NASA CONTRACTOR REPORT

NASA CR-28

NASA CR-2808

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

Volume II - Program Users Manual

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION · WASHINGTON, D. C. · SEPTEMBER 1977

1. Report No. NASA CR-2808	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle NSEG - A Segmented Mission Analysis Program for Low and High Speed Aircraft. Volume II - Program Users Manual		5. Report Date September 1977
		6. Performing Organization Code
7. Author(s) D. S. Hague and H. L. Rozendaal		8. Performing Organization Report No.
9. Performing Organization Name and Address Aerophysics Research Corporation Bellevue, WA 98009		10. Work Unit No.
		11. Contract or Grant No. NAS1 - 13599
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C.		13. Type of Report and Period Covered Contractor Report
		14. Sponsoring Agency Code

15. Supplementary Notes

Langley Technical Monitor: Walter A. Vahl

Volume II of Final Report

16. Abstract

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. 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. 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.

17. Key Words (Suggested by Author(s)) Mission Analysis; Trajectories; Air-breathing Propulsion; Turbojets; Ramjets		18. Distribution Statement Unclassified - Unlimited Subject Category 01	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 174	22. Price* $6.75

*For sale by the National Technical Information Service, Springfield, Virginia 22161

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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.

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

D. S. Hague and H. L. Rozendaal

AEROPHYSICS RESEARCH CORPORATION

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 (CØMTAB) 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_8, at the Control Data Cybernet Centers 135000_8, and at Langley Research Center 150000_8.

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)
CHRNUM	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
EDMHPT	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
FLYMHP	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

GTI1I2 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

HNSEG Utility routine; prints out a heading identifying the NSEG program version

INIMHP Initialize M-h point calculation

INDXCK Detects incorrect data input names

INSEG Controls error check in data input (Program)

IVNAME Decomposes data input cards

INISEG Initializes NSEG II (Program)

INITZ Initializes the TZ array, the array which contains the data necessary for the serial execution of flight path segments as specified by input data

INIWGT Initial weight breakdown computations

INX01.. INX22 Input routines for Options 1 through 22. Written in Macro-Fortran language and assembled on CDC 6600 Fortran. The present program uses the CDC 6600 Fortran versions directly without the need to use Macro-Fortran

LANDIN Provides organized print out of landing inputs

LANDNG Performs landing calculations

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

OPTX19	Performs a tank drop
OPTX20	Performs Option 20 calculation, fuel allowance for specified time at given power setting or T/W ratio
OPTX21	Performs engine scaling when dual engine propulsion is selected
OPTX22	Range matching generalized iterative control option
OUTATM	*Atmosphere output control program* *(Program)*
OUTXXX	Provides output from mission segment options
OVWGTE	Computes the overall weight empty including stores, tank, and pylon combinations
PAGHED	Provides the output page heading
PATH	Computes conditions along a climb or descent arc
PAYLOD	Computes vehicle payload including store, tank, and pylon contributions

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

SETYIC	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 CØMTAB 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 calculations

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_i = Array of altitude values, in feet

TM_i = Array of temperature values, ° F absolute

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

HG_1 = -16505.

TM_i = Desired temperature profile

PG_1 = 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

$$(F_N)'_i = F_{N_i}/DR \quad ; i = 1, 2, 3$$

$$(\dot{F}F)'_i = \dot{F}F_i/(100 \times TR^{1.5}) \quad ; \quad i = 1, 2$$

$$(\dot{F}F)'_3 = \dot{F}F_3/TR^{1.5}$$

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 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 × 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 (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

SYMBOL	DESCRIPTION
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

SYMBOL	DESCRIPTION
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

SYMBOL	DESCRIPTION
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. $\dot{W} = \dot{W}(PSD, M, h)$ 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

SYMBOL	DESCRIPTION
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. $\dot{W} = \dot{W}(PSD, M, h)$ 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

SYMBOL	DESCRIPTION
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 tablein 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:

Mach	CASEN
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_{t_0}) and total temperature (T_{t_0}) 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

$$P_{t_0} = 2116.22 * p^* \qquad (p^* \text{ in atmospheres})$$

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_{r_0}) 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 ($p_{r_{t_0}}$) can be determined from Table II. Freestream total pressure is then given by

$$P_{t_0} = (P_{r_{t_0}}/P_{r_0}) \; * \; P_0$$

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

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

where A_{T_J} 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

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

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 (δ_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

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

where

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

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

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

F_{T_J} = 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_{t_3}. The maximum turbojet thrust to air flow rate is found from Table VI using the two-dimensional table lookup routine DISCOT, given T_{t_3} and the log to the base ten of the ratio of total pressure at Station 3 at thecompressor 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_{t_3}/P_{t_1} from Table IV, given M_1, and multiplying by P_{t_1}/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_{t_3}.

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.,

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

In the above expression γ 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

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

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

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

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:

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

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, Tt_2. The maximum ramjet air flow is then, simply,

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

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

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

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

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

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

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

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.

SYMBOL	DESCRIPTION
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_α} Table.

SYMBOL	DESCRIPTION
AINLET	Engine Inlet Area (initial guess if ramjet is to be scaled) (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.

SYMBOL	DESCRIPTION
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	Engine option Selector 0 - use Turbojet only if $M \leq$ AMINRJ use Combination if AMINRJ $<$ M $<$ AMAXTJ use Ramjet only if $M \geq$ AMAXTJ 1 - use Turbojet only 2 - use Combination 3 - use Ramjet only

SYMBOL	DESCRIPTION
ETAB03	Engine Capture Area Schedule Ratio = $f(M_1)$ ETAB03 = $M_1^1, --- M_1^N$, $Ratio^1, ---, Ratio^N$ N = IE03X = Number of Data pairs
ETAB04	Inlet Pressure Recovery Schedule Ratio = $f(M_1)$ ETAB04 = $M_1^1, ---, M_1^N$, $Ratio^1, --- Ratio^N$ N = IE04X
ETAB05	Base Turbojet Corrected Airflow Schedule (LB/SEC) Airflow = $f(T_{t_3})$ ETAB05 = $T_{t_3}^1, ---, T_{t_3}^N$, $Airflow^1, ---, Airflow^N$ N = IE05X
ETAB06	Turbojet Gross Thrust/Airflow rate Schedule (LB Thrust/(LB Airflow/SEC)) FGWA = $f(T_{t_3}, \text{Log}_{10}\ (P_{t_3}/P_N))$ ETAB06 = $T_{t_3}^1, ---, T_{t_3}^N$, $L_{10}^1, ---, L_{10}^M$, $FGWA_1^1, ---, FGWA_1^N$, $FGWA_M^1, ---, FGWA_M^N$, N = IE06X M = IE06Z

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

SYMBOL	DESCRIPTION
CLZTAB	C_L at zero angle of attack $C_{L_0} = f(M_0,h)$ CLZTAB = $M_0^1,---,M_0^N,\ h^1,---h^M,$ $C_{L_{0_1}}^{\ 1},---,C_{L_{0_1}}^{\ N},$ $C_{L_{0_M}}^{\ 1},---,C_{L_{0_M}}^{\ M}$ N = ICLZX M = ICLZY
CLATAB	Lift Curve Slope Table $C_{L_\alpha} = f(M_0,h)$ CLATAB = $M_0^1,---,M_0^N,\ h^1,---,h^M,$ $C_{L_{\alpha_1}}^{\ 1},---C_{L_{\alpha_1}}^{\ N},$ $C_{L_{\alpha_M}}^{\ 1},---C_{L_{\alpha_M}}^{\ N}$ N = ICLAX M = ICLAY

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

$$C_{D_j} = C_{D_{0j}}(h, M) + C_{D_{induced_j}}(C_L, M) \quad ; \quad j = 1, 2, 3$$

and

$$C_{D_j} = C_{D_{0j}}(h, M) + K1_j\, C_L^2 + K2_j(C_L - C_{L_{min}}(M))^2 + K3_j\, C_L^3; \quad j = 1, 2, 3$$

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

$$C_D = C_{D_1} + C_{D_2} + C_{D_3}$$

or select the lowest drag configuration

$$C_D = \mathrm{Min}[C_{D_1}, C_{D_2}, C_{D_3}]$$

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

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

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

$$C_{D_S} = \sum_j (C_{D_{S_j}} N_{S_j} + C_{D_{SP_j}} N_{SP_j}) \quad ; \quad j = 1, 2, 3$$

where

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

N_{S_j} = number of store pairs, type j

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

N_{SP_j} = 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

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

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

SYMBOL	DESCRIPTION
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; $C_{D_{01}} = C_{D_{01}}(h, M)$
ATAB41	Zero lift drag, System 2; $C_{D_{02}} = C_{D_{02}}(h, M)$
ATAB42	Zero lift drag, System 3; $C_{D_{03}} = C_{D_{03}}(h, M)$
ATAB43	Drag due to lift, System 1; $C_{D_{i_1}} = C_{D_{i_1}}(C_L, M)$
ATAB44	Drag due to lift, System 2; $C_{D_{i_2}} = C_{D_{i_2}}(C_L, M)$
ATAB45	Drag due to lift, System 3; $C_{D_{i_3}} = C_{D_{i_3}}(C_L, M)$
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, $C_{D_{01}} = C_{D_{01}}(h, M)$
ATAB47	Zero lift drag, System 2, $C_{D_{02}} = C_{D_{02}}(h, M)$
ATAB48	Zero lift drag, System 3, $C_{D_{03}} = C_{D_{03}}(h, M)$
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_α}, C_{LMAX}, and α_{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, $(hour^{-1})$
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
FLAPPDL	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,

$$(H_O, AMS) \rightarrow (HE, AME)$$

where

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

(HE, 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.

<u>Data for Option 1.</u>

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

end MACH *number* =ν,

end ALTITUDE=η, *(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 ν and η are decimal numbers and must contain a decimal point.

end MACH *number* =ν,

end ALTITUDE=η,*(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/δ 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 ν is a decimal number and therefore must contain a decimal point.

end WEIGHT=ν, *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 ν is a decimal number and must contain a decimal point.

cruise TIME=ν, *(hours)*

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

TOTAL RANGE *flown including this segment* =ν, *(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 η is a decimal number and must contain a decimal point.

WEIGHT *at end of cruise* =η, 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 ν is a decimal number and must contain a decimal point.

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

TOTAL RANGE *flown including this segment* =ν, *(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 ν is a decimal number and must contain a decimal point.

cruise TIME=ν, *(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 ν and η are decimal numbers and must contain a decimal point.

maximum RANGE *to refuel* =η, *(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=ν, *(pounds)*

fuel transfer RATE= η, *(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 ν and η must be integer numbers and *cannot* contain a decimal point.

$$\text{TRANSFER} \left\{ \begin{matrix} \text{MACH} \\ \text{ALTITUDE} \\ \text{WEIGHT} \end{matrix} \right\} \text{FROM SEGMENT}(\nu) \text{ TO SEGMENT}(\eta)$$

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 ν, η, and λ 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* =ν,

ALTITUDE *for flight condition 2* =η, *(feet)*

WEIGHT *for flight condition 2* =λ, *(pounds)*

get data for flight condition 1 from SEGMENT (ℓ)

CHOOSE *on the basis of* {MAXIMUM / MINIMUM} {MACH / ALTITUDE / WEIGHT}

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 ν must be a decimal point. The weight of the vehicle will be computed by subtracting ν from the current vehicle weight.

WEIGHT *change* =ν,(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 ν and η are decimal numbers and must contain a decimal point.

new MACH *number* =ν,
new ALTITUDE = γ, *(feet)*
new vehicle WEIGHT=η, *(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 δ, ν, η, β, and λ 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* =ν, *(pounds)*

GIVEN WEIGHT=λ, *(pounds)*

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

GIVEN ALTITUDE=η, *(feet)*

GIVEN GLEVEL=δ,

COMPUTE *best* CRUISE *altitude*

COMPUTE CEILING *for rate of climb* =β, *(feet/min)*

COMPUTE MACH *for best* LIFT/DRAG *ratio*

COMPUTE MACH *for* CL=δ,

COMPUTE MAX*imum endurance* MACH *for* CL=δ,

COMPUTE MAX*imum* MACH *number*

COMPUTE MACH *number for* MAX*imum* RATE *of climb*

COMPUTE MACH, ALTITUDE *point for* MAX*imum range factor*

COMPUTE MACH *for* MAX*imum range factor*

COMPUTE MACH(ν), ALTITUDE *point for* MAX*imum range factor*

COMPUTE MACH(ν), *for* MAX*imum 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 (ν) where ν 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 ν 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* =η, *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 eixsts, 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 η and λ are decimal numbers and must contain a decimal point.

fuel WEIGHT *change* =λ, *(pounds)*

WARM-UP TIME=η, *(minutes)*

loiter TIME=η, *(minutes)*

η DEG λ 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 η and ν are decimal numbers and must contain a decimal point.

GIVEN TIME=ν, *(minutes)*

compute fuel allowance for a POWER *setting* =η,

compute fuel allowance for thrust/weight RATIO=η,

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 (α, β, etc.) are decimal numbers and must contain a decimal point

PROPULSIVE *mode* = DUAL

SCALE TURBO*jet* THRUST = α,

NOTE: If α < 3.0, then α must be the thrust/weight ratio instead of thrust.

or

SCALE TURBO*jet corrected* AIRFLOW = β,

SCALE RAM*jet* = *ramjet thrust* MARGIN = ε, *cruise* MACH = γ,
cruise ALTITUDE = δ

engine DEBUG *print requested*

turbojet reference PRESSURE = *underwing pressure*

compute alpha for scaling based on current WEIGHT

END

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 α and β are decimal numbers and must contain a decimal point. The numbers A and B are integers.

START *loop at beginning of* SEGMENT (A)----------------- {WEIGHT / RANGE / MACH} *is to be varied*

FINISH *loop at end of* SEGMENT (B)--------------------- {WEIGHT / RANGE / MACH} *is to be satisfied*

NUMBER *of iterations* = α,

DESIRED *value of dependent variable* = β,

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 ± 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
$IPSEG_i$	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_i
IPRGSV	Controls RG array print as each segment is computed = 0, omit print = 1, print RG_i
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^2)

ALMXTO — Angle of attack for take-off C_l 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
BFOBEX	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	*Internally computed drag coefficient*
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	*Internally computed stores drag coefficient*
CDTANK	*Internally computed tanks drag coefficient*
CFOCAV	Average flap chord to wing chord ratio, landing and take-off analysis
CL	*Internally computed lift coefficient*
CLATOT	Linear lift curve slope per degree, landing and take-off analysis
CLC	*Internally computed lift coefficient*
CLCD	*Internally computed lift/drag coefficient*
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

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

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

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

11.5 E's

END	Signifies end of a data block
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
ETAB03... ETAB10	Engine data tables used in dual engine propulsion option. See Section 6.2.3 for description
ERRFP	*Undefined error indicator in PATH, internal*
ERRH	*Altitude error in PATH, internal*
ERRM	Mach number error in PATH, internal
E10	*Internal thrust error indicator, ENDAT and CMAX dumped from CRCOMP*
E11	*Internal error indicator, dumped from CRCOMP*

11.6 F's

FF	Reserve fuel fraction (.05 for Mil C-5011A rules)
FFLMIN	Minimum fuel flow (unfactored) per engine
FFR	*Internally computed total fuel flow rate*
FFRMIN	*Internally computed total fuel flow rate minimum*
FLAPDC	Flap deflection, landing
FLAPDT	Flap deflection, take-off
FN	*Internally computed net thrust per engine*
FNO	*Internally set thrust in FILLPM and FLITOL*
FNMIN	*Internally computed minimum total thrust*
FNL	*Landing thrust, internally set*
FPOL	Fraction of initial payload dropped or off-loaded during a mission
FUEL	
FUEL1	First fuel value, buddy refuel
FUEL2	Second fuel value, buddy refue
FUEL3	Third fuel value, buddy refuel
FUELIN	*Internally computed total internal fuel*
FUELT1	*Internally computed fuel weight, tanks 1*
FUELT2	*Internally computed fuel weight, tanks 2*
FUELT3	*Internally computed fuel weight, tanks 3*
FUELTO	Total fuel, including tank fuel at take-off
FUELTK	*Internally computed total tank fuel*
FUELUS	*Internally computed total usable fuel at take-off*
FWC	*Internally computed fuel weight change in CLIMB*

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
GRNDFL	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	*Not used; was in OPT17*
HOVT	*Not used; was in OPT17*
HOVTM1	*Not used; was in OPT17*

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_α}
ICLZX ICLZY	Table size indicator for C_{L_0}
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_α}
INDCLZ	Table usage indicator for C_{L_0}

INDA01... INDA12, INDA40, INDA41 .... INDA60	Aerodynamic table indicators
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 $C_{L_{max}}$ selection: = 0, $C_{L_{max}}$ given by CLMAX value = 1, $C_{L_{max}} = C_{L_{max}}$(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, $\dot{E}/\dot{W}$ map = 3, L/D map = 4, Range factor map = 5, thrust map = 6, drag map
INDMAP (Contd.)	= 7, SFC map = 8, $\dot{W}$ 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. [$\dot{E}/\dot{W}$] 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 ..., ... INDT06	Propulsion table indicators
INDTRN	Turn calculation C_L selection indicator: = 0, turn at constant velocity = 1, turn using $C_{L_{max}}$
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 MISION.
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 IPLF2 IPLF3	Indicator to control allocation of tank fuel to payload: = 0, don't include in payload = 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 of .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*

11.11 L's

LOCLM	*Internal, location of CLMTAB in TAB array*
LOCNG	
LOCRG	*Internal, location of RG array in C array*
LOCSAC	*Internal, starting location of aerodynamic tables in TAB array*
LOCTFF	*Internal, starting location of propulsion tables in TAB array*
LOCTZ	*Internal, location of TZ array in C array*
LTT10X	
LTT10Y	
LTT10W	Not used
LTT10Z	
LTT11X	
LTT11Y	
LTT11W	
LTT11Z	

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	*Internally computed, total payload*
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	*Internal, computed in OUTXXX, SEGOUT*
PQ2	*Internal, computed in OUTXXX, SEGOUT*
PQ3	*Internal, computed in SEGOUT*
PQ4	*Internal, computed in SEGOUT*
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 RANGE3	Three range values for buddy refuel mission segment option
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, S[illegible]*
STYP2	*Internal, number of stores type 2 left, SACSP, ST[illegible]*
STYP3	*Internal, number of stores type 3 left, SACSP, STO[illegible]*

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	
TPTYP1	*Internal, number of tank pylons type 1 left, SACTP, TANKS*
TPTYP2	*Internal, number of tank pylons type 2 left, SACTP, TANKS*
TPTYP3	*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*
TTYP1	*Internal, number of tanks type 1 left,SACTP, TANKS*
TTYP2	*Internal, number of tanks type 2 left,SACTP, TANKS*
TTYP3	*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
WGTFT1	Weight of fuel in tank pair type 1
WGTFT2	Weight of fuel in tank pair type 2
WGTFT3	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
WGTSP1	Weight of store pylon pair type 1
WGTSP2	Weight of store pylon pair type 2
WGTSP3	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
WGTTP1	Weight of tank pylon pair type 1
WGTTP2	Weight of tank pylon pair type 2
WGTTP3	Weight of tank pylon pair type 3
WGTUF1	Weight of usable fuel in tank pair type 1
WGTUF2	Weight of usable fuel in tank pair type 2
WGTUF3	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 ant 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	*Internal variables in FLYMHP, FLIXCP, OPTXX2*
XAA	*Internal, controls INDMHP setting in CMAX. Control maximum R/C or dh/dW in OPTX14*
XAO	*Internal dM/dh in FLYMHP, FLIXCP, OPTXX1*
XBO XB1	*Internal, used in EMAX, FLIENV, FLIXEP, FLIXCP. XBO QLIM, XB1 AMLIM in OPTX14*
XFLEN	*Internal indicator. Controls call to FLITEN in MISION. Set in RNSEG*
XISO	Specific impulse at take-off
XMAXG	Maximum ground roll
XMLOD	*Internal, set in RNSEG*
XMSEG	*Internal, used in INSEG, set in RNSEG*
XNZZ	*Internal, error indicator set in BERAN, CHECK, CLIMB, CRCOMP, OPTXX1, OUTXXX, etc.*
XQ12	*Internal, used in OPTX14*
XQA1	*Internal, altitude variable GOGO OUTXXX*
XQAE	*Internal, altitude variable GOGO, OUTXXX*
XQBD	*Internal, indicator controlling CHECK Option and used in EMAX, FLIMHC, FLIXCP, GOGO*
XQFP	*Internal constant, FLYMHP, FLIMHC, FLIXEP, FLIXRP, FLIXCP, OPTXX1, OUTXXX, etc.*
XQR1	*Internal, range variable GOGO, RUN*
XQR2	*Internal, used in RUN*
XQR3	*Internal, used in RUN*
XQSW	Aerodynamic reference area

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.*

I1.23 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 ZX7	*Internal, used in PATH, RUN. ZX6 = 0.0 in SEGINI*
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 ZY6 ZY7 ZY8 ZY9 ZY10	Not used

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) MISION 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^k_{ij} 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, $\dot{h}$ climb
= 3, $\dot{M}$ 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 $L \simeq W$

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

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° 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° 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.

