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## NSEG - A SEGMENTED MISSION ANALYSIS PROGRAM FOR LOW AND HIGH SPEED AIRCRAFT

### Volume II - Program Users Manual

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TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
1	INTRODUCTION-----	1
2	PROGRAM STRUCTURE-----	2
3	SUBROUTINE LIST-----	3
4	DATA DECK STRUCTURE-----	23
5	ATMOSPHERE OPTIONS-----	25
	5.1 Data Input for Atmosphere-----	25
6	PROPULSION-----	27
	6.1 Simplified Propulsion Systems - Introduction-----	27
	6.1.1 Relevant Subroutines-----	28
	6.1.2 Data Input-----	29
	6.1.2.1 General-----	29
	6.1.2.2 Dry Power, CASEN = 1-----	29
	6.1.2.3 Wet Power, CASEN = 2-----	30
	6.1.2.4 Maximum Power, CASEN = 3-----	31
	6.1.2.5 Automatic Propulsion Switching, CASEN = 4-----	31
	6.2 Turbojet, Ramjet and/or Combined Engines with Inlet Pre-Compression Effects (Combined Engine Option)-----	32
	6.2.1 Analytical Description-----	32
	6.2.1.1 Freestream Properties-----	33
	6.2.1.2 Flowfield Conditions at Station 1-----	33
	6.2.1.3 Inlet and Ram Force Computations-----	33
	6.2.1.4 Flowfield Conditions at Station 2-----	34
	6.2.1.5 Turbojet Airflow, Fuel Flow, and Thrust Computations-----	34
	6.2.1.6 Ramjet Airflow, Fuel Flow, and Thrust Computations-----	37
	6.2.2 Usage-----	39
	6.2.3 Input Data for Dual Engine Option-----	40
7	AERODYNAMICS-----	45
	7.1 Introduction-----	45
	7.2 Aerodynamic Subroutines-----	46
	7.3 Data Input-----	46
	7.3.1 General-----	46
	7.3.2 Aerodynamics Option 8-----	47
	7.3.3 Aerodynamics Option 9-----	48
8	LANDING AND TAKE-OFF CALCULATION-----	50
	8.1 Data Input, Take-Off-----	50
	8.2 Data Input, Landing-----	51

## TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
9	MISSION SEGMENT OPTIONS -----	52
	9.1 Option 1. Climb or Descent Path -----	53
	9.2 Option 2. Maximum Rate of Climb or Maximum Range Descent Path -----	55
	9.3 Option 3. Radius Mission Option -----	57
	9.4 Option 4. Cruise Climb to a Specified Weight ----	58
	9.5 Option 5. Cruise Climb for Specified Range or Time -----	59
	9.6 Option 6. Constant Altitude Cruise to a Specified End Weight -----	60
	9.7 Option 7. Constant Altitude Cruise for a Specified Range -----	61
	9.8 Option 8. Constant Altitude Cruise for a Specified Time -----	62
	9.9 Option 9. Buddy Refuel -----	63
	9.10 Option 10. Mach-Altitude-Weight Transfer -----	65
	9.11 Option 11. NSEG Logic Option -----	66
	9.12 Option 12. Instant Weight Change -----	67
	9.13 Option 13. Instant Mach-Altitude Change -----	68
	9.14 Option 14. General Purpose and Point Condition Calculation Option -----	69
	9.15 Option 15. Iterate to Fly a Specified Distance --	73
	9.16 Option 16. Climb or Accelerate -----	74
	9.17 Option 17. Fuel Weight Change for Time, Turn, Combat, etc. -----	76
	9.18 Option 18. -----	77
	9.19 Option 19. -----	78
	9.20 Option 20. Fuel Allowance -----	79
	9.21 Option 21. Dual Engine Scaling -----	80
	9.22 Option 22. Generalized Iteration Control Segment	82
10	PRINT CONTROL INDICATORS -----	84
11	ALPHABETIC LIST OF INPUT AND INTERNAL VARIABLES -----	85
12	FLIGHT PATH INEQUALITIES -----	117
13	GENERALIZED PERFORMANCE ANALYSIS -----	118
	13.1 Contour Plotting Data and Options -----	118
	13.1.1 Specific Energy Time Derivative, $\dot{E}$ -----	120
	13.1.2 Specific Energy/Fuel Flow, $\dot{E}/\dot{m}$ -----	120
	13.1.3 Lift/Drag, $L/D$ -----	120
	13.1.4 Range Factor, $R_F$ -----	120
	13.1.5 Thrust -----	120
	13.1.6 Drag -----	121
	13.1.7 Specific Fuel Consumption, SFC -----	121
	13.1.8 Fuel Flow Rate, $\dot{m}$ -----	121

## TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
13 (cont'd)	
13.1.9 Specific Energy -----	121
13.1.10 Lift/(Thrust-Drag), L/(T-D) -----	121
13.1.11 Turn Radius -----	122
13.1.12 Time to Turn -----	122
13.2 Organized Mission Segments and Flight Envelope --	123
13.2.1 Flight Envelope Calculation -----	123
13.2.2 Climb Path History -----	123
13.2.3 Endurance vs. Weight at Several Altitudes -----	123
13.2.4 Optimum Cruise Climb vs. Weight at Various Mach Numbers -----	123
13.2.5 Constant Altitude, Constant Mach Cruise at Various Weights -----	124
13.2.6 Take-Off and Landing Calculations -----	124
13.2.7 ML/D Calculation at Given Altitude, Various Mach Numbers and $C_L$ Values -----	124

## LIST OF FIGURES

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
1	NSEG Overlay Structure-----	125
2	Basic NSEG Data Output-----	126
3	Some Possible Additional NSEG Data Blocks-----	127
4	Flow Chart, ENCASE-----	128
5	Flow Chart, ENDAT-----	129
6	Flow Chart, ENSET-----	132
7	Reference Stations and Geometry-----	135
8	Spillage Lift and Drag Computations-----	136
9	Typical Table Data-----	137
10	Flow Chart, Subroutine ENGINS-----	140
11	Flow Chart, Subroutine DRAG-----	161
12	Flow Chart, SACNS1-----	162
13	Flow Chart, Subroutine SACSN2-----	163
14	Flow Chart, SACSP-----	164
15	Flow Chart, SACTP-----	165
16	Path Finder Options of NSEG Mission Option 1-----	166
17	EDOT Map-----	167
18	Flow Chart, FLITEN-----	168

## PREFACE

The NSEG program was originally constructed by Mr. L. H. Leet of the United States Air Force Aeronautical Systems Division, Wright-Patterson Air Force Base. The code was subsequently modified and extended by Aerophysics Research Corporation under contract F33615-73-C-3039. The current version of the NSEG (Version III) extends the program applicability to higher speed (hypersonic turbo-ramjet) aircraft. It also includes various improvements generated by Mr. David T. Johnson of the Air Force Flight Dynamics Laboratory. The authors wish to extend their thanks to Mr. Walter Vahl of NASA for his extensive assistance during formulation and checkout of the turbo-ramjet propulsion system model now available in NSEG. The analytic basis of the turbo-ramjet model is due to Mr. Vahl.

Mr. D. S. Hague of Aerophysics Research Corporation served as project leader for the present study. Dr. H. L. Rozendaal provided specialist support in the fields of propulsion system analysis and computer sciences. Mr. R. T. Jones, formerly of Aerophysics Research Corporation, has also made significant contributions to the NSEG code in studies preceding the present one.

Additional details and copies of the program deck can be obtained from NASA Langley Research Center.



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**1. INTRODUCTION**

Program NSEG is a rapid mission analysis code based on the use of approximate flight path equations of motion. Equation form varies with the segment type, for example, accelerations, climbs, cruises, descents, and decelerations. Realistic and detailed vehicle characteristics are specified in tabular form and a variety of layered atmosphere options are available. The mission specification is open-ended in that the upper limit on the number of flight segments to be included in a mission profile (currently one hundred and forty-nine) can be increased by increasing the size of a single common block (COMTAB) above its current size of 3000 words. The code contains an English language oriented input procedure for describing the mission segment sequence to be employed. In addition to its mission performance calculation capabilities the code also contains extensive flight envelope performance mapping capabilities. For example, rate-of-climb, turn rates, and energy maneuverability parameter values may be mapped in the Mach-altitude plane. Where suitable graphics capabilities exist these maps may be drawn by machine in the form of contour plots.

The code contains several approximate flight path optimization capabilities based on Rutowski energy-like criteria. These flight path optimization formulations permit inclusion of minimum time or fuel flight segments and maximum range segments during climb or descent segments. Approximate take off and landing analyses are also performed. At high speeds centrifugal lift effects are accounted for. Extensive turbojet and ramjet engine scaling procedures are incorporated in the code. Take off and landing analyses are also available which employ a high lift aerodynamic analysis model based on the Air Force Flight Dynamics Laboratory DATCOM method. Alternatively, user supplied high lift aerodynamics can be employed.

This report is Volume II of 3 volumes. Total program documentation consists of:

Volume I. Theoretical Development

Volume II. Program User's Manual

Volume III. Test Problems

## 2. PROGRAM STRUCTURE

NSEG has eight overlays. Program structure is defined in Figure 1. The main control program is NSEG II. This program calls the next level of overlay, 1.0, 2.0, and 3.0 directly. Overlays 3.1 and 3.2 are, in turn, directly called from the program MISION of overlay 3.0. The remaining two overlays, 3.3 and 3.4, are called from subroutine FLITEN which is also directly called from program MISION.

Gross functions of each overlay are as follows:

OVERLAY 0.0, NSEG II - Main controlling program.

OVERLAY 1.0, INISEG - Initialize the program including common blocks and input directories.

OVERLAY 2.0, INSEG - Read the input data.

OVERLAY 3.0, MISION - Control program for mission and performance calculations.

OVERLAY 3.1, OUTATM - Controls printout of the atmospheric properties employed.

OVERLAY 3.2, ENSEG - Controls generalized performance calculations.

OVERLAY 3.3, FLIRAN - Generates data for performance contour maps.

OVERLAY 3.4, FLIMAP - Produces performance contour maps.

The program consists of approximately ten boxes of cards (twenty thousand source cards). Coding is predominantly written in the algebraic FORTRAN language. The program currently operates on the CDC 6400 and 6600 series computers. Core requirement depends strongly on the computer center at which the program is run. At Lawrence Radiation Center the retractable binary loads are 115000<sub>8</sub>, at the Control Data Cybernet Centers 135000<sub>8</sub>, and at Langley Research Center 150000<sub>8</sub>.

Constants utilized in the NSEG code employ English Units (lb., ft., sec., naut. mi., and degrees Rankine) exclusively. It is imperative therefore that input quantities employ English Units; constants utilized in the illustrations reproduced in the text reflect this convention. Provisions of NASA Policy Directive (NPD 220.4) have been waived for those portions of this report that pertain to the NSEG computer code.

### 3. SUBROUTINE LIST

**AHMACH** Writes out the z array which contains scaled engine data vs. Mach number and altitude.

**ALTA** Entry point in ATMOSD

**ASCALE** Constructs the z array from the atmosphere routine

**ATMOSD** Controls atmospheric property calculations

**ATMOS3** 1962 standard atmosphere (Original NSEG)

**ATMOS9** Arbitrary temperature profile atmosphere

**ASRCH** Looks for a table location associated with a given starting location in common block /TABNAM/ which contains names and locations of input table names and data, respectively.

**AUGMT** Dummy routine to supply thrust augmentation

**BCDDEC** Part of input procedure

BCDINT Part of input procedure

BERAN Calculates altitude for maximum range factor given Mach number and weight

BSCALE Assists in setting up the Z array (see AHMACH) from the atmosphere routine

CBFUEL Computes time to turn through specified angle; in Option 17 Combat

CHANGE Sets NSR to zero

CHECK Provides instantaneous conditions when lift equals weight

CHMACH Writes out the z array (see AHMACH)

CHRUNUM Detects illegal input characters on data cards

CLIMB Calculates climbs and descents

**COMPAC**      **Compacts card images**

**CMAX**      **Calculates Mach number for maximum rate of climb or minimum fuel climb given altitude and weight**

**CONPLT**    **Contour plotting routine for performance maps in overlay 3.4**

**CRCOMP**    **Computes range factor optional**

**CSCALE**    **Sets up atmospheric z array**

**DBOUT**     **Sets up tape 25**

**DISCØT**    **Two dimensional table lookup subroutine**

**DORDER**    **Sorts input list in alphabetic and numeric order**

**DRAG**      **Aerodynamic control routine**

**DSERCH**    **Carries out directory search for input**

**DUMPRG** Dumps the RG array, the array which contains data relative to completed segments (e.g. option, range, weight, fuel, etc.)

**DUMPTZ** Dumps the TZ array, the array which contains data necessary for the serial execution of flight path segments as specified by input data

**EDMIPT** Locates maximum performance criteria along specific energy contour

**EDCLMB** Performs maximum  $\dot{E}$  climb

**EMAX** Calculates Mach number for maximum endurance given weight and altitude

**ELT** Provides elapsed computer time computation

**ENCASE** Controls automatic selection of propulsion option.

**ENDAT** Calculates thrust and specific fuel consumption

**ENERGY** Computes energy maneuverability parameters at specified G-level, Mach number, weight, and altitude

**ENGINS** Engine simulation subroutine for the turbojet, ramjet and/or combined engine propulsion option.

*ENSEG*      *Controls mission simulations*      *(Program)*

—

ENSET      Modifies input propulsion data basis for tabular thrust and  
fuel flow option

ERROR      Reports table errors to user

FCLMAX      Finds  $C_L$  Max

FLYMP      Flies the vehicle between two M-h points

FETCH      Reads each input card

FILLPM      Initializes vehicle data mission segment options

FILBCD      Part of input routine

FNLOSS      User supplied routine to given propulsion losses

FUELIF Computes in-flight fuel used, its disposition, tank drop times,  
and fuel remaining

FILLTZ Fills the C array from the term array and gives optional print  
of term array. The term array is a 10 word array of segment-  
related data created by the input option selected (INXX1-INSS21).  
The C array contains the term arrays in serial fashion for  
subsequent mission execution.

FLIMHC Constant altitude-constant Mach number cruise

FLITEN Controls generalized performance calculations

FLIMAP *Controls performance plots (Program)*

FLIRAN *Controls generalized performance calculations (Program)*

FLIENV Given weight and a set of Mach numbers, computes flight envelope

FLIXEP Computes endurance performance

FLIXPR Begins range performance calculations



FLIXCP      Computes climb performance

FLITOL      Controls take-off and landing calculation

FLIMLD      Computes range factor performance

FUELLD      Computes initial fuel load, its disposition, and useable fuel  
load

GT1112      Part of table look up routine

GOGO        Calculates constant Mach or  $C_L$  cruises where independent variable  
is time or distance

HDAMPT      Finds maximum of performance criteria at constant altitude

HDCLMB      Flies maximum rate of climb path

HIHO        Controls N dimensional table look up routine



**LINES** Controls the number of lines printed on each page

**LISTZL** Notates a plot

**LNCLMB** Controls linear Mach-altitude path calculation

**MAP01** Prepare E map

**MAP02** Prepares E/m map

**MAP03** Prepares L/D Map

**MAP04** Prepares range factor map.  $\left(\frac{V}{SFC}\right) \left(\frac{L}{D}\right)$

**MAP05** prepares thrust map

**MAP06** Prepares drag map

MAP07      Prepares specific fuel consumption map

MAP08      Prepares fuel flow map

MAP09      Prepares specific energy map

MAP10      Prepares lift/(thrust-drag) map

MAP11      Prepares radius of turn map

MAP12      Prepares time to turn map

MAPOUT     Controls map outputs

MDCLMB     Flies best acceleration path

MDHPT      Finds maximum performance criteria at constant Mach number

MHPTAB      Outputs Mach-altitude path histories in tabular form

MHPATH      Draws a Mach-altitude path

MISION      *Main program for Overlay 3*, which performs all flight path and flight envelope calculations

NDATA1      Directory of input data

NDATA2      Directory of table names

NDATA3      Extension of input data directory

NDATA4      Contains data (temperature and pressure vs. altitude) to describe an arbitrary atmosphere used in ATMOS9

NDTLV      N-dimensional table look-up routine

OBSHOK      Given supersonic flow properties ahead of a wedge this routine computes flow properties behind the resulting shock wave. Two dimensional isentropic flow is assumed

OPTXXI      Performs Option 1 calculation, climb or descent path

OPTXX2      Performs Option 2 calculation, maximum rate of climb or minimum sink rate

- OPTXX3 Performs Option 3 calculation, radius mission option
- OPTXX4 Performs Option 4 calculation, cruise climb to specified weight
- OPTXX5 Performs Option 5 calculation, cruise climb for specified range or time
- OPTXX6 Performs Option 6 calculation, constant altitude cruise to specified end weight
- OPTXX7 Performs Option 7 calculation, constant altitude cruise for a specified range
- OPTXX8 Performs Option 8 calculation, constant altitude cruise for a given time
- OPTXX9 Performs Option 9 calculation, buddy refuel
- OPTX10 Performs Option 10 calculation, transfer Mach-altitude weight

- OPTX11 Performs Option 11 calculations, NSEG segment selection logic
- OPTX12 Performs Option 12 calculation, instantaneous weight change
- OPTX13 Performs Option 13 calculation, instantaneous Mach-altitude change at constant weight
- OPTX14 Performs Option 14 calculations, restores previous state or computes point calculation
- OPTX15 Performs Option 15 calculation, adjust range in previous segment to give specified total range
- OPTX16 Performs Option 16 calculation, climb/accelerate between specified M-h points
- OPTX17 Performs Option 17 calculations, fuel weight change in warm up, take-off, loiter, or combat
- OPTX18 Performs a store drop





PERPLT      Control program for the twelve performance maps

PHMACH      Provides organized print of Z array (see AHMACH)

PICINX      Mission segment input control routine

PLWDRP      To be used for payload drop

PNAMES      Writes directory of input names

QCLIMB      Computes constant dynamic pressure climb

QBOUND      Imposes dynamic pressure boundary limits on plots

RETRNW      Computes aircraft return weight

RFMAX      Computes Mach number and altitude combination for best range  
factor given weight; or Mach number for best range factor given  
altitude and weight

**RGSAVE** Saves the RG array (see DUMPRG); the RG array will be printed if IPRGSV is nonzero

**RNSEG** Input main control program

**RPOLY** Computes the roots of a polynomial, given the polynomial coefficients

**RUN** Calculates cruise paths

**SACSP** Store and pylon aerodynamics

**SACTP** Tank and pylon aerodynamics

**SACNS1** NSEG Option 1 clean vehicle aerodynamics

**SACNS2** NSEG Option 2 clean vehicle aerodynamics

**SEGINI** Initialize segment calculation

**SEGOUT** Outputs segment calculations on Unit 6 and Unit 15 in observation function style

SEYIC     Initializes Y, Y1, Y2, Y3 arrays

SHELL     Sorts array of names into algebraic order

SHELLX    Sorts array of values into numeric order

SLVALU    Part of table look up package

STASH     Utility routine in input procedure

STORES    Computes the number of stores *dropped* and the dropped weight

STORWT    Computes total store drop and return weights

TABRE     Controls table data read

TABUP1    Part of table look up routine

TAKEOF Prints take-off data input

TAKOFF Carries out take-off calculation and outputs result

TANKS Computes current number of tanks and pylons dropped and their drop weight

TNKSWT Computes total tank drop and return weight

TLAERO Take-off and landing aerodynamics option

TLU1 Two-dimensional table look up

TOP Calculates ceiling for a given rate of climb and weight

TLU Two-dimensional table look up routine

TSRCH      Compiles starting locations for data tables in common block  
COMTAB and stores these locations in common block TABNAM

TZRGDB     Writes TZ and RG arrays on Unit 25

UNPACK     Unpacks the MTZ array and writes the results and the TZ array  
on Unit 6

UNIT25     Controls input and output for generalized performance calcu-  
lations

VMAX       Calculates maximum Mach number for steady level flight given  
altitude and weight

VOIDXX     Sets weight, altitude, and Mach number from RG array

XALT       Computes altitude for a given pressure ratio

XCEL       Calculates constant altitude accelerations and decelerations

XCLECT     Selects the next mission segment option and passes on the TZ  
and RG arrays

**XFIT2**      **Second order curve fit routine**

**XNLTST**    **Searches card image for non-numeric character**

**XTRACT**    **Decomposes card images**

**XXINIT**    **Initializes the XX array**

#### 4. DATA DECK STRUCTURE

The basic NSEG data deck is presented in Figure 2. Major input blocks are

1. Three TITLE cards. The three TITLE cards will be used as a heading and will appear on all regular NSEG print out pages along with a page number.
2. STCASE/TABSIZ/. This data set is used to reserve space in the internal table array for the various tables to be used during the computer run.
3. STCASE/DATA1/. This data set is used to specify values for all vehicle characteristic tabular data and data used to control the print output of the program.
4. STCASE/GENPC/. This data set is used to specify data for the general performance calculations and/or performance maps. This data set is optional and need only be included if general performance calculations and/or performance maps are to be generated.
5. STCASE/MSEG/. This data set is used to specify details of the mission to be flown.
6. RUN. The run card is the indicator to the NSEG input package to stop reading data and execute the task defined by the data just processed.

Additional data cases may follow the run card; however, the following deck structure must be observed:

1. Each case must start with three title cards.
2. The STCASE/TABSIZ/ data set need not be repeated in subsequent cases unless the table sizes are to be altered. If the STCASE/TABSIZ/ data set is included in a subsequent case, then *all* tabular data must be input in that case since the starting locations for the various tables were redefined by the STCASE/TABSIZ/ data set.
3. The STCASE/DATA1/ data set need not be repeated in subsequent cases unless data items in that set are to be altered. It should be noted that all variables will have the same value as established by the previous case unless they are changed by a data card in the current case. Therefore, only data items whose values are to be changed need be given in the current case.

- d. The STCASE/GENPC/ data set is destroyed at the end of each case; therefore, if general performance calculations are required in a subsequent case, all data necessary to define the desired performance calculations must be input each time.

Some typical examples of additional NSEG data sets are presented in Figure 3.



## 5. ATMOSPHERE OPTIONS

NSEG contains the original NSEG 1962 U. S. Standard Atmosphere and an arbitrary layered atmosphere in which the temperatures or temperature and pressure at the base of each layer are input. Aerophysics Research Corporation has the following atmospheric models available in NSEG format on request.

1. ATMOS1: 1962 U. S. Standard Atmosphere, from AFFDL Gentry Arbitrary Hypersonic Body Program
2. ATMOS2: 1962 U. S. Standard Atmosphere, from Langley Research Center STOP program for supersonic transport optimization
3. ATMOS3: 1962 U. S. Standard Atmosphere; analytic model from original NSEG
4. ATMOS4: 1963 Patrick Air Force Base atmosphere
5. ATMS59: 1959 ARDC atmosphere
6. ATJAN6: 1966 January atmosphere at 30° North
7. ATJUL6: 1966 July atmosphere at 30° North
8. ATMS62: 1962 atmosphere from AFFDL ATOP program
9. ATMOS9: arbitrary atmosphere

As noted above, only atmospheric models 3 and 9 are now an integral part of NSEG. The other atmospheric models can be added and called from ATMOSD by a simple program addition.

### 5.1 Data Input for Atmosphere

IPATMD           = 0, Don't print out atmosphere model  
                  = 1, Print out atmosphere model

INDATM           = 3, Use ATMOS3  
                  = 9, Use ATMOS9

When INDATM = 9, the following additional data is required:

NHG              = Number of layers; nominally not to exceed 25

HG<sub>i</sub>             = Array of altitude values, in feet

TM<sub>i</sub>             = Array of temperature values, ° F absolute

= Array of pressures, lb./ft.<sup>2</sup>. NOTE that pressures can be determined from sea level pressure and temperature profile.  
In this case set

HG<sub>1</sub> = -16505.

TM<sub>1</sub> = Desired temperature profile

PG<sub>1</sub> = 3711.0839

## 6. PROPULSION

### 6.1 Simplified Propulsion Systems - Introduction

The simplified propulsion options in NSEG provide for the computation of a vehicle's thrust force and fuel consumption primarily by table lookup procedures. Any one of three propulsion systems, dry, wet, or maximum, may be employed at any instant along the flight path. Provision is made for automatically switching from one propulsion system to another on Mach number. Alternatively, the user may directly specify which of the three propulsion systems is to be employed.

In all options the thrust force,  $F_N$ , is specified in the form

$$F_{N_i} = F_{N_i}(h, M); \quad i = 1, 2, 3$$

In the first two options the fuel flow rate

$$\dot{F}F = \dot{F}F(PS, M, h); \quad i = 1, 2$$

In the third option

$$\dot{F}F_3 = \dot{F}F_3(h, M)$$

In the automatic Mach number propulsion system switching mode, the following sequence is employed

$$F_N, \dot{F}F = \begin{cases} F_{N_1}, \dot{F}F_1; & M \leq 1.0 \\ F_{N_3}, \dot{F}F_3; & 1.0 < M \leq 3.5 \\ F_{N_2}, \dot{F}F_2; & M > 3.5 \end{cases}$$

Within the program the propulsion system input is scaled by appropriate factors to produce the following modified thrust and fuel flow data

$$\begin{aligned} (F_N)'_i &= F_{N_i}/DR \quad ; \quad i = 1, 2, 3 \\ (\dot{F}F)'_i &= \dot{F}F_i/(100 \times TR^{1.5}) \quad ; \quad i = 1, 2 \\ (\dot{F}F)'_3 &= \dot{F}F_3/TR^{1.5} \end{aligned}$$

where DR is the atmospheric density ratio and TR is the atmospheric temperature ratio.

In the dry and wet options ( $i = 1$  and  $2$ , respectively), the power setting is specified as a percentage of maximum; hence, the factor of 100 in the scaling equations for fuel flow in the cases  $i = 1$  and  $2$ . Again, in the dry and wet options, three power setting options are possible. These correspond to

$$F_N = \begin{cases} \text{Maximum available in system} \\ \text{Required to equal drag} \\ \text{Specified value of power setting} \end{cases}$$

The corresponding fuel flows are determined from the power setting

$$PS = FN / (FN \text{ Maximum Available})$$

*It should be noted that power setting data is specified in the mission segment options of Sections 9.1 - 9.20 and hence does not form part of the basic propulsion system input.*

### 6.1.1 Relevant Subroutines

The subroutines of particular significance in the simplified propulsion system calculations are listed below,

- AHMACH - Used to *write out* the input and scaled thrust data in an organized manner. It is called from the propulsion system scaling routine ENSET.
- ASCALE - Used to *scale* the input thrust data. All input thrust data for the dry, wet, and maximum thrust options are divided by density ratio. This data resides in TTAB01, TTAB03, and TTAB05. Called from ENSET.
- BSCALE - Used to *scale* the input fuel flow data in the dry and wet options. All input fuel flow data in TTAB02 and TTAB04 is scaled by dividing by  $(100 \times \text{temperature ratio} ** 1.5)$ . Called from ENSET.
- CSCALE - Used to *scale* the input fuel flow data in the maximum power option. Input fuel flow data in TTAB06 is divided by  $(\text{temperature ratio} ** 1.5)$ . Called from ENSET.
- CHMACH - Used to *write out* the input and scaled fuel flow data for the maximum thrust case in an organized manner. Called from ENSET.
- ENCASE - Controls automatic propulsion system switching on the basis of Mach number. Called from ENDAT.
- ENDAT - Performs the actual thrust and fuel flow calculations. It is called from a variety of mission segment and point performance calculations.
- ENSET - Controls the initial propulsion system input scaling and optional print out.
- PHMACH - Used to *write out* the input and scaled fuel flow data for the dry and wet cases in an organized manner. Called from ENSET.

Flow charts for ENCASE, ENDAT, and ENSET are presented in Figures 4, 5, and 6.

## 6.1.2 Data Input

### 6.1.2.1 General

<u>SYMBOL</u>	<u>DESCRIPTION</u>
CASEN	Engine option indicator: = 1, dry = 2, wet = 3, maximum = 4, automatic selection on Mach number
FFLMIN	Minimum fuel flow
IPENDR	Raw engine data print indicator: = 0, omit raw data print = 1, print raw data
IPENDS	Scaled engine data print indicator: = 0, omit scaled data print = 1, print scaled data
NUMENG	Number of engines
PSET	Power setting indicator: = 1, maximum thrust in CASEN = 1, 2, or 3 = 2, minimum thrust in CASEN = 1, 2, or 3 = 3, specified power setting in CASEN = 1, 2, or 3
SFCFAC	Multiplier for SFC value
TSIZEF	Engine scale factor
THRMIN	Minimum thrust

### 6.1.2.2 Dry Power, CASEN = 1

<u>SYMBOL</u>	<u>DESCRIPTION</u>
INDT01	Thrust table indicator: = 0, no thrust = 1, thrust data given
TTAB01	Maximum dry thrust: $T = T(h, M)$
IT01X	Number of altitude values in TTAB01

<u>SYMBOL</u>	<u>DESCRIPTION</u>
IT01Y	Number of Mach number values in TTAB01
INDT02	Fuel flow table indicator: = 0, no fuel flow = 1, fuel flow data given
TTAB02	Dry thrust fuel flow Table in form of S.F.C.  $W = W(\text{PSD}, M, h)$ where PSD is per cent maximum
IT02X	Number of PSD values in TTAB02
IT02Y	Number of Mach number values in TTAB02
IT02W	Number of altitudes in TTAB02

6.1.2.3 Wet Power, CASEN = 2

<u>SYMBOL</u>	<u>DESCRIPTION</u>
INDT03	Thrust table indicator: = 0, no thrust = 1, thrust data given
TTAB03	Maximum wet thrust:  $T = T(h, M)$
IT03X	Number of altitude values in TTAB03
IT03Y	Number of Mach number values in TTAB03
INDT04	Fuel flow table indicator: = 0, no fuel flow = 1, fuel flow data given
TTAB04	Wet thrust fuel flow table in form of S.F.C.  $\dot{W} = \dot{W}(\text{PSD}, M, h)$ where PSD is per cent maximum
IT04X	Number of PSD values in TTAB04
IT04Y	Number of Mach number values in TTAB04
IT04W	Number of altitude values in TTAB04

6.1.2.4 Maximum Power, CASEN = 3

<u>SYMBOL</u>	<u>DESCRIPTION</u>
INDT05	Thrust table indicator: = 0, no thrust = 1, thrust data given
TTAB05	Maximum power thrust table  $T = T(h, M)$
IT05X	Number of altitude values in TTAB05
IT05Y	Number of Mach number values in TTAB05
INDT06	Fuel flow table indicator: = 0, no fuel flow = 1, fuel flow data given
TTAB06	Maximum power fuel flow table in form of S.F.C.  $\dot{W} = \dot{W}(h, M)$  (Max. PS data only)
IT06X	Number of altitude values in TTAB06
IT06Y	Number of Mach number values in TTAB06

6.1.2.5 Automatic Propulsion Switching, CASEN = 4

When CASEN = 4.0, the propulsion option is internally switched among CASEN = 1, 2, and 3 according to Mach number as follows:

<u>Mach</u>	<u>CASEN</u>
0 - 1.0	1.0
1.0 - 3.5	3.0
> 3.5	2.0

## 6.2 Turbojet, Ramjet and/or Combined Engines with Inlet Precompression Effects (Combined Engine Option)

The turbojet, ramjet and/or combined engine simulation option provided in NSEG by the ENGINs subroutine provides a more realistic engine simulation option than those described in Section 6.1 due to the following features:

1. Inlet flow field precompression effects due to airstream flow deflection are accounted for in thrust calculations.
2. A more accurate description of engine performance is provided by tabular engine data. (see 6.2.3)
3. Turbojet only, ramjet only, or turbojet/ramjet combination engine options are provided; in-flight option selection as a function of Mach number can be employed.
4. Engine-related lift and drag forces are computed and accounted for in the net thrust and the desired vehicle lift.
5. High altitude and Mach number atmospheric properties related to engine performance are described by tabular data.

The following sections provide an analytical description of the turbojet, ramjet and/or combined engine propulsion option and complete user-related information.

### 6.2.1 Analytical Description

The basic assumption of two-dimensional flow is employed in the turbojet, ramjet and/or combined engine simulation subroutine. The geometry and various flow regions relevant to the simulation are shown in Figure 7. The computations performed are divided into seven main categories as follows:

1. Free stream properties at Station 0 which are a function of aircraft Mach number and altitude.
2. Flow field conditions at Station 1, aft of the wing shock.
3. Inlet computations which yield the turbojet inlet recovery ratio and ram drag.
4. Flow field conditions at Station 2, aft of the engine inlet wedge shock.
5. Turbojet thrust, airflow, and fuel flow computations, a function of flow field conditions at Stations 1 and 3 (at the turbojet compressor face) and throttle setting.
6. Ramjet thrust and fuel flow computations, a function of flow field conditions at Station 2 and  $M_0$ .



7. Spillage drag computations, if any, are performed either in the turbojet iteration loop for the turbojet alone engine option or in the ramjet iteration loop for the ramjet alone engine option, or the combined engine option.

Details of these computations are described in the following text.

#### 6.2.1.1 FREESTREAM PROPERTIES

For freestream conditions where  $M \geq 3.5$  and altitude exceeds 19812 meters (65000 ft), real gas freestream total pressure ( $p_{t0}$ ) and total temperature ( $T_{t0}$ ) values are computed by the two-dimensional table lookup subroutine DISCOT. Linear interpolation is utilized. Plots typical of these data appear in Figure 9. Freestream total pressure in p.s.f. is then given by

$$P_{t0} = 2116.22 * p^* \quad (p^* \text{ in atmospheres})$$

If the above Mach-altitude conditions are not satisfied, total temperature and total pressure values are computed by first determining freestream static conditions ( $p_0, T_0$ ) from the 1962 Standard Atmosphere Subroutine ATMS62. Static enthalpy ( $H$ ) and pressure ratio ( $p_{r0}$ ) are then determined from Table II, given the static temperature. Total enthalpy ( $H_t$ ) can next be computed by the expression

$$H_t = H + (M_0 * a_0)^2 / 50073.2$$

Given total enthalpy, the freestream total temperature and total pressure ratio ( $p_{rt0}$ ) can be determined from Table II. Freestream total pressure is then  $p_{t0}$  given by

$$P_{t0} = (P_{rt0} / P_{r0}) * P_0$$

#### 6.2.1.2 FLOWFIELD CONDITIONS AT STATION 1

Given the free-stream flowfield parameters at Station 0, their counterparts at Station 1 aft of the wing shock are determined by the two-dimensional isentropic shock relations (NASA Report 1135). These relationships are mechanized in the subroutine OBSHOK which performs oblique shock computations for wedge angles below the critical value and normal shock computations at higher wedge angle values.

#### 6.2.1.3 INLET AND RAM FORCE COMPUTATIONS

Given flowfield parameters at Station 1 and the engine streamtube area, the ram drag is computed from the equation

$$\text{TURBOJET RAM FORCE} = \rho_1 * A_{TJ} * (M_1 * a_1)^2 + A_{TJ} (P_1 - P_0)$$

where  $A_{TJ}$  is the area of the stream tube of the airflow utilized by the turbojet. Ramjet ram forces are accounted for a priori in the ramjet specific impulse data. The ram force computed above, parallel to the vehicle wing under surface, is subsequently resolved into components in the lift and drag directions.

The engine capture ratio ( $A_c/A_{FULL}$ ) is determined from Figure 9, Table III, given  $M_1$ . The air flow rate captured by the inlet then becomes

$$W_{A_c} = W_{AFULL} * (A_c/A_{FULL}) = \rho_1 * A_{INLET} * M_1 * a_1 * (A_c/A_{FULL})$$

Capture ratio less than 1.0 indicates operation at a below design Mach number. As seen in Figure 7 the result of below design operation is that the wedge shock fails to intersect the inlet cowl resulting in inlet air spillage. This spillage produces forces (inlet spillage lift and drag) which are computed using a combination of continuity relationships and geometry as shown in Figure 8.

#### 6.2.1.4 FLOWFIELD CONDITIONS AT STATION 2

Given the flowfield parameters at Station 1, conditions at Station 2 are computed using subroutine OBSHOK as in Section 6.2.1.2 above. That is, the two-dimensional flow behind the precompression (wing) surface shock is turned again through the inlet wedge angle ( $\delta_I$ ).

