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EXPERIMENTAL AND ANALYTICAL DETERMINATION OF INTEGRATED AIRFRAME NOZZLE PERFORMANCE

Operating Manual for Twin-Nozzle/Aftbody Drag and Internal Nozzle Performance Computer Deck

E. R. GLASGOW, D. M. SANTMAN, AND L. D. MILLER, et al

LOCKHEED-CALIFORNIA COMPANY

TECHNICAL REPORT AFFDL-TR-72-101 – VOL II

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AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

EXPERIMENTAL AND ANALYTICAL DETERMINATION OF INTEGRATED AIRFRAME NOZZLE PERFORMANCE

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FOREWORD

The computer program described herein was developed by the Lockheed-California Company (Calac), Burbank, California, under Contract No. F33657-70-C-0511 of Project No. 668A. The contract was administered by the Air Force Flight Dynamics Laboratory (AFFDL), Wright-Patterson Air Force Base, Ohio, with P.C. Everling (FXM) and J.A. Laughrey (FXM) as Project Engineers. Subcontract support was provided by Pratt and Whitney Aircraft (P&WA), East Hartford, Connecticut.

This is the second of a two-volume final report to be submitted under the contract which was conducted during the period from 1 November 1969 to 31 July 1972. The report describes the operation of the end item computer program developed for predicting twin-nozzle/aftbody drag and internal nozzle performance. In addition to the three principal authors, R.A. Fox and R.D. Grennan of Calac made significant contributions toward preparation of the report manuscript. The authors are indebted to the following Calac personnel for their assistance in developing the computer program: E.L. Bragdon and M.H. Scott, Jr., of Propulsion; R.F. Smith of Aerodynamics; and T.J. Jones, B.A. Schwartz, and D.A. Tappeiner of Computer Services.

This report was submitted by the authors for AFFDL approval on 31 July 1972. A Calac report number, LR 25370, has been assigned to identify the report prior to approval.

This technical report has been reviewed and is approved.

Alfred C. Draper

PHILIP P. ANTONATOS
Chief, Flight Mechanics Division
Air Force Flight Dynamics Laboratory

ABSTRACT

A computer program has been developed for predicting twin-nozzle/aftbody drag and internal nozzle performance for fighter type aircraft having twin buried engines and dual nozzles. The program is capable of generating the installed thrust-minus-drag data required for conducting mission analysis studies of aircraft of this type. The configuration variables which can be analyzed include (1) nozzle type (convergent flap and iris, convergent-divergent with and without secondary flow, and shrouded and unshrouded plug), (2) nozzle lateral spacing, (3) interfairing type (horizontal and vertical wedge), (4) interfairing length, and (5) vertical stabilizer type (single and twin).

The performance prediction methods incorporated in the program are based almost entirely on empirical correlations. Specifically, correlations used in conjunction with one-dimensional flow relationships are employed for the prediction of the nozzle thrust and discharge coefficients, and correlations of the test data obtained during the contracted effort are employed for prediction of the aft-end drag. The prediction methods account for the effects of nozzle pressure ratio and flow separation on both internal and external nozzle surfaces.

This manual describes the operation of the computer program in terms of program input requirements, performance prediction methods, and output format and includes a presentation of sample input/output cases and a complete computer listing of the program. The program has been developed for use on the CDC 6600 computer.

VOLUME II

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LIST OF SYMBOLS

A_e	Physical nozzle exit area
$A_{e_{flow}}$	Flow area at nozzle exit
$A_{e_{sep}}$	Flow area at separation point
A_F	Frontal area
A_M	Maximum cross-sectional area
A_{MB}	Metric break cross-sectional area
A_S	Shroud area (jet plus base areas)
A_T^*	Flow area for sonic flow
A_W	Wetted surface area
$C_{D_{A_s}}$	Boattail pressure drag coefficient based on boattail cross - sectional area at nozzle exit station.
C_{d_N}	Nozzle discharge coefficient
$C_{d_{N_{max}}}$	Maximum nozzle discharge coefficient
$\hat{C}_{D_{PT}}$	Boattail pressure drag coefficient based on shroud cross - sectional area at nozzle exit station.
$C_{D_{PT}}$	Boattail pressure drag coefficient based on maximum boattail cross - sectional area
C_f	Skin friction coefficient

LIST OF SYMBOLS (CONTINUED)

C_S	Stream thrust correction factor
C_T	Thrust coefficient
D	Drag
F_{id}	Ideal gross thrust based on isentropic expansion of actual flow to freestream pressure
IMS	Integral Mean slope
K	Drag due to lift factor
L_{BT}	Boattail length
L_{eff}	Effective flat plate length
m	Mass flow rate
M_e	Exit Mach number
M_{sep}	Mach number upstream of separation point
M_T	Throat Mach number
P	Static pressure
P_b	Base pressure
P_{sep}	Static pressure upstream of separation point
P_{T_e}	Total pressure at nozzle exit
P_{T_T}	Total pressure at nozzle throat
$(P_{T_T}/P_\infty)_{CK}$	Choking pressure ratio
$(P_{T_T}/P_\infty)_{CR}$	Critical pressure ratio
$(P_{T_T}/P_\infty)_F$	Pressure ratio at which the nozzle flows full

LIST OF SYMBOLS (CONTINUED)

$(P_{T_T}/P_\infty)_L$	Pressure ratio where linear C_T extrapolation ends
q	Dynamic pressure
R_c	Lip radius of curvature
R_{e_θ}	Momentum thickness Reynolds number
R'_e	Reference Reynolds number
R_{mf}	Momentum ratio
R	Radius
T_{aw}	Adiabatic wall temperature
μ	Viscosity
α	Nozzle upstream approach angle
θ	Internal divergence angle
γ	Ratio of specific heat values

SUBSCRIPTS

b	Base
C-D	Convergent-Divergent
CONV	Convergent
e	Exit
EB	Equivalent body
L	Local
P	Primary flow
S	Secondary flow
T	Throat

NOZZLE SYMBOLS

CD	Convergent - divergent
CDE	Convergent - divergent ejector
CF	Convergent flap
CI	Convergent iris
SP	Shrouded plug
UP	Unshrouded plug

SECTION 1

INTRODUCTION

This manual presents a detailed description of the Twin-Nozzle/Aftbody Drag and Internal Nozzle Performance Computer Program. This program was developed under Contract F33657-70-C-0511, Program for Experimental and Analytical Determination of Integrated Airframe-Nozzle Performance.

The purpose of this manual is to describe in detail the capabilities and limitations of the program, the numerical methods used, and the operational procedures required to run the program. The computational procedures are presented both in the form of detailed descriptions and flow charts summarizing the methods. The input instructions consist of a description of each input required and how the input is to be implemented. The output section consists of a description of the output format and an explanation of error messages that are included. Finally, a description of the operational setup needed for program execution is provided including control cards, deck assembly instructions, and necessary external routines.

The capabilities and restrictions of the program including a flow-chart are presented in Section 2. The computational methods used to predict aft-end drag and internal nozzle performance are discussed in Section 3; and the operating instructions, consisting of user and programmer inputs and the output summary, are included in Section 4. Sample cases including examples of input coding sheets and a complete listing of the program are provided in appendixes.

SECTION 2

COMPUTER PROGRAM CAPABILITIES

2.1 GENERAL DESCRIPTION OF PROGRAM

The program consists of a main control routine, three nozzle internal performance subroutines, and an aft-end drag subroutine. The prediction methods incorporated in these subroutines are based almost entirely on empirical correlations. Specifically, correlations developed by P&WA (Reference 41) are employed for prediction of nozzle thrust and dishcarge coefficients, and correlations of Phase II test data are employed for prediction of twin-nozzle/aftbody drag. The predicted aft-end drags for a subsonic external flow must be used with caution if the user employs the aftbody maximum area station as the reference station for drag accounting since the aftbody metric break station of the Phase II model lies downstream of the maximum area station. Using the maximum area station as a reference station requires in some cases a procedure for obtaining the drag acting on the body between the maximum area and metric break stations. This drag increment is very small for subsonic external flow and may be neglected. For supersonic external flow, a procedure for obtaining this drag increment was developed and incorporated in the aft-end drag routine to predict the boattail drag aft of the maximum area station. The components of the aft-end drag include boattail pressure and friction drags and annular base drag.

Since the empirical correlations are based on Phase II data and little data was obtained in the 0.9 to 1.2 Mach number range, the predicted aft-end drags for this Mach regime should also be used with caution.

The program will analyze the following five types of nozzles: convergent, convergent-divergent, convergent-divergent ejector, unshrouded plug, and shrouded plug. The nozzle routines yield values of thrust and discharge coefficients, as well as pumping characteristics for ejector nozzles.

There are basically two types of input to the program: fixed and variable. The fixed inputs are constant for a given series of cases and consist of geometrical inputs such as nozzle type and maximum area. The variable inputs may change from case to case and consist of geometrical inputs, such as nozzle area ratio, and operating conditions such as freestream Mach number and nozzle pressure ratio. For most of the variable inputs, the user has the option of using direct input values or having the program read a curve.

2.2 COMPUTER PROGRAM LOGIC

The overall logic of the program is illustrated by the flow charts shown in Figure 1. The program consists of a main control routine, three internal

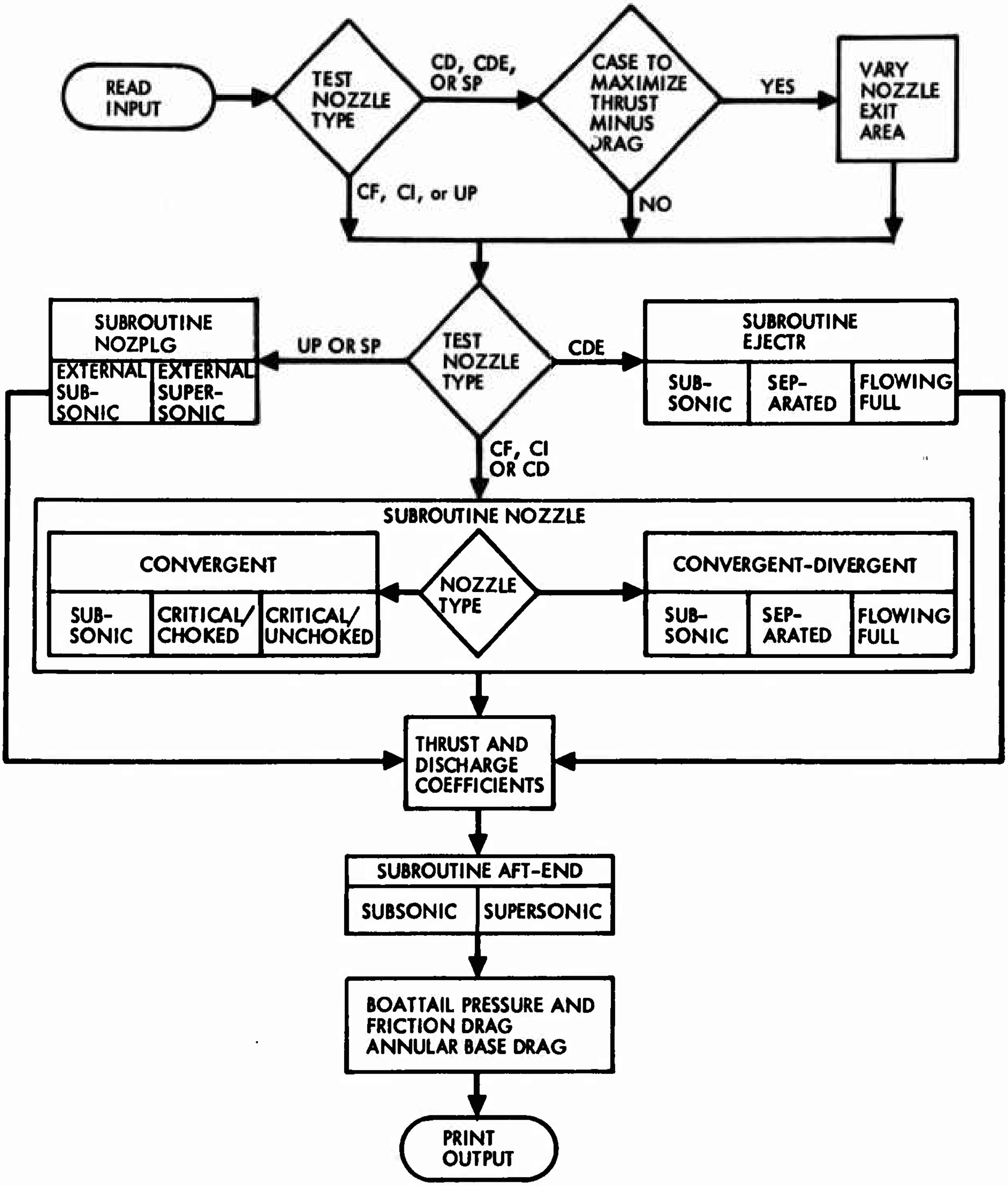

Figure 1. Overall Program Logic Diagram

performance subroutines, and an aft-end drag subroutine. Upon reading and processing of the input the appropriate internal flow routine is selected based on the nozzle type. Convergent and convergent-divergent nozzle cases are analyzed using subroutine NOZZLE, convergent-divergent ejector cases use subroutine EJECTR, and plug nozzle cases use subroutine NOZPLG. When running convergent-divergent, convergent-divergent ejector and shrouded plug nozzles, the user has the option of varying the nozzle internal expansion ratio between two input limiting values in order to obtain the maximum thrust-minus-drag for a given throat area. In all cases, the user has the option of providing either the physical throat area or the flow area at the throat. The area which is not specified as the input is obtained from the other area and the nozzle discharge coefficient.

The nozzle performance subroutines can analyze various internal flow regimes depending on the nozzle type. For convergent nozzles, separate prediction methods are employed when the throat flow is subsonic, the throat flow is critical but not choked (nozzle pressure ratio where the discharge coefficient is invariant with nozzle pressure ratio), and the flow is critical and choked. For convergent-divergent and convergent-divergent ejector nozzles, separate prediction methods are employed when the flow is subsonic throughout the nozzle, the flow is critical with separation occuring in the divergent section, and the flow is critical with no internal flow separation. Thrust and discharge coefficients for these nozzles are computed using one-dimensional flow relationships combined with empirical correction factors. The one-dimensional compound flow analysis of Bernstein (Reference 45) is employed for predicting ejector pumping characteristics.

The method employed for computing plug nozzle thrust coefficients depends on the freestream Mach number. Specifically, for a subsonic external flow, correlations involving plug pressure forces are employed which, when combined with the gross thrust at the nozzle exit, yield plug nozzle thrust coefficients. For a supersonic freestream Mach number, plug surface pressure forces are computed using an approximate construction of the expansion fan generated by the flow expansion around the cowl lip. The plug base pressure correlation is also employed for the supersonic case. Plug nozzle discharge coefficients are computed using correlations of Phase I test data.

The aft-end drag subroutine calculates the three components of the total aft-end drag of the aircraft: boattail pressure drag, boattail friction drag, and annular base drag. The routine tests the flight speed to determine whether to call the subsonic or supersonic boattail and base drag methods. Three separate correlations are employed for predicting the boattail pressure drag for a subsonic external flow: jet-off drag correlations, correlations of the drag increment from jet-off to the nozzle design pressure ratio, and correlations of the drag increment from the design pressure ratio to operation at a higher pressure ratio. The first two correlations are based on nozzle/aftbody geometry while the last correlation is based on nozzle underexpansion losses. For supersonic external flow, jet-off drag correlations and correlations of the drag increment from jet-off to the operating pressure ratio are employed.

SECTION 3

DISCUSSION OF METHODS

This section describes the methods employed for predicting twin-nozzle/aftbody drag and internal nozzle performance. The external drag methods consist primarily of the empirical correlations whose development is described in Volume I of this report (Reference 89). The nozzle internal performance methods are basically those developed by P&WA which are described in Reference 41.

3.1 TWIN-NOZZLE/AFTBODY DRAG

The computational methods employed for predicting boattail pressure and friction drags and annular base drag are presented in this subsection. All methods are based on empirical correlations of wind tunnel data and, except for the friction drag routine, are different for subsonic and supersonic speeds.

3.1.1 Boattail Pressure Drag

3.1.1.1 Subsonic Flow

This subsection present the methods for predicting the boattail drag aft of the metric break station for Mach numbers less than 1.0. The boattail drag coefficient referenced to the cross-sectional area at the metric break station (A_{MB}) is computed from the following empirical correlation of the Phase II data.

$$C_{D_{PT}} = K_1 \left(\frac{IMS}{M_\infty}\right)^{2/3} \frac{A_F}{A_{MB}} + K_2 \frac{A_S}{A_{MB}} + \frac{K_3 \, F_{id}}{q_\infty A_{MB}} \qquad (1)$$

where

$$K_1 = \hat{C}_{D_{PT}} \left(\frac{M_\infty}{IMS}\right)^{2/3} \qquad (2)$$

$$K2 = \Delta C_{D_{A_S}} \qquad (3)$$

and

$$K_3 = \frac{\Delta D}{F_{id}} \qquad (4)$$

A_F is the projected boattail frontal area, $(A_{MB} - A_S)$, A_S is the shroud area for both nozzles (sum of jet and base areas) and F_{id} is the ideal thrust of the twin jet model obtained by isentropic expansion of the exhaust flow to free-stream pressure. The first term in Equation 1 is the jet-off drag, the second term is the drag increment when going from jet-off to operation at the nozzle design pressure ratio and the third term represents the drag increment when going from design pressure ratio operation to operation at a higher pressure ratio. The design pressure ratio for convergent and convergent-divergent nozzles is defined as that pressure ratio associated with a cylindrical plume (static operation) and with critical throat flow. For unshrouded plug nozzles, the design pressure ratio is set equal to the design pressure ratio of a convergent nozzle.

The jet-off drag coefficient parameter, K_1, is presented in Figures 2 through 4 for the narrow, intermediate, and wide nozzle lateral spacings with horizontal interfairings and a single vertical tail. The drag parameter is obtained from these figures through use of the integral mean slope (IMS) of the equivalent body of revolution and the shroud to metric break area ratio (A_S/A_{MB}). The correlation results shown in Figures 2 through 4 are applicable for all nozzle configurations except the narrow-spaced normal-power convergent-flap configuration. Correlation results for this configuration are presented in Figure 5. Correlation results for narrow spaced configurations with vertical interfairings are presented in Figure 6. Figure 7 presents correlation results for wide spaced configurations with twin vertical tails. A linear interpolation and extrapolation for area ratios other than those presented in the figures is employed.

The drag parameter, K_2, for determining the increment in drag when going from jet-off to jet-on at the nozzle design pressure ratio is presented in Figures 8 through 10 for narrow, intermediate and wide nozzle lateral spacings and for Mach numbers ranging from 0.6 to 0.9. This drag increment is presented in terms of an increment in drag coefficient referenced to the twin nozzle shroud exit area (sum of jet and base areas) and is correlated as a function of boattail trailing edge θ_E, at the nozzle exit. The results shown in the figures are applicable for all configurations.

For convergent and convergent-divergent nozzle installations, the drag parameter, K_3, which is the increment in drag when going from design pressure ratio operation to operation at a higher pressure ratio, is presented in Figures 11 through 13 as a function of the nozzle underexpansion loss. The drag increment, which is normalized by the ideal thrust, is dependent on both the Mach number and shroud exit to metric break area ratio. Figure 14 and 15 present the drag parameter, K_3, for the normal and maximum A/B plug nozzles, respectively. The drag parameter in these figures is presented as a function of a reference convergent nozzle underexpansion loss.

3.1.1.2 Supersonic Flow

This subsection presents the methods for predicting the boattail drag aft of the maximum area (exclusive of wing) station for Mach numbers greater than

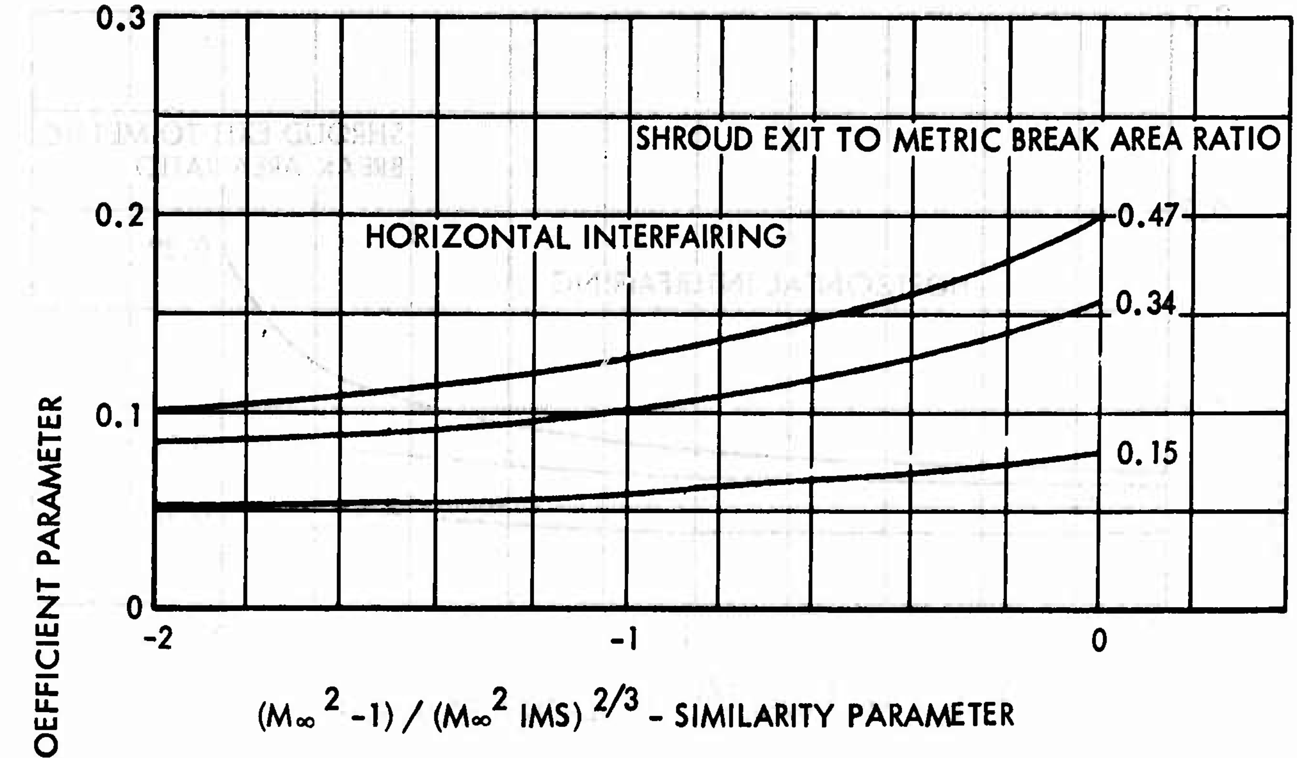

Figure 2. Transonic Similarity Correlation of Jet-Off Total Boattail Drag - Narrow Spacing

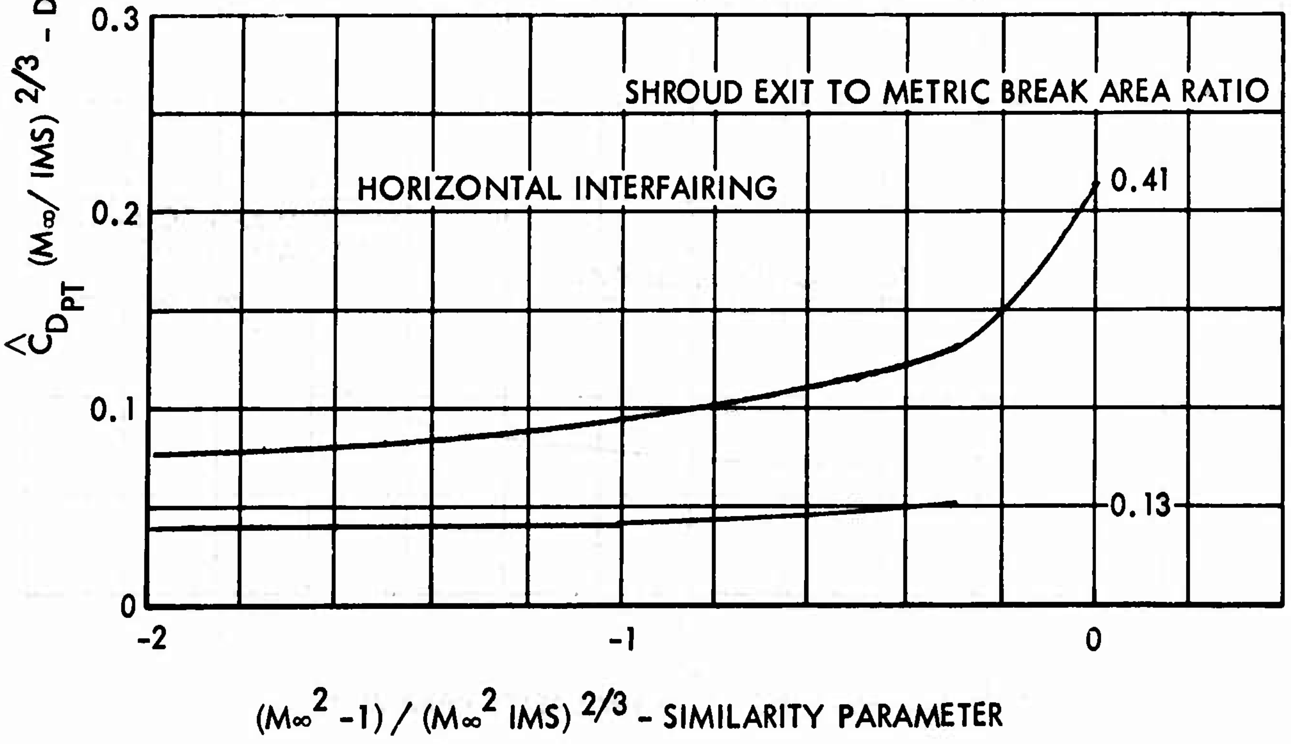

Figure 3. Transonic Similarity Correlation of Jet-Off Total Boattail Drag - Intermediate Spacing

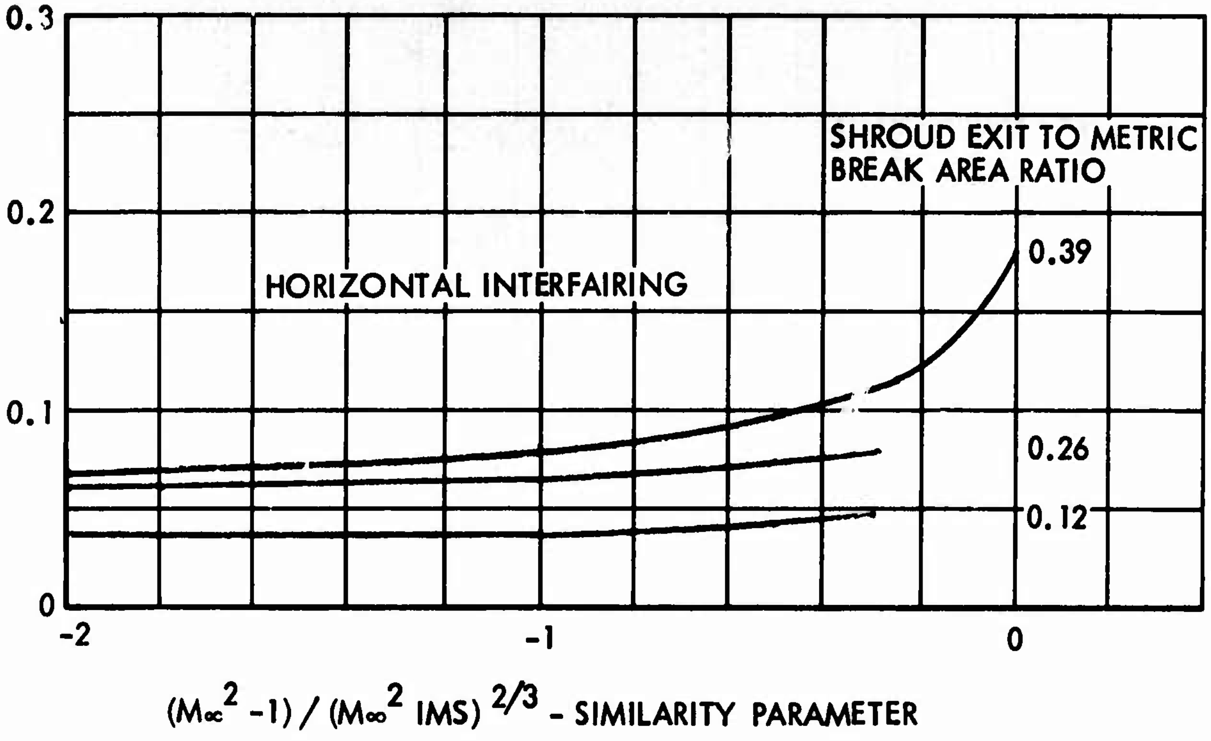

Figure 4. Transonic Similarity Correlation of Jet-Off Total Boattail Drag - Wide Spacing

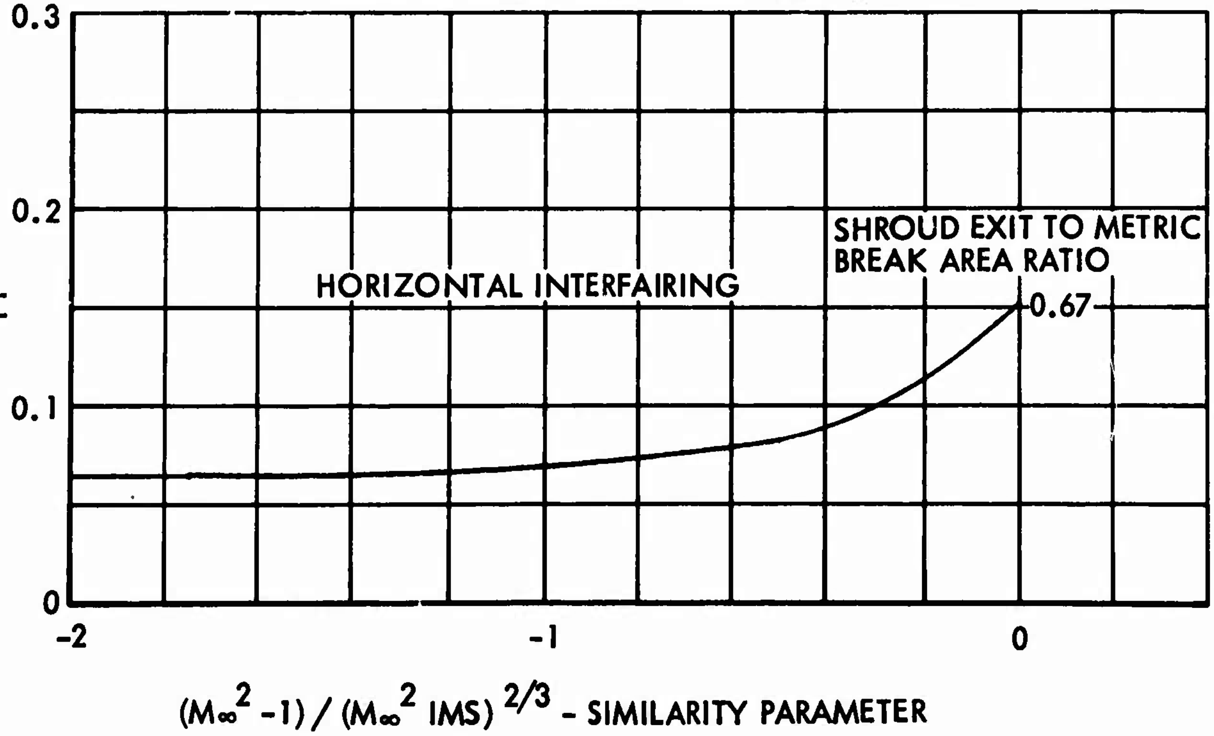

Figure 5. Transonic Similarity Correlation of Jet-Off Total Boattail Drag - Narrow Spacing - Convergent Flap Nozzle

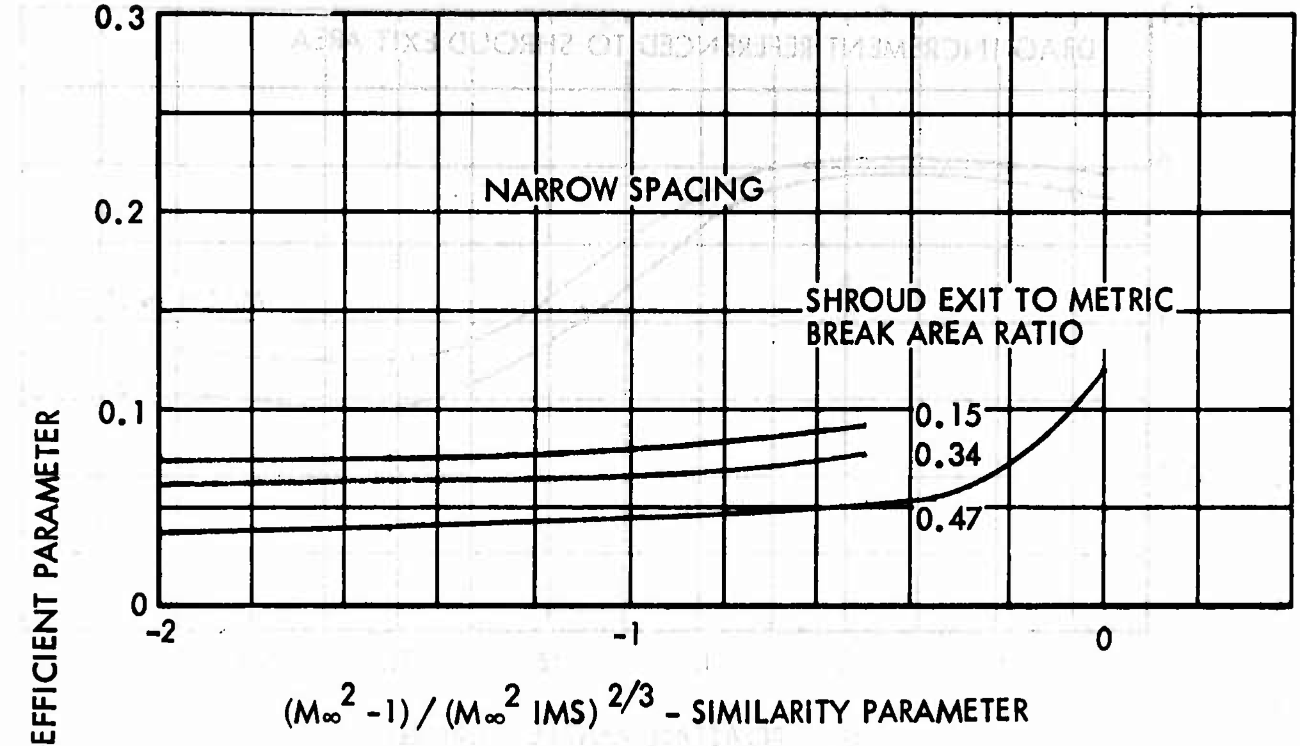

Figure 6. Transonic Similarity Correlation of Jet-Off Total Boattail Drag - Vertical Interfairing

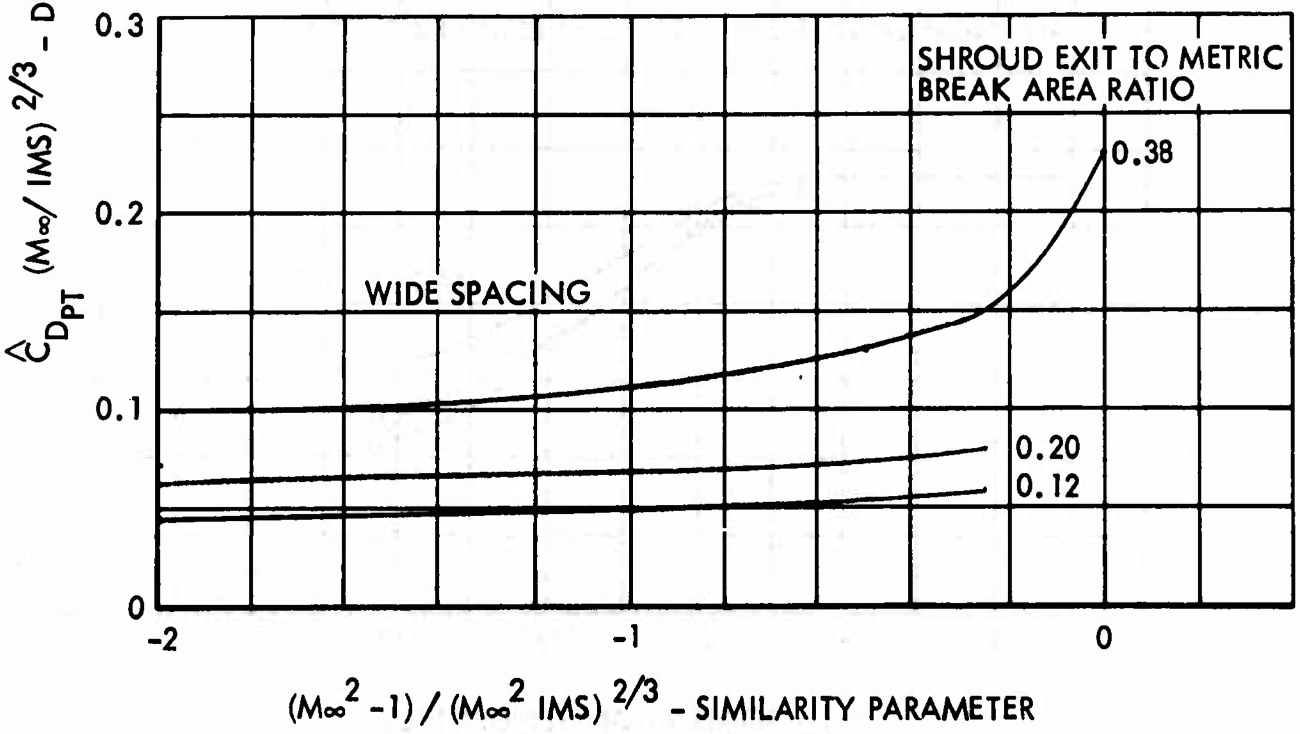

Figure 7. Transonic Similarity Correlation of Jet-Off Total Boattail Drag - Twin Vertical Tails

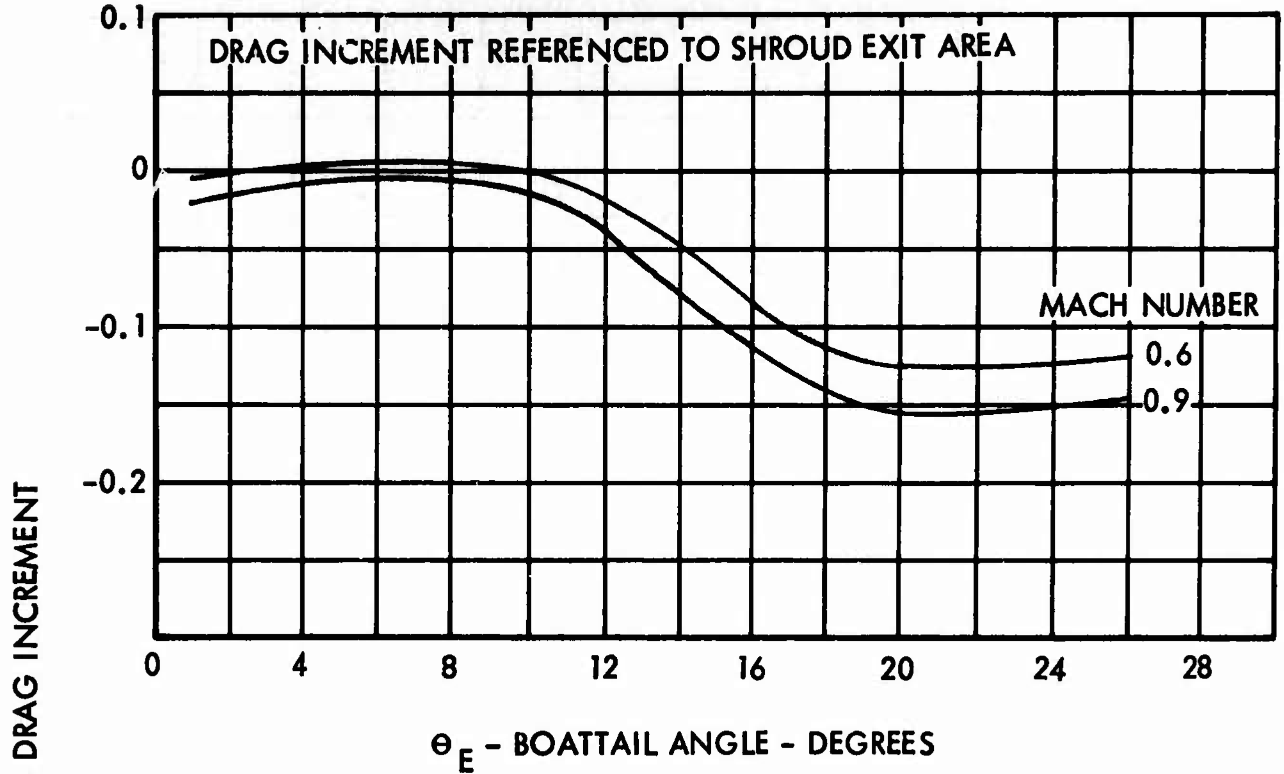

Figure 8. Correlation of Drag Increment From Jet-Off To Design Pressure Ratio - Narrow Spacing