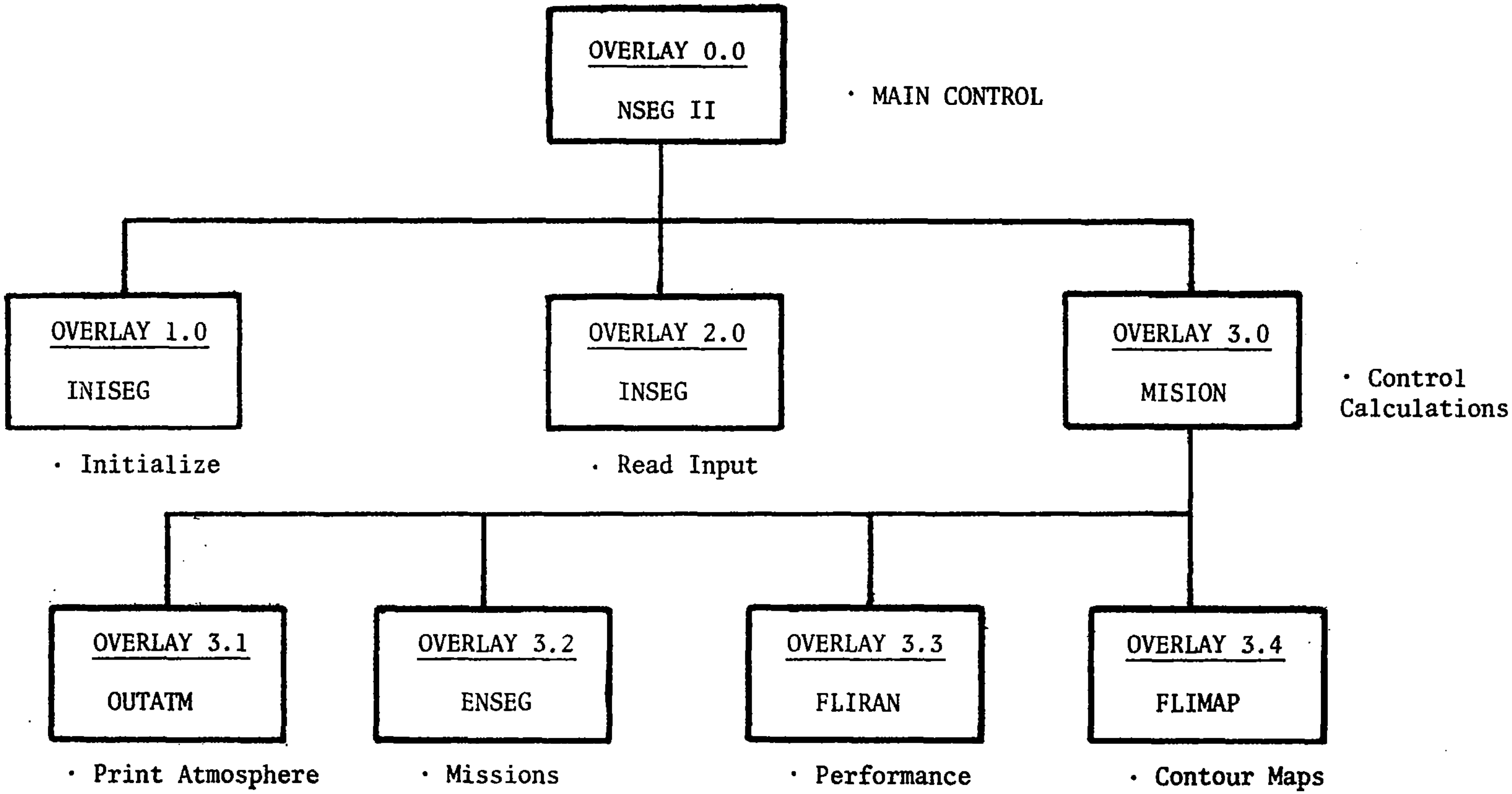


FIGURE 1. NSEG OVERLAY STRUCTURE

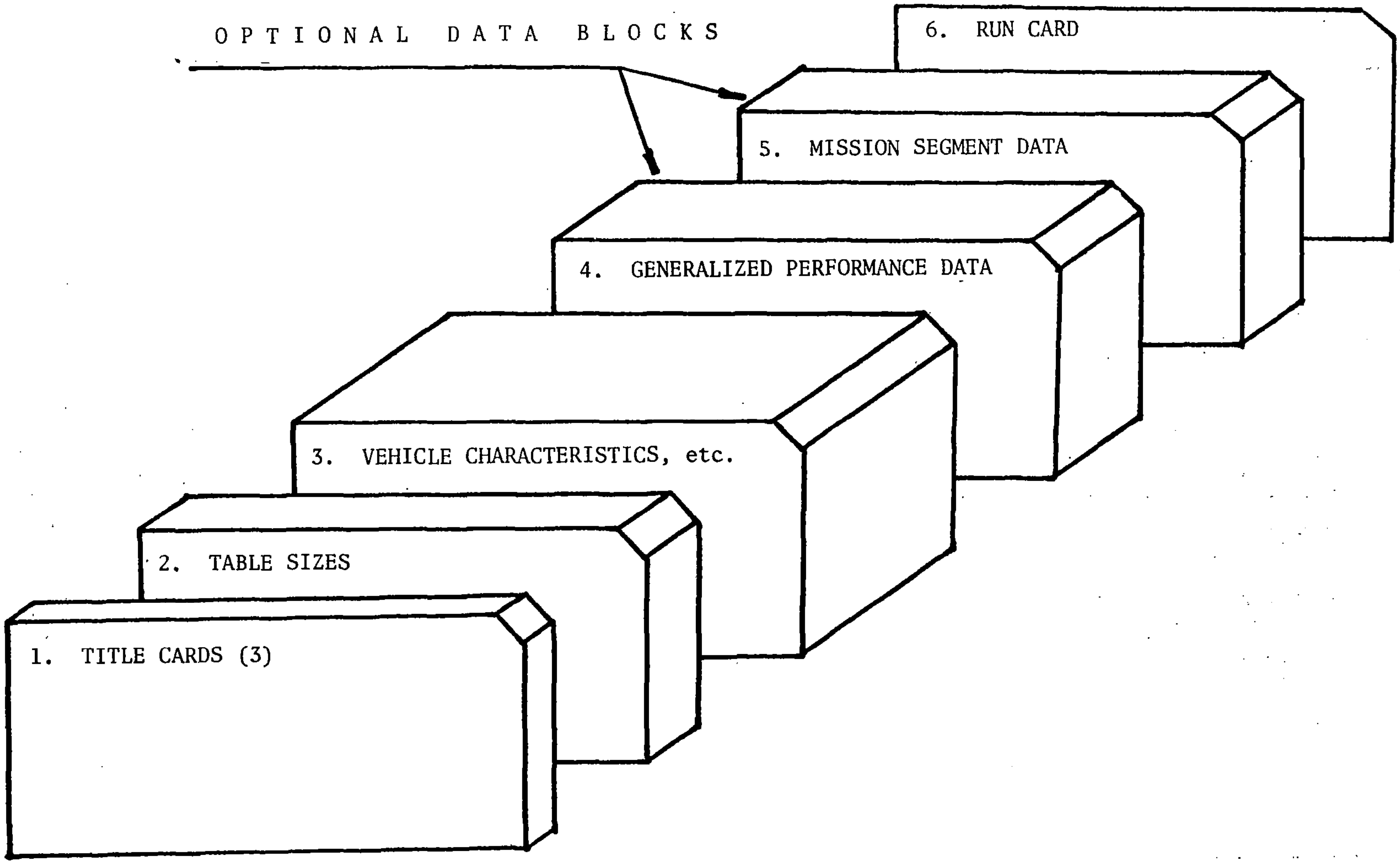


FIGURE 2. BASIC NSEG DATA OUTPUT

(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

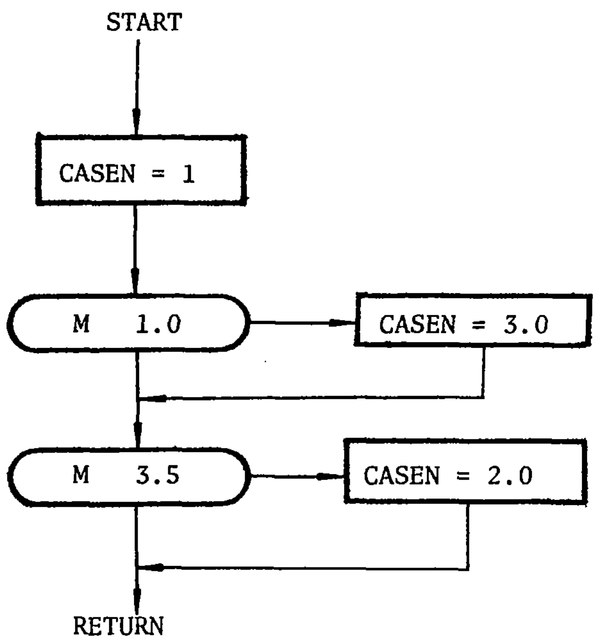
(e)

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

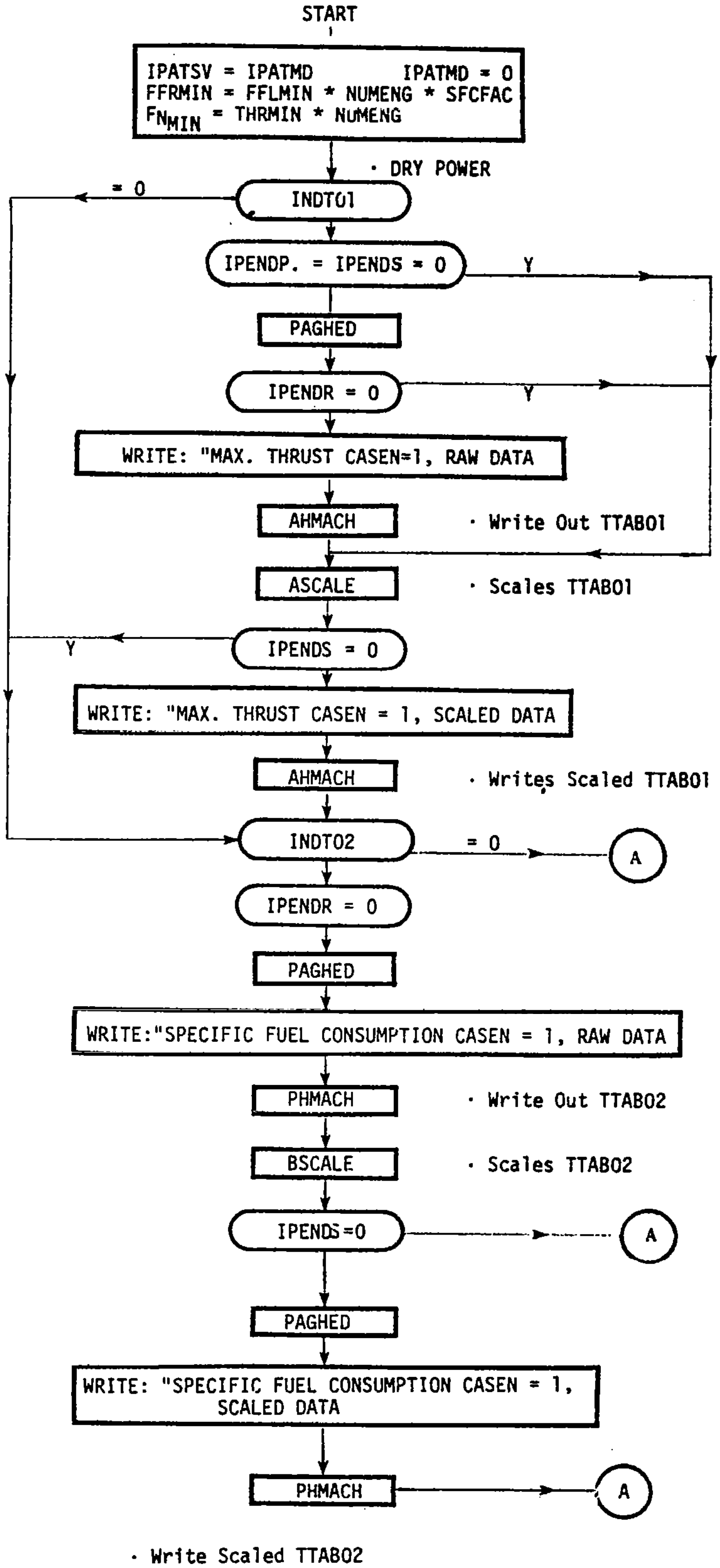


FIGURE 5. FLOW CHART ENDAT

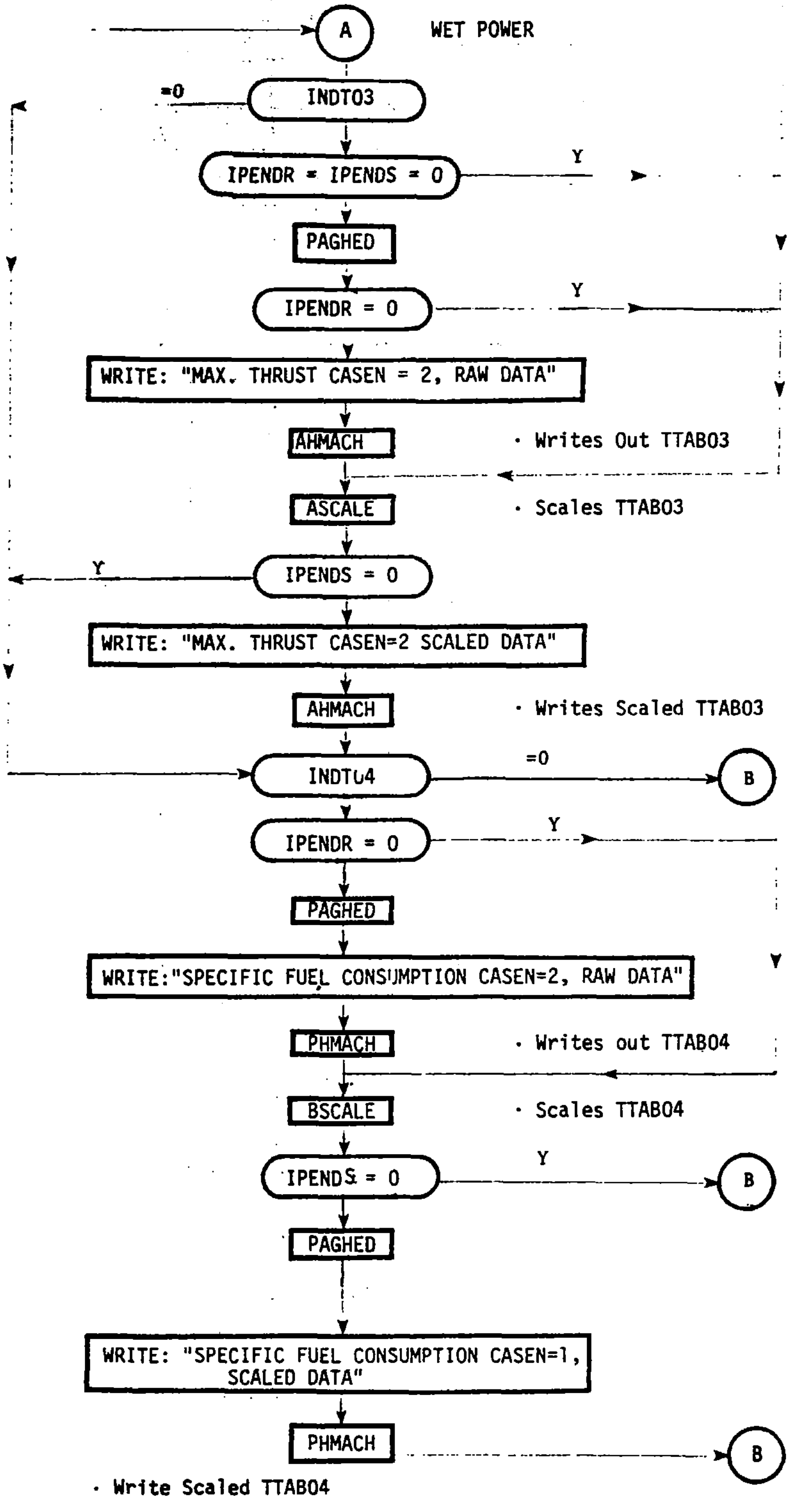


FIGURE 5. FLOW CHART ENDAT (CONTINUED)

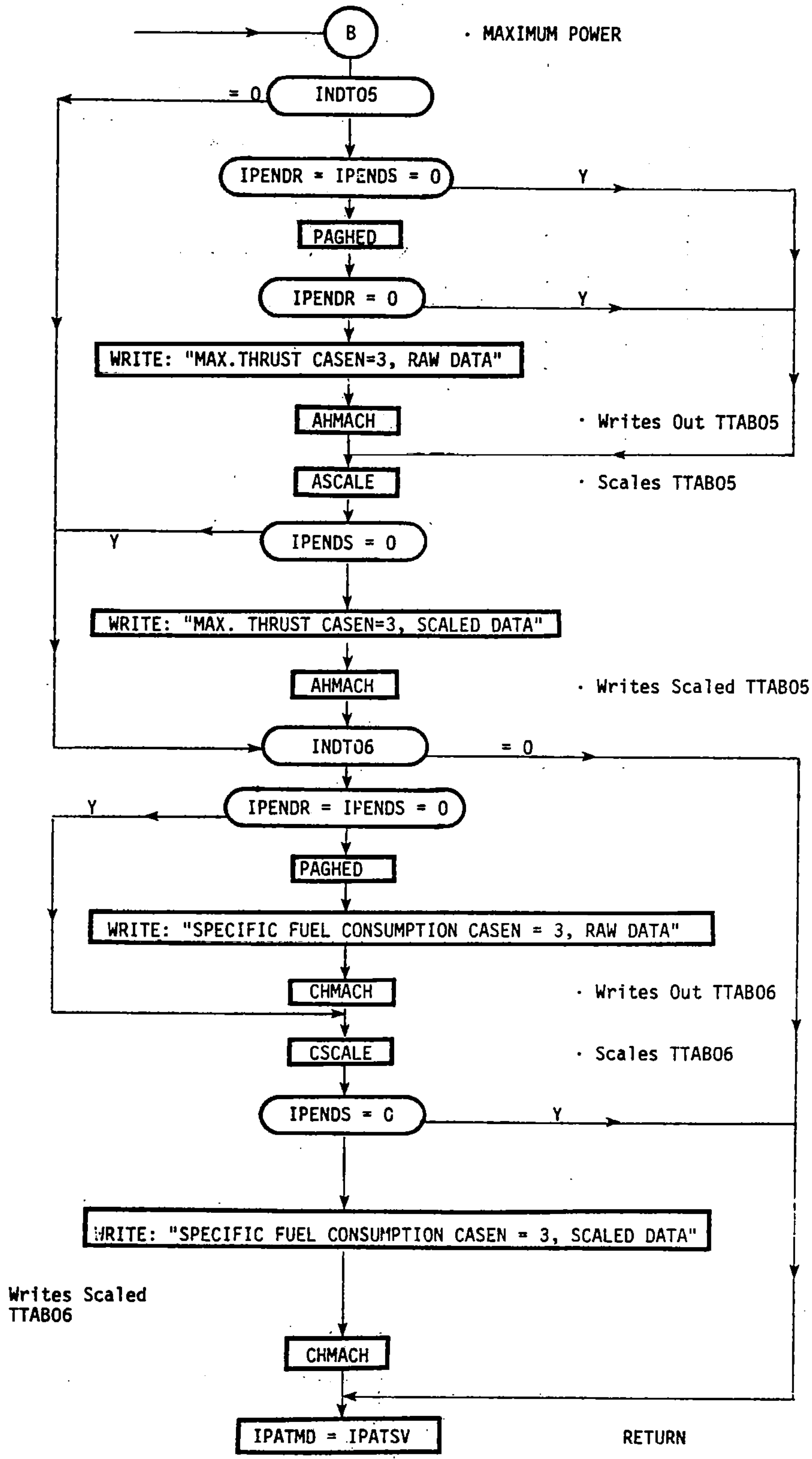


FIGURE 5. FLOW CHART ENDAT (CONCLUDED)

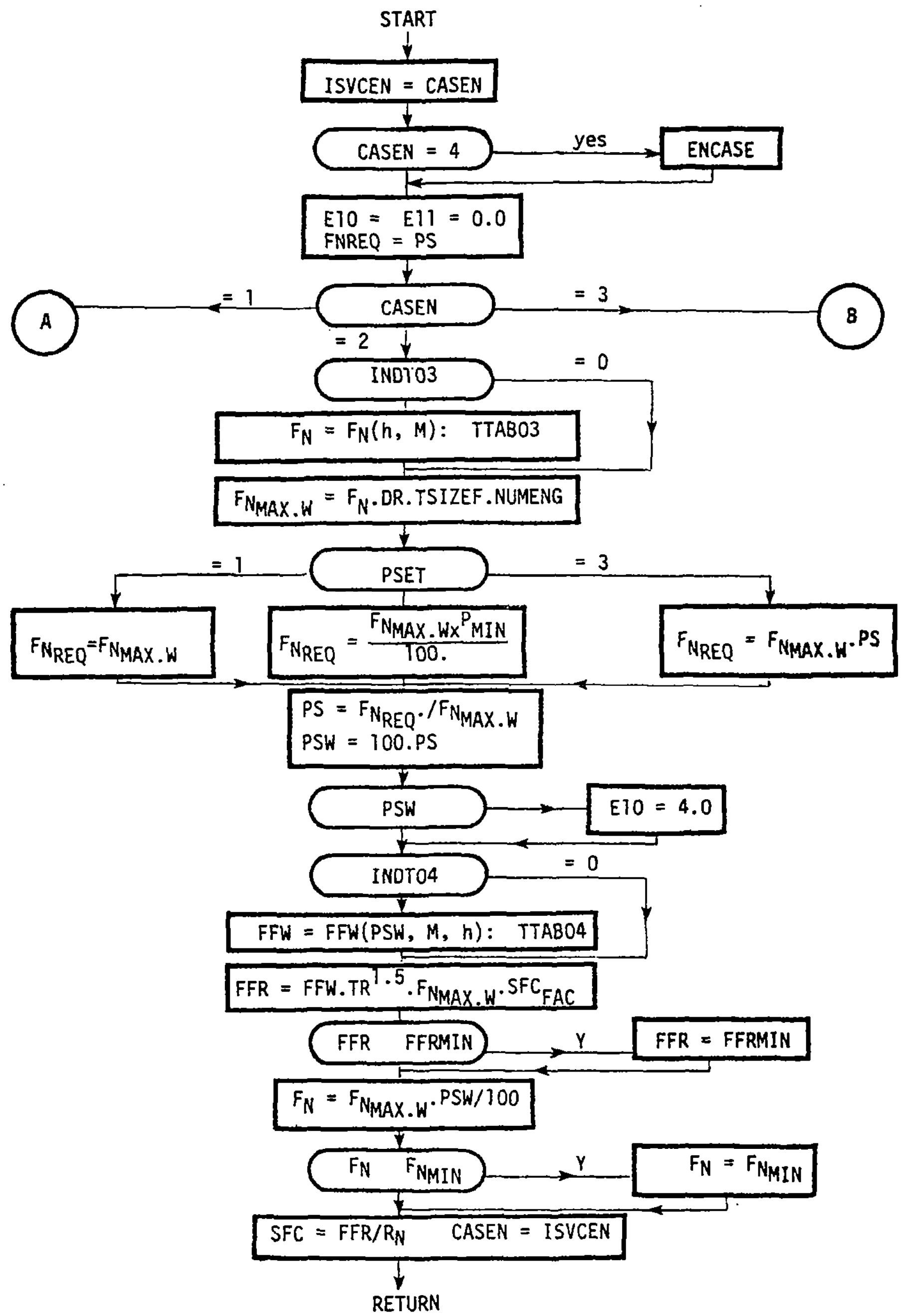


FIGURE 6. FLOW CHART ENSET

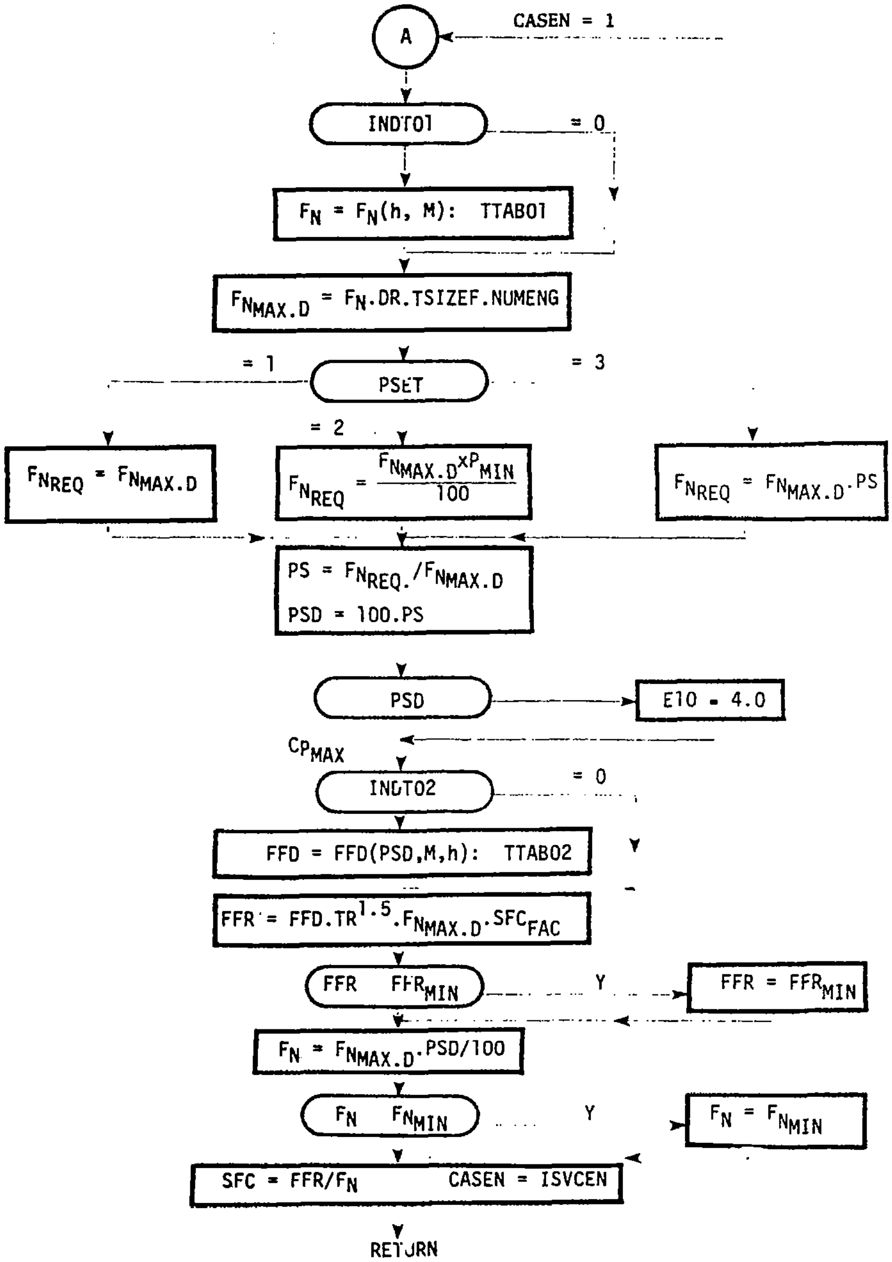


FIGURE 6. FLOW CHART ENSET (CONTINUED)

