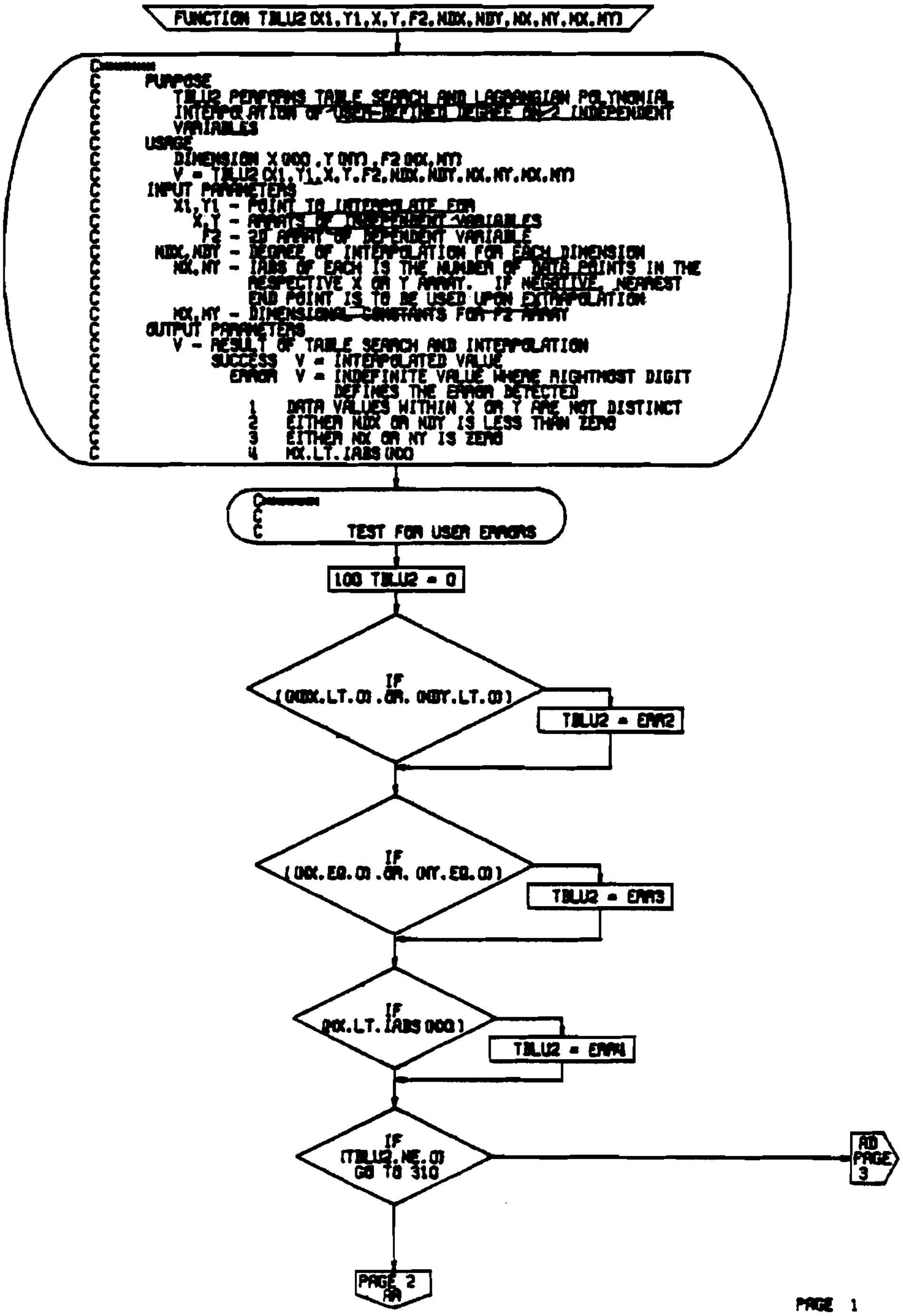


Table 105: FLOWCHART FOR SUBROUTINE TBLU2



```
C**********
C       PURPOSE
C          TBLU2 PERFORMS TABLE SEARCH AND LAGRANGIAN POLYNOMIAL
C          INTERPOLATION OF USER-DEFINED DEGREE ON 2 INDEPENDENT
C          VARIABLES
C       USAGE
C          DIMENSION X(MX),Y(MY),F2(MX,MY)
C          V = TBLU2(X1,Y1,X,Y,F2,NDX,NDY,NX,NY,MX,MY)
C       INPUT PARAMETERS
C          X1,Y1 - POINT TO INTERPOLATE FOR
C            X,Y - ARRAYS OF INDEPENDENT VARIABLES
C             F2 - 2D ARRAY OF DEPENDENT VARIABLE
C        NDX,NDY - DEGREE OF INTERPOLATION FOR EACH DIMENSION
C          NX,NY - IABS OF EACH IS THE NUMBER OF DATA POINTS IN THE
C                  RESPECTIVE X OR Y ARRAY.  IF NEGATIVE, NEAREST
C                  END POINT IS TO BE USED UPON EXTRAPOLATION
C          MX,MY - DIMENSIONAL CONSTANTS FOR F2 ARRAY
C       OUTPUT PARAMETERS
C          V - RESULT OF TABLE SEARCH AND INTERPOLATION
C              SUCCESS  V = INTERPOLATED VALUE
C                ERROR  V = INDEFINITE VALUE WHERE RIGHTMOST DIGIT
C                           DEFINES THE ERROR DETECTED
C                  1   DATA VALUES WITHIN X OR Y ARE NOT DISTINCT
C                  2   EITHER NDX OR NDY IS LESS THAN ZERO
C                  3   EITHER NX OR NY IS ZERO
C                  4   MX.LT.IABS(NX)
```

```
C**********
C
C
C               TEST FOR USER ERRORS
```

Table 105: FLOWCHART FOR SUBROUTINE TBLU2 (CONTINUED)

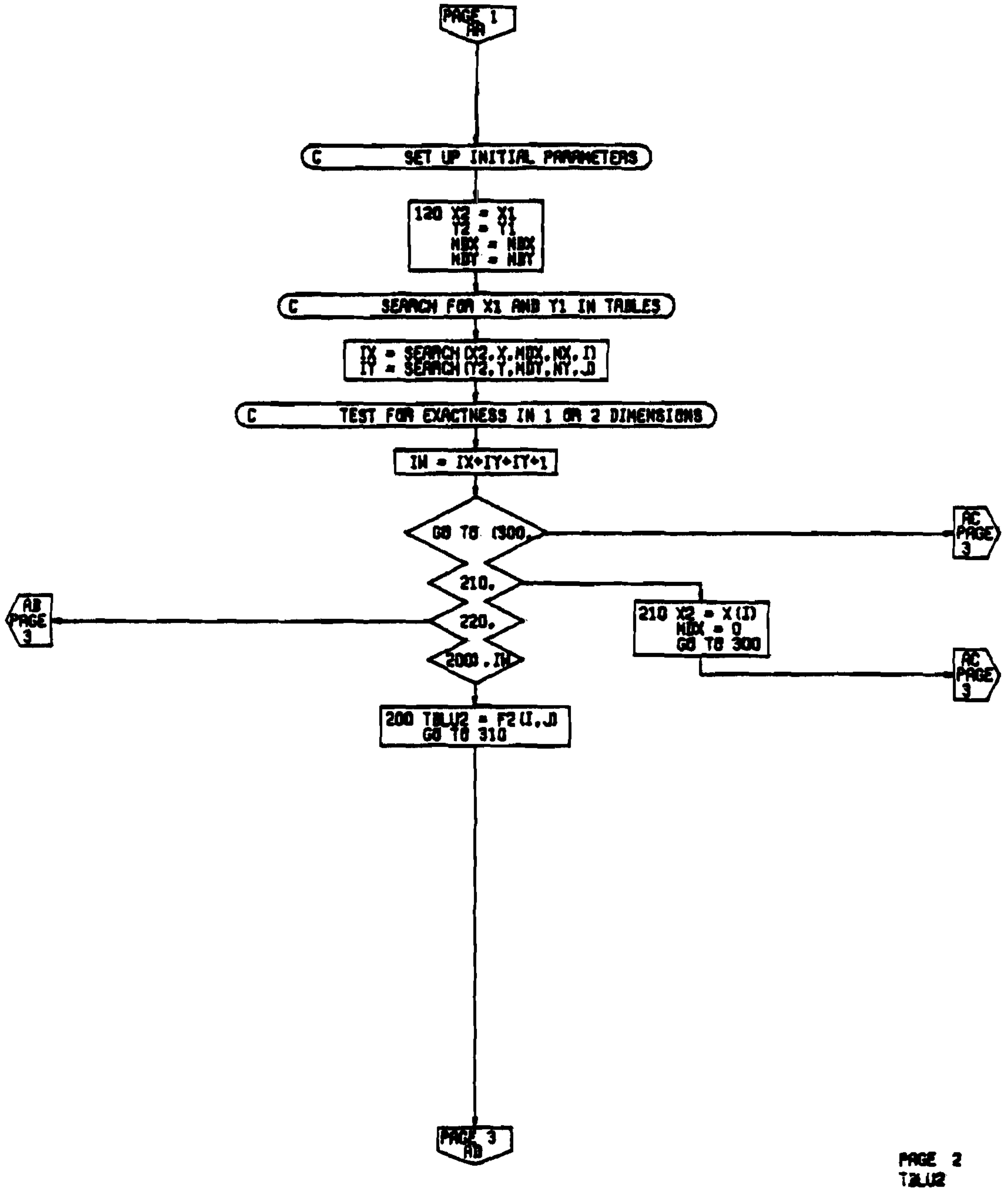
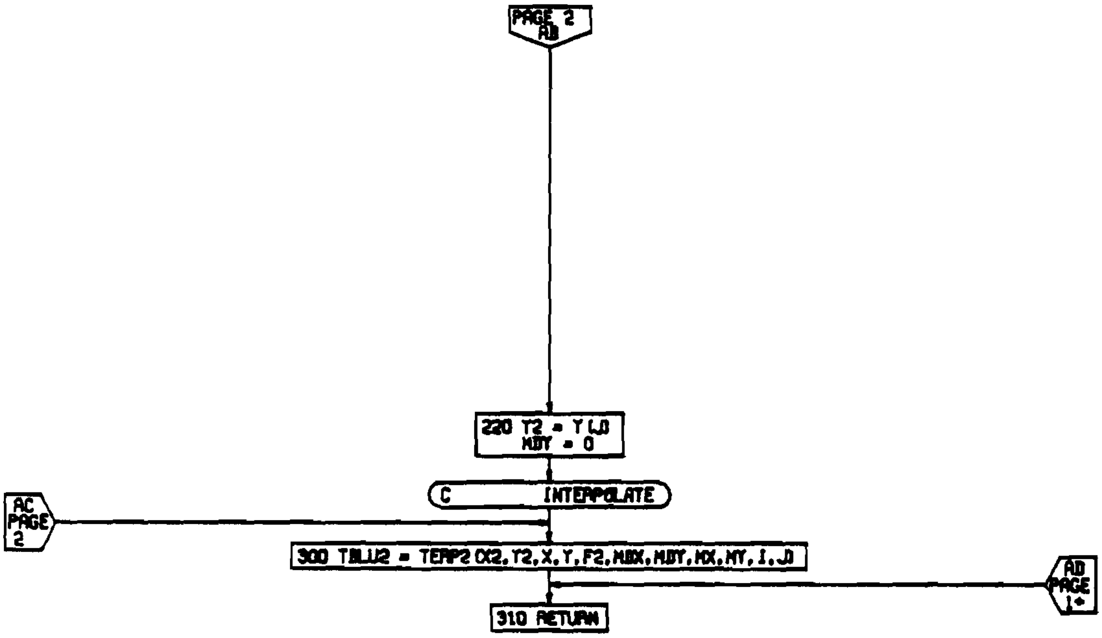
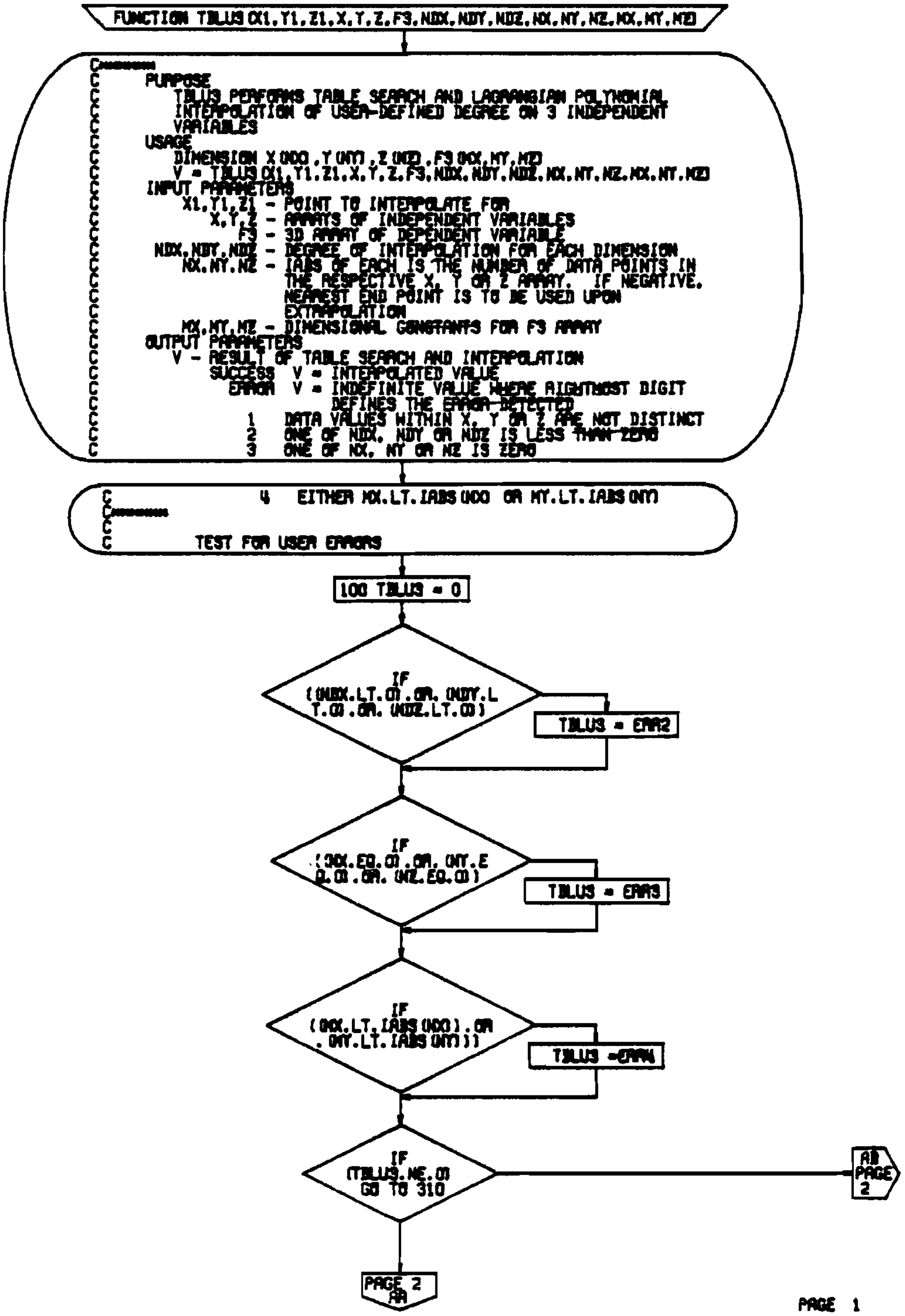


Table 105: FLOWCHART FOR SUBROUTINE TBLU2 (CONCLUDED)



PAGE 3
TBLU2

Table 106: FLOWCHART FOR SUBROUTINE TBLU3



```
FUNCTION TBLU3(X1,Y1,Z1,X,Y,Z,F3,NDX,NDY,NDZ,NX,NY,NZ,MX,MY,MZ)
```

```
C********
C     PURPOSE
C        TBLU3 PERFORMS TABLE SEARCH AND LAGRANGIAN POLYNOMIAL
C        INTERPOLATION OF USER-DEFINED DEGREE ON 3 INDEPENDENT
C        VARIABLES
C     USAGE
C        DIMENSION X(NX),Y(NY),Z(NZ),F3(MX,MY,MZ)
C        V = TBLU3(X1,Y1,Z1,X,Y,Z,F3,NDX,NDY,NDZ,NX,NY,NZ,MX,MY,MZ)
C     INPUT PARAMETERS
C          X1,Y1,Z1 - POINT TO INTERPOLATE FOR
C             X,Y,Z - ARRAYS OF INDEPENDENT VARIABLES
C                F3 - 3D ARRAY OF DEPENDENT VARIABLE
C       NDX,NDY,NDZ - DEGREE OF INTERPOLATION FOR EACH DIMENSION
C          NX,NY,NZ - IABS OF EACH IS THE NUMBER OF DATA POINTS IN
C                     THE RESPECTIVE X, Y OR Z ARRAY.  IF NEGATIVE.
C                     NEAREST END POINT IS TO BE USED UPON
C                     EXTRAPOLATION
C          MX,MY,MZ - DIMENSIONAL CONSTANTS FOR F3 ARRAY
C     OUTPUT PARAMETERS
C        V - RESULT OF TABLE SEARCH AND INTERPOLATION
C           SUCCESS  V = INTERPOLATED VALUE
C             ERROR  V = INDEFINITE VALUE WHERE RIGHTMOST DIGIT
C                        DEFINES THE ERROR DETECTED
C               1    DATA VALUES WITHIN X, Y OR Z ARE NOT DISTINCT
C               2    ONE OF NDX, NDY OR NDZ IS LESS THAN ZERO
C               3    ONE OF NX, NY OR NZ IS ZERO
C               4    EITHER MX.LT.IABS(NX) OR MY.LT.IABS(NY)
C********
C
C        TEST FOR USER ERRORS
```

Table 106: FLOWCHART FOR SUBROUTINE TBLU3 (CONCLUDED)

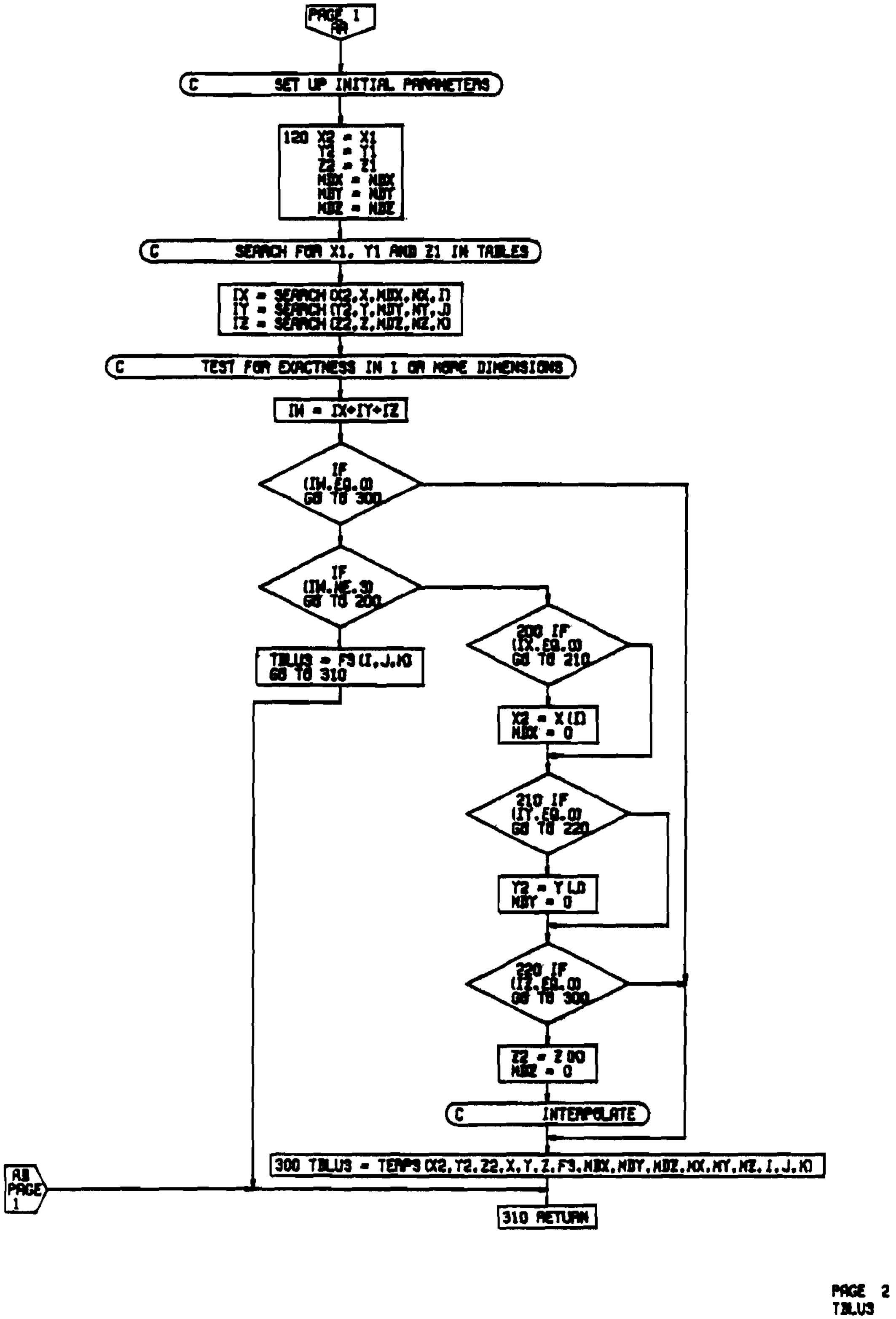
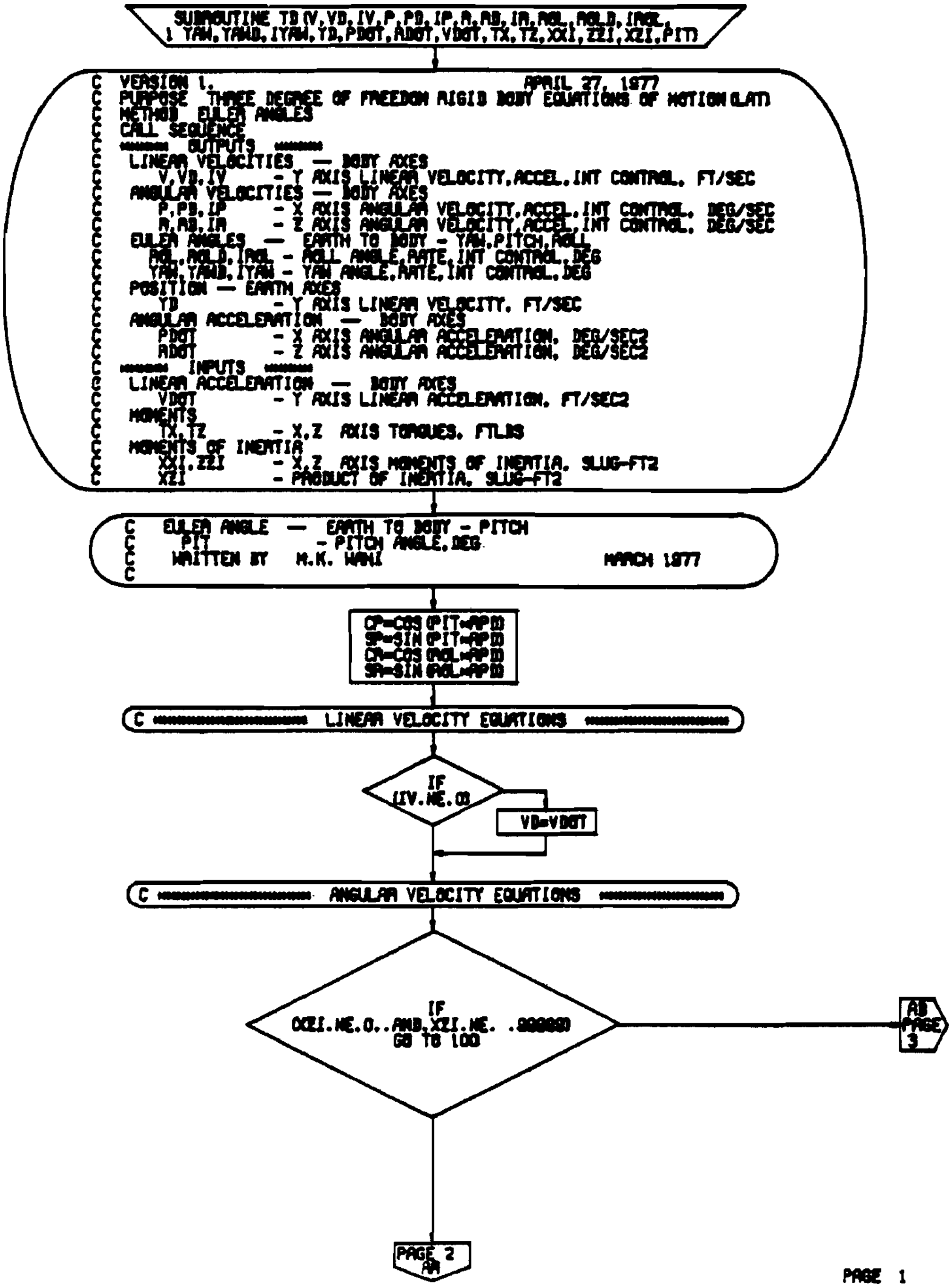