#### 6.2.1.5 TURBOJET AIRFLOW, FUEL FLOW, AND THRUST COMPUTATIONS

For a base size turbojet, airflow and fuel flow requirements at full throttle are first determined via the one-dimensional table lookup routine FTLUP. The corresponding maximum thrust is determined via the two-dimensional table lookup routine DISCOT. The corrected airflow ( $W\sqrt{\theta}/\delta$ ) requirement is determined from Table V, given the total temperature at Station 3,  $T_{t_3}$ . This value is then used to determine the turbojet airflow at any flight condition by the equation

$$W_A = (W_A)_{corrected} * \frac{\delta}{\sqrt{\theta}} * F_{TJ}$$

where

$(W_A)_{corrected}$  = the base engine corrected airflow rate

$\delta = P_{t_3} / 2116.22$ , ratio of compressor face total pressure to sea level static pressure

$\theta = T_{t_3} / 518.67$ , ratio of compressor face total temperature to sea level static temperature

$F_{TJ}$  = the turbojet scaling factor obtained by specifying  
(1) desired net thrust at sea level standard conditions  
or (2) desired turbojet airflow at sea level standard conditions

Note: It is assumed that  $T_{t_3} = T_{t_2} = T_{t_1} = T_{t_0}$  (Figure 7).

The fuel flow rate to air flow ratio is determined from Figure 9, Table VII, given  $T_{t3}$ . The maximum turbojet thrust to air flow rate is found from Table VI using the two-dimensional table lookup routine DISCOT, given  $T_{t3}$  and the log to the base ten of the ratio of total pressure at Station 3 at the compressor face and a reference turbojet discharge region static pressure  $P_N$  which may be the underwing pressure or the freestream static pressure. The above pressure ratio is obtained by first determining  $P_{t3}/P_{t1}$  from Table IV, given  $M_1$ , and multiplying by  $P_{t1}/P_N$ .

The fuel flow rate, maximum thrust and specific fuel consumption are then computed as follows:

$$(W_f)_{MAX} = W_A * (W_f/W_A)$$

$$F_{MAX} = (F_G/W_A) * W_A$$

$$(SFC)_{MAX} = (W_f)_{MAX} / (F_N)_{MAX}$$

Where  $(F_N)_{MAX}$  is the maximum net thrust of the turbojet given by the expression

$$(F_N)_{MAX} = F_{MAX} - \text{Ram Force}$$

Note that the specific fuel consumption given above has units of (Lb.Fuel/Sec)/Lb.Thrust. The non-standard time unit is employed to be compatible with subsequent weight computations in NSEG. The fuel/air ratio  $W_f/W_A$  is obtained from Table VII, given  $T_{t3}$ .

The program is constructed to allow thrust required in the flight direction to be determined either by a turbojet throttle setting input or a thrust required input. If the throttle setting option is exercised, thrust required is computed as

$$F_R = T_J * F_N$$

where  $T_J$  is the turbojet throttle setting input. If  $F_R$  is input greater than the net thrust which the turbojet can provide in the combined engine mode, the excess thrust will be provided by the ramjet, if possible. Prior to entering the turbojet iteration loop the maximum turbojet net thrust is computed

$$(F_N)_{MAX} = F_{MAX} - \text{RAM DRAG}$$

and miscellaneous iteration parameters are initialized.

The purpose of the turbojet iteration loop is to provide the net thrust required, if possible, totally by throttling the turbojet. This procedure requires that spillage drag, a function of turbojet throttle setting, be accounted for in the net thrust, i.e.,

$$F_{TJ} = F_R = (F_{TOT})_{TJ} * \cos\gamma - \text{RAM DRAG} - \text{SPILLAGE DRAG}$$

In the above expression  $\gamma$  is the angle between the wing under surface and the freestream direction, RAM DRAG is the component of RAM FORCE in the freestream direction and SPILLAGE DRAG includes drag components due to inlet spillage and excess captured air spillage, if any.

The logic within this loop first tests the turbojet throttle setting. If this value is less than one, iteration commences. Otherwise, turbojet throttle setting and total thrust are adjusted to their maximum values and a check for the combined engine option is made. If the combined engine option is not requested, an optional message will indicate that the thrust requested is higher than that which can be provided. Within the iteration loop, throttled turbojet performance parameters are computed by first determining the throttled engine SFC ratio from Table VIII, given the throttled net thrust to maximum net thrust ratio. The throttled SFC, fuel flow rate, and airflow rate then become simply

$$\text{SFC} = (\text{SFC})_{\text{MAX}} * \text{SFC}/(\text{SFC})_{\text{MAX}}$$

$$(W_f)_{\text{TJ}} = \text{SFC} * (F_{\text{TOT}})_{\text{TJ}}$$

$$(W_A)_{\text{TJ}} = (W_f)_{\text{TJ}} / (W_f/W_A)$$

Since the throttled net thrust to maximum net thrust ratio required to compute turbojet airflow rate is a function of turbojet ram force which itself is a function of turbojet airflow rate, an iteration loop encompassing the above computations is required to ensure that the turbojet airflow rate used to compute the net thrust ratio is equal to that used to compute the ram drag.

If  $W_A$  as computed above is less than the previously computed inlet captured airflow rate, the excess is spilled by the turbojet and results in either a spillage drag, a ramjet thrust, or both. If  $W_A$  is greater than the inlet captured airflow rate, the excess is assumed to be available from suck-in doors.

If, (1) the turbojet throttle setting equals one and the combined engine option is selected or (2) a desired turbojet throttle setting has been specified by the subroutine input data the net turbojet thrust available in the freestream direction is computed by the expression:

$$F_{\text{TJ}} = (F_{\text{TOT}})_{\text{TJ}} * \cos \gamma - \text{RAM DRAG} - \text{INLET SPILLAGE DRAG}$$

and logic flow exits to ramjet calculations.

If the turbojet throttle setting is less than one, the spilled air lift and drag components due to spillage of excess captured air (engine spillage) are computed as shown in Figure 8. The available turbojet thrust is updated to account for engine spillage drag by the equation

$$F_{TJ} = (F_{TOT})_{TJ} * \cos \gamma - \text{RAM DRAG} - \text{INLET SPILLAGE DRAG} - \text{ENGINE SPILLAGE DRAG}$$

A maximum throttle setting check followed by a satisfactory thrust level check are performed; satisfaction of either results in a return to the calling routine. The iteration loop following no exit is a simple application of Newton's method which attempts to satisfy the required thrust level within one tenth of one per cent. A maximum of ten iterations is allowed to complete this requirement. The independent variable in this process is the total turbojet thrust. In the event convergence is not achieved in ten iterations, an error message is printed and a return to the calling program is executed with the engine parameters computed on the last iteration.

#### 6.2.1.6 RAMJET AIRFLOW, FUEL FLOW, AND THRUST COMPUTATIONS

The ramjet computation sequence is constructed similar to that for the turbojet. The maximum ramjet air flow rate to the full capture inlet air flow rate is computed from Table X given the total temperature at Station 2,  $T_{t2}$ . The maximum ramjet air flow is then, simply,

$$(W_A)_{RJ \text{ MAX}} = \frac{(W_A)_{MAX}}{(W_A)_{FULL}} * (W_A)_{FULL}$$

The ramjet actual fuel/air ratio divided by the stoichiometric fuel/air ratio and ramjet specified impulse are determined from Table IX as a function of freestream Mach number. Engine spillage drag, if any, ramjet and total fuel flow rates, air flow rates, and net available thrust levels are computed in the ramjet iteration loop via the equations

$$(W_f)_{RJ} = \frac{(W_f/W_A)_{RJ}}{(W_f/W_A)_{\text{Stoichiometric}}} * (W_A)_{RJ} * (W_f/W_A)_{\text{Stoichiometric}}$$

$$F_{RJ} = (W_f)_{RJ} * I_{SP} * \cos \gamma - \text{SPILLAGE DRAG}$$

$$(W_f)_{TOT} = (W_f)_{RJ} + (W_f)_{TJ}$$

$$(W_A)_{TOT} = (W_A)_{RJ} + (W_A)_{TJ}$$

$$F_{NET} = F_{RJ} + F_{TJ}$$

Where the ramjet air flow rate above is either due to the air flow spilled from the turbojet or the maximum ramjet air flow rate, which ever is less. In the latter case, the excess air is spilled at pressure  $P_2$  and engine spillage forces are computed. The term SPILLAGE DRAG above consists of only engine spillage drag in the combined engine option but includes inlet spillage drag in the ramjet only option. The ramjet iteration loop again applies Newton's method to satisfy, if possible, the thrust level requested within .1 per cent using the ramjet air flow rate as the independent variable. If this condition cannot be satisfied, an appropriate message is printed and a return to the calling routine is executed with the engine parameters last computed. A flowchart of the combined engine subroutine (ENGINS) appears in Figure 10.

## 6.2.2 Usage

The turbojet, ramjet and/or combined engine propulsion option (ICASEN = 5) provided by the engine simulation in subroutine ENGINs requires the input data presented in Section 6.2.3. This data describes "base" turbojet and ramjet engines and relevant airframe geometry. These base engines may be scaled, if desired, by utilizing NSEG input option (21) described in Section 9.21. Scaling must be accomplished in the first mission segment, Segment (2). (Segment (1) may never be used as a mission segment; the data array locations which would be employed are utilized for other mission parameters.)

Turbojet scaling of the base engine is accomplished by (1) specifying a desired net turbojet thrust (LB) at zero velocity at sea level or (2) specifying the sea level corrected airflow rate (LB/sec) for the desired engine. The ramjet is scaled by varying the inlet area to provide a specified ramjet net thrust at cruise Mach number and altitude. A ramjet thrust margin may also be specified. If option (21) is not exercised in segment (2) the engines utilized will be described by the base engine data and the input inlet area, AINLET.

Maximum and throttled (specified) power settings can be employed with the turbojet, ramjet and/or combined engine propulsion option. If throttling is not specified the thrust provided will be such that the thrust component in the freestream direction is equal to that requested (equal to vehicle drag in the unaccelerated mode). The ENGINs subroutine is called by the general propulsion subroutine, ENDAT. An iteration is provided in ENDAT which automatically alters the vehicle angle of attack until the sum of the vehicle aerodynamic lift and the thrust component in the lift direction is equal to the lift necessary for the flight condition specified (equal to the vehicle weight less centrifugal lift for level flight).

6.2.3 Input Data for Turbojet, Ramjet, and/or  
Combined Engine Option

In addition to the segment data described in Section 9.21 the following data is required to utilize the turbojet, ramjet and/or combined engine propulsion option.

<u>SYMBOL</u>	<u>DESCRIPTION</u>
INDE03	Indicator for usage of engine data table 3.
INDE04	Indicator for usage of engine data table 4.
INDE05	Indicator for usage of engine data table 5.
INDE06	Indicator for usage of engine data table 6.
INDE07	Indicator for usage of engine data table 7.
INDE08	Indicator for usage of engine data table 8.
INDE09	Indicator for usage of engine data table 9.
INDE10	Indicator for usage of engine data table 10.
	NOTE: All the above indicators must be set positive for this option.
INDCLZ	Indicator for usage of $C_{L0}$ Table.
INDCLA	Indicator for usage of $C_{L\alpha}$ Table.

<u>SYMBOL</u>	<u>DESCRIPTION</u>
AINLET	Engine Inlet Area (initial guess if ramjet is to be scaled) ( $\text{ft}^2$ ).
DELWNG	Angle from vehicle reference line to wing lower surface (degrees).
DELIN	Inlet wedge angle (degrees).
AMAXTJ	Maximum Mach number for turbojet operation.
AMINRJ	Minimum Mach number for ramjet operation.



<u>SYMBOL</u>	<u>DESCRIPTION</u>
IE03X	Number of Mach number ( $M_0$ ) values in ETAB03.
IE04X	Number of Mach number ( $M_1$ ) values in ETAB04.
IE05X	Number of Temperature values ( $T_{t_3}$ ) in ETAB05.
IE06X	Number of Temperature values ( $T_{t_3}$ ) in ETAB06.
IE06Z	Number of Pressure ratio values $\log_{10} (P_{t_3}/P_N)$ in ETAB06.
IE07X	Number of Temperature values ( $T_{t_3}$ ) in ETAB07.
IE08X	Number of Throttle setting values in ETAB08.
IE09X	Number of Mach number ( $M_0$ ) values in ETAB09.
IE10X	Number of Temperature values ( $T_{t_3}$ ) in ETAB10.
ICLAX	Number of Mach number values in CLATAB.
ICLAY	Number of Altitude values in CLATAB.
ICLZX	Number of Mach number values in CLZTAB.
ICLZY	Number of Altitude values in CLZTAB.
IEØP	<p>Engine option Selector</p> <p>0 - use Turbojet only if <math>M \leq AMINRJ</math>  use Combination if <math>AMINRJ &lt; M &lt; AMAXTJ</math>  use Ramjet only if <math>M \geq AMAXTJ</math></p> <p>1 - use Turbojet only</p> <p>2 - use Combination</p> <p>3 - use Ramjet only</p>

<u>SYMBOL</u>	<u>DESCRIPTION</u>
ETAB03	<p>Engine Capture Area Schedule</p> $\text{Ratio} = f(M_1)$ $\text{ETAB03} = M_1^1, \dots, M_1^N, \text{Ratio}^1, \dots, \text{Ratio}^N$ <p><math>N = \text{IE03X} = \text{Number of Data pairs}</math></p>
ETAB04	<p>Inlet Pressure Recovery Schedule</p> $\text{Ratio} = f(M_1)$ $\text{ETAB04} = M_1^1, \dots, M_1^N, \text{Ratio}^1, \dots, \text{Ratio}^N$ <p><math>N = \text{IE04X}</math></p>
ETAB05	<p>Base Turbojet Corrected Airflow Schedule (LB/SEC)</p> $\text{Airflow} = f(T_{t_3})$ $\text{ETAB05} = T_{t_3}^1, \dots, T_{t_3}^N, \text{Airflow}^1, \dots, \text{Airflow}^N$ <p><math>N = \text{IE05X}</math></p>
ETAB06	<p>Turbojet Gross Thrust/Airflow rate Schedule (LB Thrust/(LB Airflow/SEC))</p> $\text{FGWA} = f(T_{t_3}, \text{Log}_{10}(P_{t_3}/P_N))$ $\text{ETAB06} = T_{t_3}^1, \dots, T_{t_3}^N, L_{10}^1, \dots, L_{10}^M,$ $\text{FGWA}_1^1, \dots, \text{FGWA}_1^N,$ $\text{FGWA}_M^1, \dots, \text{FGWA}_M^N,$ <p><math>N = \text{IE06X}</math></p> <p><math>M = \text{IE06Z}</math></p>

<u>SYMBOL</u>	<u>DESCRIPTION</u>
ETAB07	<p>Turbojet Fuel/Air Ratio</p> $WFWA = f(T_{t_3})$ $ETAB07 = T_{t_3}^1, \dots, T_{t_3}^N, WFWA^1, \dots, WFWA^N$ <p>N = IE07X</p>
ETAB08	<p>Turbojet Specific Fuel Consumption Schedule</p> <p>SFCR = f(<math>T_r</math>)    <math>T_r</math> = Turbojet Throttle Setting</p> $ETAB08 = T_r^1, \dots, T_r^N, SFCR^1, \dots, SFCR^N$ <p>N = IE08X</p>
ETAB09	<p>Ramjet Specific Impulse and Scaled (by stoichiometric ratio) Fuel to Air Ratio</p> $ISP = f_1(M_0)$ $\phi = f_2(M_0)$ $ETAB09 = M_0^1, \dots, M_0^N, ISP^1, \dots, ISP^N, \phi^1, \dots, \phi^N$ <p>N = IE09X</p>
ETAB10	<p>Ramjet Maximum Airflow Rate Schedule</p> $WOWRAM = f(T_{t_3})$ $ETAB10 = T_{t_3}^1, \dots, T_{t_3}^N, WOWRAM^1, \dots, WOWRAM^N$ <p>N = IE10X</p>

<u>SYMBOL</u>	<u>DESCRIPTION</u>
CLZTAB	<p data-bbox="517 353 917 387"><math>C_L</math> at zero angle of attack</p> $C_{L0} = f(M_0, h)$ $CLZTAB = M_0^1, \dots, M_0^N, h^1, \dots, h^M,$ $C_{L0_1}^1, \dots, C_{L0_1}^N,$ $C_{L0_M}^1, \dots, C_{L0_M}^M$ <p data-bbox="517 747 659 771">N = ICLZX</p> <p data-bbox="517 807 659 830">M = ICLZY</p>
CLATAB	<p data-bbox="517 926 856 956">Lift Curve Slope Table</p> $C_{L\alpha} = f(M_0, h)$ $CLATAB = M_0^1, \dots, M_0^N, h^1, \dots, h^M,$ $C_{L\alpha_1}^1, \dots, C_{L\alpha_1}^N,$ $C_{L\alpha_M}^1, \dots, C_{L\alpha_M}^N$ <p data-bbox="517 1333 659 1357">N = ICLAX</p> <p data-bbox="517 1393 659 1417">M = ICLAY</p>

## 7. AERODYNAMICS

### 7.1 Introduction

Aerodynamics options in NSEG compute the total vehicle drag force given the required lift force. Lift force required is determined in the various mission segment options available in NSEG. There are two basic *clean vehicle* aerodynamics options; in each option a total of three aerodynamic systems may be defined. Aerodynamic specifications in the two clean vehicle options are

$$C_{Dj} = C_{D_{Oj}}(h, M) + C_{D_{inducedj}}(C_L, M) \quad ; \quad j = 1, 2, 3$$

and

$$C_{Dj} = C_{D_{Oj}}(h, M) + K_{1j} C_L^2 + K_{2j} (C_L - C_{L_{min}}(M))^2 + K_{3j} C_L^3;$$
$$j = 1, 2, 3$$

In either option the user may optionally sum the system drag components so that

$$C_D = C_{D1} + C_{D2} + C_{D3}$$

or select the lowest drag configuration

$$C_D = \text{Min}[C_{D1}, C_{D2}, C_{D3}]$$

or finally, any one of the clean vehicle aerodynamic systems may be specified

$$C_D = C_{Dj} \quad ; \quad j = 1 \text{ or } 2 \text{ or } 3$$

Store and tank drags together with their associated pylons may also be specified. Three systems of stores are available; each system may involve any number of store pairs and store pylon pairs. The aerodynamic form employed for store drag is

$$C_{DS} = \sum_j (C_{DSj} N_{Sj} + C_{D_{SPj}} N_{SPj}) \quad ; \quad j = 1, 2, 3$$

where

$C_{DSj}$  = drag of single store pair, type j

$N_{Sj}$  = number of store pairs, type j

$C_{D_{SPj}}$  = drag of single pair of store pylons, type j

$N_{SPj}$  = number of store pylon pairs, type j, *whose drag is not included in the clean vehicle drag tables*

Similarly, tank system drags are written in the form

$$C_{DT} = \sum_j (C_{DTj} N_{Tj} + C_{DTPj} N_{Tj}) \quad ; j = 1, 2, 3$$

where the notation is similar to that employed for stores.

## 7.2 Aerodynamic Subroutines

The subroutines of particular significance in aerodynamic drag calculations are

DRAG - The control program for aerodynamic drag calculations

SACNS1 - First clean vehicle aerodynamics option available in NSEG

SACNS2 - Second clean vehicle aerodynamics option available in NSEG

SACSP - Store and store pylon drag calculation

SACTP - Tank and tank pylon drag calculation

Flow charts for these five subroutines are presented in Figures 10 through 14.

## 7.3 Data Input

### 7.3.1 General

<u>SYMBOL</u>	<u>DESCRIPTION</u>
INDAER	Aerodynamic option indicator: = 8, Option 8, tabular = 9, Option 9, derivatives ≠ 8 or 9, error
CASE	Aerodynamic case indicator: = -1, Use smallest drag from Systems 1, 2, and 3 = 1, Use System 1 = 2, Use System 2 = 3, Use System 3 = 4, Sum System 1, 2, and 3

### 7.3.2 Aerodynamics Option 8

ATAB40	Zero lift drag, System 1; $C_{D01} = C_{D01}(h, M)$
ATAB41	Zero lift drag, System 2; $C_{D02} = C_{D02}(h, M)$
ATAB42	Zero lift drag, System 3; $C_{D03} = C_{D03}(h, M)$
ATAB43	Drag due to lift, System 1; $C_{Di1} = C_{Di1}(C_L, M)$
ATAB44	Drag due to lift, System 2; $C_{Di2} = C_{Di2}(C_L, M)$
ATAB45	Drag due to lift, System 3; $C_{Di3} = C_{Di3}(C_L, M)$
IA40X	Number of altitude value in ATAB40
IA41X	Number of altitude value in ATAB41
IA42X	Number of altitude value in ATAB42
IA43X	Number of $C_L$ value in ATAB43
IA44X	Number of $C_L$ value in ATAB44
IA45X	Number of $C_L$ value in ATAB45
IA40Y	Number of Mach number values in ATAB40
IA41Y	Number of Mach number values in ATAB41
IA42Y	Number of Mach number values in ATAB42
IA43Y	Number of Mach number values in ATAB43
IA44Y	Number of Mach number values in ATAB44
IA45Y	Number of Mach number values in ATAB45
INDA40	Table control indicator ATAB40
INDA41	Table control indicator ATAB41
INDA42	Table control indicator ATAB42
INDA43	Table control indicator ATAB43
INDA44	Table control indicator ATAB44
INDA45	Table control indicator ATAB45

### 7.3.3 Aerodynamics Option 9

ATAB46	Zero lift drag, System 1, $C_{D01} = C_{D01}(h, M)$
ATAB47	Zero lift drag, System 2, $C_{D02} = C_{D02}(h, M)$
ATAB48	Zero lift drag, System 3, $C_{D03} = C_{D03}(h, M)$
ATAB49	Coefficient of $C_L^2$ , System 1, $K_{11} = K_{11}(M)$
ATAB50	Coefficient of $C_L^2$ , System 2, $K_{12} = K_{12}(M)$
ATAB51	Coefficient of $C_L^2$ , System 3, $K_{13} = K_{13}(M)$
ATAB52	Coefficient of $(C_L - C_{L_{min}})^2$ , System 1, $K_{21} = K_{21}(M)$
ATAB53	Coefficient of $(C_L - C_{L_{min}})^2$ , System 2, $K_{22} = K_{22}(M)$
ATAB54	Coefficient of $(C_L - C_{L_{min}})^2$ , System 3, $K_{23} = K_{23}(M)$
ATAB55	Coefficient of $C_L^3$ , System 1, $K_{31} = K_{31}(M)$
ATAB56	Coefficient of $C_L^3$ , System 2, $K_{32} = K_{32}(M)$
ATAB57	Coefficient of $C_L^3$ , System 3, $K_{33} = K_{33}(M)$
ATAB58	Minimum drag $C_L$ , System 1, $C_{L_{min.1}} = C_{L_{min.1}}(M)$
ATAB59	Minimum drag $C_L$ , System 2, $C_{L_{min.2}} = C_{L_{min.2}}(M)$
ATAB60	Minimum drag $C_L$ , System 3, $C_{L_{min.3}} = C_{L_{min.3}}(M)$
IA46X	Number of altitude values in ATAB46
IA47X	Number of altitude values in ATAB47
IA48X	Number of altitude values in ATAB48
IA46Y	Number of Mach number values in ATAB46
IA47Y	Number of Mach number values in ATAB47
IA48Y	Number of Mach number values in ATAB48
INDA46	Table control indicator ATAB46
INDA47	Table control indicator ATAB47



INDA48	Table control indicator ATAB48
INDA49	Table control indicator ATAB49
INDA50	Table control indicator ATAB50
INDA51	Table control indicator ATAB51
INDA52	Table control indicator ATAB52
INDA53	Table control indicator ATAB53
INDA54	Table control indicator ATAB54
INDA55	Table control indicator ATAB55
INDA56	Table control indicator ATAB56
INDA57	Table control indicator ATAB57
INDA58	Table control indicator ATAB58
INDA59	Table control indicator ATAB59
INDA60	Table control indicator ATAB60

## 8. LANDING AND TAKE-OFF CALCULATION

NSEG contains an approximate landing and take-off calculation. This model has its own aerodynamic (DATCOM) and propulsion data. It is not a mission segment option at the present time; however, it is used to perform landing and take-off analyses independently of the mission sequence. The landing and take-off analysis options are selected by data input via Option 17. Where detailed high lift aerodynamic values are known, the DATCOM calculations may be bypassed. In this case the values of  $C_{L\alpha}$ ,  $C_{LMAX}$ , and  $\alpha_{MAX}$  (CLATØT, CLMXTØ, ALMXTØ) are specified directly in data input.

### 8.1 Data Input, Take-Off

WO	Weight at start of take-off, in pounds. NOTE that if WO < 0.0 take-off calculation is omitted.
AG	Ground roll body angle, degrees
AMAXG	Maximum ground rotation angle, degrees
ARTHEO	Theoretical wing aspect ratio
BFOBEX	Flap span to exposed wing span ratio
CDO	Drag coefficient at zero lift
CDPLG	Flat plate drag coefficient of gear
CFOCAV	Average flap chord to wing chord ratio
CLO	Lift coefficient at zero angle of attack
CLATOT	Total linear lift curve slope, per degree
DFK	Induced drag factor
FLAPDT	Take-off flap deflection, per degree
FNO	Take-off thrust, in pounds
FFR	Take-off fuel flow rate, in pounds per hour
GRNDFT	Take-off ground roll friction coefficient
SFC	Internal, specific fuel consumption, (hour <sup>-1</sup> )
SPLG	Flat plate area of gear

SREF	Wing reference area
TRATIO	Wing taper ratio
WO	See above
WINCID	Wing incidence, degrees
WSLEFC	Wing leading edge sweep angle, degrees
XISO	Internal, specific impulse at take-off, in seconds

## 8.2 Data Input, Landing

The landing calculation uses the take-off data with the following modifications:

WL	Landing weight. NOTE that if $WL \leq 0.0$ , no landing performance calculation is performed.
CDPCHT	Flat plate drag coefficient of landing chute
FLAPDDL	Landing flap deflection
FNL	Landing thrust
GRNDFL	Landing ground roll friction coefficient
SPCHUT	Flat plate area of landing chute
WL	See above
XMAXG	Maximum ground roll distance, in feet. It is ignored if equal to 0.0; otherwise the thrust required to achieve the desired ground roll is computed.

## 9. MISSION SEGMENT OPTIONS

NSEG contains twenty-one mission segment options listed below.

1. Climb or descent, includes approximately optimal paths
2. Maximum rate of climb or maximum range descent
3. Radius mission
4. Cruise-climb to specified weight
5. Cruise-climb for specified range or time
6. Constant altitude cruise to a specified end weight
7. Constant altitude cruise for a specified range
8. Constant altitude cruise for a specified time
9. Buddy refuel
10. Mach-altitude-weight transfer
11. NSEG logic option
12. Instantaneous weight change
13. Instantaneous Mach-altitude change
14. General purpose and point condition calculations
15. Iterate to fly a specified total distance
16. Climb or accelerate
17. Fuel weight change
18. Not used
19. Not used
20. Fuel allowance
21. Turbojet, ramjet and/or combined engine scaling option
22. Range matching generalized iterative control option

Data input descriptions and typical cases are described in the remainder of this section.

### 9.1. Option 1. Climb or Descent Path

This option calculates a climb or descent path between two Mach-altitude points,

$$(H_0, AMS) \rightarrow (H_E, AME)$$

where

( $H_0$ , AMS) - the initial Mach-altitude point and is taken as the current Mach number and altitude point

( $H_E$ , AME) - final Mach-altitude point

If the value of the final Mach-altitude point is known, it can be specified directly as data. In some cases the final Mach-altitude point is the result of a calculation in a previous segment. In this case, Option 10 would be used to transfer the Mach number and altitude from the segment in which it was calculated into the segment in which the climb-descent path is to be computed. Range, time, and fuel used in the climb or descent are accounted for when Option 1 is specified. It also allows either forward or reverse flight path calculation.

When using Option 1, the intermediate Mach-altitude points may be selected in any one of seventeen ways. Figure 16 shows the various methods available for selecting the intermediate Mach-altitude points along the flight path. If this option is used for climb paths, thrust equal to maximum should be specified; for descent paths, thrust equal to minimum should be specified. The flight path is adjusted at the beginning and end to meet the specified end points.

#### Data for Option 1.

The following is a list of all possible data statements for Option 1. The information in *italics* is optional. Note that  $\nu$  and  $\eta$  are decimal numbers and must contain a decimal point.

*end MACH number = $\nu$ ,*

*end ALTITUDE= $\eta$ , (feet)*

*USE MAX EDOT as basis for selection of Mach-altitude points*

*USE MAX EDOT/MDOT as basis for selection of Mach-altitude points*

*USE MAX L/D as basis for selection of Mach-altitude points*

*USE MAX RANGE FACTOR as basis for selection of Mach-altitude points*

*USE MAX L/(FN-DRT) as basis for selection of Mach-altitude points*

*search for Mach-altitude point using* CONSTANT ENERGY  
*search for Mach-altitude point using* CONSTANT ALTITUDE  
*search for Mach-altitude point using* CONSTANT MACH NUMBER  
*fly* CONSTANT Q path  
*fly* LINEAR Mach-altitude path  
REVERSE calculation (with respect to flight path)  
*forward calculation (with respect to flight path)* \*

Example Data Set for Option 1.

END SEGMENT(3)  
END MACH NUMBER = 2.00,  
END ALTITUDE = 45000.0,  
USE MAX EDOT  
CONSTANT ENERGY  
THRUST = MAXIMUM  
SEGMENT(3), OPTION(1)

The maximum E path flown by this option is shown in Figure 16.  
A list of all flight paths available in Option 1 is presented in  
the following figure.

---

\* An entire statement appearing in italics denotes the default option.  
The statement has no effect on the program.

## 9.2. Option 2. Maximum Rate of Climb or Maximum Range Descent Path

Option 2 calculates a climb or descent such that the vehicle follows a flight path for maximum rate of climb or minimum rate of sink. The program determines the speed for maximum rate of climb at intermediate altitudes. The initial condition is the Mach-altitude-weight at the end of the previous segment. The flight path is adjusted at the beginning and at the end to meet the specified end points.

### Data for Option 2.

The following is a list of data statements for Option 2. The information in italics is optional. Note that  $v$  and  $\eta$  are decimal numbers and must contain a decimal point.

*end MACH number =v,*

*end ALTITUDE= $\eta$ , (feet)*

*calculate DESCENT path*

*calculate climb path \**

*REVERSE calculation (with respect to flight path)*

*forward calculation (with respect to flight path) \**

### Example Data Set for Option 2. (Climb Path Calculation)

END SEGMENT (5)

THRUST=MAX

END MACH NUMBER 0.76,

END ALTITUDE = 37500.0, (FEET)

SEGMENT (5), OPTION (2)

\* An entire statement appearing in italics denotes the default option. The statement has no effect on the program.

It should be noted that Option 2 was part of the original NSEG program of Reference 1 and was included in the current version of NSEG without modification in order to retain the same option number as that of the original program.

It is recommended that the maximum  $\dot{E}$  climb of Option 1 be used in place of Option 2.



### 9.3. Option 3. Radius Mission Option

When Option 3 is specified, the program performs an iteration process such that the range gained in some sequential portion of a mission is made equal to the range gained in some other sequential portion of the mission. The range adjustable segment must be either an Option 5 segment or an Option 7 segment.

#### Data for Option 3.

The following is a list of data statements for Option 3; information in italics is optional. Note that *i*, *j*, *k*, *l*, and *m* must be integer numbers; therefore, decimal points should not be used.

```
START first LEG at segment(i)  
END first LEG at segment (j)  
START RETURN LEG at segment(k)  
END RETURN LEG at segment (l.)  
ADJUST range in segment(m)
```

#### Example Data Set for Option 1.

```
END SEGMENT (30)
```

```
ADJUST RANGE IN SEGMENT (8)
```

```
END RETURN LEG AT SEGMENT (29)
```

```
START RETURN LEG AT SEGMENT (17)
```

```
END FIRST LEG AT SEGMENT (12)
```

```
START FIRST LEG AT SEGMENT (3)
```

```
SEGMENT (30), OPTION (3)
```

#### 9.4. Option 4. Cruise Climb to a Specified Weight

Mission option 4 calls for the computation of a cruise climb flight segment from one weight to another at *constant Mach number* and *constant lift coefficient*. This type of cruise climb is also called a constant  $w/\delta$  cruise since the vehicle weight divided by the pressure ratio is a constant. The flight path for this option may be computed using one step or five steps.

##### Data for Option 4.

The following is a list of data statements for Option 4; information in italics is optional. Note that  $v$  is a decimal number and therefore must contain a decimal point.

*end WEIGHT=v, pounds*

*make five FLIGHT PATH corrections*

DO NOT *make FLIGHT PATH corrections*

##### Example Data Set for Option 4.

END SEGMENT (15)

THRUST = THRUST REQUIRED

MAKE FIVE FLIGHT PATH CORRECTIONS

END WEIGHT = 335000.0, POUNDS

SEGMENT (15), OPTION (4)

## 9.5. Option 5. Cruise Climb for Specified Range or Time

Mission Option 5 calls for the computation of a cruise climb flight segment for a specified range or a specified time. As in Option 4 this cruise climb flight path is at constant Mach and constant lift coefficient.

### Data for Option 5.

The following is a list of data statements for Option 5; information in *italics* is optional. Note that *v* is a decimal number and must contain a decimal point.

*cruise TIME=v, (hours)*

*cruise RANGE=v, (n. miles in this segment)*

TOTAL RANGE *flown including this segment =v, (n.m.)*

NO RANGE *credit*

REVERSE *calculation (with respect to flight path)*

*forward calculation with respect to flight path \**

### Example Data Set for Option 5.

END SEGMENT (17)

THRUST = THRUST REQUIRED

TOTAL RANGE FLOWN INCLUDING THIS SEGMENT = 1500.0, (N.M.)

SEGMENT (17), OPTION (5)

\* An entire statement appearing in *italics* denotes the default option. The entire statement has no effect on the program.

## 9.6. Option 6. Constant Altitude Cruise to a Specified End Weight

Option 6 calculates a constant altitude cruise path to a specified end weight. The constant altitude cruise may be performed at a constant Mach number or at a constant lift coefficient. The initial condition is the Mach-altitude-weight at the end of the previous segment.

This option provides the capability of flying the path backwards by specifying a weight that is larger than the vehicle weight at the end of the previous segment.

### Data for Option 6.

The following is a list of data statements for Option 6; information in italics is optional. Note that  $\eta$  is a decimal number and must contain a decimal point.

WEIGHT *at end of cruise* = $\eta$ , POUNDS

*cruise at constant* LIFT *coefficient*

*cruise at constant* Mach number \*

### Example Data Set for Option 6.

END SEGMENT (21)

THRUST = THRUST REQUIRED

WEIGHT AT END OF CRUISE = 76000.0, POUNDS

CRUISE AT CONSTANT MACH NUMBER

SEGMENT (21), OPTION (6)

\* An entire statement appearing in italics denotes the default option. The statement has no effect on the program.

### 9.7. Option 7. Constant Altitude Cruise for a Specified Range

This mission option calls for the computation of a constant altitude cruise flight segment for a specified range at constant Mach number.

#### Data for Option 7.

The following is a list of data statements for Option 7; information in italics is optional. Note that  $v$  is a decimal number and must contain a decimal point.

RANGE *flown in this segment* =  $v$ , (n.m.)

TOTAL RANGE *flown including this segment* =  $v$ , (n.m.)

REVERSE *calculation (with respect to flight path)*

*forward calculation (with respect to flight path)\**

#### Example Data Set for Option 7.

END SEGMENT (29)

TOTAL RANGE = 2700.0, (N.M.)

THRUST = THRUST REQUIRED

SEGMENT (29), OPTION (7)

---

\* An entire statement appearing in italics denotes the default option. The statement has no effect on the program.

## 9.8. Option 8. Constant Altitude Cruise for a Specified Time

This mission option calls for the computation of a constant altitude cruise flight segment for a specified time at either constant Mach number or constant lift coefficient. This option may also be used to compute fuel required for loiter by specification of no range credit in the data set.