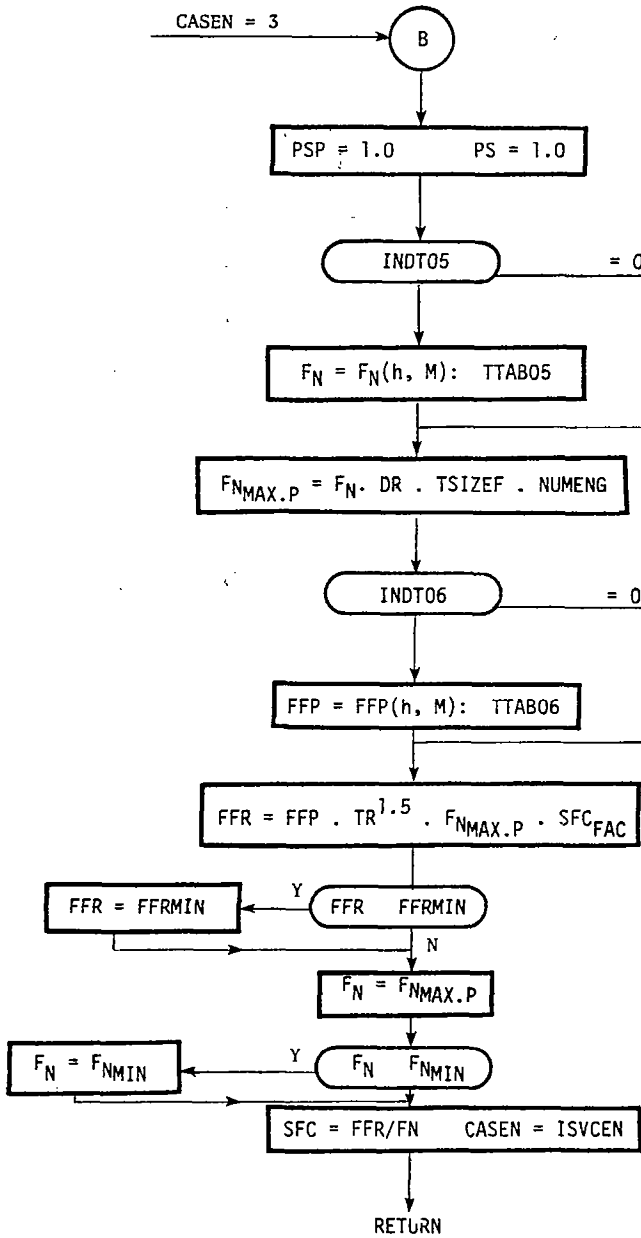
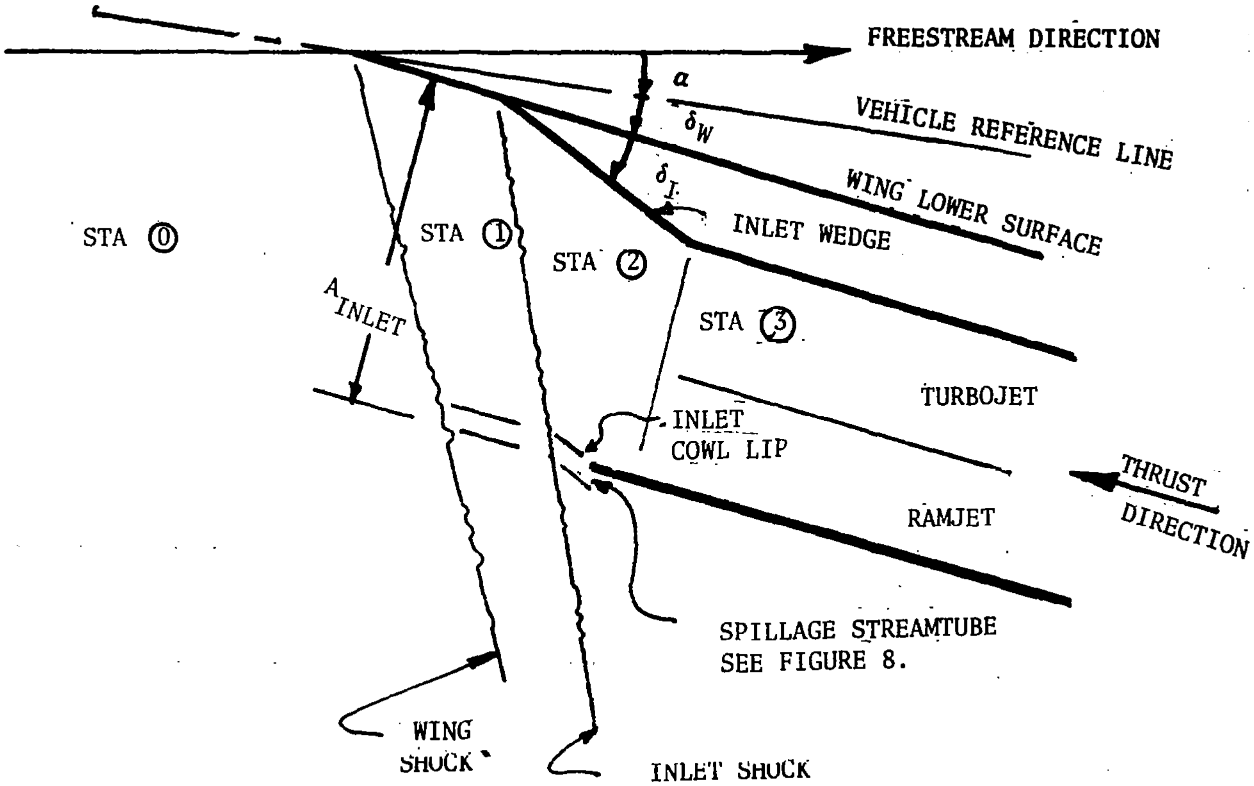
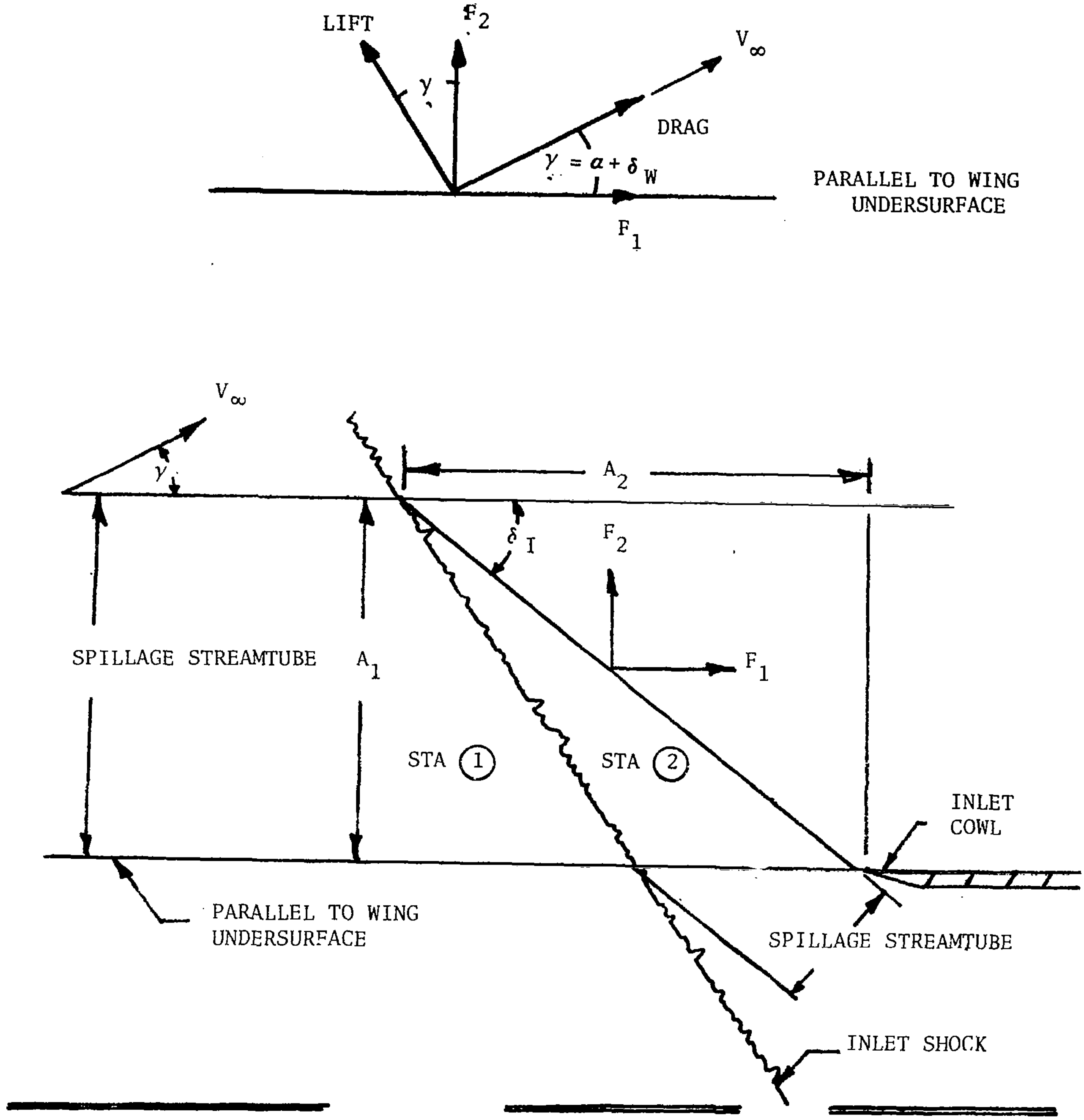


FIGURE 6. FLOW CHART ENSET (CONCLUDED)



$\gamma \equiv \alpha + \delta_W$

FIGURE 7. REFERENCE STATIONS AND GEOMETRY



A_1 = SPILLED AIRFLOW/ $p_1 v_1$

$A_2 = A_1/\text{TAN}\,\delta_I$

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

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

FIGURE 8. SPILLAGE LIFT AND DRAG COMPUTATIONS

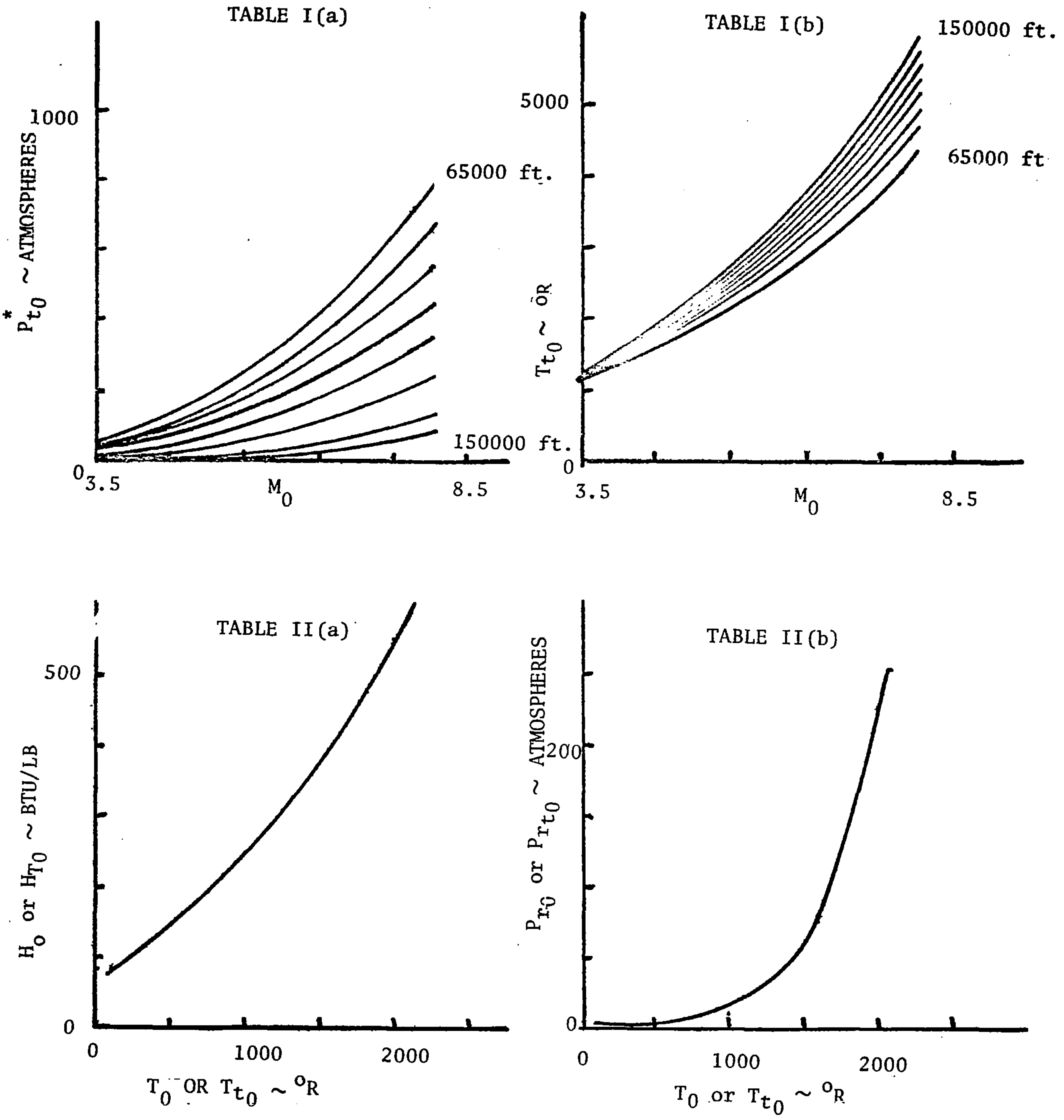


FIGURE 9. TYPICAL TABLE DATA

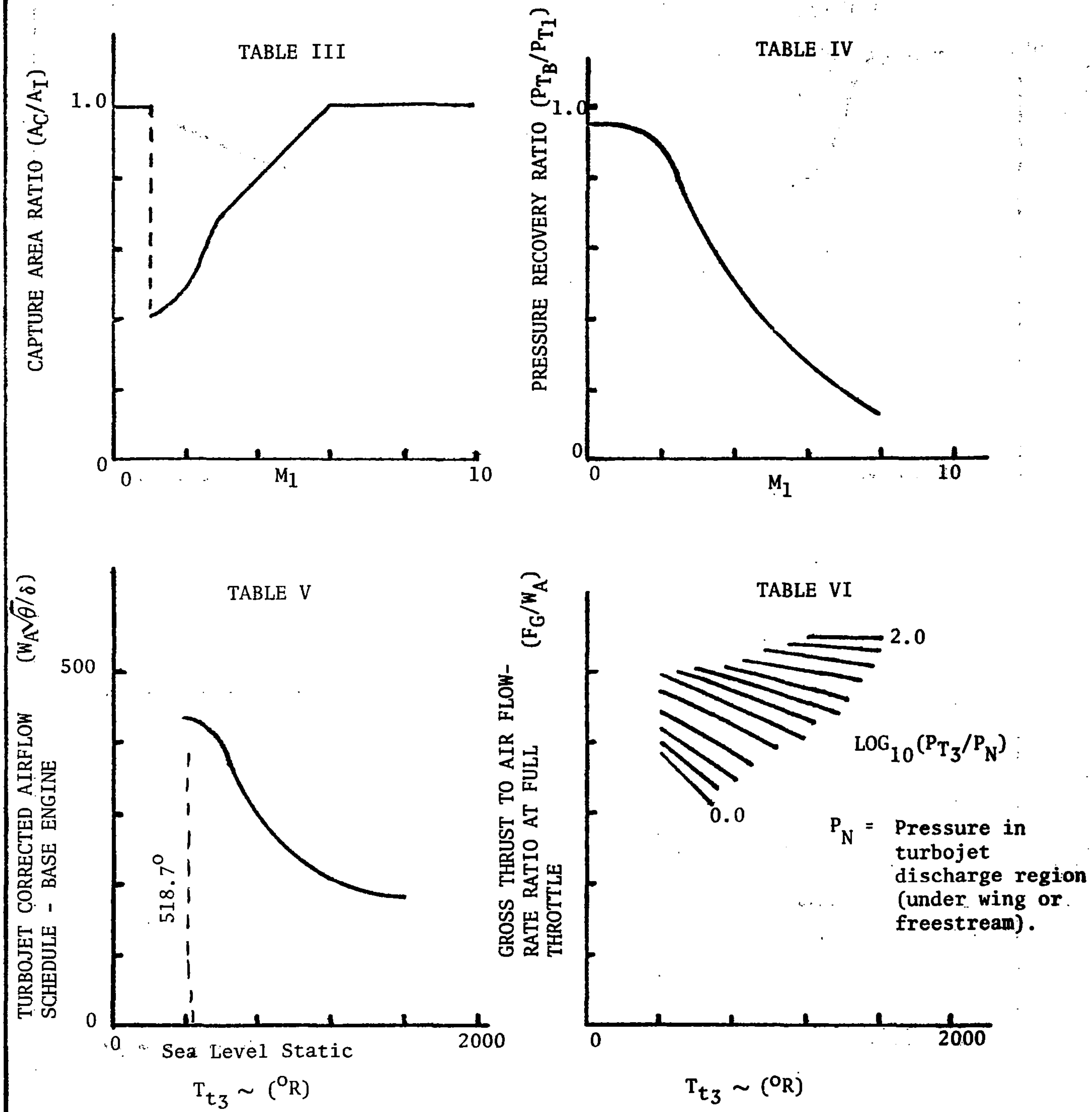


FIGURE 9. TYPICAL TABLE DATA (cont'd)