Table 107: FLOWCHART FOR SUBROUTINE TD



```
      SUBROUTINE TD(V,VD,IV,P,PD,IP,R,RD,IR,ROL,ROLD,IROL,
     1 YAW,YAWD,IYAW,YD,PDOT,RDOT,VDOT,TX,TZ,XXI,ZZI,XZI,PIT)
C   VERSION 1.                                     APRIL 27, 1977
C   PURPOSE  THREE DEGREE OF FREEDOM RIGID BODY EQUATIONS OF MOTION(LAT)
C   METHOD  EULER ANGLES
C   CALL SEQUENCE
C   ****** OUTPUTS ******
C    LINEAR VELOCITIES  — BODY AXES
C      V,VD,IV        - Y AXIS LINEAR VELOCITY,ACCEL,INT CONTROL, FT/SEC
C    ANGULAR VELOCITIES — BODY AXES
C      P,PD,IP        - X AXIS ANGULAR VELOCITY,ACCEL,INT CONTROL, DEG/SEC
C      R,RD,IR        - Z AXIS ANGULAR VELOCITY,ACCEL,INT CONTROL, DEG/SEC
C    EULER ANGLES  —  EARTH TO BODY - YAW,PITCH,ROLL
C     ROL,ROLD,IROL - ROLL ANGLE,RATE,INT CONTROL,DEG
C     YAW,YAWD,IYAW - YAW ANGLE,RATE,INT CONTROL,DEG
C    POSITION — EARTH AXES
C      YD             - Y AXIS LINEAR VELOCITY, FT/SEC
C    ANGULAR ACCELERATION  —  BODY AXES
C      PDOT           - X AXIS ANGULAR ACCELERATION, DEG/SEC2
C      RDOT           - Z AXIS ANGULAR ACCELERATION, DEG/SEC2
C   ****** INPUTS ******
C    LINEAR ACCELERATION  —  BODY AXES
C      VDOT           - Y AXIS LINEAR ACCELERATION, FT/SEC2
C    MOMENTS
C      TX,TZ          - X,Z  AXIS TORQUES, FTLBS
C    MOMENTS OF INERTIA
C      XXI,ZZI        - X,Z  AXIS MOMENTS OF INERTIA, SLUG-FT2
C      XZI            - PRODUCT OF INERTIA, SLUG-FT2

C    EULER ANGLE  —  EARTH TO BODY - PITCH
C      PIT             - PITCH ANGLE,DEG
C     WRITTEN BY   M.K. WANI                          MARCH 1977
C

      CP=COS(PIT*APD)
      SP=SIN(PIT*APD)
      CR=COS(ROL*APD)
      SR=SIN(ROL*APD)

C ************** LINEAR VELOCITY EQUATIONS **************

      IF (IV.NE.0)
      VD=VDOT

C ************** ANGULAR VELOCITY EQUATIONS **************

      IF
      (XZI.NE.0..AND.XZI.NE. .99999)
      GO TO 100
```

Table 107: FLOWCHART FOR SUBROUTINE TD (CONTINUED)

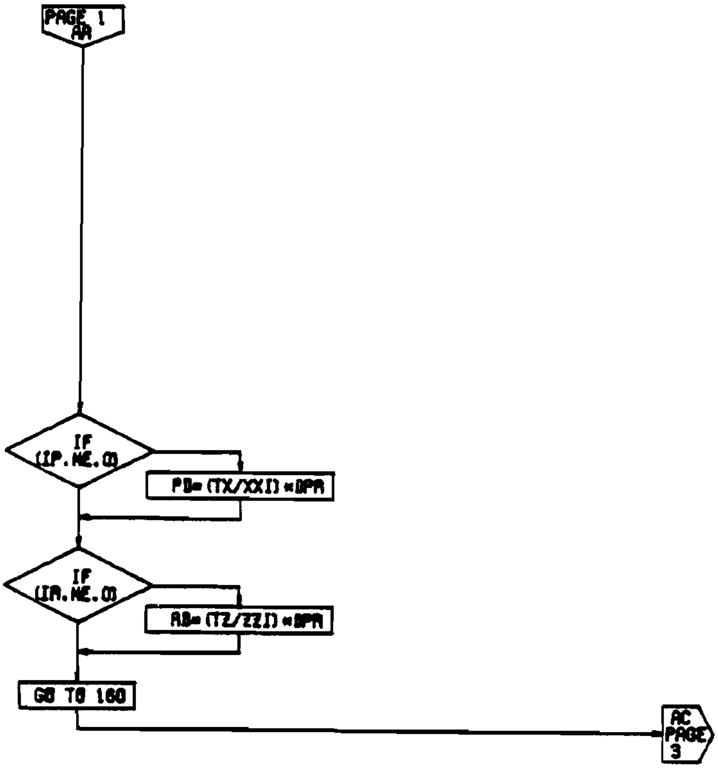


Table 107: FLOWCHART FOR SUBROUTINE TD (CONCLUDED)

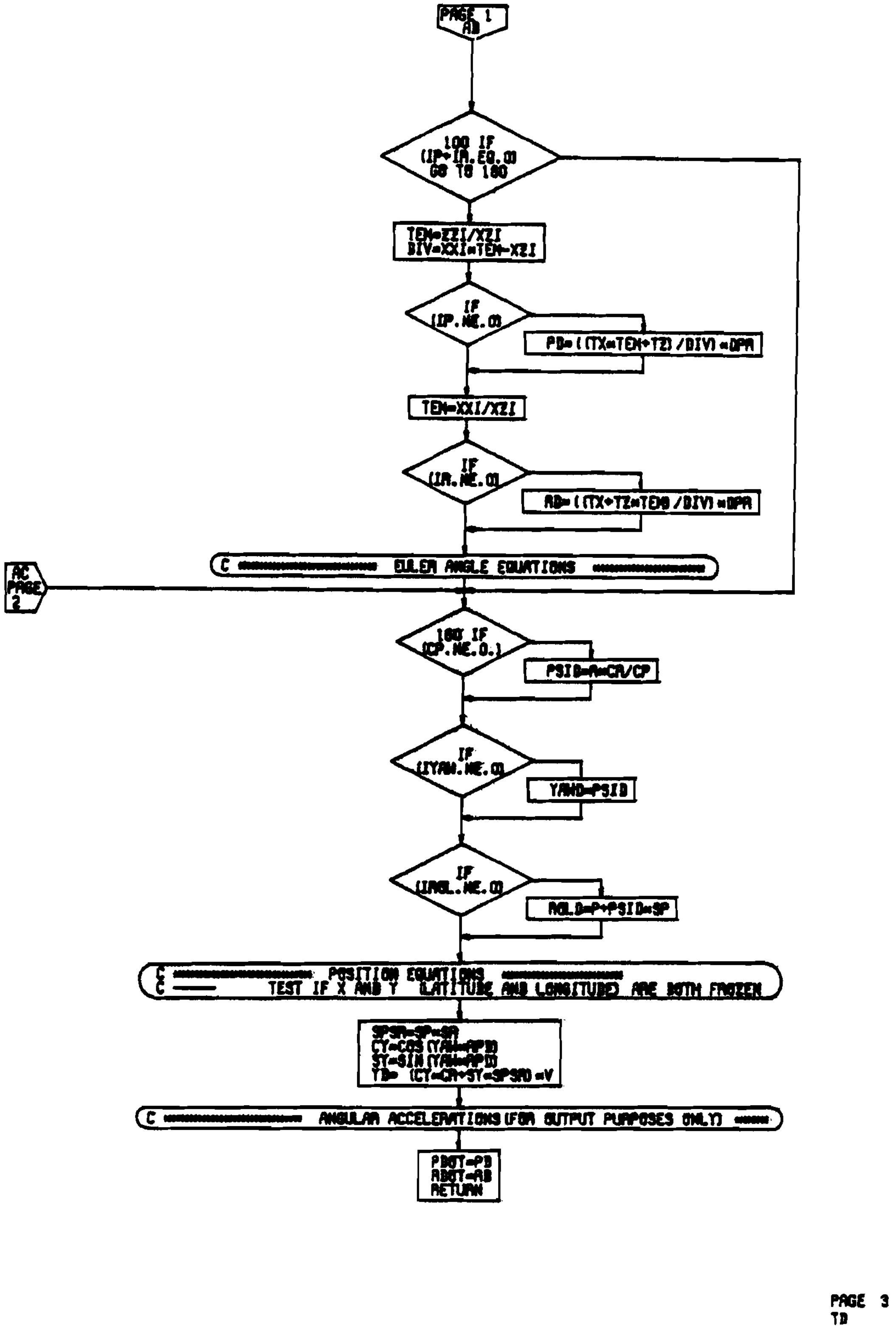


Table 108: FLOWCHART FOR SUBROUTINE TERRA

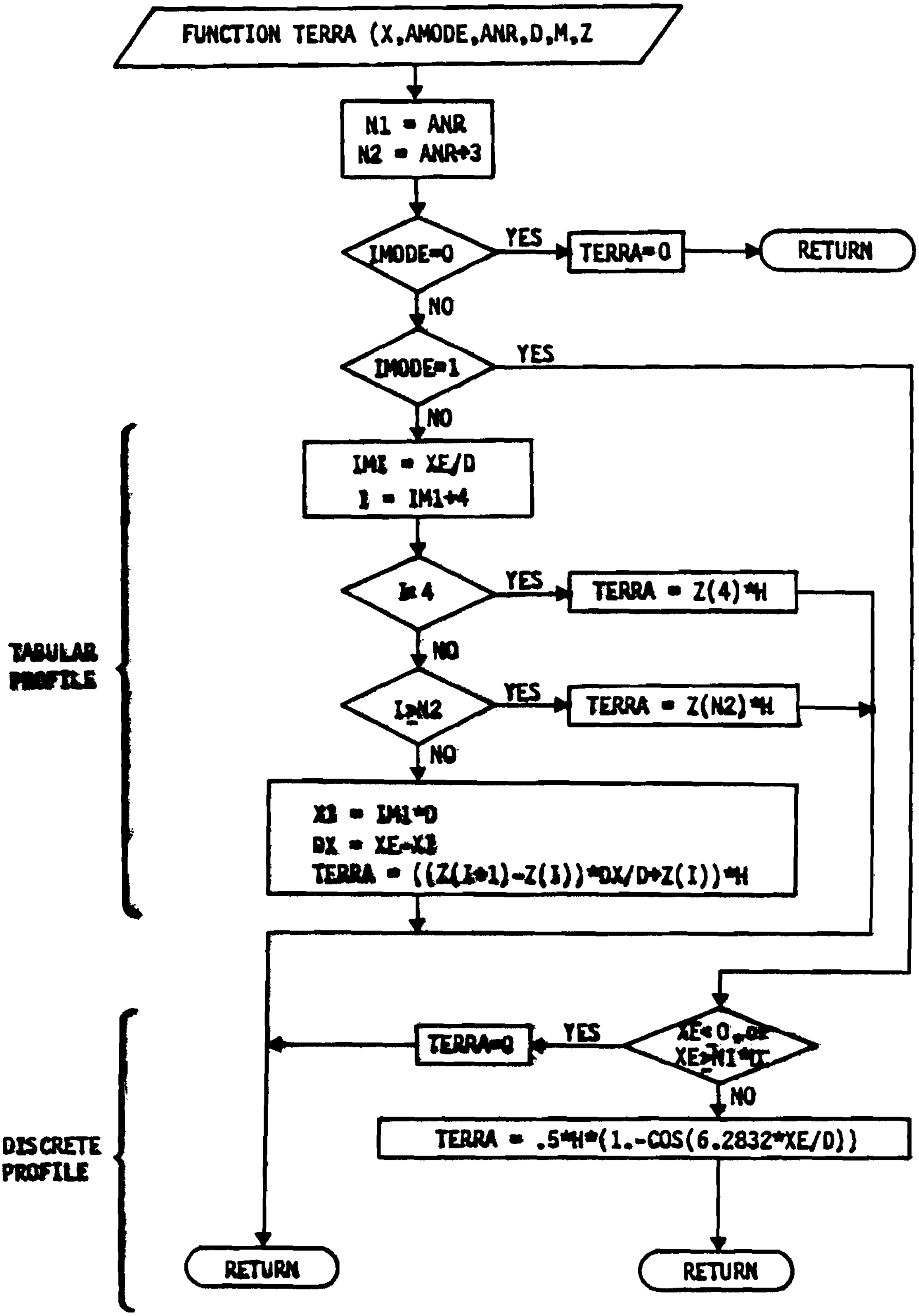
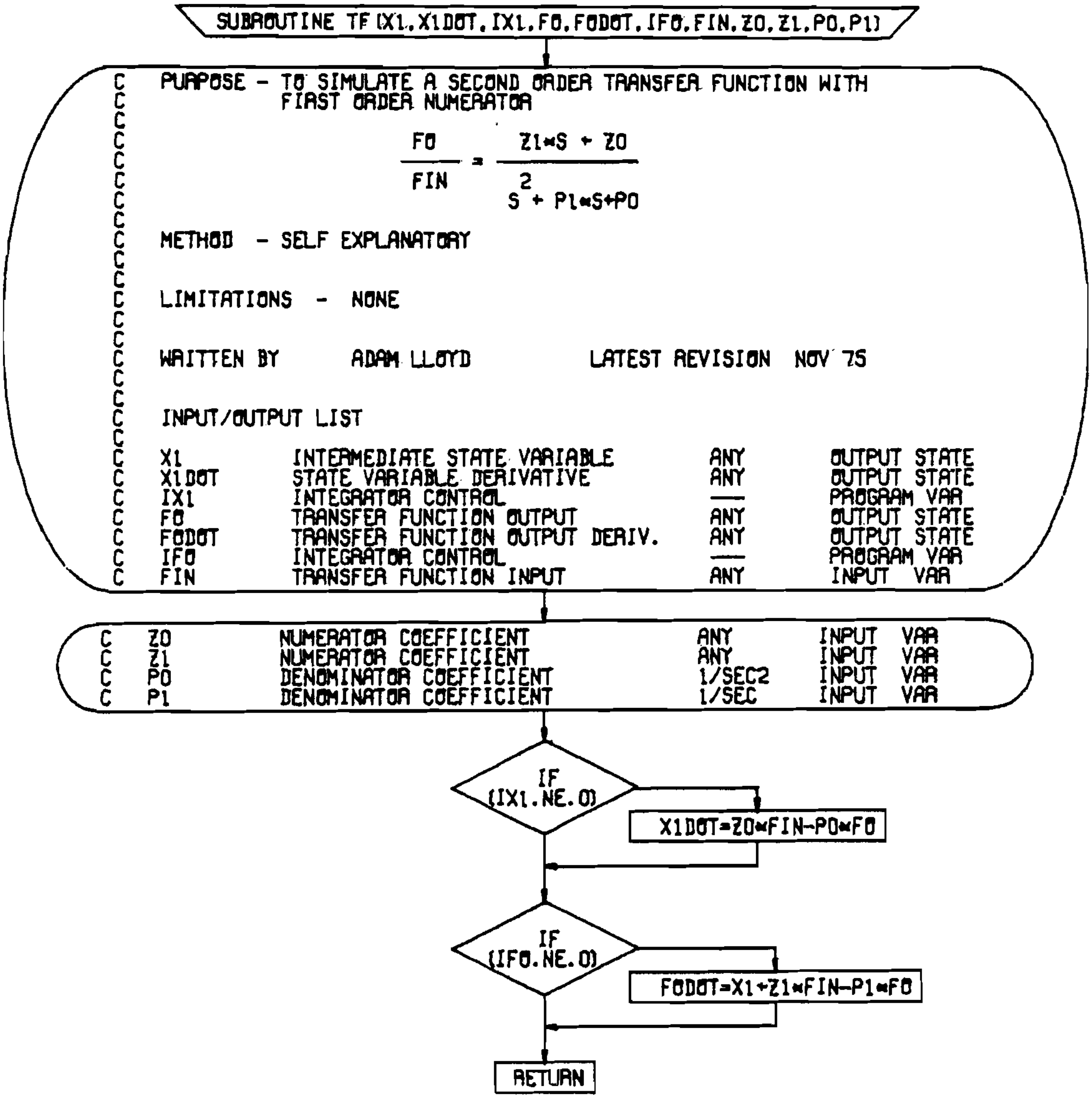


Table 109: FLOWCHART FOR SUBROUTINE TF

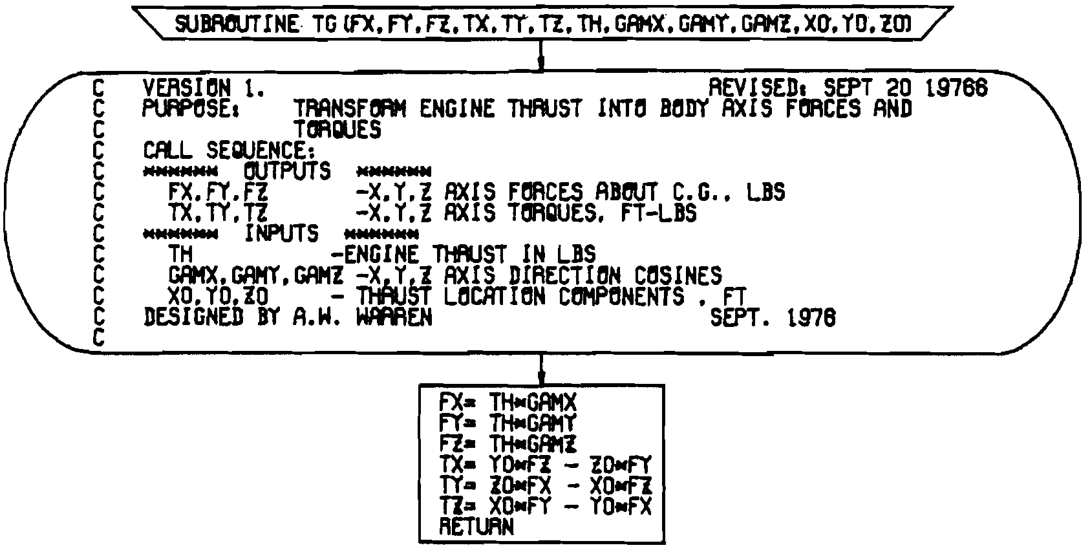


```
SUBROUTINE TF(X1,X1DOT,IX1,F0,F0DOT,IF0,FIN,Z0,Z1,P0,P1)

C     PURPOSE - TO SIMULATE A SECOND ORDER TRANSFER FUNCTION WITH
C               FIRST ORDER NUMERATOR
C
C                        F0       Z1*S + Z0
C                       ---- =   -----------
C                        FIN       2
C                                 S + P1*S+P0
C
C     METHOD  - SELF EXPLANATORY
C
C
C     LIMITATIONS  -  NONE
C
C
C     WRITTEN BY      ADAM LLOYD           LATEST REVISION   NOV 75
C
C
C     INPUT/OUTPUT LIST
C
C     X1          INTERMEDIATE STATE VARIABLE          ANY        OUTPUT STATE
C     X1DOT       STATE VARIABLE DERIVATIVE            ANY        OUTPUT STATE
C     IX1         INTEGRATOR CONTROL                   ---        PROGRAM VAR
C     F0          TRANSFER FUNCTION OUTPUT             ANY        OUTPUT STATE
C     F0DOT       TRANSFER FUNCTION OUTPUT DERIV.      ANY        OUTPUT STATE
C     IF0         INTEGRATOR CONTROL                   ---        PROGRAM VAR
C     FIN         TRANSFER FUNCTION INPUT              ANY        INPUT  VAR

C     Z0          NUMERATOR COEFFICIENT                ANY        INPUT  VAR
C     Z1          NUMERATOR COEFFICIENT                ANY        INPUT  VAR
C     P0          DENOMINATOR COEFFICIENT              1/SEC2     INPUT  VAR
C     P1          DENOMINATOR COEFFICIENT              1/SEC      INPUT  VAR
```

Table 110: FLOWCHART FOR SUBROUTINE TG



```
SUBROUTINE TG (FX,FY,FZ,TX,TY,TZ,TH,GAMX,GAMY,GAMZ,XO,YO,ZO)

C    VERSION 1.                                       REVISED: SEPT 20 19766
C    PURPOSE:     TRANSFORM ENGINE THRUST INTO BODY AXIS FORCES AND
C                 TORQUES
C    CALL SEQUENCE:
C    ******** OUTPUTS  ********
C      FX,FY,FZ         -X,Y,Z AXIS FORCES ABOUT C.G., LBS
C      TX,TY,TZ         -X,Y,Z AXIS TORQUES, FT-LBS
C    ******** INPUTS  ********
C      TH             -ENGINE THRUST IN LBS
C      GAMX,GAMY,GAMZ -X,Y,Z AXIS DIRECTION COSINES
C      XO,YO,ZO       - THRUST LOCATION COMPONENTS , FT
C    DESIGNED BY A.W. WARREN                        SEPT. 1976
C

FX= TH*GAMX
FY= TH*GAMY
FZ= TH*GAMZ
TX= YO*FZ - ZO*FY
TY= ZO*FX - XO*FZ
TZ= XO*FY - YO*FX
RETURN
```

Table 111: FLOWCHART FOR SUBROUTINE TK

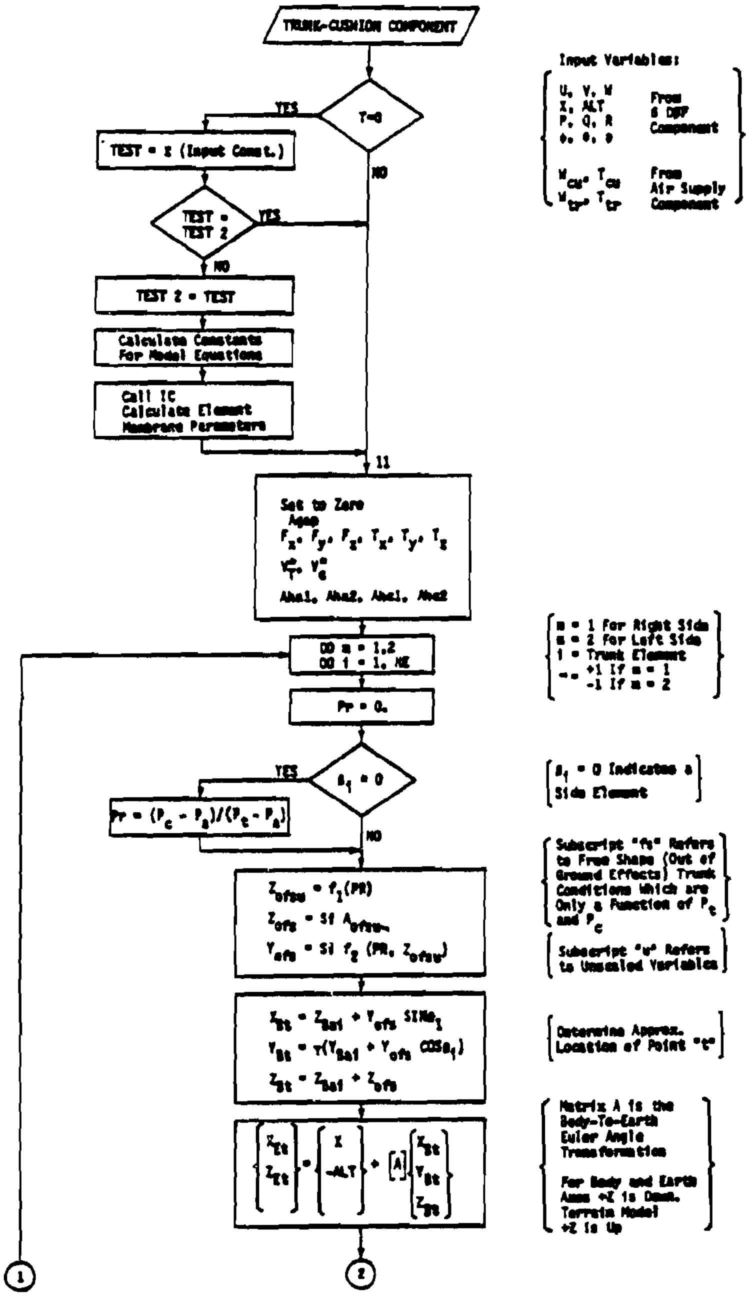


Table 111: FLOWCHART FOR SUBROUTINE TK (CONTINUED)

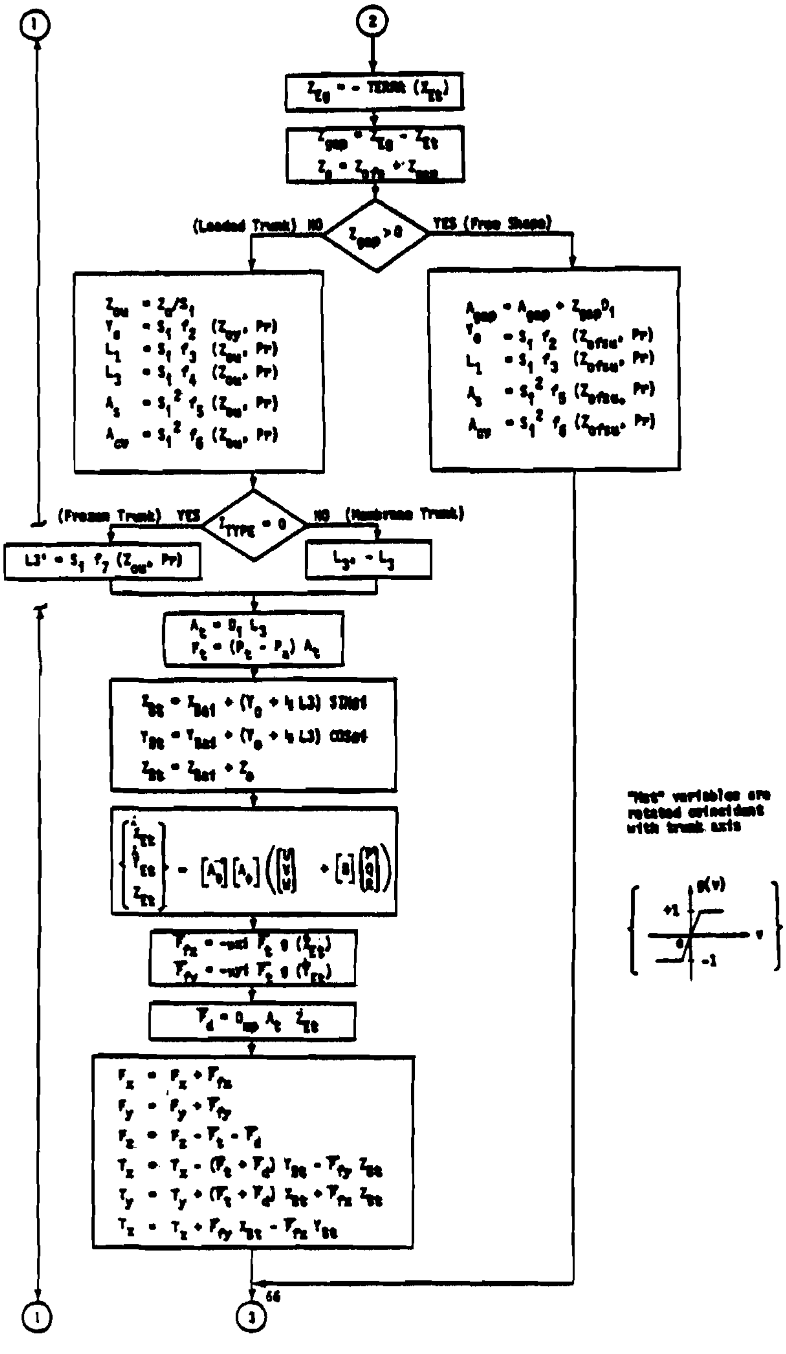


Table 111: FLOWCHART FOR SUBROUTINE TK (CONCLUDED)

