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**CALCULATION OF INVISCID SURFACE
STREAMLINES AND HEAT TRANSFER
ON SHUTTLE TYPE CONFIGURATIONS**

*Part II. - Description of Computer Program
by Fred R. DeJarnette
and
Michael H. Jones*

Prepared by
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FOREWORD

This research was supported under contract NAS1-10277 with the National Aeronautics and Space Administration's Langley Research Center. The technical monitor on the contract was H. Harris Hamilton II. The results are published in two parts:

Part I. - Description of Basic Method (NASA CR-111921)

Part II. - Description of Computer Program (NASA CR-111922)

Part I contains a detailed description of the theoretical approach and basic equations that were used to obtain a solution to the problem. The present part (Part II) contains a detailed description of the computer program and is intended to serve primarily as a user's manual.

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INTRODUCTION

Part I of this report (NASA CR-111921) presents a description of the basic method used to calculate laminar, transitional, and turbulent heating rates on arbitrary blunt-nosed three-dimensional bodies at angles of attack in hypersonic flows. The present report (Part II) gives a description of the computer program used in Part I. The main program and each subprogram are described by defining the pertinent symbols involved, a detailed flow diagram, and a complete computer program listing.

Input and output parameters are discussed in detail. Listings are given for the inputs used in Part I to compute heating rates on (1) a blunted 15° half-angle cone at 20° incidence and Mach 10.6, (2) a blunted 70° slab delta wing at 10° incidence and Mach 8, and (3) the HL-10 lifting body at 20° incidence and Mach 10. In addition, the computer program output for two streamlines on the blunted 15° half-angle cone is listed.

PROGRAM DESCRIPTION

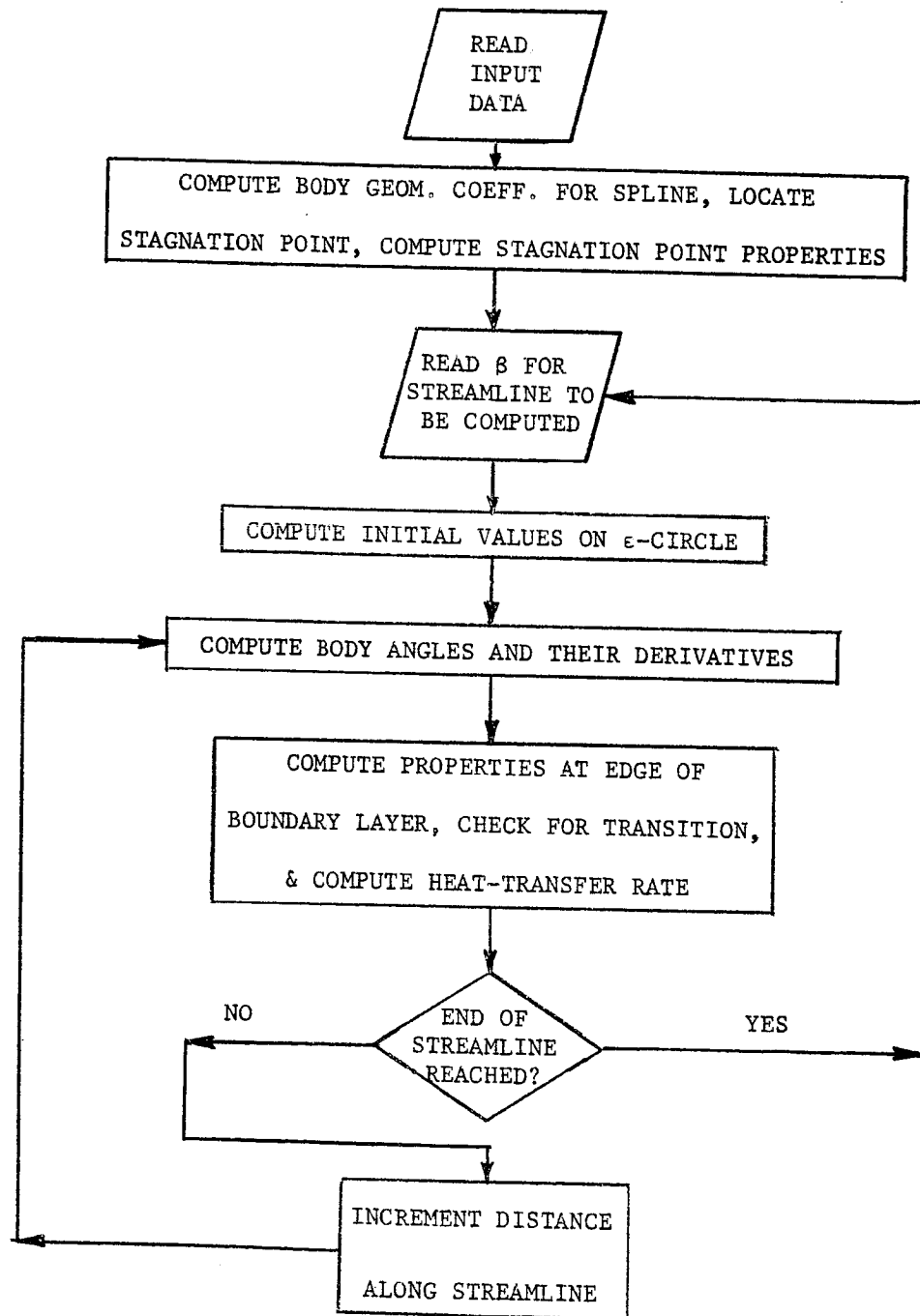
Descriptions of the main program and each subprogram are given below along with the pertinent symbols used in each program. Program inputs and outputs are described in subsequent sections. The complete computer program is listed in Appendix A, and a detailed flow diagram is given in Appendix B.

Main Program

The main program reads part of the input data, calculates the initial data for each streamline on the ϵ -circle around the stagnation point, and then calculates and prints the heating rates and other pertinent data along each streamline independently of the other streamlines. A simple flow diagram for the entire computer program is given in figure 1, whereas a detailed flow diagram is given in Appendix B. The program variables are listed below, and the corresponding symbols used in Part I of this report are given if applicable.

ALP	angle of attack, α (radians)
ALPD	angle of attack, α (degrees)
B	ratio of principal velocity gradients at stagnation point
BBAR	pressure gradient parameter, $\bar{\beta}$
BBARS	pressure gradient parameter at stagnation point, $\bar{\beta}_s$
BETA	coordinate normal to streamline on body surface, β (radians)
BETAD	BETA in degrees
CAL	cosine of ALP
CPSI	cosine of PSI
CST	constant to convert units of body coordinates to feet
CTHM	constant used to calculate laminar momentum thickness
DDLB	$\frac{1}{h} \frac{\partial \delta}{\partial \beta} \phi$
DDP	$\frac{\partial \delta}{\partial \phi} \phi$
DDX	$\frac{\partial \delta}{\partial x} \phi$
DEPS	radius of ϵ -circle around stagnation point

FIGURE 1. SIMPLIFIED FLOW DIAGRAM



DGB	$\frac{1}{h} \frac{\partial \Gamma}{\partial \beta}$
DGP	$\frac{\partial \Gamma}{\partial \phi}$
DGS	$\frac{D\Gamma}{DS}$
DGX	$\frac{\partial \Gamma}{\partial x}$
DLPH	body angle δ_ϕ
DPB	$\frac{1}{h} \frac{\partial}{\partial \beta} (p/p_s)$
DPHB	$\frac{1}{h} \frac{\partial \phi}{\partial \beta}$
DPS	$\frac{D(p/p_s)}{DS}$
DPSIS	$\frac{D\psi}{DS}$
DS	integration step size along a streamline
DSB	$-\frac{1}{h} \frac{\partial \sigma}{\partial \beta}$
DSS	$-\frac{D\sigma}{DS}$
DTHB	$\frac{1}{h} \frac{\partial \theta}{\partial \beta}$
DUEDPS	$\frac{DU_e}{D\psi}$
DUEDS	$\frac{DU_e}{DS}$
DXB	$\frac{1}{h} \frac{\partial x}{\partial \beta}$
D2PB	$\frac{1}{h} \frac{\partial}{\partial \beta} \left[\frac{1}{h} \frac{\partial}{\partial \beta} (p/p_s) \right]$
EM	Mach number at edge of boundary layer, M_e
EMIN	freestream Mach number, M_∞

EMS	$(EM)^2$, M_e^2
EM2	same as EMS
FF	body radius, f
FF0	body radius at stagnation point, f_s
F(1)	$\frac{Dx}{DS}$
F(2)	$\frac{D\phi}{DS}$
F(3)	$\frac{Dh}{DS}$
F(4)	$\frac{p}{p_s} \frac{U_e}{V_\infty} h^2$
F(5)	$\left\{ \begin{array}{ll} \frac{\rho_e U_e}{\mu_e CST} & \text{for KP} = 0, \\ \frac{D\theta}{DS} & \text{for KP} \neq 0 \end{array} \right.$
F(6)	$\left\{ \begin{array}{ll} \frac{D\theta_m}{DS} & \text{for KP} = 0, \\ \frac{D}{DS} \left(\frac{Dh}{DS} \right) & \text{for KP} \neq 0 \end{array} \right.$
F(7)	$\left\{ \begin{array}{ll} \frac{D(HI)}{DS} & \text{for KP} = 0, \\ \frac{\rho_e U_e}{\mu_e CST} & \text{for KP} \neq 0 \end{array} \right.$
F(8)	$\frac{D\theta_m}{DS}$ for KP \neq 0
F(9)	$\frac{D(HI)}{DS}$ for KP \neq 0
GM	body angle Γ
HC	compressible form factor, H
HE	enthalpy at edge of boundary layer, h_e (ft ² /sec ²)
HI	incompressible form factor, H_i
HMAX	maximum integration step size
HS	stagnation enthalpy, H_s (ft ² /sec ²)

HSP QWS(6006)/(HS-HW), for a perfect gas HSP is the stagnation point
heat transfer coefficient (BTU/ft²-sec-°R)

HTR transformed form factor, H_{tr}

HW wall enthalpy, h_w (ft²/sec²)

IMAX see Description of Input

ISTG indicator variable, see Diagnostic Messages

K see function RUNGE subprogram, K=RUNGE

KBM

KG

KMAX

KP } see Description of Input

KPØ

KS

KTR

L counter for integration steps along a streamline

L1 indicator variable, L1 = 1 for laminar region, L1 = 2 for
transitional and turbulent regions

L2 indicator variable, L2 = 1 for laminar region, L2 = 2 for last
integration step before the beginning of transition, L2 = 3 for
interior of transition region, and L2 = 4 for last integration
step of transition region

MR see function RUNGE subprogram

NAM see Description of Input

NCS see subroutine SPCH

NMAX see Description of Input

NR number of differential equations to be integrated in RUNGE subprogram

NT indicator variable, NT = 1 for laminar region, NT = 2 fully turbulent
region, NT = 3 for laminar region over entire body

PE surface pressure, p (lb/ft²)

PHID circumferential angle, ϕ (degrees)

PIN freestream pressure, p_∞ (lb/ft²)

PØP pressure ratio, p/p_s

PØRV $p_s/(\rho_s V_\infty^2)$

PNEWT	$(1 - \frac{p_{\infty}}{p_s})$
PS	stagnation pressure, p_s (lb/ft ²)
PSI	angle ψ
QØQS	heating rate ratio, $q_w/q_{w,s}$
QØQSB	QØQS (1 - ZW)/(0.85 + 0.15TE - ZW), for a perfect gas QØQSB is the ratio of the local to the stagnation point heat transfer coefficient
QWB	(QØQSB)(QWSB), (BTU-sec/ft ⁴)
QWL	laminar heating rate, $q_{w,lam}$ (BTU/ft ² -sec)
QWLB	laminar value of QWB
QWS	stagnation point heat-transfer rate, $q_{w,s}$ (BTU/ft ² -sec)
QWSB	QWS/(HS - HW)
QWT	turbulent heating rate, $q_{w,turb}$ (BTU/ft ² -sec)
QWTB	turbulent value of QWB
RHØE	density at edge of boundary layer, ρ_e (slug/ft ³)
RHØIN	freestream density, ρ_{∞} (slug/ft ³)
RHØS	stagnation density, ρ_s (slug/ft ³)
RHØSW	wall density at stagnation point, $\rho_{w,s}$ (slug/ft ³)
RNF	Reynolds number per foot, $\rho_e U_e / \mu_e$ (1/ft)
RNM	momentum thickness Reynolds number, Rn_m
RN1	integrated unit Reynolds number, Rn_1
S	distance along a streamline from stagnation point
SAL	sine (ALP)
STR	STR=Y(1) for KTR=-1, STR=RNM for KTR=0, or STR=RN1 for KTR=1
TE	enthalpy ratio, t_e
THE	inclination angle of inviscid surface streamline, θ
THM	laminar momentum thickness, $\theta_{m,lam}$
TIN	freestream temperature, T_{∞}
TRE	} see Description of Input
TRI	
TW	wall temperature, °R
UE	velocity at edge of boundary layer, U_e (ft/sec)
UØU	velocity ratio, U_e/V_{∞}
VIN	freestream velocity, V_{∞} (ft/sec)

VISC coefficient of viscosity at edge of boundary layer, μ_e (slug/ft-sec)
 VISS coefficient of viscosity at stagnation point, μ_s (slug/ft-sec)
 VISW wall coefficient of viscosity, μ_w (slug/ft-sec)
 WFN weighting function, w_f
 XØ axial location of stagnation point, x_s
 YY y-coordinate
 Y(I) $\int_0^S F(I)DS$, where $I = 1, 2, \dots, NR$
 ZW wall enthalpy ratio, ζ_w
 ZZ z-coordinate

Function RUNGE Subprogram

Function RUNGE is a subprogram which uses the fourth-order Runge-Kutta method to integrate a system of NR first-order ordinary differential equations with a variable step size. As a criterion for varying the computing interval, the differential equations are integrated over an interval of step size H first and then over the same interval with two step sizes of H/2. The two solutions are then compared to give an estimate of the error for each variable. If any error is larger than $EPS = 10^{-4}$, these answers are discarded and the computing interval H is halved. If all of the error estimates are less than EPS, the answers are allowed and the integration process continues. In addition, the step size is either doubled or set equal to HMAX, whichever is the smaller, for the next integration cycle.

The function RUNGE is used in the Main Program and has the form

$$K = \text{RUNGE}(Y, F, S, DS, NR, HMAX, MR)$$

where K can have one of three values:

- K = 0 implies the completion of an integration cycle
- K = 1 implies the integration cycle has not been completed
- K = 2 implies the step size has been halved down to a value below 10^{-8} .

The dummy arguments used in the subprogram itself are

$$\text{FUNCTION RUNGE}(Y, F, X, H, N, HMAX, MR)$$

where

Y array of dependent variables to be integrated
F array of first derivatives of the dependent variables, $F = \frac{dY}{dX}$
X independent variable (distance along a streamline)
H integration step size
N number of differential equations
HMAX maximum integration step size
MR indicator variable, if MR = 1 the previous integration interval is recomputed with a new step size H determined in the main program

Subroutine STAGN

Subroutine STAGN locates the Newtonian stagnation point and calculates the two principal radii of curvature there. A call to STAGN has the form

CALL STAGN(ALP,IMAX,KMAX,XØ,RPER,B,ISTG)

where the arguments are

ALP angle of attack, α (radians)
IMAX
KMAX] see Description of Input
XØ axial location of stagnation point
RPER principal radius of curvature in a plane perpendicular to plane of symmetry at stagnation point, R_T
B ratio of principal radii of curvature, R_T/R_{11}
ISTG indicator variable, -1 for negative angle of attack, 0 for stagnation point not found, or +1 for stagnation point found

Other program variables are

FF body radius, f
RPAR principal radius of curvature in plane of symmetry at stagnation point, R_{11}

Subroutine NEWP

This subroutine calculates the modified Newtonian pressure and its first and second derivatives with respect to both the axial (x) and circumferential

(ϕ) directions. A call to NEWP has the form

CALL NEWP(AA,F)

where the dummy arguments are

AA same as PNEWT in main program, $AA = 1 - \frac{p_{\infty}}{p_s}$

F body radius, f

Other program variables are

CA cosine (ALP)

CP $\cos \phi$

FF body radius squared, f^2

FXP $\frac{\partial^2 f}{\partial x \partial \phi}$

FXPP $\frac{\partial^3 f}{\partial x \partial \phi^2}$

FXXP $\frac{\partial^3 f}{\partial x^2 \partial \phi}$

F3X $\frac{\partial^3 f}{\partial x^3}$

PE ratio of static to stagnation pressure, p/p_s

PP $\frac{\partial(p/p_s)}{\partial \phi}$

PPP $\frac{\partial^2(p/p_s)}{\partial \phi^2}$

PX $\frac{\partial(p/p_s)}{\partial x}$

PXP $\frac{\partial^2(p/p_s)}{\partial x \partial \phi}$

PXX $\frac{\partial^2(p/p_s)}{\partial x^2}$

SA sine (ALP)

SP $\sin \phi$

Variables in labeled COMMON /COM 2/ and /COM 5/ are calculated in subroutine STRMLN.

Subroutine STRMLN

For a given axial ($x=XX$) and circumferential ($\phi=PPH$) location on the body, this subroutine calculates the body radius (f), body angles Γ and δ_ϕ , and their derivatives in the axial and circumferential directions. A call to subroutine STRMLN has the form

CALL STRMLN(XX,PPH,DLPH,DDP,DDX,GM,DGP,DGX,F,IMAX,KMAX)

where the arguments are

XX axial position, x

PPH circumferential position, ϕ

DLPH body angle δ_ϕ

DDP $\frac{\partial \delta_\phi}{\partial \phi}$

DDX $\frac{\partial \delta_\phi}{\partial x}$

GM body angle Γ

DGP $\frac{\partial \Gamma}{\partial \phi}$

DGX $\frac{\partial \Gamma}{\partial x}$

F body radius, f

IMAX]
KMAX] see Description of Input

Other program variables are

FF body radius squared, f^2

FFP $\frac{\partial f^2}{\partial \phi}$

FFX $\frac{\partial f^2}{\partial x}$

FFXP $\frac{\partial^2 f^2}{\partial x \partial \phi}$

$$\text{FFXPP} \quad \frac{\partial^3 f^2}{\partial x \partial \phi^2}$$

$$\text{FFXX} \quad \frac{\partial^2 f^2}{\partial x^2}$$

$$\text{FFXXP} \quad \frac{\partial^3 f^2}{\partial x^2 \partial \phi}$$

$$\text{FF2P} \quad \frac{\partial^2 f^2}{\partial \phi^2}$$

$$\text{FF3P} \quad \frac{\partial^3 f^2}{\partial \phi^3}$$

$$\text{FP} \quad \frac{\partial f}{\partial \phi}$$

$$\text{FPP} \quad \frac{\partial^2 f}{\partial \phi^2}$$

$$\text{FX} \quad \frac{\partial f}{\partial x}$$

$$\text{FXX} \quad \frac{\partial^2 f}{\partial x^2}$$

$$\text{F2} \quad 2f$$

Subroutine BGEØM

Subroutine BGEØM reads the input data for the body geometry and calculates the coefficients for the two-dimensional cubic spline function used to represent the body geometry. A call to subroutine BGEØM has the form

CALL BGEØM(IMAX,KMAX)

where the arguments are defined in Description of Input. Other program variables are

$$\text{AMD}(I,K) \quad \frac{\partial^3 f^2}{\partial \phi^3} (x_i, \phi_k)$$

AMDD(I)]
 AMDD(K)] temporary storage for elements of AMD(I,K)

$AMF(I,K) \frac{\partial^2 f^2}{\partial \phi^2} (x_i, \phi_k)$
 $AMFF(I)$ } temporary storage for elements of $AMF(I,K)$
 $AMFF(K)$ }
 $AMFT(J) \frac{\partial^2 f^2}{\partial \phi^2} (\phi_j)$ corresponding to input coordinates

 $AMG(I,K) \frac{\partial^3 f^2}{\partial \phi^2 \partial x} (x_i, \phi_k)$

 $AMGG(I)$ } temporary storage for elements of $AMG(I,K)$
 $AMGG(K)$ }
 $BMD(I,K) \frac{\partial^2}{\partial x^2} AMD(I,K)$

 $BMDD(I)$ temporary storage for elements of $BMD(I,K)$
 $BMF(I,K) \frac{\partial^2}{\partial x^2} AMF(I,K)$

 $BMFF(I)$ temporary storage for elements of $BMF(I,K)$
 $BMG(I,K) \frac{\partial^2}{\partial x^2} AMG(I,K)$

 $BMGG(I)$ temporary storage for elements of $BMG(I,K)$

 $DLP(I,K) \frac{\partial f^2}{\partial \phi} (x_i, \phi_k)$

 $DLPP(I)$ } temporary storage for elements of $DLP(I,K)$
 $DLPP(K)$ }
 $FN(I,K) f^2(x_i, \phi_k)$
 $FNN(I)$ } temporary storage for elements of $FN(I,K)$
 $FNN(K)$ }
 $FT(J) f^2(\phi_j)$ corresponding to input coordinates

 $GAM(I,K) \frac{\partial f^2}{\partial x} (x_i, \phi_k)$
 $GAMM(I)$ } temporary storage for elements of $GAM(I,K)$
 $GAMM(K)$ }

 $HP(K) \phi_k - \phi_{k-1}$
 $HPT(J) \phi_j - \phi_{j-1}$

HX(I) $x_i - x_{i-1}$
 I subscript corresponding to axial position
 J subscript corresponding to input circumferential position
 K subscript corresponding to rearranged circumferential position
 JM number of input circumferential locations
 JMM(I) number of input circumferential locations at $x = X(I)$
 PH(K) rearranged circumferential position, ϕ_k
 PHI(J) input circumferential position, ϕ_j
 X(I) input axial position, x_i
 XMD(I,K) $\frac{\partial^2}{\partial x^2}$ DLP(I,K)
 XMDD(I) temporary storage for elements of XMD(I,K)
 XMF(I,K) $\frac{\partial^2}{\partial x^2}$ FN(I,K)
 XMFF(I) temporary storage for elements of XMF(I,K)
 XMG(I,K) $\frac{\partial^2}{\partial x^2}$ GAM(I,K)
 XMGG(I) temporary storage for elements of XMG(I,K)
 Y(J) input y-coordinate, see Description of Input
 YY(I,J) input y-coordinate at $x = X(I)$
 Z(J) input z-coordinate, see Description of Input
 ZZ(I,J) input z-coordinate at $x = X(I)$

Note: The dimensions on the variables involving the subscripts I, J, and K in the program listing are 20 for each subscript.

Subroutine SPLINE

For an array of dependent variables, this subroutine solves the tri-diagonal matrix system of algebraic equations to determine the coefficients for the spline function. A call to SPLINE has the form

CALL SPLINE(H,DE,K,AM,E,G,N)

where the dummy arguments are

H(J) array representing the difference between the J+1 independent variable and the J independent variable

DE(J) array of dependent variables

K number of points used for the spline fit; J=1,2,...,K

AM(J) array of coefficients for spline function

E,G derivative (slope) of the dependent variable at J=1 and J=K, respectively

N indicator variable:

- (1) N = - 2 indicates AM(2)=AM(1) and AM(K-1)=AM(K) are used in place of specifying E and G.
- (2) N = - 1 indicates AM(1)=0 and AM(K)=0 are used in place of specifying E and G.
- (3) N = 0 indicates E is specified but AM(K-1)=AM(K) is used in place of specifying G.
- (4) N = 1 indicates both E and G are specified.

Other program variables are

A(J) }
 B(J) } array of constants in the system of algebraic equations
 C(J) }
 D(J) }

J subscript indicating position of dependent and independent variables; J=1,2,...,K

P(J) }
 Q(J) } array of parameters used in the algorithm for solving the system of
 U(J) } algebraic equations

Note: This subroutine calculates the coefficients for spline functions in both the axial and circumferential directions. Therefore, the dimension on the subscripted variables must be the number of points used in the axial or circumferential directions, whichever is greater. The computer program listed in Appendix A uses a dimension of 20.

Function FSPL

The function FSPL calculates the value of the dependent variable corresponding to a given value of the independent variable for any one of

the several spline functions. The function FSPL appears in the program in the form

$$\text{FSPL}(\text{AM1}, \text{AM2}, \text{X1}, \text{X2}, \text{Y1}, \text{Y2}, \text{X})$$

where the dummy arguments are

AM1 coefficient for spline function at X1
AM2 coefficient for spline function at X2
X value of independent variable, where $X1 \leq X < X2$
X1 } two successive members of the array of independent variables, used to
X2 } determine the spline function, which bracket the current value of the
independent variable X.
Y1 dependent variable corresponding to X1
Y2 dependent variable corresponding to X2

Function DFSPL

This function calculates the first derivative of the spline function computed in function FSPL. It appears in the program as

$$\text{DFSPL}(\text{AM1}, \text{AM2}, \text{X1}, \text{X2}, \text{Y1}, \text{Y2}, \text{X})$$

where the dummy arguments are the same as those in function FSPL.

Function D2FPL

This function calculates the second derivative of the spline function computed in function FSPL. It appears in the program as

$$\text{D2FPL}(\text{AM1}, \text{AM2}, \text{X1}, \text{X2}, \text{Y1}, \text{Y2}, \text{X})$$

and the dummy arguments are the same as those in function FSPL.

Subroutine STGPR

Subroutine STGPR computes stagnation properties for perfect gas or equilibrium air. A call to subroutine STGPR has the form

$$\text{CALL STGPR}(\text{PIN}, \text{TIN}, \text{VIN}, \text{RH0IN}, \text{EMIN}, \text{PS}, \text{RH0S}, \text{HS}, \text{KG})$$

where the arguments are

PIN freestream pressure, p_∞ (lb/ft²)
 TIN freestream temperature, T_∞ (°R)
 VIN freestream velocity, V_∞ (ft/sec)
 RHØIN freestream density, ρ_∞ (slug/ft³)
 EMIN freestream Mach number, M_∞
 PS stagnation pressure, p_s (lb/ft²)
 RHØS stagnation density, ρ_s (slug/ft³)
 HS stagnation enthalpy, H_s (ft²/sec²)
 KG indicator variable; KG=0 for perfect gas or KG=1 for equilibrium air
 Other program variables are
 HIN freestream enthalpy, h_∞ (ft²/sec²)
 H2 enthalpy aft of normal shock wave, h_2 (ft²/sec²)
 P2 pressure aft of normal shock wave, p_2 (lb/ft²)
 RHØ2 density aft of normal shock wave, ρ_2 (slug/ft³)
 RIN gas constant for air, \bar{R} (53.35045 x 32.1741 ft²/sec²-°R)
 V2 velocity aft of normal shock wave, v_2 (ft/sec)

Subroutine PRØP

This subroutine computes the local fluid properties at the edge of the boundary layer from the stagnation properties and local pressure for a perfect gas or equilibrium air. A call to subroutine PRØP has the form

CALL PRØP (PS,HS,RHØS,PE,HE,RHØE,UE,VISC,EMS,KG)

where the dummy arguments are

PS stagnation pressure, p_s (lb/ft²)
 HS stagnation enthalpy, H_s (ft²/sec²)
 RHØS stagnation density, ρ_s (slug/ft³)
 PE local surface pressure, p (lb/ft²)
 HE enthalpy at edge of boundary layer, h_e (ft²/sec²)
 RHØE density at edge of boundary layer, ρ_e (slug/ft³)
 UE velocity at edge of boundary layer, U_e (ft/sec)
 VISC coefficient of viscosity at edge of boundary layer, μ_e (slug/ft-sec)
 EMS Mach number squared at edge of boundary layer, M_e^2

KG indicator variable; KG=0 for perfect gas, KG=1 for equilibrium air

Subroutine SPCH

Subroutine SPCH computes the turbulent skin friction coefficient from the Spalding-Chi method based on momentum thickness. The corresponding turbulent heat transfer rate is calculated from von Karman's form of Reynolds Analogy. A call to subroutine SPCH has the form

CALL SPCH(ZW,HE,RHØE,UE,HS,RNM,CF,QW,QWB,NCS)

where the arguments are

ZW wall enthalpy ratio, ζ_w
HE enthalpy at edge of boundary layer, h_e (ft²/sec²)
RHØE density at edge of boundary layer, ρ_e (slug/ft³)
UE velocity at edge of boundary layer, U_e (ft/sec)
HS stagnation enthalpy, H_s (ft²/sec²)
RNM momentum thickness Reynolds number, Rn_m
CF turbulent skin friction coefficient, C_f
QW turbulent heat-transfer rate, $q_{w,turb}$ (BTU/ft²-sec)
QWB $q_{w,turb} / (h_{aw} - h_w)$, (BTU-sec/ft⁴)
NCS indicator variable; if NCS=0 the value of U from the previous step is used in the Newton-Rhapson iteration scheme for U, if NCS=1 the initial value of U for the iteration scheme is calculated from an approximate equation

Other program variables are

AØG h_{aw}/h_e
AØS h_{aw}/h_w
CFI incompressible skin friction coefficient, $C_{f,i}$
FC F_c , see note below
FRD $F_{R\delta}$
PR Prandtl number, Pr
RAF Reynolds Analogy Factor, $2N_{ST}/C_f$
REC recovery factor (0.89)
SØG h_w/h_e

$$U = 0.4 U_4^+$$

Note: The equation used to compute FC in the program listing in Appendix A is valid only for a perfect gas. After the listing of the program was printed, additions were made to subroutine SPCH to calculate FC for equilibrium air as indicated in Part I - Description of Basic Method.

Subroutine PRESS

Subroutine PRESS computes and prints modified Newtonian pressures corresponding to input body geometry coordinates, and then a two-dimensional spline fit to this data is obtained. If input pressure data are supplied, this pressure data is read-in and also printed in this subroutine, and a new two-dimensional spline fit to this data is calculated to replace the spline fit to the modified Newtonian pressures. A call to subroutine PRESS has the form

CALL PRESS(KP,PNEWT)

where the arguments are

KP see Description of Input

PNEWT $(1 - p_\infty/p_s)$

Other program variables are

AMP(I,K) $\frac{\partial^2 p/p_s}{\partial \phi^2} (x_i, \phi_k)$

AMPT(J) $\frac{\partial^2 p/p_s}{\partial \phi^2} (\phi_j)$

BMP(I,K) $\frac{\partial^2}{\partial x^2} \text{AMP}(I,K)$

BMPP(I) temporary storage for elements of BMP(I,K)

FF body radius, f

HX2(I) $X2(I) - X2(I-1)$

HPT(J) $\phi_j - \phi_{j-1}$

HP2(K) $\phi_k - \phi_{k-1}$

IM2X,I see Description of Input
 J subscript corresponding to input circumferential position
 JM number of input circumferential positions
 JMM(I) number of input circumferential positions at X2(I)
 K subscript corresponding to rearranged circumferential position
 KM2X see Description of Input
 LL indicator variable; LL=1 for modified Newtonian pressures at input body geometry coordinates, and LL=2 for input pressure data
 PHI(J) input circumferential position, ϕ_j
 PH2(K) rearranged circumferential position, ϕ_k
 PN(I,K) $p/p_s(x_1, \phi_k)$
 PNN(I) } temporary storage for elements of PN(I,K)
 PNN(K) }
 PØP pressure ratio, p/p_s
 PR pressure ratio, p/p_s
 PT(J) $p/p_s(\phi_j)$
 PX(K) $\frac{\partial p/p_s}{\partial \sqrt{x}}(0, PH2(K))$
 PXE(K) $\frac{\partial p/p_s}{\partial \sqrt{x}}(X2(IM2X), PH2(K))$
 PXPP(K) $\frac{\partial^2}{\partial \phi^2} PX(K)$
 PXPPE(K) $\frac{\partial^2}{\partial \phi^2} PXE(K)$
 XMP(I,K) $\frac{\partial^2 p/p_s}{\partial x^2}(x_1, \phi_k)$
 XMPP(I) temporary storage for elements of XMP(I,K)
 XT axial location, x
 X2(I) \sqrt{XT}
 Y(J) y-coordinate of ϕ_j
 YY(I,J) y-coordinate at x_1, ϕ_j

Z(J) z-coordinate of ϕ_j
 ZZ(I,J) z-coordinate at x_i, ϕ_j

Subroutine PDER

For a given position on the body, this subroutine calculates the pressure ratio (p/p_s) and its derivatives from the two-dimensional spline pressure function. If pressure data are input this function is a spline fit to the input pressure data; otherwise, the function is a spline fit to the modified Newtonian pressures corresponding to the input body geometry coordinates. A call to subroutine PDER has the form

CALL PDER(XX,PPH,PE,DPDP,DP2P,DPDX,DPXP,DPXX)

where the dummy arguments are

XX axial position on body, x
 PPH circumferential position on body, ϕ
 PE pressure ratio, p/p_s
 DPDP $\frac{\partial(p/p_s)}{\partial\phi}$
 DP2P $\frac{\partial^2(p/p_s)}{\partial\phi^2}$
 DPDX $\frac{\partial(p/p_s)}{\partial x}$
 DPXP $\frac{\partial^2(p/p_s)}{\partial x \partial \phi}$
 DPXX $\frac{\partial^2(p/p_s)}{\partial x^2}$

Other program variables are defined in subroutine PRESS

Subroutine LAGR

This subroutine calculates the axial pressure derivatives (with respect to \sqrt{x}) at the nose ($x=0$) and end of the body for $\phi = \phi_k$ from

Lagrangian Interpolation functions. These pressure derivatives are used as "end conditions" for pressure spline functions in the axial direction in subroutine PRESS. A call to subroutine LAGRAN has the form

CALL LAGRAN (XX,X, FN, IMAx, M, N, F, FP)

where the dummy arguments are

XX axial location where derivative is to be evaluated, \sqrt{x}
 X(I) array of independent variables (\sqrt{x})
 FN(J) array of dependent variables (p/p_s)
 IMAx number of axial stations
 M points to the left of XX to be used in Lagrangian Interpolation
 N points to the right of XX to be used in Lagrangian Interpolation
 F p/p_s at $x=XX$ and $\phi=\phi_k$
 FP $\frac{\partial (p/p_s)}{\partial \sqrt{x}}$ at $x=XX$ and $\phi=\phi_k$

Subroutine TRANS

Subroutine TRANS is used only if transition is specified by geometric location on the body (KTR=-1 in input data). It reads the body coordinates specifying the beginning and end of transition, and it calculates the coefficients for a one-dimensional spline function for each set of data. A call to subroutine TRANS has the form

IF(KTR .EQ. -1) CALL TRANS

and the program variables are

AMTB(L) $\frac{\partial^2}{\partial \phi^2}$ XB(L)

AMTE(M) $\frac{\partial^2}{\partial \phi^2}$ XE(M)

L subscript corresponding to a body coordinate used to specify beginning of transition; L=1,2,...,LMAX

LMAX number of coordinates used to specify beginning of transition (see Description of Input)

M subscript corresponding to a body coordinate used to specify end of transition; M=1,2,...,MMAX

MMAX number of coordinates used to specify end of transition (see Description of Input)

PHB(L) circumferential location of input coordinate for beginning of transition, $\phi(L)$

PHE(M) circumferential location of input coordinate for end of transition, $\phi(M)$

XB(L) } Cartesian coordinates of position L specifying beginning of transition

YB(L) }

ZB(L) }

XE(M) } Cartesian coordinates of position M specifying end of transition

YE(M) }

ZE(M) }

Subroutine BEGTR

This subroutine is used only when transition is specified by geometric location on the body (KTR=-1 in input data). For a given circumferential location (PPH) it calculates the corresponding axial location (XTB) of the beginning of transition. A call to subroutine BEGTR has the form

IF(KTR .EQ. -1) CALL BEGTR(PPH,XTB)

Subroutine ENDTR

This subroutine also is used only when transition is specified by geometric location on the body (KTR=-1 in input data). For a given circumferential location (PPH) it calculates the corresponding axial location (XTE) of the end of transition. A call to subroutine ENDTR has the form

IF(KTR .EQ. -1) CALL ENDTR(PPH,XTE)

DESCRIPTION OF INPUT

The input data for the computer program are listed below in the proper sequence. Read statements for the input data appear in the Main Program

unless noted otherwise. In a subsequent section the input data used in the examples in Part I of this report are listed. The steps which describe the input are:

Step 1.

```
READ (1,1000) NAM
```

```
1000 FORMAT (20A3)
```

NAM is the name used for the body designation.

Step 2.

```
READ (1,1) IMAX,KMAX
```

```
1 FORMAT (2I5)
```

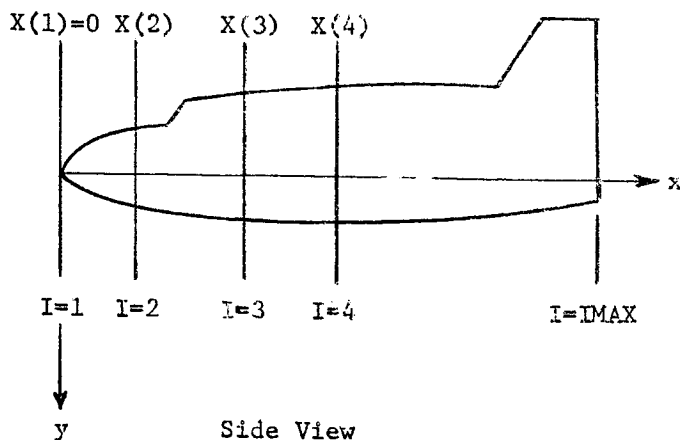
This read statement appears in subroutine BGEØM.

IMAX number of axial stations used to input body geometry data, including the nose point ($x=0$) and the last axial station. Although IMAX includes the nose point ($x=0$), body geometry data are not input for this point since the body radius f is zero for all circumferential angles ϕ . (See Sketch 1 on next page)

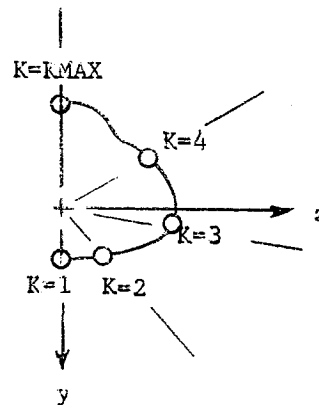
KMAX number of equally spaced circumferential planes to be used to spline fit the body geometry in the circumferential direction, including the windward ($\phi=0$) and leeward ($\phi=\pi$) planes but only for the half body $0 \leq \phi \leq \pi$. These equally spaced circumferential planes are generally different from the circumferential angles corresponding to the input coordinates described in step 3. Although the input body coordinates are not generally equally spaced in the circumferential direction and generally differ from one body cross section (axial station) to another, a one-dimensional spline fit to the input data at each cross section is used in the program to calculate rearranged body points which are equally spaced in the circumferential direction. This rearrangement of geometry data is needed to facilitate the spline fit in the axial direction. (See Sketch 1.)

Dimension statements in the program require that

$IMAX \leq 20$ and $KMAX \leq 20$.



Side View



View from Rear of Rearranged Circumferential Planes (Equally Spaced)

Sketch 1 - Body geometry

Step 3.

```

DØ 11 I=2,IMAX
  READ(1,3)JM,X(I)
  3 FØRMAT(15,F10.5)
  READ(1,4)((Z(J),Y(J)),J=1,JM)
  4 FØRMAT(8F10.5)
11 CØNTINUE

```

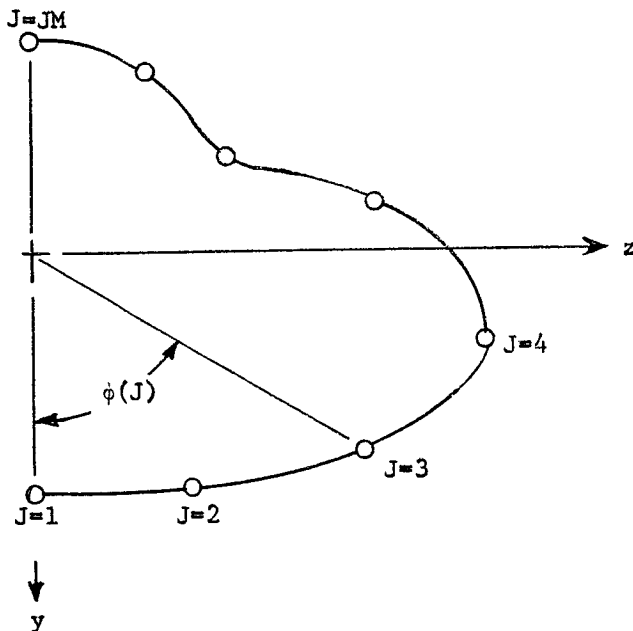
The statements above appear in subroutine BGEØM, and they are the read statements to input the Cartesian coordinates of the points used to describe the body geometry.

I subscript corresponding to axial station number, where $I=1$ is the nose point ($x=0$) and $I=IMAX$ is the last axial station number. As noted in step 2, body geometry data are not input for the nose point ($I=1$), and therefore the DØ loop listed above starts with $I=2$.

JM number of circumferential points input at axial station number I (see Sketch 2 on next page.)

X(I) axial distance from the nose point ($x=0$) to axial station I. The axial stations are not required to be equally spaced, but the spline fit in the axial direction is generally more accurate when the axial stations are spaced approximately equally. (See Sketch 1 above.)

J subscript corresponding to an input circumferential point, where
 J=1 is the windward plane and J=JM is the leeward plane.
 Z(J) z-coordinate for point J
 Y(J) y-coordinate for point J



Sketch 2. - Input coordinates of body cross section (viewed from rear).

The points J=1,2,3,...,JM do not have to be equally spaced. However, it is required that J=1 corresponds to the windward plane, J=JM corresponds to the leeward plane, and $\phi(J+1) > \phi(J)$ where $\phi(J) = \tan^{-1}(Z(J)/Y(J))$. Also, JM may vary from one axial station to another and is not related to KMAX except the dimension statement in the program has $JM \leq 20$. The coordinates X(I), Y(J), and Z(J) may be input with any consistent unit of length since the constant CST in step 4 below is used to convert this unit to feet.

Step 4.

```
READ(1,900)PIN,TIN,VIN,TRI,TRE,CST,HMAX,KG,KTR,KS,NMAX,KP0,KE
```

```
900 FORMAT(7E10.0/5I10)
```

PIN freestream static pressure, p_∞ (lb/ft²)

TIN freestream temperature, T_∞ (°R)

VIN freestream velocity, V_∞ (ft/sec)

TRI value of integrated unit Reynolds number Rn_1 or momentum thickness Reynolds number Rn_m , if either of these two parameters is used to specify the beginning of transition. If transition is specified by geometric location or not specified at all, any number may be input for TRI
 TRE same explanation as given above for TRI except TRE corresponds to the end of transition
 CST constant to convert units of input body geometry coordinates to feet
 HMAX maximum step size along a streamline for integration by Runge-Kutta method; HMAX has the same units as the input body geometry coordinates
 KG indicator variable; $KG=0$ for perfect gas, $KG=1$ for equilibrium air
 KTR indicator variable for transition; $KTR=-1$ for beginning and end of transition based on geometric location, $KTR=0$ for transition based on integrated unit Reynolds number Rn_1 , or $KTR=1$ for transition based on momentum thickness Reynolds number Rn_m . When transition is not specified, KTR may be any other integer as long as $KS=0$ is input
 KS $KS=0$ for laminar heating rates only, otherwise any other integer may be input
 NMAX maximum number of integration steps along a streamline
 KPØ when the additional print out (see Description of Output) is desired, set $KPØ=1$; otherwise any other integer may be input

Step 5. X

The data in this step are input only if the beginning and end of transition is specified by geometric location ($KTR=-1$). Otherwise, skip this step and go to step 6.

The statements below appear in subroutine TRANS, and they are the read statements for the Cartesian coordinates of points along the body used to specify the beginning and end of transition by geometric location.

```

    READ(1,1)LMAX
    1 FØRMAT(I5)
      READ(1,3)((XB(L),YB(L),ZB(L)),L=1,LMAX)
    3 FØRMAT(8E10.0)
      READ(1,1)MMAX
      READ(1,3)((XE(M),YE(M),ZE(M)),M=1,MMAX)
  
```


The variables are

LMAX total number of input points used to specify beginning of transition, including one in the windward plane and one in the leeward plane ($0 \leq \phi \leq \pi$)

L subscript corresponding to input point to specify beginning of transition; where $1 \leq L \leq LMAX$, $L=1$ must be the windward plane ($\phi=0$) and $L=LMAX$ must be the leeward plane ($\phi=\pi$)

$\left. \begin{array}{l} XB(L) \\ YB(L) \\ ZB(L) \end{array} \right\}$ x, y, and z coordinates, respectively, for input points used to specify beginning of transition by geometric location. The units are the same as those used for specifying the body geometry coordinates. Also it is required that $\phi(L+1) > \phi(L)$ where $\phi(L) = \tan^{-1}(ZB(L)/YB(L))$ and $\phi(1)=0$, $\phi(LMAX)=\pi$

The variables listed below pertain to the end of transition, and the same general comments given above for the variables pertaining to the beginning of transition apply to these variables also.

MMAX total number of input points used to specify end of transition

M subscript corresponding to input point to specify end of transition, $1 \leq M \leq MMAX$

$\left. \begin{array}{l} XE(M) \\ YE(M) \\ ZE(M) \end{array} \right\}$ x, y, and z coordinates, respectively, for input points used to specify end of transition

Step 6.

READ(1,2)ALPD,ZW,KBM,KP

2 FORMAT(2F10.5,2I5)

ALPD angle of attack, α (degrees)

ZW ratio of wall to freestream stagnation enthalpy, ζ_w

KBM total number of streamlines to compute for the half body ($0 \leq \phi \leq \pi$)

KP indicator variable; KP=0 for simplified streamlines (see Part I for explanation), KP=1 for streamlines computed from modified Newtonian pressures, KP=2 for streamlines computed from input pressure distribution

Step 7.

The data in this step are input only if surface pressures from some other source are supplied (KP=2). Otherwise, skip this step and go to step

8. The pressure data are read-in as the ratio of surface pressure to stagnation pressure around the circumference of the body at several axial stations, in a manner similar to the body geometry coordinates described above. The statements below appear in subroutine PRESS.

```

      READ(1,15)PN(1,1),IM2X,KM2X
15  FØRMAT(F10.5,2I5)
      DØ.11 I=2,IM2X
      IF(LL.NE.1)READ(1,3)JM,XT
3   FØRMAT(I5,F10.5)
      IF(LL.NE.1)READ(1,4)((Z(J),Y(J),PT(J),J=1,JM)
4   FØRMAT(6F10.5)
11  CØNTINUE

```

The program variables are:

PN(1,1)	ratio of pressure at the nose point (x=0) to stagnation pressure
IM2X	number of axial stations where pressure data are supplied, including the nose point (x=0) and the last station. Note that these axial stations are not required to coincide with the axial stations used above for the input body geometry coordinates
KM2X	number of equally spaced circumferential planes to be used to spline fit the rearranged pressure data in the circumferential direction, including the windward ($\phi=0$) and leeward ($\phi=\pi$) planes. Although the value of KM2X generally differs from KMAX, the same comments given for KMAX above apply here also.
I	axial station number, where I=1 is the nose point (x=0) and I=IM2X is the last station number
JM	number of circumferential positions where pressure data are input
XT	axial distance from the nose to the local axial station, in the same units as input body geometry coordinates
Z(J)	y and z-coordinates, respectively, of position J where pressure ratio is input (units are same as input body geometry coordinates). Note that $\phi(J+1) > \phi(J)$, where $\phi(J) = \tan^{-1}(Z(J)/Y(J))$
Y(J)	
PT(J)	ratio of surface to stagnation pressure at position J
J	subscript corresponding to a circumferential position where pressure ratio is input, where J=1 is the windward ($\phi=0$) plane and J=JM is the leeward ($\phi=\pi$) plane.

Note that JM may vary from one axial station to another and the points $J=1,2,\dots,JM$ do not have to be equally spaced. However, the dimension statement in the program limit JM, IM2X and KM2X to 20.

Step 8.

```
KB=1
3 READ(1,4)BETAD
4 FFORMAT(F10.5)
19 IF(KB.GE.KBM)GØ TØ 10
KB=KB+1
GØ TØ 3
```

The statements above read-in a value of BETAD for each streamline to be computed, where

KB streamline number, $1 \leq KB \leq KBM$

KBM total number of streamlines for half-body $0 \leq \phi \leq \pi$

BETAD angular orientation (β) of each streamline on the ϵ -circle (see page 36 of Part I), measured in degrees with BETAD=0. corresponding to windward streamline, BETAD = 180. corresponding to leeward streamline, and $0 < \text{BETAD} < 180$. A total of KBM values of BETAD must be input.

DESCRIPTION OF OUTPUT

An example of the output obtained from the computer program for two streamlines ($\beta=1^\circ$ and 45°) on a blunted 15° half-angle cone at 20° incidence and $M_\infty = 10.6$ is given in Appendix C. The format for the output was changed slightly in Appendix C to facilitate printing it in this report.

The output data printed are:

1. Body designation specified by NAM in the input data
2. If transition is specified by geometric location (KTR=-1), the Cartesian coordinates of the input points for the beginning of transition (XB,YB,ZB) and end of transition (XE,YE,ZE) are printed. The total number of points used to specify the beginning of transition is given by LMAX, and the number for the end of transition is MMAX.
3. Freestream properties: pressure (p_∞), temperature (T_∞), density (ρ_∞), velocity (V_∞), and Mach number (M_∞).
4. Stagnation properties: pressure (p_s), density (ρ_s), and enthalpy (H_s).

5. Input parameters TRI, TRE, CST, KG, KTR, KP, HMAX, NMAX, KPØ, KS, IMAX, and KMAX.
6. The input body geometry coordinates are printed, and the modified Newtonian pressure (ratioed to stagnation pressure) is printed next to the coordinates of each point. The modified Newtonian pressure ratio corresponding to each input body coordinate is printed even when input pressure data from some other source is supplied.
7. If input pressures (ratioed to stagnation pressure) are supplied, this data is printed along with the corresponding body coordinates.
8. ANG. OF ATTACK - angle of attack, α (degrees)
 ZETA(WALL) - wall enthalpy ratio, ζ_w
 NO. OF STREAMLINES TO BE CALCULATE - KBM
 B - ratio of principal radii of curvature at stagnation point, R_T/R_{11}
 TW - wall temperature, T_w ($^{\circ}R$)
 QWS - stagnation-point heat-transfer rate, $q_{w,s}$ (BTU/ft²-sec)
 HSP - $QWS(6006)/(H_s - h_w)$, (BTU/ft²-sec- $^{\circ}R$) where the factor 6006 is the specific heat at constant pressure for a perfect gas (air), H_s is the stagnation enthalpy, and h_w is the wall enthalpy.
 Note that for a perfect gas HSP is the stagnation-point heat-transfer coefficient.
9. For each position along a streamline, the normal print-out gives the following data:

X - x-location from nose Y - y-location Z - z-location H - scale factor or "equivalent radius", h S - distance along the streamline, measured from the stagnation point	}	same units as input body geometry data
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	---	----------------------------------------------
- BBAR - pressure gradient parameter, $\bar{\beta}$
 P/PS - ratio of local to stagnation pressure, p/p_s
 QW/QWS - ratio of local to stagnation-point heat-transfer rate, $q_w/q_{w,s}$
10. If KPØ=1 is input, then the following additional data are printed at each position along a streamline:
 - UE - velocity at edge of boundary layer, U_e (ft/sec)
 - HE - enthalpy at edge of boundary layer, h_e (ft²/sec²)

RHØE - density at edge of boundary layer, ρ_e (slug/ft³)
MUE - coefficient of viscosity at edge of boundary layer, μ_e
(slug/ft-sec)
MACH NO - Mach number at edge of boundary layer, M_e
RN/FT - Reynolds number per foot, $\rho_e U_e / \mu_e$ (ft⁻¹)
MOM THK - momentum thickness, θ_m (ft)
RNM - momentum thickness Reynolds number, Rn_m
RN1 - integrated unit Reynolds number, Rn_1
R - body radius, f (in units of input body data)
PHI - angular position on body, ϕ (degrees)

$$DR/DPHI - \frac{\partial f}{\partial \phi} \quad (\text{same units as } R)$$

$$D2R/DPHI2 - \frac{\partial^2 f}{\partial \phi^2} \quad (\text{same units as } R)$$

$$DR/DX - \frac{\partial f}{\partial x}$$

$$D2R/DX2 - \frac{\partial^2 f}{\partial x^2} \quad (\text{units of } R^{-1})$$

QB/QSB = (QW/QWS)*(H_s-h_w)/(h_{aw}-h_w) where H_s is freestream stagnation enthalpy, h_{aw} is adiabatic wall enthalpy, and h_w is wall enthalpy.

DIAGNOSTIC MESSAGES

Listed below are descriptions of diagnostic messages printed in the output:

1. NEGATIVE ANGLE OF ATTACK ENCOUNTERED, STAG. POINT SET TO 0.0, PROGRAM CONTINUING. If a negative angle of attack α is input to the program, then the program places the stagnation point at the nose (x=0) in subroutine STAGN, assigns the value -1 to the indicator variable ISTG, prints the message above and continues the computations. For those examples where a negative angle of attack is desired, the body geometry data should be input upside down and then a positive angle of attack can be used in the input.

2. STAGNATION POINT NOT FOUND, RUN ABORTED. An iterative technique is used to locate the Newtonian stagnation point in subroutine STAGN. If the stagnation point should not be located, the program assigns ISTG=0, prints the message above, and terminates the calculations.
3. CALCULATIONS FOR BETA = _____ HAS TERMINATED AFTER _____ INTEGRATIONS. If the computations along a particular streamline should reach the end of the body before the number of integration steps (L) has reached the maximum allowed (NMAX in the list of input), then the message above is printed at the end of the computations for that streamline.
4. *** SUBSCRIPT OUT OF RANGE ***, CALCULATIONS FOR STREAMLINE NO. _____ DISCONTINUED. When the number of integration steps (L) along a streamline has reached the maximum allowed (NMAX) before the end of the body is reached, the message above is printed.
5. INTEGRATION OF STREAMLINE _____ DISCONTINUED DUE TO STEP SIZE, *** H = _____ ***. When the integration step size (H) in function RUNGE is decreased to a value less than 10^{-8} , the message above is printed and computations for this streamline are discontinued.
6. SCALE FACTOR (H) GOING NEG., *** H = _____ STREAMLINE _____ DISCONTINUED. The message above is printed if the scale factor or "equivalent radius" (H) becomes less than 10^{-4} , and the computations for that streamline are discontinued.
7. REY NO (RNM) GOING NEG., *** RNM = _____, STREAMLINE _____ DISCONTINUED. If the momentum thickness Reynolds number (Rn_m) becomes less than 10^{-4} , the message above is printed, and the computations for that streamline are discontinued.
8. **** BEGINNING OF TRANSITION ****. This message is written just before the print-out at the beginning of the transition region.
9. **** END OF TRANSITION ****. This message is written just after the print-out at the end of the transition region.

TEST CASES

Test cases were calculated for: Case I. - A blunted 15° half-angle cone at $\alpha = 20^\circ$ and $M_\infty = 10.6$, Case II. - A blunted 70° slab delta wing

at $\alpha = 10^\circ$ and $M_\infty = 8$, and Case III. - The HL-10 Lifting Body at $\alpha = 20^\circ$ and $M_\infty = 10$. Inputs for these cases are given below, and output data for two streamlines on the blunted 15° half-angle cone are given in Appendix C. Results for all three cases are presented graphically in Part I of this report, and the results for the blunted 15° half-angle cone are also shown to compare favorably with experimental data.

Case I. - Blunted 15° Half-Angle Cone

Input data for a blunted 15° half-angle cone at $\alpha = 20^\circ$ and $M_\infty = 10.6$ are presented on the pages which follow. Written beside each section of input data is the step number which describes that data in Description of Input. Step 1 corresponds to the body designation, and for Step 2 the body geometry was specified by input coordinates at 19 axial stations (IMAX=19) and 20 planes around the half body for the rearranged circumferential points (KMAX=20). As noted in Part I of this report, the body geometry could be represented by simple analytical expressions, but the coordinates of 20 points around the circumference of the half body at 19 axial stations were used to generate the body geometry in order to test the accuracy of the doubly cubic spline function. This data corresponds to Step 3 of the input, and the coordinates are input in inches.

Freestream properties are shown in Step 4, where $p_\infty = 2.6614 \text{ lb/ft}^2$, $T_\infty = 89.971^\circ\text{R}$, and $V_\infty = 4928.1 \text{ ft/sec}$. Since only laminar heating rates were calculated here, TRI=0 and TRE=0. In order to convert the input coordinates from inches to feet, a value of CST=0.0833333 was used. The maximum step size was set at HMAX=0.4, and a perfect gas (KG=0) was specified. Again, since only laminar heating rates were calculated, KTR could be any integer (KTR=0 was used here) and KS=0. The maximum number of integration steps along a streamline was input as NMAX=100, and since the additional print-out along each streamline was desired, KPØ=1.

Step 5 of the input data was not included because transition was not required. For step 6, an angle of attack (ALPD) of 20° , wall enthalpy ratio (ZW) of 0.251, number of streamlines (KBM) of 2, and streamline computation by modified Newtonian pressures (KP=1) were input. Step 7 of

Input for Case 1

BLUNTED 15-DEG. CONE

19	20	1	2	3
0.00000	.06855	.03557	.21318	.07018
.13275	.17056	.15901	.14638	.18094
.20952	.05306	.21539	.01785	.21529
.19793	-.08682	.18094	-.11821	.15201
.10287	-.19008	.07018	-.20442	.03557
20	.13710			0.00000
0.00000	.28987	.04771	.28592	.09412
.17804	.22875	.21327	.19633	.24267
.28100	.07116	.28888	.02394	.28888
.26546	-.11644	.24267	-.15855	.21327
.13796	-.27494	.09412	-.27417	.04771
20	.20564			0.00000
0.00000	.33458	.05507	.33002	.10864
.20550	.26403	.24616	.22660	.28010
.32434	.08213	.33344	.02763	.33344
.30640	-.13440	.28010	-.18300	.24616
.15924	-.23425	.10064	-.31645	.05507
20	.27419			0.00000
0.00000	.36120	.05945	.35627	.11728
.22185	.28503	.26574	.24463	.30238
.35014	.08867	.35996	.02983	.35996
.33077	-.14509	.30238	-.19756	.26574
.17191	-.31766	.11728	-.34163	.05945
20	.28169			0.00000
0.00000	.36321	.05978	.35825	.11793
.22309	.28662	.26722	.24599	.30406
.35209	.08916	.36197	.02999	.36197
.33261	-.14590	.30406	-.19865	.26722
.17287	-.31945	.11793	-.34353	.05978
20	.30000			0.00000
0.00000	.47170	.06941	.41595	.13693
.25301	.33278	.31026	.28561	.35303
.40880	.10352	.42026	.03482	.42026
.38618	-.16940	.15303	-.23065	.31026
.20071	-.37088	.13693	-.39685	.06941
20	.75000			0.00000
0.00000	.19009	.10287	.20442	.07018
.13275	.08682	.18094	.14638	.18094
.20952	-.05306	.21539	.01785	.21529
.19793	.17056	.15201	-.11821	.15201
.10287	-.19008	.03557	-.20442	.03557
20	.13710			0.00000
0.00000	.28987	.09412	.28592	.09412
.17804	.22875	.24267	.19633	.24267
.28100	.07116	.28888	.02394	.28888
.26546	-.11644	.21327	-.15855	.21327
.13796	-.27494	.04771	-.27417	.04771
20	.20564			0.00000
0.00000	.33458	.10864	.33002	.10864
.20550	.26403	.28010	.22660	.28010
.32434	.08213	.33344	.02763	.33344
.30640	-.13440	.24616	-.18300	.24616
.15924	-.23425	.05507	-.31645	.05507
20	.27419			0.00000
0.00000	.36120	.11728	.35627	.11728
.22185	.28503	.30238	.24463	.30238
.35014	.08867	.35996	.02983	.35996
.33077	-.14509	.26574	-.19756	.26574
.17191	-.31766	.05945	-.34163	.05945
20	.28169			0.00000
0.00000	.36321	.11793	.35825	.11793
.22309	.28662	.30406	.24599	.30406
.35209	.08916	.36197	.02999	.36197
.33261	-.14590	.26722	-.19865	.26722
.17287	-.31945	.05978	-.34353	.05978
20	.30000			0.00000
0.00000	.47170	.13693	.41595	.13693
.25301	.33278	.35303	.28561	.35303
.40880	.10352	.42026	.03482	.42026
.38618	-.16940	.31026	-.23065	.31026
.20071	-.37088	.06941	-.39685	.06941
20	.75000			0.00000
0.00000	.19009	.10287	.20442	.07018
.13275	.08682	.18094	.14638	.18094
.20952	-.05306	.21539	.01785	.21529
.19793	.17056	.15201	-.11821	.15201
.10287	-.19008	.03557	-.20442	.03557
20	.13710			0.00000
0.00000	.28987	.09412	.28592	.09412
.17804	.22875	.24267	.19633	.24267
.28100	.07116	.28888	.02394	.28888
.26546	-.11644	.21327	-.15855	.21327
.13796	-.27494	.04771	-.27417	.04771
20	.20564			0.00000
0.00000	.33458	.10864	.33002	.10864
.20550	.26403	.28010	.22660	.28010
.32434	.08213	.33344	.02763	.33344
.30640	-.13440	.24616	-.18300	.24616
.15924	-.23425	.05507	-.31645	.05507
20	.27419			0.00000
0.00000	.36120	.11728	.35627	.11728
.22185	.28503	.30238	.24463	.30238
.35014	.08867	.35996	.02983	.35996
.33077	-.14509	.26574	-.19756	.26574
.17191	-.31766	.05945	-.34163	.05945
20	.28169			0.00000
0.00000	.36321	.11793	.35825	.11793
.22309	.28662	.30406	.24599	.30406
.35209	.08916	.36197	.02999	.36197
.33261	-.14590	.26722	-.19865	.26722
.17287	-.31945	.05978	-.34353	.05978
20	.30000			0.00000
0.00000	.47170	.13693	.41595	.13693
.25301	.33278	.35303	.28561	.35303
.40880	.10352	.42026	.03482	.42026
.38618	-.16940	.31026	-.23065	.31026
.20071	-.37088	.06941	-.39685	.06941
20	.75000			0.00000
0.00000	.19009	.10287	.20442	.07018
.13275	.08682	.18094	.14638	.18094
.20952	-.05306	.21539	.01785	.21529
.19793	.17056	.15201	-.11821	.15201
.10287	-.19008	.03557	-.20442	.03557
20	.13710			0.00000
0.00000	.28987	.09412	.28592	.09412
.17804	.22875	.24267	.19633	.24267
.28100	.07116	.28888	.02394	.28888
.26546	-.11644	.21327	-.15855	.21327
.13796	-.27494	.04771	-.27417	.04771
20	.20564			0.00000
0.00000	.33458	.10864	.33002	.10864
.20550	.26403	.28010	.22660	.28010
.32434	.08213	.33344	.02763	.33344
.30640	-.13440	.24616	-.18300	.24616
.15924	-.23425	.05507	-.31645	.05507
20	.27419			0.00000
0.00000	.36120	.11728	.35627	.11728
.22185	.28503	.30238	.24463	.30238
.35014	.08867	.35996	.02983	.35996
.33077	-.14509	.26574	-.19756	.26574
.17191	-.31766	.05945	-.34163	.05945
20	.28169			0.00000
0.00000	.36321	.11793	.35825	.11793
.22309	.28662	.30406	.24599	.30406
.35209	.08916	.36197	.02999	.36197
.33261	-.14590	.26722	-.19865	.26722
.17287	-.31945	.05978	-.34353	.05978
20	.30000			0.00000
0.00000	.47170	.13693	.41595	.13693
.25301	.33278	.35303	.28561	.35303
.40880	.10352	.42026	.03482	.42026
.38618	-.16940	.31026	-.23065	.31026
.20071	-.37088	.06941	-.39685	.06941
20	.75000			0.00000
0.00000	.19009	.10287	.20442	.07018
.13275	.08682	.18094	.14638	.18094
.20952	-.05306	.21539	.01785	.21529
.19793	.17056	.15201	-.11821	.15201
.10287	-.19008	.03557	-.20442	.03557
20	.13710			0.00000
0.00000	.28987	.09412	.28592	.09412
.17804	.22875	.24267	.19633	.24267
.28100	.07116	.28888	.02394	.28888
.26546	-.11644	.21327	-.15855	.21327
.13796	-.27494	.04771	-.27417	.04771
20	.20564			0.00000
0.00000	.33458	.10864	.33002	.10864
.20550	.26403	.28010	.22660	.28010
.32434	.08213	.33344	.02763	.33344
.30640	-.13440	.24616	-.18300	.24616
.15924	-.23425	.05507	-.31645	.05507
20	.27419			0.00000
0.00000	.36120	.11728	.35627	.11728
.22185	.28503	.30238	.24463	.30238
.35014	.08867	.35996	.02983	.35996
.33077	-.14509	.26574	-.19756	.26574
.17191	-.31766	.05945	-.34163	.05945
20	.28169			0.00000
0.00000	.36321	.11793	.35825	.11793
.22309	.28662	.30406	.24599	.30406
.35209	.08916	.36197	.02999	.36197
.33261	-.14590	.26722	-.19865	.26722
.17287	-.31945	.05978	-.34353	.05978
20	.30000			0.00000
0.00000	.47170	.13693	.41595	.13693
.25301	.33278	.35303	.28561	.35303
.40880	.10352	.42026	.03482	.42026
.38618	-.16940	.31026	-.23065	.31026
.20071	-.37088	.06941	-.39685	.06941
20	.75000			0.00000
0.00000	.19009	.10287	.20442	.07018
.13275	.08682	.18094	.14638	.18094
.20952	-.05306	.21539	.01785	.21529
.19793	.17056	.15201	-.11821	.15201
.10287	-.19008	.03557	-.20442	.03557
20	.13710			0.00000
0.00000	.28987	.09412	.28592	.09412
.17804	.22875	.24267	.19633	.24267
.28100	.07116	.28888	.02394	.28888
.26546	-.11644	.21327	-.15855	.21327
.13796	-.27494	.04771	-.27417	.04771
20	.20564			0.00000
0.00000	.33458	.10864	.33002	.10864
.20550	.26403	.28010	.22660	.28010
.32434	.08213	.33344	.02763	.33344
.30640	-.13440	.24616	-.18300	.24616
.15924	-.23425	.05507	-.31645	.05507
20	.27419			0.00000
0.00000	.36120	.11728	.35627	.11728
.22185	.28503	.30238	.24463	.30238
.35014	.08867	.359		

0.00000	.48869	.06044	.48202	.15868	.46221	.23259	.42979
.30016	.38564	.35954	.33098	.40911	.26729	.44753	.19630
.47373	.11997	.48702	.04036	.48702	-.04036	.47373	-.11997
.44753	-.19630	.40911	-.26729	.35954	-.33098	.30016	-.38564
.23259	-.42979	.15868	-.46221	.08044	-.43202	0.00000	-.48869
20 1.00000							
0.00000	.55568	.09146	.54810	.18043	.52557	.26447	.48870
.34130	.43851	.40882	.37635	.46519	.30393	.50887	.22321
.53867	.13641	.55378	.04589	.55378	-.04589	.53867	-.13641
.50887	-.22321	.46519	-.30393	.40882	-.37635	.34130	-.43851
.26447	-.48870	.18043	-.52557	.09146	-.54810	0.00000	-.55568
20 2.00000							
0.00000	.82363	.13556	.81239	.26743	.77900	.39200	.72436
.50588	.64996	.60596	.55783	.68951	.45048	.75425	.33085
.79842	.20219	.82081	.06801	.82081	-.06801	.79842	-.20219
.75425	-.33085	.68951	-.45048	.60596	-.55783	.50588	-.64996
.39200	-.72436	.26743	-.77900	.13556	-.81239	0.00000	-.92363
20 3.00000							
0.00000	1.09157	.17967	1.07669	.35443	1.03243	.51953	.96001
.67046	.86141	.80310	.73930	.91383	.59703	.99963	.43848
1.05817	.26797	1.08785	.09014	1.08785	-.09014	1.05817	-.26797
.99963	-.43848	.80310	-.59703	.80310	-.73930	.67046	-.86141
.51953	-.96001	.35443	-1.03243	.17967	-1.07669	0.00000	-1.09157
20 4.00000							
0.00000	1.35952	.22377	1.34098	.44144	1.28586	.64706	1.19567
.83504	1.07286	1.00023	.92078	1.13815	.74359	1.24502	.54611
1.31792	.33374	1.35488	.11227	1.35488	-.11227	1.31792	-.33374
1.24502	-.54611	1.13815	-.74359	1.00023	-.92078	.83504	-1.07286
.64706	-1.19567	.44144	-1.28586	.22377	-1.34098	0.00000	-1.35952
20 5.00000							
0.00000	1.76145	.28992	1.73742	.57194	1.66601	.83836	1.54915
1.08190	1.39003	1.29594	1.19300	1.47462	.96342	1.61309	.70757
1.70755	.43241	1.75543	.14546	1.75543	-.14546	1.70755	-.43241
1.61309	-.70757	1.47462	-.96342	1.29594	-1.19300	1.08190	-1.39003
.83836	-1.54915	.57194	-1.66601	.28992	-1.73742	0.00000	-1.76145
20 7.00000							
0.00000	2.16337	.35608	2.13387	.70245	2.04615	1.02965	1.90263
1.32877	1.70720	1.59164	1.46521	1.81110	1.18325	1.98116	.86902
2.09717	.53108	2.15598	.17865	2.15598	-.17865	2.09717	-.53108

Input for Case I (concluded)

1.98116	-0.86902	1.81110	-1.18325	1.59164	-1.46521	1.32877	-1.70720
1.02965	-1.90263	.70245	-2.04615	.35608	-2.13387	0.00000	-2.16337
20 10.00000							
0.00000	2.96722	.48839	2.92675	.96345	2.80645	1.41224	2.60959
1.82250	2.34155	2.18305	2.00964	2.48406	1.62291	2.71730	1.19192
2.87642	.72841	2.95708	.24503	2.95708	-.24503	2.97642	-.72841
2.71730	-1.19192	2.48406	-1.62291	2.18305	-2.00964	1.82250	-2.34155
1.41224	-2.60959	.96345	-2.80645	.48839	-2.92675	0.00000	-2.96722
20 13.00000							
0.00000	3.77107	.62070	3.71963	1.22446	3.56674	1.79483	1.31635
2.31624	2.97590	2.77446	2.55407	3.15701	2.06258	3.45364	1.91482
3.65567	.92574	3.75819	.31141	3.75819	-.31141	3.65567	-.92574
3.45344	-1.51482	3.15701	-2.06258	2.77446	-2.55407	2.31624	-2.97590
1.79483	-3.31655	1.22446	-3.56674	.62070	-3.71963	0.00000	-3.77107
20 16.00000							
0.00000	4.57491	.75301	4.51252	1.48547	4.32703	2.17742	4.02352
2.80997	3.61025	3.36587	3.09850	3.82996	2.50224	4.18958	1.83772
4.43492	1.12307	4.55929	.37779	4.55929	-.37779	4.43492	-1.12307
4.18958	-1.83772	3.82996	-2.50224	3.36587	-3.09850	2.80997	-3.61025
2.17742	-4.02352	1.48547	-4.32703	.75301	-4.51252	0.00000	-4.57491
20 19.00000							
0.00000	5.37876	.88532	5.30540	1.74648	5.08733	2.56001	4.73048
3.30370	4.24460	3.95728	3.64294	4.50292	2.94190	4.92573	2.16062
5.21417	1.32041	5.36039	.44417	5.36039	-.44417	5.21417	-1.32041
4.92573	-2.16062	4.50292	-2.94190	3.95728	-3.64294	3.30370	-4.24460
2.56001	-4.73048	1.74648	-5.08733	.88532	-5.30540	0.00000	-5.37876
20 22.00000							
0.00000	6.18261	1.01762	6.09829	2.00749	5.84762	2.94260	5.43744
3.79744	4.87895	4.54869	4.18737	5.17587	3.38157	5.66187	2.48353
5.99342	1.51774	6.16149	.51056	6.16149	-.51056	5.99342	-1.51774
5.66187	-2.48353	5.17587	-3.38157	4.54869	-4.18737	3.79744	-4.87895
2.94260	-5.43744	2.00749	-5.84762	1.01762	-6.09829	0.00000	-6.18261
2.6614	89.971	4928.103	0.	0.	.083333333	.4	
20.	0	0	100	1			
1.0	.251	2	1				
45.0							

4
6
8

the input data was omitted because modified Newtonian pressures were used in lieu of an input pressure distribution.

The input data given here only have two streamlines to be calculated for Step 8 - BETAD of 1 degree and 45 degrees. Note, however, that the data presented in Part I of this report used BETAD values of 1°, 10°, 15°, and 45°.

A complete listing of the output data for this case is given in Appendix C. For an explanation of this data, see Description of Output. From the data listed in Appendix C, it is observed that the integration step size along a streamline is small near the stagnation point, but it increases rapidly downstream due to the variable step-size Runge-Kutta integration routine. The streamlines move from the windward side of the body and approach the leeward plane downstream. The scale factor or "equivalent radius" increases all along the BETAD = 1° streamline, but it decreases along the BETAD = 45° streamline after it has "essentially" reached the leeward plane ($\text{PHI} = 180.$). It should be noted, however, that the streamlines are continued into the "shadowed" region of the body where the surface pressure is assumed to be freestream static pressure. It is possible that the flow separates from the body somewhere in this region, and therefore the calculated properties are questionable there. Along each streamline the heating-rate ratio QW/QWS decreases and then gradually levels out. The computational time (CPU) for this case on an IBM 360/75 computer was 1:47 minutes.

Case II. - Blunted 70° Slab Delta Wing

Input data are given on the following pages for a 70° swept delta wing with a cylindrical leading edge which is tangent to a flat slab on the upper and lower surfaces. The blunt nose is a spherical cap, and the radius of both the spherical cap and cylindrical leading edge is one foot. Again, the step number corresponding to that in the Description of Input is written beside each section of the input data.

Step 1 corresponds to the body designation, and in Step 2 the body geometry is specified by input coordinates at 19 axial stations ($\text{IMAX}=19$) and 19 planes around the half body for the rearranged circumferential points

Input for Case 11 (continued)

0.0	0.98669	0.25589	0.95500	0.49454	0.85658	0.70263	0.70263
0.86675	0.50042	0.97279	0.26066	1.00958	0.00000	0.97279	-0.26066
0.86675	-0.50042	0.70263	-0.70263	0.49455	-0.85657	0.25589	-0.95500
0.00000	-0.98669						
13	0.95000						
0.0	0.99875	0.25872	0.96555	0.50328	0.87171	0.72015	0.72015
0.89346	0.51584	1.00654	0.26970	1.04598	0.00000	1.00654	-0.26970
0.89346	-0.51584	0.72015	-0.72015	0.50328	-0.87171	0.25872	-0.96555
0.00000	-0.99875						
13	1.05000						
0.0	1.00000	0.26089	0.97365	0.51156	0.98604	0.73722	0.73722
0.91989	0.53110	1.04020	0.27872	1.08238	0.00000	1.04020	-0.27872
0.91989	-0.53110	0.73722	-0.73722	0.51156	-0.98604	0.26089	-0.97365
0.00000	-1.00000						
13	1.15000						
0.0	1.00000	0.26277	0.98068	0.51937	0.89958	0.75383	0.75383
0.94602	0.54618	1.07377	0.28772	1.11877	0.00000	1.07378	-0.28772
0.94602	-0.54618	0.75383	-0.75383	0.51938	-0.89958	0.26277	-0.98068
0.00000	-1.00000						
13	1.25000						
0.0	1.00000	0.26437	0.98664	0.52673	0.91233	0.76999	0.76999
0.97186	0.56110	1.10725	0.29669	1.15517	0.00000	1.10725	-0.29669
0.97186	-0.56110	0.76999	-0.76999	0.52673	-0.91233	0.26437	-0.98664
0.00000	-1.00000						
13	1.35000						
0.0	1.00000	0.26568	0.99152	0.53363	0.92427	0.78570	0.78570
0.99741	0.57585	1.14064	0.30564	1.19157	0.00000	1.14064	-0.30563
0.99741	-0.57585	0.78570	-0.78570	0.53363	-0.92427	0.26568	-0.99152
0.00000	-1.00000						
13	1.45000						
0.0	1.00000	0.26669	0.99531	0.54006	0.93540	0.80095	0.80095
1.02267	0.59044	1.17394	0.31456	1.22796	0.00000	1.17394	-0.31456
1.02267	-0.59044	0.80095	-0.80095	0.54006	-0.93540	0.26669	-0.99531
0.00000	-1.00000						
13	1.55000						
0.0	1.00000	0.26741	0.99800	0.54601	0.94572	0.81573	0.81573
1.04763	0.60485	1.20715	0.32346	1.26436	0.00000	1.20715	-0.32345
1.04763	-0.60485	0.81573	-0.81573	0.54601	-0.94572	0.26741	-0.99800
0.00000	-1.00000						

3

Input for Case II (concluded)

13	1.65000	0.26795	0.99957	0.55149	0.95521	0.83005	0.83005
0.0	1.00000	1.24027	0.83233	1.30076	0.00000	1.24027	-0.32233
1.07230	0.61909	0.83005	-0.83005	0.55145	-0.95521	0.26783	-0.99957
0.00000	-1.00000						
13	1.75000	0.26795	1.00000	0.55648	0.95366	0.84390	0.84390
0.0	1.00000	1.27330	0.34118	1.33715	0.00000	1.27330	-0.34118
1.09667	0.63316	0.84390	-0.84390	0.55644	-0.95366	0.26795	-1.00000
0.00000	-1.00000						
13	1.85000	0.26795	1.00000	0.56098	0.97165	0.85727	0.85727
0.0	1.00000	1.30624	0.35001	1.37355	0.00000	1.30624	-0.35000
1.12074	0.64706	0.85727	-0.85727	0.56098	-0.97165	0.26795	-1.00000
0.00000	-1.00000						
13	1.95000	0.26795	1.00000	0.56497	0.97998	0.87016	0.87016
0.0	1.00000	1.33909	0.35881	1.40995	0.00000	1.33909	-0.35881
1.14452	0.66079	0.87016	-0.87016	0.56497	-0.97998	0.26795	-1.00000
0.00000	-1.00000						

1000.	416.	0600.	1000.	2000.	1.		
0.	0.	0	1	100	1		
10.	0.4	0.4	8	1			
0.							
1.							
10.							
30.							
60.							
90.							
170.							
179.							