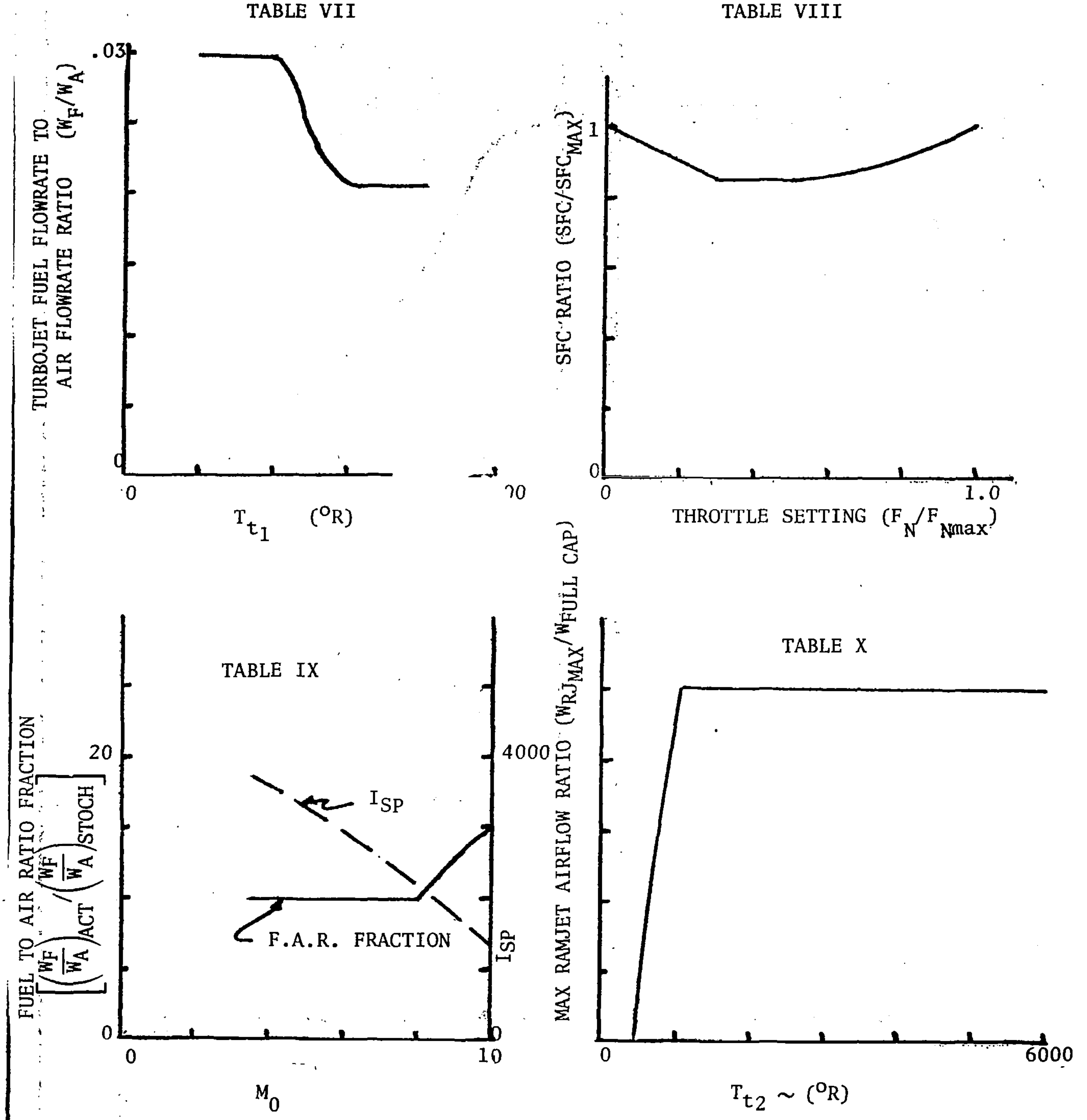
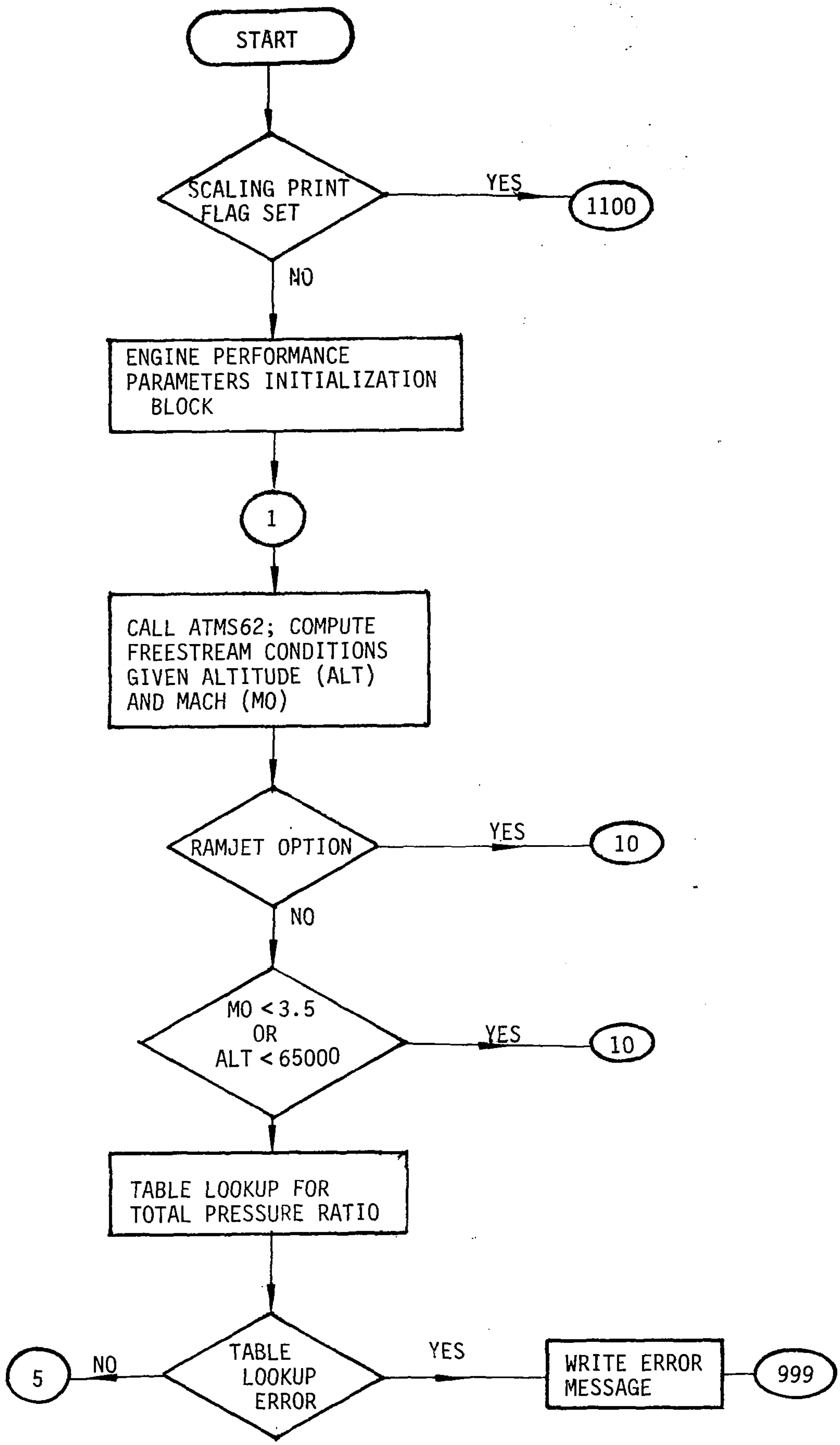
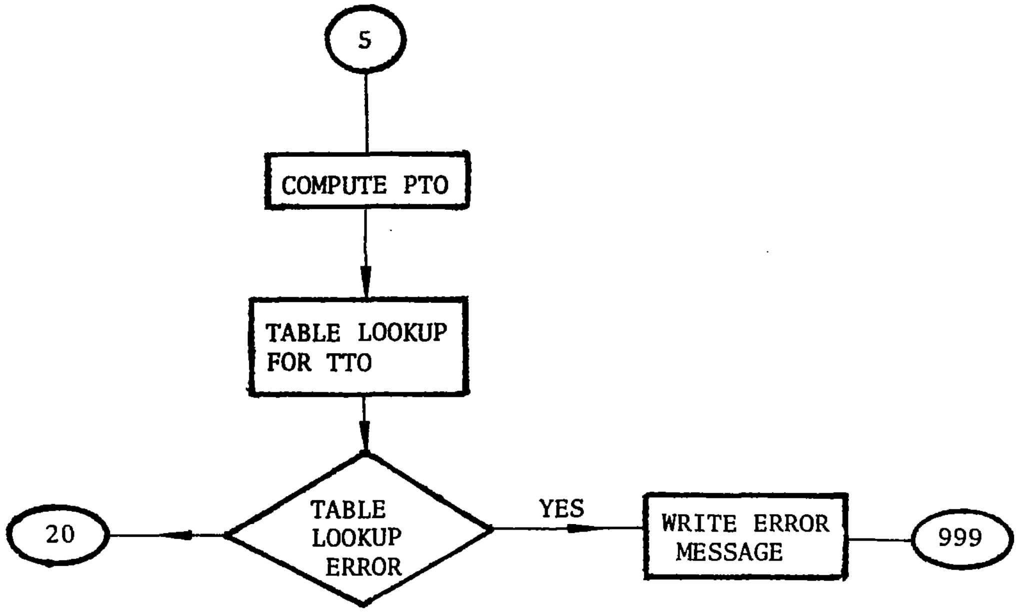
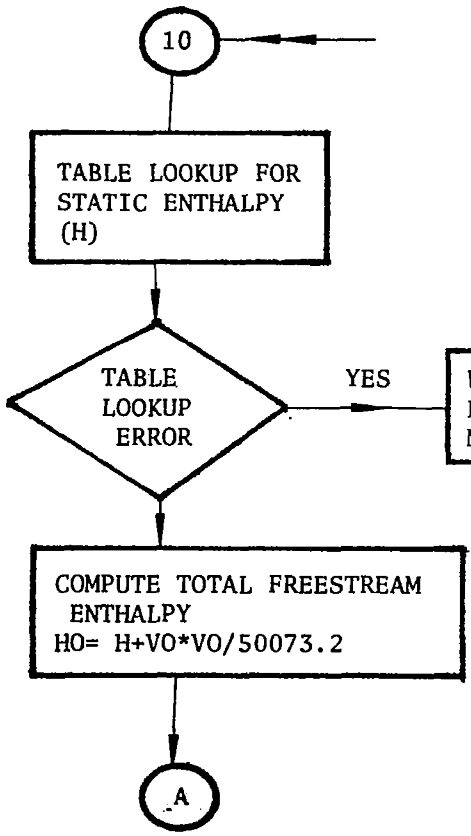


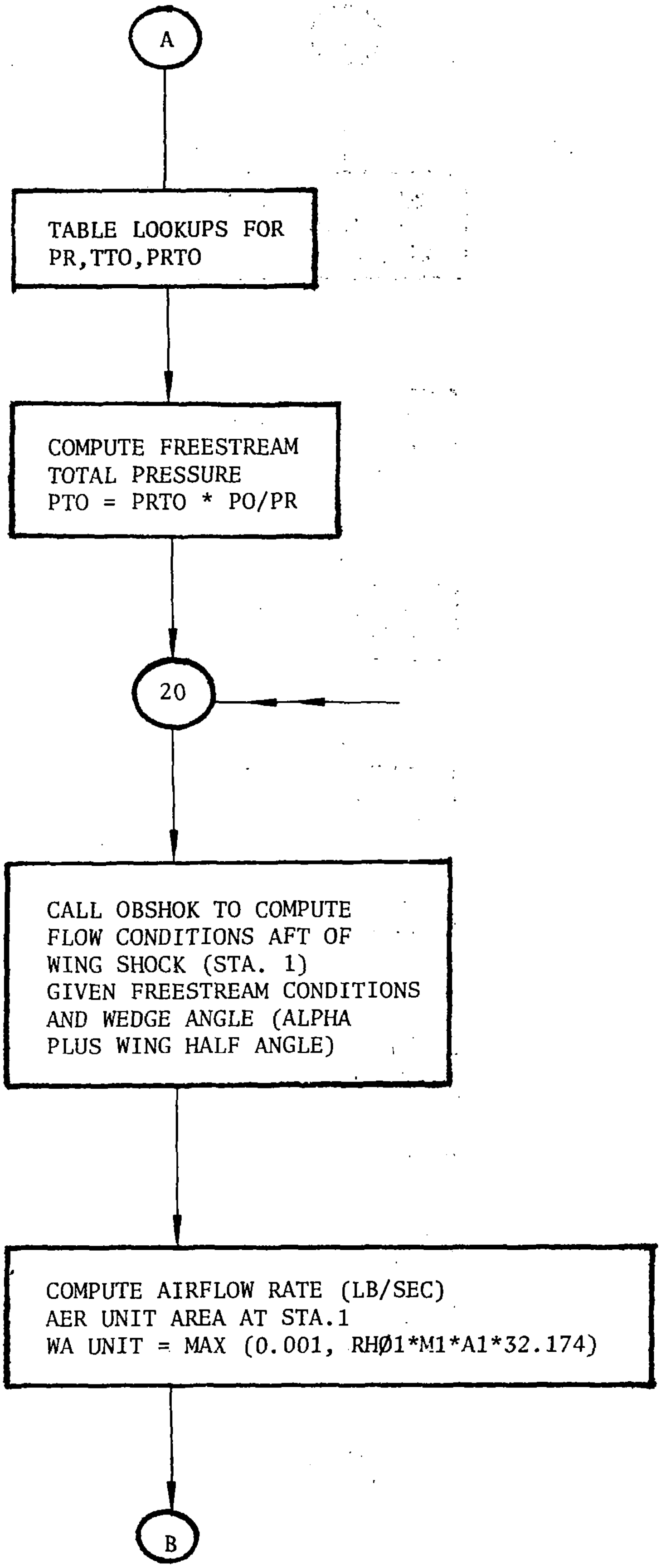
FIGURE 9. TYPICAL TABLE DATA (concluded)

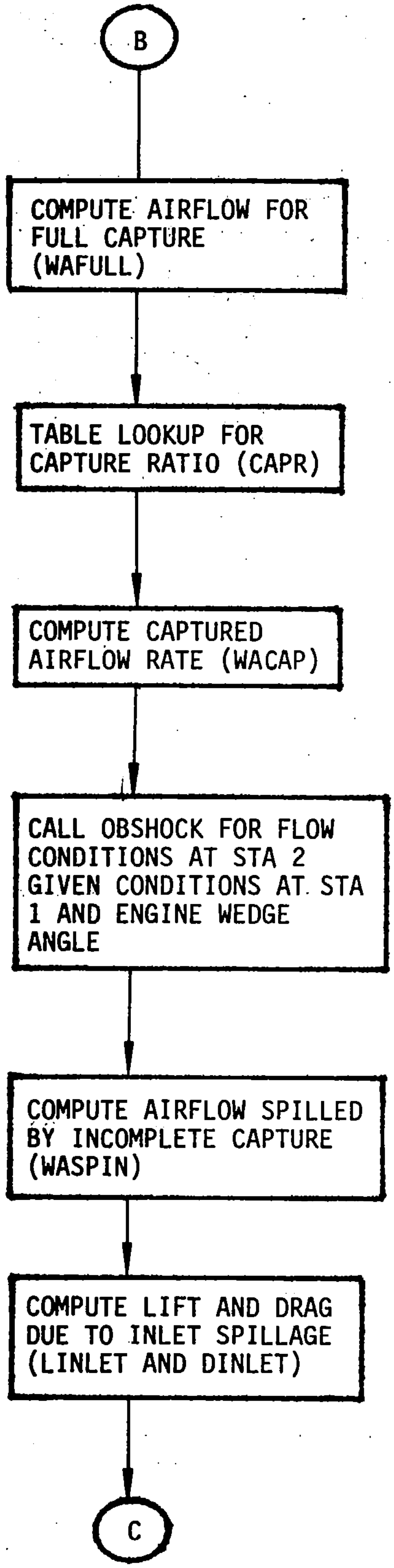
FIGURE 10. FLOW CHART SUBROUTINE ENGINS

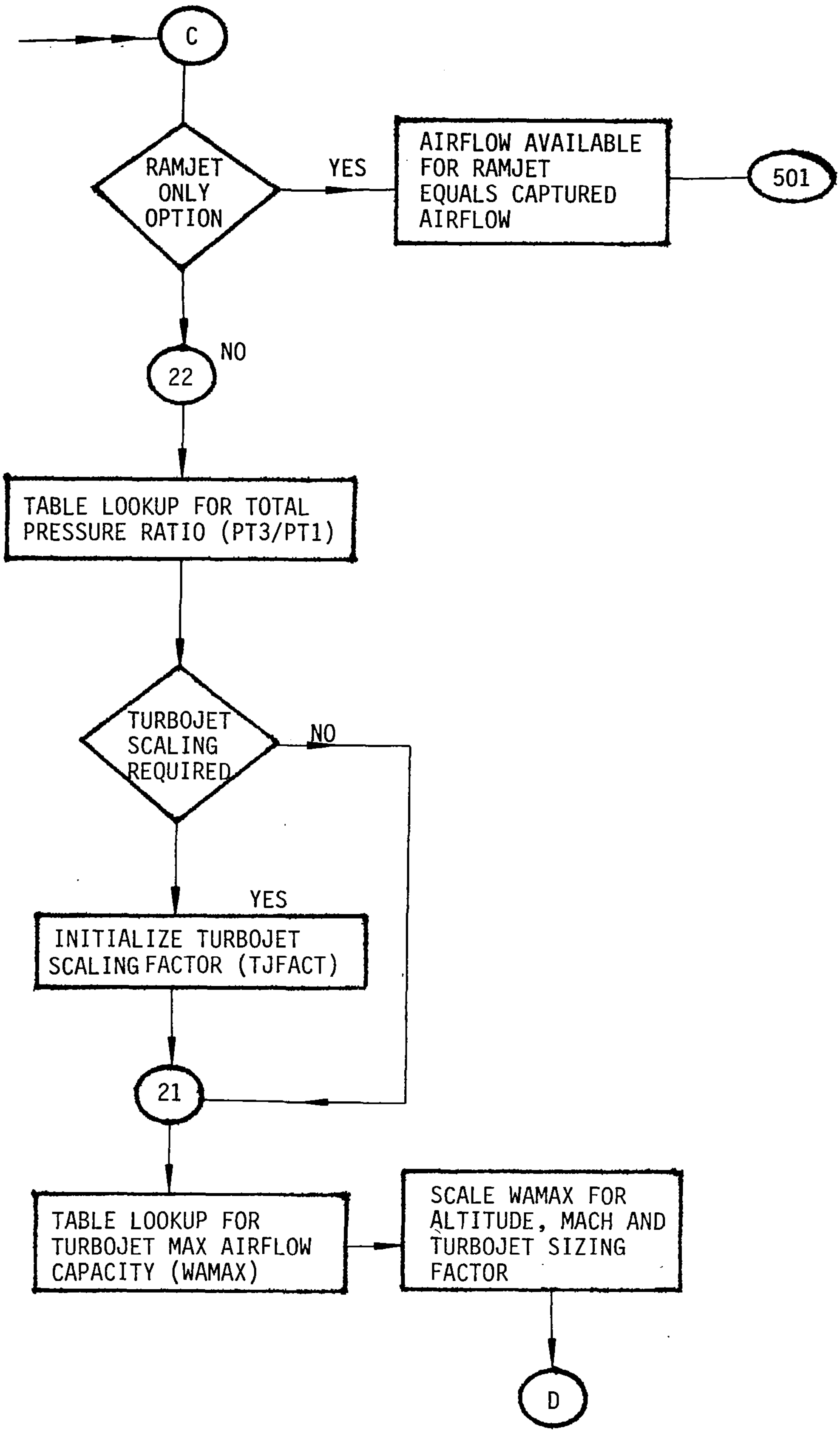


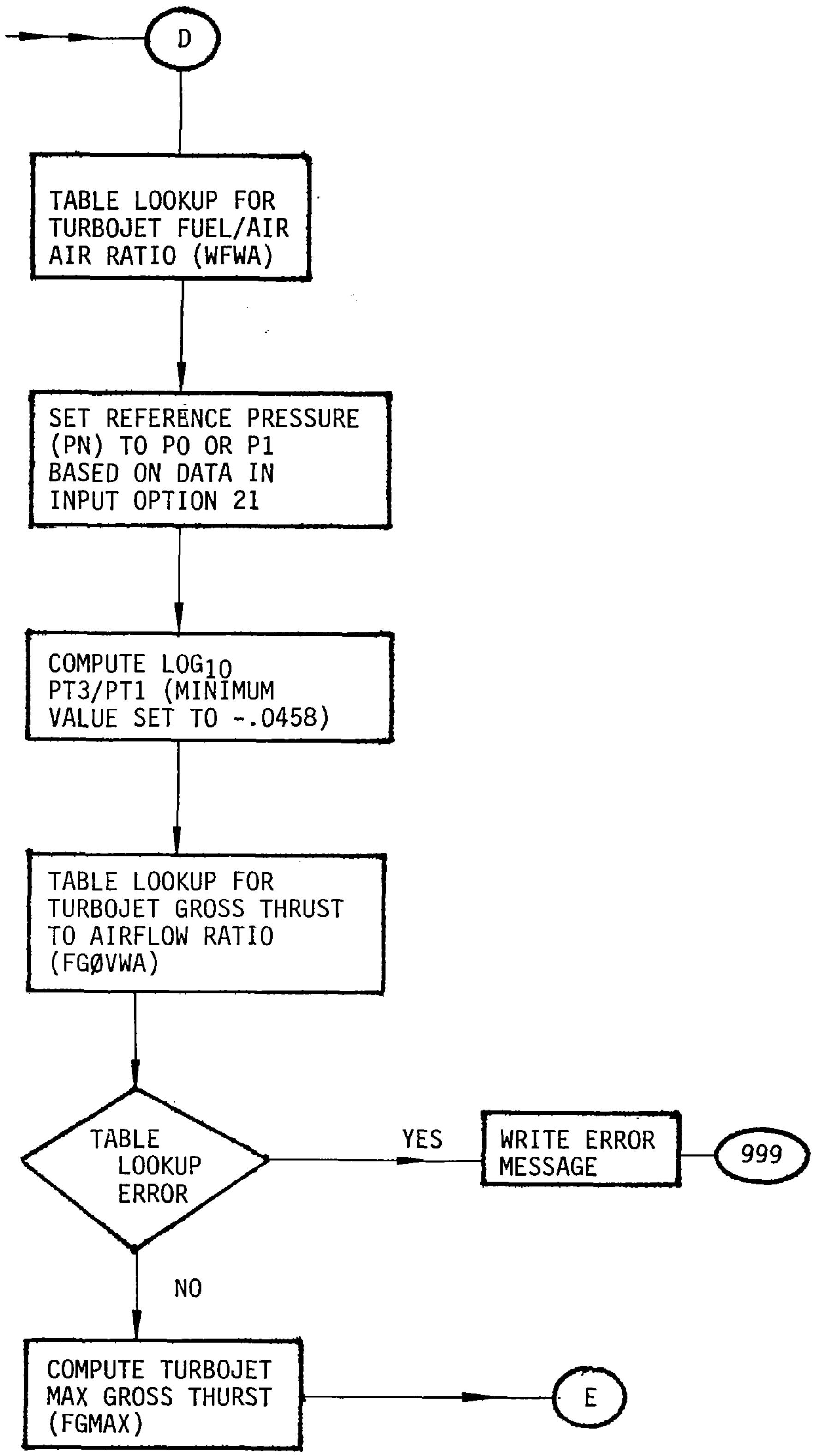

5
COMPUTE PTO
TABLE LOOKUP FOR TTO
TABLE LOOKUP ERROR
YES
WRITE ERROR MESSAGE
999
20

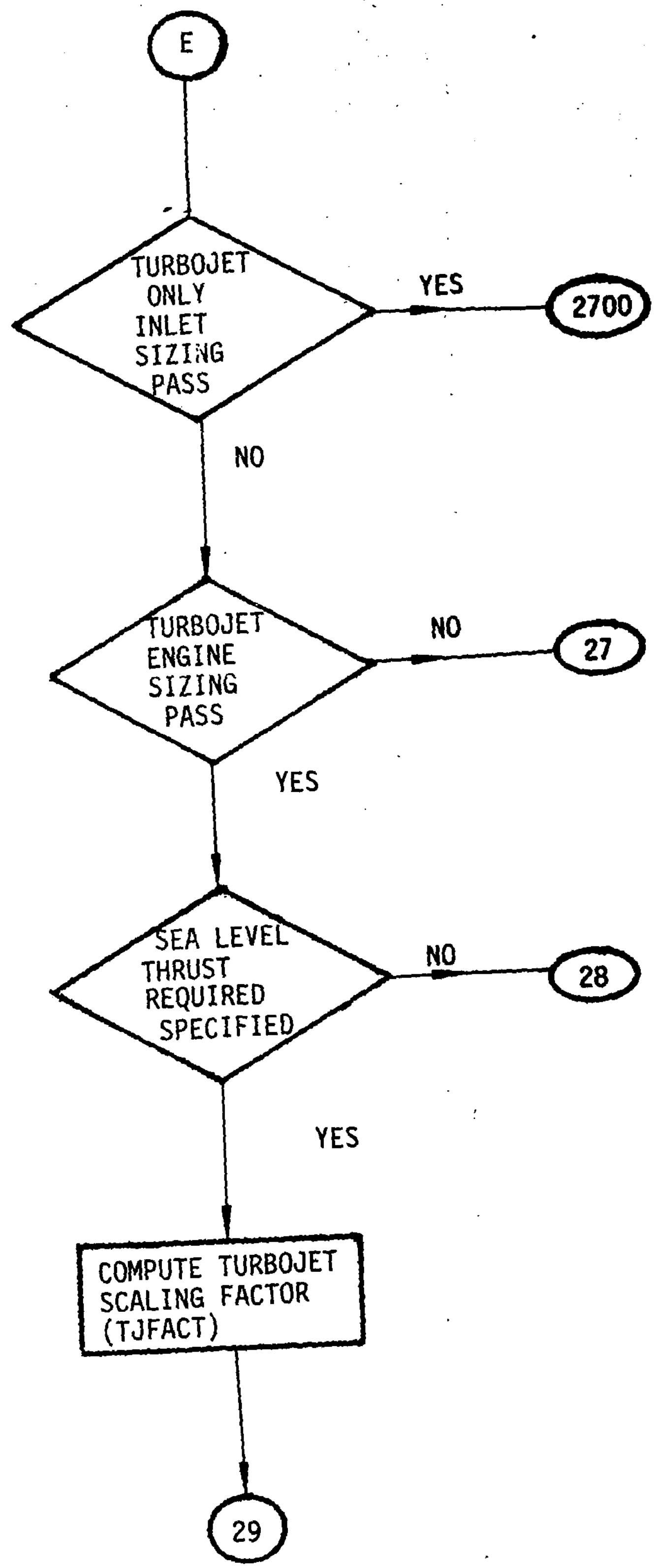

10
TABLE LOOKUP FOR STATIC ENTHALPY (H)
TABLE LOOKUP ERROR
YES
WRITE ERROR MESSAGE
999
COMPUTE TOTAL FREESTREAM ENTHALPY
HO= H+VO*VO/50073.2
A