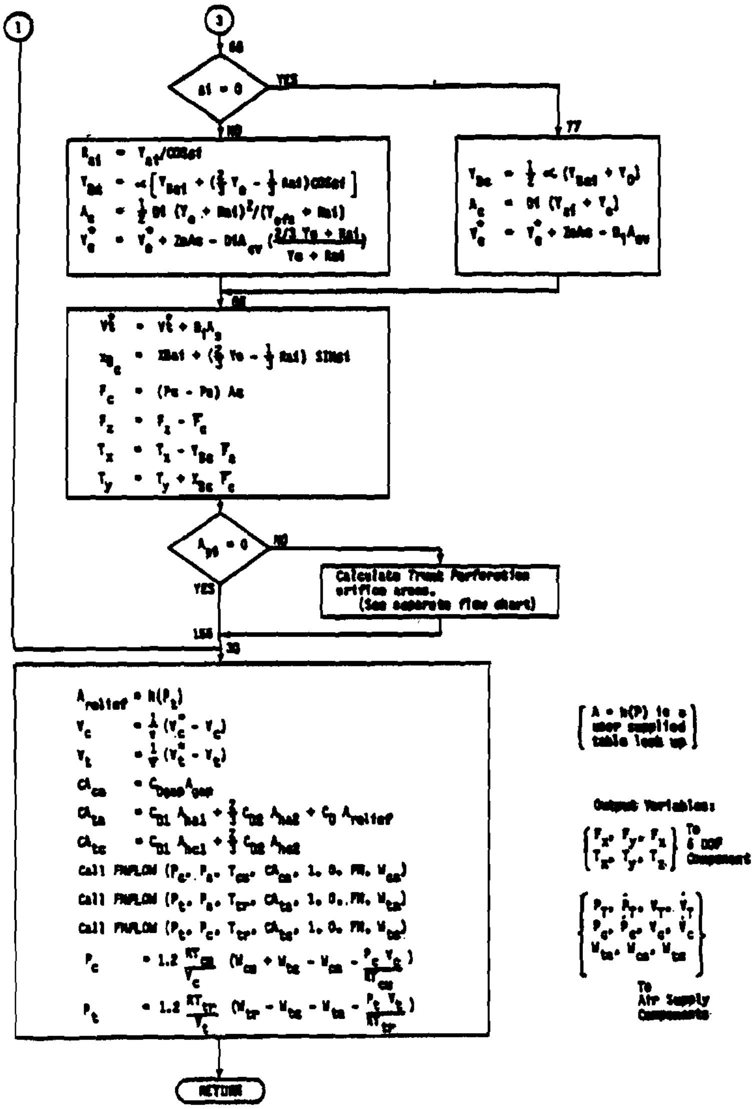
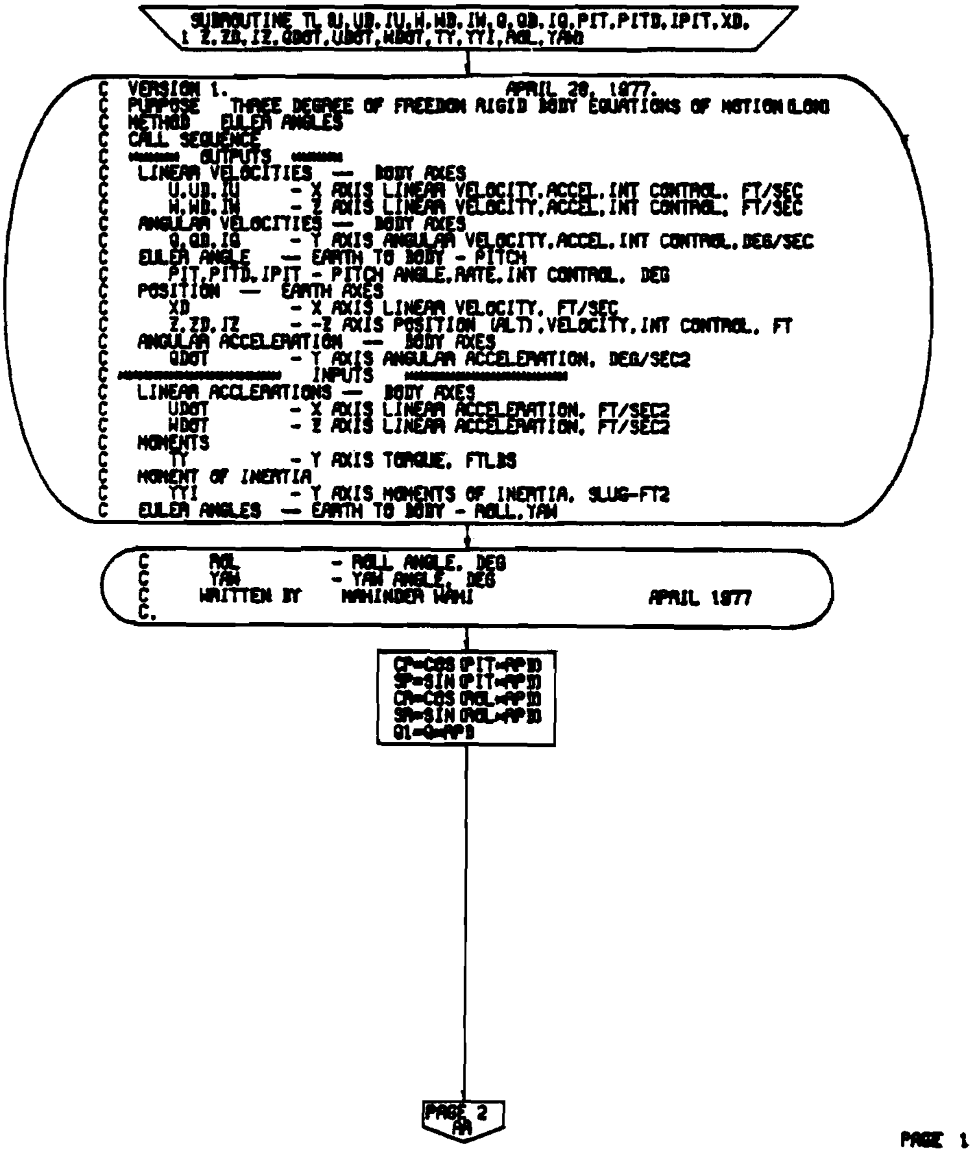


Table 112: FLOWCHART FOR SUBROUTINE TL



```
      SUBROUTINE TL(U,UD,IU,W,WD,IW,Q,QD,IQ,PIT,PITD,IPIT,XD,
     1 Z,ZD,IZ,QDOT,UDOT,WDOT,TY,YYI,ROL,YAW)
C  VERSION 1.                                    APRIL 28, 1977.
C  PURPOSE   THREE DEGREE OF FREEDOM RIGID BODY EQUATIONS OF MOTION(LONG
C  METHOD   EULER ANGLES
C  CALL SEQUENCE
C  ------- OUTPUTS -------
C   LINEAR VELOCITIES  ---   BODY AXES
C      U,UD,IU      - X AXIS LINEAR VELOCITY,ACCEL,INT CONTROL, FT/SEC
C      W,WD,IW      - Z AXIS LINEAR VELOCITY,ACCEL,INT CONTROL, FT/SEC
C   ANGULAR VELOCITIES ---   BODY AXES
C      Q,QD,IQ      - Y AXIS ANGULAR VELOCITY,ACCEL,INT CONTROL,DEG/SEC
C   EULER ANGLE    --- EARTH TO BODY - PITCH
C      PIT,PITD,IPIT - PITCH ANGLE,RATE,INT CONTROL, DEG
C   POSITION  ---   EARTH AXES
C      XD           - X AXIS LINEAR VELOCITY, FT/SEC
C      Z,ZD,IZ      - -Z AXIS POSITION (ALT),VELOCITY,INT CONTROL, FT
C   ANGULAR ACCELERATION  ---   BODY AXES
C      QDOT         - Y AXIS ANGULAR ACCELERATION, DEG/SEC2
C-----------------------   INPUTS   -----------------------
C   LINEAR ACCLERATIONS ---   BODY AXES
C      UDOT         - X AXIS LINEAR ACCELERATION, FT/SEC2
C      WDOT         - Z AXIS LINEAR ACCELERATION, FT/SEC2
C   MOMENTS
C      TY           - Y AXIS TORQUE, FTLBS
C   MOMENT OF INERTIA
C      YYI          - Y AXIS MOMENTS OF INERTIA, SLUG-FT2
C   EULER ANGLES  --- EARTH TO BODY - ROLL,YAW
C       ROL          - ROLL ANGLE, DEG
C       YAW          - YAW ANGLE, DEG
C     WRITTEN BY    MAHINDER WAHI                    APRIL 1977
C.
      CP=COS(PIT*RPD)
      SP=SIN(PIT*RPD)
      CR=COS(ROL*RPD)
      SR=SIN(ROL*RPD)
      Q1=Q*RPD
```

Table 112: FLOWCHART FOR SUBROUTINE TL (CONCLUDED)

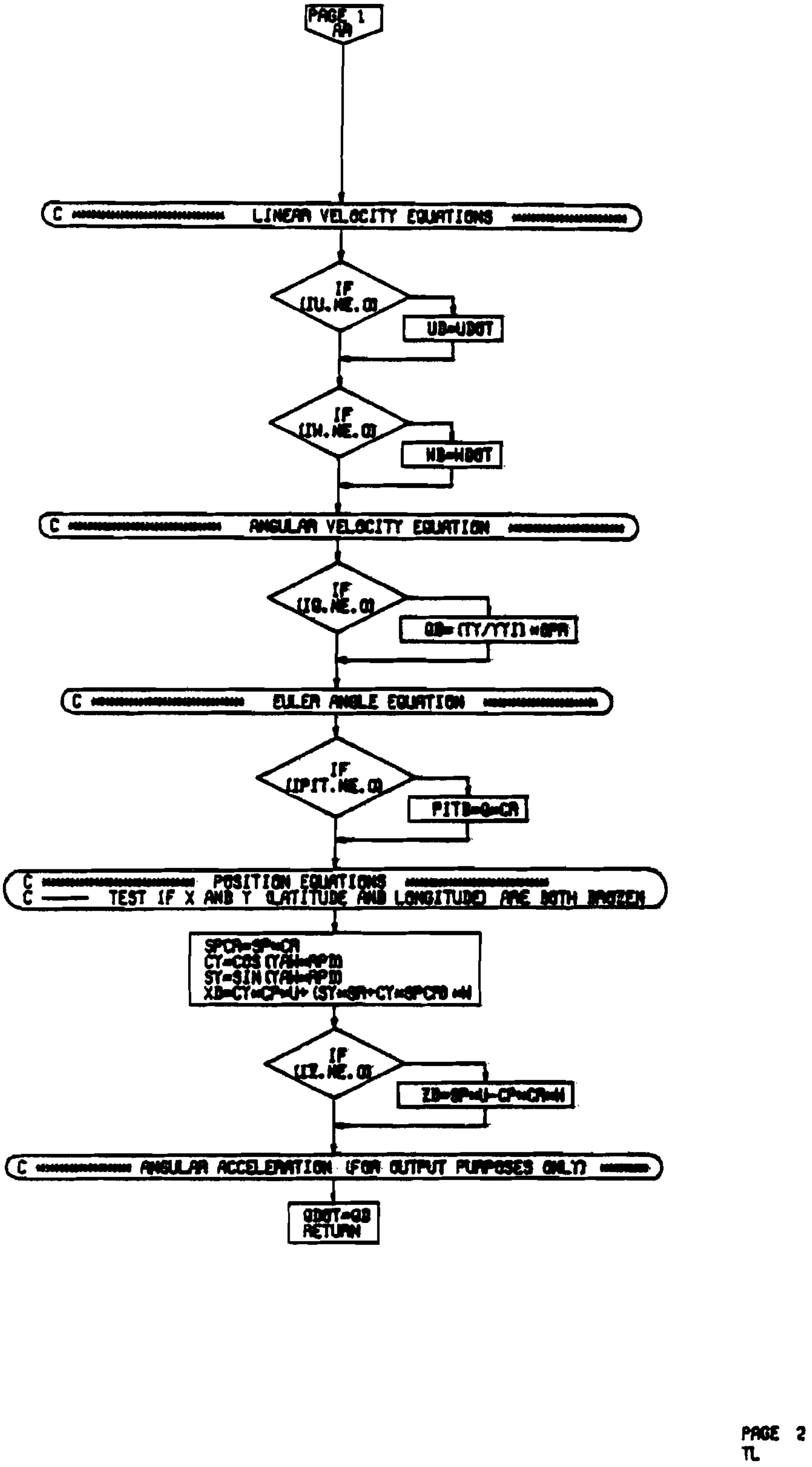
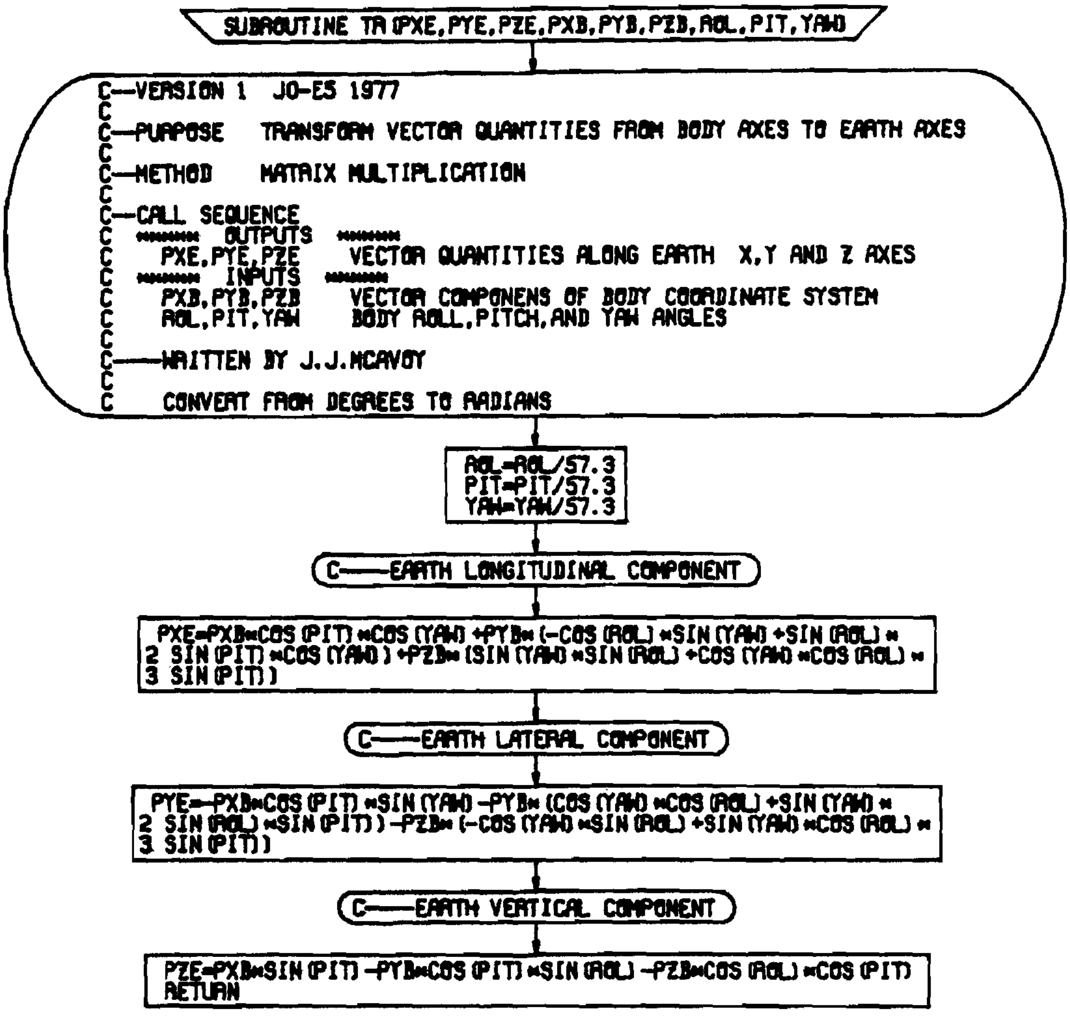


Table 113: FLOWCHART FOR SUBROUTINE TR



```
SUBROUTINE TR(PXE,PYE,PZE,PXB,PYB,PZB,ROL,PIT,YAW)

C--VERSION 1  JO-ES 1977
C
C--PURPOSE   TRANSFORM VECTOR QUANTITIES FROM BODY AXES TO EARTH AXES
C
C--METHOD    MATRIX MULTIPLICATION
C
C--CALL SEQUENCE
C  ********  OUTPUTS  ********
C    PXE,PYE,PZE    VECTOR QUANTITIES ALONG EARTH  X,Y AND Z AXES
C  ********  INPUTS  ********
C    PXB,PYB,PZB    VECTOR COMPONENS OF BODY COORDINATE SYSTEM
C    ROL,PIT,YAW    BODY ROLL,PITCH,AND YAW ANGLES
C
C-----WRITTEN BY J.J.MCAVOY
C
C    CONVERT FROM DEGREES TO RADIANS

      ROL=ROL/57.3
      PIT=PIT/57.3
      YAW=YAW/57.3

C-----EARTH LONGITUDINAL COMPONENT

      PXE=PXB*COS(PIT)*COS(YAW)+PYB*(-COS(ROL)*SIN(YAW)+SIN(ROL)*
     2 SIN(PIT)*COS(YAW))+PZB*(SIN(YAW)*SIN(ROL)+COS(YAW)*COS(ROL)*
     3 SIN(PIT))

C-----EARTH LATERAL COMPONENT

      PYE=-PXB*COS(PIT)*SIN(YAW)-PYB*(COS(YAW)*COS(ROL)+SIN(YAW)*
     2 SIN(ROL)*SIN(PIT))-PZB*(-COS(YAW)*SIN(ROL)+SIN(YAW)*COS(ROL)*
     3 SIN(PIT))

C-----EARTH VERTICAL COMPONENT

      PZE=PXB*SIN(PIT)-PYB*COS(PIT)*SIN(ROL)-PZB*COS(ROL)*COS(PIT)
      RETURN
```

Table 114: FLOWCHART FOR SUBROUTINE TRUNK

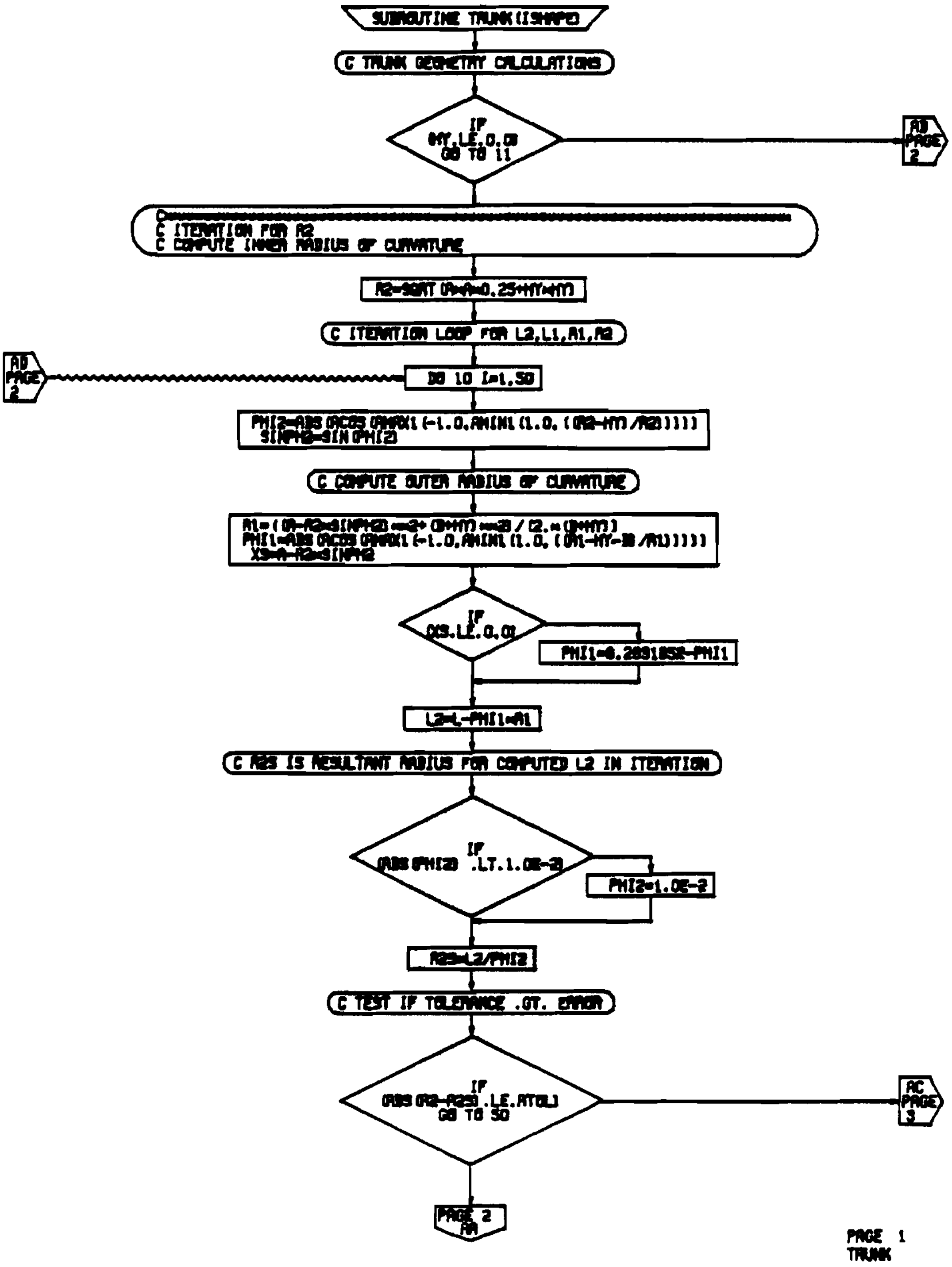


Table 114: FLOWCHART FOR SUBROUTINE TRUNK (CONTINUED)

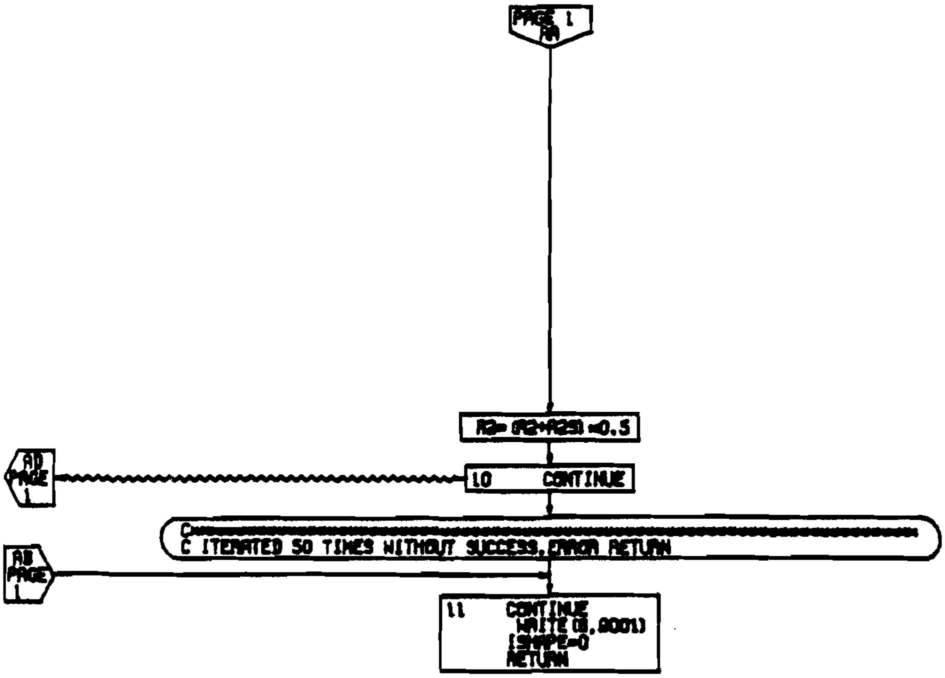
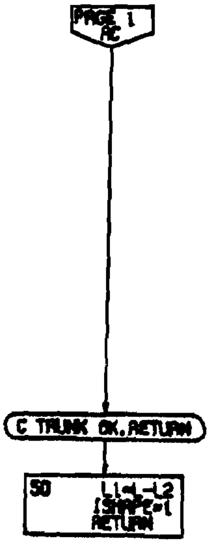


Table 114: FLOWCHART FOR SUBROUTINE TRUNK (CONCLUDED)