### Data for Option 8.

The following is a list of data statements for Option 8; information in italics is optional. Note that  $v$  is a decimal number and must contain a decimal point.

*cruise* TIME= $v$ , (*hours*)

NO RANGE *credit*

*cruise at constant* LIFT *coefficient*

*cruise at constant* Mach number \*

REVERSE *calculation (with respect to flight path)*

*forward calculation (with respect to flight path)* \*

### Example Data Set for Option 8.

END SEGMENT (24)

CRUISE TIME = 2.5, (HOURS)

CONSTANT LIFT COEFFICIENT

THRUST = THRUST REQUIRED

SEGMENT (24), OPTION (8)

\* An entire statement appearing in italics denotes the default option. The statement has no effect on the program.

### 9.9. Option 9. Buddy Refuel

Option 9 will determine where the "optimum" in flight buddy refuel should take place and how much fuel will be transferred. The user must input three points of the tanker off load curve in the DATA1 data block. The names of the tanker off load data are shown below.

POINT	(RANGE (N.M.))	FUEL AVAILABLE (POUNDS)
1	RANGE 1	FUEL 1
2	RANGE 2	FUEL 2
3	RANGE 3	FUEL 3

The tanker off load data will be curve fitted to determine the coefficients of a quadratic equation and the quadratic equation will then be used in the mission option to determine fuel available as a function of range.

The cruise out to the refuel point will be one of the following:

1. Constant Mach, constant  $C_L$
2. Constant Mach, constant altitude
3. Constant  $C_L$ , constant altitude

Option 9 is similar to Option 4 and Option 6 except that the segment end weight will be determined by the refuel criteria. The vehicle will cruise out until one of the following conditions is satisfied:

1. The fuel receivable equals the fuel available.
2. The distance flown equals the maximum allowable distance to refuel if such a constraint exists
3. The minimum in-flight weight of the receiver is reached.

If the fuel receivable exceeds the fuel available at the start of the mission segment in which Option 9 is used, transfer of the fuel will take place at that point in the mission.

#### Data for Option 9.

The following is a list of data statements for Option 9; information in italics is optional. Note that  $v$  and  $\eta$  are decimal numbers and must contain a decimal point.

*maximum RANGE to refuel =  $\eta$ , (n.m.)*

*no maximum refuel range is to be considered \**

*cruise at CONSTANT CL, constant altitude*

*cruise at CONSTANT MACH, constant CL*

*CRUISE AT CONSTANT MACH, constant altitude*

*maximum in flight WEIGHT= $\nu$ , (pounds)*

*fuel transfer RATE= $\eta$ , (pounds/minute)*

Note that if the fuel transfer rate is not specified or is specified as a value less than or equal to zero, the fuel transfer will be instantaneous.

Example Data Set for Option 9.

END SEGMENT (21)

MAXIMUM RANGE TO REFUEL = 2200.0, (N.M.)

CRUISE AT CONSTANT MACH, CONSTANT CL

MAXIMUM IN FLIGHT WEIGHT = 450000.0, POUNDS

SEGMENT (21), OPTION (9)

\* An entire statement appearing in italics denotes the default option. The statement has no effect on the program.



## 9.10. Option 10. Mach-Altitude-Weight Transfer

Option 10 transfers values calculated in any segment into some other segment; for example, the end Mach-altitude point for a climb may be the result of an Option 14 point calculation. Option 10 would be used to transfer the Mach-altitude values from the segment in which the information was calculated into the segment in which the climb is to be performed.

### Data for Option 10.

The following data statement is used for Option 10. Note that  $v$  and  $n$  must be integer numbers and *cannot* contain a decimal point.

$$\text{TRANSFER } \left\{ \begin{array}{l} \text{MACH} \\ \text{ALTITUDE} \\ \text{WEIGHT} \end{array} \right\} \text{ FROM SEGMENT}(v) \text{ TO SEGMENT}(n)$$

### Example Data Sets for Option 10.

END SEGMENT(17)

TRANSFER MACH ALTITUDE WEIGHT FROM SEGMENT(3) TO SEGMENT(30)

SEGMENT(17), OPTION(10)

... NOTE MACH ALTITUDE AND WEIGHT MAY BE IN ANY ORDER

END SEGMENT(16)

TRANSFER ALTITUDE FROM SEGMENT(9) TO SEGMENT(21)

SEGMENT(16), OPTION(10)

... NOTE ONLY VALUES SPECIFIED WILL BE TRANSFERRED

END SEGMENT(15)

TRANSFER ALTITUDE MACH FROM SEGMENT(6) TO SEGMENT(19)

SEGMENT(15), OPTION(10)

... THREE EXAMPLES OF USING OPTION(10)

## 9.11 Option 11. NSEG Logic Option

This option allows for choosing one of two sets of flight conditions (Mach, altitude, and weight) by deciding which has the largest or smallest value of the variable used as the basis of selection. The user specifies the Mach, altitude, and weight for flight condition 2 and the segment in which flight condition 1 was calculated. The user also specifies the basis of selection:

Maximum Mach  
Minimum Mach  
Maximum Altitude  
Minimum Altitude  
Maximum Weight  
Minimum Weight

### Data for Option 11.

The following is a list of data statements for Option 11; information in italics is optional. Note that  $v$ ,  $\eta$ , and  $\lambda$  are decimal numbers and must contain a decimal point;  $l$  is an integer number and *cannot* contain a decimal point.

*MACH number for flight condition 2 =  $v$ ,*

*ALTITUDE for flight condition 2 =  $\eta$ , (feet)*

*WEIGHT for flight condition 2 =  $\lambda$ , (pounds)*

*get data for flight condition 1 from SEGMENT ( $l$ )*

CHOOSE on the basis of  $\left\{ \begin{array}{l} \text{MAXIMUM} \\ \text{MINIMUM} \end{array} \right\} \left\{ \begin{array}{l} \text{MACH} \\ \text{ALTITUDE} \\ \text{WEIGHT} \end{array} \right\}$

### Example Data Set for Option 11.

END SEGMENT (6)

GET FLIGHT CONDITION 1 FROM SEGMENT (4)

CHOOSE ON MAXIMUM MACH

MACH = 2.25,

WEIGHT = 78000.0, (POUNDS)

ALTITUDE = 64000.0, (FEET)

SEGMENT (6), OPTION (11)

## 9.12. Option 12. Instant Weight Change

This option allows instant changes in the vehicle weight; for example, changes that would occur with the dropping of an internal payload.

### Data for Option 12.

The following data statement is used for Option 12. Note that  $v$  must be a decimal point. The weight of the vehicle will be computed by subtracting  $v$  from the current vehicle weight.

WEIGHT *change* =  $v$ , (POUNDS)

### Example Data Set for Option 12.

END SEGMENT (9)

WEIGHT CHANGE = 10000.0, POUNDS

... DROP 10000.0 POUND WEAPON

SEGMENT (9), OPTION 12

END SEGMENT (8)

WEIGHT CHANGE = -74000.0, POUNDS

... INSTANT REFUEL OF 74000.0 POUNDS

SEGMENT (8), OPTION (12)

### 9.13. Option 13. Instant Mach-Altitude Change

This option provides the user with a method of changing the Mach-altitude-weight point of the vehicle. Option 13 changes any combination of Mach number, weight, and altitude.

#### Data for Option 13.

The following is a list of data statements for Option 13; information in italics is optional. Note that  $v$  and  $\eta$  are decimal numbers and must contain a decimal point.

*new MACH number* =  $v$ ,  
*new ALTITUDE* =  $\gamma$ , (*feet*)  
*new vehicle WEIGHT* =  $\eta$ , (*pounds*)

#### Example Data Set for Option 13.

END SEGMENT (31)

NEW MACH NUMBER = 0.42,

NEW WEIGHT = 38000.0, (POUNDS)

SEGMENT (31), OPTION (13)

#### 9.14. Option 14. General Purpose and Point Condition Calculation Option

Option 14 is used for either of two basic functions:

1. Restoring of the vehicle to the Mach, altitude, and weight condition at the end of the specified segment. Vehicle return weight is restored if WEIGHT is set to zero.
2. Calculating the point condition

When using the point condition calculation feature of Option 14, the flight condition for the calculation may either be specified or taken as the vehicle flight conditions at the end of the previous segment.

The point calculations that can be performed using Option 14 are

1. Compute best cruise altitude for specified weight and Mach number.
2. Compute ceiling for the specified rate of climb, Mach number, and weight.
3. Compute Mach number for best lift to drag ratio for the specified altitude and weight.
4. Compute Mach number for lift equal to weight at the specified lift coefficient, weight and altitude.
5. Compute maximum endurance Mach for the specified altitude, weight, and maximum lift coefficient.
6. Compute maximum Mach number for the specified altitude and weight.
7. Compute Mach number for maximum rate of climb at the specified altitude and weight.
8. Compute altitude and Mach number for maximum range factor at the specified weight.
9. Compute Mach number for maximum range factor at the specified altitude and weight.
10. Compute the various energy maneuverability parameters at the specified G level, Mach number, weight, and altitude.

Data for Option 14.

Following is a list of data statements for Option 14; information in italics is optional. Note that  $\delta$ ,  $v$ ,  $\eta$ ,  $\beta$ , and  $\lambda$  are decimal numbers and must contain a decimal point;  $l$  is an integer number and must not contain a decimal point.

RESTORE *vehicle to flight conditions at end of segment (l)* .

*use flight conditions from previous segment \**

GIVEN MACH number =  $v$ , (*pounds*)

GIVEN WEIGHT =  $\lambda$ , (*pounds*)

NOTE: If weight = 0.0, then weight will be internally set to return weight.

GIVEN ALTITUDE =  $\eta$ , (*feet*)

GIVEN GLEVEL =  $\delta$ ,

COMPUTE *best CRUISE altitude*

COMPUTE CEILING *for rate of climb* =  $\beta$ , (*feet/min*)

COMPUTE MACH *for best LIFT/DRAG ratio*

COMPUTE MACH *for CL* =  $\delta$ ,

COMPUTE MAXimum *endurance MACH for CL* =  $\delta$ ,

COMPUTE MAXimum MACH *number*

COMPUTE MACH *number for MAXimum RATE of climb*

COMPUTE MACH, ALTITUDE *point for MAXimum range factor*

COMPUTE MACH *for MAXimum range factor*

COMPUTE MACH( $v$ ), ALTITUDE *point for MAXimum range factor*

COMPUTE MACH( $v$ ), *for MAXimum range factor*

COMPUTE ENERGY *maneuverability parameters*

Note that for maximum range factor calculation the user can specify the upper limit on Mach number; i.e., MACH ( $v$ ) where  $v$  is upper Mach number limit. If it is not specified AMLIM is used.

---

\* An entire statement appearing in italics denotes the default option. The statement has no effect on the program.

END SEGMENT(18)

GIVEN GLEVEL = 1.5, ALTITUDE = 18000.0, (FEET)

GIVEN MACH = 0.71

COMPUTE ENERGY MANEUVERABILITY PARAMETERS

SEGMENT(18), OPTION(14)

...

END SEGMENT(17)

GIVEN ALTITUDE = 18000.0, (FEET)

GIVEN WEIGHT = 70000.0, (POUNDS)

COMPUTE MACH FOR BEST LIFT DRAG/RATIO

SEGMENT(17), OPTION(14)

...

END SEGMENT(16)

COMPUTE BEST CRUISE ALTITUDE

USE FLIGHT CONDITIONS FROM PREVIOUS SEGMENT AND

SEGMENT(16), OPTION(14)

... SAMPLE DATA SETS FOR OPTION(14)

Example Data Set for Option 14.

END SEGMENT(21)

RESTORE VEHICLE TO FLIGHT CONDITIONS AT END OF SEGMENT(3)

SEGMENT(21), OPTION(14)

END SEGMENT(20)

COMPUTE CEILING FOR RATE OF CLIMB = 100.0, (FEET/MIN)

GIVEN MACH = 0.72, WEIGHT = 220000.0, (POUNDS)

SEGMENT(20), OPTION(14)

...

END SEGMENT(19)

COMPUTE MAX ENDURANCE MACH FOR CL = 0.7

GIVEN ALTITUDE = 32000.0, WEIGHT = 270000.0, (POUNDS)

SEGMENT(19), OPTION(14)

...

*(continued)*



### 9.15. Option 15. Iterate to Fly a Specified Distance

This option provides an iteration process that forces the vehicle to have accumulated a specified distance at the end of this segment. The range flown in a specified segment is automatically adjusted by the program until the total range flown is within a tolerance of one nautical mile of the range specified.

#### Data for Option 15.

The following data statement is used for Option 15; information in italics is optional. Note that  $v$  is a decimal number and must contain a decimal point;  $l$  is an integer number and *must not* contain a decimal point.

*adjust range in segment (l) to give a total range =  $\eta$ , n.m.*

#### Example Data Set for Option 15.

END SEGMENT(23)

ADJUST SEGMENT(13) SO TOTAL RANGE=1650.0, N.M.

SEGMENT(23), OPTION(15)

## 9.16. Option 16. Climb or Accelerate

With Option 16 two Mach-altitude conditions are specified by the segment numbers in which they were calculated. Option 16 makes decisions as per MIL-C-Rules to determine if fuel is to be "burned" while going from Condition 1 to Condition 2.

The decision process is

If  $H_2$  is greater than  $H_1$

or

If  $H_2$  equals  $H_1$

and

$M_2$  is greater than  $M_1$   
then

The vehicle will fly (burning fuel) to Condition 2 from Condition 1

If neither of these conditions exists, the program will move the vehicle to Condition 2 with no change in weight or performance.

Note that Option 16 cannot be used to descend or decelerate.

### Data for Option 16.

The following is a list of data statements for Option 16; information in italics is optional. Note that  $l$  and  $j$  are integer numbers and must not contain a decimal point.

*obtain condition ONE from segment ( $l$ )*

*obtain condition TWO from segment ( $j$ )*

*NO RANGE credit for this segment*

*RANGE credit for this segment*

*forward calculation (with respect to flight path) \**

*REVERSE calculation (with respect to flight path)*

---

\* An entire statement appearing in italics denotes the default option. The statement has no effect on the program.

Example Data Set for Option 16.

END SEGMENT(12)

RANGE CREDIT

FORWARD CALCULATION

GET CONDITION TWO FROM SEGMENT(4)

GET CONDITION ONE FROM SEGMENT(7)

SEGMENT(12), OPTION(16)

9.17. Option 17. Fuel Weight Change for Time, Turn, Combat, etc.

The fuel weight change may be computed or input depending on the needs of the program. If the option of computing the fuel weight change is desired, fuel used during warm-up, take-off, loiter, or combat can be computed by the program. Landing calculations are also controlled by Option 17.

Data for Option 17.

The following data statements are used by Option 17; information in italics is optional. Note that  $\eta$  and  $\lambda$  are decimal numbers and must contain a decimal point.

*fuel WEIGHT change* = $\lambda$ , (*pounds*)

WARM-UP TIME= $\eta$ , (*minutes*)

*loiter TIME*= $\eta$ , (*minutes*)

$\eta$  DEG  $\lambda$  G TURNS

COMPUTE COMBAT *fuel allowance*

COMPUTE WARM-UP and TAKE-OFF *fuel allowance*

COMPUTE *loiter fuel allowance*

COMPUTE LANDING *performance*

Example Data Sets for Option 17.

END SEGMENT(27)

720.0 DEG 4.2 G TURNS

COMPUTE COMBAT FUEL ALLOWANCE

THRUST=MAX

SEGMENT(27), OPTION(17)

END SEGMENT(26)

LOITER TIME=15.0, (MINUTES)

COMPUTE LOITER FUEL ALLOWANCE

THRUST=THRUST REQUIRED

SEGMENT(26), OPTION(17)

9.18. Option 18.

Option 18 is not used in the current version of the NSEG program.

9.19. Option 19.

Option 19 is not used in the current version of the NSEG program.

## 9.20. Option 20. Fuel Allowance

Option 20 computes a fuel allowance for (a) a specified time at a specified power setting and (b) a specified time at a specified thrust to weight ratio.

### Data for Option 20.

The following data statements are used by Option 20; information in italics is optional. Note that  $\eta$  and  $\nu$  are decimal numbers and must contain a decimal point.

GIVEN TIME= $\nu$ , (*minutes*)

*compute fuel allowance for a POWER setting = $\eta$ ,*

*compute fuel allowance for thrust/weight RATIO= $\eta$ ,*

### Example Data Set for Option 20.

END SEGMENT(36)

POWER SETTING=0.45,

GIVEN TIME=13.0, (MINUTES)

SEGMENT(36), OPTION(20)

END SEGMENT(35)

THRUST/WEIGHT RATIO=.25,

GIVEN TIME=17.0, (MINUTES)

SEGMENT(35), OPTION(20)

## 9.21 Option 21. Turbojet, Ramjet and/or Combined Engine Scaling

Option 21 performs engine scaling computations by performing appropriate calls to subroutine ENGINs. Turbojet scaling is performed by computing a scaling factor by which the base engine airflow schedule (input) is multiplied throughout the flight regime. This factor is computed based on a desired net thrust at sea level or a desired turbojet corrected airflow at sea level. For an aircraft utilizing turbojet engines only, the cruise Mach number and altitude must also be input to allow sizing of the turbojet inlet area to meet airflow requirements at the specified cruise condition. The ramjet scaling, which sizes the combined engine inlet area, is performed at the specified cruise Mach number and altitude to provide net thrust equal to drag plus a specified thrust margin at cruise.

The lift coefficient utilized in drag coefficient calculations is the specified cruise lift coefficient (CLC) input in the general data section. If CLC is not input (or is input as zero) the lift coefficient for scaling is computed using the cruise Mach number and altitude and lift equal to 75% of the gross takeoff weight.

A final option for ramjet scaling is the same as that just mentioned except current weight, Mach number, and altitude are used to compute the lift coefficient. This option allows the combined engine inlet area to be scaled during the mission, if desired. An additional input to this option allows the usage of turbojet engine reference pressure ( $P_N$ ) to be specified as the Wing Undersurface Pressure; if reference pressure is not specified ambient static pressure is used. Finally, a combined engine option debug print can be requested for engine performance evaluation during climb segments. Option 21 must be exercised in Segment (2) if the combined engine option is to be employed and engine scaling is desired. If no scaling is desired the base turbojet engine airflow schedule and combined engine inlet area specified in the general data section will be employed.

### Data for Option 21

The following data statements are used by Option 21; information in italics is optional. Note that all numbers ( $\alpha$ ,  $\beta$ , etc.) are decimal numbers and must contain a decimal point

PROPULSIVE *mode* = DUAL

SCALE TURBOjet THRUST =  $\alpha$ ,

or

SCALE TURBOjet corrected AIRFLOW =  $\beta$ ,

SCALE RAMjet = *ramjet thrust* MARGIN =  $\epsilon$ , *cruise* MACH =  $\gamma$ ,

*cruise* ALTITUDE =  $\delta$

*engine* DEBUG *print requested*

*turbojet reference* PRESSURE = *underwing pressure*

*compute alpha for scaling based on current* WEIGHT

END

NOTE: If $\alpha < 3.0$ , then $\alpha$ must be the thrust/weight ratio instead of thrust.
--



Sample Data Set for Option 21

/SEGMENT (2), OPTION (21)

/PROPULSIVE MODE = DUAL

/SCALE TURBOJET - SEA LEVEL CORRECTED AIRFLOW = 398.65, (LBS/SEC)

/SCALE RAMJET -- THRUST MARGIN = .1

/REFERENCE PRESSURE = WING UNDERSURFACE PRESSURE

/CRUISE MACH = 6., ALTITUDE = 120000., (FT)

/ENGINE DEBUG PRINT REQUESTED

/END

## 9.22 Option 22. Generalized Iteration Control Option

Option 22 is a generalized iteration loop used to vary a specified parameter (independent variable) in a specified mission segment such that a specified parameter (dependent variable) either satisfies a given input value to within 0.1% or the maximum number of iterations input is exceeded. As currently mechanized the dependent variable must be either Mach number, total range, or weight. The independent variable must be either Mach number, weight or range as specified in the segment where the iteration loop begins. For example, if the independent variable is specified as RANGE, this range will be either total range at the end of the iteration loop or range to be flown in the initial segment of the iteration loop depending on the input option used in the initial segment. In any case the independent variable must be one of the parameters input in the segment data for the initial segment in the iteration loop.

### Data for Option 22.

The following data statements are used by Option 22; information in italics is optional. Note that the numbers  $\alpha$  and  $\beta$  are decimal numbers and must contain a decimal point. The numbers A and B are integers.

START <i>loop at beginning of</i> SEGMENT (A)-----	$\left. \begin{array}{l} \text{WEIGHT} \\ \text{RANGE} \\ \text{MACH} \end{array} \right\}$	<i>is to be varied</i>
FINISH <i>loop at end of</i> SEGMENT (B)-----	$\left. \begin{array}{l} \text{WEIGHT} \\ \text{RANGE} \\ \text{MACH} \end{array} \right\}$	<i>is to be satisfied</i>

NUMBER of iterations =  $\alpha$ ,

DESIRED value of dependent variable =  $\beta$ ,

END

### Example Input for Option 22.

```
SEGMENT(27), OPTION(22)
```

```
START LOOP AT SEGMENT(4)----WEIGHT IS TO BE VARIED
```

```
FINISH LOOP AT END OF SEGMENT(26)----RANGE IS TO BE SATISFIED
```

---

NUMBER OF ITERATIONS = 3.

---

DESIRED RANGE = 1500., NAUTICAL MILES

---

END

The default value for the number of iterations is 3. Note that if specified the number of iterations must be a decimal number.

In the above example Segment(4) could, for example, utilize Option(13) to define a new value of weight and Segment(26) could utilize Option(6) to cruise to a specified weight. The initial value of weight in Segment(4) will be varied by Option(22) until the total range at the end of Segment(26) is  $1500 \pm 1.5$  nautical miles or the number of iterations exceeds 3, whichever occurs first.

## 10. PRINT CONTROL INDICATORS

IPDICN            Input dictionary print control:  
= 0, omit print  
= 1, print input dictionary in alphabetic and numeric  
                  order

IPSEG<sub>i</sub>            Array indicating the final printout segment order and  
                  selection

IPATMD            Atmospheric tabular print indicator:  
= 0, omit print  
= 1, print tabulation of atmospheric properties as a  
                  function of altitude

IPTZIN            Controls initial TERM array print  
= 0, omit print  
= 1, print term array from FILLTZ as each mission  
                  segment is processed

IPENDS            Scaled propulsion system data print control  
= 0, omit print  
= 1, print scaled propulsion data

IPENDR            Raw (input) propulsion system data print control  
= 0, omit print  
= 1, print raw propulsion data

IPTZXX            Controls TERM array print as each segment is computed:  
= 0, omit print  
= 1, print TZ<sub>i</sub>

IPRGSV            Controls RG array print as each segment is computed  
= 0, omit print  
= 1, print RG<sub>i</sub>

IPDGPC            Generalized performance print control  
= 0, omit detailed print  
= 1, provide detailed print

AOUT             A five digit compressed term to control the printers:  
1st digit controls CHECK data output  
2nd digit controls PATH data output  
3rd digit controls CLIMB data output  
4th digit controls XCEL data output  
5th digit controls RUN and GOGO data output

                  If AOUT is zero, the printing control will take on the value  
                  of the previous mission segment. The digit "1" indicates  
                  DO NOT print out the data computed in the corresponding  
                  Subroutine; "2" indicates print out all data computed in the  
                  corresponding subroutine

## 11. ALPHABETIC LIST OF INPUT AND INTERNAL VARIABLES

### 11.1 A's

ACG	Internal variable computed in CHECK
ACV	Internal variable computed in CHECK
AERODYNAMIC MODE	Optional way of specifying aerodynamic case number (CASE)
AG	Ground roll body angle
AINLET	Engine inlet area (not required if ramjet is to be scaled) (ft <sup>2</sup> )
ALMXTO	Angle of attack for take-off C <sub>L</sub> MAX if internal table not to be used
AM	Initial Mach number for computation of flight envelope
AMACH	Mach number array used in ML/D calculation
AMAXG	Maximum ground rotation angle
AMAXTJ	Maximum Mach number for turbojet operation
AME	End Mach number for Mach-altitude paths on performance maps
AMF	Final Mach number for performance maps. Also end of climb Mach number FLITEN climb path history. If AMF=0.0, end of climb Mach number is determined from maximum range factor
AMI	Initial Mach number for performance maps
AMINRJ	Minimum Mach number for ramjet operation
AMLIM	Maximum allowable Mach number in FLITEN searches
AMSW1	First Mach number for propulsion system switch when CASEN=4.
AMSW2	Second Mach number for propulsion system switch when CASEN=4.
AMS	Start Mach number for Mach-altitude paths on performance maps
AMTO	Initial Mach number for take-off
AN	Initial variable set in CHECK
AOUT	A five digit compressed term to control the printers: 1st digit controls CHECK data output 2nd digit controls PATH data output 3rd digit controls CLIMB data output 4th digit controls XCEL data output 5th digit controls RUN and GOGO data output  If AOUT is zero, the printing control will take on the value of the previous mission segment. The digit "1" indicates DO NOT print out the data computed in the corresponding

AOUT (contd)      subroutine; "2" indicates print out all data computed in the corresponding subroutine.

AREFF              Not used.

ATABXX             Aerodynamic table XX

ATMOS              Internal program array containing atmospheric properties at given altitude

AVOID               Compressed term 10 on First Mission Card

AVOID1 and  
AVOID2              Two digit terms to be used only when mission data change cards are used. (These terms must be zero the first time the mission is computed). The first variable, AVOID1, represents a segment number,  $n_1$ , and the last variable, AVOID2, represents another segment number  $n_2$ . AVOID1 equal to non-zero value indicates that the computations in mission segments  $n_1$  through  $n_2$  will give the same results as the corresponding mission segments of the previous mission; therefore, segments  $n_1$  through  $n_2$  will not be recomputed but will use the values computed in the previous mission.

AVSFC               Internal variable computed in GOGO and RUN

11.2 B's

**BAREWT**

Vehicle bare weight

**BFOEX**

Flap span to exposed wing span ratio. Used in take-off and landing calculations.

### 11.3 C's

CASE	Aerodynamic case indicator for selecting systems 1, 2, and 3
CASEN	Propulsive case indicator for selecting systems 1, 2, and 3
CCPXX	Compacted integer used in UPACK. Consists of 5 characters: 1st character = propulsion option 2nd character = aerodynamic option 3rd character = throttle setting 4th and 5th characters = number of integration steps NOTE: CCPXX is the 6th word in the Tt array printed after each segment data block is processed.
CD	<i>Internally computed drag coefficient</i>
CDDELT	Drag coefficient increment used in FLIMLD
CDO	Drag coefficient at zero lift. Landing and take-off analysis
CDPCHT	Flat plate drag coefficient of parachute, landing and take-off analysis
CDPLG	Flat plate drag coefficient, landing and take-off analysis
CDSTOR	<i>Internally computed stores drag coefficient</i>
CDTANK	<i>Internally computed tanks drag coefficient</i>
CFOCAV	Average flap chord to wing chord ratio, landing and take-off analysis
CL	<i>Internally computed lift coefficient</i>
CLATOT	Linear lift curve slope per degree, landing and take-off analysis
CLC	<i>Internally computed lift coefficient</i>
CLCD	<i>Internally computed lift/drag coefficient</i>
CLIMBQ	Dynamic pressure for constant climb. If set to zero, dynamic pressure of End Point (AME, HE) will be used.



CLMAX            Maximum cruise lift coefficient when INDCLM=0. (When  
INDCLM = 1,  $C_{L_{max}}$  is found from CLMTAB in the form

$$C_{L_{max}} = C_{L_{max}}(M, \text{CASE})$$

CLMTAB           Table of  $C_{L_{max}}$  as function of (M, CASE) when INDCLM = 1

CLMXTO           Maximum  $C_L$  for take-off computations if internal tables  
are not to be used

CLO              Lift coefficient at zero angle of attack. Landing and  
take-off analysis

CLZZ              *Internally computed maximum lift coefficient in FLIENV*

#### 11.4 D's

<b>DAC</b>	<i>Internally computed acceleration in XCEL</i>
<b>DATE</b>	Date of a particular calculation
<b>DELAN</b>	Mach number increment in generalized performance calculations
<b>DELH</b>	Incremental altitude in generalized performance calculations
<b>DELWT</b>	Weight decrement or increment in generalized performance calculations
<b>DFK</b>	<i>Not used. Referenced in LANDIN</i>
<b>DMC</b>	<i>Internally computed Mach number; used in PATH</i>
<b>DRT</b>	<i>Internally computed drag force</i>

## 11.5 E's

END	Signifies end of a data block	E10
ENDPTH	End of path indicator for E climb: = -1, Don't exceed terminal altitude = 0, terminal arc along final constant energy line = 1, Don't exceed terminal Mach number	E11
ETAB03...	Engine data tables used in dual engine propulsion option.	E12
ETAB10	See Section 6.2.3 for description	E13
ERRFP	<i>Undefined error indicator in PATH, internal</i>	E14
ERRH	<i>Altitude error in PATH, internal</i>	E15
ERRM	Mach number error in PATH, internal	E16
E10	<i>Internal thrust error indicator, ENDAT and CMAX dumped from CRCOMP</i>	E17
E11	<i>Internal error indicator, dumped from CRCOMP</i>	E18

## 11.6 F's

FF	Reserve fuel fraction (.05 for Mil C-5011A rules)
FFLMIN	Minimum fuel flow (unfactored) per engine
FFR	<i>Internally computed total fuel flow rate</i>
FFRMIN	<i>Internally computed total fuel flow rate minimum</i>
FLAPDC	Flap deflection, landing
FLAPDT	Flap deflection, take-off
FN	<i>Internally computed net thrust per engine</i>
FNO	<i>Internally set thrust in FILLPM and FLITOL</i>
FNMIN	<i>Internally computed minimum total thrust</i>
FNL	<i>Landing thrust, internally set</i>
FPOL	Fraction of initial payload dropped or off-loaded during a mission
FUEL	
FUEL1	First fuel value, buddy refuel
FUEL2	Second fuel value, buddy refuel
FUEL3	Third fuel value, buddy refuel
FUELIN	<i>Internally computed total internal fuel</i>
FUEL1	<i>Internally computed fuel weight, tanks 1</i>
FUEL2	<i>Internally computed fuel weight, tanks 2</i>
FUEL3	<i>Internally computed fuel weight, tanks 3</i>
FUELTO	Total fuel, including tank fuel at take-off
FUELTK	<i>Internally computed total tank fuel</i>
FUELUS	<i>Internally computed total usable fuel at take-off</i>
FWC	<i>Internally computed fuel weight change in CLIMB</i>

11.7 G's

GLEVEL	Number of 'g's' pulled in performance contour map calculations
GLIMIT	Limiting 'g's' in radius of turn and time to turn contour map
GRNFL	Ground roll friction coefficient, landing
GRNDFT	Ground roll friction coefficient, take-off

11.8 H's

HE	End altitude on Mach-altitude path
HF	Final altitude on contour maps
HG	Specified altitudes in arbitrary atmosphere
HI	Initial altitude on contour maps
HO	Initial altitude on Mach-altitude path
HOVSFC	<i>Not used; was in OPT17</i>
HOVT	<i>Not used; was in OPT17</i>
HOVTM1	<i>Not used; was in OPT17</i>

## 11.9 I's

IA40X, IA41X ..... IA48X	Number of first independent variable values in three-dimensional aerodynamic tables
IA40Y, IA41Y ..... IA48Y	Number of second independent variable values in three-dimensional aerodynamic tables
ICLAX ICLAY	Table size indicator for $C_{L\alpha}$
ICLZX ICLZY	Table size indicator for $C_{L0}$
ICLMX	Number of Mach number values in CLMTAB
ICLMY	Number of CASE values in CLMTAB
IDRSP1 ISRSP2 IDRSP3	Drop store pylon indicators: = 0, Don't drop = 1, drop
IDRTP1 IDRTP2 IDRTP3	Drop tank pylon indicators: = 0, don't drop = 1, drop
IEOP IE03X IE04X IE05X IE06X IE06X IE07X IE08X IE09X IE010X	Table size indicators for combined engine simulation data
INDE03 INDE04 INDE05 INDE06 INDE07 INDE08 INDE09 INDE10	Table usage indicators for combined engine data
INDCLA	Table usage indicator for $C_{L\alpha}$
INDCLZ	Table usage indicator for $C_{L0}$

INDA01... Aerodynamic table indicators  
 INDA12,  
 INDA40, INDA41  
 .... INDA60

INDAER Clean vehicle aerodynamic indicator  
 = 8, general model  
 = 9, derivatives

INDATM Atmosphere indicator  
 = 3, use original NSEG model  
 = 9, use arbitrary model atmosphere

INDCLM Controls  $C_{Lmax}$  selection:  
 = 0,  $C_{Lmax}$  given by CLMAX value  
 = 1,  $C_{Lmax} = C_{Lmax}(M, CASE)$ : CLMTAB

INDGPC Flight envelope calculation control indicator

INDMAP Selects which performance contour map is to be drawn in  
 current data block:  
 = 0, no maps  
 = 1,  $\dot{E}$  map  
 = 2,  $E/W$  map  
 = 3,  $L/D$  map  
 = 4, Range factor map  
 = 5, thrust map  
 = 6, drag map

INDMAP = 7,  $SFC$  map  
 (Contd.) = 8,  $W$  map  
 = 9, energy map  
 = 10,  $L/(T-D)$  map  
 = 11, turn radius map  
 = 12, time to turn map

INDMHP Controls contours to which tangency criteria is applied  
 (see IPATH):  
 = 1, use max  $[\dot{E}]$  condition  
 = 2, use max.  $[E/W]$  condition  
 = 3, use max.  $[L/D]$  condition  
 = 4, use max. [range factor] condition  
 = 5, use max.  $[L/(T-D)]$  condition

INDTOA Nonzero specifies that CLMXTO and ALMXTO will be used for  
 take-off and landing computations in lieu of internal tables

INDT01 ..., Propulsion table indicators  
 .... INDT06

INDRN Turn calculation  $C_L$  selection indicator:  
 = 0, turn at constant velocity  
 = 1, turn using  $C_{Lmax}$

INDZLT Selects contour levels on performance maps:  
 = 0, program computes levels  
 = 1, levels specified in ZLTAB



**IPATH** Controls tangency condition for Mach-altitude path inscribed on performance contour maps:  
 = -1, no paths  
 = 0, all paths  
 = 1, energy tangency climb  
 = 2, altitude tangency climb  
 = 3, Mach tangency climb  
 = 4, linear M-h climb  
 = 5, constant q climb

**IPATMD** Generate and print atmospheric table indicator. Controls call to Overlay 3.1 in MISIQN.

**IPDGPC** Detail print indicator for flight envelope calculations

**IPDICN** Data base directory print control

**IPENDR** Print raw propulsion system data indicator

**IPENDS** Print scaled propulsion system data indicator

**IPLF1** Indicator to control allocation of tank fuel to payload:  
**IPLF2** = 0, don't include in payload  
**IPLF3** = 1, include in payload

**IPRGSV** Print the RG array from each mission segment indicator

**IPSEG** Array giving mission segments to be printed and their order at printing

**IPXX** Array of print control indicators:  
 IPXX(1), controls BERAN, CRCOMP, and CHECK print if .TRUE.  
 (2)  
 (3)  
 (4), controls PATH print if .TRUE.  
 (5), controls CLIMB print if .TRUE.  
 (6), controls XCEL print if .TRUE.  
 (7), controls RUN print if .TRUE.  
 (8), controls GOGO print if .TRUE.  
 (9)  
 (10)

NOTE THAT in FLITEN calculations the IPXX array is set internally to .TRUE.