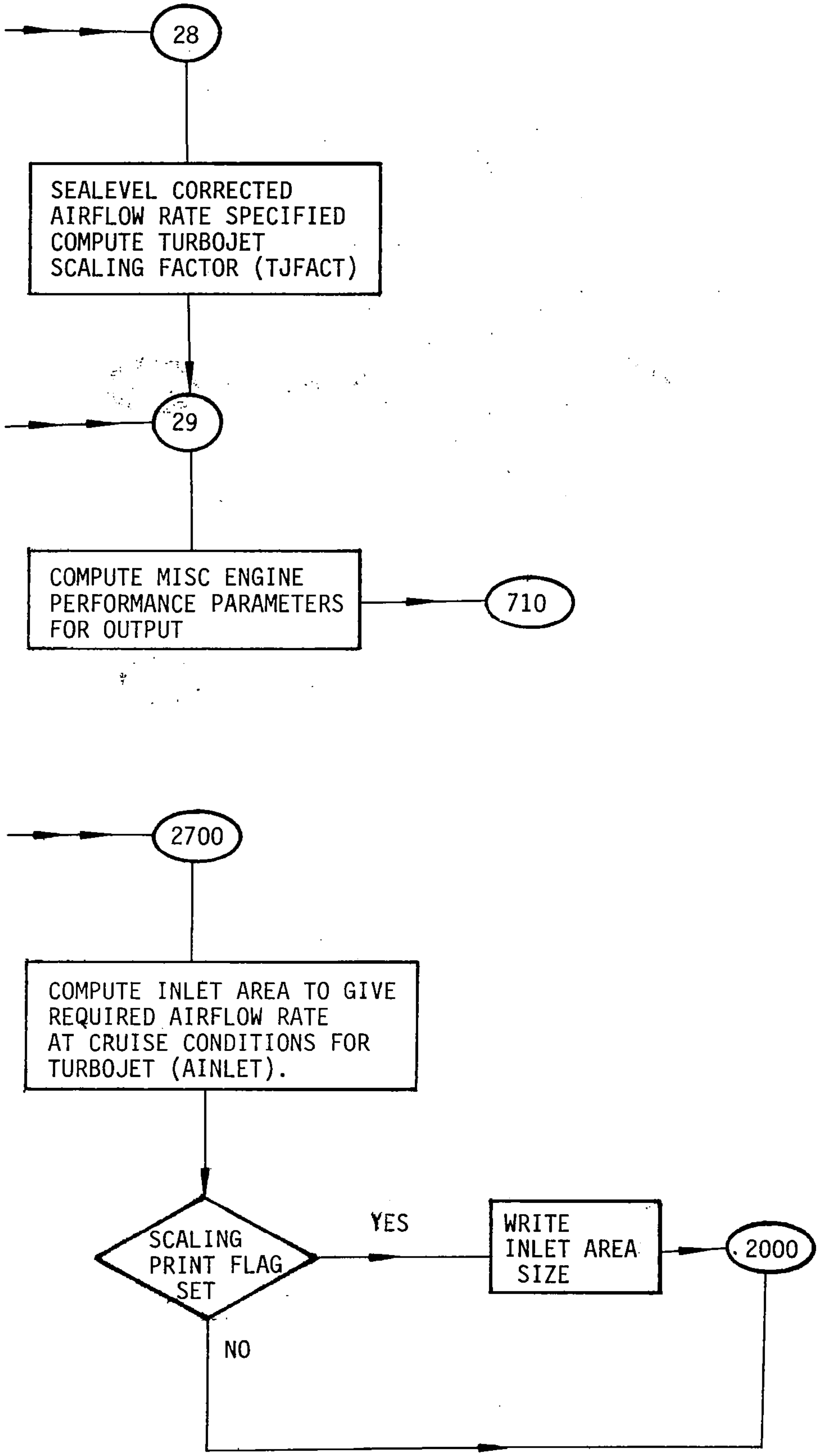

A
TABLE LOOKUPS FOR
PR,TTO,PRTO
COMPUTE FREESTREAM
TOTAL PRESSURE
PTO = PRTO * PO/PR
20
CALL OBSHOK TO COMPUTE
FLOW CONDITIONS AFT OF
WING SHOCK (STA. 1)
GIVEN FREESTREAM CONDITIONS
AND WEDGE ANGLE (ALPHA
PLUS WING HALF ANGLE)
COMPUTE AIRFLOW RATE (LB/SEC)
AER UNIT AREA AT STA.1
WA UNIT = MAX (0.001, RHØ1*M1*A1*32.174)
B

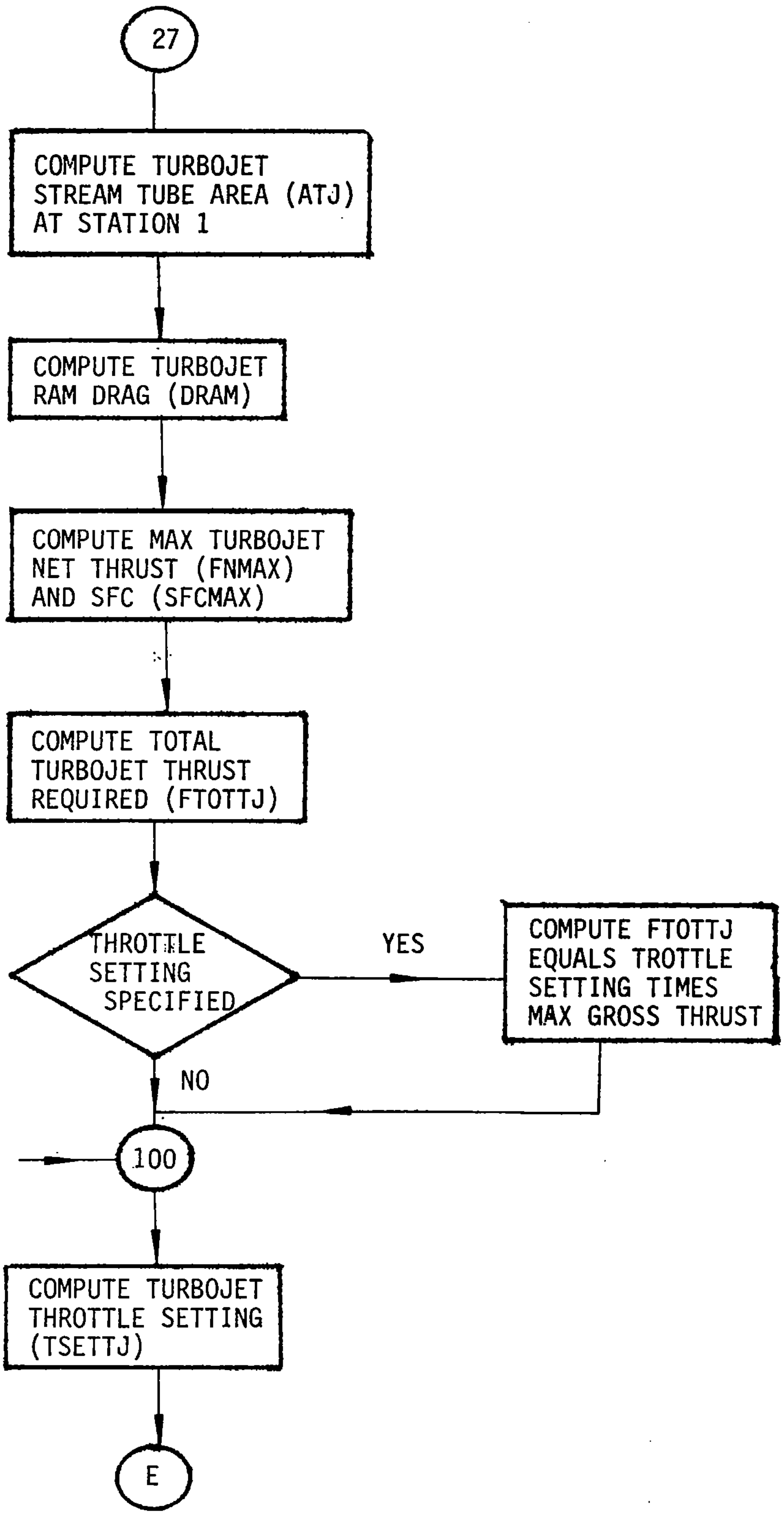

B
COMPUTE AIRFLOW FOR FULL CAPTURE (WAFULL)
TABLE LOOKUP FOR CAPTURE RATIO (CAPR)
COMPUTE CAPTURED AIRFLOW RATE (WACAP)
CALL OBSHOCK FOR FLOW CONDITIONS AT STA 2 GIVEN CONDITIONS AT STA 1 AND ENGINE WEDGE ANGLE
COMPUTE AIRFLOW SPILLED BY INCOMPLETE CAPTURE (WASPIN)
COMPUTE LIFT AND DRAG DUE TO INLET SPILLAGE (LINLET AND DINLET)
C

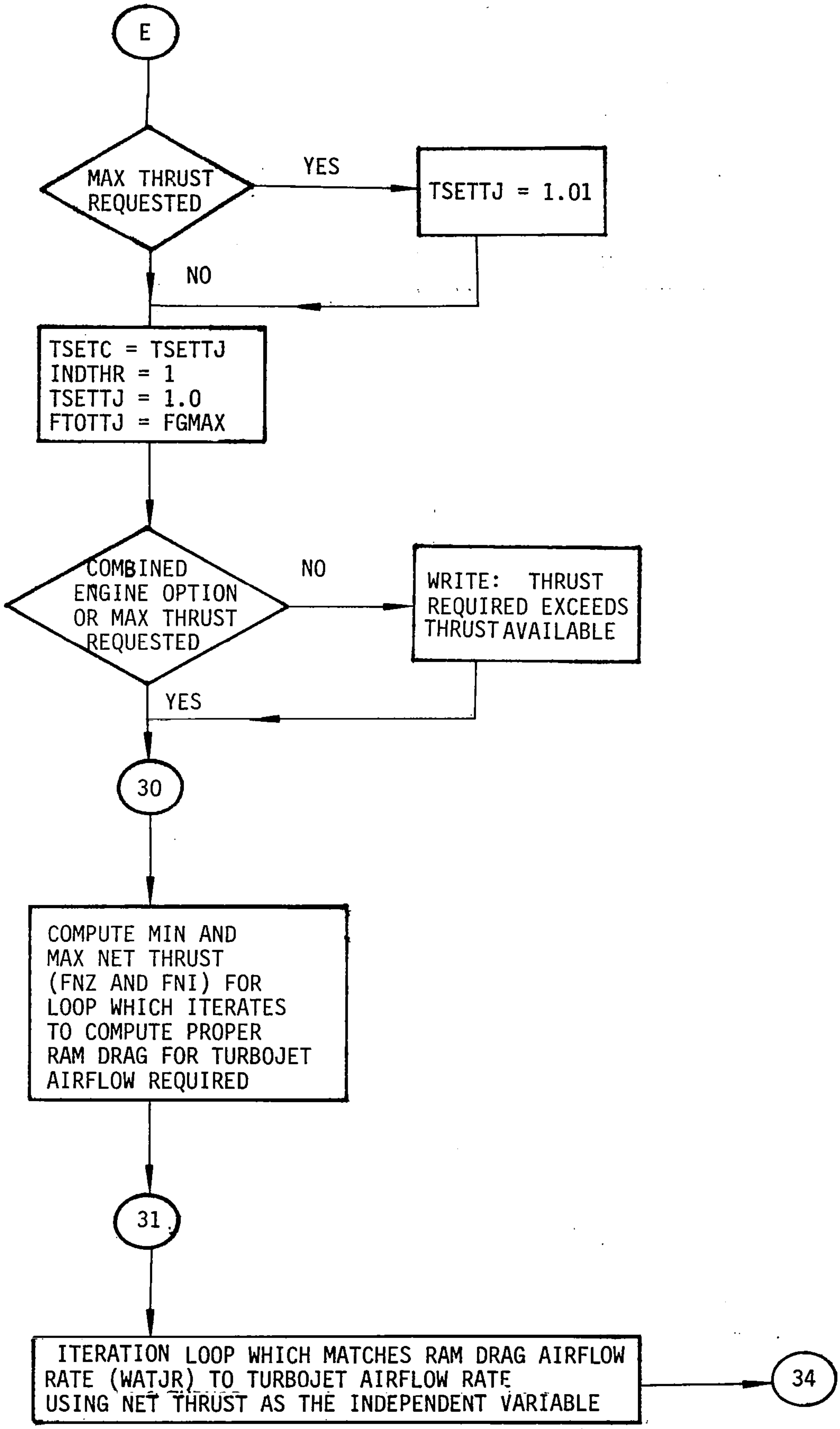

C
RAMJET ONLY OPTION
YES
AIRFLOW AVAILABLE FOR RAMJET EQUALS CAPTURED AIRFLOW
501
NO
22
TABLE LOOKUP FOR TOTAL PRESSURE RATIO (PT3/PT1)
TURBOJET SCALING REQUIRED
NO
YES
INITIALIZE TURBOJET SCALING FACTOR (TJFACT)
21
TABLE LOOKUP FOR TURBOJET MAX AIRFLOW CAPACITY (WAMAX)
SCALE WAMAX FOR ALTITUDE, MACH AND TURBOJET SIZING FACTOR
D

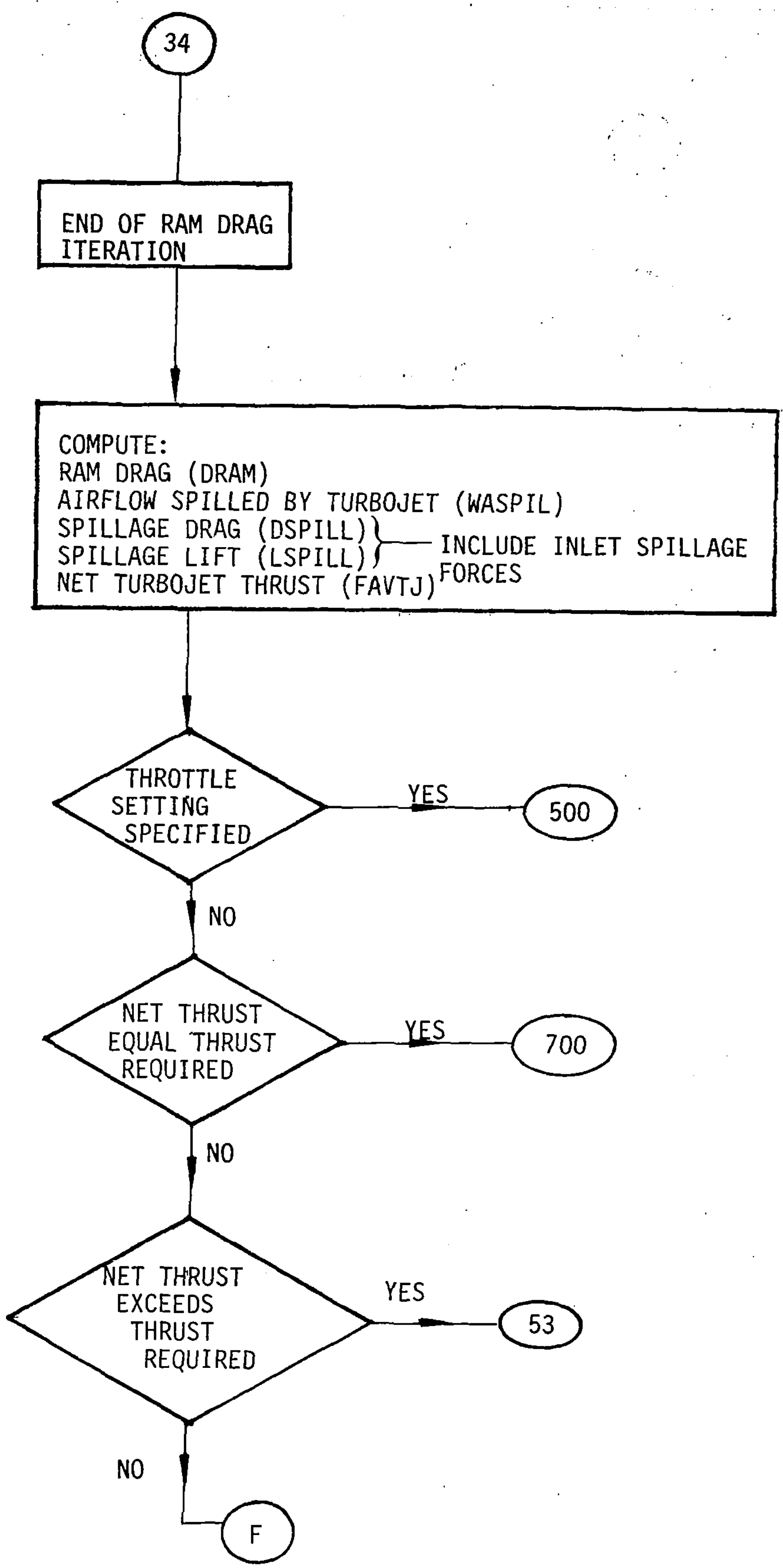

D
TABLE LOOKUP FOR TURBOJET FUEL/AIR AIR RATIO (WFWA)
SET REFERENCE PRESSURE (PN) TO PO OR P1 BASED ON DATA IN INPUT OPTION 21
COMPUTE LOG10 PT3/PT1 (MINIMUM VALUE SET TO -.0458)
TABLE LOOKUP FOR TURBOJET GROSS THRUST TO AIRFLOW RATIO (FGØVWA)
TABLE LOOKUP ERROR
YES
WRITE ERROR MESSAGE
999
NO
COMPUTE TURBOJET MAX GROSS THURST (FGMAX)
E

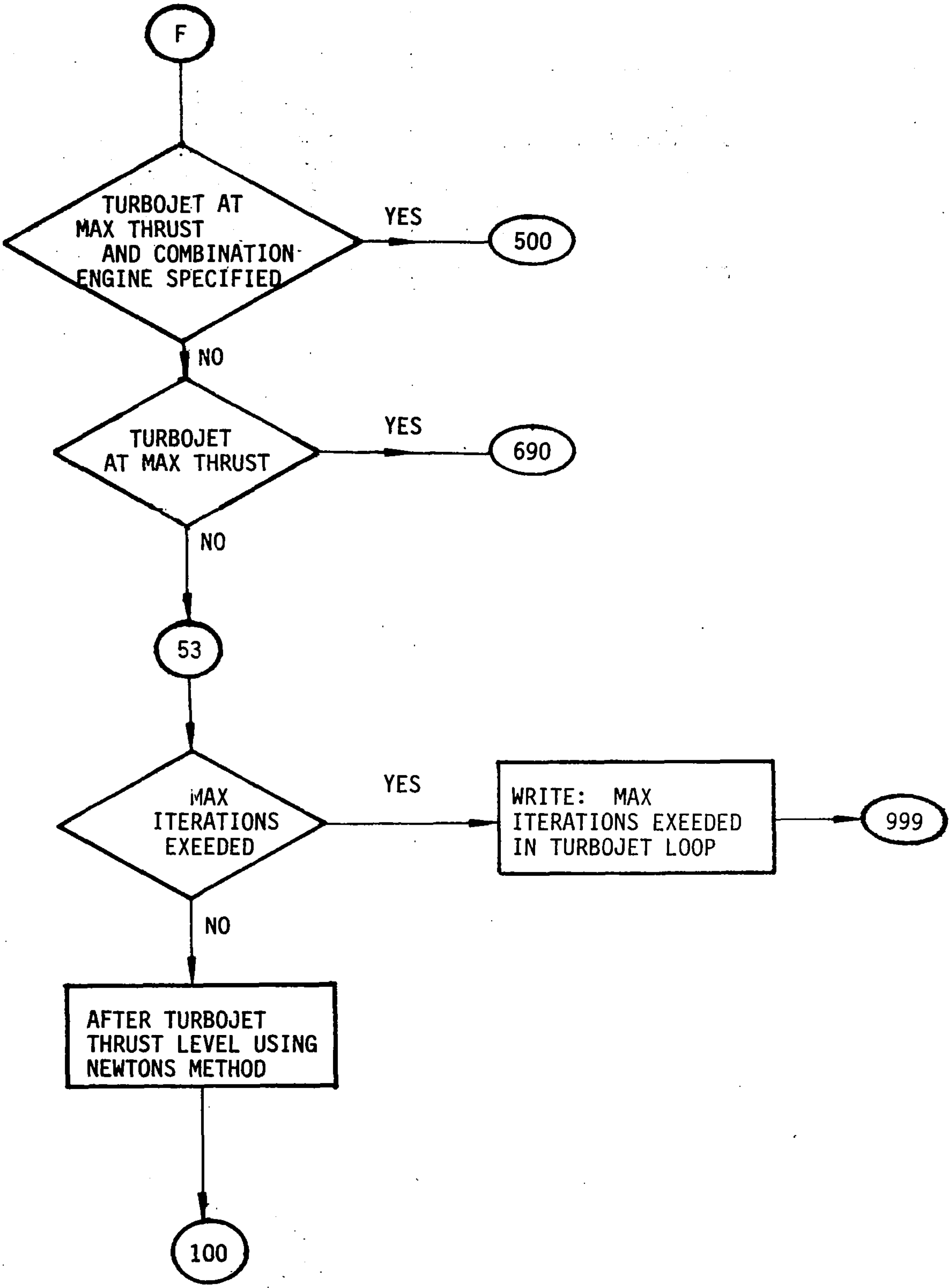

E
TURBOJET ONLY INLET SIZING PASS
YES
2700
NO
TURBOJET ENGINE SIZING PASS
NO
27
YES
SEA LEVEL THRUST REQUIRED SPECIFIED
NO
28
YES
COMPUTE TURBOJET SCALING FACTOR (TJFACT)
29