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TRUNK

Table 115: FLOWCHART FOR SUBROUTINE TS

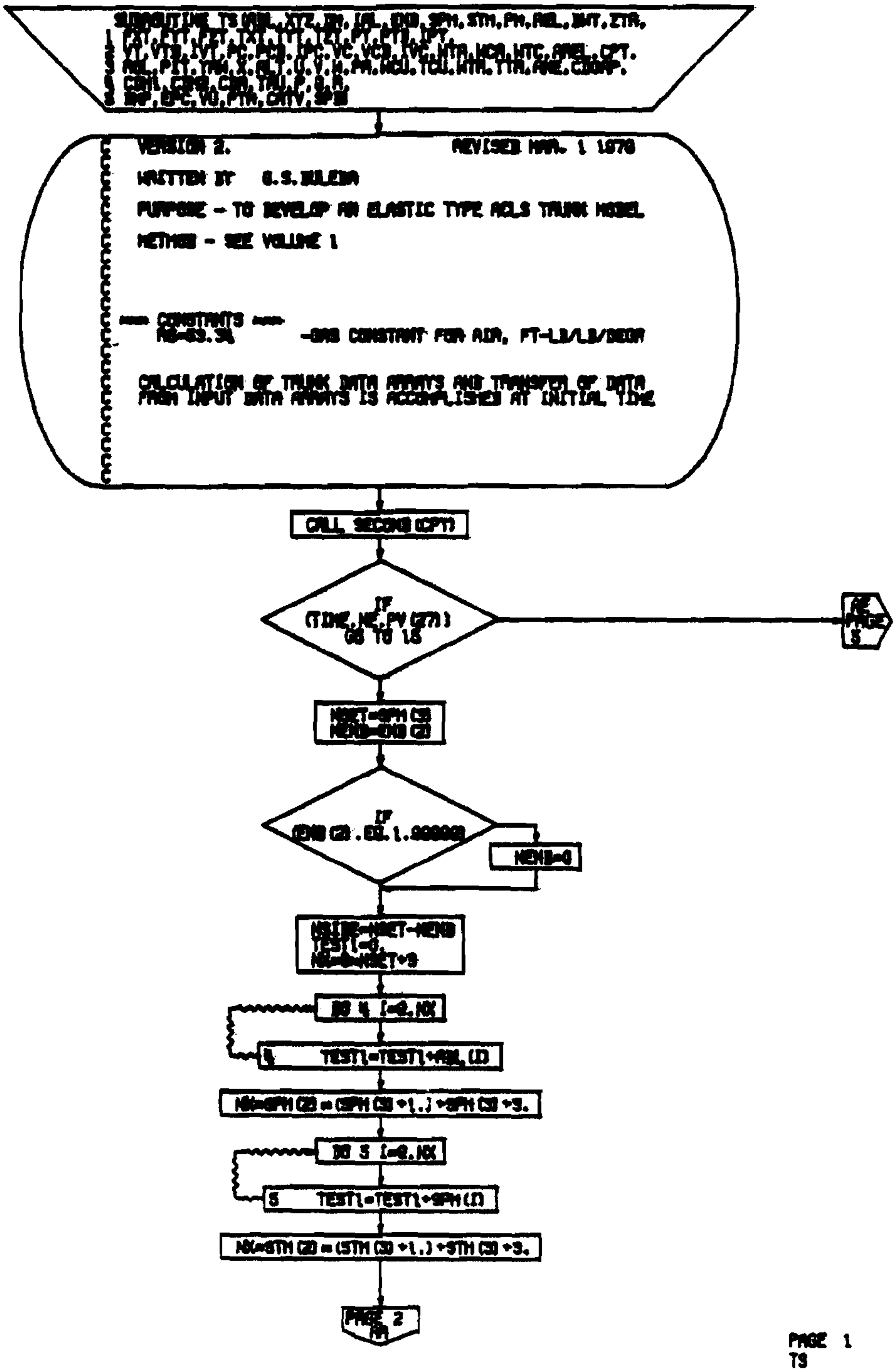
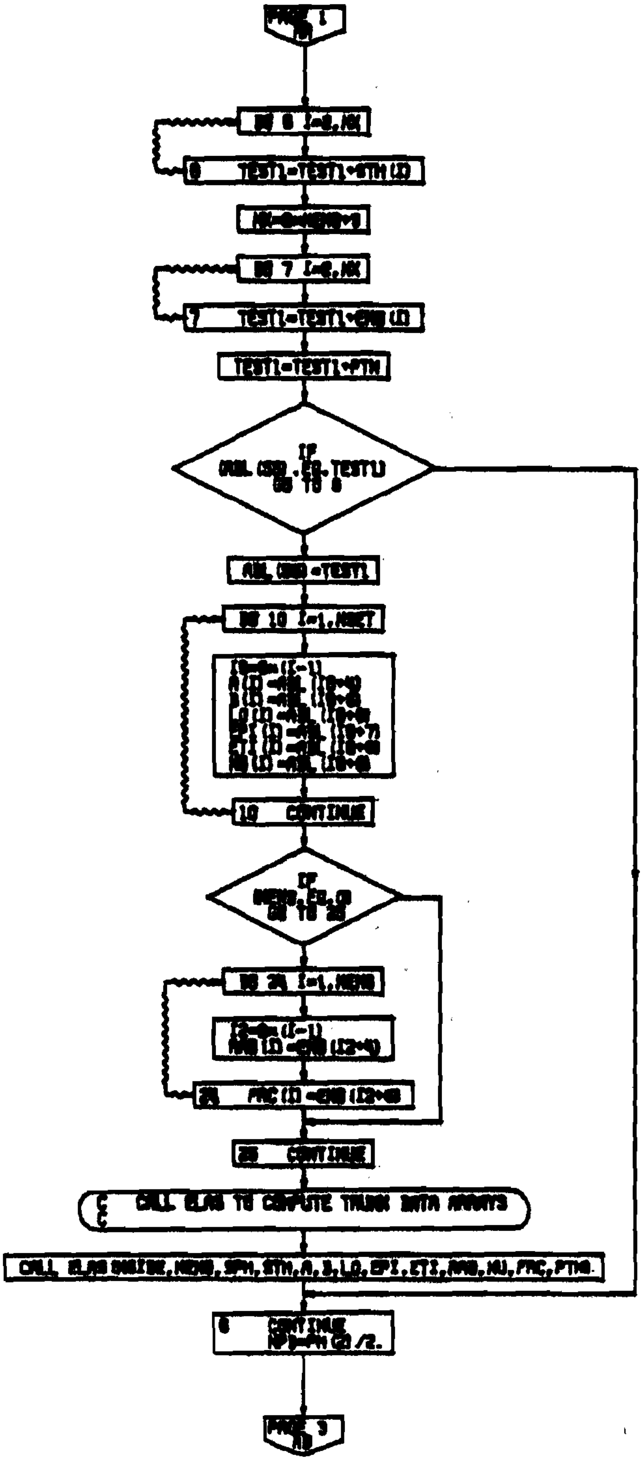


Table 115: FLOWCHART FOR SUBROUTINE TS (CONTINUED)



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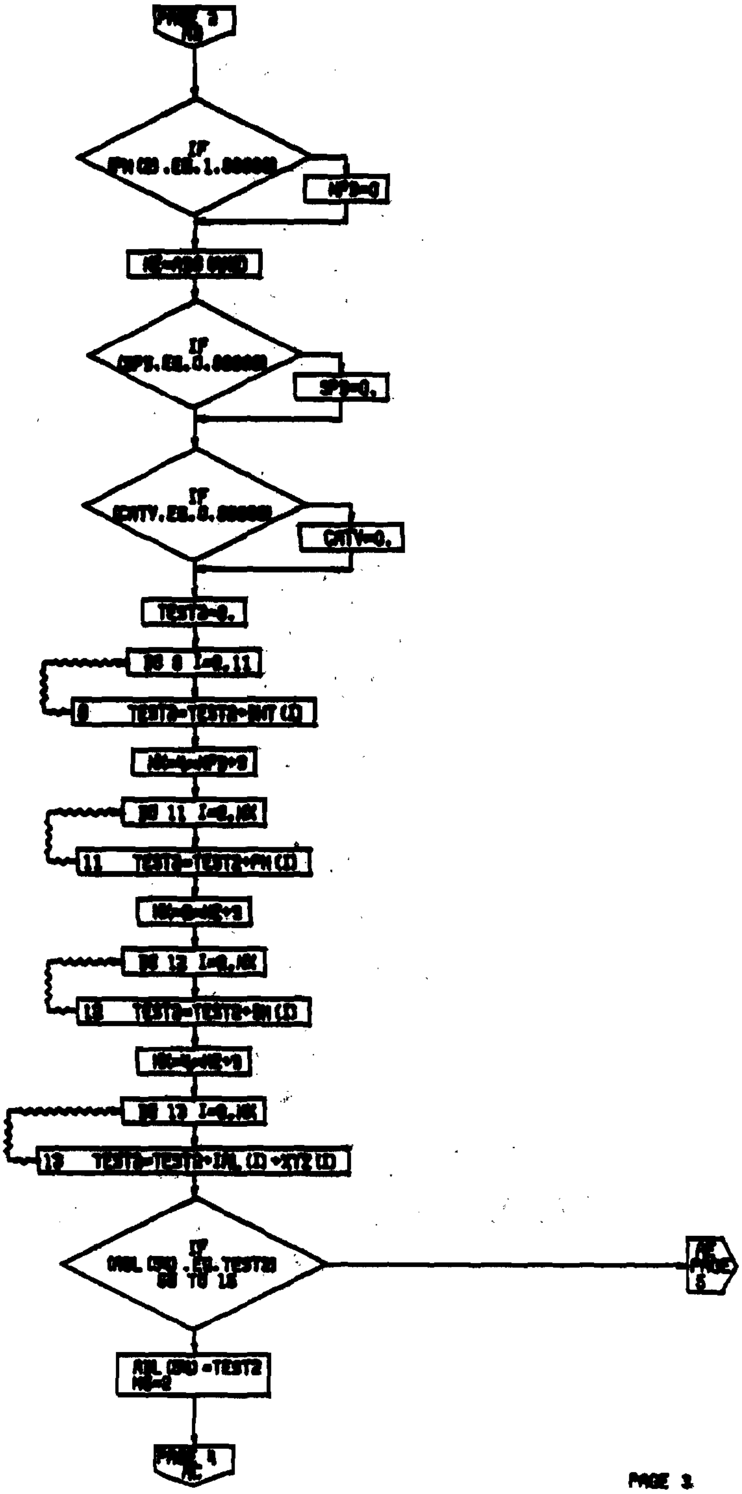
TS

Table 115: FLOWCHART FOR SUBROUTINE TS (CONTINUED)



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TS

Table 115: FLOWCHART FOR SUBROUTINE TS (CONTINUED)

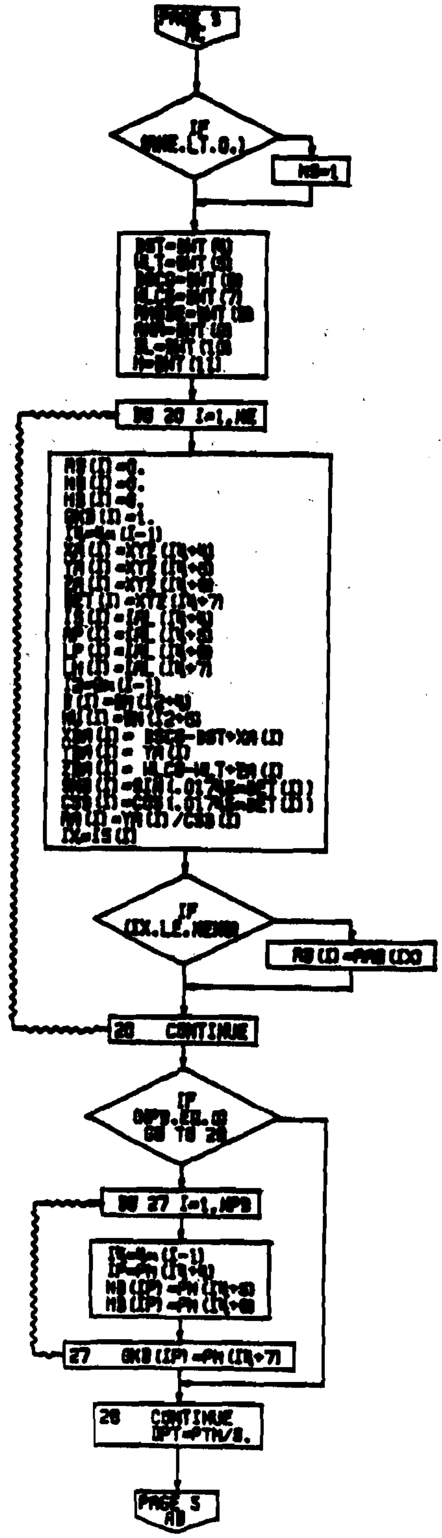

Table 115: FLOWCHART FOR SUBROUTINE TS (CONTINUED)

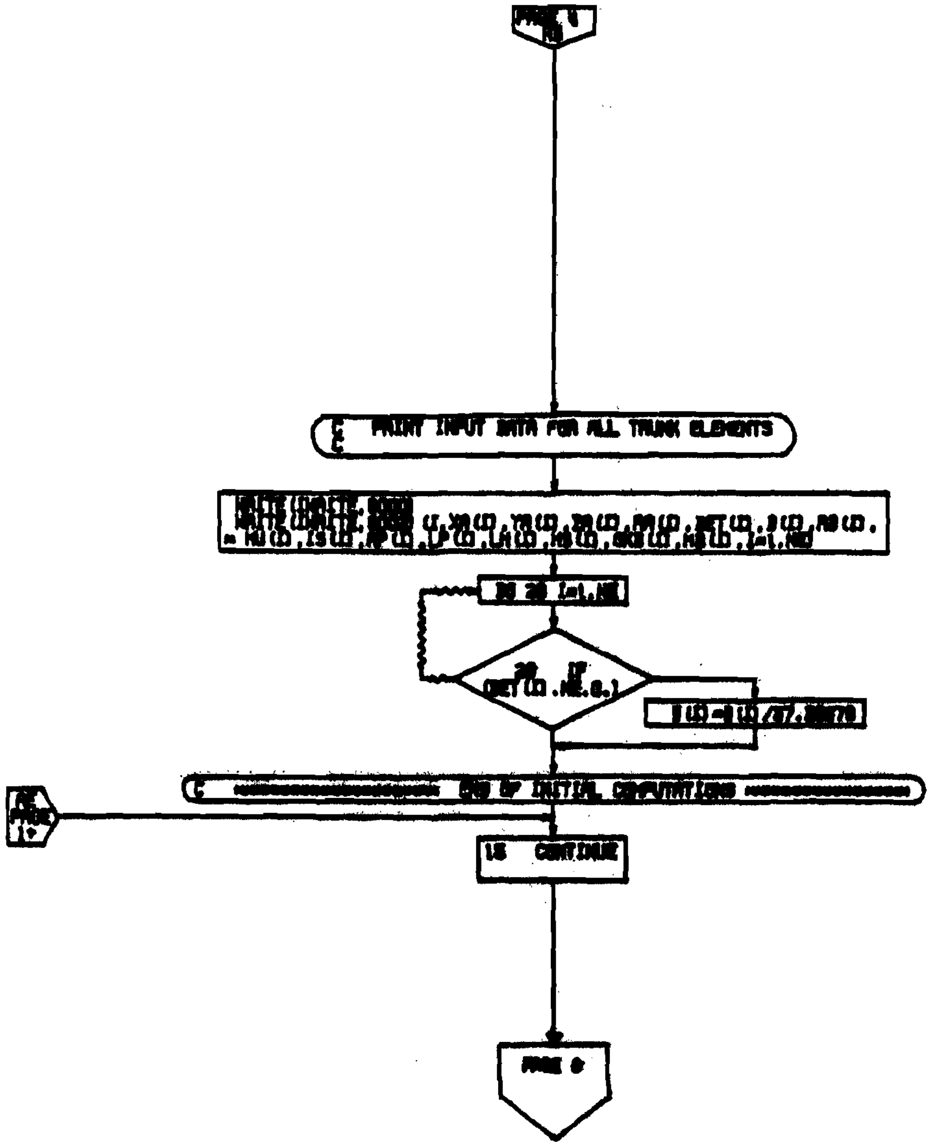

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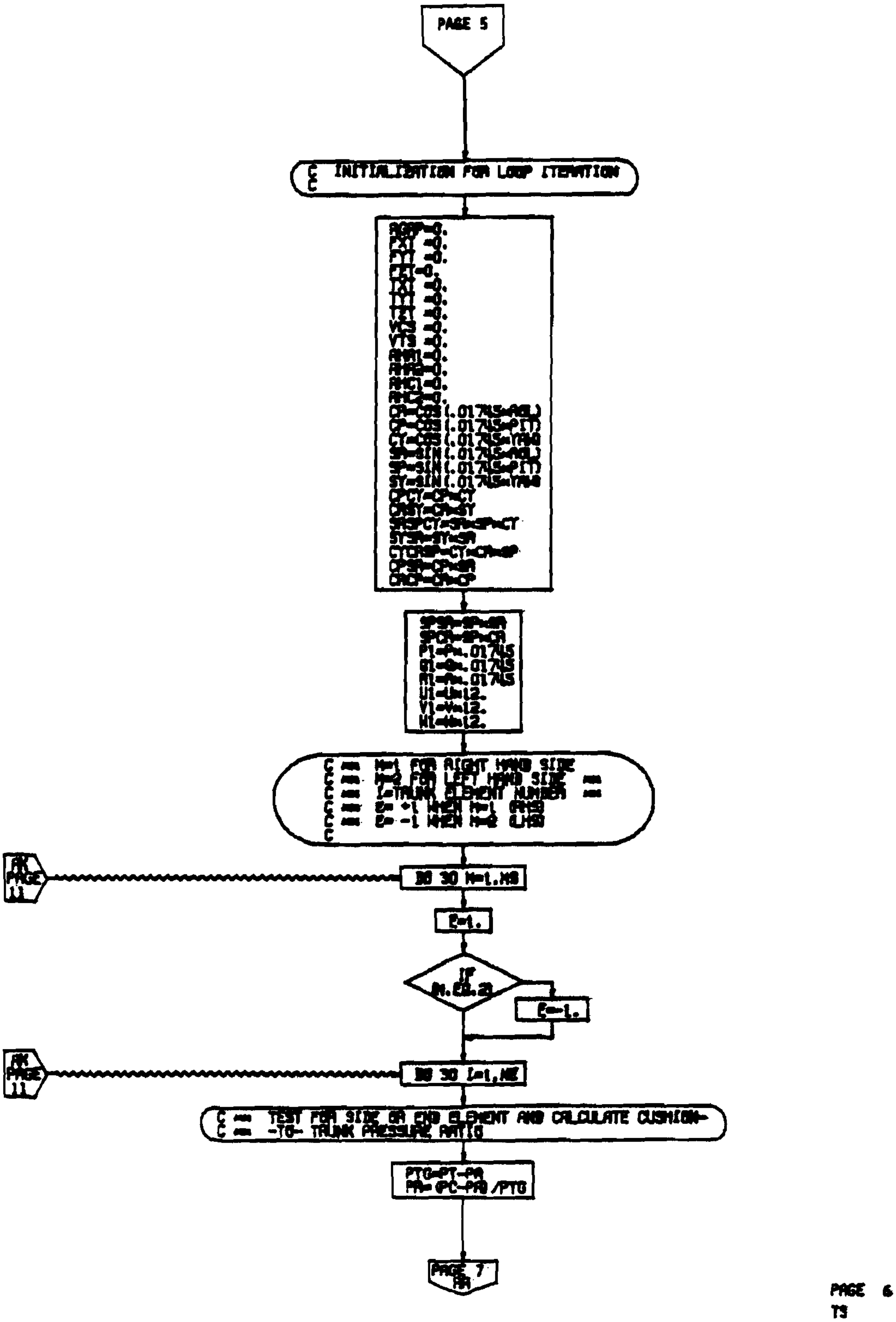
Table 115: FLOWCHART FOR SUBROUTINE TS (CONTINUED)



```
C   INITIALIZATION FOR LOOP ITERATION
C
AGAP=0.
FXT =0.
FYT =0.
FZT=0.
TXT =0.
TYT =0.
TZT =0.
VCS =0.
VTS =0.
AHA1=0.
AHA2=0.
AHC1=0.
AHC2=0.
CR=COS(.01745*ROL)
CP=COS(.01745*PIT)
CY=COS(.01745*YAW)
SR=SIN(.01745*ROL)
SP=SIN(.01745*PIT)
SY=SIN(.01745*YAW)
CPCY=CP*CY
CRSY=CR*SY
SRSPCY=SR*SP*CY
SYSR=SY*SR
CYCRSP=CY*CR*SP
CPSR=CP*SR
CRCP=CR*CP

SPSR=SP*SR
SPCR=SP*CR
P1=P*.01745
Q1=Q*.01745
R1=R*.01745
U1=U*12.
V1=V*12.
W1=W*12.

C ***  N=1 FOR RIGHT HAND SIDE
C ***  N=2 FOR LEFT HAND SIDE   ***
C ***  I=TRUNK ELEMENT NUMBER   ***
C ***  E= +1 WHEN N=1 (RHS)
C ***  E= -1 WHEN N=2 (LHS)
C

DO 30 N=1,NS
E=1.
IF (N.EQ.2)
E=-1.
DO 30 I=1,NE

C ***  TEST FOR SIDE OR END ELEMENT AND CALCULATE CUSHION-
C ***  -TO- TRUNK PRESSURE RATIO

PTG=PT-PA
PR=(PC-PA)/PTG
```

Table 115: FLOWCHART FOR SUBROUTINE TS (CONTINUED)

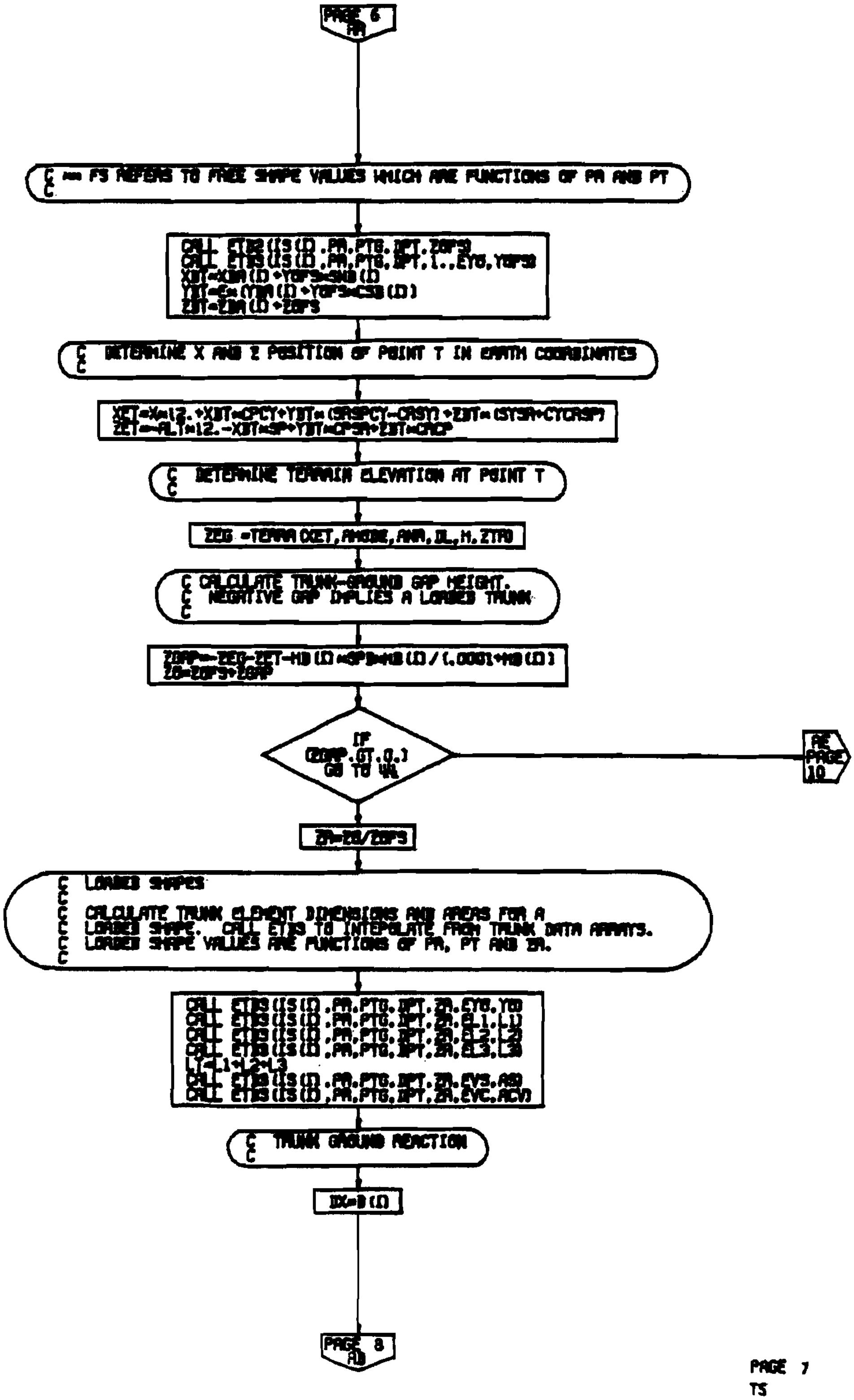


Table 115: FLOWCHART FOR SUBROUTINE TS (CONTINUED)

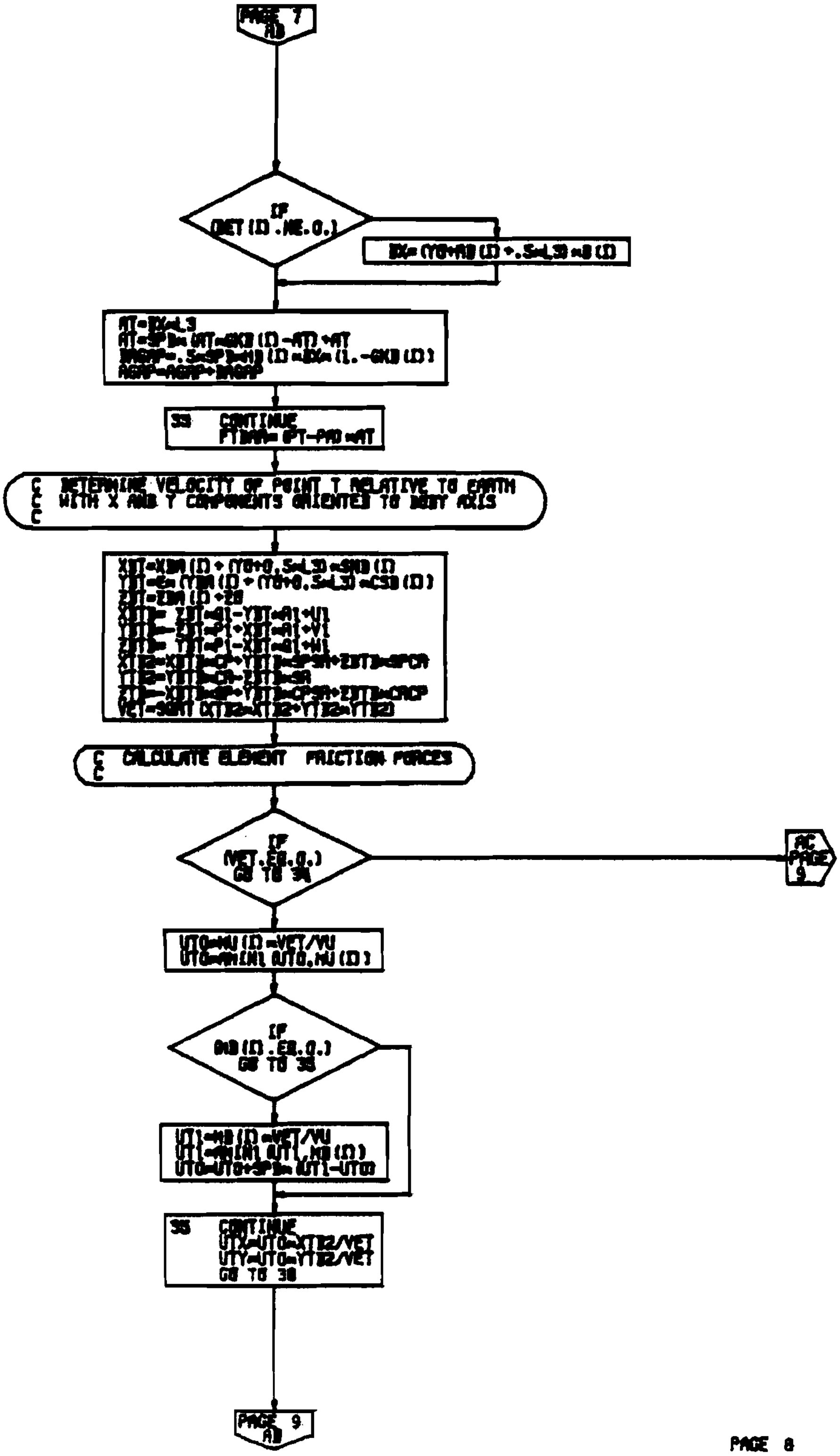


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Table 115: FLOWCHART FOR SUBROUTINE TS (CONTINUED)