3

4

6

8

(KMAX=19). The coordinates of 13 points around the circumference of the half body at 19 axial stations were used to generate the body geometry in Step 3. All body coordinates were input in feet.

In Step 4 the freestream properties are $p_{\infty} = 10^3$ lb/ft², $T_{\infty} = 416^{\circ}\text{R}$, and $V_{\infty} = 8000$ ft/sec. For this case transition was assumed to begin at a momentum thickness Reynolds number of 10^3 (TRI= 10^3) and end at 2×10^3 (TRE= 2×10^3) for each inviscid surface streamline. Since the input body coordinates have units of feet, CST = 1.0. A maximum integration step size of HMAX = 0.05 was input, and a perfect gas (KG=0) was specified. Since transition was based on momentum thickness Reynolds number, KTR=0 and KS=1. The maximum number of integration steps allowed along a streamline was NMAX=100, and KP ϕ =1 was input to obtain the additional print-out data along each streamline.

Input data corresponding to Step 5 were omitted because transition was not specified by geometric location. In Step 6 the angle of attack was ALPD= 10° , the wall enthalpy ratio was set at ZW=0.4, the number of streamlines to be calculated was KBM=8, and the streamlines were calculated from modified Newtonian pressures (KP=1).

Step 7 was omitted since surface pressures from some other source were not used. For the 8 streamlines to be calculated, the values of BETAD in Step 8 are 0, 1, 10, 30, 60, 90, 170, and 179 degrees.

The computational time (CPU) for this case was 3:02 minutes on an IBM 360/75 computer. Surface streamlines and heating rate ratios are presented graphically in Part I of this report.

Case III. - HL-10 Lifting Body

The third, and last, test case computed was for the HL-10 lifting body, which is described in Part I of this report. Input data for this case are listed on the following pages, where again the Step numbers corresponding to the steps in the Description of Input are written beside each section of input data. Step 1 gives the body designation, and Step 2 lists the number of axial body stations (IMAX=20) and rearranged circumferential planes (KMAX=20) used to describe the body geometry. In Step 3 the

Input for Case III (continued)

0.0	28.81049	15.00000	28.57819	18.00000	27.70070	20.00000	26.56920
21.71739	25.00000	23.07059	23.00000	24.33679	19.00000	24.52669	16.00000
24.90120	12.00000	24.03679	8.00000	23.38469	4.00000	22.37920	0.0
21.71689	-2.00000	19.99849	-6.00000	17.61240	-10.00000	14.29470	-14.00000
10.72210	-17.00000	7.00000	-18.92519	3.00000	-19.94550	0.0	-20.15099
20 64.82199							
0.0	30.75479	20.00000	30.02029	24.65939	27.00000	26.52460	24.00000
27.36110	21.00000	27.56219	18.36859	27.49419	15.00000	27.30989	12.00000
26.99409	9.00000	26.52899	6.00000	25.89200	3.00000	25.05429	0.0
23.97769	-3.00000	22.07619	-7.00000	19.45630	-11.00000	16.80959	-14.00000
12.00000	-17.55959	8.00000	-19.26479	4.00000	-20.18729	0.0	-20.47539
20 75.40500							
0.0	32.24239	20.00000	32.14760	23.00000	31.49159	26.00000	29.94739
28.03419	28.00000	29.72179	25.00000	30.59639	20.00000	30.54909	17.00000
30.31290	13.00000	29.85370	9.00000	28.90790	4.00000	27.78690	0.0
26.25159	-4.00000	23.52840	-9.00000	19.89539	-13.47460	15.00000	-17.13770
12.00000	-18.55890	9.00000	-19.56250	5.00000	-20.38589	0.0	-20.73000
20 85.98799							
0.0	33.29259	26.00000	32.51759	30.00000	30.10809	31.73439	28.00000
33.32458	24.00000	33.62650	20.00000	33.42360	15.00000	33.14780	12.00000
34.74249	9.00000	32.19170	6.00000	31.47859	3.00000	30.57329	0.0
29.43900	-3.00000	28.01959	-6.00000	25.51799	-10.00000	21.86549	-14.00000
15.00000	-18.16809	11.00000	-19.51729	6.00000	-20.49449	0.0	-20.86909
20 96.57100							
0.0	33.85390	28.00000	33.36349	31.00000	32.09209	33.10649	30.47899
35.02829	28.00000	36.45799	24.00000	36.65169	20.00000	36.48039	16.00000
36.10170	12.00000	35.49109	8.00000	34.61269	4.00000	33.41209	0.0
31.80040	-4.00000	29.61679	-8.00000	26.50369	-12.00000	20.00000	-16.78459
16.00000	-18.48329	11.00000	-19.83469	5.00000	-20.65909	0.0	-20.84949
20 107.15399							
0.0	33.90619	31.00000	33.36938	33.00000	32.57889	36.46750	30.00000
38.52119	27.00000	39.64119	23.00000	39.69679	21.00000	39.61189	18.00000
39.31830	14.00000	38.80170	10.00000	37.79810	5.00000	36.30899	0.0
34.15770	-5.00000	30.92819	-10.00000	36.71030	-14.00000	20.12309	-17.56670
15.12310	-19.11530	10.12130	-20.04340	6.12310	-20.45889	0.0	-20.66879
20 117.73700							
0.0	33.46039	34.00000	32.86449	37.00000	31.42609	39.01639	29.82059
41.21680	27.00000	42.62610	23.00000	42.73349	21.00000	42.65430	18.00000
42.75439	15.00000	41.83459	10.00000	40.81009	5.00000	39.28569	0.0

Input for Case III (continued)

16.50929	-6.00000	11.63770	-12.00000	25.71589	-15.88430	20.71589	-17.04259
16.73589	-18.88809	10.73590	-19.83849	5.74590	-20.22620	0.0	-20.34109
20.128.31994							
0.0	32.44829	36.00000	32.11670	36.00000	31.42399	41.00000	29.61049
43.51900	27.00000	44.72420	25.00000	45.76309	21.00000	45.75049	19.30000
45.61659	16.00000	44.84398	10.00000	43.91910	5.00000	42.36609	0.0
40.06679	-5.00000	36.29900	-10.09060	31.26519	-14.00000	24.82300	-16.62209
18.82300	-18.48239	13.92300	-19.26239	8.82300	-19.69769	0.0	-19.89330
20.138.90300							
0.0	30.93349	38.00000	30.80659	49.00000	30.39319	41.00000	29.90979
44.00000	28.09470	46.88989	25.00000	48.62500	21.00000	48.79270	18.00000
48.56899	14.00000	48.12360	10.00000	47.12549	5.00000	45.55530	0.0
42.53090	-6.00000	36.67619	-12.00000	27.33229	-16.50470	22.33229	-17.77499
17.33989	-18.58519	12.33990	-19.06679	8.33990	-19.27289	0.0	-19.35519
20.149.48599							
0.0	29.07959	41.00000	28.93649	44.00000	28.04230	47.00000	26.23549
50.00850	23.00000	51.69220	19.00000	51.81719	17.00000	51.73830	14.00000
51.58479	12.00000	51.95019	8.00000	50.16969	4.00000	48.95829	0.0
45.66669	-6.00000	49.18509	-12.00000	34.23889	-14.56540	26.23889	-16.98029
20.23889	-17.96199	16.23889	-18.36079	10.23890	-18.60169	0.0	-18.75479
20.160.06899							
0.0	26.96669	44.00000	26.84409	47.00000	25.93230	50.00000	24.10269
52.15849	22.00000	53.53859	20.00000	54.59170	17.00000	54.67299	15.00000
54.77460	12.00000	54.36319	8.00000	51.56850	4.00000	52.27829	0.0
49.62140	-5.00000	44.71519	-10.00000	35.27080	-14.91200	28.27080	-16.56009
22.27080	-17.41260	16.27080	-17.87999	12.27080	-18.07579	0.0	-18.10010
20.170.60199							
0.0	24.72069	46.00000	24.70699	48.00000	24.37659	50.00000	23.64229
52.00000	22.50060	54.83420	20.00000	56.86409	17.00000	57.82639	14.00000
57.90140	12.00000	57.67639	8.00000	57.05069	4.00000	55.85550	0.0
52.27129	-6.00000	47.71860	-10.00000	40.30280	-13.68310	33.30280	-15.55810
26.30280	-15.60489	20.30280	-17.09489	14.30280	-17.33060	0.0	-17.36429
20.181.23499							
0.0	22.28999	49.00000	22.27739	51.00000	21.93629	54.00000	20.64499
56.94600	18.39809	58.96309	16.00000	60.08009	14.00000	60.74939	12.00000
60.94310	10.29810	60.96189	8.00000	60.55550	4.00000	59.59659	0.0
55.27220	-6.68150	46.87349	-12.14370	39.87349	-14.92730	31.87349	-15.65060
26.87349	-10.11378	21.87349	-16.39409	16.87349	-16.53260	0.0	-16.58260

Input for Case III (concluded)

1000.	416.	10000.	10.	20.	.08333	18.1235	(4)
	-1		1	100	0		
33.073	23.32329	0.	33.073	0.	17.19768	33.073	-18.78110
0.							(5)
54.2390	28.81049	0.0	54.2390	0.	22.3792	54.2390	-20.15099
0.							(6)
20.	0.1	0	1				(8)
0.							
1.							
10.							
30.							
60.							
90.							
170.							
179.							

coordinates of the input body points are listed at 20 axial locations and 19 circumferential positions, where all coordinates are input in inches.

The freestream properties are given in Step 4, where $p_{\infty} = 10^3$ lb/ft², $T_{\infty} = 416$ °R, and $V_{\infty} = 10^4$ ft/sec. In this case transition was specified by geometric location; therefore TRI and TRE could be any numbers (values of TRI=10. and TRE=20. were arbitrarily input). Since the input body coordinates were in inches, a value of CST = 0.08333 was used. The maximum integration step size was chosen to be HMAX = 18.1235, which is one-tenth of the distance from the nose to the last axial body station. Equilibrium air (KG=1) was used for this case, and KTR=-1 was input because transition is specified by geometric location. For laminar, transitional, and turbulent heating, any non-zero value of KS may be used, and here KS=1 was input. The number of integration steps along a streamline was limited to NMAX=100, and only the normal print-out along each streamline was desired (KPØ=0).

In Step 5 data was input to specify beginning and end of transition by geometric location. Three points were used to specify the beginning (IMAX=3) and end (MMAX=3) of transition. In each case the axial location was arbitrarily chosen to be $x = 33.073$ " for beginning and $x = 54.239$ " for end of transition.

For Step 6, the angle of attack was ALPD = 20°, wall enthalpy ratio ZW = 0.1, number of streamlines KBM = 5, and the streamlines were calculated by the "simplified method" discussed in Part I (KP=0). Step 7 was omitted. For the five streamlines to be calculated, values of BETAD in Step 8 are 0, 45, 90, 135, and 180 degrees.

Heating-rate ratios for this case are presented graphically in Part I of this report for the windward streamline. The computational time for this case (CPU) was 1:48 minutes on the IBM 360/75 computer.

ACCURACY AND LIMITATIONS OF METHOD

The method used in the computer program described herein is applicable to a large class of configurations subject to the following restrictions:

1. The body must have at least one plane of symmetry, and the free-stream velocity vector must be parallel to this plane of symmetry.

2. The body radius $r = f(x, \phi)$ must be single valued.
3. The nose of the body must be blunted, and at $x=0$ $f(0, \phi)=0$ and $\frac{\partial f}{\partial x}(0, \phi) \rightarrow \infty$.

A two-dimensional cubic spline function is utilized to represent both the body geometry and the input pressure distribution. The computer program listed in Appendix A has dimension statements which limit the number of axial and circumferential positions to 20; however, these dimensions could be changed to accommodate as many positions as desired. As indicated in Part I of this report, the spline function does not smooth out data points (although it does smooth derivatives), and therefore data points used in the spline function should be reasonably accurate. When pressure data from some other source are used, they should be smoothed before using them in the computer program.

The accuracy of the spline function is affected by both the number and location of data points used. More accurate results are generally obtained when the data points are nearly evenly spaced in the axial and circumferential directions. In some cases a large number of data points are needed to make the spacing between data points nearly even and also have a reasonable number of points in regions where the data is highly varying. As an example, consider the cross sectional geometry of a blunted slab delta wing far downstream of the nose. At this axial station the thickness of the wing is small compared to the span, and a large number of body coordinates are needed to make the data evenly spaced in the circumferential direction and still have a reasonable number of points near the tip of the wing.

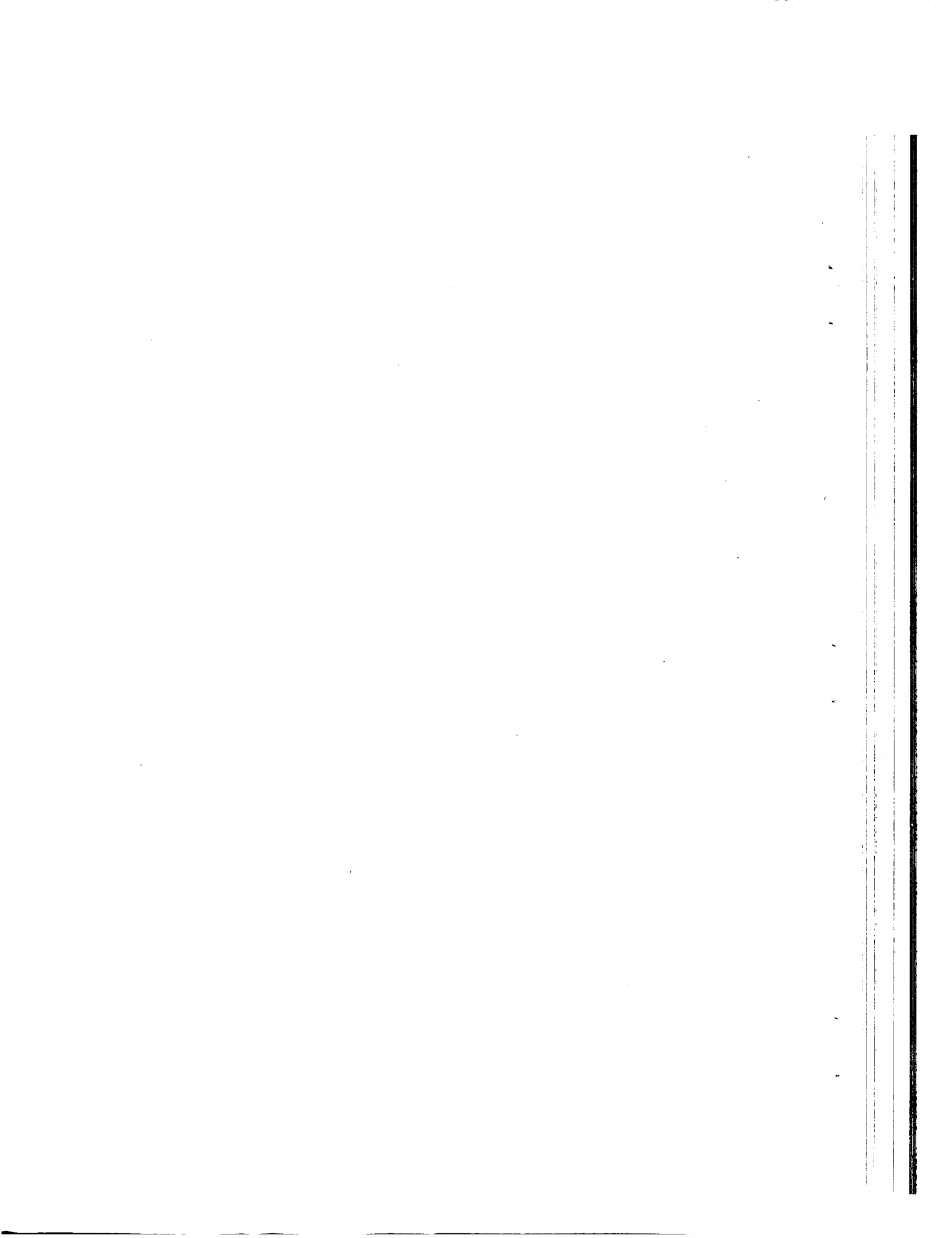
Input freestream properties for this method are limited to supersonic speeds, and when modified Newtonian pressures are used the speed should be hypersonic. Although the angle of attack is not limited to small angles, heating rates on the lee side of the body are questionable at large angles of attack. The approximate methods used to calculate heating rates are more accurate for cold walls ($\zeta_w \ll 1$) than hot walls.

In Part I of this report the present method was found to predict laminar heating rates very well on the blunted 15° half-angle cone at 20° incidence and $M_\infty = 10.6$. Additional comparisons of the present theory with

experimental data on other body shapes and for transitional and turbulent heating are needed to assess the accuracy of the theory more thoroughly.

CONCLUDING REMARKS

The computer program described in this report was developed to calculate inviscid surface streamlines, and laminar, transitional, and turbulent heating rates on shuttle-type configurations. Approximate methods were employed to keep the computational time and storage down to relatively small values but provide reasonably accurate results. Input and output data were programed to be easily used by the ordinary engineer who is not trained as a computer specialist. Although the computer program was developed on an IBM 360/75 computer, it is also compatible with the IBM 370/165, CDC 6400, and CDC 6600 computers.



APPENDIX A

PROGRAM LISTING
from IBM 360/75 Computer

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MAIN PROGRAM

```

DIMENSION Y(9),F(9),NAM(20)
COMMON X(20),FN(20,20),RO,XMF(20,20),HX(20),GAM(20,20),AMF(20,20),
1HP(20),PH(20),PHI(20),FT(20),HPT(20),AMFT(20),AMFF(20),
2 FNN(20),BMFF(20),XMF(20),8MF(20,20),DLP(20,20),DLPP(20)
COMMON/COM3/CAL,SAL,CPH,SPH
COMMON/COM4/POP,DPDX,DPXX,DPXP,DPDP,DP2P
COMMON/COM5/F2,FX,FPX,FP,FPP
INTEGER RUNGE
PI=3.1415927
READ(1,1000) NAM
1000 FORMAT(20A3)
WRITE(3,1001) NAM
1001 FORMAT(2X,20A3)
CALL BGEOM(IMAX,KMAX)
READ(1,900)PIN,TIN,VIN,TRI,TRE,CST,HMAX,KG,KTR,KS,NMAX,KPO
900 FORMAT(7E10.0/5I10)
IF(KTR.EQ.-1)CALL TRANS
C KG=0 FOR PERF. GAS, KG=1 FOR EQUIL. AIR, KTR=-1 FOR TRANSITION
C BASED ON GEOM. LOC., KTR=0 FOR R.N.(MOM THK), KTR=1 FOR INTEGR. UNIT
C R.N., TRI=BEG. OF TRANSITION, TRE=END OF TRANSITION, CST CONVERTS
C BODY UNITS TO FT., KS=0 FOR STREAMLINES ONLY, KPO=1 FOR ADD'L PRINT
C COMPUTE BODY GEOMETRY
READ(1,2)ALPD,ZM,KBM,KP
2 FORMAT(2F10.5,2I5)
ALP=ALPD*PI/180.
SAL=SIN(ALP)
CAL=COS(ALP)
C KP=0 FOR SIMPLIFIED STRMLNS, KP=1 FOR NEWP, KP=2 FOR INPUT PRESSURES
C COMPUTE STAGNATION POINT XO,GIVEN AN ANGLE OF ATTACK,ALP
CALL STAGN(ALP,IMAX,KMAX,XO,RPER,B,ISTG)
C ISTG IS AN INDICATOR VARIABLE
C IF ISTG=-1 => NEGATIVE ANGLE OF ATTACK
C IF ISTG=0 => STAGNATION POINT NOT FOUND
C IF ISTG=1 => STAGNATION POINT FOUND
CALL STGPR(PIN,TIN,VIN,RHOIN,EMIN,PS,RHOS,HS,KG)
WRITE(3,1002)PIN,TIN,RHOIN,VIN,EMIN
1002 FORMAT(//,47X,22HFREE STREAM PROPERTIES,//,1X,18HPRESSURE(LB/SQ FT
1),10X,11HTEMP(DEG R),10X,20HDENSITY(SLUGS/CU FT),10X,16HVELOCITY(F
2T/SEC),10X,8HMACH NO.,//

```

```

403X,E14.6,11X,E14.6,11X,E14.6,14X,E14.6,9X,E14.6,6//)
WRITE(3,1009)PS,RHOS,HS
1009 FORMAT(/,44X,21HSTAGNATION PROPERTIES,/,10X,18HPRESSURE(LB/SQ FT
1),10X,20HDENSITY(SLUGS/CU FT),10X,22HENTHALPY(SQ FT/SQ SEC),//
3,12X,E14.6,15X,E14.6,17X,E14.6//)
WRITE(3,1007)TRI,IRE,CST,KG,KTR,KP,HMAX,NMAX,KPO,KS,IMAX,KMAX
1007 FORMAT(/,12X,5HTRI =,E14.6,10X,5HTRE =,E14.6,10X,5HCS =,E14.6,10X,5HST =,E14.6,6//
1,12X,4HKG =,110,15X,5HKTR =,110,14X,4HKP =,110
2,12X,6HHMAX =,E14.6,9X,6HNMAX =,110,13X,5HKPO =,110//
3,12X,4HKS =,110,15X,6HIMAX =,110,13X,6HKMAX =,110//)
PNEWT=1.-PIN/PS
CALL PRESS(KP,PNEWT)
HW=ZW#HS
TW=HW/6006.
VISH=2.27E-08*TH#1.5/(TW+198.6)
RHOSW=PS/(TW*1716.)
CALL PROP(PS,HS,RHOS,PS,HE,RHOE,UE,VISS,EMS,KG)
DUEFPS=SQRT(2.*(PS-PIN)/RHOS)/VIN
CTHM1=2.*PS*VISH#VIN/(1716.*TW)
CTHM=0.4696*SQRT(CTHM1/CST)
C DUEFPS=D(UE/VIN)/D(PIN), CTHM=CONST. FOR MOM. THK.
IF(I1STG)28,30,33
28 WRITE(3,29)
29 FORMAT(/,2X,40H*** NEGATIVE ANGLE OF ATTACK ENCOUNTERED,/,6X,42HSTA
1AG. POINT SET TO 0.0, PROGRAM CONTINUING)
33 WRITE(3,21)ALPD,ZW,KBM
21 FORMAT(/,2X,23HSTREAMLINE CALCULATIONS,/,5X,11HINPUT DATA,/,5X
1,16HANG. OF ATTACK= E12.5,2X,4HDEG=,/,5X,12HZETA(WALL)= E12.5,/,5X
2,36HNO. OF STREAMLINES TO BE CALCULATED=,13)
KB=1
C KBM IS MAX NO OF BETAS READ IN, KB.LT.KBM
IF(ALP.NE.0.) CALL STRMLN(XO,0.,DLP,DDP,DDX,GM,DGP,DGX,FFO,IMAX,
1KMAX)
IF(ALP.EQ.0.)FFO=0.
WRITE(3,15)B,XO
15 FORMAT(/,5X,2HB=E12.5,/,5X,20HSTAGNATION POINT,XO=E12.5)
IF(B-GE.1.)BBARS=1./(B+1.)
IF(B.LT.1.)BBARS=B/(B+1.)
53 C BBARS IS B.L. BETA AT STAG. PT.

```

```

BEXP=BBARS**+.686
G7=(1.116+.411*BEXP)/(1.+0.527*BEXP)
AS=.1-.08*(BBARS-.5)
BS=.5-AS
Q01=SQRT((B+1.)*DUEDPS*VIN/(RPER*CST))
C QWS=STAG. PT. H. T. IN BTU/(FT*FT*SEC)
  ZONK=.892E-03
  QWS=ZONK*Q01*(RHOSW*VISM)**AS*(RHOS*VISS)**BS*(HS-HW)/G7
  QWSB=QWS/(HS-HW)
  HSP=QWSB*6006.
  WRITE(3,1003)TW,QWS,HSP
1003 FORMAT(//,5X,4HTW=,E14.6,6H DEG R,10X,5HQWS =,E14.6
  1,14H BTU/SQ FT-SEC,10X,5HHSP =,E14.6,20H BTU/SQ FT-SEC-DEG R,/)
  G5=SQRT(DUEDPS*2.*(B+1.)/RPER)
  PORV=PS/(RHOS*VIN**2)
  DEPS=0.1*RPER
  3 READ(1,4)BETAD
  4 FORMAT(F10.5)
  BETA=BETAD*PI/180.
  L1=1
  L2=1
  MR=0
  STR=0.
  NT=1
  NR=5
  IF(KP.GE.1)NR=7
  IF(KS.EQ.0)NT=3
  NCS=1
  DS = 0.1*DEPS
  WRITE(3,41)KD,BETAD
41 FORMAT(//,2X,18HFOR STREAMLINE NO.12,12H WHERE BETA=E12.5,3HDEG,/,
  12X,32HTHE CALCULATIONS ARE AS FOLLOWS:)
  WRITE(3,42)
42 FORMAT(//,13X,1HX,13X,1HY,14X,1HZ,14X,1HH,14X,1HS,13X,4HBBAR
  1,10X,4HP/PS,8X,6HQW/QWS)
  IF(KPO.EQ.1)WRITE(3,1005)
1005 FORMAT(13X,2HUE,12X,2HHE,11X,4HHRDE,11X,3HMUE,11X,7HMACH NO,10X
  1,5HRN/FT,9X,7HMOM THK,6X,3HRNM,/,12X,3HRNI,13X,1HR,12X,3PHI,11X
  2,7HDR/DPHI,7X,9HD2R/DPHI2,8X,5HDR/DX,9X,7HD2R/DX2,5X,6HQB/QSB,/)

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```

C Y(1)=XX, Y(2)=PPH, Y(3)=H
C F(1)=DX/DS, F(2)=D(PHI)/DS, F(3)=DH/DS
C F(4)=(POP)(UOU)(H)**2,
  CBE=cos(BETA)
  SBE=sin(BETA)
  CB4=B*CBE**2*SBE**2
  CB5=(B*CBE)**2+SBE**2
  Y(1)=XO+DEPS*(CBE*SAL+CAL*DEPS*CB4/2./RPER)
  ZZ=DEPS*SBE
  YY=FFO+DEPS*(CBE*CAL-SAL*DEPS*CB4/2./RPER)
  IF(ABS(YY).LT.(1.E-05*ZZ))Y(2)=PI/2.
  IF(ABS(YY).GE.(1.E-05*ZZ))Y(2)=ATAN(ZZ/YY)
  IF(Y(2).LT.0.)Y(2)=PI+Y(2)
  Y(3)=DEPS*CB4/SQRT(CB5)
  Y(4)=DUEDEPS*CB4**2*DEPS**4/RPER/(2.*B+2.)
  CALL SIRMLN(Y(1),Y(2),DLPH,DDP,DDX,GM,DGP,DGX,FF,IMAX,KMAX)
  SGM=sin(GM)
  CGM=cos(GM)
  TN=-SAL*SIN(DLPH-Y(2))
  TD=CAL*CGM-SAL*SGM*cos(DLPH-Y(2))
  IF(ABS(TD).LT.(1.E-05*ABS(TN)))Y(5)=PI/2.
  IF(ABS(TD).GE.(1.E-05*ABS(TN)))Y(5)=ATAN(TN/TD)
  IF(Y(5).LT.0.)Y(5)=PI+Y(5)
  Y(6)=B*(CB4/CB5)**2 Add a statement to set Y(2)=0. and Y(5)=0. if BETAD=0.
L=0
EXET=2.*(B-1.)
IF(B.LT.1.)EXET=2*(1./B-1.)
AS1=SBE**2
IF(B.LT.1.)AS1=CBE**2
BS1=(1.-AS1**2)**2
IF(B.LT.1.)BS1=BS1/B**4
SUM=0.
DO 90 MQ=1,9,2
AMQ=MQ
SUM=SUM+4.*SQRT(AS1+BS1*(.1*AMQ)**EXET)
IF(MQ.EQ.9)GO TO 91
90 SUM=SUM+2.*SQRT(AS1+BS1*(.1*(AMQ+1.))**EXET)
91 S=DEPS*.1/3.*(SQRT(AS1)+SQRT(AS1+BS1)+SUM)
Y(NR)=DUEDEPS*(DEPS*CB4)**2*CST*RHDS/2./RPER/VISS

```

```

K=0
IF(KP.EQ.0)GO TO 22
IF(KP.GE.1)GO TO 71
5 K=RUNGE(Y,F,S,DS,NR,HMAX,MR)
IF(K.EQ.2)GO TO 310
IF(Y(3).LE.1.E-04)GO TO 74
22 CALL STRMLN(Y(1),Y(2),DLPH,DDP,DDX,GM,DGP,DGX,FF,IMAX,KMAX)
C CPSI=COS(PSI), SPSI=SIN(PSI), STH=SIN(THETA), CTH=COS(THETA)
C DGB=D(GM)/(H*D(BETA)), --DSB=D(SIG)/(H*D(BETA))
SGM=SIN(GM)
CGM=COS(GM)
CPSI=CAL*SGM+SAL*CGM*COS(DLPH-Y(2))
SPSI=SQRT(1.-CPSI*CPSI)
STH=SAL*SIN(Y(2)-DLPH)/SPSI
F(1)=(CAL-CPSI*SGM)/SPSI
CTH=F(1)/CGM
IF(ABS(CTH).LT.1.E-05)THE=PI/2.
IF(ABS(CTH).GE.1.E-05)THE = ATAN(STH/CTH)
IF(CTH.LT.0.)THE=PI+THE
F(2)=(STH*COS(DLPH)-CTH*SIN(DLPH)*SGM)/FF
IF(Y(2).LE.0.0.OR.Y(2).GE.PI)F(2)=0.
AA1=-STH*CGM
AA2=(CTH*COS(DLPH)+STH*SIN(DLPH)*SGM)/FF
DGB=AA1*DGX+AA2*DGP
DSB=AA1*DDX+AA2*(DDP-1.)
F(3)=Y(3)*CPSI/SPSI*(STH*DGB-CTH*CGM*DSB)
POP=PNEWT*CPSI*(CPSI+ABS(CPSI))/2.+1.-PNEWT
PE=POP*PS
CALL PROP(PS,HS,RHOS,PE,HE,RHOE,UE,VISC,EM2,KG)
EM=SQRT(EM2)
DGS=F(1)*DGX+F(2)*DGP
DSS=F(1)*DDX+F(2)*(DDP-1.)
DPSIS=-CTH*DGS-CGM*STH*DSS
UOU=UE/VIN
ROR=RHOE/RHOS
PUH=POP*UOU*Y(3)
BIFF=.5*(CPSI+ABS(CPSI))
DPS=-2.*PNEWT*BIFF*SPSI*DPSIS
DUEDS=-PORV*DPS/ROR/UOU

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```

F(4)=PUH*Y(3)
F(5)=RHOE*UE/VISC*CST
RNF=F(5)/CST
RNI=Y(5)
THM=CTHM*SQRT(Y(4))/(UE*Y(3)*RHDE)
RNM=F(5)*THM
GO TO (74,80),LI
74 CONTINUE
IF(K.EQ.1)GO TO 5
6 L=L+1
IF(Y(3).LE.1.E-04)GO TO 312
IF(RNM.LE.1.E-04)GO TO 314
C DGS=D(GM)/DS, -DSS=D(SIG)/DS, DPSIS=D(PST)/DS
C BBAR=B.L.BETA, ZW=H(W)/H(E), ZWP=ZETA(W)/ZETA(W.S)
C FROM NASA TR R-118
62 TE=HE/HS
BBAR=Y(4)*2.*DUEDS/(TE*PUH*UDU*Y(3))
IF(DPS.GT.0.) BBAR = 0.
63 AA4 = BBAR*.686
AA5=(1.+0.527*AA4)/(1.116+.411*AA4)
AA6=1.1-0.1625*TE+.0625*TE*TE
AA7=(.85+.15*TE-ZW)/(1.-ZW)
ZWP=G7*AA5*AA6*AA7
QQQS=PUH*ZWP/SQRT(Y(4))/G5
QQQS8=QQQS/AA7
QWL=QQQS*QMS
QWLB=QQQS8*QWSB
YY=FF*COS(Y(2))
ZZ=FF*SIN(Y(2))
THMF=THM*CST
PHID=Y(2)*180./PI
GO TO (75,76,73),NT
73 QW=QWL
7 WRITE(3,17)Y(1),YY,ZZ,Y(3),S,BBAR,POP,QQQS
17 FORMAT(2X,8(3X,E12.5))
IF(KPO.EQ.1)WRITE(3,1008)UE,HE,RHOE,VISC,EM,RNF,THMF,RNM,RNI,FF
1,PHID,FP,FPP,FX,FX8,QQQS8
1008 FORMAT(3X,8(3X,E12.5),/,4X,8(3X,E12.5),/)
IF(BETAD.GE.180..AND.Y(1).LT.(1.E-04*X(2)))GO TO 50

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```

IF(L-NMAX)8,8,9
8 IF(Y(1).LT.X(IMAX)).AND.KP.EQ.0) GO TO 5
IF(Y(1).LT.X(IMAX)).AND.KP.GE.1) GO TO 70
WRITE(3,14)BETAD,L
14 FORMAT(/,2X,26H*** CALCULATIONS FOR BETA=E12.5,15H HAS TERMINATED,
1/,5X,5HAFTR13,16H INTEGRATIONS **)
19 IF(KB.GE.KBM)GO TO 10
KB=KB+1
GO TO 3
9 WRITE(3,18) KB
18 FORMAT(/,2X,30H*** SUBSCRIPT OUT OF RANGE **/,6X,32HCALCULATIONS
1 FOR STREAMLINE NO. ,I2,13H DISCONTINUED)
GO TO 19
10 WRITE(3,101) KB
101 FORMAT(/,2X,20HTHE CALCULATIONS FOR, I3,31H STREAMLINES HAS BEEN CD
MPLETED,/,2X,19HPROGRAM TERMINATING)
GO TO 32
310 WRITE(3,311) KB,DS
311 FORMAT(/,2X,25HINTEGRATION OF STREAMLINE, I2,30H DISCONTINUED DUE T
10 STEP SIZE,/,5X,6H*** H=E12.5,4H ***)
GO TO 19
312 WRITE(3,313)Y(3),KB
313 FORMAT(/,2X,33HSCALE FACTOR (H) GOING NEG ,***H=E12.5,/,2X,
110HSTREAMLINEI3,12HDISCONTINUED)
GO TO 19
314 WRITE(3,315)RNM,KB
315 FORMAT(/,2X,31HREY NO (RNM) GOING NEG,*** RNM=E12.5,/,2X
1,10HSTREAMLINEI3,12HDISCONTINUED)
GO TO 19
30 WRITE(3,31)
31 FORMAT(/,2X,43H*** STAGNATION POINT NOT FOUND, RUN ABORTED)
GO TO 32
C NOSE REGION FOR BETA=PI
50 Y(2)=PI
IF(KP.GE.1)Y(5)=0.
GO TO 8
C ROUTINE FOR NEWP OR INPUT PRESSURES
70 K=RUNGE(Y,F,S,DS,NR,HMAX,MR)
IF (K.EQ.2) GO TO 310

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IF(Y(3).LE.1.E-04)GO TO 72
71 CALL STRLEN(Y(1),Y(2),DLPH,DDP,DDX,GM,DGP,DGX,FF,IMAX,KMAX)
THE=Y(5)
SPH = SIN(Y(2))
CPH = COS(Y(2))
SGM = SIN(GM)
CGM = COS(GM)
STH = SIN(Y(5))
CTH = COS(Y(5))
SDLP = SIN(DLPH)
CDLP = COS(DLPH)
F(1) = CTH*CGM
F(2) = (STH*CDLP-CTH*SDLP*SGM)/FF
IF(Y(2).LE.0.0.0R.Y(2).GE.PI)F(2)=0.
F(3) = Y(6)
CALL PDER(Y(1),Y(2),POP,DPDP,DP2P,DPDX,DPXP,DPXX)
PE=PS*POP
CALL PROP(PS,HS,RHOS,PE,HE,RHOE,UE,VISC,EM2,KG)
EM=SQRTE(M2)
UOU=UE/VIN
PUH=POP*UOU*Y(3)
F(4) = PUH*Y(3)
ROR=RHOE/RHOS
DSS = F(1)*DDX+F(2)*((DDP-1.))
DXB = -STH*CGM
DPHB = (CTH*CDLP+STH*SDLP*SGM)/FF
DPB = DXB*DPDX+DPHB*DPDP
UESQ=UOU**2
F(5)=-DPB*PORV/UESQ/ROR+SGM*DSS
IF(Y(2).LE.0.0.0R.Y(2).GE.PI)F(5)=0.
C F(5) = D(THETA)/DS, F(6) = D2H/D(S**2)
HT1=CGM**2*CDLP*(DDX*DGP-DGX*(DDP-1.))/FF
HT2=(DPB*PORV/UESQ/ROR)**2*(3.-EM2)
DSB = DXB*DDX+DPHB*(DDP-1.)
DTHB = Y(6)/Y(3)+SGM*DSB
DPS = F(1)*DPDX+F(2)*DPDP
DGB = DXB*DGX+DPHB*DGP
DDLB = DXB*DDX+DPHB*DDP
HT3=-CTH*SDLP+STH*CDLP*SGM

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HT4 = DPDX*STH*SGM*DGB
HT5=DPDP/FF*(STH*SDLP*CGM*DGB+HT3*(DDL*DPHB*FF))
HT6= STH*CGM*(STH*CGM*DPXX-DPHB*DPXP)
HT7= DPHB*(-STH*CGM*DPXP+DPHB*DP2P)
D2PB = -DTHB*DPS+HT4+HT5+HT6+HT7
F(6)=Y(3)*(-D2PB*PORV/UESQ/ROR-HT2+HT1)
F(7)=RHOE*UE/VISC*CST
RNF=F(7)/CST
RNI=Y(7)
THM=CTHM*SQRT(Y(4))/((UE*Y(3))*RHOE)
RNM=F(7)*THM
DUES=-PORV*DPS/(ROR*UOU)
GO TO (72,80),L1
72 CONTINUE
IF (K.EQ. 1 ) GO TO 70
IF(Y(3).LE.1.E-04)GO TO 312
IF(RNM.LE.1.E-04)GO TO 314
L = L+1
GO TO 62
75 STRL=STR
STR=Y(L)
TRIL=TRI
TREL=TRE
IF(KTR.EQ.0)STR=RNM
IF(KTR.EQ.1)STR=RNI
GO TO (81,82,83,84),L2
81 IF(KTR.EQ.-1)CALL BEGR(Y(2),TRI)
IF(STR.LT.TRI)GO TO 73
DS=DS*(TRIL-STRL)/(STR-STRL-TRI+TRIL)
MR=1
L2=2
GO TO 8
82 NR=NR+2
MR=0
L1=2
L2=3
Y(NR-1)=THM
HC=1.2168/.4696
HTR=(HC-UE**2/2./HE)*HE/HS

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```

HI=HTR-(HW/HS-1.)#1.3
Y(NR)=HI
WRITE(3,1004)
1004 FORMAT(/,10X,21H***BEGINNING OF TRANSITION***/)
WRITE(3,17)Y(1),YY,ZZ,Y(3),S,BBAR,POP,QQOS
IF(KPO.EQ.1)WRITE(3,1008)UE,HE,RRDE,VISC,EM,RNF,THMF,RNM,RN1,FF
1,PHID,FP,FPP,FX,FXX,QQQS)
K=1
DS=DS/30
GO TO 80
03 IF(KTR.EQ.-1)CALL ENDTR(Y(2),TREL)
IF(STR.GE.TREL)GO TO 85
NCS=0
XI=4.74*(STR-TRI)/(YRE-TRI)
EXW=EXP(-.412*XI**2)
WFN=1.-EXW
QW=QWL+WFN*(QWT-QWL)
QWB=QWLB+WFN*(QWTB-QWLB)
QQS=QW/QWS
QQSB=QWB/QWSB
GO TO 7
85 DS=DS*(TREL-STRL)/(STR-STRL-TRE+TREL)
MR=1
LZ=4
GO TO 8
84 MR=0
NT=2
QQS=QWT/QWS
QQSB=QWTB/QWSB
QW=QWT
WRITE(3,17)Y(1),YY,ZZ,Y(3),S,BBAR,POP,QQOS
IF(KPO.EQ.1)WRITE(3,1008)UE,HE,RRDE,VISC,EM,RNF,THMF,RNM,RN1,FF
1,PHID,FP,FPP,FX,FXX,QQQS)
WRITE(3,1006)
1006 FORMAT(/,10X,25H***END OF TRANSITION***/)
GO TO 8
76 QW=QWT
QQS=QWT/QWS
QQSB=QWTB/QWSB

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```

GO TO 7
80 RNM=F(NR-2)*Y(NR-1)
   IF(RNM.LE.1.E-04)GO TO 86
   CALL SPCH(ZW,HE,RHOE,UE,HS,RNM,CF,QMT,QMTB,NCS)
   HC=HS/HE*(Y(NR)+(HW/HS-1.)*1.3)+UE**2/2./HE
   F(NR-1)=(EM2-2.-HC)*Y(NR-1)*DUEDS/UDU+CF/2.-Y(NR-1)*F(3)/Y(3)
   W1=Y(NR)+1.
   W2=Y(NR)-1.
   W3=W1*W2
   W4=HW/HS-1.
   W5=W4*(2.6*W2-.15*W1**2/4.3)
   W6=Y(NR)*W1/2.*DUEDS/UDU*HS/HE
   W7=.03*Y(NR)*W3*CF/2./Y(NR-1)
   F(NR)=-W6*(W3+W5)-W7
86 IF(KP.EQ.0)GO TO 74
   IF(KP.GE.1)GO TO 72
32 CALL EXIT
   END
FUNCTION RUNGE(Y,F,X,H,N,HMAX,MR)
INTEGER RUNGE
DIMENSION PHI(9),SAVEY(9),Y1(9),Y2(9),YKP(9),FKP(9),Y(N),F(N)
DATA M,LOOP,EPS/0,0,1.E-04/
M=M+1
GO TO (2,3,4,5),M
2 IF(LOOP.GT.0)GO TO 21
  IF(MR.EQ.1)GO TO 91
  IF(H.GE.HMAX)H=HMAX
  DO 20 J=1,N
    YKP(J)=Y(J)
    FKP(J)=F(J)
    X=X
20 DO 22 J=1,N
    SAVEY(J)=Y(J)
    PHI(J)=F(J)
22 Y(J)=SAVEY(J)+0.5*H*F(J)
    X=X+0.5*H
  RUNGE=1
  RETURN
3 DO 33 J=1,N

```

```

PHI(J)=PHI(J)+2.0*F(J)
33 Y(J)=SAVEY(J)+0.5*H*F(J)
RUNGE=1
RETURN
4 DO 44 J=1,N
PHI(J)=PHI(J)+2.0*F(J)
44 Y(J)=SAVEY(J)+H*F(J)
X=X+0.5*H
RUNGE=1
RETURN
5 DO 55 J=1,N
55 Y(J)=SAVEY(J)+(PHI(J)+F(J))*H/6.0
IF(LOOP-1)56,58,60
56 DO 57 J=1,N
Y2(J)=Y(J)
F(J)=FKP(J)
57 Y(J)=YKP(J)
X=XG
H=H/2.
M=1
LOOP=1
GO TO 21
58 DO 59 J=1,N
59 Y1(J)=Y(J)
LOOP=2
RUNGE=1
M=0
RETURN
60 DO 62 J=1,N
IF(Y(J).LT-1.E-20)GO TO 62
ER=(Y(J)-Y2(J))/Y(J)
IF(ABS(ER)-EPS)61,61,80
61 CONTINUE
62 CONTINUE
70 H=4.*H
LOOP=0
RUNGE=0
M=0
RETURN

```

```

80 DO 81 J=1,N
   Y(J)=YKP(J)
   F(J)=FKP(J)
81 Y2(J)=Y1(J)
   X=X0
   H=H/2.
   IF(H.LT.1.E-08)GO TO 90
   LOOP=1
   M=1
   GO TO 21
90 RUNGE=2
   RETURN
91 DO 92 J=1,N
   Y(J)=YKP(J)
92 F(J)=FKP(J)
   X=X0
   H=H/2.
   GO TO 21

```

END

```

SUBROUTINE STAGN(ALP,IMAX,KMAX,X0,RPER,B,ISTG)
COMMON X(20),FN(20,20),RO,XMF(20,20),HX(20),GAM(20,20),AMF(20,20),
1HP(20),PH(20),Z(20),Y(20),PHI(20),FT(20),HPT(20),AMFT(20),AMFF(20)
2,FNN(20),BMFF(20),XMF(20),BMP(20,20),DLP(20,20),DLPP(20)
   ISTG=0
   XO=0.0
C DETERMINE THE SIGN OF ALPHA
   IF(ALP)1,2,3
C IF ALPHA<0, THE STAGNATION POINT IS SET TO 0.0
   1 XO=0.0
   ISTG=-1
   GO TO 10
   2 XO=0.0
   ISTG=1
   10 PI02=3.1415927/2.
   DO 8 K=2,KMAX
   IF(PI02.LT.PH(K))GO TO 9
   8 CONTINUE
   9 FPER=FSPL(AMF(2,K-1),AMF(2,K),PH(K-1),PH(K),FN(2,K-1),FN(2,K)
   1,PI02)

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```

XMPER=FSPL(BMF(2,K-1),BMF(2,K),PH(K-1),PH(K),XMF(2,K-1),XMF(2,K)
1,PI02)
RPER=FFPER/(2.*X(2))-XMPER*X(2)/4.
RPAR=FN(2,1)/(2.*X(2))-XMF(2,1)*X(2)/4.
B=RPER/RPAR
RETURN
3 CALP=COS(ALP)
SG1=1.0
DO 4 I=2,IMAX
CALL STRMLN(X(I),0.,DLPH,DDP,DDX,GM,DGP,DGX,FF,IMAX,KMAX)
SG2=SIN(GM)
IF(CALP-LI.SG1.AND.CALP.GE.SG2)GO TO 5
4 SG1=SG2
ISTG=0
RETURN
5 IMX=I
IMN=I-1
X1=X(IMN)+(X(IMX)-X(IMN))*(SG1-CALP)/(SG1-SG2)
DO 6 J=1,10
CALL STRMLN(X1,0.,DLPH,DDP,DDX,GM,DGP,DGX,FF,IMAX,KMAX)
SG=SIN(GM)
CG=COS(GM)
DX=(CALP-SG)/CG/DGX
XD=X1+DX
IF(ABS(DX/X1).LE.1.0E-04)GO TO 7
IF(X0.LE.X(IMN))X0=X(IMN)+(X1-X(IMN))/2.
IF(X0.GT.X(IMX))X0=X1+(X(IMX)-X1)/2.
6 X1=X0
ISTG=0
RETURN
7 ISTG=1
CALL STRMLN(X0,0.,DLPH,DDP,DDX,GM,DGP,DGX,FF,IMAX,KMAX)
RPER=FF/(SIN(ALP))*(1.-DDP)
B=FF*DGX/(DDP-1.0)
RETURN
END

```

```

SUBROUTINE NEWP(AA,F)
MODIFIED NEWTONIAN PRESSURES AND DERIVATIVES
COMMON/COM2/FFX,FFXX,FF3X,FFP,FF2P,FF3P,FFXP,FFXPP,FFXXP

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COMMON/COM3/CA,SA,CP,SP
COMMON/COM4/PE,PX,PXX,PXP,PP,PPP
COMMON/COM5/F2,FX,FXX,FP,FPP
FF=F**2
FX=(FF3X-6.*FX*FXX)/F2
FXP=(FFXP-2.*FP*FX)/F2
FXPP=(FFXPP-4.*FP*FXP-2.*FPP*FX)/F2
FXXP=(FFXXP-4.*FX*FXP-2.*FP*FXX)/F2
TD=FFP/2./FF
TDP=(FF2P/FF-4.*TD**2)/2.
TOPP=(FF3P/FF-FF2P*FFP/FF/FF-8.*TD*TDP)/2.
TDX=(FFXP-2.*TD*FXX)/2./FF
TDPX=(FFXPP/FF-FF2P*FX/FF/FF-8.*TD*TDX)/2.
TDXX=(FFXXP-2.*TD*FXX-2.*FXX*TDX)/2./FF-FX/FF*TDX
T=CA*FX+SA*(CP+SP*TD)
TX=CA*FXX+SA*SP*TDX
TXX=CA*F3X+SA*SP*TDXX
TXP=CA*FXP+SA*(CP*TDX+SP*TDPX)
TP=CA*FXP+SA*(-SP+CP*TD+SP*TDP)
TPP=CA*FXPP+SA*(-CP-SP*TD+2.*CP*TD+SP*TDP)
D=1.+FX**2+TD**2
DX=2.*(FX*FXX+TD*TDX)
DXX=2.*(FX*F3X+FXX**2+TD*TDXX+TDX**2)
DXP=2.*(FX*FXP+FXP*FXX+TD*TDXP+TDP*TDX)
DP=2.*(FX*FXP+TD*TDX)
DPP=2.*(FX*FXPP+FXP**2+TD*TDPP+TDP**2)
CPSI2=T**2/D
PX=(2.*T*TX/D-CPSI2*DX/D)*AA
PXX=AA*(2.*(T*TX+TX**2)-CPSI2*DXX)/D-2.*DX*PX/D
PP=(2.*T*TP/D-CPSI2*DP/D)*AA
PXP=AA*(2.*(T*TXP+TP*TX)-CPSI2*DXP)/D-(DX*PP+DP*PX)/D
PPP=AA*(2.*(T*TPP+TP**2)-CPSI2*DPP)/D-2.*DP*PP/D
C  CA=COS(ALP), SA=SIN(ALP), CP=COS(PPH), SP=SIN(PPH)
C  COS(PSI)**2=T**2/D, TD=TAN(DLPH)
C  P=AA*COS(PSI)**2+1.-AA
PE=AA*(T+ABS(T))/2./D+1.-AA
RETURN
END
SUBROUTINE STRMLN(XX,PPH,DLPH,DDP,DDX,GM,UGP,DGX,F,IMAX,KMAX)

```

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COMMON X(20),FN(20,20),RO,XMF(20,20),HX(20),GAM(20,20),AMF(20,20),
1HP(20),PH(20),Z(20),Y(20),PHI(20),FT(20),HPT(20),AMFT(20),AMFF(20)
2,FNN(20),BMFF(20),XMF(20),BMF(20,20),DLP(20,20),DLPP(20),
3GAMM(20),AMDD(20),AMGG(20),AMD(20,20),AMG(20,20),XMDD(20),XMG(20),
4,XMD(20,20),XMG(20,20),BMD(20,20),BMG(20,20),BMDD(20),BMGG(20)
COMMON/COM2/FFX,FFX,FFX,FFX,FFX,FFX,FFX,FFX,FFX,FFX,FFX,FFX,FFX,FFX
COMMON/COM5/F2,FX,FX,FX,FP,FP
C LOCATE I AND K FOR X AND PHI
IF(XX.LT.(1.E-04*X(2)))XX=1.E-04*X(2)
DO 22 I=2,IMAX
IF(XX.LT.X(I))GO TO 23
22 CONTINUE
23 DO 24 K=2,KMAX
IF(PPH.LT.PH(K))GO TO 25
24 CONTINUE
C COMPUTE F
25 AMF1=FSPL(BMF(I-1,K-1),BMF(I,K-1),X(I-1),X(I),AMF(I-1,K-1),AMF(I,K
1-1),XX)
AMF2=FSPL(BMF(I-1,K),BMF(I,K),X(I-1),X(I),AMF(I-1,K),AMF(I,K),XX)
F1=FSPL(XMF(I-1,K-1),XMF(I,K-1),X(I-1),X(I),FN(I-1,K-1),FN(I,K-1),
1XX)
F2=FSPL(XMF(I-1,K),XMF(I,K),X(I-1),X(I),FN(I-1,K),FN(I,K),XX)
FF=FSPL(AMF1,AMF2,PH(K-1),PH(K),F1,F2,PPH)
C COMPUTE DLPH,DDP,AND D2DP
FFP=DFSPL(AMF1,AMF2,PH(K-1),PH(K),F1,F2,PPH)
FF2P=D2FPL(AMF1,AMF2,PH(K-1),PH(K),F1,F2,PPH)
AMFX1=DFSPL(BMF(I-1,K-1),BMF(I,K-1),X(I-1),X(I),AMF(I-1,K-1),
1AMF(I,K-1),XX)
AMFX2=DFSPL(BMF(I-1,K),BMF(I,K),X(I-1),X(I),AMF(I-1,K),AMF(I,K),
1XX)
FX1=DFSPL(XMF(I-1,K-1),XMF(I,K-1),X(I-1),X(I),FN(I-1,K-1),FN(I,K-1
1),XX)
FX2=DFSPL(XMF(I-1,K),XMF(I,K),X(I-1),X(I),FN(I-1,K),FN(I,K),XX)
FFX=FSPL(AMFX1,AMFX2,PH(K-1),PH(K),FX1,FX2,PPH)
FFXP=DFSPL(AMFX1,AMFX2,PH(K-1),PH(K),FX1,FX2,PPH)
AMFXX1=D2FPL(BMF(I-1,K-1),BMF(I,K-1),X(I-1),X(I),AMF(I-1,K-1),
1AMF(I,K-1),XX)
AMFXX2=D2FPL(BMF(I-1,K),BMF(I,K),X(I-1),X(I),AMF(I-1,K),AMF(I,K),
1XX)

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FXX1=D2FPL(XMF(I-1,K-1),XMF(I,K-1),X(I-1),X(I),FN(I-1,K-1),
1FN(I,K-1),XX)
FXX2=D2FPL(XMF(I-1,K),XMF(I,K),X(I-1),X(I),FN(I-1,K),FN(I,K),XX)
FFXX=FSPL(AMFXX1,AMFXX2,PH(K-1),PH(K),FXX1,FXX2,PPH)
TDLP=FFP/2./FF
DLPH=ATAN(TDLP)
CDLP=COS(DLPH)
SDLP=SIN(DLPH)
T2=2.*SQRT(FF)
DDP=CDLP**2*(FF2P/2./FF-2.*TDLP**2)
DDX=CDLP**2/FF*(FFXP/2.-TDLP*FFX)
TGM=FFX*CDLP/T2
GM=ATAN(TGM)
CGM=COS(GM)
T3=FFXX*CDLP-FFX*SDLP*DDX
DGX=CGM**2*(T3-2.*TGM**2/CDLP)/T2
DGP=CGM**2*(FFXP*CDLP-FFX*SDLP*(DDP+1.))/T2
F=SQRT(FF)
AMD1=FSPL(BMD(I-1,K-1),BMD(I,K-1),X(I-1),X(I),AMD(I-1,K-1),AMD(I,K
1-1),XX)
AMD2=FSPL(BMD(I-1,K),BMD(I,K),X(I-1),X(I),AMD(I-1,K),AMD(I,K),XX)
FFP1=DFSPL(AMF1,AMF2,PH(K-1),PH(K),F1,F2,PH(K-1))
FFP2=DFSPL(AMF1,AMF2,PH(K-1),PH(K),F1,F2,PH(K))
FFP2=DFSPL(AMD1,AMD2,PH(K-1),PH(K),FFP1,FFP2,PPH)
AMG1=DFSPL(BMG(I-1,K-1),BMG(I,K-1),X(I-1),X(I),AMG(I-1,K-1),AMG(I,
1K-1),XX)
AMG2=DFSPL(BMG(I-1,K),BMG(I,K),X(I-1),X(I),AMG(I-1,K),AMG(I,K),XX)
F2X1=DFSPL(XMG(I-1,K-1),XMG(I,K-1),X(I-1),X(I),GAM(I-1,K-1),GAM(I,
1K-1),XX)
F2X2=DFSPL(XMG(I-1,K),XMG(I,K),X(I-1),X(I),GAM(I-1,K),GAM(I,K),XX)
FFXX=FSPL(AMG1,AMG2,PH(K-1),PH(K),F2X1,F2X2,PPH)
FFXPP=D2FPL(AMF1,AMF2,PH(K-1),PH(K),F1,F2,PPH)
FFXXP=DFSPL(AMG1,AMG2,PH(K-1),PH(K),F2X1,F2X2,PPH)
FF3P=D2FPL(AMD1,AMD2,PH(K-1),PH(K),FFP1,FFP2,PPH)
AMGX1=D2FPL(BMG(I-1,K-1),BMG(I,K-1),X(I-1),X(I),AMG(I-1,K-1),
1AMG(I,K-1),XX)
AMGX2=D2FPL(BMG(I-1,K),BMG(I,K),X(I-1),X(I),AMG(I-1,K),AMG(I,K),
1XX)
F3X1=D2FPL(XMG(I-1,K-1),XMG(I,K-1),X(I-1),X(I),GAM(I-1,K-1),GAM(I,

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1K-1),XX)
F3X2=D2FPL(XMG(I-1,K),XMG(I,K),X(I-1),X(I),GAM(I-1,K),GAM(I,K),
1XX)
FF3X=FSPL(AMGX1,AMGX2,PH(K-1),PH(K),F3X1,F3X2,PPH)
F2=2.*F
FX=FFX/F2
FXX=(FFXX-2.*FX**2)/F2
FP=FFP/F2
FPP=(FF2P-2.*FP**2)/F2
RETURN
END
SUBROUTINE BGGEOM(IMAX,KMAX)
COMMON X(20),FN(20,20),RO,XMF(20,20),HX(20),GAM(20,20),AMF(20,20),
1HP(20),PH(20),Z(20),Y(20),PHI(20),FT(20),HPT(20),AMFT(20),AMFF(20)
2,FNN(20),BMFF(20),XMFF(20),BMF(20,20),DLP(20,20),DLPP(20),
3GAMN(20),AMDD(20),AMGG(20),AMD(20,20),AMG(20,20),XMDD(20),XMGG(20)
4,XMD(20,20),XMG(20,20),BMD(20,20),BMG(20,20),BMDD(20),BMGG(20)
COMMON/COM1/ PH2(20),PN(20,20),AMP(20,20),HX2(20),BMP(20,20),
1XMP(20,20),IM2X,KM2X,HP2(20),X2(20)
COMMON/COM7/YY(20,20),ZZ(20,20),JMM(20)
C CALCULATE REARRANGED CIRCUMFERENTIAL POSITIONS AND I=1 INFO
FN(1,1)=0.0
X(1)=0.0
FX=1.
READ(1,1)IMAX,KMAX
1 FORMAT(2I5)
IM2X = IMAX
KM2X = KMAX
RO=1.0
PI=3.1415927
AKM=KMAX-1
DO 2 K=1,KMAX
FN(1,K)=FN(1,1)
AMF(1,K)=0.
HP(K)=PI/AKM
AK=K-1
2 PH(K)=AK*HP(K)
DO 11 I=2,IMAX
READ(1,3)JM,X(I)

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3  FORMAT(15,F10.5)
   JMM(I) = JM
   READ(1,4)((Z(J),Y(J)),J=1,JM)
4  FORMAT(8F10.5)
   DO 41 J=1,JM
   YY(I,J) = Y(J)
   ZZ(I,J) = Z(J)
   C  CALCULATE F AND PHI FOR INPUT COORD
      PHI(I)=0.
      PHI(JM)=PI
      FT(I)=Y(I)**2
      FT(JM)=Y(JM)**2
      JMMI=JM-1
      DO 5 J=2,JMMI
      FT(J)=Y(J)**2+Z(J)**2
      IF(ABS(Y(J)).LT.1.E-06)PHI(J)=PI/2.
      IF(ABS(Y(J)).GE.1.E-06)PHI(J)=ATAN(Z(J)/Y(J))
      IF(PHI(J).LT.0.)PHI(J)=PI+PHI(J)
5  HPT(J)=PHI(J)-PHI(J-1)
   HPT(JM)=PHI(JM)-PHI(JM-1)
   HPT(I)=0.0
   C  SPLINE FIT INPUT COORD
      CALL SPLINE(HPT,FT,JM,AMFT,0.,0.,1)
      KMXMI=KMAX-1
   C  CALCULATE REARRANGED F
      DO 8 K=2,KMXMI
      DO 6 J=2,JM
      IF(PH(K).LT.PHI(J))GO TO 7
6  CONTINUE
7  FN(I,K)=FSPL(AMFT(J-1),AMFT(J),PHI(J-1),PHI(J),FT(J-1),FT(J),PH(K)
   1)
8  CONTINUE
   FN(I,1)=FT(I)
   FN(I,KMAX)=FT(JM)
   DO 9 K=1,KMAX
   FNN(K)=FN(I,K)
   C  SPLINE FIT REARRANGED F
      CALL SPLINE(HP,FNN,KMAX,AMFF,0.,0.,1)
      DO 10 K=1,KMAX

```

```

10 AMF(I,K)=AMFF(K)
   HX(I)=X(I)-X(I-1)
11 CONTINUE
   HX(I)=0.0
   DO 14 K=1,KMAX
   DO 12 I=1,IMAX
     AMF(I)=AMF(I,K)
     FNN(I)=FN(I,K)
12 SPLINE FIT AMF AND F IN X-DIRECTION
   CALL SPLINE(HX,AMFF,IMAX,BMFF,0.0,1.0,-2)
   CALL SPLINE(HX,FNN,IMAX,XMFF,FX,1.0,-2)
   DO 13 I=1,IMAX
     BMF(I,K)=BMFF(I)
     XMF(I,K)=XMFF(I)
13 CONTINUE
14 CONTINUE
15 CALCULATE DLP AND GAM AT NODES
   DO 15 K=1,KMAX
     DLP(I,K)=0.0
     GAM(I,K)=DFSPL(XMF(I,K),XMF(2,K),X(1),X(2),FN(1,K),FN(2,K),0.0)
   DO 151 I=2,IMAX
     DLP(I,1)=0.0
     DLP(I,KMAX)=0.0
     DO 151 K=1,KMAX
       IF(K.EQ.1.OR.K.EQ.KMAX)GO TO 150
       DLP(I,K)=DFSPL(AMF(I,K),AMF(I,K+1),PH(K),PH(K+1),FN(I,K),FN(I,K+1),
         PH(K))
150 GAM(I,K)=DFSPL(XMF(I-1,K),XMF(I,K),X(I-1),X(I),FN(I-1,K),FN(I,K),X
     I(I))
151 CONTINUE
16 SPLINE FIT DLP AND GAM IN PHI-DIRECTION
   DO 18 I=1,IMAX
   DO 16 K=1,KMAX
     DLPP(K)=DLP(I,K)
     GAMM(K)=GAM(I,K)
16 CALL SPLINE(HP,DLPP,KMAX,AMDD,1.0,1.0,-1)
   CALL SPLINE(HP,GAMM,KMAX,AMGG,0.0,0.0,1)
   DO 17 K=1,KMAX
     AMD(I,K)=AMDD(K)
     AMG(I,K)=AMGG(K)
17

```

```

18 CONTINUE
C  SPLINE FIT DLP, GAM, AMD, AND AMG IN X-DIRECTION
DO 21 K=1, KMAX
GX= 1./(1.+FX**2)*XMF(1,K)
DO 19 I=1, IMAX
DLPP(I)=DLP(I,K)
GAMM(I)=GAM(I,K)
AMDD(I)=AMD(I,K)
19  AMGG(I)=AMG(I,K)
CALL SPLINE(HX, AMDD, IMAX, BMDD, 0., 0., -2)
CALL SPLINE(HX, AMGG, IMAX, BMGG, 0., 1., -2)
CALL SPLINE(HX, DLPP, IMAX, XMDD, 0., 1., -2)
CALL SPLINE(HX, GAMM, IMAX, XMGG, GX, 1., -2)
DO 20 I=1, IMAX
XMD(I,K)=XMDD(I)
XMG(I,K)=XMGG(I)
BMD(I,K)=BMDD(I)
20  BMG(I,K)=BMGG(I)
21 CONTINUE
RETURN
END
SUBROUTINE SPLINE(H, DE, K, AM, E, G, N)
DIMENSION H(K), DE(K), AM(K), A(20), B(20), C(20), D(20), Q(20), U(20),
IP(20)
C  E IS LEFT DERIV, G IS RIGHT DERIV, N=1 FOR E & G SPECIFIED,
C  N=0 FOR E SPECIFIED, N=-1 FOR NEITHER SPECIFIED AND M=0 AT BOTH ENDS
C  N=-2 FOR M AT END POINTS = M NEXT TO END POINTS
A(1)=0.
B(1)=1.
C(1)=.5
IF(N.EQ.-1)C(1)=0.
IF(N.EQ.-2)C(1)=-1.
D(1)=3.*(DE(2)-DE(1))/H(2)-E)/H(2)
IF(N.LT.0)D(1)=0.
A(K)=.5
IF(N.EQ.-1)A(K)=0.
B(K)=1.
IF(N.EQ.0)A(K)=-B(K)
IF(N.EQ.-2)A(K)=-B(K)

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```

C(K)=0.
D(K)=3.*(G-(DE(K)-DE(K-1))/H(K))/H(K)
IF(N.LT.0)D(K)=0.
IF(N.EQ.0)D(K)=0.
Q(I)=-C(I)
U(I)=D(I)
P(I)=B(I)
DO 20 J=2,K
IF(J.EQ.K)GO TO 21
B(J)=1.
C(J)=H(J+1)/(H(J)+H(J+1))/2.
A(J)=.5-C(J)
D(J)=3.*(DE(J+1)-DE(J))/H(J+1)-(DE(J)-DE(J-1))/H(J)+H(J+
1))
21 P(J)=A(J)*Q(J-1)+B(J)
Q(J)=-C(J)/P(J)
20 U(J)=(D(J)-A(J)*U(J-1))/P(J)
AM(K)=U(K)
KMI=K-1
DO 22 J=1,KMI
JR=K-J
22 AM(JR)=Q(JR)*AM(JR+1)+U(JR)
RETURN
END
FUNCTION FSPL(AM1,AM2,X1,X2,Y1,Y2,X)
H=X2-X1
T1=((X2-X)**3)*AM1/6./H
T2=AM2*(X-X1)**3/6./H
U1=Y1-AM1*H**2/6.
T3=U1*(X2-X)/H
U2=Y2-AM2*H**2/6.
T4=U2*(X-X1)/H
FSPL=T1+T2+T3+T4
RETURN
END
FUNCTION DFSPL(AM1,AM2,X1,X2,Y1,Y2,X)
H=X2-X1
T1=-AM1*(X2-X)**2/2./H
T2=AM2*(X-X1)**2/2./H

```

```

T3=(Y2-Y1)/H
T4=(AM1-AM2)*H/6.
DFSPL=T1+T2+T3+T4
RETURN
END
FUNCTION D2FPL(AM1,AM2,X1,X2,Y1,Y2,X)
T1=AM1*(X2-X)/(X2-X1)
T2=AM2*(X-X1)/(X2-X1)
D2FPL=T1+T2
RETURN
END
SUBROUTINE STGPR(PIN,TIN,VIN,RHOIN,EMIN,PS,RHOS,HS,KG)
RIN=53.35045*32.1741
HIN=3.5*RIN*TIN
RHOIN=PIN/TIN/RIN
HS=HIN+VIN**2/2.
EMIN=VIN/SQRT(1.4*PIN/RHOIN)
IF(KG.EQ.0)GO TO 5
C KG=0 FOR PERFECT GAS, KG=1 FOR EQUIL. AIR
A1=RHOIN*VIN
A2=PIN+A1*VIN
WRITE(3,1) HIN,RHOIN
1 FORMAT(/,2X,2(E12.5,2X))
VO=0.0
DO 2 J=1,10
P2=A2-A1*VO
H2=HS-VO*VO/2.
PR=(P2/2117.)**.965
HR=(H2/2.119E+08)**.6123
DEN=1.-1.0477*(1.-HR)
RH02=0.0294*.002498*PR/DEN
V2=A1/RH02
IF(ABS((V2-VO)/V2).LT.1.E-05)GO TO 3
2 VO=V2
3 HRS=(HS/H2)**.3877
HR2=(H2/2.119E+08)**.3877
PR2=(P2/2117.)**.035
TT=0.035*0.0294*0.002498*2.119E+08
T3=.3877*1.0477*2117.

```

```

T4=TT/T3/PR2*HR2
PS=P2*(1.+T4*(HRS-1.))**(1./0.035)
PSEX=(PS/2117.)*0.965
HSEX=(HS/2.119E+08)**0.6123
DENN=1.-1.0477*(1.-HSEX)
RHOS=0.0294*0.002498*PSEX/DENN
WRITE(3,4)P2,H2,RHD2,V2,PS,HS,RHOS,J
4 FORMAT(/,2X,7(E12.5,1X),I3)
GO TO 6
5 EM2=EMIN**2
T3=7.*EM2-1.
T4=EM2+5.
PS=PIN*(1.2*EM2)**3.5*(6./T3)**2.5
RHOS=RHOIN*6.*EM2/T4*(7.2*EM2/T3)**2.5
6 RETURN
END

```

```

SUBROUTINE PROP(PS,HS,RHOS,PE,HE,RHDE,UE,VISC,EMS,KG)
C EQUIL. PROPERTIES AT EDGE OF B.L.
IF(KG.EQ.0)GO TO 8
C KG=0 FOR PERFECT GAS, KG=1 FOR EQUIL. AIR
A1=.3877*1.0477*2117.
A2=.035*.0294*0.002498*2.119E+08
HSR=(HS/2.119E+08)**.3877
PSR=(PS/2117.)**.035
POPR=(PE/PS)**.035
A3=A1*PSR*(POPR-1.)/(A2*HSR)
HE=HS*(A3+1.)*(1./0.3877)
PER=(PE/2117.)*.965
HER=(HE/2.119E+08)**.6123
A4=1.-1.0477*(1.-HER)
RHDE=.002498*.0294*PER/A4
IF((HS-HE).GE.1.E-04)GO TO 6
UE=SQRT(-2.*HS*A3/.3877)
GO TO 7
6 UE=SQRT(2.*(HS-HE))
7 AEM2=.965*RHDE/PE-.6123*1.0477*HER/HE/A4
EMS=UE**2*AEM2
C AEM2=(SPEED OF SOUND)**-2,EMS=MACH**2,VISC=CDEF. OF VISC.
HER2=(HE/2.119E+08)**.3329

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```

A5=1.-1.0213*(1.-HER2)
PER2=(PE/2117.)*.992
A6=2.498*3.584E-10*.225
VISC=A6*PER2/A5/RHOE
GO TO 9
8 PER=(PE/PS)**(2./7.)
HE=HS*PER
TE=HE/6006.
VISC=2.27E-08*TE**1.5/(TE+198.6)
RHOE=RHOS*(PE/PS)**(5./7.)
UES=2.*(HS-HE)
UE=SQRT(UES)
EMS=UES*RHOE/(1.4*PE)
9 RETURN
END
SUBROUTINE SPCH(ZM,HE,RHOE,UE,HS,RNM,CF,QW,QWB,NGS)
C SPALDING-CHI METHOD FOR TURBULENT B.L.
C PR=PRANDTL NO., REC=RECOVERY FACTOR,
C RA=PR-1.+ALOG((5.*PR+1.)/6.)
DATA PR,REC,RA/0.725,0.89,-.535283/
SOG=ZM*HS/HE
CC=REC*UE**2/HE/2.
AOG=1.+CC
AOS=AOG/SOG
FRD=AOS**.772/SOG**.702
BB=AOG-SOG
T1=SQRT(CC)*2.
T2=SQRT(SOG*CC)*2.
FC=(ATAN((2.*CC-BB)/T1)+ATAN(BB/T2))**(-2)*CC
R=FRD*RNM
IF(NCS.EQ.0)GO TO 4
CFI=.0179*R**(-.205)
U=.4*SQRT(2./CFI)
IF(U.GT.100.)U=100.
4 CONTINUE
C
DO 2 L=1,15
U2=U**2
U3=U*U2

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See note on page 19
concerning FC

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U4=U*U3
U5=U*U4
T1=2./U+1.-U2/6.-U3/12.-U4/40.-U5/180.
C SOG=T(S)/T(G), AOG=T(AW)/T(G), AOS=T(AW)/T(S),
C RNM=REY. ND. BASED ON MOM. THK., U=K*U(+/G), ZW=T(S)/T(STAG)
EXU=EXP(U)
G=U2/.96+((1.-2./U)*EXU+T1)/4.*8
T2=-2./U2-U/3.-U2/4.-U3/10.-U4/36.
GP=U/.48+((1.-2./U+2./U2)*EXU+T2)/4.*8
FN=R-G
DU=FN/GP
U=U+DU
IF(ABS(DU/U).LT.1.0E-05)GO TO 3
IF(ABS(DU/U).GT.0.5)U=U-DU/2.
IF(U.GT.100.)U=100.
2 CONTINUE
C
3 CFI=.32/U**2
CF=CFI/FC
C RAF=REYNOLDS ANALOGY FACTOR=2*N(ST)/CF
C FROM BERTRAM'S & NEAL'S AGARD ARTICLE, 1965
RAF=1./((1.+2./U**RA)
QWB=RHOE*UE*RAF*CF/(2.*778.)
QW=QWB*HE*BB
RETURN
END
SUBROUTINE PRESS(KP,PNEWT)
DIMENSION PX(20),PXPP(20),PT(20),Z(20),Y(20),PHI(20),HPT(20),
1AMPT(20),PNN(20),AMPP(20),BMPP(20),XMPP(20),PXE(20),PXPPE(20)
COMMON X(20)
COMMON/COM1/ PH2(20),PN(20,20),AMP(20,20),HX2(20),BMP(20,20),
1XMP(20,20),IM2X,KM2X,HP2(20),X2(20)
COMMON/COM3/CAL,SAL,CPH,SPH
COMMON/COM4/POP
COMMON/COM7/YY(20,20),ZZ(20,20),JMN(20)
PI=3.1415927
X2(1)=0.0
LL = 1
19 CONTINUE

```