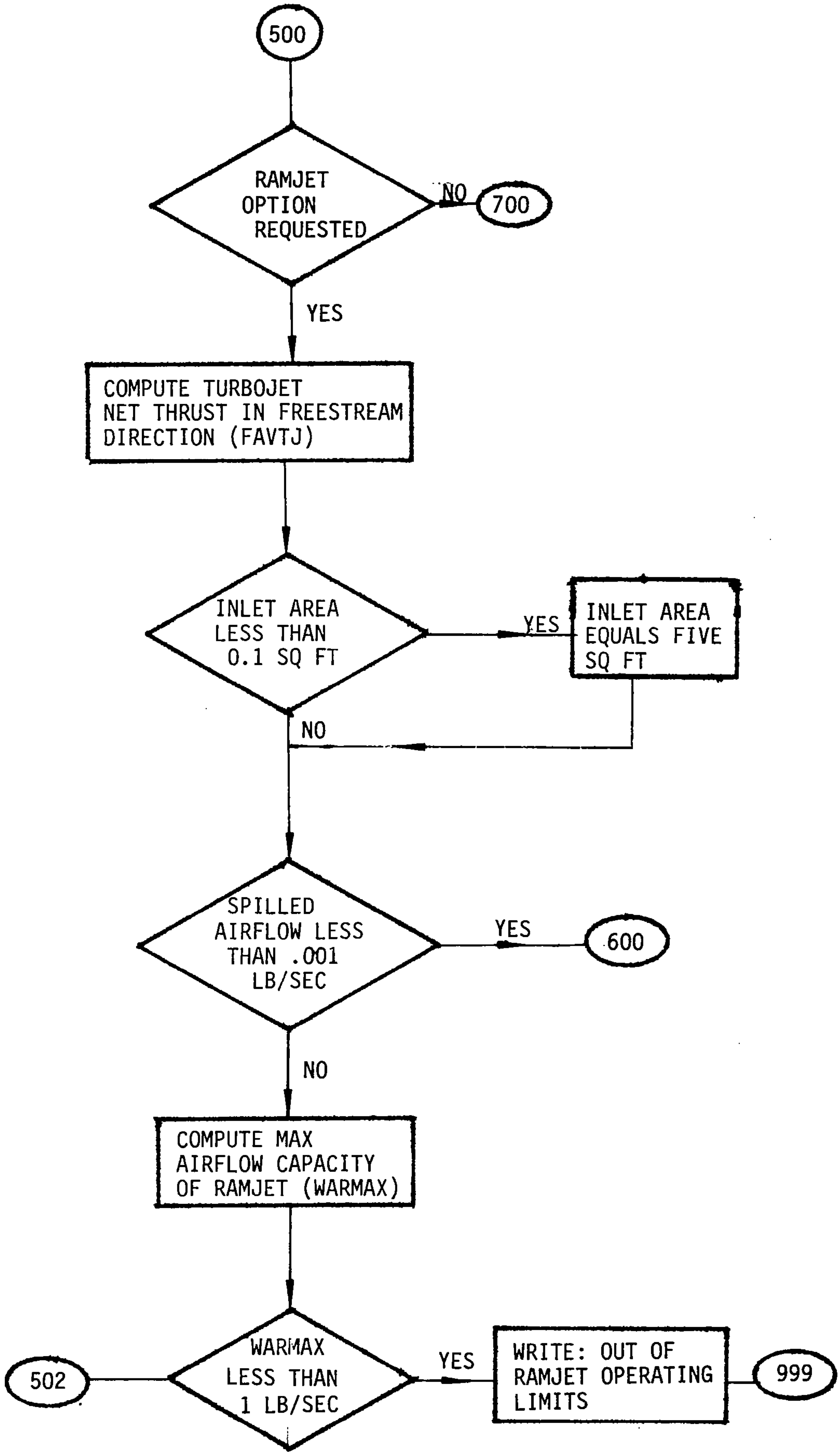

28
SEALEVEL CORRECTED AIRFLOW RATE SPECIFIED COMPUTE TURBOJET SCALING FACTOR (TJFACT)
29
COMPUTE MISC ENGINE PERFORMANCE PARAMETERS FOR OUTPUT
710
2700
COMPUTE INLET AREA TO GIVE REQUIRED AIRFLOW RATE AT CRUISE CONDITIONS FOR TURBOJET (AINLET).
SCALING PRINT FLAG SET
YES
NO
WRITE INLET AREA SIZE
2000

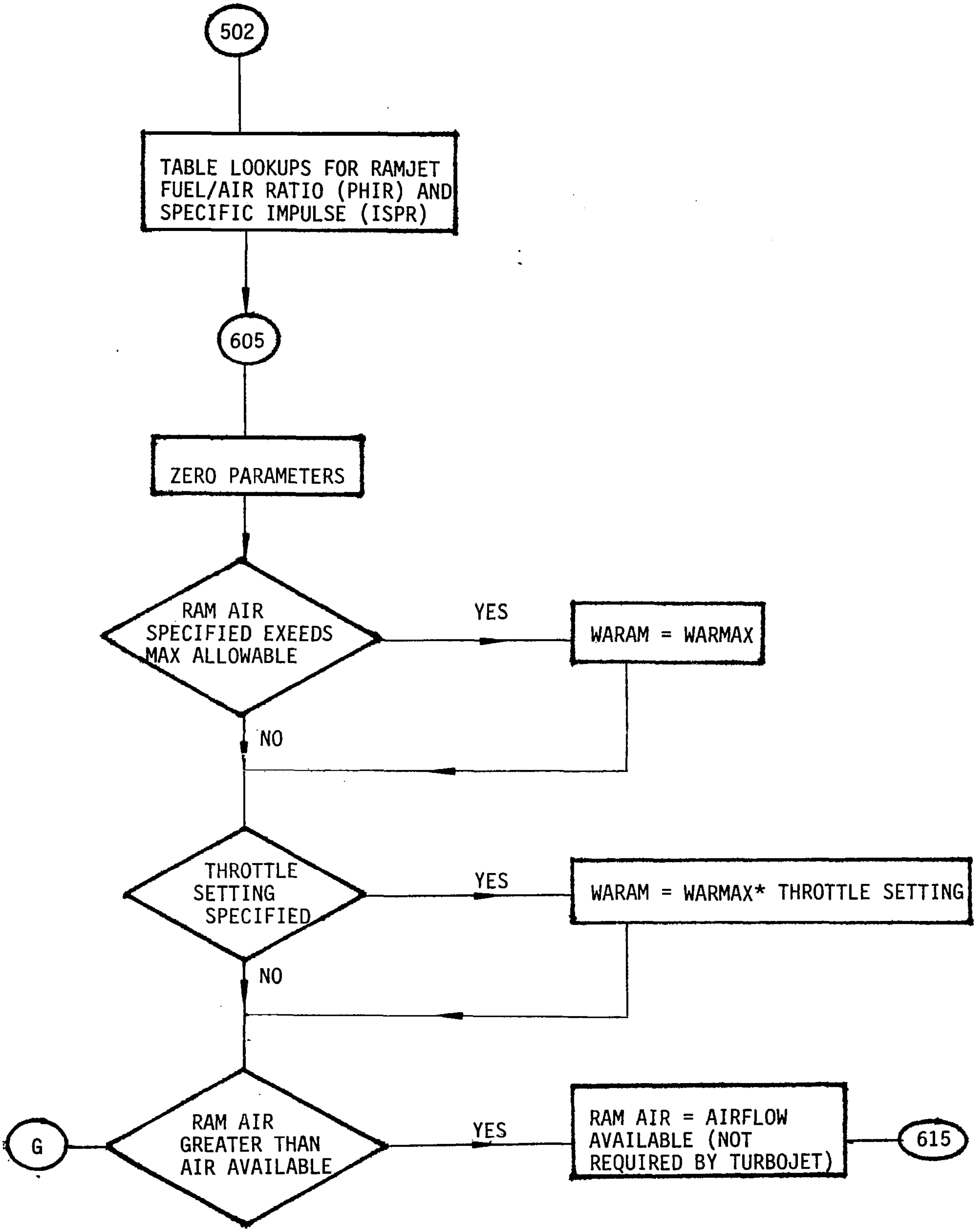

27
COMPUTE TURBOJET STREAM TUBE AREA (ATJ) AT STATION 1
COMPUTE TURBOJET RAM DRAG (DRAM)
COMPUTE MAX TURBOJET NET THRUST (FNMAX) AND SFC (SFCMAX)
COMPUTE TOTAL TURBOJET THRUST REQUIRED (FTOTTJ)
THROTTLE SETTING SPECIFIED
YES
COMPUTE FTOTTJ EQUALS TROTTLE SETTING TIMES MAX GROSS THRUST
NO
100
COMPUTE TURBOJET THROTTLE SETTING (TSETTJ)
E

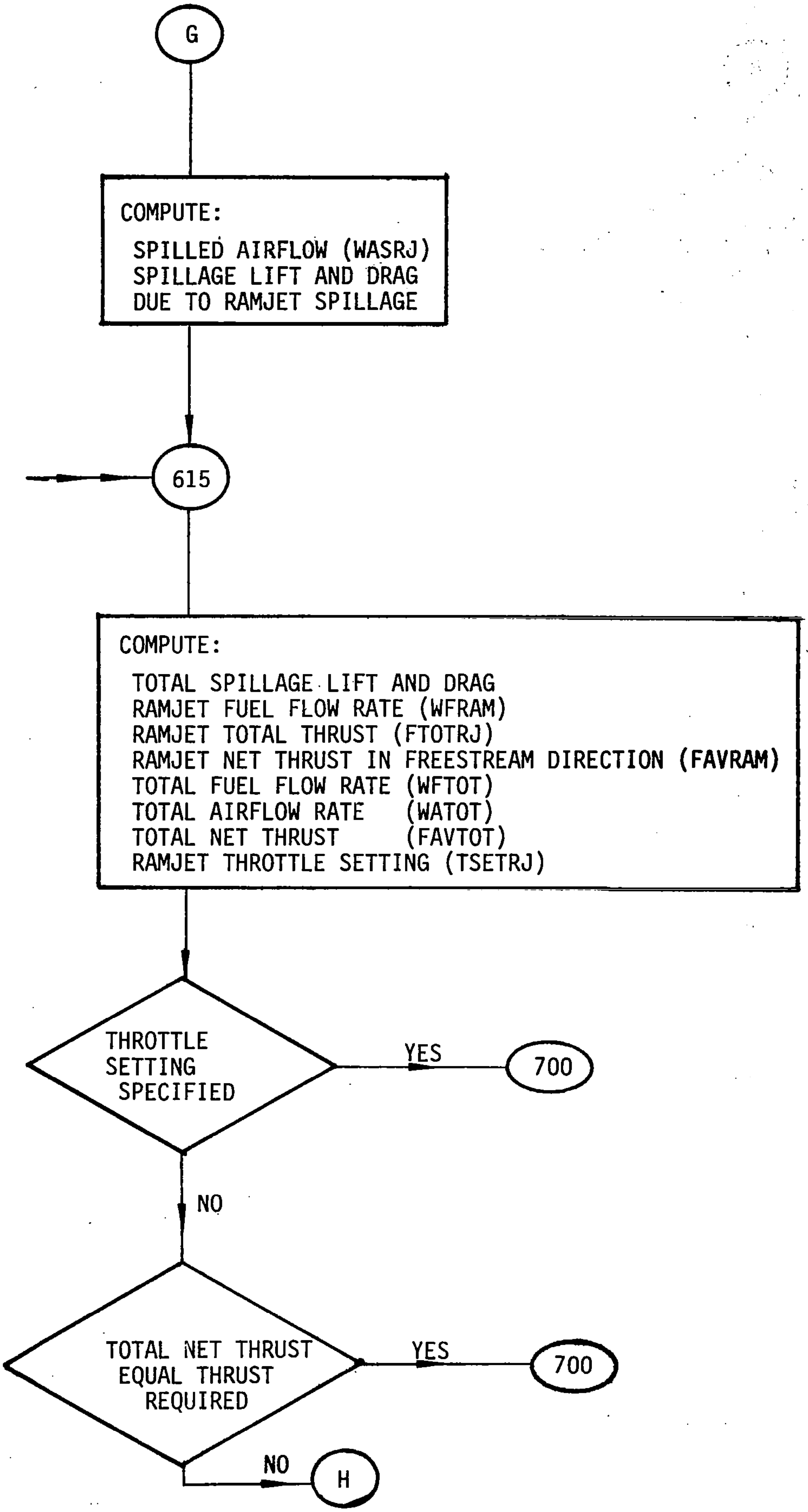

E
MAX THRUST REQUESTED
YES
TSETTJ = 1.01
NO
TSETC = TSETTJ
INDTHR = 1
TSETTJ = 1.0
FTOTTJ = FGMAX
COMBINED ENGINE OPTION OR MAX THRUST REQUESTED
NO
WRITE: THRUST REQUIRED EXCEEDS THRUST AVAILABLE
YES
30
COMPUTE MIN AND MAX NET THRUST (FNZ AND FNI) FOR LOOP WHICH ITERATES TO COMPUTE PROPER RAM DRAG FOR TURBOJET AIRFLOW REQUIRED
31
ITERATION LOOP WHICH MATCHES RAM DRAG AIRFLOW RATE (WATJR) TO TURBOJET AIRFLOW RATE USING NET THRUST AS THE INDEPENDENT VARIABLE
34

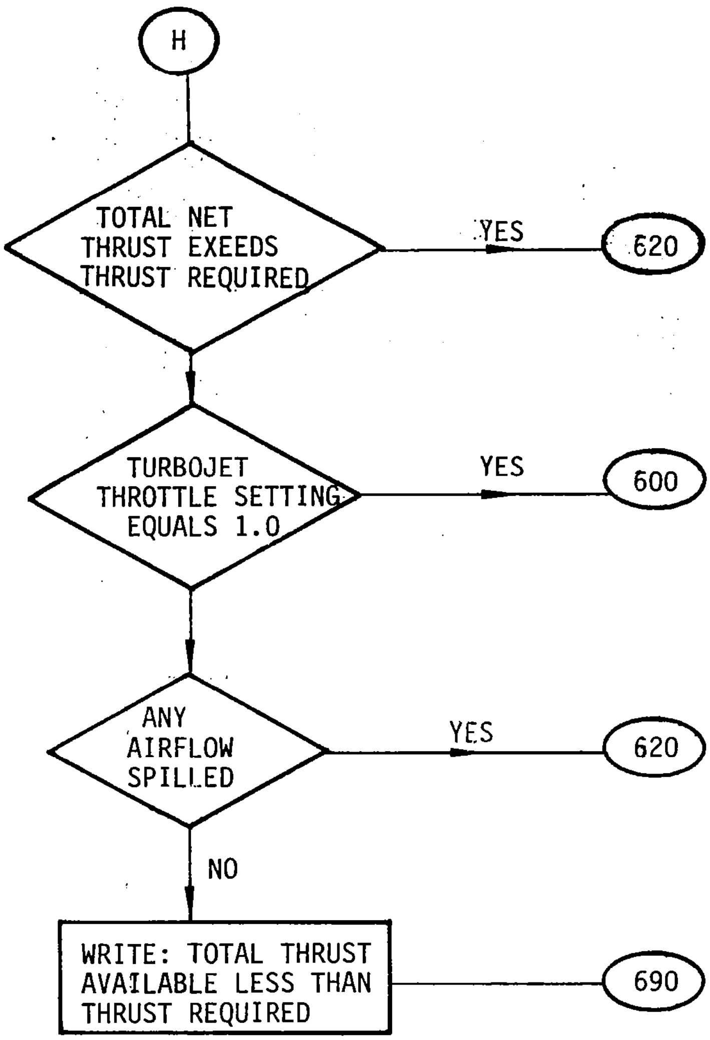

34
END OF RAM DRAG ITERATION
COMPUTE:
RAM DRAG (DRAM)
AIRFLOW SPILLED BY TURBOJET (WASPIL)
SPILLAGE DRAG (DSPILL)
SPILLAGE LIFT (LSPILL)
INCLUDE INLET SPILLAGE FORCES
NET TURBOJET THRUST (FAVTJ)
THROTTLE SETTING SPECIFIED
YES
500
NO
NET THRUST EQUAL THRUST REQUIRED
YES
700
NO
NET THRUST EXCEEDS THRUST REQUIRED
YES
53
NO
F

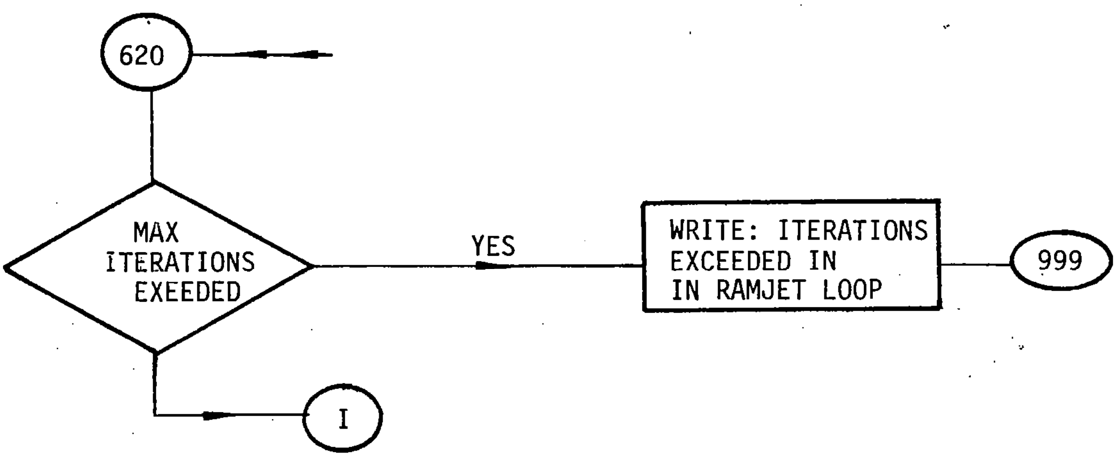

F
TURBOJET AT MAX THRUST AND COMBINATION ENGINE SPECIFIED
YES
500
NO
TURBOJET AT MAX THRUST
YES
690
NO
53
MAX ITERATIONS EXEEDED
YES
WRITE: MAX ITERATIONS EXEEDED IN TURBOJET LOOP
999
NO
AFTER TURBOJET THRUST LEVEL USING NEWTONS METHOD
100

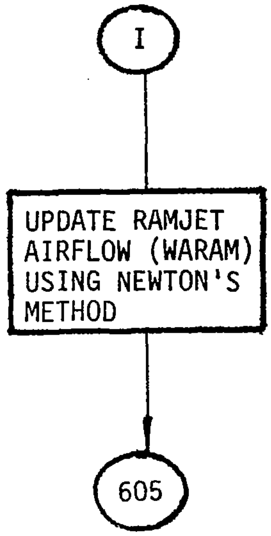

500
RAMJET OPTION REQUESTED
NO
700
YES
COMPUTE TURBOJET NET THRUST IN FREESTREAM DIRECTION (FAVTJ)
INLET AREA LESS THAN 0.1 SQ FT
YES
INLET AREA EQUALS FIVE SQ FT
NO
SPILLED AIRFLOW LESS THAN .001 LB/SEC
YES
600
NO
COMPUTE MAX AIRFLOW CAPACITY OF RAMJET (WARMAX)
502
WARMAX LESS THAN 1 LB/SEC
YES
WRITE: OUT OF RAMJET OPERATING LIMITS
999

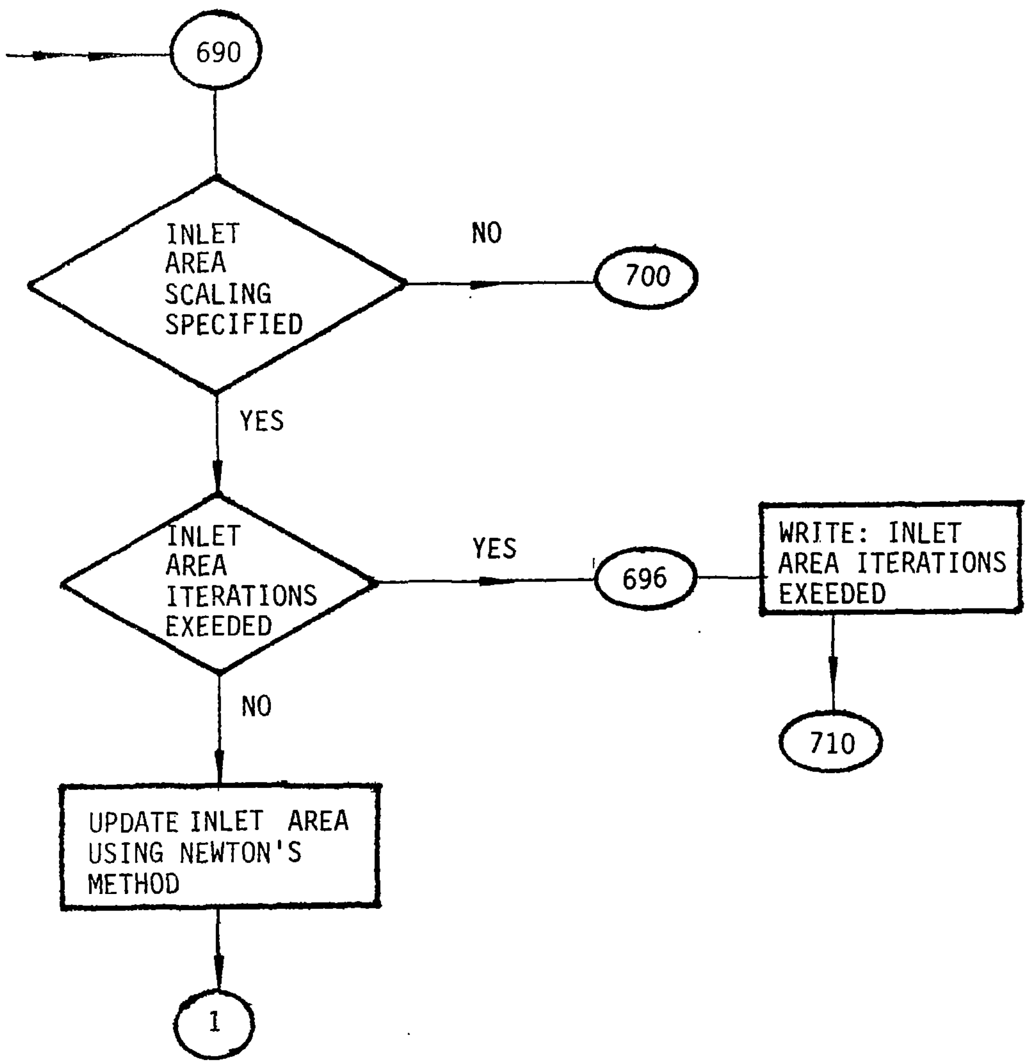

502
TABLE LOOKUPS FOR RAMJET FUEL/AIR RATIO (PHIR) AND SPECIFIC IMPULSE (ISPR)
605
ZERO PARAMETERS
RAM AIR SPECIFIED EXEEDS MAX ALLOWABLE
YES
WARAM = WARMAX
NO
THROTTLE SETTING SPECIFIED
YES
WARAM = WARMAX* THROTTLE SETTING
NO
G
RAM AIR GREATER THAN AIR AVAILABLE
YES
RAM AIR = AIRFLOW AVAILABLE (NOT REQUIRED BY TURBOJET)
615