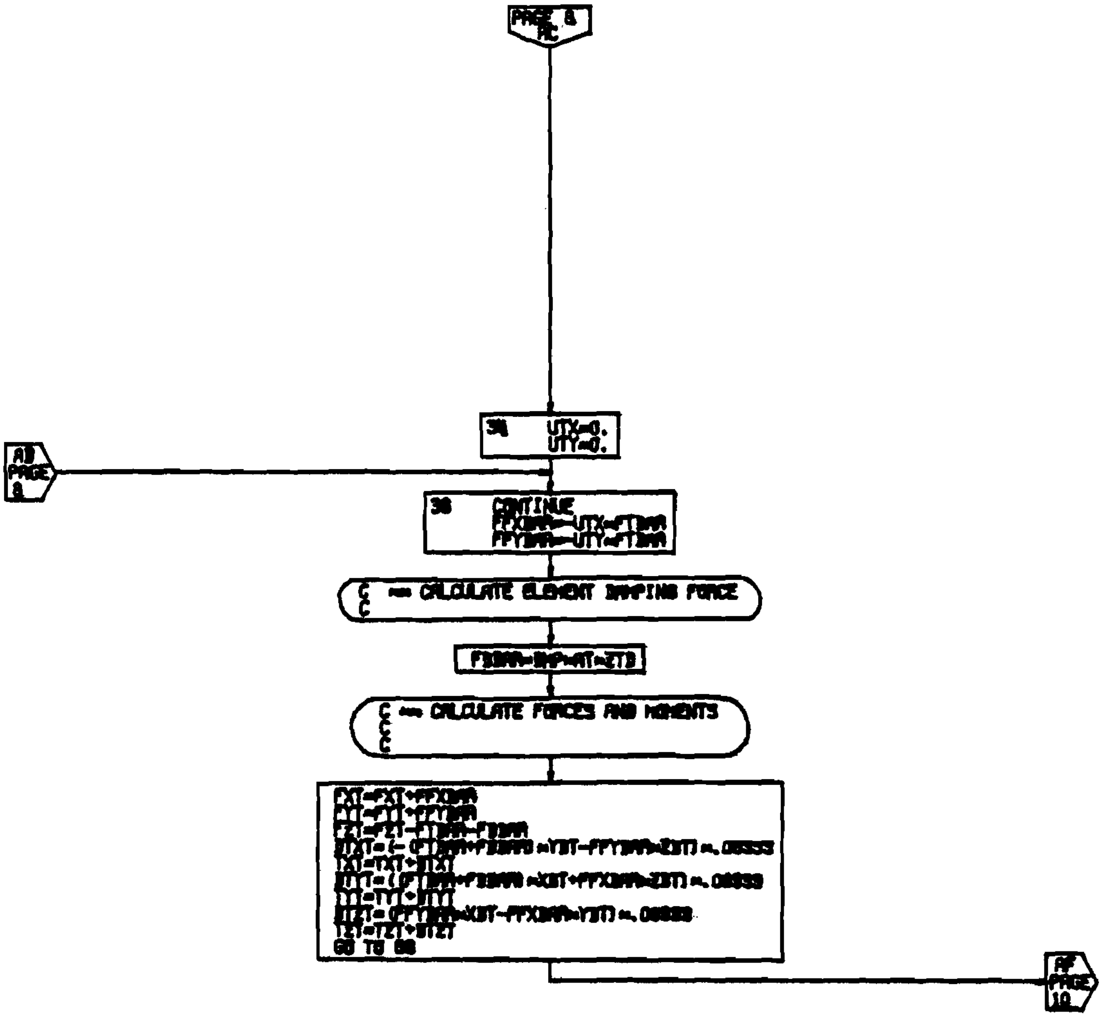


Table 115: FLOWCHART FOR SUBROUTINE TS (CONTINUED)

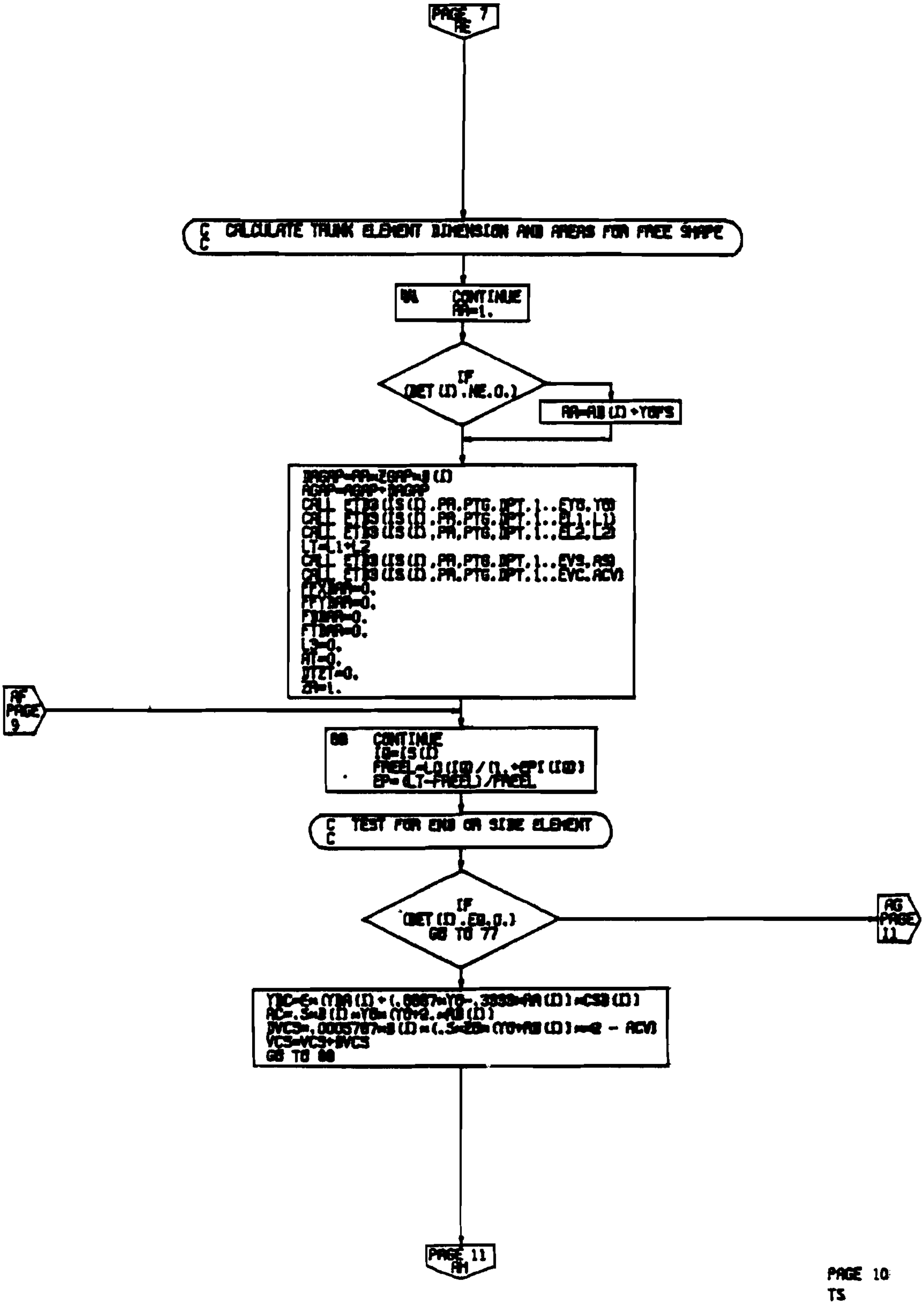
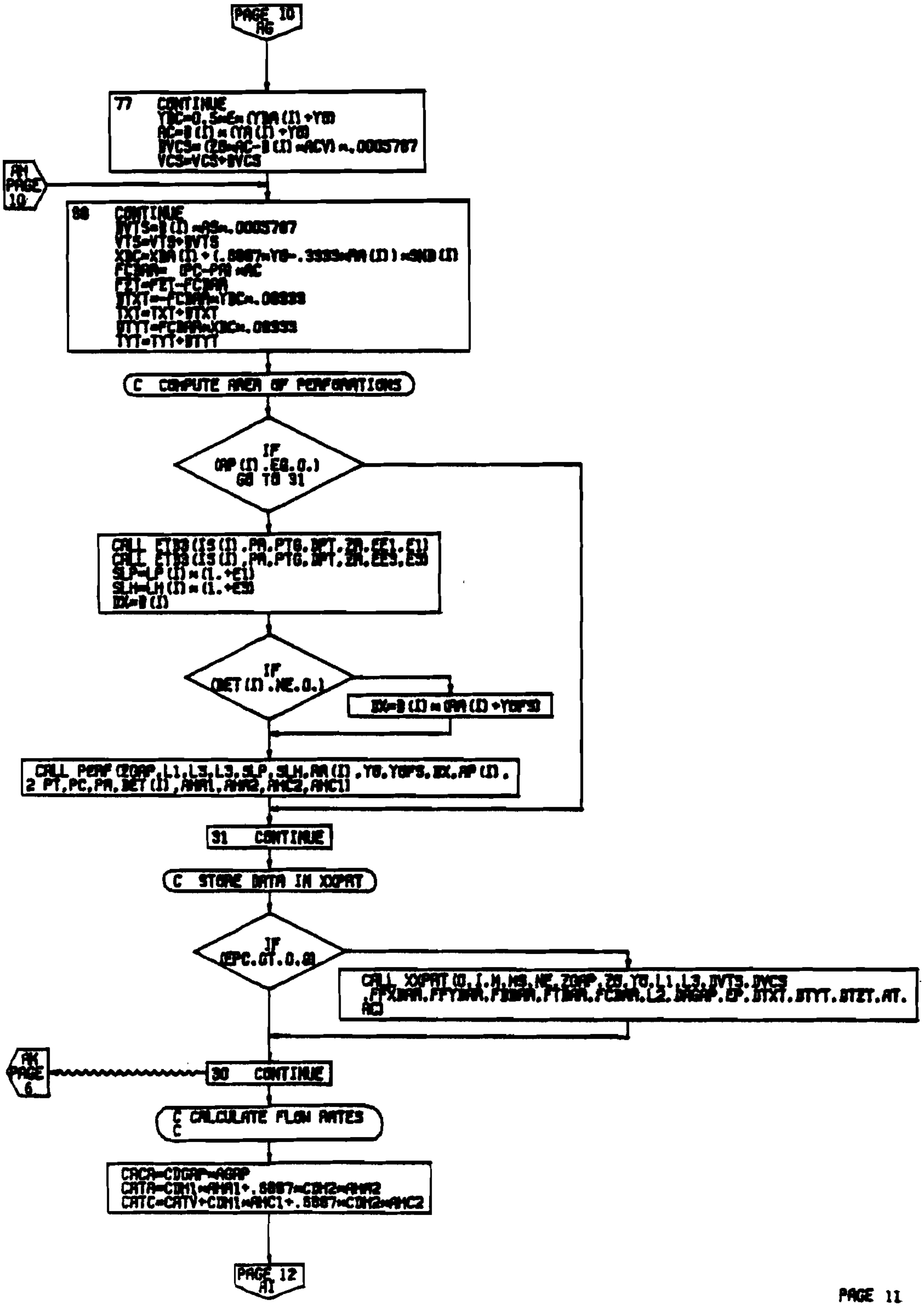


Table 115: FLOWCHART FOR SUBROUTINE TS (CONTINUED)



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TS

Table 115: FLOWCHART FOR SUBROUTINE TS (CONTINUED)

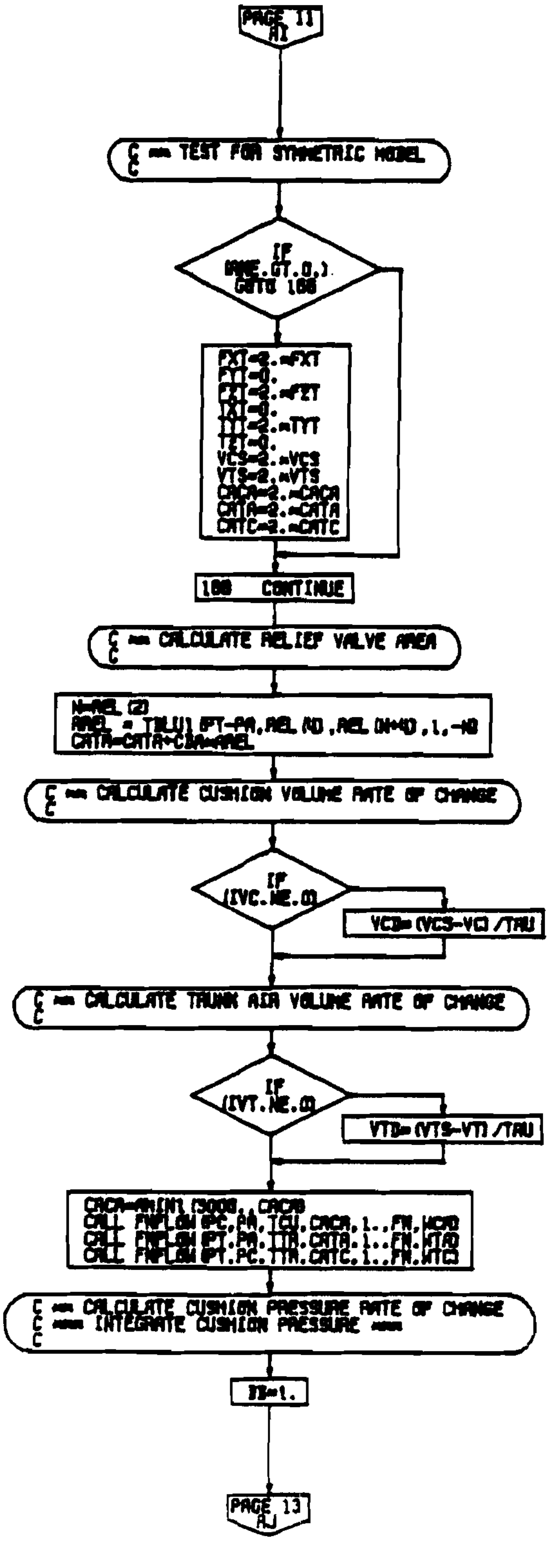
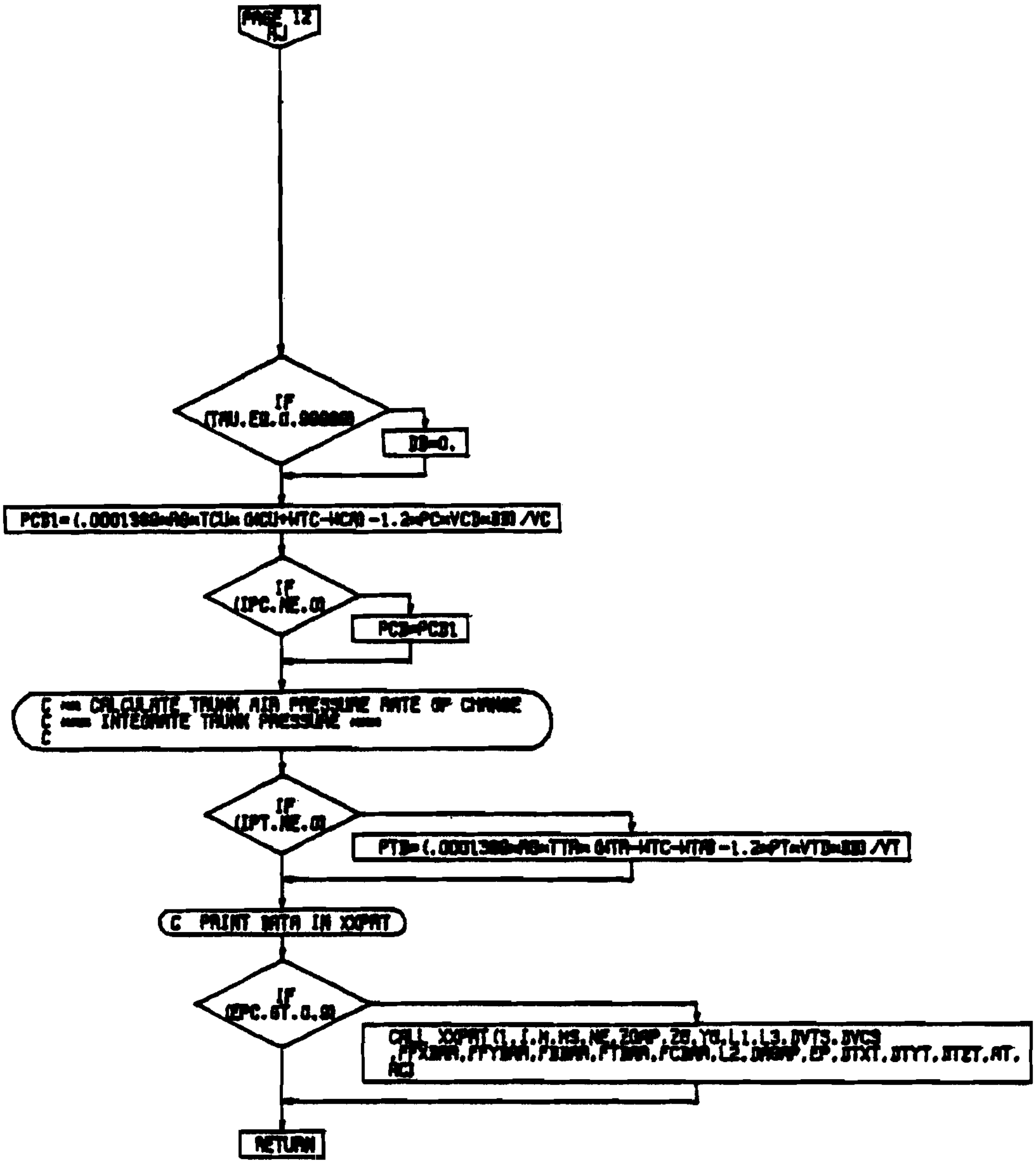


Table 115: FLOWCHART FOR SUBROUTINE TS (CONCLUDED)



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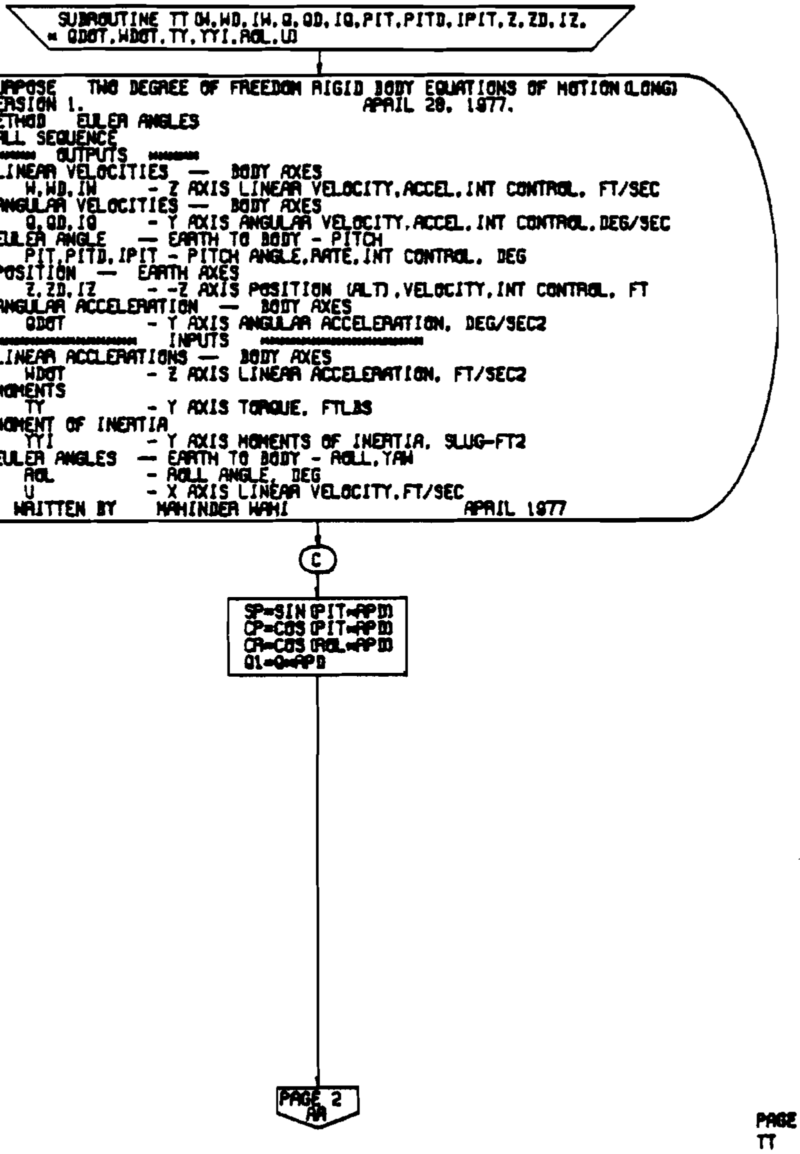
TS

Table 116: FLOWCHART FOR SUBROUTINE TT



```
      SUBROUTINE TT(W,WD,IW,Q,QD,IQ,PIT,PITD,IPIT,Z,ZD,IZ,
     * QDOT,WDOT,TY,YYI,ROL,U)
```

```
C   PURPOSE   TWO DEGREE OF FREEDOM RIGID BODY EQUATIONS OF MOTION(LONG)
C   VERSION 1.                                  APRIL 28, 1977.
C   METHOD   EULER ANGLES
C   CALL SEQUENCE
C   ******** OUTPUTS ********
C    LINEAR VELOCITIES  --  BODY AXES
C       W,WD,IW       - Z AXIS LINEAR VELOCITY,ACCEL,INT CONTROL, FT/SEC
C    ANGULAR VELOCITIES --  BODY AXES
C       Q,QD,IQ       - Y AXIS ANGULAR VELOCITY,ACCEL,INT CONTROL,DEG/SEC
C    EULER ANGLE    -- EARTH TO BODY - PITCH
C       PIT,PITD,IPIT - PITCH ANGLE,RATE,INT CONTROL, DEG
C    POSITION  --  EARTH AXES
C       Z,ZD,IZ       - -Z AXIS POSITION (ALT),VELOCITY,INT CONTROL, FT
C    ANGULAR ACCELERATION  --  BODY AXES
C       QDOT          - Y AXIS ANGULAR ACCELERATION, DEG/SEC2
C ************************  INPUTS  **************************
C    LINEAR ACCLERATIONS --  BODY AXES
C       WDOT          - Z AXIS LINEAR ACCELERATION, FT/SEC2
C    MOMENTS
C       TY            - Y AXIS TORQUE, FTLBS
C    MOMENT OF INERTIA
C       YYI           - Y AXIS MOMENTS OF INERTIA, SLUG-FT2
C    EULER ANGLES  -- EARTH TO BODY - ROLL,YAW
C       ROL           - ROLL ANGLE, DEG
C       U             - X AXIS LINEAR VELOCITY,FT/SEC
C      WRITTEN BY    MAHINDER WAHI                      APRIL 1977
```

```
SP=SIN(PIT*RPD)
CP=COS(PIT*RPD)
CR=COS(ROL*RPD)
Q1=Q*RPD
```

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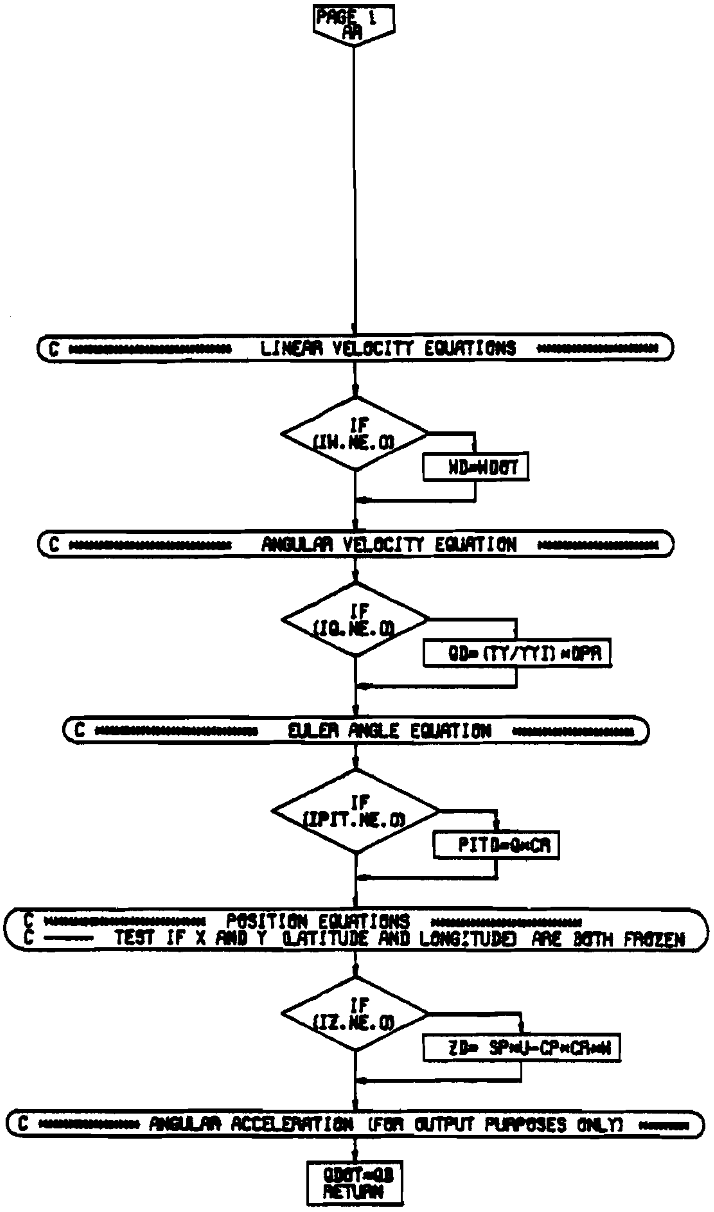
TT