**IPTZIN** Print term array as each mission segment data is processed indicator

**IPTZXX** Print term array as each mission segment is started indicator

ISEG            *Internal variable which counts segment number, (ENSEG)*

ISEC            *Internally computed second value in calls to CLOCK*

IT01X,...  
...IT06X        *Number of values for first variable in three or four  
dimensional propulsion tables*

IT01Y,...  
...IT06Y        *Number of values for second variable in three or four  
dimensional propulsion tables*

IT02W  
IT04W           *Number of values for third variable in four dimensional  
propulsion tables*

ITZ            *Internally computed location for position of segment in  
TZ array*

11.10 J's

JDRPS1      *Number of store pairs type 1 to be dropped*

JDRPS2      *Number of store pairs type 2 to be dropped*

JDRPS3      *Number of store pairs type 3 to be dropped*

JDRPT1      *Number of tank pairs type 1 to be dropped*

JDRPT2      *Number of tank pairs type 2 to be dropped*

JDRPT3      *Number of tank pairs type 3 to be dropped*



11.12 M's

MAXSEG            *Maximum number of mission segments*

MDROP1           *Number of tank pairs type 1 dropped, internal*

MDROP2           *Number of tank pairs type 2 dropped, internal*

MDROP3           *Number of tank pairs type 3 dropped, internal*

MIN               *Internally set minutes from CLOCK*

MTAB01           **Mission segment data tables**

MTAB02

MTAB03

### 11.13 N's

NAM            Number of Mach numbers in generalized performance calculations

NAT10

NAT11

NCASE

NDROP1        Number of stores type 1 dropped, internal

NDROP2        Number of stores type 2 dropped, internal

NDROP3        Number of stores type 3 dropped, internal

NH             Number of altitudes in generalized performance calculations

NHG            Number of altitudes employed in arbitrary atmosphere model

NPAGE         *Page counter, internal*

NSDROP

NSTOR1        Number of store pairs type 1

NSTOR2        Number of store pairs type 2

NSTOR3        Number of store pairs type 3

NTANK1        Number of tank pairs type 1

NTANK2        Number of tank pairs type 2

NTANK3        Number of tank pairs type 3

NUMCON        Number of contours in performance map

NUMENG        Number of engines

NUMSEG        *Internally computed mission segment number, set to 1 in INISEG*

NWT            Number of take-off weights for climb path

11.14 O's

**OPTION**

*Internally set mission option indicator*

11.15 P's

PAIRS	Number of tank pairs carried in simple tank option. See ENERGY, OPTXX3
PAYWT	<i>Internally computed, total payload</i>
PLWINT	Internal payload weight
PM	Array of specified pressures at base of each layer in arbitrary atmosphere model; in pounds per square foot. If pressures are free, omit.
PQ1	<i>Internal, computed in OUTXXX, SEGOUT</i>
PQ2	<i>Internal, computed in OUTXXX, SEGOUT</i>
PQ3	<i>Internal, computed in SEGOUT</i>
PQ4	<i>Internal, computed in SEGOUT</i>
PQ5	Not used
PQ6	Not used
PQ7	Not used
PQ8	Not used
PQ9	Not used
PQ10	Not used
PS	Power setting, propulsion
PSET	Throttling option: = 1, maximum available dry, wet or maximum power = 2, minimum available = 3, at specified power setting



11.16 Q's

QLIM

Maximum allowable dynamic pressure

QS

*Internal, product of dynamic pressure and wing area;  
computed in CHECK, PATH, CRCOMP, EDMHPT, etc.*

## 11.17 R's

RANGE                    *Internally computed range, ENSEG*

RANGE1  
RANGE2                    **Three range values for buddy refuel mission segment option**  
RANGE3

RC                        *Internal, rate of climb; computed in PATH*

RCM                       *Internal range increment, FLIENV*

RCMAX                    *Internal, used in OPTXXZ*

RCSC                     **Rate of climb at service ceiling**

RETWGT                  *Internal, return weight*

RFAC                     *Internal, Breguet range factor; computed in CHECK, CRCOMP*

RN                        *Internal, summed range FLIMHC*

RXC                       *Internal, range covered in time DT; computed in CLIMB*

II.18 S's

SFC *Internal, specific fuel consumption, ENDAT*

SFCFAC Factor applied to specific fuel consumption

SPCHUT Flat plate area of drag chute

SPTYP1 *Internal, number of store pylons type 1 left, SACSP, STORES*

SPTYP2 *Internal, number of store pylons type 2 left, SACSP, STORES*

SPTYP3 *Internal, number of store pylons type 3 left, SACSP, STORES*

SPLG Flat plate area of landing gear

SQ

SREF Wing reference area

STWRET

STWDRP

STYP1 *Internal, number of stores type 1 left, SACSP, STORES*

STYP2 *Internal, number of stores type 2 left, SACSP, STORES*

STYP3 *Internal, number of stores type 3 left, SACSP, STORES*

11.19 T's

TAC *Internal, time to accelerate, XCEL*

TCMAX *Internal, time variable OPTXX2, OPTXX4*

TERM *Internal, array of particular mission segment data*

TEWT Weight of empty fuel tank pair, simple tank option (old NSEG)

TFWT Weight of fuel in tank pair, simple tank option (old NSEG)

TIME *Internal, mission time, ENSEG*

TITLE Title card, read in INSEG

TM Array of temperatures used in arbitrary atmosphere

TMINRJ Minimum ramjet throttle setting for combined engine option

TMINTJ Minimum turbojet throttle setting for combined engine option

TOL *Internal, tolerance set in CLIMB*

TOTSWD *Internal, total store and pylon weight dropped, STORES*

TOTTFD *Internal, total tank fuel dropped or consumed, TANKS*

TOTTWD *Internal, total weight of tank and pylons dropped, TANKS*

TPWT

TPTY1 *Internal, number of tank pylons type 1 left, SACTP, TANKS*

TPTY2 *Internal, number of tank pylons type 2 left, SACTP, TANKS*

TPTY3 *Internal, number of tank pylons type 3 left, SACTP, TANKS*

TRATIO Wing taper ratio, landing and take-off aerodynamics

TSIZEF Engine sizing factor

TSWT *Internal, total tank and store system weight, TNKSWT*

TSWDRP *Internal, total store system weight dropped*

TSWDRP *Internal, total store system weight returned*

TSWRET *Internal, total store system weight returned*

TTABXX            Propulsion table number XX

TTCC             *Internal variable in CLIMB*

TTR              *Internal, time to cruise, RUN; used in several options*

TTY1             *Internal, number of tanks type 1 left, SACTP, TANKS*

TTY2             *Internal, number of tanks type 2 left, SACTP, TANKS*

TTY3             *Internal, number of tanks type 3 left, SACTP, TANKS*

TZ                *Internal, array of mission segment data. Contains all segments and is aggregate of TERM arrays*

TZ13

11.20 V's

- VN            *Internal, velocity knots, CHECK*
- VX            *Internal, velocity in feet per second, CHECK*
- V50           *Internal, velocity at 50 foot obstacle, take-off analysis*

11.21 W's

W Initial weight

W1 *Internal, weight FLIMHC*

W2 *Internal, weight FLIMHC*

W50 *Internal, weight at 50-foot obstacle, take-off analysis*

WFF Final weight, endurance and range performance

WGTO Initial weight

WGTF1 Weight of fuel in tank pair type 1

WGTF2 Weight of fuel in tank pair type 2

WGTF3 Weight of fuel in tank pair type 3

WGTS1 Weight of store pair type 1

WGTS2 Weight of store pair type 2

WGTS3 Weight of store pair type 3

WGTS1P1 Weight of store pylon pair type 1

WGTS1P2 Weight of store pylon pair type 2

WGTS1P3 Weight of store pylon pair type 3

WGTT1 Empty weight of tank pair type 1

WGTT2 Empty weight of tank pair type 2

WGTT3 Empty weight of tank pair type 3

WGTP1 Weight of tank pylon pair type 1

WGTP2 Weight of tank pylon pair type 2

WGTP3 Weight of tank pylon pair type 3

WGUF1 Weight of usable fuel in tank pair type 1

WGUF2 Weight of usable fuel in tank pair type 2

WGUF3 Weight of usable fuel in tank pair type 3

WI Initial weight, endurance and range performance

WINCID Wing incidence used in take-off and landing analysis

WL Weight at start of landing; also control landing analysis  
in FILLPM

WO Initial take-off weight; also contains take-off analysis  
in FILLPM

WSLEFC Wing leading edge sweep angle; used in landing and take-off  
analysis

WT Weight used in general performance calculations

WTKEP Internal set to initial segment weight in OPTXX7 and other  
options

WUTO Warm up and take-off fuel weight allowance

WUTOFU



## 11.22 X's

XA1 XA2 XA3	<i>Internal variables in FLYMHP, FLIXCP, OPTXX2</i>
XAA	<i>Internal, controls INDMHP setting in CMAX. Control maximum R/C or dh/dw in OPTX14</i>
XAO	<i>Internal dm/dh in FLYMHP, FLIXCP, OPTXX1</i>
XBO XB1	<i>Internal, used in EMAX, FLIENV, FLIXEP, FLIXCP. XBO QLIM, XB1 AMLIM in OPTX14</i>
XFLEN	<i>Internal indicator. Controls call to FLITEN in MISION. Set in RNSEG</i>
XISO	<i>Specific impulse at take-off</i>
XMAXG	<i>Maximum ground roll</i>
XMLOD	<i>Internal, set in RNSEG</i>
XMSEG	<i>Internal, used in INSEG, set in RNSEG</i>
XNZZ	<i>Internal, error indicator set in BERAN, CHECK, CLIMB, CRCOMP, OPTXX1, OUTXXX, etc.</i>
XQ12	<i>Internal, used in OPTX14</i>
XQA1	<i>Internal, altitude variable GOGO OUTXXX</i>
XQAE	<i>Internal, altitude variable GOGO, OUTXXX</i>
XQBD	<i>Internal, indicator controlling CHECK Option and used in EMAX, FLIMHC, FLIXCP, GOGO</i>
XQFP	<i>Internal constant, FLYMHP, FLIMHC, FLIXEP, FLIXRP, FLIXCP, OPTXX1, OUTXXX, etc.</i>
XQR1	<i>Internal, range variable GOGO, RUN</i>
XQR2	<i>Internal, used in RUN</i>
XQR3	<i>Internal, used in RUN</i>
XQSW	<i>Aerodynamic reference area</i>

XQT1            *Internal, time variable GOGO, RUN*

XQT2            *Internal, used in RUN*

XQT3            *Internal, used in RUN*

XQW1            *Internal, weight variable in GOGO, OUTXXX, RUN*

XQW2            *Internal, weight variable in GOGO, OUTXXX, RUN*

XQWE            *Internal, minimum weight in CLIMB*

XSTEP

XTT             *Internal, limiting altitude change in FLYMHP. Also used in  
FLIMHC, FLIXEP, FLIXRP, FLIXCP, GOGO, INIMHP, OPTXX1, etc.*

11.23 Y's

YZA

*Internal, variable used in CHECK, CLIMB, PATH, etc.*

11.24 Z's

ZLTAB            Table of "Z" levels, contour plotting, used when INDZLT = 1.

ZMAX10          Minimum L/(T-D); map 10

ZMAX11          Maximum "Z" contour, map 11 (turn radius)

ZMAX12          Maximum "Z" contour, map 12 (time to turn)

ZX5             *Internal, number of tanks dropped, simple option, ENERGY*

ZX6             *Internal, used in PATH, RUN. ZX6 = 0.0 in SEGINI*

ZX7

ZX8             *Internal, set to WGTO in SEGINI*

ZX9             Not used

ZX10            *Internal, weight term in ENERGY. Set to total non-fuel weight dropped in OPTX12. Set to PAYWT in SEGINI*

ZY1

ZY2

ZY3

ZY4

ZY5             Not used

ZY6

ZY7

ZY8

ZY9

ZY10

## 12. FLIGHT PATH INEQUALITIES

AMAXTJ	Maximum Mach number for turbojet operation
AMINRJ	Minimum Mach number for ramjet operation
AMLIM	Limiting flight Mach number
CLMAX	Limiting $C_L$ value when INDCLM = 0
CLMTAB	Table of $C_{L_{max}}$ as function of (MACH, CASE) when INDCLM = 1
FNMIN	Minimum thrust
FFRMIN	Minimum fuel flow
GLEVEL	Load factor
QLIM	Dynamic pressure limit
TMINRJ	Minimum ramjet throttle setting for combined engine option
TMINTJ	Minimum turbojet throttle setting for combined engine option

### 13. GENERALIZED PERFORMANCE ANALYSIS

Two types of generalized performance calculations are available in NSEG:

1. Contour maps of specified performance function with or without superimposed climbs, descents, or accelerations
2. Organized sets of mission segments for a range of weights, Mach numbers, and altitudes

Generalized performance calculations are controlled from subroutine FLITEN which is called directly from the Main program of Overlay (3.0) MISSION when the internal variable XFLEN is .TRUE. Contour maps are prepared in FLIMAP Overlay (3.4), and organized missions are prepared in FLIRAN Overlay (3.3). Figure 17 presents a flow chart for subroutine FLITEN.

Each map generated requires a self-contained block of data which terminates with an END card. Vehicle data and contour map data, such as map limits, may be altered in any map data block. All map data blocks are contained in the GENPC data region, Figure 17.

#### 13.1 Contour Plotting Data and Options

A set of point calculations (i.e., vehicle capability at given flight conditions) are carried out over a two-dimensional array of Mach/altitudes,  $M_i, h_j$ . The resulting matrix of capabilities,  $F_{ij}^k$  is then supplied automatically to the CONPLOT routines, and the contours of the function  $F^k$  in the Mach/altitude plane are obtained in the form of CALCOMP, Houston plotter, or CRT display device output. At the present time twelve functions,  $F^1$  to  $F^{12}$ , may be output in contour form. Each contour plot and input is described below.

AME	End climb Mach number
AMF	Highest Mach number on contour grid
AMI	Lowest Mach number on contour grid
AMS	Start climb Mach number
ENDPTH	Terminal maneuver indicator: =-1, don't exceed terminal altitude = 1, allowed to exceed terminal altitude

**GLEVEL**    Number of 'g' pulled by vehicle  
**HE**        End climb altitude  
**HF**        Highest altitude on contour grid  
**HI**        Lowest altitude on contour grid  
**HO**        Initial climb altitude  
  
**INDGPC**    Generalized performance calculation indicator. Must be set  
to INDGPC = 8 for maps  
  
**INDMAP**    Map indicator:  
= 0, no map  
= i, produce map i  
  
**INDZLT**    Contour level indicator:  
= 0, Internally computed by NSEG  
= 1, specified directly by user  
  
**IPATH**    Superimposed path indicator:  
=-1, no paths  
= 0, all paths  
= 1,  $\dot{E}$  climb  
= 2, h climb  
= 3, M climb  
= 4, linear M-h climb  
= 5, constant dynamic pressure climb  
  
**IPDGPC**    Controls print out of grid details:  
= 0, don't print  
= 1, print  
  
**NAM**        Number of Mach numbers in grid, (Max. = 21)  
  
**NH**        Number of altitudes in grid (Max. = 21)  
  
**NUMCON**    Number of contour levels to be used  
  
**ZLTAB**    Table of contour levels to be defined on map when INDZLT=1

In addition, the appropriate aerodynamic and propulsive data must be specified.

### 13.1.1 Specific Energy Time Derivative, $\dot{E}$ (INDMAP=1)

The specific energy time derivative is computed according to the expression

$$\dot{E}(M,h) = (T-D)V/W$$

where

$\dot{E}$  - energy total time derivative

T - thrust obtained at a specified power setting or at T=D. Wet, dry, or maximum power options are available

D - drag computed for a specified load factor

V - flight velocity

W - aircraft weight

### 13.1.2 Specific Energy/Fuel Flow, $\dot{E}/\dot{m}$ , (INDMAP=2)

The  $\dot{E}/\dot{m}$  contour presents the specific energy time derivative over the fuel flow map. Since

$$\dot{E}/\dot{m} = \frac{dE/dt}{dm/dt} = \frac{dE}{dm}$$

The point calculation employed is

$$\dot{E}/\dot{m} = (T-D)V/(W\dot{m})$$

where  $\dot{m}$  is the fuel flow rate.

### 13.1.3 Lift/Drag, L/D, (INDMAP=3)

Lift/drag contours present a measure of the airplane's aerodynamic efficiency. The L/D maps indicate its range capability in unpowered flight and partially reflect the cruise range capability. Maps can be produced for any specified load factor.

### 13.1.4 Range Factor, $R_F$ , (INDMAP=4)

Range factor contours present a measure of vehicle cruise range capability. Maps are produced for level flight with thrust equal to drag at a specified aircraft weight.

$$R_F = \left(\frac{V}{SFC}\right) \left(\frac{L}{D}\right)$$

where SFC is the specific fuel consumption.

### 13.1.5 Thrust (INDMAP=5)

The thrust map is available as a device for examining thrust input data or the thrust component of other mapped functions. The map can be obtained for wet, dry, maximum, or throttled power setting.



### 13.1.6 Drag (INDMAP=6)

The drag map provides a device for inspecting drag data input or the drag component of any other map. Drag maps are produced for a specified load factor.

### 13.1.7 Specific Fuel Consumption, SFC, (INDMAP=7)

Specific fuel consumption maps are provided as a data input inspection device or as an aid to visualizing the specific fuel consumption component of other maps. Maps may be obtained for wet, dry, maximum, or throttled power settings.

### 13.1.8 Fuel Flow Rate, $\dot{m}$ , (INDMAP = 8)

The fuel flow maps are provided as a data input inspection device or as an aid to visualizing the fuel flow component of other maps. Maps may be obtained for wet, dry, maximum, or throttled power settings.

### 13.1.9 Specific Energy (INDMAP=9)

The specific energy map

$$E = h + V^2/2g$$

is provided as a user's convenience in visualizing the trajectory points between constant energy lines and any other set of contours.

### 13.1.10 Lift/(Thrust-Drag), $L/(T-D)$ , (INDMAP=10)

The lift/(thrust-drag) contours are useful for determination of maximum range powered flight. Assuming that maximum range flight occurs at small flight path angles with  $L \approx W$

$$R \approx \int \frac{L}{T-D} dE$$

Therefore, the energy-like approximation to maximum range flight occurs when  $L/(T-D)$  is a maximum at each energy level. It should be noted that when  $T - D = 0$ , no energy gain is possible; therefore, this singular condition must be avoided. In NSEG the per cent excess of thrust over drag which is acceptable is the program input ZMAX10.

### 13.1.11 Turn Radius (INDMAP = 11)

Turn radius maps give a gross indication of aircraft's combat capability. Turn radius is computed by equating the aircraft's lift capability in steady state or decelerating flight using the expression

$$R = w \left( \frac{V^2}{g} \right) \left[ \frac{1.0}{(qSC_L)^2 - W^2} \right]^{1/2}$$

where  $C_L$  is determined so that

1. INDTRN = 0
2. thrust equals drag for steady state flight
3. INDTRN = 1
4.  $C_L = C_{L_{max}}$  for minimum instantaneous turn radius

The maximum turn radius to be plotted is given by ZMAX11.

### 13.1.12 Time to Turn, (INDMAP=12)

Time to turn through  $180^\circ$  is presented as a supplement to the turn radius map. When the minimum instantaneous turn radius calculation is employed, the maps do not give a true time to turn. They merely indicate how long a time the aircraft would take to turn *if it could maintain its current turn rate*. When steady state turns are considered, true time to turn is obtained *which will frequently be much longer than is required for a decelerating turn*.

The maximum time to turn  $180^\circ$  plotted is given by ZMAX12.

## 13.2 Organized Mission Segments and Flight Envelope

These calculations are retained in the original NSEG program form. General data required is

- |       |                          |
|-------|--------------------------|
| AMLIM | Maximum Mach number      |
| CLMAX | Maximum lift coefficient |
| QLIM  | Dynamic pressure limit   |

Appropriate propulsion and aerodynamic data must also be specified.

### 13.2.1 Flight Envelope Calculation (INDGPC = 1)

AM Initial Mach number for computation of flight envelope  
DELAM Mach increment for flight envelope  
DELWT Weight increment for computation of several flight envelopes  
NWT Number of weights for computation flight envelope  
WT Initial weight for computation of flight envelope

### 13.2.2 Climb Path History, (INDGPC=2)

AMF End of climb Mach number (if zero, RFMAX will be used)  
DELWT Incremental weight for climb performance  
NWT Number of weights to compute climb path  
WT Initial take-off weight for climb performance  
WUTO Warm-up and take-off fuel

### 13.2.3 Endurance vs. Weight at Several Altitudes, (INDGPC = 3)

DELH Incremental altitude  
H Initial altitude for endurance computation  
WFF Final weight for endurance  
WI Initial weight for endurance computation

The number of weights, NWT, is computed internally and is less than or equal to 9.

### 13.2.4 Optimum Cruise Climb vs. Weight at Various Mach Numbers (INDGPC=4)

AM Initial Mach number for cruise climb  
DELAM Incremental Mach number  
NAM Number of Mach numbers  
WI Initial cruise weight  
WFF Final cruise weight

The number of weights, NWT, is internally computed and is less than or equal to 9.

#### 13.2.5 Constant Altitude, Constant Mach Cruise at Various Weights, (INDGPC = 5)

AMI Initial Mach number for constant altitude cruise  
DELH Incremental altitude  
DELAM Incremental Mach number  
NH Number of altitudes  
NAM Number of Mach numbers  
WFF Final weight for cruise  
WI Initial weight for cruise

The number of weights, NWT, is internally computed and is less than or equal to 9.

#### 13.2.6 Take-Off and Landing Calculations (INDGPC = 6)

Data has already been presented in Section 8.

#### 13.2.7 ML/D Calculation at Given Altitude, Various Mach Numbers and $C_L$ Values, (INDGPC = 7)

AMACH Mach number value table  
H Given altitude  
NAM Number of Mach numbers, less than or equal to 9.

Note that ML/D is computed for  $C_L$  in the range 0 to 1.6 at .05  $C_L$  intervals.

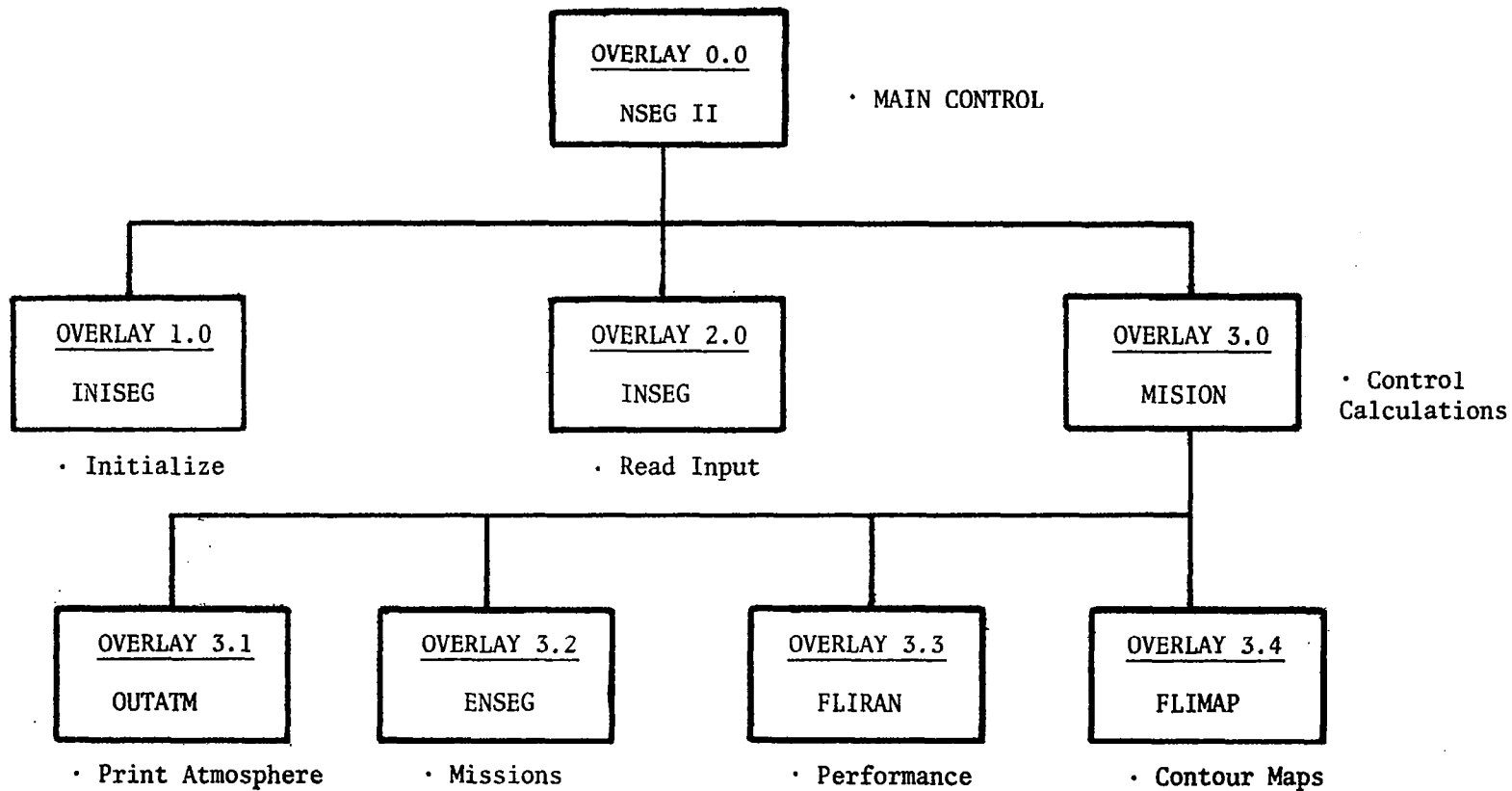


FIGURE 1. NSEG OVERLAY STRUCTURE

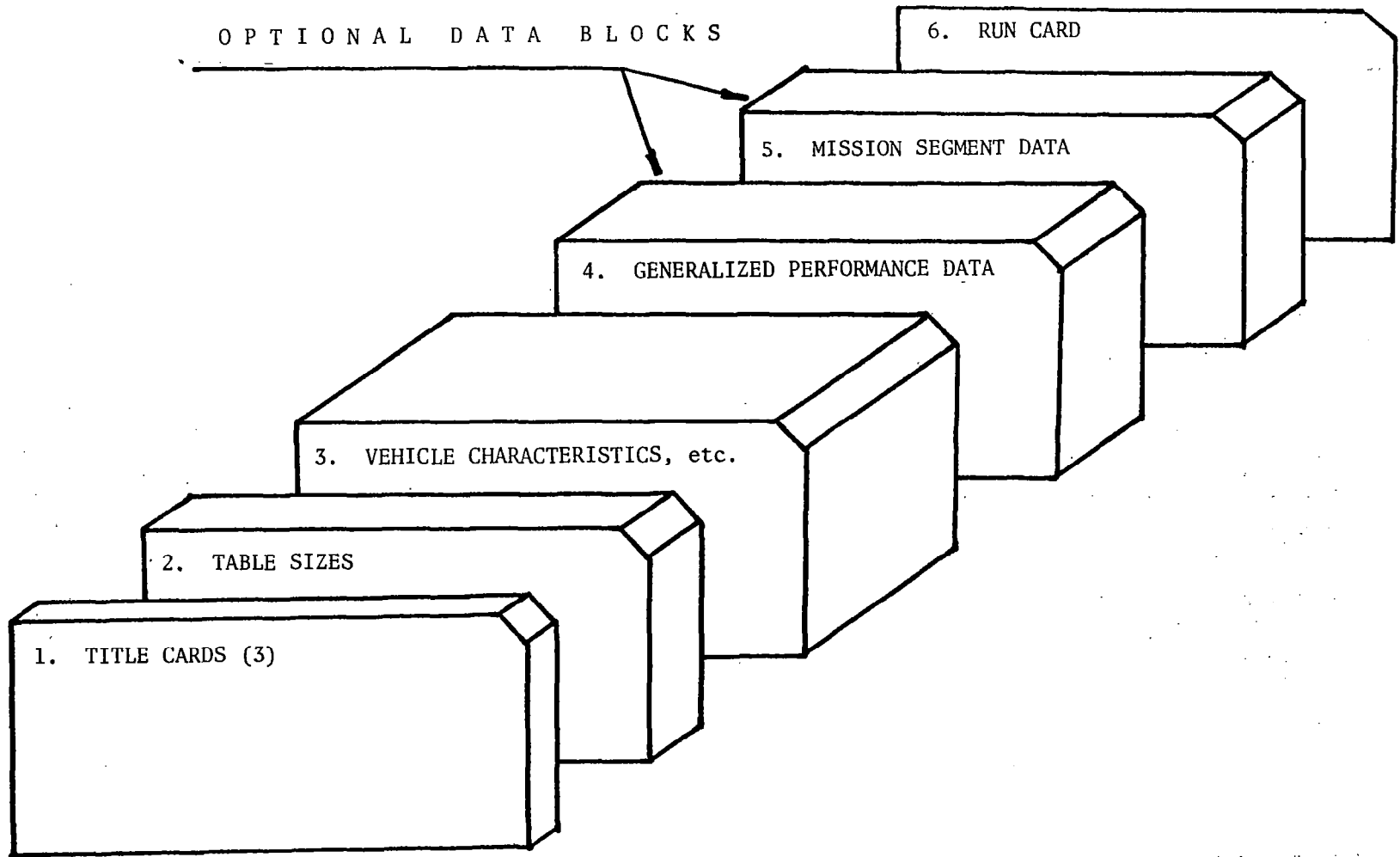


FIGURE 2. BASIC NSEG DATA OUTPUT

(a)

1. TITLE
2. TABLE SIZES
3. VEHICLE DATA
4. GENERAL PERFORMANCE
5. MISSION
6. RUN CARD

(b)

1. TITLE
4. GENERAL PERFORMANCE
6. RUN CARD

(c)

1. TITLE
5. MISSION
6. RUN CARD

(d)

1. TITLE
3. VEHICLE DATA
5. MISSION
6. Run Card

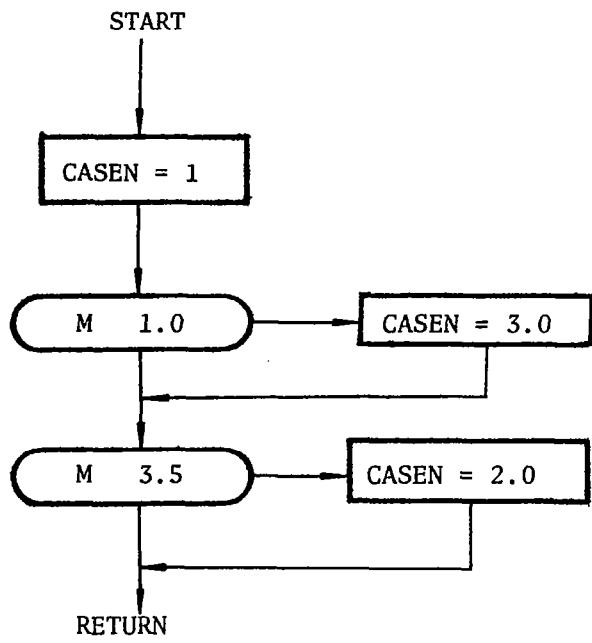
(e)

1. TITLE
2. TABLE SIZES
3. VEHICLE DATA
4. GENERAL PERFORMANCE
6. RUN CARD

(f)

1. TITLE
2. TABLE SIZES
3. VEHICLE DATA
5. MISSION
6. RUN CARD

FIGURE 3. SOME POSSIBLE ADDITIONAL NSEG DATA BLOCKS



\* Provides automatic propulsion switching on Mach number

FIGURE 4. FLOW CHART, ENCASE



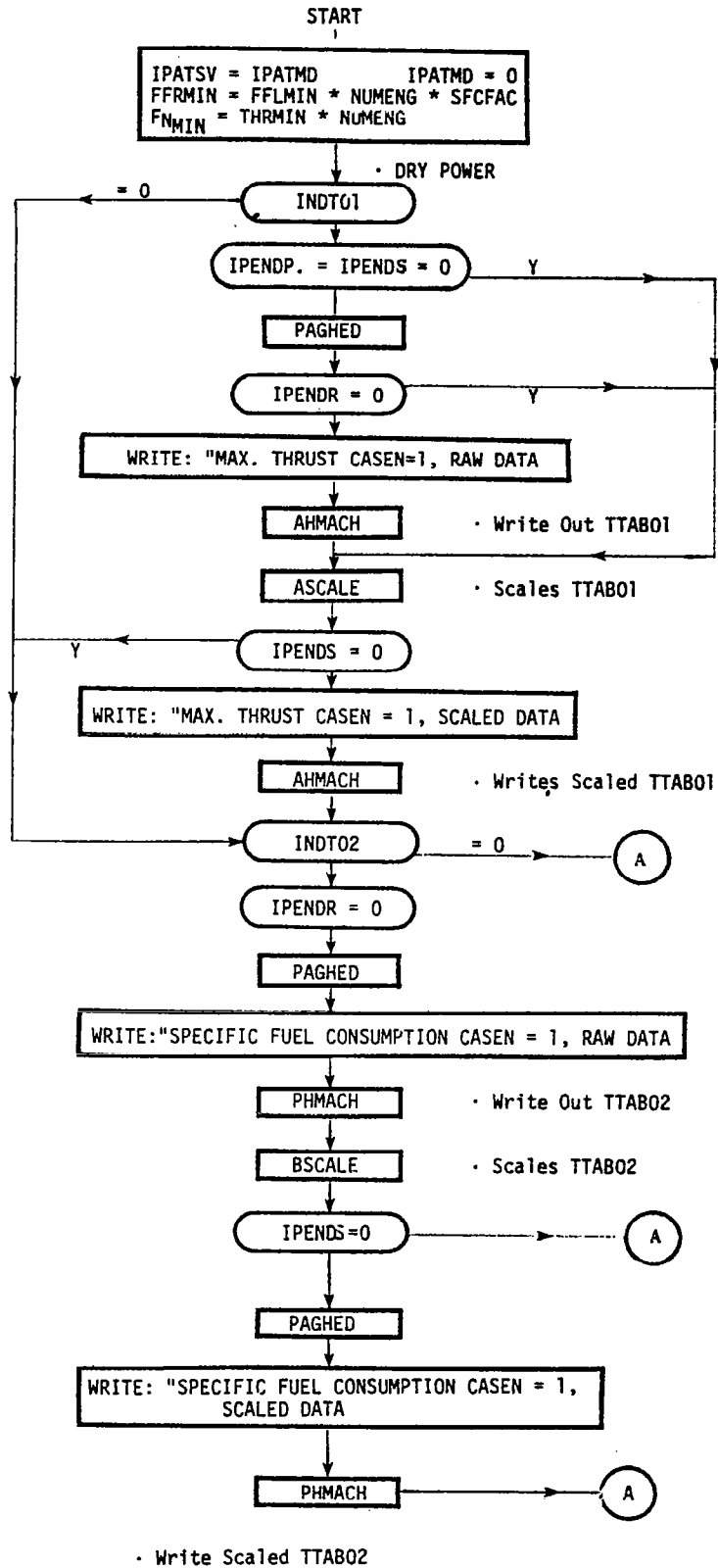


FIGURE 5. FLOW CHART ENDAT

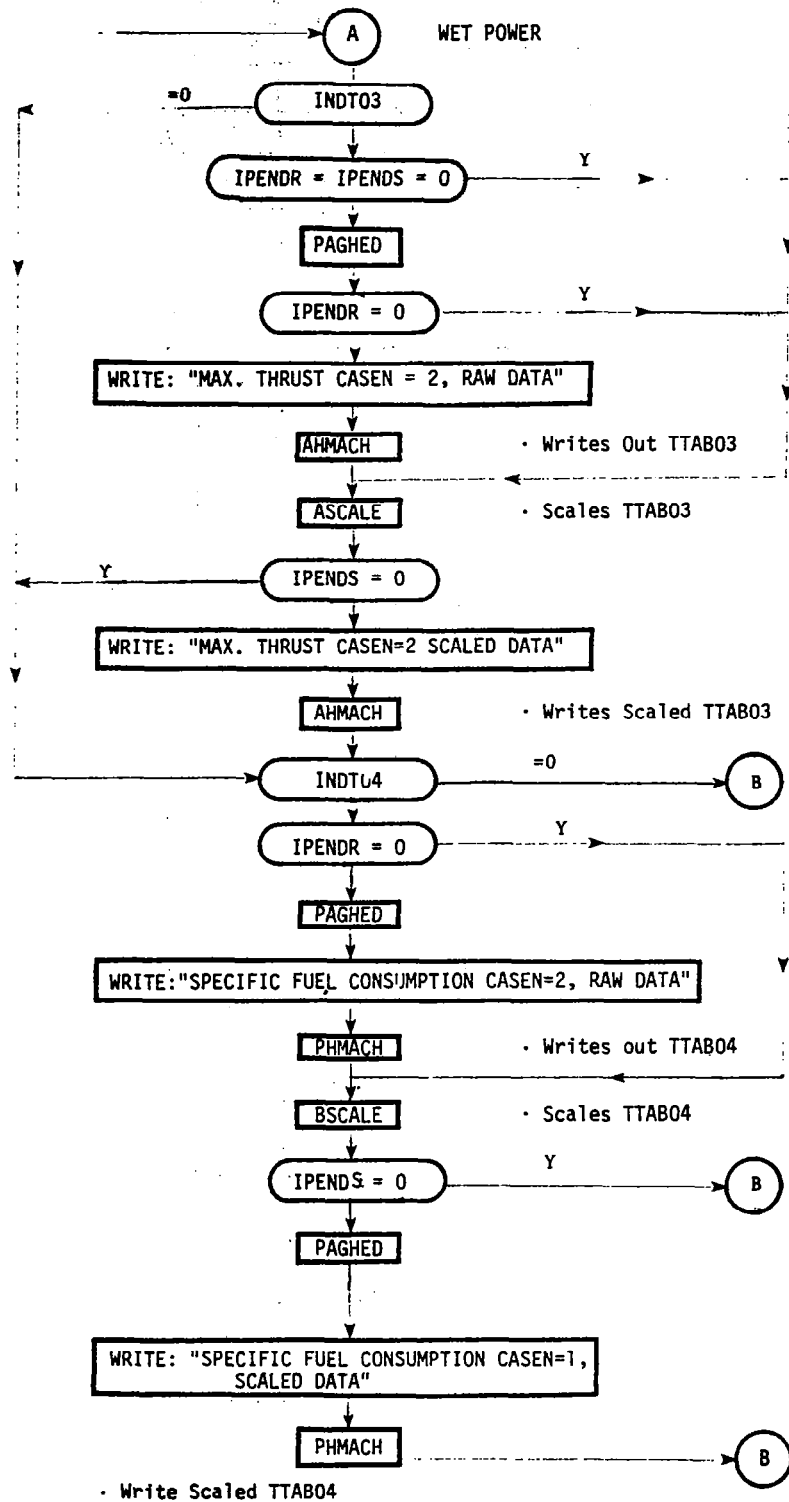


FIGURE 5. FLOW CHART ENDAT (CONTINUED)