```

PN(1,1)= PNEWT*CAL**2+1.-PNEWT
IF(LL.EQ.1) GO TO 20
READ(1,15)PN(1,1),IM2X,KM2X
15 FORMAT(F10.5,2I5)
C XT IS VALUE OF X, X2(I) IS SQR(X)
C SPLINE FIT IS FOR PRESSURE VS. SQR(X)
20 AKM=KM2X-1
DO 2 K=1,KM2X
PN(1,K)=PN(1,1)
HP2(K)=PI/AKM
AK=K-1
AMP(1,K)=0.0
2 PH2(K)=AK*HP2(K)
DO 11 I=2,IM2X
JM = JMM(I)
XT=X(I)
IF(LL.NE.1)READ(1,3)JM,XT
3 FORMAT(15,F10.5)
IF(LL.EQ.1)WRITE(3,43)
43 FORMAT(/,4X,30HMOD.NEWT.PRESS.AT INPUT COORD.)
WRITE(3,31) JM,I,XT
31 FORMAT(/,4X,7HFOR JM=15,2X,6HAND X(,12,2H)=F10.5/,4X,30HTHE Z,Y
1 AND P COORDINATES ARE:)
X2(I)=SQR(XT)
DO 21 J=1,JM
Z(J)=ZZ(I,J)
21 Y(J)=YY(I,J)
4 FORMAT(6 F10.5)
IF(I.EQ.IM2X)WRITE(3,43)
44 FORMAT(/,2X,45HINPUT OF Y,Z AND P COORDINATES HAS TERMINATED)
C CALCULATE PHI FOR INPUT POINTS
PHI(1)=0.0
PHI(JM)=PI
JMM1=JM-1
DO 5 J=2,JMM1
IF(ABS(Y(J))-1.E-06)PHI(J)=PI/2.
IF(ABS(Y(J))-GE.1.E-06)PHI(J)=ATAN(Z(J)/Y(J))
IF(PHI(J).LT.0.)PHI(J)=PI+PHI(J)

```

```

5 HPT(J)=PHI(J)-PHI(J-1)
  HPT(JM)=PHI(JM)-PHI(JM-1)
  IF(LL.NE.1)GO TO 23
  DO 22 J=1,JM
  CALL STRMLN(XT,PHI(J),DLPH,DDP,DBX,GM,DGP,DGX,FF,IM2X,KM2X)
  CPH=COS(PHI(J))
  SPH= SIN(PHI(J))
  CALL NEWP(PNEWT,FF)
22 PT(J)=POP
23 CONTINUE
  DO 41 J=1,JM
41 WRITE(3,42)J,Z(J),J,Y(J),J,PT(J)
42 FORMAT(/,4X,2HZ(,12,2H)=F10.5,4X,2HY(,12,2H)=F10.5,4X,5HP/PS(,12
1,2H)=F10.5)
C SPLINE FIT INPUT PTS.
  CALL SPLINE(HPT,PT,JM,AMPT,0.,0.,1)
  KMXM1=KM2X-1
C CALCULATE REARRANGED P
  DO 8 K=2,KMXM1
  DO 6 J=2,JM
  IF(PH2(K).LT.PHI(J))GO TO 7
6 CONTINUE
7 PN(I,K)=FSPL(AMPT(J-1),AMPT(J),PHI(J-1),PHI(J),PT(J-1),PT(J),
1PH2(K))
8 CONTINUE
  PN(I,1)=PT(1)
  PN(I,KM2X)=PT(JM)
  DO 9 K=1,KM2X
9 PNN(K)=PN(I,K)
C SPLINE FIT REARRANGED P
  CALL SPLINE(HP2,PNN,KM2X,AMPP,0.,0.,1)
  DO 10 K=1,KM2X
10 AMP(I,K)=AMPP(K)
  HX2(I)=X2(I)-X2(I-1)
11 CONTINUE
  DO 14 K=1,KM2X
  DO 12 I=1,IM2X
12 PNN(I)=PN(I,K)
  CALL LAGR(0.,X2,PNN,IM2X,1,4,PR,PX(K))

```

```

CALL LAGR(X2(IM2X),X2,PNN,IM2X,4,1,PR,PXE(K))
CALL SPLINE(HX2,PNN,IM2X,XMPP,PX(K),PXE(K),I)
DO 13 I=1,IM2X
  13 XMP(I,K)=XMPP(I)
  14 CONTINUE
CALL SPLINE(HP2,PX,KM2X,PXPP,0,0,0,1)
CALL SPLINE(HP2,PXE,KM2X,PXPPE,0,0,0,1)
DO 16 K=1,KM2X
  16 DO 17 I=1,IM2X
    17 AMPP(I)=AMP(I,K)
  CALL SPLINE(HX2,AMPP,IM2X,BMPP,PXPP(K),PXPPE(K),I)
  DO 18 I=1,IM2X
    18 BMP(I,K)=BMPP(I)
  16 CONTINUE
  IF(LL.EQ.2)RETURN
  LL=2
  IF(KP.EQ.2)GO TO 19
  RETURN
END

SUBROUTINE PDER(XX,PPH,PE,DPDP,DP2P,DPDX,DPXP,DPXX)
COMMON/COM1/ PH2(20),PN(20,20),AMP(20,20),HX2(20),BMP(20,20),
  1XMP(20,20),IM2X,KM2X,HP2(20),X2(20)
  SX=SQRT(XX)
  DO 22 I=2,IM2X
    IF(SX.LT.X2(I))GO TO 23
  22 CONTINUE
  23 DO 24 K=2,KM2X
    IF(PPH.LT.PH2(K)) GO TO 25
  24 CONTINUE
  C COMPUTE P
  25 AMP1=FSPL(BMP(I-1,K-1),BMP(I,K-1),X2(I-1),X2(I),AMP(I-1,K-1),
    1AMP(I,K-1),SX)
    AMP2=FSPL(BMP(I-1,K),BMP(I,K),X2(I-1),X2(I),AMP(I-1,K),AMP(I,K),
    1SX)
    P1=FSPL(XMP(I-1,K-1),XMP(I,K-1),X2(I-1),X2(I),PN(I-1,K-1),PN(I,K-1)
    1),SX)
    P2=FSPL(XMP(I-1,K),XMP(I,K),X2(I-1),X2(I),PN(I-1,K),PN(I,K),SX)
  C COMPUTE PP,DPDP,DP2P
  PE=FSPL(AMP1,AMP2,PH2(K-1),PH2(K),P1,P2,PPH)

```

```

DDP=DFSPL(AMP1,AMP2,PH2(K-1),PH2(K),P1,P2,PPH)
DP2P=D2FPL(AMP1,AMP2,PH2(K-1),PH2(K),P1,P2,PPH)
AMPX1=DFSPL(BMP(I-1,K-1),BMP(I,K-1),X2(I-1),X2(I),AMP(I-1,K-1),AMP
1(I,K-1),SX)
AMPX2=DFSPL(BMP(I-1,K),BMP(I,K),X2(I-1),X2(I),AMP(I-1,K),AMP(I,K),
1SX)
PX1=DFSPL(XMP(I-1,K-1),XMP(I,K-1),X2(I-1),X2(I),PN(I-1,K-1),PN(I,K
1-1),SX)
PX2=DFSPL(XMP(I-1,K),XMP(I,K),X2(I-1),X2(I),PN(I-1,K),PN(I,K),SX)
DPDX=FSPL(AMPX1,AMPX2,PH2(K-1),PH2(K),PX1,PX2,PPH)/2./SX
DPXP=DFSPL(AMPX1,AMPX2,PH2(K-1),PH2(K),PX1,PX2,PPH)/2./SX
AMPXX1=D2FPL(BMP(I-1,K-1),BMP(I,K-1),X2(I-1),X2(I),AMP(I-1,K-1),
1AMP(I,K-1),SX)
AMPXX2=D2FPL(BMP(I-1,K),BMP(I,K),X2(I-1),X2(I),AMP(I-1,K),AMP(I,K),
1,SX)
PXX1=D2FPL(XMP(I-1,K-1),XMP(I,K-1),X2(I-1),X2(I),PN(I-1,K-1),PN(I,
1K-1),SX)
PXX2=D2FPL(XMP(I-1,K),XMP(I,K),X2(I-1),X2(I),PN(I-1,K),PN(I,K),SX)
DPXX=FSPL(AMPXX1,AMPXX2,PH2(K-1),PH2(K),PXX1,PXX2,PPH)/4./XX-DPDX/
12./XX
RETURN
END

```

```

SUBROUTINE LAGRAN(XX,X, FN, IMA, M, N, F, FP)
DIMENSION X(21), FN(21), TX(21)
C F AND FP(DERIV. OF F) BY LAGRANGIAN INTERPOLATION
C IMAX IS TOTAL PTS. AVAILABLE. M IS PTS. TO
C LEFT OF XX, N IS PTS. TO RIGHT OF XX TO
C BE USED IN INTERPOLATION
DO 2 I=2, IMA
IF(XX-LT.X(I))GO TO 3
2 CONTINUE
3 JO=I-M
IF(JO)4,4,5
4 JO=1
JM=M+N
IF(JM.GT.IMAX)JM=IMAX
GO TO 7
5 JM=JO+M+N-1
IF(IMAX-JM)6,7,7

```

```

6 JO=JO-(IMAX-JM)
  IF(JO.LT.1)JO=1
  JM=IMAX
7 CONTINUE
  F=0.0
  FP=0.0
  DO 10 J=JO, JM
10 TX(J)=XX-X(J)
  KM=JM-JO+1
  KM2=KM-2
  DO 8 K=1, KM
  D=1.
  AN=1.
  ANP=0.0
  JOK=JO+K-1
  DO 9 J=JO, JM
  TR=1.
  JK=J+K-1
  IF(JK.GT.JM)JK=JK-JM+JO-1
  IF(JK.EQ.JOK)GO TO 9
  TT=X(JOK)-X(JK)
  D=D*TT
  AN=AN*TX(JK)
  JKN=JK-1
  DO 11 L=1, KM2
  JKN=JKN+1
  IF(JKN.GT.JM)JKN=JKN-JM+JO-1
  IF(JKN.EQ.JOK)JKN=JKN+1
  IF(JKN.GT.JM)JKN=JKN-JM+JO-1
11 TR=TR*TX(JKN)
  ANP=ANP+TR
9 CONTINUE
  F=F+AN*FN(JOK)/D
  FP=FP+ANP*FN(JOK)/D
8 CONTINUE
  RETURN
  END
SUBROUTINE TRANS
COMMON/COM6/XB(20), YB(20), ZB(20), PHB(20), HPB(20), AMTB(20), XE(20)

```

```

1, YE(20), ZE(20), PHE(20), HPE(20), AMTE(20), LMAX, MMAX
C SPLINE FIT DATA FOR BEG. & END OF TRANSITION BY GEOMETRIC LOCATION
PI=3.1415927
READ(1,1) LMAX
1 FORMAT(I5)
WRITE(3,6) LMAX
6 FORMAT(/, 2X, 70HINPUT COORD. FOR BEGINNING OF TRANSITION BY GEOMET
IRIC LOCATION, LMAX =, I3)
READ(1,3) ((XB(L), YB(L), ZB(L)), L=1, LMAX)
3 FORMAT(8E10.0)
DO 2 L=1, LMAX
WRITE(3,4) L, XB(L), YB(L), ZB(L)
4 FORMAT(/, 4X, 3HXB(, I2, 2H)=, F10.5, 5X, 3HYB(, I2, 2H)=, F10.5, 5X, 3HZB(
1, I2, 2H)=, F10.5)
2 CONTINUE
WRITE(3,5)
5 FORMAT(/, 2X, 74HINPUT OF X, Y, AND Z COORDINATES FOR BEGINNING OF TR
ANSITION HAS TERMINATED)
PHB(1)=0.0
LMI=LMAX-1
DO 7 L=2, LMI
PHB(L)=ARCOS(YB(L)/SQRT(YB(L)**2+ZB(L)**2))
7 HPB(L)=PHB(L)-PHB(L-1)
PHB(LMAX)=PI
HPB(LMAX)=PI-PHB(LMAX-1)
CALL SPLINE(HPB, XB, LMAX, AMTB, 0., 0., 1)
READ(1, 1) MMAX
WRITE(3, 8) MMAX
8 FORMAT(/, 2X, 69HINPUT COORDINATES FOR END OF TRANSITION BY GEOMETR
IC LOCATION, MMAX =, I3)
READ(1, 3) ((XE(M), YE(M), ZE(M)), M=1, MMAX)
DO 9 M=1, MMAX
WRITE(3, 10) M, XE(M), YE(M), ZE(M)
10 FORMAT(/, 4X, 3HXE(, I2, 2H)=, F10.5, 5X, 3HYE(, I2, 2H)=, F10.5, 5X, 3HZE(, I2
1, 2H)=, F10.5)
9 CONTINUE
WRITE(3, 11)
11 FORMAT(/, 2X, 68HINPUT OF X, Y, AND Z COORDINATES FOR END OF TRANSITI
ON HAS TERMINATED)

```

Note: on CDC computer
ARCØS must be replaced
with ACØS

Note: on CDC computer
ARCOS must be replaced
with ACOS

```

PHE(1)=0.0
MM1=MMAX-1
DO 12 M=2,MM1
PHE(M)=ARCOS(YE(M)/SQRT(YE(M)**2+ZE(M)**2))
12 HPE(M)=PHE(M)-PHE(M-1)
PHE(MMAX)=PI
HPE(MMAX)=PI-PHE(MMAX-1)
CALL SPLINE(HPE,XE,MMAX,AMTE,0.,0.,1)
RETURN
END

```

```

SUBROUTINE REGTR(PPH,XTR)
COMMON/COM6/XB(20),YB(20),ZB(20),PHB(20),HPB(20),AMTB(20),XEB(20)
1,YE(20),ZE(20),PHE(20),HPE(20),AMTE(20),LMAX,MMAX
C ROUTINE TO COMPUTE X FOR BES. OF TRANS. (XTB)
DO 13 L=2,LMAX
IF(PPH.LT.PHD(L))GO TO 14
13 CONTINUE
14 XTB=FSPL(AMTB(L-1),AMTB(L),PHB(L-1),PHB(L),XB(L-1),XB(L),PPH)
RETURN
END

```

```

SUBROUTINE FNDTR(PPH,XTE)
COMMON/COM6/XB(20),YB(20),ZB(20),PHB(20),HPB(20),AMTB(20),XEB(20)
1,YE(20),ZE(20),PHE(20),HPE(20),AMTE(20),LMAX,MMAX
C ROUTINE TO COMPUTE X FOR END OF TRANS. (XTE)
DO 15 M=2,MMAX
IF(PPH.LT.PHE(M))GO TO 16
15 CONTINUE
16 XTE=FSPL(AMTE(M-1),AMTE(M),PHE(M-1),PHE(M),XE(M-1),XE(M),PPH)
RETURN
END

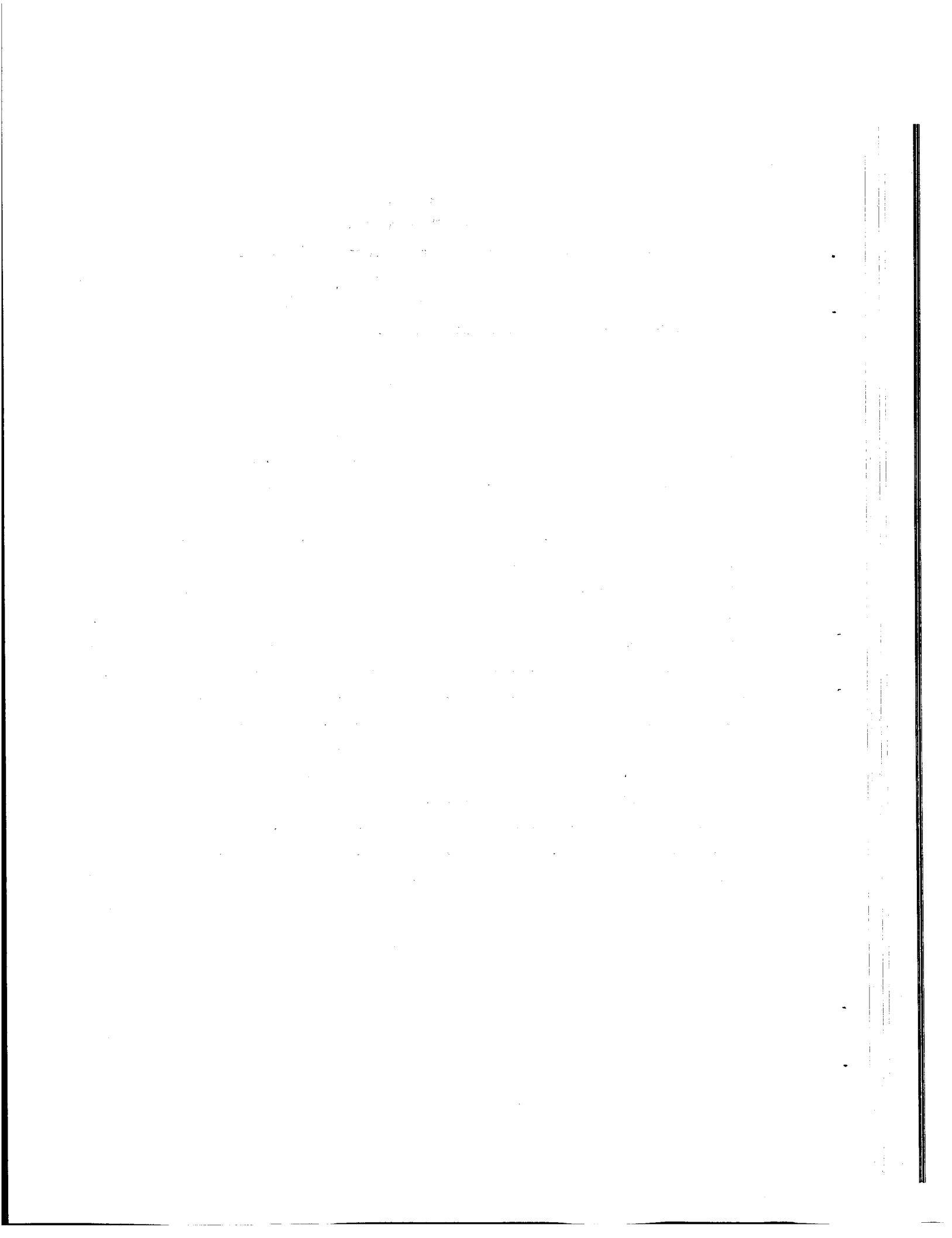
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APPENDIX B
DETAILED FLOW DIAGRAM

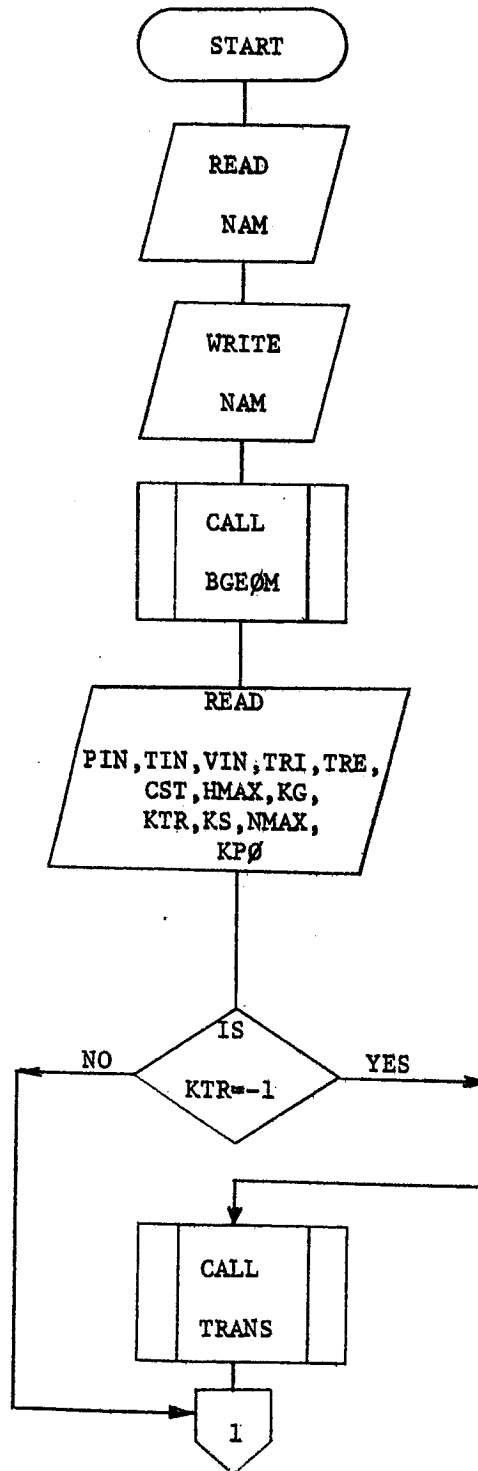
Symbols used in the flow diagram conform to the International Organization for Standardization (ISO) Recommendation on Flowchart Symbols for Information Processing, and are consistent with the fewer symbols adopted by the American National Standards Institute, Inc. (ANSI).

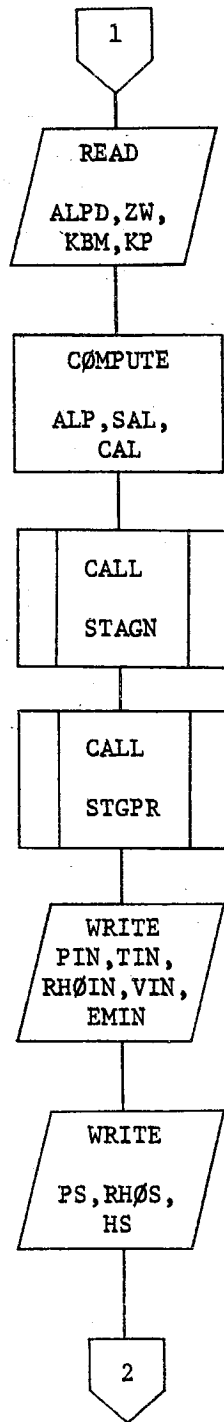
CONTENTS

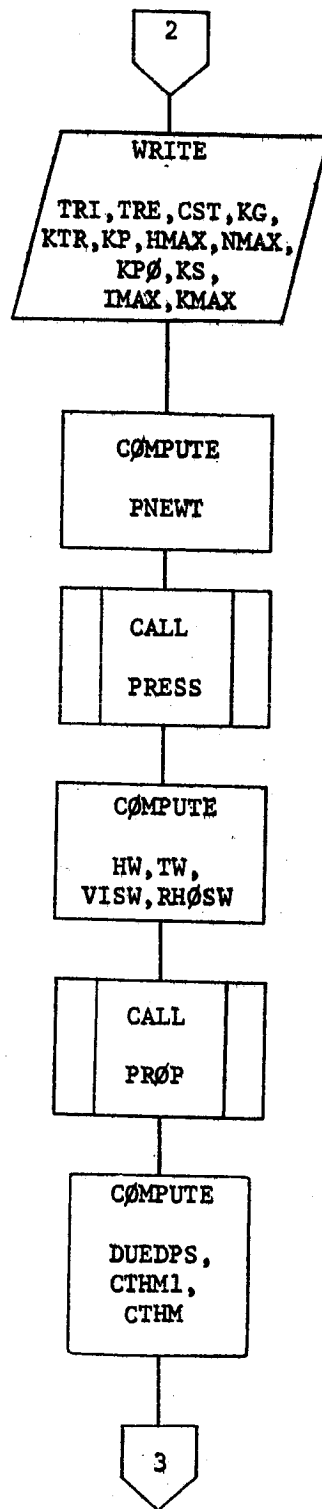
Main Program	87
Function RUNGE	118
Subroutine STAGN	128
Subroutine NEWP	134
Subroutine STRMLN	135
Subroutine BGEØM	138
Subroutine SPLINE	154
Function FSPL	159
Function DFSPL	160
Function D2FPL	161
Subroutine STGPR	162
Subroutine PRØP	165
Subroutine SPCH	167
Subroutine PRESS	170
Subroutine PDER	185
Subroutine LAGRΝ	187
Subroutine TRANS	194
Subroutine BEGTR	200
Subroutine ENDTR	201

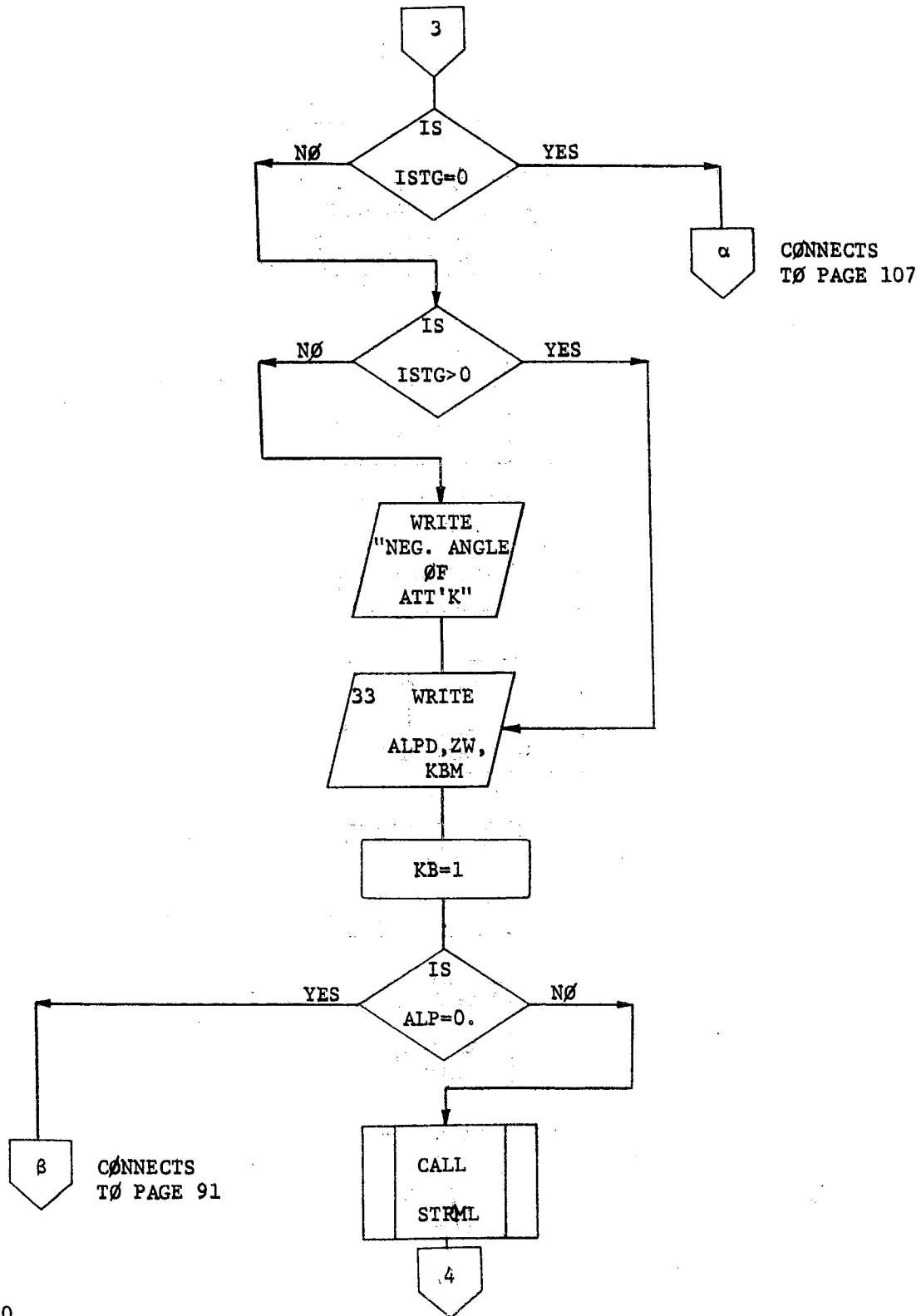


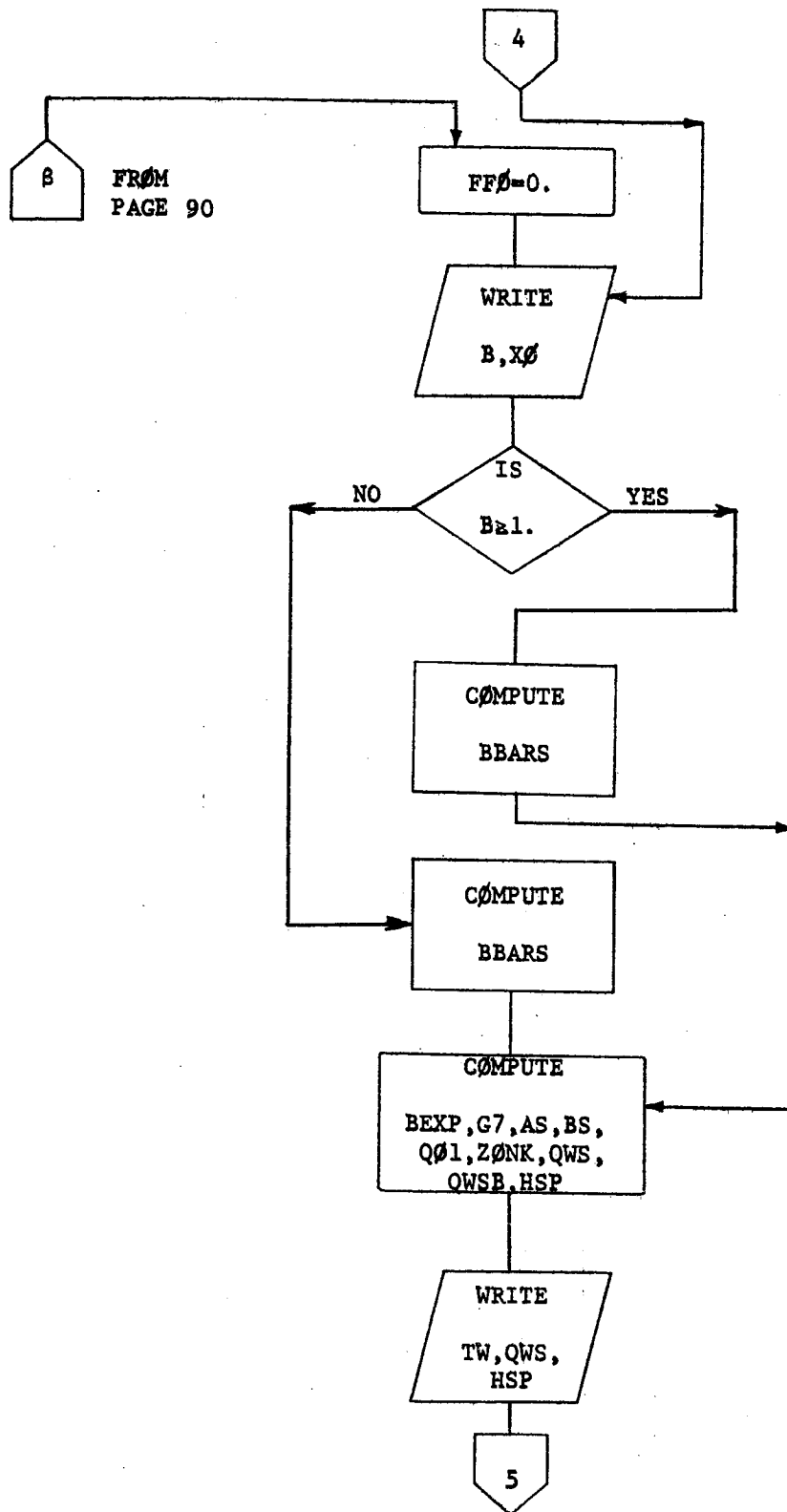
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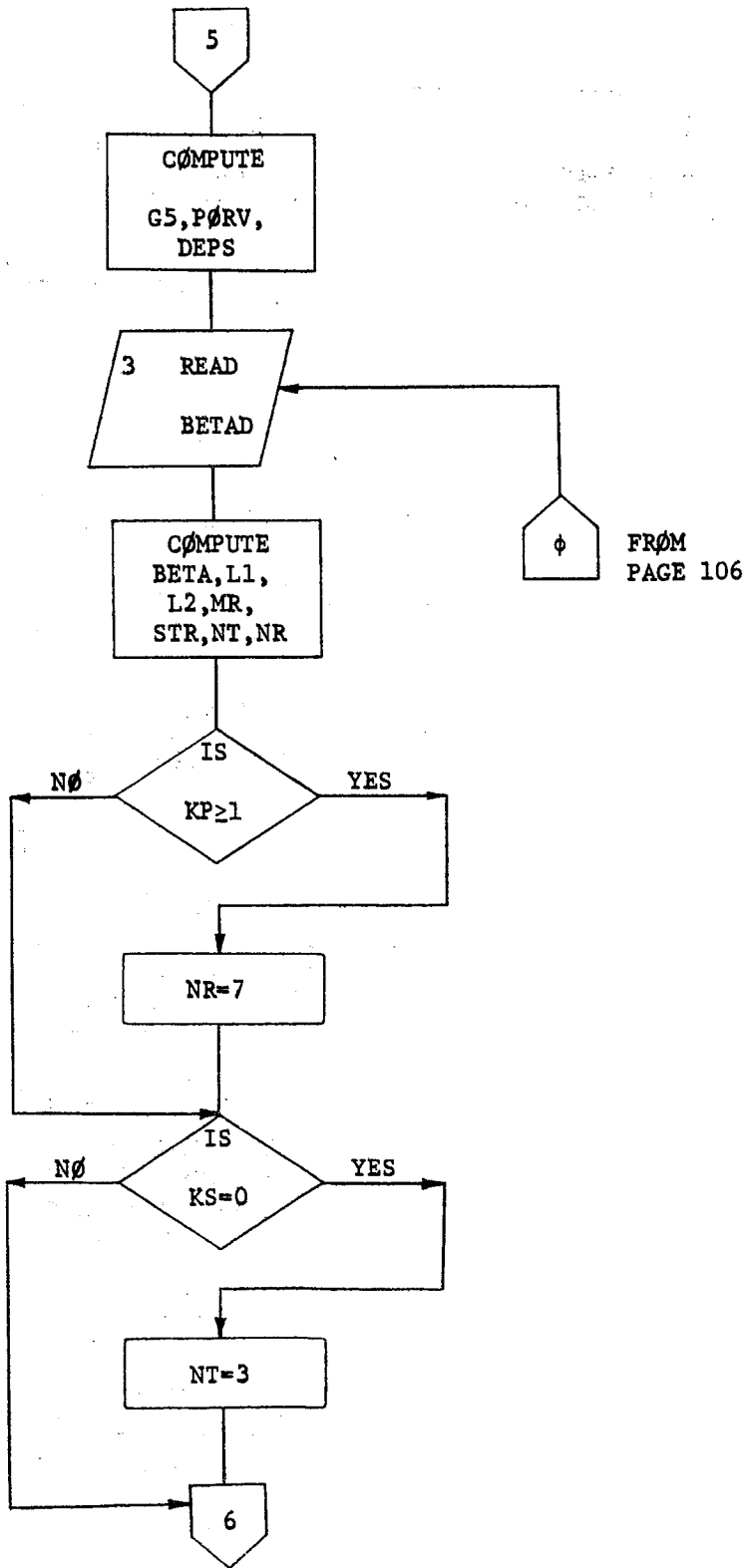


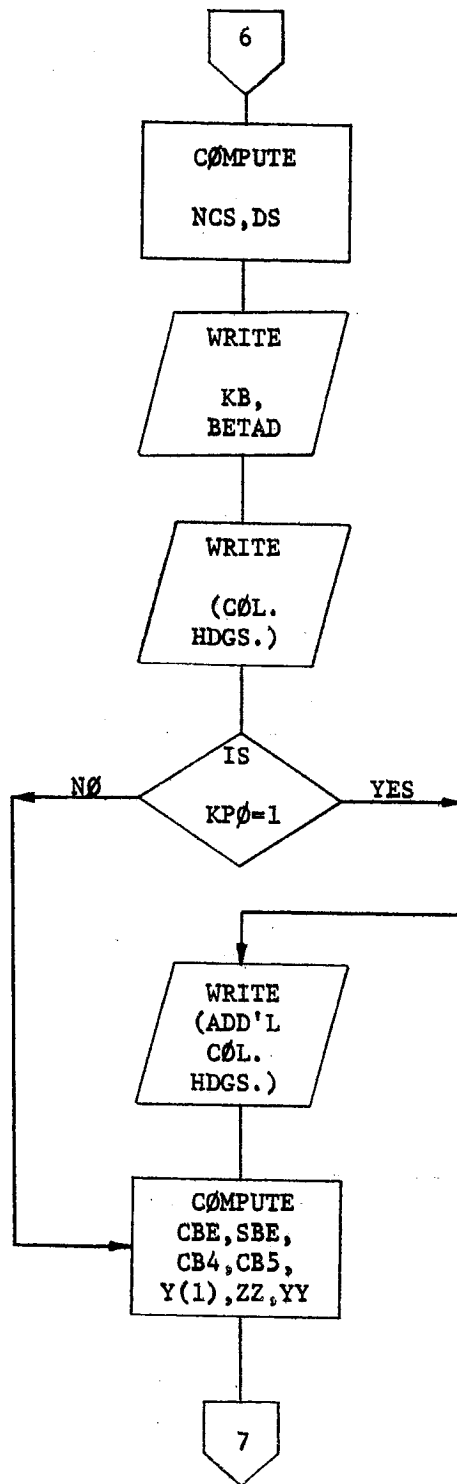


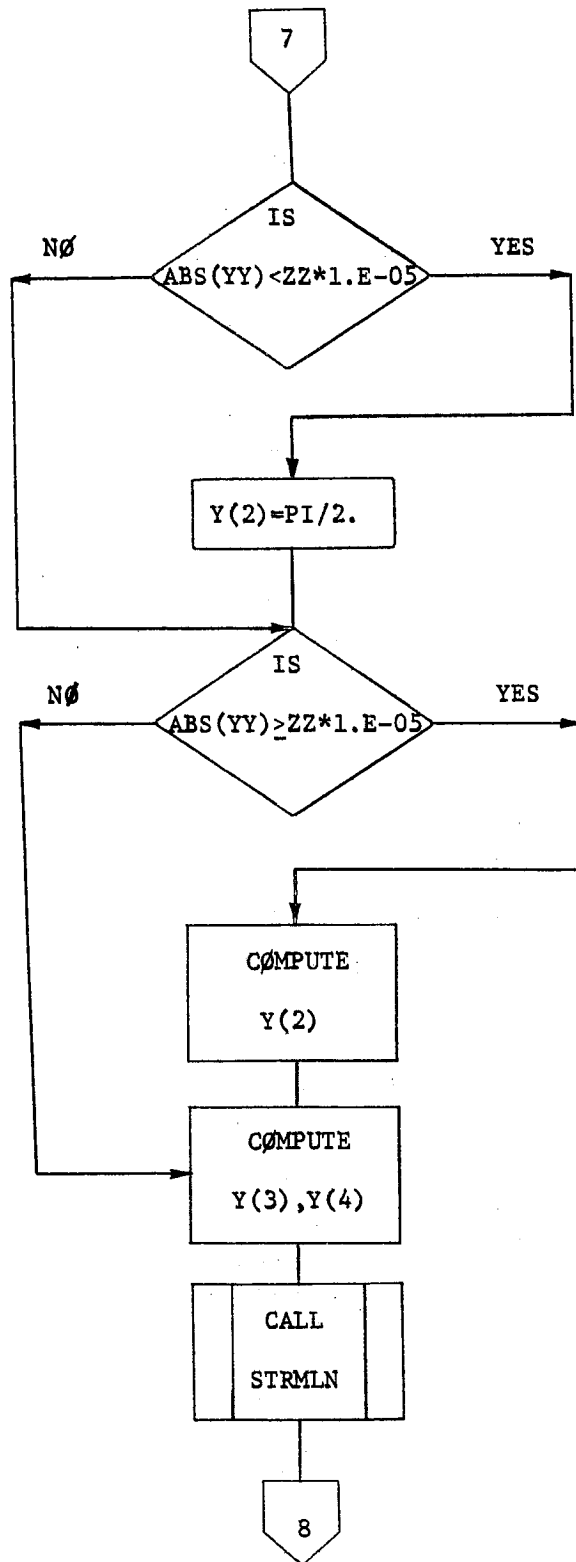


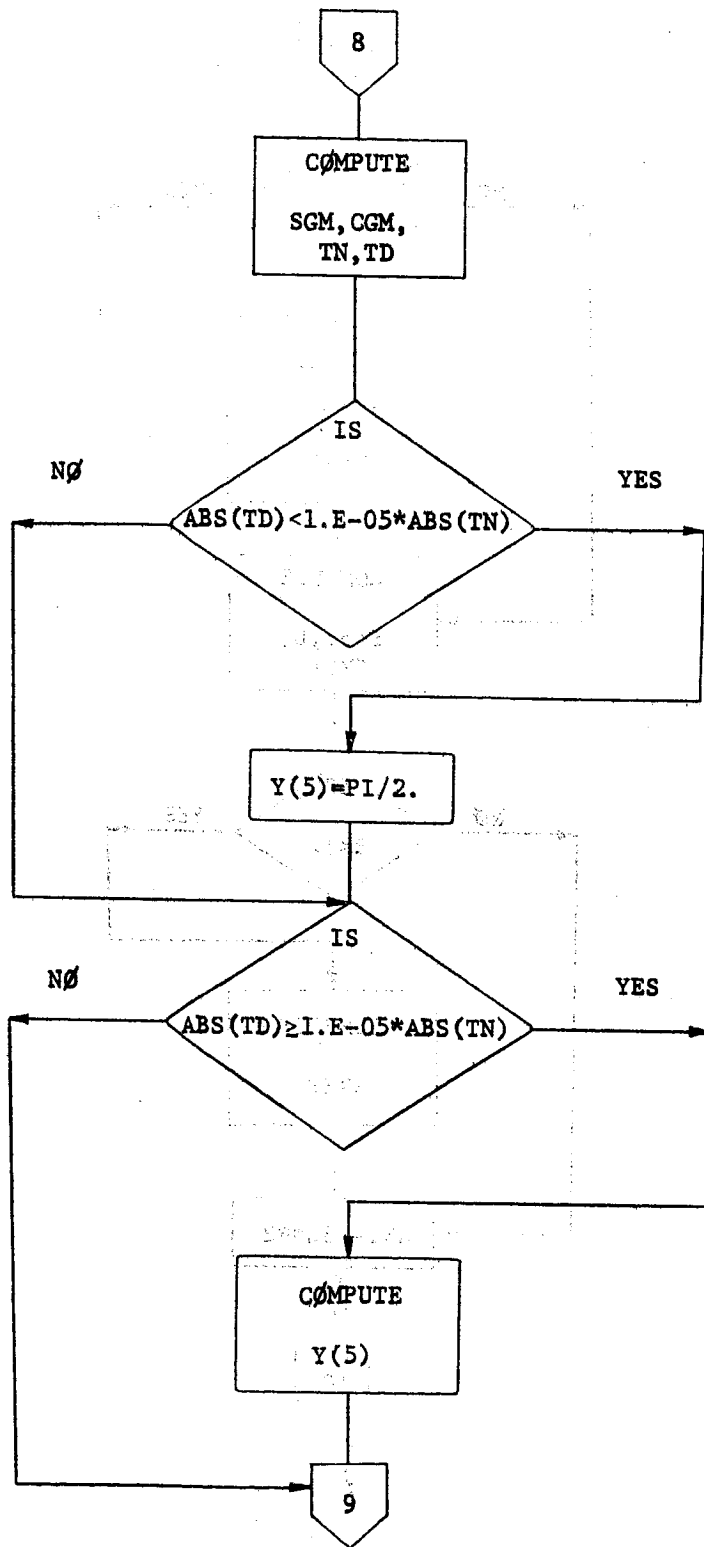


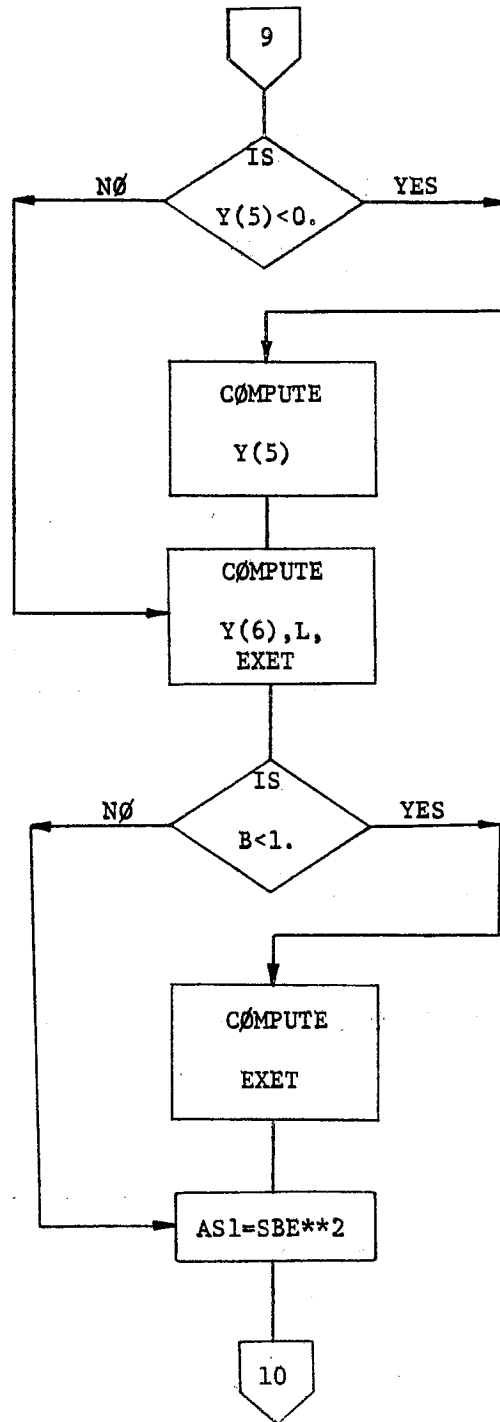


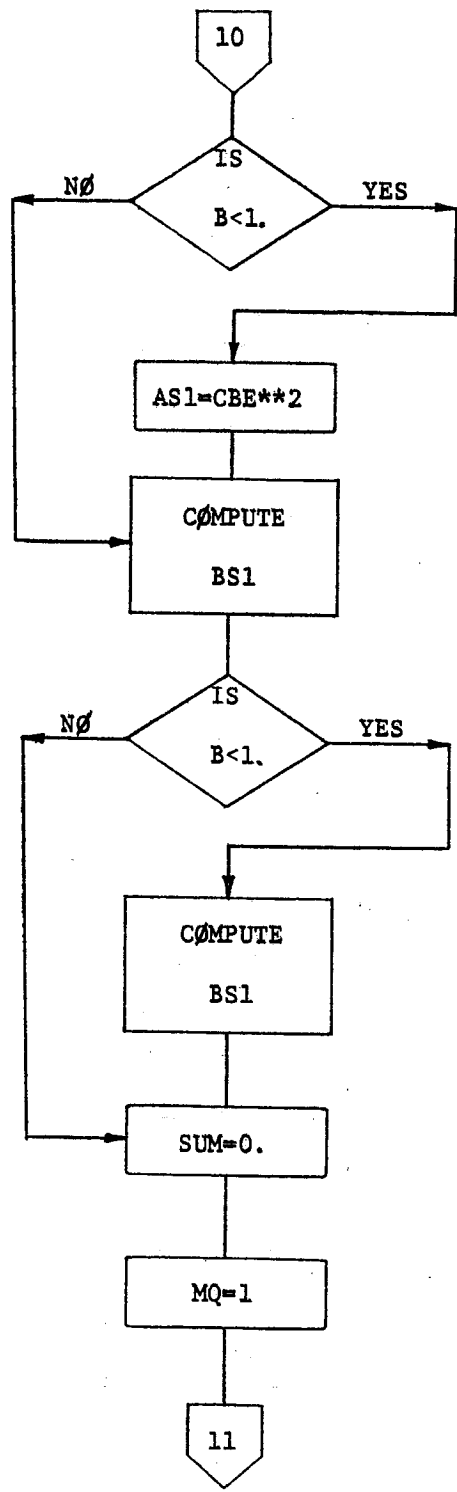


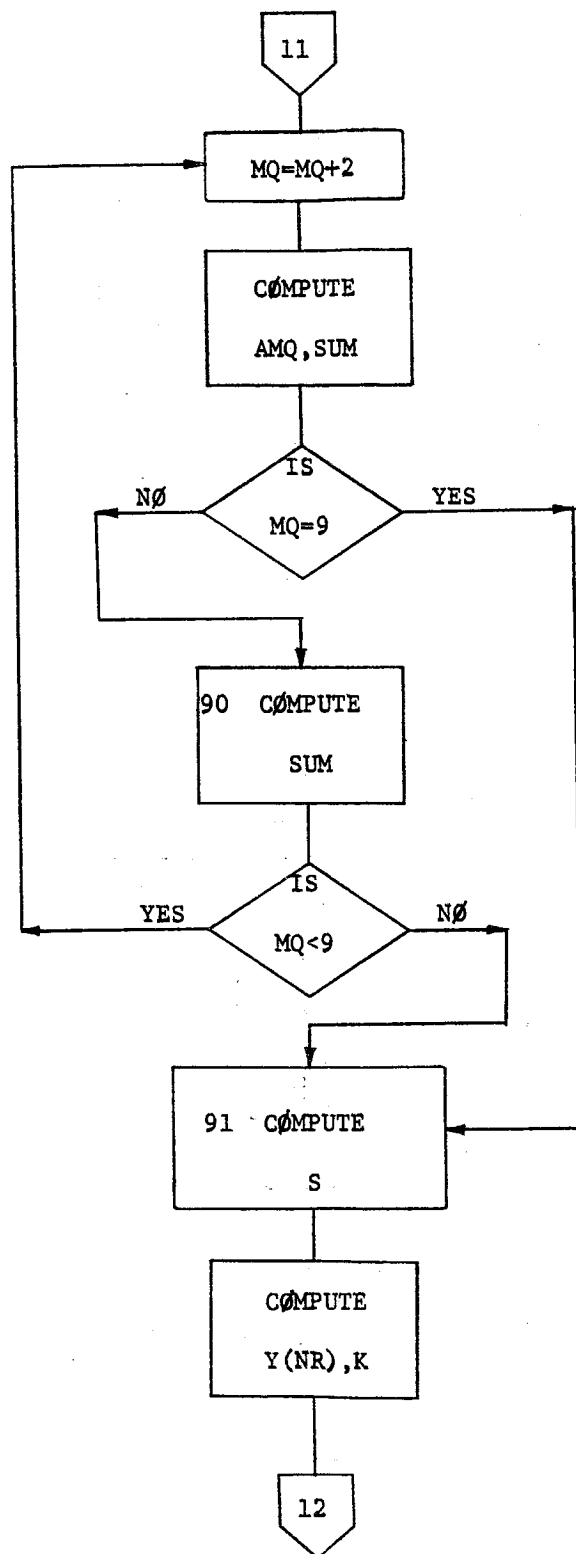


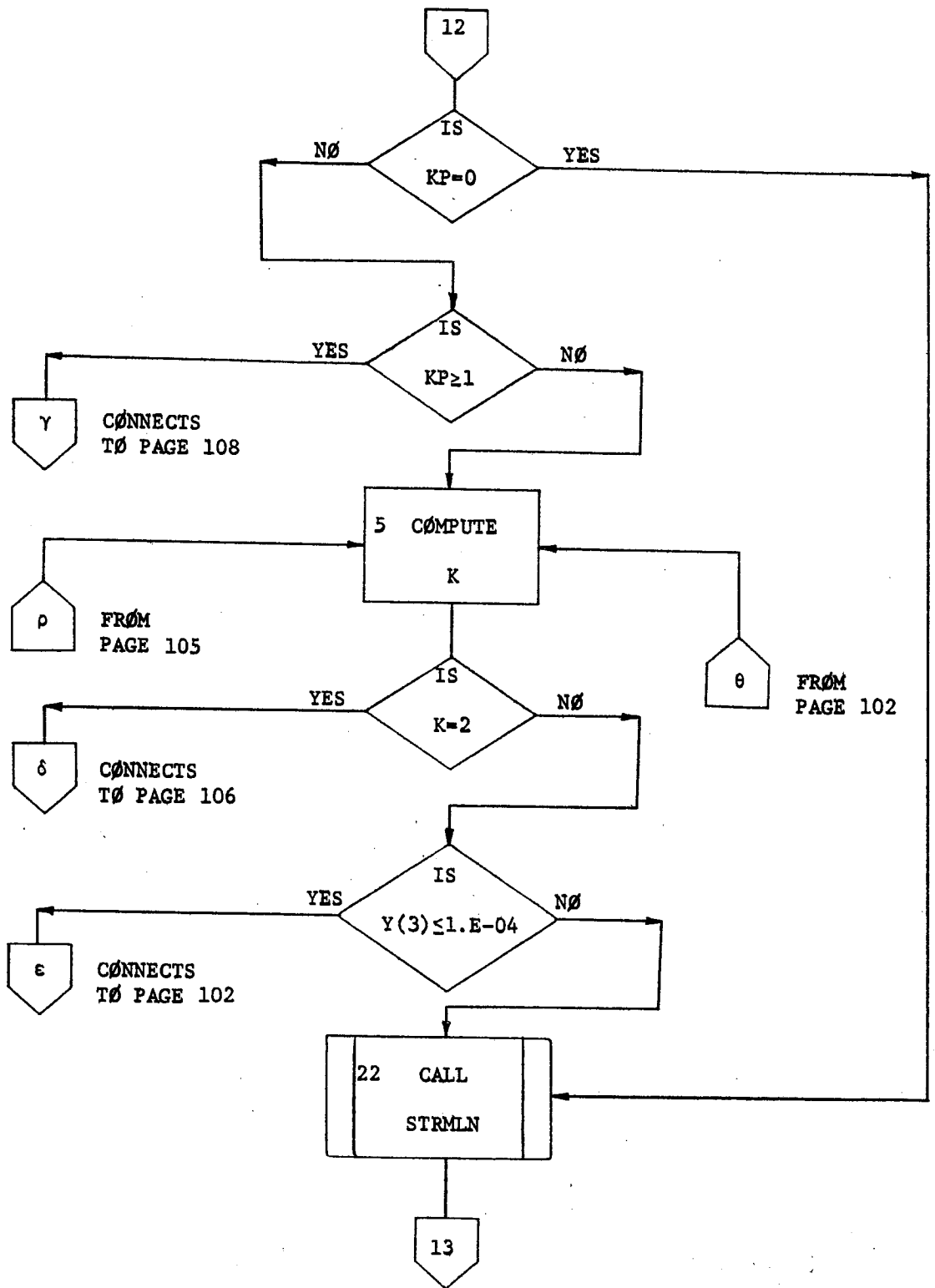


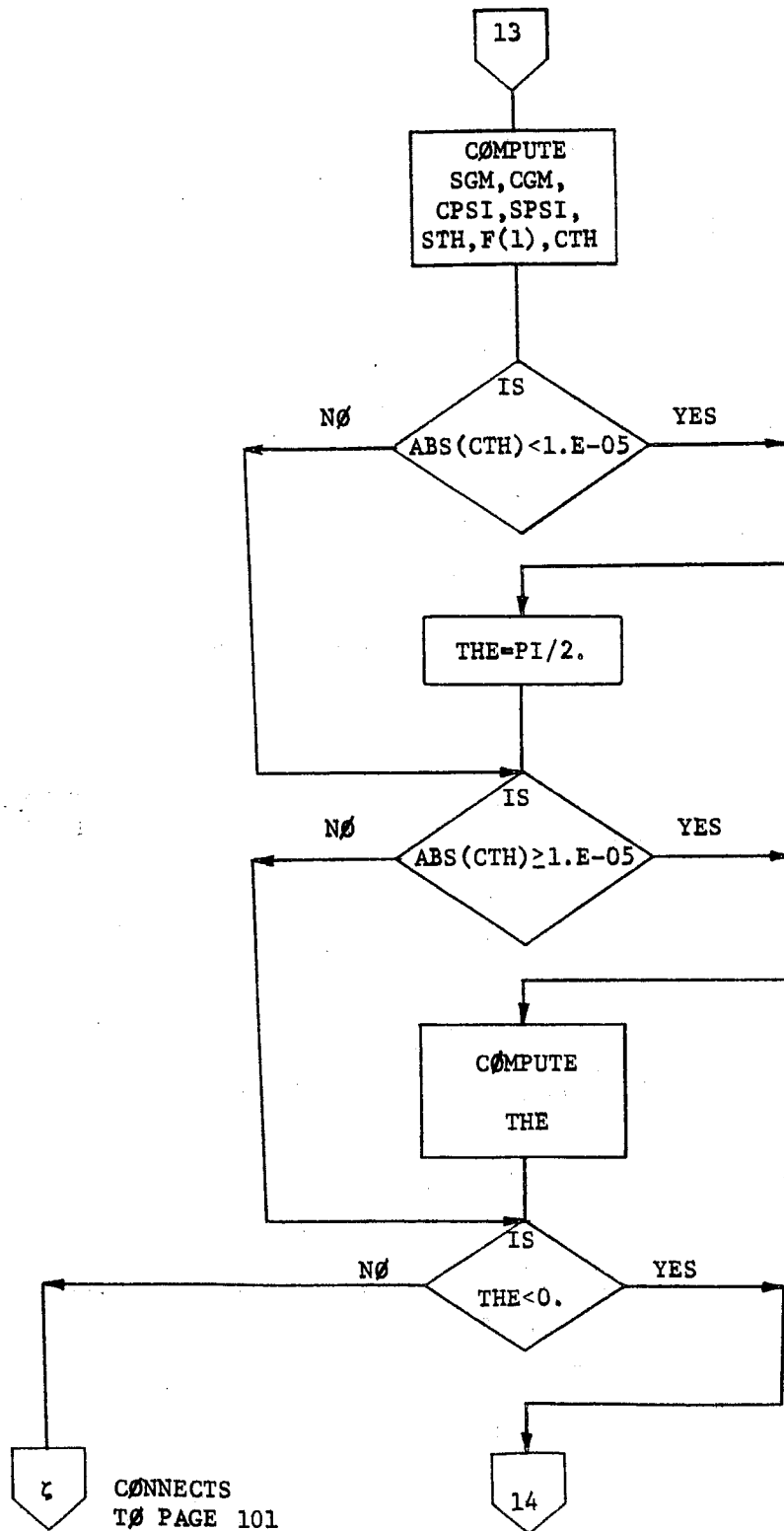




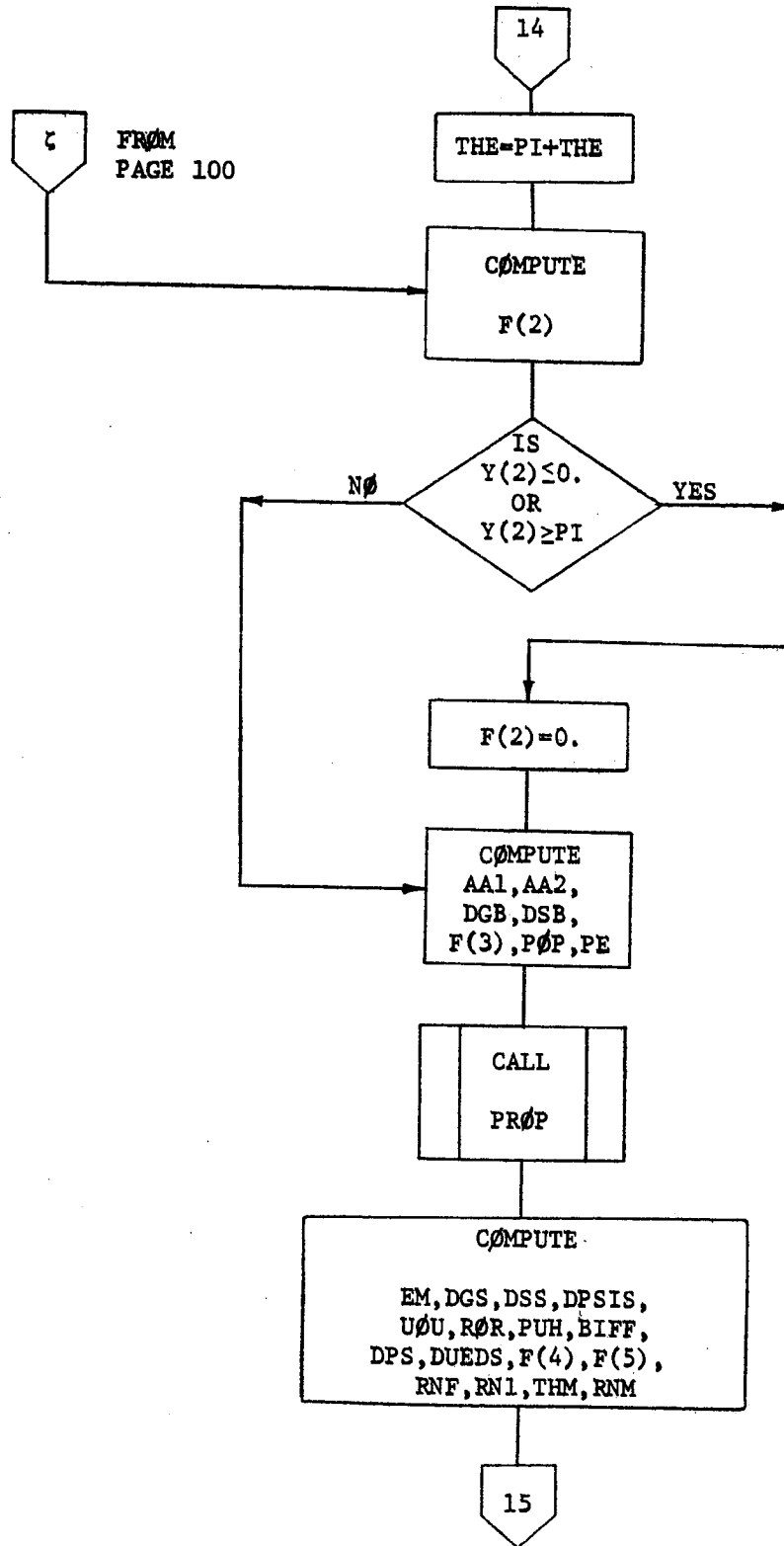


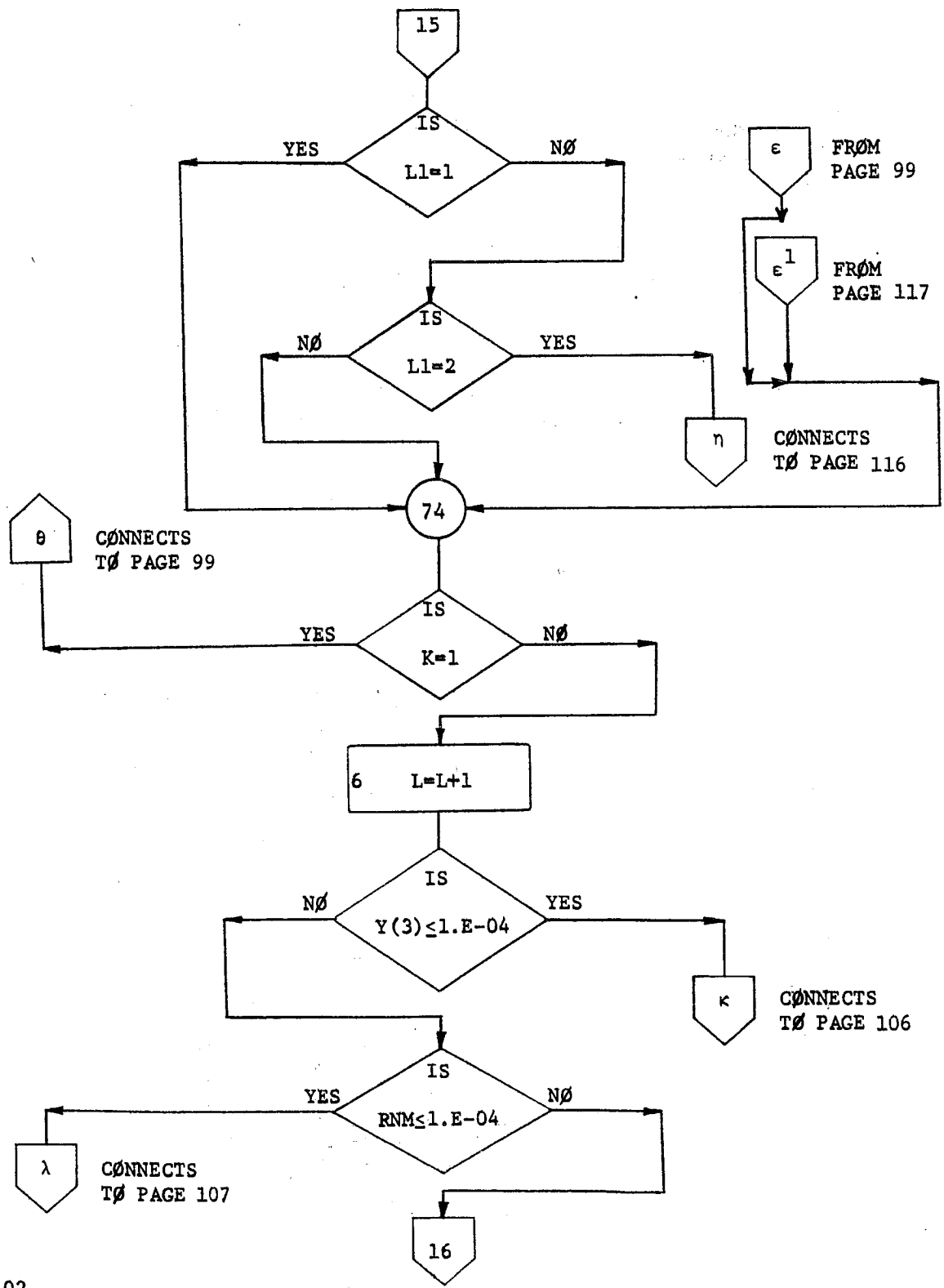


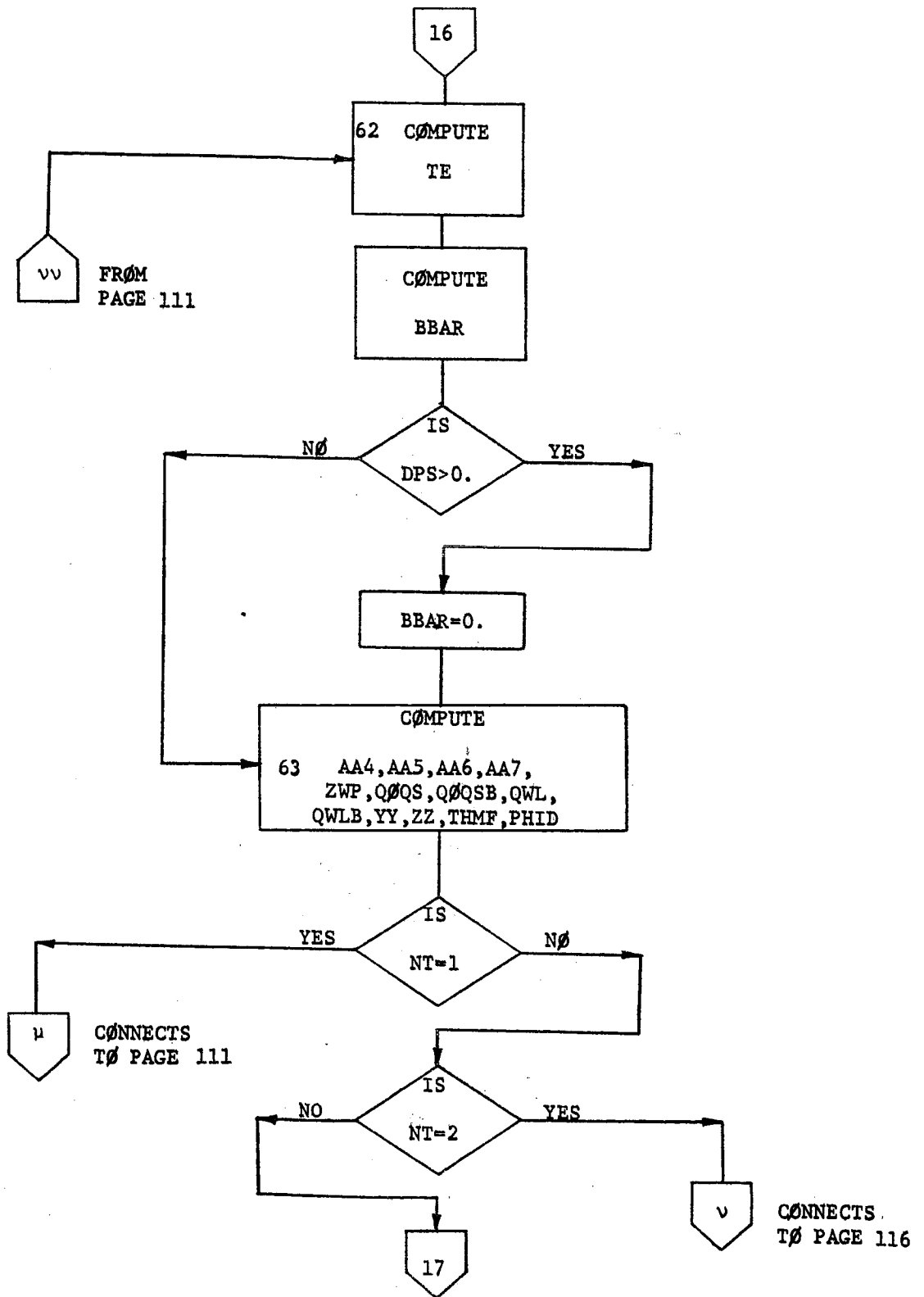


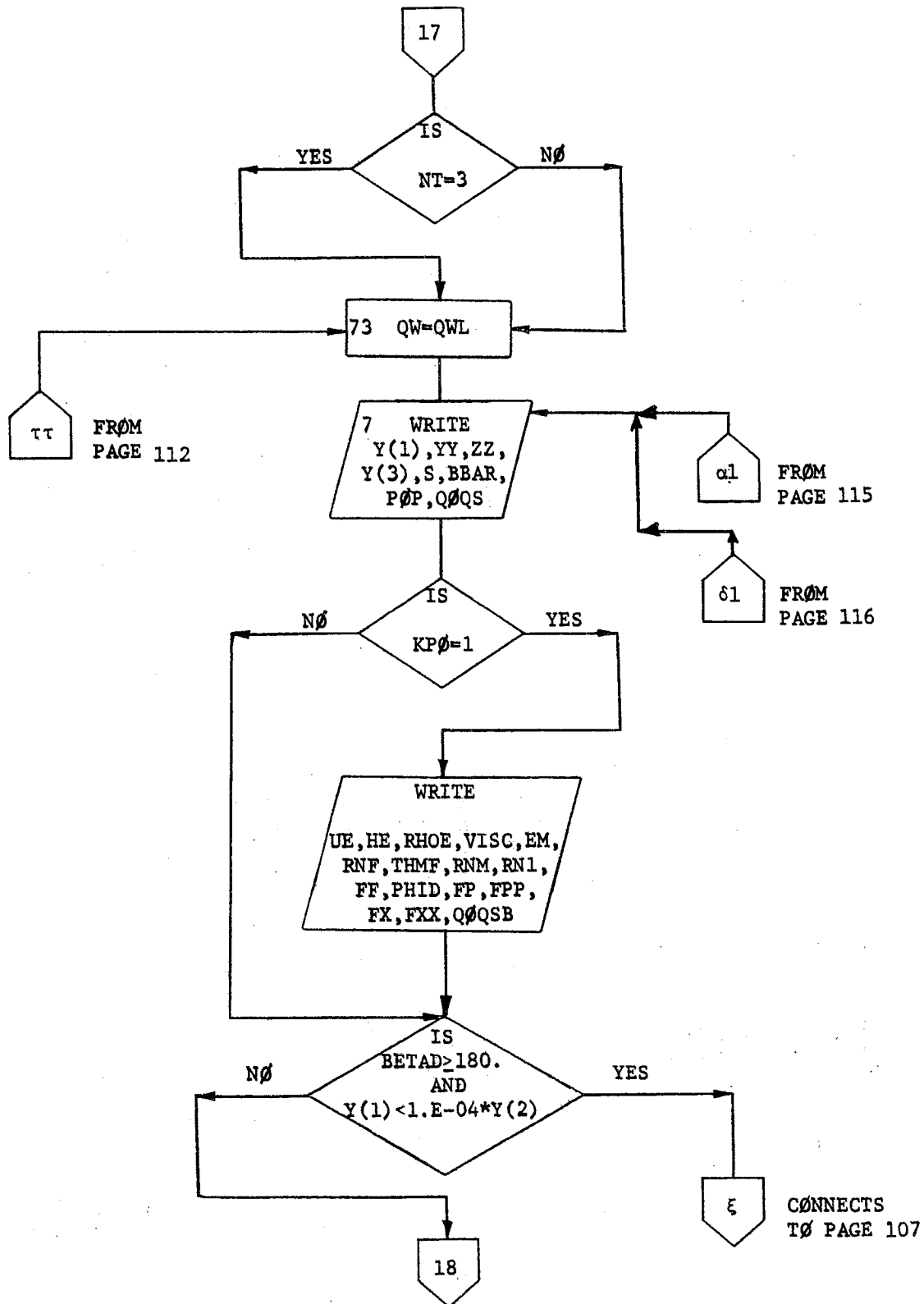


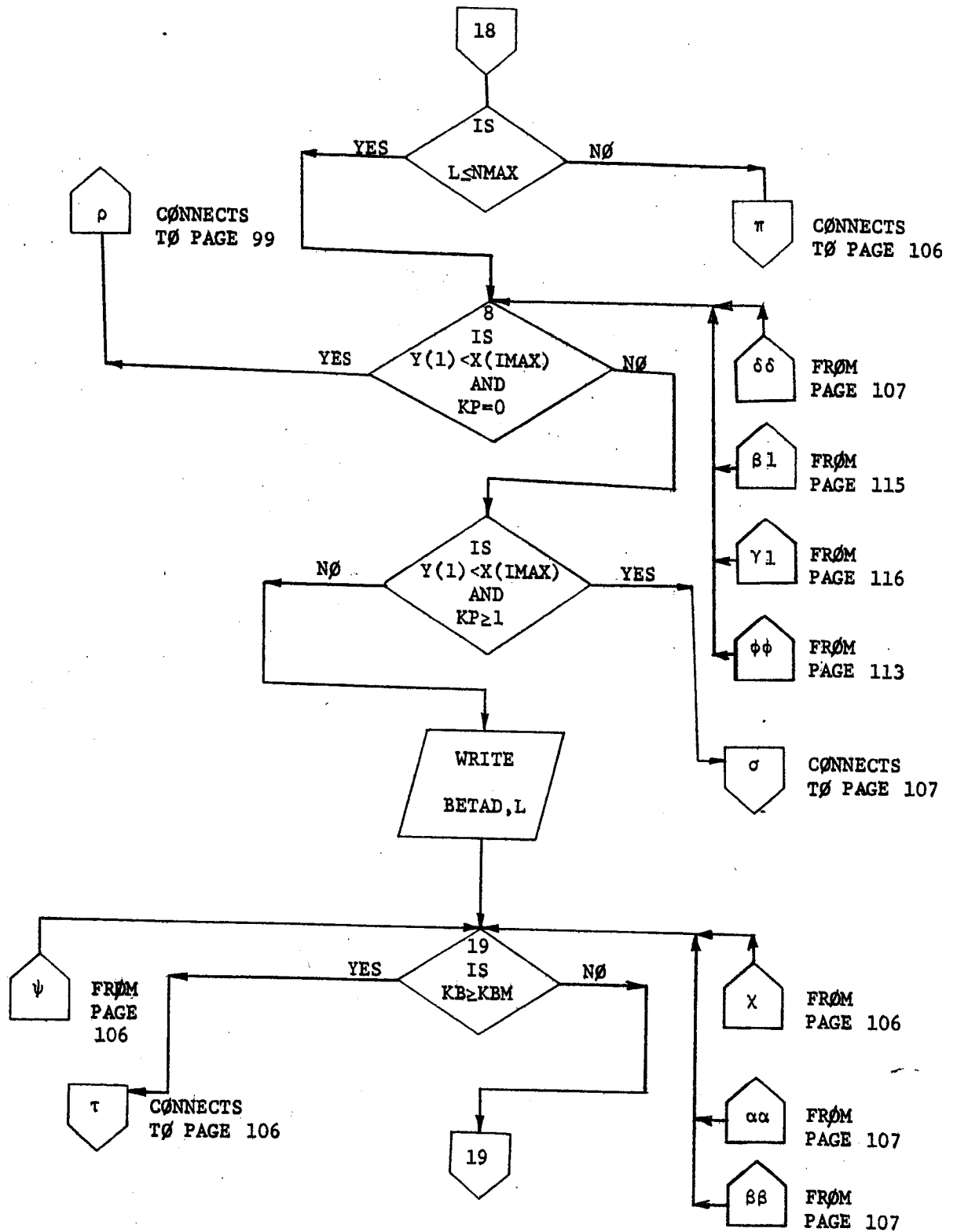
CONNECTS
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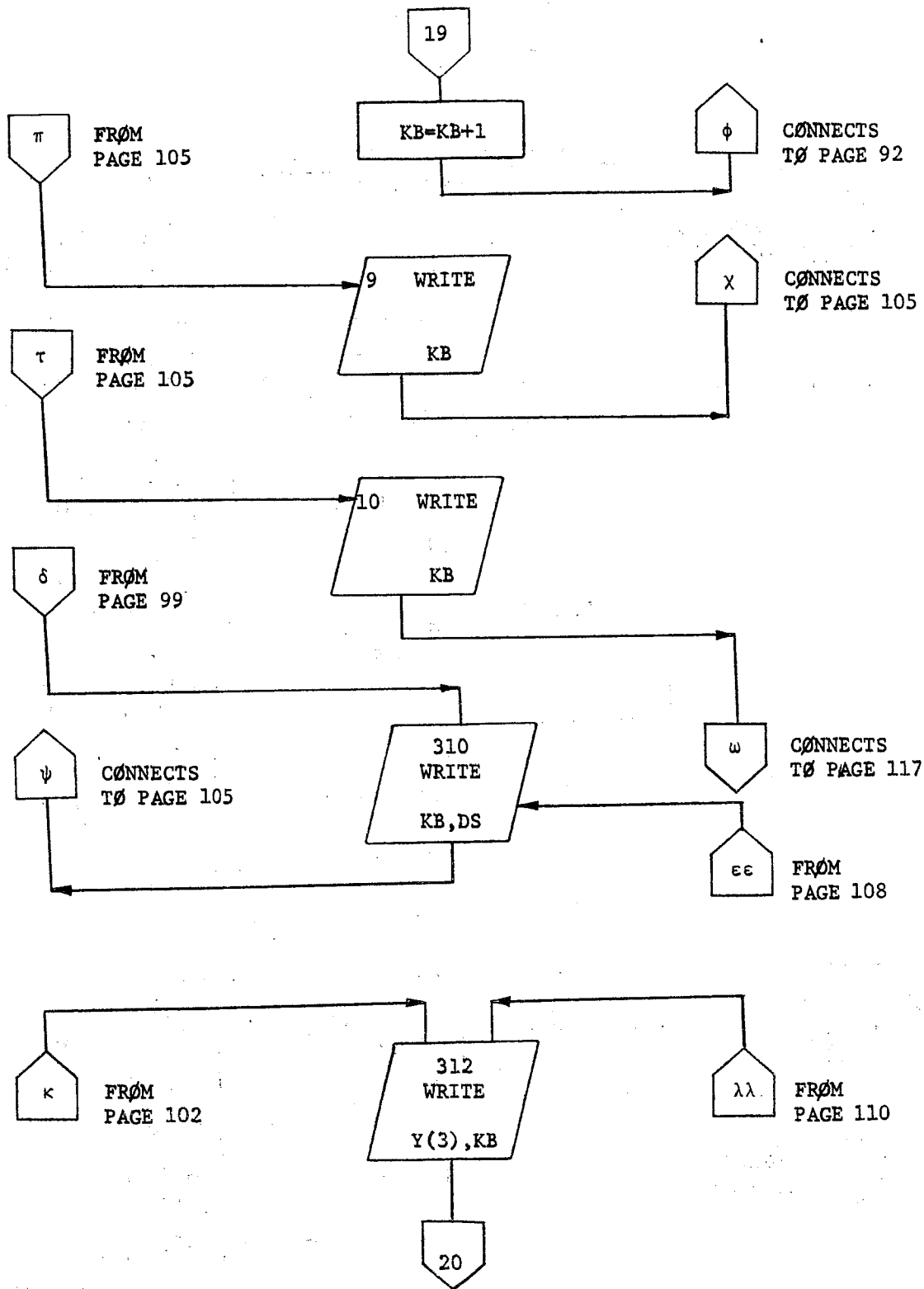