Table 116: FLOWCHART FOR SUBROUTINE TT (CONCLUDED)



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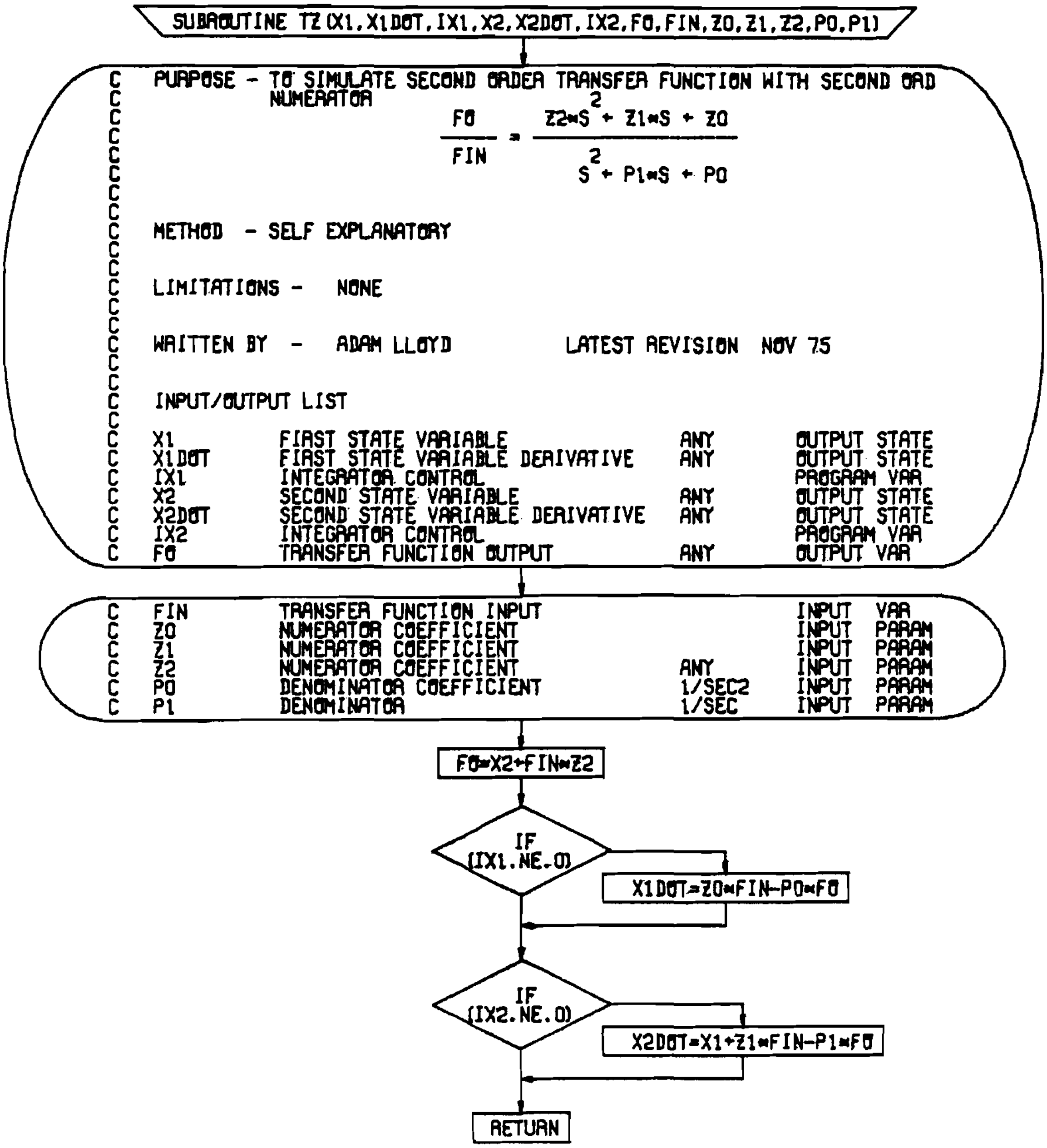
TT

Table 117: FLOWCHART FOR SUBROUTINE TZ



```
SUBROUTINE TZ (X1,X1DOT,IX1,X2,X2DOT,IX2,FO,FIN,Z0,Z1,Z2,P0,P1)

C    PURPOSE - TO SIMULATE SECOND ORDER TRANSFER FUNCTION WITH SECOND ORD
C              NUMERATOR                          2
C                                FO        Z2*S  + Z1*S + Z0
C                               ----- =  ---------------------
C                               FIN              2
C                                               S  + P1*S + P0
C
C
C    METHOD  - SELF EXPLANATORY
C
C
C    LIMITATIONS -   NONE
C
C
C    WRITTEN BY  -   ADAM LLOYD          LATEST REVISION  NOV 75
C
C
C    INPUT/OUTPUT LIST
C
C    X1          FIRST STATE VARIABLE                 ANY      OUTPUT STATE
C    X1DOT       FIRST STATE VARIABLE DERIVATIVE      ANY      OUTPUT STATE
C    IX1         INTEGRATOR CONTROL                            PROGRAM VAR
C    X2          SECOND STATE VARIABLE                ANY      OUTPUT STATE
C    X2DOT       SECOND STATE VARIABLE DERIVATIVE     ANY      OUTPUT STATE
C    IX2         INTEGRATOR CONTROL                            PROGRAM VAR
C    FO          TRANSFER FUNCTION OUTPUT             ANY      OUTPUT VAR

C    FIN         TRANSFER FUNCTION INPUT                       INPUT  VAR
C    Z0          NUMERATOR COEFFICIENT                         INPUT  PARAM
C    Z1          NUMERATOR COEFFICIENT                         INPUT  PARAM
C    Z2          NUMERATOR COEFFICIENT                ANY      INPUT  PARAM
C    P0          DENOMINATOR COEFFICIENT              1/SEC2   INPUT  PARAM
C    P1          DENOMINATOR                          1/SEC    INPUT  PARAM

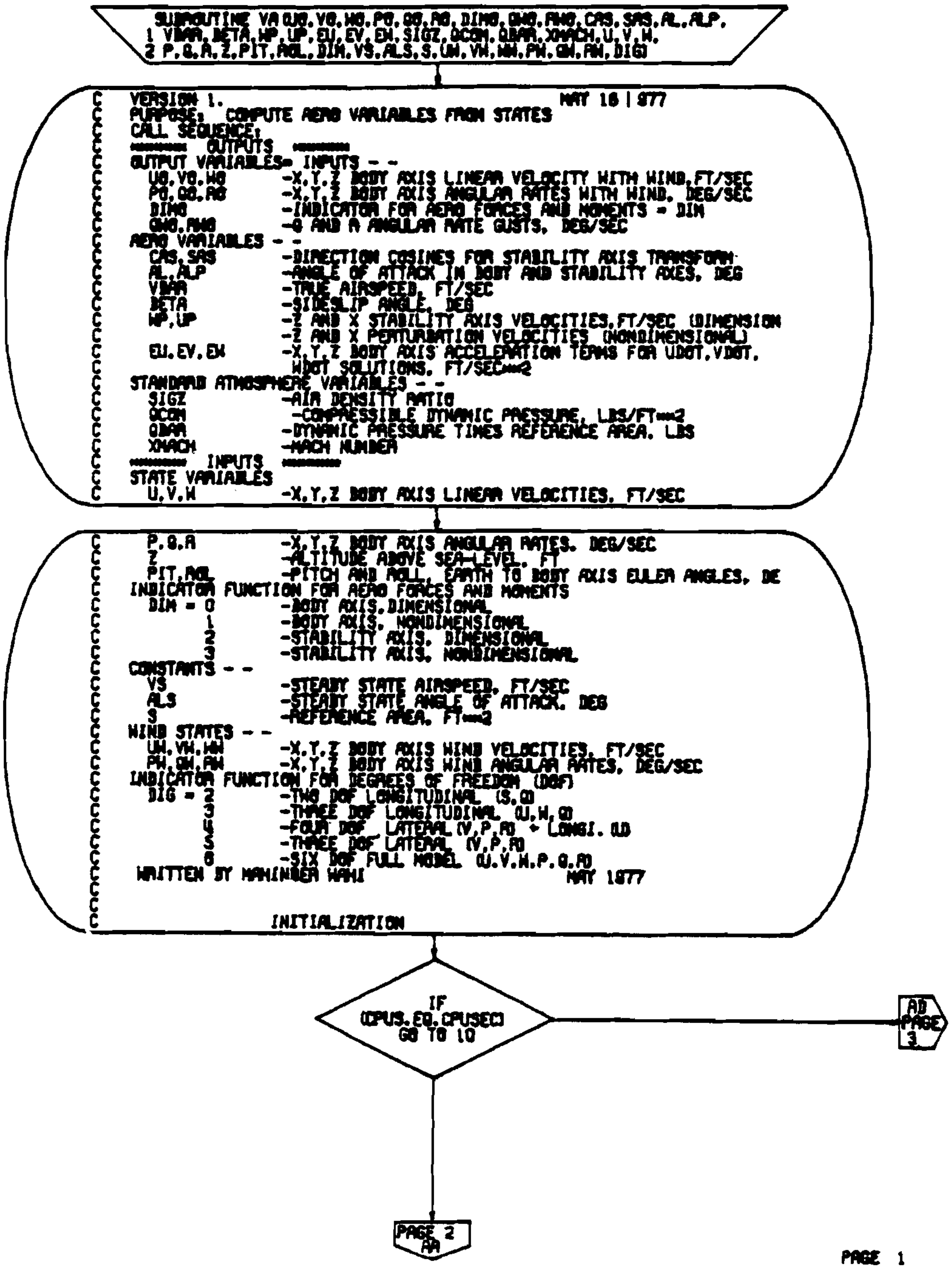
FO=X2+FIN*Z2

IF (IX1.NE.0)
    X1DOT=Z0*FIN-P0*FO

IF (IX2.NE.0)
    X2DOT=X1+Z1*FIN-P1*FO

RETURN
```

Table 118: FLOWCHART FOR SUBROUTINE VA



```
      SUBROUTINE VA(UG.VG.WG.PG.QG.RG.DIMG.QWG.RWG.CAS.SAS.AL.ALP.
     1 VBAR.BETA.WP.UP.EU.EV.EW.SIGZ.QCOM.QBAR.XMACH.U.V.W.
     2 P.Q.R.Z.PIT.ROL.DIM.VS.ALS.S.UW.VW.WW.PW.QW.RW.DIG)
C     VERSION 1.                                       MAY 16 1977
C     PURPOSE:  COMPUTE AERO VARIABLES FROM STATES
C     CALL SEQUENCE:
C     ********  OUTPUTS  ********
C     OUTPUT VARIABLES= INPUTS - -
C        UG.VG.WG      -X.Y.Z BODY AXIS LINEAR VELOCITY WITH WIND,FT/SEC
C        PG.QG.RG      -X.Y.Z BODY AXIS ANGULAR RATES WITH WIND. DEG/SEC
C        DIMG          -INDICATOR FOR AERO FORCES AND MOMENTS = DIM
C        QWG.RWG       -Q AND R ANGULAR RATE GUSTS, DEG/SEC
C     AERO VARIABLES - -
C        CAS.SAS       -DIRECTION COSINES FOR STABILITY AXIS TRANSFORM
C        AL.ALP        -ANGLE OF ATTACK IN BODY AND STABILITY AXES, DEG
C        VBAR          -TRUE AIRSPEED, FT/SEC
C        BETA          -SIDESLIP ANGLE, DEG
C        WP,UP         -Z AND X STABILITY AXIS VELOCITIES,FT/SEC (DIMENSION
C                      -Z AND X PERTURBATION VELOCITIES (NONDIMENSIONAL)
C        EU.EV.EW      -X.Y.Z BODY AXIS ACCELERATION TERMS FOR UDOT,VDOT,
C                       WDOT SOLUTIONS. FT/SEC**2
C     STANDARD ATMOSPHERE VARIABLES - -
C        SIGZ          -AIR DENSITY RATIO
C        QCOM           -COMPRESSIBLE DYNAMIC PRESSURE, LBS/FT**2
C        QBAR          -DYNAMIC PRESSURE TIMES REFERENCE AREA. LBS
C        XMACH         -MACH NUMBER
C     ********  INPUTS  ********
C     STATE VARIABLES
C        U.V.W         -X.Y.Z BODY AXIS LINEAR VELOCITIES. FT/SEC
C        P.Q.R         -X.Y.Z BODY AXIS ANGULAR RATES. DEG/SEC
C        Z             -ALTITUDE ABOVE SEA-LEVEL. FT
C        PIT.ROL       -PITCH AND ROLL, EARTH TO BODY AXIS EULER ANGLES, DE
C     INDICATOR FUNCTION FOR AERO FORCES AND MOMENTS
C        DIM = 0       -BODY AXIS.DIMENSIONAL
C              1       -BODY AXIS, NONDIMENSIONAL
C              2       -STABILITY AXIS, DIMENSIONAL
C              3       -STABILITY AXIS, NONDIMENSIONAL
C     CONSTANTS - -
C        VS            -STEADY STATE AIRSPEED, FT/SEC
C        ALS           -STEADY STATE ANGLE OF ATTACK, DEG
C        S             -REFERENCE AREA, FT**2
C     WIND STATES - -
C        UW.VW.WW      -X.Y.Z BODY AXIS WIND VELOCITIES, FT/SEC
C        PW.QW.RW      -X.Y.Z BODY AXIS WIND ANGULAR RATES, DEG/SEC
C     INDICATOR FUNCTION FOR DEGREES OF FREEDOM (DOF)
C        DIG = 2       -TWO DOF LONGITUDINAL (S,Q)
C              3       -THREE DOF LONGITUDINAL (U,W,Q)
C              4       -FOUR DOF  LATERAL (V,P,R) + LONGI. (U)
C              5       -THREE DOF LATERAL (V,P,R)
C              6       -SIX DOF FULL MODEL (U.V.W.P.Q.R)
C      WRITTEN BY MAHINDER WAHI                          MAY 1977
C
C
C                  INITIALIZATION
      IF
      (CPUS.EQ.CPUSEC)
      GO TO 10
```

Table 118: FLOWCHART FOR SUBROUTINE VA (CONTINUED)

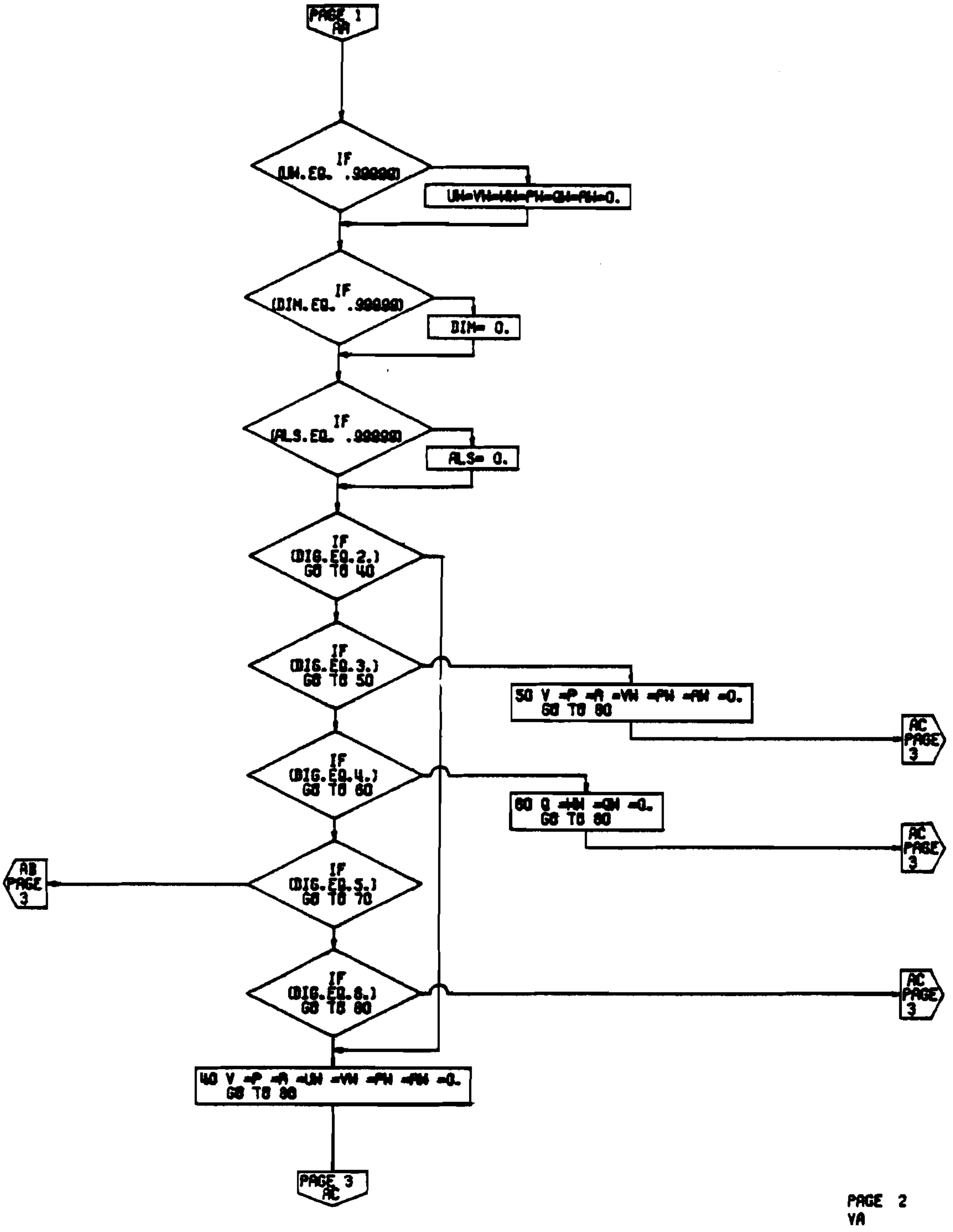
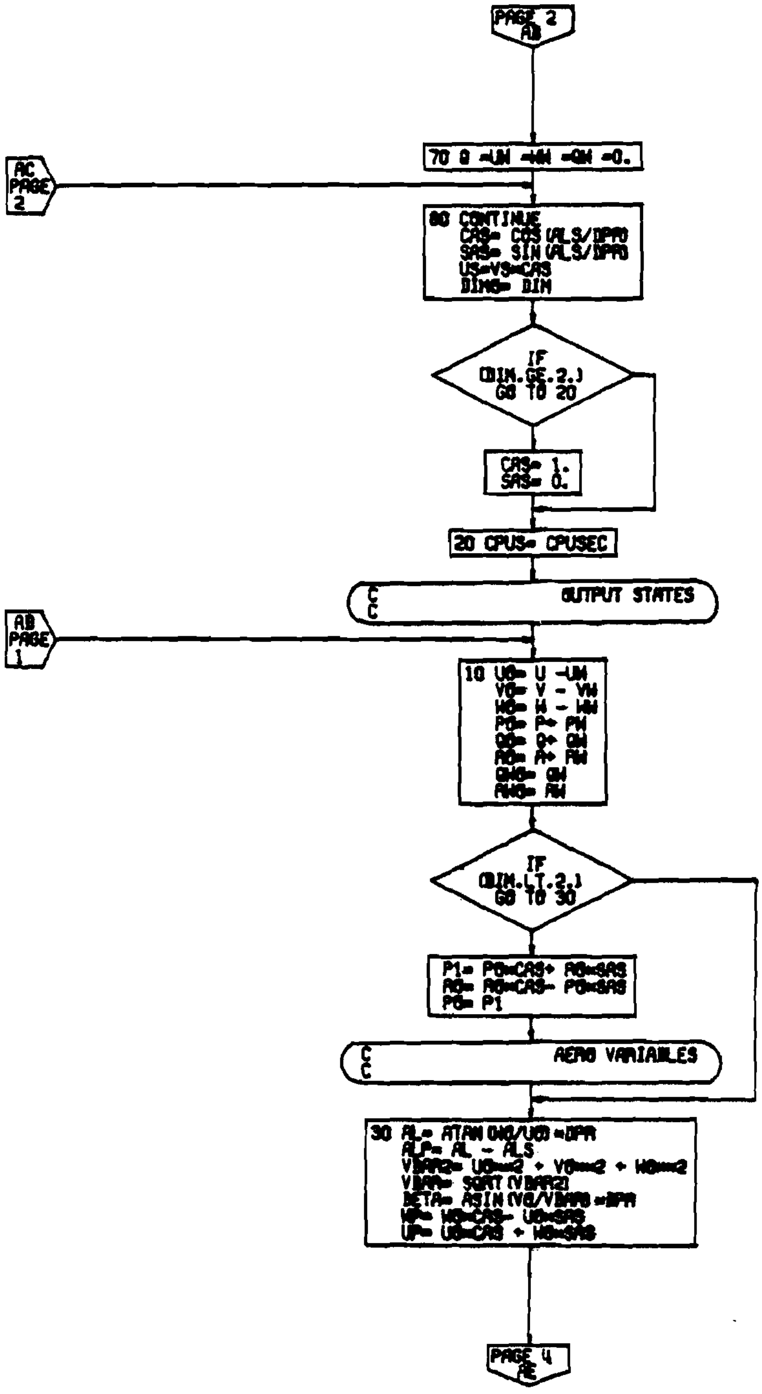


Table 118: FLOWCHART FOR SUBROUTINE VA (CONTINUED)



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VA

Table 118: FLOWCHART FOR SUBROUTINE VA (CONCLUDED)