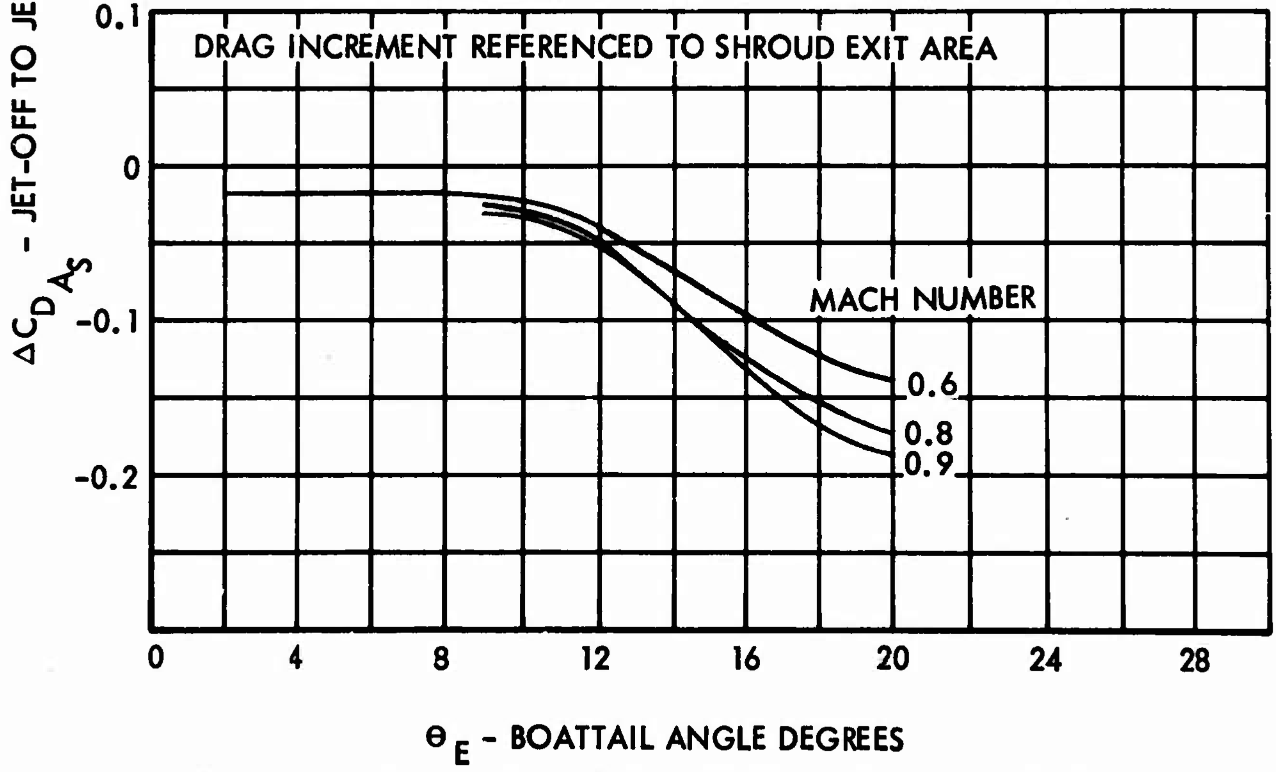

Figure 9. Correlation of Drag Increment From Jet-Off To Design Pressure Ratio - Intermediate Spacing

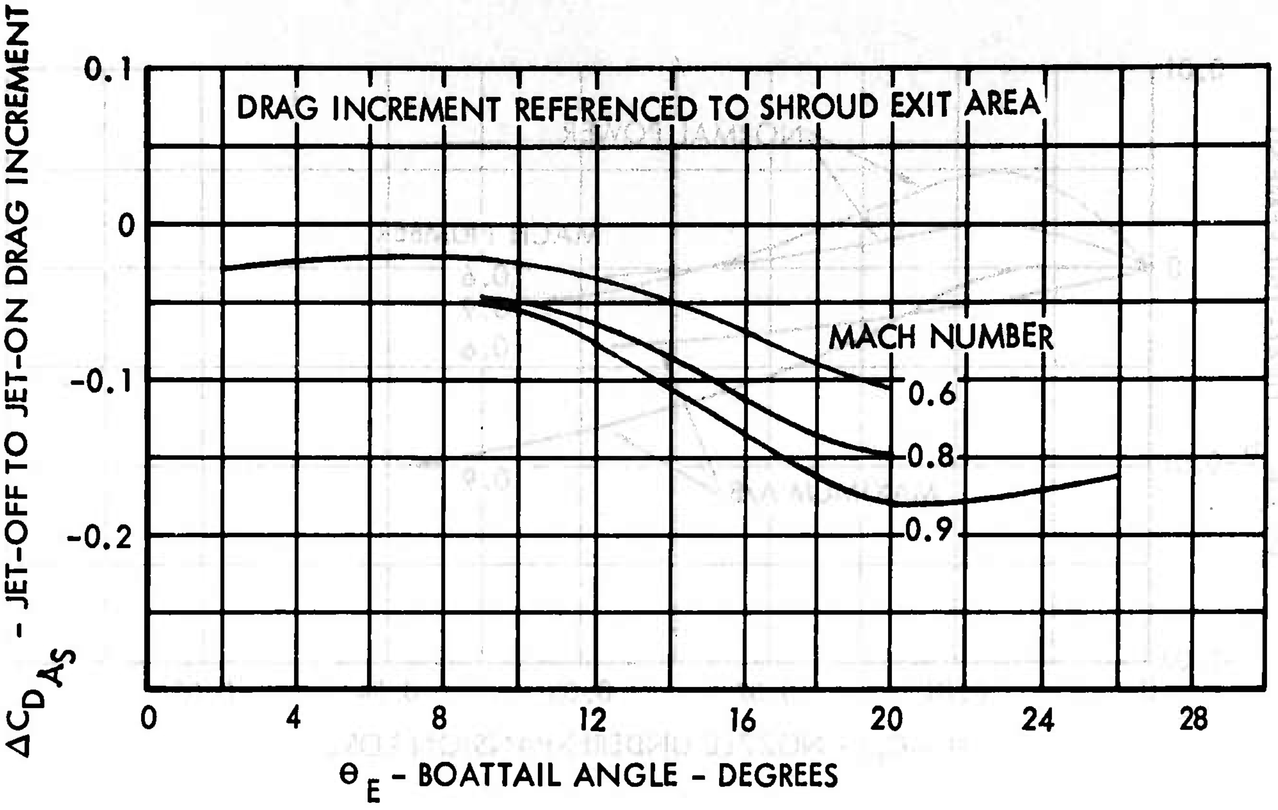

Figure 10. Correlation of Drag Increment From Jet-Off To Design Pressure Ratio - Wide Spacing

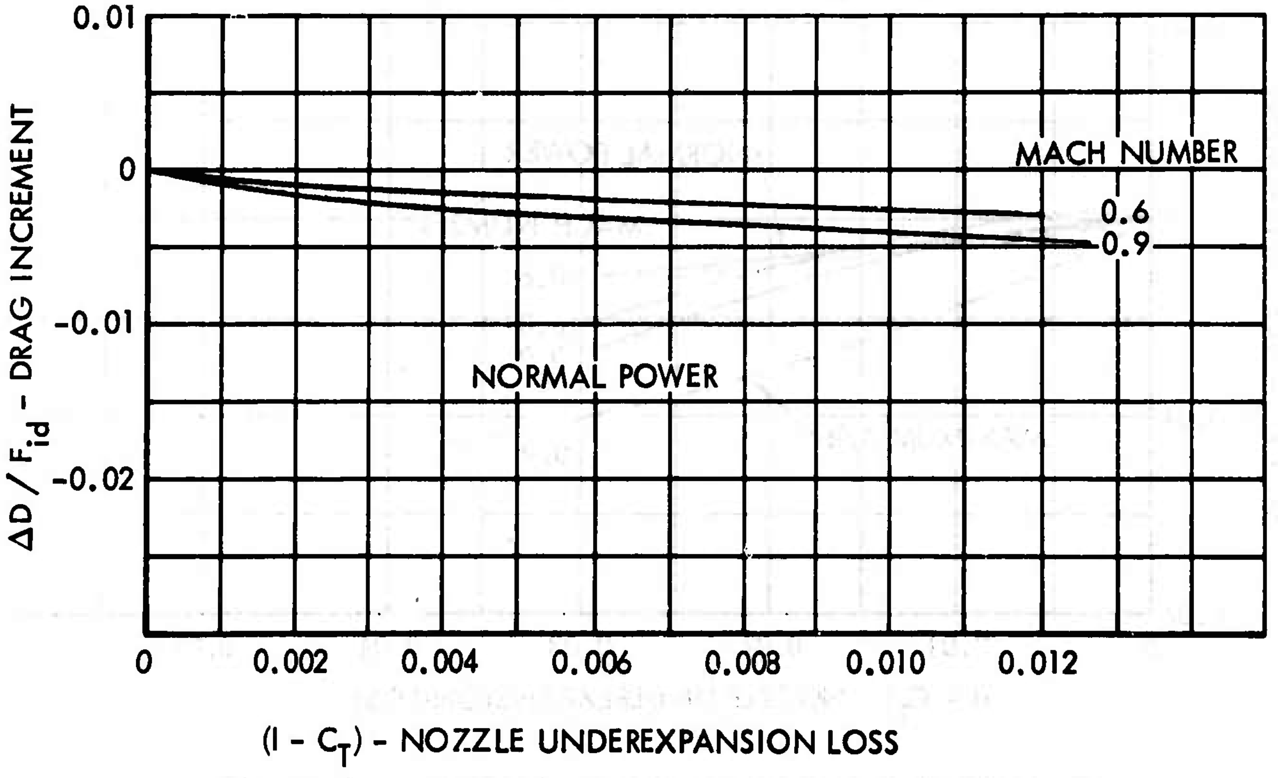

Figure 11. Correlation of Drag Increment From Design To Operating Pressure Ratio - Convergent-Divergent Nozzle

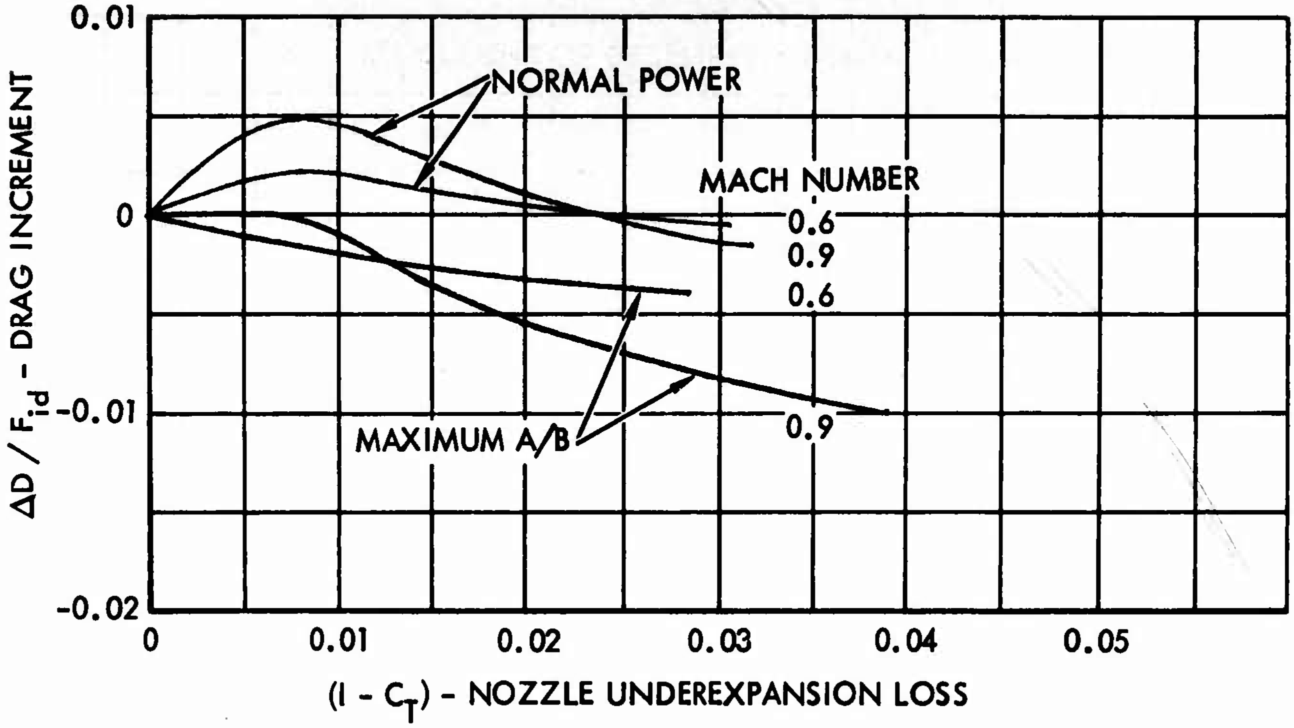

Figure 12. Correlation of Drag Increment From Design to Operating Pressure Ratio - Convergent-Flap Nozzle

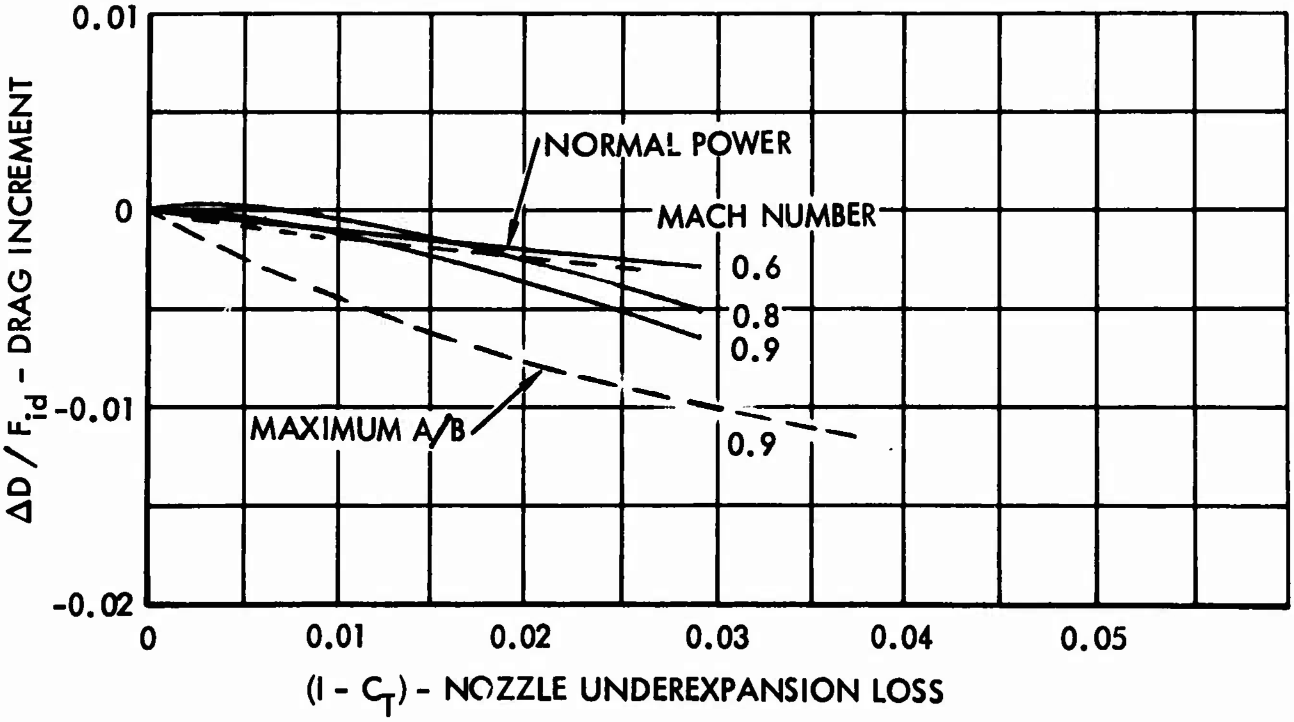

Figure 13. Correlation of Drag Increment From Design to Operating Pressure Ratio - Convergent-Iris Nozzle

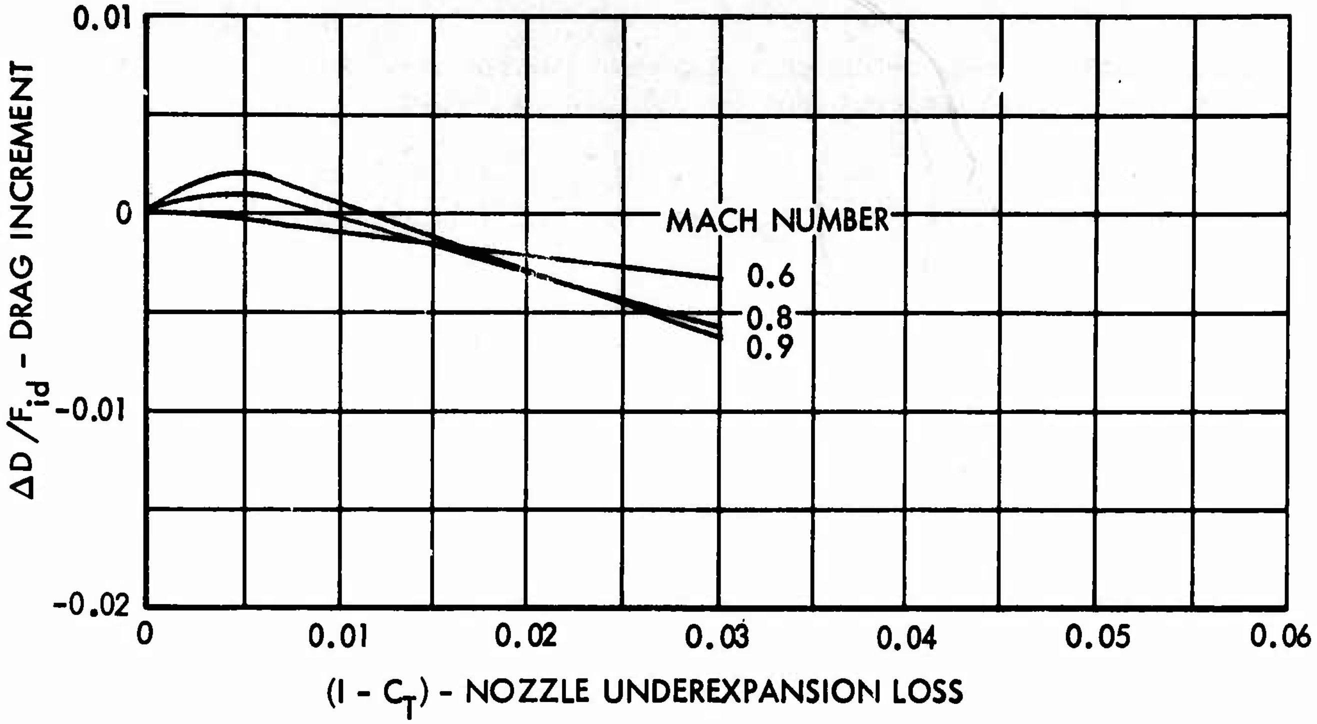

Figure 14. Correlation of Drag Increment From Design to Operating Pressure Ratio - Normal Power Plug Nozzle

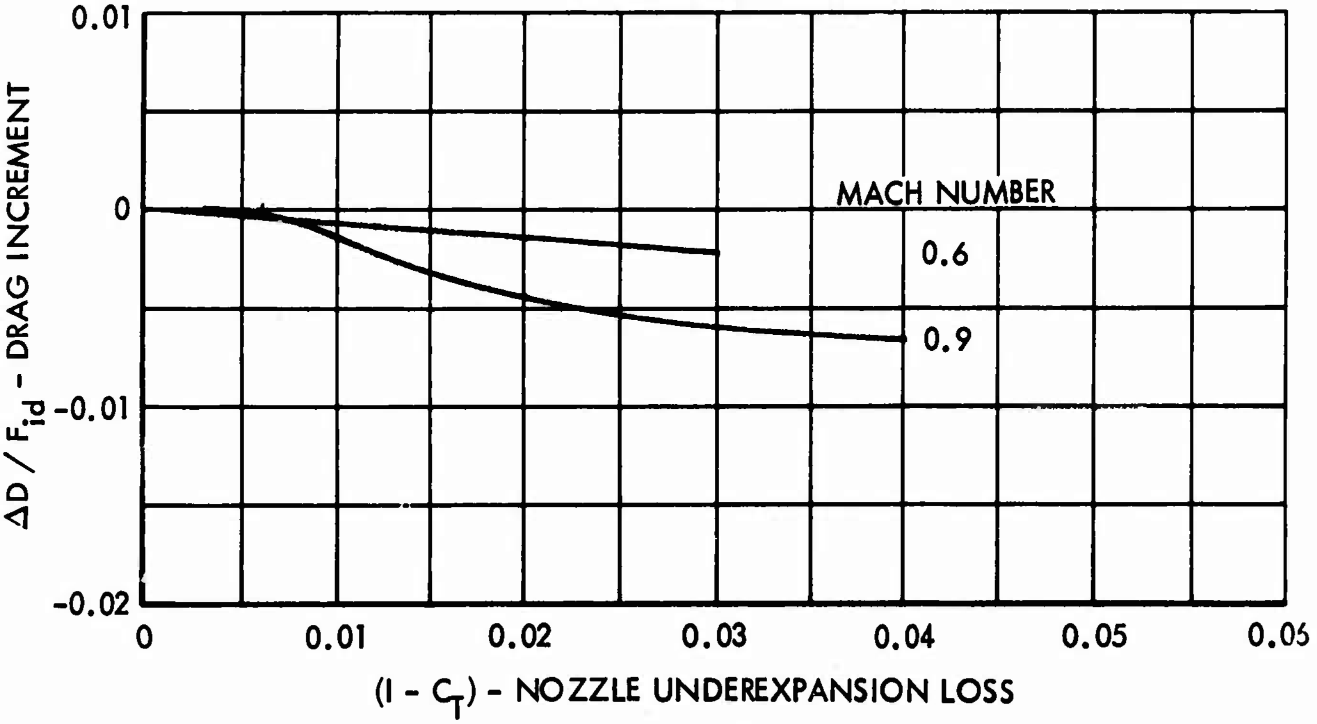

Figure 15. Correlation of Drag Increment From Design to Operating Pressure Ratio - Maximum A/B Power Plug Nozzle

1.0. Boattail drag coefficients, based on maximum area, for a supersonic external flow are computed from the following equation

$$C_{D_{PT}} = \hat{C}_{D_{EB}} \left(\frac{\hat{C}_{D_{PT}}}{\hat{C}_{D_{EB}}} \right) \frac{A_F}{A_M} + K_4 \left(\frac{P_e - P_L}{P_\infty} \right) \left(\frac{A_S}{A_M} \right) \left(\frac{P_\infty}{q_\infty} \right) \qquad (5)$$

where the first term is the jet-off drag and the second term is the increment in drag when going from jet-off to jet-on operations.

The equivalent body drag is obtained by entering the method-of-characteristics boattail drag correlation curves presented in Figure 16 with the Mach number and IMS. The ratio of jet-off drag to equivalent body drag ($\hat{C}_{D_{PT}}/\hat{C}_{D_{EB}}$) is obtained from the correlation results presented in Figure 17 as a function of Mach number and vertical stabilizer tape.

For jet-on operation, K_4, which is the increment in drag from jet-off operation normalized by the product of the difference between the nozzle internal exit pressure and the local boattail surface pressure (assuming no flow separation), is obtained from Figure 18 as a function of nozzle mean boattail angle. The mean boattail angle used is the mean angle over a distance corresponding to one-third of the nozzle exit radius. This length was selected as being representative of the flow separation length. The local boattail flow properties are obtained from a method-of-characteristics solution (a large mesh size was employed to minimize computer time).

The correlation results presented in Figure 18 are restricted to pressure coefficients $(P_e - P_L)/q_L$ greater than 1.4. This pressure coefficient value was based on the empirical observation that little or no separation occurs for lower values. The results are also not applicable for Mach numbers greater than 1.6; a linear variation of K_5 with Mach number from the Mach 1.6 value to a K_5 value of zero at a Mach number of 2.0 is recommended.

3.1.2 Boattail Friction Drag

The required input for computation of the boattail friction drag is the boattail length (L_{BT}), the wetted surface area (A_W), and either the momentum thickness (θ) at the start of the boattail or an effective flat plate length (L_{eff}) upstream of the start of the boattail. With these inputs, an average boattail skin friction coefficient is computed by use of Sivells-Payne correlation (Reference 12) which, when combined with the wetted area, yields the friction drag as discussed below.

With an input momentum thickness at the start of the boattail the reference length Reynolds number, R'_{e_1}, is obtained by iterative solution of the following equation

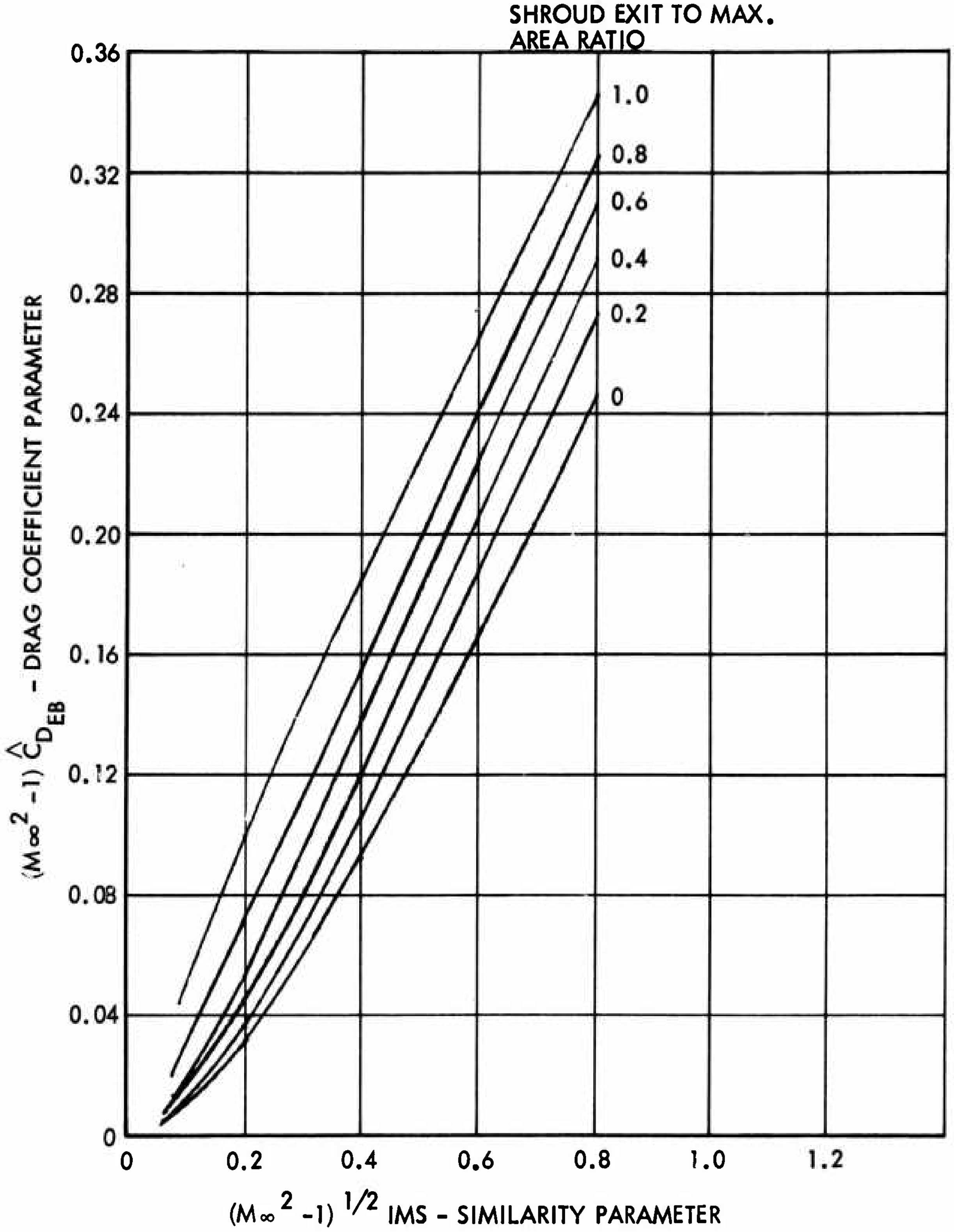

Figure 16. IMS/Supersonic Similarity Correlation Of Method-Of-Characteristics Boattail Pressure Drag

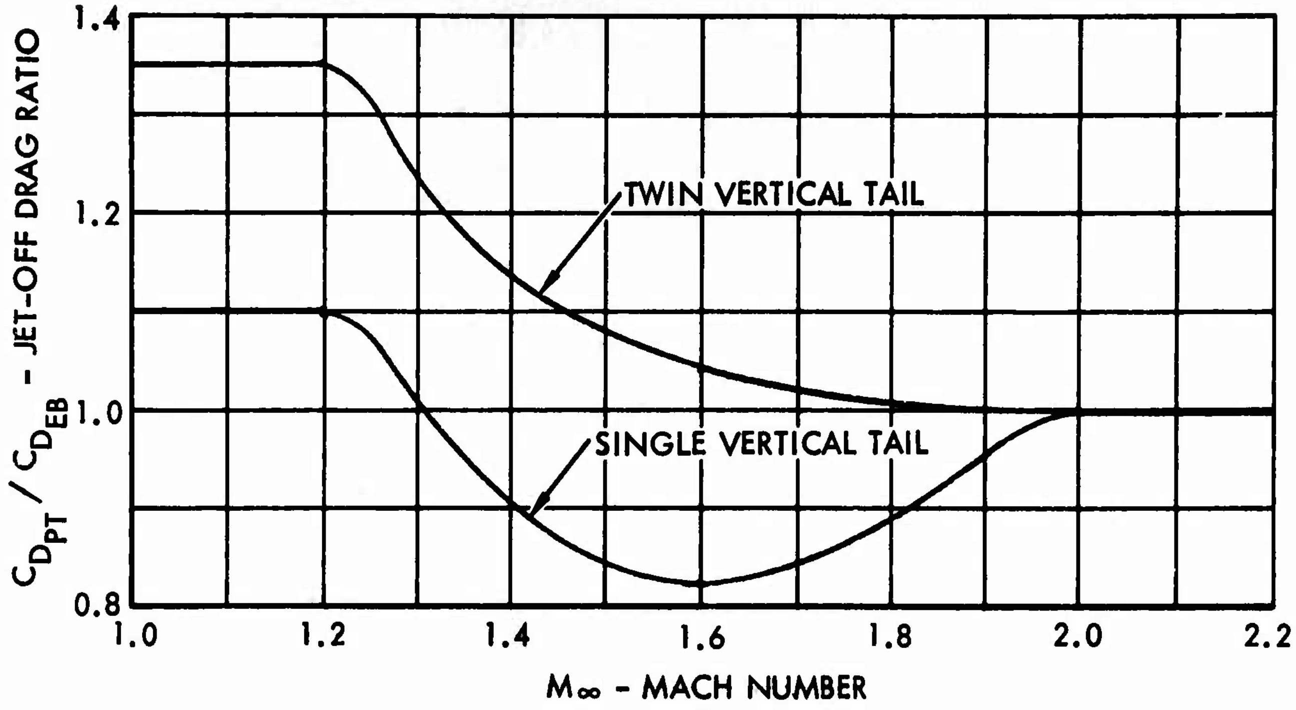

Figure 17. Equivalent Body Correlation Of Phase II Data

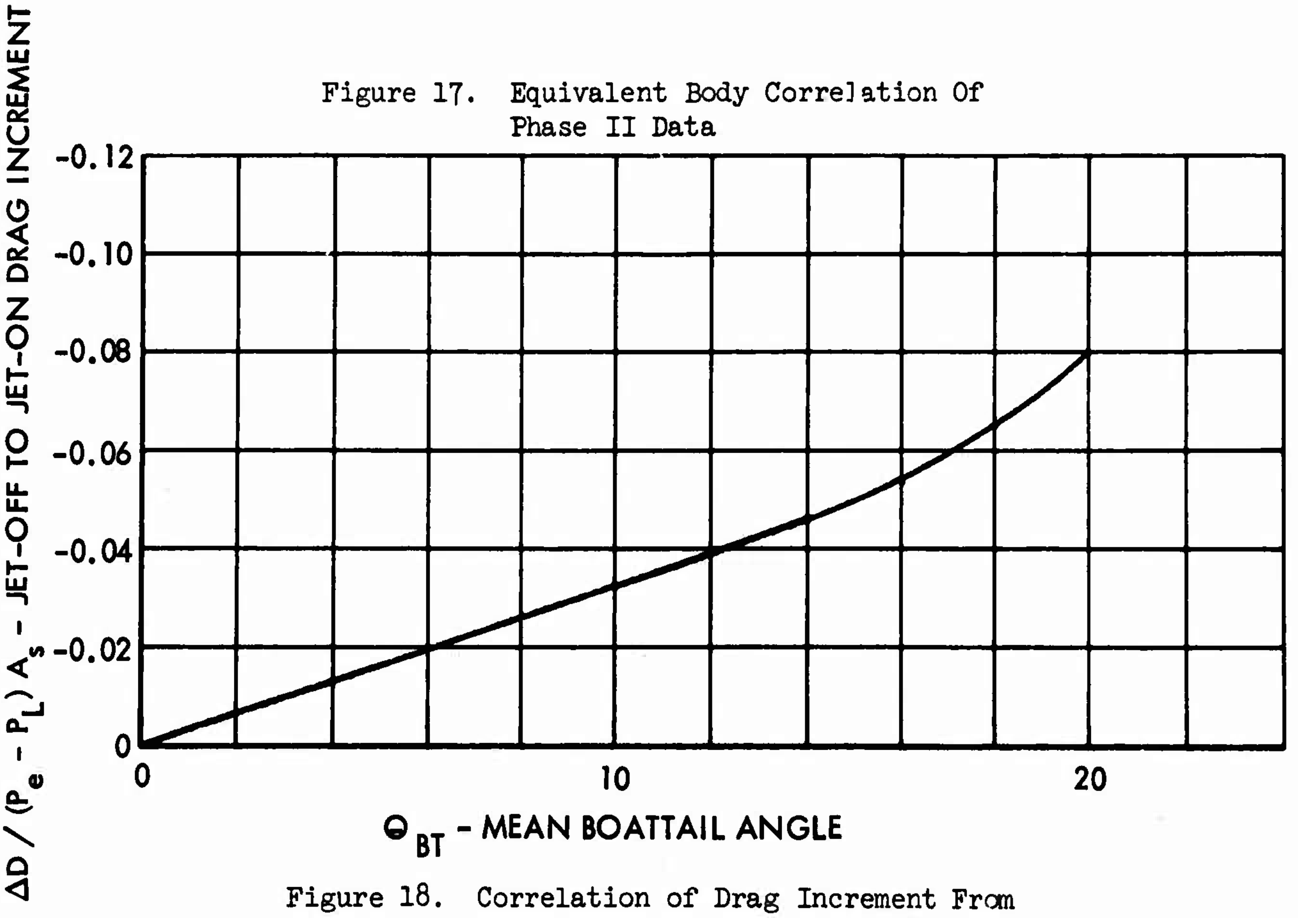

Figure 18. Correlation of Drag Increment From Jet-Off To Jet-On Operation - Supersonic Flow

$$R_{e_\theta} = \frac{\mu_1'}{\mu_1} \, (0.044 \, R_{e_1'})/(\mathrm{Log}_{10} \, R_{e_1'} \; - 1.5)^2 \tag{6}$$

where the primed quantities denote values evaluated at the reference temperature, T_1 , which is obtained from the following equation

$$T_1' \; = \; T_1 \left[1 + 0.035 \, M_\infty^2 + 0.45 \left(\frac{T_{aw}}{T_1} \; -1 \right) \right] \tag{7}$$

where

$$T_{aw} \; = \; T_1 \left[1.0 + \left(\frac{\gamma - 1}{2} \right) \left(0.89 \right) M_\infty^2 \right] \tag{8}$$

If an effective flat plate length upstream of the boattail is input, the reference Reynolds number is obtained from the following equation:

$$R_{e_1}' \; = \; \frac{\rho_1 \; U_\infty \; L_{eff}}{12 g \; \mu_1'} \tag{9}$$

The local skin friction correlation equation taken from Reference 12 is

$$C_{f_1} = \frac{\left| 0.088 \; (\mathrm{Log}_{10} \; R_{e_1}' \; - \; 2.3686) \right| \;\; T_1}{(\mathrm{Log}_{10} \; R_{e_1}' \; - \; 1.5) \;\; 3 \;\; T_1'} \tag{10}$$

The local skin friction coefficient at the end of the boattail is computed in a manner similar to that described above except that the length employed in the computation of the reference length Reynolds number is

$$L_2 = L_{eff} + L_{BT} \tag{11}$$

If the momentum thickness Reynolds number is input, the effective flat plate length at the start of the boattail is computed as follows:

$$L_{eff} = \frac{12 \; g \; \mu_1 \; R_{e_1}}{\rho_1 \; U_\infty} \tag{12}$$

The skin friction drag coefficient based on maximum area is

$$C_{D_f} = \frac{(C_{f_1} + C_{f_2})}{2} \; \frac{A_W}{A_M} \tag{13}$$

3.1.3 Annular Base Drag

The annular base pressure for a subsonic external flow is computed from the following modification (developed in Reference 89) of the Brazzel-Henderson base pressure correlation (Reference 33).

$$\frac{P_b}{P_\infty} = \frac{0.9 + 0.0167\,(R_{mf})}{0.94 + 0.06\,(A_S/A_M)} \tag{14}$$

where R_{mf} is the nozzle exit to freestream momentum ratio, defined as

$$R_{m_f} = \frac{(MV)_e}{(MV)_\infty} = \frac{\gamma_e\, P_e\, A_e\, M_e^2}{\gamma_\infty\, P_\infty\, A_M\, M_\infty^2} \tag{15}$$

For a supersonic external flow, the following base pressure correlation developed by Brazzel-Henderson is also employed.

$$\frac{P_b}{P_\infty} = \left[\frac{T_e}{T_e^*}\right]\left[\frac{3.5}{0.5 + 3.0\,A_S/A_M}\right]\left[0.19 + 1.28\left(\frac{R_{m_f}}{1 + R_{m_f}}\right)\right] + 0.047\,(5 - M_\infty)\left[2\left(\frac{\Delta x_e}{D_M}\right) + \left(\frac{\Delta x_e}{D_M}\right)^2\right] \tag{16}$$

The first term on the right side of Equation (16) normalizes the jet temperature to the jet temperature of a sonic nozzle. The second term corrects for boattail effects, and the third term is a correlation based on the ratio of nozzle exit momentum flux to freestream momentum flux. A nozzle position (relative to the end of the boattail) correction is obtained by the fourth term.

3.2 NOZZLE THRUST COEFFICIENT

This section describes the numerical methods employed for computation of nozzle thrust and discharge coefficients. Prediction methods for convergent, convergent-divergent, convergent-divergent ejector, and plug nozzles are described. The thrust coefficient is defined as the ratio of actual gross thrust to ideal gross thrust based on isentropic expansion of the actual mass flow to freestream pressure. The discharge coefficient is defined as the ratio of actual mass flow to ideal mass flow computed assuming one-dimensional sonic flow at the nozzle throat.

3.2.1 Convergent Nozzles

Convergent nozzle thrust coefficients are computed by use of the following equation,

$$C_T = \frac{C_S \left[\dfrac{P_e}{P_{T_T}} \dfrac{A_{e_{flow}}}{A_T^*} \left(1 + \gamma M_e^2\right) + \dfrac{P_e'}{P_{T_T}} \left(\dfrac{A_e}{A_T^*} - \dfrac{A_{e_{flow}}}{A_T^*}\right)\right] - \dfrac{P_\infty}{P_{T_T}} \dfrac{A_e}{A_T^*}}{F_{i_p} / (P_{T_T} A_T^*)} \tag{17}$$

where

$$\frac{F_{i_p}}{P_{T_T} A_T^*} = \left\{ \frac{2\gamma^2}{\gamma-1} \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{\gamma-1}} \left[1 - \left(\frac{P_\infty}{P_{T_T}}\right)^{\frac{\gamma-1}{\gamma}}\right] \right\}^{1/2} \tag{18}$$

The term enclosed within the brackets in Equation 17 is the total momentum of the flow at the nozzle exit, normalized by $P_{T_T} A_T^*$.

The stream thrust correction factor, C_S, in the above equation is assumed to be 0.997. Equation 17 differs slightly from the equation presented in Reference 41 with the addition of the second term within the brackets. This term represents the pressure force (normalized by $P_{T_T} A_T^*$) exerted on the area increment between the physical and effective exit flow areas. The pressure, P_e', is assumed to be equal to freestream pressure for nozzle pressure ratios less than critical (unity throat Mach number for one-dimensional flow). For nozzle pressure ratios greater than the choking pressure ratio (pressure ratio where the flow field is fixed and the discharge coefficient is independent of pressure ratio) P_e' is assumed equal to the exit pressure, P_e. A linear variation of P_e with nozzle pressure ratio is assumed between the critical and choking pressure ratios. The critical pressure ratio, $(P_{T_T}/P_\infty)_{CR}$, and choking pressure ratio, $(P_{T_T}/P_\infty)_{CK}$, are computed from the following equations.

$$(P_{T_T}/P_\infty)_{CR} = \left(\frac{\gamma + 1}{2}\right)^{\gamma/(\gamma - 1)} \tag{19}$$

$$(P_{T_T}/P_\infty)_{CK} = 3.5 - \text{Tan}\left\{23.8063\ (C_{dN_{max}} - 0.95)\right\} \tag{20}$$

Equation 20 was empirically derived (Reference 41) and represents the nozzle pressure ratio at which the discharge coefficient, $C_{dN_{max}}$, remains fixed.