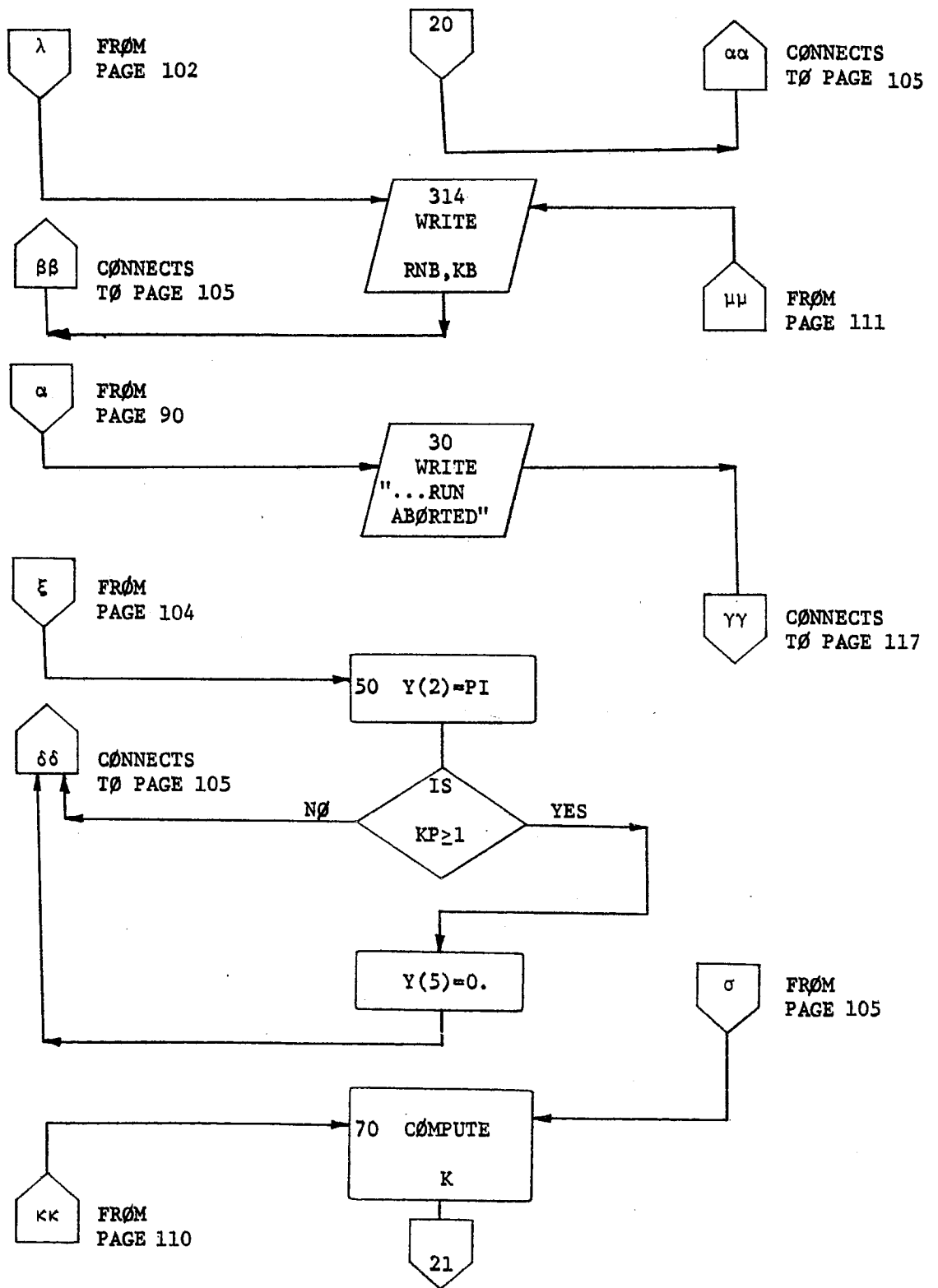


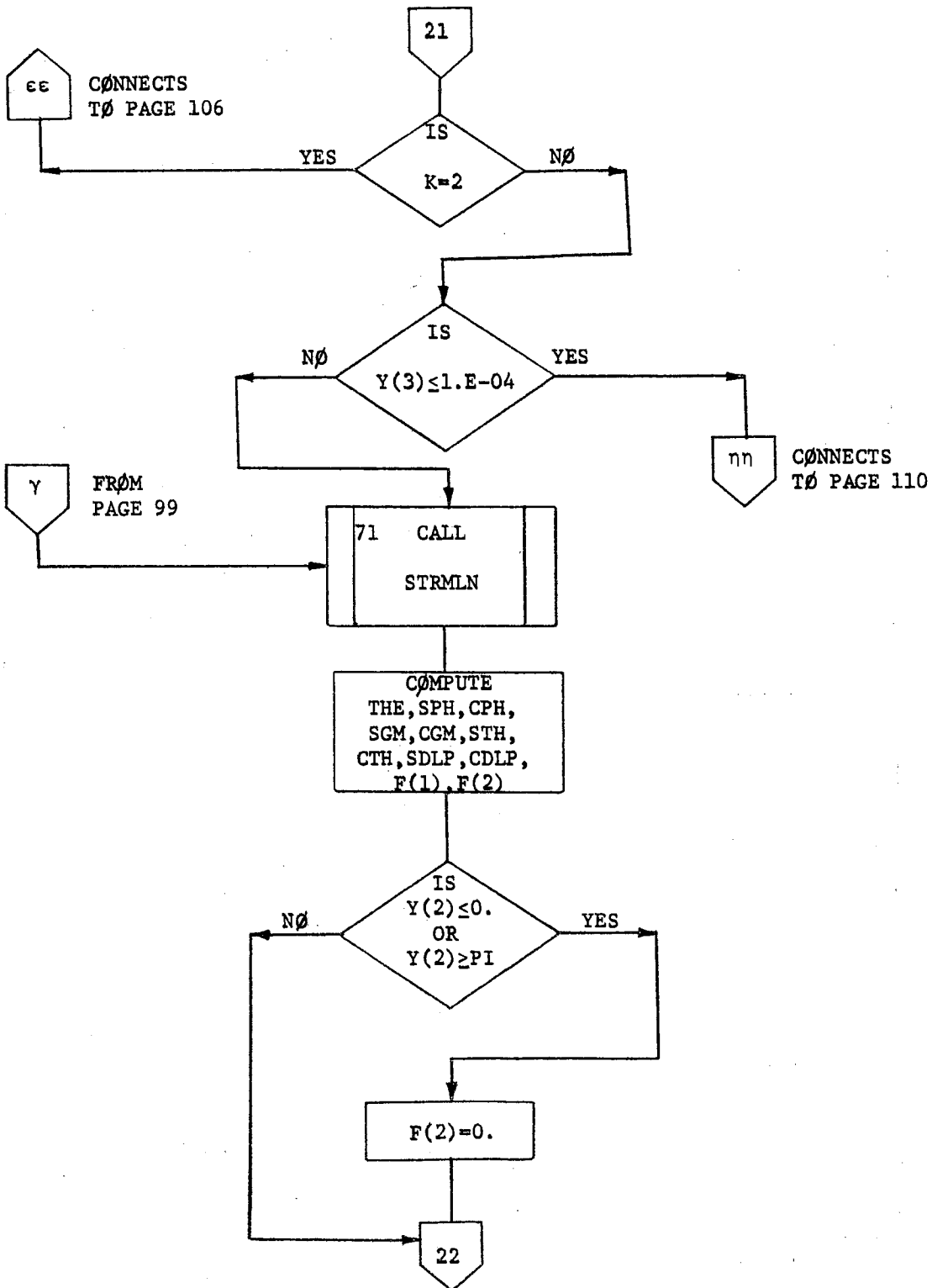


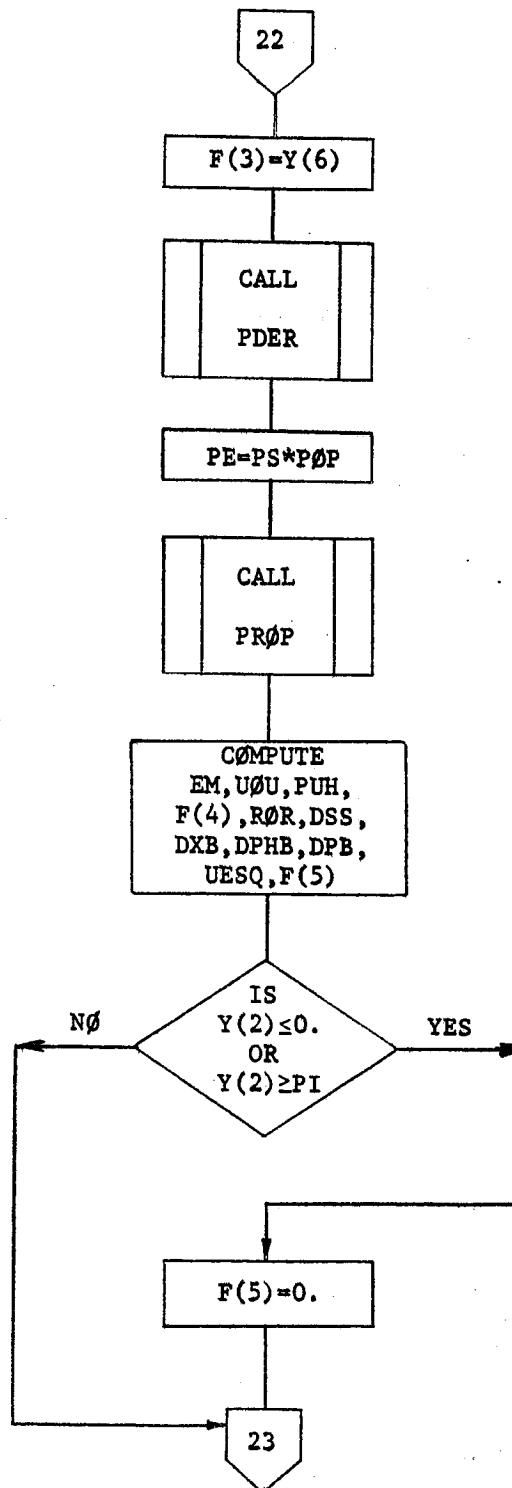


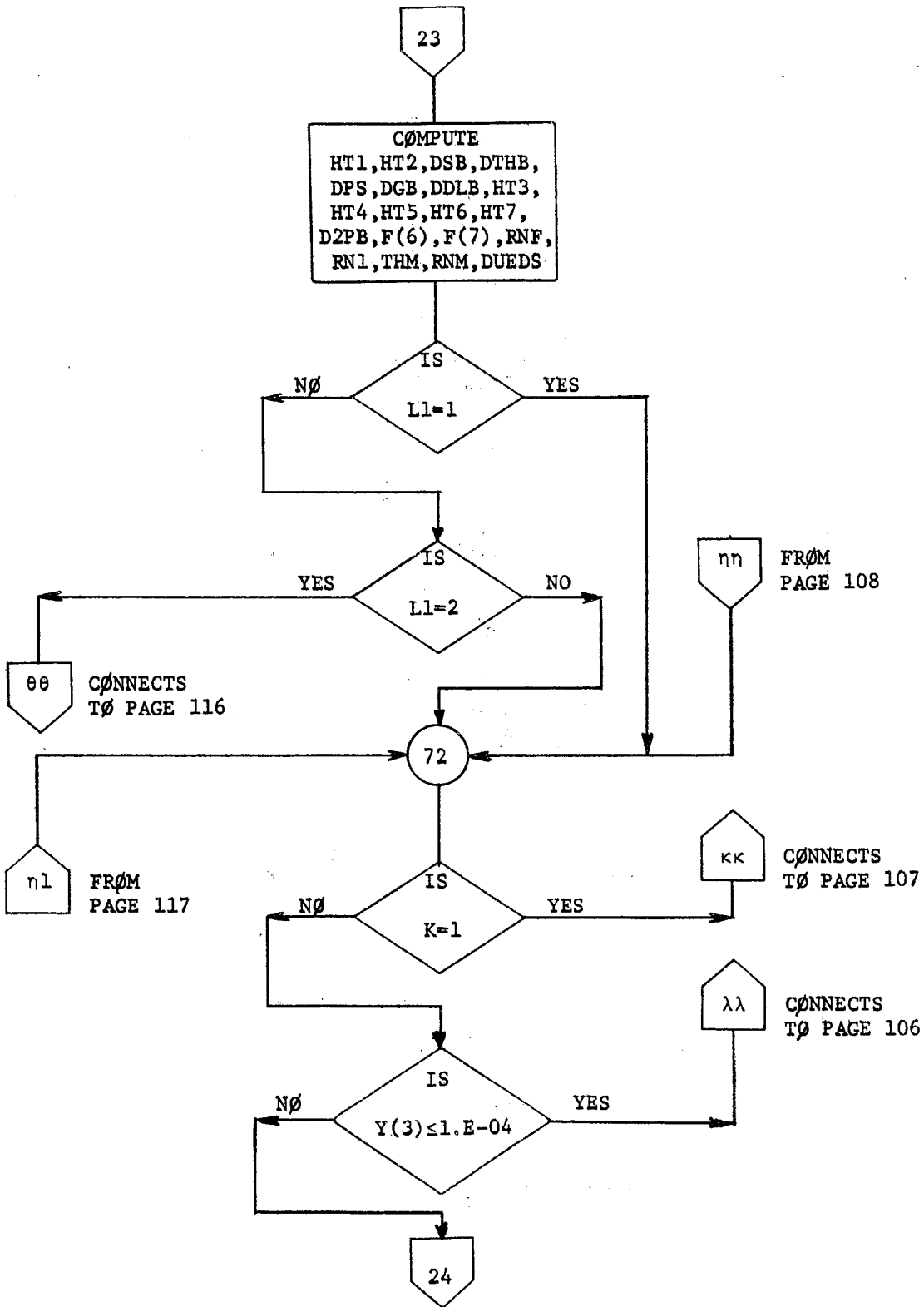


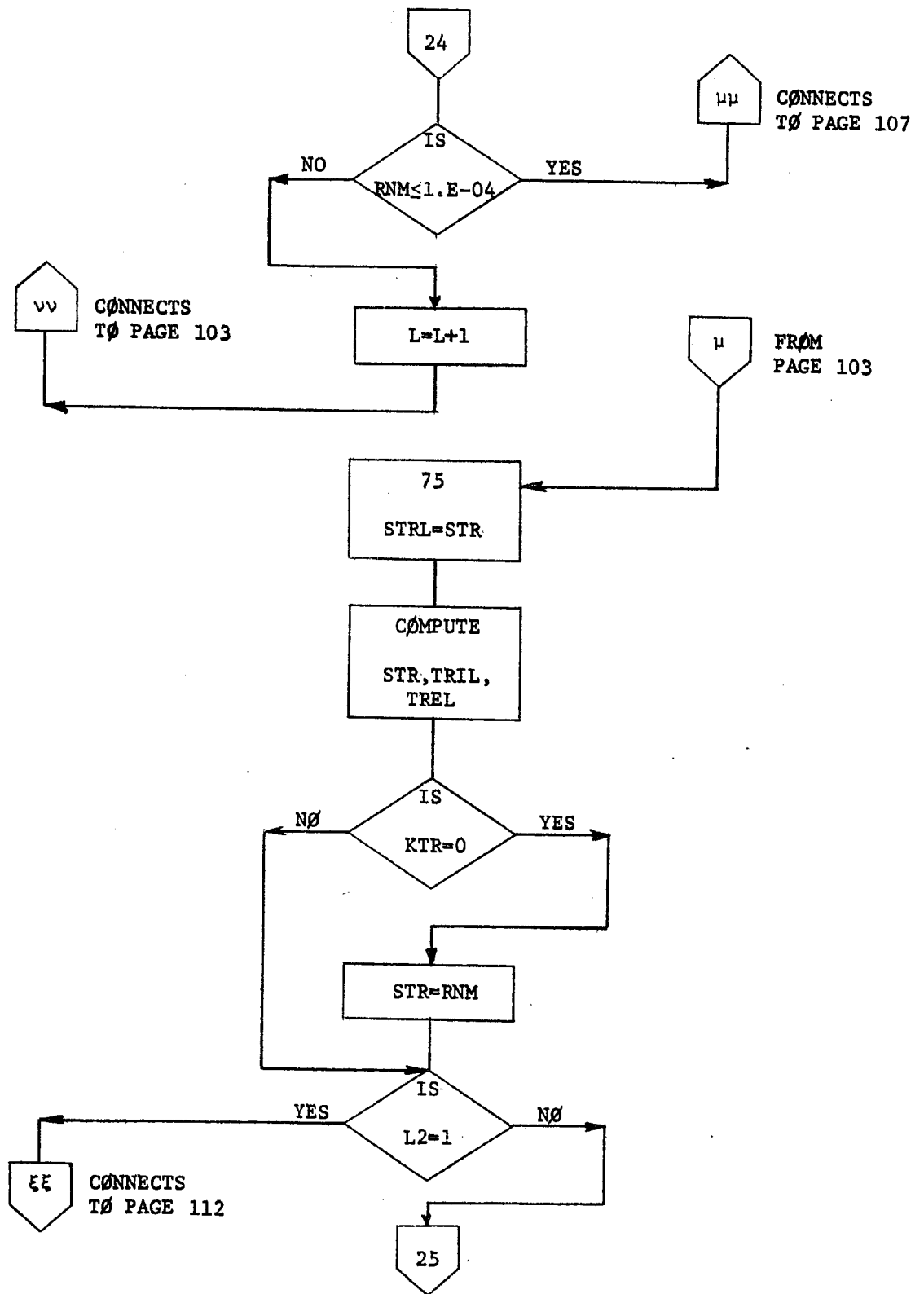


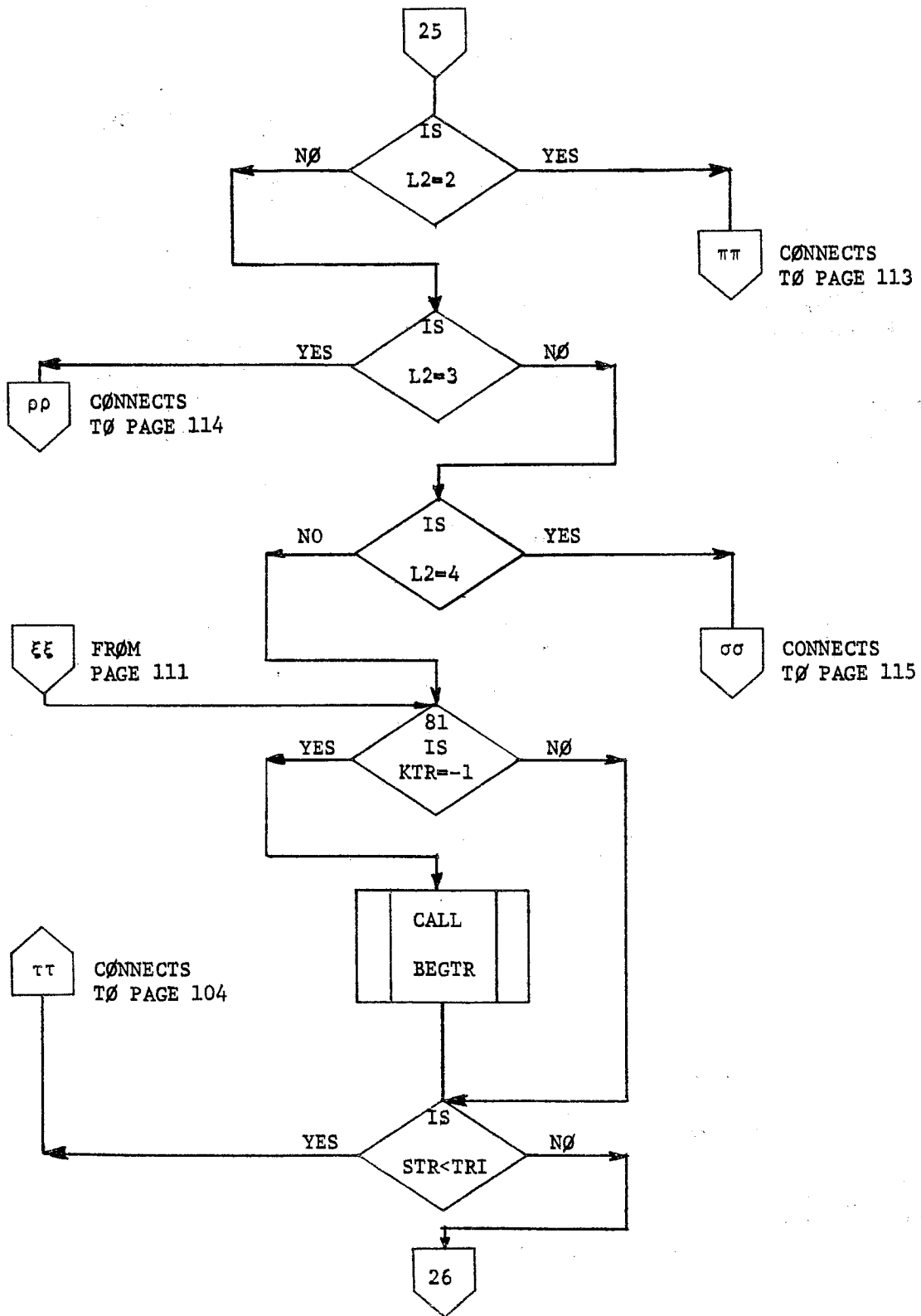


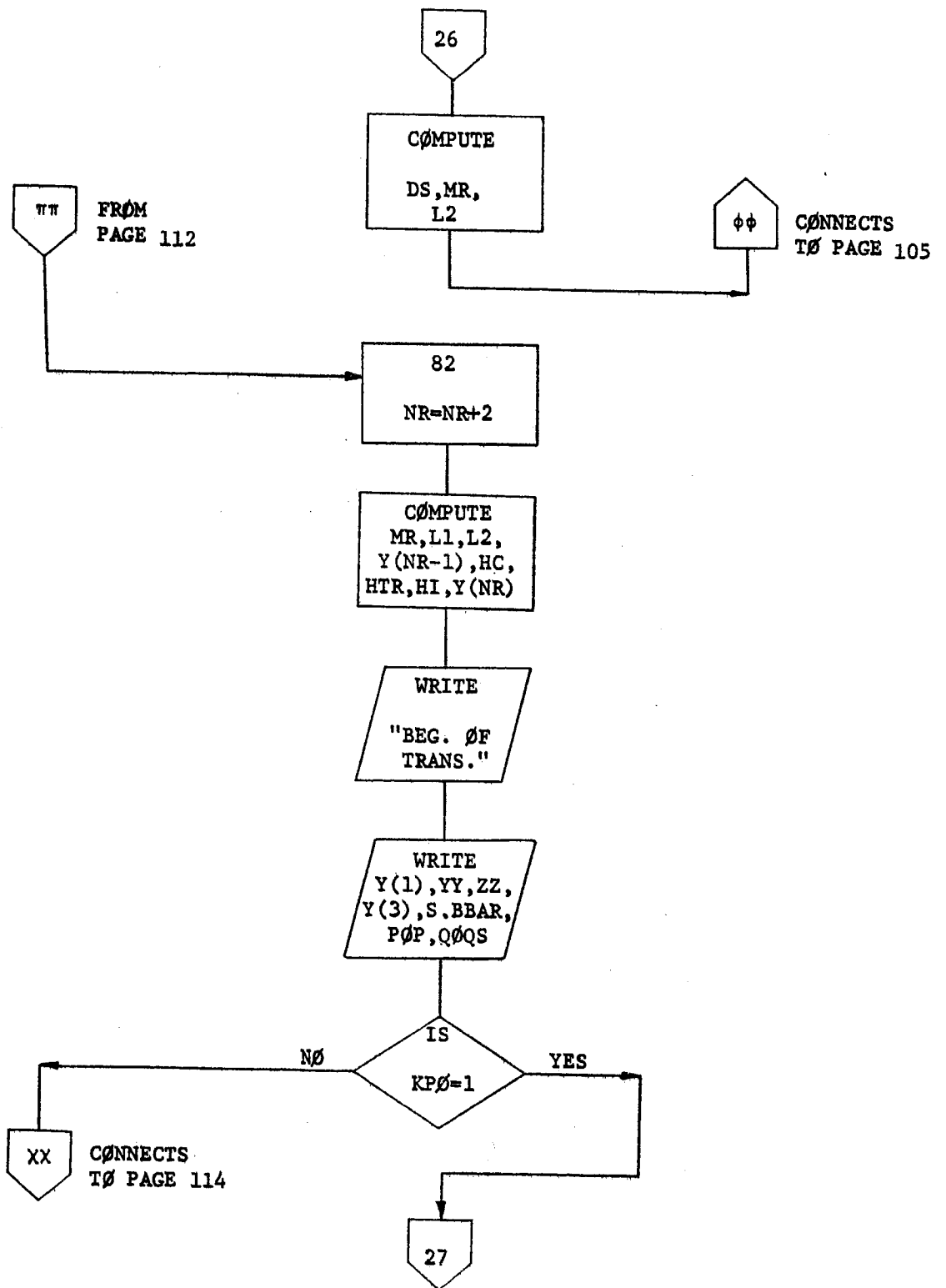


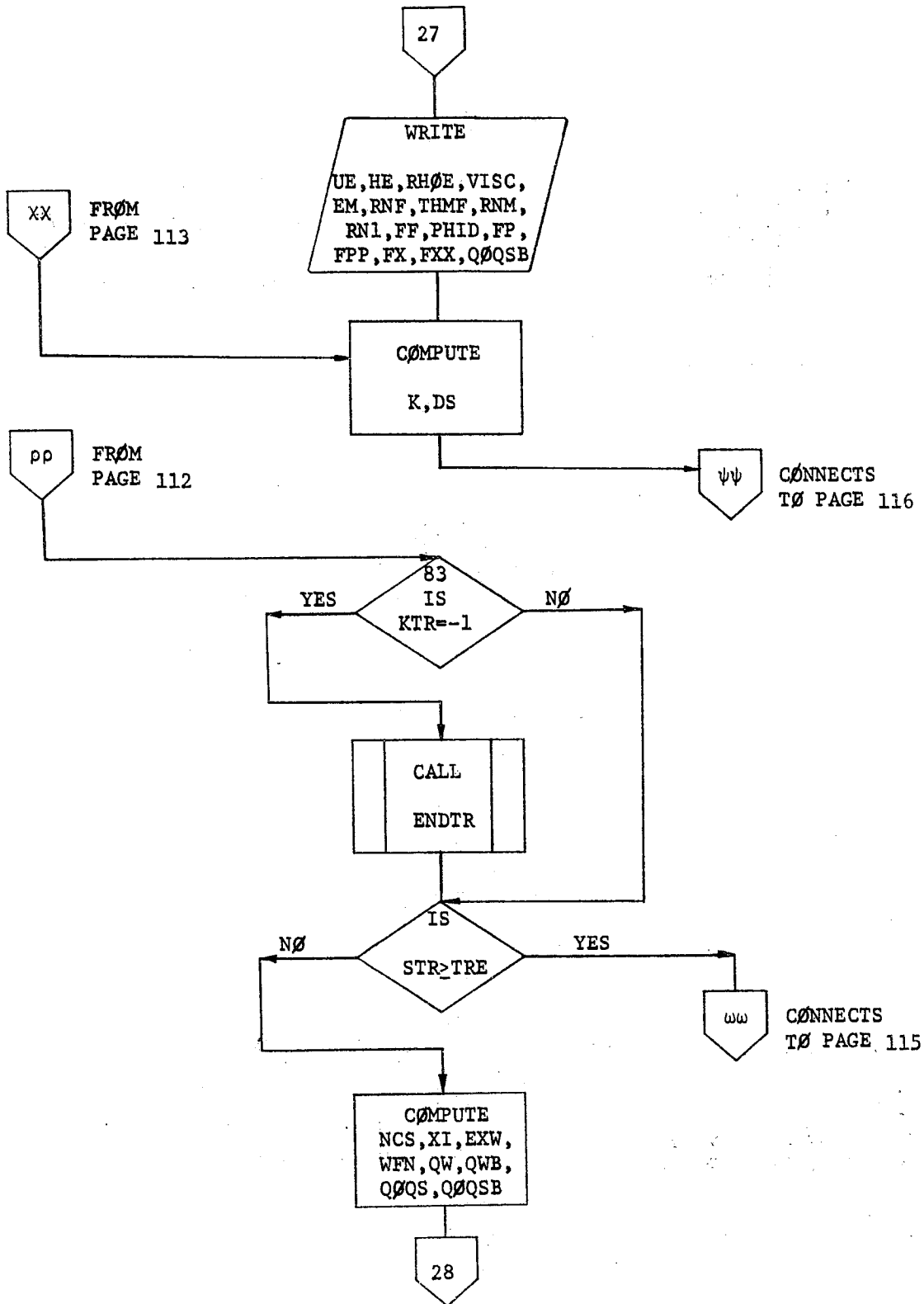


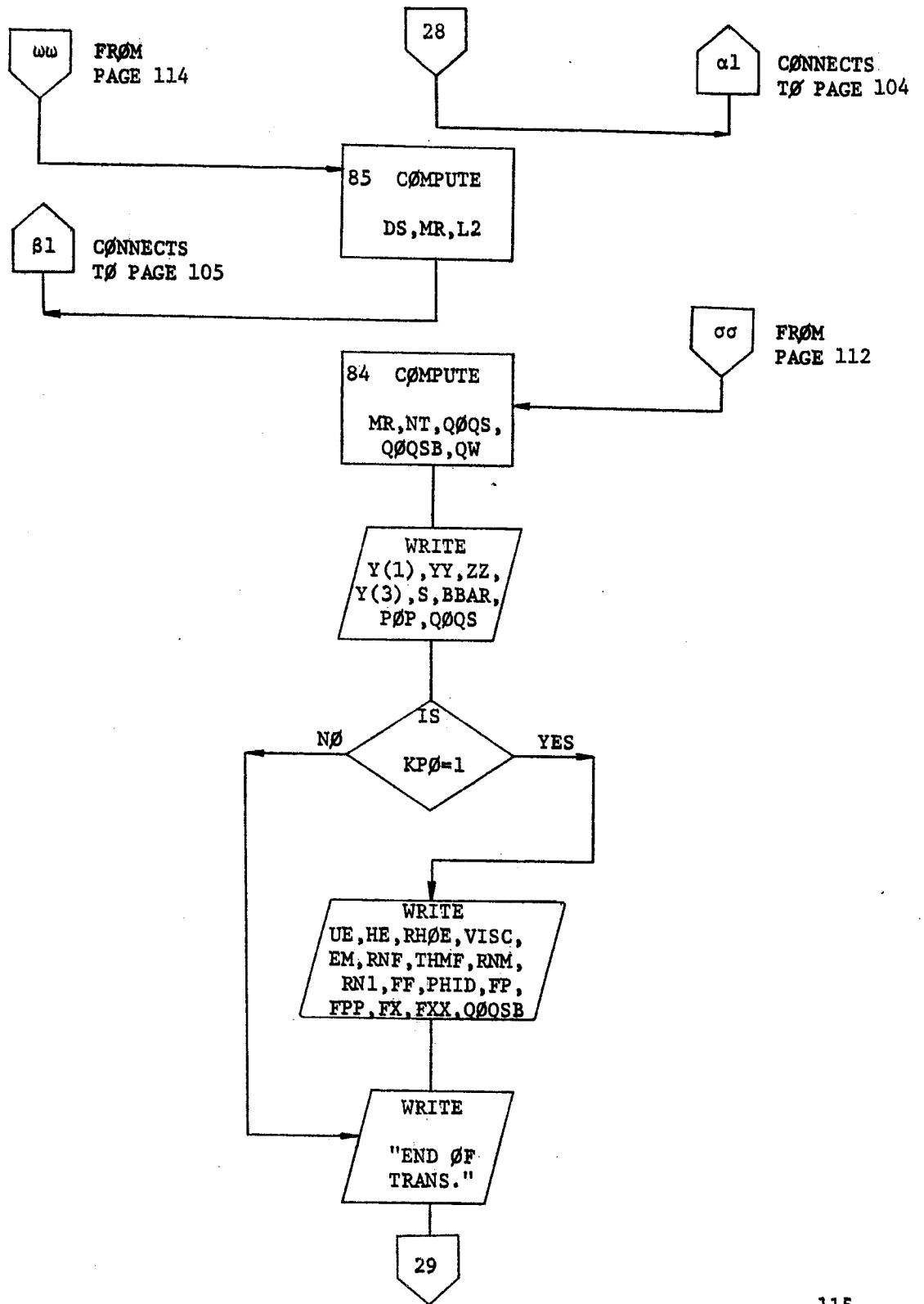


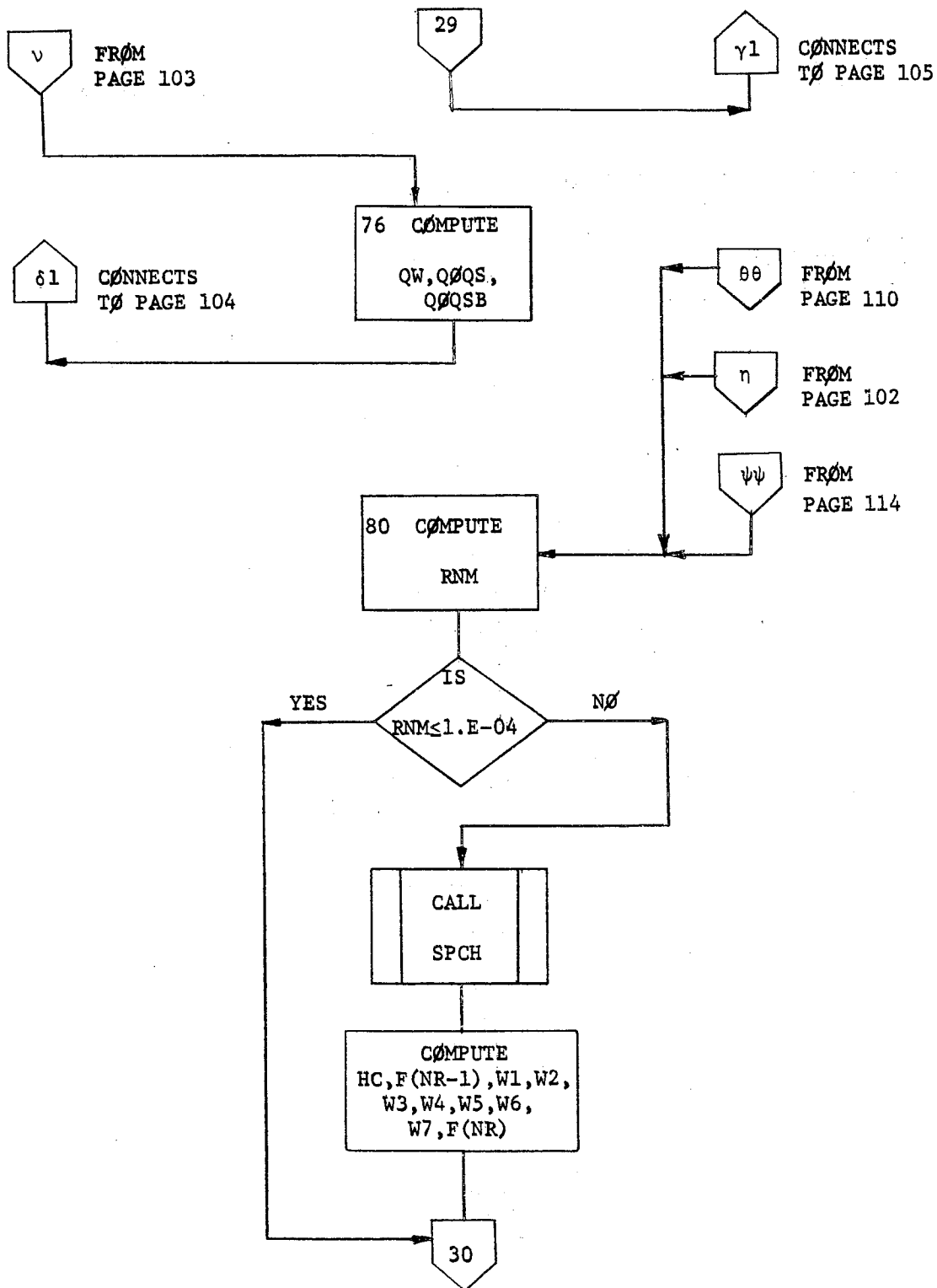


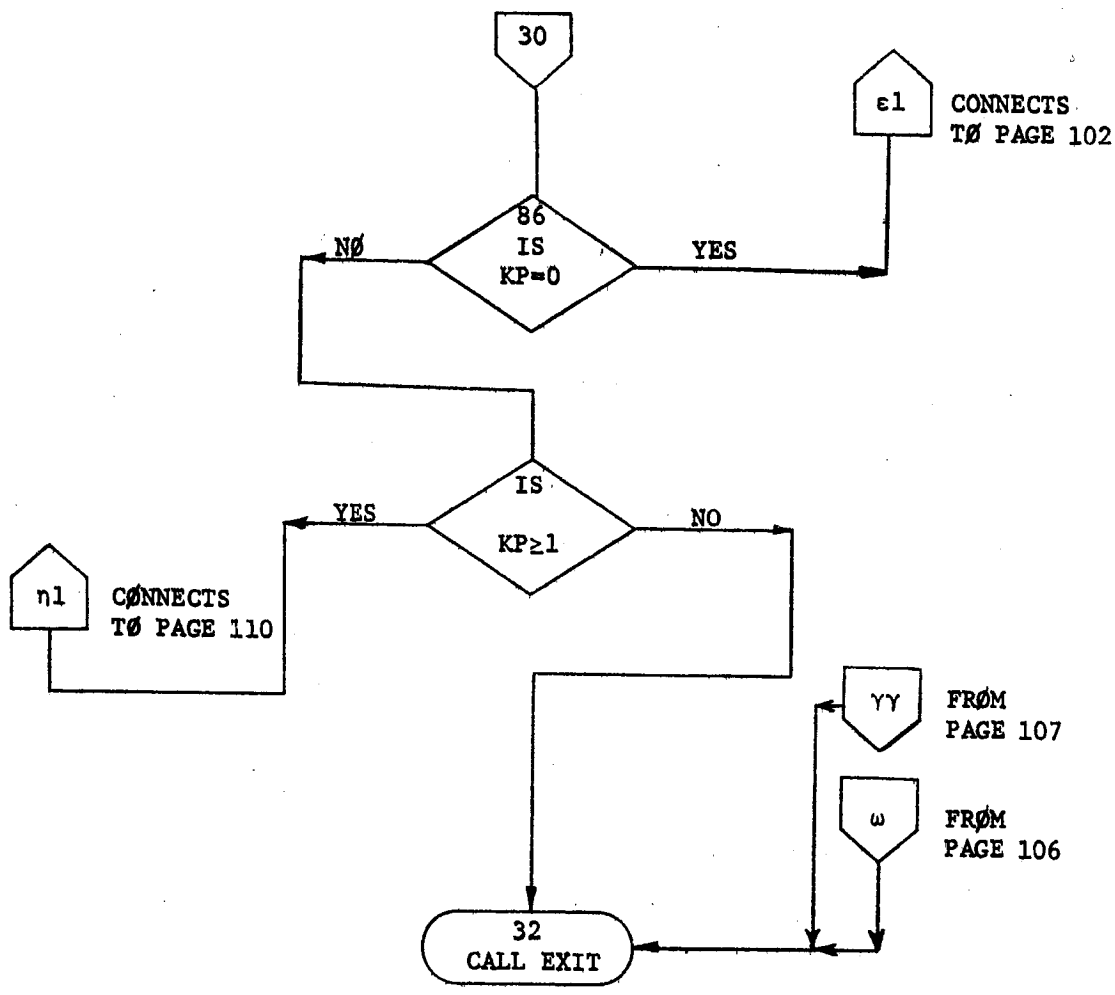




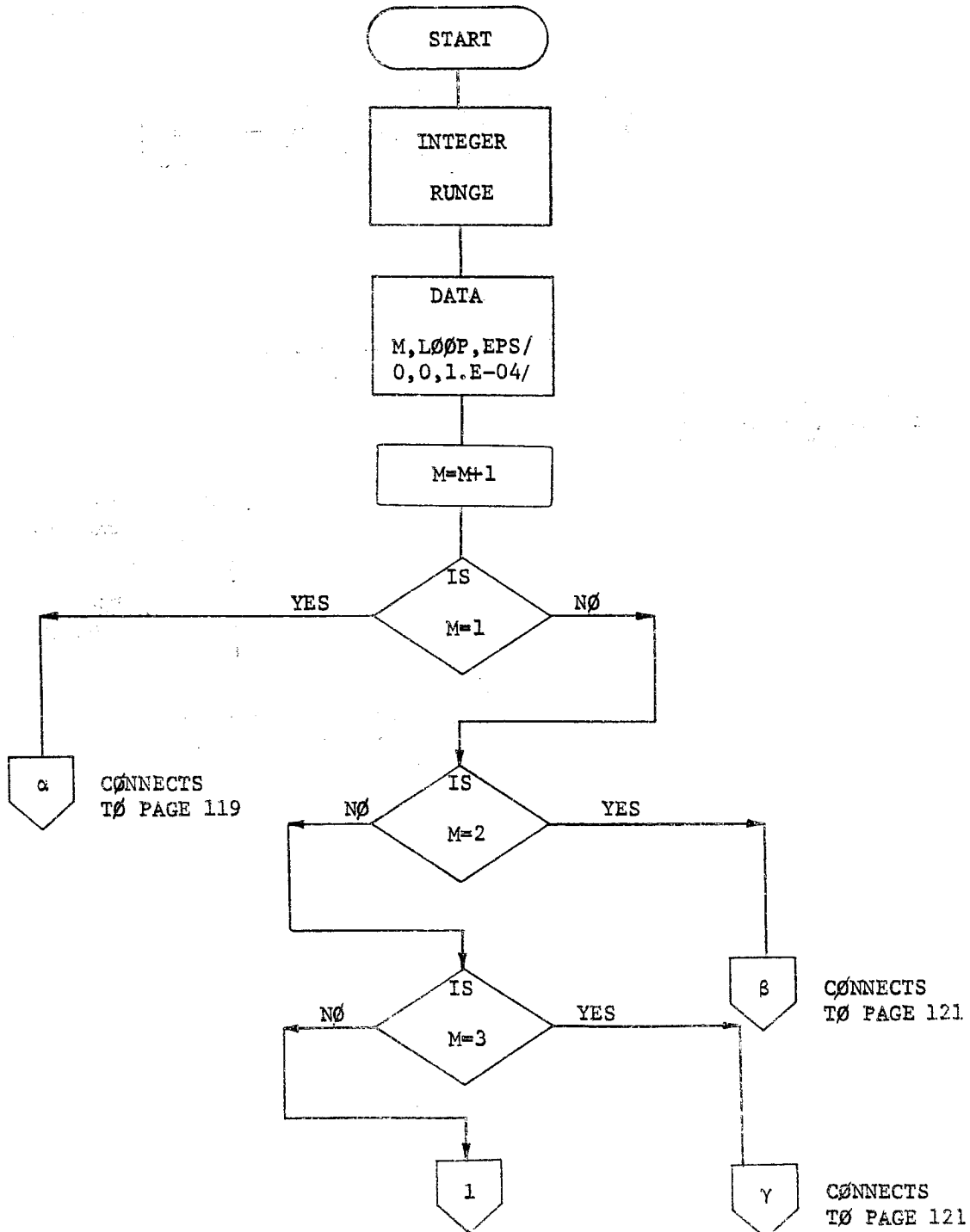


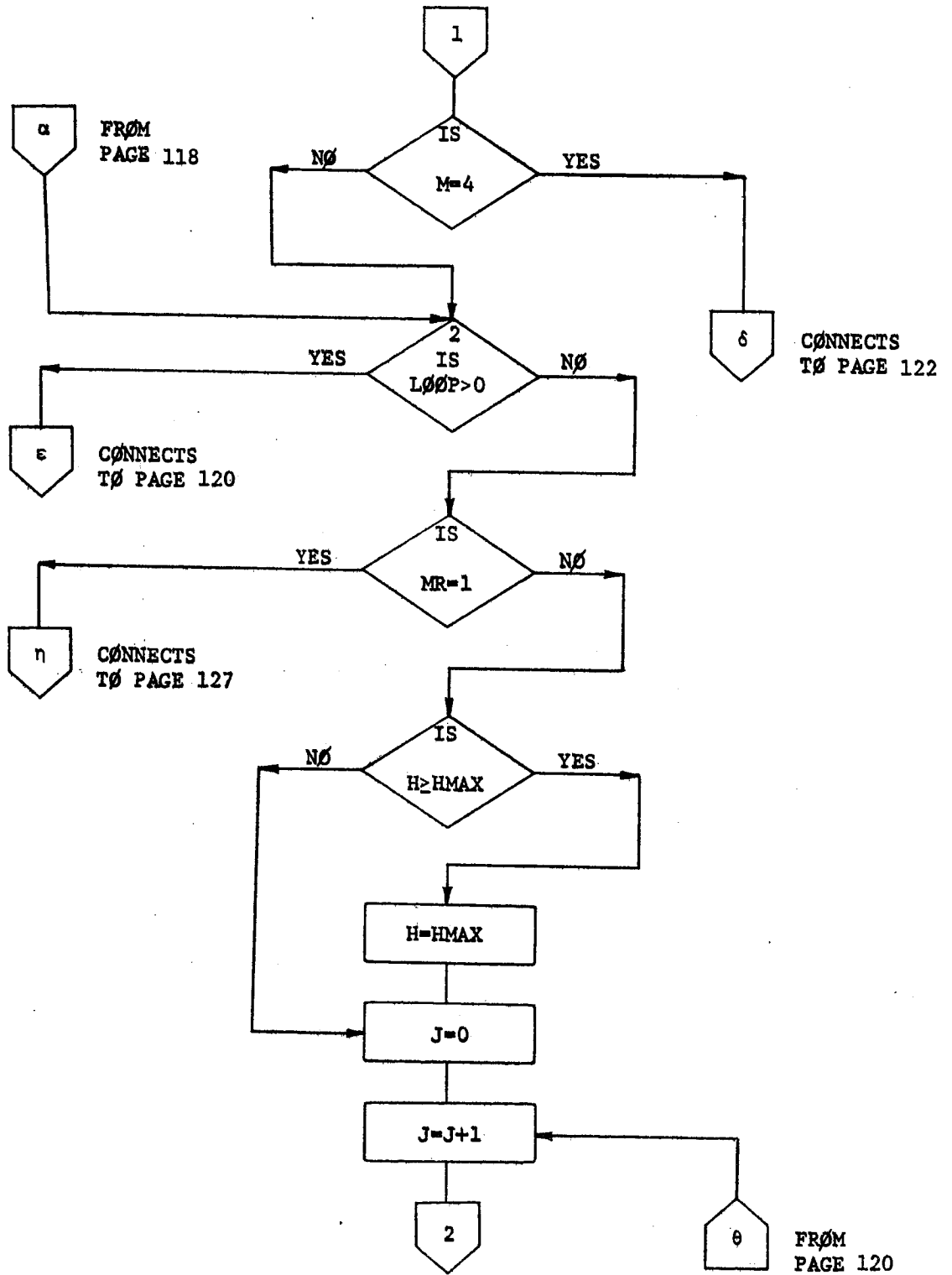


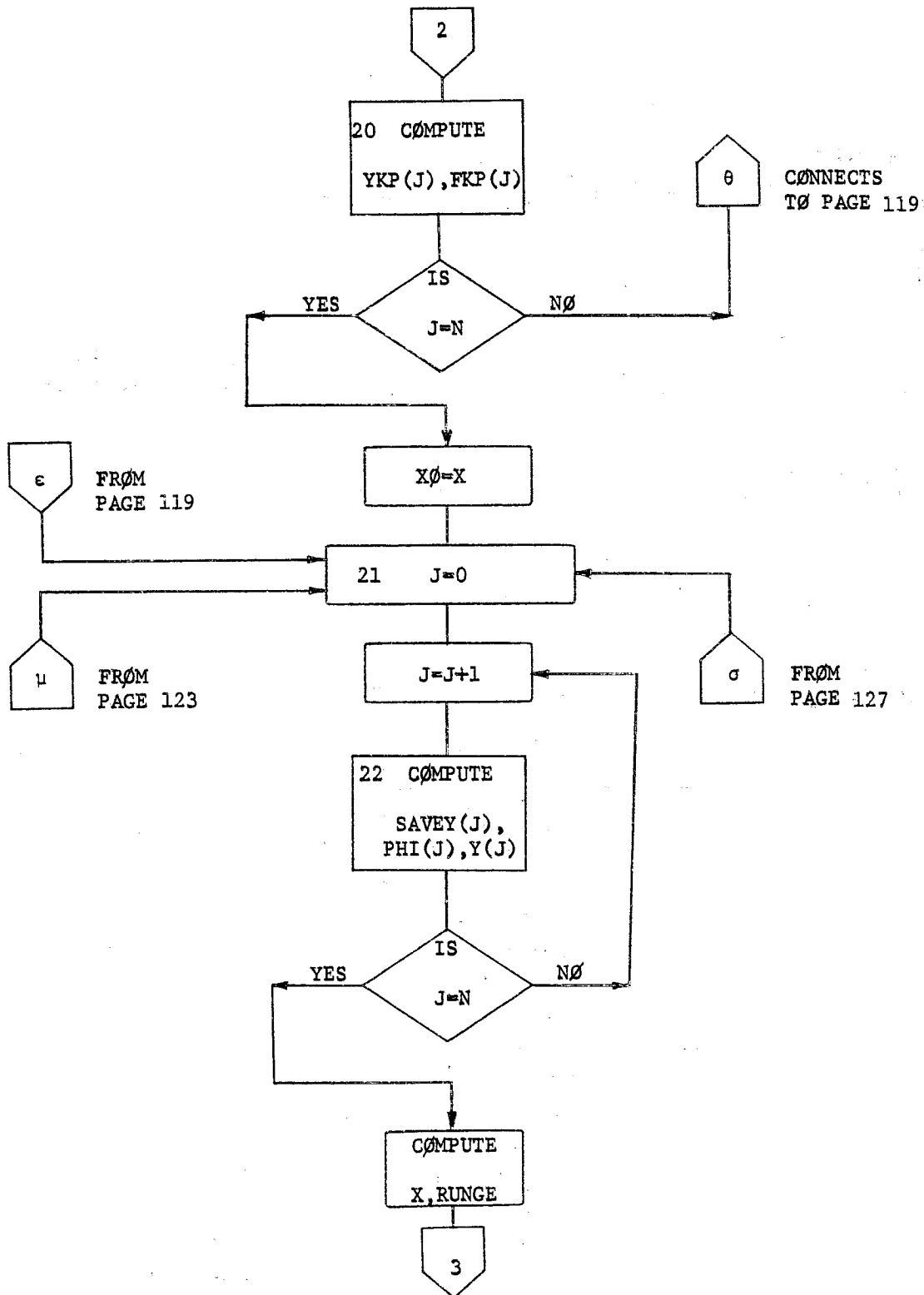


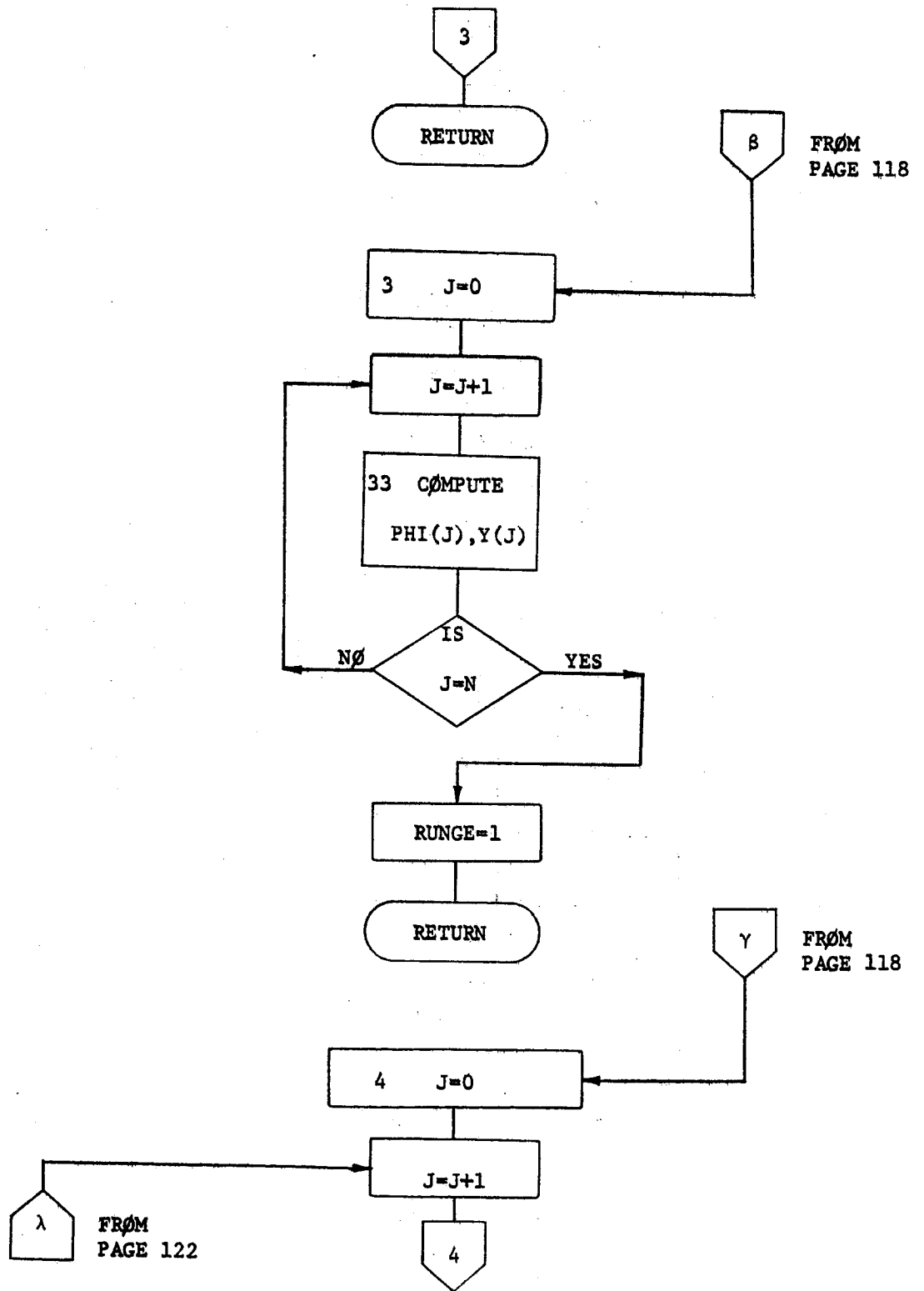


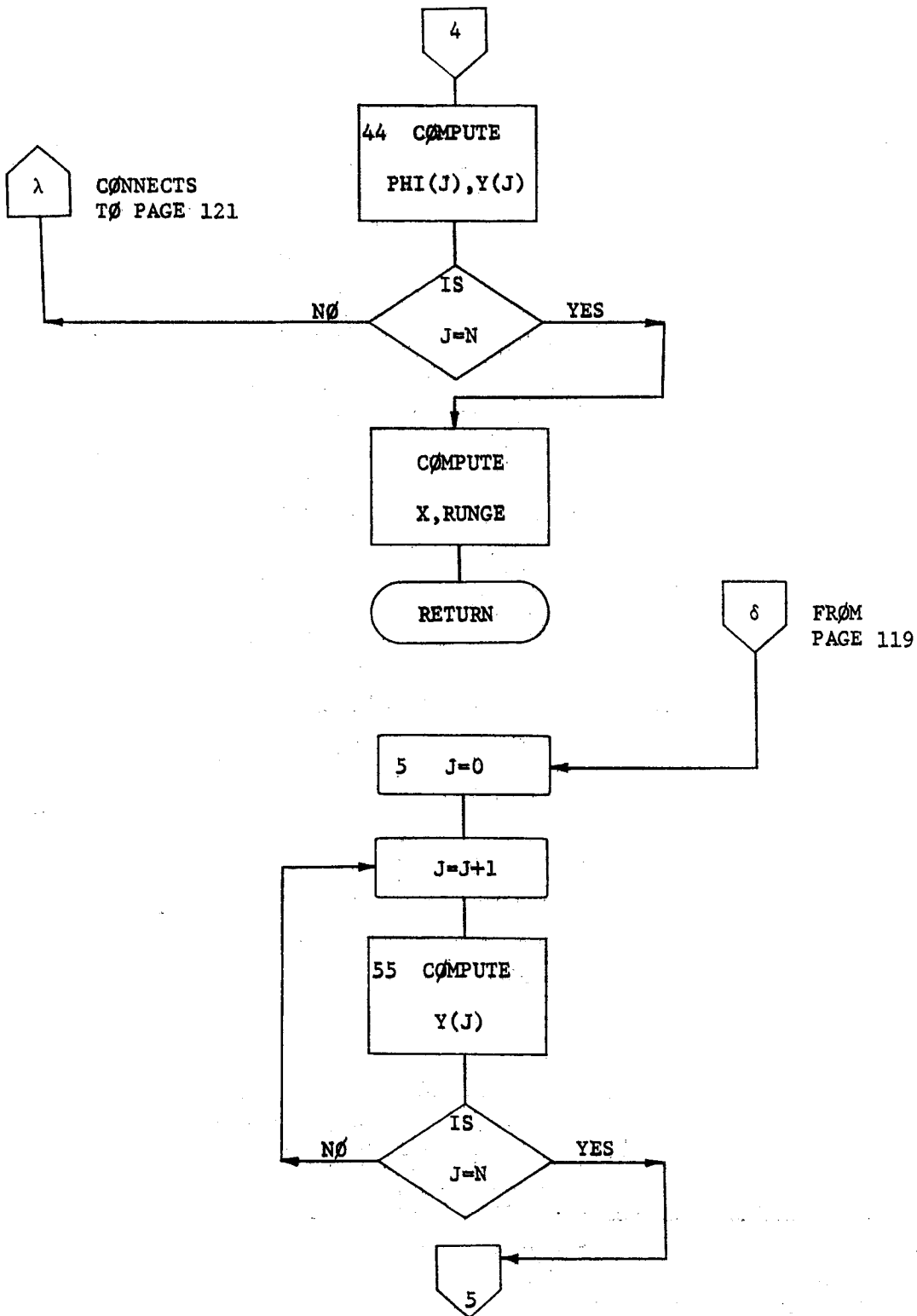
FUNCTION RUNGE(Y, F, X, H, N, HMAX, MR)

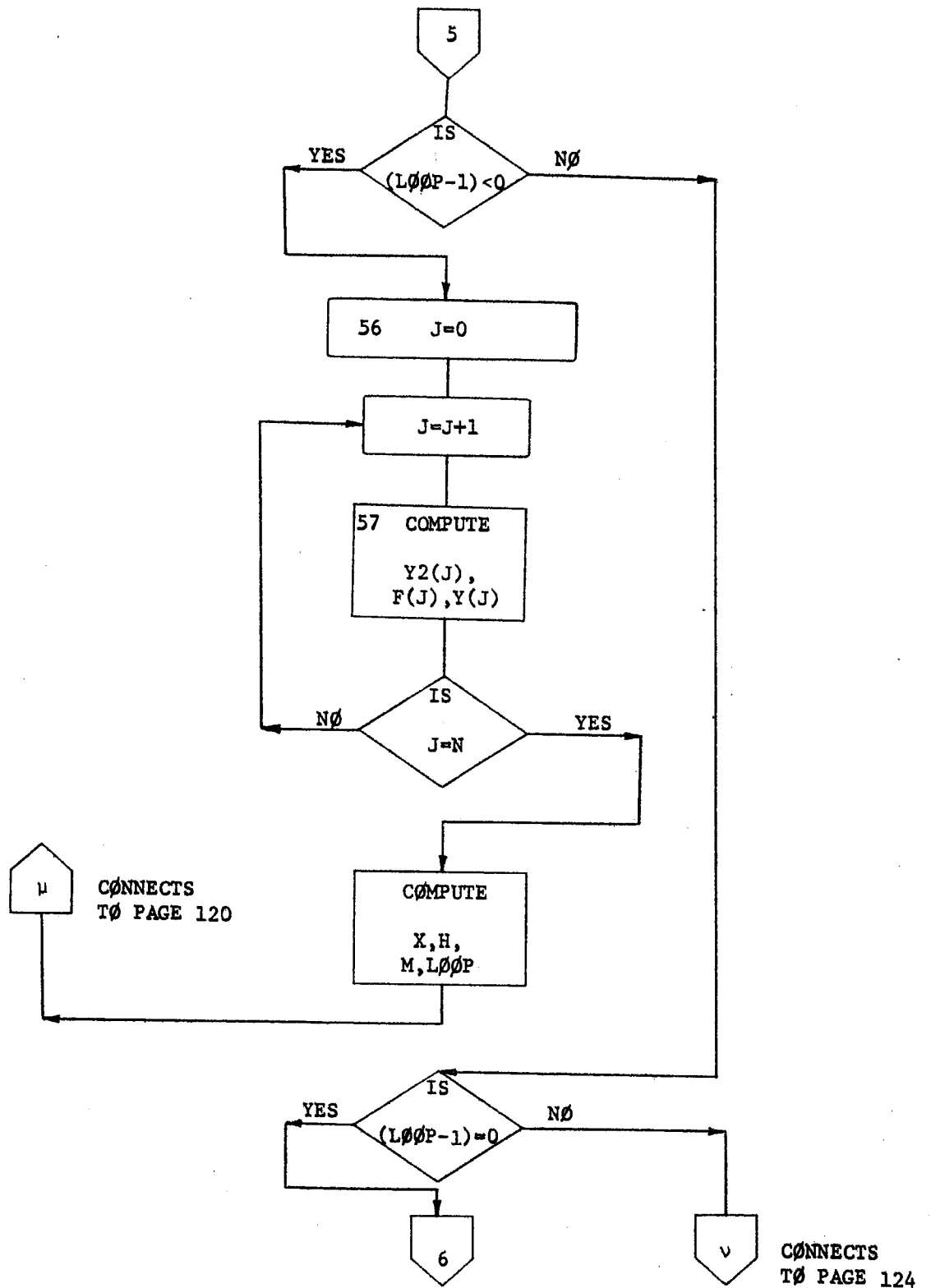


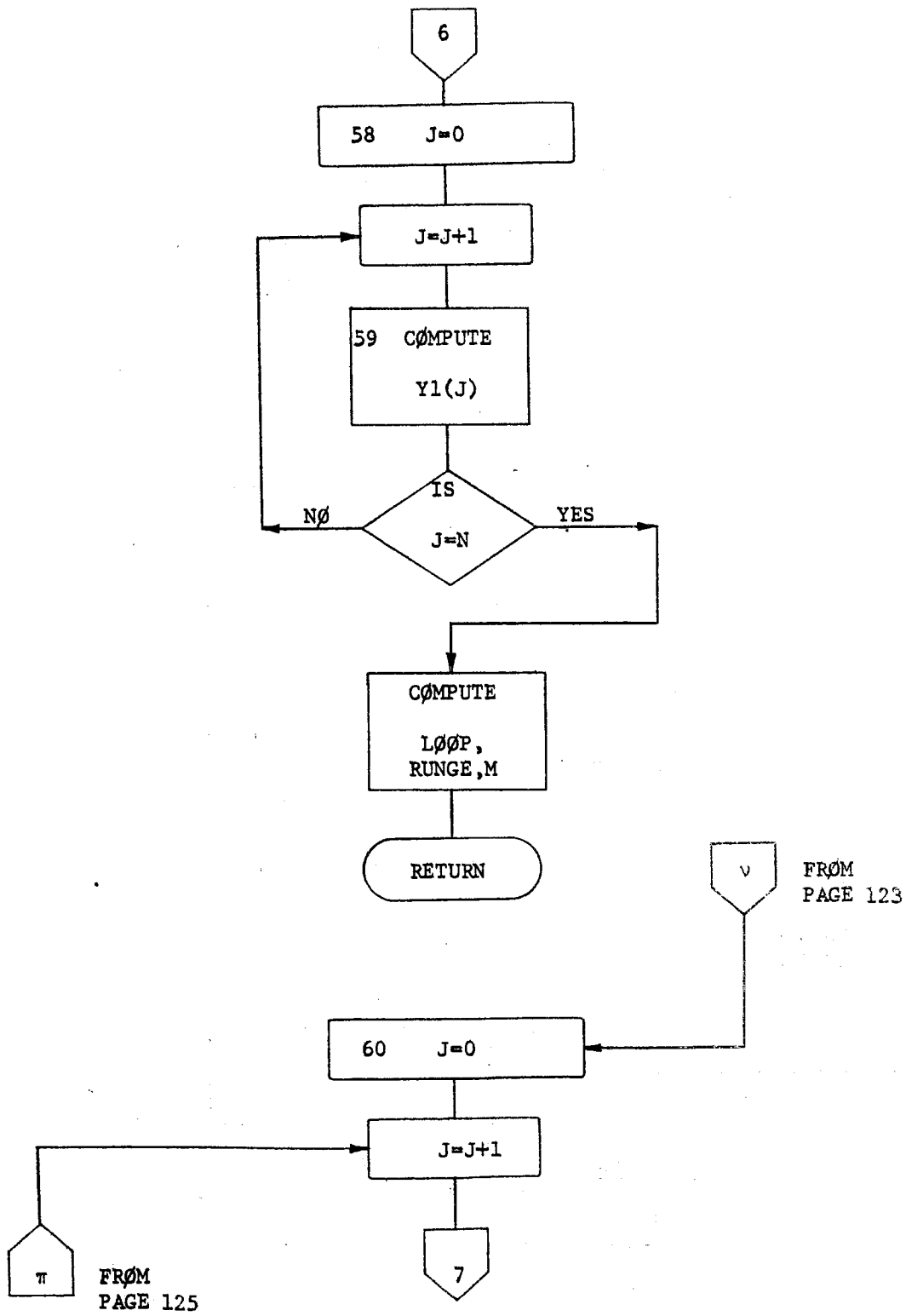


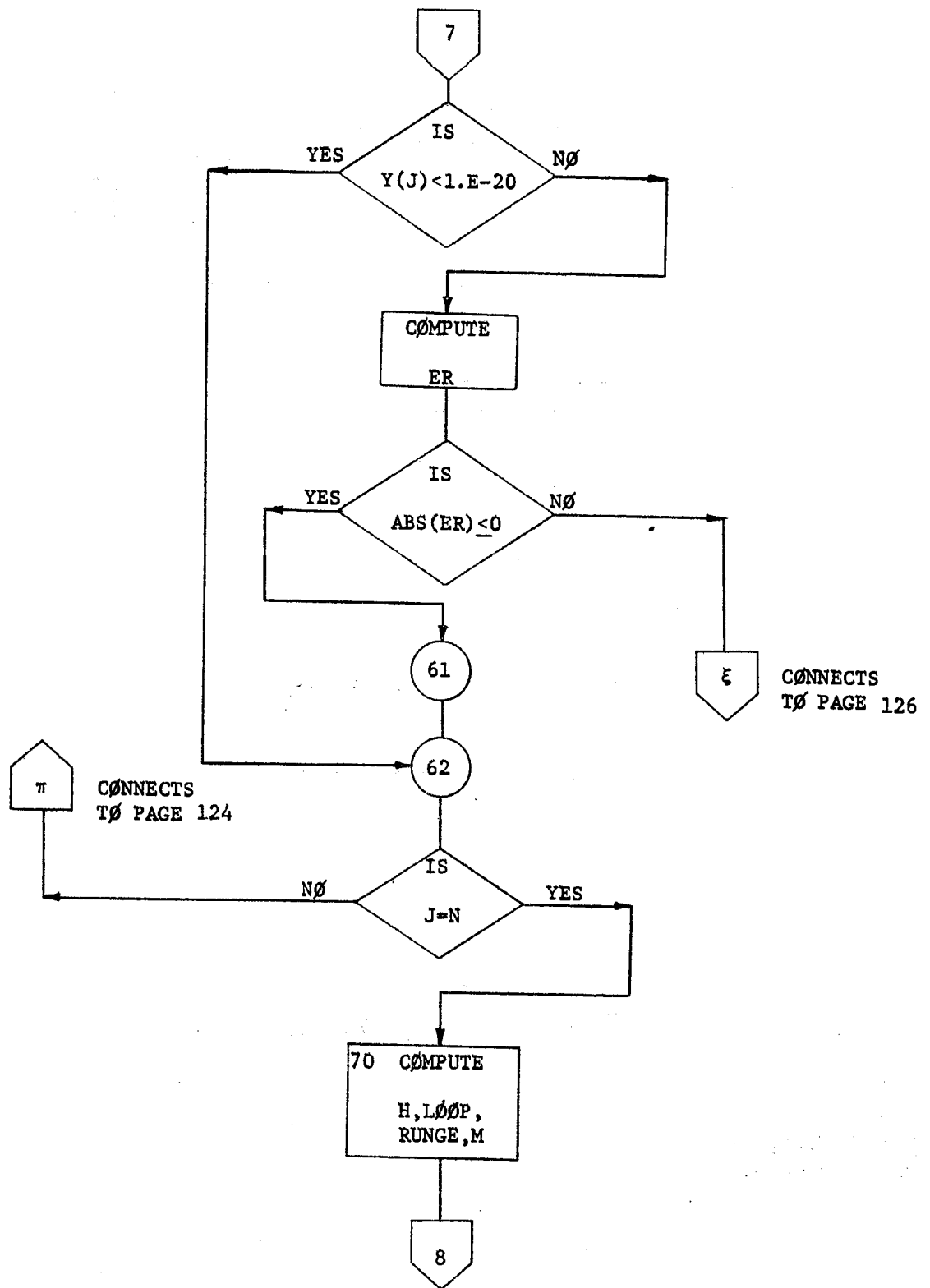


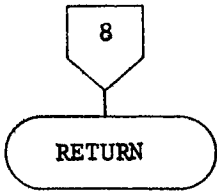




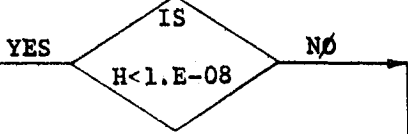
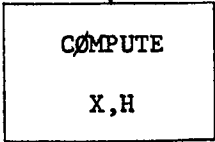
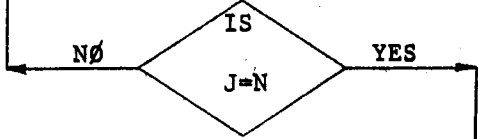
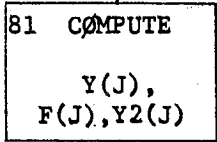
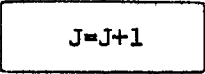
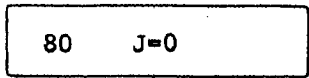