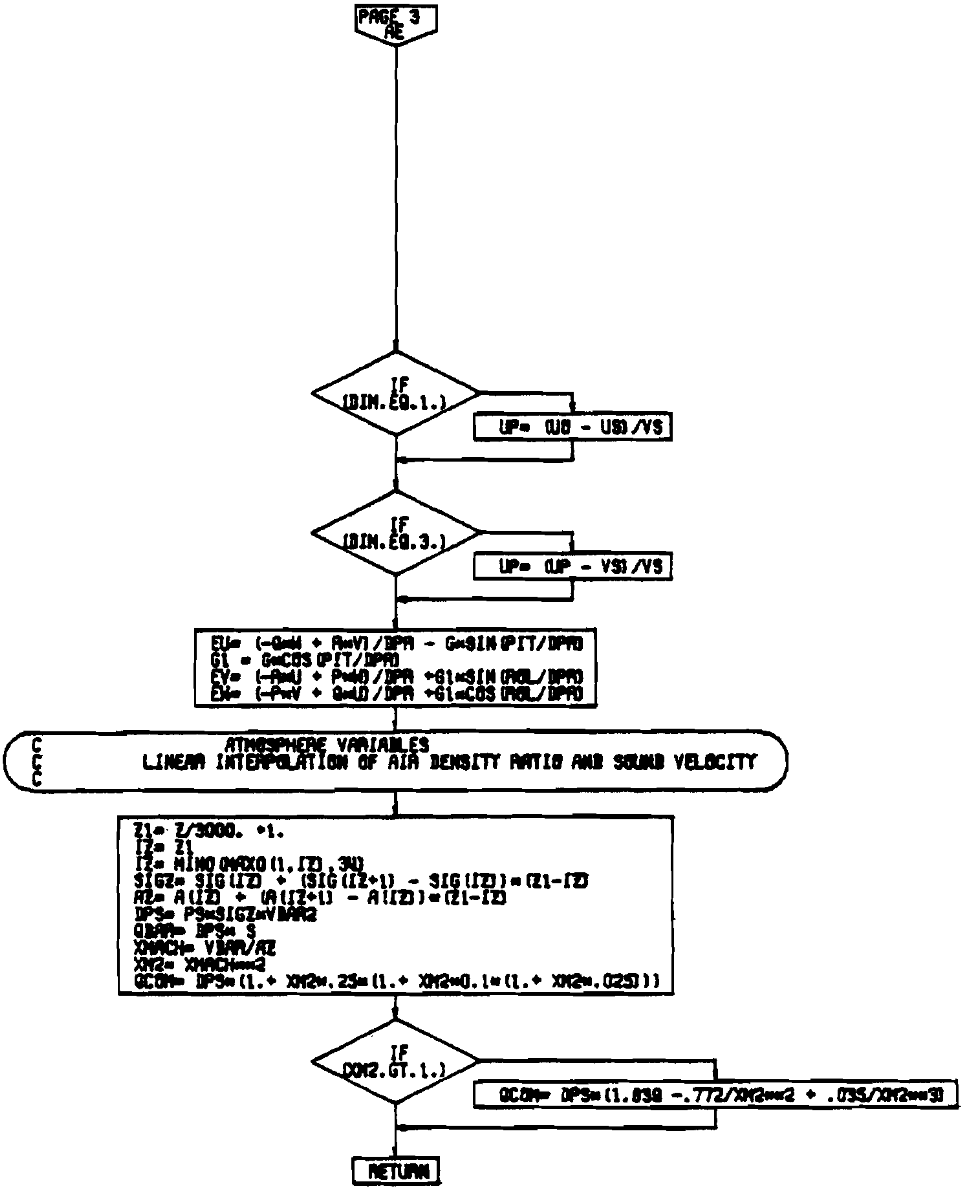


Table 119: FLOWCHART FOR SUBROUTINE VALVE

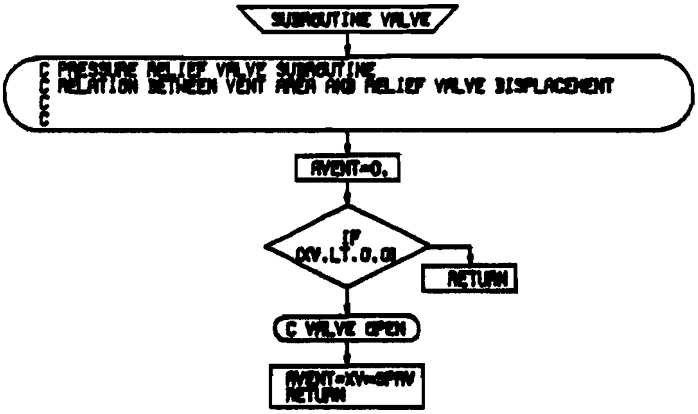


Table 120: FLOWCHART FOR SUBROUTINE VLX

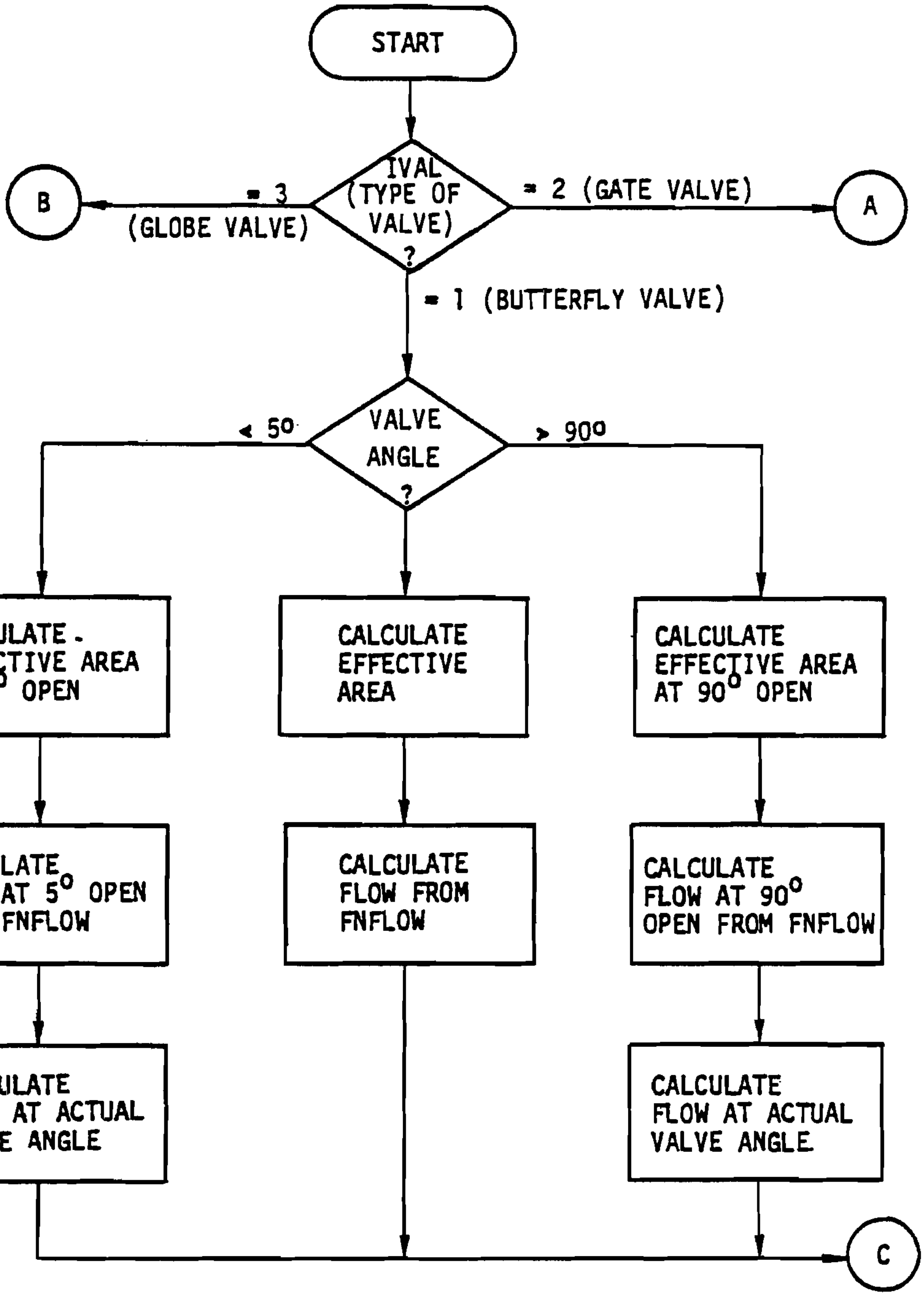


Table 120: FLOWCHART FOR SUBROUTINE VLX (CONCLUDED)

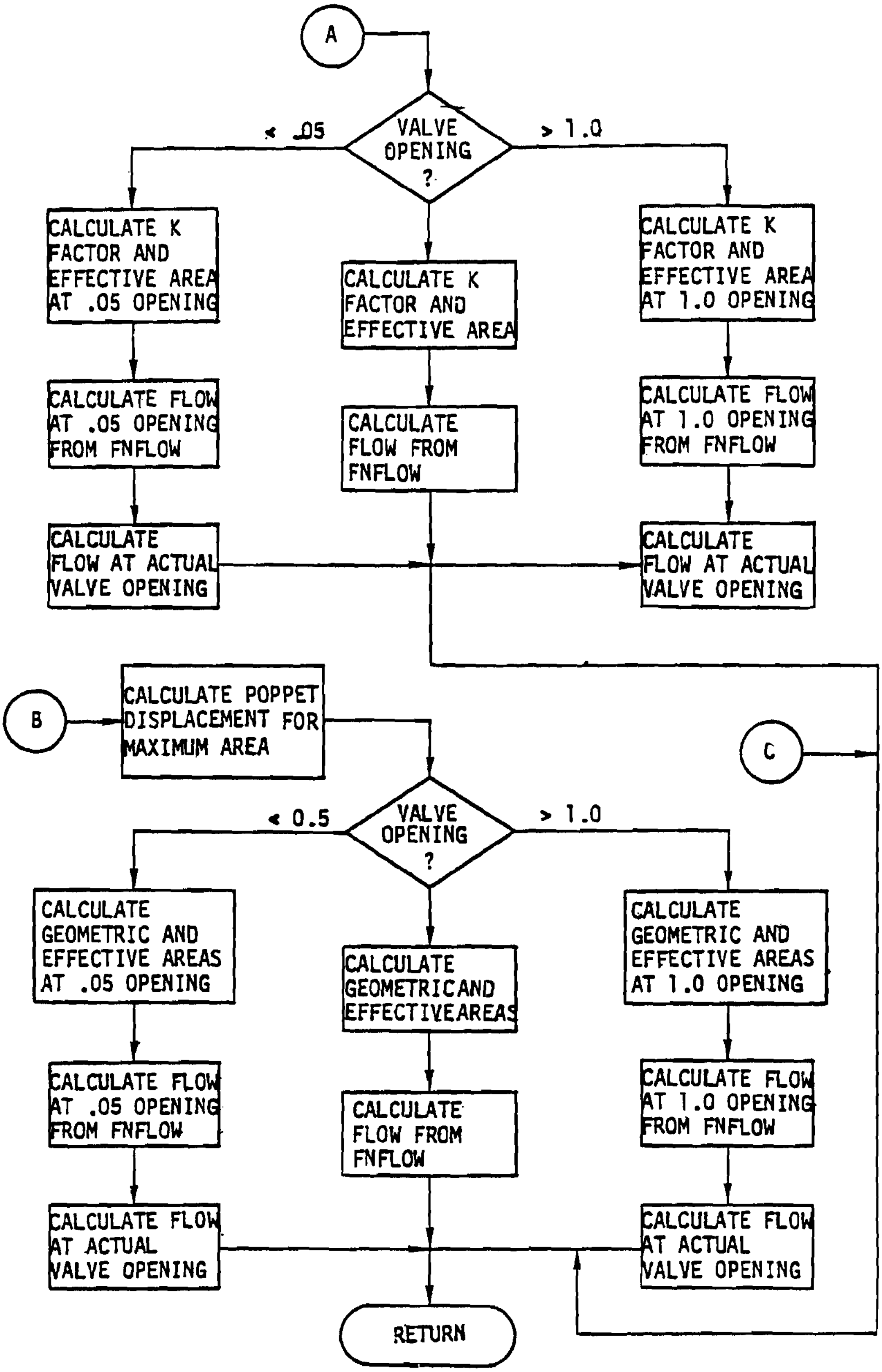


Table 121: FLOWCHART FOR SUBROUTINE VPRINB

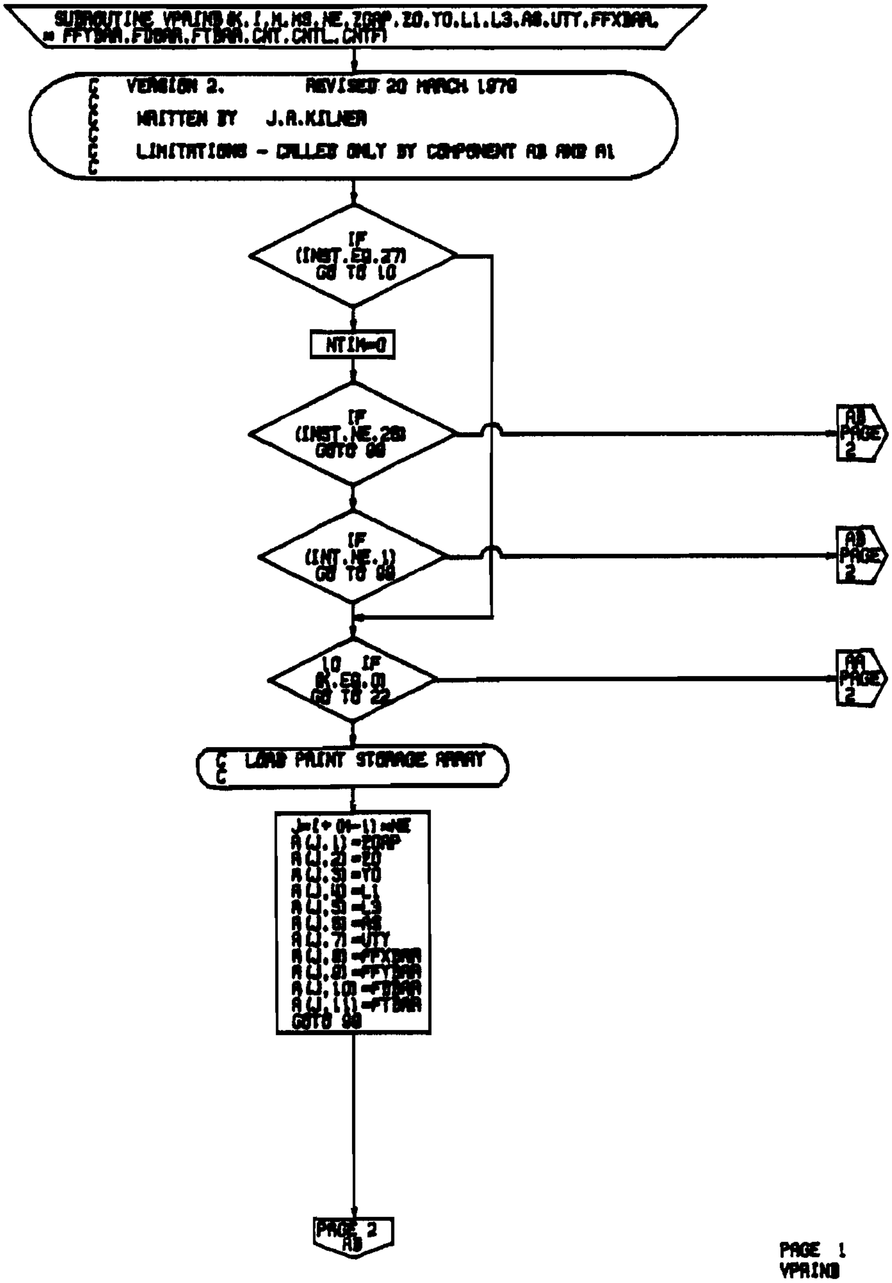


Table 121: FLOWCHART FOR SUBROUTINE VPRINB (CONCLUDED)

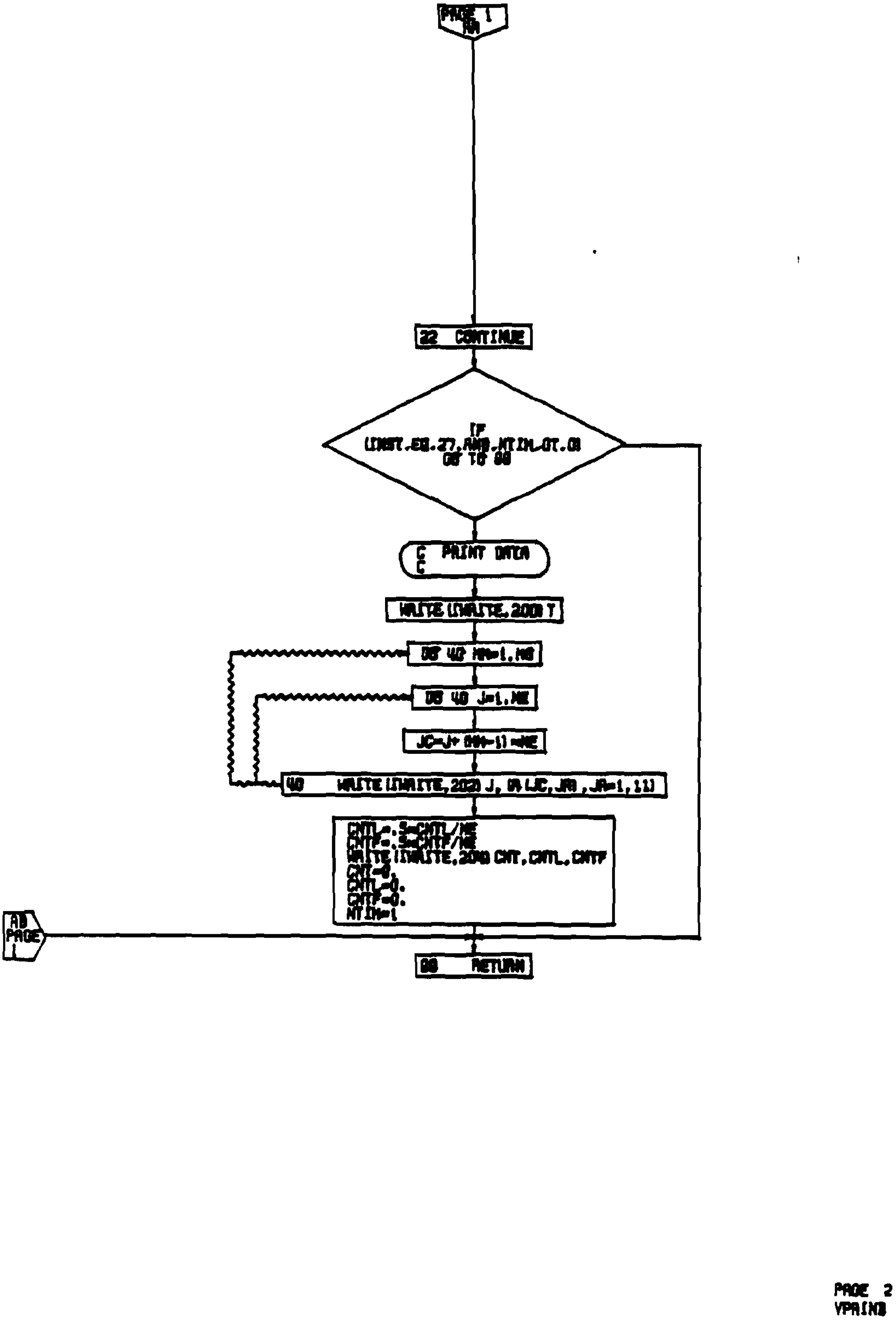


Table 122: FLOWCHART FOR SUBROUTINE VPRINT

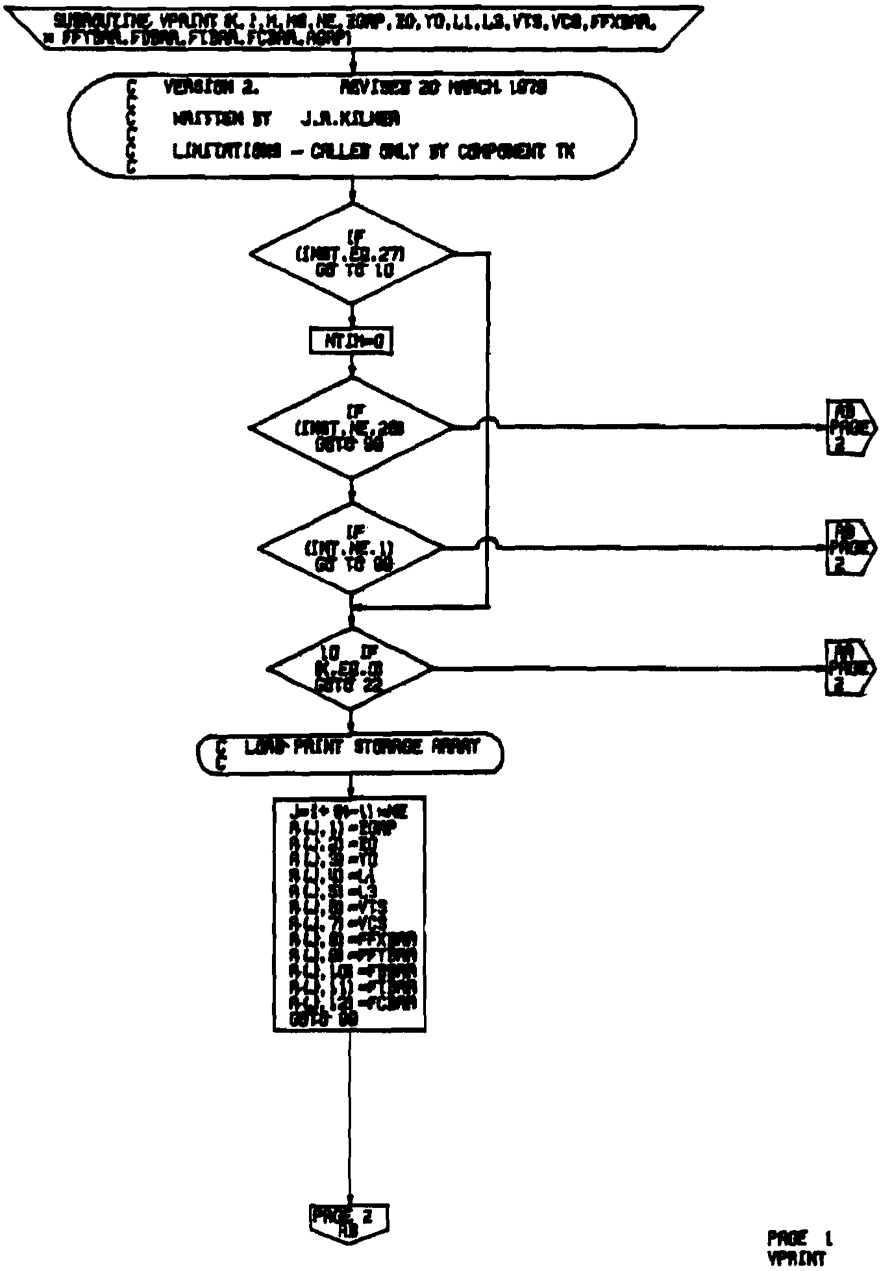
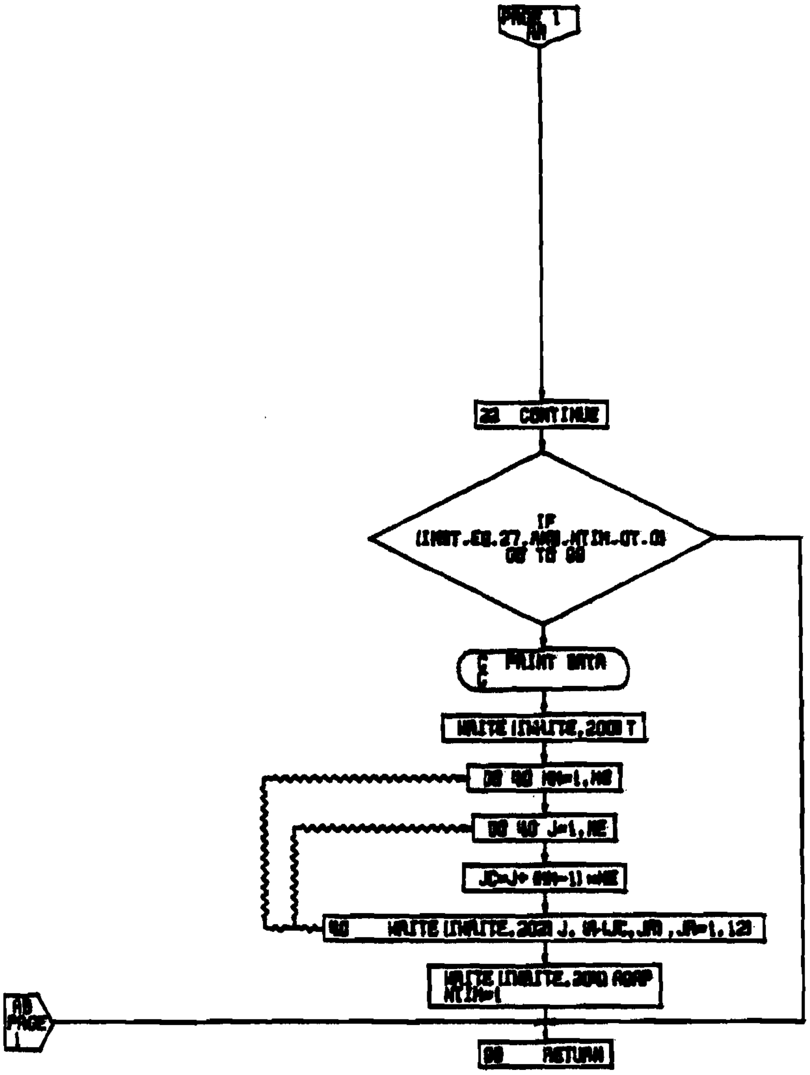


Table 122: FLOWCHART FOR SUBROUTINE VPRINT (CONCLUDED)



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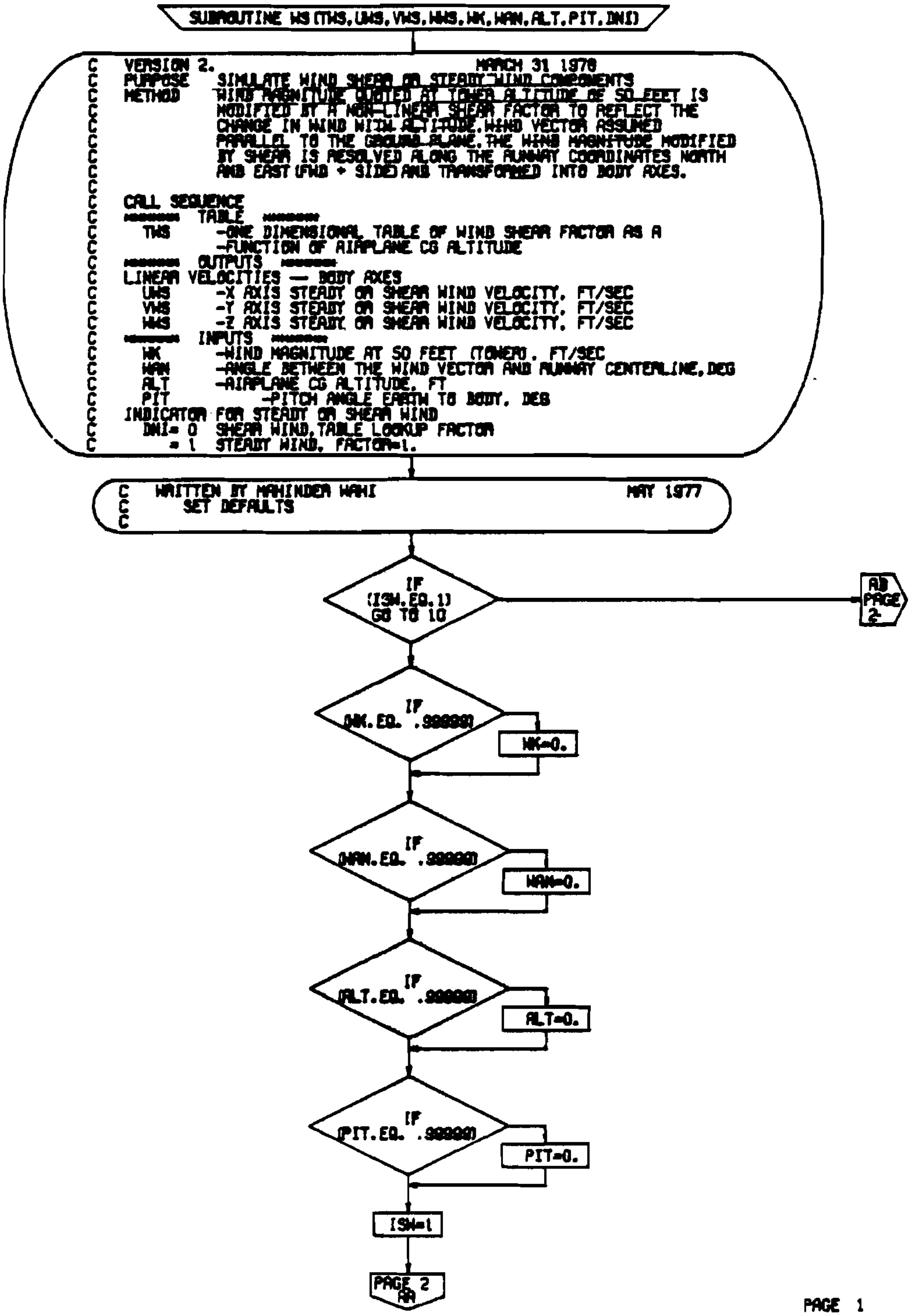
VPRINT