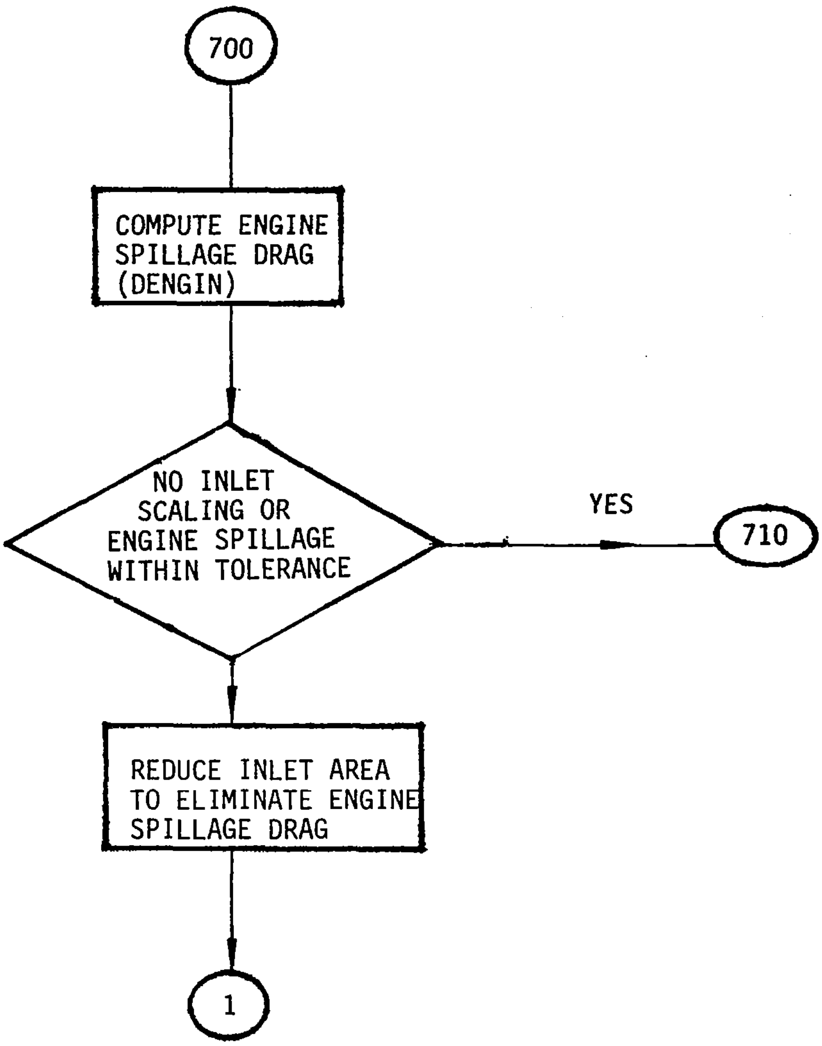

G
COMPUTE:
SPILLED AIRFLOW (WASRJ)
SPILLAGE LIFT AND DRAG
DUE TO RAMJET SPILLAGE
615
COMPUTE:
TOTAL SPILLAGE LIFT AND DRAG
RAMJET FUEL FLOW RATE (WFRAM)
RAMJET TOTAL THRUST (FTOTRJ)
RAMJET NET THRUST IN FREESTREAM DIRECTION (FAVRAM)
TOTAL FUEL FLOW RATE (WFTOT)
TOTAL AIRFLOW RATE (WATOT)
TOTAL NET THRUST (FAVTOT)
RAMJET THROTTLE SETTING (TSETRJ)
THROTTLE SETTING SPECIFIED
YES
700
NO
TOTAL NET THRUST EQUAL THRUST REQUIRED
YES
700
NO
H

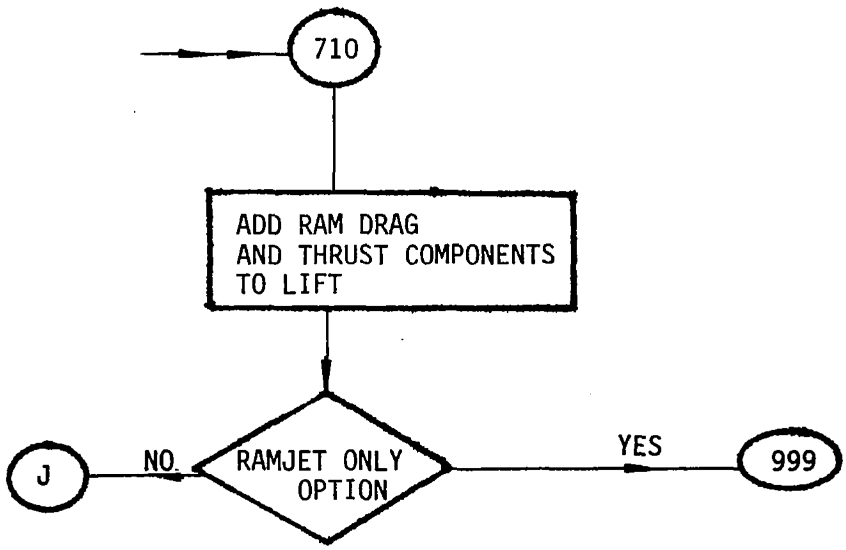

H
TOTAL NET THRUST EXEEDS THRUST REQUIRED
YES
620
TURBOJET THROTTLE SETTING EQUALS 1.0
YES
600
ANY AIRFLOW SPILLED
YES
620
NO
WRITE: TOTAL THRUST AVAILABLE LESS THAN THRUST REQUIRED
690

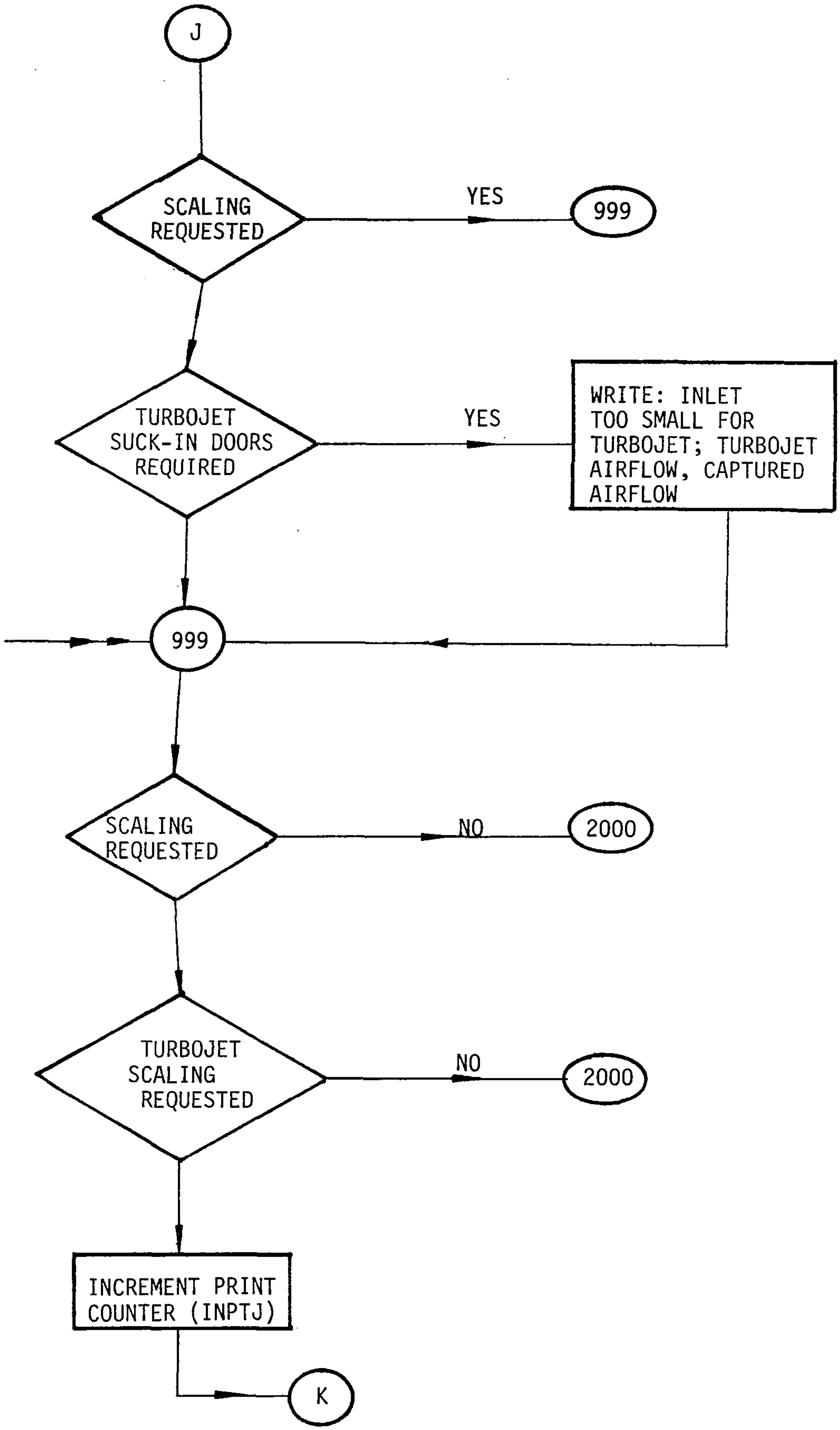

620
MAX ITERATIONS EXEEDED
YES
WRITE: ITERATIONS EXCEEDED IN IN RAMJET LOOP
999
I

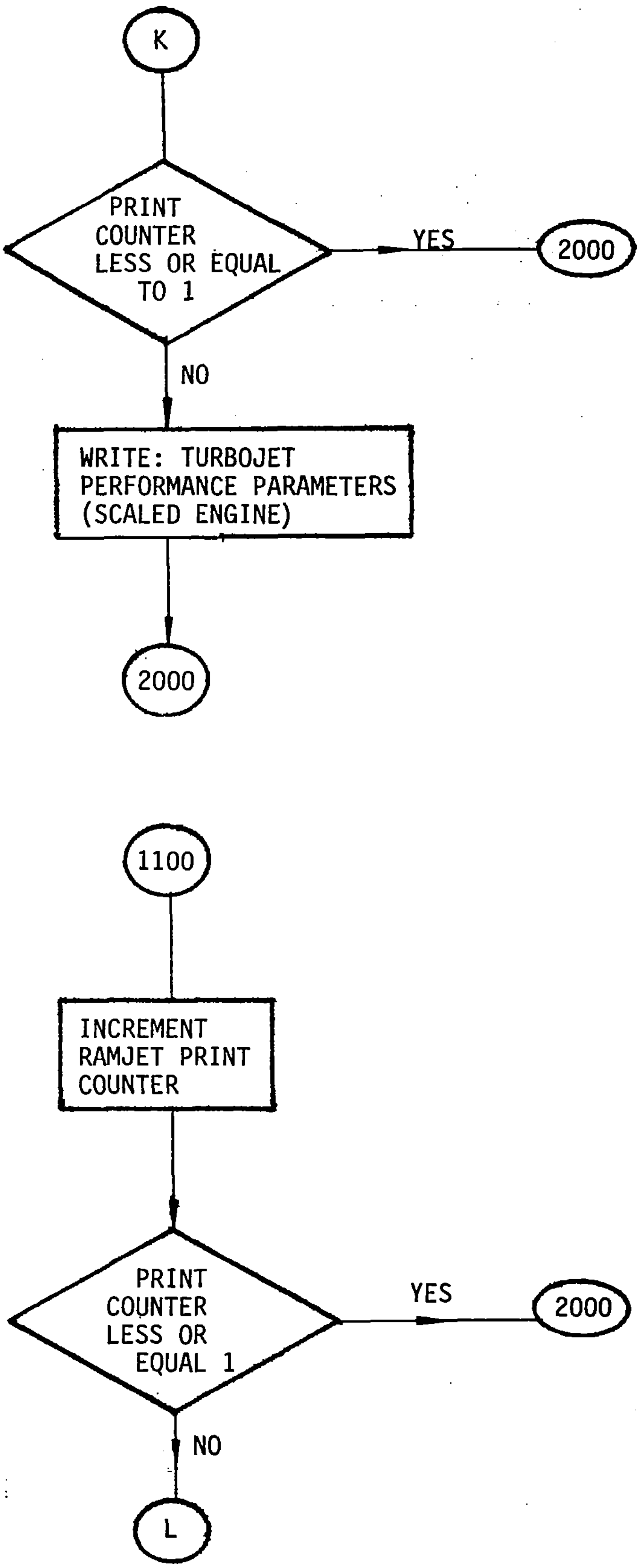

I
UPDATE RAMJET AIRFLOW (WARAM) USING NEWTON'S METHOD
605

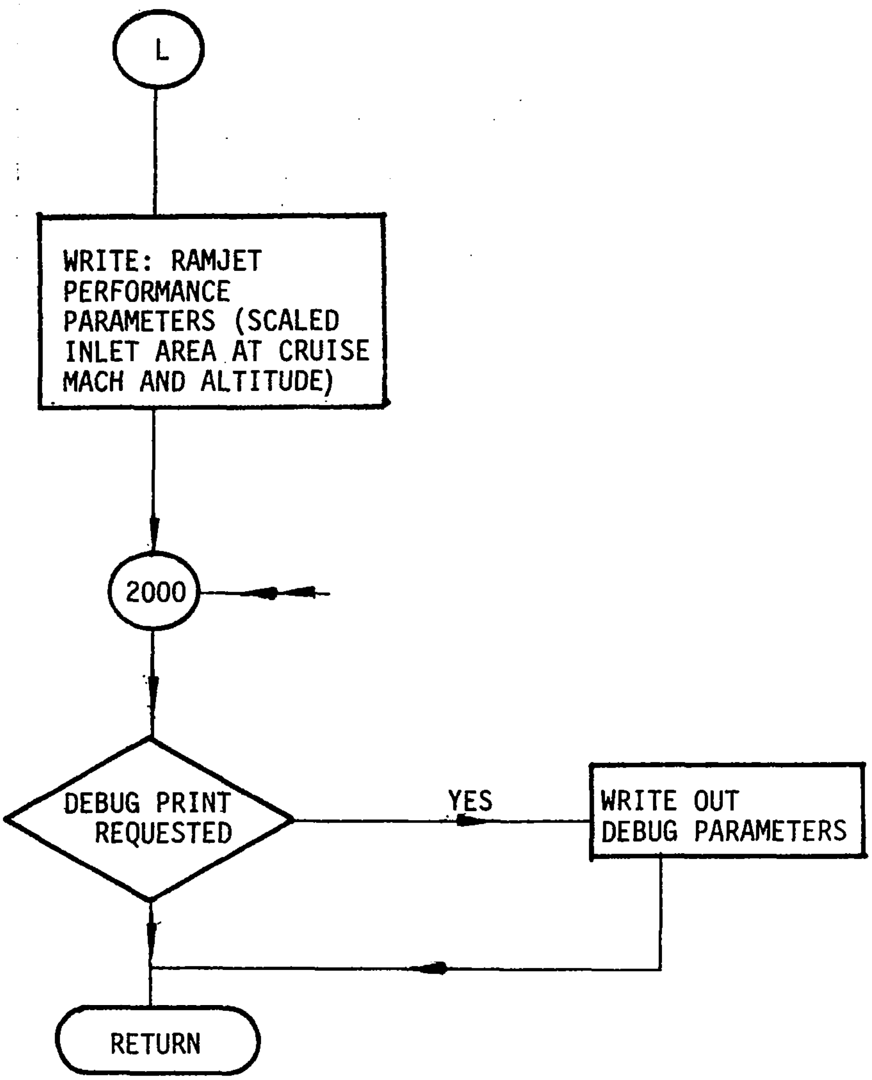

690
INLET AREA SCALING SPECIFIED
NO
700
YES
INLET AREA ITERATIONS EXEEDED
YES
696
WRITE: INLET AREA ITERATIONS EXEEDED
710
NO
UPDATE INLET AREA USING NEWTON'S METHOD
I


700
COMPUTE ENGINE SPILLAGE DRAG (DENGIN)
NO INLET SCALING OR ENGINE SPILLAGE WITHIN TOLERANCE
YES
710
REDUCE INLET AREA TO ELIMINATE ENGINE SPILLAGE DRAG
1


710
ADD RAM DRAG AND THRUST COMPONENTS TO LIFT
RAMJET ONLY OPTION
NO
J
YES
999


J
SCALING REQUESTED
YES
999
TURBOJET SUCK-IN DOORS REQUIRED
YES
WRITE: INLET TOO SMALL FOR TURBOJET; TURBOJET AIRFLOW, CAPTURED AIRFLOW
999
SCALING REQUESTED
NO
2000
TURBOJET SCALING REQUESTED
NO
2000
INCREMENT PRINT COUNTER (INPTJ)
K


K
PRINT COUNTER LESS OR EQUAL TO 1
YES
2000
NO
WRITE: TURBOJET PERFORMANCE PARAMETERS (SCALED ENGINE)
2000
1100
INCREMENT RAMJET PRINT COUNTER
PRINT COUNTER LESS OR EQUAL 1
YES
2000
NO
L



L
WRITE: RAMJET PERFORMANCE PARAMETERS (SCALED INLET AREA AT CRUISE MACH AND ALTITUDE)
2000
DEBUG PRINT REQUESTED
YES
WRITE OUT DEBUG PARAMETERS
RETURN