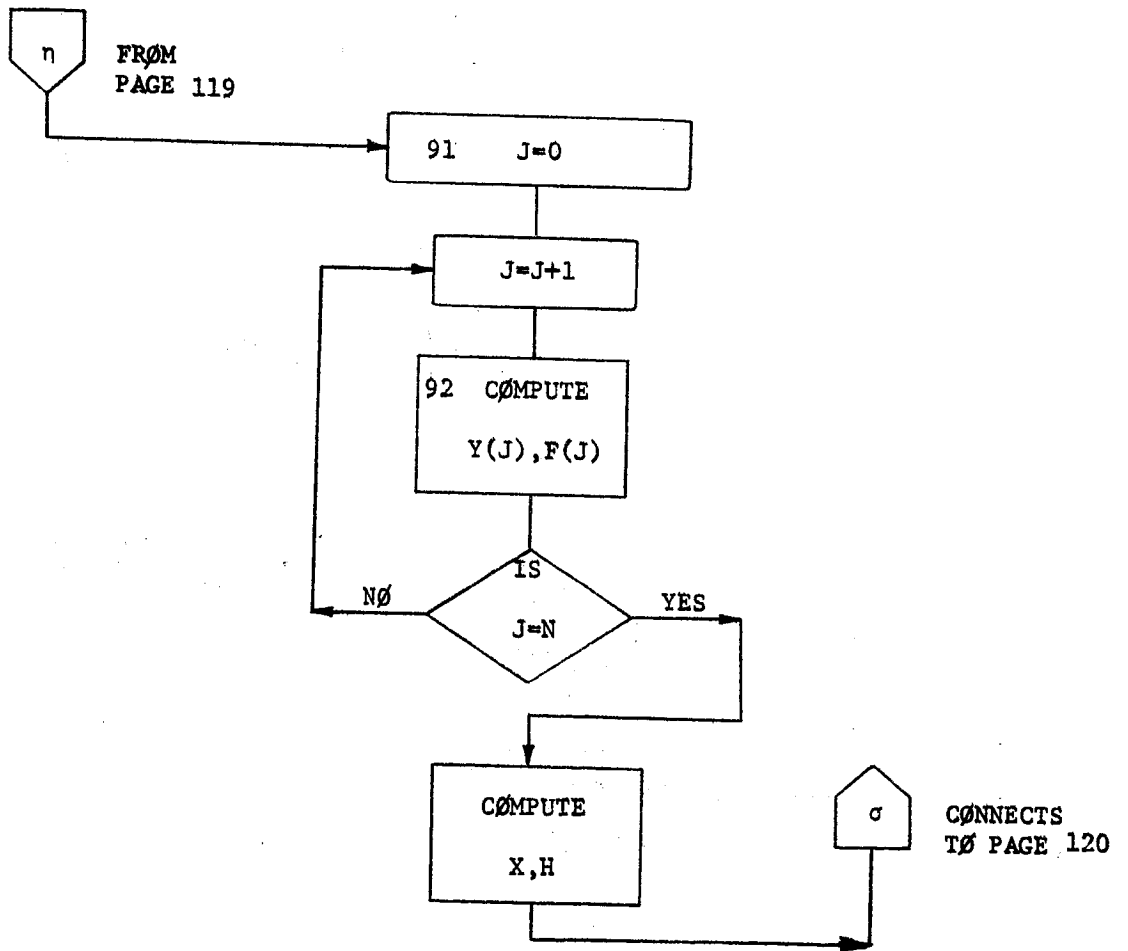
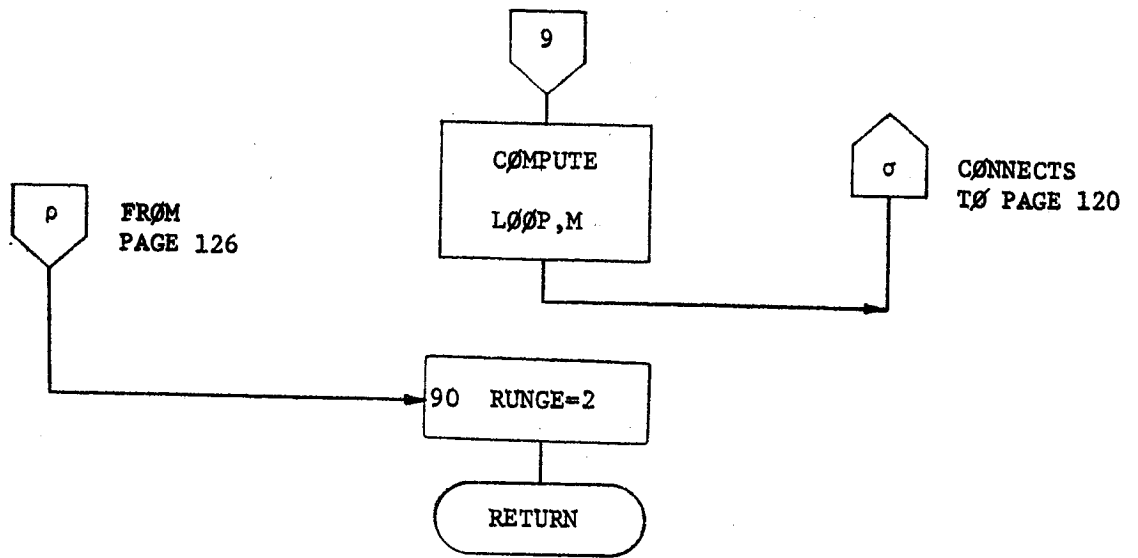


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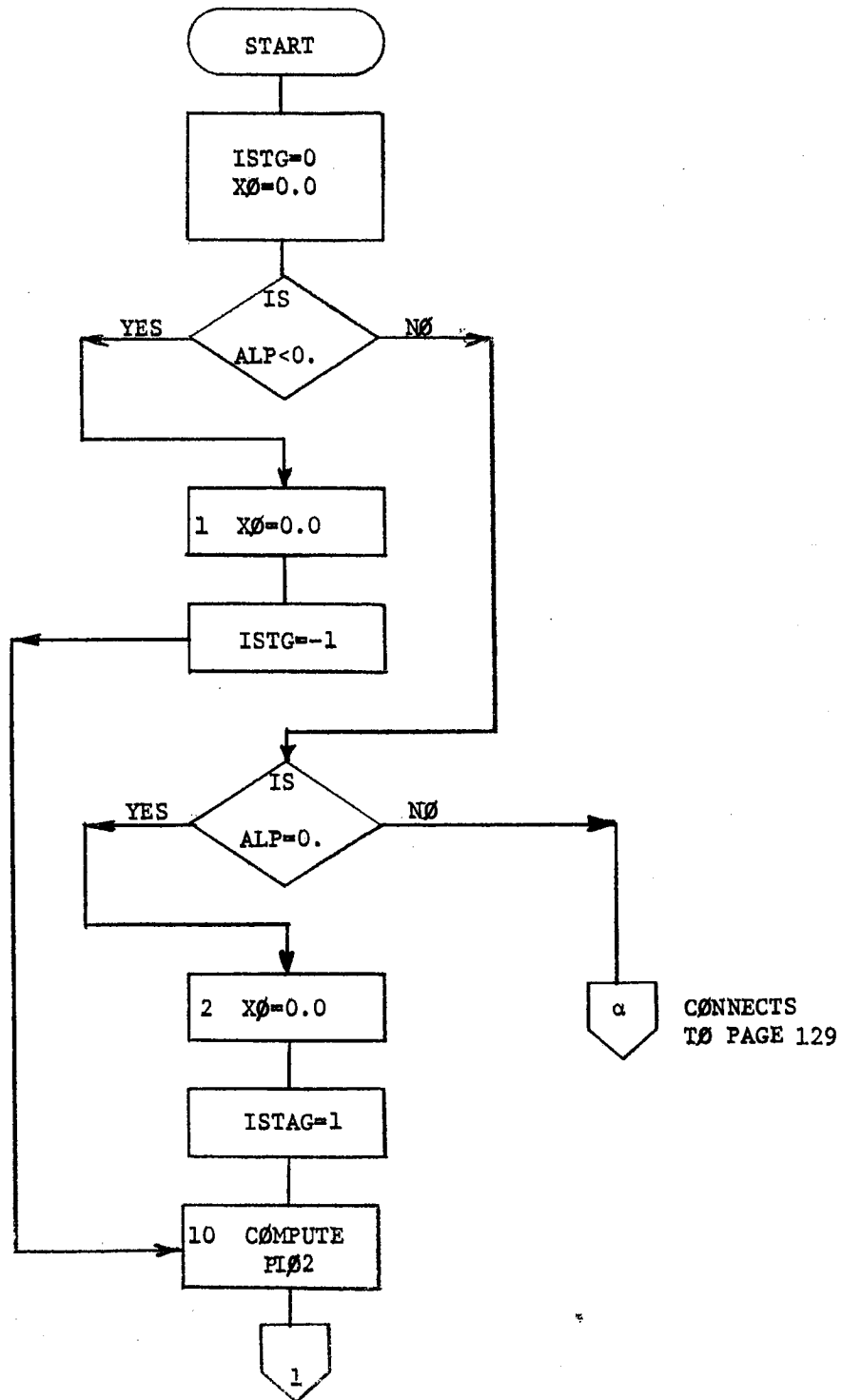


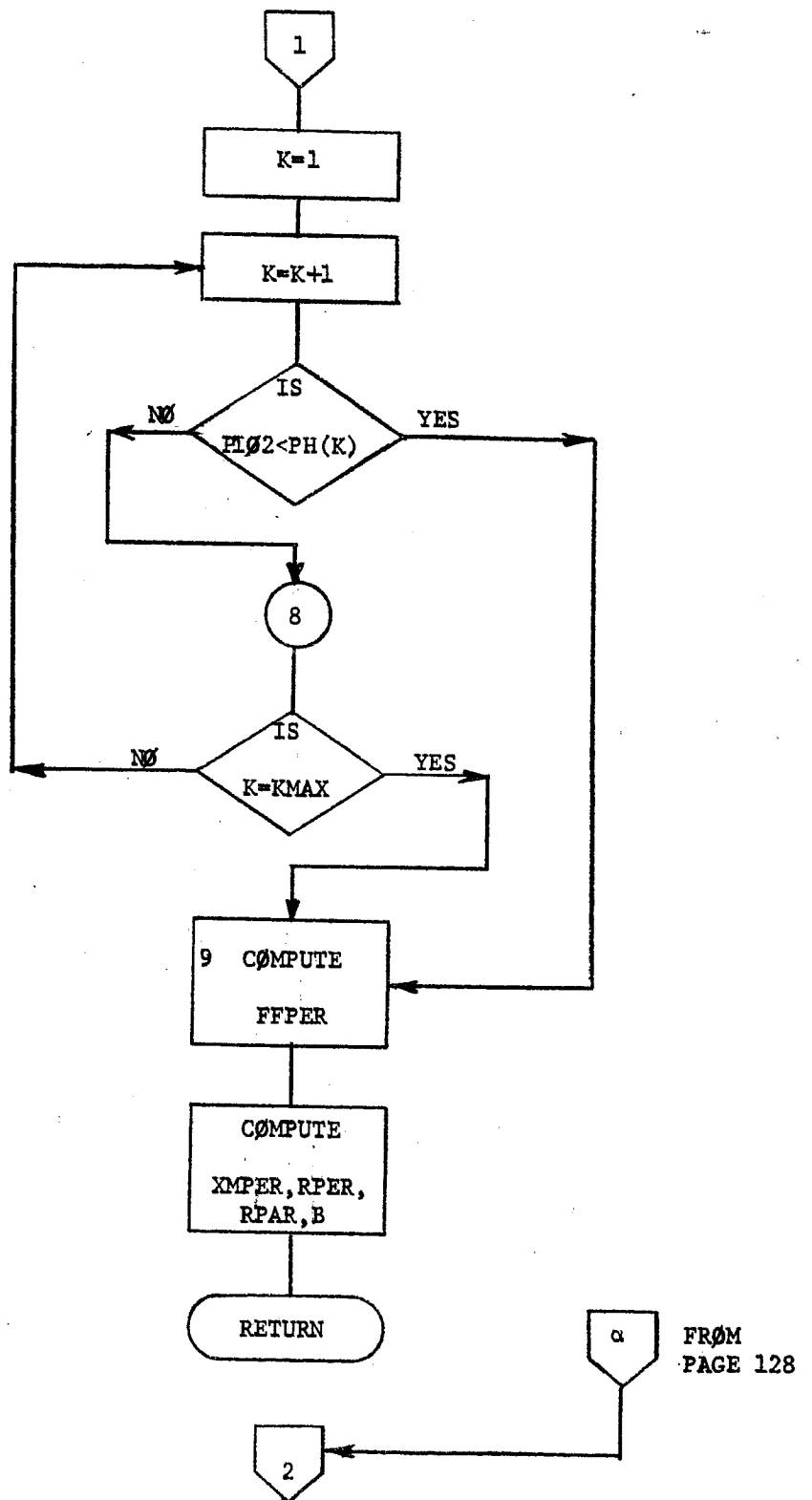
CONNECTS
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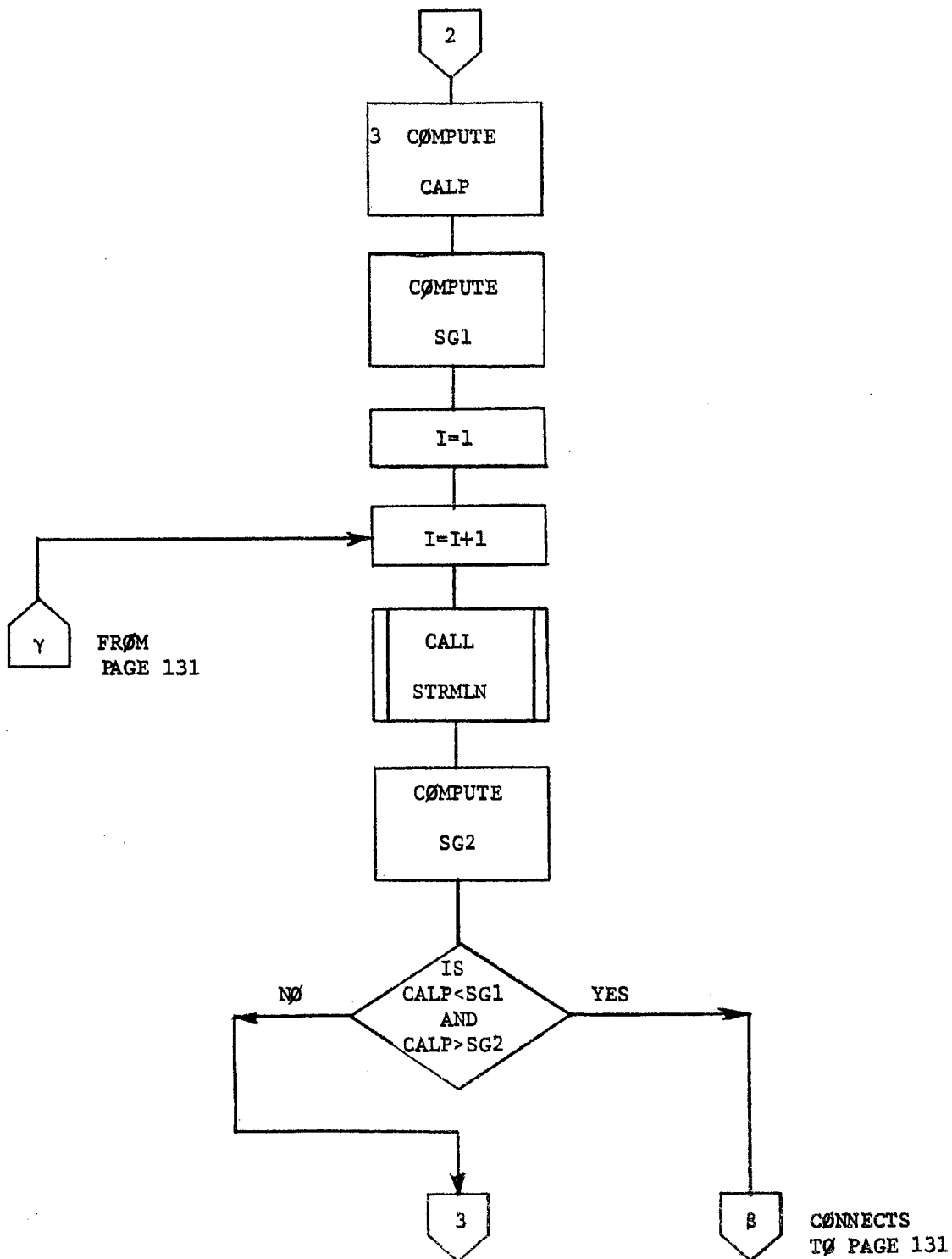


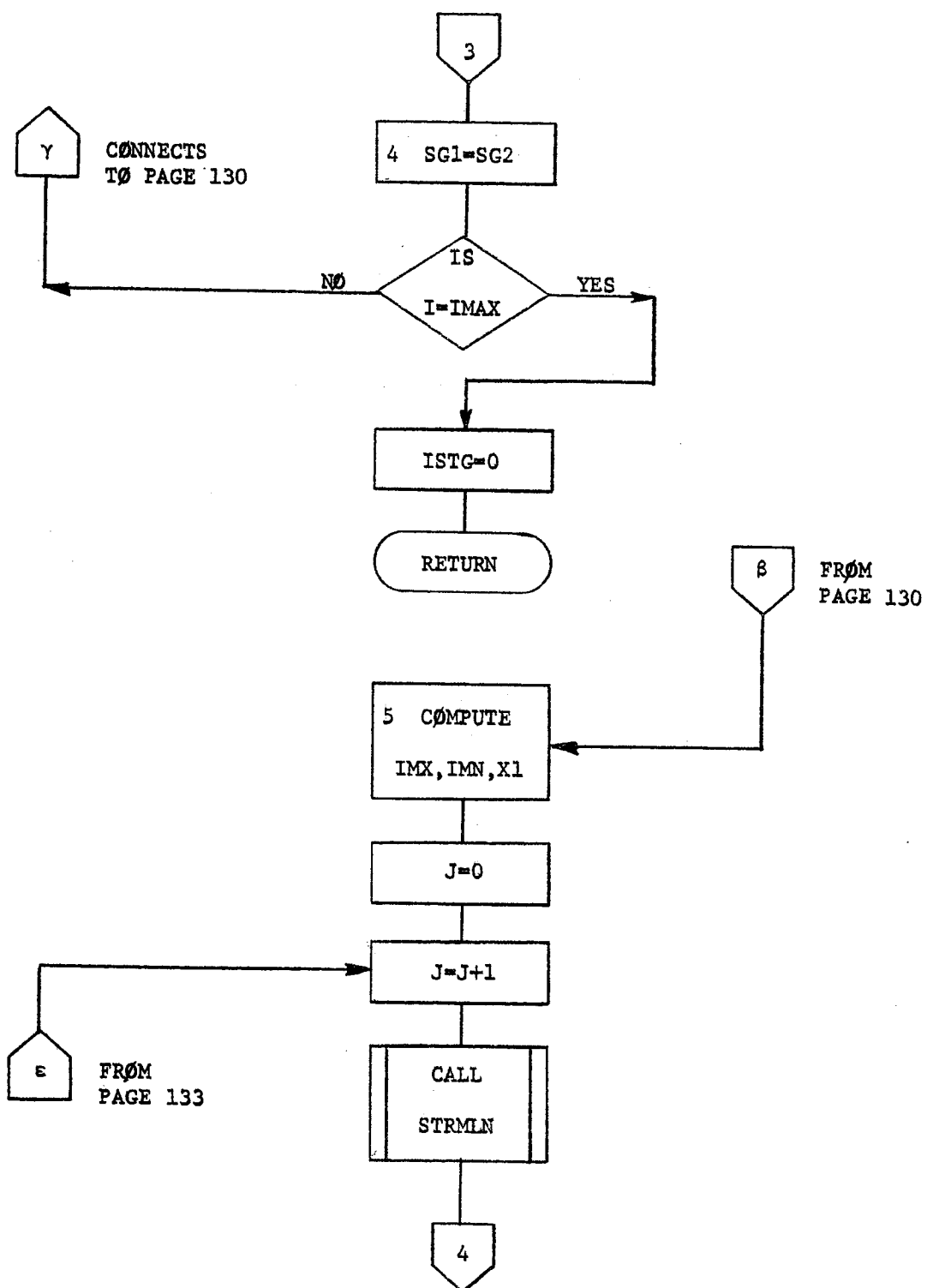


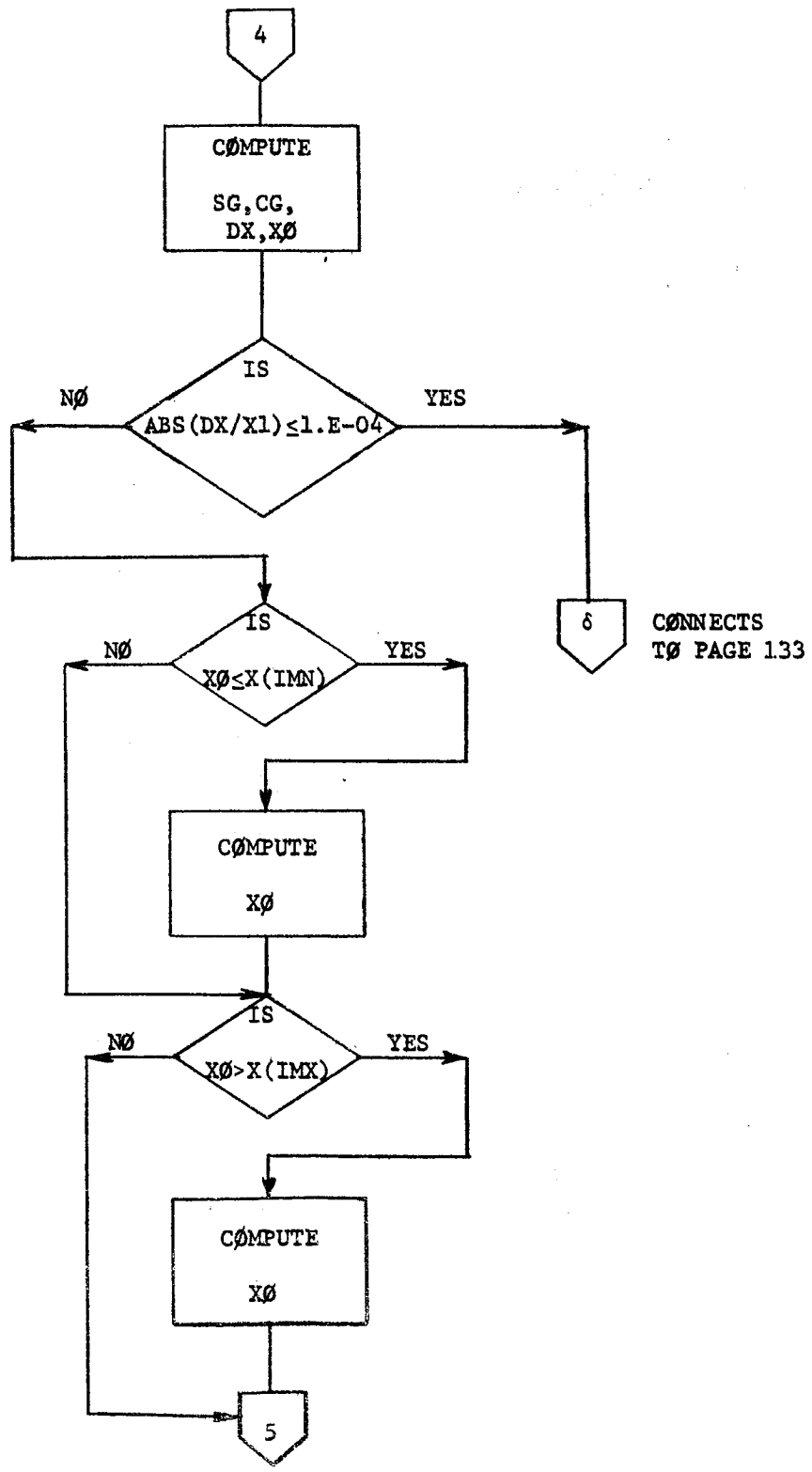
SUBROUTINE STAGN(ALP, IMAX, KMAX, XØ, RPER, B, ISTG)

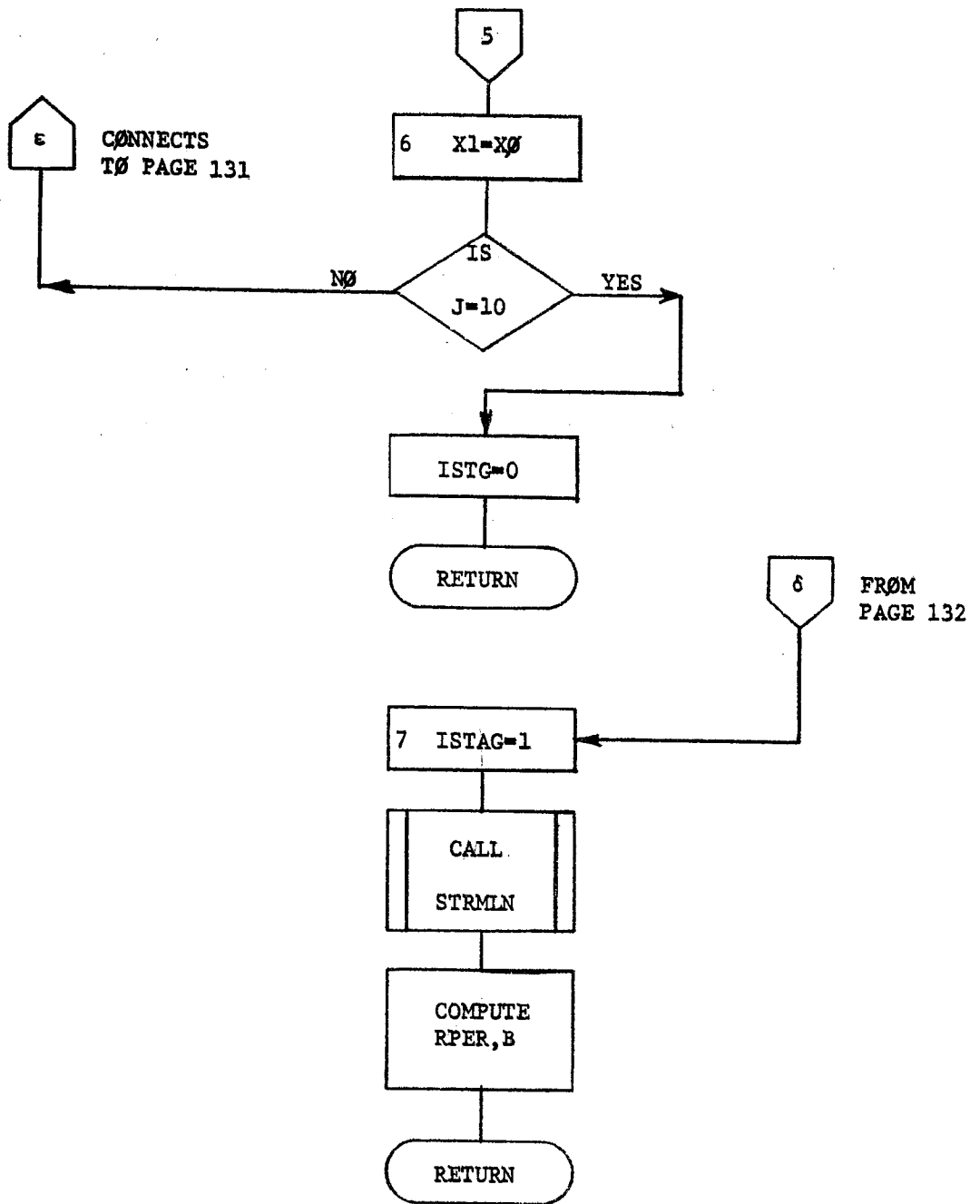




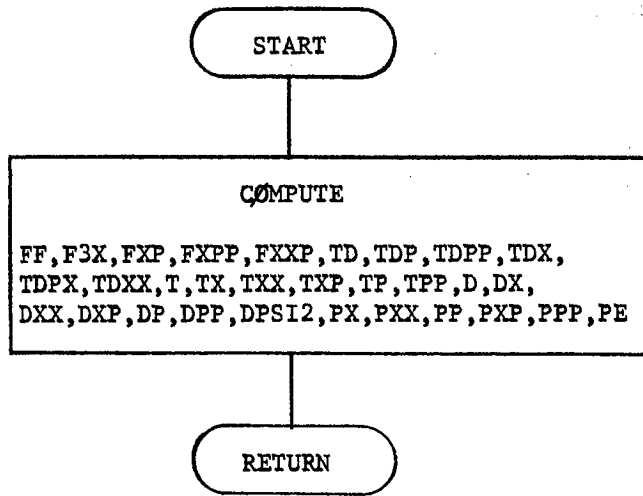




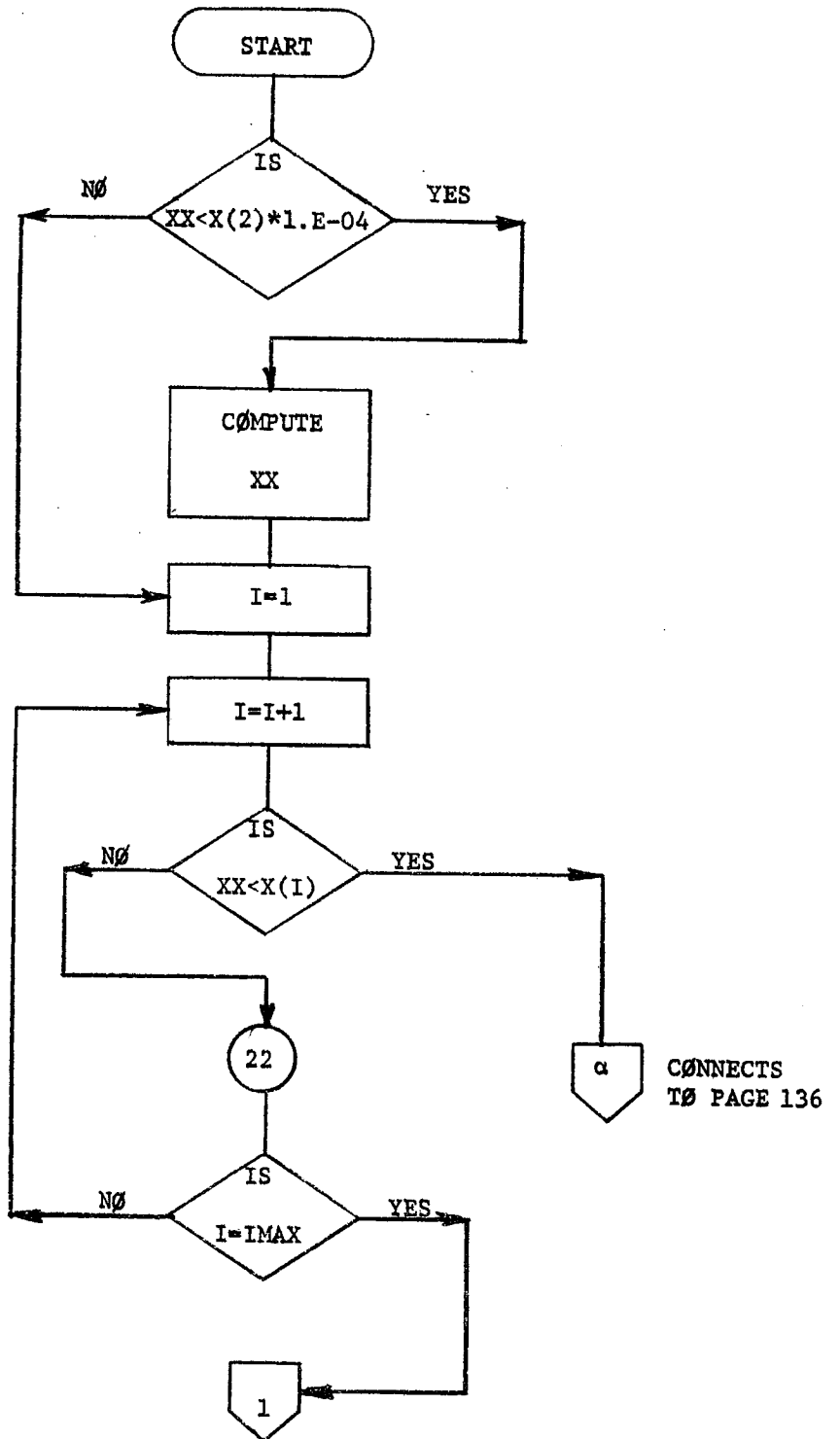


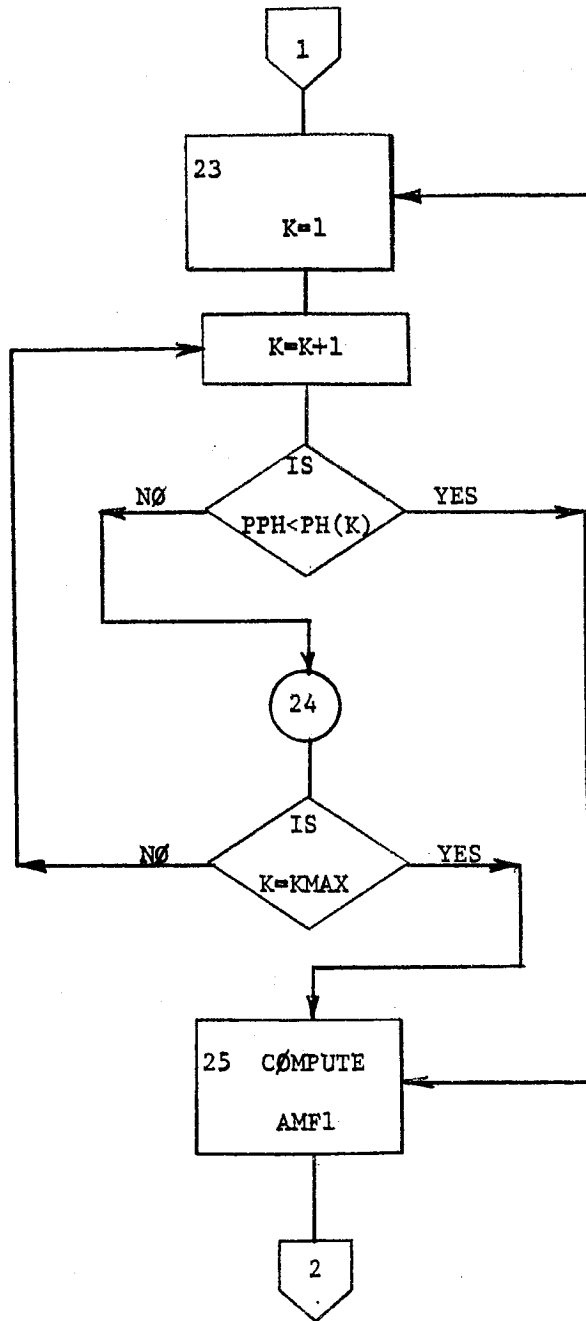


SUBROUTINE NEWP(AA,F)



SUBROUTINE STRMLN (XX, PH, DLPH, DDP, DDX, GM, DGP, DGX, F, IMAX, KMAX)





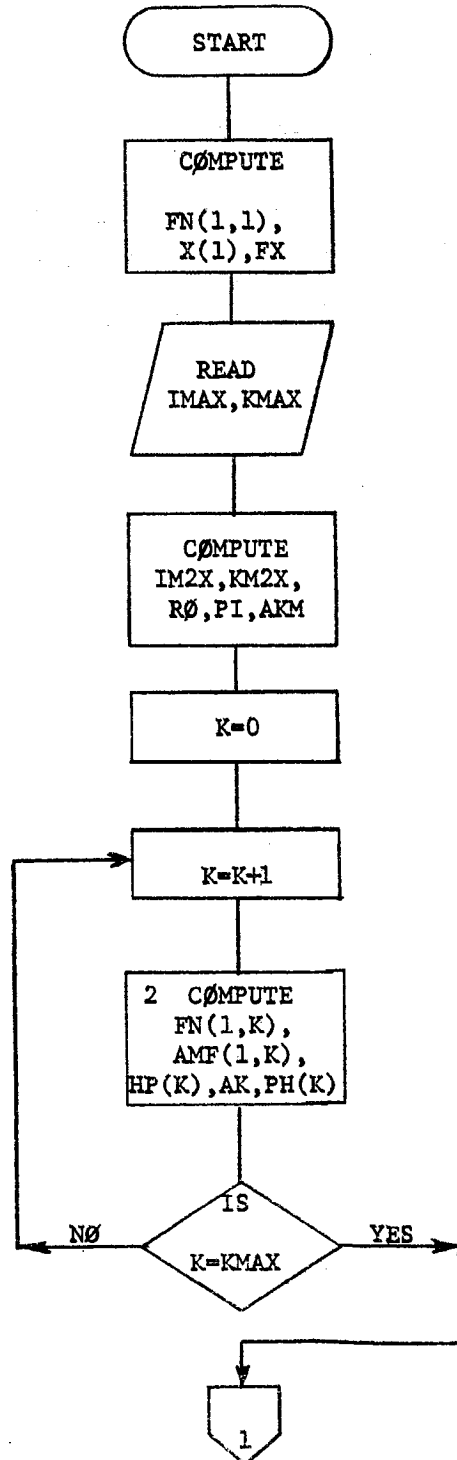
2

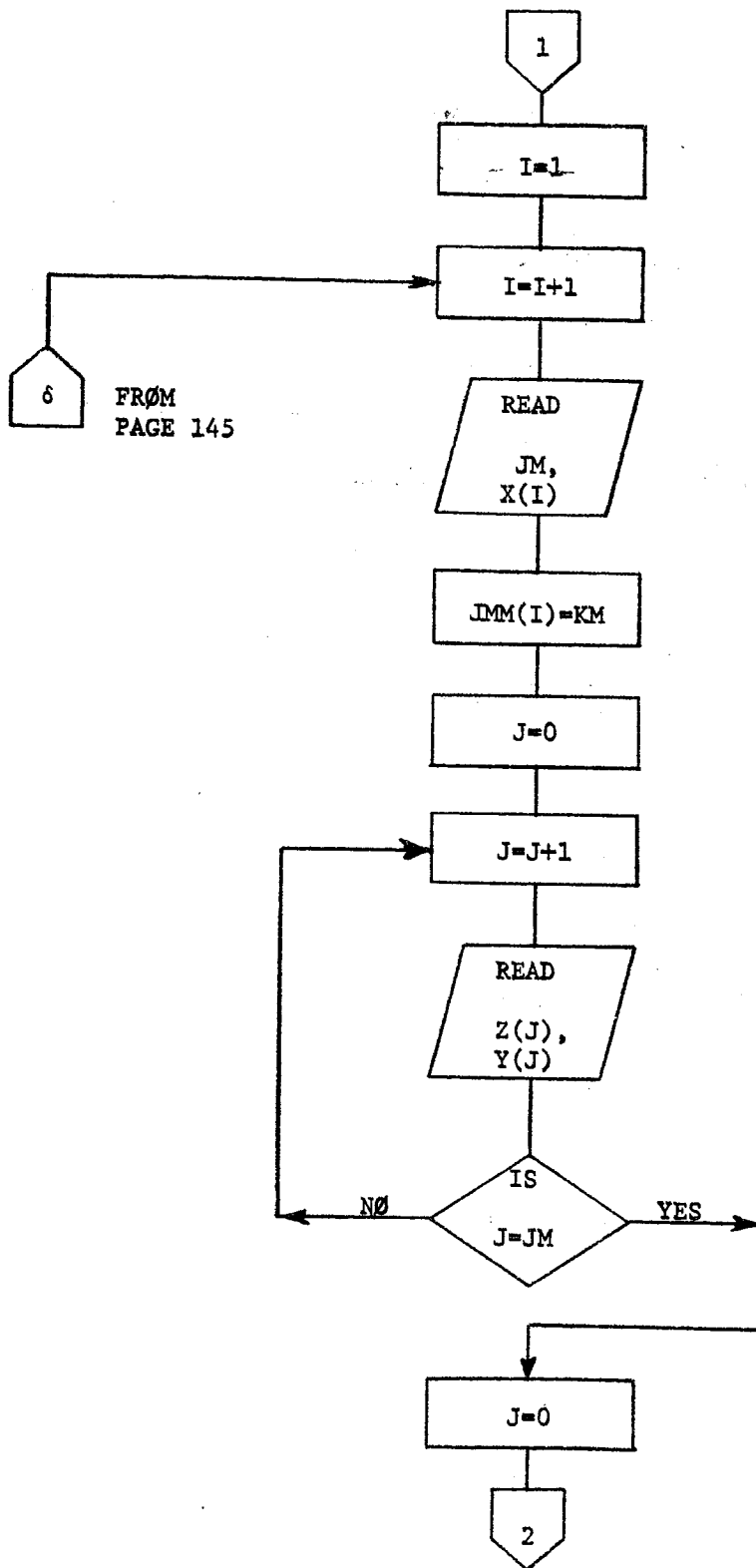
COMPUTE

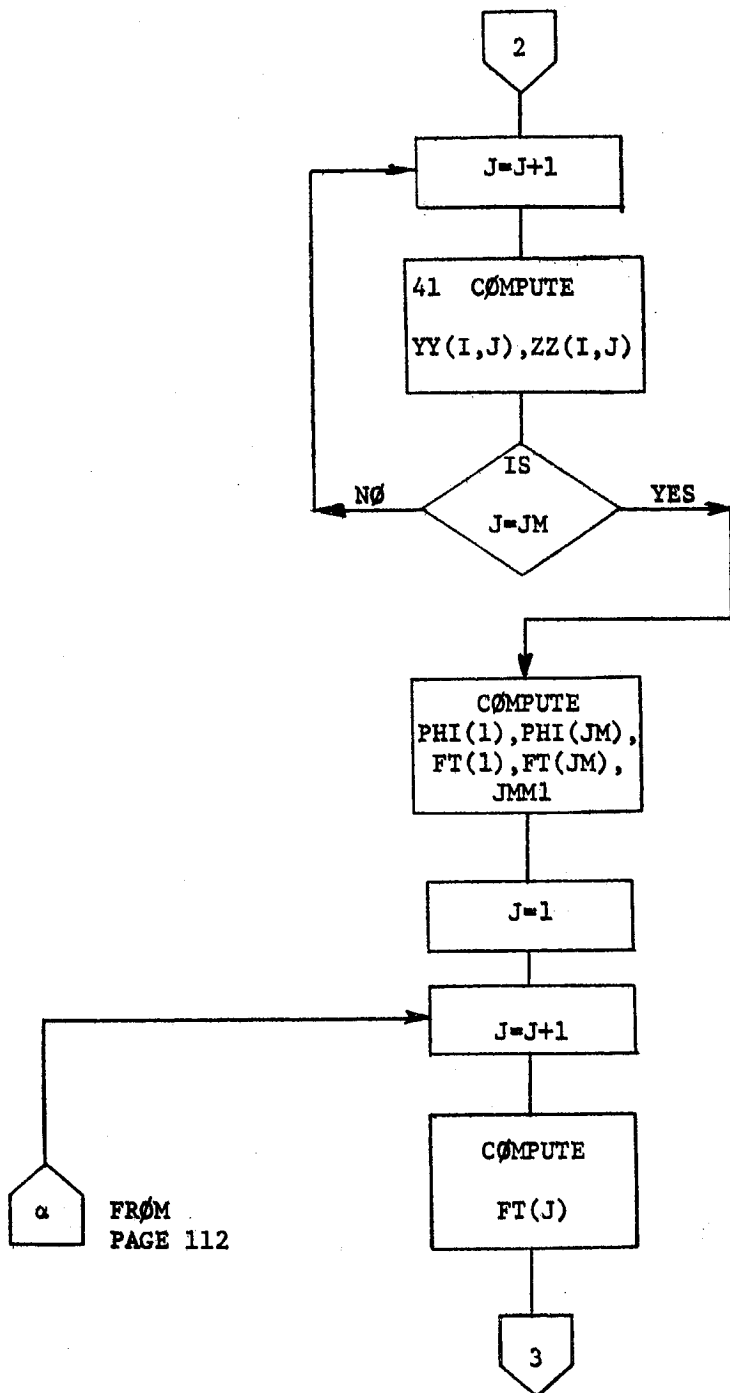
AMF2, F1, F2, FF, FFP, FF2P, AMFX1, AMFX2, FX1, FX2, FFX, FFXP, AMFXX1,
AMFXX2, FXX1, FXX2, FFX, TDLP, DLPH, CDLP, SDLP, T2, DDP, DDX, TGM,
GM, CGM, T3, DGX, DGP, F, AMD1, AMD2, FFP1, FFP2, AMG1, AMG2, F2X1, F2X2,
FFX, FFXPP, FFXP, FF3P, AMGX1, AMGX2, F3X1, F3X2, FF3X, F2, FX, FXX,
FP, FPP

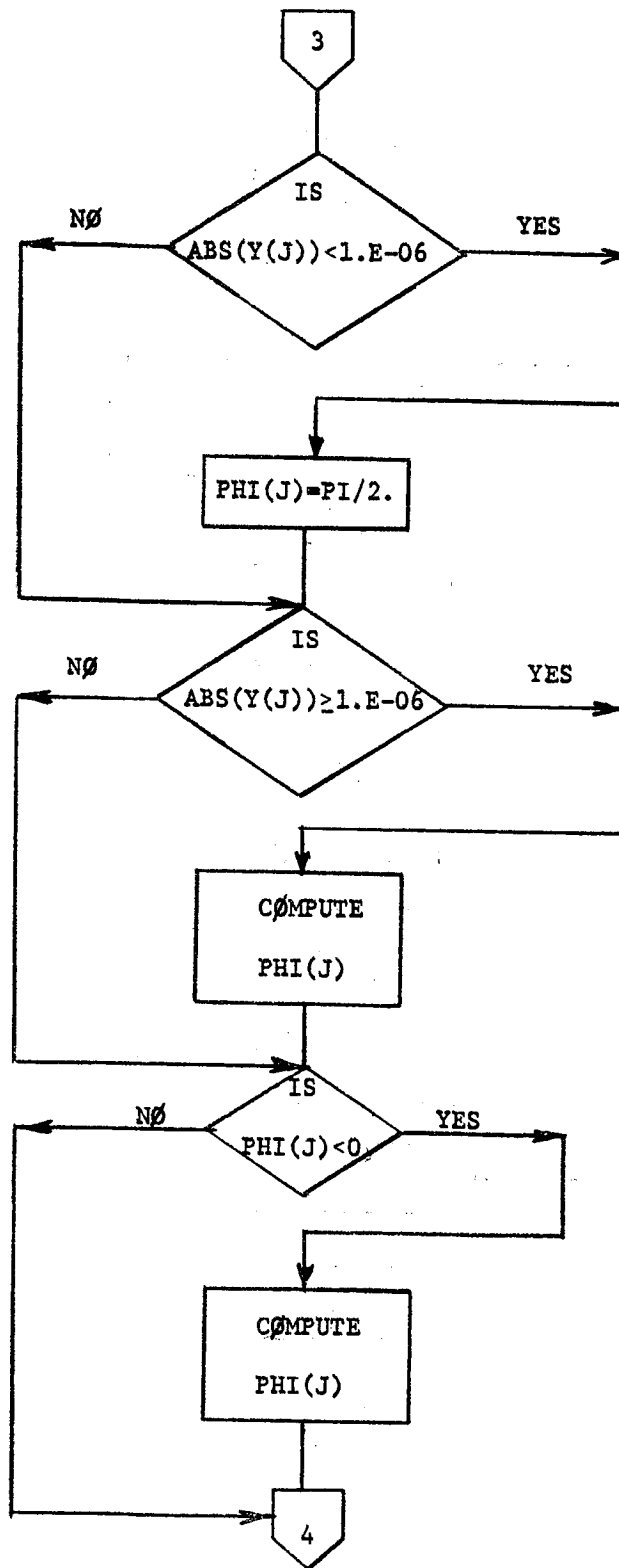
RETURN

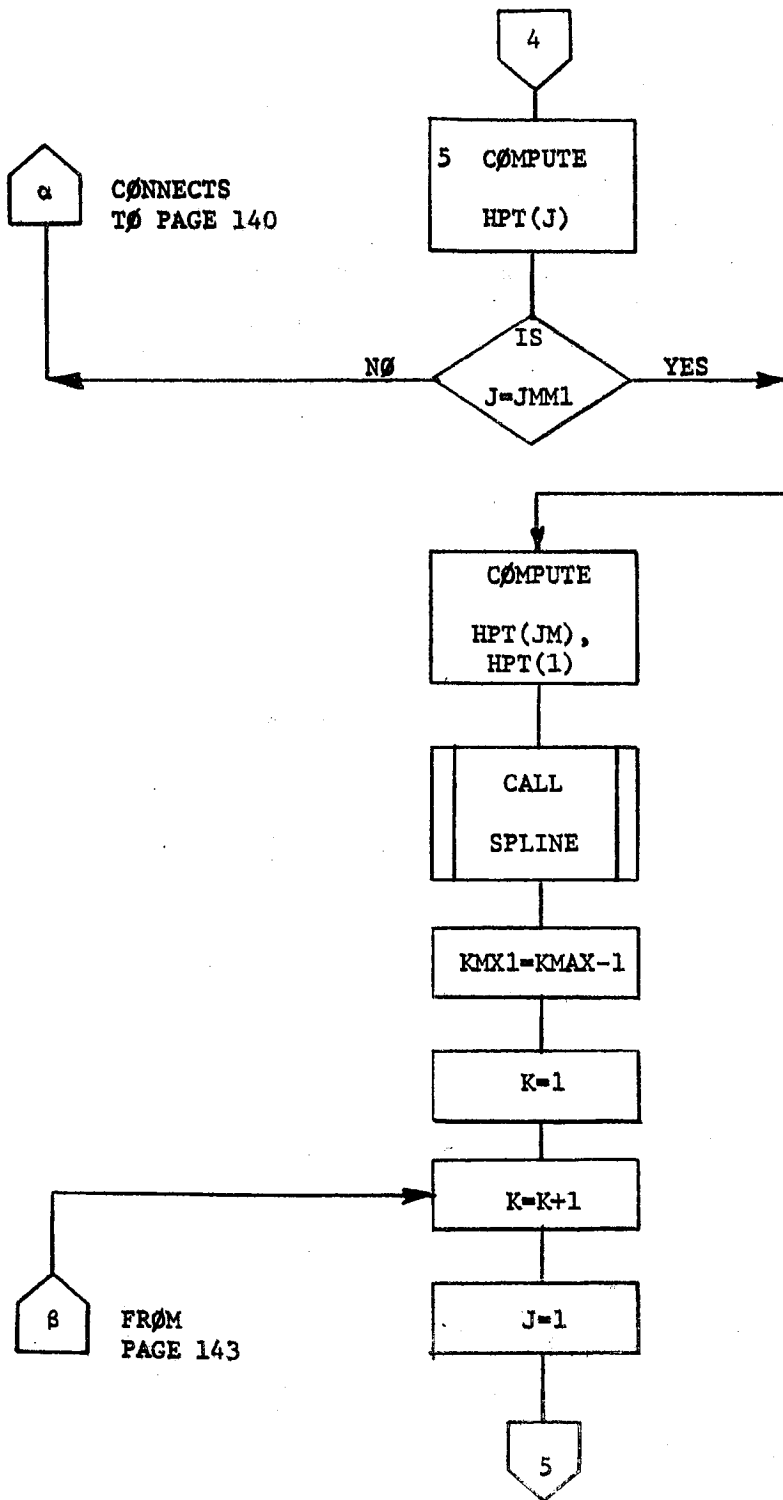
SUBROUTINE BGEØM(IMAX,KMAX)

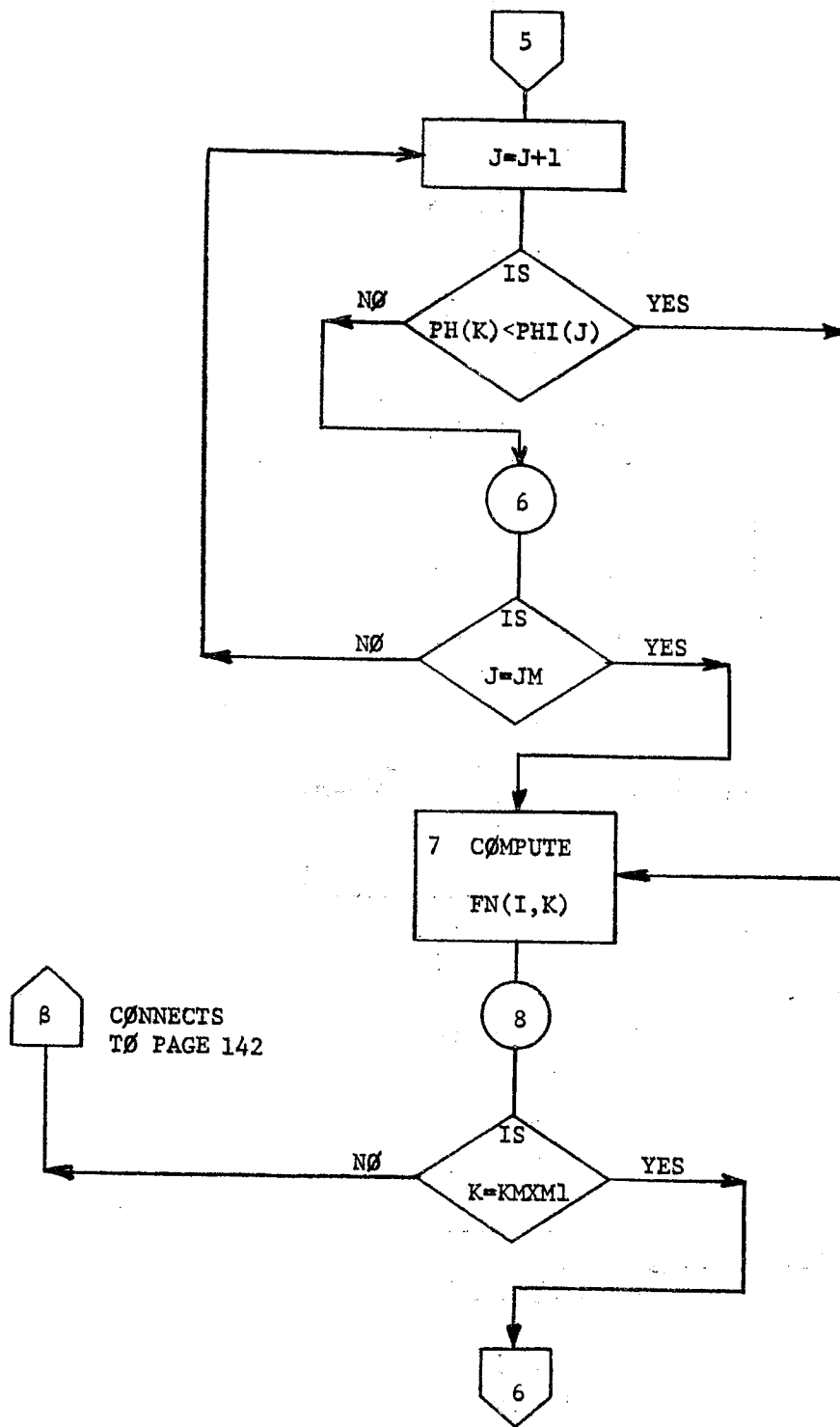


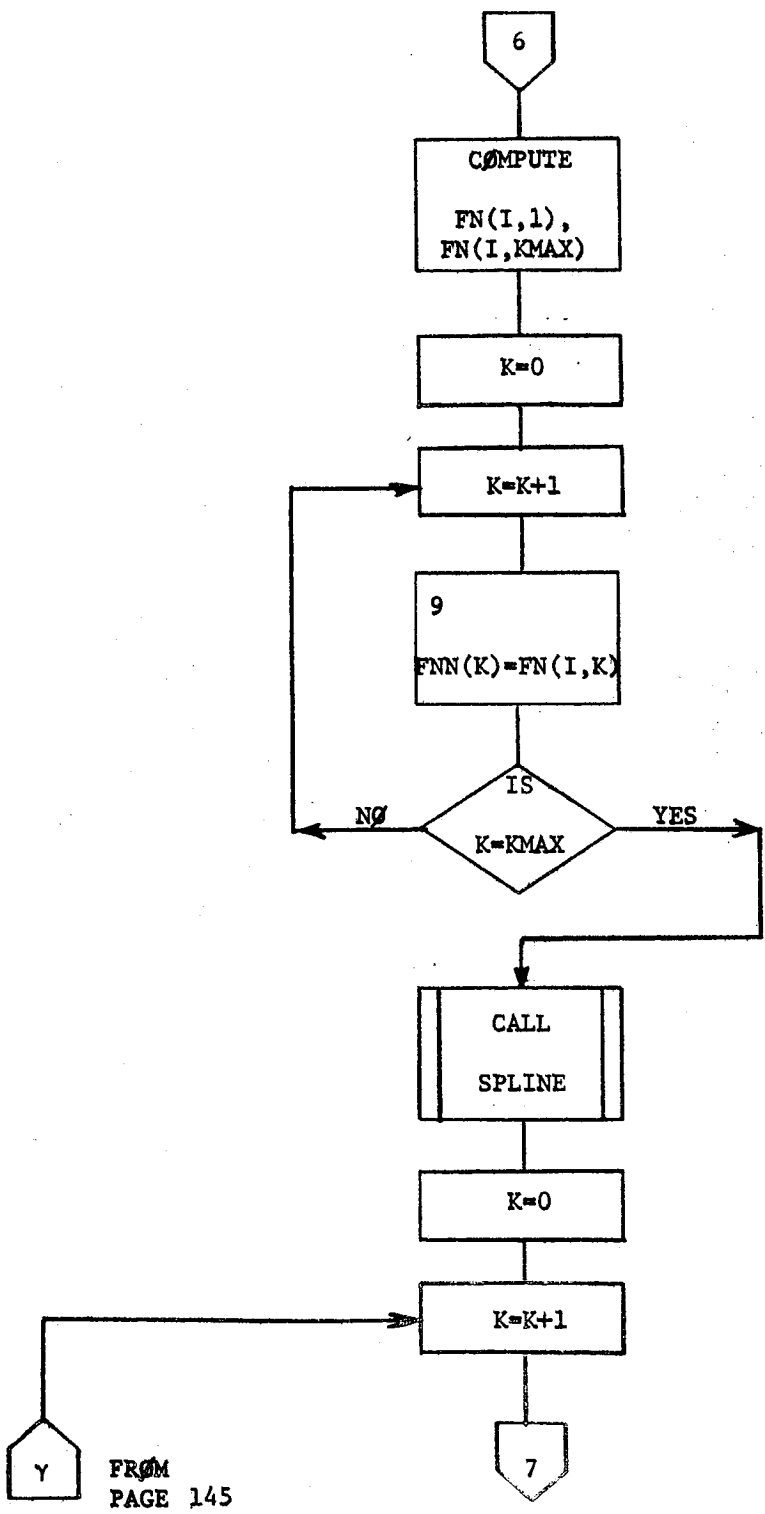




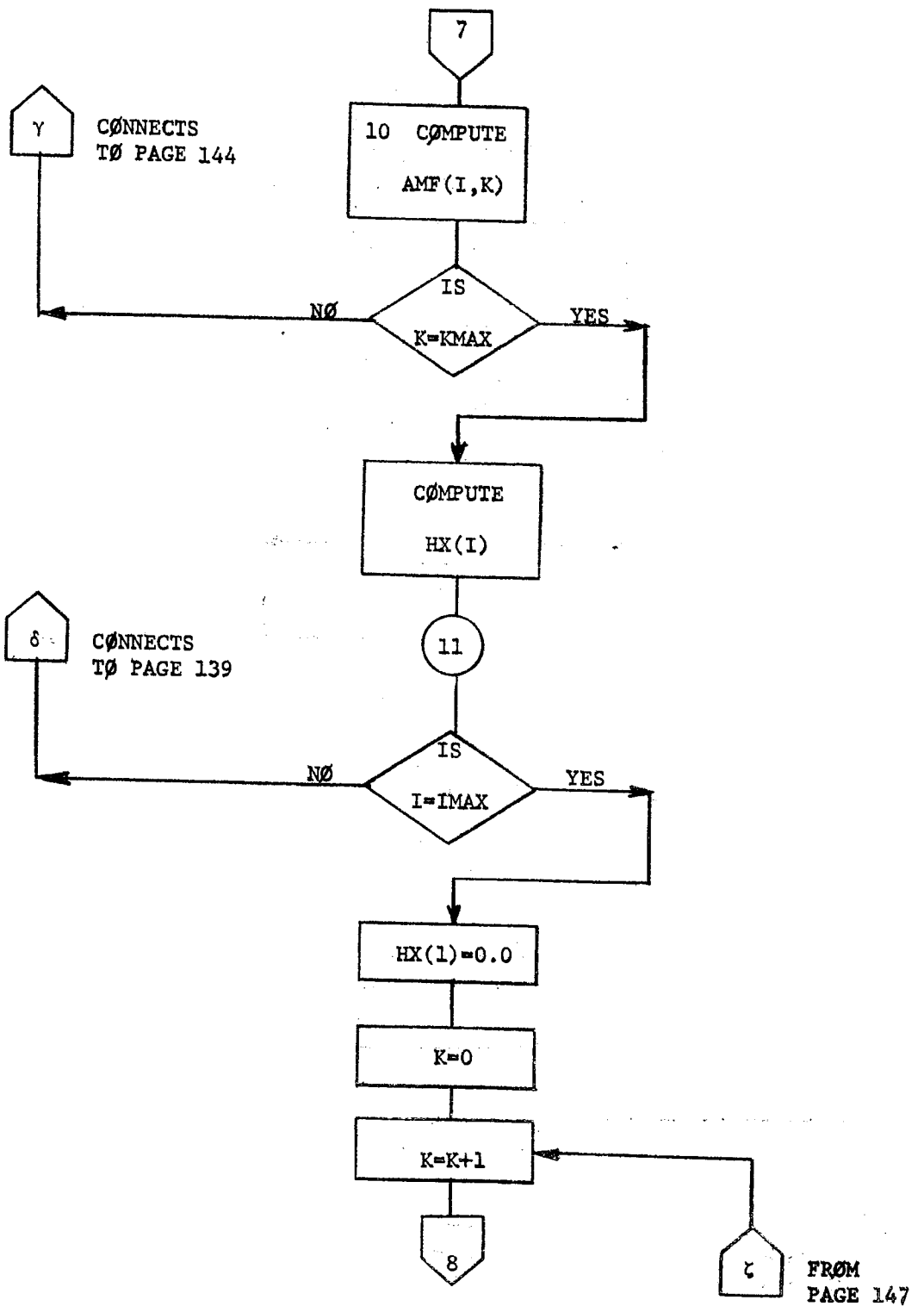


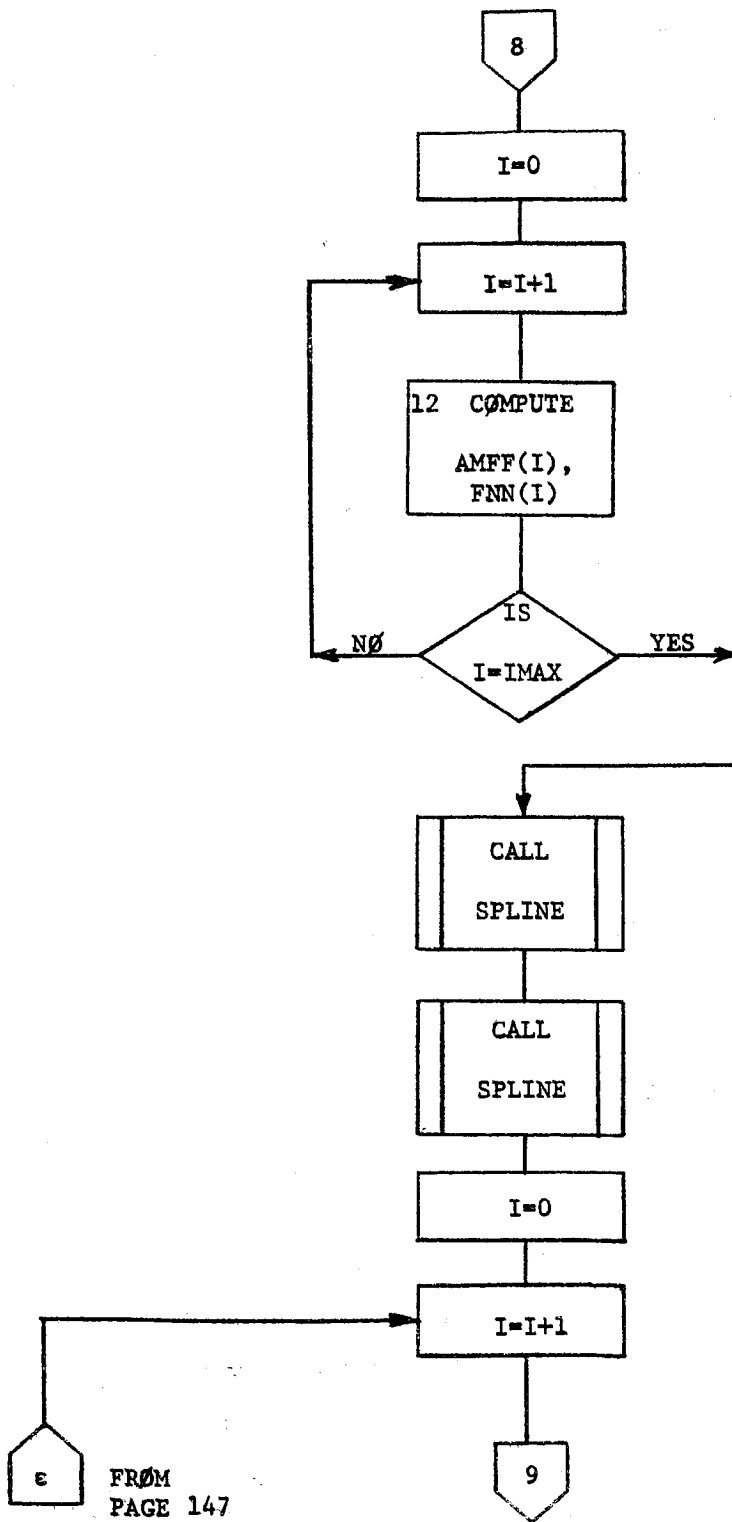


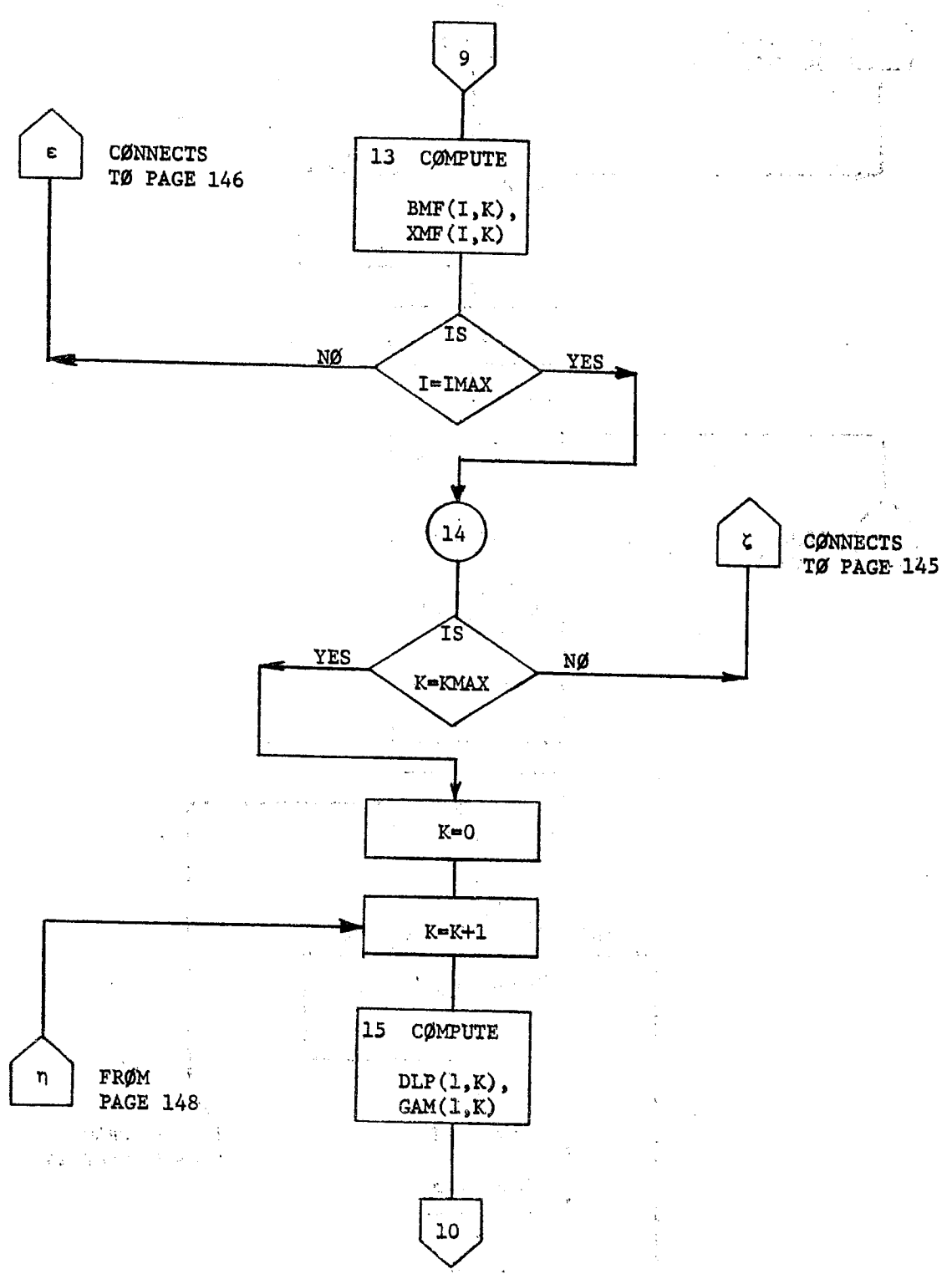


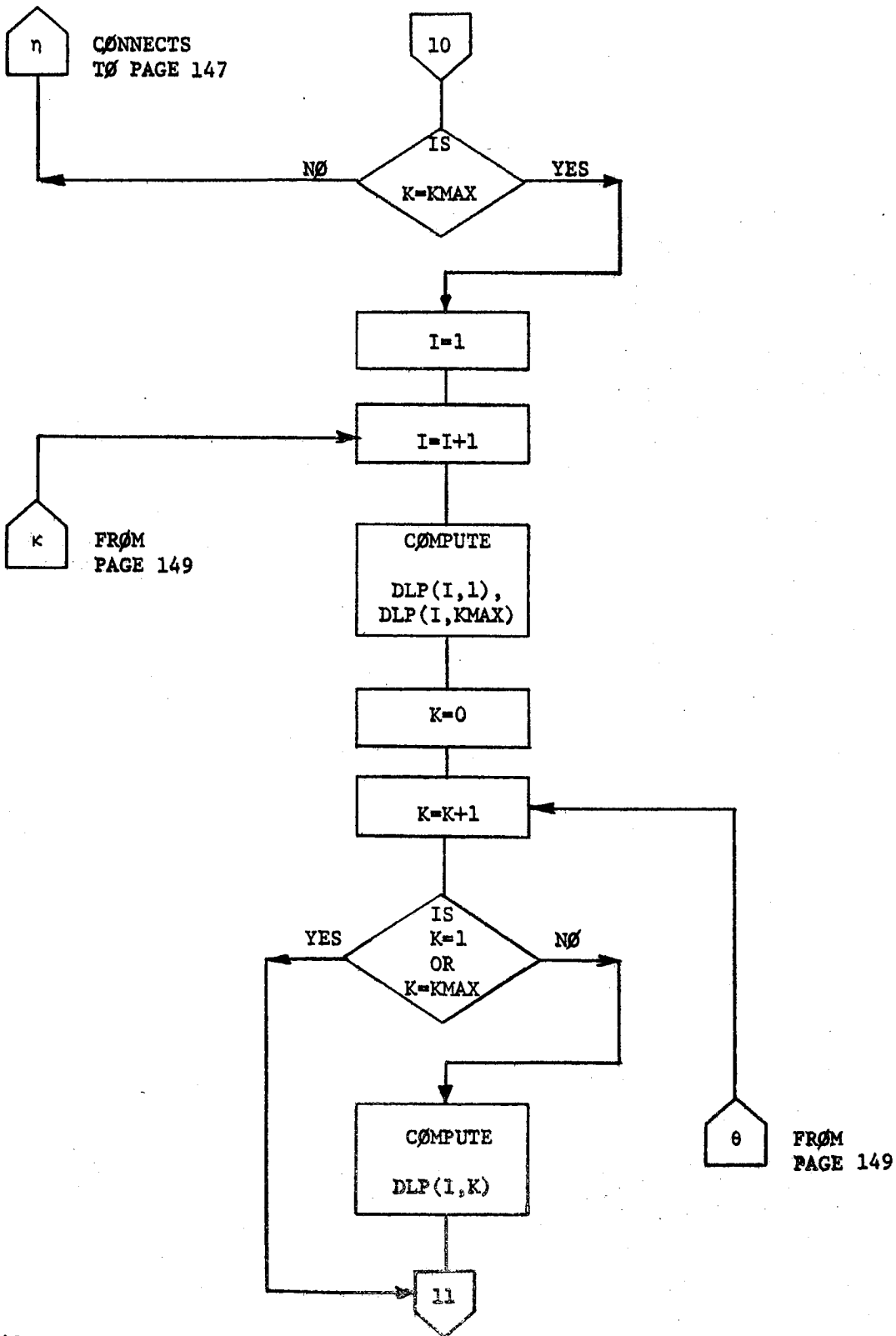


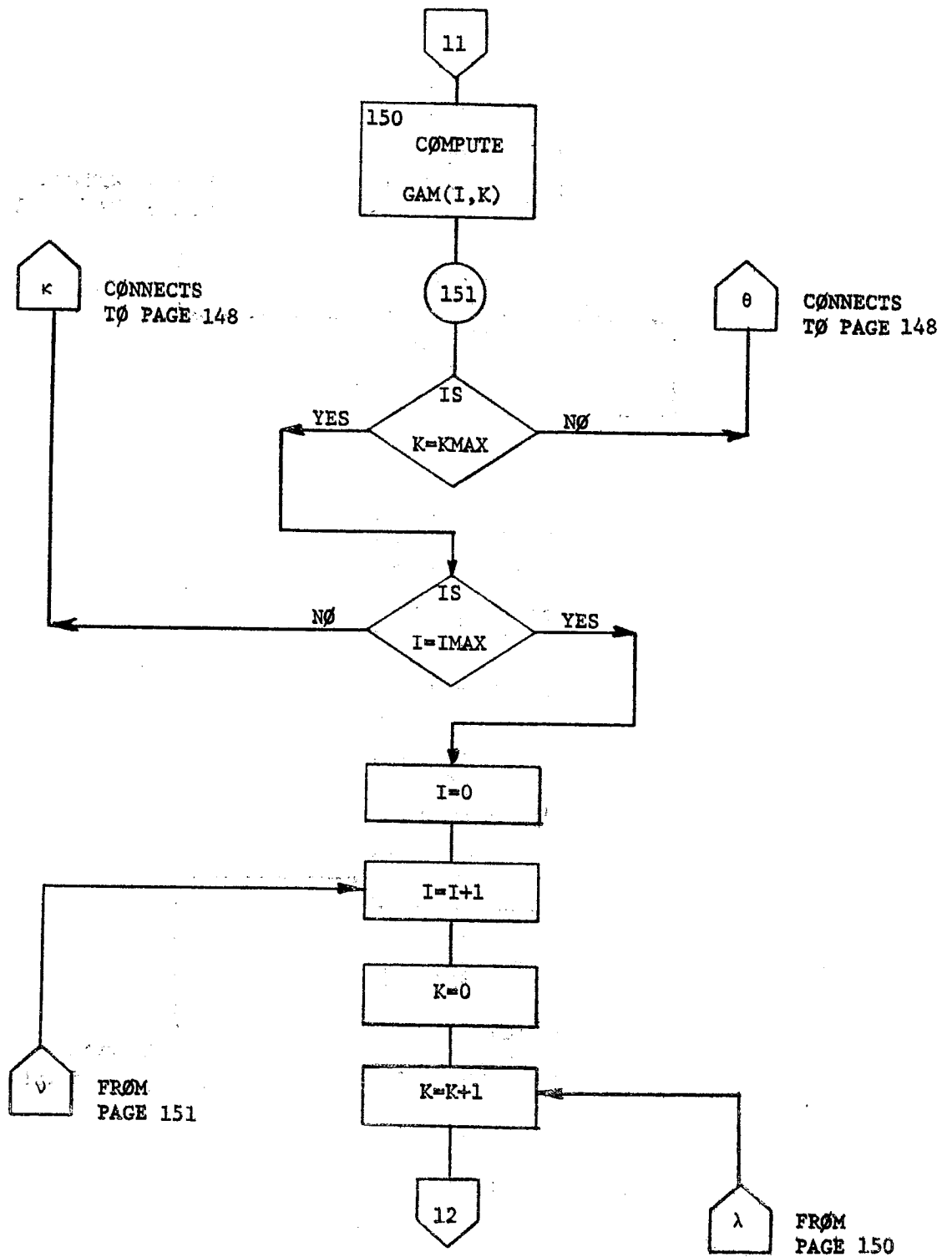
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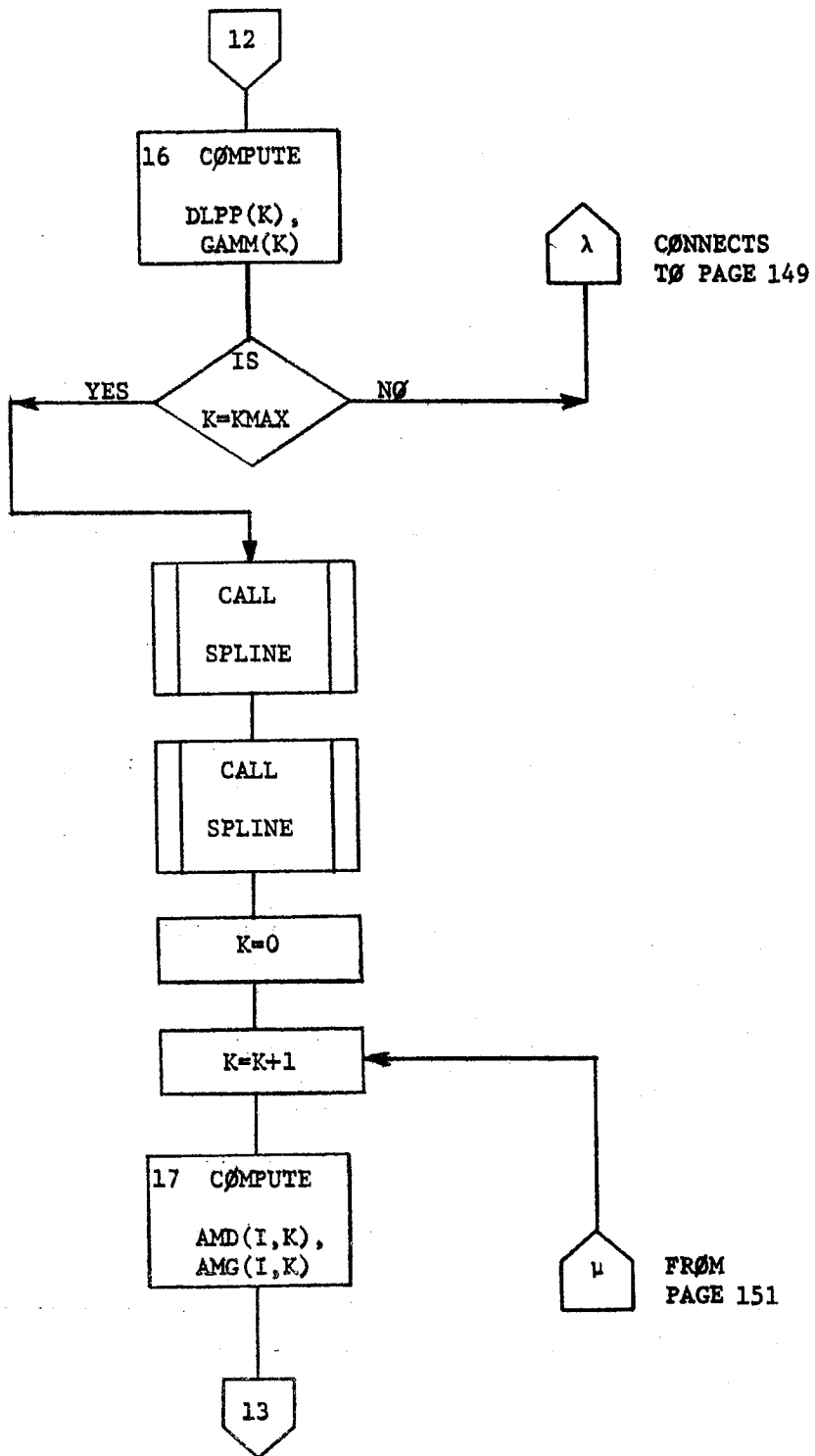