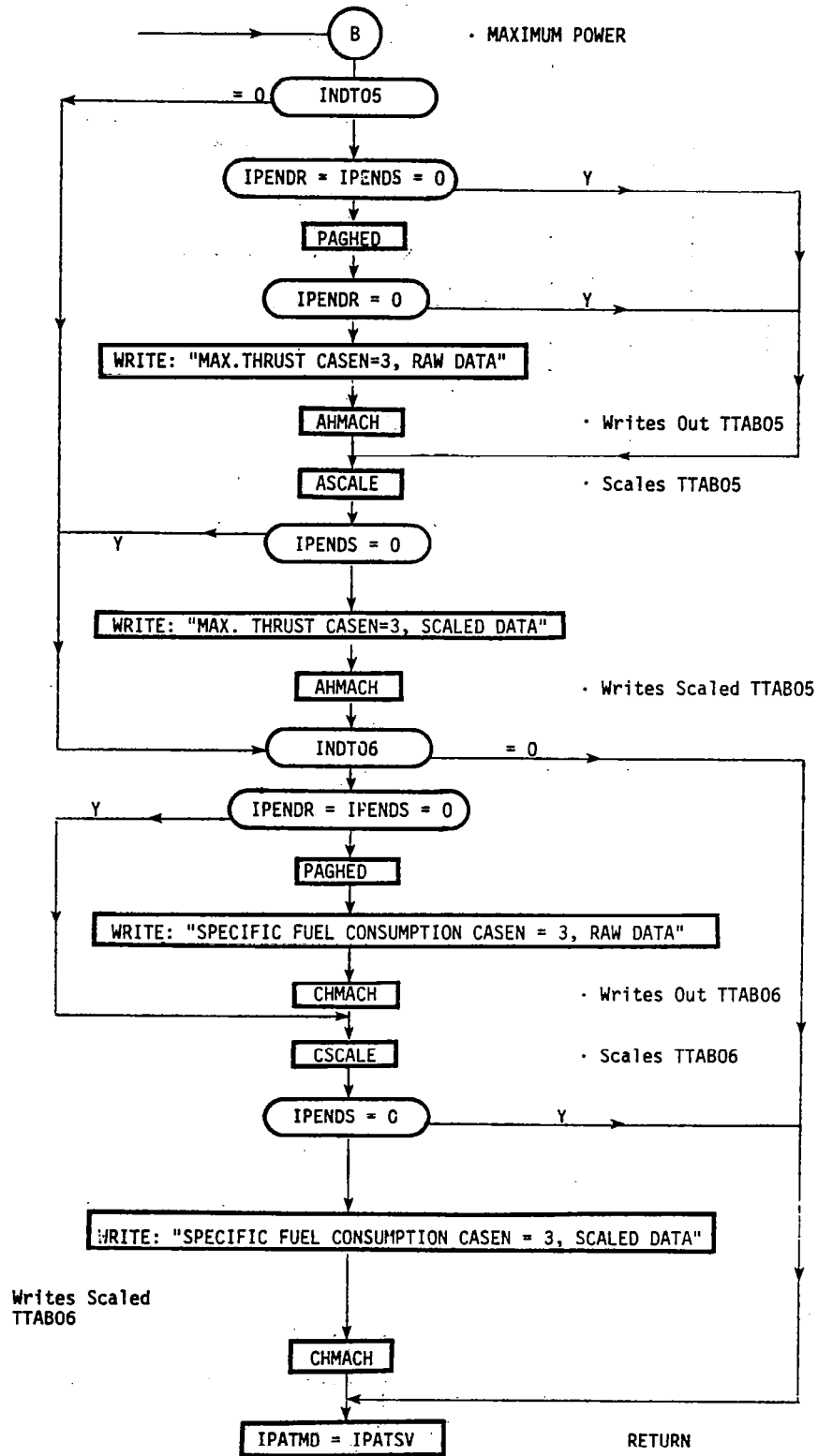


FIGURE 5. FLOW CHART ENDAT (CONCLUDED)

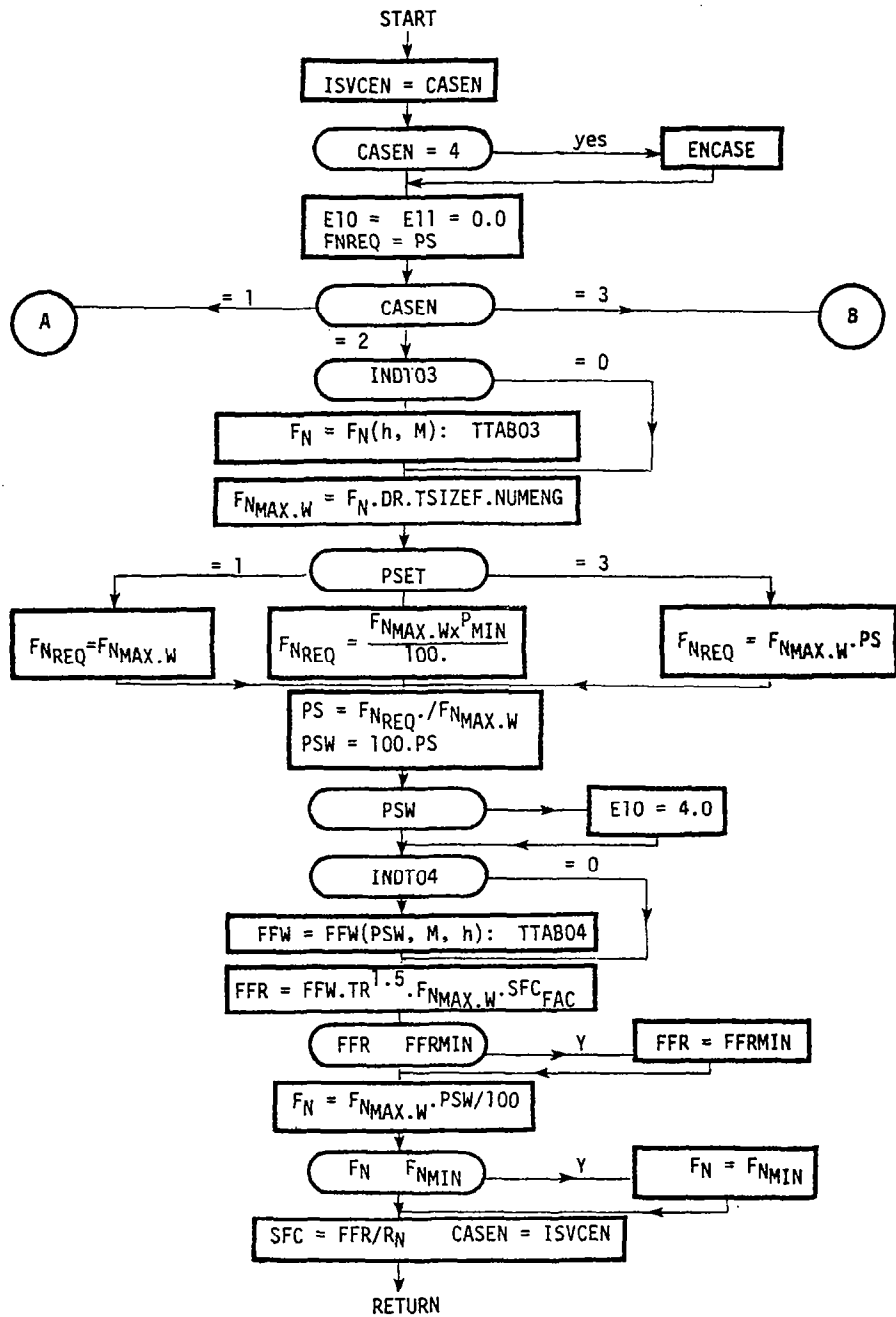


FIGURE 6. FLOW CHART ENSET

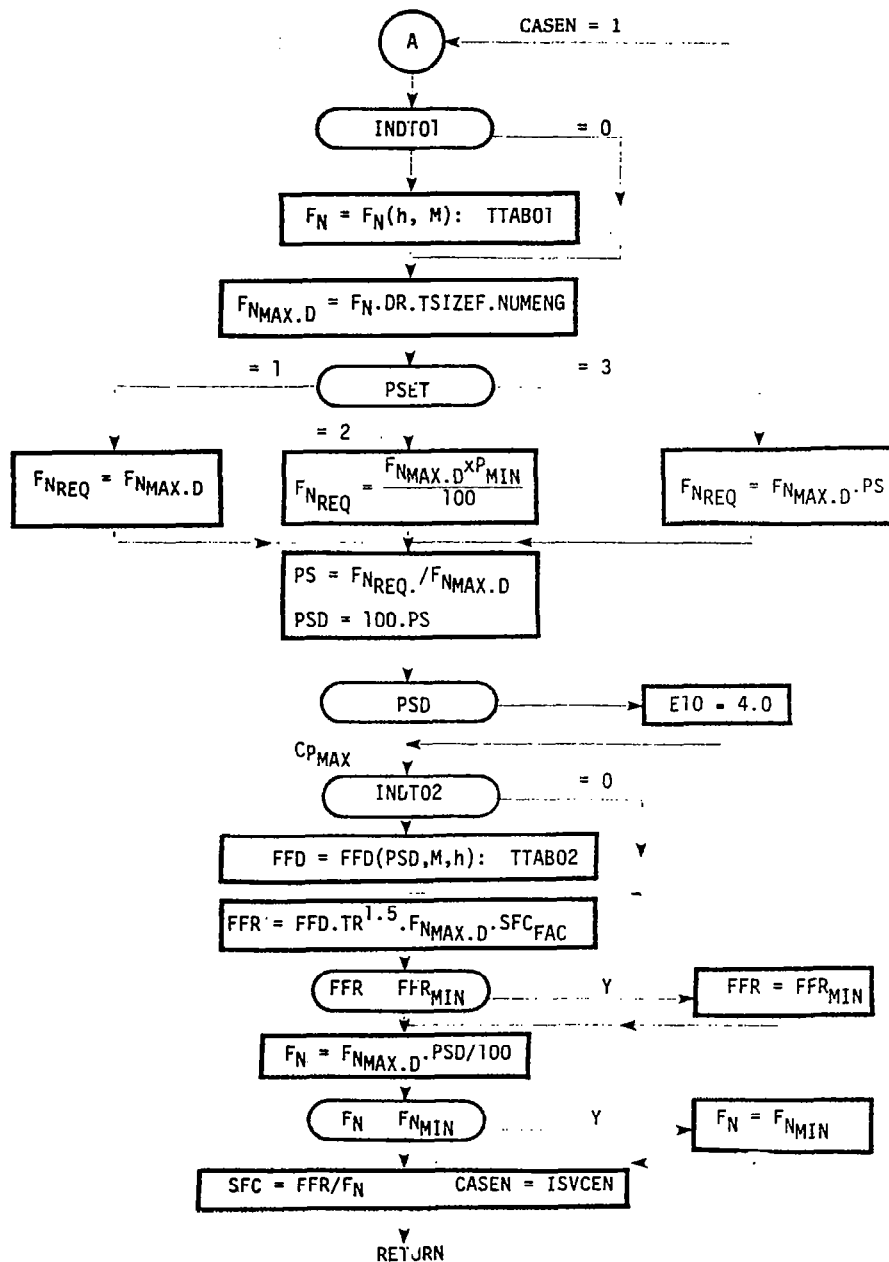


FIGURE 6. FLOW CHART ENSET (CONTINUED)

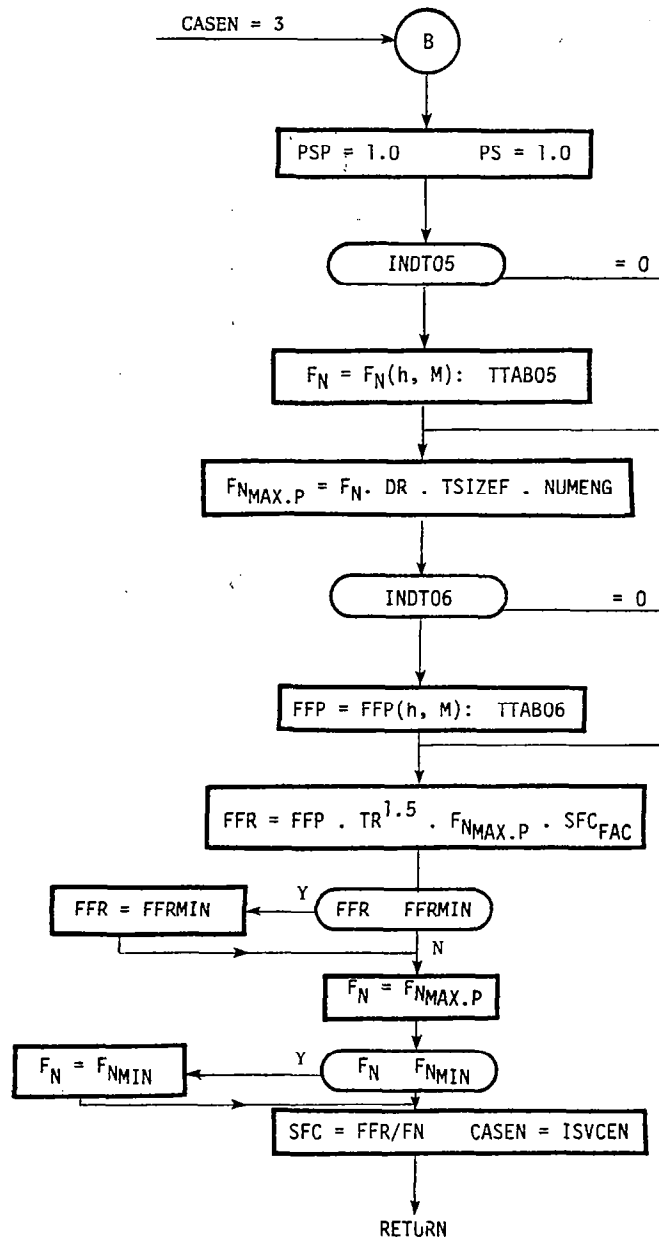
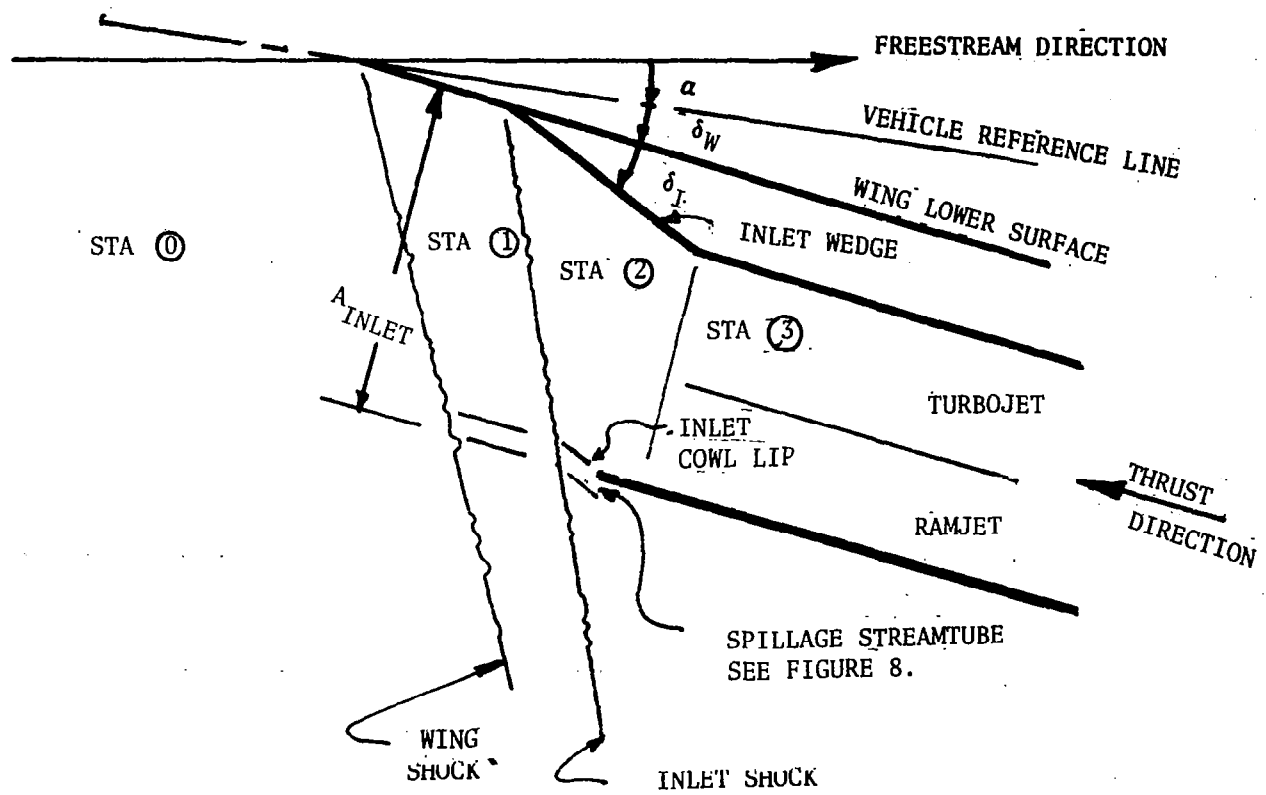
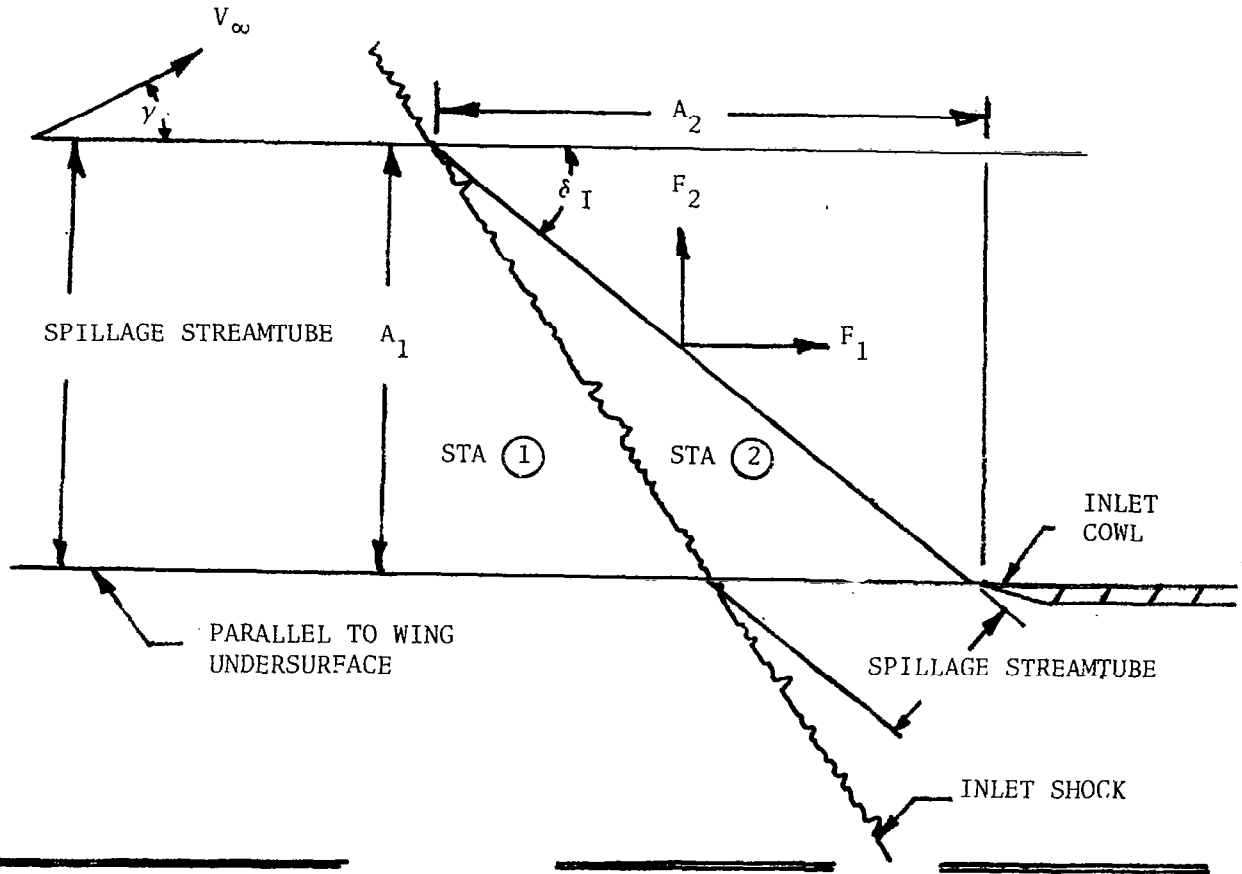
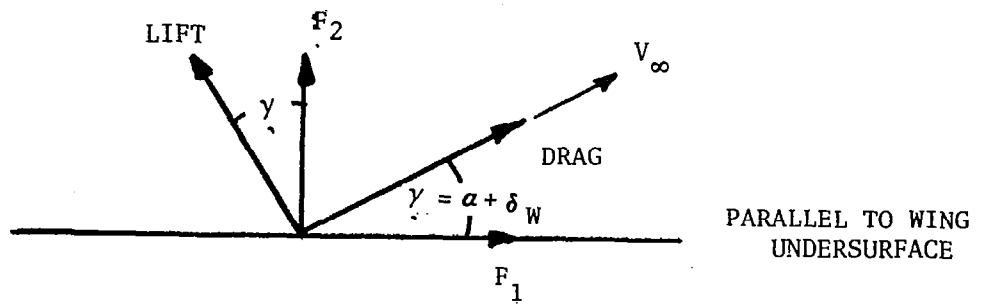


FIGURE 6. FLOW CHART ENSET (CONCLUDED)



$$\gamma \equiv \alpha + \delta_W$$

FIGURE 7. REFERENCE STATIONS AND GEOMETRY



$$A_1 = \text{SPILLED AIRFLOW} / p_1 v_1$$

$$A_2 = A_1 / \tan \delta_I$$

$$F_1 = (P_2 - P_0) A_1 \quad F_2 = (P_2 - P_1) A_2$$

$$L_{\text{SPILL}} = (F_2 \cos \gamma - F_1 \sin \gamma) \quad D_{\text{SPILL}} = F_1 \cos \gamma + F_2 \sin \gamma$$

FIGURE 8. SPILLAGE LIFT AND DRAG COMPUTATIONS



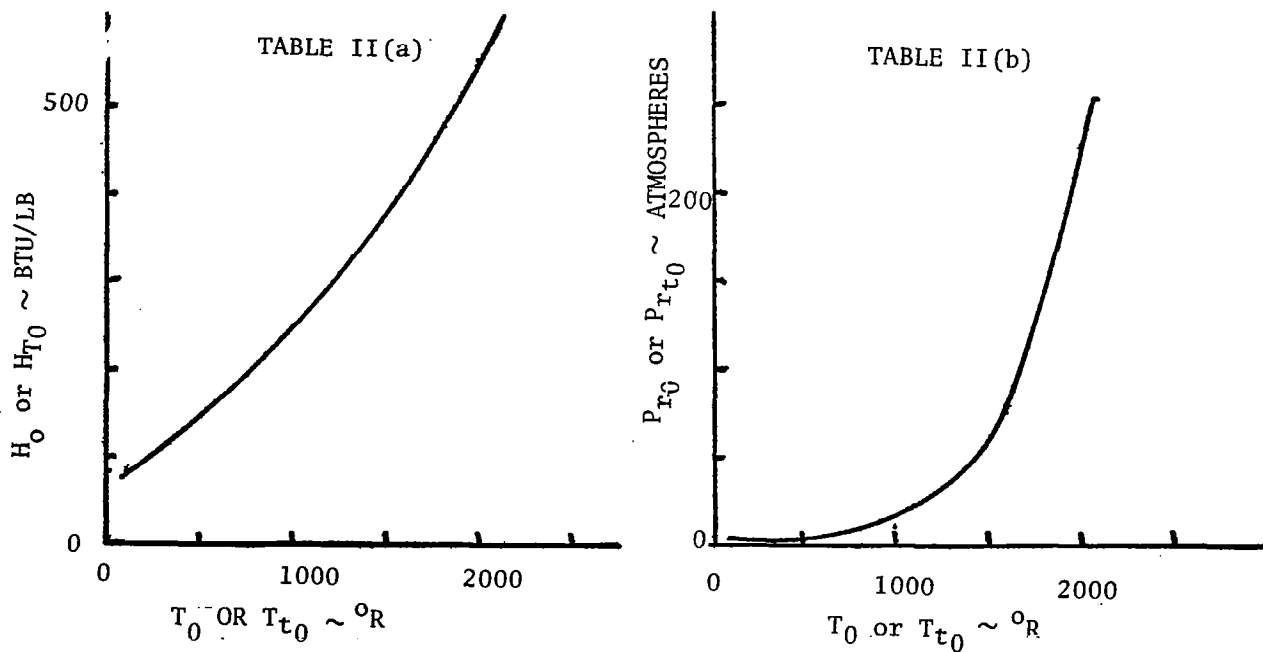
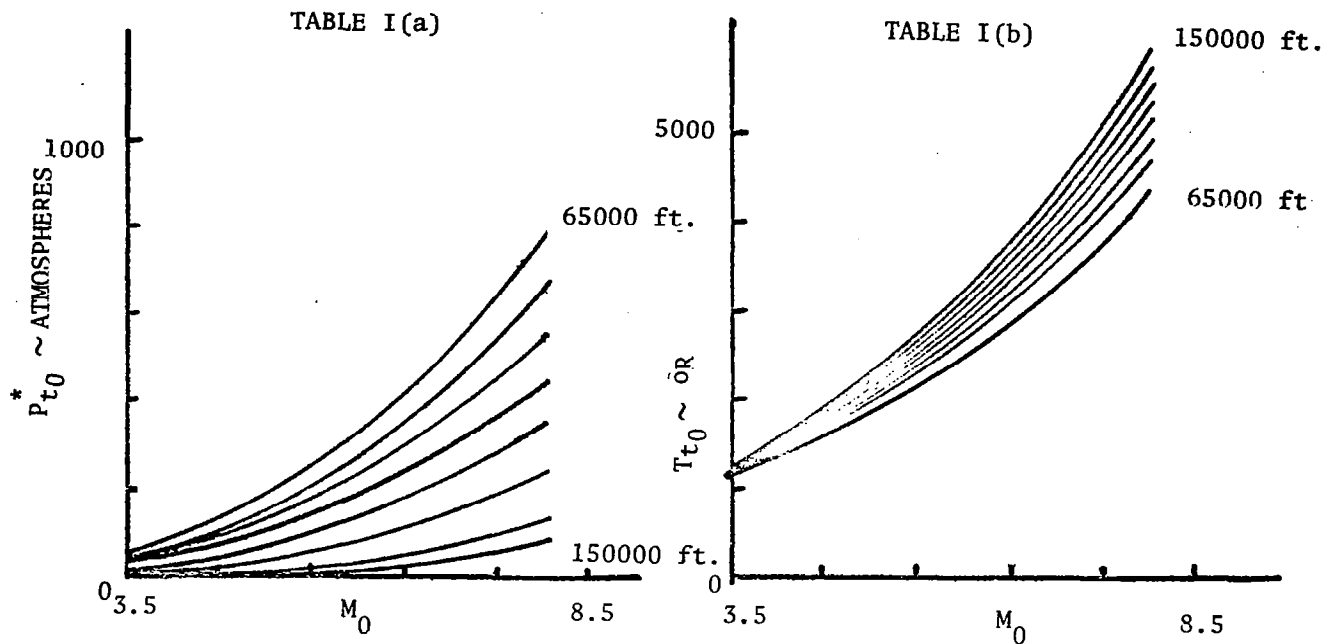


FIGURE 9. TYPICAL TABLE DATA

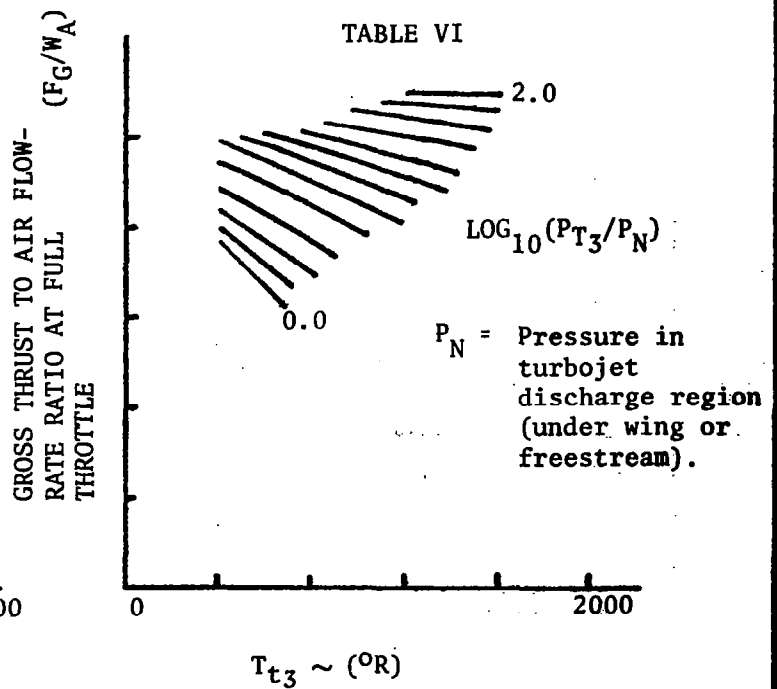
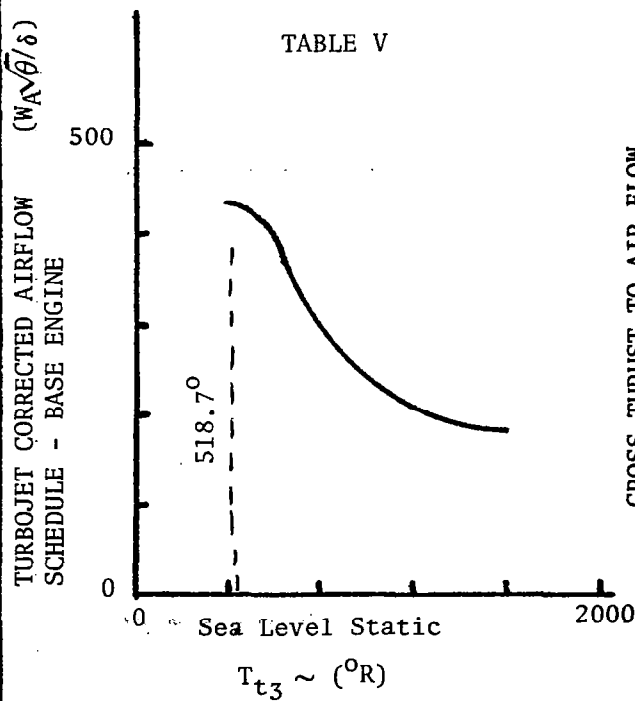
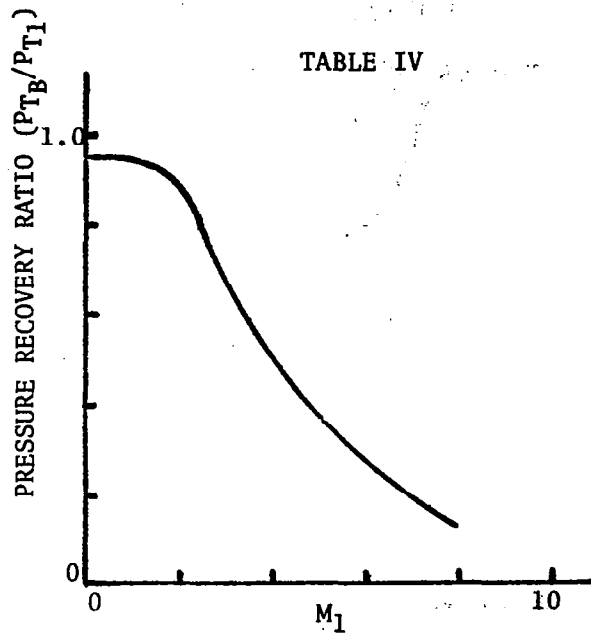
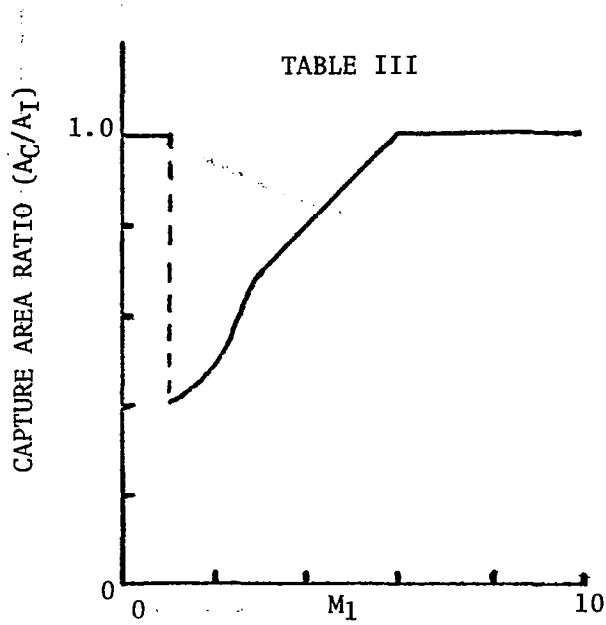


FIGURE 9. TYPICAL TABLE DATA (cont'd)