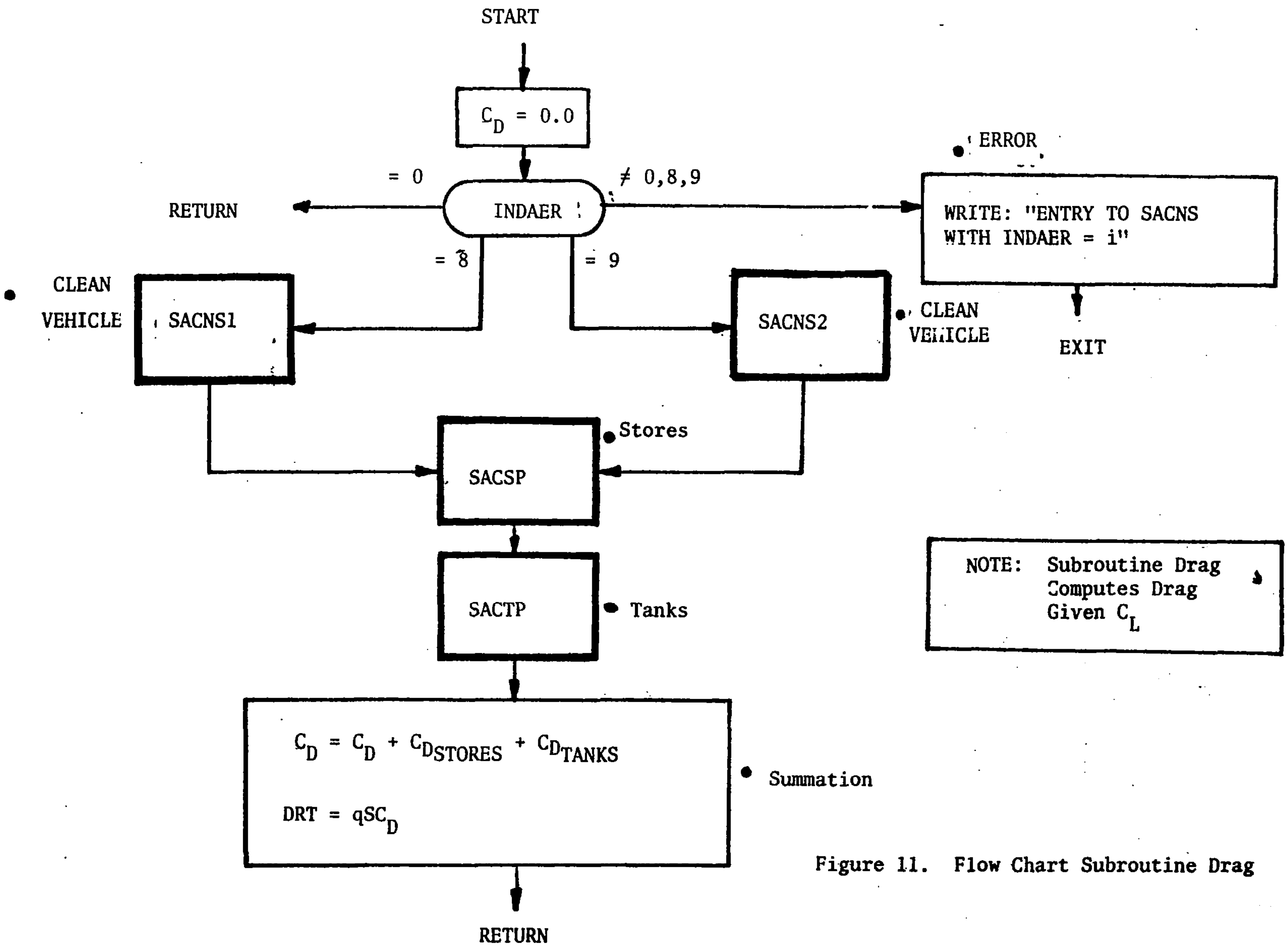


Figure 11. Flow Chart Subroutine Drag

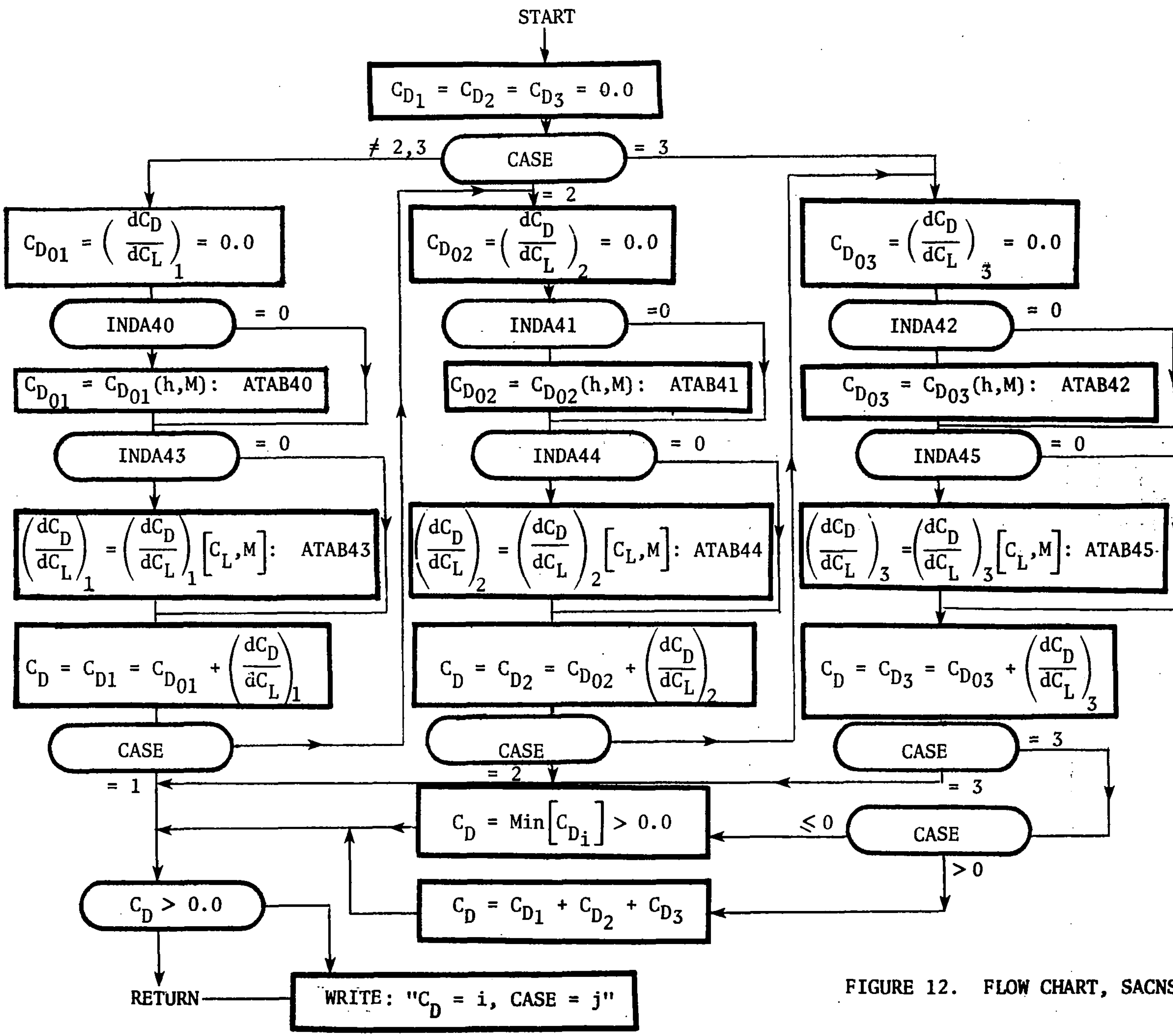


FIGURE 12. FLOW CHART, SACNS1

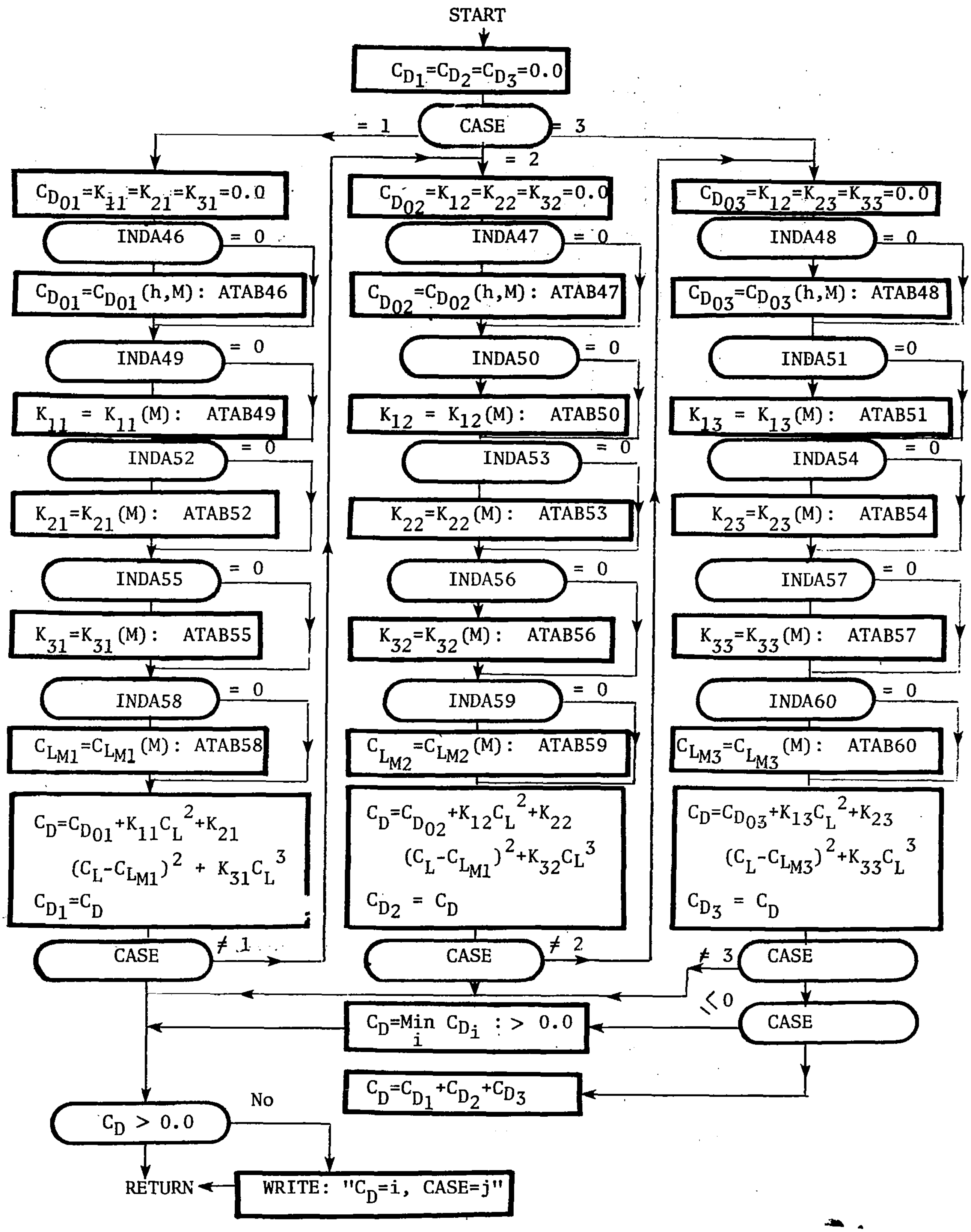


FIGURE 13. FLOW CHART, SUBROUTINE SACSN2

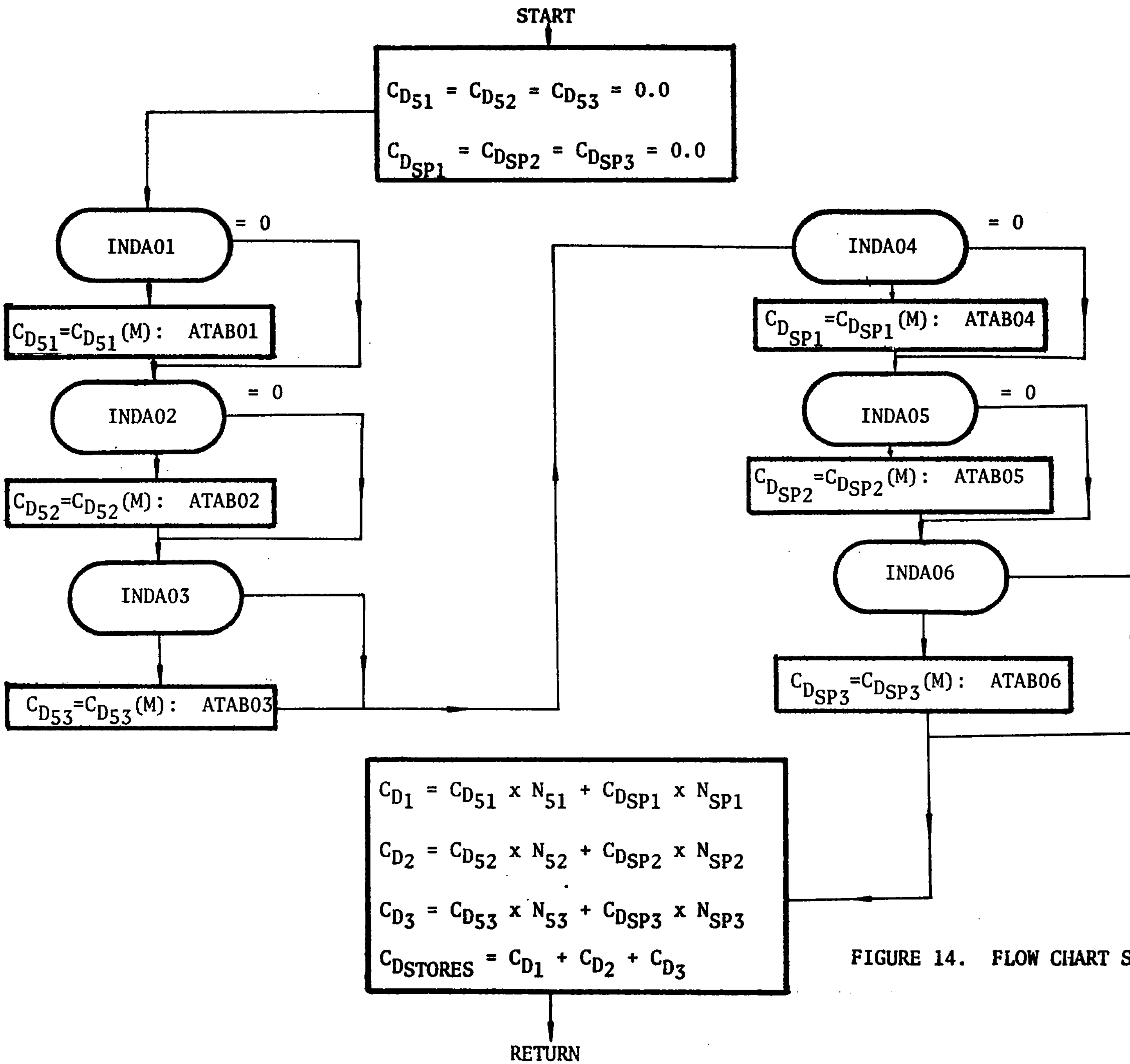


FIGURE 14. FLOW CHART SACSP

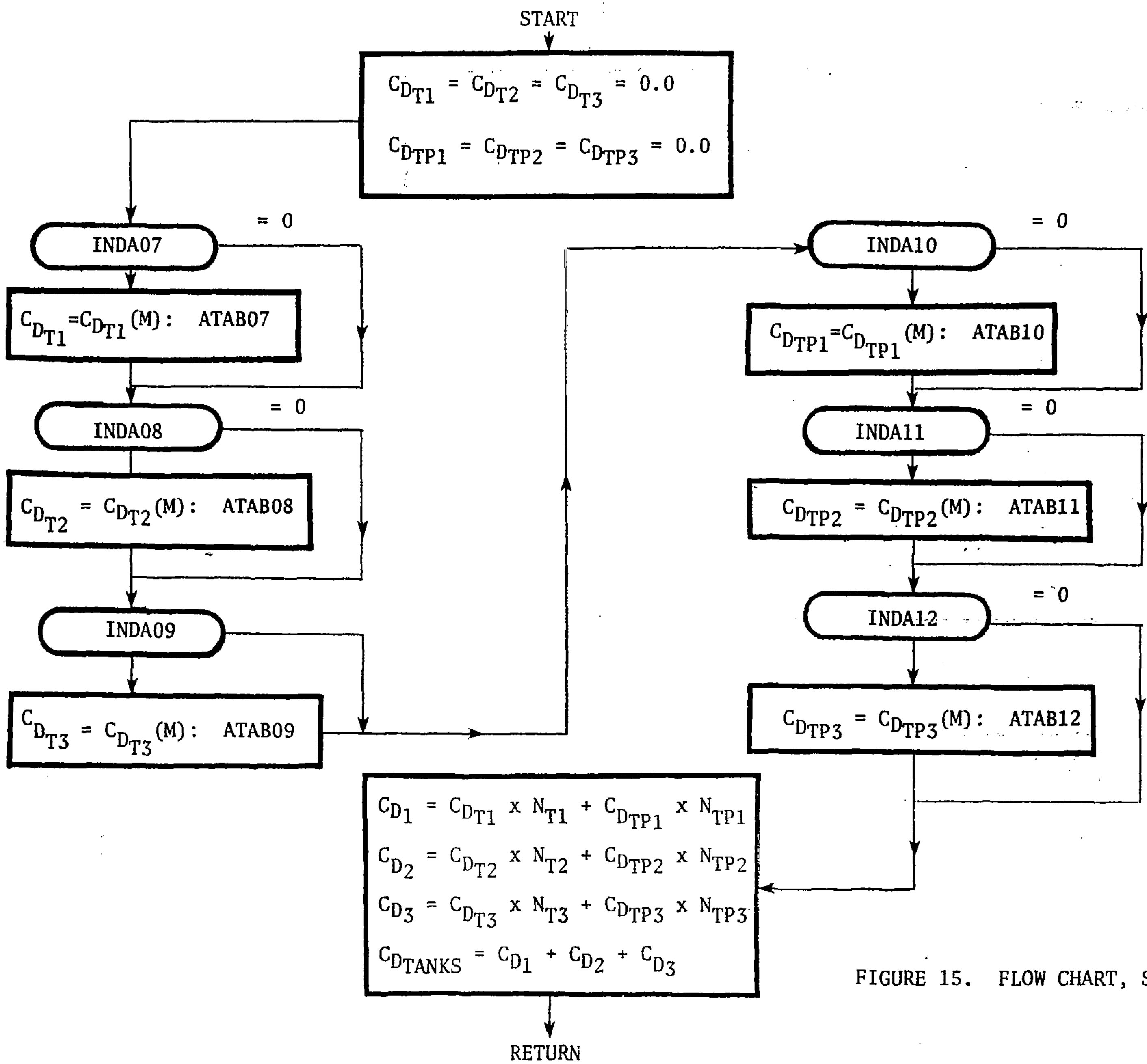


FIGURE 15. FLOW CHART, SACTP

SEARCH FOR MACH ALTITUDE POINT USING	BASIS FOR SELECTION OF MACH ALTITUDE POINT				
	MAX $\dot{E}$	MAX $\dot{E}/\dot{M}$	MAX ℓ/D	MAX Range Factor	MAX $\ell/(FN-DRT)$
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

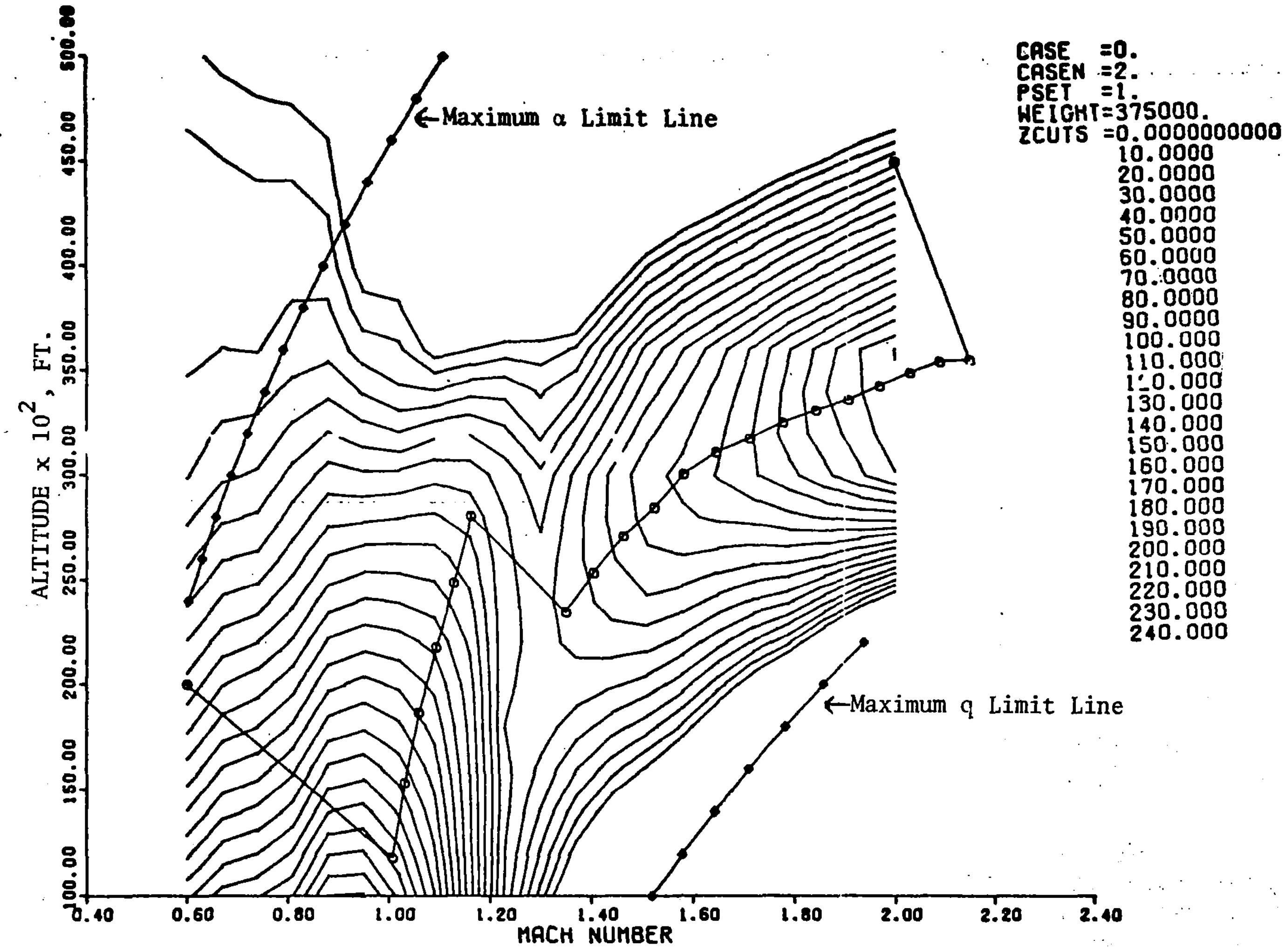


FIGURE 17. EDOT MAP

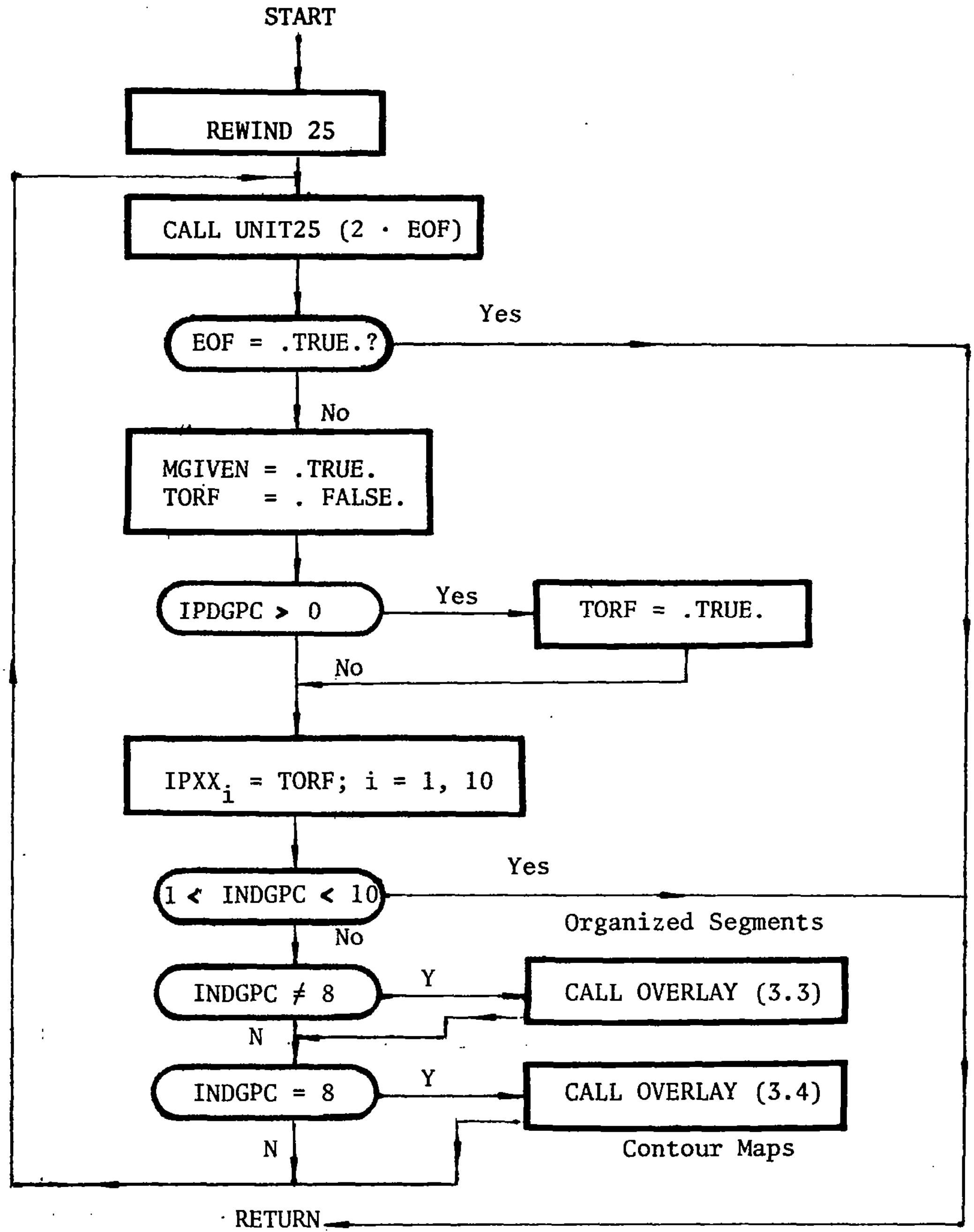


FIGURE 18. FLOW CHART FLITEN

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