As discussed in Reference 41, the discharge coefficient, $C_{dN_{max}}$, is sensitive to both the upstream approach angle, α, and the nozzle lip radius of curvature, R_c. Correlations of the discharge coefficient ($C_{dN_{max}}$) as a function of approach angle and radius of curvature ratio, R_c/R_T, are presented in Figures 19 and 20 respectively. The appropriate discharge coefficient, $C_{dN_{max}}$, to be used in Equation 20 is the larger of the two values obtained from Figures 19 and 20.

The nozzle discharge coefficient obtained as described above is, of course, the appropriate discharge coefficient for nozzle pressure ratios greater than the choking pressure ratio (i.e., $C_{dN} = C_{dN_{max}}$). For nozzle pressure ratios less than the choking pressure ratio, the nozzle discharge coefficient, C_{dN}, is determined from the following equation:

$$C_{dN} = C_{dN_{max}} - C_2 \left\{\frac{P_{T_T}}{P_\infty} - \left(\frac{P_{T_T}}{P_\infty}\right)_{CK}\right\}^2 + C_3 \left\{\frac{P_{T_T}}{P_\infty} - \left(\frac{P_{T_T}}{P_\infty}\right)_{CK}\right\}^3 \tag{21}$$

where

$$C_2 = 8\ B^3 / \left[(C_{dN_{max}} - 0.965)^2 + 4\ B^2\right] \tag{22}$$

and

$$C_3 = 0.0011 - 0.00205\ \left[\text{Sin}\ (74.8\ (C_{dN_{max}} - 0.952))\right]$$
$$+ \left[(0.92 - C_{dN_{max}})\ 0.0574 + \text{ABS}\ ((0.92 - C_{dN_{max}})\ .0574)\right] /2 \tag{23}$$

The constant, B, is set equal to 0.01. The above equations are empirically derived in Reference 41.

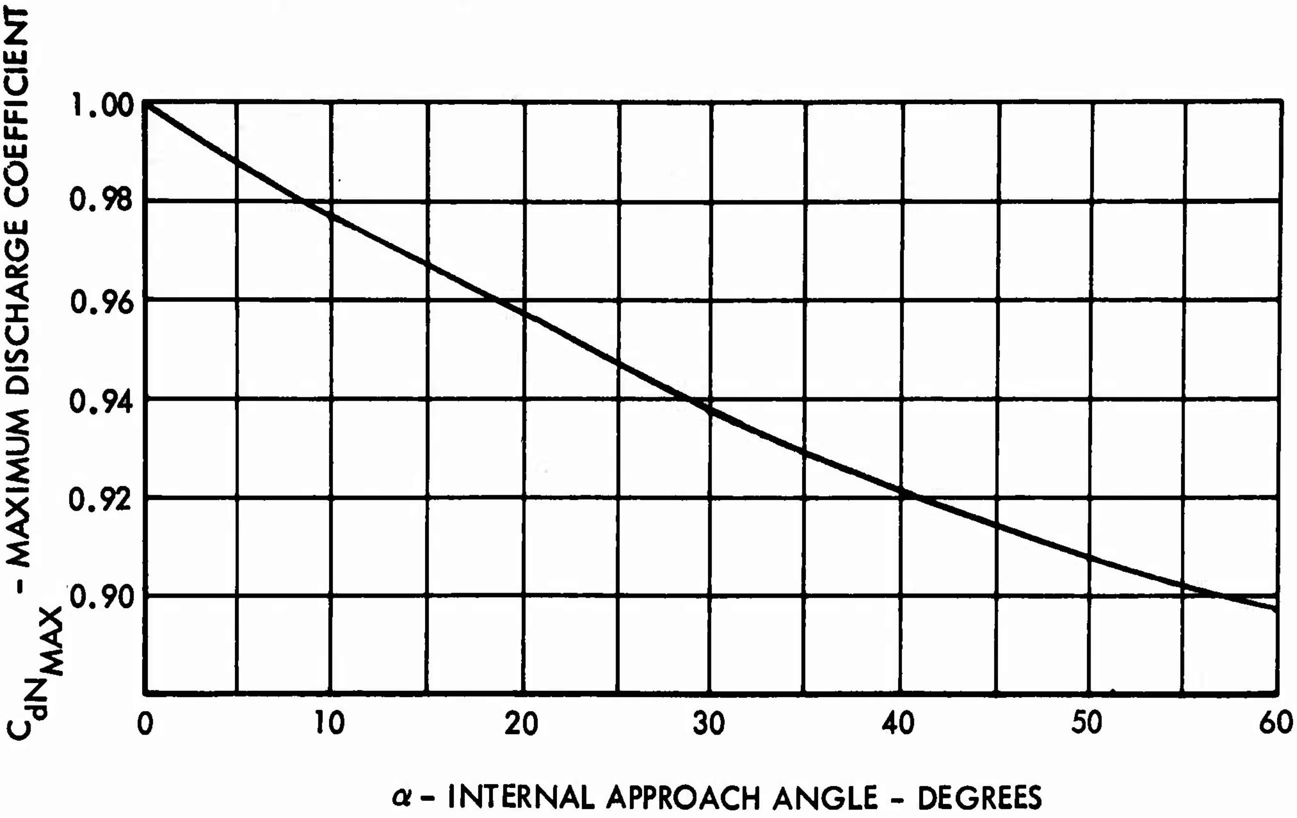

Figure 19. Correlation of Maximum Discharge Coefficient with Internal Approach Angle

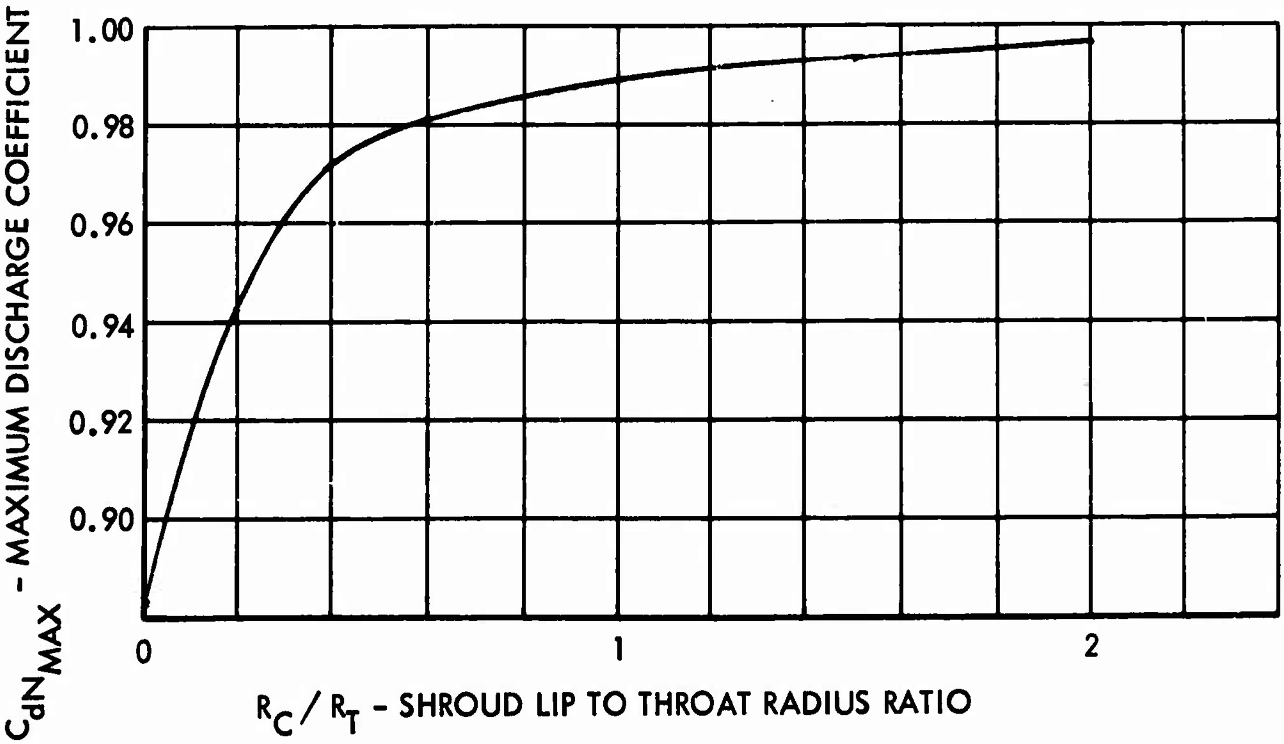

Figure 20. Correlation of Maximum Discharge Coefficient with Shroud Lip Curvature

The area ratios employed in the thrust coefficient equation (Equation 17) are obtained as follows. For nozzle pressure ratios less than critical, the ratio of actual to sonic flow areas ($A_{e_{flow}}/A_T^*$) is obtained in the usual manner from the exit Mach number, M_e. For nozzle pressure ratios greater than critical, the actual sonic flow area ratio is unity. The physical exit to sonic flow area ratio is obtained from the following equation for nozzle pressure ratios less than critical.

$$\frac{A_e}{A_T^*} = \frac{A_e}{A_{e_{flow}}} \; \frac{A_{e_{flow}}}{A_T^*} = \frac{1}{C_{dN}} \; \frac{A_{e_{flow}}}{A_T^*} \qquad (24)$$

For nozzle pressure ratios greater than critical, the exit to sonic flow area ratio is equal to the inverse of the discharge coefficient.

3.2.2 Convergent-Divergent Nozzle

The method employed for computing convergent-divergent nozzle thrust coefficients depends upon whether the flow is unchoked, choked with internal flow separation, or choked and flowing full (i.e., no internal separation). For nozzle pressure ratios less than critical (unity throat Mach number for one-dimensional flow), the flow is subsonic and the nozzle is treated as a subsonic diffuser. The computational procedure is as follows. A throat Mach number is first assumed and a recovery loss coefficient $\Delta P_T/q_T$, is obtained from Figure 21 as a function of nozzle internal divergence angle, θ. The nozzle exit to throat total pressure ratio is obtained from the following equation.

$$\frac{P_{T_e}}{P_{T_T}} = \frac{q_T}{P_{T_T}} \left(\frac{P_{T_T}}{q_T} - \frac{\Delta P_{T_T}}{q_T} \right) \qquad (25)$$

The nozzle exit to sonic area ratio is then computed as

$$\frac{A_e}{A_e^*} = \frac{A_e}{A_T^*} \left(\frac{A_T^*}{A_e^*} \right) = \frac{A_e}{A_T^*} \left(\frac{P_{T_e}}{P_{T_T}} \right) \qquad (26)$$

$$\frac{A_e}{A_T^*} = \frac{A_{T_{flow}}}{A_T^*} \left(\frac{A_T}{A_{T_{flow}}} \right) \left(\frac{A_e}{A_T} \right) \qquad (27)$$

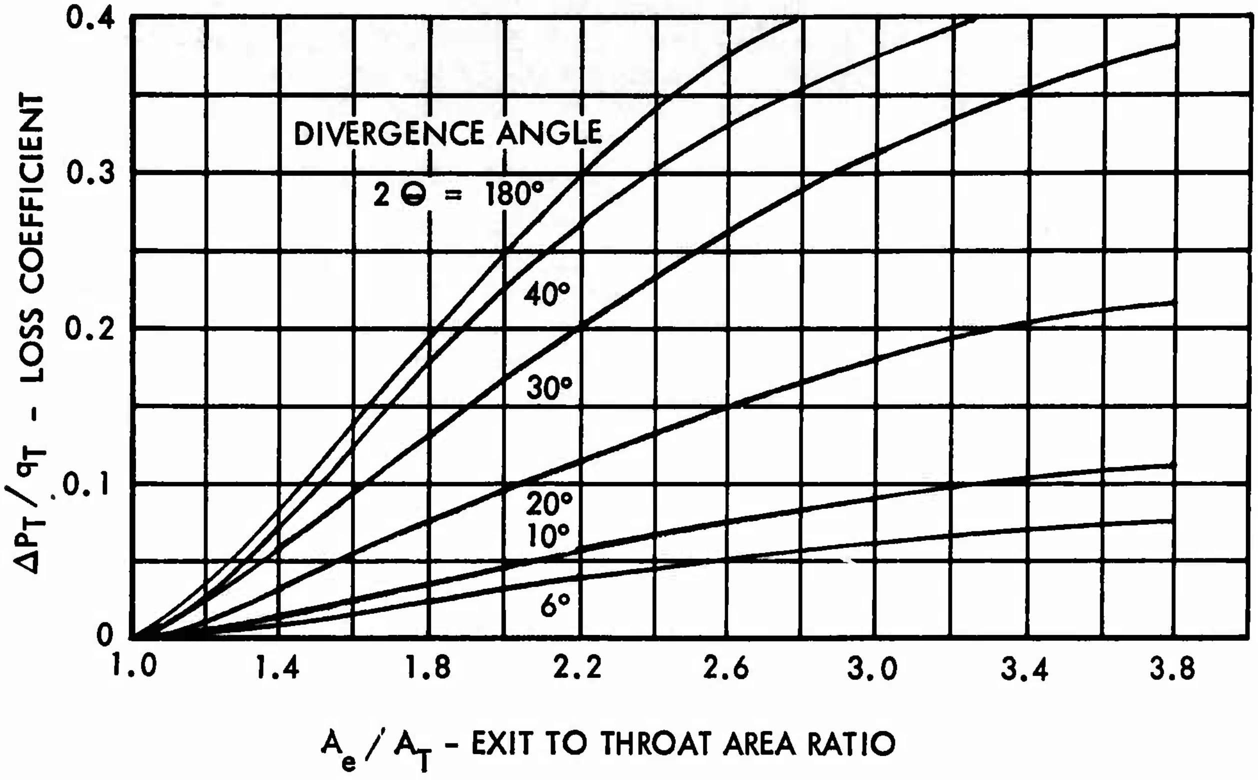

Figure 21. Correlation of Nozzle Internal Divergence Loss

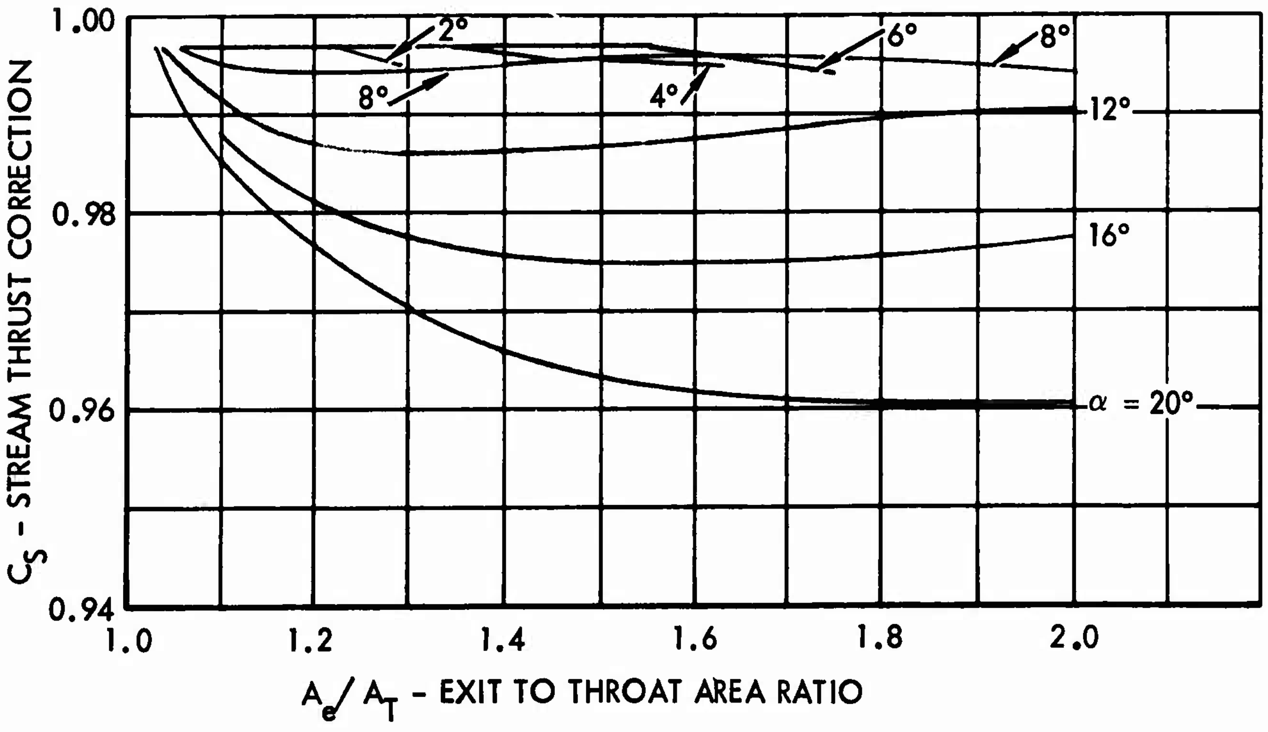

Figure 22. Correlation of Stream Thrust Correction Factor

The throat flow to sonic flow area ratio in Equation 27 is obtained as a function of the assumed throat Mach number and the throat flow to geometric throat area ratio is obtained from the nozzle discharge coefficient ($A_{T_{flow}}/A_T = C_{dN}$). The discharge coefficient is taken as the larger of the two values obtained from Figures 19 and 20. The exit to sonic area ratio obtained from Equation 26 yields an exit Mach number which in turn yields an exit static pressure. If the exit static pressure does not equal the freestream static pressure the calculations are repeated using a different value for the throat Mach number. The thrust coefficient is then computed from Equation 17 with A_e assumed equal to $A_{e_{flow}}$. The stream thrust correction factor is obtained from Figure 22 as a function of exit to sonic flow area ratio and internal divergence angle.

For nozzle pressure ratios greater than critical but less than that required for the nozzle to flow full (no separation), two computational procedures are employed. For nozzle pressure ratios slightly greater than critical, a linear variation of thrust coefficient from the critical value of thrust coefficient is assumed. This linear variation is terminated (based on empirical observation) at a nozzle pressure ratio computed from the following equation.

$$\left(\frac{P_{T_T}}{P_\infty}\right)_L = \left(\frac{P_{T_T}}{P_e}\right)\left(\frac{P_e}{P_\infty}\right) \tag{28}$$

where P_{T_T}/P_e is obtained (assuming the nozzle flows full) from one dimensional flow relationships and

$$\left(\frac{P_e}{P_\infty}\right)_L = 0.1 \left\{10^{0.0332\theta} + 0.72\right\} \left[10\left(\frac{A_e}{A_T} - 1\right)\right]^{-0.77} \tag{29}$$

The thrust coefficient for nozzle pressure ratios greater than the computed pressure ratio from Equation 28, but less than that for the flowing full case, is computed from the following equation.

$$C_T = \frac{C_S\left[\frac{P_{sep}}{P_{T_T}}\,\frac{A_{e_{sep}}}{A_T^*}\,(1 + \gamma\, M_{sep}^2)\right] + \int \frac{PdA}{P_{T_T}\, A_T^*} - \frac{P_\infty\, A_e}{P_{T_T}\, A_T^*}}{F_{ip}/\,(P_{T_T}\, A_T^*)} \tag{30}$$

where P_{sep} is the static pressure just upstream of the separation point, $A_{e_{sep}}$ is the flow area at the separation point, M_{sep} is the Mach number at the separation point, and the integral term is the pressure force acting on the nozzle inner surface in the separated flow region. The stream thrust parameter, C_s, is obtained from Figure 22 as a function of A_{sep}/A^*_T and θ. The surface static (upstream of separation point) to total pressure ratio is computed from the following equation.

$$\frac{P_{sep}}{P_{T_T}} = 0.63 + 0.04 \ln (0.01) \frac{P_\infty}{P_{T_T}} \tag{31}$$

Equation 31 results determine the Mach number, M_{sep}, which in turn locates (through the area ratio function) the separation point. The integral term in Equation 30 is computed from the following empirical equation.

$$\int \frac{PdA}{P_{T_T} A^*_T} = \frac{P_\infty}{P_{T_T}} \left(\frac{6 + \frac{P_{sep}}{P_{T_T}} \frac{P_{T_T}}{P_\infty}}{7} \right) \left(\frac{A_e}{A^*_T} - \frac{A_{sep}}{A^*_T} \right) \tag{32}$$

When the nozzle is flowing full, Equation 17 is used for computing thrust coefficients. The exit flow area ($A_{e_{flow}}$) is, however, set equal to the physical area (Ae). The pressure ratio (P_{T_T}/P_∞) where the nozzle is just flowing full is computed from the following equation.

$$\left(\frac{P_{T_T}}{P_\infty} \right)_F = \frac{P_{sep}}{P_\infty} \left(\frac{P_{T_T}}{P_e} \right) \tag{33}$$

where P_{T_T}/P_e is obtained from a one-dimensional flowing full analysis and P_{sep}/P_∞ is a constant obtained from Equation 31 (after rearranging).

The nozzle discharge coefficient for convergent-divergent nozzles is defined as the ratio of actual mass flow to ideal convergent nozzle mass flow, or

$$C_{d_N} = \frac{(\dot{m}_{C-D})_{act}}{(\dot{m}_{CONV})_{id}} \tag{34}$$

In terms of ideal conditions, the above equation becomes

$$C_{d_N} = \frac{(\dot{m}_{C\text{-}D})_{id}}{(\dot{m}_{CONV})_{id}} \; \frac{A_{T\,flow}}{A_T} \tag{35}$$

where $A_{T\,flow}/A_T$ is the larger of the two values obtained from Figures 19 and 20. For pressure ratios greater than critical for the reference convergent nozzle, the ideal mass flow for the C-D nozzle is identical to the ideal mass flow of the convergent nozzle. Thus, the discharge coefficients can be obtained, as previously described, from Figures 19 and 20. For pressure ratios less than critical for the reference convergent nozzle, the ideal C-D nozzle mass flow is greater than the ideal convergent nozzle mass flow. This is because the critical pressure ratio for a C-D nozzle is lower than the critical pressure ratio for a convergent nozzle due to the diffusion in the divergent section. The discharge coefficient equation is rewritten, therefore, as

$$C_{d_N} = \frac{M_T \left(1 + \frac{\gamma-1}{2} M_T^{\,2}\right)^{-\left(\frac{\gamma+1}{2(\gamma-1)}\right)}}{M_e \left(1 + \frac{\gamma-1}{2} M_e^{\,2}\right)^{-\left(\frac{\gamma+1}{2(\gamma-1)}\right)}} \; \frac{A_{T\,flow}}{A_T} \tag{36}$$

where M_T is the C-D nozzle throat Mach number and M_e is the exit Mach number of the reference convergent nozzle.

3.2.3 Convergent-Divergent Ejector Nozzle

The computational method employed for predicting C-D ejector nozzle performance follows closely the method employed for C-D nozzles. The primary difference is the addition of a routine for computing the ejector pumping characteristics. The method employed is the one-dimensional compound-compressible flow analysis of Bernstein (Reference 45). Bernstein's method is programmed so as to obtain secondary to primary mass flow ratio as a function of secondary to primary total pressure ratio and vice versa.

With the addition of the nozzle secondary flow, the nozzle thrust coefficient equation with no internal flow separation becomes

$$C_T = \frac{C_S \left[\frac{P_e}{P_{T_P}} \frac{A_{e_P}}{A^*_{T_P}} \left(1 + \gamma M_{e_P}^{\,2}\right) + \frac{P_e}{P_{T_P}} \frac{A_{e_S}}{A^*_{T_P}} \left(1 + \gamma M_{e_S}^{\,2}\right)\right]}{\left(\frac{Fid}{P_{T_P} A^*_{T_P}}\right)_P + \left(\frac{Fid}{P_{T_P} A^*_{T_P}}\right)_S} - \frac{P_\infty A_e}{P_{T_P} A^*_{T_P}} \tag{37}$$

where the secondary and primary flow areas, Mach numbers, and exit pressure at the nozzle exit are obtained from standard one-dimensional calculations employing the secondary to primary mass flow ratios and total pressure ratios. The stream thrust correction factor, C_S, is obtained from Figure 22 as a function of internal divergence angle and shroud exit to primary nozzle area ratio. For cases with internal flow separation, the thrust coefficients are computed by a method similar to that employed for C-D nozzles. Primary nozzle discharge coefficients are also computed in the same manner as for C-D nozzles.

3.2.4 Plug Nozzles

The plug nozzle performance routine is based on both analytical and empirical correlation methods. Specifically, for supersonic flight Mach numbers a combined analytical/empirical method is employed, while an empirical method is employed for subsonic flight Mach numbers. The reason for this is that, for supersonic flight Mach numbers, the nozzle pressure ratio is sufficiently high such that there is little or no influence of the external flow on the plug surface pressure distributions. For subsonic flight Mach numbers, the influence of the external flow is felt over a large portion of the plug surface, especially at low nozzle pressure ratios.

The method employed for computing the plug surface pressure force and nozzle thrust coefficient for a supersonic external flow is as follows. First, the total flow expansion around the shroud lip is computed assuming the flow expands to freestream static pressure. This flow turning is divided into a number of equal turning increments. For the initial flow angle increment, the Mach number at the shroud lip is computed using the Prandtl-Meyer relationship. The right running characteristic ray is then constructed and its intersection with the plug surface computed. For this computation, the characteristic ray is assumed to be straight. The plug surface Mach number at the intersection point is obtained from the Prandtl-Meyer relationship assuming a flow deflection equal to twice the flow turning increment at the shroud lip. This procedure accounts, approximately, for the expansion fan reflection from the plug surface. The method is approximate, since the actual characteristic ray is curved rather than straight, as assumed. Nonetheless the surface pressure distributions computed as described are in excellent agreement with exact method-of-characteristic calculations.

The above procedure is repeated until the flow is expanded to freestream pressure or the end of the plug is reached. In the former case, where the last ray intersects the surface upstream of the plug base, the external flow will definitely influence the plug surface pressure distributions. It is assumed, however, that the region influenced by the external flow is small. It is further assumed that the pressures in this region are near freestream pressure. Based on empirical observations, the above assumptions will introduce little error provided the nozzle pressure ratio is greater than approximately 4.0 and the plug configuration is similar to those tested.

The nozzle gross thrust is the sum of the gross thrust at the nozzle exit, the plug surface pressure force, and the plug base force (or drag). The gross thrust at the nozzle exit for unshrouded nozzles is computed in the same manner as for convergent nozzles and for shrouded plug nozzles in the same manner as for C-D nozzles. Plug base pressure correlations are employed for computing plug base forces. The plug base pressure is computed from the following correlation equation:

$$\frac{P_b}{P_{T_T}} = \frac{4.312}{\left(P_{T_T}/P_\infty\right)^{1.975}} \tag{38}$$

This equation is applicable for nozzle pressure ratios ranging from approximately 4.5 to the pressure ratio where the ratio of base pressure to nozzle total pressure remains invariant with nozzle pressure ratio. The plug base to nozzle total pressure ratio becomes invariant with pressure ratio when the last characteristic ray from the shroud lip lies downstream of the base wake region.

The invariant base pressure is computed from the following equation:

$$\frac{P_b}{P_{T_T}} = 0.517\left(\frac{P_P}{P_{T_T}}\right)_e + 0.0046 \tag{39}$$

where $(P_P/P_{T_T})_e$ is the ratio of plug surface static pressure just upstream of the plug base to nozzle total pressure. For nozzle pressure ratios less than 4.5, the base pressure is assumed equal to freestream static pressure.

For a subsonic external flow, the plug nozzle thrust coefficient is computed from the following equation:

$$C_T = C_{T_e} + \frac{\Delta D}{Fid} - K_4 \tag{40}$$

where

$$K_4 = \frac{\Delta D}{Fid} - (C_T - C_{T_e}) \tag{41}$$

C_{T_e} in the above equation is the ratio of computed gross thrust at the nozzle exit to ideal gross thrust (Fid) obtained by expanding the flow isentropically to freestream static pressure, and ΔD is the drag increment between operation at the design pressure ratio and operation at a higher pressure ratio and is obtained from Figures 14 and 15 as a function of the underexpansion loss, $(1-C_{T_e})$. The plug thrust/drag parameter, K_4, is obtained through interpolation and extrapolation of the correlation results presented in Figures 23 and 24.

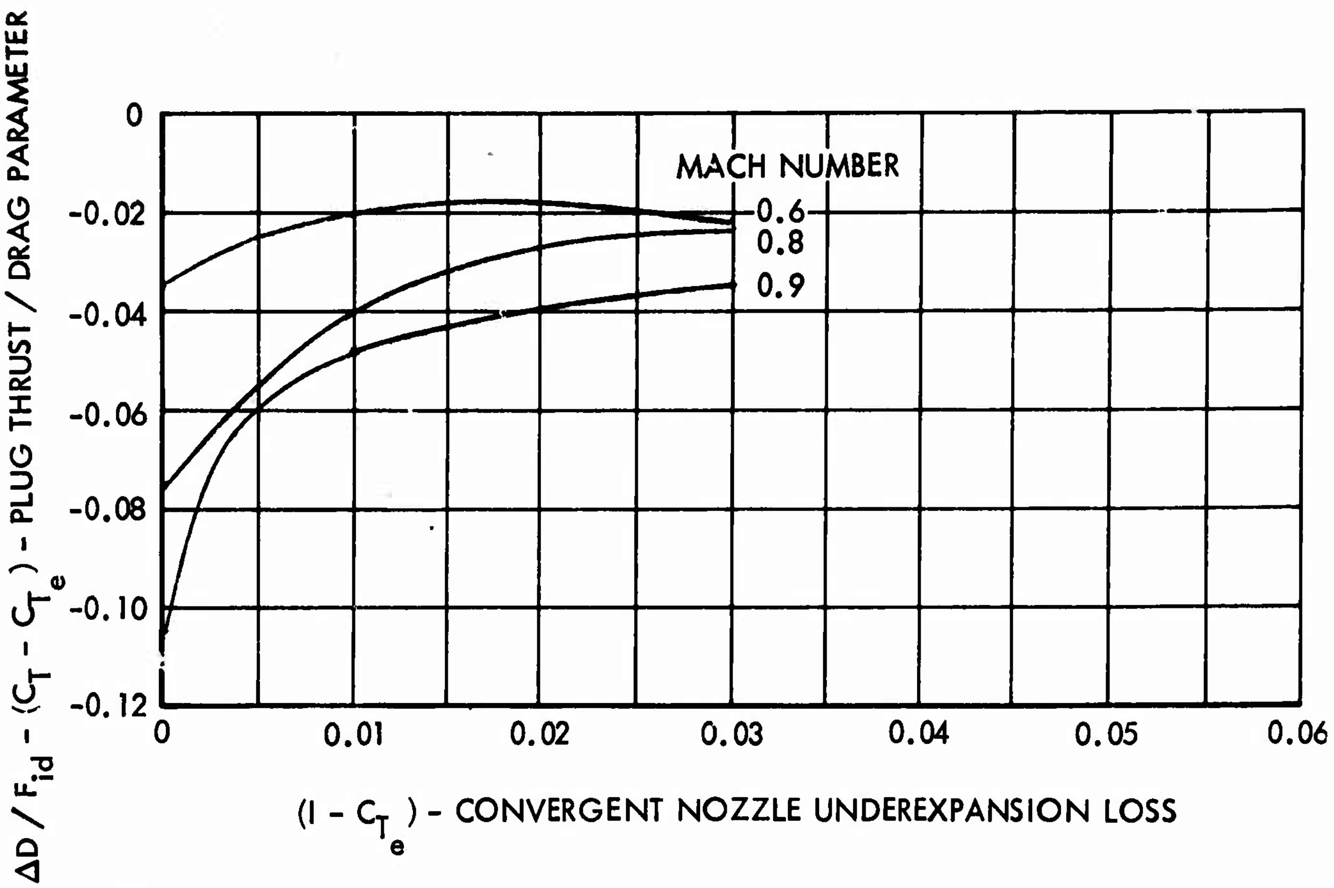

Figure 23. Correlation of Plug Thrust and Boattail Drag Increment - Normal Power Plug Nozzle

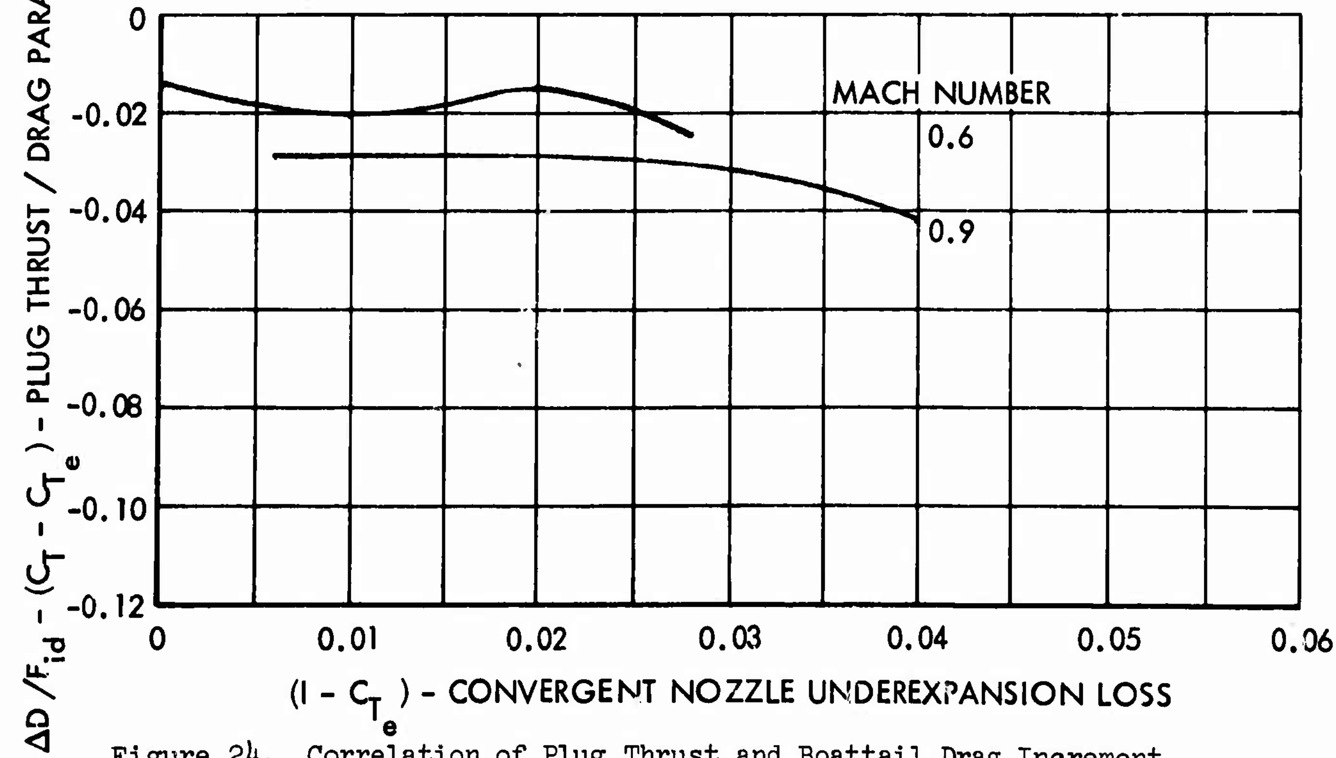

Figure 24. Correlation of Plug Thrust and Boattail Drag Increment - Maximum A/B Power Plug Nozzle

SECTION 4

OPERATING INSTRUCTIONS

4.1 INPUT REQUIREMENTS

The input for the external drag and internal nozzle performance computer program consists of fixed and variable parameters in a main 25 card set plus optional curve data and input routine control cards. The fixed inputs, which are constants for each computer run, are discussed in Subsection 4.1.1. The variable inputs, which allow a series of values or curve data to be input for each run, are discussed in Subsection 4.1.2, followed by a description of the required input control cards in Subsection 4.1.3. The 25 card main input data set is summarized in Table 1, including card numbers, data descriptions and locations, available input options, and where appropriate, identifiers for the optional curve data inputs. Tables 2 and 3 describe the input curve formats. Sample input sheets are given in Appendix A.

4.1.1 Fixed Input

The fixed input data required are the title, the basic aircraft external geometric data, and the nozzle internal geometry data. The title, on card 1, may consist of any combination of alpha-numeric characters and may be placed anywhere in columns 1 through 72. This title will be printed at the top of each page of computer printout. The first three inputs on card 2 are input keys for selection of nozzle spacing, nozzle type, and interfairing type, and have the options shown in Table 1. The inputs are integers (no decimal) input in fields of 3 columns starting with column 1. The integer inputs must be right-adjusted; i.e., the final digit must fall in the last column of the input field. The last six inputs on card 2 are real numbers (input with decimals) in fields of six columns starting with column 10. These inputs include wing area, maximum cross-sectional area, ratio of metric break area to maximum area, the initial boattail length, initial boattail integral mean slope (IMSF), and boattail wetted area for the portion of the aftbody between the maximum are a location and the metric break.