TABLE VII

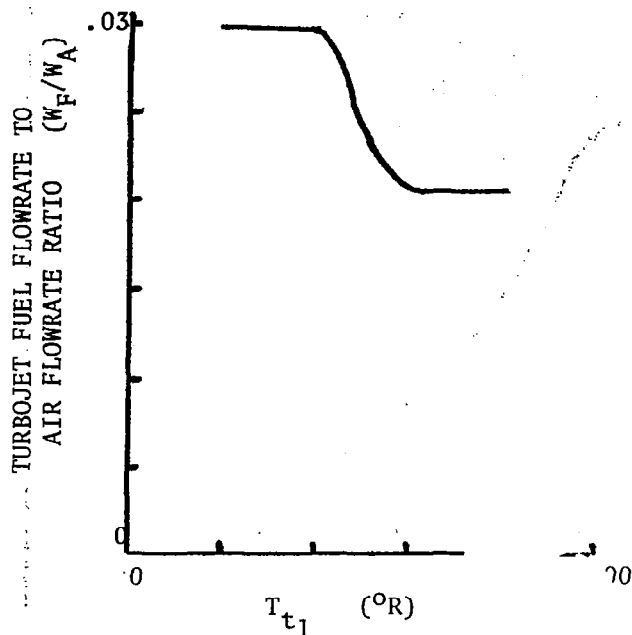


TABLE VIII

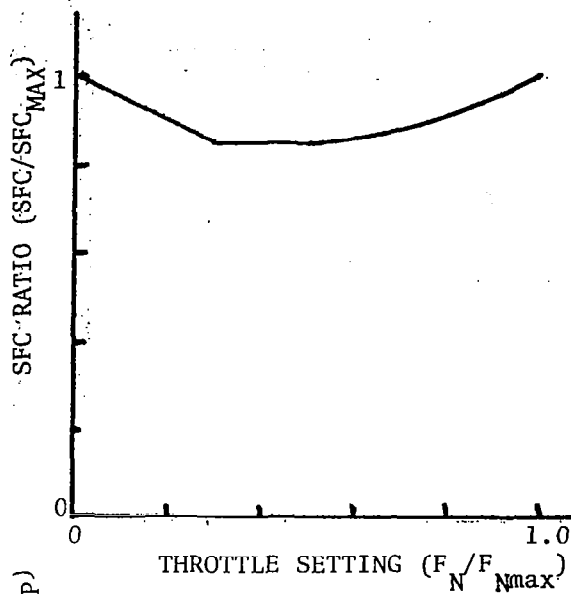


TABLE IX

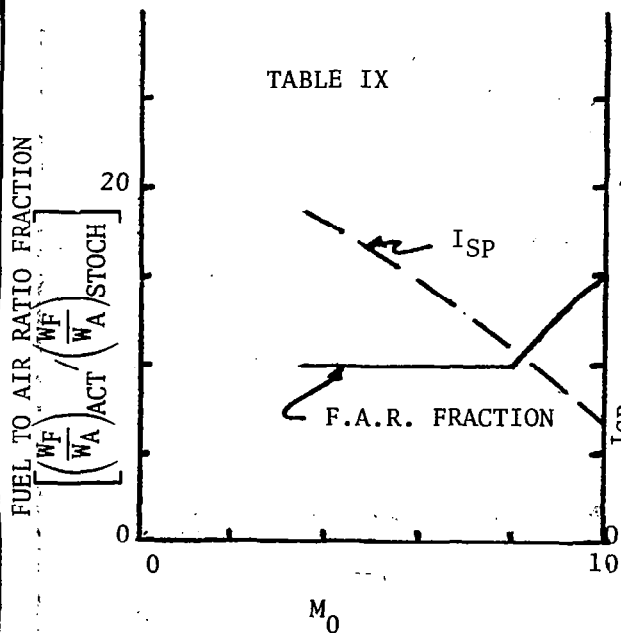


TABLE X

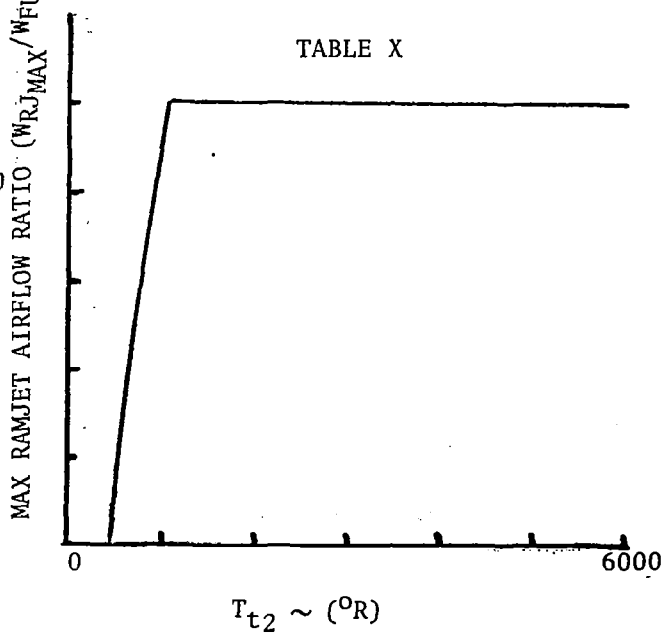
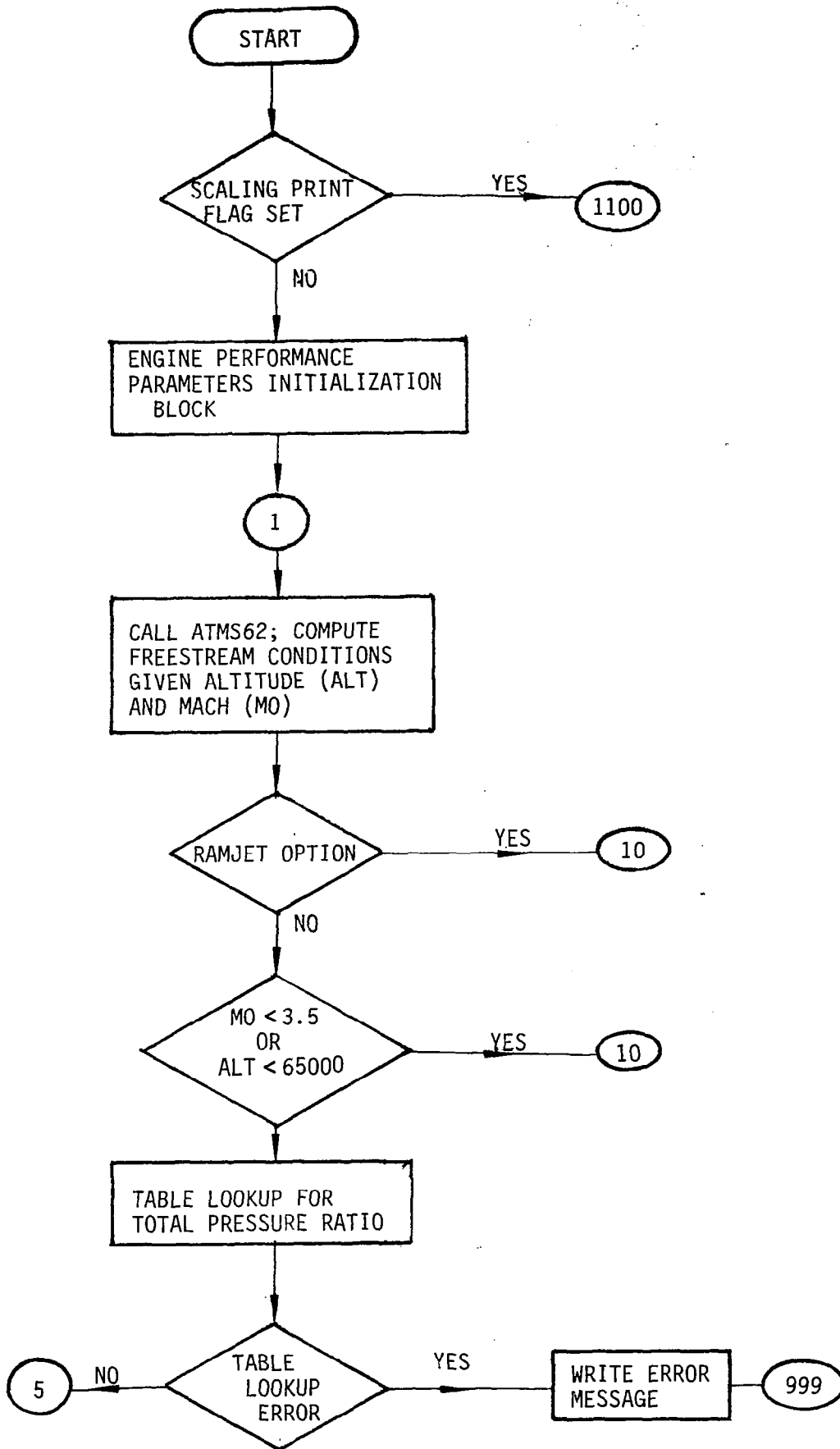
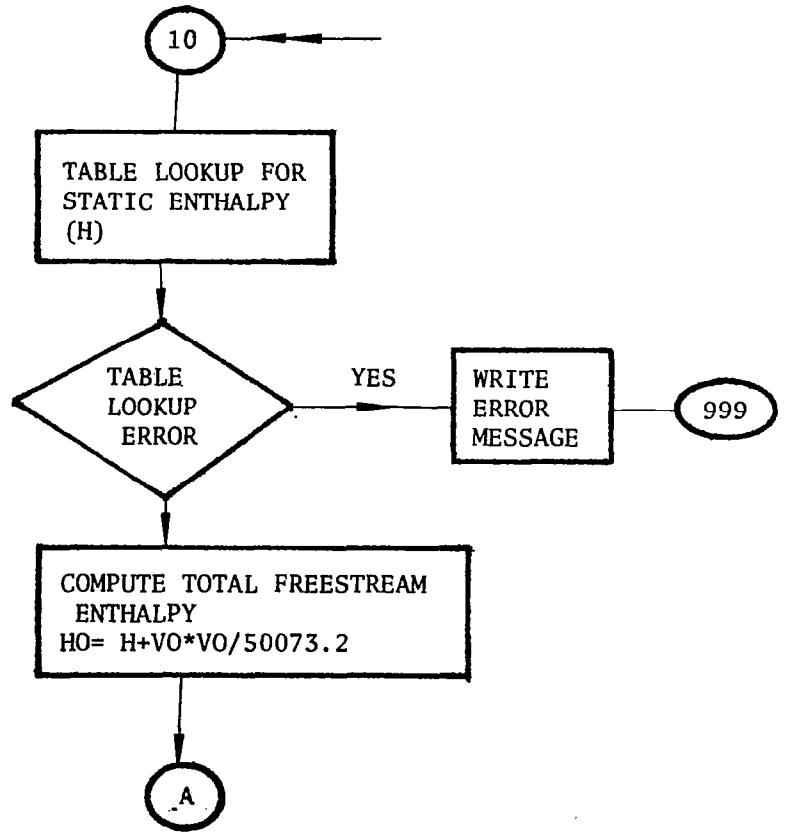
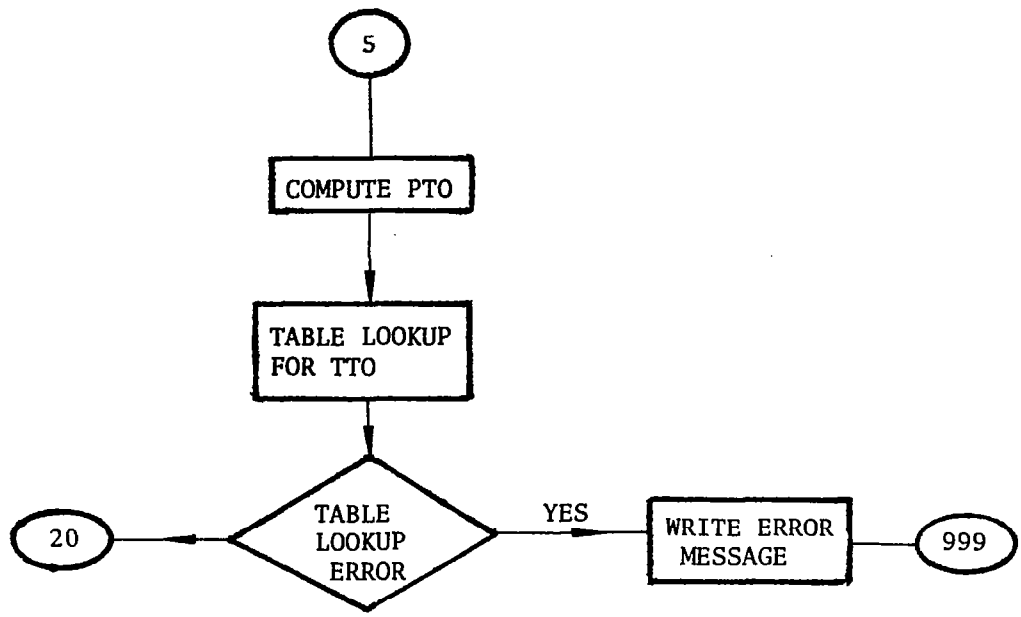
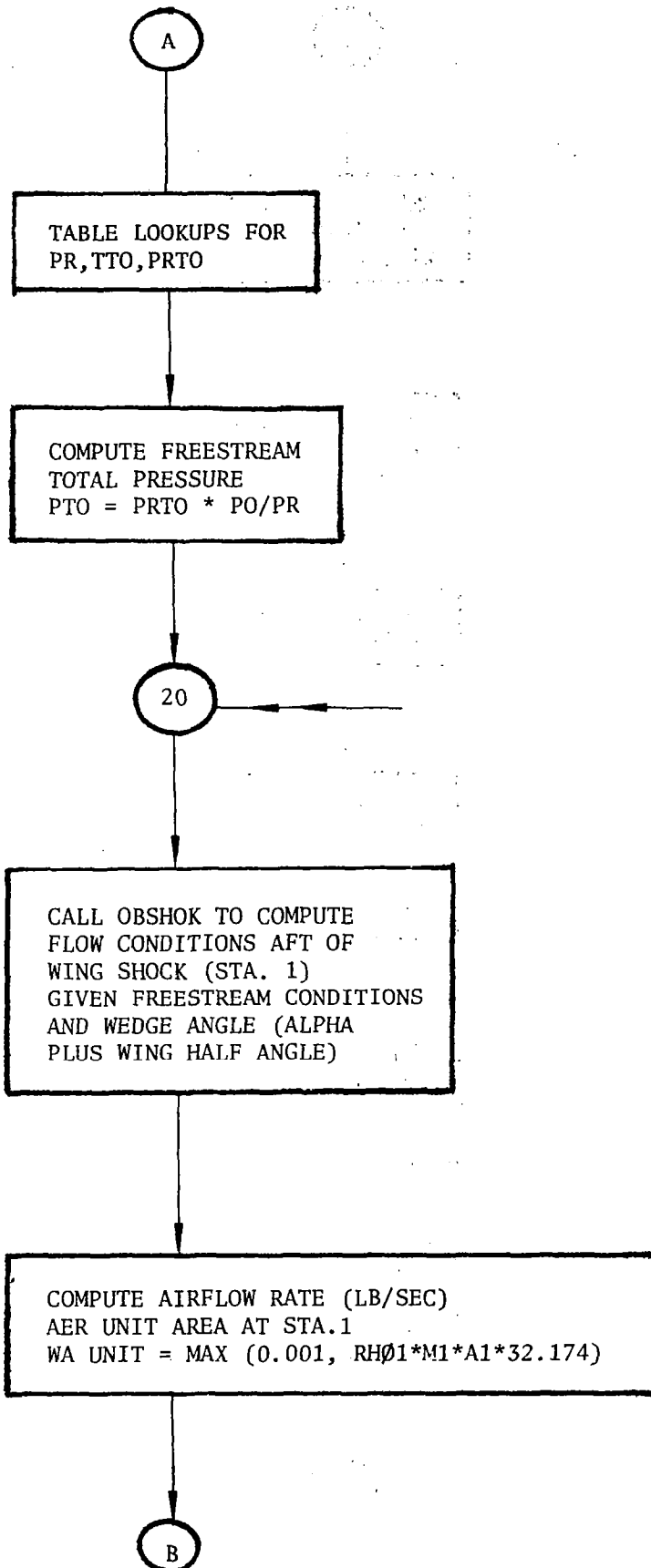


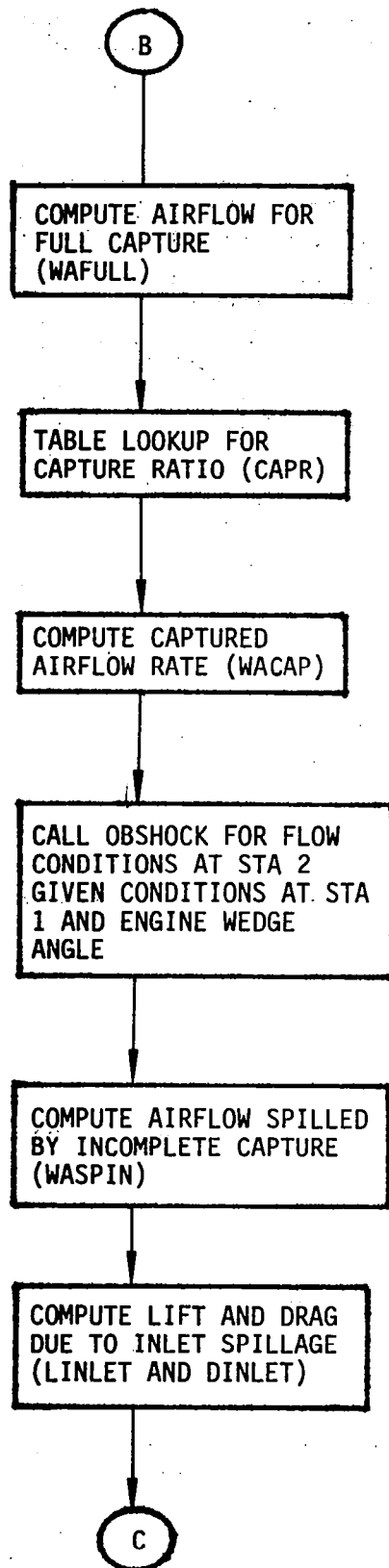
FIGURE 9. TYPICAL TABLE DATA (concluded)

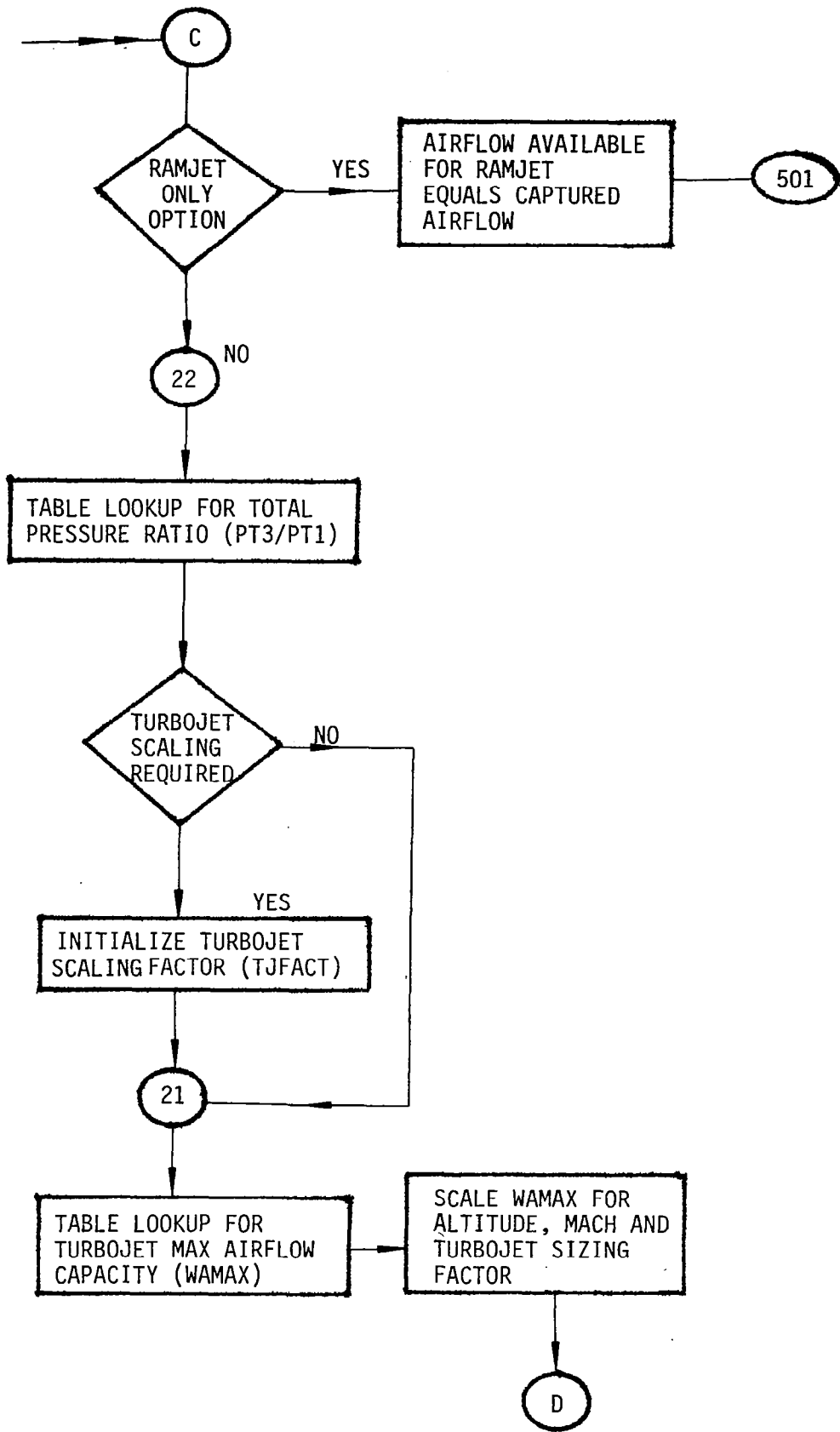
FIGURE 10. FLOW CHART SUBROUTINE ENGINES