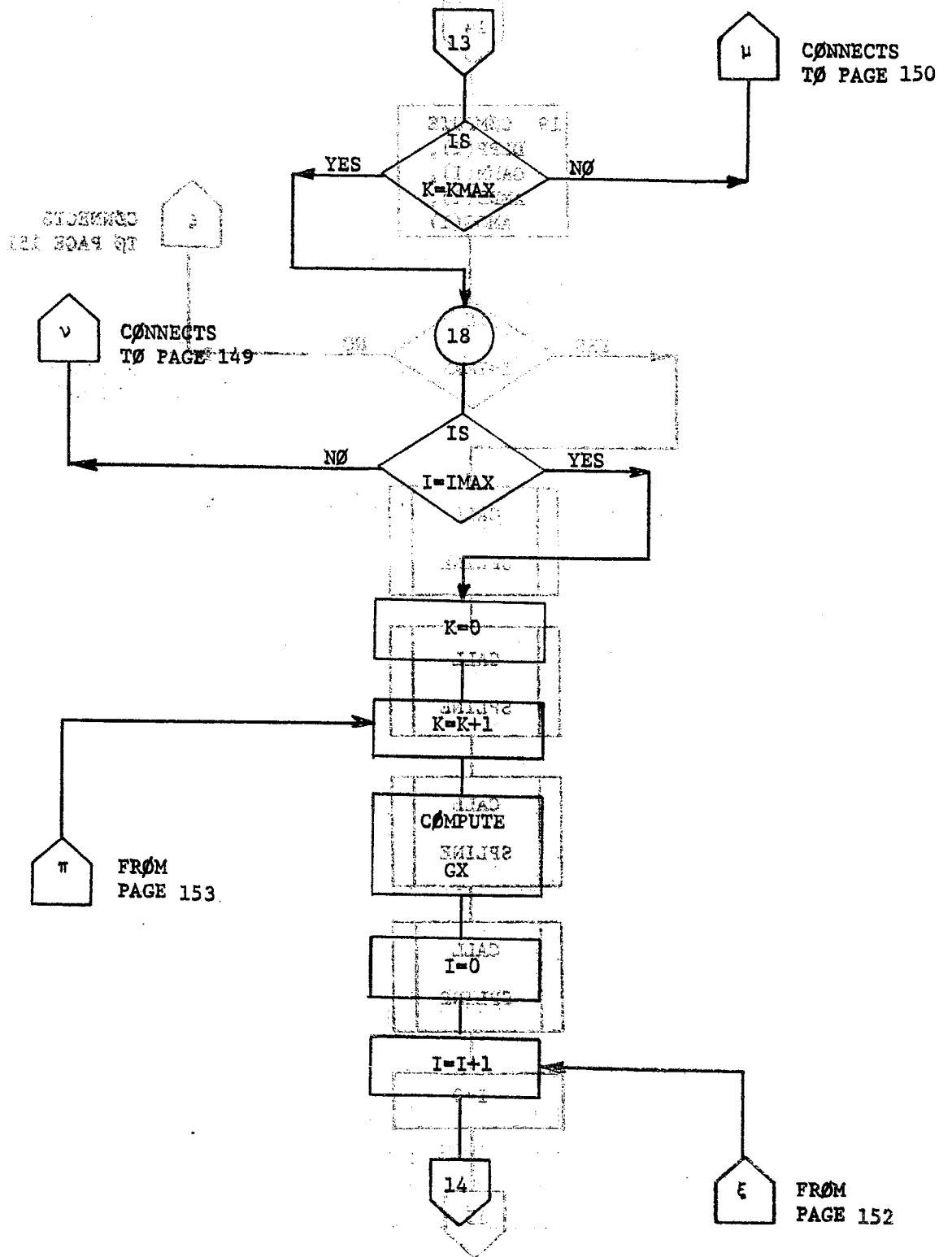


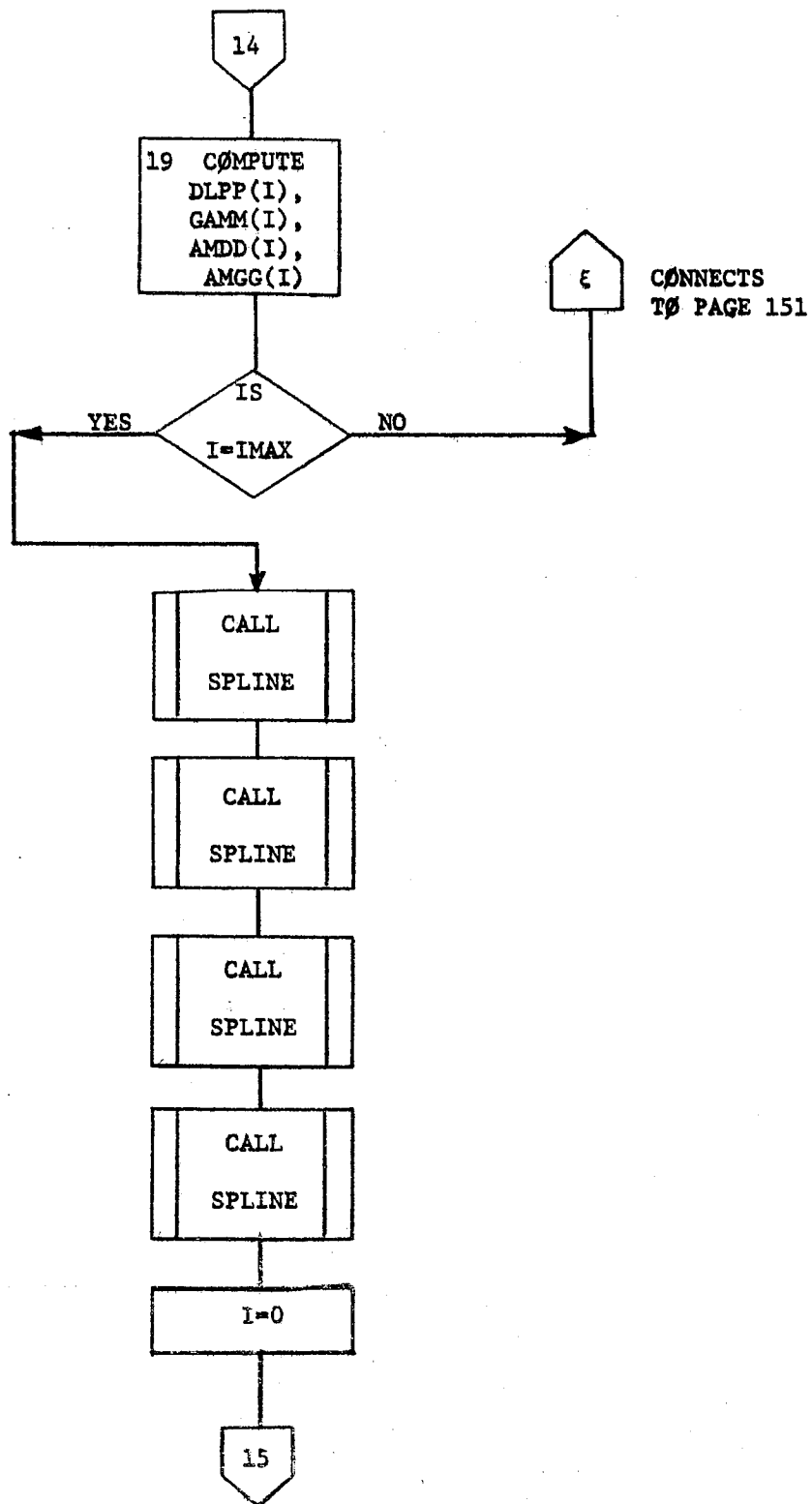


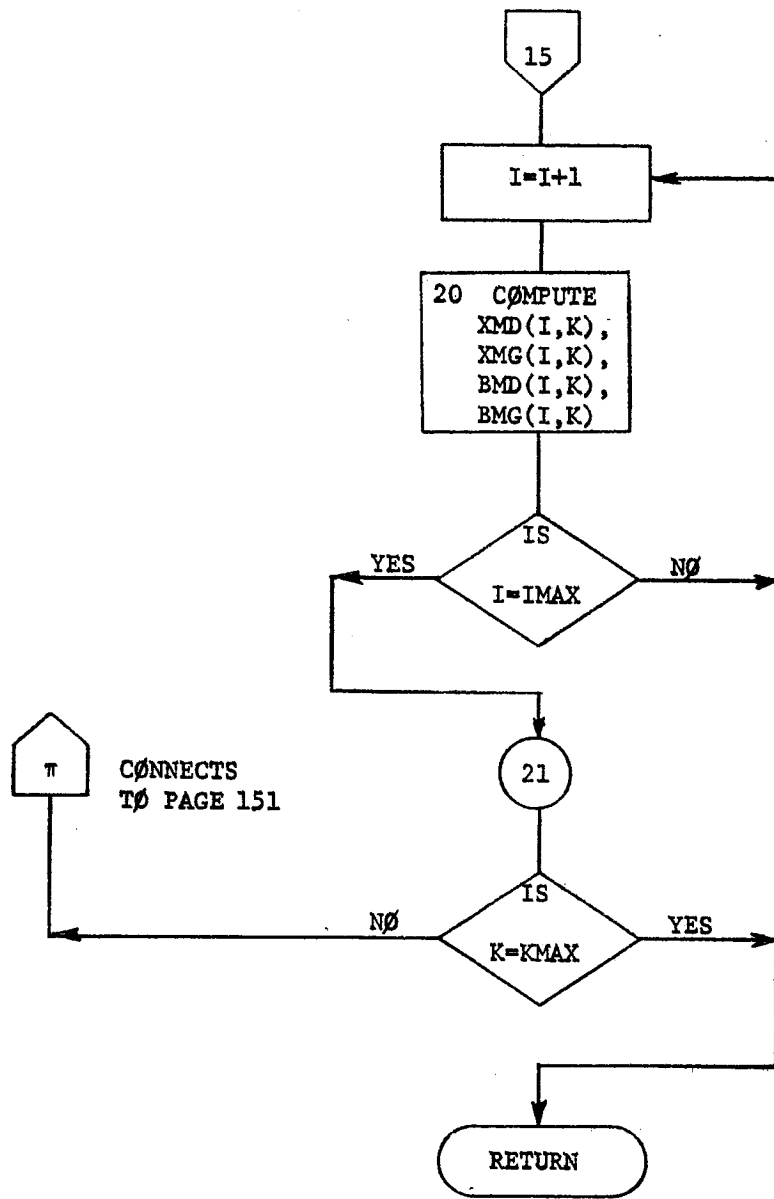




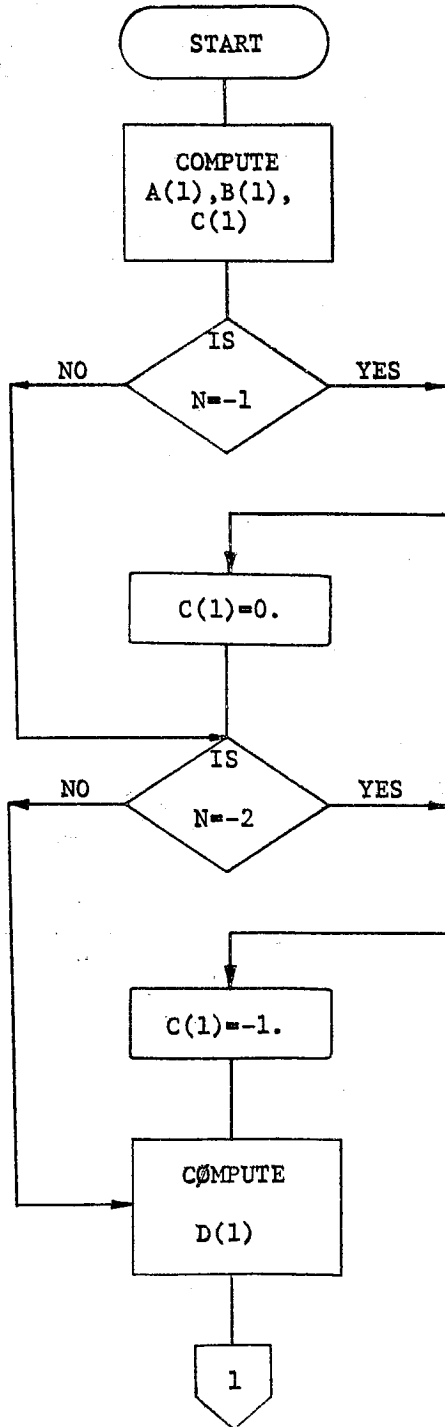


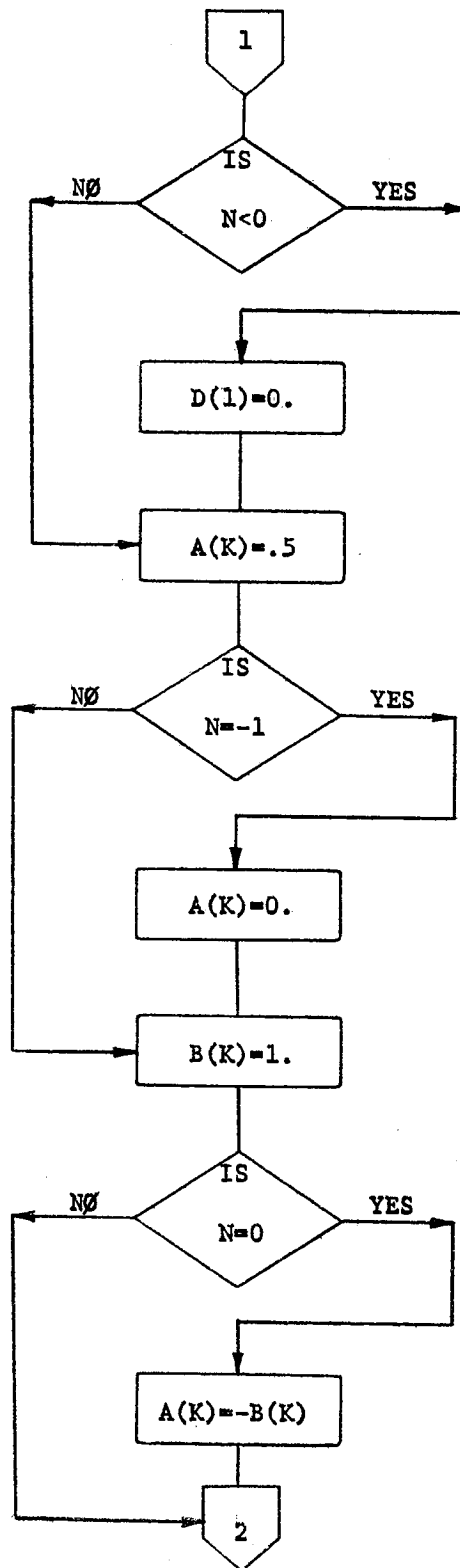


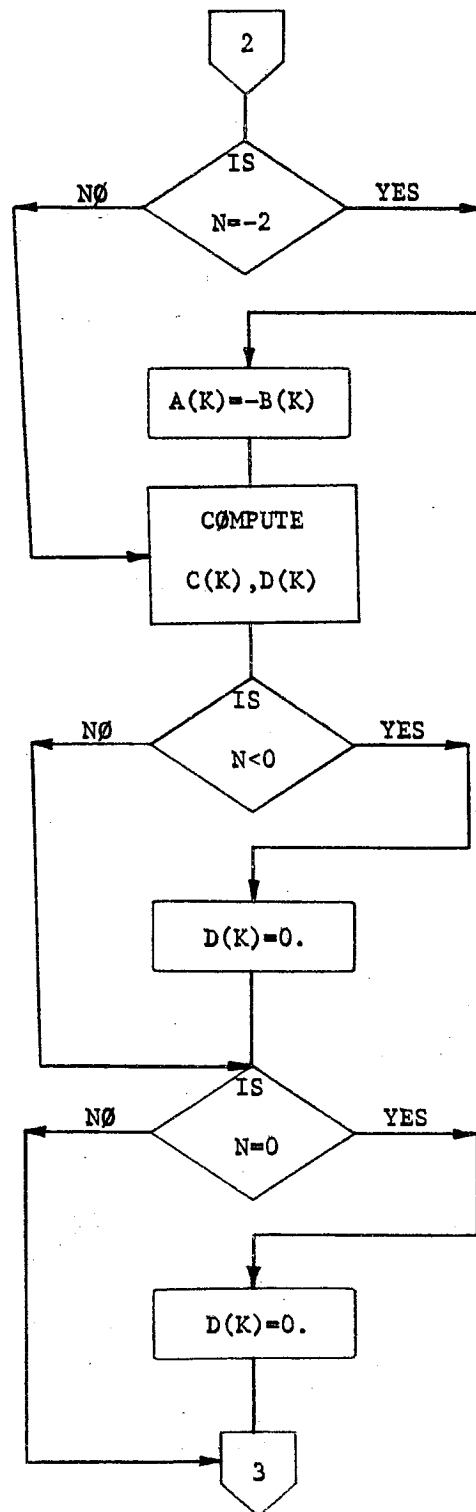


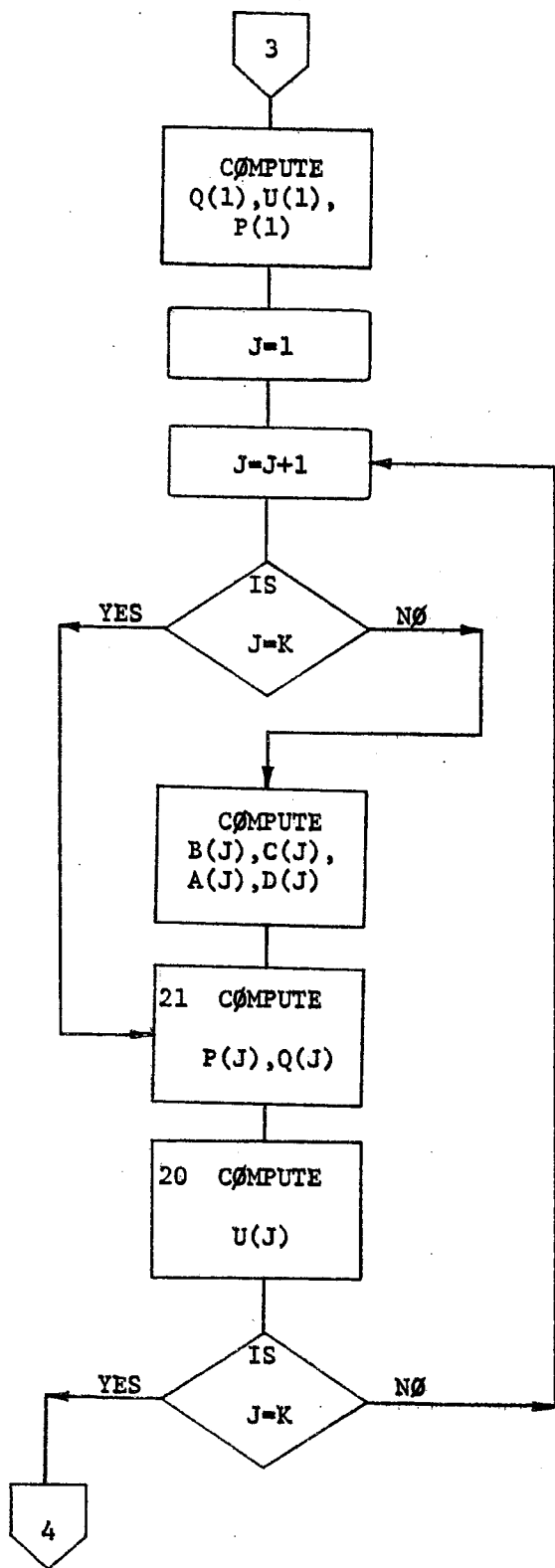


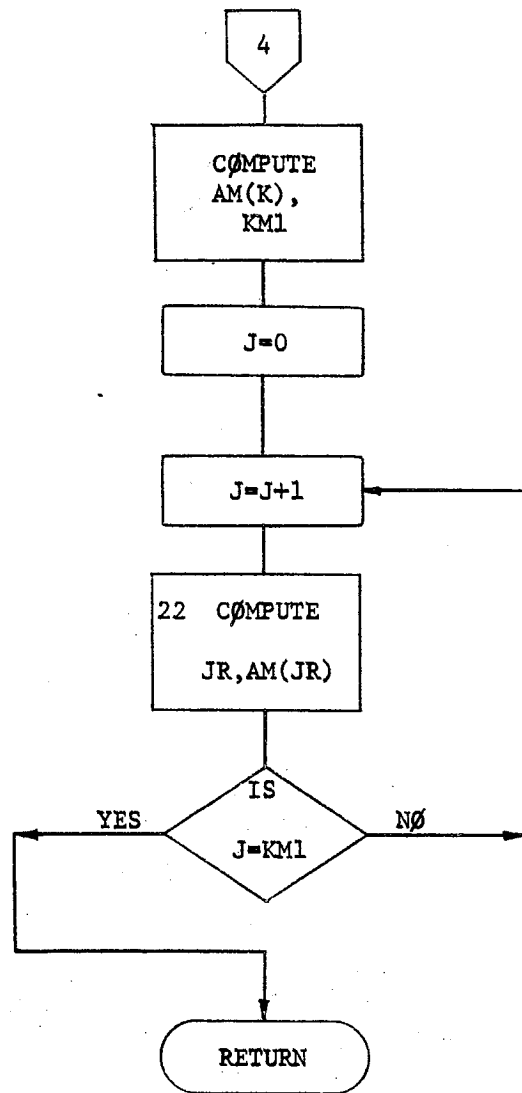
SUBROUTINE SPLINE(H,DE,K,AM,E,G,N)



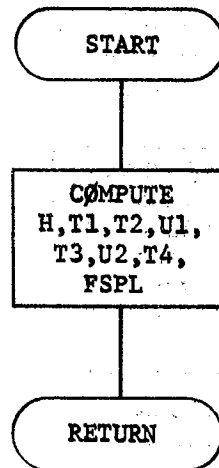




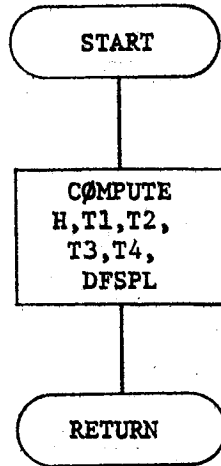




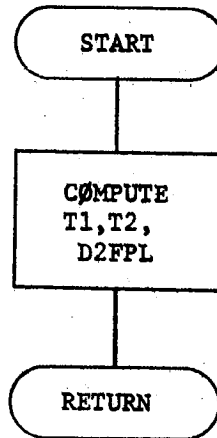
FUNCTION FSPL(AM1,AM2,X1,X2,Y1,Y2,X)



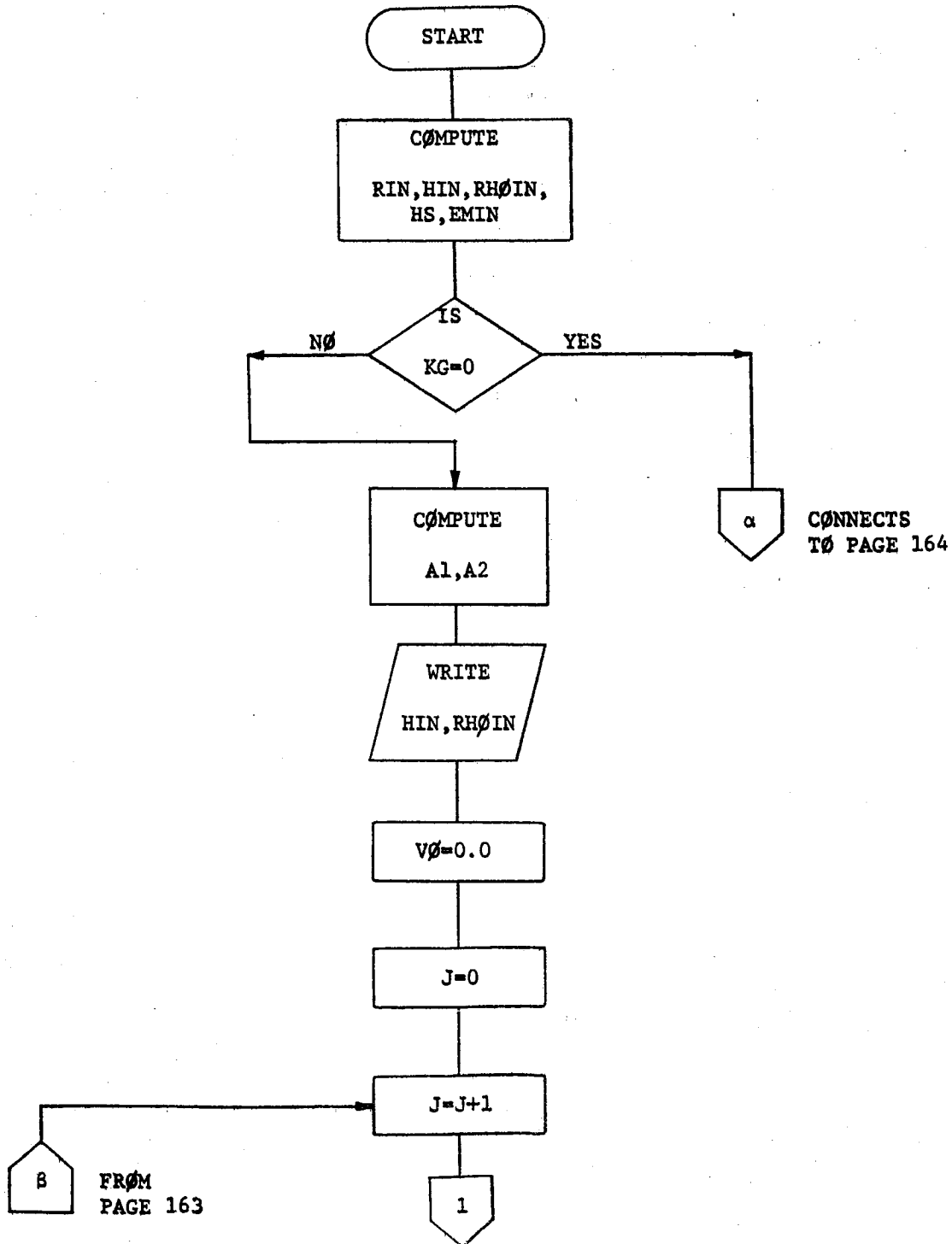
FUNCTION DFSPL(AM1,AM2,X1,X2,Y1,Y2,X)

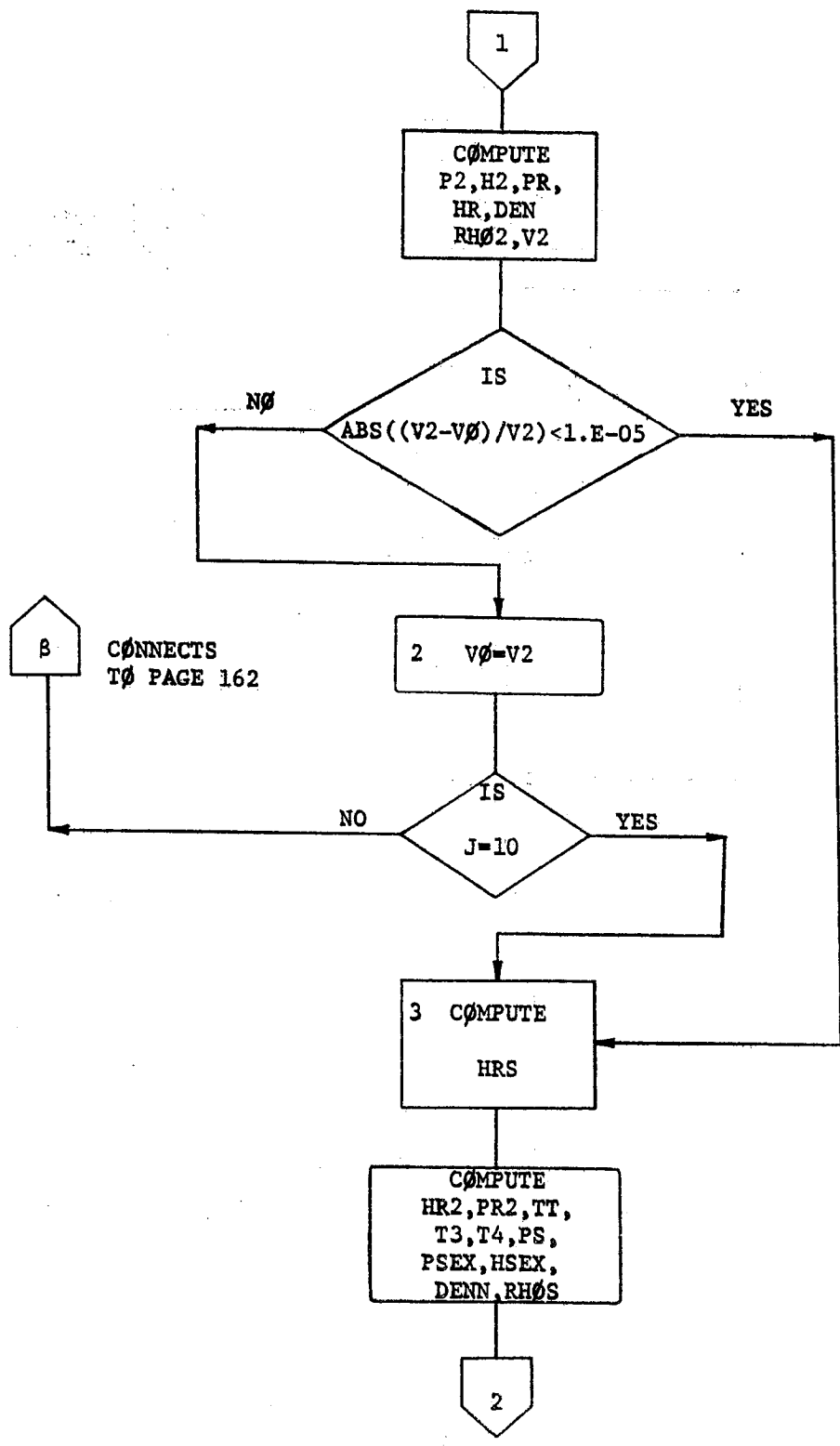


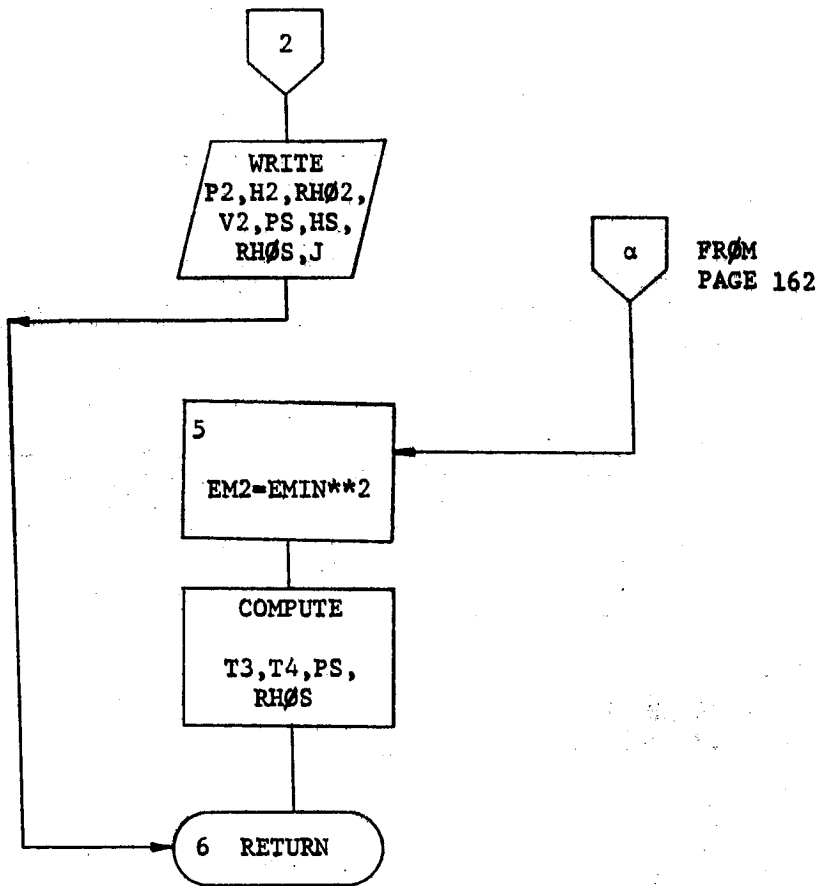
FUNCTION D2FPL(AM1,AM2,X1,X2,Y1,Y2,X)



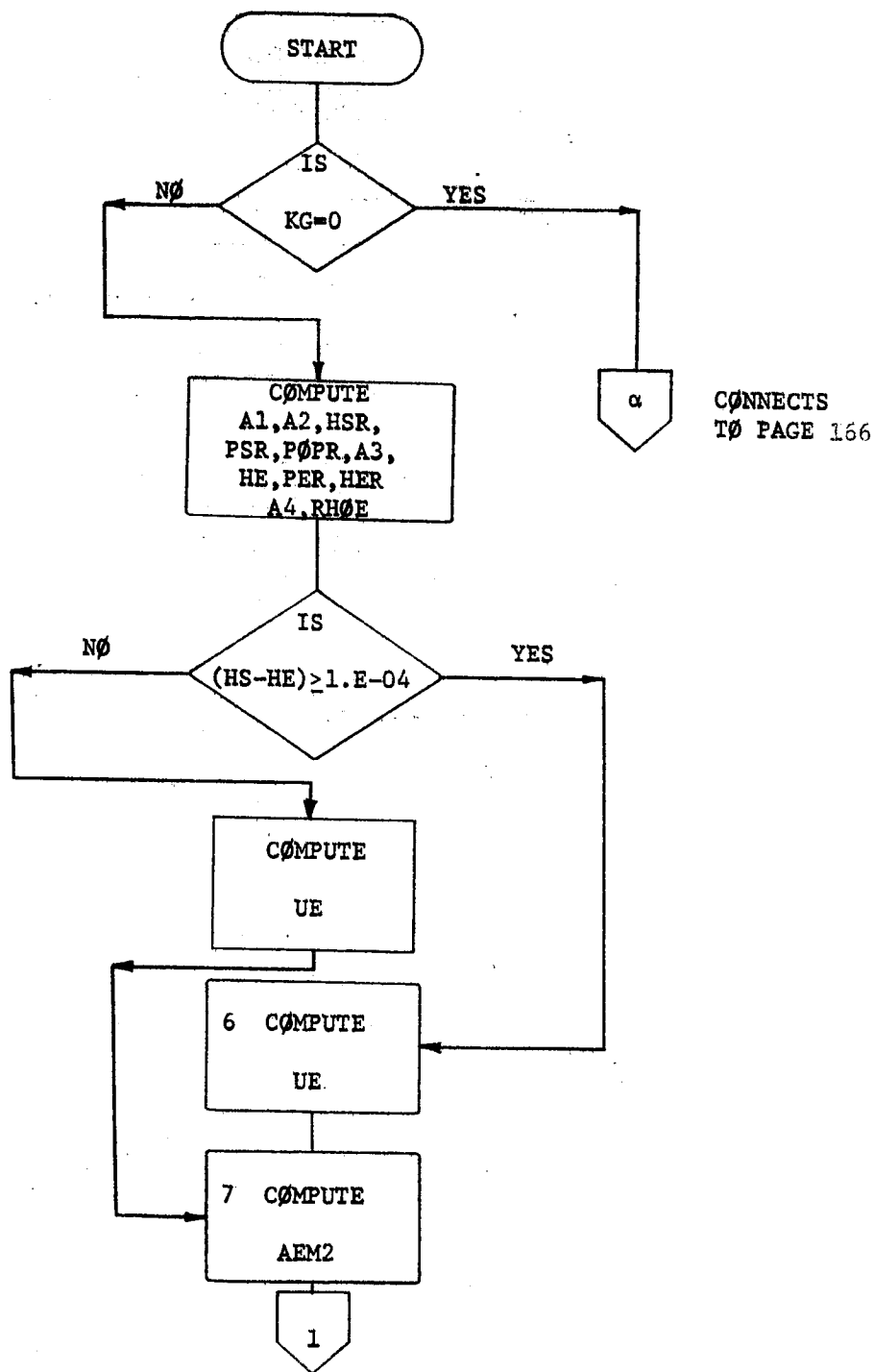
SUBROUTINE STGPR(PIN, TIN, VIN, RHØIN, EMIN, PS, RHØS, HS, KG)

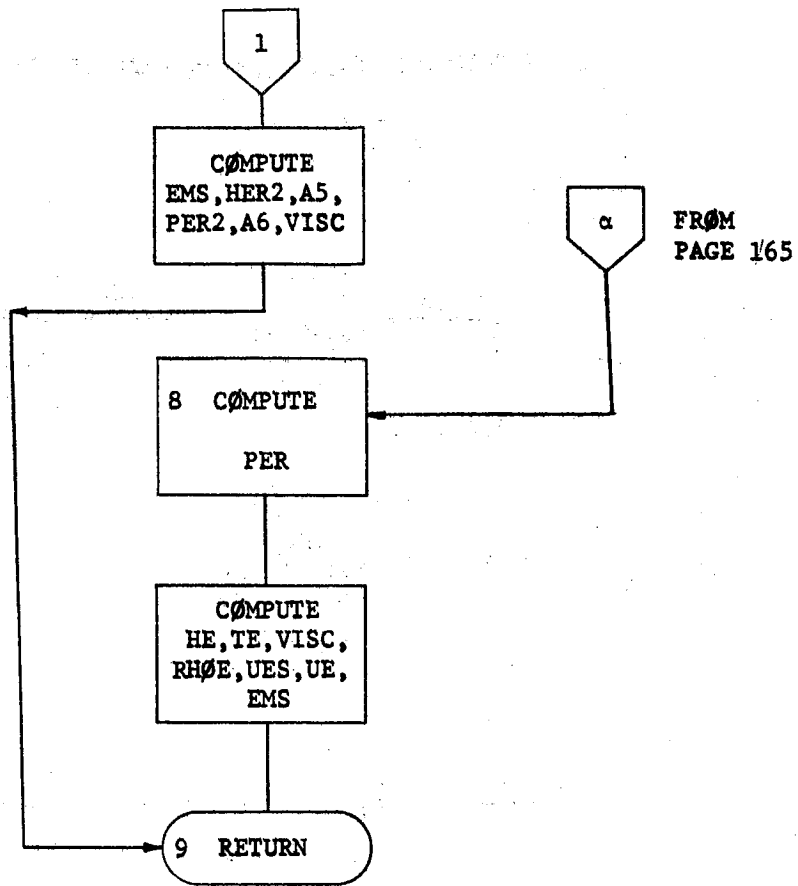




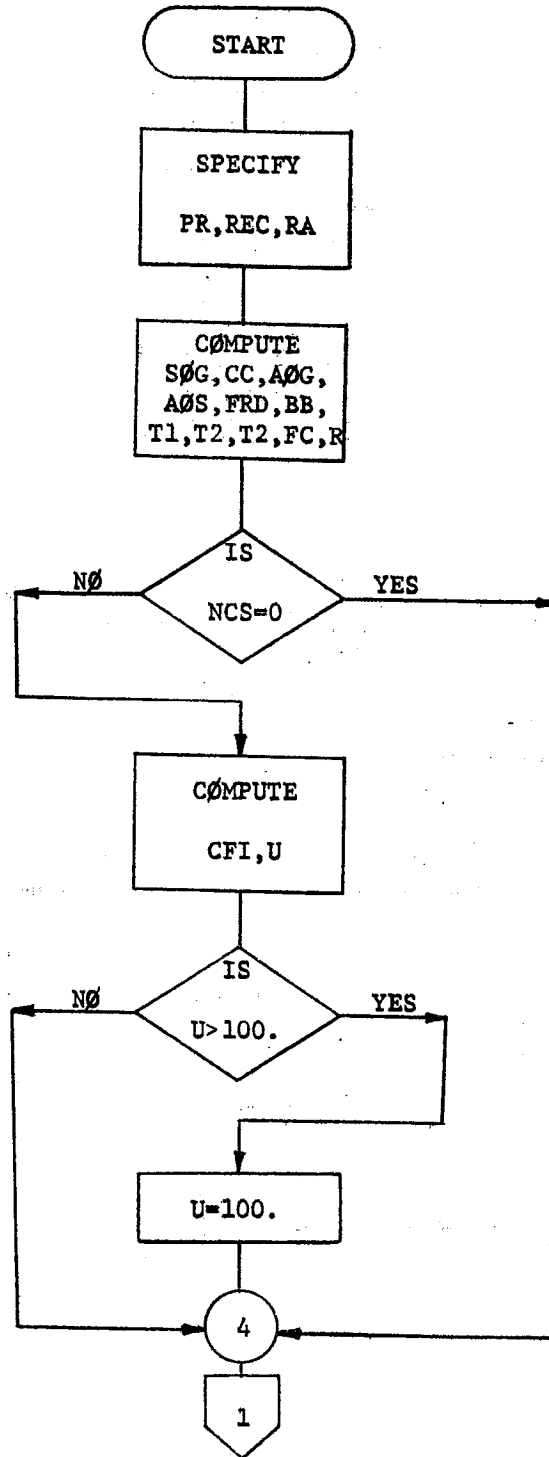


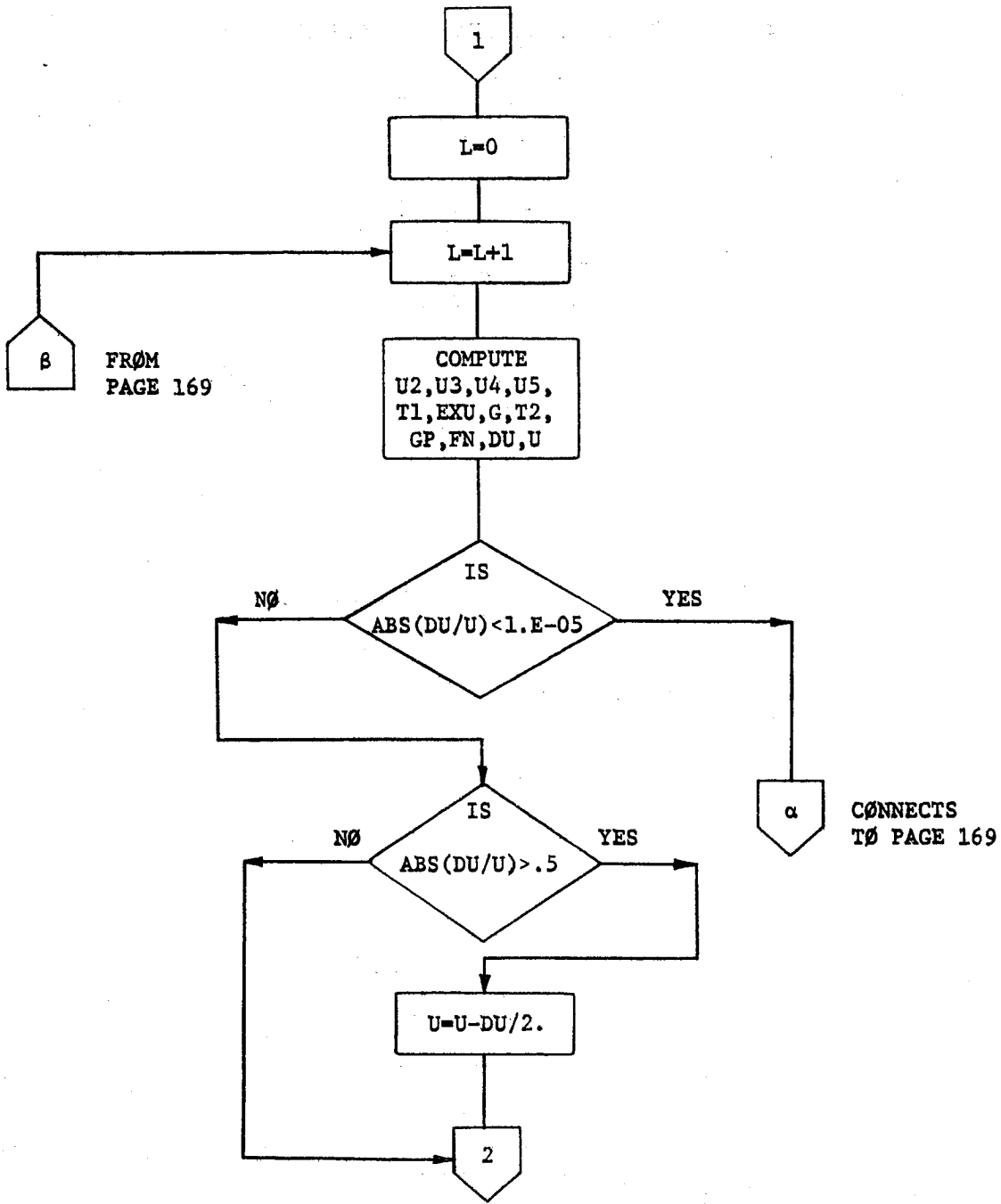
SUBROUTINE PRCP (PS, HS, RHOS, PE, HE, RHOE, UE, VISC, EMS, KG)

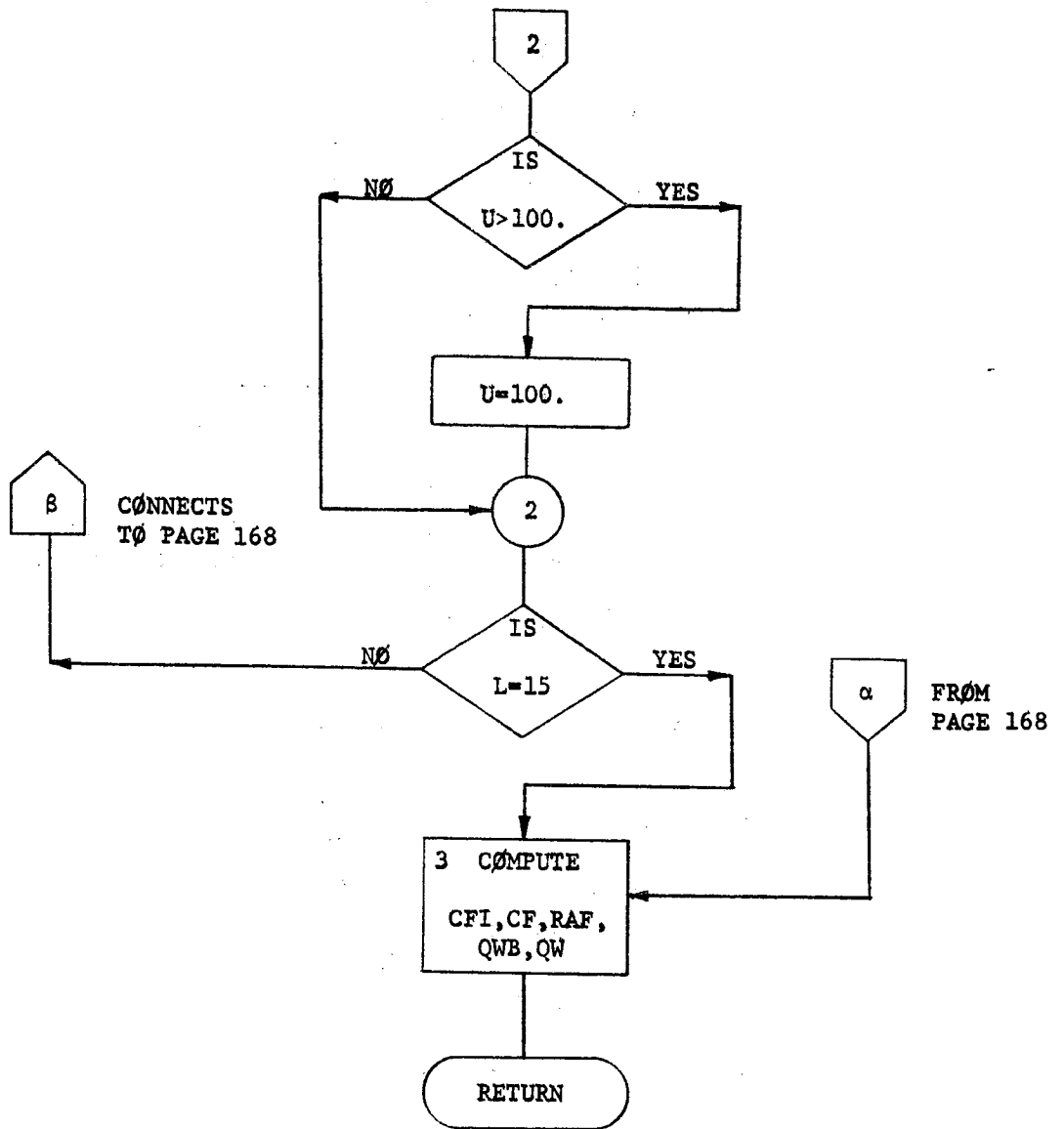




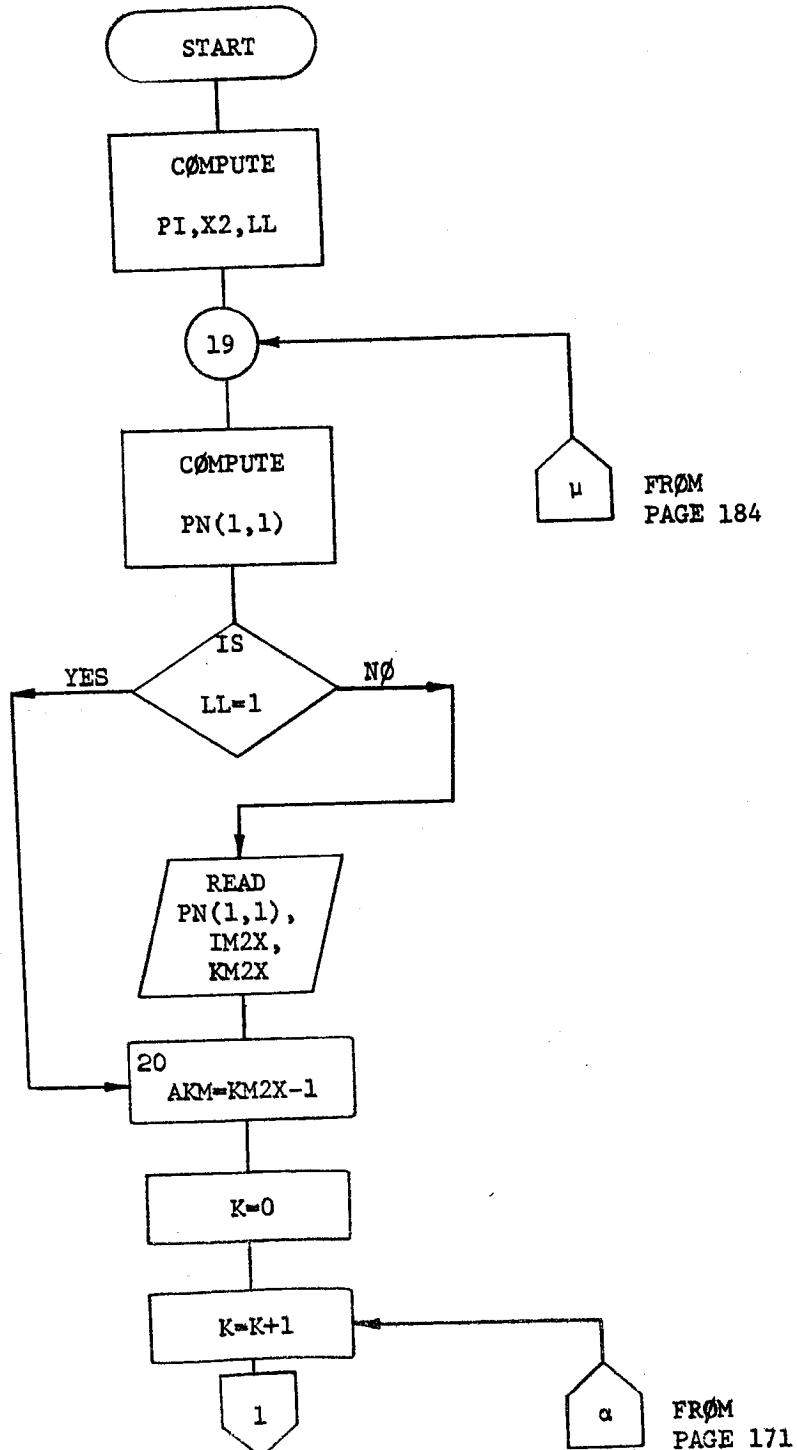
SUBROUTINE SPCH(ZW, HE, RHØE, UE, HS, RNM, CF, QW, QWB, NCS)

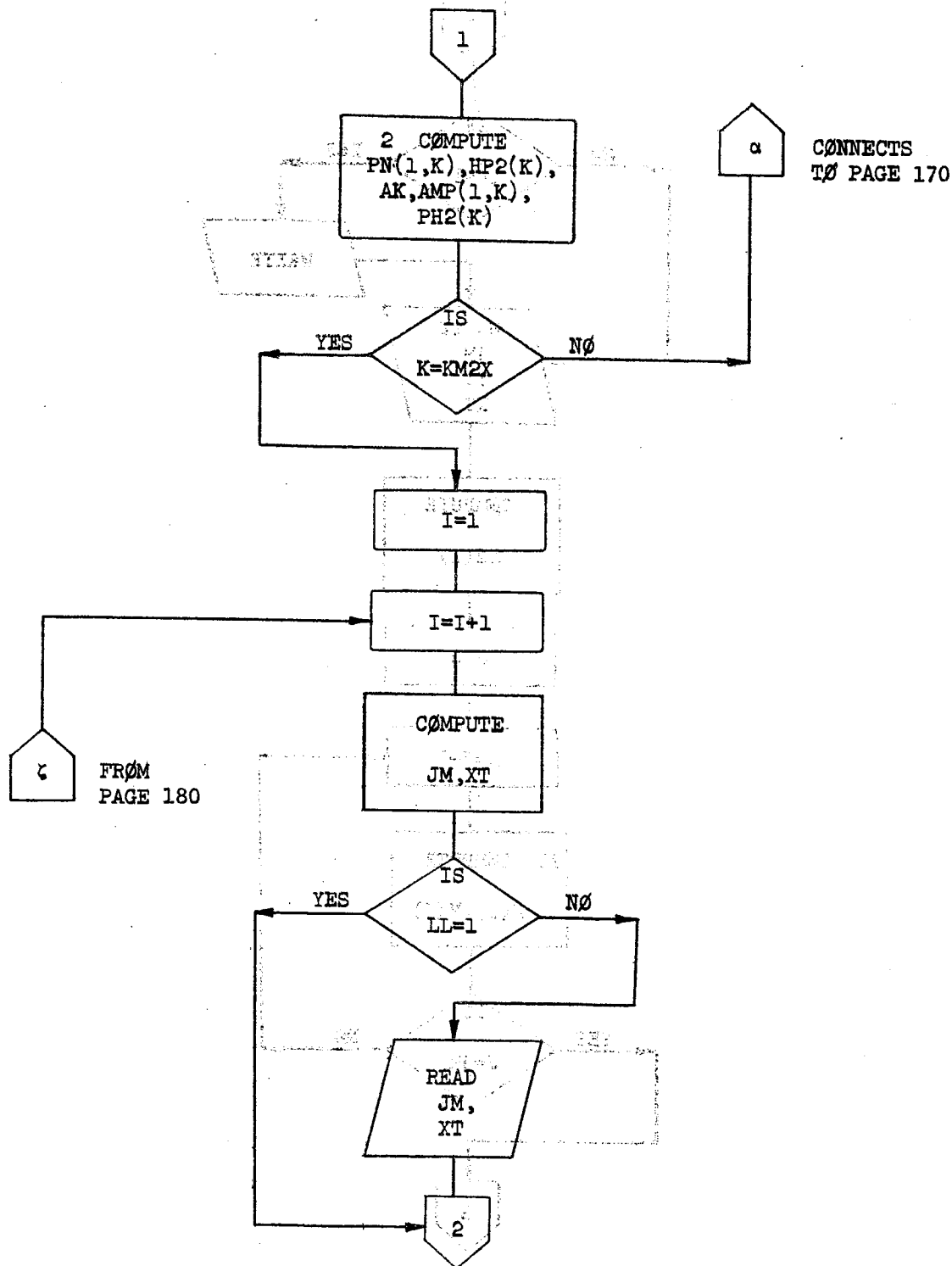


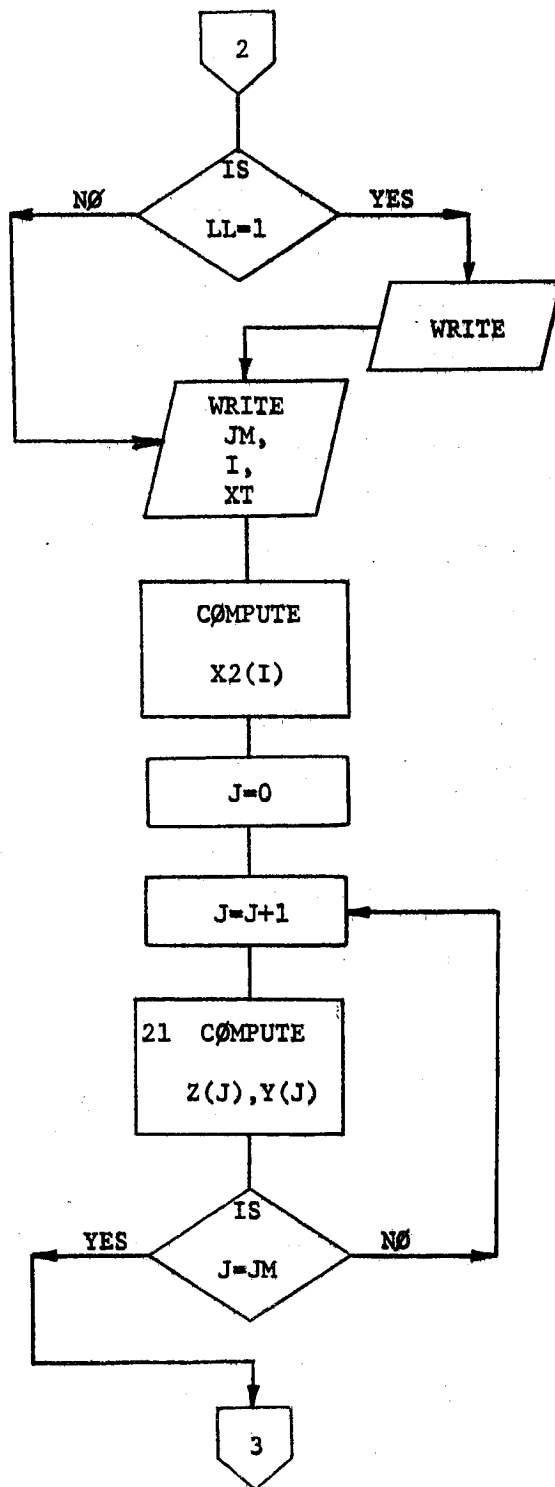


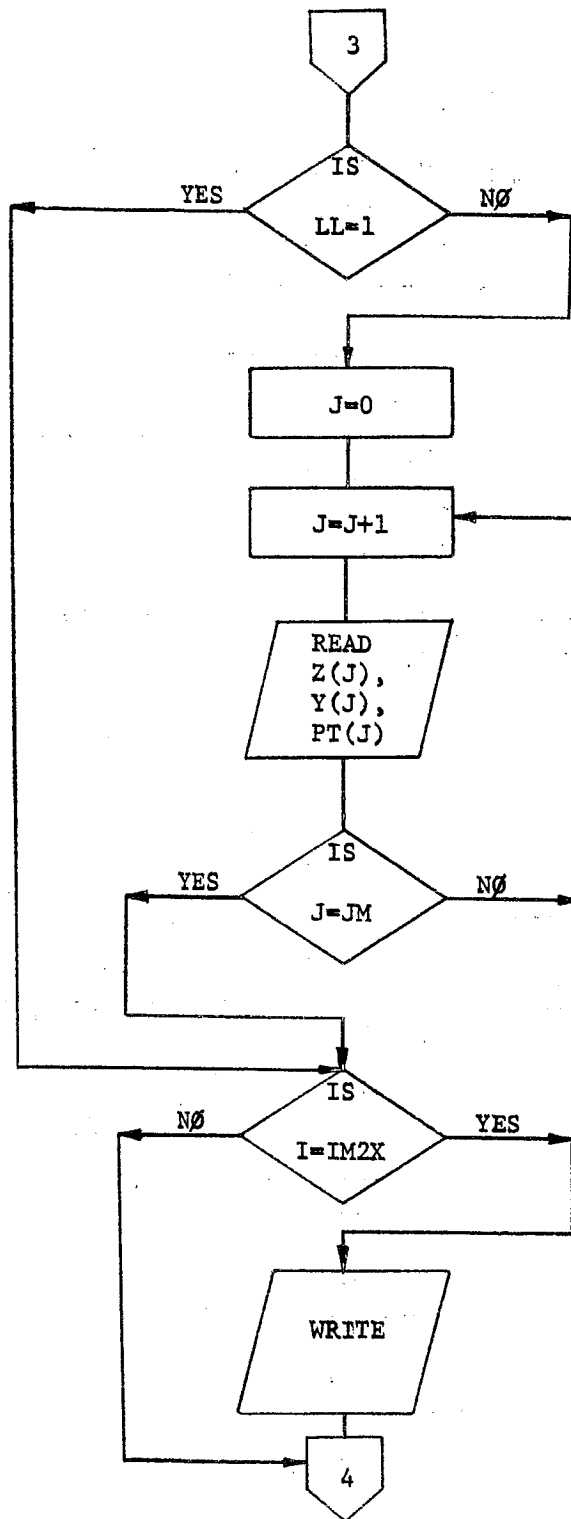


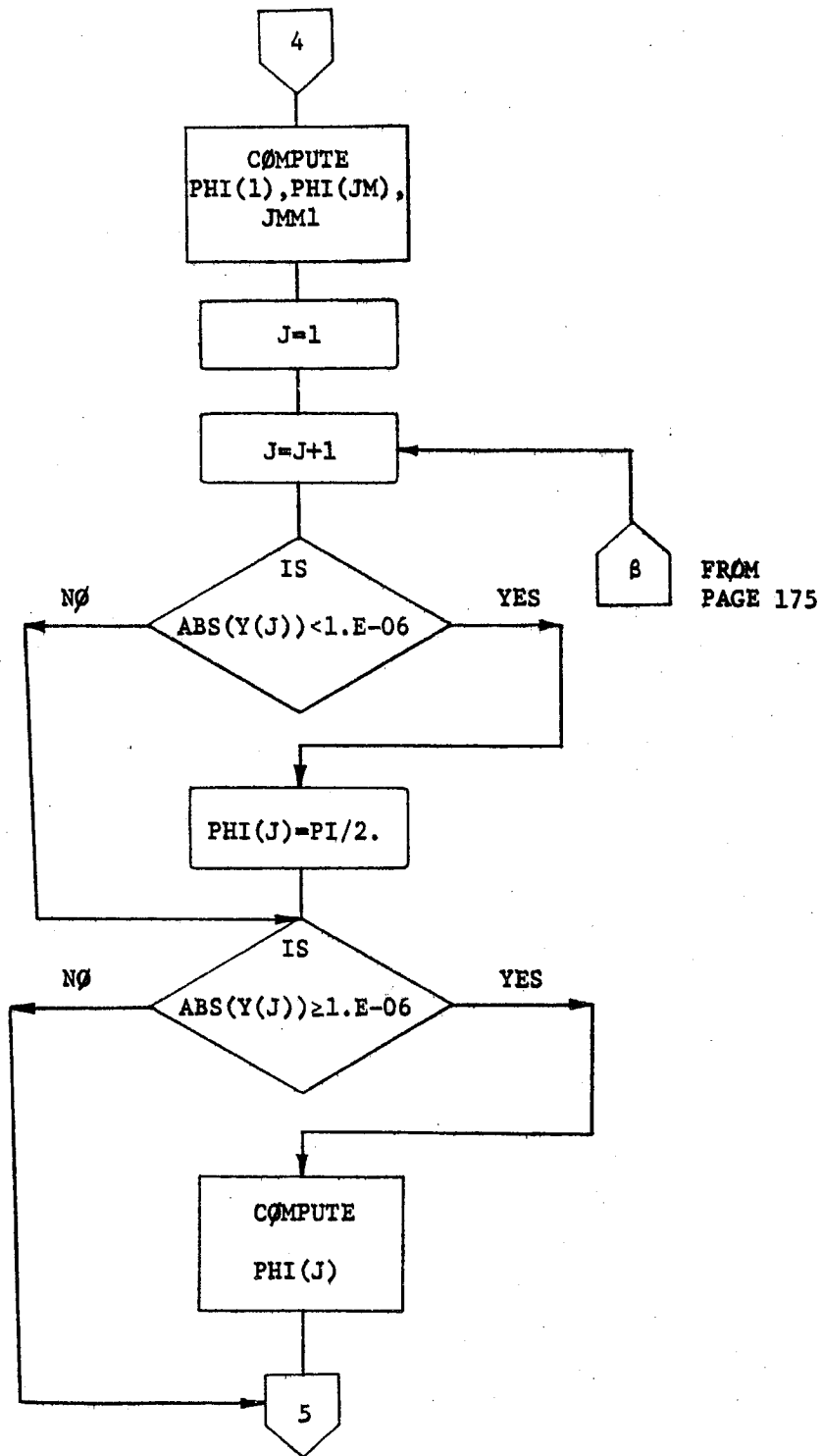
SUBROUTINE PRESS (KP, PNEWT)