Nozzle internal fixed inputs are shown in Table 1 under each nozzle type heading. The nozzle fixed inputs are on the last non-blank card in the data set; however, enough blank cards must be added at the end of the set to make a total of 25 cards. The inputs required for convergent nozzles are the minimum and maximum throat areas corresponding to normal and max A/B power settings, input as real numbers on the first two fields of 6 on card 22. For convergent-divergent nozzles, the axial length of the nozzle divergent section, the minimum nozzle expansion ratio, and the maximum nozzle expansion ratio are input as real numbers on card 22 in fields of 6 columns, starting with column 1. The fixed inputs for the convergent-divergent ejector nozzle

TABLE 1. MAIN DATA SET INPUT KEY

CARD	QUANTITY	TYPE	MODE	COLUMNS	INPUT OPTIONS	
					CODE	DESCRIPTION
1	Title	Fixed	Alpha-numeric	1 - 72		Title or identification of case to be printed at top of print-out
2	Nozzle Spacing Ratio, S/D	Fixed	Integer	1 - 3	1	Narrow ($S/D \approx 1.25$) single vertical
					2	Intermediate ($S/D \approx 1.625$) single vertical
					3	Wide ($S/D \approx 2.0$) single vertical
					4	Wide with twin vertical
	Nozzle Type, NT	Fixed	Integer	4 - 6	1	Convergent
					2	Convergent-Divergent
					3	Convergent-Divergent Ejector
					4	Unshrouded Plug
					5	Shrouded Plug
	Interfairing Type, IT	Fixed	Integer	7 - 9	1	Horizontal
					2	Vertical
	Wing Area, A_{Wing}	Fixed	Real	10 - 15		Reference Area, ft^2
	Maximum Area, A_M	Fixed	Real	16 - 21		Aircraft maximum area excluding lifting portion of wing -- ft^2
	Metric Break Area Ratio, A_{MB}/A_M	Fixed	Real	22 - 27		Fuselage area at wing trailing edge station, $A_{MB}/A_M \approx 0.85$
	Initial Boattail Length to Maximum Diameter Ratio, L_{MB}/D_M	Fixed	Real	28 - 33		Axial distance between A_M and A_{MB} stations

TABLE 1. MAIN DATA SET INPUT KEY (Continued)

CARD	QUANTITY	TYPE	MODE	COLUMNS	INPUT OPTIONS	
					CODE	DESCRIPTION
	IMSF	Fixed	Real	34 - 39		IMS for initial boattail surface. Enter -1. for curve $(X = X/D_M, Y = A/A_M, Z = 0)$ IDC020
	Initial Boattail Wetted Area Ratio A_{W_F}/A_M	Fixed	Real	40 - 45		Wetted area for initial boattail surface
				46 - 72		Blank
3	Flight Speed	Variable	Mixed*		1	Freestream Mach number
					2	True air speed - knots
					3	True air speed - mph
					4	Indicated air speed - knots
					5	Indicated air speed - mph
4	Freestream Pressure	Variable	Mixed		1	Ambient pressure, psf
					2	Geometric altitude, ft.
					3	Geopotential altitude, ft.
					4	Reynolds number per foot, millions
5	Freestream Temperature	Variable	Mixed		1	Ambient temperature, ^{o}R
					2	Non-standard temperature increment, ^{o}R
					3	Total temperature, ^{o}R
6	Nozzle Power Setting, PS	Variable	Mixed		1	Clean wind tunnel model
					2	Actual aircraft model
7	Nozzle Pressure Ratio, P_{T_P}/P_∞	Variable	Mixed		1	Input P_{T_P}/P_∞
					2	Curve $(X=M_\infty, Y=P_{T_P}/P_\infty, Z=0)$ IDC072
					3	Curve $(X=M_\infty, Y=P_{T_P}/P_\infty, Z=PS)$ IDC073

TABLE 1. MAIN DATA SET INPUT KEY (Continued)

CARD	QUANTITY	TYPE	MODE	COLUMNS	INPUT OPTIONS	
					CODE	DESCRIPTION
8	Nozzle Specific Heat Ratio, γ_p	Variable	Mixed		1	Input γ_p
					2	Curve (X=PS, Y=γ_p, Z=0) IDC082
9	Nozzle Throat Area	Variable	Mixed		1	Input physical area, A_T -- ft^2
					2	Curve (X=M_∞, Y=A_T, Z=0) IDC092
					3	Input flow area, $A_{T_{flow}}$ -- ft^2
					4	Curve (X=M_∞, Y=$A_{T_{flow}}$, Z=0) IDC094
10	Nozzle Throat Approach Angle, α	Variable	Mixed		1	Input α, degrees
					2	Curve (X=A_T, Y=α, Z=0) IDC102
11	Nozzle Throat Geometry	Variable	Mixed		1	Input Rc/R_T if $NT < 4$ Input RcR_T/S^2 if $NT \geq 4$
					2	Curve (X=A_T, Y=R_c/R_T or R_cR_T/S^2, Z=0) IDC112
12	Nozzle Expansion Ratio, A_E/A_T	Variable	Mixed		1	A_E/A_T = 1.0 (convergent & Unshrouded plug nozzles)
					2	Input A_E/A_T, exit to throat area ratio
					3	Curve (X=A_T, Y=A_E/A_T, Z=0) IDC123
					4	Maximum thrust minus drag

TABLE 1. MAIN DATA SET INPUT KEY (Continued)

CARD	QUANTITY	TYPE	MODE	COLUMNS	INPUT OPTIONS	
					CODE	DESCRIPTION
13	Nozzle Annular Base Area Ratio, A_B/A_E	Variable	Mixed		1	Input A_B/A_E, base to exit area ratio
					2	Curve ($X=A_E$, $Y=A_B/A_E$, $Z=0$) IDC132
14	Nozzle Base Length to Diameter Ratio, $\Delta X/D_M$	Variable	Mixed		1	Input $\Delta X/D_M$
					2	Curve ($X=A_E$, $Y=\Delta X/D_M$, $Z=0$) IDC142
15	Nozzle Boattail Trailing Edge Angle, θ_E	Variable	Mixed		1	Input θ_E, degrees
					2	Curve ($X=A_E$, $Y=\theta_E$, $Z=0$) IDC152
16	Mean Nozzle Boattail Trailing Edge Angle, θ_M	Variable	Mixed		1	Input θ_M, degrees
					2	Curve ($X=A_E$, $Y=\theta_M$, $Z=0$) IDC162
17	Total Boattail Length to Diameter Ratio, L/D_M	Variable	Mixed		1	Input L/D_M
					2	Curve ($X=A_M-A_F$, $Y=L/D_M$, $Z=0$) IDC172
18	IMS for Surface Aft of Metric Break Station, IMSA	Variable	Mixed		1	Input IMSA
					2	Curve ($X=A_M-A_F$, $Y=IMSA$, $Z=0$) IDC182
					3	Curve ($X=X/D_M$, $Y=A/A_M$, $Z=0$) IDC183

TABLE 1. MAIN DATA SET INPUT KEY (Continued)

CARD	QUANTITY	TYPE	MODE	COLUMNS	INPUT OPTIONS	
					CODE	DESCRIPTION
19	Adjusted Projected Frontal Area Ratio, $\Delta A/A_M$	Variable	Mixed		1	Input $\Delta A/A_M$
					2	Curve $(X=A_M-A_F,\ Y=\Delta A/A_M,\ Z=0)$ IDC192
20	Boundary Layer Momentum Thickness Ratio, θ/D_M	Variable	Mixed		1	Input θ/D_M
					2	Curve $(X=M_\infty,\ Y=\theta/D_M,\ Z=0)$ IDC202
					3	Curve $(X=M_\infty,\ Y=\theta/D_M,\ Z=R_e/ft.)$ IDC203
					4	Input effective flat plate length to maximum diameter ratio instead of θ/D_M
21	Total Boattail Wetted Area Ratio, A_W/A_M	Variable	Mixed		1	Input A_W/A_M
					2	Curve $(X=A_E,\ Y=A_W/A_M,\ Z=0)$ IDC212
CONVERGENT NOZZLE						
22	Minimum Nozzle Throat Area, $A_{T_{MIN}}$	Fixed	Real	1 - 6		Normal power throat area
	Maximum Nozzle Throat Area, $A_{T_{MAX}}$	Fixed	Real	7 - 12		Max A/B throat area
				13 - 72		Blank
23-25				1 - 72		Blank

TABLE 1. MAIN DATA SET INPUT KEY (Continued)

CARD	QUANTITY	TYPE	MODE	COLUMNS	INPUT OPTIONS	
					CODE	DESCRIPTION
CONVERGENT-DIVERGENT NOZZLE						
22	Length of Internal Expansion Surface, FL	Fixed	Real	1 - 6		Surface length between A_T and A_E stations, ft.
	Minimum Nozzle Expansion Ratio, $(A_E/A_T)_{MIN}$	Fixed	Real	7 - 12		Minimum physical exit to throat area ratio
	Maximum Nozzle Expansion Ratio $(A_E/A_T)_{MAX}$	Fixed	Real	13 - 18		Maximum physical exit to throat area ratio
				19 - 72		Blank
23-25				1 - 72		Blank
CONVERGENT-DIVERGENT EJECTOR NOZZLE						
22	Shroud Throat Area Ratio, A_{ST}/A_T	Variable	Mixed		1	Input A_{ST}/A_T
					2	Curve $(X=A_T, Y=A_{ST}/A_T, Z=0)$ IDC222
23	Pumping Characteristics	Variable	Mixed		1	Input P_{T_S}/P_{T_P}
					2	Curve $(X=M_\infty, Y=P_{T_S}/P_{T_P}, Z=0)$ IDC232
					3	Input Corrected W_S/W_P
					4	Curve $(X=M_\infty, Y=\text{Corrected } W_S/W_P, Z=0)$ IDC234

TABLE 1. MAIN DATA SET INPUT KEY (Continued)

CARD	QUANTITY	TYPE	MODE	COLUMNS	INPUT OPTIONS	
					CODE	DESCRIPTION
24	Secondary to Primary Gas Constant Ratio, R_S/R_P	Variable	Mixed		1	Input R_S/R_P
					2	Curve (X=PS, Y=R_S/R_P, Z=0) IDC242
25	Length of Internal Expansion Surface, FL	Fixed	Real	1 - 6		Surface length between A_{ST} and A_E stations, ft.
	Minimum Nozzle Expansion Ratio, (A_E/A_T) Min	Fixed	Real	7 - 12		Minimum physical exit to throat area ratio
	Maximum Nozzle Expansion Ratio, (A_E/A_T) Max	Fixed	Real	13 - 18		Maximum physical exit to throat area ratio
	Secondary Flow Specific Heat Ratio, γS	Fixed	Real	19 - 24		Secondary air usually obtained from inlet, $\gamma S = 1.4$
				25 - 72		Blank
PLUG NOZZLES						
22	Plug Legnth to Diameter Ratio, L_p/D_M	Variable	Mixed		1	Input L_p/D_M
					2	Curve (X=A_T, Y=L_p/D_M, Z=0) IDC222
23	Plug Angle, αp	Fixed	Real	1 - 6		Conical plug angle, degrees
	Plug Base Area, A_{Pb}	Fixed	Real	7 - 12		Truncated plug base area, ft^2

TABLE 1. MAIN DATA SET INPUT KEY (Continued)

CARD	QUANTITY	TYPE	MODE	COLUMNS	INPUT OPTIONS	
					CODE	DESCRIPTION
	Minimum Nozzle Throat Area, $A_{T_{Min}}$	Fixed	Real	13 - 18		Normal power throat area
	Maximum Nozzle Throat Area, $A_{T_{Max}}$	Fixed	Real	19 - 24		Max A/B throat area
	Minimum Nozzle Expansion Ratio, (A_E/A_T) Min	Fixed	Real	25 - 30		Minimum physical exit to throat area ratio
	Maximum Nozzle Expansion Ratio, (A_E/A_T) Max	Fixed	Real	31 - 36		Maximum physical exit to throat area ratio
				37 - 72		Blank
24-25				1 - 72		Blank

---

* Format for the mixed mode variable input cards is:

Columns	Quantity	Mode
1 - 3	Card number	Integer
4 - 6	Number of input values	Integer
7 - 9	Input code	Integer
10 - 69	10 fields of 6 columns for input data	Real

TABLE 2. UNIVARIANT CURVE DATA INPUT KEY

CARD	COLUMNS	MODE	CODE	DESCRIPTION
1	1-6	Alpha-Numeric	--	Curve identifier
	7-9	Integer	1	Linear interpolation
			2	Parabolic interpolation
	10-12	Integer	0	No extrapolation on X
			1	Extrapolation on X
	13-15	Integer	--	Number of X and Y numbers
2	1-72	Real	--	Data in order X, Y, X, Y, . . . in fields of six columns each. May require several cards

TABLE 3. BIVARIANT CURVE DATA INPUT KEY

CARD	COLUMNS	MODE	CODE	DESCRIPTION
1	1-6	Alpha-Numeric	--	Curve identifier
	7-9	Integer	3	Linear interpolation on both X and Z
			4	Parabolic interpolation on both X and Z
			5	Parabolic interpolation on X and linear on Z
	10-12	Integer	-1	Extrapolation on X only
			0	No extrapolation
			1	Extrapolation on both X and Z
	13-15	Integer	--	Number of Z values to be read (may be up to 19)
	16-72	Integer	--	Number of X and Y numbers for each Z, in order of input, in fields of 3 columns each
2	1-72	Real	--	Data in order Z, X, Y, X, Y, . . ., Z, X, Y, . . . in fields of six columns each. May require several cards.

are on card 25 and are the same as for the convergent-divergent nozzle except for the addition of the secondary flow specific heat ratio (real number) in columns 19 through 24. The plug nozzle fixed inputs, real numbers in the first six fields of 6 columns on card 23, are the conical plug angle, the plug base area, the minimum throat area, the maximum throat area, the minimum nozzle expansion ratio, and the maximum nozzle expansion ratio.

The following nomenclature is employed for the fixed input terms in Table 1. Self explanatory items are not included.

S/D - Nozzle Spacing Ratio - The ratio of the distance between the centerlines of the nozzles to the maximum nozzle diameter. The approximate values of 1.25 for narrow, 1.625 for intermediate, and 2.0 for wide spaced nozzles are suggested since the data correlations are based on data for these ratios.

NT - Nozzle Type - Convergent type nozzles include convergent-flap and convergent-iris types.

IT - Interfairing Type - The distinguishing characteristics of the interfairings is the orientation of the trailing edge (vertical or horizontal).

A_{MB}/A_M - Metric Break Area Ratio - The approximate value of 0.85 is suggested since the data correlations were obtained with this value.

IMSF - Forward Integral Mean Slope - IMS value for the surface between the maximum fuselage area and the metric break stations. A negative input means that an area distribution curve (X/D_M vs A/A_M) is being included and IMSF will be computed internally.

A_{W_F}/A_M - Initial Boattail Wetted Area Ratio - The wetted area (not including the lifting portion of the wing) from the maximum fuselage area station to the metric break station, divided by the maximum area.

$(A_E/A_T)_{MIN}$ - Minimum Nozzle Expansion Ratio - The minimum expansion ratio used to test for maximum thrust-minus-drag.

$(A_E/A_T)_{MAX}$ - Maximum Nozzle Expansion Ratio - The maximum expansion ratio used to test for maximum thrust-minus-drag. Twenty expansion ratio values are tested between the minimum and maximum values.

4.1.2 Variable Inputs

The variable inputs are those data which are changed as parameters of the performance analysis plus the portions of the aircraft internal and external geometry which change with variations of these parameters. Each type of variable input occurs on a different card, allowing the user to input several values of each run parameter on each card. The program runs all possible combinations of the run parameters, cycling from larger to smaller sequence card numbers and from left to right for a given sequence number.

The input cards for the variable input data, cards 3 through 21 plus nozzle type dependent cards, all have the same data format. The first three fields on each card are of 3 columns each, starting with column 1. These three inputs are integers and include, in order, a sequence or identification number which is the same as the card number, the number of values of the variable input which appear on the card, and an input code selecting from the possible input types allowed for each variable input, as noted in Table 1. All the integer inputs must be right-adjusted in their respective fields. Up to ten values of each parameter may be input on each card in the following ten real number fields of six columns each, columns 10 through 69.

The following input code (ICODE) combinations for input of the freestream conditions in cards 3, 4 and 5 are unacceptable.

ICODE (3)	ICODE (4)	ICODE (5)
1	1	2
1	4	2
≥2	1	2
≥2	1	3
≥2	4	1
≥2	4	2
≥2	4	3

If any of these ICODE combinations are used, an error message will result with a brief description of the inconsistency.

The following nomenclature is employed for the variable input items in Table 1.

PS - Power Setting - The value of power setting is used only as an independent variable on optional user-supplied curves (see cards 7, 8, and CD ejector card 24). The scheme of the power setting values is left up to the user.

P_{T_P}/P_∞ - Nozzle Pressure Ratio - Primary total to freestream pressure ratio in the case of an ejector nozzle.

γ_P - Nozzle Specific Heat Ratio - Primary stream specific heat ratio in the case of an ejector nozzle.

Nozzle Throat Area - Either the physical throat area (A_T) or the aerodynamic throat area ($A_{T_{flow}}$) may be input. Whichever is input, the program will compute the other internally.

α - Nozzle Throat Approach Angle - The angle between the internal wall and the nozzle centerline in the conical part (if any) upstream of the nozzle (primary) throat. For plug nozzles, enter zero.

Nozzle Throat Geometry - For convergent, convergent-divergent, and convergent-divergent ejector nozzles, the ratio of the internal contour radius of curvature (if any) at the nozzle (primary) throat to the throat radius (R_C/R_T). For plug nozzles, the input value is $R_C R_T/S^2$, where R_C is the average radius of curvature between the internal shroud and plug at the throat, R_T is the average radius between the shroud and the plug at the throat, measured from the nozzle centerline, and S is the height of the throat region measured normal to the plug.

A_E/A_T - Nozzle Expansion Ratio - A value not equal to 1.0 for the case of a convergent or unshrouded plug nozzle will result in an error message. A request for the maximum thrust-minus-drag will perturb the expansion ratio from the minimum to the maximum value.

$\Delta X/D_M$ - Nozzle Base Length to Diameter Ratio - The axial distance covered by the base of a nozzle, such as in the case of a flap nozzle, divided by the equivalent maximum diameter.

θ_M - Mean Nozzle Boattail Trailing Edge Angle - The mean boattail angle at the end of the boattail over a distance of one-third the exit radius.

L/D_M - Total Boattail Length to Diameter Ratio - The total length from the maximum area station to the end of the nozzle or interfairing, whichever extends further, divided by the equivalent maximum diameter. The independent variable in the curve IDC172 is the difference between the maximum and total frontal areas, equivalent to the base plus exit areas.

IMSA - Aft Integral Mean Slope - A code equal to 3 means an area distribution curve is being furnished consisting of X/D_M versus A/A_M aft of the metric break in order to calculate IMAS internally. The initial area (metric break area) must be the maximum area of the array and the areas must be continually decreasing with increasing X.

$\Delta A/A_M$ - Adjusted Projected Frontal Area Ratio - An non-zero input is used when the configuration is characterized by an increase in area distribution, such as in the case of the fantail portion of a maximum afterburning nozzle. The value of ΔA is that frontal area, forward and rearward facing, which is not included in the frontal area determined by taking the maximum minus the exit plus base areas.

θ_E - Nozzle Boattail Trailing Edge Angle - The nozzle boattail angle at the trailing edge of the boattail surface.

A_W/A_M - Total Boattail Wetted Area Ratio - The wetted area (not including the control surfaces) from the maximum area station to the end of the body.

A_{ST}/A_T - Shroud Throat Area Ratio - The ratio of the minimum area of the mixed region of an ejector nozzle to the primary throat area.

Pumping Characteristics - User has the option of furnishing either the secondary to primary total pressure ratio, P_{TS}/P_{TP}, or the corrected mass flow ratio, $W_S\sqrt{T_{TS}} / W_P\sqrt{T_{TP}}$.

L_P/D_M - Plug Length to Diameter Ratio - The length of the exposed portion of the plug divided by the equivalent maximum diameter of the configuration.

Most of the variable inputs may be input as curves as an allowable option. To exercise this option, the user places a 1 in column 6 (number of input values) and the appropriate input code in column 9. The data curves are then input as either univariant (one independent and one dependent variable) or bi-variant (one dependent and two independent variables) according to the input code selected. The identifier (name) of each curve (as given in Table 1) is formed by adding' the (two-digit) card number and (one-digit) input code number to the characters IDC. For instance, a bivariant curve for nozzle pressure ratio is called IDC073. The curve data are input on cards following the 25 cards in the main input set.

Univariant curve data must begin with a card containing the curve identifier (alpha-numeric) in columns 1 through 6, an interpolation code integer in columns 7 through 9, an extrapolation code integer in columns 10 through 12, and the total number (integer) of input fields for X and Y data for the curve in columns 13 through 15. The succeeding cards contain the data in the order X_1, Y_1, X_2, Y_2 ... in real number (decimal) fields of six columns each starting in column 1. The univariant curve data input key is found in Table 2.

Bivariant curve data begin with a card containing the identifier (columns 1 through 6), the interpolation code in columns 7 through 9, the extrapolation code in columns 10 through 12, the number of Z values (integer, columns 13 through 15), and the number of X and Y fields for each Z in integer fields of three columns each starting with column 16 and input in the same order as the Z values. The following cards contain the data in the order Z_1, X_{11}, Y_{11}, X_{12}, Y_{12}, ... Z_2, X_{21}, Y_{21}, X_{22}, Y_{22}, ... in real number fields of six columns each starting in column 1. The bivariant curve data input key is found in Table 3. An example of each curve type is given in Appendix A.

4.1.3 Input Routine Control Cards

The input routine control card follows a complete main input set of 25 cards and optional input curves and allows the user one of four options. If further variations in the nozzle independent variable-type inputs (cards 3 - 21) are desired with the inclusion of a new title card, a 99 card (columns 2 and 3) containing the number of variation cards to follow (columns 5 and 6) is used. If no new title card is to follow but variation cards are included, an 88 card is used (8 in columns 2 and 3, the number of variation cards in columns 5 and 6). The variation input cards need contain only those data changed from the previous case but may not be used to change either fixed input or nozzle-dependent variable input. Additional optional data curves follow the variation cards but a new curve may not be used to replace a curve used in the basic case. If another basic case of 25 cards is to follow, an 888 card is used (columns 1, 2, and 3, all other columns blank) followed by the 25 cards and optional data curves. The input routine is terminated by the use of a 999 card. The arrangement of the input, curve, and control cards is shown in Figure 25.

4.2 PROGRAM OUTPUT

The aircraft geometric characteristics and internal and external performance parameters are printed at the end of each case. Input inconsistency or non-convergence of a program iterative routine causes the program to print an error message and advance to the next case. A discussion of the output format, including a listing of all the error messages, is presented below.

4.2.1 Format Description

The input title for the computer run is printed out at the beginning of each set of output data. This is followed by the configuration description (nozzle spacing, interfairing type, nozzle type, vertical stabilizer type, and clean or actual aircraft model) at the left side of the page. The aft-end geometric characteristics and the internal and external performance parameters are listed in four columns, each of which contains descriptive variable names and the associated input or computed value. The first (left hand) column lists the input flight conditions and computed performance parameters. The next column lists the fixed and nozzle-power setting dependent aircraft geometric parameters. Nozzle internal areas and exhaust flow characteristics are listed in the third column. The fourth and final column contains the boattail pressure and friction drags, the base drag, and the total aft-end drag in both force and coefficient forms. The drag coefficient reference area and the portion of the aircraft to which the analysis applies are defined by the comment lines printed out after the numerical data. Sample output pages are shown in Appendix A.

4.2.2 Error Messages

An inconsistent set of input data or a convergence failure in a program subroutine will result in an error message being printed out. When a situation causing an error message is encountered, the program ceases computation on the case being processed and proceeds to the next case. Each error message contains a brief description of the type of error and is generally self-explanatory. In the throat area iteration in the main routine, a location number is printed out in case of non-convergence identifying which of several similar iterations the case passed through.

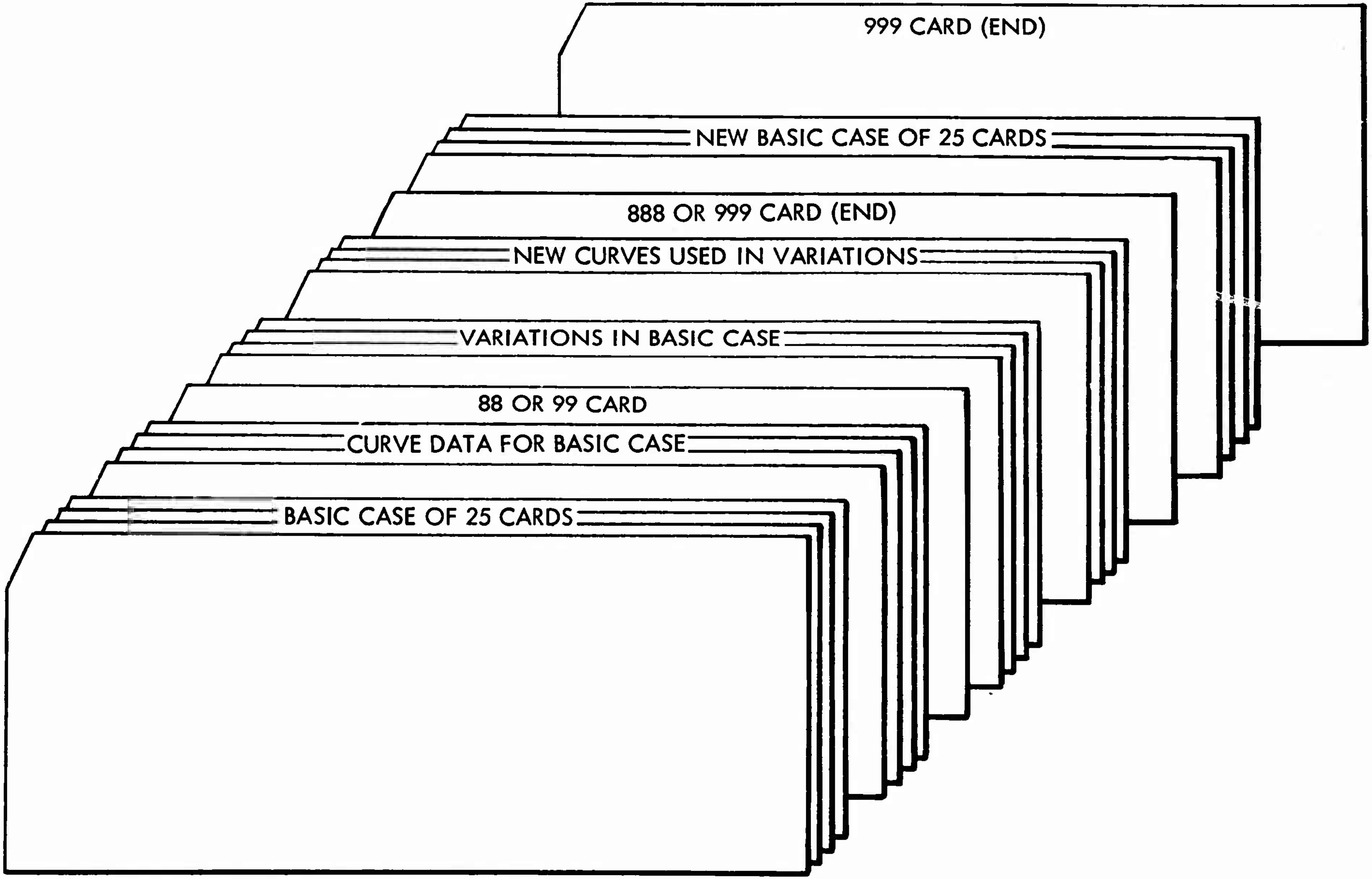

Figure 25. Data Deck Arrangement

Input inconsistencies found by the main program are as follows:

DIMENSIONAL FLIGHT SPEED INPUT REQUIRES AMBIENT PRESSURE AND TEMPERATURE INPUTS
NON-STANDARD TEMPERATURE INCREMENT MAY BE USED ONLY WITH ALTITUDE INPUT FOR PRESSURE
NON-UNITY DIVERGENCE AREA INPUT FOR NON-DIVERGING NOZZLE

Additional input data checks are made by nozzle performance subroutines. Error messages from these checks are:

Subroutine EJECTR
  SECONDARY FLOW TOTAL PRESSURE LESS THAN FREESTREAM STATIC
Subroutine NOZPLG
  PLUG NOZZLE MUST BE CHOKED

Error messages which may result from non-convergence of iterative computations are as follows:

MAIN Routine
  A_T WILL NOT CONVERGE
  INPUT TEMPERATURE ITERATION WILL NOT CONVERGE
Subroutine AFTEND
  REYNOLDS NUMBER ITERATION FAILED
  EXTERNAL EXIT MACH NUMBER ITERATION FAILED
Subroutine EJECTR
  PUMPING CHARACTERISTICS ITERATION FAILED
  EXIT PRESSURE ITERATION FAILED
  MACH NUMBER ITERATION FAILED
  RECOMPRESSION PRESSURE GREATER THAN THROAT PRESSURE
  UNCHOKED WSWP GREATER THAN CHOKED WSWP
Subroutine NOZZLE
  NOZZLE THROAT AREA ITERATION FAILED
  NOZZLE EXIT MACH NUMBER ITERATION FAILED
  COMPUTED NOZZLE DIVERGENCE AREA LESS THAN UNITY
Subroutine NOZPLG
  MACH NUMBER ITERATION FAILED AT LOCAL EXPANSION ANGLE
  NOZZLE EXIT MACH NUMBER ITERATION FAILED

4.3 PROGRAM SETUP

The computer program has been written in FORTRAN IV compatible with the SCOPE 3.3 system for the CDC 6600 digital computer. The program requires 300,000 octal bytes of core, 20 seconds of run time per 100 cases, and standard input/output files, except an alternate file used by LSTDAT, described below.

The computer program source deck contains one main routine and 13 subroutines. These are listed below in hierarchical order, i.e., each indentation indicates that the subroutines in that list are first used by the subroutines in the preceeding list.

- MAIN
    - AFTEND
    - ATMO2
    - EJECTR
    - FLTSPD
    - ITRATI
    - LSTDAT
    - NOZPLG
    - NOZZLE
    - XTRP
        - AREAS
        - ITERAT
        - ITRATA
        - ITRATE

A brief description of each routine is provided below:

MAIN - Processes input, calls subroutines, and prints results.

AFTEND - Computes twin-nozzle/aftbody drag.

ATMO2 - Obtains ambient pressure and temperature for the 1962 U.S. standard atmosphere.

EJECTR - Computes thrust coefficient for a convergent-divergent ejector nozzle.

FLTSPD - Provides freestream Mach number, true air speed, and indicated air speed provided one of these parameters is known.

ITRATI - One-dimensional solution of a non-linear equation.

LSTDAT - Reads in from regular input file, stores an alternate input file to be read by the program for the purpose of listing the input data

NOZPLG - Computes thrust coefficient for shrouded and unshrouded plug nozzles.

NOZZLE - Computes thrust coefficient for convergent and convergent-divergent nozzles.

XTRP - Interpolates and extrapolates input data curves.

AREAS - Determines area and Mach number for both primary and secondary ejector nozzle flow streams provided the pumping characteristics and static to total pressure ratios for one of the streams is known.

ITERAT - Computes Mach number from the Prandtl-Meyer expansion angle.

ITRATA - N-dimensional non-linear simultaneous equation solution.

ITRATE - One-dimensional solution of a non-linear equation.

The order for deck assembly is standard. Job control cards are placed at the front, followed by the source deck containing the main routine and subroutines listed above. Cards with case input data including the input curves, follow the source deck. As noted earlier, only standard input and output files are required, except for the alternate file used by LSTDAT.

APPENDIX I

SAMPLE CASES

TITLE: Figure 26. Sample Computer Program Input - Case 1

PREPARED BY	DATE	CHECKED BY	DATE	JOB NO.	GROUP	PAGE	OF
				W.O.	EWA	1	1
						ID	SEQ

```
TEST CASE 1 - CONVERGENT-DIVERGENT NOZZLE - MAXIMUM THRUST-MINUS-DRAG   C-D   01
  1  2  118.525 1.689 .8216 1.586 .1359  6.05                           C-D   02
  3  2  1   0.9   1.2                                                   C-D   03
  4  1  1  630.                                                         C-D   04
  5  1  1  512.                                                         C-D   05
  6  1  1   3.0                                                         C-D   06
  7  1  1   5.0                                                         C-D   07
  8  1  1   1.4                                                         C-D   08
  9  1  1  .185                                                         C-D   09
 10  1  1    2.                                                         C-D   10
 11  1  1    0.                                                         C-D   11
 12  1  4                                                               C-D   12
 13  1  1 .0635                                                         C-D   13
 14  1  1    0.                                                         C-D   14
 15  1  1    7.                                                         C-D   15
 16  1  1    5.                                                         C-D   16
 17  1  1  3.19                                                         C-D   17
 18  1  1  .594                                                         C-D   18
 19  1  1    0.                                                         C-D   19
 20  1  1   .01                                                         C-D   20
 21  1  1 13.23                                                         C-D   21
  .305   1.2   1.6                                                      C-D   22
                    (BLANK CARDS)                                       C-D   23
                       ↓     ↓                                          C-D   24
                                                                        C-D   25
888                                                                     C-D   26
```

TITLE: Figure 27. Sample Computer Program Input - Case 2

PREPARED BY	DATE	CHECKED BY	DATE	JOB NO.	GROUP	PAGE	OF
				W.O.	EWA	1	2
						ID	SEQ

```
TEST CASE 2 - C-D EJECTOR NOZZLE - FLIGHT SPEED, ALTITUDE INPUT         C-DE  01
  3  3  118.525  2.05 0.873 0.977 .1592   8.0                           C-DE  02
  3  2  3  600.  800.                                                   C-DE  03
  4  1  230000.                                                         C-DE  04
  5  1  3  480.                                                         C-DE  05
  6  1  1   11.                                                         C-DE  06
  7  1  3                                                               C-DE  07
  8  1  1   1.4                                                         C-DE  08
  9  1  3  .085                                                         C-DE  09
 10  1  2                                                               C-DE  10
 11  1  1    0.                                                         C-DE  11
 12  1  3                                                               C-DE  12
 13  1  1  .051                                                         C-DE  13
 14  1  1    0.                                                         C-DE  14
 15  1  1   22.                                                         C-DE  15
 16  1  1   15.                                                         C-DE  16
 17  1  1   2.3                                                         C-DE  17
 18  1  1  .712                                                         C-DE  18
 19  1  1    0.                                                         C-DE  19
 20  1  1   .01                                                         C-DE  20
 21  1  1  15.2                                                         C-DE  21
 22  1  1 1.506                                                         C-DE  22
 23  2  3   0.2   0.4                                                   C-DE  23
 24  1  1   1.0                                                         C-DE  24
   .52 1.001 1.001   1.4                                                C-DE  25
```

FORM 8104-1

TITLE: Figure 27. Sample Computer Program Input - Case 2 (Continued)

PREPARED BY	DATE	CHECKED BY	DATE	JOB NO.	GROUP	PAGE	OF
				W.O.	EWA	2	2

```
IDC073  3  1  2 24 24                                                   C-DE  26
1.    0.    0.    .6    3.    .8    4.    .9    4.    1.1   5.    1.2   C-DE  27
6.    1.4   7.    1.6   9.    1.8   10.   2.0   12.   2.2   13.   2.5   C-DE  28
16.   11.   0.    0.    .6    3.    .8    3.    .9    3.    1.1   5.    C-DE  29
1.2   6.    1.4   7.    1.6   9.    1.8   10.   2.0   12.   2.2   13.   C-DE  30
2.5   16.                                                               C-DE  31
IDC102  2  1 16                                                         C-DE  32
.0322 76.5  .0644 58.   .0967 41.5  .1289 28.0  .1611 17.2  .1846 11.29 C-DE  33
.1846 11.29 .2255 11.29                                                 C-DE  34
IDC123  2  1 18                                                         C-DE  35
0.    1.    .0322 1.165 .0644 1.35  .0967 1.555 .1289 1.77  .1611 1.99  C-DE  36
.1846 2.14  .1846 2.14  .2255 2.14                                      C-DE  37
888                                                                     C-DE  38
```

FORM 8104-1

TITLE: Figure 28. Sample Computer Program Input - Case 3

PREPARED BY	DATE	CHECKED BY	DATE	JOB NO. / W.O.	GROUP / EWA	PAGE 1	OF 2

```
TEST CASE 3 - CØNVERGENT NØZZLE - CALCULATE IMSF, IMSA FRØM AREA DIST.  CØNV  01
  1  1  118.525 1.689 .8216 1.586    -1.   6.05                         CØNV  02
  3  1  1   0.9                                                         CØNV  03
  4  1  4   2.5                                                         CØNV  04
  5  1  3  510.                                                         CØNV  05
  6  1  1   1.0                                                         CØNV  06
  7  2  1   3.0  4.0                                                    CØNV  07
  8  1  1   1.4                                                         CØNV  08
  9  1  3  .181                                                         CØNV  09
 10  1  2                                                               CØNV  10
 11  1  2                                                               CØNV  11
 12  1  1   1.0                                                         CØNV  12
 13  1  1  .045                                                         CØNV  13
 14  1  1    0.                                                         CØNV  14
 15  1  1   19.                                                         CØNV  15
 16  1  1   18.                                                         CØNV  16
 17  1  1 3.191                                                         CØNV  17
 18  1  3                                                               CØNV  18
 19  1  1    0.                                                         CØNV  19
 20  1  1 .0064                                                         CØNV  20
 21  1  1 13.23                                                         CØNV  21
.08785 .1847                                                            CØNV  22
                   (BLANK CARDS)                                        CØNV  23
                      ↓     ↓                                           CØNV  24
                                                                        CØNV  25
```

FORM 8104-1

TITLE: Figure 28. Sample Computer Program Input - Case 3 (continued)

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```
IDC020  1  0 58                                                         CONV  26
0.0   1.0   .0422 .9992 .0990 .9984 .1558 .9971 .2127 .9951 .2695 .9926 CONV  27
.3263 .9893 .3831 .9852 .4400 .9799 .4968 .9741 .5536 .9679 .6105 .9605 CONV  28
.6673 .9527 .7241 .9449 .7810 .9367 .8378 .9280 .8946 .9194 .9514 .9104 CONV  29
1.008 .9009 1.065 .8910 1.122 .8812 1.179 .8721 1.236 .8631 1.292 .8569 CONV  30
1.349 .8520 1.406 .8466 1.463 .8405 1.520 .8331 1.586 .8216             CONV  31
IDC102  2  1 16                                                         CONV  32
.076  0.0   .0879 2.25  .10   4.0   .12   6.0   .1348 7.0   .16   8.23  CONV  33
.1846 9.1   .24   9.77                                                  CONV  34
IDC112  2  1 12                                                         CONV  35
.059  0.0   .0879 .1    .112  .16   .1348 .2    .1846 .25   .24   .271  CONV  36
IDC183  1  0 68                                                         CONV  37
1.586 .8216 1.633 .8154 1.690 .8127 1.747 .8096 1.804 .8022 1.861 .7944 CONV  38
1.918 .7845 1.974 .7726 2.031 .7578 2.088 .7381 2.145 .7167 2.202 .6961 CONV  39
2.259 .6723 2.315 .6491 2.372 .6219 2.429 .5950 2.486 .5660 2.543 .5391 CONV  40
2.600 .5123 2.656 .4831 2.713 .4494 2.770 .4163 2.798 .3974 2.827 .3771 CONV  41
2.855 .3553 2.884 .3320 2.912 .3063 2.941 .2792 2.973 .2435 2.997 .2372 CONV  42
3.054 .2294 3.111 .2236 3.168 .2197 3.191 .2185                         CONV  43
888                                                                     CONV  44
```

FORM 8104-1

TITLE: Figure 29. Sample Computer Program Input - Case 4

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				W.O.	EWA	1	2
						ID	SEQ

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TEST CASE 4 - UNSHRØUDED PLUG NØZZLE - VARY ALTITUDE, CALC. IMSF, IMSA  U PL  01
  4  4  118.525  2.05  .873  .977   -1.   8.0                           U PL  02
  3  1  1   0.9                                                         U PL  03
  4  2  220000.40000.                                                   U PL  04
  5  1  2   25.                                                         U PL  05
  6  1  2   1.0                                                         U PL  06
  7  1  1   4.0                                                         U PL  07
  8  1  1   1.4                                                         U PL  08
  9  1  1 .1795                                                         U PL  09
 10  1  1    0.                                                         U PL  10
 11  1  1    6.                                                         U PL  11
 12  1  1   1.0                                                         U PL  12
 13  1  1 .1485                                                         U PL  13
 14  1  1    0.                                                         U PL  14
 15  1  1   24.                                                         U PL  15
 16  1  1   20.                                                         U PL  16
 17  1  1 2.188                                                         U PL  17
 18  1  3                                                               U PL  18
 19  1  1    0.                                                         U PL  19
 20  1  1  .006                                                         U PL  20
 21  1  1  15.2                                                         U PL  21
 22  1  1 .2194                                                         U PL  22
   15. .0315 .0865 .1795                                                U PL  23
                         (BLANK CARDS)                                  U PL  24
                            ↓     ↓                                     U PL  25
```

FORM 8104-1

TITLE: Figure 29. Sample Computer Program Input - Case 4 (Continued)

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W.O. | EWA | ID | SEQ

```
IDC020    1  040                                                        U PL  26
0.    1.    .0396 .9992 .0912 .9975 .1428 .9947 .1944 .9914 .2460 .9870 U PL  27
.2975 .9819 .3491 .9765 .4007 .9707 .4523 .9639 .5039 .9568 .5555 .9483 U PL  28
.6071 .9388 .6586 .9287 .7102 .9192 .7618 .9107 .8134 .9029 .8650 .8955 U PL  29
.9166 .8870 .9768 .8728                                                 U PL  30
IDC183    1  058                                                        U PL  31
.9768 .8728 1.020 .8555 1.071 .8440 1.123 .8318 1.174 .8159 1.226 .7996 U PL  32
1.278 .7813 1.329 .7606 1.381 .7386 1.432 .7135 1.484 .6868 1.536 .6603 U PL  33
1.587 .6309 1.639 .6004 1.690 .5672 1.742 .5329 1.794 .4964 1.845 .4615 U PL  34
1.897 .4262 1.948 .3876 2.0   .3425 2.026 .3405 2.051 .3415 2.077 .3432 U PL  35
2.103 .3456 2.129 .3459 2.155 .3422 2.180 .3314 2.192 .3225             U PL  36
999                                                                     U PL  37
```

FORM 8104-1

```
           TEST CASE 1 - CONVERGENT-DIVERGENT NOZZLE - MAXIMUM THRUST-MINUS-DRAG

CONFIGURATION
   NARROW SPACING
   HORIZONTAL INTERFAIRING
   CONVERGENT-DIVERGENT NOZZLE
   SINGLE VERTICAL STABILIZER
   CLEAN AIRCRAFT MODEL

FLIGHT CONDITIONS          FIXED AIRFRAME               NOZZLE PARAMETERS                AFT-END DRAG
MACH NO          0.9000    WING AREA          18.52     FLOWING FULL                     DBT PRESS           29.2
P AMB,PSF         630.0    MAX AREA            1.689    THROAT GEOM AREA     0.1850      DBT FRICT            8.4
T AMB,R           512.0    M.B.AREA            1.388    THROAT FLOW AREA     0.1839      D BASE               0.7
                           INIT.BT.LENGTH      2.326    EXIT AREA            0.2220      D TOTAL             38.3
PERFORMANCE                INIT.BT AWET       10.218    GAMMA                1.4000
PS               3.0000                                 CS                   0.9969      CDBT PRESS       0.00441
PTJ/PAMB         5.0000    VARIABLE AIRFRAME            CDN                  0.9940      CDBT FRICT       0.00127
CT               0.9930    BASE AREA           0.014    WSWP                 0.0         CD BASE          0.00011
C(T-DT)          0.9328    TOTAL A FRONTAL     1.217    PTS/PTP              0.0         CD TOTAL         0.00579
                           METRIC A FRONTAL    0.915
                           IMSA               0.5940
                           IMST               0.4367

ALL DRAGS FOR TWO NOZZLES
DRAG COEFFICIENTS REFERENCED TO WING AREA
DRAGS ARE FOR AFT-END AFT OF METRIC BREAK
ALL AREAS ARE IN SQUARE FEET


           TEST CASE 1 - CONVERGENT-DIVERGENT NOZZLE - MAXIMUM THRUST-MINUS-DRAG

CONFIGURATION
   NARROW SPACING
   HORIZONTAL INTERFAIRING
   CONVERGENT-DIVERGENT NOZZLE
   SINGLE VERTICAL STABILIZER
   CLEAN AIRCRAFT MODEL

FLIGHT CONDITIONS          FIXED AIRFRAME               NOZZLE PARAMETERS                AFT-END DRAG
MACH NO          1.2000    WING AREA          18.52     FLOWING FULL                     DBT PRESS          123.2
P AMB,PSF         630.0    MAX AREA            1.689    THROAT GEOM AREA     0.1850      DBT FRICT           25.2
T AMB,R           512.0    M.B.AREA            1.388    THROAT FLOW AREA     0.1839      D BASE              -1.8
                           INIT.BT.LENGTH      2.326    EXIT AREA            0.2812      D TOTAL            146.6
PERFORMANCE                INIT.BT AWET       10.218    GAMMA                1.4000
PS               3.0000                                 CS                   0.9969      CDBT PRESS       0.01047
PTJ/PAMB         5.0000    VARIABLE AIRFRAME            CDN                  0.9940      CDBT FRICT       0.00214
CT               0.9920    BASE AREA           0.018    WSWP                 0.0         CD BASE         -0.00015
C(T-DT)          0.7618    TOTAL A FRONTAL     1.091    PTS/PTP              0.0         CD TOTAL         0.01247
                           METRIC A FRONTAL    0.789
                           IMSA               0.5940
                           IMST               0.4272

ALL DRAGS FOR TWO NOZZLES
DRAG COEFFICIENTS REFERENCED TO WING AREA
DRAGS ARE FOR AFT-END AFT OF MAXIMUM AREA
ALL AREAS ARE IN SQUARE FEET
```