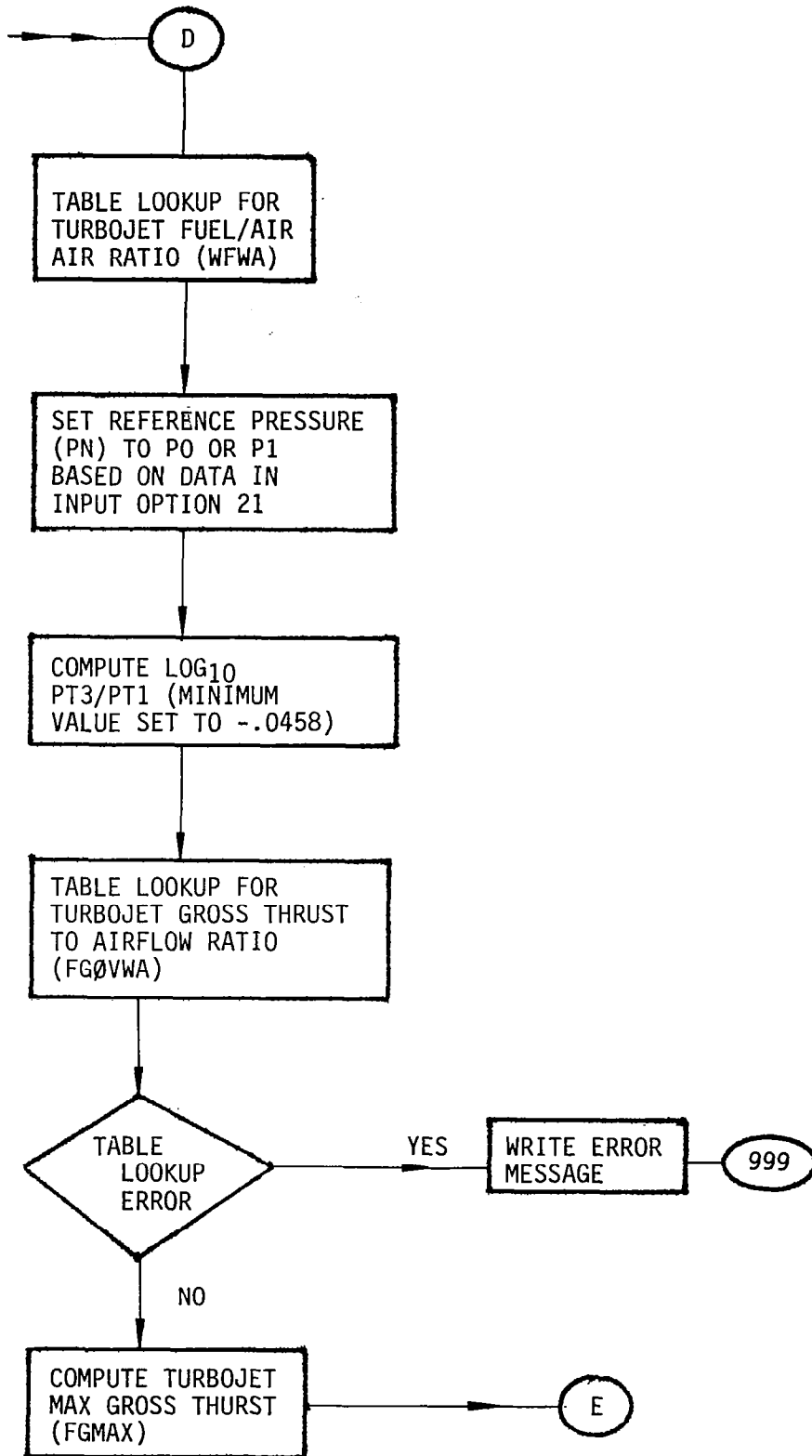


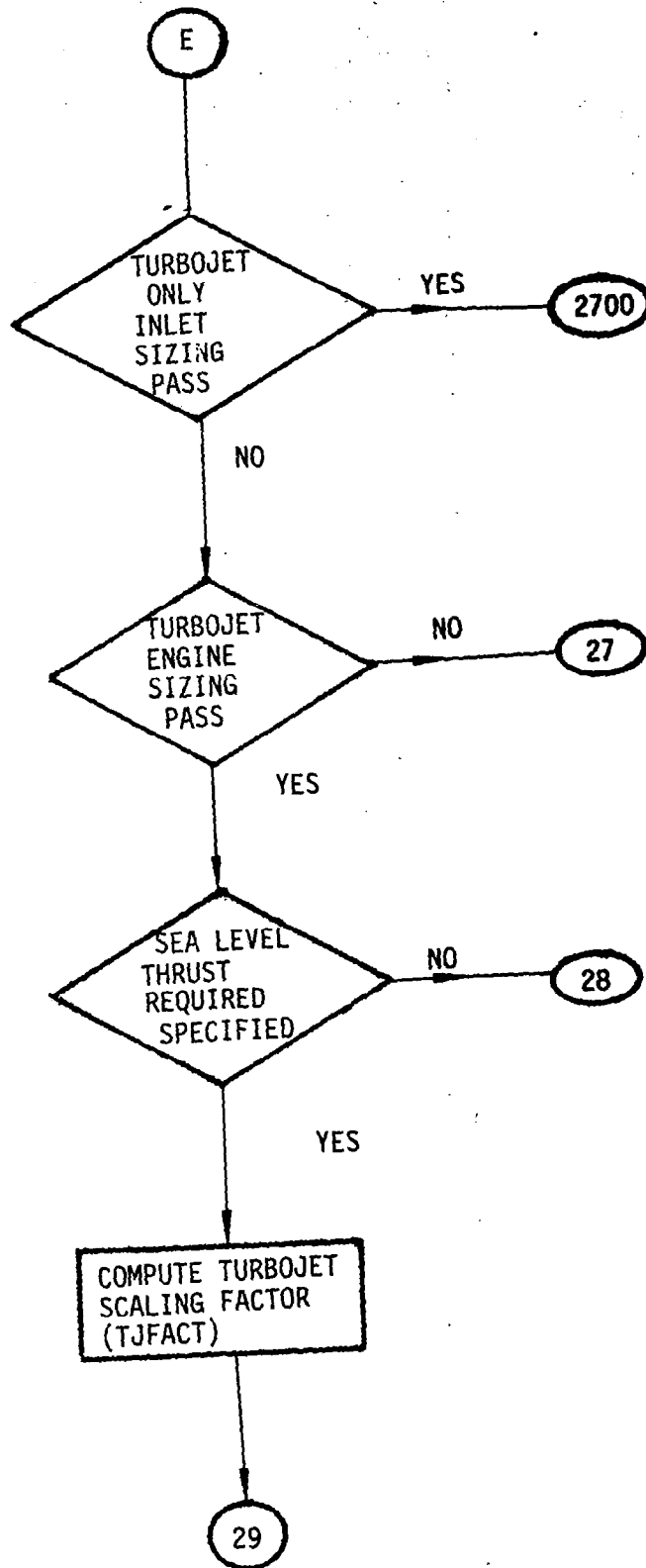


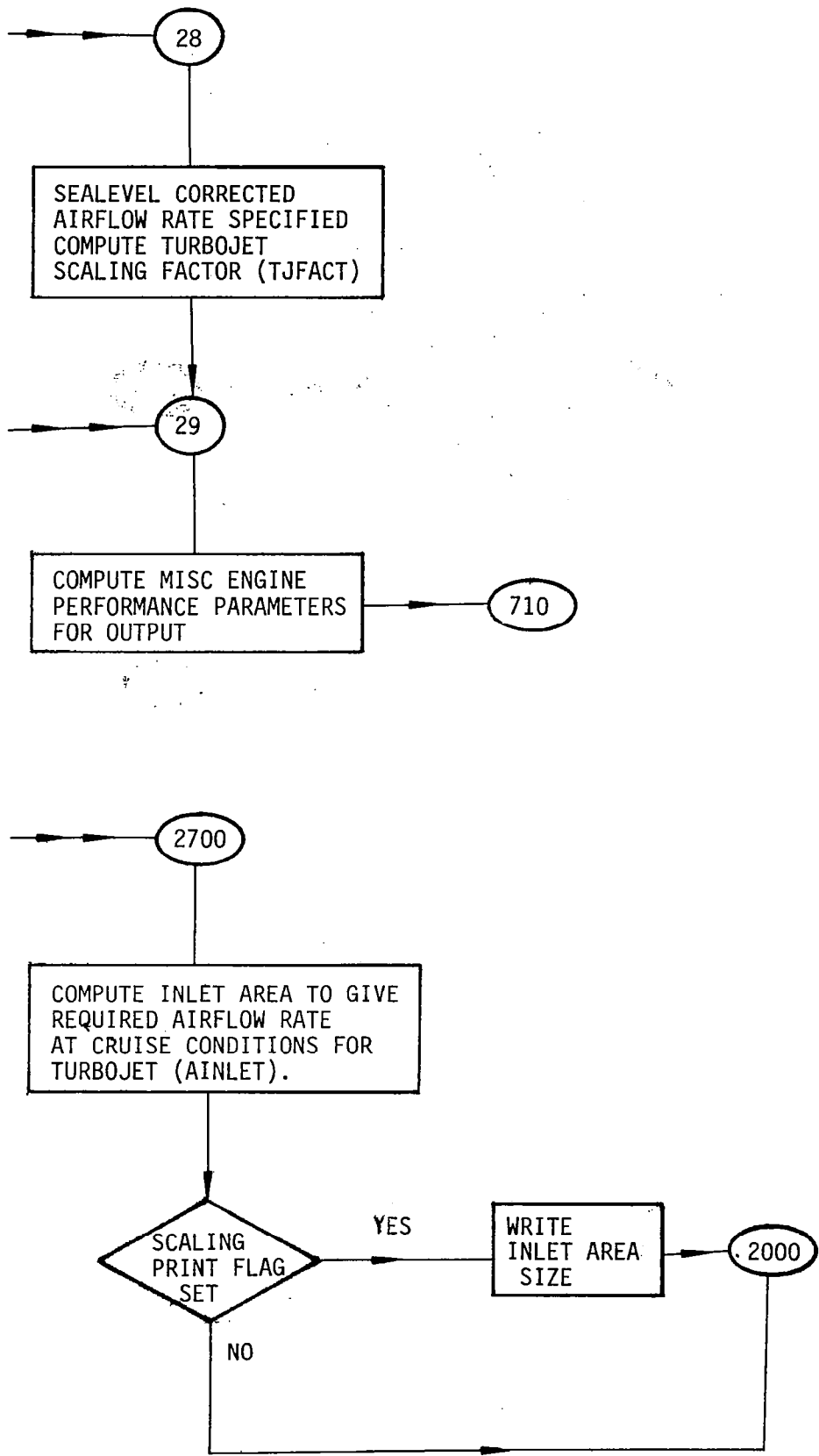


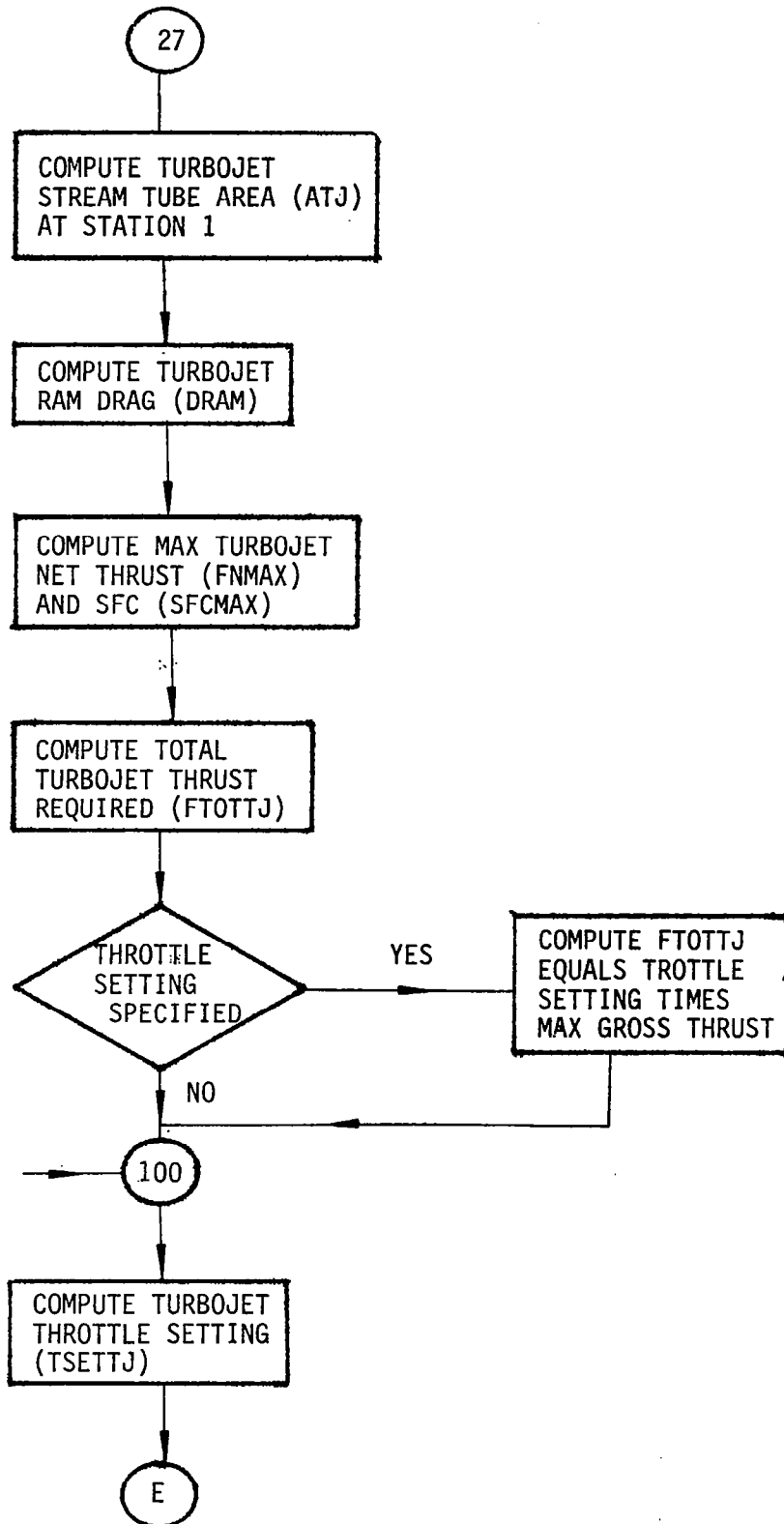


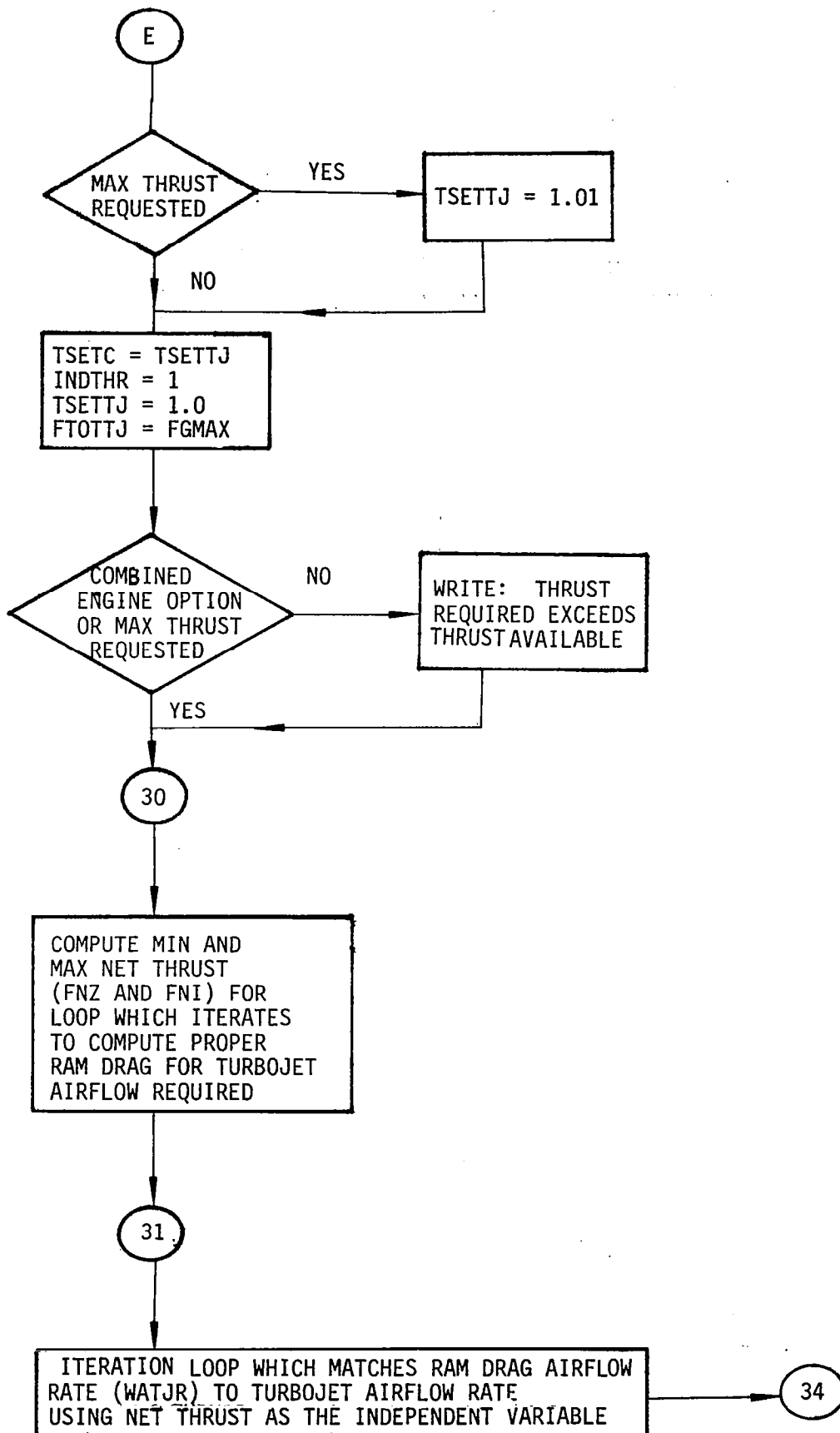


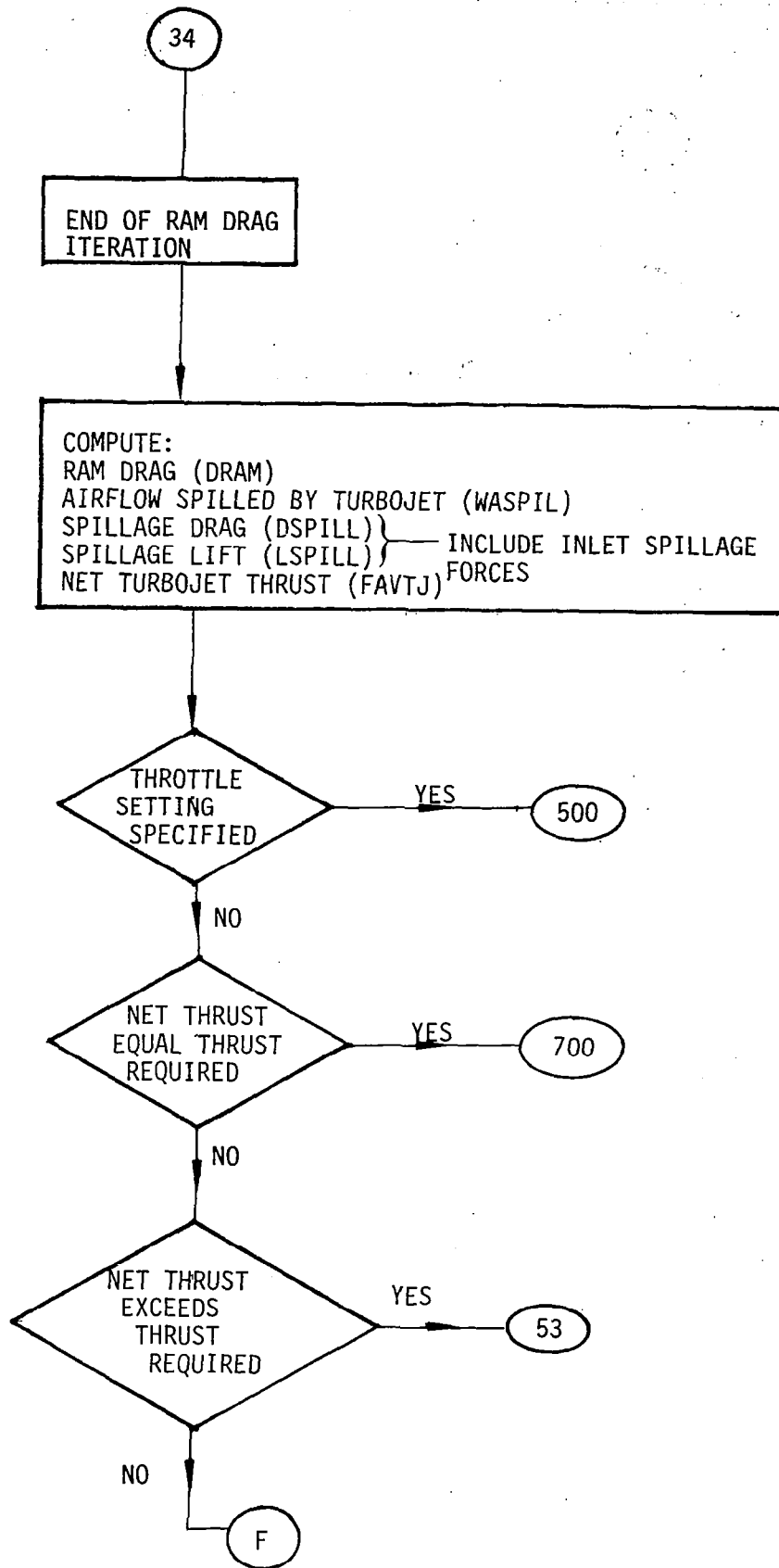


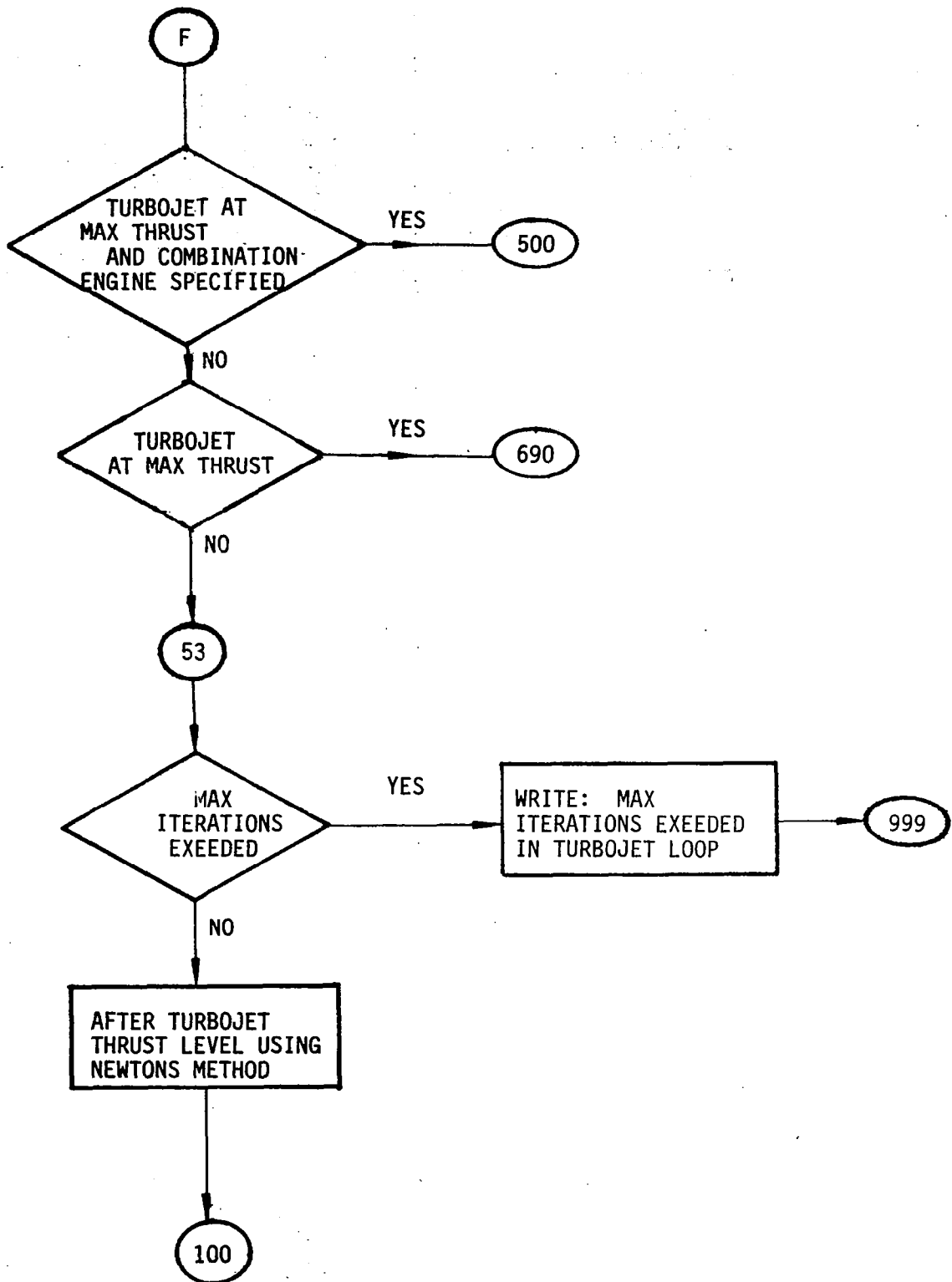


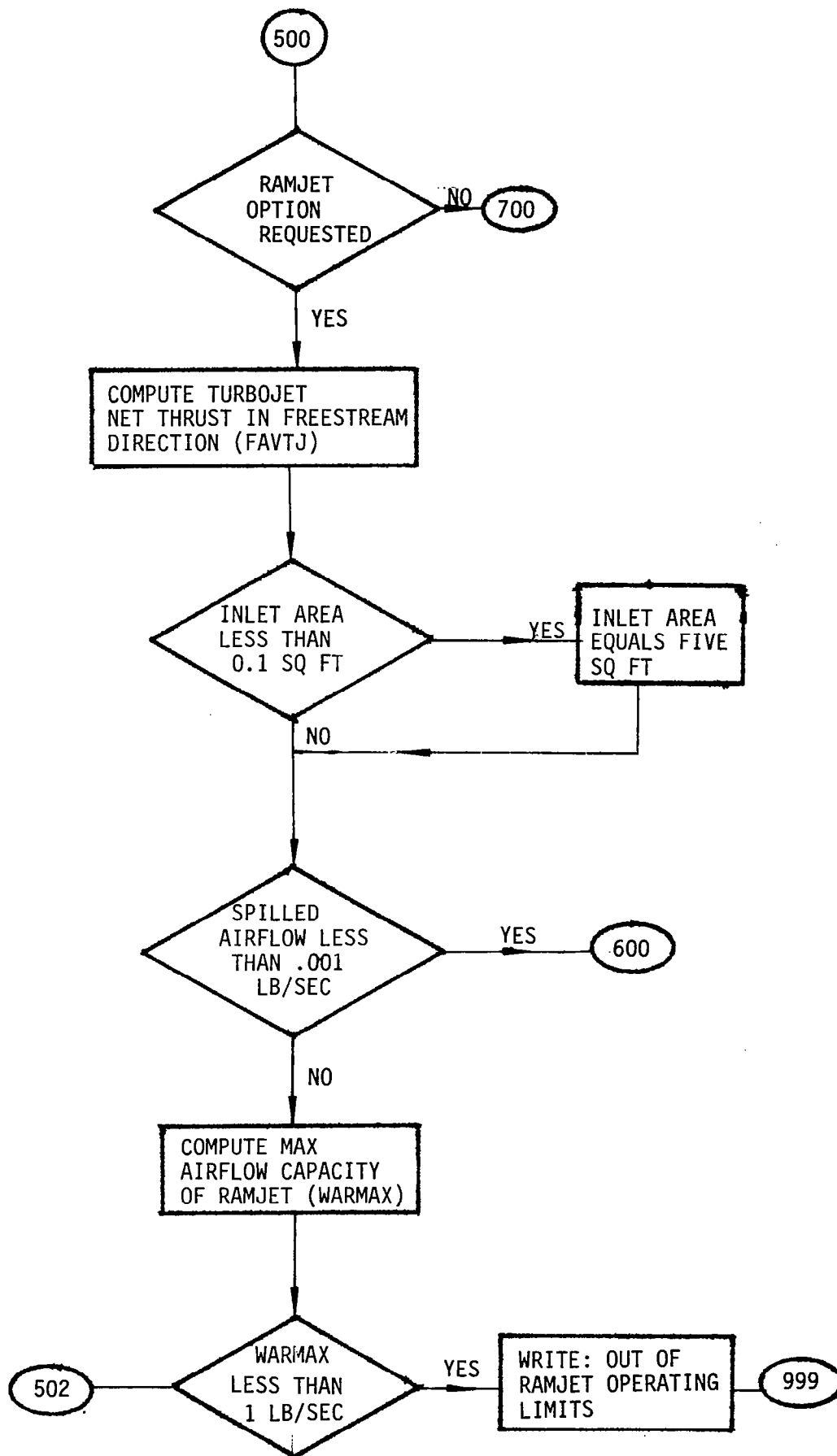




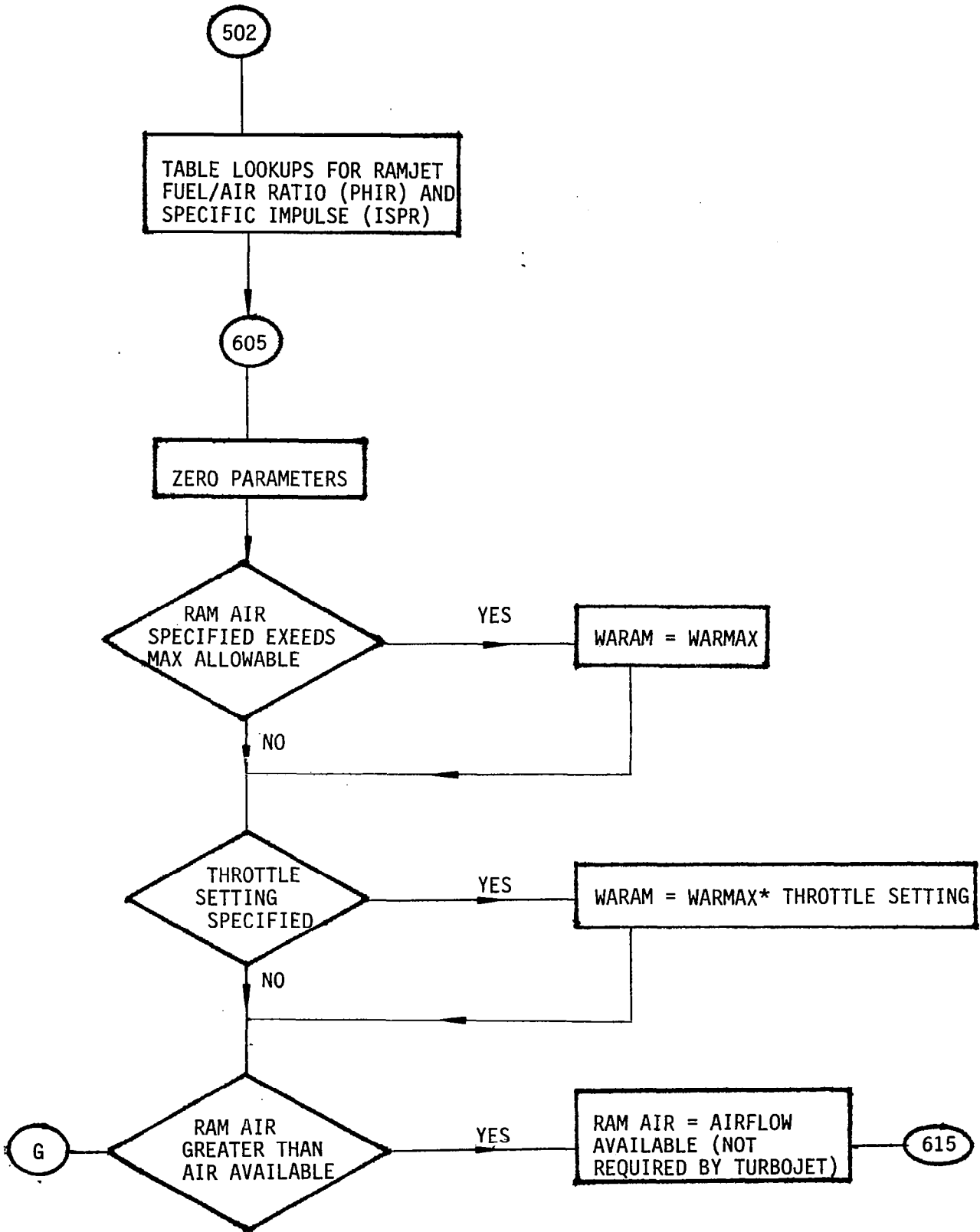


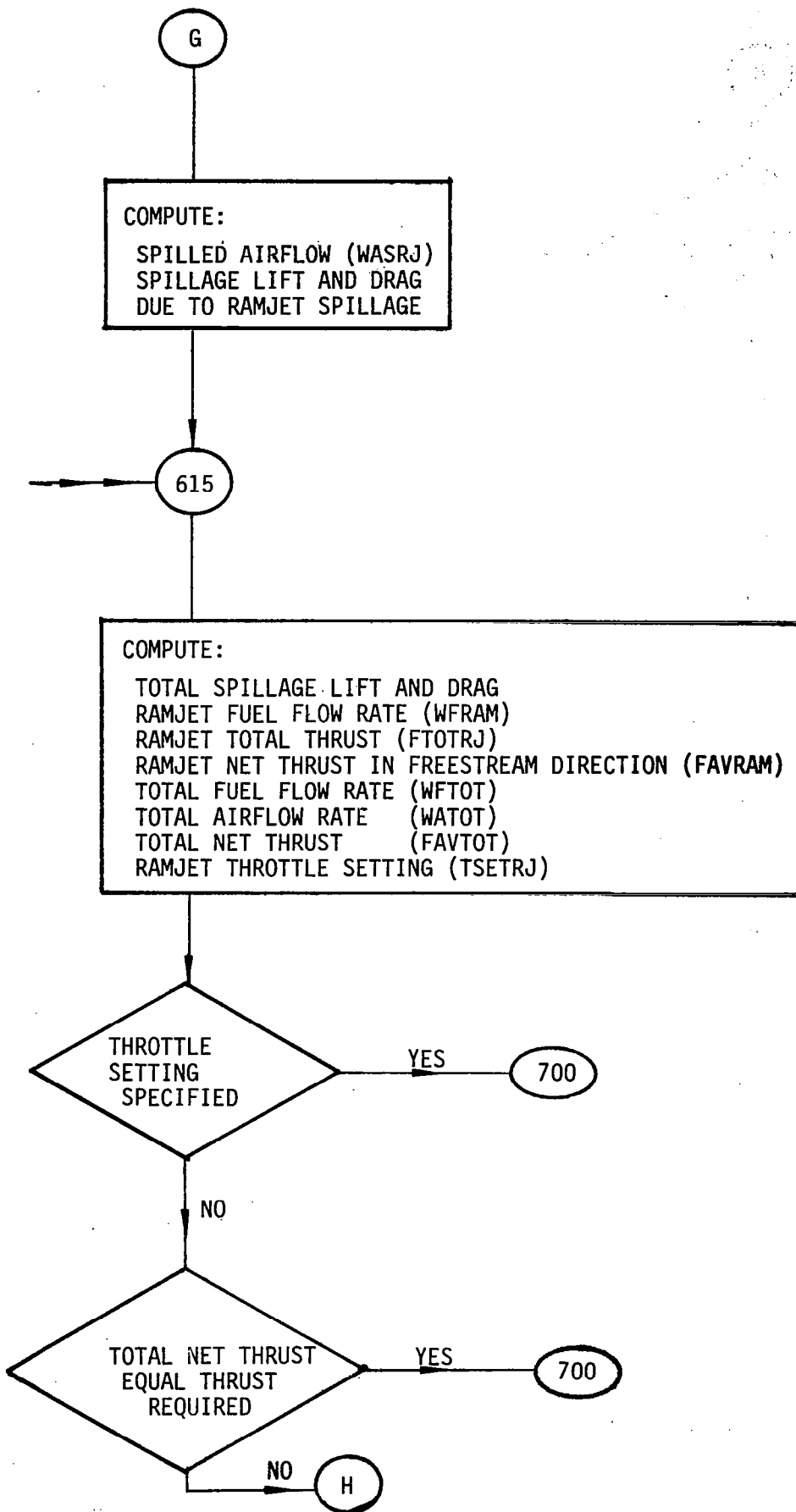


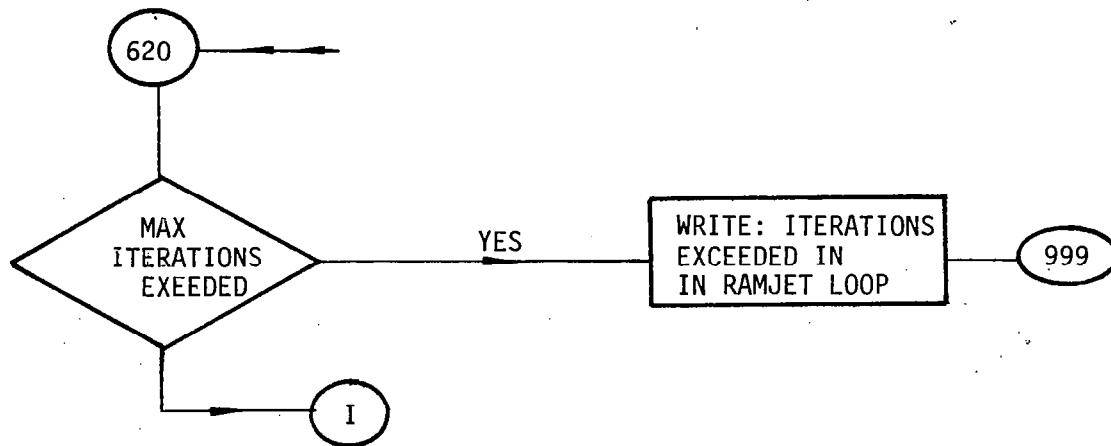
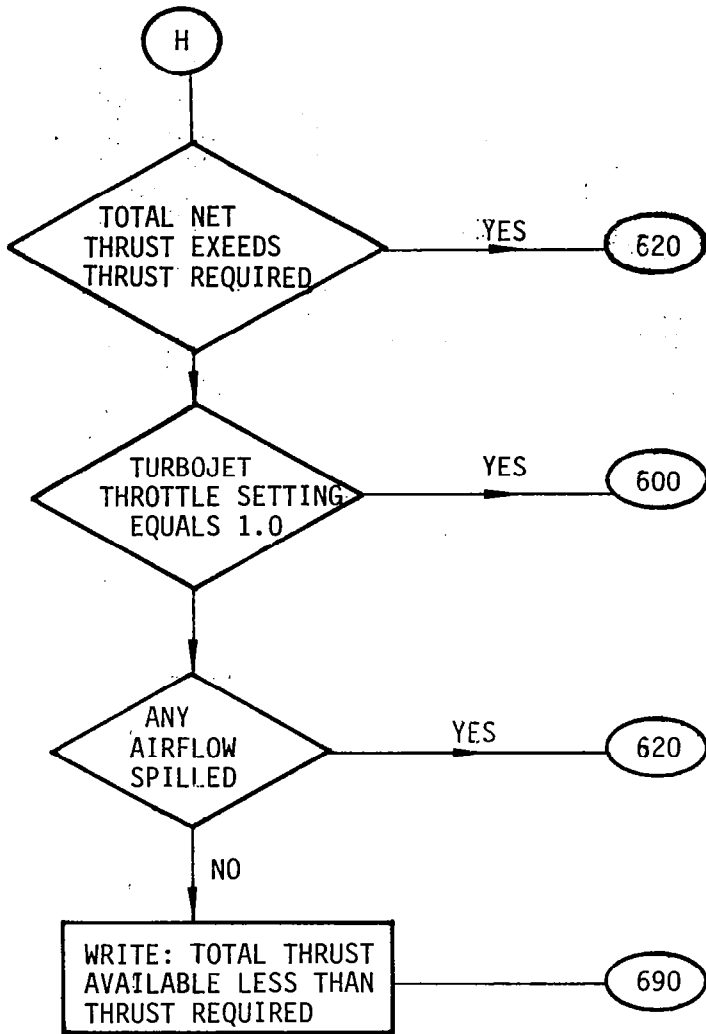


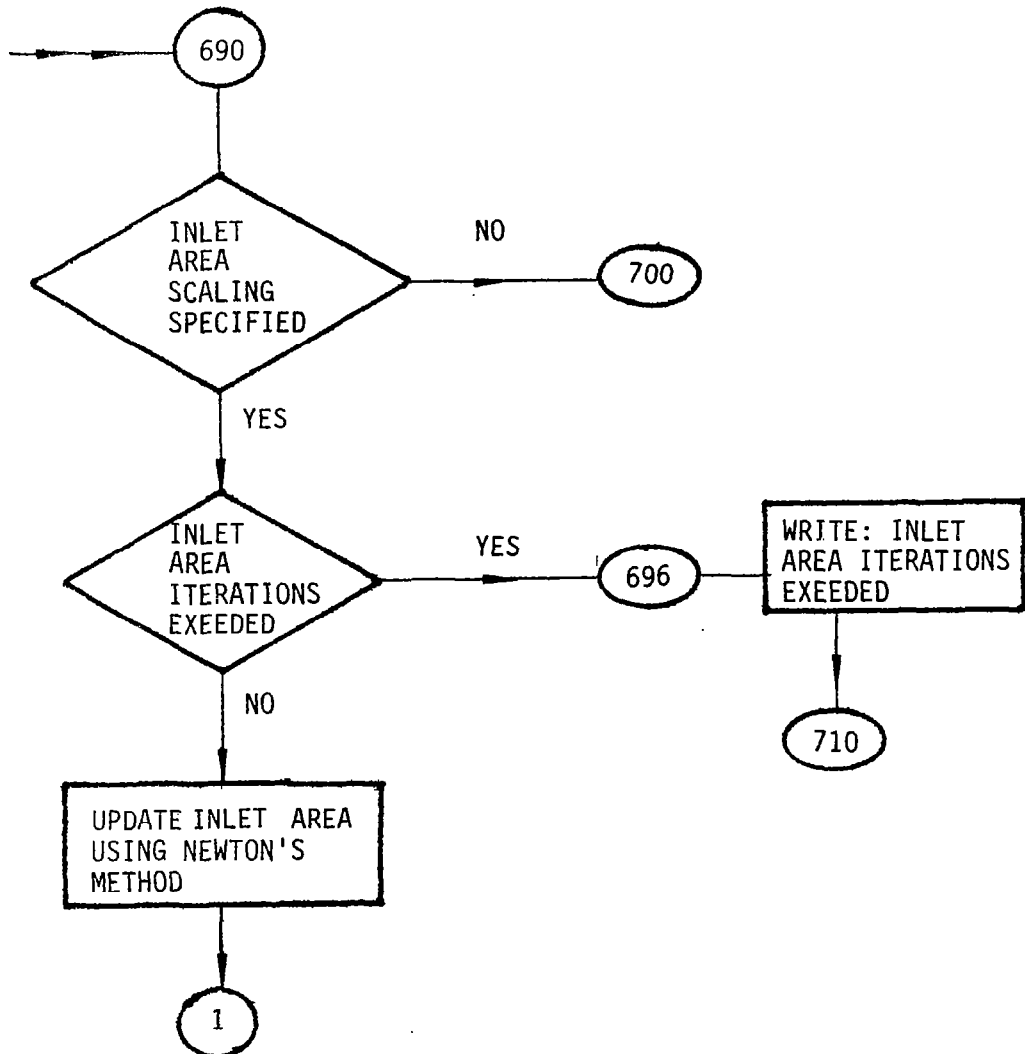
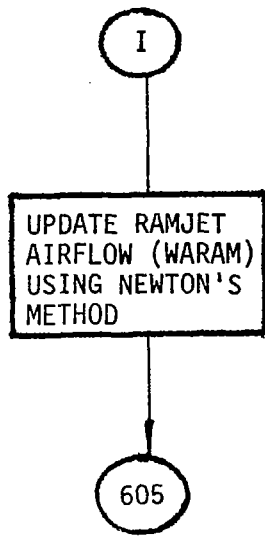


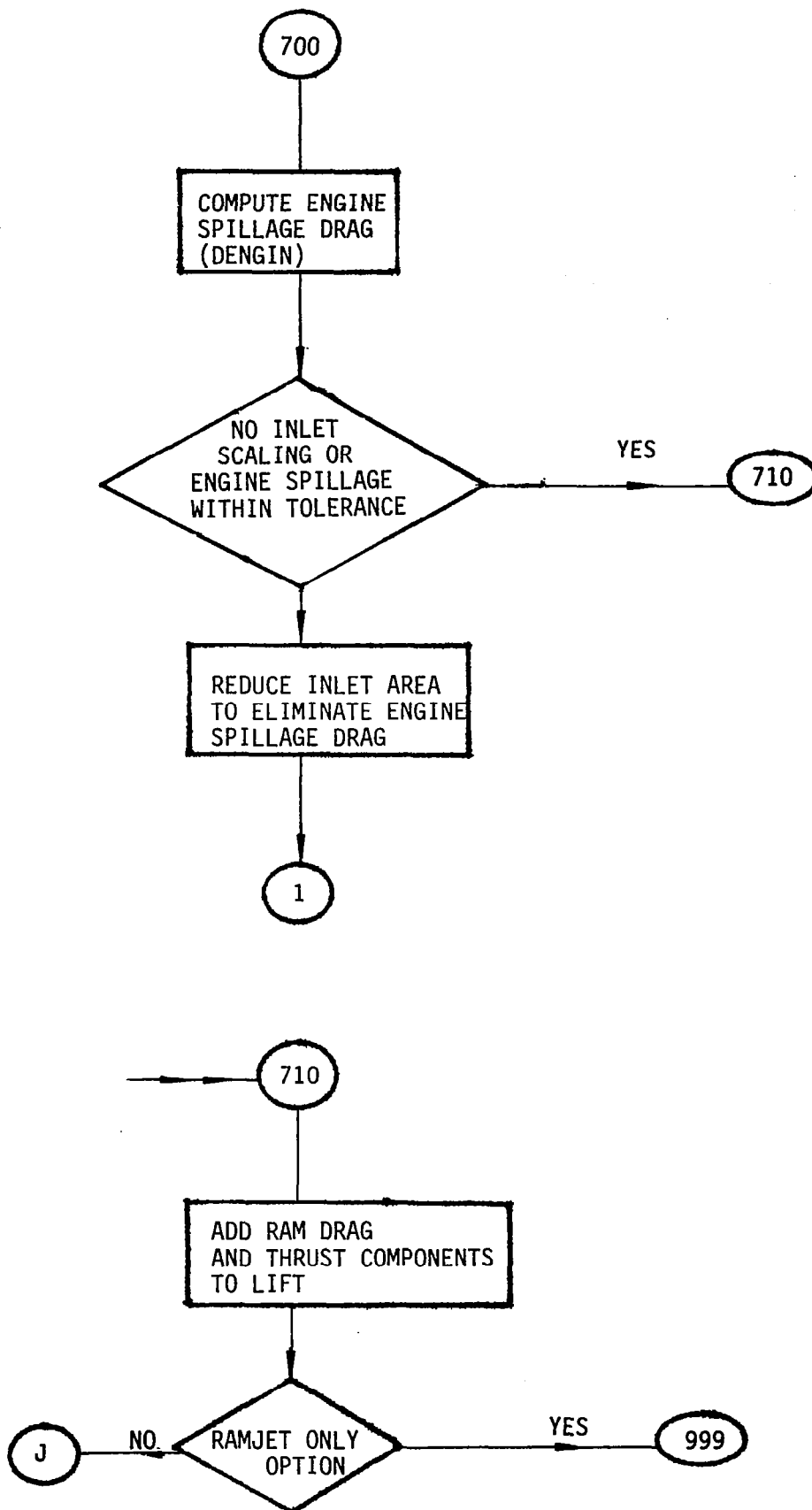


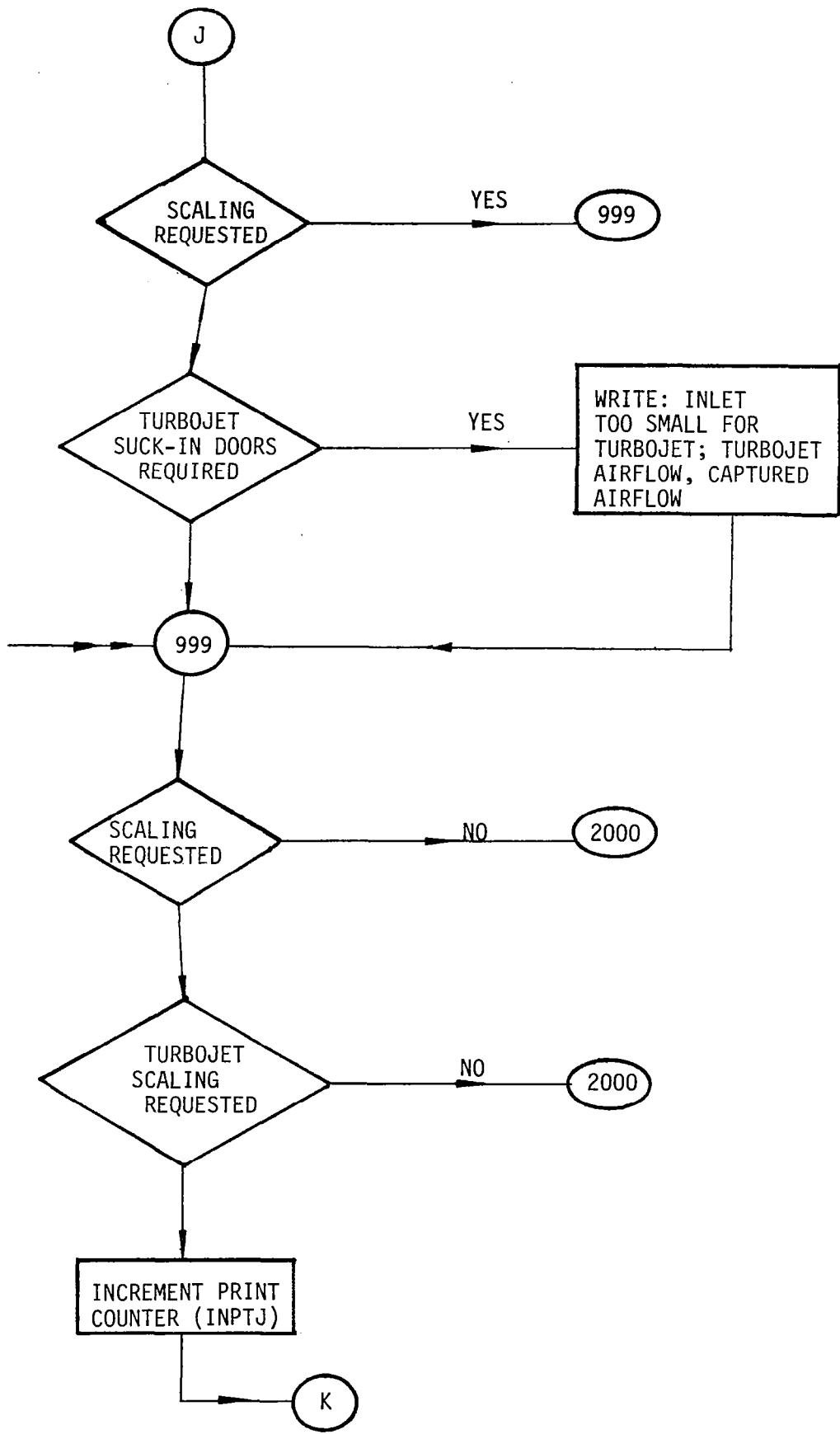


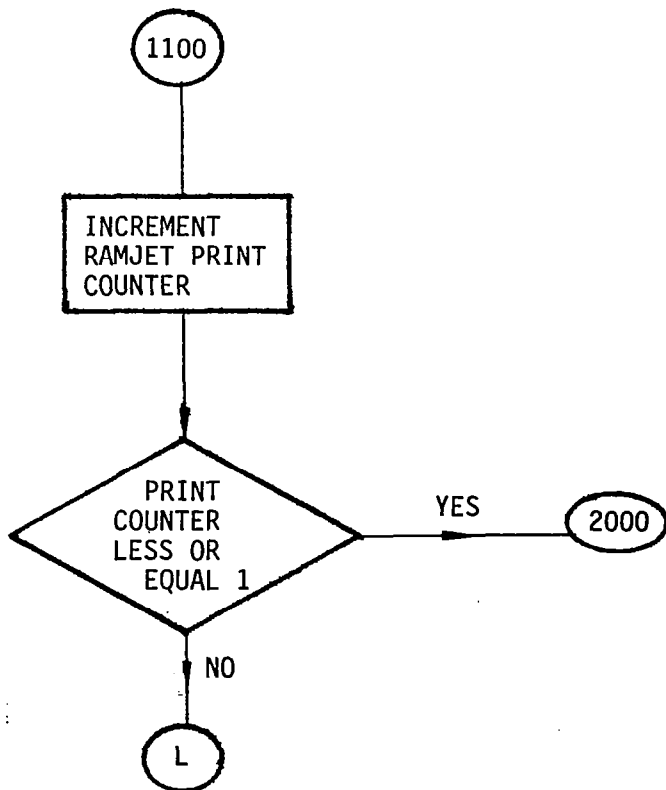
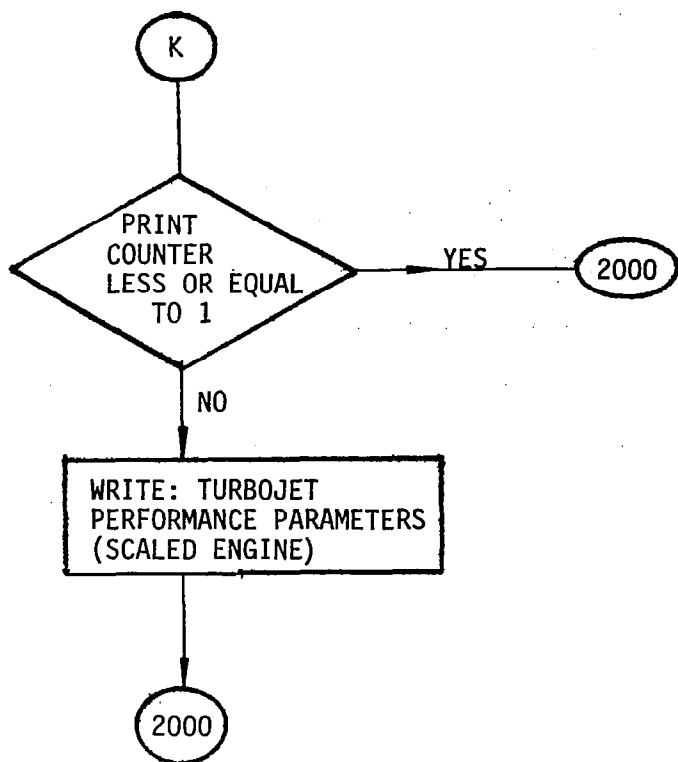