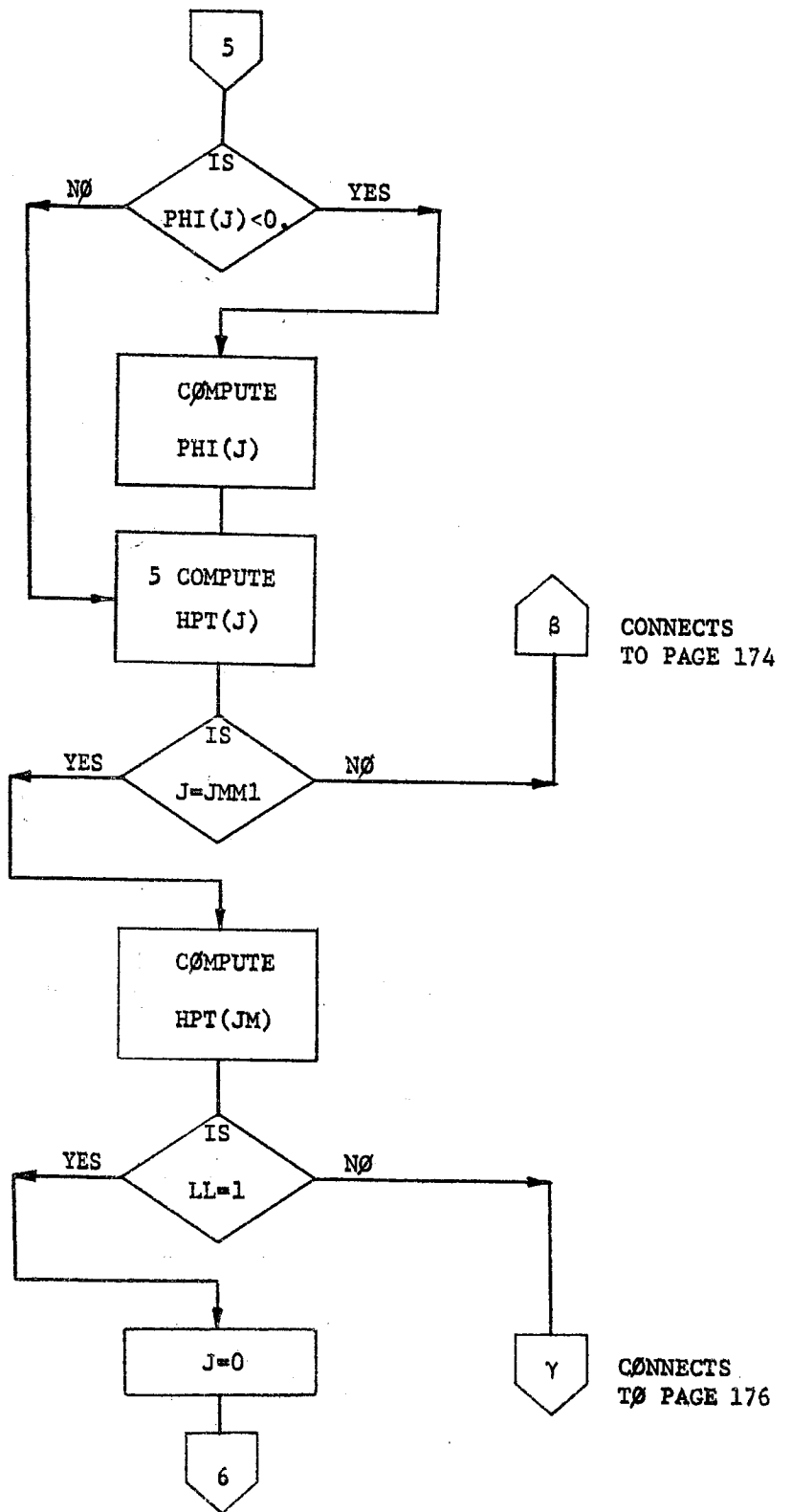


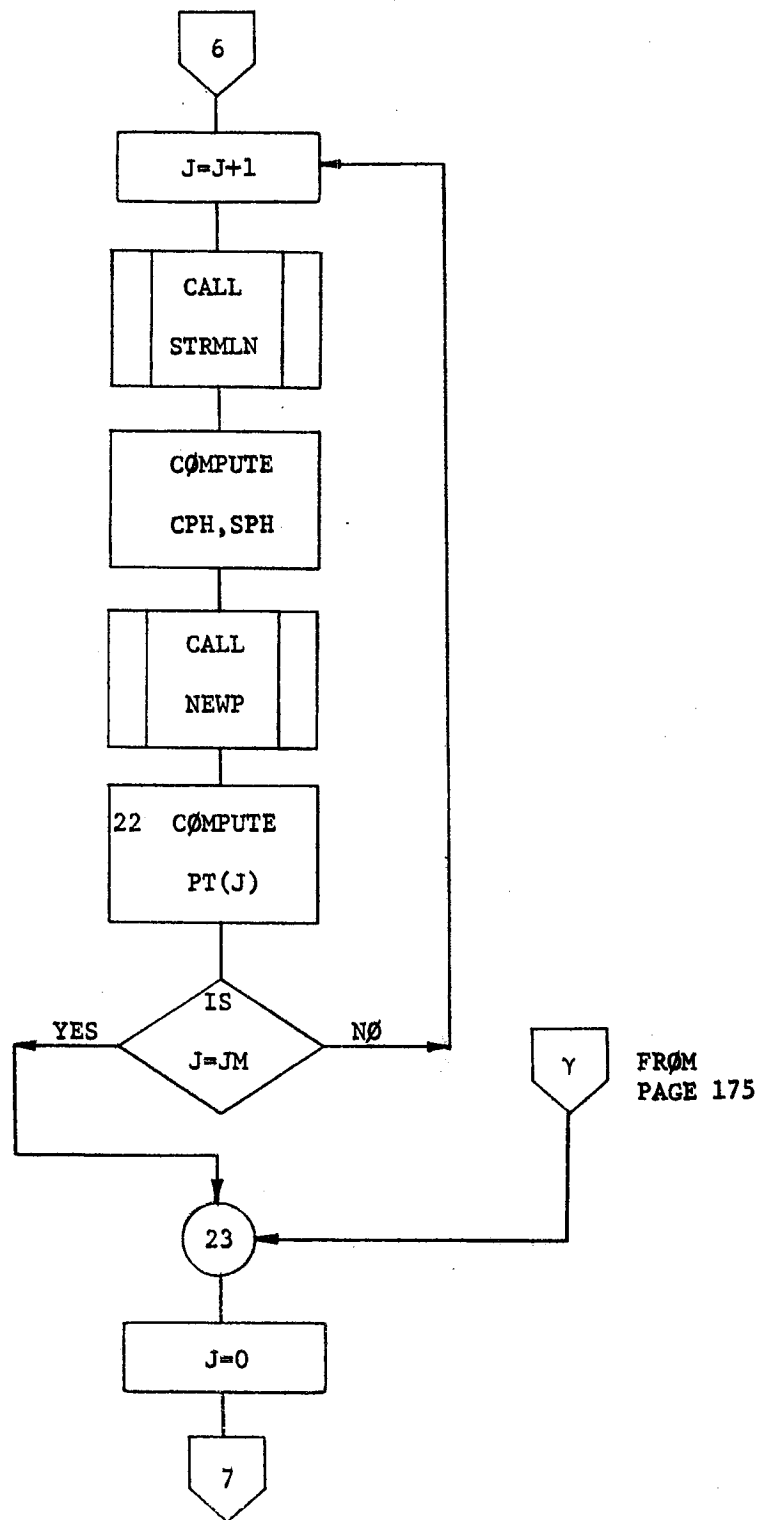


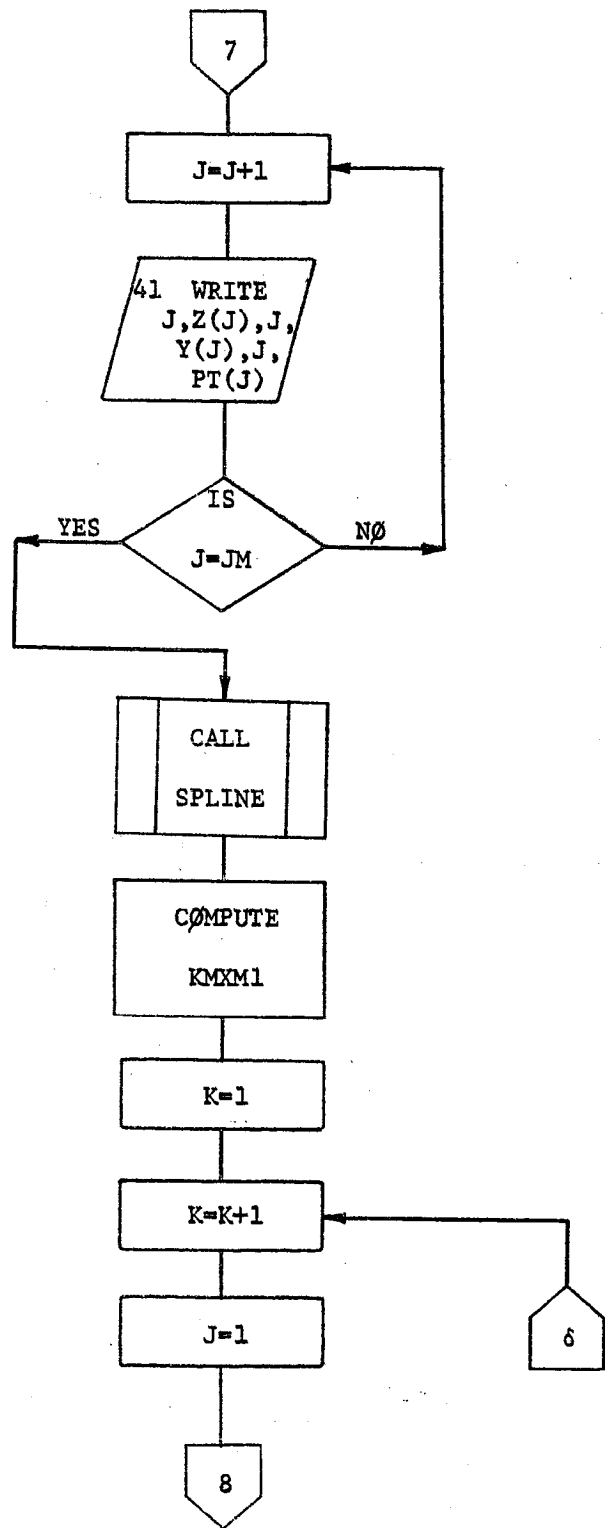




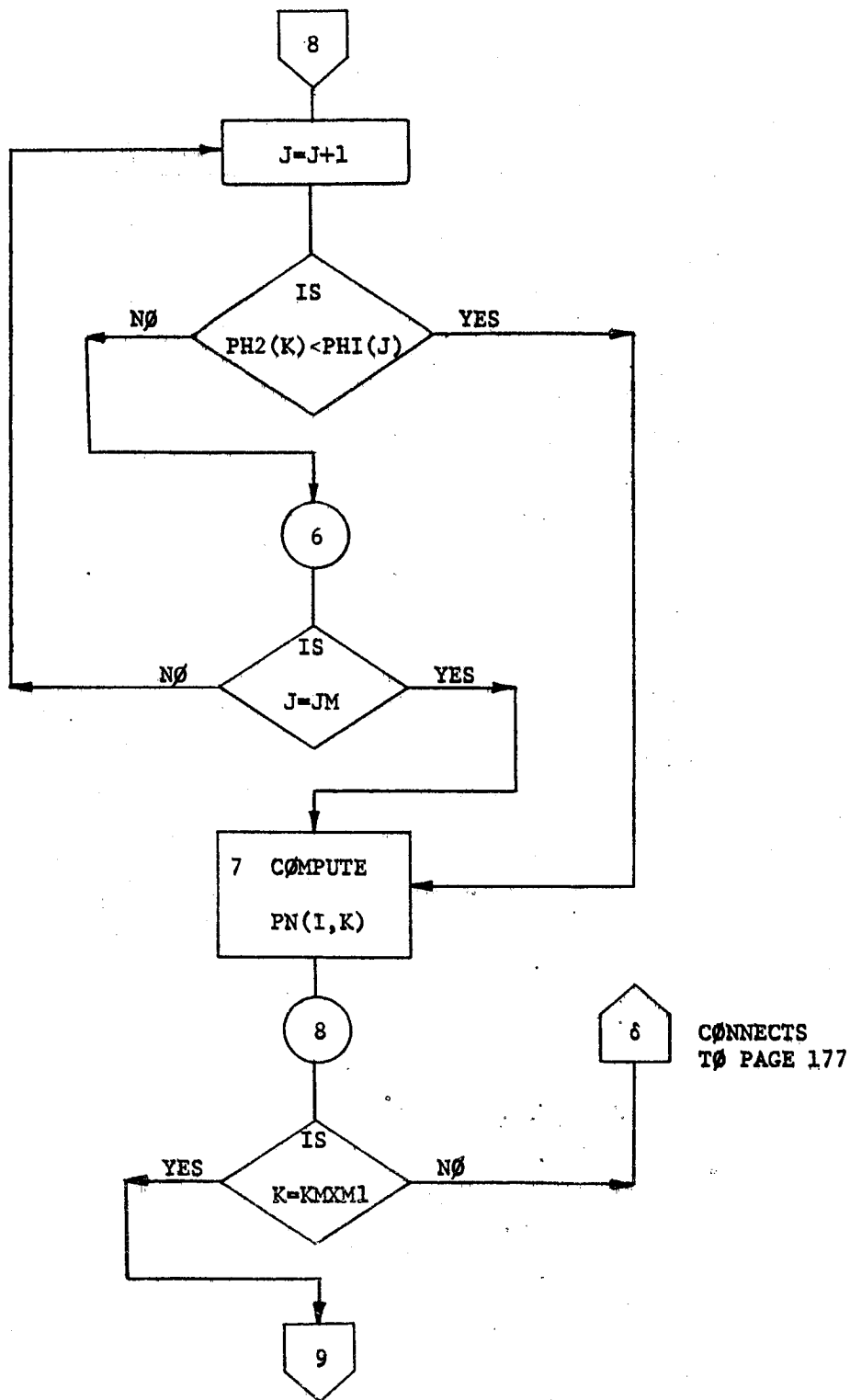


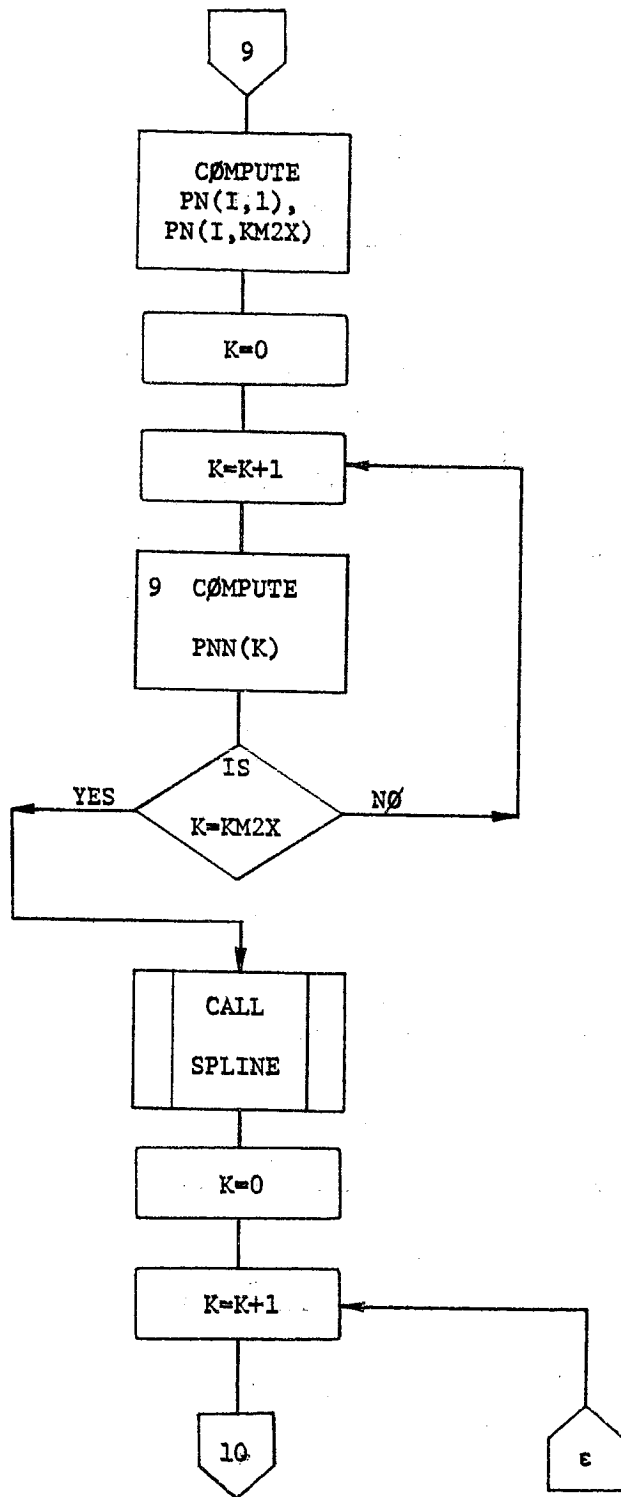




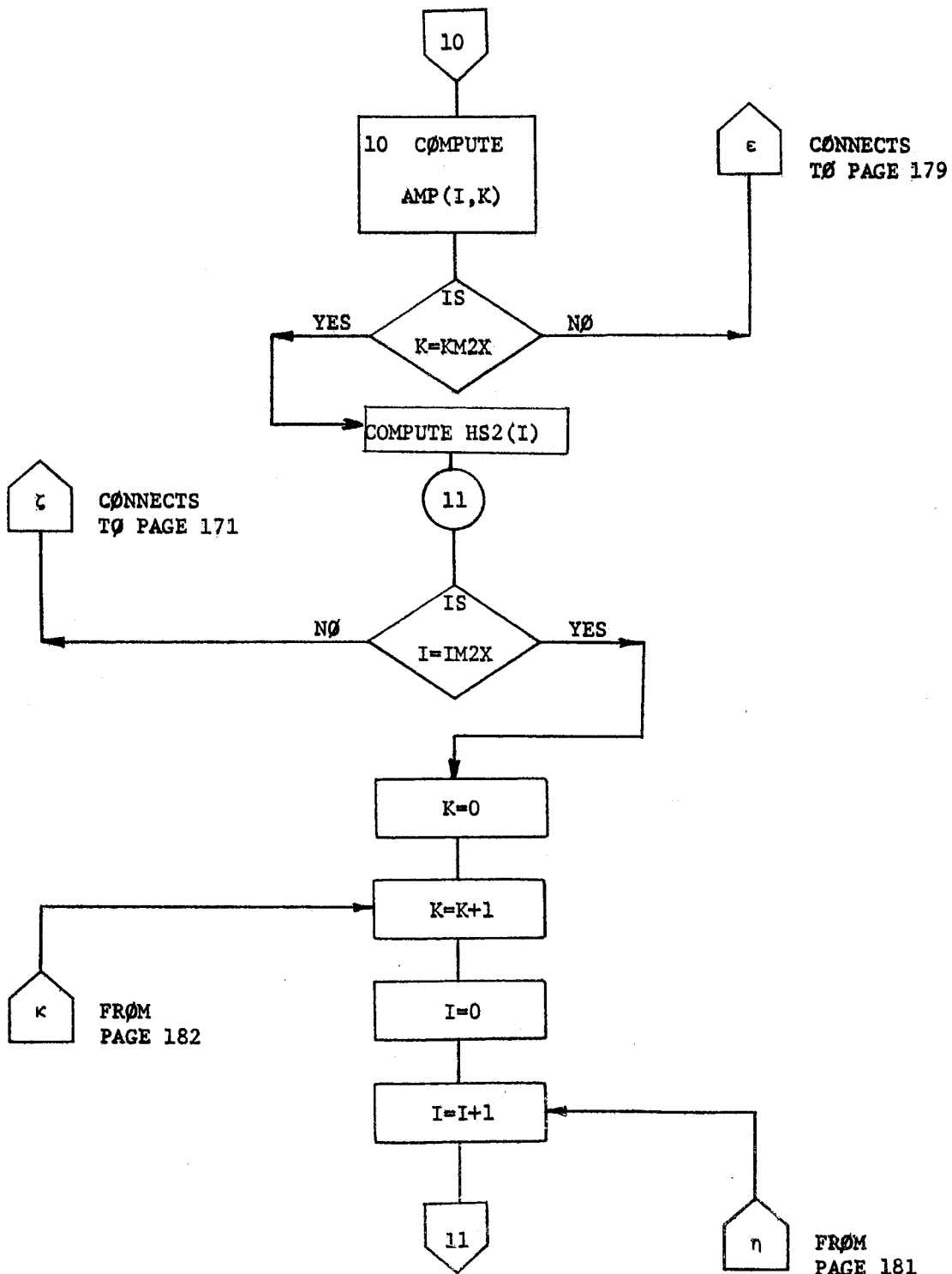


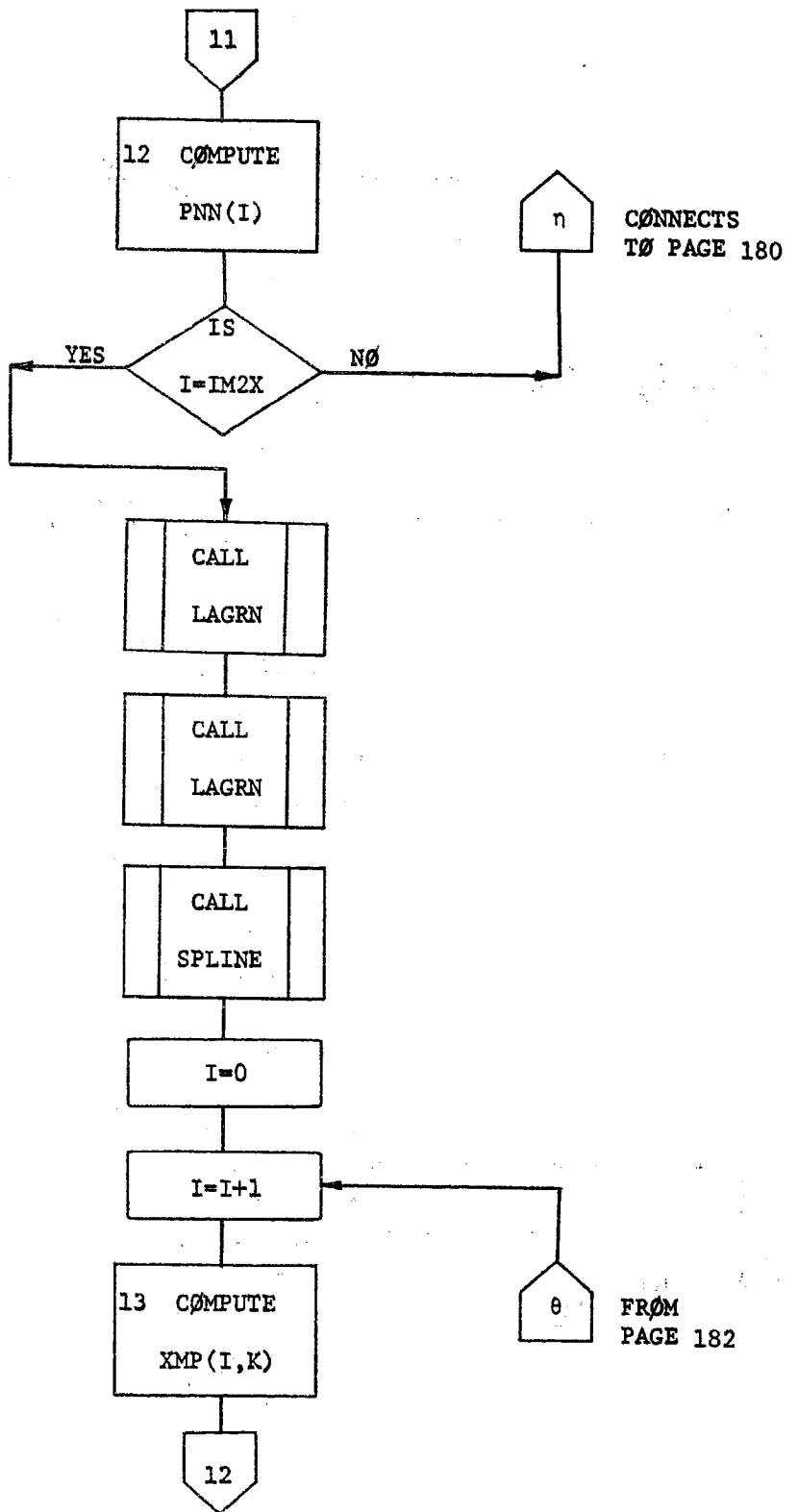
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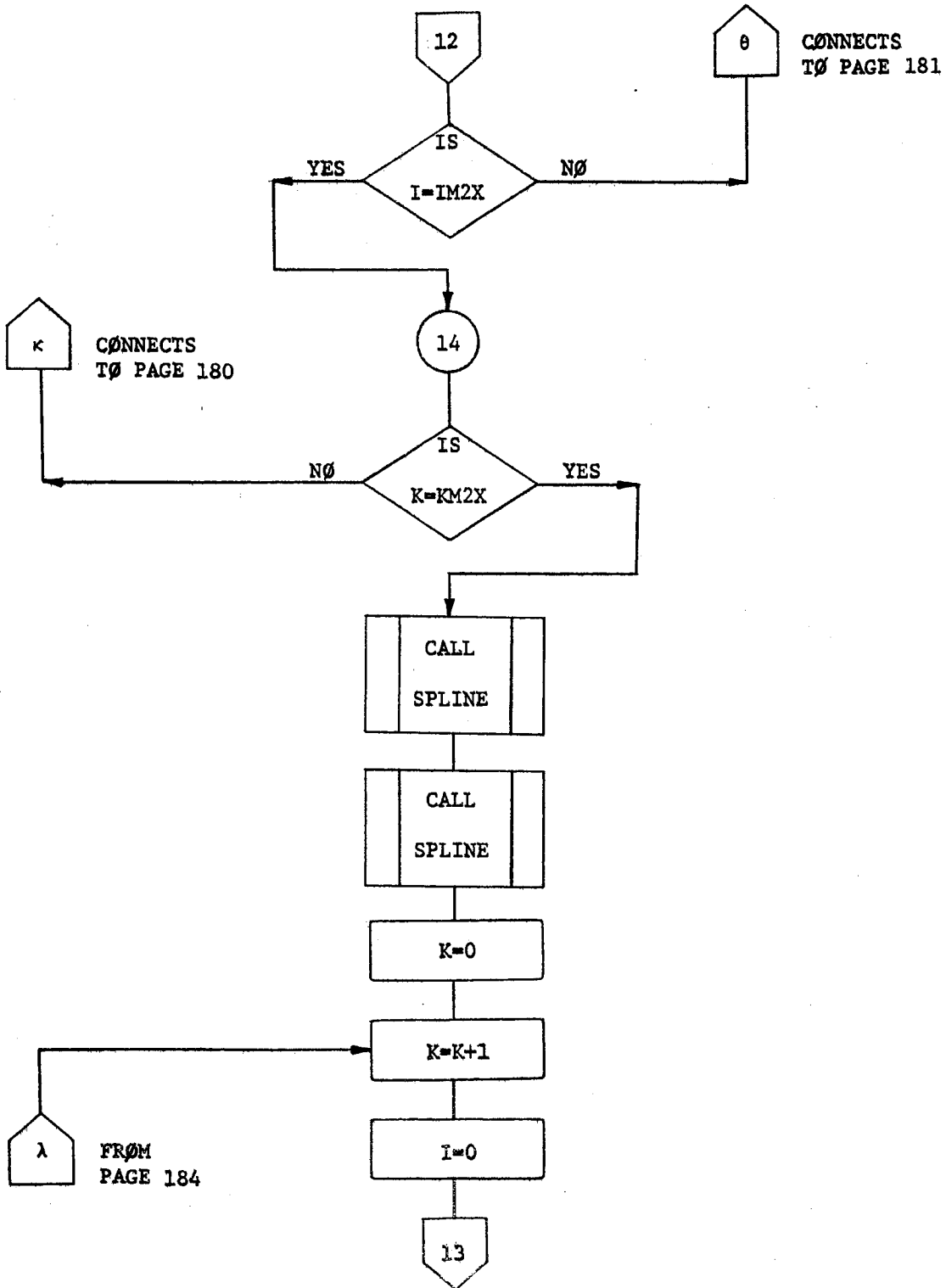


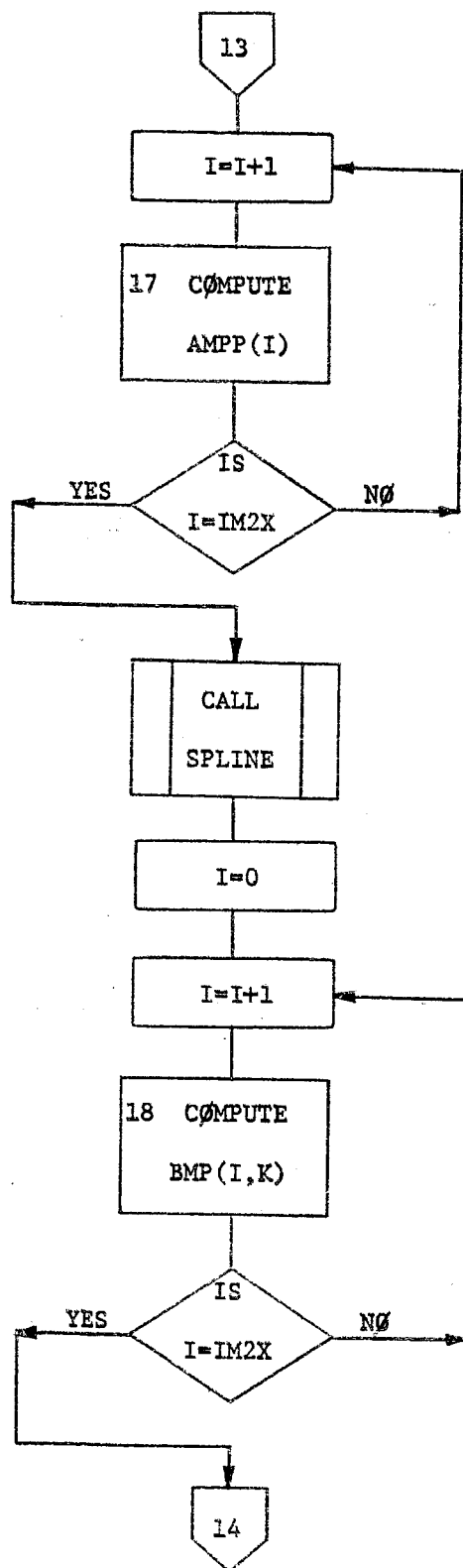


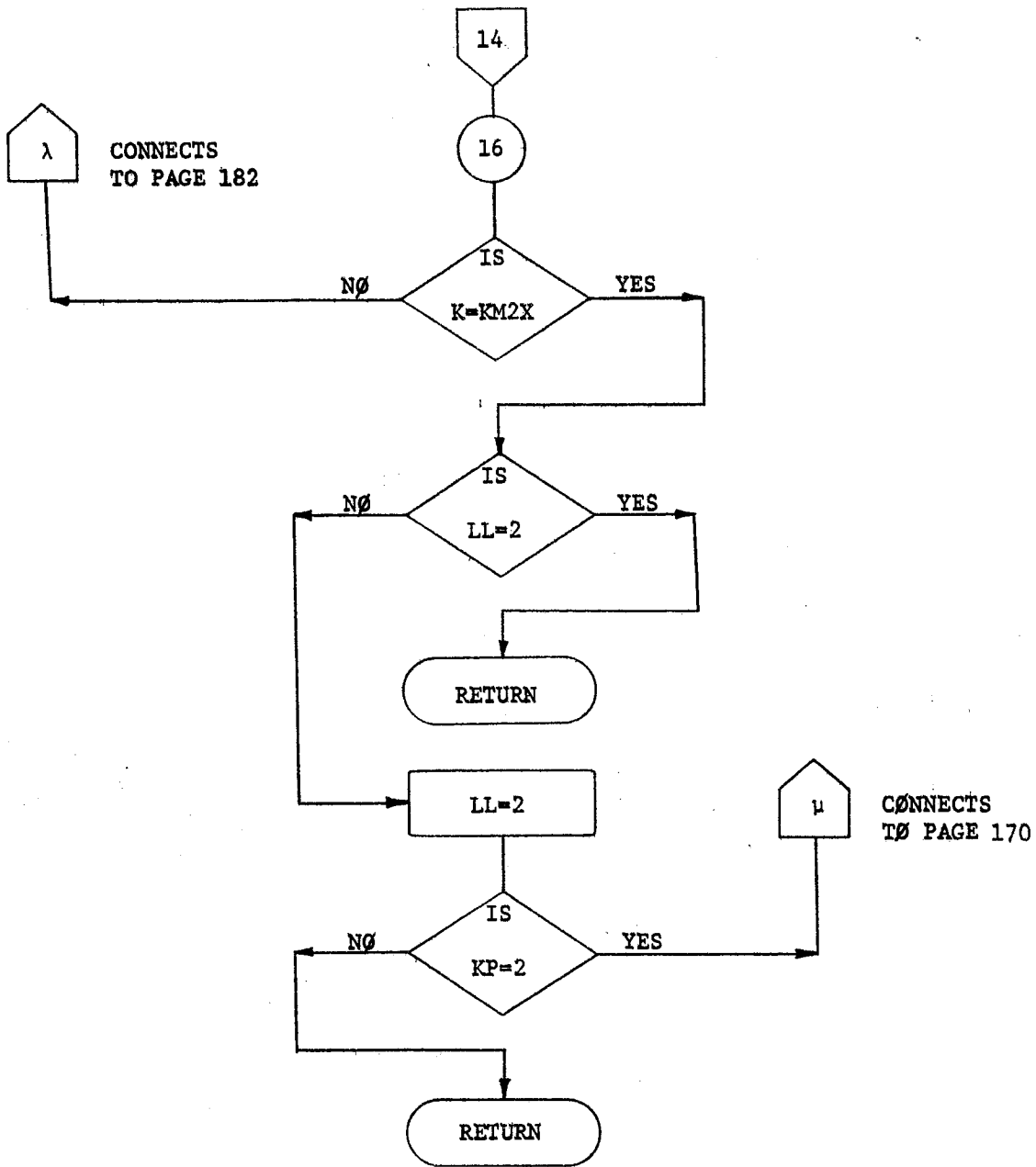
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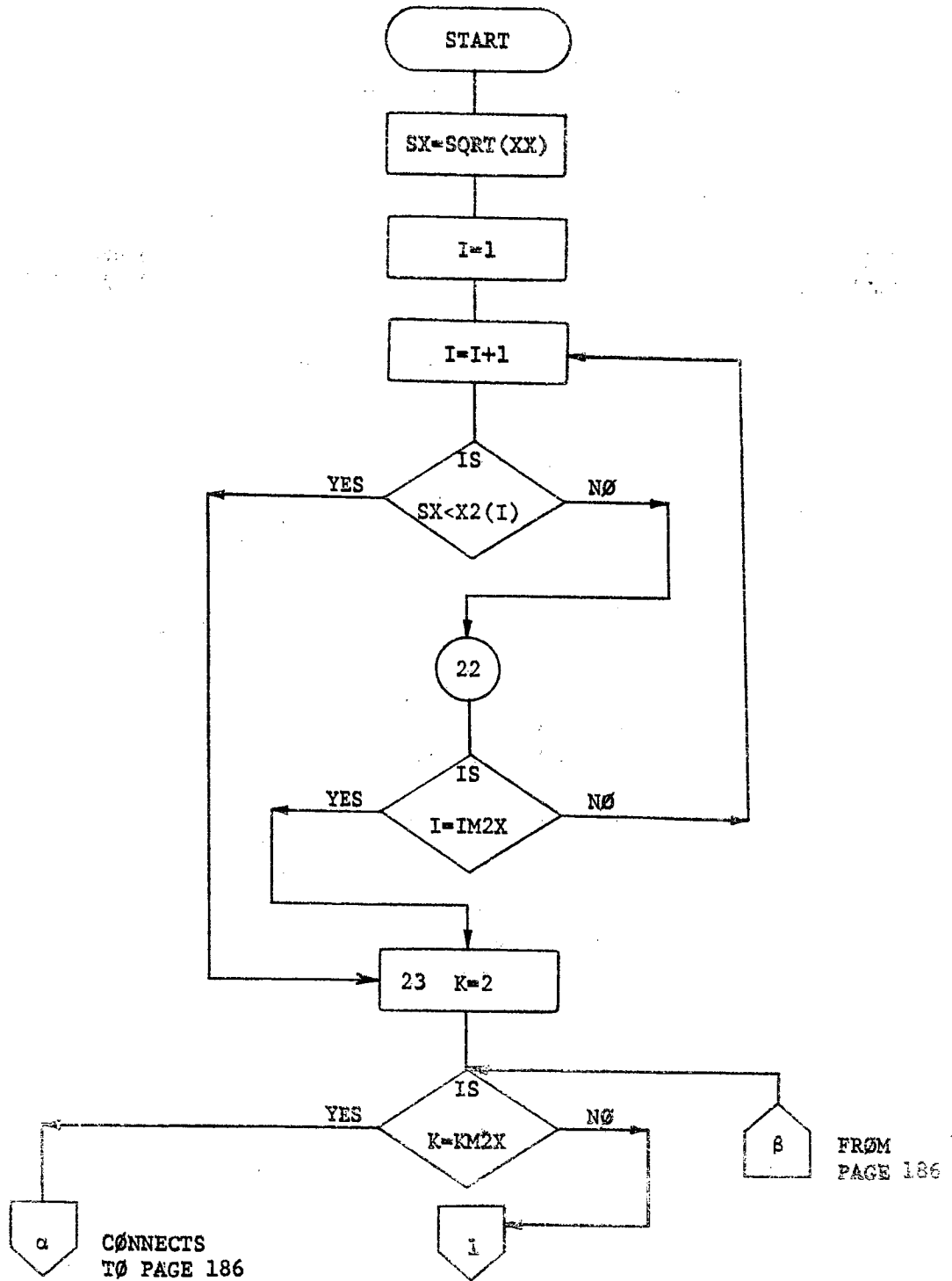


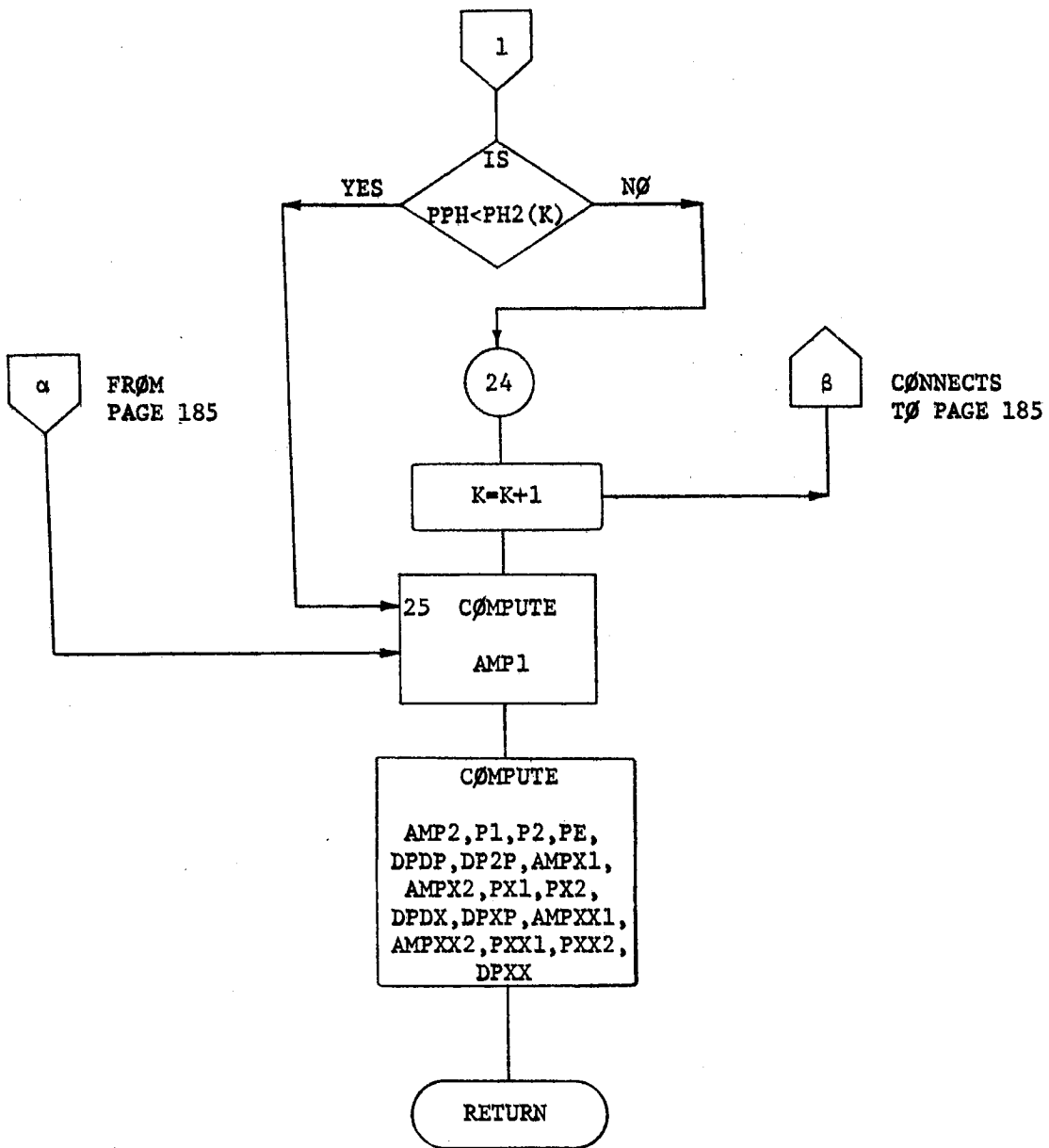




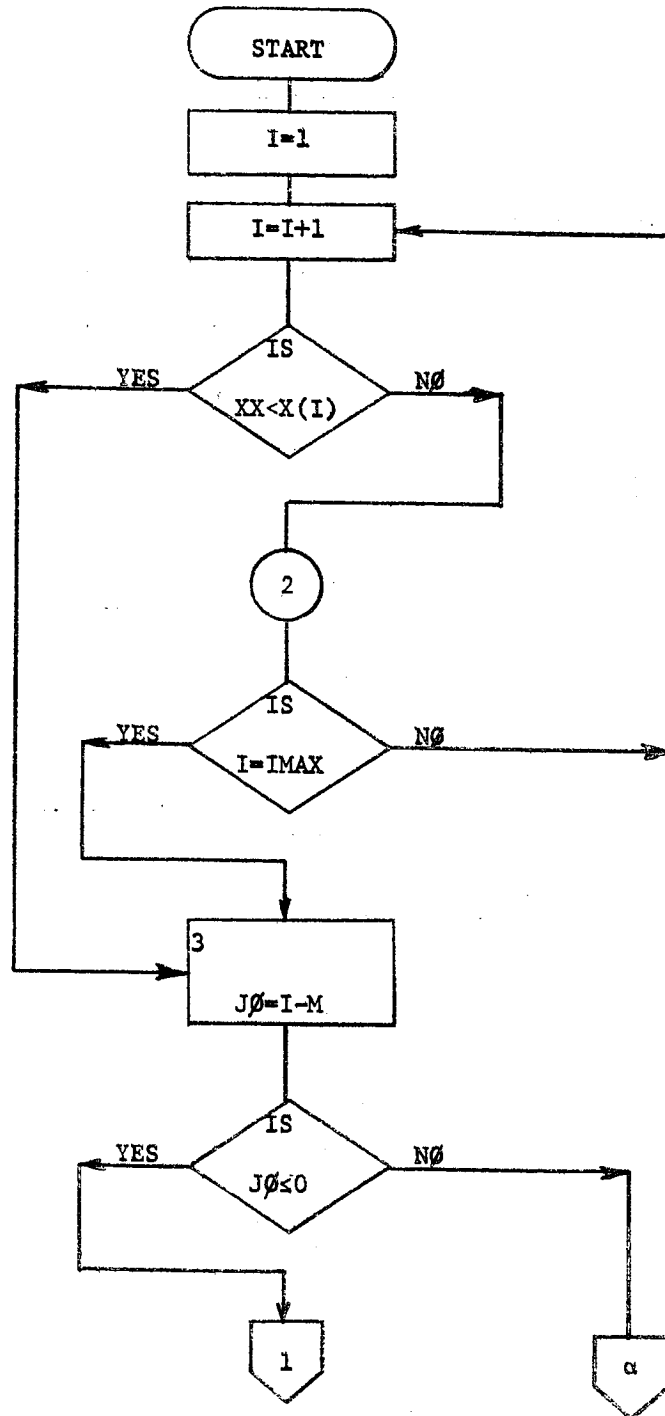


SUBROUTINE PDER(XX, PPH, PE, DPDP, DP2P, DFDX, DPXP, DPXX)

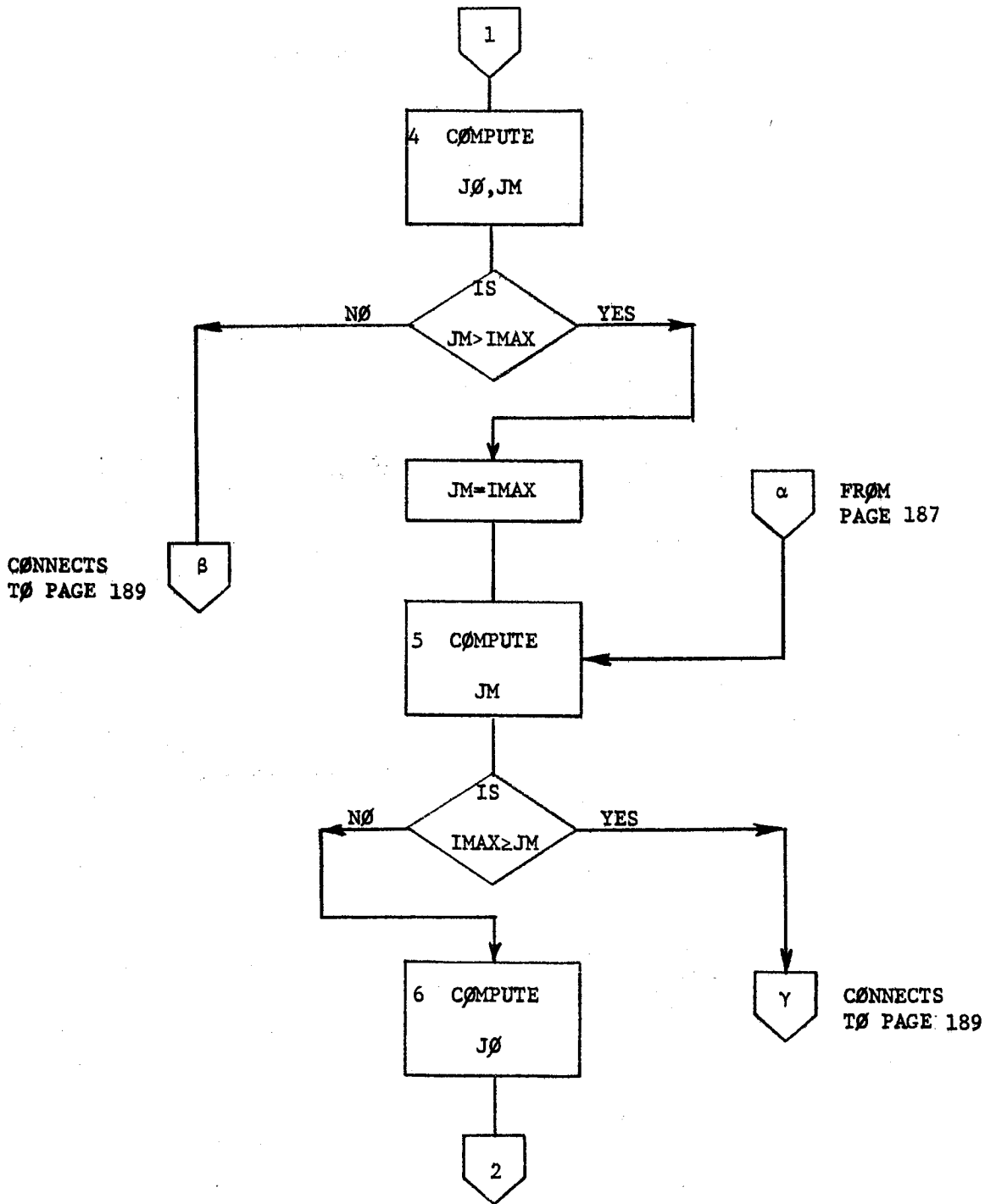


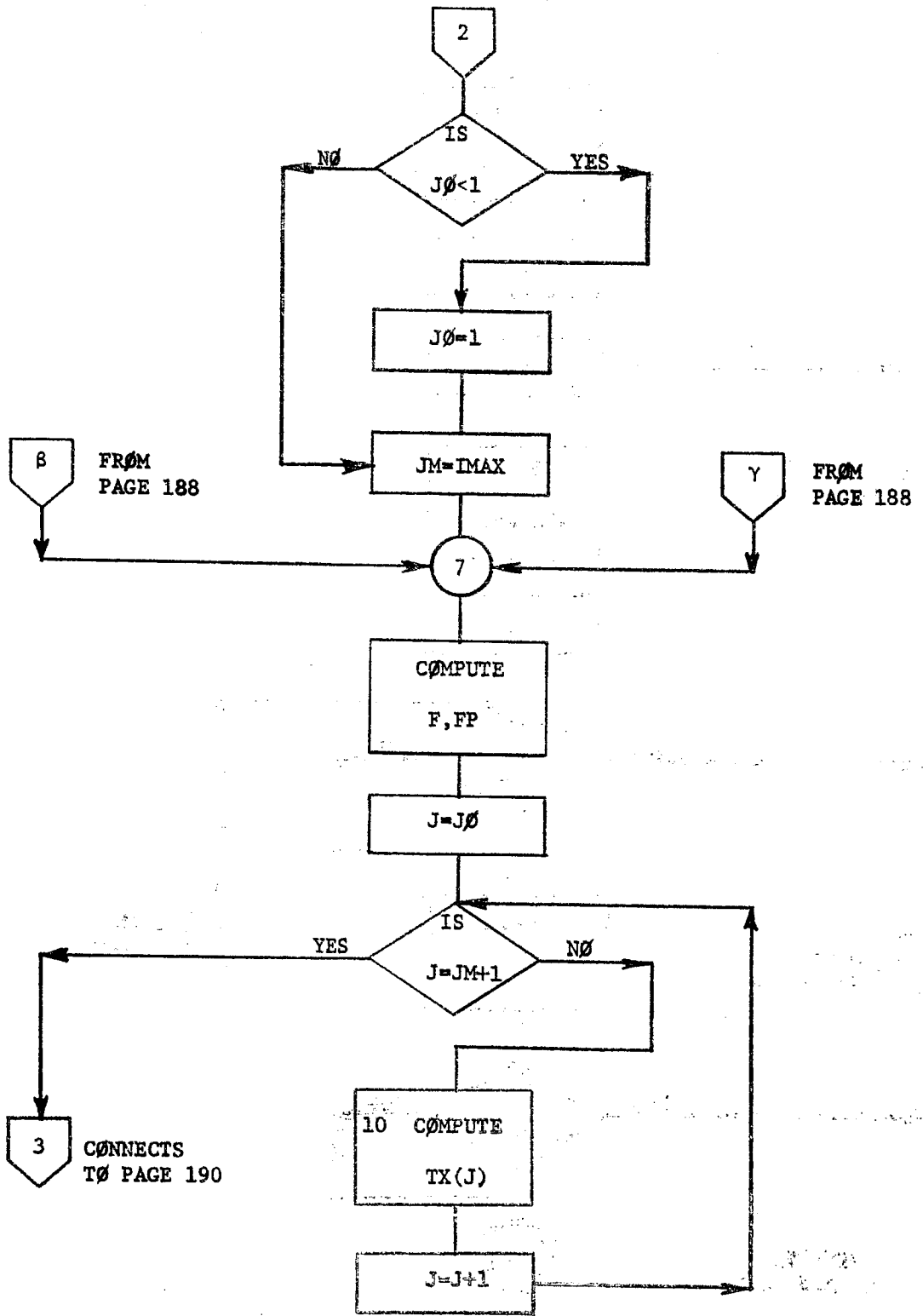


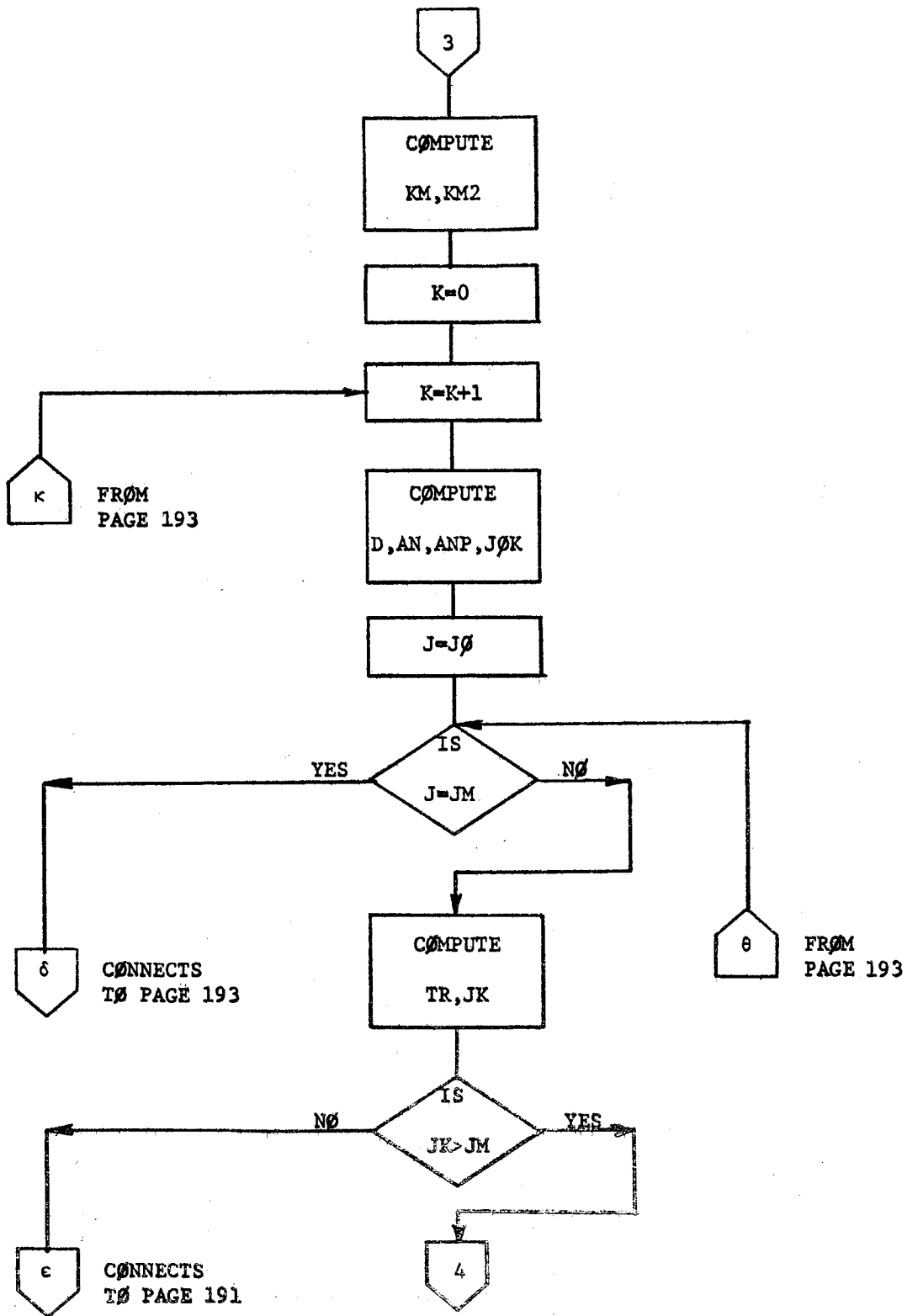
SUBROUTINE LAGRN (XX,X, FN, IMAX,M,N,F,FP)

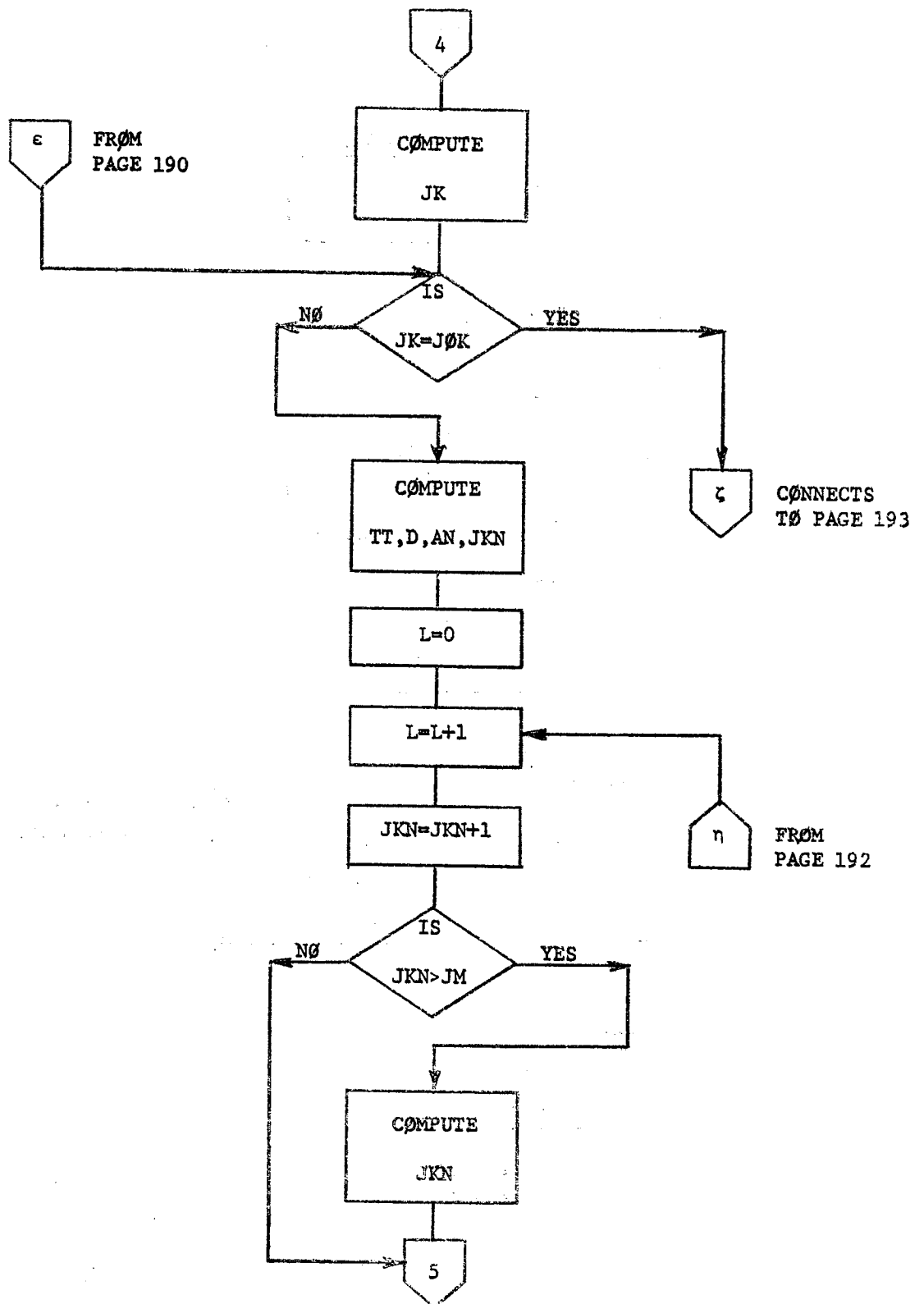


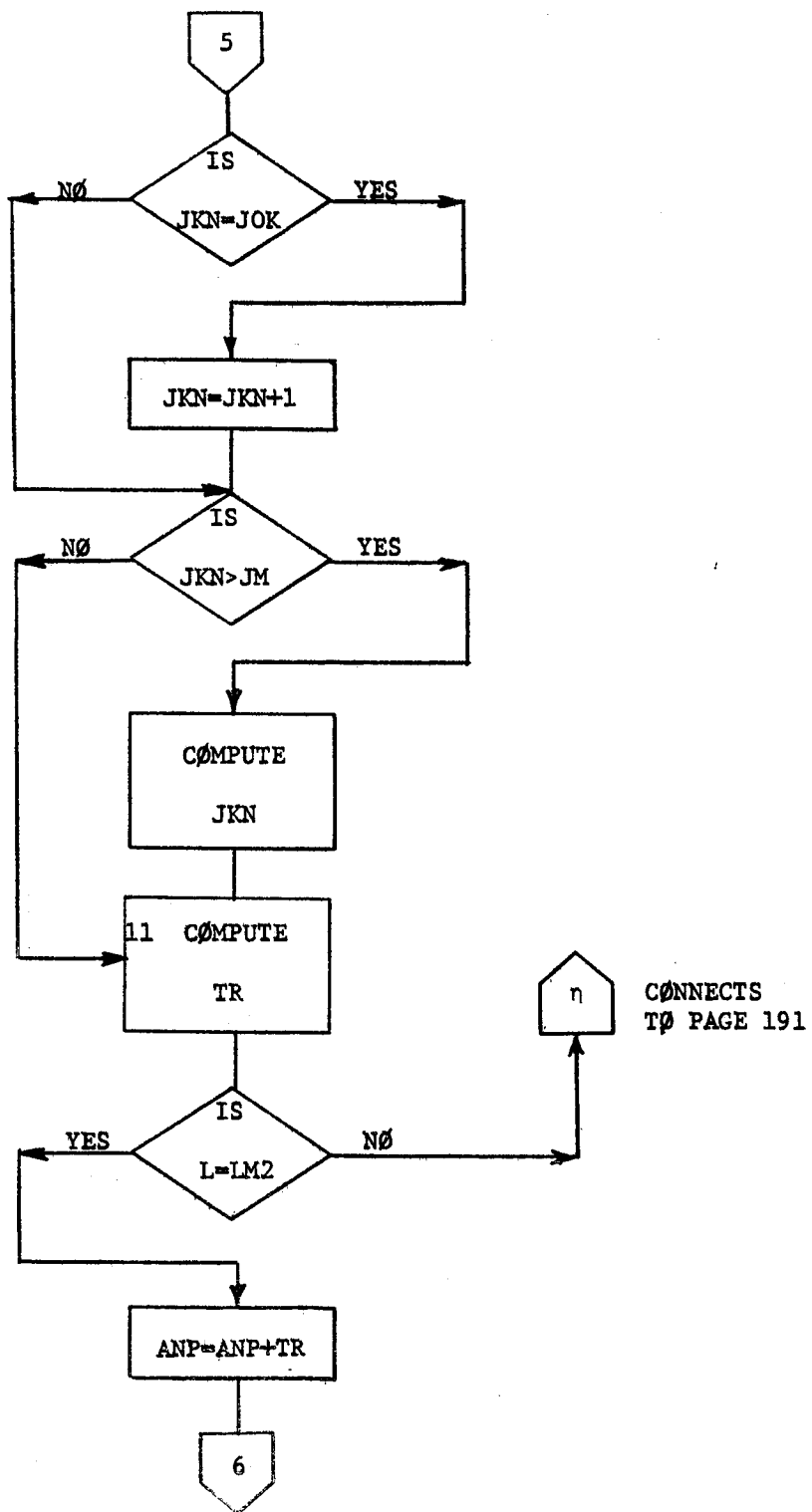
CONNECTS
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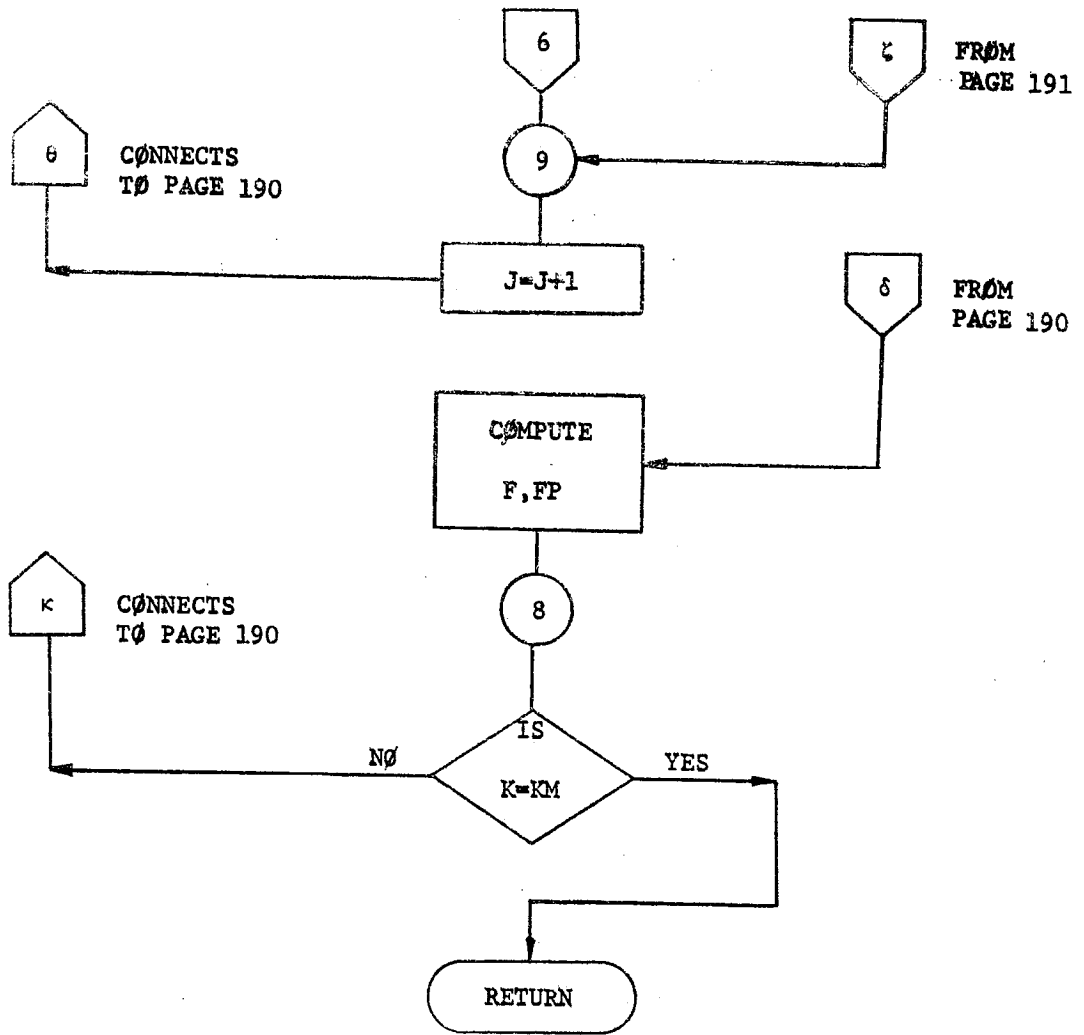




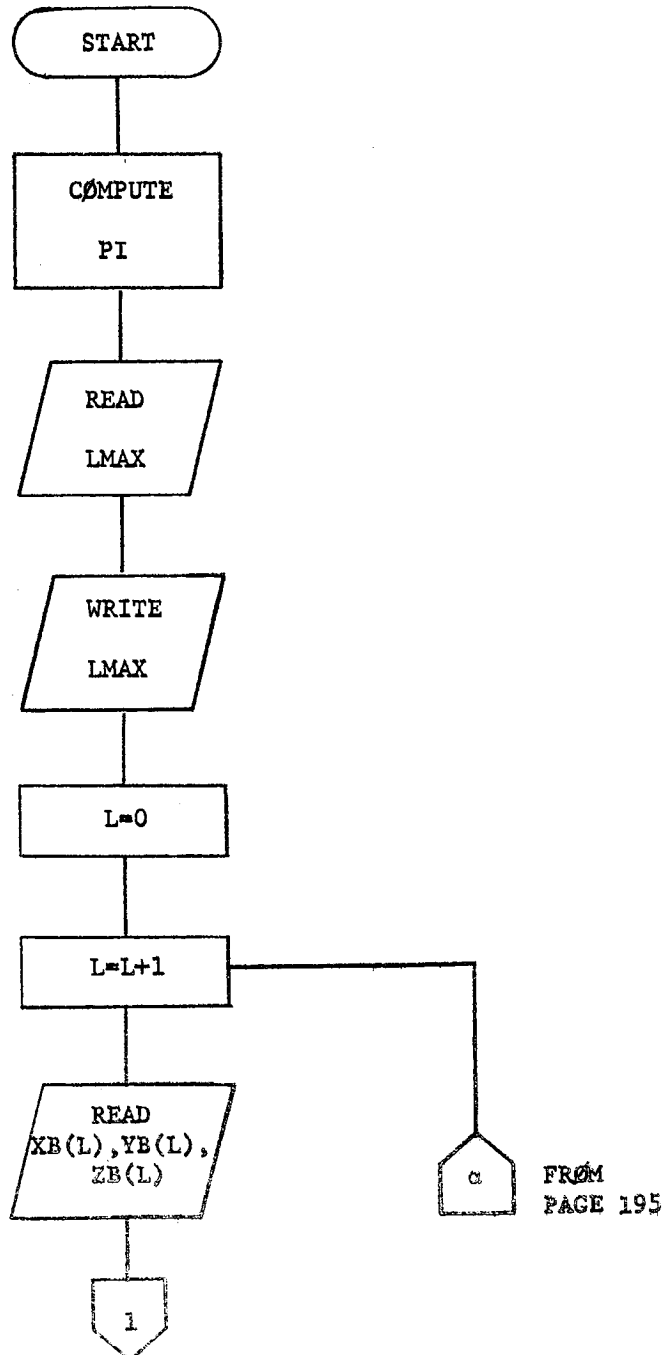


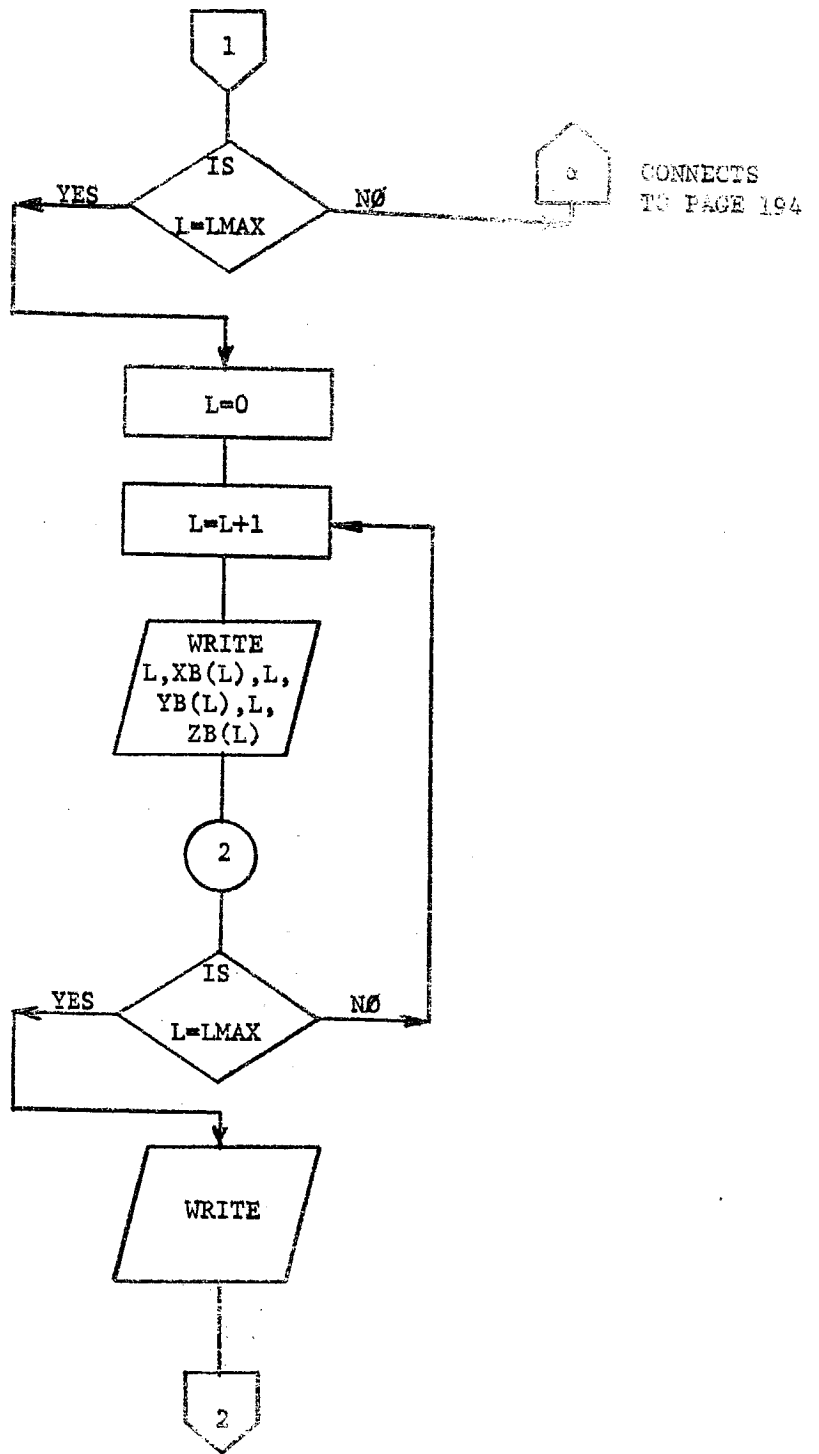


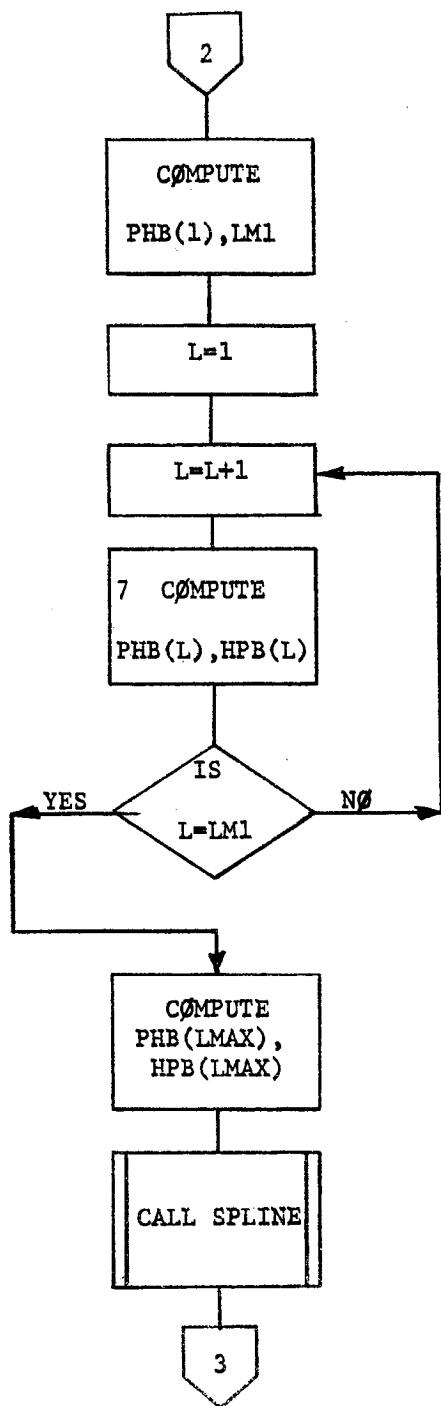


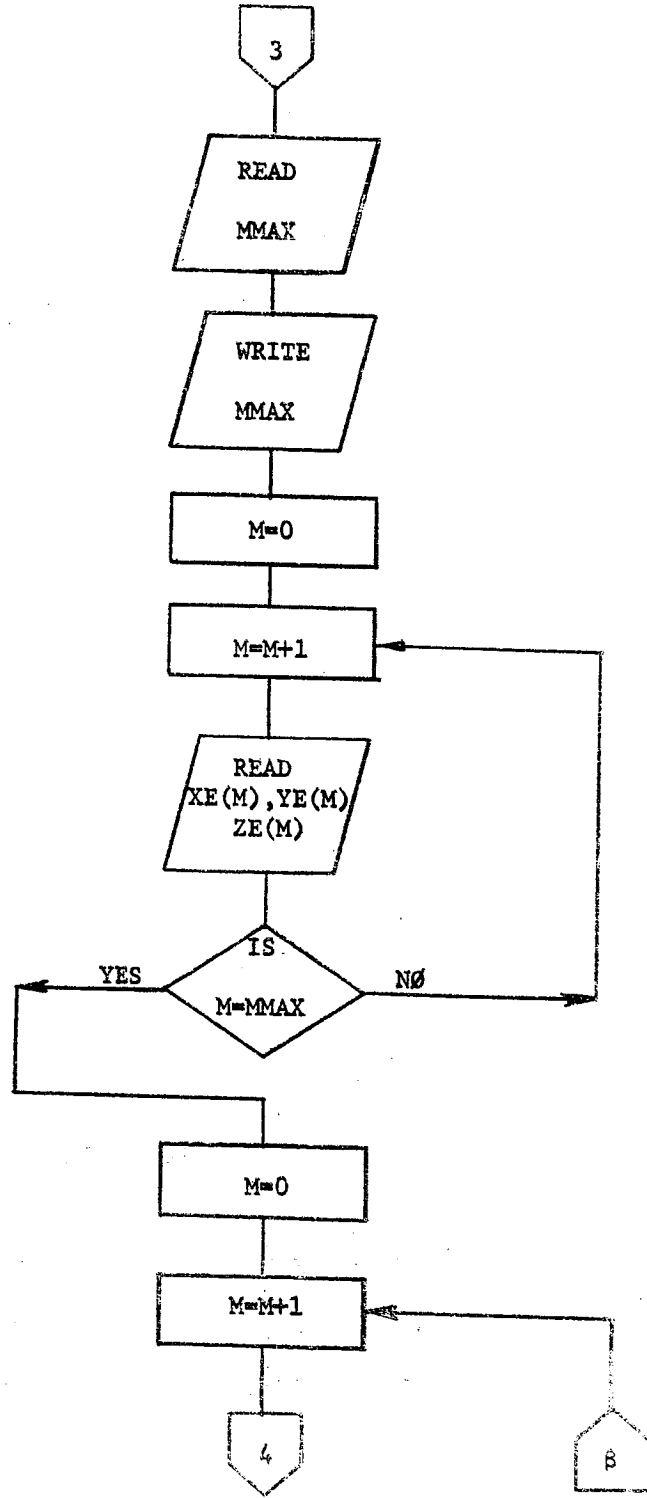


SUBROUTINE TRANS

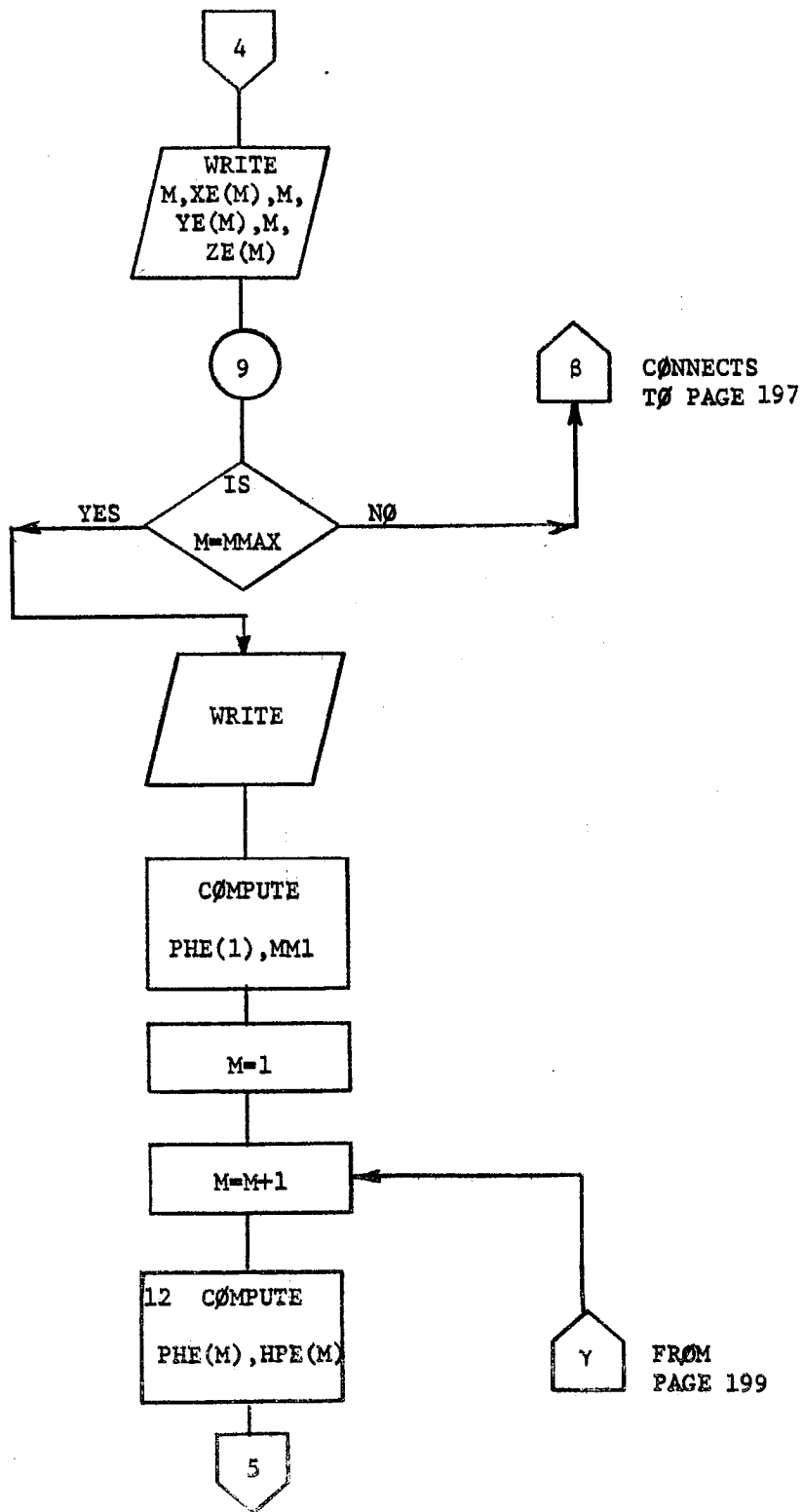


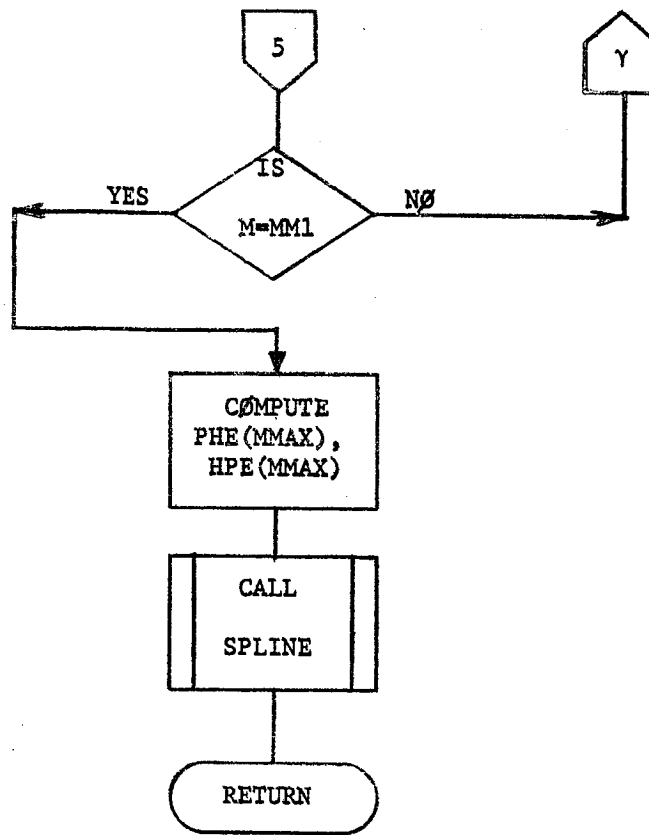






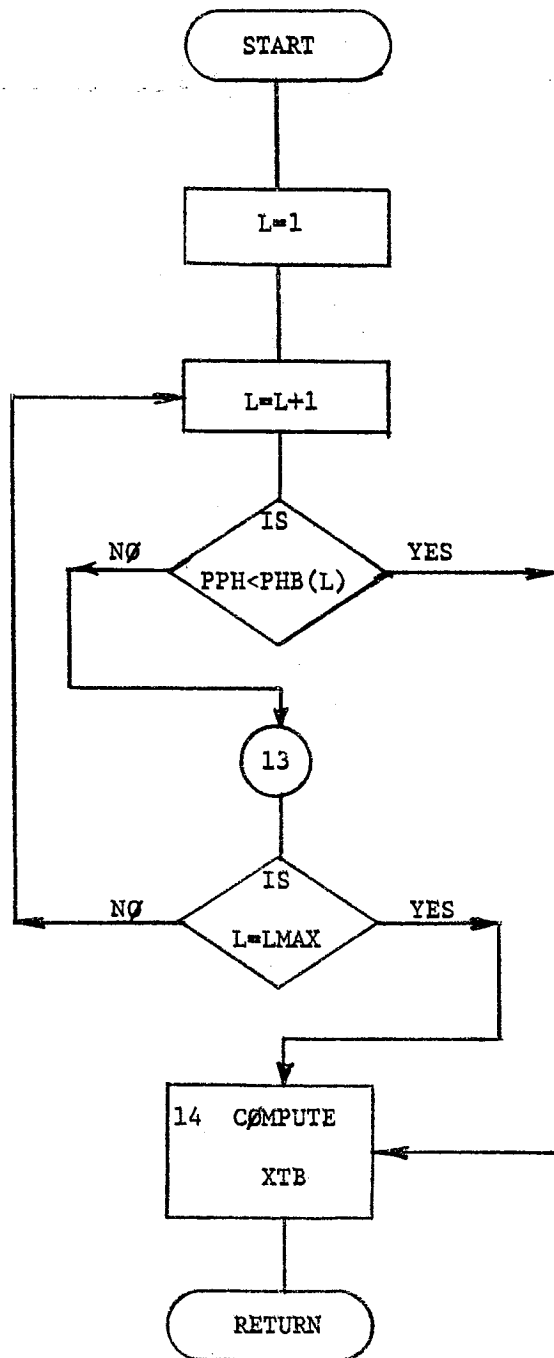
FROM
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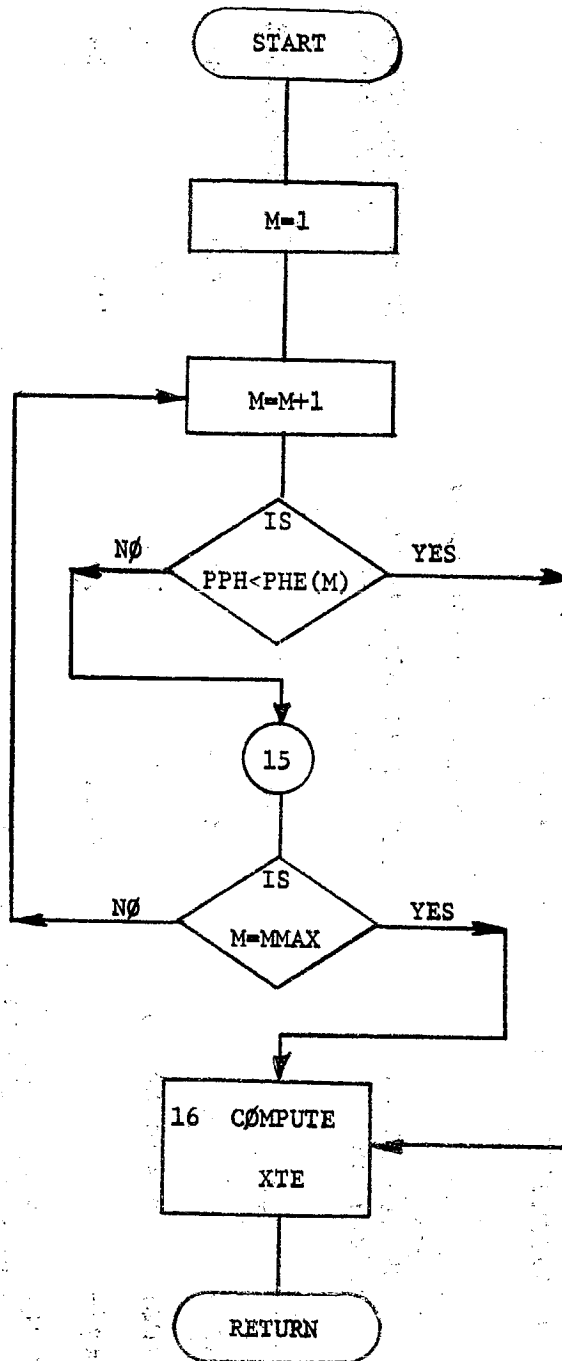


CONNECTS
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SUBROUTINE BEGTR(PPH,XTB)



SUBROUTINE ENDTR(PPH,XTE)



APPENDIX C OUTPUT FOR CASE I

BLUNTED 15-DEG. CONE

FREE STREAM PROPERTIES

PRESSURE(LB/SQ FT) 0.266140E 01
 TEMP(DEG R) 0.899710E 02
 DENSITY(SLUGS/CU FT) 0.172331E-04
 VELOCITY(FT/SEC) 0.492810E 04
 MACH NO. 0.105985E 02

STAGNATION PROPERTIES

PRESSURE(LB/SQ FT) 0.386136E 03
 DENSITY(SLUGS/CU FT) 0.106553E-03
 ENTHALPY(LB FT/SQ SEC) 0.126836E 08

TRI = 0.0
 KG = 0
 HMAX = 0.400000E 00
 KS = 0
 TRE = 0.0
 KTR = 0
 NMAX = 100
 IMAX = 19
 CST = 0.833333E-01
 KP = 1
 KPO = 1
 KMAX = 20

MOD.NEWT.PRESS.AT INPUT COORD.