Figure 30. Sample Computer Program Output - Case 1

```
          TEST CASE 2 - C-D EJECTOR NOZZLE - FLIGHT SPEED, ALTITUDE INPUT

CONFIGURATION
   WIDE SPACING
   HORIZONTAL INTERFAIRING
   CONVERGENT-DIVERGENT EJECTOR NOZZLE
   SINGLE VERTICAL STABILIZER
   CLEAN AIRCRAFT MODEL


FLIGHT CONDITIONS         FIXED AIRFRAME              NOZZLE PARAMETERS              AFT-END DRAG
MACH NO       0.8841      WING AREA          18.52    FLOWING FULL                   DBT PRESS          7.3
P AMB,PSF      629.7      MAX AREA           2.050    THROAT GEOM AREA    0.0928     DBT FRICT          9.5
T AMB,R        415.1      M.B.AREA           1.790    THROAT FLOW AREA    0.0850     D BASE             0.4
                          INIT.BT.LENGTH     1.578    EXIT AREA           0.1419     D TOTAL           17.2
PERFORMANCE               INIT.BT AWET      16.400    GAMMA               1.4000
PS           11.0000                                  CS                  0.9970     CDBT PRESS    0.00114
PTJ/PAMB      3.0000      VARIABLE AIRFRAME           CDN                 0.9161     CDBT FRICT    0.00149
CT            0.9965      BASE AREA          0.007    WSWP                0.2000     CD BASE       0.00007
C(T-DT)       0.8926      TOTAL A FRONTAL    1.752    PTS/PTP             0.4231     CD TOTAL      0.00270
                          METRIC A FRONTAL   1.491
                          IWSA              0.7120
                          IWST              0.5900

ALL DRAGS FOR TWO NOZZLES
DRAG COEFFICIENTS REFERENCED TO WING AREA
DRAGS ARE FOR AFT-END AFT OF METRIC BREAK
ALL AREAS ARE IN SQUARE FEET
```

```
          TEST CASE 2 - C-D EJECTOR NOZZLE - FLIGHT SPEED, ALTITUDE INPUT

CONFIGURATION
   WIDE SPACING
   HORIZONTAL INTERFAIRING
   CONVERGENT-DIVERGENT EJECTOR NOZZLE
   SINGLE VERTICAL STABILIZER
   CLEAN AIRCRAFT MODEL


FLIGHT CONDITIONS         FIXED AIRFRAME              NOZZLE PARAMETERS              AFT-END DRAG
MACH NO       0.8841      WING AREA          18.52    FLOWING FULL                   DBT PRESS          7.3
P AMB,PSF      629.7      MAX AREA           2.050    THROAT GEOM AREA    0.0928     DBT FRICT          9.5
T AMB,R        415.1      M.B.AREA           1.790    THROAT FLOW AREA    0.0850     D BASE             0.4
                          INIT.BT.LENGTH     1.578    EXIT AREA           0.1419     D TOTAL           17.2
PERFORMANCE               INIT.BT AWET      16.400    GAMMA               1.4000
PS           11.0000                                  CS                  0.9970     CDBT PRESS    0.00114
PTJ/PAMB      3.0000      VARIABLE AIRFRAME           CDN                 0.9161     CDBT FRICT    0.00149
CT            0.9955      BASE AREA          0.007    WSWP                0.4000     CD BASE       0.00007
C(T-DT)       0.9096      TOTAL A FRONTAL    1.752    PTS/PTP             0.6639     CD TOTAL      0.00269
                          METRIC A FRONTAL   1.491
                          IWSA              0.7120
                          IWST              0.5900

ALL DRAGS FOR TWO NOZZLES
DRAG COEFFICIENTS REFERENCED TO WING AREA
DRAGS ARE FOR AFT-END AFT OF METRIC BREAK
ALL AREAS ARE IN SQUARE FEET
```

Figure 31. Sample Computer Program Output - Case 2

```
            TEST CASE 2 - C-D EJECTOR NOZZLE - FLIGHT SPEED, ALTITUDE INPUT

CONFIGURATION
   WIDE SPACING
   HORIZONTAL INTERFAIRING
   CONVERGENT-DIVERGENT EJECTOR NOZZLE
   SINGLE VERTICAL STABILIZER
   CLEAN AIRCRAFT MODEL


FLIGHT CONDITIONS            FIXED AIRFRAME                 NOZZLE PARAMETERS                 AFT-END DRAG
MACH NO          1.1788      WING AREA           18.52      FLOWING FULL                      DBT PRESS          274.4
P AMB,PSF         629.7      MAX AREA            2.050      THROAT GEOM AREA     0.0928       DBT FRICT           32.0
T AMB,R           375.6      M.B.AREA            1.790      THROAT FLOW AREA     0.0850       D BASE              -5.2
                             INIT.BT.LENGTH      1.578      EXIT AREA            0.1419       D TOTAL            301.2
PERFORMANCE                  INIT.BT AWET       16.400      GAMMA                1.4000
PS              11.0000                                     CS                   0.9970       CDBT PRESS       0.02418
PTJ/PAMB         5.7878      VARIABLE AIRFRAME              CDN                  0.9161       CDBT FRICT       0.00282
CT               0.9906      BASE AREA           0.007      WSWP                 0.2000       CD BASE         -0.00046
C(T-DT)          0.2482      TOTAL A FRONTAL     1.752      PTS/PTP              0.4231       CD TOTAL         0.02655
                             METRIC A FRONTAL    1.491
                             IMSA               0.7120
                             IMST               0.5900

ALL DRAGS FOR TWO NOZZLES
DRAG COEFFICIENTS REFERENCED TO WING AREA
DRAGS ARE FOR AFT-END AFT OF MAXIMUM AREA
ALL AREAS ARE IN SQUARE FEET
```

```
            TEST CASE 2 - C-D EJECTOR NOZZLE - FLIGHT SPEED, ALTITUDE INPUT

CONFIGURATION
   WIDE SPACING
   HORIZONTAL INTERFAIRING
   CONVERGENT-DIVERGENT EJECTOR NOZZLE
   SINGLE VERTICAL STABILIZER
   CLEAN AIRCRAFT MODEL


FLIGHT CONDITIONS            FIXED AIRFRAME                 NOZZLE PARAMETERS                 AFT-END DRAG
MACH NO          1.1788      WING AREA           18.52      FLOWING FULL                      DBT PRESS          274.4
P AMB,PSF         629.7      MAX AREA            2.050      THROAT GEOM AREA     0.0928       DBT FRICT           32.0
T AMB,R           375.6      M.B.AREA            1.790      THROAT FLOW AREA     0.0850       D BASE              -6.3
                             INIT.BT.LENGTH      1.578      EXIT AREA            0.1419       D TOTAL            300.1
PERFORMANCE                  INIT.BT AWET       16.400      GAMMA                1.4000
PS              11.0000                                     CS                   0.9970       CDBT PRESS       0.02418
PTJ/PAMB         5.7878      VARIABLE AIRFRAME              CDN                  0.9161       CDBT FRICT       0.00282
CT               0.9753      BASE AREA           0.007      WSWP                 0.4000       CD BASE         -0.00055
C(T-DT)          0.3491      TOTAL A FRONTAL     1.752      PTS/PTP              0.6639       CD TOTAL         0.02645
                             METRIC A FRONTAL    1.491
                             IMSA               0.7120
                             IMST               0.5900

ALL DRAGS FOR TWO NOZZLES
DRAG COEFFICIENTS REFERENCED TO WING AREA
DRAGS ARE FOR AFT-END AFT OF MAXIMUM AREA
ALL AREAS ARE IN SQUARE FEET
```

Figure 31. Sample Computer Program Output - Case 2 (Continued)

```
          TEST CASE 3 - CONVERGENT NOZZLE - CALCULATE IMSF, IMSA FROM AREA DIST.

CONFIGURATION
   NARROW SPACING
   HORIZONTAL INTERFAIRING
   CONVERGENT NOZZLE
   SINGLE VERTICAL STABILIZER
   CLEAN AIRCRAFT MODEL

FLIGHT CONDITIONS          FIXED AIRFRAME                 NOZZLE PARAMETERS                  AFT-END DRAG
MACH NO         0.9000     WING AREA          18.52       FLOWING FULL                       DBT PRESS              9.5
P AMB,PSF        667.2     MAX AREA            1.689      THROAT GEOM AREA     0.1847        DBT FRICT              9.0
T AMB,R          438.9     M.B.AREA            1.388      THROAT FLOW AREA     0.1810        D BASE                 0.5
                           INIT.BT.LENGTH      2.326      EXIT AREA            0.1847        D TOTAL               19.0
PERFORMANCE                INIT.BT AWET       10.218      GAMMA                1.4000
PS              1.0000                                    CS                   0.9970        CDBT PRESS         0.00135
PTJ/PAMB        3.0000     VARIABLE AIRFRAME              CDN                  0.9798        CDBT FRICT         0.00128
CT              0.9952     BASE AREA           0.008      WSWP                 0.0           CD BASE            0.00008
C(T-DT)         0.9394     TOTAL A FRONTAL     1.303      PTS/PTP              0.0           CD TOTAL           0.00271
                           METRIC A FRONTAL    1.002
                           IMSA                0.5910
                           IMST                0.4420

ALL DRAGS FOR TWO NOZZLES
DRAG COEFFICIENTS REFERENCED TO WING AREA
DRAGS ARE FOR AFT-END AFT OF METRIC BREAK
ALL AREAS ARE IN SQUARE FEET


          TEST CASE 3 - CONVERGENT NOZZLE - CALCULATE IMSF, IMSA FROM AREA DIST.

CONFIGURATION
   NARROW SPACING
   HORIZONTAL INTERFAIRING
   CONVERGENT NOZZLE
   SINGLE VERTICAL STABILIZER
   CLEAN AIRCRAFT MODEL

FLIGHT CONDITIONS          FIXED AIRFRAME                 NOZZLE PARAMETERS                  AFT-END DRAG
MACH NO         0.9000     WING AREA          18.52       FLOWING FULL                       DBT PRESS              4.7
P AMB,PSF        667.2     MAX AREA            1.689      THROAT GEOM AREA     0.1847        DBT FRICT              9.0
T AMB,R          438.9     M.B.AREA            1.388      THROAT FLOW AREA     0.1810        D BASE                 0.5
                           INIT.BT.LENGTH      2.326      EXIT AREA            0.1847        D TOTAL               14.2
PERFORMANCE                INIT.BT AWET       10.218      GAMMA                1.4000
PS              1.0000                                    CS                   0.9970        CDBT PRESS         0.00067
PTJ/PAMB        4.0000     VARIABLE AIRFRAME              CDN                  0.9798        CDBT FRICT         0.00128
CT              0.9850     BASE AREA           0.008      WSWP                 0.0           CD BASE            0.00007
C(T-DT)         0.9567     TOTAL A FRONTAL     1.303      PTS/PTP              0.0           CD TOTAL           0.00202
                           METRIC A FRONTAL    1.002
                           IMSA                0.5910
                           IMST                0.4420

ALL DRAGS FOR TWO NOZZLES
DRAG COEFFICIENTS REFERENCED TO WING AREA
DRAGS ARE FOR AFT-END AFT OF METRIC BREAK
ALL AREAS ARE IN SQUARE FEET
```

Figure 32. Sample Computer Program Output - Case 3

```
          TEST CASE 4 - UNSHROUDED PLUG NOZZLE - VARY ALTITUDE, CALC. IMSF, IMSA

CONFIGURATION
   WIDE SPACING
   HORIZONTAL INTERFAIRING
   UNSHROUDED PLUG NOZZLE
   TWIN VERTICAL STABILIZERS
   ACTUAL AIRCRAFT

FLIGHT CONDITIONS           FIXED AIRFRAME                 NOZZLE PARAMETERS                  AFT-END DRAG
MACH NO           0.9000    WING AREA           18.52      FLOWING FULL                       DBT PRESS              13.4
P AMB,PSF          972.5    MAX AREA            2.050      THROAT GEOM AREA     0.1795        DBT FRICT              15.5
T AMB,R            472.3    M.B.AREA            1.790      THROAT FLOW AREA     0.1759        D BASE                  2.8
                            INIT.BT.LENGTH      1.578      EXIT AREA            0.1795        D TOTAL                31.6
PERFORMANCE                 INIT.BT AWET       16.400      GAMMA                1.4000
PS                1.0000                                   CS                   0.9589        CDBT PRESS        0.00131
PTJ/PAMB          4.0000    VARIABLE AIRFRAME              CDN                  0.9800        CDBT FRICT        0.00151
CT                0.9705    BASE AREA           0.027      WSWP                 0.0           CD BASE           0.00028
C(T-DT)           0.9259    TOTAL A FRONTAL     1.711      PTS/PTP              0.0           CD TOTAL          0.00309
                            METRIC A FRONTAL    1.451
                            IMSA               0.5996
                            IMST               0.5002

ALL DRAGS FOR TWO NOZZLES
DRAG COEFFICIENTS REFERENCED TO WING AREA
DRAGS ARE FOR AFT-END AFT OF METRIC BREAK
ALL AREAS ARE IN SQUARE FEET


          TEST CASE 4 - UNSHROUDED PLUG NOZZLE - VARY ALTITUDE, CALC. IMSF, IMSA

CONFIGURATION
   WIDE SPACING
   HORIZONTAL INTERFAIRING
   UNSHROUDED PLUG NOZZLE
   TWIN VERTICAL STABILIZERS
   ACTUAL AIRCRAFT

FLIGHT CONDITIONS           FIXED AIRFRAME                 NOZZLE PARAMETERS                  AFT-END DRAG
MACH NO           0.9000    WING AREA           18.52      FLOWING FULL                       DBT PRESS               5.4
P AMB,PSF          391.7    MAX AREA            2.050      THROAT GEOM AREA     0.1795        DBT FRICT               7.0
T AMB,R            415.0    M.B.AREA            1.790      THROAT FLOW AREA     0.1759        D BASE                  1.1
                            INIT.BT.LENGTH      1.578      EXIT AREA            0.1795        D TOTAL                13.5
PERFORMANCE                 INIT.BT AWET       16.400      GAMMA                1.4000
PS                1.0000                                   CS                   0.9589        CDBT PRESS        0.00131
PTJ/PAMB          4.0000    VARIABLE AIRFRAME              CDN                  0.9800        CDBT FRICT        0.00169
CT                0.9705    BASE AREA           0.027      WSWP                 0.0           CD BASE           0.00028
C(T-DT)           0.9233    TOTAL A FRONTAL     1.711      PTS/PTP              0.0           CD TOTAL          0.00328
                            METRIC A FRONTAL    1.451
                            IMSA               0.5996
                            IMST               0.5002

ALL DRAGS FOR TWO NOZZLES
DRAG COEFFICIENTS REFERENCED TO WING AREA
DRAGS ARE FOR AFT-END AFT OF METRIC BREAK
ALL AREAS ARE IN SQUARE FEET
```

Figure 33. Sample Computer Program Output - Case 4

APPENDIX II

PROGRAM LISTINGS

```
 DIMENSION DOB( 171),DOB1( 8),RCRTCD(32),FIG5(32),DOB2(45)        MAIN 000
 DIMENSION AA(50), XX(50), DIFF(49), FG2181(36), NVARY(24)        MAIN 001
 DIMENSION IDC072(50),IDC073(300),IDC082(50),IDC092(50),IDC094(50),MAIN 002
1 IDC102(50),IDC112(50),IDC123(50),IDC132(50),IDC142(50),IDC152(50)MAIN 003
2 ,IDC162(50),IDC172(50),IDC182(50),IDC183(100),IDC192(50),       MAIN 004
3 IDC202(50),                                                     MAIN 005
3  IDC203(300),IDC212(50),IDC222(50),IDC232(50),IDC234(50),        MAIN 006
4  IDC242(50),IBLK(23),IDC(1700),INCURV(22),CURV(300)             MAIN 007
 DIMENSION TITLE(18),QIN(30,10),INUM(30),ICODE(30)                MAIN 008
 EQUIVALENCE (IDC(1),IDC072(1)),(IDC( 51), IDC073(1))             MAIN 009
1(IDC(351),IDC082(1)),(IDC(401),IDC092(1)),(IDC(451),IDC094(1)),  MAIN 010
2(IDC(501),IDC102(1)),(IDC(551),IDC112(1)),(IDC(601),IDC123(1)),  MAIN 011
3(IDC(651),IDC132(1)),(IDC(701),IDC142(1)),(IDC(751),IDC152(1)),  MAIN 012
4(IDC(801),IDC162(1)),(IDC(851),IDC172(1)),(IDC(901),IDC182(1)),  MAIN 013
6(IDC( 951),IDC183(1)),(IDC(1051),IDC192(1)),(IDC(1101),IDC202(1)),MAIN 014
6(IDC(1401),IDC203(1)),(IDC(1451),IDC212(1)),(IDC(1501),IDC222(1)),MAIN 015
7(IDC(1550),IDC232(1)),(IDC(1601),IDC234(1)),(IDC(1651),IDC242(1)) MAIN 016
 EQUIVALENCE (INUM3,INUM(3)),(INUM4,INUM(4)),(INUM5,INUM(5)),     MAIN 017
1(INUM6 ,INUM( 6)),(INUM7 ,INUM( 7)),(INUM8 ,INUM( 8)),          MAIN 018
2(INUM9 ,INUM( 9)),(INUM10,INUM(10)),(INUM11,INUM(11)),          MAIN 019
3(INUM12,INUM(12)),(INUM13,INUM(13)),(INUM14,INUM(14)),          MAIN 020
4(INUM15,INUM(15)),(INUM16,INUM(16)),(INUM17,INUM(17)),          MAIN 021
5(INUM18,INUM(18)),(INUM19,INUM(19)),(INUM20,INUM(20)),          MAIN 022
6(INUM21,INUM(21)),(INUM22,INUM(22)),(INUM23,INUM(23)),          MAIN 023
7(INUM24,INUM(24))                                                MAIN 024
 DATA DOB/ *NARR*,*OW S*,*PACI*,*NG  *,*    *,*    *,*    *,*    *,MAIN 025
1*    *,   *INTE*,*RMED*,*IATE*,* SPA*,*CING*,*    *,*    *,*    *,MAIN 026
2*    *,   *WIDE*,* SPA*,*CING*,*    *,*    *,*    *,*    *,*    *,MAIN 027
3*    *,   *WIDE*,* SPA*,*CING*,*    *,*    *,*    *,*    *,*    *,MAIN 028
4*    *,   *HORI*,*ZONT*,*AL I*,*NTER*,*FAIR*,*ING *,*    *,*    *,MAIN 029
5*    *,   *VERT*,*ICAL*,* INT*,*ERFA*,*IRIN*,*G   *,*    *,*    *,MAIN 030
6*    *,   *CONV*,*ERGE*,*NT N*,*OZZL*,*E   *,*    *,*    *,*    *,MAIN 031
7*    *,   *CONV*,*ERGE*,*NT-D*,*IVER*,*GENT*,* NOZ*,*ZLE *,*    *,MAIN 032
8*    *,   *CONV*,*ERGE*,*NT-D*,*IVER*,*GENT*,* EJE*,*CTOR*,* NOZ*,MAIN 033
9*ZLE *,   *UNSH*,*ROUD*,*ED P*,*LUG *,*NOZZ*,*LE  *,*    *,*    *,MAIN 034
A*    *,   *SHRO*,*UDED*,* PLU*,*G NO*,*ZZLE*,*    *,*    *,*    *,MAIN 035
B*    *,   *SING*,*LE V*,*ERTI*,*CAL *,*STAB*,*ILIZ*,*ER  *,*    *,MAIN 036
C*    *,   *TWIN*,* VER*,*TICA*,*L ST*,*ABIL*,*IZER*,*S   *,*    *,MAIN 037
D*    *,   *CLEA*,*N AI*,*RCRA*,*FT M*,*ODEL*,*    *,*    *,*    *,MAIN 038
E*    *,   *ACTU*,*AL A*,*IRCR*,*AFT *,*    *,*    *,*    *,*    *,MAIN 039
F*    */                                                          MAIN 040
 DATA DOB2/*SUBS*,*ONIC*,* FLO*,*W (U*,*NCHO*,*CKED*,*)   *,*    *,MAIN 041
G*    *,   *SEPA*,*RATE*,*D-CU*,*SP I*,*NTER*,*POLA*,*TION*,*    *,MAIN 042
H*    *,   *SEPA*,*RATE*,*D FL*,*OW  *,*    *,*    *,*    *,*    *,MAIN 043
I*    *,   *FLOW*,*ING *,*FULL*,*    *,*    *,*    *,*    *,*    *,MAIN 044
J*    *,   *CRIT*,*ICAL*,*-UNC*,*HOKE*,*D   *,*    *,*    *,*    *,MAIN 045
K*    */                                                          MAIN 046
 DATA DOB1/*METR*,*IC B*,*REAK*,*    *,*MAXI*,*MUM *,*AREA*,*    */MAIN 047
 INTEGER O                                                        MAIN 048
 REAL    LMBDM,IMSF,LEXP,     IDC ,LP,LMB                         MAIN 049
 REAL     IDC072,IDC073,IDC082,IDC092,IDC094,IDC102,IDC112,IDC123, MAIN 050
1 IDC132,IDC142,IDC152,IDC162,IDC172,IDC182,IDC192,IDC202,IDC203,  MAIN 051
2 IDC212,IDC222,IDC232,IDC234,IDC242,IDC183                       MAIN 052
 DATA IBLK/0,     350, 400,      500, 550, 600, 650, 700, 750, 800,MAIN 053
1 850, 900,     1050, 1100,      1450, 1500, 1550,        1650/   MAIN 054
 F3(TERM1)=3.5-SIN(23.8062*(TERM1-.95))/COS(23.8062*(TERM1-.95))  MAIN 055
 C2(TRM1) =8.E-6/((TRM1-.965)**2+4.E-4)                           MAIN 056
 C3(TRMX) = .0011-.00205*SIN(74.8*(TRMX -.952))+((.92-TRMX)*.0574+ MAIN 057
1 ABS((.92-TRMX)*.0574))/2.                                       MAIN 058
```

***CONTINUING

```
      F4(TARM1,TARM2)=TARM1-C2(TARM1)*(TARM2-F3(TARM1))**2+C3(TARM1)
     1 *(TARM2-F3(TARM1))**3
       DATA RCRTCD  /  2.,      1.,      0.,      28.,
     A         0.,     .883,  .05,     .9,      .1,      .917,   .15,     .932,
     B         .2,     .943,  .3,      .961,    .4,      .972,   .5,      .977,
     C         .6,     .981,  .8,      .986,    1.0,     .989,   1.2,     .992,
     D         1.6,    .995,  2.0,     .996     /
       DATA FIG5   /   2.,    1.,      0.,      28.,
     1         0.,     .998,  5.,      .988,    10.,     .978,   15.,     .968,
     2         20.,    .958,  25.,     .947,    30.,     .937,   35.,     .929,
     3         40.,    .921,  50.,     .908,    60.,     .897,   70.,     .888,
     4         80.,    .882,  90.,     .877     /
       DATA FG2181 /   2.,    1.,      0.,      32.,
     A         0.,     .953,  1.,      .96,     2.,      .966,   3.,      .971,
     B         4.,     .975,  5.,      .978,    6.,      .98,    7.,      .982,
     C         8.,     .983,  9.,      .984,    10.,     .9848,  11.,     .9851,
     D         12.,    .9855, 13.,     .9858,   14.,     .9859,  15.,     .9859 /
      D= 3
      CALL LSTDAT(D)
      IND = 888
      IVARY = 19
      DO 1 I = 1,22
    1 NVARY(I) = 0
      PI = 3.1415927
      GAMFS = 1.4
      RRR = 1716.5
      GRAV = 32.174
      RAD = .017453
    5 READ(D,1000)TITLE
      INUM22=1
      INUM23=1
      INUM24=1
      IF(IND .EQ. 888)
     1READ(D,1010) ISD,NT,IT,AWING,AM,AMBAM,LMBDM,IMSF,AWFAM
    6 DO 10 J = 1,IVARY
      READ(D,1015) ICARD,INUM(ICARD),ICODE(ICARD), (QIN(ICARD,I),I=1,10)
      IF(IND .NE. 888) NVARY(ICARD) = ICARD
   10 CONTINUE
      IF(NVARY(4) .EQ. 0 .AND. IND. NE. 888) GO TO 250
      IF(ICODE(4).NE.4)GO TO 12
      DO11 I=1,10
   11 QIN(4,I)=QIN(4,I)*1.E6
      IF(NVARY(4).NE.0)GO TO 250
   12 IF (NT .NE. 1) GO TO 15
      READ(D,1020)ATMIN,ATMAX,Q,Q,(Q,I=1,12)
      GO TO 25
   15 IF (NT .NE. 2) GO TO 20
      READ(D,1020)FL,AEATMN,AEATMX
      READ(D,1020)(Q,I=1,12)
      GO TO 25
   20 IF(NT .NE. 3) GO TO 24
      DO 21 J=1,3
   21 READ(D,1015)ICARD,INUM(ICARD),ICODE(ICARD),(QIN(ICARD,I),I=1,10)
      READ(D,1020)LEXP,AEATMN,AEATMX,GAMS
      GO TO 25
   24 READ(D,1015)ICARD,INUM(ICARD),ICODE(ICARD),(QIN(ICARD,I),I=1,10)
      READ(D,1030)ALPHAP,APB,ATMIN,ATMAX,AEATMN,AEATMX

***CONTINUING
```

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      READ(0,1020)(Q,I=1,8)
 25   IF(ICODE(12).EQ.4 .AND. NT.GT.1)DAEAT=(AEATMX -AEATMN)/20.
      IF(IMSF .GE. 0.) GO TO 250
      READ(0,1040)( INCURV( J),J=1,22)
      NIMSF = INCURV(3)/2
      READ(0,1030) ((XX(I),AA(I)) ,I=1,NIMSF)
      NIM1 = NIMSF-1
      SA = 0.
      DO 370 I=1,NIM1
 370  DIFF(I)=(AA(I+1)-AA(I))/(XX(I+1)-XX(I))
      DO 380 I = 1,NIM1
      ADIFF =-AA(I+1)+AA(I)
 380  SA    =      ADIFF*DIFF(I) +ADIFF*(DIFF(I+1)-DIFF(I))/2. + SA
      IMSF = SA/(1.-AA(NIMSF))
      IMSF = ABS( IMSF)
 250  IF(IND .NE. 888) GO TO 265
      DO 26 I=1,1700
 26   IDC(I) = 0.
 265  DO 30 I=7,24
      IF(IND .NE. 888 .AND. NVARY(I   ) .EQ. 0) GO TO 30
      ILOC = IBLK(I-6)
      IF(I .EQ. 7 .AND. ICODE(7) .EQ. 3) ILOC=ILOC+50
      IF(I.EQ. 9 .AND. ICODE( 9).EQ.4)ILOC=ILOC+50
      IF(I .EQ. 20 .AND. ICODE(20) .EQ. 3) ILOC=ILOC+300
      IF(I.EQ.18 .AND. ICODE(18).EQ.3)ILOC=ILOC+50
      IF(I.EQ.23 .AND. ICODE(23).EQ.4)ILOC=ILOC+50
      IF( NT.NE.3             .AND.I.GE.22)GO TO 30
      IF (ICODE(I) .EQ. 1 )GO TO 30
      IF (ICODE(I) .EQ. 3 .AND.(I .EQ. 9 .OR. I .EQ.23 ))
     1GO TO 30
      IF(ICODE(I) .EQ.  4 .AND.(I .EQ.20 .OR. I.EQ.12))GO TO 30
      IF(ICODE(I).EQ.2.AND.I.EQ.12)GO TO 30
      IF(I.GT.22 .AND. ICODF(I).EQ.3) GO TO 30
      READ(0,1040)( INCURV( J),J=1,22)
      IN = INCURV(3)
      IF(ICODE(I) .NE.  3) GO TO 29
      IF(I .EQ. 12 .OR. I.EQ.18)GO TO 29
C***BIVARIATE
      NUMZ = INCURV(3)
      NUMZ4=NUMZ+3
      ZMAX = 0.
      IK=0
      IZSUM = 0.
      DO 27 J= 4,NUMZ4
      IZSUM = IZSUM + INCURV(J)
 27   ZMAX = AMAX1(FLOAT(INCURV(J)),ZMAX)
      IZMAX=ZMAX
      IZMX1=IZMAX+1
      NUMZXY = 2 + IZSUM
      READ(0,1030) (CURV(K),K=1,NUMZXY)
      DO 28  IR = 1,NUMZ
      IZ = INCURV(IR+3)+1
      DO 280 IS=1,IZ
 280  IDC(ILOC+IK+6+IS)=CURV(IS+IZMX1*(IR-1))
      IDC(ILOC+IK+6)=IZ-1
      IK = IK+ IZ + 1
 28   CONTINUE


***CONTINUING
```

```
      IDC(ILOC+5) =  INCURV(3)
      IDC(ILOC+4) =  ZMAX + 2.
      IDC(ILOC+1) =  INCURV(1)
      IDC(ILOC+2) =  INCURV(2)
      GO TO 30
29    IDC(ILOC+4) =  INCURV(3)
      IDC(ILOC+1) =  INCURV(1)
      IDC(ILOC+2) =  INCURV(2)
      READ(0,1030)(IDC(J+ILOC+4),J=1,IN)
30    CONTINUE
      DM = 2.*SQRT(AM/PI)
      LPRINT = 2
390   IF(ICODE(18) .NE. 3) GO TO 40
      SA = 0.
      AMAMB =  1./AMBAM
      DMDMB =  1./SQRT(AMBAM)
      NIMSA = IDC183(4)/2.
      NIMA1 = NIMSA-1
      DO 395  I = 1,NIMSA
      XX(I) = (IDC183(2*I+3)-LMBDM)*DMDMB
      AA(I) =  IDC183(2*I+4)*AMAMB
      IF(I.GE. 2) DIFF(I-1) =(AA(I)-AA(I-1))/(XX(I)-XX(I-1))
395   CONTINUE
      DO 397  I = 1,NIMA1
397   SA =(AA(I)-AA(I+1))*DIFF(I)+(AA(I)-AA(I+1))*(DIFF(I+1)-DIFF(I))/2.
     1 + SA
     QIN(18,1)=SA/(1.-AA(NIMSA))
     QIN(18,1)=ABS(QIN(18,1))
40    DO 3003   I3=1,INUM3
      DO 3004   I4=1,INUM4
      DO 3005   I5=1,INUM5
      DO 3006   I6=1,INUM6
      DO 3007   I7=1,INUM7
      DO 3008   I8=1,INUM8
      DO 3009   I9=1,INUM9
      DO 3010  I10=1,INUM10
      DO 3011  I11=1,INUM11
      DO 3012  I12=1,INUM12
      DO 3013  I13=1,INUM13
      DO 3014  I14=1,INUM14
      DO 3015  I15=1,INUM15
      DO 3016  I16=1,INUM16
      DO 3017  I17=1,INUM17
      DO 3018  I18=1,INUM18
      DO 3019  I19=1,INUM19
      DO 3020  I20=1,INUM20
      DO 3021  I21=1,INUM21
      DO 3022  I22=1,INUM22
      DO 3023  I23=1,INUM23
      DO 3024  I24=1,INUM24
      V3         =QIN(C3,I3 )
      V4         =QIN(C4,I4 )
      V5         =QIN(C5,I5 )
      V6         =QIN(C6,I6 )
      V7         =QIN(C7,I7 )
      V8         =QIN(C8,I8 )
      V9         =QIN(C9,I9 )
```

***CONTINUING

```
      V10       =QIN(10,I10)
      V11       =QIN(11,I11)
      V12       =QIN(12,I12)
      V13       =QIN(13,I13)
      V14       =QIN(14,I14)
      V15       =QIN(15,I15)
      V16       =QIN(16,I16)
      V17       =QIN(17,I17)
      V18       =QIN(18,I18)
      V19       =QIN(19,I19)
      V20       =QIN(20,I20)
      V21       =QIN(21,I21)
      V22       =QIN(22,I22)
      V23       =QIN(23,I23)
      V24       =QIN(24,I24)
      V209 = 0.
      FLAGO = 0.
      ITMO = 0
      IF(ICODE(3) .GE. 2 ) GO TO 35
C ICODE(3) = 1 SECTION  ****
      IF (ICODE(4) .NE. 1) GO TO 31
      IF (ICODE(5) .EQ. 1) GO TO 47
      IF(ICODE(5) .EQ. 2) GO TO 2001
      V5          = QIN(5,I5)/(1.+.2*QIN(3,I3)**2)
      GO TO 47
 31   IF (ICODE(4) .NE. 2) GO TO 33
      GEOPA = QIN(4,I4)/(QIN(4,I4)/2.084482E7 + 1.)
 32   CALL ATMO2(GEOPA, 0., V5, V4, ERR)
      IF(ICODE(5) .EQ. 1) V5 = QIN(5,I5)
      IF(ICODE(5) .EQ. 2) V5 = V5 + QIN(5,I5)
      IF(ICODE(5) .EQ. 3) V5 = QIN(5,I5)/(1.+.2*QIN(3,I3)**2)
      GO TO 47
 33   IF(ICODE(4) .NE. 3) GO TO 34
      GEOPA = QIN(4,I4)
      GO TO 32
 34   IF(ICODE(5) .EQ. 2) GOTO 2001
      IF(ICODE(5) .EQ. 3) V5 = QIN(5,I5)/(1.+.2*QIN(3,I3)**2)
      V4 = QIN(4,I4)*RRR*V5*2.27E-8*(V5)**(1.5)/(V3*SQRT(GAMFS*RRR*V5)*
     1 (V5+198.6))
      GO TO 47
C ICODE(3) = 2 SECTION ****
 35   IF(ICODE(4) .NE. 1) GO TO 37
      IF(ICODE(5) .EQ. 2) GO TO 2001
      IF(ICODE(5) .EQ. 3) GO TO 2000
 36   CALL FLTSPD(ICODE(3), QIN(3,I3),V3,VK,VM,VI,VMI,V4,V5)
      IF(ICODE(5) - 3) 47,38,38
 37   IF(ICODE(4) .NE. 2) GO TO 39
      GEOPA = QIN(4,I4)/(QIN(4,I4)/2.084482E7 + 1.)
 361  CALL ATMO2 (GEOPA, 0.,V5,V4 ,ERR)
      IF(ICODE(5) .EQ. 1) V5 = QIN(5,I5)
      IF(ICODE(5) .EQ. 2) V5 = QIN(5,I5)+V5
      IF(ICODE(5) .NE. 3) GO TO 36
      KT = 0
      GO TO 36
 38   TTF = V5*(1. + .2*V3**2)-QIN(5,I5)
      SAVV5 = V5
      CALL ITRATE (V5, TTF, 0., KT)
```

***CONTINUING

```
      IF(ABS(TTF) .LT. 001) GO TO 47
      IF(KT .GT. 25) GO TO 2007
      IF(SAVV5 -V5 .GT. 0.) V5 = AMAX1(V5, .8*SAVV5)
      IF(SAVV5 -V5 .LT. 0.) V5 = AMIN1(V5, 1.2*SAVV5)
      IF(KT .EQ. 1) V5 = 1.01*V5
      GO TO 38
39    IF(ICODE(4) .NE. 3) GO TO 2000
      GEOPA =  QIN(4,I4)
      GO TO 361
47    IF(ICODE(7).LE.1) GO TO49
      IF(ICODE(7).GE.3) GO TO48
      CALL XTRP (V3 ,V7,0.,IDC072)
      GO TO 49
48    CALL XTRP (V3,V7,V6,IDC073)
49    IF (ICODE(8).LE.1) GO TO 50
      CALL XTRP (V6,V8,0.,IDC082)
50    IF(NT.GE.4) GO TO 127
      IF(ICODE(9).GE.3) GO TO 66
      IF(ICODE(9).LE.1) GO TO 54
      CALL XTRP (V3,V9,0.,IDC092)
54    IF (ICODE(10).LE.1) GO TO 56
55    CALL XTRP(V9,V10,0.,IDC102)
56    IF (ICODE(11).LE.1) GO TO 58
      CALL XTRP(V9,V11,0.,IDC112)
58    CALL XTRP(V10,V58,0.,FIG5)
      CALL XTRP(V11,V59,0.,RCRTOD)
      V60=AMAX1(V59,V58 )
      A = F3(V60)
      IF (NT.NE.1) GO TO 64
      IF (V7.GE.F3(V60)   )  GO TO 64
      V60 =  F4(V60,V7)
64    V64 = V9*V60
      GO TO 153
66    IF (ICODE(9).EQ.3) GO TO 67
      CALL XTRP (V3,V9,0.,IDC094)
67    IF (ICODE(10).GE.2)GO TO 94
      IF (ICODE(11).GE.2)GO TO 79
      CALL XTRP (V10,V68,0.,FIG5)
      CALL XTRP (V11,V69,0.,RCRTOD)
      V70=AMAX1(V68,V69)
      V60=V70
      A = F3(V70)
      IF(NT.NE.1) GO TO 76
      IF (V7.GE. F3(V70)) GO TO 76
      V70=F4(V70,V7)
      V60=V70
76    V76=V9/V70
      V64=V9
      V9=V76
      GO TO 153
79    V79=V9
      KONV=0
80    CALL XTRP(V79,V11,0.,IDC112)
      CALL XTRP(V11,V81,0.,RCRTOD)
      V82=V79*V81
      CALL ITRATI (V79,(V9-V82)/V9,0.0,  AM, 30,-70,3,KONV)
      IF (KONV-2) 80,84,2003
```

***CONTINUING

```
   84 CALL  XTRP(V10,V84,0.0,FIG5)
      V85= AMAX1(V81,V84)
      V60= V85
      A = F3(V85)
      IF(NT .NE. 1) GO TJ 91
      IF(V7 .GE.F3(V85))GO TO 91
      V85= F4(V85,V7)
      V60= V85
   91 V91= V9/V85
      V64= V9
      V9= V91
      GJ TJ 153
   94 IF(ICODE(11) .GE. 2) GO TO 112
      KJNV=0
      V96=V9
 97   CALLXTRP(V96,V10,0.0,IDC102)
      CALL  XTRP(V10,V98,0.0,FIG5)
      V99= V96*V98
      CALL  ITRATI (V96,(V9-V99)/V9,0.,AM,30,-70,3,KONV)
      IF (KONV-2) 97,101,2004
  101 CALL  XTRP(V11,V101,0.0,RCRTCD)
      V102= AMAX1(V98,V101)
      V60= V102
      A = F3(V102)
      IF(NT.NE. 1) GO TO 108
      IF(V7 .GE.F3(V102))GO TO 108
      V102= F4(V102,V7)
      V60= V102
 108  V108= V9/V102
      V64= V9
      V9= V108
      GJ TJ 153
 112  V112=V9
      KJNV=0
  113 CALL  XTRP(V112,V10,0.0,IDC102)
      CALL  XTRP(V10,V114,0.0,FIG5)
      CALL  XTRP(V112,V11,0.0,IDC112)
      CALL  XTRP(V11,V116,0.0,RCRTCD)
      V117= AMAX1(V114,V116)
      A = F3(V117)
      IF(NT .NE. 1) GO TJ 121
      IF(V7 .GE.F3(V117))GO TO 121
      V117= F4(V117,V7)
 121  V121= V112*V117
      CALL  ITRATI (V112,(V9-V121)/V9,0.,AM,30,-70,3,KONV)
      IF (KONV-2) 113,123,2005
 123  V60= V117
      V64= V9
      V9= V112
      GJ TJ 153
 127  IF (ICODE(9).GE.3) GO TO 136
      IF ( ICODE(9).LE.1) GO TO 130
      CALL  XTRP (V3,V9,0.,IDC092)
 130  IF (ICODE(11).LE.1) GO TO 132
      CALL  XTRP (V9,V11,0.,IDC112)
 132  CALL  XTRP (V11,V132,0.,FG2181)
      V60=V132
```

***CONTINJING

```
      V64= V9*V132
      GO TO 153
136   IF (ICODE(9).EQ.3) GO TO 138
      CALL XTRP (V3,V9,0.,IDC094)
138   IF (ICODE(11).LE.1) GO TO 148
      V139=V9
      KONV=0
139   CALL XTRP ( V139,V11,0.,IDC112)
      CALL XTRP ( V11,V141,0.,FG2181)
      V142=V139*V141
      CALL ITRATI (V139,(V9-V142)/V9,0.,AM,30,-70,3,KONV)
      IF (KONV-2) 139,144,2005
144   V60=V141
      V64=V9
      V9=V139
      GO TO 153
148   CALL XTRP (V11,V148,0.,FG2181)
      V149=V9/V148
      V60=V148
      V64=V9
      V9=V149
153   IF (ICODE(12).GE.4) GO TO 157
      IF (ICODE(12).LE.2) GO TO 158
      CALL XTRP (V9,V12,0.,IDC123)
      GO TO 158
157   V12= AEATMN
158   IF(V12.NE.1.  AND. (NT.LE.1 .OR. NT.EQ.4))GO TO 2008
      V158= V12*V9
      IF(ICODE(13).LE.1) GO TO 161
      CALL XTRP (V158,V13,0.,IDC132)
161   IF (ICODE(14).LE.1) GO TO 163
      CALL XTRP (V158,V14,0.,IDC142)
163   IF (ICODE(15).LE.1) GO TO 165
      CALL XTRP (V158,V15,0.,IDC152)
165   IF(ICODE(16).LE.1) GO TO 167
      CALL XTRP (V158,V16,0.,IDC162)
167   IF (NT.LT.4) GO TO 168
      IF (ICODE(22) .LE. 1) GO TO 1671
      CALL XTRP(V9,V22,0.,IDC222)
1671  AEP = V158/COS(ALPHAP*RAD)**2
      RPB = SQRT(APB/PI)
      LP = V22*DM
      RP = LP*TAN(ALPHAP*RAD)
      RPT = RP + RPB
      APT = PI*RPT**2
      V168 = AEP + APT + V13*V158
      GO TO 169
168   V168=2.*(V158+V13*V158)
169   IF (ICODE(17).LE.1) GO TO 171
      CALL XTRP (V168,V17,0.,IDC172)
171   IF (ICODE(18).NE.2) GO TO 173
      CALL XTRP (V168,V18,0.,IDC182)
173   IF (ICODE(19).LE.1) GO TO 175
      CALL XTRP (V168,V19,0.,IDC192)
175   IF (ICODE(20).LE.1) GO TO 185
      IF (ICODE(20).GE.4) GO TO 183
      IF (ICODE(20).EQ.3) GO TO 180
```

***CONTINUING