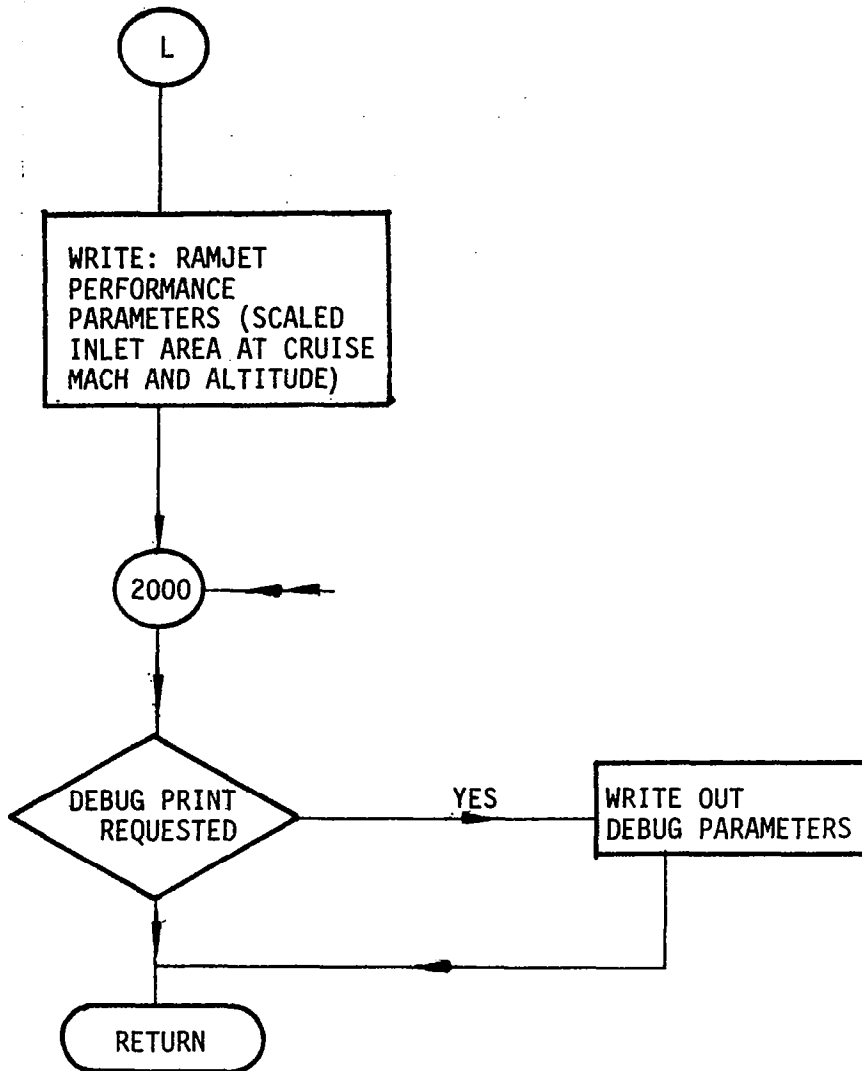




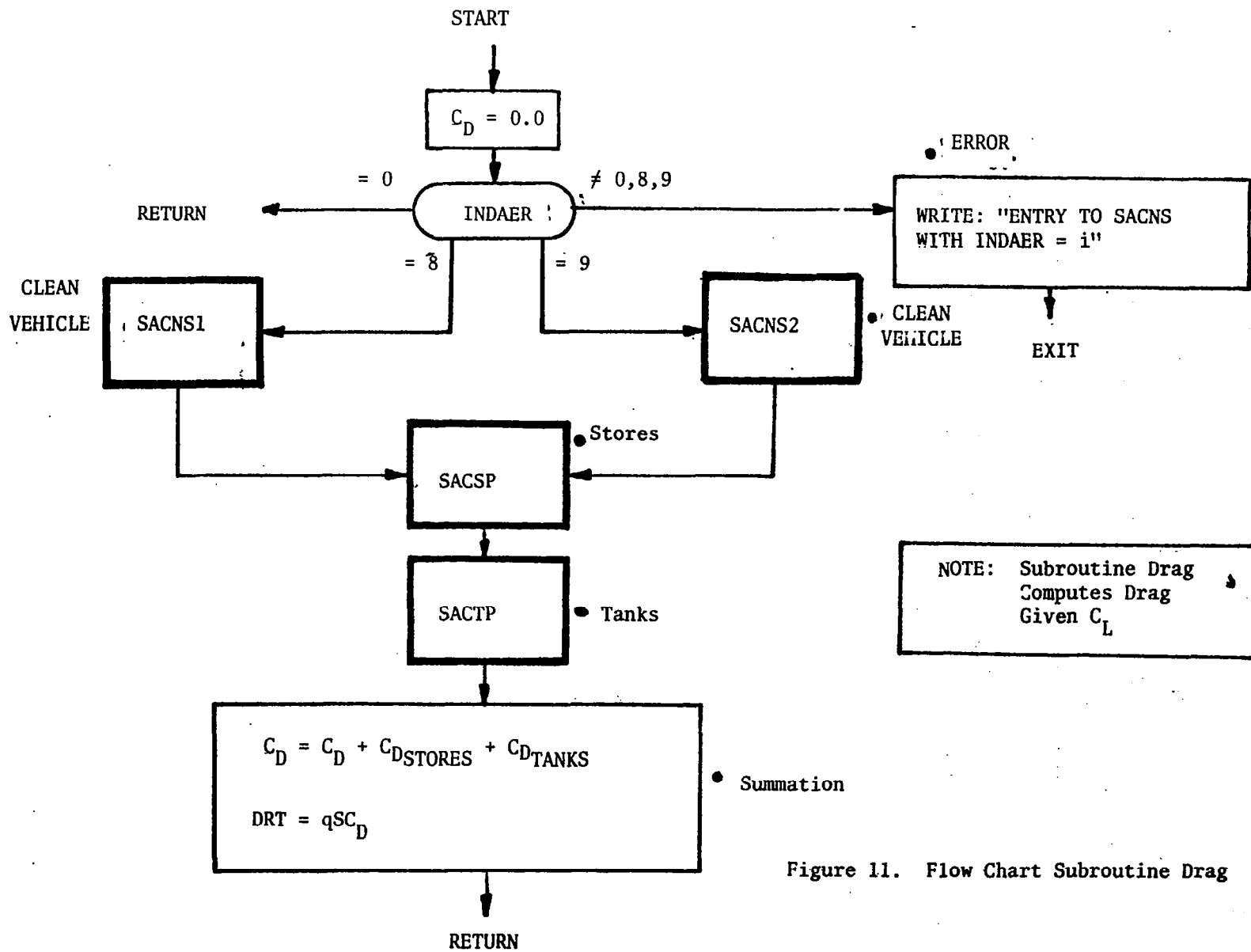












NOTE: Subroutine Drag Computes Drag Given  $C_L$

Figure 11. Flow Chart Subroutine Drag

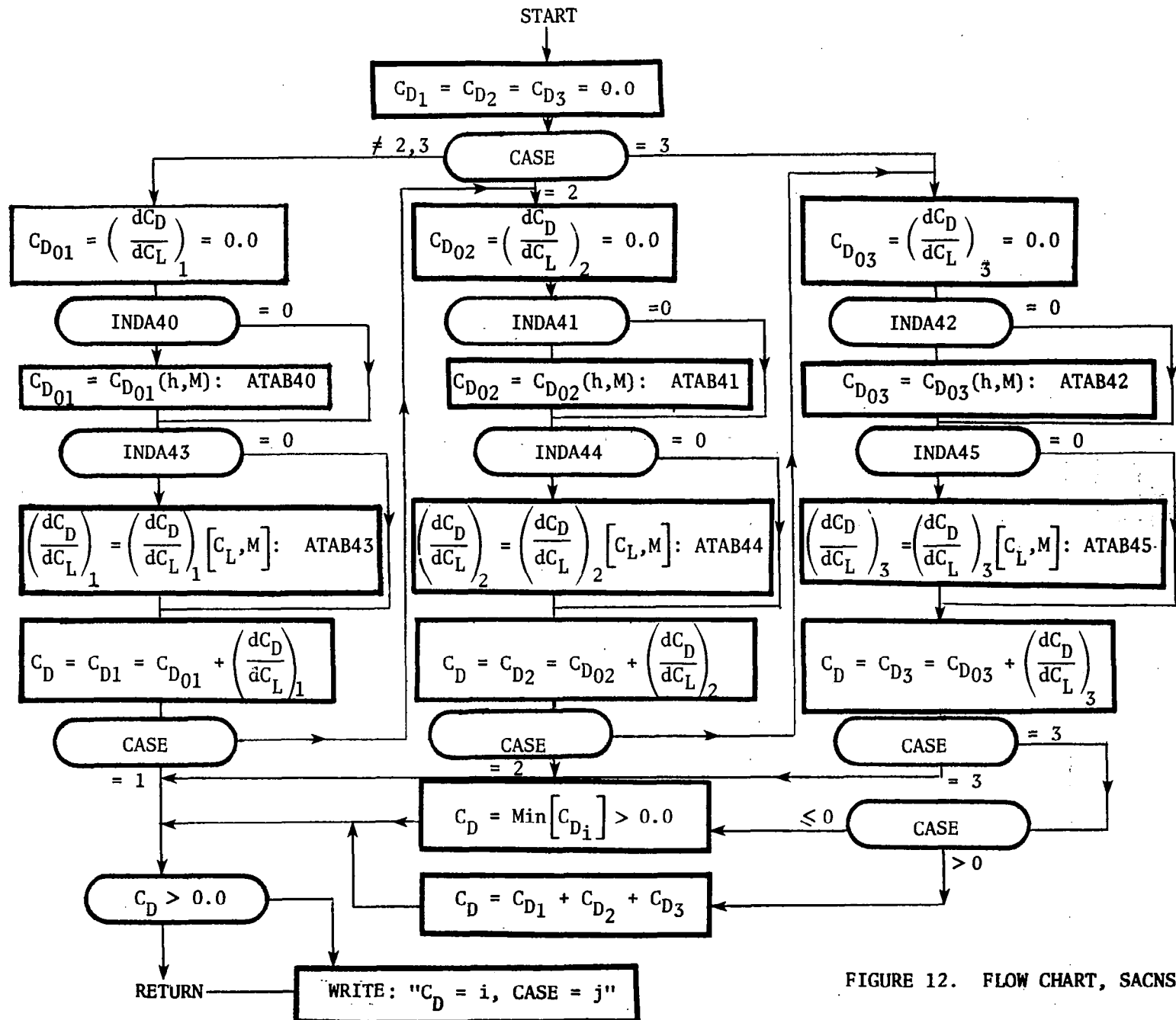


FIGURE 12. FLOW CHART, SACNS1

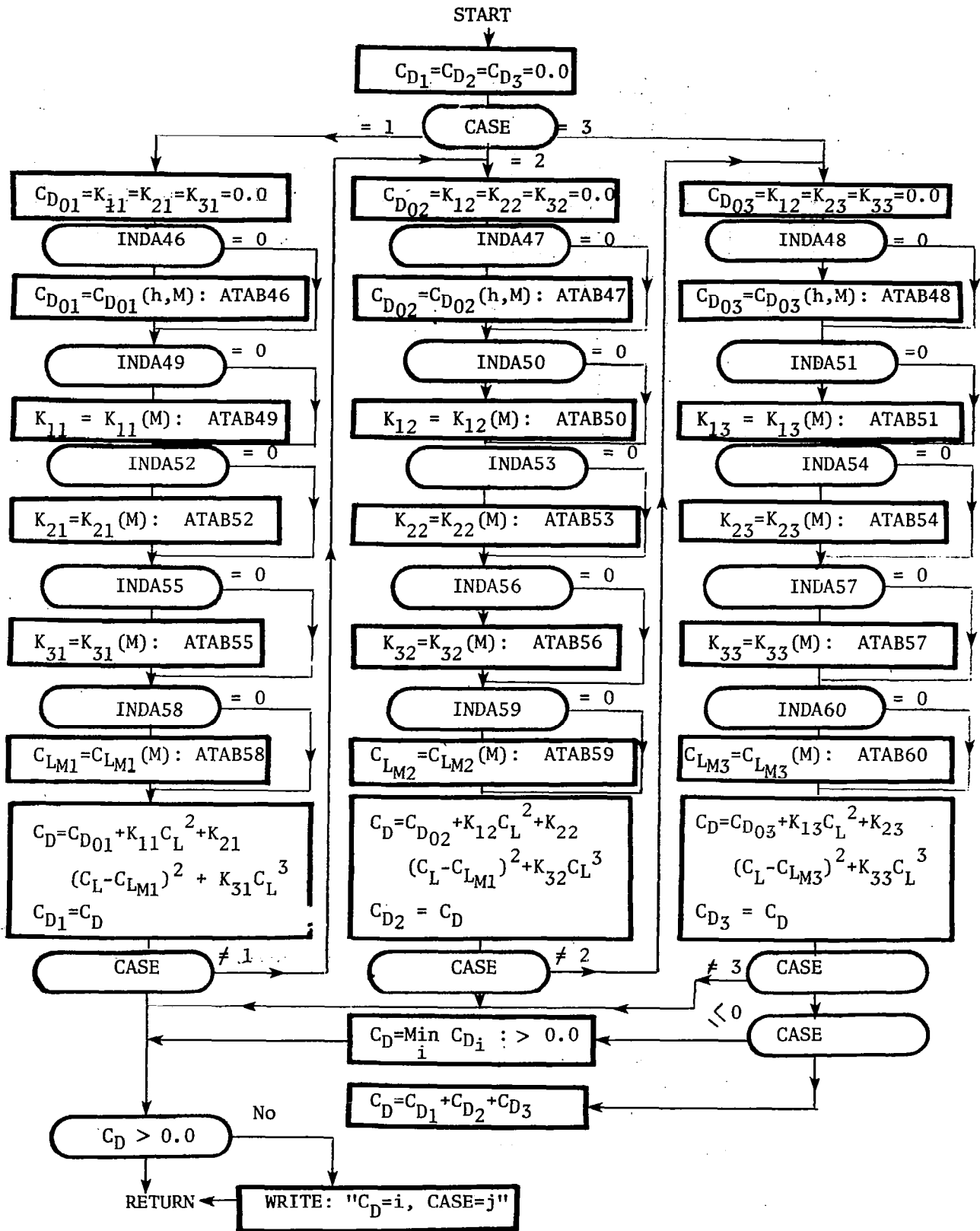


FIGURE 13. FLOW CHART, SUBROUTINE SACS2

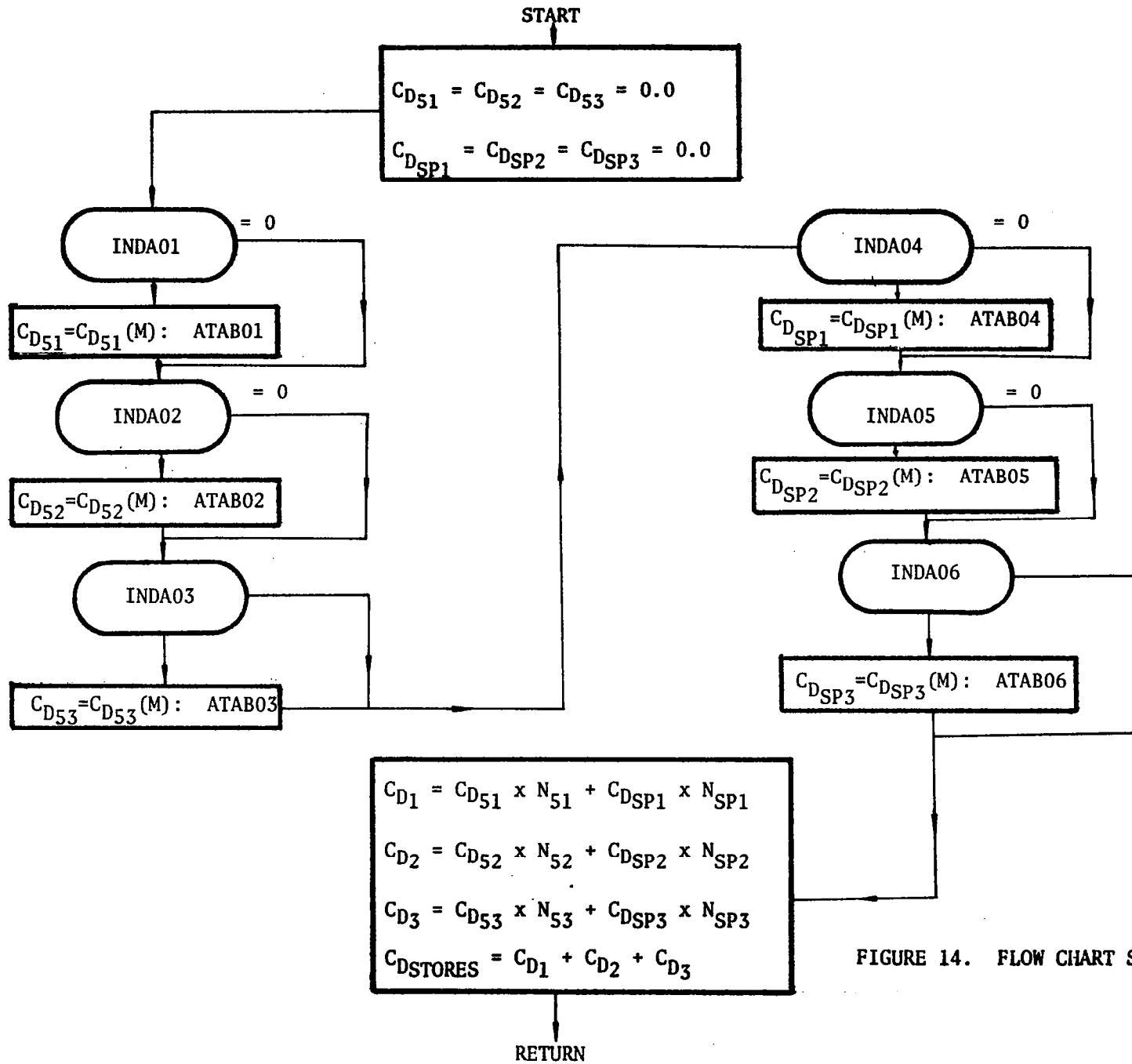


FIGURE 14. FLOW CHART SACSP

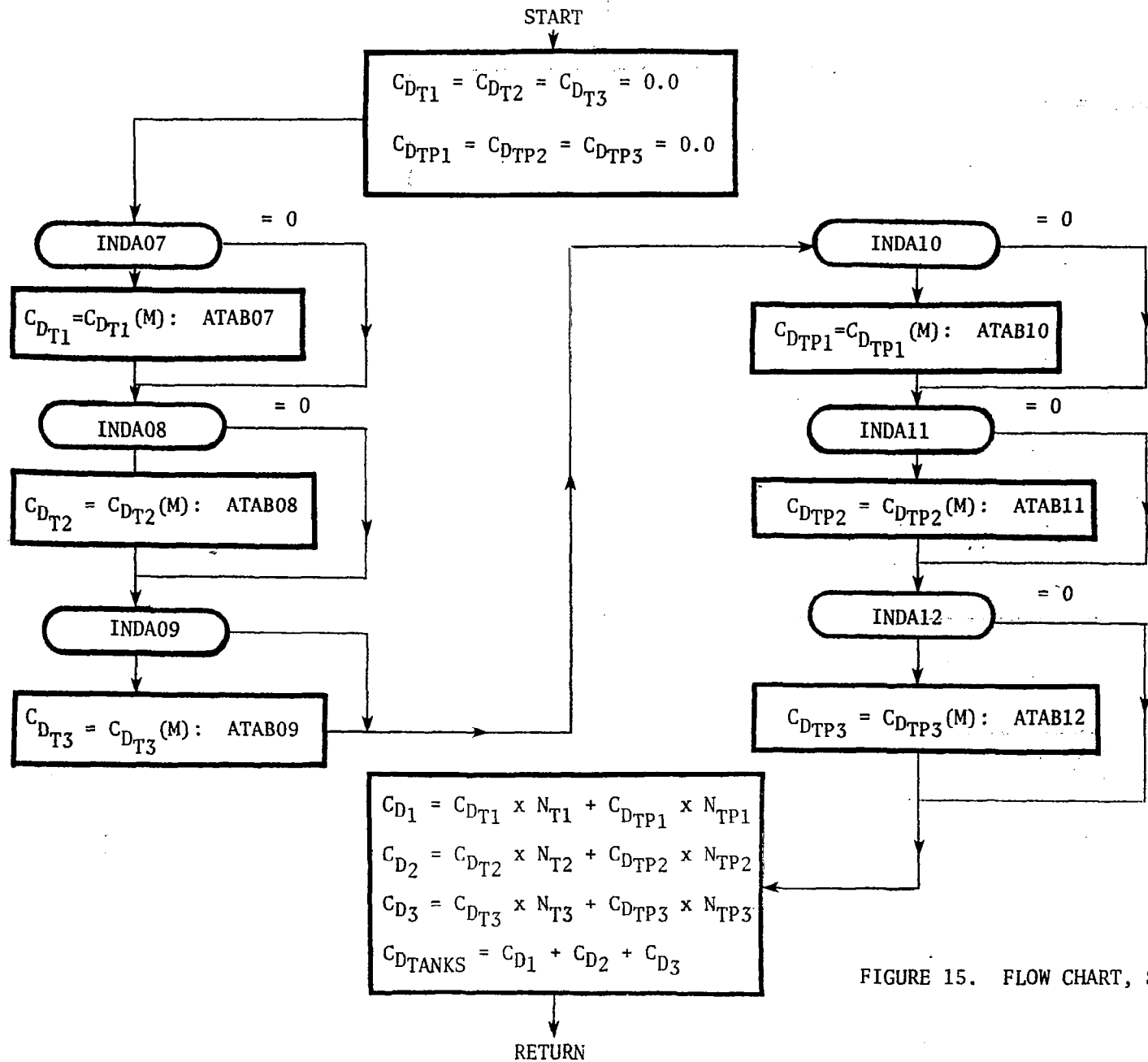


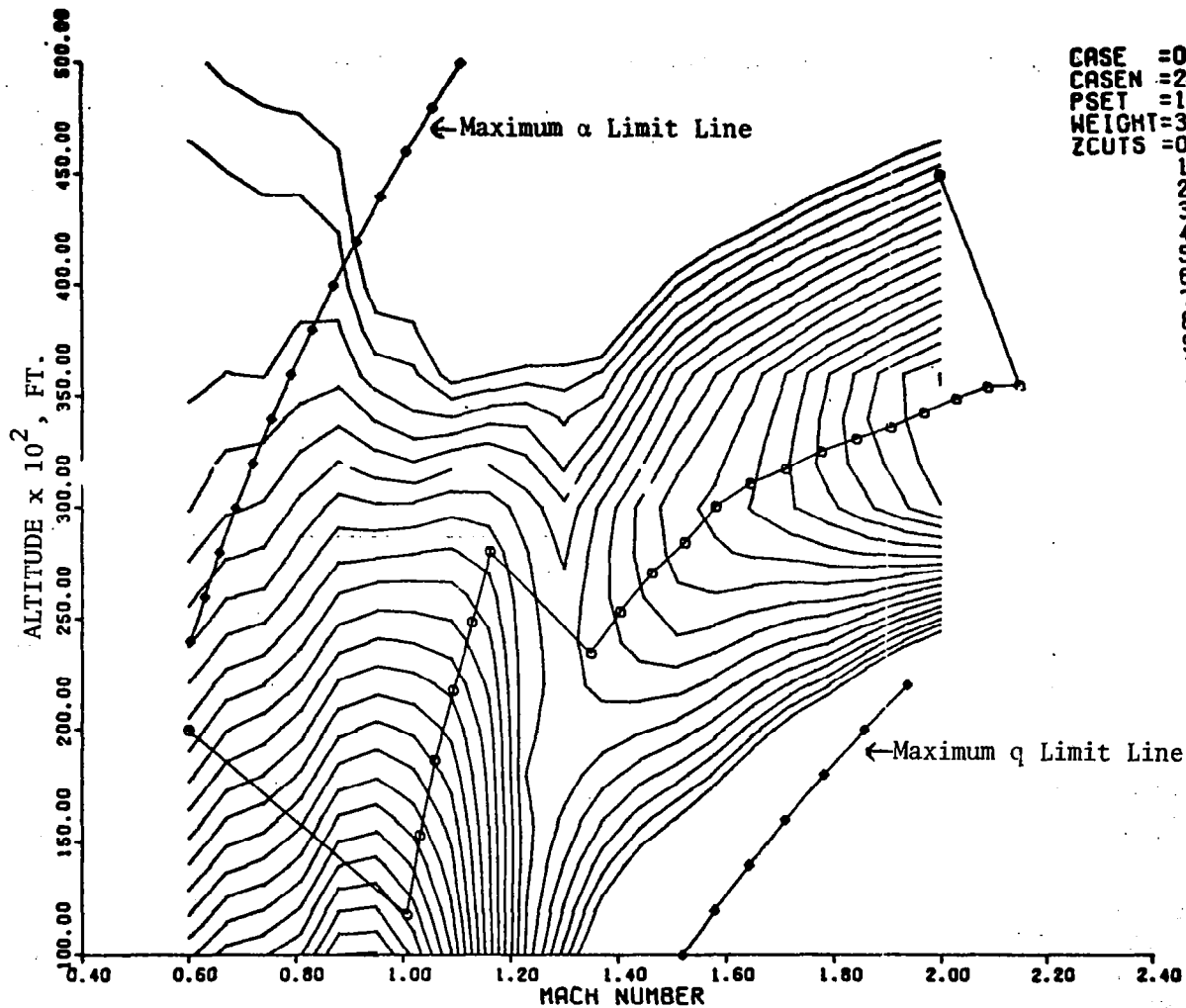
FIGURE 15. FLOW CHART, SACTP

SEARCH FOR MACH ALTITUDE POINT USING	BASIS FOR SELECTION OF MACH ALTITUDE POINT				
	MAX E	MAX E/M	MAX L/D	MAX Range Factor	MAX L/(FN-DRT)
Constant Energy IPATH=1	INDMHP=1	INDMHP=2	INDMHP=3	INDMHP=4	INDMHP=5
Constant Altitude IPATH=2	INDMHP=1	INDMHP=2	INDMHP=3	INDMHP=4	INDMHP=5
Constant Mach Number IPATH=3	INDMHP=1	INDMHP=2	INDMHP=3	INDMHP=4	INDMHP=5
IPATH=4	Linear Mach Altitude Path Fly from (HO, AMS) → (HE AME)				
IPATH=5	Fly Constant Q Path				

If IPATH = 0, all five paths will be generated using the function specified by INDMHP as the basis for selecting each Mach altitude point along the path.

If IPATH < 0, no path will be generated.

FIGURE 16. PATH FINDER OPTIONS OF NSEG MISSION OPTION 1.



CASE = 0.  
 CASEN = 2.  
 PSET = 1.  
 WEIGHT = 375000.  
 ZCUTS = 0.0000000000  
 10.0000  
 20.0000  
 30.0000  
 40.0000  
 50.0000  
 60.0000  
 70.0000  
 80.0000  
 90.0000  
 100.000  
 110.000  
 120.000  
 130.000  
 140.000  
 150.000  
 160.000  
 170.000  
 180.000  
 190.000  
 200.000  
 210.000  
 220.000  
 230.000  
 240.000

FIGURE 17. EDOT MAP

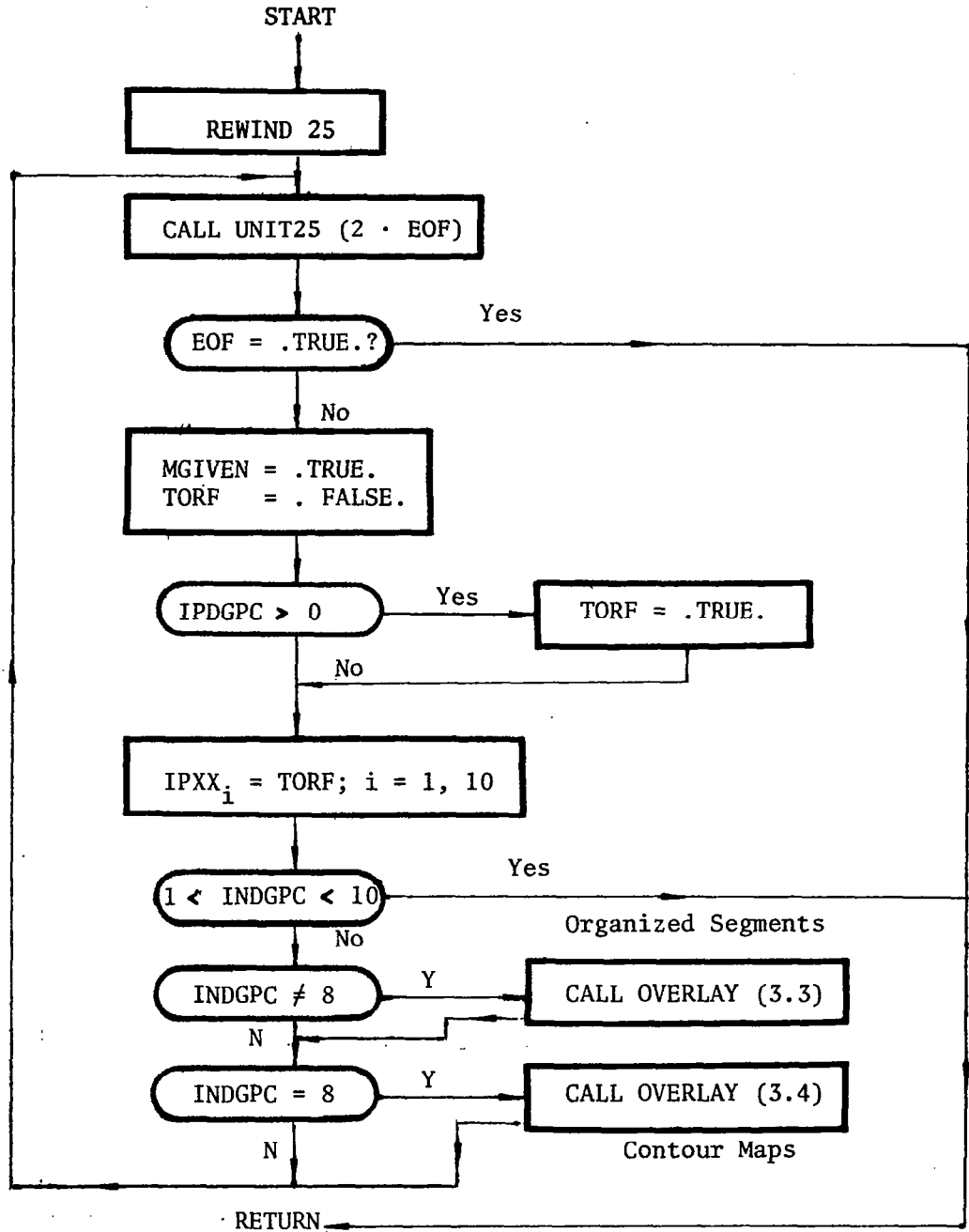


FIGURE 18. FLOW CHART FLITEN