FOR JM = 20 AND XI(2)= 0.06855
 THE Z, Y AND P COORDINATES ARE:

Z(1)= 0.0	Y(1)= 0.21613	P/PS(1)= 0.93178
Z(2)= 0.03557	Y(2)= 0.21318	P/PS(2)= 0.92665
Z(3)= 0.07018	Y(3)= 0.20442	P/PS(3)= 0.91145
Z(4)= 0.10287	Y(4)= 0.19008	P/PS(4)= 0.88682
Z(5)= 0.13275	Y(5)= 0.17056	P/PS(5)= 0.85380
Z(6)= 0.15901	Y(6)= 0.14638	P/PS(6)= 0.81390

Z(7)=	0.18094	Y(7)=	0.11821	P/PS(7)=	0.76857
Z(8)=	0.19793	Y(8)=	0.08682	P/PS(8)=	0.71955
Z(9)=	0.20952	Y(9)=	0.05306	P/PS(9)=	0.66862
Z(10)=	0.21539	Y(10)=	0.01785	P/PS(10)=	0.61757
Z(11)=	0.21539	Y(11)=	-0.01785	P/PS(11)=	0.56799
Z(12)=	0.20952	Y(12)=	-0.05306	P/PS(12)=	0.52106
Z(13)=	0.19793	Y(13)=	-0.08682	P/PS(13)=	0.47797
Z(14)=	0.18094	Y(14)=	-0.11821	P/PS(14)=	0.43963
Z(15)=	0.15901	Y(15)=	-0.14638	P/PS(15)=	0.40667
Z(16)=	0.13275	Y(16)=	-0.17056	P/PS(16)=	0.37929
Z(17)=	0.10287	Y(17)=	-0.19008	P/PS(17)=	0.35798
Z(18)=	0.07018	Y(18)=	-0.20442	P/PS(18)=	0.34271
Z(19)=	0.03557	Y(19)=	-0.21318	P/PS(19)=	0.33354
Z(20)=	0.0	Y(20)=	-0.21613	P/PS(20)=	0.33046

MOD.NEWT.PRESS.AT INPUT COORD.

FOR JM = 20 AND X(3)= 0.13710
THE Z,Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	0.28987	P/PS(1)=	0.74217
Z(2)=	0.04771	Y(2)=	0.28592	P/PS(2)=	0.73604
Z(3)=	0.09412	Y(3)=	0.27417	P/PS(3)=	0.71786
Z(4)=	0.13796	Y(4)=	0.25494	P/PS(4)=	0.68867
Z(5)=	0.17804	Y(5)=	0.22875	P/PS(5)=	0.65001
Z(6)=	0.21327	Y(6)=	0.19633	P/PS(6)=	0.60356
Z(7)=	0.24267	Y(7)=	0.15855	P/PS(7)=	0.55163
Z(8)=	0.26546	Y(8)=	0.11644	P/PS(8)=	0.49664
Z(9)=	0.28100	Y(9)=	0.07116	P/PS(9)=	0.44069
Z(10)=	0.28888	Y(10)=	0.02394	P/PS(10)=	0.38611
Z(11)=	0.28888	Y(11)=	-0.02394	P/PS(11)=	0.33439
Z(12)=	0.28100	Y(12)=	-0.07116	P/PS(12)=	0.28704
Z(13)=	0.26546	Y(13)=	-0.11644	P/PS(13)=	0.24517
Z(14)=	0.24267	Y(14)=	-0.15855	P/PS(14)=	0.20924
Z(15)=	0.21327	Y(15)=	-0.19633	P/PS(15)=	0.17952
Z(16)=	0.17804	Y(16)=	-0.22875	P/PS(16)=	0.15593
Z(17)=	0.13796	Y(17)=	-0.25494	P/PS(17)=	0.13810
Z(18)=	0.09412	Y(18)=	-0.27417	P/PS(18)=	0.12572

Z(19)= 0.04771 Y(19)= -0.28592 P/PS(19)= 0.11851
Z(20)= 0.0 Y(20)= -0.28987 P/PS(20)= 0.11611

MOD. NEWT. PRESS. AT INPUT COORD.

FOR JM = 20 AND X(4) = 0.20564
THE Z, Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	0.33458	P/PS(1)=	0.53630
Z(2)=	0.05507	Y(2)=	0.33002	P/PS(2)=	0.53028
Z(3)=	0.10864	Y(3)=	0.31645	P/PS(3)=	0.51260
Z(4)=	0.15924	Y(4)=	0.29425	P/PS(4)=	0.48416
Z(5)=	0.20550	Y(5)=	0.26403	P/PS(5)=	0.44691
Z(6)=	0.24616	Y(6)=	0.22660	P/PS(6)=	0.40308
Z(7)=	0.28010	Y(7)=	0.18300	P/PS(7)=	0.35501
Z(8)=	0.30640	Y(8)=	0.13440	P/PS(8)=	0.30460
Z(9)=	0.32434	Y(9)=	0.08213	P/PS(9)=	0.25510
Z(10)=	0.33344	Y(10)=	0.02763	P/PS(10)=	0.20810
Z(11)=	0.33344	Y(11)=	-0.02763	P/PS(11)=	0.16553
Z(12)=	0.32434	Y(12)=	-0.08213	P/PS(12)=	0.12866
Z(13)=	0.30640	Y(13)=	-0.13440	P/PS(13)=	0.09776
Z(14)=	0.28010	Y(14)=	-0.18300	P/PS(14)=	0.07320
Z(15)=	0.24616	Y(15)=	-0.22660	P/PS(15)=	0.05427
Z(16)=	0.20550	Y(16)=	-0.26403	P/PS(16)=	0.04057
Z(17)=	0.15924	Y(17)=	-0.29425	P/PS(17)=	0.03127
Z(18)=	0.10864	Y(18)=	-0.31645	P/PS(18)=	0.02543
Z(19)=	0.05507	Y(19)=	-0.33002	P/PS(19)=	0.02222
Z(20)=	0.0	Y(20)=	-0.33458	P/PS(20)=	0.02121

MOD. NEWT. PRESS. AT INPUT COORD.

FOR JM = 20 AND X(5) = 0.27419
THE Z, Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	0.36120	P/PS(1)=	0.34043
Z(2)=	0.05945	Y(2)=	0.35627	P/PS(2)=	0.33498
Z(3)=	0.11728	Y(3)=	0.34163	P/PS(3)=	0.32000

Z(4)=	0.17191	Y(4)=	0.31766	P/PS(4)=	0.29659
Z(5)=	0.22185	Y(5)=	0.28503	P/PS(5)=	0.26581
Z(6)=	0.26574	Y(6)=	0.24463	P/PS(6)=	0.22921
Z(7)=	0.30238	Y(7)=	0.19756	P/PS(7)=	0.19003
Z(8)=	0.33077	Y(8)=	0.14509	P/PS(8)=	0.15201
Z(9)=	0.35014	Y(9)=	0.08867	P/PS(9)=	0.11558
Z(10)=	0.35996	Y(10)=	0.02983	P/PS(10)=	0.08347
Z(11)=	0.35996	Y(11)=	-0.02983	P/PS(11)=	0.05638
Z(12)=	0.35014	Y(12)=	-0.08867	P/PS(12)=	0.03522
Z(13)=	0.33077	Y(13)=	-0.14509	P/PS(13)=	0.02058
Z(14)=	0.30238	Y(14)=	-0.19756	P/PS(14)=	0.01158
Z(15)=	0.26574	Y(15)=	-0.24463	P/PS(15)=	0.00759
Z(16)=	0.22185	Y(16)=	-0.28503	P/PS(16)=	0.00689
Z(17)=	0.17191	Y(17)=	-0.31766	P/PS(17)=	0.00689
Z(18)=	0.11728	Y(18)=	-0.34163	P/PS(18)=	0.00689
Z(19)=	0.05945	Y(19)=	-0.35627	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-0.36120	P/PS(20)=	0.00689

MOD. NEWT. PRESS. AT INPUT COORD.

FOR JM = 20 AND X(6)= 0.28169
THE Z, Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	0.36321	P/PS(1)=	0.33039
Z(2)=	0.05978	Y(2)=	0.35825	P/PS(2)=	0.32499
Z(3)=	0.11793	Y(3)=	0.34353	P/PS(3)=	0.31020
Z(4)=	0.17287	Y(4)=	0.31943	P/PS(4)=	0.28718
Z(5)=	0.22309	Y(5)=	0.28662	P/PS(5)=	0.25685
Z(6)=	0.26722	Y(6)=	0.24599	P/PS(6)=	0.22071
Z(7)=	0.30406	Y(7)=	0.19865	P/PS(7)=	0.18219
Z(8)=	0.33261	Y(8)=	0.14590	P/PS(8)=	0.14503
Z(9)=	0.35209	Y(9)=	0.08916	P/PS(9)=	0.10943
Z(10)=	0.36197	Y(10)=	0.02999	P/PS(10)=	0.07830
Z(11)=	0.36197	Y(11)=	-0.02999	P/PS(11)=	0.05215
Z(12)=	0.35209	Y(12)=	-0.08916	P/PS(12)=	0.03198
Z(13)=	0.33261	Y(13)=	-0.14590	P/PS(13)=	0.01833
Z(14)=	0.30406	Y(14)=	-0.19865	P/PS(14)=	0.01027
Z(15)=	0.26722	Y(15)=	-0.24599	P/PS(15)=	0.00715

Z(16)=	0.22309	Y(16)=	-0.28662	P/PS(16)=	0.00689
Z(17)=	0.17287	Y(17)=	-0.31943	P/PS(17)=	0.00689
Z(18)=	0.11793	Y(18)=	-0.34353	P/PS(18)=	0.00689
Z(19)=	0.05978	Y(19)=	-0.35825	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-0.36321	P/PS(20)=	0.00689

MOD.NEWT.PRESS.AT INPUT COORD.

FOR JM = 20 AND X(7)= 0.50000
THE Z, Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	0.42170	P/PS(1)=	0.33439
Z(2)=	0.06941	Y(2)=	0.41595	P/PS(2)=	0.32936
Z(3)=	0.13693	Y(3)=	0.39885	P/PS(3)=	0.31436
Z(4)=	0.20071	Y(4)=	0.37088	P/PS(4)=	0.29047
Z(5)=	0.25901	Y(5)=	0.33278	P/PS(5)=	0.25960
Z(6)=	0.31026	Y(6)=	0.28561	P/PS(6)=	0.22412
Z(7)=	0.35303	Y(7)=	0.23065	P/PS(7)=	0.18612
Z(8)=	0.38618	Y(8)=	0.16940	P/PS(8)=	0.14780
Z(9)=	0.40880	Y(9)=	0.10352	P/PS(9)=	0.11181
Z(10)=	0.42026	Y(10)=	0.03482	P/PS(10)=	0.07985
Z(11)=	0.42026	Y(11)=	-0.03482	P/PS(11)=	0.05345
Z(12)=	0.40880	Y(12)=	-0.10352	P/PS(12)=	0.03324
Z(13)=	0.38618	Y(13)=	-0.16940	P/PS(13)=	0.01919
Z(14)=	0.35303	Y(14)=	-0.23065	P/PS(14)=	0.01091
Z(15)=	0.31026	Y(15)=	-0.28561	P/PS(15)=	0.00730
Z(16)=	0.25901	Y(16)=	-0.33278	P/PS(16)=	0.00689
Z(17)=	0.20071	Y(17)=	-0.37088	P/PS(17)=	0.00689
Z(18)=	0.13693	Y(18)=	-0.39885	P/PS(18)=	0.00689
Z(19)=	0.06941	Y(19)=	-0.41595	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-0.42170	P/PS(20)=	0.00689

MOD.NEWT.PRESS.AT INPUT COORD.

FOR JM = 20 AND X(8)= 0.75000
THE Z, Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	0.48869	P/PS(1)=	0.33344
Z(2)=	0.08044	Y(2)=	0.48202	P/PS(2)=	0.32830
Z(3)=	0.15868	Y(3)=	0.46221	P/PS(3)=	0.31336
Z(4)=	0.23259	Y(4)=	0.42979	P/PS(4)=	0.28964
Z(5)=	0.30016	Y(5)=	0.38564	P/PS(5)=	0.25895
Z(6)=	0.35954	Y(6)=	0.33098	P/PS(6)=	0.22327
Z(7)=	0.40911	Y(7)=	0.26729	P/PS(7)=	0.18517
Z(8)=	0.44753	Y(8)=	0.19630	P/PS(8)=	0.14709
Z(9)=	0.47373	Y(9)=	0.11997	P/PS(9)=	0.11122
Z(10)=	0.48702	Y(10)=	0.04036	P/PS(10)=	0.07950
Z(11)=	0.48702	Y(11)=	-0.04036	P/PS(11)=	0.05313
Z(12)=	0.47373	Y(12)=	-0.11997	P/PS(12)=	0.03293
Z(13)=	0.44753	Y(13)=	-0.19630	P/PS(13)=	0.01898
Z(14)=	0.40911	Y(14)=	-0.26729	P/PS(14)=	0.01074
Z(15)=	0.35954	Y(15)=	-0.33098	P/PS(15)=	0.00726
Z(16)=	0.30016	Y(16)=	-0.38564	P/PS(16)=	0.00689
Z(17)=	0.23259	Y(17)=	-0.42979	P/PS(17)=	0.00689
Z(18)=	0.15868	Y(18)=	-0.46221	P/PS(18)=	0.00689
Z(19)=	0.08044	Y(19)=	-0.48202	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-0.48869	P/PS(20)=	0.00689

MOD. NEWT. PRESS. AT INPUT COORD.

FOR JM = 20 AND X(9) = 1.00000
THE Z, Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	0.55568	P/PS(1)=	0.33369
Z(2)=	0.09146	Y(2)=	0.54810	P/PS(2)=	0.32859
Z(3)=	0.18043	Y(3)=	0.52557	P/PS(3)=	0.31361
Z(4)=	0.26447	Y(4)=	0.48870	P/PS(4)=	0.28988
Z(5)=	0.34130	Y(5)=	0.43851	P/PS(5)=	0.25913
Z(6)=	0.40882	Y(6)=	0.37635	P/PS(6)=	0.22350
Z(7)=	0.46519	Y(7)=	0.30393	P/PS(7)=	0.18542
Z(8)=	0.50887	Y(8)=	0.22321	P/PS(8)=	0.14726
Z(9)=	0.53867	Y(9)=	0.13641	P/PS(9)=	0.11140
Z(10)=	0.55378	Y(10)=	0.04589	P/PS(10)=	0.07959
Z(11)=	0.55378	Y(11)=	-0.04589	P/PS(11)=	0.05321
Z(12)=	0.53867	Y(12)=	-0.13641	P/PS(12)=	0.03301

Z(13)=	0.50887	Y(13)=	-0.22321	P/PS(13)=	0.01903
Z(14)=	0.46519	Y(14)=	-0.30393	P/PS(14)=	0.01079
Z(15)=	0.40882	Y(15)=	-0.37635	P/PS(15)=	0.00727
Z(16)=	0.34130	Y(16)=	-0.43851	P/PS(16)=	0.00689
Z(17)=	0.26447	Y(17)=	-0.48870	P/PS(17)=	0.00689
Z(18)=	0.18043	Y(18)=	-0.52557	P/PS(18)=	0.00689
Z(19)=	0.09146	Y(19)=	-0.54810	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-0.55568	P/PS(20)=	0.00689

MOD. NEWT. PRESS. AT INPUT COORD.

FOR JM = 20 AND X(10) = 2.00000
THE Z, Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	0.82363	P/PS(1)=	0.33360
Z(2)=	0.13556	Y(2)=	0.81239	P/PS(2)=	0.32848
Z(3)=	0.26743	Y(3)=	0.77900	P/PS(3)=	0.31353
Z(4)=	0.39200	Y(4)=	0.72436	P/PS(4)=	0.28982
Z(5)=	0.50588	Y(5)=	0.64996	P/PS(5)=	0.25907
Z(6)=	0.60596	Y(6)=	0.55783	P/PS(6)=	0.22343
Z(7)=	0.68951	Y(7)=	0.45048	P/PS(7)=	0.18533
Z(8)=	0.75425	Y(8)=	0.33085	P/PS(8)=	0.14722
Z(9)=	0.79842	Y(9)=	0.20219	P/PS(9)=	0.11134
Z(10)=	0.82081	Y(10)=	0.06801	P/PS(10)=	0.07955
Z(11)=	0.82081	Y(11)=	-0.06801	P/PS(11)=	0.05319
Z(12)=	0.79842	Y(12)=	-0.20219	P/PS(12)=	0.03299
Z(13)=	0.75425	Y(13)=	-0.33085	P/PS(13)=	0.01902
Z(14)=	0.68951	Y(14)=	-0.45048	P/PS(14)=	0.01077
Z(15)=	0.60596	Y(15)=	-0.55783	P/PS(15)=	0.00727
Z(16)=	0.50588	Y(16)=	-0.64996	P/PS(16)=	0.00689
Z(17)=	0.39200	Y(17)=	-0.72436	P/PS(17)=	0.00689
Z(18)=	0.26743	Y(18)=	-0.77900	P/PS(18)=	0.00689
Z(19)=	0.13556	Y(19)=	-0.81239	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-0.82363	P/PS(20)=	0.00689

MOD. NEWT. PRESS. AT INPUT COORD.

FOR JM = 20 AND X(11)= 3.00000
THE Z,Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	1.09157	P/PS(1)=	0.33361
Z(2)=	0.17967	Y(2)=	1.07669	P/PS(2)=	0.32851
Z(3)=	0.35443	Y(3)=	1.03243	P/PS(3)=	0.31354
Z(4)=	0.51953	Y(4)=	0.96001	P/PS(4)=	0.28983
Z(5)=	0.67046	Y(5)=	0.86141	P/PS(5)=	0.25908
Z(6)=	0.80310	Y(6)=	0.73930	P/PS(6)=	0.22343
Z(7)=	0.91383	Y(7)=	0.59703	P/PS(7)=	0.18535
Z(8)=	0.99963	Y(8)=	0.43848	P/PS(8)=	0.14723
Z(9)=	1.05817	Y(9)=	0.26797	P/PS(9)=	0.11135
Z(10)=	1.08785	Y(10)=	0.09014	P/PS(10)=	0.07956
Z(11)=	1.08785	Y(11)=	-0.09014	P/PS(11)=	0.05319
Z(12)=	1.05817	Y(12)=	-0.26797	P/PS(12)=	0.03299
Z(13)=	0.99963	Y(13)=	-0.43848	P/PS(13)=	0.01902
Z(14)=	0.91383	Y(14)=	-0.59703	P/PS(14)=	0.01077
Z(15)=	0.80310	Y(15)=	-0.73930	P/PS(15)=	0.00727
Z(16)=	0.67046	Y(16)=	-0.86141	P/PS(16)=	0.00689
Z(17)=	0.51953	Y(17)=	-0.96001	P/PS(17)=	0.00689
Z(18)=	0.35443	Y(18)=	-1.03243	P/PS(18)=	0.00689
Z(19)=	0.17967	Y(19)=	-1.07669	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-1.09157	P/PS(20)=	0.00689

MOD.NEWT.PRESS.AT INPUT COORD.

FOR JM = 20 AND X(12)= 4.00000
THE Z,Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	1.35952	P/PS(1)=	0.33362
Z(2)=	0.22377	Y(2)=	1.34098	P/PS(2)=	0.32849
Z(3)=	0.44144	Y(3)=	1.28586	P/PS(3)=	0.31354
Z(4)=	0.64706	Y(4)=	1.19567	P/PS(4)=	0.28983
Z(5)=	0.83504	Y(5)=	1.07286	P/PS(5)=	0.25907
Z(6)=	1.00023	Y(6)=	0.92078	P/PS(6)=	0.22344
Z(7)=	1.13815	Y(7)=	0.74359	P/PS(7)=	0.18535
Z(8)=	1.24502	Y(8)=	0.54611	P/PS(8)=	0.14723
Z(9)=	1.31792	Y(9)=	0.33374	P/PS(9)=	0.11134

Z(10)=	1.35488	Y(10)=	0.11227	P/PS(10)=	0.07955
Z(11)=	1.35488	Y(11)=	-0.11227	P/PS(11)=	0.05319
Z(12)=	1.31792	Y(12)=	-0.33374	P/PS(12)=	0.03299
Z(13)=	1.24502	Y(13)=	-0.54611	P/PS(13)=	0.01902
Z(14)=	1.13815	Y(14)=	-0.74359	P/PS(14)=	0.01077
Z(15)=	1.00023	Y(15)=	-0.92078	P/PS(15)=	0.00727
Z(16)=	0.83504	Y(16)=	-1.07286	P/PS(16)=	0.00689
Z(17)=	0.64706	Y(17)=	-1.19567	P/PS(17)=	0.00689
Z(18)=	0.44144	Y(18)=	-1.28586	P/PS(18)=	0.00689
Z(19)=	0.22377	Y(19)=	-1.34098	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-1.35952	P/PS(20)=	0.00689

MOD.NEWT.PRESS.AT INPUT COORD.

FOR JM = 20 AND X(13)= 5.50000
THE Z,Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	1.76145	P/PS(1)=	0.33361
Z(2)=	0.28992	Y(2)=	-1.73742	P/PS(2)=	0.32850
Z(3)=	0.57194	Y(3)=	1.66601	P/PS(3)=	0.31354
Z(4)=	0.83836	Y(4)=	1.54915	P/PS(4)=	0.28982
Z(5)=	1.08190	Y(5)=	1.39003	P/PS(5)=	0.25907
Z(6)=	1.29594	Y(6)=	1.19300	P/PS(6)=	0.22344
Z(7)=	1.47462	Y(7)=	0.96342	P/PS(7)=	0.18535
Z(8)=	1.61309	Y(8)=	0.70757	P/PS(8)=	0.14724
Z(9)=	1.70755	Y(9)=	0.43241	P/PS(9)=	0.11134
Z(10)=	1.75543	Y(10)=	0.14546	P/PS(10)=	0.07955
Z(11)=	1.75543	Y(11)=	-0.14546	P/PS(11)=	0.05320
Z(12)=	1.70755	Y(12)=	-0.43241	P/PS(12)=	0.03299
Z(13)=	1.61309	Y(13)=	-0.70757	P/PS(13)=	0.01902
Z(14)=	1.47462	Y(14)=	-0.96342	P/PS(14)=	0.01077
Z(15)=	1.29594	Y(15)=	-1.19300	P/PS(15)=	0.00727
Z(16)=	1.08190	Y(16)=	-1.39003	P/PS(16)=	0.00689
Z(17)=	0.83836	Y(17)=	-1.54915	P/PS(17)=	0.00689
Z(18)=	0.57194	Y(18)=	-1.66601	P/PS(18)=	0.00689
Z(19)=	0.28992	Y(19)=	-1.73742	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-1.76145	P/PS(20)=	0.00689

MOD.NEWT.PRESS.AT INPUT COORD.

FOR JM = 20 AND X(14)= 7.00000
THE Z,Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	2.16337	P/PS(1)=	0.33361
Z(2)=	0.35608	Y(2)=	2.13387	P/PS(2)=	0.32850
Z(3)=	0.70245	Y(3)=	2.04615	P/PS(3)=	0.31354
Z(4)=	1.02965	Y(4)=	1.90263	P/PS(4)=	0.28982
Z(5)=	1.32877	Y(5)=	1.70720	P/PS(5)=	0.25907
Z(6)=	1.59164	Y(6)=	1.46521	P/PS(6)=	0.22344
Z(7)=	1.81110	Y(7)=	1.18325	P/PS(7)=	0.18535
Z(8)=	1.98116	Y(8)=	0.86902	P/PS(8)=	0.14723
Z(9)=	2.09717	Y(9)=	0.53108	P/PS(9)=	0.11134
Z(10)=	2.15598	Y(10)=	0.17865	P/PS(10)=	0.07955
Z(11)=	2.15598	Y(11)=	-0.17865	P/PS(11)=	0.05320
Z(12)=	2.09717	Y(12)=	-0.53108	P/PS(12)=	0.03299
Z(13)=	1.98116	Y(13)=	-0.86902	P/PS(13)=	0.01902
Z(14)=	1.81110	Y(14)=	-1.18325	P/PS(14)=	0.01077
Z(15)=	1.59164	Y(15)=	-1.46521	P/PS(15)=	0.00727
Z(16)=	1.32877	Y(16)=	-1.70720	P/PS(16)=	0.00689
Z(17)=	1.02965	Y(17)=	-1.90263	P/PS(17)=	0.00689
Z(18)=	0.70245	Y(18)=	-2.04615	P/PS(18)=	0.00689
Z(19)=	0.35608	Y(19)=	-2.13387	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-2.16337	P/PS(20)=	0.00689

MOD.NEWT.PRESS.AT INPUT COORD.

FOR JM = 20 AND X(15)= 10.00000
THE Z,Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	2.96722	P/PS(1)=	0.33362
Z(2)=	0.48839	Y(2)=	2.92675	P/PS(2)=	0.32850
Z(3)=	0.96345	Y(3)=	2.80645	P/PS(3)=	0.31354
Z(4)=	1.41224	Y(4)=	2.60959	P/PS(4)=	0.28982
Z(5)=	1.82250	Y(5)=	2.34155	P/PS(5)=	0.25907
Z(6)=	2.18305	Y(6)=	2.00964	P/PS(6)=	0.22344

Z(7)=	2.48406	Y(7)=	1.62291	P/PS(7)=	0.18535
Z(8)=	2.71730	Y(8)=	1.19192	P/PS(8)=	0.14723
Z(9)=	2.87642	Y(9)=	0.72841	P/PS(9)=	0.11134
Z(10)=	2.95708	Y(10)=	0.24503	P/PS(10)=	0.07955
Z(11)=	2.95708	Y(11)=	-0.24503	P/PS(11)=	0.05320
Z(12)=	2.87642	Y(12)=	-0.72841	P/PS(12)=	0.03299
Z(13)=	2.71730	Y(13)=	-1.19192	P/PS(13)=	0.01902
Z(14)=	2.48406	Y(14)=	-1.62291	P/PS(14)=	0.01077
Z(15)=	2.18305	Y(15)=	-2.00964	P/PS(15)=	0.00727
Z(16)=	1.82250	Y(16)=	-2.34155	P/PS(16)=	0.00689
Z(17)=	1.41224	Y(17)=	-2.60959	P/PS(17)=	0.00689
Z(18)=	0.96345	Y(18)=	-2.80645	P/PS(18)=	0.00689
Z(19)=	0.48839	Y(19)=	-2.92675	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-2.96722	P/PS(20)=	0.00689

MOD.NEXT.PRESS.AT INPUT COORD.

FOR JM = 20 AND X(16)= 13.00000
 THE Z, Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	3.77107	P/PS(1)=	0.33361
Z(2)=	0.62070	Y(2)=	3.71963	P/PS(2)=	0.32850
Z(3)=	1.22446	Y(3)=	3.56674	P/PS(3)=	0.31354
Z(4)=	1.79483	Y(4)=	3.31655	P/PS(4)=	0.28983
Z(5)=	2.31624	Y(5)=	2.97590	P/PS(5)=	0.25907
Z(6)=	2.77446	Y(6)=	2.55407	P/PS(6)=	0.22344
Z(7)=	3.15701	Y(7)=	2.06258	P/PS(7)=	0.18535
Z(8)=	3.45344	Y(8)=	1.51482	P/PS(8)=	0.14723
Z(9)=	3.65567	Y(9)=	0.92574	P/PS(9)=	0.11134
Z(10)=	3.75819	Y(10)=	0.31141	P/PS(10)=	0.07955
Z(11)=	3.75819	Y(11)=	-0.31141	P/PS(11)=	0.05320
Z(12)=	3.65567	Y(12)=	-0.92574	P/PS(12)=	0.03299
Z(13)=	3.45344	Y(13)=	-1.51482	P/PS(13)=	0.01902
Z(14)=	3.15701	Y(14)=	-2.06258	P/PS(14)=	0.01077
Z(15)=	2.77446	Y(15)=	-2.55407	P/PS(15)=	0.00727
Z(16)=	2.31624	Y(16)=	-2.97590	P/PS(16)=	0.00689
Z(17)=	1.79483	Y(17)=	-3.31655	P/PS(17)=	0.00689
Z(18)=	1.22446	Y(18)=	-3.56674	P/PS(18)=	0.00689

Z(19)=	0.62070	Y(19)=	-3.71963	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-3.77107	P/PS(20)=	0.00689

MOD.NEWT.PRESS.AT INPUT COORD.

FOR JM = 20 AND X(17)= 16.00000
THE Z,Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	4.57491	P/PS(1)=	0.33361
Z(2)=	0.75301	Y(2)=	4.51252	P/PS(2)=	0.32850
Z(3)=	1.48547	Y(3)=	4.32703	P/PS(3)=	0.31354
Z(4)=	2.17742	Y(4)=	4.02352	P/PS(4)=	0.28983
Z(5)=	2.80997	Y(5)=	3.61025	P/PS(5)=	0.25907
Z(6)=	3.36587	Y(6)=	3.09850	P/PS(6)=	0.22344
Z(7)=	3.82996	Y(7)=	2.50224	P/PS(7)=	0.18535
Z(8)=	4.18958	Y(8)=	1.83772	P/PS(8)=	0.14723
Z(9)=	4.43492	Y(9)=	1.12307	P/PS(9)=	0.11134
Z(10)=	4.55929	Y(10)=	0.37779	P/PS(10)=	0.07955
Z(11)=	4.55929	Y(11)=	-0.37779	P/PS(11)=	0.05319
Z(12)=	4.43492	Y(12)=	-1.12307	P/PS(12)=	0.03299
Z(13)=	4.18958	Y(13)=	-1.83772	P/PS(13)=	0.01902
Z(14)=	3.82996	Y(14)=	-2.50224	P/PS(14)=	0.01077
Z(15)=	3.36587	Y(15)=	-3.09850	P/PS(15)=	0.00727
Z(16)=	2.80997	Y(16)=	-3.61025	P/PS(16)=	0.00689
Z(17)=	2.17742	Y(17)=	-4.02352	P/PS(17)=	0.00689
Z(18)=	1.48547	Y(18)=	-4.32703	P/PS(18)=	0.00689
Z(19)=	0.75301	Y(19)=	-4.51252	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-4.57491	P/PS(20)=	0.00689

MOD.NEWT.PRESS.AT INPUT COORD.

FOR JM = 20 AND X(18)= 19.00000
THE Z,Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	5.37876	P/PS(1)=	0.33362
Z(2)=	0.88532	Y(2)=	5.30540	P/PS(2)=	0.32850
Z(3)=	1.74648	Y(3)=	5.08733	P/PS(3)=	0.31354

Z(4)=	2.56001	Y(4)=	4.73048	P/PS(4)=	0.28982
Z(5)=	3.30370	Y(5)=	4.24460	P/PS(5)=	0.25907
Z(6)=	3.95728	Y(6)=	3.64294	P/PS(6)=	0.22344
Z(7)=	4.50292	Y(7)=	2.94190	P/PS(7)=	0.18535
Z(8)=	4.92573	Y(8)=	2.16062	P/PS(8)=	0.14723
Z(9)=	5.21417	Y(9)=	1.32041	P/PS(9)=	0.11134
Z(10)=	5.36039	Y(10)=	0.44417	P/PS(10)=	0.07955
Z(11)=	5.36039	Y(11)=	-0.44417	P/PS(11)=	0.05320
Z(12)=	5.21417	Y(12)=	-1.32041	P/PS(12)=	0.03299
Z(13)=	4.92573	Y(13)=	-2.16062	P/PS(13)=	0.01902
Z(14)=	4.50292	Y(14)=	-2.94190	P/PS(14)=	0.01077
Z(15)=	3.95728	Y(15)=	-3.64294	P/PS(15)=	0.00727
Z(16)=	3.30370	Y(16)=	-4.24460	P/PS(16)=	0.00689
Z(17)=	2.56001	Y(17)=	-4.73048	P/PS(17)=	0.00689
Z(18)=	1.74648	Y(18)=	-5.08733	P/PS(18)=	0.00689
Z(19)=	0.88532	Y(19)=	-5.30540	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-5.37876	P/PS(20)=	0.00689

MOD.NEWT.PRESS.AT INPUT COORD.

FOR JM = 20 AND X(19)= 22.00000
THE Z,Y AND P COORDINATES ARE:

Z(1)=	0.0	Y(1)=	6.18261	P/PS(1)=	0.33361
Z(2)=	1.01762	Y(2)=	6.09829	P/PS(2)=	0.32850
Z(3)=	2.00749	Y(3)=	5.84762	P/PS(3)=	0.31354
Z(4)=	2.94260	Y(4)=	5.43744	P/PS(4)=	0.28983
Z(5)=	3.79744	Y(5)=	4.87895	P/PS(5)=	0.25907
Z(6)=	4.54869	Y(6)=	4.18737	P/PS(6)=	0.22344
Z(7)=	5.17587	Y(7)=	3.38157	P/PS(7)=	0.18535
Z(8)=	5.66187	Y(8)=	2.48353	P/PS(8)=	0.14723
Z(9)=	5.99342	Y(9)=	1.51774	P/PS(9)=	0.11134
Z(10)=	6.16149	Y(10)=	0.51056	P/PS(10)=	0.07955
Z(11)=	6.16149	Y(11)=	-0.51056	P/PS(11)=	0.05320
Z(12)=	5.99342	Y(12)=	-1.51774	P/PS(12)=	0.03299
Z(13)=	5.66187	Y(13)=	-2.48353	P/PS(13)=	0.01902
Z(14)=	5.17587	Y(14)=	-3.38157	P/PS(14)=	0.01077
Z(15)=	4.54869	Y(15)=	-4.18737	P/PS(15)=	0.00727

Z(16)=	3.79744	Y(16)=	-4.87895	P/PS(16)=	0.00689
Z(17)=	2.94260	Y(17)=	-5.43744	P/PS(17)=	0.00689
Z(18)=	2.00749	Y(18)=	-5.84762	P/PS(18)=	0.00689
Z(19)=	1.01762	Y(19)=	-6.09829	P/PS(19)=	0.00689
Z(20)=	0.0	Y(20)=	-6.18261	P/PS(20)=	0.00689

STREAMLINE CALCULATIONS

INPUT DATA:

ANG. OF ATTACK= 0.20000E 02 DEG.
 ZETA(WALL)= 0.25100E 00
 NO. OF STREAMLINES TO BE CALCULATED = 2

B = 0.99335E 00
 STAGNATION POINT, X0 = 0.22615E-01

TW = 0.530067E 03 DEG. R QWS = 0.359411E 02 BTU/SQ FT-SE
 HSP = 0.227223E-01 BTU/SQ FT-SEC-DEG R

FOR STREAMLINE NO. 1 WHERE BETA = 0.10000E 01 DEG.
 THE CALCULATIONS ARE AS FOLLOWS:

X	Y	Z	H
S	BBAR	P/PS	QW/QWS
UE	HE	RHOE	MUE
MACH NO	RN/FT	MOM THK	RNM
RN1	R	PHI	DR/DPHI
D2R/DPHI2	DR/DX	D2R/DX2	QB/QSB
0.37092E-01	0.16261E 00	0.65007E-03	0.37250E-01
0.37256E-01	0.68442E 00	0.99188E 00	0.91683E 00
0.24302E 03	0.12654E 08	0.10593E-03	0.95220E-06
0.10802E 00	0.27036E 05	0.14879E-03	0.40228E 01
0.93173E-02	0.16261E 00	0.22905E 00	-0.35879E-05
-0.96113E-04	0.20780E 01	-0.32710E 02	0.91726E 00

0.38723E-01	0.16596E 00	0.71488E-03	0.40984E-01
0.40961E-01	0.62739E 00	0.98977E 00	0.94247E 00
0.27279E 03	0.12646E 08	0.10577E-03	0.95186E-06
0.12129E 00	0.30313E 05	0.14407E-03	0.43671E 01
0.89127E 01	0.16596E 00	0.24681E 00	-0.37898E-05
-0.93940E-04	0.20262E 01	-0.30774E 02	0.94303E 00
0.42086E-01	0.17260E 00	0.84333E-03	0.48377E-01
0.46431E-01	0.57318E 00	0.98498E 00	0.96654E 00
0.33081E 03	0.12629E 08	0.10541E-03	0.95109E-06
0.14719E 00	0.36663E 05	0.13969E-03	0.51216E 01
0.29715E 02	0.17260E 00	0.27994E 00	-0.42541E-05
-0.58745E-04	0.19287E 01	-0.27364E 02	0.96737E 00
0.49205E-01	0.18569E 00	0.10972E-02	0.62974E-01
0.63331E-01	0.54111E 00	0.97310E 00	0.97492E 00
0.44369E 03	0.12585E 08	0.10450E-03	0.94915E-06
0.19775E 00	0.48848E 05	0.13759E-03	0.67211E 01
0.62861E 02	0.18569E 00	0.33854E 00	-0.48620E-05
-0.74779E-04	0.17545E 01	-0.21995E 02	0.97643E 00
0.56838E-01	0.19848E 00	0.13481E-02	0.77392E-01
0.78231E-01	0.53646E 00	0.95817E 00	0.96854E 00
0.55480E 03	0.12530E 08	0.10335E-03	0.94670E-06
0.24782E 00	0.60568E 05	0.13774E-03	0.83425E 01
0.15083E 03	0.19849E 00	0.38916E 00	-0.52737E-05
-0.55729E-04	0.16029E 01	-0.18031E 02	0.97090E 00
0.64973E-01	0.21096E 00	0.15964E-02	0.91650E-01
0.93131E-01	0.54053E 00	0.94023E 00	0.95743E 00
0.66544E 03	0.12462E 08	0.10196E-03	0.94370E-06
0.29805E 00	0.71899E 05	0.13851E-03	0.99588E 01
0.23311E 03	0.21097E 00	0.43355E 00	-0.51271E-05
-0.31210E-04	0.14696E 01	-0.15039E 02	0.96079E 00
0.82698E-01	0.23490E 00	0.20838E-02	0.11964E 00
0.12293E 00	0.55405E 00	0.89566E 00	0.92620E 00
0.88668E 03	0.12291E 08	0.98488E-04	0.93603E-06

0.39990E 00	0.93295E 05	0.14105E-03	0.13160E 02
0.43863E 03	0.23491E 00	0.50826E 00	-0.35900E-05
0.33884E-04	0.12443E 01	-0.10921E 02	0.93198E 00
0.10227E 00	0.25736E 00	0.25574E-02	0.14684E 00
0.15273E 00	0.56701E 00	0.84157E 00	0.88306E 00
0.11045E 04	0.12074E 08	0.94202E-04	0.92627E-06
0.50258E 00	0.11232E 06	0.14508E-03	0.16296E 02
0.69451E 03	0.25737E 00	0.56933E 00	-0.40027E-06
0.10582E-03	0.10596E 01	-0.82818E 01	0.89165E 00
0.14644E 00	0.29727E 00	0.34555E-02	0.19841E 00
0.21233E 00	0.61310E 00	0.71573E 00	0.77453E 00
0.15205E 04	0.11528E 08	0.83910E-04	0.90125E-06
0.70808E 00	0.14156E 06	0.15741E-03	0.22283E 02
0.13301E 04	0.29729E 00	0.66599E 00	0.65593E-05
0.15928E-03	0.76852E 00	-0.51671E 01	0.78893E 00
0.19637E 00	0.32969E 00	0.42718E-02	0.24528E 00
0.27193E 00	0.85924E 00	0.56690E 00	0.65621E 00
0.19487E 04	0.10785E 08	0.71039E-04	0.86613E-06
0.93823E 00	0.15983E 06	0.17505E-03	0.27978E 02
0.20827E 04	0.32972E 00	0.74234E 00	0.70036E-05
0.11879E-03	0.54246E 00	-0.41477E 01	0.67649E 00
0.20960E 00	0.33653E 00	0.44595E-02	0.25606E 00
0.28683E 00	0.97469E 00	0.52278E 00	0.62243E 00
0.20715E 04	0.10538E 08	0.67045E-04	0.85417E-06
0.10089E 01	0.16259E 06	0.18096E-03	0.29422E 02
0.22830E 04	0.33656E 00	0.75920E 00	0.76488E-05
0.15989E-03	0.49264E 00	-0.41644E 01	0.64425E 00
0.23683E 00	0.34862E 00	0.48116E-02	0.27627E 00
0.31663E 00	0.10888E 01	0.43119E 00	0.54209E 00
0.23280E 04	0.99738E 07	0.58427E-04	0.82624E-06
0.11655E 01	0.16462E 06	0.19650E-03	0.32349E 02
0.26903E 04	0.34866E 00	0.79074E 00	0.41804E-05
0.27427E-03	0.39713E 00	-0.37105E 01	0.56632E 00

0.26494E 00	0.35848E 00	0.51324E-02	0.29469E 00
0.34643E 00	0.88841E 00	0.35680E 00	0.45950E 00
0.25437E 04	0.94485E 07	0.51035E-04	0.79943E-06
0.13084E 01	0.16238E 06	0.21602E-03	0.35077E 02
0.30969E 04	0.35851E 00	0.82027E 00	-0.61819E-05
0.13740E-03	0.30505E 00	-0.23727E 01	0.48423E 00
0.27209E 00	0.36058E 00	0.52080E-02	0.29902E 00
0.35388E 00	0.75869E 00	0.34369E 00	0.44087E 00
0.25829E 04	0.93480E 07	0.49689E-04	0.79422E-06
0.13357E 01	0.16159E 06	0.22077E-03	0.35675E 02
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0.22397E 01	0.10781E 06	0.13494E-02	0.14548E 03
0.16420E 06	0.35313E 01	0.82631E 02	0.30970E-04
-0.28979E-04	0.26795E 00	-0.21943E-05	0.52792E-01
0.12428E 02	0.24207E 00	0.36096E 01	0.22676E 03
0.13676E 02	0.92886E 00	0.76801E-01	0.42714E-01
0.36308E 04	0.60922E 07	0.17037E-04	0.60460E-06
0.23259E 01	0.10231E 06	0.14497E-02	0.14832E 03
0.16770E 06	0.36177E 01	0.86163E 02	0.20545E-04
-0.28594E-03	0.26795E 00	-0.21913E-05	0.47676E-01
0.12748E 02	0.21157E-01	0.37034E 01	0.23771E 03
0.14076E 02	0.10594E 01	0.66553E-01	0.38172E-01
0.36975E 04	0.58480E 07	0.15381E-04	0.58833E-06
0.24175E 01	0.96662E 05	0.15640E-02	0.15118E 03
0.17102E 06	0.37034E 01	0.89673E 02	0.64595E-06
-0.44994E-03	0.26795E 00	-0.20440E-05	0.42791E-01
0.13065E 02	-0.20852E 00	0.37828E 01	0.24866E 03
0.14476E 02	0.12125E 01	0.57180E-01	0.33890E-01
0.37640E 04	0.55998E 07	0.13800E-04	0.57142E-06
0.25150E 01	0.90903E 05	0.16951E-02	0.15409E 03
0.17415E 06	0.37885E 01	0.93155E 02	-0.23391E-04
-0.40087E-03	0.26795E 00	-0.18329E-05	0.38158E-01
0.13381E 02	-0.44565E 00	0.38474E 01	0.25957E 03
0.14876E 02	0.13913E 01	0.48707E-01	0.29882E-01
0.38301E 04	0.53490E 07	0.12306E-04	0.55392E-06
0.26184E 01	0.85093E 05	0.18460E-02	0.15708E 03
0.17708E 06	0.38731E 01	0.96607E 02	-0.49206E-04
-0.13600E-03	0.26795E 00	-0.13312E-05	0.33796E-01
0.13694E 02	-0.68889E 00	0.38967E 01	0.27045E 03

0.15276E 02	0.16026E 01	0.41138E-01	0.26166E-01
0.38953E 04	0.50970E 07	0.10908E-04	0.53588E-06
0.27281E 01	0.79289E 05	0.20202E-02	0.16018E 03
0.17982E 06	0.39571E 01	0.10003E 03	-0.59158E-04
0.13195E-03	0.26795E 00	-0.57991E-06	0.29727E-01
0.14006E 02	-0.93694E 00	0.39306E 01	0.28127E 03
0.15676E 02	0.18499E 01	0.34457E-01	0.22751E-01
0.39594E 04	0.48453E 07	0.96110E-05	0.51739E-06
0.28440E 01	0.73549E 05	0.22220E-02	0.16343E 03
0.18237E 06	0.40407E 01	0.10341E 03	-0.42818E-04
0.34986E-03	0.26795E 00	0.28027E-06	0.25965E-01
0.14317E 02	-0.11885E 01	0.39489E 01	0.29201E 03
0.16076E 02	0.21343E 01	0.28645E-01	0.19648E-01
0.40218E 04	0.45962E 07	0.84229E-05	0.49857E-06
0.29661E 01	0.67944E 05	0.24558E-02	0.16686E 03
0.18472E 06	0.41239E 01	0.10675E 03	0.95799E-06
0.45003E-03	0.26795E 00	0.88889E-06	0.22525E-01
0.14626E 02	-0.14422E 01	0.39518E 01	0.30262E 03
0.16476E 02	0.24572E 01	0.23663E-01	0.16866E-01
0.40821E 04	0.43520E 07	0.73484E-05	0.47961E-06
0.30939E 01	0.62544E 05	0.27259E-02	0.17049E 03
0.18690E 06	0.42067E 01	0.11005E 03	0.22452E-04
0.32487E-03	0.26795E 00	0.11548E-05	0.19421E-01
0.14934E 02	-0.16969E 01	0.39394E 01	0.31304E 03
0.16876E 02	0.28032E 01	0.19464E-01	0.14407E-01
0.41395E 04	0.41158E 07	0.63914E-05	0.46072E-06
0.32262E 01	0.57426E 05	0.30357E-02	0.17433E 03
0.18890E 06	0.42893E 01	0.11330E 03	0.22726E-04
0.46111E-05	0.26795E 00	0.11673E-05	0.16661E-01
0.15242E 02	-0.19513E 01	0.39120E 01	0.32318E 03
0.17276E 02	0.31402E 01	0.15999E-01	0.12275E-01
0.41933E 04	0.38916E 07	0.55562E-05	0.44227E-06
0.33610E 01	0.52680E 05	0.33853E-02	0.17834E 03
0.19073E 06	0.43717E 01	0.11651E 03	0.83962E-05

-0.29077E-03	0.26795E 00	0.11453E-05	0.14254E-01
0.15549E 02	-0.22043E 01	0.38702E 01	0.33294E 03
0.17676E 02	0.34162E 01	0.13205E-01	0.10469E-01
0.42426E 04	0.36839E 07	0.48443E-05	0.42469E-06
0.34950E 01	0.48394E 05	0.37698E-02	0.18244E 03
0.19241E 06	0.44539E 01	0.11966E 03	-0.59017E-05
-0.30794E-03	0.26795E 00	0.11174E-05	0.12203E-01
0.15855E 02	-0.24546E 01	0.38147E 01	0.34219E 03
0.18076E 02	0.35368E 01	0.11016E-01	0.89796E-02
0.42862E 04	0.34980E 07	0.42562E-05	0.40853E-06
0.36235E 01	0.44655E 05	0.41754E-02	0.18645E 03
0.19398E 06	0.45362E 01	0.12276E 03	-0.23416E-04
-0.10769E-03	0.26795E 00	0.12089E-05	0.10503E-01
0.16163E 02	-0.27013E 01	0.37462E 01	0.35074E 03
0.18476E 02	0.33855E 01	0.93693E-02	0.77918E-02
0.43229E 04	0.33399E 07	0.37913E-05	0.39443E-06
0.37401E 01	0.41552E 05	0.45755E-02	0.19012E 03
0.19540E 06	0.46185E 01	0.12579E 03	-0.92975E-05
0.13926E-03	0.26795E 00	0.12131E-05	0.91403E-02
0.16471E 02	-0.29433E 01	0.36657E 01	0.35840E 03
0.18876E 02	0.28747E 01	0.81995E-02	0.68808E-02
0.43517E 04	0.32150E 07	0.34468E-05	0.38308E-06
0.38374E 01	0.39155E 05	0.49325E-02	0.19313E 03
0.19674E 06	0.47011E 01	0.12876E 03	0.19789E-05
0.26183E-03	0.26795E 00	0.10333E-05	0.80903E-02
0.16780E 02	-0.31796E 01	0.35744E 01	0.36501E 03
0.19276E 02	0.20127E 01	0.74435E-02	0.62034E-02
0.43718E 04	0.31274E 07	0.32167E-05	0.37497E-06
0.39088E 01	0.37503E 05	0.52044E-02	0.19518E 03
0.19802E 06	0.47840E 01	0.13165E 03	0.11248E-04
0.28066E-03	0.26795E 00	0.71640E-06	0.73057E-02
0.16936E 02	-0.32955E 01	0.35251E 01	0.36788E 03
0.19476E 02	0.14950E 01	0.72016E-02	0.59313E-02

0.43785E 04	0.30980E 07	0.31417E-05	0.37223E-06
0.39333E 01	0.36955E 05	0.52978E-02	0.19578E 03
0.19864E 06	0.48256E 01	0.13307E 03	0.10143E-04
0.25678E-03	0.26795E 00	0.58670E-06	0.69891E-02
0.17248E 02	-0.35221E 01	0.34201E 01	0.37278E 03
0.19876E 02	0.59421E 00	0.69358E-02	0.54916E-02
0.43861E 04	0.30649E 07	0.30584E-05	0.36913E-06
0.39613E 01	0.36340E 05	0.53987E-02	0.19619E 03
0.19986E 06	0.49094E 01	0.13584E 03	0.49655E-05
0.15818E-03	0.26795E 00	0.53421E-06	0.64750E-02
0.17563E 02	-0.37415E 01	0.33074E 01	0.37684E 03
0.20276E 02	0.48018E-01	0.68631E-02	0.51098E-02
0.43882E 04	0.30557E 07	0.30355E-05	0.36827E-06
0.39692E 01	0.36170E 05	0.54153E-02	0.19587E 03
0.20106E 06	0.49937E 01	0.13852E 03	-0.15922E-05
0.57871E-04	0.26795E 00	0.64454E-06	0.60259E-02
0.17881E 02	-0.39535E 01	0.31881E 01	0.38046E 03
0.20676E 02	0.0	0.68804E-02	0.50406E-02
0.43877E 04	0.30579E 07	0.30409E-05	0.36847E-06
0.39673E 01	0.36210E 05	0.53918E-02	0.19524E 03
0.20227E 06	0.50788E 01	0.14112E 03	-0.22789E-05
0.37167E-04	0.26795E 00	0.76284E-06	0.59440E-02
0.17960E 02	-0.40053E 01	0.31574E 01	0.38135E 03
0.20776E 02	0.0	0.68883E-02	0.50492E-02
0.43874E 04	0.30589E 07	0.30434E-05	0.36857E-06
0.39664E 01	0.36229E 05	0.53845E-02	0.19507E 03
0.20257E 06	0.51002E 01	0.14175E 03	0.10371E-04
0.52652E-04	0.26795E 00	0.78886E-06	0.59540E-02
0.18000E 02	-0.40311E 01	0.31418E 01	0.38179E 03
0.20826E 02	0.0	0.68919E-02	0.50532E-02
0.43873E 04	0.30593E 07	0.30446E-05	0.36861E-06
0.39660E 01	0.36237E 05	0.53810E-02	0.19499E 03
0.20272E 06	0.51109E 01	0.14207E 03	0.12409E-04
0.64107E-04	0.26795E 00	0.76971E-06	0.59587E-02

0.18080E 02	-0.40823E 01	0.31106E 01	0.38268E 03
0.20926E 02	0.0	0.68981E-02	0.50606E-02
0.43871E 04	0.30601E 07	0.30465E-05	0.36868E-06
0.39654E 01	0.36252E 05	0.53745E-02	0.19484E 03
0.20302E 06	0.51323E 01	0.14269E 03	0.16032E-04
0.92141E-04	0.26795E 00	0.78392E-06	0.59674E-02
0.18241E 02	-0.41832E 01	0.30470E 01	0.38449E 03
0.21126E 02	0.0	0.69062E-02	0.50726E-02
0.43869E 04	0.30611E 07	0.30491E-05	0.36878E-06
0.39645E 01	0.36271E 05	0.53637E-02	0.19455E 03
0.20363E 06	0.51753E 01	0.14393E 03	0.20887E-04
0.15526E-03	0.26795E 00	0.72558E-06	0.59813E-02
0.18563E 02	-0.43799E 01	0.29160E 01	0.38818E 03
0.21526E 02	0.11134E-01	0.69096E-02	0.51242E-02
0.43868E 04	0.30616E 07	0.30501E-05	0.36882E-06
0.39641E 01	0.36279E 05	0.53483E-02	0.19403E 03
0.20484E 06	0.52618E 01	0.14635E 03	0.28419E-04
0.25596E-03	0.26795E 00	0.50975E-06	0.60422E-02
0.18889E 02	-0.45695E 01	0.27804E 01	0.39193E 03
0.21926E 02	0.33701E-01	0.69032E-02	0.51728E-02
0.43870E 04	0.30608E 07	0.30481E-05	0.36874E-06
0.39648E 01	0.36264E 05	0.53379E-02	0.19357E 03
0.20605E 06	0.53489E 01	0.14868E 03	0.35014E-04
0.24351E-03	0.26795E 00	0.24515E-06	0.60995E-02
0.19216E 02	-0.47522E 01	0.26405E 01	0.39570E 03
0.22326E 02	0.30111E-01	0.68944E-02	0.51739E-02
0.43872E 04	0.30596E 07	0.30454E-05	0.36864E-06
0.39658E 01	0.36243E 05	0.53291E-02	0.19314E 03
0.20725E 06	0.54365E 01	0.15094E 03	0.34164E-04
0.66263E-04	0.26795E 00	-0.38373E-07	0.61010E-02
0.19380E 02	-0.48411E 01	0.25692E 01	0.39757E 03
0.22526E 02	0.20653E-01	0.68911E-02	0.51619E-02
0.43873E 04	0.30592E 07	0.30443E-05	0.36860E-06

0.39661E 01	0.36236E 05	0.53244E-02	0.19293E 03
0.20786E 06	0.54806E 01	0.15204E 03	0.30874E-04
-0.79056E-04	0.26795E 00	-0.16857E-06	0.60869E-02
0.19710E 02	-0.50139E 01	0.24239E 01	0.40131E 03
0.22926E 02	0.50047E-02	0.68879E-02	0.51371E-02
0.43874E 04	0.30588E 07	0.30433E-05	0.36856E-06
0.39665E 01	0.36228E 05	0.53142E-02	0.19252E 03
0.20907E 06	0.55690E 01	0.15420E 03	0.39408E-04
-0.29880E-03	0.26795E 00	-0.53514E-06	0.60577E-02
0.20042E 02	-0.51803E 01	0.22755E 01	0.40502E 03
0.23326E 02	0.0	0.68879E-02	0.51265E-02
0.43874E 04	0.30588E 07	0.30433E-05	0.36856E-06
0.39665E 01	0.36228E 05	0.53032E-02	0.19212E 03
0.21027E 06	0.56580E 01	0.15629E 03	0.32878E-04
-0.37869E-03	0.26795E 00	-0.10113E-05	0.60451E-02
0.20376E 02	-0.53405E 01	0.21244E 01	0.40871E 03
0.23726E 02	0.0	0.68896E-02	0.51375E-02
0.43874E 04	0.30590E 07	0.30438E-05	0.36858E-06
0.39663E 01	0.36232E 05	0.52922E-02	0.19175E 03
0.21148E 06	0.57475E 01	0.15831E 03	0.19463E-04
-0.33067E-03	0.26795E 00	-0.14882E-05	0.60582E-02
0.20712E 02	-0.54947E 01	0.19708E 01	0.41241E 03
0.24126E 02	0.0	0.68917E-02	0.51483E-02
0.43873E 04	0.30593E 07	0.30445E-05	0.36861E-06
0.39661E 01	0.36237E 05	0.52816E-02	0.19139E 03
0.21269E 06	0.58374E 01	0.16027E 03	0.17064E-05
-0.19673E-03	0.26795E 00	-0.17563E-05	0.60708E-02
0.21049E 02	-0.56430E 01	0.18153E 01	0.41611E 03
0.24526E 02	0.0	0.68931E-02	0.51581E-02
0.43873E 04	0.30595E 07	0.30449E-05	0.36862E-06
0.39659E 01	0.36240E 05	0.52719E-02	0.19105E 03
0.21390E 06	0.59278E 01	0.16217E 03	-0.98646E-05
-0.54979E-04	0.26795E 00	-0.16893E-05	0.60823E-02

0.21388E 02	-0.57858E 01	0.16578E 01	0.41981E 03
0.24926E 02	0.0	0.68936E-02	0.51668E-02
0.43873E 04	0.30595E 07	0.30451E-05	0.36863E-06
0.39659E 01	0.36241E 05	0.52631E-02	0.19074E 03
0.21510E 06	0.60186E 01	0.16401E 03	-0.42362E-05
0.36107E-05	0.26795E 00	-0.11835E-05	0.60926E-02

0.21728E 02	-0.59231E 01	0.14989E 01	0.42352E 03
0.25325E 02	0.97009E-03	0.68935E-02	0.51817E-02
0.43873E 04	0.30595E 07	0.30451E-05	0.36863E-06
0.39659E 01	0.36241E 05	0.52550E-02	0.19045E 03
0.21631E 06	0.61098E 01	0.16580E 03	-0.11520E-04
-0.90761E-05	0.26795E 00	-0.38535E-06	0.61102E-02

0.22070E 02	-0.60552E 01	0.13386E 01	0.42723E 03
0.25725E 02	0.16920E-02	0.68931E-02	0.51921E-02
0.43873E 04	0.30595E 07	0.30449E-05	0.36862E-06
0.39659E 01	0.36240E 05	0.52477E-02	0.19018E 03
0.21752E 06	0.62014E 01	0.16753E 03	0.64796E-05
-0.65084E-04	0.26795E 00	0.50460E-06	0.61225E-02

*** CALCULATIONS FOR BETA =0.10000E 01 HAS TERMINATED
AFTER 93 INTEGRATIONS **

FOR STREAMLINE NO. 2 WHERE BETA = 0.45000E 02 DEG.
THE CALCULATIONS ARE AS FOLLOWS:

X	Y	Z	H
S	BBAR	P/PS	QW/QWS
UE	HE	RHOE	MUE
MACH NO	RN/FT	MDM THK	RNM
RN1	R	PHI	DR/DPHI
D2R/DPHI2	DR/DX	D2R/DX2	QB/QSB
0.33368E-01	0.15237E 00	0.26340E-01	0.37250E-01
0.41158E-01	0.72033E 00	0.99219E 00	0.89825E 00

0.23824E 03	0.12655E 08	0.10596E-03	0.95225E-06
0.10589E 00	0.26509E 05	0.15225E-03	0.40361E 01
0.93798E-02	0.15463E 00	0.98078E 01	-0.46050E-05
0.45506E-04	0.22093E 01	-0.38022E 02	0.89865E 00
0.34631E-01	0.15470E 00	0.28954E-01	0.40954E-01
0.44883E-01	0.65260E 00	0.99011E 00	0.92819E 00
0.26816E 03	0.12648E 08	0.10580E-03	0.95192E-06
0.11922E 00	0.29804E 05	0.14656E-03	0.43682E 01
0.87518E 01	0.15739E 00	0.10601E 02	0.53337E-05
0.67907E-04	0.21625E 01	-0.36060E 02	0.92872E 00
0.37265E-01	0.15935E 00	0.34150E-01	0.48269E-01
0.52333E-01	0.58865E 00	0.98537E 00	0.95743E 00
0.32647E 03	0.12630E 08	0.10544E-03	0.95115E-06
0.14525E 00	0.36190E 05	0.14120E-03	0.51101E 01
0.29249E 02	0.16296E 00	0.12096E 02	0.19980E-04
0.10478E-03	0.20724E 01	-0.32492E 02	0.95824E 00
0.42947E-01	0.16849E 00	0.44452E-01	0.62665E-01
0.67233E-01	0.54975E 00	0.97356E 00	0.96995E 00
0.43988E 03	0.12587E 08	0.10453E-03	0.94923E-06
0.19604E 00	0.48441E 05	0.13841E-03	0.67048E 01
0.81850E 02	0.17425E 00	0.14779E 02	0.32529E-04
0.14706E-03	0.19056E 01	-0.26595E 02	0.97144E 00
0.49162E-01	0.17738E 00	0.54661E-01	0.76856E-01
0.82133E-01	0.54158E 00	0.95870E 00	0.96478E 00
0.55125E 03	0.12532E 08	0.10339E-03	0.94678E-06
0.24622E 00	0.60198E 05	0.13836E-03	0.83287E 01
0.14934E 03	0.18561E 00	0.17127E 02	0.28250E-04
0.14610E-03	0.17555E 01	-0.22023E 02	0.96710E 00
0.55892E-01	0.18601E 00	0.64778E-01	0.90875E-01
0.97033E-01	0.54277E 00	0.94089E 00	0.95382E 00
0.66168E 03	0.12465E 08	0.10202E-03	0.94381E-06
0.29633E 00	0.71520E 05	0.13909E-03	0.99478E 01
0.23116E 03	0.19696E 00	0.19201E 02	0.13069E-04
0.98928E-04	0.16202E 01	-0.18452E 02	0.95713E 00

0.70859E-01	0.20237E 00	0.84673E-01	0.11835E 00
0.12683E 00	0.55873E 00	0.89679E 00	0.92289E 00
0.88168E 03	0.12295E 08	0.98577E-04	0.93623E-06
0.39758E 00	0.92833E 05	0.14167E-03	0.13152E 02
0.43562E 03	0.21937E 00	0.22705E 02	-0.54221E-05
-0.84918E-04	0.13866E 01	-0.13395E 02	0.92859E 00

0.87755E-01	0.21748E 00	0.10400E 00	0.14487E 00
0.15663E 00	0.57968E 00	0.84245E 00	0.88160E 00
0.11012E 04	0.12077E 08	0.94272E-04	0.92643E-06
0.50102E 00	0.11206E 06	0.14551E-03	0.16306E 02
0.69052E 03	0.24107E 00	0.25558E 02	-0.12364E-04
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0.18643E 00	0.60494E 00	0.78021E 00	0.83092E 00
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0.60616E 00	0.12860E 06	0.15083E-03	0.19396E 02
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0.21623E 00	0.63700E 00	0.71265E 00	0.77344E 00
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0.71284E 00	0.14210E 06	0.15768E-03	0.22406E 02
0.13267E 04	0.28118E 00	0.29990E 02	-0.42208E-04
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0.29073E 00	0.87197E 00	0.52873E 00	0.61672E 00
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0.36592E 04	0.36148E 00	0.38558E 02	0.76836E-05
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0.29035E 04	0.84684E 07	0.38812E-04	0.74715E-06
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0.57757E 00	0.26583E 00	0.35379E 00	0.45929E 00
0.72284E 00	0.25041E 00	0.20846E 00	0.23412E 00
0.30265E 04	0.81036E 07	0.34767E-04	0.72684E-06
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0.63055E 00	0.25505E 00	0.37887E 00	0.48909E 00
0.78244E 00	0.36544E 00	0.19509E 00	0.22066E 00
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0.84204E 00	0.44324E 00	0.17972E 00	0.20501E 00
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0.73514E 00	0.22667E 00	0.42844E 00	0.54937E 00
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0.35843E 04	0.62599E 07	0.18234E-04	0.61556E-06
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0.14082E 01	0.11238E 01	0.70536E-01	0.91882E-01
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0.14738E 05	0.59855E 00	0.88597E 02	-0.10283E-05
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0.39600E 04	0.48427E 07	0.95978E-05	0.51719E-06
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0.14910E 01	-0.23286E 00	0.64658E 00	0.93562E 00
0.18254E 01	0.30422E 01	0.24588E-01	0.38417E-01
0.40703E 04	0.44000E 07	0.75524E-05	0.48337E-06
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0.43546E 04	0.32022E 07	0.34125E-05	0.38190E-06
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0.43867E 04	0.30621E 07	0.30513E-05	0.36887E-06

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0.42135E-04	0.26794E 00	-0.29891E-02	0.11462E-01
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0.43874E 04	0.30591E 07	0.30439E-05	0.36859E-06
0.39663E 01	0.36233E 05	0.28849E-02	0.10453E 03
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0.43873E 04	0.30596E 07	0.30452E-05	0.36864E-06
0.39658E 01	0.36243E 05	0.30122E-02	0.10917E 03
0.22483E 05	0.10064E 01	0.16537E 03	0.23836E-04
-0.18715E-03	0.26796E 00	0.17401E-02	0.10674E-01
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0.43873E 04	0.30594E 07	0.30446E-05	0.36861E-06
0.39660E 01	0.36238E 05	0.31418E-02	0.11385E 03
0.23691E 05	0.10993E 01	0.17498E 03	-0.59520E-04
0.13732E-03	0.26795E 00	0.11290E-02	0.10206E-01
0.32048E 01	-0.11463E 01	0.16196E-01	0.95875E 00
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0.43873E 04	0.30594E 07	0.30447E-05	0.36861E-06
0.39660E 01	0.36238E 05	0.32068E-02	0.11621E 03
0.24295E 05	0.11465E 01	0.17919E 03	-0.15637E-04
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0.43873E 04	0.30594E 07	0.30447E-05	0.36861E-06
0.39660E 01	0.36238E 05	0.32150E-02	0.11651E 03
0.24371E 05	0.11524E 01	0.17969E 03	-0.45516E-05
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0.24408E 05	0.11553E 01	0.17994E 03	-0.11849E-05
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0.43873E 04	0.30594E 07	0.30447E-05	0.36861E-06
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0.43873E 04	0.30594E 07	0.30447E-05	0.36861E-06
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0.43873E 04	0.30594E 07	0.30447E-05	0.36861E-06
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0.43873E 04	0.30594E 07	0.30447E-05	0.36861E-06
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0.43873E 04	0.30594E 07	0.30447E-05	0.36861E-06
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0.43873E 04	0.30594E 07	0.30447E-05	0.36861E-06
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0.43873E 04	0.30594E 07	0.30447E-05	0.36861E-06
0.39660E 01	0.36239E 05	0.62406E-02	0.22615E 03
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0.99646E 01	-0.29577E 01	-0.35920E-03	0.57837E 00
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0.43873E 04	0.30594E 07	0.30447E-05	0.36861E-06
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-0.19383E-03 0.26795E 00 0.42930E-06 0.28195E-02

0.14566E 02 -0.41907E 01 -0.50893E-03 0.32218E 00
0.16737E 02 0.74550E-06 0.68924E-02 0.22501E-02
0.43873E 04 0.30594E 07 0.30447E-05 0.36861E-06
0.39660E 01 0.36239E 05 0.12085E-01 0.43794E 03
0.63067E 05 0.41907E 01 0.18001E 03 -0.52045E-05
-0.16775E-03 0.26795E 00 0.81071E-06 0.26533E-02

0.14920E 02 -0.42856E 01 -0.52045E-03 0.30250E 00
0.17137E 02 0.43370E-06 0.68924E-02 0.21099E-02
0.43873E 04 0.30594E 07 0.30447E-05 0.36861E-06
0.39660E 01 0.36239E 05 0.12888E-01 0.46703E 03
0.64275E 05 0.42856E 01 0.18001E 03 -0.68415E-05
-0.14020E-03 0.26795E 00 0.11127E-05 0.24880E-02

0.15274E 02 -0.43804E 01 -0.53196E-03 0.28282E 00
0.17537E 02 0.0 0.68924E-02 0.19704E-02
0.43873E 04 0.30594E 07 0.30447E-05 0.36861E-06
0.39660E 01 0.36239E 05 0.13800E-01 0.50010E 03
0.65483E 05 0.43804E 01 0.18001E 03 -0.94807E-05
-0.11275E-03 0.26795E 00 0.12383E-05 0.23235E-02

0.15628E 02 -0.44752E 01 -0.54348E-03 0.26314E 00
0.17937E 02 0.0 0.68924E-02 0.18315E-02
0.43873E 04 0.30594E 07 0.30447E-05 0.36861E-06
0.39660E 01 0.36239E 05 0.14847E-01 0.53802E 03
0.66691E 05 0.44752E 01 0.18001E 03 0.68809E-05
-0.86860E-04 0.26795E 00 0.13652E-05 0.21597E-02

0.15982E 02 -0.45701E 01 -0.55500E-03 0.24346E 00
0.18337E 02 0.0 0.68924E-02 0.16931E-02
0.43873E 04 0.30594E 07 0.30447E-05 0.36861E-06
0.39660E 01 0.36239E 05 0.16060E-01 0.58200E 03

0.67899E 05 0.45701E 01 0.18001E 03 -0.10090E-04
-0.63853E-04 0.26795E 00 0.13434E-05 0.19965E-02

*** SUBSCRIPT OUT OF RANGE ***
CALCULATIONS FOR STREAMLINE NO. 2 DISCONTINUED

THE CALCULATIONS FOR 2 STREAMLINES HAS BEEN COMPLETED
PROGRAM TERMINATING