```
      CALL XTRP  (V3,V20,0.,IDC202)
      GO TO 185
  180 V180 = V4*V3*SQRT(1.40*RRR*V5)*(V5+198.6)/(2.27E-8*(V5)**(1.5))/
     1(RRR*V5)
      CALL XTRP (V3,V20,V180,IDC203)
      GO TO 185
  183 TAW= V5*(1.+.2*.89*V3**2)
      TPRI = V5*(1.+.035*V3**2+.45*(TAW/V5-1.))
      LEFF = QIN(20,I20)*DM
      AMUP =  2.27E-8*TPRI **1.5/(TPRI+198.6)
      RHO = GRAV*V4/(RRR*V5)
      UFS = V3*SQRT(GAMFS*RRR*V5)
      RHOP = GRAV*V4/(RRR*TPRI)
      REP = LEFF*RHOP*UFS/(AMUP*GRAV)
      AMU=  2.27E-8*V5 **1.5/(V5+198.6)
      RETHET=AMUP/AMU* .044*REP   /(ALOG10(REP   )-1.5)**2
      V20= GRAV*RETHET*AMU/(RHO*UFS*DM)
  185 IF(ICODE(21).LE.1) GO TO 187
      CALL XTRP (V158,V21,0.,IDC212)
  187 IF (NT.LE.2) GO TO 204
      IF (NT.GE.4) GO TO 204
      IF (ICODE(22).LE.1) GO TO 191
      CALL XTRP (V9,V22,0.,IDC222)
  191 IF (ICODE(23).GE.3) GO TO 196
      QQQ=1.
      IF (ICODE(23).LE.1) GO TO 195
      CALL XTRP (V3,V23,0.,IDC232)
  195 GO TO 199
  196 QQQ=2.
      IF (ICODE(23).EQ.3) GO TO 199
      CALL XTRP (V3,V23,0.,IDC234)
  199 IF (ICODE(24).LE.1) GO TO 204
      CALL XTRP (V6,V24,0.,IDC242)
  204 AB  = V13*V158
      AWF = AWFAM*AM
      LMB = LMBDM*DM
      WSOWP1 = 0.
      PTSPTP = 0.
      IF(NT.NE.3)GAMS = V8
      QMODEL = ICODE(6)
      CDN = V60
      NOZERR=0
      IF(NT .LE. 2) CALL NOZZLE(V9,V64,V12,V8,V7,QMODEL,NT,FL,CDN,CT,
     1 FLAG,NOZERR ,TID,CS,XMOM,CTID,A,XMEXIT)
      IF(NOZERR .NE. 0.) GO TO 217
      VOO = V12/V22
      IF(NT. EQ. 3) CALL EJECTR(V9*V22,V64,VOO,1./V22,V7,V23,QQQ,V8,GAMS
     1,V24 ,CDN,CT,WSOWP1,PTSPTP,FLAG,NOZERR,LEXP,CTID,XMOM,QMODEL,
     2    CS,TID,XMEXIT)
      IF(NOZERR .NE. 0.) GO TO 217
      IF(NT .GE.4) CALL NOZPLG(V9,V12,LP,ALPHAP,APB,V8,V7,CDN,CT,FLAG,
     1 NOZERR,TID,CS,QMODEL ,V3,CTID,XMOM,ATMIN,ATMAX,KMEXIT)
      IF(NOZERR .NE. 0.) GO TO 217
      QFS=GAMFS/2.*V4*V3**2
      AMB = AMBAM*AM
      CALL AFTEND(V3,QFS,V4,V5,
     2                         V64,V158,AB,NT,V8,V7,AMB  ,AM,LMBDM,ISD,IT,
```

***CONTINUING

```
     1 IMSF,V18,V15,V16,V14,V20,AWFAM,V21,AWING,V19,V17,
     3                                                  DBTP,DBTF,DB,DT,
     2 CDBTP,CDBTF,CDB,CDT,CTMTD,AFTERR,CTID,XMOM,V9,TID,CT,TMD,IMST,
     5 ATMIN,ATMAX,XMEXIT,GAMS)
      IF(AFTERR .NE. 0.) GO TO 217
      IF(ICODE (12).LE.3) GO TO 216
      IF (FLAGQ.EQ.1.) GO TO 216
      ITMD=ITMD+1
      V209 = AMAX1(V209,TMD)
      IF(V209 .EQ. TMD) V210 = V12
      IF(ITMD.GT.21)    GO TO 214
      V12=V12+DAEAT
      GO TO 158
  214 V12=V210
      FLAGQ=1.
      GO TO 158
 2000 WRITE (6,2500)
 2500 FORMAT(  *0DIMENSIONAL FLIGHT SPEED INPUT REQUIRES AMBIENT PRESSUR
     2E AND TEMPERATURE INPUTS*)
      GO TO   217
 2001 WRITE (6,2501)
 2501 FORMAT(  *0NON-STANDARD TEMPERATURE INCREMENT MAY BE USED ONLY WIT
     1H ALTITUDE INPUT FOR PRESSURE*)
      GO TO   217
 2003 WRITE (6,2503)
 2503 FORMAT (*OAT=V79 WILL NOT CONVERGE*)
      GO TO   217
 2004 WRITE (6,2504)
 2504 FORMAT (*OAT=V96 WILL NOT CONVERGE*)
      GO TO   217
 2005 WRITE (6,2505)
 2505 FORMAT(*OAT= V112  WILL NOT CONVERGE*)
      GO TO   217
 2007 WRITE (6,2507)
 2507 FORMAT (  *INPUT TEMPERATURE ITERATION WILL NOT CONVERGE*)
      GO TO 217
 2008 WRITE (6,2508)
 2508 FORMAT (  *0 NON-UNITY DIVERGENCE AREA INPUT FOR NON-DIVERGING NOZ
     1ZLE*)
      GO TO 217
C PUT OUT CASE ANSWERS
  216 IF (LPRINT .NE. 2) GO TO 2160
      WRITE(6,3999)
      LPRINT = 0
      WRITE (6,3998) TITLE
      GO TO 2161
 2160 WRITE (6,4000) TITLE
 2161 AF = AM-V168
      AFMET = AMB-V168
      IFLAG=FLAG
      ISDX=100
      IF(ISD.EQ.4)ISDX=109
      WRITE (6,4001) (DOB(ISD*9-9+L),L=1,9),(DOB(IT*9+27+L),L=1,9),
     1 (DOB(NT*9+45+L),L=1,9),(DOB(ISDX-1+L),L=1,9),(DOB(ICODE(6)*9+108+
     2 L),L=1,9)
      WRITE (6,4002)
      WRITE (6,4003)  V3,AWING,(DOB2(IFLAG*9+L-9),L=1,7)  ,DBTP ,V4,AM,
```

***CONTINUING

```
     1 V9,DBTF ,V5,AMB,V64,DB  ,LMB,V158,DT  ,AWF,V8
      WRITE(6,4004) V6,CS,CDBTP ,V7,CDN,CDBTF ,CT,AB,WSOWP1,CDB,
     1 CTMTD,AF,PTSPTP,COT  ,AFMET,V18 ,IMST
      IF(V3 .LT. 1.) WRITE(6,4005)(DOB1(J),J=1,4)
      IF(V3 .GE. 1.) WRITE(6,4005)(DOB1(J),J=5,8)
      LPRINT = LPRINT + 1
217   CONTINUE
3024  CONTINUE
3023  CONTINUE
3022  CONTINUE
3021  CONTINUE
3020  CONTINUE
3019  CONTINUE
3018  CONTINUE
3017  CONTINUE
3016  CONTINUE
3015  CONTINUE
3014  CONTINUE
3013  CONTINUE
3012  CONTINUE
3011  CONTINUE
3010  CONTINUE
3009  CONTINUE
3008  CONTINUE
3007  CONTINUE
3006  CONTINUE
3005  CONTINUE
3004  CONTINUE
3003  CONTINUE
      READ(0,1010)IND,IVARY
      IF(IND.EQ.999)STOP
      DO 3025 I =1,22
3025  NVARY(I) = 0
      IF(IND .EQ. 88)GO TO 6
      IF(IND .EQ. 99)GO TO 5
      IVARY = 19
      GO TO 5
9999  STOP
1000  FORMAT(18A4)
1010  FORMAT(3I3,6F6.0)
1015  FORMAT(3I3,10F6.0)
1020  FORMAT(4F6.0)
1030  FORMAT(12F6.0)
1040  FORMAT(6X,22I3)
3998  FORMAT (1H ,T21,18A4)
3999  FORMAT (1H1)
4000  FORMAT (1H0,/,/,T21,18A4)
4001  FORMAT (1H0, T10, *CONFIGURATION*, /,T13, 5(9A4,/,T13))
4002  FORMAT (1H0, T10, *FLIGHT CONDITIONS*, T37, *FIXED AIRFRAME*,
     1 T65, *NOZZLE PARAMETERS*,T96, *AFT-END DRAG*
4003  FORMAT (1H , T10, *MACH NO*,8X, F7.4,5X,*WING AREA*, 7X, F7.2,5X,
     1 7A4,  3X, *DBT PRESS*,6X, F7.1,/,1H , T10,*P AMB,PSF*,6X, F7.1,
     2 5X, *MAX AREA*, 8X, F7.3, 5X, *THROAT GEOM AREA*, 3X, F7.4, 5X,
     3 *DBT FRICT*, 6X, F7.1,/,1H ,T10,*T AMB,R*, 8X,F7.1,5X,*M.B.AREA*,
     4 8X,F7.3, 5X, *THROAT FLOW AREA*, 3X, F7.4, 5X, *D BASE*,9X,F7.1,/
     5 1H ,T37, *INIT.BT.LENGTH*, 2X,F7.3, 5X, *EXIT AREA*,10X,F7.4,5X,
     6 *D TOTAL*, 8X,F7.1,/,1H , T10, *PERFORMANCE*, 15X, *INIT.BT AWET*
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***CONTINUING

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      7 , 4X,F7.3, 5X,*GAMMA*,14X,F7.4 )                                  MAIN 629
 4004 FORMAT (1H ,T10, *PS*,13X,F7.4, T65,*CS*,17X, F7.4,5X,*CDBT PRESS*MAIN 630
      1 , 4X, F8.5,/,1H ,T10,*PTJ/PAMB*,7X,F7.4,5X,*VARIABLE AIRFRAME*,   MAIN 631
      2 11X, *CON*, 16X, F7.4, 5X, *CDBT FRICT*,4X,F8.5,/,1H ,T10, *CT*, MAIN 632
      3 13X, F7.4, 5X,*BASE AREA*, 7X,F7.3,5X, *WSWP*, 15X, F7.4,5X,      MAIN 633
      4 *CD BASE*, 7X,F8.5,/,1H ,T10,*C(T-DT)*,8X,F7.4, 5X,*TOTAL A FRONTMAIN 634
      5AL*,1X,F7.3,5X,*PTS/PTP*,12X, F7.4,5X, *CD TOTAL*,6X,F8.5,/,1H ,   MAIN 635
      6 T37, *METRIC A FRONTAL*,F7.3,/,1H ,T37,*IMSA*,12X, F7.4,/,1H ,    MAIN 636
      7 T37, *IMST*, 12X,F7.4 )                                           MAIN 637
 4005 FORMAT(1H0, T10, *ALL DRAGS FOR TWO NOZZLES*,/,1H , T10, *DRAG COEMAIN 638
      1FFICIENTS REFERENCED TO WING AREA*, /,1H , T10, *DRAGS ARE FOR AFTMAIN 639
      2-END AFT OF *,4A4, /, 1H , T10, *ALL AREAS ARE IN SQUARE FEET* )  MAIN 640
       END                                                                MAIN 641

***END
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```
***BEGIN

      SUBROUTINE AREAS(PTPOP,PTSPTP,GAM,WSOWP1)                         AREAS000
      COMMON /AREA/GAMM,GAMMS,GAMS,APOAT,ASOAT,QMP,QMS                  AREAS005
      PTSOP = PTPOP*PTSPTP                                              AREAS010
      QMP = SQRT(2./GAMM*(PTPOP**(GAMM/GAM)-1.))                        AREAS015
      QMS = SQRT(2./GAMMS*(PTSOP**(GAMMS/GAMS)-1.))                     AREAS020
      BP = 1. + GAMM/2.*QMP**2                                          AREAS025
      BS = 1. + GAMMS/2.*QMS                                            AREAS030
      APOAT = 1./(WSOWP1*SQRT(BP/BS)*QMP/QMS+1.)                        AREAS035
      ASOAT = 1. - APOAT                                                AREAS040
      RETURN                                                            AREAS045
      END                                                               AREAS050

***END
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***BEGIN

      SUBROUTINE ATMO2(ALT,DELT,TAM,PAM,ERR)                            ATMO2000
      ERR = 0                                                           ATMO2001
      ALTKM = ALT*304.8E-6                                              ATMO2002
      IF(ALTKM .GT. 11.)GO TO 10                                        ATMO2003
      TAM = 288.15 - 6.5*ALTKM                                          ATMO2004
      PAM = 2116.22*((288.15-6.5*ALTKM)/288.15)**5.255876               ATMO2005
      GO TO 40                                                          ATMO2006
 10   IF (ALTKM .GT. 20.) GO TO 20                                      ATMO2007
      TAM = 216.65                                                      ATMO2008
      PAM = 472.685*EXP(-.157688*(ALTKM-11.))                           ATMO2009
      GO TO 40                                                          ATMO2010
 20   IF (ALTKM .GT. 32.) GO TO 30                                      ATMO2011
      TAM = 216.65 + (ALTKM-20.)                                        ATMO2012
      PAM = 114.345*(216.65/TAM)**34.1632                               ATMO2013
      GO TO 40                                                          ATMO2014
 30   IF (ALTKM .GT. 47.) GO TO 60                                      ATMO2015
      TAM = 228.65 + 2.8*(ALTKM-32.)                                    ATMO2016
      PAM = 18.129 * (228.65/TAM)**12.20111                             ATMO2017
 40   TAM = (TAM*1.8) + DELT                                            ATMO2018
 50   RETURN                                                            ATMO2019
 60   WRITE(6,1000)                                                     ATMO2020
      GO TO 50                                                          ATMO2021
 1000 FORMAT(1H0,*ATMO ROUTINE LIMITS EXCEEDED* )                       ATMO2022
      END                                                               ATMO2023

***END
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```
***BEGIN

      SUBROUTINE AFTEND(MO,Q,PO,TO,AJCD,AE,AB,NT,GAM,PTPFS,AMB  ,AM,     AFTEN000
     1 LMBDM,ISD,IT,IMSF,IMSA,THETAE,THETAM,DELXDM,THETDM,AWFAM,AWTAM,   AFTEN001
     2 AWING,DELAAM,LDM,DBTP,DBTF,DB,DT,CDBTP,CDBTF,CDB,CDT,CTMTD,       AFTEN002
     3 AFTERR ,CT   ,XMOM,AT,TID,CV,TMD,IMST,ATMIN,ATMAX,ME,GAMS)        AFTEN003
      DIMENSION K2MO1(40) , K2MO2(40) , K6IMST(149) , K3THET(26)         AFTEN004
      DIMENSION K4IMS1(101) , K4IMS2(95) , K4IMS3(101)                   AFTEN005
      DIMENSION K4IMS4(107) , K4IMS5(95) , K4IMS6(30)                    AFTEN006
      DIMENSION K5THM1(125) , K5THM2(93) , K5THM3(109)                   AFTEN007
      DIMENSION K1CVL1(93),K1CVS1(93)                                    AFTEN008
      DIMENSION K1CV(69)                                                 AFTEN009
      DIMENSION K1CVL2(71) , K1CVS2(93)                                  AFTEN010
      DIMENSION K1CVL3(71) , K1CVS3(93)                                  AFTEN011
      REAL    MO,IMST1,LDM,IMSF,IMSA,IMST,ME,K1CV,K1CVS1,K1CVL1          AFTEN012
      REAL    K1CVS2,K1CVL2,K1CVS3,K1CVL3,K2MO1,K2MO2,K3THET             AFTEN013
      REAL    K4IMS1,K4IMS2,K4IMS3,K4IMS4,K4IMS5,K4IMS6                  AFTEN014
      REAL    K5THM1,K5THM2,K5THM3,K6IMST                                AFTEN015
      REAL      LMB,LMBDM,LL,MU,MUP,LEFF,LVAR,LT                         AFTEN016
      DATA K1CV  /   5.,     1.,     0.,     16.,    4.,                 AFTEN017
     A        14.,   0.,     0.,     0.,     .002, -.00075,.004,  -.0013, AFTEN018
     B        .006, -.0018, .008, -.0022, .01,    -.0025,.012,  -.0027,  AFTEN019
     C        14.,   .6,     0.,     0.,     .002, -.00075,.004,  -.0013, AFTEN020
     D        .006,  -.0018,.008,   -.0022,.01,    -.0025,.012,  -.0027, AFTEN021
     E        14.,   .8,     0.,     0.,     .002, -.0014, .004,  -.0024, AFTEN022
     F        .006,  -.003, .008, -.00335,.01,   -.00355,.012,  -.0036,  AFTEN023
     G        14.,   .9,     0.,     0.,     .002, -.0014, .004,  -.0024, AFTEN024
     H        .006,  -.0032,.008,   -.0039,.01,    -.0044,.012,  -.0048/ AFTEN025
      DATA K1CVL1   / 5.,    1.,     0.,     22.,    4.,                 AFTEN026
     A        20.,   0.,     0.,     0.,     .002, .0008,  .004,  .0016, AFTEN027
     B        .006,  .0022, .008,   .0022, .01,   .0019,  .014,  .0012,  AFTEN028
     C        .018,  .0007, .022,   .0002, .03,   -.0006,                AFTEN029
     D        20.,   .6,     0.,     0.,     .002, .0008,  .004,  .0016, AFTEN030
     E        .006,  .0022, .008,   .0022, .01,   .0019,  .014,  .0012,  AFTEN031
     F        .018,  .0007, .022,   .0002, .03,   -.0005,                AFTEN032
     G        20.,   .8,     0.,     0.,     .002, .0014,  .004,  .0027, AFTEN033
     H        .006,  .0035, .008,   .0038, .01,   .0033,  .014,  .0022,  AFTEN034
     I        .018,  .0013, .024,   .0001, .03,   -.0008,                AFTEN035
     J        20.,   .9,     0.,     0.,     .002,  .0018, .004,  .0034, AFTEN036
     K        .006,  .0045, .008,   .0049, .01,    .0043, .014,  .0028,  AFTEN037
     L        .018,  .0016, .024,   .0001, .03,    -.0012   /            AFTEN038
      DATA K1CVS1 /  5.,     1.,     0.,     22.,    4.,                 AFTEN039
     A        20.,   0.,     0.,     0.,     .004,  -.0005,.008,  -.0015, AFTEN040
     B        .012,  -.0025,.016,   -.0031,.02,    -.0035,.022,  -.0037, AFTEN041
     C        .024,  -.0038,.026,   -.0039,.028,   -.004,                AFTEN042
     D        20.,   .6,     0.,     0.,     .004,  -.0005,.008,  -.0015, AFTEN043
     E        .012,  -.0025,.016,   -.0031,.02,    -.0035,.022,  -.0037, AFTEN044
     F        .024,  -.0038,.026,   -.0039,.028,   -.004,                AFTEN045
     G        20.,   .8,     0.,     0.,     .004, -.0003, .008,  -.001,  AFTEN046
     H        .012,  -.0024,.016,   -.0038,.02,   -.0047, .024,  -.0054, AFTEN047
     I        .028,  -.0061,.032,   -.0068,.036,  -.0074,                AFTEN048
     J        20.,   .9,     0.,     0.,     .004,  .0002, .008,  -.0002, AFTEN049
     K        .012,  -.0024,.016,   -.0042,.02,   -.0054, .024,  -.0064, AFTEN050
     L        .028,  -.0074,.032,   -.0084,.039,  -.01    /              AFTEN051
      DATA K1CVL2 /  5.,     1.,     0.,     22.,    3.,                 AFTEN052
     A        20.,   0.,     0.,     0.,     .002,  -.0002,.004,  -.0004, AFTEN053

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B        .006,  -.0007,.008,  -.001, .01,   -.0012,.014,  -.0017,  AFTEN054
C        .018,  -.0022,.022,  -.0026,.025,  -.0029,                AFTEN055
D        20.,   .6,    0.,    0.,    .002,  -.0002,.004,  -.0004,  AFTEN056
E        .006,  -.0007,.008,  -.001, .01,   -.0012,.014,  -.0017,  AFTEN057
F        .018,  -.0022,.022,  -.0026,.025,  -.0029,                AFTEN058
G        20.,   .9,    0.,    0.,    .004,  -.0017,.008,  -.0037,  AFTEN059
H        .012,  -.0053,.016,  -.0065,.02,   -.076, .024,  -.0086,  AFTEN060
I        .028,  -.0096,.032,  -.0104,.036,  -.0112   /             AFTEN061
 DATA K1CVS2 /  5.,    1.,    0.,    22.,   4.,                    AFTEN062
A        20.,   0.,    0.,    0.,    .004,  -.0001,.008,  -.0007,  AFTEN063
B        .012,  -.0012,.016,  -.0016,.02,   -.002, .022,  -.0022,  AFTEN064
C        .024,  -.0024,.026,  -.0026,.028,  -.0028,                AFTEN065
D        20.,   .6,    0.,    0.,    .004,  -.0001,.008,  -.0007,  AFTEN066
E        .012,  -.0012,.016,  -.0016,.02,   -.002, .022,  -.0022,  AFTEN067
F        .024,  -.0024,.026,  -.0026,.028,  -.0028,                AFTEN068
G        20.,   .8,    0.,    0.,    .002,  .0001, .004,  .0002,   AFTEN069
H        .006,  0.,    .008,  -.0006,.012,  -.0019,.016,  -.0028,  AFTEN070
I        .02,   -.0036,.024,  -.0043,.028,  -.0049,                AFTEN071
J        20.,   .9,    0.,    0.,    .002,  0.,    .004,  0.,      AFTEN072
K        .006,  -.0003,.008,  -.0009,.012,  -.0023,.016,  -.0035,  AFTEN073
L        .02,   -.0045,.024,  -.0054,.028,  -.0063   /             AFTEN074
 DATA K1CVL3 /  5.,    1.,    0.,    22.,   3.,                    AFTEN075
A        20.,   0.,    0.,    0.,    .004,  -.0002,.008,  -.0005,  AFTEN076
B        .012,  -.0008,.016,  -.001, .02,   -.0013,.022,  -.0015,  AFTEN077
C        .024,  -.0016,.026,  -.0018,.028,  -.0019,                AFTEN078
D        20.,   .6,    0.,    0.,    .004,  -.0002,.008,  -.0005,  AFTEN079
E        .012,  -.0008,.016,  -.001, .02,   -.0013,.022,  -.0015,  AFTEN080
F        .024,  -.0016,.026,  -.0018,.028,  -.0019,                AFTEN081
G        20.,   .9,    0.,    0.,    .004,  .0003, .006,  .0002,   AFTEN082
H        .008,  -.0007,.012,  -.0023,.016,  -.0035,.02,   -.0044,  AFTEN083
I        .026,  -.0053,.032,  -.006, .04,   -.0066   /             AFTEN084
 DATA K1CVS3 /  5.,    1.,    0.,    22.,   4.,                    AFTEN085
A        20.,   0.,    0.,    0.,    .002,  -.0001,.004,  -.0002,  AFTEN086
B        .006,  -.0004,.008,  -.0006,.012,  -.0011,.016,  -.0016,  AFTEN087
C        .02,   -.0021,.024,  -.0026,.028,  -.0030,                AFTEN088
D        20.,   .6,    0.,    0.,    .002,  -.0001,.004,  -.0002,  AFTEN089
E        .006,  -.0004,.008,  -.0006,.012,  -.0011,.016,  -.0016,  AFTEN090
F        .02,   -.0021,.024,  -.0026,.028,  -.0030,                AFTEN091
G        20.,   .8,    0.,    0.,    .002,  .0004, .004,  .0006,   AFTEN092
H        .006,  .0007, .008,  .0003, .012,  -.0008,.016,  -.0019,  AFTEN093
I        .02,   -.003, .024,  -.0041,.028,  -.0052,                AFTEN094
J        20.,   .9,    0.,    0.,    .002,  .0008, .004,  .0015,   AFTEN095
K        .006,  .0019, .008,  .0011, .012,  -.0005,.016,  -.0019,  AFTEN096
L        .02,   -.0032,.024,  -.0045,.028,  -.0057   /             AFTEN097
 DATA  K2M01  / 2.,    1.,    0.,    36.,                          AFTEN098
*        1.0,   1.1,   1.1,   1.1,   1.2,   1.1,                   AFTEN099
A        1.2,   1.1,   1.3,   .982,  1.4,   .932,  1.5,   .86,     AFTEN100
B        1.6,   .85,   1.7,   .88,   1.8,   .936,  1.9,   .98,     AFTEN101
C        2.0,   1.0,   2.1,   1.0,   2.2,   1.0,   2.3,   1.0,     AFTEN102
D        2.4,   1.0,   2.5,   1.0,   2.6,   1.0  /                 AFTEN103
 DATA K2M02  /  2.,    1.,    0.,    36.,                          AFTEN104
*        1.0,   1.3621,1.1,   1.3621,1.2,   1.3621,                AFTEN105
A        1.2,   1.3621,1.3,   1.20,  1.4,   1.12,  1.5,   1.067,   AFTEN106
B        1.6,   1.0316,1.7,   1.012, 1.8,   1.00,  1.9,   1.0,     AFTEN107
C        2.0,   1.0,   2.1,   1.0,   2.2,   1.0,   2.3,   1.0,     AFTEN108
D        2.4,   1.0,   2.5,   1.0,   2.6,   1.0  /                 AFTEN109
 DATA K3THET  / 2.,    1.,    0.,    22.,                          AFTEN110
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     A     0.,    0.,    2.,    .006,  4.,    .013,  6.,    .019,   AFTEN111
     B     8.,    .026,  10.,   .0325, 12.,   .039,  14.,   .046,   AFTEN112
     C     16.,   .054,  18.,   .065,  20.,   .08    /              AFTEN113
      DATA K4IMS1  / 5.,    1.,    0.,    32.,   3.,              AFTEN114
     A     16.,   .15,   -2.0,  .052,  -1.5,  .055,  -1.25, .056,   AFTEN115
     B     -1.0,  .059,  -.75,  .063,  -.5,   .068,  -.25,  .074,   AFTEN116
     C     0.,    .080,  14*0.,                                    AFTEN117
     D     16.,   .34,   -2.0,  .085,  -1.5,  .091,  -1.25, .096,   AFTEN118
     E     -1.0,  .102,  -.75,  .110,  -.5,   .121,  -.25,  .1375,  AFTEN119
     F     0.,    .157,  14*0.,                                    AFTEN120
     G     30.,   .47,   -2.0,  .10,   -1.5,  .112,  -1.25, .12,    AFTEN121
     H     -1.0,  .129,  -.75,  .14,   -.5,   .152,  -.25,  .17,    AFTEN122
     I     0.,    .198,  .25,   .244,  .55,   .344,  .55,   .344,   AFTEN123
     J     .75,   .291,  1.0,   .246,  1.25,  .216,  1.5,   .198  / AFTEN124
      DATA K4IMS2  / 5.,    1.,    0.,    30.,   3.,              AFTEN125
     A     12.,   .13,   -1.8,  .041,  -1.5,  .040,  -1.0,  .043,   AFTEN126
     B     -.75,  .044,  -.5,   .048,  -.3,   .051,  16*0.,         AFTEN127
     C     12.,   .30,   -1.75, .072,  -1.5,  .075,  -1.0,  .085,   AFTEN128
     D     -.75,  .094,  -.5,   .105,  -.3,   .118,  16*0.,         AFTEN129
     E     28.,   .41,   -1.7,  .08,   -1.5,  .083,  -1.0,  .095,   AFTEN130
     F     -.75,  .103,  -.5,   .115,  -.25,  .144,  0.,    .212,   AFTEN131
     G     .25,   .34,   .38,   .424,  .38,   .424,  .5,    .40,    AFTEN132
     H     1.0,   .295,  1.25,  .26,   1.4,   .24    /              AFTEN133
      DATA K4IMS3  / 5.,    1.,    0.,    32.,   3.,              AFTEN134
     A     16.,   .12,   -1.75, .038,  -1.5,  .037,  -1.25, .037,   AFTEN135
     B     -1.,   .038,  -.75,  .04,   -.5,   .043,  -.25,  .047,   AFTEN136
     C     -.1,   .05,   14*0.,                                    AFTEN137
     D     16.,   .26,   -1.75, .061,  -1.5,  .061,  -1.25, .063,   AFTEN138
     E     -1.,   .065,  -.75,  .069,  -.5,   .073,  -.25,  .079,   AFTEN139
     F     -.1,   .083,  14*0.,                                    AFTEN140
     G     30.,   .39,   -1.75, .069,  -1.5,  .073,  -1.25, .077,   AFTEN141
     H     -1.,   .083,  -.75,  .09,   -.5,   .098,  -.25,  .116,   AFTEN142
     I     0.,    .18,   .25,   .275,  .47,   .393,  .47,   .393,   AFTEN143
     J     .75,   .341,  1.,    .303,  1.25,  .27,   1.6,   .229  / AFTEN144
      DATA K4IMS4  / 5.,    1.,    0.,    34.,   3.,              AFTEN145
     A     12.,   .15,   -1.75, .075,  -1.5,  .076,  -1.0,  .08,    AFTEN146
     B     -.75,  .084,  -.5,   .088,  -.3,   .092,  20*0.,         AFTEN147
     C     12.,   .34,   -1.7,  .062,  -1.5,  .063,  -1.0,  .066,   AFTEN148
     D     -.75,  .07,   -.5,   .074,  -.3,   .077,  20*0.,         AFTEN149
     E     32.,   .47,   -1.7,  .04,   -1.5,  .04,   -1.0,  .045,   AFTEN150
     F     -.5,   .052,  -.35,  .055,  -.35,  .055,  -.25,  .07,    AFTEN151
     G     0.,    .115,  .25,   .177,  .5,    .256,  .6,    .289,   AFTEN152
     H     .6,    .289,  .75,   .258,  1.0,   .214,  1.25,  .179,   AFTEN153
     I     1.4,   .161   /                                          AFTEN154
      DATA K4IMS5  / 5.,    1.,    0.,    30.,   3.,              AFTEN155
     A     14.,   .116,  -1.65, .045,  -1.5,  .045,  -1.25, .047,   AFTEN156
     B     -1.0,  .049,  -.75,  .052,  -.5,.055,-.22,.061,14*0.,    AFTEN157
     C     14.,   .20,   -1.65, .064,  -1.5,  .064,  -1.25, .065,   AFTEN158
     D     -1.0,  .068,  -.75,  .071,  -.5,.075,-.25,.08, 14*0.,    AFTEN159
     E     28.,   .38,   -1.78, .1,    -1.5,  .103,  -1.25, .106,   AFTEN160
     F     -1.0,  .112,  -.75,  .119,  -.5,   .13,   -.25,  .149,   AFTEN161
     G     0.,    .23,   .25,   .428,  .5,    .47,   .5,    .47,    AFTEN162
     H     .75,   .394,  1.0,   .345,  1.32,  .308          /       AFTEN163
      DATA K4IMS6  / 2.,    1.,    0.,    26.,                    AFTEN164
     A     -1.75, .065,  -1.5,  .066,  -1.25, .067,  -1.0,  .07,    AFTEN165
     B     -.75,  .075,  -.5,   .088,  -.25,  .112,  0.,    .15,    AFTEN166
     C     .25,   .215,  .48,   .3,    .48,   .3,    .75,   .25,    AFTEN167