Table 123: FLOWCHART FOR SUBROUTINE WS



```
      SUBROUTINE WS(TWS,UWS,VWS,WWS,WK,WAN,ALT,PIT,DNI)
C     VERSION 2.                            MARCH 31 1978
C     PURPOSE     SIMULATE WIND SHEAR OR STEADY WIND COMPONENTS
C     METHOD      WIND MAGNITUDE QUOTED AT TOWER ALTITUDE OF 50 FEET IS
C                 MODIFIED BY A NON-LINEAR SHEAR FACTOR TO REFLECT THE
C                 CHANGE IN WIND WITH ALTITUDE.WIND VECTOR ASSUMED
C                 PARALLEL TO THE GROUND PLANE.THE WIND MAGNITUDE MODIFIED
C                 BY SHEAR IS RESOLVED ALONG THE RUNWAY COORDINATES NORTH
C                 AND EAST (FWD + SIDE) AND TRANSFORMED INTO BODY AXES.
C
C     CALL SEQUENCE
C     -------     TABLE     -------
C       TWS       -ONE DIMENSIONAL TABLE OF WIND SHEAR FACTOR AS A
C                 -FUNCTION OF AIRPLANE CG ALTITUDE
C     -------     OUTPUTS   -------
C     LINEAR VELOCITIES -- BODY AXES
C       UWS       -X AXIS STEADY OR SHEAR WIND VELOCITY, FT/SEC
C       VWS       -Y AXIS STEADY OR SHEAR WIND VELOCITY, FT/SEC
C       WWS       -Z AXIS STEADY OR SHEAR WIND VELOCITY, FT/SEC
C     -------     INPUTS    -------
C       WK        -WIND MAGNITUDE AT 50 FEET (TOWER), FT/SEC
C       WAN       -ANGLE BETWEEN THE WIND VECTOR AND RUNWAY CENTERLINE,DEG
C       ALT       -AIRPLANE CG ALTITUDE, FT
C       PIT             -PITCH ANGLE EARTH TO BODY, DEG
C     INDICATOR FOR STEADY OR SHEAR WIND
C       DNI= 0    SHEAR WIND,TABLE LOOKUP FACTOR
C          = 1    STEADY WIND, FACTOR=1.
C   WRITTEN BY MAHINDER WAHI                               MAY 1977
C       SET DEFAULTS
C
```

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WS

Table 123: FLOWCHART FOR SUBROUTINE WS (CONTINUED)

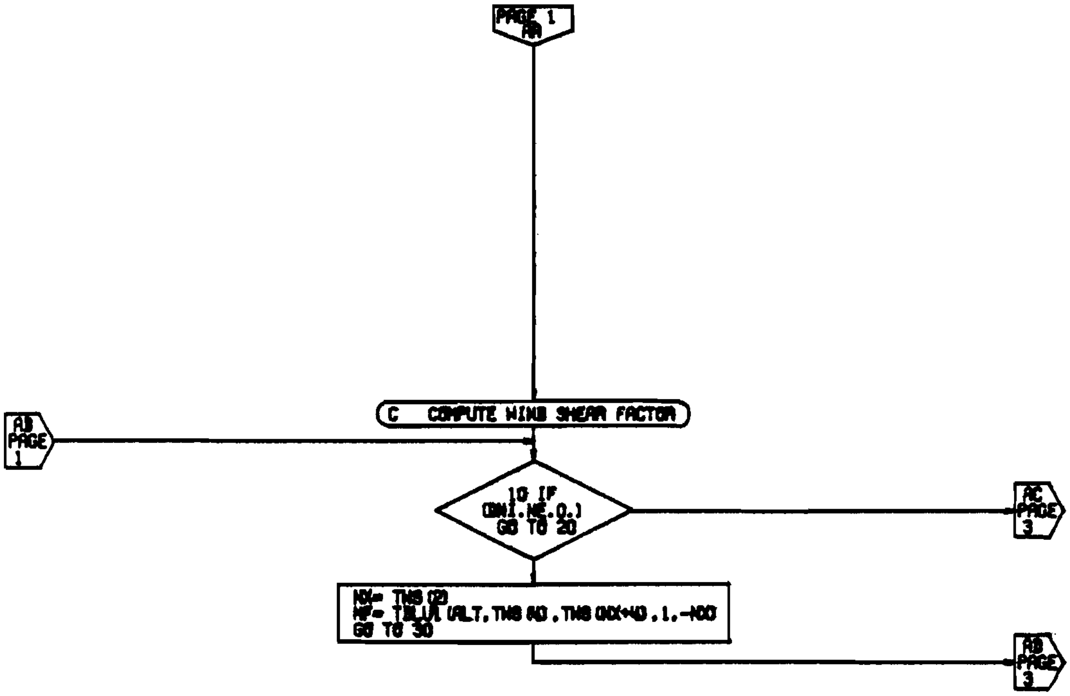
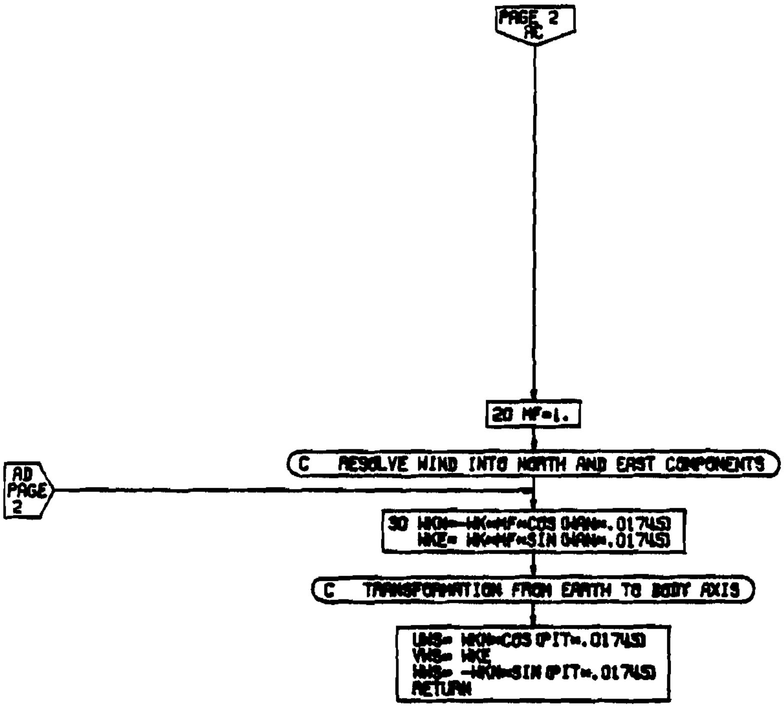


Table 123: FLOWCHART FOR SUBROUTINE WS (CONCLUDED)



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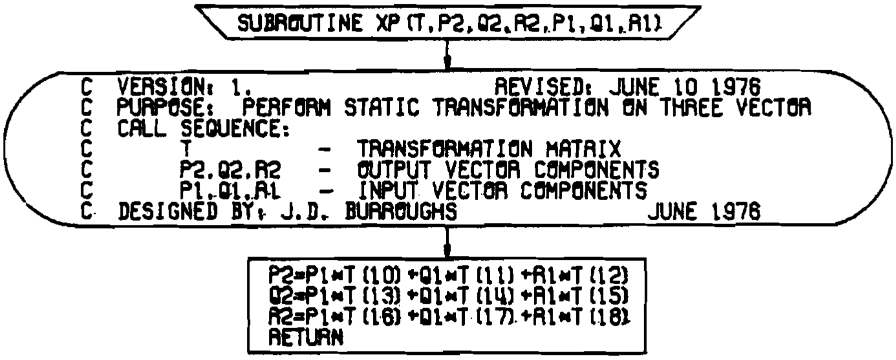
WS

Table 124: FLOW FOR SUBROUTINE XP

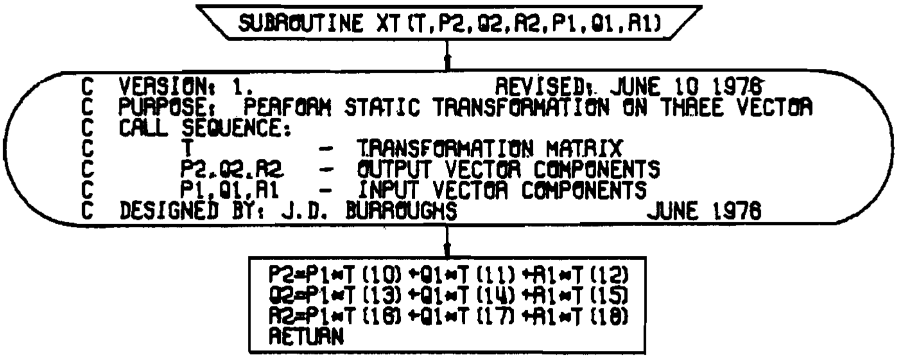


```
SUBROUTINE XP (T,P2,Q2,R2,P1,Q1,R1)
```

```
C  VERSION: 1.                        REVISED: JUNE 10 1976
C  PURPOSE:  PERFORM STATIC TRANSFORMATION ON THREE VECTOR
C  CALL SEQUENCE:
C       T             -  TRANSFORMATION MATRIX
C       P2.Q2.R2      -  OUTPUT VECTOR COMPONENTS
C       P1.Q1.R1      -  INPUT VECTOR COMPONENTS
C  DESIGNED BY: J.D. BURROUGHS                     JUNE 1976
```

```
P2=P1*T (10) +Q1*T (11) +R1*T (12)
Q2=P1*T (13) +Q1*T (14) +R1*T (15)
R2=P1*T (16) +Q1*T (17) +R1*T (18)
RETURN
```

Table 125: FLOWCHART FOR SUBROUTINE XT

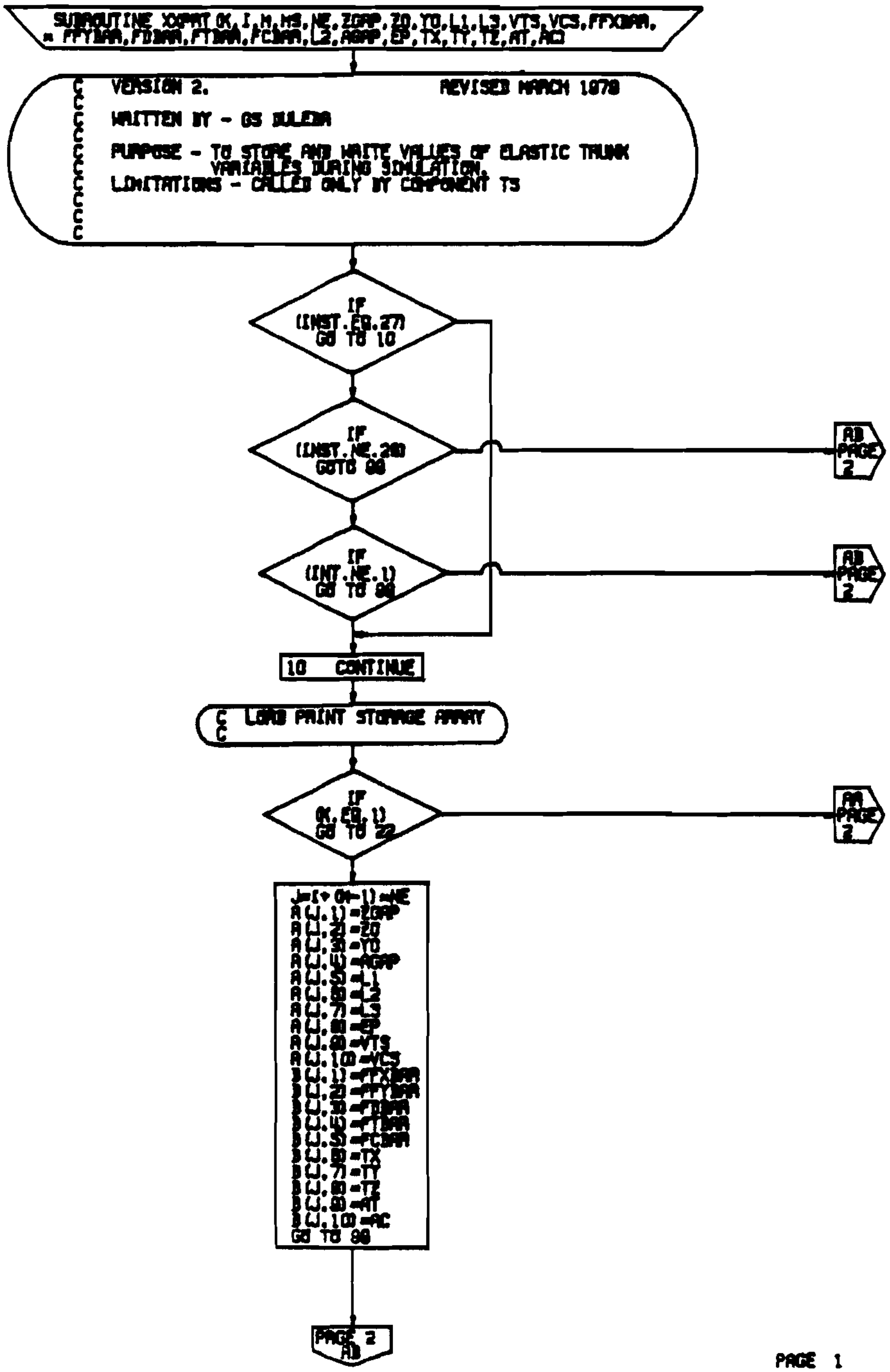


```
SUBROUTINE XT (T,P2,Q2,R2,P1,Q1,R1)

C   VERSION: 1.                              REVISED: JUNE 10 1976
C   PURPOSE:  PERFORM STATIC TRANSFORMATION ON THREE VECTOR
C   CALL SEQUENCE:
C        T            -  TRANSFORMATION MATRIX
C        P2,Q2,R2     -  OUTPUT VECTOR COMPONENTS
C        P1,Q1,R1     -  INPUT VECTOR COMPONENTS
C   DESIGNED BY: J.D. BURROUGHS                          JUNE 1976

P2=P1*T (10) +Q1*T (11) +R1*T (12)
Q2=P1*T (13) +Q1*T (14) +R1*T (15)
R2=P1*T (16) +Q1*T (17) +R1*T (18)
RETURN
```

Table 126: FLOWCHART FOR SUBROUTINE XXPRT



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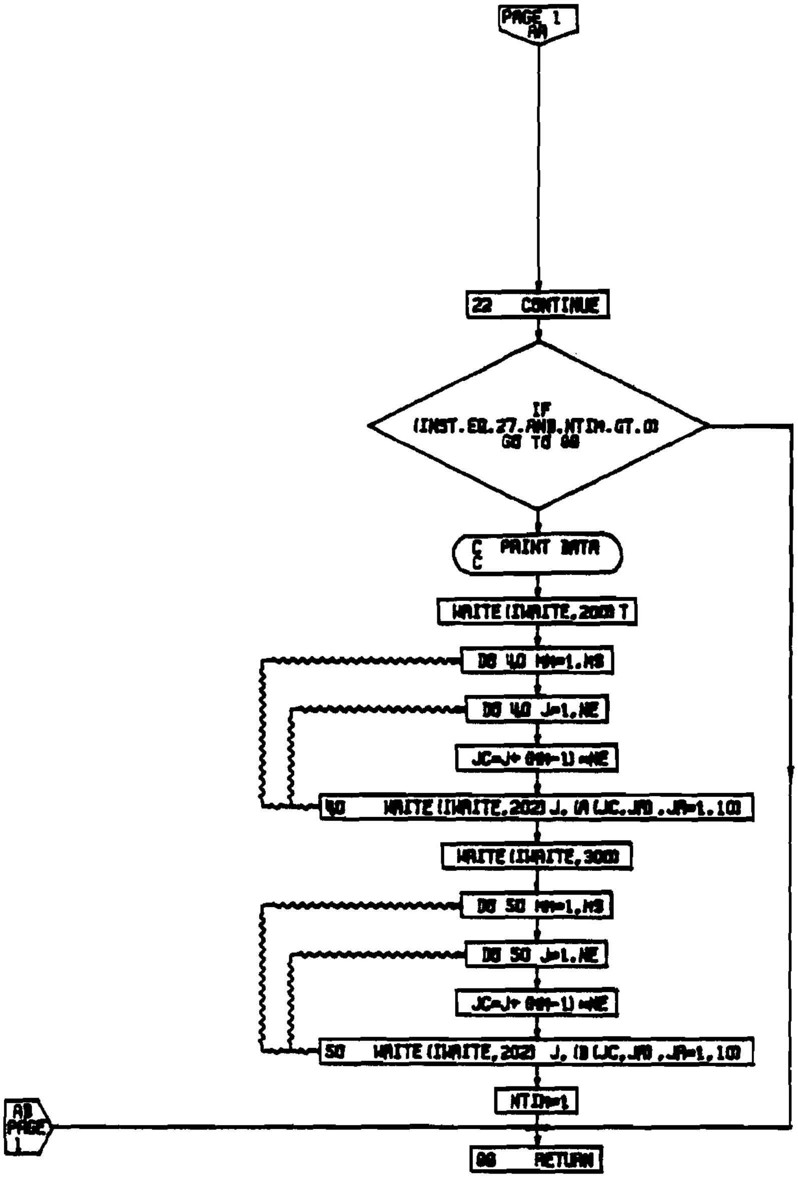
XXPRT

Table 126: FLOWCHART FOR SUBROUTINE XXPRT (CONCLUDED)



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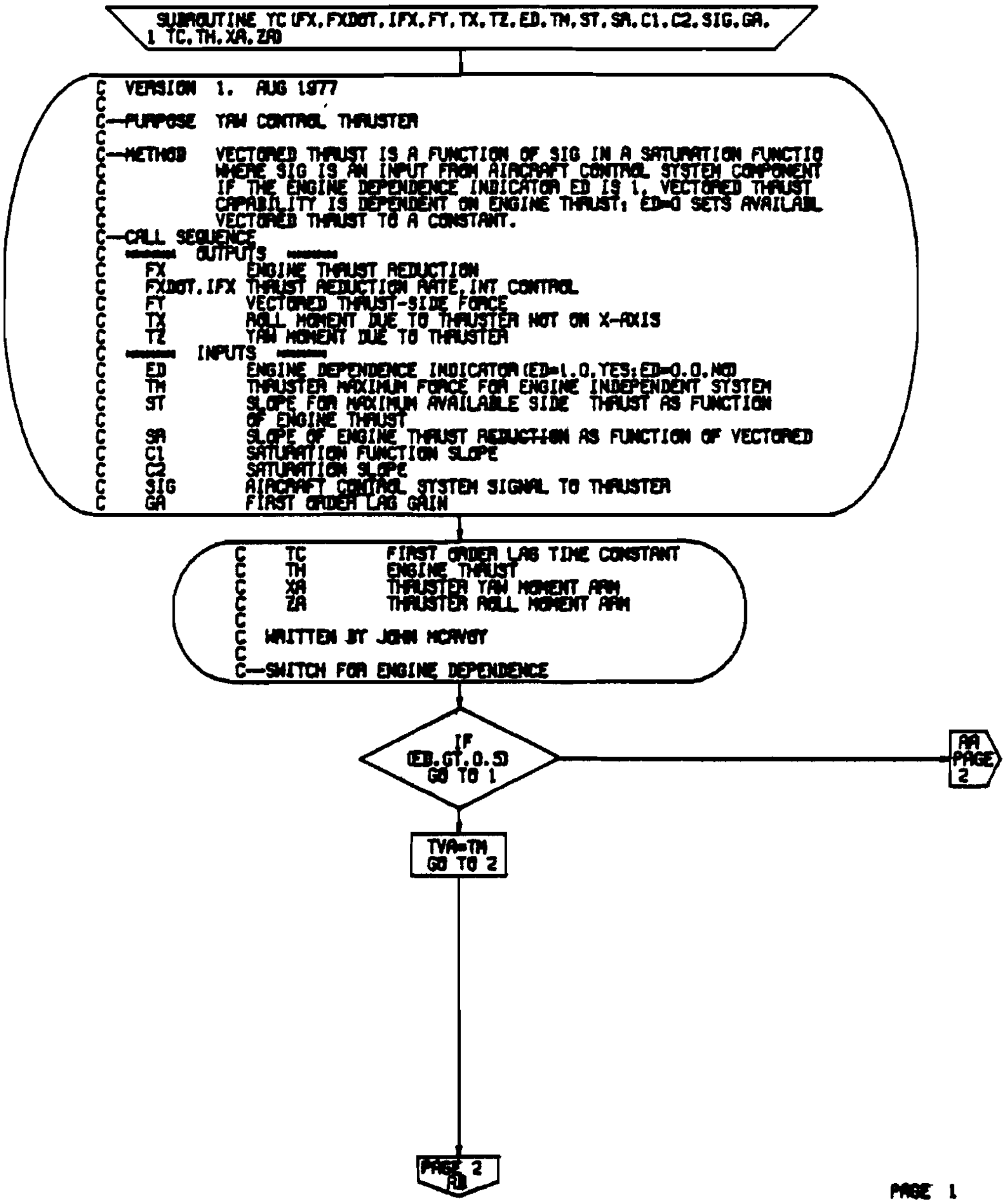
XXPRT

Table 127: FLOWCHART FOR SUBROUTINE YC



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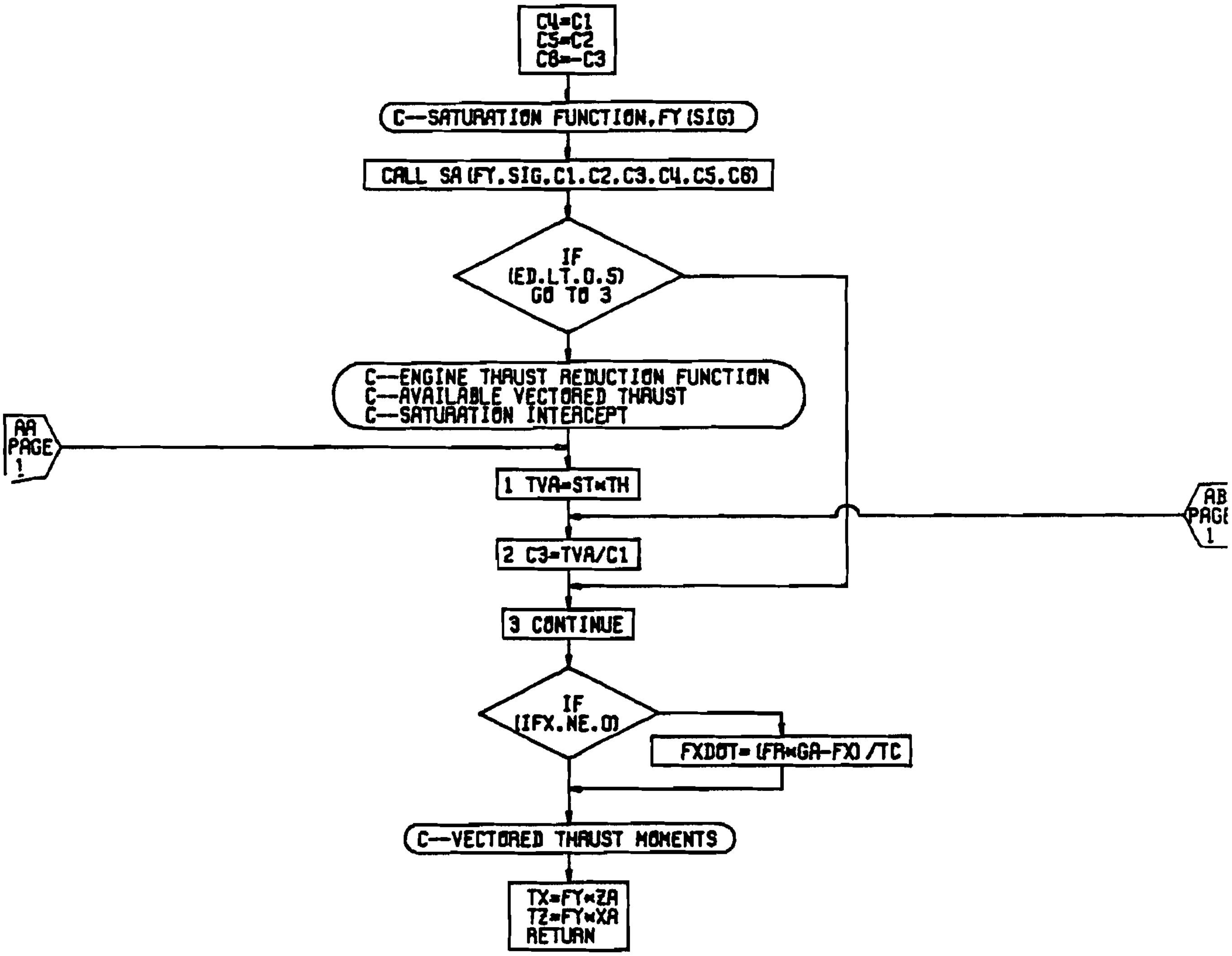
      SUBROUTINE YC(FX,FXDOT,IFX,FT,TX,TZ,ED,TM,ST,SA,C1,C2,SIG,GA,
     1 TC,TH,XA,ZA)
C  VERSION  1.  AUG 1977
C
C--PURPOSE  YAW CONTROL THRUSTER
C
C--METHOD   VECTORED THRUST IS A FUNCTION OF SIG IN A SATURATION FUNCTIO
C           WHERE SIG IS AN INPUT FROM AIRCRAFT CONTROL SYSTEM COMPONENT
C           IF THE ENGINE DEPENDENCE INDICATOR ED IS 1, VECTORED THRUST
C           CAPABILITY IS DEPENDENT ON ENGINE THRUST; ED=0 SETS AVAILABL
C           VECTORED THRUST TO A CONSTANT.
C--CALL SEQUENCE
C  ------  OUTPUTS  ------
C    FX         ENGINE THRUST REDUCTION
C    FXDOT,IFX  THRUST REDUCTION RATE,INT CONTROL
C    FT         VECTORED THRUST-SIDE FORCE
C    TX         ROLL MOMENT DUE TO THRUSTER NOT ON X-AXIS
C    TZ         YAW MOMENT DUE TO THRUSTER
C  ------  INPUTS  ------
C    ED         ENGINE DEPENDENCE INDICATOR(ED=1.0,YES;ED=0.0,NO)
C    TM         THRUSTER MAXIMUM FORCE FOR ENGINE INDEPENDENT SYSTEM
C    ST         SLOPE FOR MAXIMUM AVAILABLE SIDE  THRUST AS FUNCTION
C               OF ENGINE THRUST
C    SA         SLOPE OF ENGINE THRUST REDUCTION AS FUNCTION OF VECTORED
C    C1         SATURATION FUNCTION SLOPE
C    C2         SATURATION SLOPE
C    SIG        AIRCRAFT CONTROL SYSTEM SIGNAL TO THRUSTER
C    GA         FIRST ORDER LAG GAIN
C    TC         FIRST ORDER LAG TIME CONSTANT
C    TH         ENGINE THRUST
C    XA         THRUSTER YAW MOMENT ARM
C    ZA         THRUSTER ROLL MOMENT ARM
C
C  WRITTEN BY JOHN MCAVOY
C
C--SWITCH FOR ENGINE DEPENDENCE
```

Table 127: FLOWCHART FOR SUBROUTINE YC (CONCLUDED)



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