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D        1.0,    .218   /                                                  AFTEN168
 DATA K5THM1   / 5.,     1.,     0.,     30.,    4.,                       AFTEN169
A        28.,    0.,     0.,     -.008, 2.,      -.003, 4.,      .001,     AFTEN170
B        6.,     .004,   8.,     .006,  10.,     .002,  12.,     -.018,    AFTEN171
C        14.,    -.049, 16.,     -.085, 18.,     -.114, 20.,     -.125,    AFTEN172
D        22.,    -.125, 24.,     -.122, 26.,     -.120,                    AFTEN173
E        28.,    .6,     0.,     -.008, 2.,      -.003, 4.,      .001,     AFTEN174
F        6.,     .004,   8.,     .006,  10.,     .002,  12.,     -.018,    AFTEN175
G        14.,    -.049, 16.,     -.085, 18.,     -.114, 20.,     -.125,    AFTEN176
H        22.,    -.125, 24.,     -.122, 26.,     -.120,                    AFTEN177
I        28.,    .8,     0.,     -.026, 2.,      -.019, 4.,      -.014,    AFTEN178
J        6.,     -.009, 8.,      -.006, 10.,     -.009, 12.,     -.037,    AFTEN179
K        14.,    -.075, 16.,     -.113, 18.,     -.145, 20.,     -.158,    AFTEN180
L        22.,    -.156, 24.,     -.152, 25.,     -.147,                    AFTEN181
M        28.,    .9,     0.,     -.026, 2.,      -.019, 4.,      -.014,    AFTEN182
N        6.,     -.009, 8.,      -.006, 10.,     -.009, 12.,     -.037,    AFTEN183
O        14.,    -.075, 16.,     -.113, 18.,     -.145, 20.,     -.158,    AFTEN184
P        22.,    -.156, 24.,     -.152, 26.,     -.147           /         AFTEN185
 DATA K5THM2   / 5.,     1.,     0.,     22.,    4.,                       AFTEN186
A        20.,    0.,     2.,     -.017, 4.,      -.016, 6.,      -.016,    AFTEN187
B        8.,     -.017, 10.,     -.02,  12.,     -.038, 14.,     -.067,    AFTEN188
C        16.,    -.099, 18.,     -.127, 20.,     -.138,                    AFTEN189
D        20.,    .6,     2.,     -.017, 4.,      -.015, 6.,      -.016,    AFTEN190
E        8.,     -.017, 10.,     -.02,  12.,     -.038, 14.,     -.067,    AFTEN191
F        16.,    -.099, 18.,     -.127, 20.,     -.138,                    AFTEN192
G        20.,    .8,     2.,     -.027, 4.,      -.027, 6.,      -.027,    AFTEN193
H        8.,     -.029, 10.,     -.034, 12.,     -.056, 14.,     -.087,    AFTEN194
I        16.,    -.123, 18.,     -.155, 20.,     -.172,                    AFTEN195
J        20.,    .9,     2.,     -.022, 4.,      -.021, 6.,      -.021,    AFTEN196
K        8.,     -.022, 10.,     -.026, 12.,     -.049, 14.,     -.087,    AFTEN197
L        16.,    -.132, 18.,     -.17,  20.,     -.187           /         AFTEN198
 DATA K5THM3   / 5.,     1.,     0.,     26.,    4.,                       AFTEN199
A        24.,    0.,     2.,     -.027, 4.,      -.024, 6.,      -.022,    AFTEN200
B        8.,     -.021, 10.,     -.026, 12.,     -.04,  14.,     -.059,    AFTEN201
C        16.,    -.08,  18.,     -.1,   20.,     -.109, 22.,     -.108,    AFTEN202
D        24.,    -.103,                                                    AFTEN203
E        24.,    .6,     2.,     -.027, 4.,      -.024, 6.,      -.022,    AFTEN204
F        8.,     -.021, 10.,     -.026, 12.,     -.04,  14.,     -.059,    AFTEN205
G        16.,    -.08,  18.,     -.1,   20.,     -.109, 22.,     -.108,    AFTEN206
H        24.,    -.103,                                                    AFTEN207
I        24.,    .8,     2.,     -.052, 4.,      -.048, 6.,      -.046,    AFTEN208
J        8.,     -.045, 10.,     -.048, 12.,     -.064, 14.,     -.087,    AFTEN209
K        16.,    -.112, 18.,     -.136, 20.,     -.148, 22.,     -.146,    AFTEN210
L        24.,    -.14,                                                     AFTEN211
M        24.,    .9,     2.,     -.056, 4.,      -.053, 6.,      -.05,     AFTEN212
N        8.,     -.049, 10.,     -.054, 12.,     -.077, 14.,     -.104,    AFTEN213
O        16.,    -.135, 18.,     -.165, 20.,     -.179, 22.,     -.177,    AFTEN214
P        24.,    -.17           /                                          AFTEN215
 DATA K6IMST   / 3.,     1.,     0.,     24.,    6.,                       AFTEN216
A        18.,    0.,     0.,     0.,     .1,     .01,    .2,     .031,     AFTEN217
B        .3,     .06,    .4,     .093,   .5,     .128,   .6,     .166,     AFTEN218
C        .7,     .205,   .8,     .246,   0.,     0.,     0.,     0.,       AFTEN219
D        20.,    .2,     0.,     0.,     .1,     .012,   .2,     .037,     AFTEN220
E        .3,     .069,   .4,     .105,   .5,     .146,   .6,     .188,     AFTEN221
F        .7,     .23,    .8,     .273,   .9,     .317,   0.,     0.,       AFTEN222
G        22.,    .4,     0.,     0.,     .1,     .016,   .2,     .045,     AFTEN223
H        .3,     .079,   .4,     .119,   .5,     .162,   .6,     .205,     AFTEN224
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     I          .7,    .248,  .8,    .29,   .9,    .333,  1.0,   .377,     AFTEN225
     J          22.,   .6,    0.,    0.,    .1,    .018,  .2,    .052,     AFTEN226
     K          .3,    .095,  .4,    .138,  .5,    .18,   .6,    .224,     AFTEN227
     L          .7,    .266,  .8,    .309,  .9,    .351,  1.0,   .394,     AFTEN228
     M          22.,   .8,    0.,    0.,    .1,    .03,   .2,    .07,      AFTEN229
     N          .3,    .112,  .4,    .153,  .5,    .196,  .6,    .24,      AFTEN230
     O          .7,    .283,  .8,    .325,  .9,    .364,  1.0,   .402,     AFTEN231
     P          22.,   1.0,   0.,    0.,    .1,    .048,  .2,    .098,     AFTEN232
     Q          .3,    .144,  .4,    .185,  .5,    .225,  .6,    .265,     AFTEN233
     R          .7,    .305,  .8,    .345,  .9,    .385,  .93,   .4     /  AFTEN234
      PI = 3.1415927                                                       AFTEN235
      GAMFS = 1.4                                                          AFTEN236
      RRR = 1716.5                                                         AFTEN237
      GRAV = 32.174                                                        AFTEN238
      AO= AE + AB                                                          AFTEN239
      DELA = DELAAM*AM                                                     AFTEN240
      AWF = AWFAM*AM                                                       AFTEN241
      AWT = AWTAM*AM                                                       AFTEN242
      AP=AE-DELA/2.                                                        AFTEN243
      GAMAV = (GAM+GAMS)/2.                                                AFTEN244
      PEPE = XMOM/(GAMAV*AE*ME**2)                                         AFTEN245
      DM =2.*SQRT(AM/PI)                                                   AFTEN246
      DELX = DELXDM*DM                                                     AFTEN247
      AFTERR =0.0                                                          AFTEN248
6     THETR = THETAM* .017453                                              AFTEN249
      RMZA=IMSA*(AMB/AM)**1.5                                              AFTEN250
      IMST=(RMZA/AMB*(AMB-2.0*(AP+AB))+IMSF/AM*(AM-AMB))*AM/(AM-2.*        AFTEN251
     1     (AP+AB))                                                        AFTEN252
   40 RMF= XMOM    *2.0          /(1.4*AM*MO**2)                           AFTEN253
      IF(MO .GT. 1.0) GO TO 60                                             AFTEN254
      PBPE= (0.9+0.0167*RMF)/(0.94+0.06*(2.0*(AB+AE)/AM))                  AFTEN255
      DB  = (1.0-PBPE)*PO*2.0*AB                                           AFTEN256
      GO TO 62                                                             AFTEN257
   60 TETE= (1.0+(GAM-1.0)/2.0)/(1.0+(GAM-1.0)/2.0*ME**2)                  AFTEN258
      DEQ= SQRT(2.0*AM/3.141592)                                           AFTEN259
      PBPE=TETE*3.5/(.5+6.*(AB+AE)                                         AFTEN260
     1                         /AM)*(0.19+1.28*RMF/(1.0+RMF))+             AFTEN261
     1     .047*(5.0-MO)*(2.0*DELX/DEQ+(DELX/DEQ)**2)                      AFTEN262
      DB  = (1.0-PBPE)*PO*2.0*AB                                           AFTEN263
62    IF(MO .LE. 1.0) GO TO 100                                            AFTEN264
      X= SQRT(MO**2-1.0)*IMST                                              AFTEN265
      Z= 2.0*(AP+AB)/AM                                                    AFTEN266
      CALL XTRP(X,RK6,Z,K6IMST)                                            AFTEN267
      IF(ISD .LE. 3) CALL XTRP(MO,RK2,0.,K2MO1)                            AFTEN268
      IF(ISD .GE. 4) CALL XTRP(MO,RK2,0.,K2MO2)                            AFTEN269
      RK3= 0.0                                                             AFTEN270
      IF(MO .GE. 2.0) GO TO 75                                             AFTEN271
      X1= 0.0                                                              AFTEN272
      X3= LDM*SQRT(4.0*AM/3.141592)                                        AFTEN273
      Y1= DEQ/2.0                                                          AFTEN274
      Y3= SQRT((AE+AB)/3.141592)                                           AFTEN275
      Y2= Y3+(X3-X1)*TAN(THETR)                                            AFTEN276
      XM1= MO                                                              AFTEN277
      XM2= MO                                                              AFTEN278
      XM3= MO                                                              AFTEN279
      NV= 1                                                                AFTEN280
      ALPHAO= ATAN(1.0/SQRT(XM2**2-1.0))                                   AFTEN281
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      THETAR=-THETR/2.0                                                 AFTEN282
   65 ALPHA= ATAN(1.0/SQRT(XM3**2-1.0))                                 AFTEN283
      ALPHAR= (ALPHA+ALPHAO)*0.5                                        AFTEN284
      ALP= TAN(ALPHAO)-TAN(THETAR-ALPHAR)                               AFTEN285
      BET= (Y3-Y1)/ALP                                                  AFTEN286
      CET= X1*TAN(ALPHAO)/ALP                                           AFTEN287
      DET= X3*TAN(THETAR-ALPHAR)/ALP                                    AFTEN288
      XX2= BET+CET-DET                                                  AFTEN289
      YY2= (XX2-X1)*TAN(ALPHAO)+Y1                                      AFTEN290
      YR= (YY2+Y3)/2.0                                                  AFTEN291
      T3TT= 1.0/(1.0+0.2*XM3**2)                                        AFTEN292
      T2TT= 1.0/(1.0+0.2*XM2**2)                                        AFTEN293
      TRTT= (T3TT+T2TT)/2.0                                             AFTEN294
      ERQ= SQRT(TRTT/T3TT)/COS(ALPHAR)                                  AFTEN295
      FRQ= TAN(THETAR)*TAN(ALPHAR)                                      AFTEN296
      GRQ= YR*(FRQ+1.0)                                                 AFTEN297
      XM4=ERQ*(FRQ/GRQ*(X3-XX2)+THETR)+XM2*SQRT(T2TT/T3TT)              AFTEN298
      IF(ABS(XM4-XM3).LE. 0.0001*XM3)GO TO 70                           AFTEN299
      XM3= XM4                                                          AFTEN300
      IF(XM4.LE. 1.01 .AND. NN.EQ. 1) XM3= 1.2*MO                       AFTEN301
      IF(XM4.LE. 1.01 .AND. NN.GT. 1) GO TO 70                          AFTEN302
      NN= NN+1                                                          AFTEN303
      IF(NN.LE. 100) GO TO 65                                           AFTEN304
      AFTERR= 1.0                                                       AFTEN305
      WRITE (6,9960)                                                    AFTEN306
      RETURN                                                            AFTEN307
   70 XML= AMAX1(1.05,XM4)                                              AFTEN308
      PLPE= ((1.0+0.2*MO**2)/(1.0+0.2*XML**2))**3.5                     AFTEN309
      QL= 0.7*PO*XML**2*PLPE                                            AFTEN310
      IF((PEPE-PLPE)*PO/QL .GE. 1.4) CALL XTRP(THETAM,RK3,0.,K3THET)    AFTEN311
   75 DBTP = RK6/(MO**2-1.0)*Q*(AM-2.0*(AP+AB))*RK2-                    AFTEN312
     1        2.0*RK3*AQ*(PEPE-PLPE)*PO                                 AFTEN313
      GO TO 211                                                         AFTEN314
  100 X= (MO**2-1.0)/((MO**2*IMSA)**.6666667)                           AFTEN315
      X = AMAX1(X,-2.)                                                  AFTEN316
      Z= 2.0*(AP+AB)/AMB                                                AFTEN317
      IF(NT.EQ.1 .AND. DELXDM .GT. 0.) GO TO 145                        AFTEN318
      IF(IT.EQ.1 .AND. ISD .EQ. 1) CALL XTRP(X,RK4,Z,K4IMS1)            AFTEN319
      IF(IT.EQ.1 .AND. ISD .EQ. 2) CALL XTRP(X,RK4,Z,K4IMS2)            AFTEN320
      IF(IT.EQ.1 .AND. ISD .EQ. 3) CALL XTRP(X,RK4,Z,K4IMS3)            AFTEN321
      IF(IT.EQ.2 .AND. ISD .EQ. 1) CALL XTRP(X,RK4,Z,K4IMS4)            AFTEN322
      IF(IT.EQ.1 .AND. ISD .EQ. 4) CALL XTRP(X,RK4,Z,K4IMS5)            AFTEN323
      GO TO 148                                                         AFTEN324
 145  CALL XTRP(X,RK4,Z,K4IMS6)                                         AFTEN325
 148  IF(ISD .EQ. 1) CALL XTRP(THETAE,RK5,MO,K5THM1)                    AFTEN326
      IF(ISD .EQ. 2) CALL XTRP(THETAE,RK5,MO,K5THM2)                    AFTEN327
      IF(ISD .GE. 3) CALL XTRP(THETAE,RK5,MO,K5THM3)                    AFTEN328
      FID= PTPFS*PO*AJCD*  SQRT(2.0*GAM**2/(GAM-1.0)*(2.0/(GAM+1.0))**  AFTEN329
     1      ((GAM+1.0)/(GAM-1.0))*(1.0-(1.0/PTPFS)**((GAM-1.0)/GAM)))   AFTEN330
      RK1= 0.0                                                          AFTEN331
      IF(CT.GT.1.)GO TO 210                                             AFTEN332
      IF(NT .EQ. 1) GO TO 185                                           AFTEN333
      IF(NT .LE. 3) CALL XTRP(1.-CT,RK1,MO,K1CV)                        AFTEN334
      IF(NT.LE.3)GO TO 210                                              AFTEN335
      IF(NT .GE. 4) CALL XTRP(1.-CT,RKL,MO,K1CVL3)                      AFTEN336
      IF(NT .GE. 4) CALL XTRP(1.-CT,RKS,MO,K1CVS3)                      AFTEN337
      GO TO 186                                                         AFTEN338
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185   IF(DELXDM.EQ. 0.) CALL XTRP(1.-CT,RKL,MO,K1CVL2)                  AFTEN339
      IF(DELXDM.EQ. 0.) CALL XTRP(1.-CT,RKS,MO,K1CVS2)                  AFTEN340
      IF(DELXDM.GT. 0.) CALL XTRP(1.-CT,RKL,MO,K1CVL1)                  AFTEN341
      IF(DELXDM.GT. 0.) CALL XTRP(1.-CT,RKS,MO,K1CVS1)                  AFTEN342
186   RK1 = RKS + (AT-ATMIN)*(RKL-RKS)/(ATMAX-ATMIN)                    AFTEN343
210   DBTP = RK4*((MSA/MO)**.6666667*Q*(AMB-2.0*(AP+AB))+RK5*Q*2.0*     AFTEN344
     1          (AF+AB)+RK1*2.0*FID                                      AFTEN345
211   LMB = LMBDM*DM                                                    AFTEN346
      LL = LDM*DM                                                       AFTEN347
      FTHETA = THETDM*DM                                                AFTEN348
      RHO = PO*GRAV/(RRR*TO)                                            AFTEN349
      MU =  2.27E-8*TO **(1.5)/(TO+198.6)                               AFTEN350
      UO = MO*SQRT(GAMFS*RRR*TO)                                        AFTEN351
      RETHET = RHO*UO*FTHETA/(GRAV*MU)                                  AFTEN352
      TAW = TO*(1.+.178*MO**2)                                          AFTEN353
      TP = TO*(1. + .035*MO**2 + .45*(TAW/TO -1.))                      AFTEN354
      MUP =  2.27E-8*TP **(1.5)/(TP+198.6)                              AFTEN355
      KT = 0                                                            AFTEN356
      RETHP = 1.E6                                                      AFTEN357
215   FUNC = RETHET -MUP*.044*RETHP/(ALOG10(RETHP)-1.5)**2/MU           AFTEN358
      SAVRP = RETHP                                                     AFTEN359
      CALL ITRATE(RETHP,FUNC,0.,KT)                                     AFTEN360
      IF(ABS(FUNC) .LT. 1.E+2) GO TO 225                                AFTEN361
      IF(SAVRP-RETHP .GT. 0.)RETHP = AMAX1(RETHP, .8*SAVRP)             AFTEN362
      IF(SAVRP-RETHP .LT. 0.)RETHP = AMIN1(RETHP, 1.2*SAVRP)            AFTEN363
      IF(KT.GT.99)GO TO 220                                             AFTEN364
      IF(KT.EQ.1)RETHP = 1.01*RETHP                                     AFTEN365
      GO TO 215                                                         AFTEN366
220   AFTERR = 1.                                                       AFTEN367
      WRITE(6,9970)                                                     AFTEN368
      RETURN                                                            AFTEN369
225   RHOP = PO*GRAV/(RRR*TP)                                           AFTEN370
      LEFF = GRAV*MUP*RETHP/(RHOP*UO) + LMB                             AFTEN371
      LVAR = LL - LMB                                                   AFTEN372
      AWET = AWT - AWF                                                  AFTEN373
      LFLG = 1                                                          AFTEN374
230   LT = LEFF + LVAR                                                  AFTEN375
      RELP = RHOP*UO*LT/(GRAV*MUP)                                      AFTEN376
      CF =(.088*(ALOG10(RELP) - 2.3686))*TO/(ALOG10(RELP)-1.5)**3 /TP   AFTEN377
      DBTF = CF*Q*AWET                                                  AFTEN378
      IF(MO .LT. 1.) GO TO 250                                          AFTEN379
      IF(LFLG .EQ. 2) GO TO 235                                         AFTEN380
      LFLG = 2                                                          AFTEN381
      LEFF = LEFF - LMB                                                 AFTEN382
      LVAR = LMB                                                        AFTEN383
      AWET = AWF                                                        AFTEN384
      DBTF1 = DBTF                                                      AFTEN385
      GO TO 230                                                         AFTEN386
235   DBTF =(DBTF1 + DBTF)                                              AFTEN387
250   DT = DBTP + DB + DBTF                                             AFTEN388
      QAWING = Q*AWING                                                  AFTEN389
      CDBTP = DBTP/QAWING                                               AFTEN390
      CDBTF = DBTF/QAWING                                               AFTEN391
      CDB = DB/QAWING                                                   AFTEN392
      TMD = TID*PTPFS*PO*AJCD*CV - DT                                   AFTEN393
      CTMTD = TMD/(TID*PTPFS*PO*AJCD)                                   AFTEN394
      CDT = DT/QAWING                                                   AFTEN395
```

```
      RETURN                                                            AFTEN396
 9960 FORMAT(* EXTERNAL EXIT MACH NUMBER ITERATION FAILED*)             AFTEN397
 9970 FORMAT (*0 REYNOLDS NUMBER ITERATION FAILED*)                     AFTEN398
      END                                                               AFTEN399

***END
```

***BEGIN

```
      SUBROUTINE EJECTR(AT,ATFLOW,AEOAT,APTOAT,ANPR,DUMVAR,QQQ,GAM,GAMS,EJECT001
     1 RSRP,CDN,CT,WSOWP1,PTSPTP,FLAG,NOZERR,FL,CTID,XMOM,QMODEL,   CS, EJECT002
     2 TID,XMEXIT)                                                      EJECT003
      DIMENSION X(2), XMIN(2), XMAX(2), EPS(2), F(2)                    EJECT004
      DIMENSION FIG5(32) , FIG11A(157) , FIG11B(112) , FIG11(269)       EJECT005
      EQUIVALENCE (FIG11A(1),FIG11(1)), (FIG11B(1),FIG11(158))          EJECT006
      REAL    MP,MEP,MS,MES,ME                                          EJECT007
      COMMON /AREA/GAMM,GAMMS,GAMSP,APOAT,ASOAT,MP,MS                   EJECT008
      DATA FIG11A /  5.,     1.,     0.,     24.,    11.,               EJECT009
     A         14.,    0.,     1.025, .997,  1.1,    .997,  1.2,    .997,  EJECT010
     B         1.3,    .997,   1.4,   .997,  1.5,    .997,  1.56,   .997,  EJECT011
     C         0.,     0.,     0.,    0.,    0.,     0.,    0.,     0.,    EJECT012
     D         14.,    2.,     1.025, .997,  1.1,    .997,  1.2,    .997,  EJECT013
     E         1.2,    .997,   1.25,  .996,  1.3,    .995,  1.3,    .995,  EJECT014
     F         0.,     0.,     0.,    0.,    0.,     0.,    0.,     0.,    EJECT015
     G         20.,    4.,     1.025, .997,  1.1,    .997,  1.2,    .997,  EJECT016
     H         1.3,    .997,   1.33,  .997,  1.33,   .997,  1.4,    .9965, EJECT017
     I         1.5,    .996,   1.6,   .9952, 1.63,   .995,  0.,     0.,    EJECT018
     J         22.,    6.,     1.025, .997,  1.1,    .997,  1.2,    .997,  EJECT019
     K         1.4,    .997,   1.5,   .997,  1.56,   .997,  1.56,   .997,  EJECT020
     L         1.6,    .996,   1.7,   .9945, 1.8,    .993,  2.0,    .9928, EJECT021
     M         22.,    8.,     1.025, .997,  1.06,   .997,  1.06,   .997,  EJECT022
     N         1.1,    .9955,  1.2,   .9945, 1.3,    .995,  1.4,    .9955, EJECT023
     O         1.5,    .996,   1.6,   .9965, 1.8,    .996,  2.0,    .994,  EJECT024
     P         22.,    10.,    1.025, .997,  1.045,  .997,  1.045,  .997,  EJECT025
     Q         1.1,    .993,   1.2,   .991,  1.3,    .991,  1.4,    .9915, EJECT026
     R         1.5,    .992,   1.6,   .9925, 1.8,    .9935, 2.0,    .994,  EJECT027
     S         22.,    12.,    1.025, .997,  1.032,  .997,  1.032,  .997/  EJECT028
      DATA FIG11B   /                                                   EJECT029
     A         1.1,    .9915,  1.2,   .9875, 1.3,    .986,  1.4,    .9862, EJECT030
     B         1.5,    .9865,  1.6,   .9875, 1.8,    .989,  2.0,    .990,  EJECT031
     C         22.,    14.,    1.025, .997,  1.032,  .997,  1.032,  .997,  EJECT032
     D         1.1,    .990,   1.2,   .9835, 1.3,    .9815, 1.4,    .981,  EJECT033
     E         1.5,    .981,   1.6,   .9812, 1.8,    .982,  2.0,    .9835, EJECT034
     F         22.,    16.,    1.025, .997,  1.025,  .997,  1.1,    .988,  EJECT035
     G         1.2,    .9815,  1.3,   .978,  1.4,    .976,  1.5,    .975,  EJECT036
     H         1.6,    .9753,  1.7,   .9756, 1.8,    .976,  2.0,    .977,  EJECT037
     I         22.,    18.,    1.025, .997,  1.1,    .986,  1.2,    .978,  EJECT038
     J         1.3,    .973,   1.4,   .971,  1.5,    .969,  1.6,    .968,  EJECT039
     K         1.7,    .968,   1.8,   .968,  1.9,    .9685, 2.0,    .969,  EJECT040
     L         22.,    20.,    1.025, .997,  1.1,    .9845, 1.2,    .976,  EJECT041
     M         1.3,    .970,   1.4,   .966,  1.5,    .963,  1.6,    .9622, EJECT042
     N         1.7,    .9618,  1.8,   .9615, 1.9,    .9612, 2.0,    .9612 / EJECT043
      NOZERR=0                                                          EJECT044
      CTID = 1.                                                         EJECT045
      GAMSP = GAMS                                                      EJECT046
      PI = 4.*ATAN(1.)                                                  EJECT047
      RAD = .0174533                                                    EJECT048
      RS = 53.35                                                        EJECT049
      RP = RS/RSRP                                                      EJECT050
      APT = APTOAT*AT                                                   EJECT051
      CDN = ATFLOW/APT                                                  EJECT052
      AE = AEOAT * AT                                                   EJECT053
      RE = SQRT(AE/PI)                                                  EJECT054
```

***CONTINUING

```
      RT = SQRT(AT/PI)                                                  EJECT055
      THET = ATAN((RE-RT)/SQRT(FL-(RE-RT)**2))                          EJECT056
      THETA = THET / RAD                                                EJECT057
      IF(DUMVAR.GT. 0.0) GO TO 3                                        EJECT058
      PTSPTP= 1.0                                                       EJECT059
      WSOWP1= 0.0                                                       EJECT060
      FFIDS= 0.0                                                        EJECT061
      AEOAPS= AE/ATFLOW                                                 EJECT062
      G12GM1=(GAM+1.0)/(2.0*(GAM-1.0))                                  EJECT063
      QMQ = 1.                                                          EJECT064
      KTE= 0                                                            EJECT065
    4 FUNC5 = AEOAPS-((2.+(GAM  -1.)*QMQ**2)/(GAM  +1))**G12GM1/QMQ     EJECT066
      SVQMQE = QMQ                                                      EJECT067
      CALL ITRATE(QMQ, FUNC5, 0., KTE)                                  EJECT068
      IF (ABS(FUNC5) .LE. 1.E-4) GO TO 5                                EJECT069
      IF (KTE.GT. 25) GO TO 475                                         EJECT070
      IF (KTE.EQ. 1) QMQ = 1.01                                         EJECT071
      IF (SVQMQE - QMQ  .GT. 0.)QMQ  = AMAX1(QMQ , .5*(1.+SVQMQE))      EJECT072
      IF (SVQMQE - QMQ  .LT. 0.)QMQ  = AMIN1(QMQ , 1.2*SVQMQE)          EJECT073
      GO TO 4                                                           EJECT074
    5 PQPTT = (1. + .5* QMQ**2 *(GAM  -1.))**(-GAM  /(GAM  -1.))        EJECT075
      FSAAPS =PQPTT*AEOAPS*(1.+GAM  *QMQ**2)                            EJECT076
      CALL XTRP(AEOAPS,CS,THETA,FIG11)                                  EJECT077
      IF (QMODEL .GE.2.)CS = CS-.007                                    EJECT078
      FFID= GAM*SQRT(2./(GAM-1.)*(2./(GAM+1.))**((GAM+1.)/(GAM-1.))     EJECT079
     1 *(1.-(1./ANPR)**((GAM-1.)/GAM)))                                 EJECT080
      FLAG = 4.                                                         EJECT081
      TID = FFID                                                        EJECT082
      XMEXIT = QMQ                                                      EJECT083
      CT =(CS*FSAAPS- AEOAPS/ANPR)/FFID                                 EJECT084
      IF(PQPTT.GT. 1./ANPR)CTID= (FSAAPS-AEOAPS/ANPR)/FFID              EJECT085
      XMOM= (PQPTT*AEOAPS*GAM*QMQ**2)*ANPR*ATFLOW                       EJECT086
      GO TO 500                                                         EJECT087
    3 IF(QQQ.EQ.2.) GO TO 2                                             EJECT088
      PTSPTP=DUMVAR                                                     EJECT089
      IF(ANPR*PTSPTP .GE. 1.) GO TO 2                                   EJECT090
      WRITE(6,1020)                                                     EJECT091
      GO TO 490                                                         EJECT092
    2 GAMP = GAM + 1.                                                   EJECT093
      GAMM = GAM - 1.                                                   EJECT094
      GAMPS = GAMS + 1.                                                 EJECT095
      GAMMS = GAMS - 1.                                                 EJECT096
      ZZ = 0.                                                           EJECT097
      AEOAPS = AEOAT/APTOAT/CDN                                         EJECT098
      ATOAPS = 1./APTOAT/CDN                                            EJECT099
C***  WASWAP SECTION                                                    EJECT100
      IF(QQQ.EQ.1.) GO TO 19                                            EJECT101
      WSOWP1=DUMVAR                                                     EJECT102
      WSOWP2=DUMVAR                                                     EJECT103
      KONV=0                                                            EJECT104
      X(1)  = .25                                                       EJECT105
      X(2)  = .75                                                       EJECT106
      XMIN(1) = 0.                                                      EJECT107
      XMIN(2) = 0.                                                      EJECT108
      XMAX(1) = 1.                                                      EJECT109
      XMAX(2) = 1.                                                      EJECT110
      EPS(1) = 1.E-4                                                    EJECT111
```

***CONTINUING

```
      EPS(2) = 1.E-4                                                    EJECT112
   10 POPTP=X(1)                                                        EJECT113
      POPTS=X(2)                                                        EJECT114
      PTSPTP=X(1)/X(2)                                                  EJECT115
      WSOWPA =ATOAPS*SQRT(2./GAMM*(GAMP/2.)**(GAMP/GAMM))-(1./POPTP)**(1EJECT116
     1./GAM)/SQRT(1.-POPTP**(GAMM/GAM))                                 EJECT117
      F(1)=                                                             EJECT118
     1WSOWP1 - WSOWPA*SQRT(RP/RS*GAMS/GAM*GAMM/GAMMS*(1.-POPTS**(GAMMS/ EJECT119
     1GAMS)))*PTSPTP*POPTS**(1./GAMS)                                   EJECT120
      WSOWPB = GAMS/GAM*PTSPTP*(GAMM/2.*(POPTP**((1.-GAM)/GAM)-1.)**(-1.EJECT121
     1) - 1.) *POPTS**(1./GAMS)*SQRT(2./RS*GAMS/GAMMS* (1.-POPTS**(GAMMSEJECT122
     2/GAMS)))                                                          EJECT123
      F(2)=                                                             EJECT124
     1WSOWP2 - WSOWPB/((1.-GAMMS/2.*(POPTS**((1.-GAMS)/GAMS)-1.)**(-1.) EJECT125
     1 )*POPTP**(1./GAM)*SQRT(2./RP*GAM/GAMM*(1.-POPTP**(GAMM/GAM))))   EJECT126
      CALL ITRATA(2,X,F,XMIN,XMAX,EPS,30,KONV)                          EJECT127
      IF(KONV - 2) 10,11,485                                            EJECT128
   11 PPOPTP=POPTP                                                      EJECT129
      IF(X(1).LT.0. .OR. X(2).LT.0.)GO TO 485                           EJECT130
      IF(ANPR*PTSPTP .GE. 1.) GO TO 46                                  EJECT131
      WRITE(6,1020)                                                     EJECT132
      GO TO 490                                                         EJECT133
   19 KT = 0                                                            EJECT134
      POPTP=PTSPTP*.75                                                  EJECT135
      POPTS = POPTP/PTSPTP                                              EJECT136
   20 POPTS=POPTP/PTSPTP                                                EJECT137
      WSOWP1 =ATOAPS*SQRT(2./GAMM*(GAMP/2.)**(GAMP/GAMM))-(1./POPTP)**(1EJECT138
     1./GAM)/SQRT(1.-POPTP**(GAMM/GAM))                                 EJECT139
      WSOWP1 = WSOWP1*SQRT(RP/RS*GAMS/GAM*GAMM/GAMMS*(1.-POPTS**(GAMMS/ EJECT140
     1GAMS)))*PTSPTP*POPTS**(1./GAMS)                                   EJECT141
      WSOWP2 = GAMS/GAM*PTSPTP*(GAMM/2.*(POPTP**((1.-GAM)/GAM)-1.)**(-1.EJECT142
     1) - 1.) *POPTS**(1./GAMS)*SQRT(2./RS*GAMS/GAMMS* (1.-POPTS**(GAMMSEJECT143
     2/GAMS)))                                                          EJECT144
      WSOWP2 = WSOWP2/((1.-GAMMS/2.*(POPTS**((1.-GAMS)/GAMS)-1.)**(-1.) EJECT145
     1 )*POPTP**(1./GAM)*SQRT(2./RP*GAM/GAMM*(1.-POPTP**(GAMM/GAM))))   EJECT146
      FUNKY = WSOWP1 - WSOWP2                                           EJECT147
       SPOPTP = POPTP                                                   EJECT148
      CALL ITRATE(POPTP, FUNKY, 0., KT)                                 EJECT149
      IF(ABS(FUNKY) .LT. .001) GO TO 40                                 EJECT150
      IF(KT .GT. 25) GO TO 485                                          EJECT151
      IF (SPOPTP - POPTP  .GT. 0.) POPTP =AMAX1(POPTP , .8*SPOPTP)      EJECT152
      IF (SPOPTP - POPTP  .LT. 0.) POPTP =AMIN1(POPTP,.5*(SPOPTP+       EJECT153
     1 PTSPTP))                                                         EJECT154
      IF(KT .EQ. 1) POPTP = 1.01* POPTP                                 EJECT155
      GO TO 20                                                          EJECT156
   40 PPOPTP = POPTP                                                    EJECT157
      WSOWP1 = .5*( WSOWP1+WSOWP2)                                      EJECT158
   46 PTOPTP = PPOPTP                                                   EJECT159
      WSWP = WSOWP1                                                     EJECT160
      AEOA = AEOAPS                                                     EJECT161
      POPTPX = PPOPTP                                                   EJECT162
      XX = 1.                                                           EJECT163
      BERN = 1                                                          EJECT164
      GO TO 200                                                         EJECT165
   47 PEOPTP = POPTPZ                                                   EJECT166
      PEOPTS = POPTS                                                    EJECT167
      IF (PEOPTP .GE. 1./ANPR) GO TO 80                                 EJECT168
```

***CONTINUING

```
      ZZ = 1.                                                           EJECT169
      IF(QQQ.EQ.1.) GO TO 48                                            EJECT170
      WSOWPC = AEOAPS*SQRT(2./GAMM*(GAMP/2.)**(GAMP/GAMM))-(1./(1./ANPR)EJECT171
     1 )**(1./GAM)/SQRT(1.-(1./ANPR)**(GAMM/GAM))                       EJECT172
      PTSPTP=                                                           EJECT173
     1WSOWP1 / WSOWPC*SQRT(RP/RS*GAMS/GAM*GAMM/GAMMS*(1.-POPTS**(GAMMS/ EJECT174
     1 GAMS)))        *POPTS**(1./GAMS)                                 EJECT175
      IF(ANPR*PTSPTP .GE. 1.) GO TO 49                                  EJECT176
      WRITE(6,1020)                                                     EJECT177
      GO TO 490                                                         EJECT178
   48 WSOWPX = AEOAPS*SQRT(2./GAMM*(GAMP/2.)**(GAMP/GAMM))-(1./(1./ANPR)EJECT179
     1 )**(1./GAM)/SQRT(1.-(1./ANPR)**(GAMM/GAM))                       EJECT180
      POPTS = 1./ANPR/PTSPTP                                            EJECT181
      WSOWPX = WSOWPX*SQRT(RP/RS*GAMS/GAM*GAMM/GAMMS*(1.-POPTS**(GAMMS/ EJECT182
     1 GAMS)))*PTSPTP*POPTS**(1./GAMS)                                  EJECT183
      IF(WSOWPX.GT.WSOWP1) GO TO 480                                    EJECT184
      WSOWP1=WSOWPX                                                     EJECT185
   49 WSWP = WSOWP1                                                     EJECT186
      AEOA = ATOAPS                                                     EJECT187
      BERN = 2                                                          EJECT188
      POPTPX = POPTPZ-.1                                                EJECT189
      GO TO 200                                                         EJECT190
   50 PTOPTP = POPTPZ                                                   EJECT191
      PTOPTS = POPTS                                                    EJECT192
   80 IF (ZZ .EQ. 0.) CALL AREAS(1./PPOPTP,PTSPTP,GAM,WSOWP1)           EJECT193
      IF (ZZ .NE. 0.) CALL AREAS(1./PTOPTP,PTSPTP,GAM,WSOWP1)           EJECT194
      IF (PEOPTP .GT. 1./ANPR) GO TO 90                                 EJECT195
      CALL AREAS(ANPR,PTSPTP,GAM,WSOWP1)                                EJECT196
      AEPAPS = APOAT*AEOAT*ATOAPS                                       EJECT197
      AESAPS = ASOAT*AEOAT*ATOAPS                                       EJECT198
      MEP = MP                                                          EJECT199
      MES = MS                                                          EJECT200
      XMEXIT = APOAT*MEP + ASOAT*MES                                    EJECT201
      FFID = GAM*SQRT(2./GAMM*(2./GAMP)**(GAMP/GAMM)*(1.-(1./ANPR)**(   EJECT202
     1 GAMM/GAM)))                                                      EJECT203
      FFIDS = WSOWP1*SQRT(2.*GAM*GAMS/GAMMS*RS/RP*(2./GAMP)**(GAMP/GAMM)EJECT204
     1 * (1.-(1./ANPR*1./PTSPTP)**(GAMMS/GAMS)))                        EJECT205
      FFS = PEOPTP*AFPAPS*(1.+GAM*MEP**2)                               EJECT206
      FFSS = PEOPTS*PTSPTP*AESAPS*(1.+GAMS*MES**2)                      EJECT207
      TID = FFID + FFIDS                                                EJECT208
      CS = .995                                                         EJECT209
      IF (QMODEL .GE.2.)CS = CS-.007                                    EJECT210
      CT = (CS  *(FFS+FFSS)-AEOAT*ATOAPS/ANPR)/(FFID+FFIDS)             EJECT211
      FLAG = 1.                                                         EJECT212
      XMOM = (PEOPTP*AEPAPS*GAM*MEP**2+ PEOPTS*PTSPTP*AESAPS*GAMS*MES**2EJECT213
     1)*ANPR*ATFLOW                                                     EJECT214
      GO TO 500                                                         EJECT215
   90 PRCOPC = .63 + .04*ALOG(WSOWP1+.01)                               EJECT216
      PRCOTT = PRCOPC/ANPR                                              EJECT217
      WSWP = WSOWP1                                                     EJECT218
      BERN = 3                                                          EJECT219
      XX = 0.                                                           EJECT220
      AEOA = AEOAPS                                                     EJECT221
      POPTPX = PPOPTP-.001                                              EJECT222
      GO TO 200                                                         EJECT223
   92 PEOPTP = POPTPZ                                                   EJECT224
      PEOPTS = POPTS                                                    EJECT225
```

***CONTINUING

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      IF (PRCPTT .LE. PEUPTP) GO TO 190                                 EJECT226
      IF (PRCPTT .LE. PPOPTP) GO TO 95                                  EJECT227
      WRITE (6,1010)                                                    EJECT228
      GO TO 490                                                         EJECT229
 95   PRCPTS = PRCPTT/PTSPTP                                            EJECT230
      AIOAPS = WSOWP1/(SQRT(RP/RS*GAMS/GAM*GAMM/GAMMS*(1.-PRCPTS**(GAMMSEJECT231
     1/GAMS)))*PTSPTP*PRCPTS**(1./GAMS))                                EJECT232
      AIOAPS = AIOAPS + (1./PRCPTT)**(1./GAM)/SQRT(1.-PRCPTT**(GAMM/GAM EJECT233
     1 ))                                                               EJECT234
      AIOAPS = AIOAPS/SQRT(2./GAMM*(GAMP/2.)**(GAMP/GAMM))              EJECT235
      AIOAT = AIOAPS/ATOAPS                                             EJECT236
      PPFCSP = .1*10.**(.0332*THETA+.72)*(10.*(AEOAT-1.))**(-.77)       EJECT237
C***  MACH SECTION                                                      EJECT238
      ME = 1.                                                           EJECT239
      KT = 0                                                            EJECT240
 150  FUNKX = AEOAT  - 1./ME*((2.+GAMM*ME**2)/GAMP)**(GAMP/(2.*GAMM))   EJECT241
      SVQMEE = ME                                                       EJECT242
      CALL  ITRATE(ME,FUNKX,0.,KT)                                      EJECT243
      IF (ABS(FUNKX) .LE. 1.E-4) GO TO 160                              EJECT244
      IF (KT .GT. 25) GO TO 475                                         EJECT245
      IF (KT .EQ. 1) ME = 1.01                                          EJECT246
      IF (SVQMEE-ME .GT. 0.) ME  = AMAX1(ME, .5*(1.+SVQMEE))            EJECT247
      IF (SVQMEE-ME .LT. 0.) ME  = AMIN1(ME, 1.2*SVQMEE)                EJECT248
      GO TO 150                                                         EJECT249
 160  CONTINUE                                                          EJECT250
      PTTPE = (1.+GAMM/2.*ME**2)**(GAM/GAMM)                            EJECT251
      PTTPCP = PPFCSP*PTTPF                                             EJECT252
      IF (PTTPCP .GE. ANPR) GO TO 180                                   EJECT253
      CALL  AREAS(1./PRCPTT,PTSPTP,GAM,WSOWP1)                          EJECT254
      AEPAPS = APOAT*AIOAPS                                             EJECT255
      AESAPS = ASOAT*AIOAPS                                             EJECT256
      MEP = MP                                                          EJECT257
      MES = MS                                                          EJECT258
      XMEXIT = APOAT*MEP + ASOAT*MES                                    EJECT259
      FFS = PRCPTT*AEPAPS*(1.+GAM*MEP**2)                               EJECT260
      FFSS = PRCPTS*PTSPTP*AESAPS*(1.+GAMS*MES**2)                      EJECT261
      PDA = 1./ANPR*((6.+PRCPTT*ANPR)/7.)*(AEOAT*ATOAPS-AIOAPS)         EJECT262
      FFID = GAM*SQRT(2./GAMM*(2./GAMP)**(GAMP/GAMM)*(1.-(1./ANPR)**(GAMEJECT263
     1M/GAM)))                                                          EJECT264
      FFIDS = WSOWP1*SQRT(2.*GAM*GAMS/GAMMS*RS/RP*(2./GAMP)**(GAMP/GAMM)EJECT265
     1 * (1.-(1./ANPR*1./PTSPTP)**(GAMMS/GAMS)))                        EJECT266
      CALL XTRP(AIOAT, CS, THETA, FIG11)                                EJECT267
      IF (QMODEL .GE.2.)CS = CS-.007                                    EJECT268
      TID = FFID + FFIDS                                                EJECT269
      CT = (CS*(FFS+FFSS)-AEOAT*ATOAPS/ANPR+PDA)/(FFID+FFIDS)           EJECT270
      FLAG = 3.                                                         EJECT271
      XMOM = (PRCPTT*AEPAPS*GAM*MEP**2 + PRCPTS*PTSPTP*AESAPS*GAMS*MES**EJECT272
     12)*ANPR*ATFLOW                                                    EJECT273
      GO TO 500                                                         EJECT274
 180  CALL AREAS(1./PEOPTP,PTSPTP,GAM,WSOWP1)                           EJECT275
      AEPAPS = APOAT*AEOAT*ATOAPS                                       EJECT276
      AESAPS = ASOAT*AEOAT*ATOAPS                                       EJECT277
      MEP = MP                                                          EJECT278
      MES = MS                                                          EJECT279
      XMEXAA = APOAT*MEP + ASOAT*MES                                    EJECT280
      FFID = GAM*SQRT(2./GAMM*(2./GAMP)**(GAMP/GAMM)*(1.-PEOPTP**(GAMMS EJECT281
     1/GAMS)))                                                          EJECT282
```

***CONTINUING

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      FFIDS = WSOWP1*SQRT(2.*GAM*GAMS/GAMMS*RS/RP*(2./GAMP)**(GAMP/GAMM)EJECT283
     1 * (1.-PEOPTS**(GAMMS/GAMS)))                                     EJECT284
      FFS = PEOPTP*AEPAPS*(1.+GAM*MEP**2)                               EJECT285
      FFSS = PEOPTS*PTSPTP*AESAPS*(1.+GAMS*MES**2)                      EJECT286
      TID1= FFID + FFIDS                                                EJECT287
      CS = .995                                                         EJECT288
      IF(QMODEL.GE.2.)CS=CS-.007                                        EJECT289
      CTGEO = (CS   *(FFS+FFSS)-AEOAT*ATOAPS*PEOPTP)/(FFID+FFIDS)       EJECT290
      XMOM1= (PEOPTP*AEPAPS*GAM*MEP**2+ PEOPTS*PTSPTP*AESAPS*GAMS*MES**2EJECT291
     1)*ANPR*ATFLOW                                                     EJECT292
      PRCPTT = PRCOPO/PTTPCP                                            EJECT293
      PRCPTS = PRCPTT/PTSPTP                                            EJECT294
      AIOAPS = WSOWP1/(SQRT(RP/RS*GAMS/GAM*GAMM/GAMMS*(1.-PRCPTS**(GAMMSEJECT295
     1 /GAMS)))*PTSPTP*PRCPTS**(1./GAMS))                               EJECT296
      AIOAPS = AIOAPS*(1./PRCPTT)**(1./GAM)/SQRT(1.-PRCPTT**(GAMM/GAM)) EJECT297
      AIOAPS = AIOAPS/SQRT(2./GAMM*(GAMP/2.)**(GAMP/GAMM) )             EJECT298
      AIOAT = AIOAPS/ATOAPS                                             EJECT299
      CALL AREAS(1./PRCPTT,PTSPTP,GAM,WSOWP1)                           EJECT300
      AEPAPS = APOAT*AIOAPS                                             EJECT301
      AESAPS = ASOAT*AIOAPS                                             EJECT302
      MEP = MP                                                          EJECT303
      MES = MS                                                          EJECT304
      XMEXBB = APOAT*MEP + ASOAT*MES                                    EJECT305
      FFS = PRCPTT*AEPAPS*(1.+GAM*MEP**2)                               EJECT306
      FFSS = PRCPTS*PTSPTP*AESAPS*(1.+GAMS*MES**2)                      EJECT307
      PDA = 1./PTTPCP*((6.+PRCPTT*PTTPCP)/7.)*(AEOAT*ATOAPS-AIOAPS)     EJECT308
      FFID = GAM*SQRT(2./GAMM*(2./GAMP)**(GAMP/GAMM)*(1.-(1./PTTPCP)    EJECT309
     1 **(GAMM/GAM)))                                                   EJECT310
      FFIDS = WSOWP1*SQRT(2.*GAM*GAMS/GAMMS*RS/RP*(2./GAMP)**(GAMP/GAMM)EJECT311
     1      *(1.-(1./PTTPCP*1./PTSPTP)**(GAMMS/GAMS)))                  EJECT312
      CALL XTRP(AIOAT, CS, THETA, FIG11)                                EJECT313
      IF (QMODEL .GE.2.)CS = CS-.007                                    EJECT314
      CTCUSP = (CS*(FFS+FFSS)-AEOAT*ATOAPS/PTTPCP+PDA)/(FFID+FFIDS)     EJECT315
      TID2 = FFID + FFIDS                                               EJECT316
      TID = TID2 - (PTTPCP - ANPR)*(TID2-TID1)/(PTTPCP-1./PEOPTP)       EJECT317
      CT = CTCUSP-(PTTPCP-ANPR)*(CTCUSP-CTGEO)/(PTTPCP-1./PEOPTP)       EJECT318
      XMEXIT=XMEXBB-(PTTPCP-ANPR)*(XMEXBB-XMEXAA)/(PTTPCP-1./PEOPTP)    EJECT319
      FLAG = 2.                                                         EJECT320
      XMOM2= (PRCPTT*AEPAPS*GAM*MEP**2 + PRCPTS*PTSPTP*AESAPS*GAMS*MES**EJECT321
     12)*ANPR*ATFLOW                                                    EJECT322
      XMOM = XMOM2 - (PTTPCP-ANPR)*(XMOM2-XMOM1)/(PTTPCP-1./PEOPTP)     EJECT323
      GO TO 500                                                         EJECT324
  190 CALL AREAS(1./PEUPTP,PTSPTP,GAM,WSOWP1)                           EJECT325
      AEPAPS = APOAT*AEOAT*ATOAPS                                       EJECT326
      AESAPS = ASOAT*AEOAT*ATOAPS                                       EJECT327
      MEP = MP                                                          EJECT328
      MES = MS                                                          EJECT329
      XMEXIT = APOAT*MEP + ASOAT*MES                                    EJECT330
      FFID = GAM*SQRT(2./GAMM*(2./GAMP)**(GAMP/GAMM)*(1.-(1./ANPR)**(GAMEJECT331
     1M/GAM)))                                                          EJECT332
      FFIDS = WSOWP1*SQRT(2.*GAM*GAMS/GAMMS*RS/RP*(2./GAMP)**(GAMP/GAMM)EJECT333
     1 *(1.-(1./ANPR*1./PTSPTP)**(GAMMS/GAMS)))                         EJECT334
      FFS = PEUPTP*AEPAPS*(1.+GAM*MEP**2)                               EJECT335
      FFSS = PEUPTS*PTSPTP*AESAPS*(1.+GAMS*MES**2)                      EJECT336
      CALL XTRP(AEOAT, CS, THETA, FIG11)                                EJECT337
      IF (QMODEL .GE.2.)CS = CS-.007                                    EJECT338
      TID = FFID + FFIDS                                                EJECT339
```

***CONTINUING

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      CT = (C5*(FFS+FFSS)-AEOAT*ATOAPS/ANPR)/(FFID+FFIDS)               EJECT340
      FLAG = 4.                                                         EJECT341
      IF(PEUPTP .GT. 1./ANPR) CTID = (1.*(FFS+FFSS) - AEOAT*ATOAPS/ANPR)EJECT342
     1 /(FFID+FFIDS)                                                    EJECT343
      XMOM = (PEUPTP*AEPAPS*GAM*MEP**2 + PEUPTS*PTSPTP*AESAPS*GAMS*MES**EJECT344
     12)*ANPR*ATFLOW                                                    EJECT345
      GO TO 500                                                         EJECT346
C***  BERNST SECTION                                                    EJECT347
  200 KT = 0                                                            EJECT348
      IF(XX.EQ.0.)POPTPX=POPTPX/2.                                      EJECT349
  210 POPTS=POPTPX/PTSPTP                                               EJECT350
      SVPOPT = POPTPX                                                   EJECT351
      WSWPT = AEOA*SQRT(2./GAMM*(GAMP/2.)**(GAMP/GAMM))-(1./POPTPX)**(1.EJECT352
     1 /GAM)/SQRT(1.-POPTPX**(GAMM/GAM))                                EJECT353
      WSWPT = WSWPT*SQRT(RP/RS*GAMS/GAM*GAMM/GAMMS*(1.-POPTS**(GAMMS/   EJECT354
     1 GAMS)))* PTSPTP*POPTS**(1./GAMS)                                 EJECT355
      FUNKK =  WSWP - WSWPT                                             EJECT356
      CALL ITRATE(POPTPX,FUNKK, 0., KT)                                 EJECT357
      IF (ABS(FUNKK) .LT. 1.E-4) GO TO 240                              EJECT358
      IF (KT .GT. 25) GO TO 470                                         EJECT359
      IF (SVPOPT - POPTPX .GT. 0.) POPTPX=AMAX1(POPTPX, .8*SVPOPT)      EJECT360
      IF (SVPOPT - POPTPX .LT. 0.) POPTPX=AMIN1(POPTPX, .5*(SVPOPT+PTSPTEJECT361
     1P))                                                               EJECT362
      IF(KT .EQ. 1) POPTPX = 1.01*POPTPX                                EJECT363
      GO TO 210                                                         EJECT364
  240 POPTPZ = POPTPX                                                   EJECT365
      IF (BERN - 2 ) 47, 50, 92                                         EJECT366
  470 WRITE(6,1060)                                                     EJECT367
      GO TO 490                                                         EJECT368
  475 WRITE(6,1050)                                                     EJECT369
      GO TO 490                                                         EJECT370
  480 WRITE(6,1040)                                                     EJECT371
      GO TO 490                                                         EJECT372
  485 WRITE(6,1030)                                                     EJECT373
  490 NOZERR = 1                                                        EJECT374
      WRITE(6,9000)                                                     EJECT375
  500 CONTINUE                                                          EJECT376
 1010 FORMAT(1HO,*RECOMP PRESS .GT. THROAT PRESS*)                      EJECT377
 1020 FORMAT(*0 SECONDARY FLOW TOTAL PRESSURE LESS THAN FREESTREAM STATIEJECT378
     1C* )                                                              EJECT379
 1030 FORMAT(*0 PUMPING CHARACTERISTICS ITERATION FAILED* )             EJECT380
 1040 FORMAT(*0 UNCHOKED WSWP GREATER THAN CHOKED WSWP*)                EJECT381
 1050 FORMAT(*0 MACH NUMBER ITERATION FAILED*)                          EJECT382
 1060 FORMAT(*0 EXIT PRESSURE ITERATION FAILED *)                       EJECT383
 9000 FORMAT(1H ,*ERROR IN EJECTOR NOZZLE ROUTINE*)                     EJECT384
      RETURN                                                            EJECT385
      END                                                               EJECT386

***END
```

```
***BEGIN

      SUBROUTINE FLTSPD (IFSC, FSPD, AM, VOK, VOM, VOKI, VOMI,          FLTSP000
     1 PAM, TAM)                                                        FLTSP001
C           INPUT CODES                                                 FLTSP002
C                                                                       FLTSP003
C      IFS = 1  MACH NUMBER                                             FLTSP004
C      IFS = 2  TRUE AIRSPEED, KNOTS                                    FLTSP005
C      IFS = 3  TRUE AIRSPEED, MPH                                      FLTSP006
C      IFS = 4  EQUIVALENT AIRSPEED, KNOTS                              FLTSP007
C      IFS = 5  EQUIVALENT AIRSPEED, MPH                                FLTSP008
C      IFS = 6  CALIBRATED AIRSPEED, KNOTS                              FLTSP009
C      IFS = 7  CALIBRATED AIRSPEED, MPH                                FLTSP010
C                                                                       FLTSP011
C                                                                       FLTSP012
C           NOMENCLATURE                                                FLTSP013
C                                                                       FLTSP014
C     AM    - MACH NUMBER                VCASKT - CALIBRATED AIRSPEED (KTFLTSP015
C     VOM   - TRUE AIRSPEED (MPH)        VCASMP - CALIBRATED AIRSPEED (MPFLTSP016
C     VOK   - TRUE AIRSPEED (KTS)        ALTER  - GEOPOTENTIAL PRESSURE FLTSP017
C     VOMI  - EQUIVALENT AIRSPEED (MPH)           ALTITUDE (FT)         FLTSP018
C     VOKI  - EQUIVALENT AIRSPEED (KTS)                                 FLTSP019
      COMMON/FLTSP/ VCASKT, VCASMP                                      FLTSP020
      COMMON/GCALCC/ALTQ, ALTX, ALTER, GEOPH                            FLTSP021
      DIMENSION GAM (72)                                                FLTSP022
      DATA  GAM                /2.0,1.0,0.0,68.,                        FLTSP023
     10100.0,1.402,0150.0,1.402,0200.0,1.402,0250.0,1.402,0300.0,1.402, FLTSP024
     20350.0,1.402,0400.0,1.402,0450.0,1.401,0500.0,1.401,0550.0,1.400, FLTSP025
     30600.0,1.399,0650.0,1.398,0700.0,1.396,0750.0,1.394,0800.0,1.392, FLTSP026
     40900.0,1.387,1000.0,1.381,1100.0,1.374,1200.0,1.368,1300.0,1.362, FLTSP027
     51400.0,1.356,1500.0,1.350,1600.0,1.345,1700.0,1.340,1800.0,1.336, FLTSP028
     61900.0,1.332,2000.0,1.328,2100.0,1.325,2200.0,1.322,2300.0,1.319, FLTSP029
     72400.0,1.317,2600.0,1.313,2800.0,1.309,3000.0,1.306/              FLTSP030
      DIMENSION   VQCAS1(155), VQCAS2(60), VEQCAS(215)                  FLTSP031
      EQUIVALENCE  (VEQCAS(1),VQCAS1),   (VEQCAS(156),VQCAS2)           FLTSP032
      DIMENSION   VCASV1(155), VCASV2(60), VCASEQ(215)                  FLTSP033
      EQUIVALENCE  (VCASEQ(1),VCASV1),   (VCASEQ(156),VCASV2)           FLTSP034
      DATA VCASV1       / 4.0   , 1.0   , 0.0   ,30.0   ,  7.0          FLTSP035
     A , 8.0   ,  0.0  ,  0.0  , 0.0   ,  250. , 250.  , 500.  , 500.   FLTSP036
     B , 750.  , 750.  , 20*0.0                                         FLTSP037
     C , 28.0  , 5000. , 0.0   ,  0.0  , 100.  , 100.  , 150.  , 149.8  FLTSP038
     D , 200.  , 199.6 , 250.  ,  249.2, 300.  , 298.5 , 350.  , 347.8  FLTSP039
     E , 400.  , 396.8 , 450.  , 445.6 , 500.  , 494.2 , 550.  , 542.4  FLTSP040
     F , 600.  , 590.  , 650.  , 638.  , 700.  , 685.0                  FLTSP041
     G , 26.   ,15000. , 0.0   , 0.0   , 100.  , 99.8  , 150.  , 149.2  FLTSP042
     H , 200.  , 198.2 , 250.  , 246.6 , 300.  , 294.5 , 350.  , 341.8  FLTSP043
     I , 400.  , 388.4 , 450.  , 434.  , 500.  , 479.1 , 550.  , 524.   FLTSP044
     J , 600.  , 567.  , 650.  , 611.  , 2*0.0                          FLTSP045
     K , 22.0  , 25000., 0.0   ,  0.0  ,  100. , 99.4  , 150.  , 148.2  FLTSP046
     L , 200.  , 196.2 , 250.  , 243.1 , 300.  , 288.8 , 350.  , 333.1  FLTSP047
     M , 400.  , 376.1 , 450.  , 418.1 , 500.  , 460.  , 550.  , 498.   FLTSP048
     N , 6*0.0                                                          FLTSP049
     O , 18.0  , 35000., 0.0   , 0.0   , 100.  , 99.   , 150.  , 147.   FLTSP050
     P , 200.  , 193.4 , 250.  , 237.9 , 300.  , 280.3 , 350.  , 321.4  FLTSP051
     Q , 400.  , 362.  , 450.  , 402.  , 10*0.0                        /FLTSP052
      DATA VCASV2       /                                               FLTSP053

***CONTINUING
```

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     A   16.0  , 450C0., 0.0   , 0.0   ,100.   , 98.4  , 150.  , 145.    FLTSP054
     B , 200.  , 188.8 , 250.  , 229.8 , 300.  , 269.1 , 350.  , 304.    FLTSP055
     C , 400.  , 340.  , 12*0.0                                          FLTSP056
     D , 12.0  , 550C0.,  0.0  , 0.0   ,100.   , 97.4  , 150.  , 141.7   FLTSP057
     E , 200.  , 182.6 , 250.  , 220.5 , 300.  , 257.  , 16*0.0         /FLTSP058
      DATA VQCAS1      /  4.0  , 1.0   ,  0.0  ,  30.0 , 7.0             FLTSP059
     A , 8.0   , 0.0   , 0.0   , 0.0   , 250.  , 250.  , 500.  , 500.    FLTSP060
     B , 750.  , 750.  , 20*0.0                                          FLTSP061
     C , 28.0  , 500C. ,  0.0  , 0.0   , 100.  , 100.  , 149.8 ,150.     FLTSP062
     D , 199.6 , 200.  , 249.2 , 250.  , 298.6 , 300.  , 347.8 , 350.    FLTSP063
     E , 396.8 , 400.  , 445.6 , 450.  , 494.2 , 500.  , 542.4 , 550.    FLTSP064
     F , 590.  , 600.  , 638.  , 650.  , 685.  , 700.                    FLTSP065
     G , 26.   , 150C0., 0.0   ,  0.0  , 99.8  , 100.  , 149.2 , 150.    FLTSP066
     H , 198.2 , 200.  , 246.6 , 250.  , 294.6 , 300.  , 341.8 , 350.    FLTSP067
     I , 388.4 , 400.  , 434.  , 450.  , 479.1 , 500.  , 524.  , 550.    FLTSP068
     J , 567.  , 600.  , 611.  , 650.  , 2*0.0                           FLTSP069
     K , 22.0  , 25CC0., 0.0   , 0.0   , 99.4  , 100.  , 148.2 , 150.    FLTSP070
     L , 196.2 , 200.  , 243.1 , 250.  , 288.8 , 300.  , 333.1 , 350.    FLTSP071
     M , 376.1 , 400.  , 418.1 , 450.  , 460.  , 500.  , 498.  , 550.    FLTSP072
     N , 6*0.0                                                           FLTSP073
     O , 18.   , 350C0., 0.0   , 0.0   , 99.   , 100.  , 147.  , 150.    FLTSP074
     P , 193.4 , 200.  , 237.9 , 250.  , 280.3 , 300.  , 321.4 , 350.    FLTSP075
     Q , 362.  , 400.  , 402.  , 450.  , 10*0.0                         /FLTSP076
      DATA VQCAS2      /                                                 FLTSP077
     A   16.0  , 450C0., 0.0   , 0.0   , 98.4  , 100.  , 145.  , 150.    FLTSP078
     B , 188.8 , 200.  , 229.8 , 250.  , 269.1 , 300.  , 304.  , 350.    FLTSP079
     C , 340.  , 400.  , 12*0.0                                          FLTSP080
     D , 12.0  , 55CC0.,  0.0  , 0.0   , 97.4  , 100.  , 141.7 , 150.    FLTSP081
     E , 182.6 , 200.  , 220.5 , 250.  , 257.  , 300.  , 16*0.0 /        FLTSP082
      IF(ALTER.GT.0.C.AND.ALTER.LT.55000.0) GO TO 9                      FLTSP083
      ALTER=0.0                                                          FLTSP084
 9    CALL XTRP(TAM, GAMO, 0.0, GAM)                                     FLTSP085
      SQTAM = SQRT(TAM)                                                  FLTSP086
      SQGAM = SQRT(GAMO)                                                 FLTSP087
      AO = 41.427 * SQRT( TAM) * SQRT(GAMO)                              FLTSP088
      SQSIG = SQRT(PAM / (TAM * 4.0793))                                 FLTSP089
      GO TO (10, 20, 30, 40, 50, 60, 70) , IFSC                          FLTSP090
 10   AM = FSPD                                                          FLTSP091
      VOK = AM * AO * .5925                                              FLTSP092
 11   IF(IFSC .EQ. 4) GO TO 13                                           FLTSP093
      VOKI = VOK * SQSIG                                                 FLTSP094
      IF(IFSC .EQ. 3) GO TO 14                                           FLTSP095
 13   VOM = VOK / 0.869                                                  FLTSP096
      IF(IFSC .EQ. 5) GO TO 15                                           FLTSP097
 14   VOMI = VOKI / 0.869                                                FLTSP098
      IF(IFSC .EQ. 6 .OR. IFSC .EQ. 7) GO TO 80                          FLTSP099
 15   CALL XTRP(VOKI, VCASKT, ALTER, VEQCAS)                             FLTSP100
      VCASMP = VCASKT / 0.869                                            FLTSP101
      GO TO 80                                                           FLTSP102
 20   VOK = FSPD                                                         FLTSP103
 21   AM = VOK * 1.6878 / AO                                             FLTSP104
      GO TO 11                                                           FLTSP105
 30   VOM = FSPD                                                         FLTSP106
      VOK = VOM * 0.869                                                  FLTSP107
      GO TO 21                                                           FLTSP108
 40   VOKI = FSPD                                                        FLTSP109
      VOK = VOKI / SQSIG                                                 FLTSP110
```

***CONTINUING

```
      GO TO 21
 50   VOMI = FSPD
      VOK = VOMI *.869/SQSIG
      GO TO 21
 60   VCASKT = FSPD
      CALL XTRP(VCASKT, VOKI, ALTER, VCASEQ)
      VOK = VOKI / SQSIG
      VCASMP = VCASKT / 0.869
      GO TO 21
 70   VCASMP = FSPD
      VCASKT = FSPD * 0.869
      CALL XTRP(VCASKT, VOKI, ALTER, VCASEQ)
      VOK = VOKI / SQSIG
      GO TO 21
 80   RETURN
      END

***END
```

```
***BEGIN

      SUBROUTINE ITERAT(G,V,X,N)                                        ITERA000
      X= 1.1                                                            ITERA001
      Q= 1.0001                                                         ITERA002
      W1=SQRT(G)*ATAN(SQRT(1.0/G*(Q**2-1.0)))-ATAN(SQRT(Q**2-1.0))      ITERA003
      I= 0                                                              ITERA004
   10 I=I+1                                                             ITERA005
      IF(I. LE. 200) GO TO 20                                           ITERA006
      WRITE(6,9900)                                                     ITERA007
      N=2                                                               ITERA008
      RETURN                                                            ITERA009
   20 W= SQRT(G)*ATAN(SQRT(1.0/G*(X**2-1.0)))-ATAN(SQRT(X**2-1.0))      ITERA010
      IF(ABS(V-W).LT. 0.0001)RETURN                                     ITERA011
      X1= Q+(V-W1)/(W-W1)*(X-Q)                                         ITERA012
      Q=X                                                               ITERA013
      X= X1                                                             ITERA014
      W1=W                                                              ITERA015
      GO TO 10                                                          ITERA016
 9900 FORMAT(* FAILED TO CONVERGE IN ITERAT*)                           ITERA017
      END                                                               ITERA018

***END
```

```
***BEGIN

      SUBROUTINE  ITRATE(A3P,B3,B3P,LOOP)                                ITRTE000
      IF(LOOP)100,102,100                                                ITRTE001
  100 A31=A3                                                             ITRTE002
      B31=B32                                                            ITRTE003
  102 A3=A3P                                                             ITRTE004
      B32=B3-B3P                                                         ITRTE005
      IF(LOOP)104,106,104                                                ITRTE006
  104 DVISOR=B32-B31                                                     ITRTE007
      IF (DVISOR.EQ.0.)  GO TO 106                                       ITRTE008
      A3P=(B32*A31-B31*A3)/DVISOR                                        ITRTE009
  106 LOOP=LOOP+1                                                        ITRTE010
      RETURN                                                             ITRTE011
      END                                                                ITRTE012

***END
```

```
***BEGIN

      SUBROUTINE ITRATI(X,G,XMIN,XMAX,NUMIT,NSIGX,NSIGF,KONV)           ITRTI000
      F = G                                                             ITRTI001
      IF(KONV .NE. 0) GO TO 20                                          ITRTI002
C ... INITIAL ENTRY                                                     ITRTI003
      XAVE = (XMAX + XMIN) / 2.E0                                       ITRTI004
      IF( (XMAX - X) * (X - XMIN) .GE. 0.E0 ) GO TO 10                  ITRTI005
      X = XAVE                                                          ITRTI006
      GO TO 70                                                          ITRTI007
   10 KONV = 1                                                          ITRTI008
      LOOP = 0                                                          ITRTI009
      FLEAST = 1.E60                                                    ITRTI010
      XS = X                                                            ITRTI011
      FS = F                                                            ITRTI012
      LIMITS = 0                                                        ITRTI013
      NUMIT2 = NUMIT/2                                                  ITRTI014
      XMNN = XMIN                                                       ITRTI015
      XMXX = XMAX                                                       ITRTI016
   20 DABSF =  ABS(F)                                                   ITRTI017
      IF(DABSF .GT.  ABS(FLEAST)) GO TO 22                              ITRTI018
C ... SAVE BEST VALUE                                                   ITRTI019
      SAVX = X                                                          ITRTI020
      FLEAST = F                                                        ITRTI021
C ... TRY TO DECREASE INTERVAL OF APPROXIMATION                         ITRTI022
   22 IF(LIMITS .EQ. 1) GO TO 25                                        ITRTI023
      IF(F*FS .GT. 0.E0) GO TO 28                                       ITRTI024
      LIMITS = 1                                                        ITRTI025
      IF(X .GT. XS) GO TO 23                                            ITRTI026
      XMNN = X                                                          ITRTI027
      XMXX = XS                                                         ITRTI028
      FMNN = F                                                          ITRTI029
      FMXX = FS                                                         ITRTI030
      GO TO 28                                                          ITRTI031
   23 XMNN = XS                                                         ITRTI032
      XMXX = X                                                          ITRTI033
      FMNN = FS                                                         ITRTI034
      FMXX = F                                                          ITRTI035
      GO TO 28                                                          ITRTI036
   25 IF(F*FMNN .LT. 0.E0) GO TO 26                                     ITRTI037
      XMNN = X                                                          ITRTI038
      FMNN = F                                                          ITRTI039
      FMXX = FMXX/2.E0                                                  ITRTI040
      GO TO 28                                                          ITRTI041
   26 XMXX = X                                                          ITRTI042
      FMXX = F                                                          ITRTI043
      FMNN = FMNN/2.E0                                                  ITRTI044
C ... TEST FOR CONVERGENCE                                              ITRTI045
   28 C =  ABS(XMNN)                                                    ITRTI046
      IF(C .EQ. 0.E0) C = 1.E0                                          ITRTI047
      IF( ( ABS(XMXX - XMNN) / C .LT. 5.E-1*1.E1**(-NSIGX) .AND. DABSF  ITRTI048
     1     .LT. 5.E-1*1.E1**(-NSIGF) ) .OR. DABSF .EQ. 0.E0 ) GO TO 80  ITRTI049
      IF(LOOP .GT. 0) GO TO 30                                          ITRTI050
C ... PERTURB INITIAL GUESS                                             ITRTI051
      X = X+ SIGN(1.E-2*X,XAVE-X)                                       ITRTI052
      IF(X .EQ. XS) X = (XAVE+XMIN)/2.E0                                ITRTI053

***CONTINUING
```

```
      GO TO 60                                                          ITRT1054
C ... TEST FOR NONCONVERGENCE                                           ITRT1055
 30   IF(LOOP .EQ. NUMIT) GO TO 90                                      ITRT1056
C ... REGULA FALSI                                                      ITRT1057
      IF(LIMITS .NE. 1 .OR. LOOP .LE. NUMIT2) GO TO 50                  ITRT1058
      X = (FMNN*XMXX - FMXX*XMNN) /(FMNN - FMXX)                        ITRT1059
      IF( ABS(FMNN) .GT. 1.E1 .AND.  ABS(FMXX) .GT. 1.E1 .AND.          ITRT1060
     1    ABS(FMNN-FMXX)/AMIN1( ABS(FMNN), ABS(FMXX)) .GT. 1.E2)        ITRT1061
     2   X = (XMXX+XMNN) / 2.E0                                         ITRT1062
      GO TO 65                                                          ITRT1063
 50   DIV = F-FS                                                        ITRT1064
      IF(DIV .EQ. 0.E0) DIV = 1.E0                                      ITRT1065
      X1 = (F*XS-FS*X)/DIV                                              ITRT1066
      XS = X                                                            ITRT1067
      FS = F                                                            ITRT1068
      X = X1                                                            ITRT1069
C ... TEST FOR OUT OF RANGE                                             ITRT1070
 60   IF(X .LE. XMNN) X = (XS+XMNN)/2.E0                                ITRT1071
      IF(X .GE. XMXX) X = (XS+XMXX)/2.E0                                ITRT1072
C ... INCREASE ITERATION COUNTER                                        ITRT1073
 65   LOOP = LOOP+1                                                     ITRT1074
C ... RETURN                                                            ITRT1075
 70   RETURN                                                            ITRT1076
C ... CONVERGENCE                                                       ITRT1077
 80   KONV = 2                                                          ITRT1078
      GO TO 70                                                          ITRT1079
C ... NONCONVERGENCE                                                    ITRT1080
 90   KONV = 3                                                          ITRT1081
      IF(LIMITS .EQ. 1) GO TO 70                                        ITRT1082
      X = SAVX                                                          ITRT1083
      G = FLEAST                                                        ITRT1084
      GO TO 70                                                          ITRT1085
      END                                                               ITRT1086

***END
```

```
***BEGIN

      SUBROUTINE ITRATA(N,X,F,XMIN,XMAX,EPS,NUMIT,KONV)                 ITRTA000
      DIMENSION A(15,15),B(15,15),C(15,15),D(14),S(14),P(14),           ITRTA001
     1  X(N),F(N),DS(14),XS(14),FS(14),TS(15),XMIN(N),XMAX(N),          ITRTA002
     2  EPS(N),G(15,15),E(15,15),Q(15,15),R(15,15),                     ITRTA003
     3  DF(14)                                                          ITRTA004
      FUNC(A1,B1,C1,M) = AMIN1((B1-A1),(A1-C1))/M                       ITRTA005
      IF (KONV .GE. 1) GO TO 25                                         ITRTA006
C . INITIALIZATION                                                       ITRTA007
      KPT = 1                                                           ITRTA008
      LOCAL = 0                                                         ITRTA009
      KUT = 2                                                           ITRTA010
      DNN = -1.E60                                                      ITRTA011
      DO 6 J=1,N                                                        ITRTA012
      DNN = AMAX1(DNN, ABS(ALOG10(EPS(J)))+1.E-2)                       ITRTA013
      DF(J) = 1.E1                                                      ITRTA014
 6    D (J) = 0.E0                                                      ITRTA015
      NN = N+DNN+5                                                      ITRTA016
      NNN = NUMIT/NN+1                                                  ITRTA017
      KONV = 1                                                          ITRTA018
      ST = 1.E70                                                        ITRTA019
      N1= N+1                                                           ITRTA020
 7    JJJ=0                                                             ITRTA021
      L = 0                                                             ITRTA022
 8    DO 10   J=1,N1                                                    ITRTA023
 10   A(J,1) = 1.E0                                                     ITRTA024
      KOMPUT = 0                                                        ITRTA025
      K=0                                                               ITRTA026
      PMIN = 1.E70                                                      ITRTA027
      DO 15 J=1,N                                                       ITRTA028
      DS(J) = D(J)                                                      ITRTA029
      D(J) = X(J)                                                       ITRTA030
      S(J) = FUNC(X(J),XMAX(J),XMIN(J),KPT*(NN-N))                      ITRTA031
      P(J) = AMIN1(.1E0* ABS(X(J))+1.E-4, S(J)/(10*KPT))*               ITRTA032
     1          SIGN(1.E0, D(J)-DS(J))                                  ITRTA033
      IF( ABS(P(J)) .GT. PMIN) GO TO 15                                 ITRTA034
      PMIN =  ABS(P(J))                                                 ITRTA035
 15   CONTINUE                                                          ITRTA036
      DETMIN = 1.E-9*AMIN1(1.E0,PMIN**N)                                ITRTA037
C . CONVERGENCE TEST                                                    ITRTA038
 25   DO 35 J=1,N                                                       ITRTA039
      IF( ABS(F(J)) .GT. EPS(J)) GO TO 40                               ITRTA040
 35   CONTINUE                                                          ITRTA041
C . CONVERGENCE                                                         ITRTA042
      KONV=2                                                            ITRTA043
      GO TO 440                                                         ITRTA044
C . COMPUTE CONVERGENCE FUNCTION                                        ITRTA045
 40   T=0.E0                                                            ITRTA046
      DO 42 J=1,N                                                       ITRTA047
 42   T=T+ ABS(F(J))                                                    ITRTA048
C . SAVE BEST VALUE                                                     ITRTA049
      IF(T .GE. ST) GO TO 46                                            ITRTA050
      IF(L .GT. 0) L=L-1                                                ITRTA051
      IF(LOCAL .EQ. 0) L=0                                              ITRTA052
      ST = T                                                            ITRTA053

***CONTINUING
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```
      DO 44 J=1,N                                                       ITRTA054
      XS(J) = X(J)                                                      ITRTA055
      FS(J) = F(J)                                                      ITRTA056
      IF(LOCAL .EQ. 1) GO TO 44                                         ITRTA057
      S(J) = FUNC(X(J),XMAX(J),XMIN(J),NN-JJJ)                          ITRTA058
   44 CONTINUE                                                          ITRTA059
C . TEST FOR DISCONTINUITY                                               ITRTA060
   46 IF(KUT .EQ. 4) GO TO 49                                           ITRTA061
      DO 48 J=1,N                                                       ITRTA062
      IF(X(J) .EQ. XS(J)) GO TO 48                                      ITRTA063
      DFJ = 0.E0                                                        ITRTA064
      DO 47 I = 1, N                                                    ITRTA065
   47 DFJ = AMAX1(DFJ,  ABS((F(I)-FS(I))/(X(J)-XS(J))))                 ITRTA066
      IF(KOMPUT .EQ. 0) DF(J) = AMAX1(DFJ, DF(J))                       ITRTA067
      IF(DFJ .LE. 1.E2*DF(J)) GO TO 48                                  ITRTA068
      LOCAL = 1                                                         ITRTA069
      KUT = 4                                                           ITRTA070
      GO TO 49                                                          ITRTA071
   48 CONTINUE                                                          ITRTA072
C . JJJ COUNTS THE NUMBER OF ITERATIONS                                   ITRTA073
   49 JJJ = JJJ+1                                                       ITRTA074
      IF  (JJJ-NN)    50,94,94                                          ITRTA075
C . REPLACE WORST POINT                                                   ITRTA076
   50 IF(KOMPUT .EQ. 0) GO TO 100                                       ITRTA077
      TT= 0.E0                                                          ITRTA078
      DO 65  J=1,N1                                                     ITRTA079
      IF(TS(J)-TT) 65,65,60                                             ITRTA080
   60 TT= TS(J)                                                         ITRTA081
      MAXROW= J                                                         ITRTA082
   65 CONTINUE                                                          ITRTA083
      A(MAXROW,1) = 1.E0                                                ITRTA084
      DO  85 J=1,N                                                      ITRTA085
      A(MAXROW,J+1) = F(J)/EPS(J)                                       ITRTA086
   85 B(MAXROW,J) = X(J)                                                ITRTA087
      TS(MAXROW)= T                                                     ITRTA088
      GO TO 135                                                         ITRTA089
C . STORE BEST VALUE                                                      ITRTA090
   94 DO 95 JT=1,N                                                      ITRTA091
      F(JT) = FS(JT)                                                    ITRTA092
   95 X(JT) = XS(JT)                                                    ITRTA093
      KPT = KPT+1                                                       ITRTA094
      IF(KPT .GT. NNN/2) LOCAL=1                                        ITRTA095
      IF(KPT .GT. NNN) GO TO 98                                         ITRTA096
      GO TO 7                                                           ITRTA097
C . NONCONVERGENCE                                                        ITRTA098
   98 KONV = 3                                                          ITRTA099
      GO TO 440                                                         ITRTA100
C . BUILD MATRIX OF POINTS                                                ITRTA101
  100 K=K+1                                                             ITRTA102
      DO 115 J=1,N                                                      ITRTA103
      A(K,J+1) = F(J)/EPS(J)                                            ITRTA104
  115 B(K,J) = X(J)                                                     ITRTA105
      TS(K)= T                                                          ITRTA106
      IF (K-N)  120,120,130                                             ITRTA107
  120 X(K) = X(K)+P(K)                                                  ITRTA108
      IF(K-1) 440,440,125                                               ITRTA109
  125 X(K-1) = D(K-1)                                                   ITRTA110
```

***CONTINUING

```
      GO TO 440                                                         ITRTA111
C . SOLVE LINEAR SYSTEM                                                 ITRTA112
 130  X (K-1)  =  D(K-1)                                                ITRTA113
      KOMPUT = 1                                                        ITRTA114
 135  DO 140 I = 1,N1                                                   ITRTA115
      G(I,N1) = A(I,N1)                                                 ITRTA116
      Q(I,N1) = 1.E0                                                    ITRTA117
      DO 140 J = 1,N                                                    ITRTA118
      Q(I,J) = B(I,J)                                                   ITRTA119
 140  G (I,J) = A(I,J)                                                  ITRTA120
      DO 210 I1=1,N1                                                    ITRTA121
      DO 200 J1=1,N1                                                    ITRTA122
      R(I1,J1) = 0.E0                                                   ITRTA123
 200  E(I1,J1) = 0.E0                                                   ITRTA124
      DO 210 K1=1,N                                                     ITRTA125
 210  C(I1,K1) = 0.E0                                                   ITRTA126
      DO 230 J2=2,N1                                                    ITRTA127
      DO 230 I2=1,N1                                                    ITRTA128
      R(J2,J2-1) = R(J2,J2-1) + Q(I2,J2)**2                             ITRTA129
 230  E(J2,J2-1) = E(J2,J2-1) + G(I2,J2)**2                             ITRTA130
      DO 340 K3=1,N1                                                    ITRTA131
      DO 300 J3=K3,N1                                                   ITRTA132
      DO 250 I3=1,N1                                                    ITRTA133
      R(K3,J3) = R(K3,J3) + Q(I3,K3)*Q(I3,J3)                           ITRTA134
 250  E(K3,J3) = E(K3,J3) + G(I3,K3)*G(I3,J3)                           ITRTA135
      IF (K3 - J3) 280,260,260                                          ITRTA136
 260  IF (K3 - 1)  300,300,270                                          ITRTA137
 270  IF (1.E-14*E(K3,K3-1)-1.E14*E(K3,K3)) 275,340,340                 ITRTA138
 275  IF(1.E-14*R(K3,K3-1)-1.E14*R(K3,K3)) 300, 340, 340                ITRTA139
 280  IF (E(K3,K3) .LT. 1.E-60) GO TO 340                               ITRTA140
      IF(R(K3,K3) .LT. 1.E-60) GO TO 340                                ITRTA141
      E(K3,J3) = E(K3,J3)/E(K3,K3)                                      ITRTA142
      R(K3,J3) = R(K3,J3)/R(K3,K3)                                      ITRTA143
      DO 290 I4=1,N1                                                    ITRTA144
      Q(I4,J3) = Q(I4,J3) - Q(I4,K3)*R(K3,J3)                           ITRTA145
 290  G(I4,J3) = G(I4,J3) - G(I4,K3)*E(K3,J3)                           ITRTA146
 300  CONTINUE                                                          ITRTA147
      DO 340 J5=1,N                                                     ITRTA148
      DO 310 I5=1,N1                                                    ITRTA149
 310  C(K3,J5) = C(K3,J5) + G(I5,K3)*B(I5,J5)/E(K3,K3)                  ITRTA150
 340  CONTINUE                                                          ITRTA151
      DO 350 I7=2,N1                                                    ITRTA152
      IT = N1+1-I7                                                      ITRTA153
      JT = IT + 1                                                       ITRTA154
      DO 350 J7=1,N                                                     ITRTA155
      DO 350 K7=JT,N1                                                   ITRTA156
 350  C(IT,J7) = C(IT,J7) - E(IT,K7)*C(K7,J7)                           ITRTA157
C . DETERMINE IF MATRIX IS SINGULAR                                      ITRTA158
      DET = 1.E0                                                        ITRTA159
      DET1 = 1.E0                                                       ITRTA160
      DO 360 JMT=1,N1                                                   ITRTA161
      DET = DET* ABS(E(JMT,JMT))                                        ITRTA162
 360  DET1 = DET1* ABS(R(JMT,JMT))                                      ITRTA163
      IF(DET1 .GT. DETMIN**2 .AND. DET .GT. 1.E-20) GO TO 380           ITRTA164
      DO 370 J=1,N                                                      ITRTA165
      X(J) = XS(J)                                                      ITRTA166
 370  F(J) = FS(J)                                                      ITRTA167
```

***CONTINUING

```
      GO TO 8                                                           ITRTA168
C . TEST PREDICTIONS FROM MATRIX SOLUTION TO KEEP WITHIN BOUNDS         ITRTA169
 380  L = L+1                                                           ITRTA170
      DO 430 J=1,N                                                      ITRTA171
      X(J) =  C(1,J)                                                    ITRTA172
      IF(LOCAL .EQ. C) GO TO 420                                        ITRTA173
      STEP = S(J)/KUT**(L-1)                                            ITRTA174
      IF( ABS(X(J)-XS(J)) .GT. STEP) X(J) = XS(J)+ SIGN(STEP,X(J)-XS(J))ITRTA175
      GO TO 430                                                         ITRTA176
 420  IF(X(J) .LE. XMIN(J)) X(J)=XS(J)-L*S(J)                           ITRTA177
      IF(X(J) .GE. XMAX(J)) X(J)=XS(J)+L*S(J)                           ITRTA178
 430  CONTINUE                                                          ITRTA179
 440  RETURN                                                            ITRTA180
      END                                                               ITRTA181

***END
```

```
***BEGIN

      SUBROUTINE LSTDAT( NTAPE )                                        LSTDAT01
      DIMENSION CARD(20)                                                LSTDAT02
      INTEGER CARD,END1                                                 LSTDAT03
      DATA END1/*END */                                                 LSTDAT04
      DATA               NEWP/*NEWP*/                                   LSTDAT05
      J=NTAPE                                                           LSTDAT06
      REWIND J                                                          LSTDAT07
 5    LINE =0                                                           LSTDAT08
      WRITE (6,101)                                                     LSTDAT09
 101  FORMAT (11H1INPUT DATA/14H CARD COLUMNS ,                         LSTDAT10
     1  40H1234567890123456789012345678901234567890,                    LSTDAT11
     2  40H1234567890123456789012345678901234567890/1H0)                LSTDAT12
 10   READ (5,106) CARD                                                 LSTDAT13
      IF (CARD(1).EQ.END1)  GO TO 20                                    LSTDAT14
      IF (CARD(1).EQ.NEWP   ) GO TO 5                                   LSTDAT15
      WRITE (J,106) CARD                                                LSTDAT16
      WRITE (6,103) CARD                                                LSTDAT17
      LINE=LINE+1                                                       LSTDAT18
      IF (LINE-55) 10,5,5                                               LSTDAT19
 102  FORMAT (1H1)                                                      LSTDAT20
 106  FORMAT (20A4)                                                     LSTDAT21
 103  FORMAT (14X,20A4)                                                 LSTDAT22
 20   WRITE(J,106)CARD                                                  LSTDAT23
      WRITE(6,103)CARD                                                  LSTDAT24
      WRITE (6,104)                                                     LSTDAT25
      REWIND J                                                          LSTDAT26
 104  FORMAT (9H0END DATA)                                              LSTDAT27
      RETURN                                                            LSTDAT28
      END                                                               LSTDAT29

***END
```

```
***BEGIN

  SUBROUTINE NOZPLG(AT,AEAT,XE,THETAD,APB,GAMMA,PTNPP,CDN,CT,FLAG,   NOZPL000
 1 NOZERR ,TID,CS,QMODEL,MO,CTID,XMOM,ATMIN,ATMAX,XMEXIT)            NOZPL001
  REAL     MO,K1DCL3,K1DCS3,K1CVL3,K1CVS3                            NOZPL002
  DIMENSION K1CVL3(71) , K1CVS3(93)                                  NOZPL003
  DIMENSION K1DCL3(71) , K1DCS3(93)                                  NOZPL004
  DATA K1DCL3 /  5.,     1.,     0.,     22.,    3.,                 NOZPL005
 A         20.,   0.,     0.,     -.017, .002,  -.021, .004,  -.022, NOZPL006
 B         .006,  -.023,  .01,    -.02,  .014,  -.016, .018,  -.014, NOZPL007
 C         .02,   -.015,  .024,   -.019, .028,  -.025,               NOZPL008
 D         20.,   .6,     0.,     -.017, .002,  -.021, .004,  -.022, NOZPL009
 E         .006,  -.023,  .01,    -.02,  .014,  -.016, .018,  -.014, NOZPL010
 F         .02,   -.015,  .024,   -.019, .028,  -.025,               NOZPL011
 G         20.,   .9,     0.,     -.0295,.01,   -.0295,.014,  -.029, NOZPL012
 H         .02,   -.0285,.024,    -.029, .028,  -.03,  .032,  -.033, NOZPL013
 I         .036,  -.036,  .038,   -.039, .04,   -.042   /            NOZPL014
  DATA K1DCS3 /  5.,     1.,     0.,     22.,    4.,                 NOZPL015
 A         20.,   0.,     0.,     -.034, .002,  -.03,  .004,  -.026, NOZPL016
 B         .006,  -.023,  .008,   -.021, .012,  -.019, .016,  -.018, NOZPL017
 C         .02,   -.018,  .024,   -.019, .03,   -.022,               NOZPL018
 D         20.,   .6,     0.,     -.034, .002,  -.03,  .004,  -.026, NOZPL019
 E         .006,  -.023,  .008,   -.021, .012,  -.019, .016,  -.018, NOZPL020
 F         .02,   -.018,  .024,   -.019, .03,   -.022,               NOZPL021
 G         20.,   .8,     0.,     -.075, .002,  -.064, .004,  -.056, NOZPL022
 H         .006,  -.0495,.008,    -.0445,.012,  -.037, .016,  -.031, NOZPL023
 I         .02,   -.027,  .024,   -.025, .03,   -.023,               NOZPL024
 J         20.,   .9,     0.,     -.104, .002,  -.08,  .004,  -.064, NOZPL025
 K         .006,  -.055,  .008,   -.05,  .012,  -.046, .016,  -.043, NOZPL026
 L         .02,   -.041,  .024,   -.039, .03,   -.037   /            NOZPL027
  DATA K1CVL3 /  5.,     1.,     0.,     22.,    3.,                 NOZPL028
 A         20.,   0.,     0.,     0.,    .004,  -.0002,.008,  -.0005,NOZPL029
 B         .012,  -.0008,.016,    -.001, .02,   -.0013,.022,  -.0015,NOZPL030
 C         .024,  -.0016,.026,    -.0018,.028,  -.0019,              NOZPL031
 D         20.,   .6,     0.,     0.,    .004,  -.0002,.008,  -.0005,NOZPL032
 F         .012,  -.0008,.016,    -.001, .02,   -.0013,.022,  -.0015,NOZPL033
 F         .024,  -.0016,.026,    -.0018,.028,  -.0019,              NOZPL034
 G         20.,   .9,     0.,     0.,    .004,  .0003, .006,  .0002, NOZPL035
 H         .008,  -.0007,.012,    -.0023,.016,  -.0035,.02,   -.0044,NOZPL036
 I         .026,  -.0053,.032,    -.006, .04,   -.0065  /            NOZPL037
  DATA K1CVS3 /  5.,     1.,     0.,     22.,    4.,                 NOZPL038
 A         20.,   0.,     0.,     0.,    .002,  -.0001,.004,  -.0002,NOZPL039
 B         .006,  -.0004,.008,    -.0006,.012,  -.0011,.016,  -.0016,NOZPL040
 C         .02,   -.0021,.024,    -.0026,.028,  -.0030,              NOZPL041
 D         20.,   .6,     0.,     0.,    .002,  -.0001,.004,  -.0002,NOZPL042
 E         .006,  -.0004,.008,    -.0006,.012,  -.0011,.016,  -.0016,NOZPL043
 F         .02,   -.0021,.024,    -.0026,.028,  -.0030,              NOZPL044
 G         20.,   .8,     0.,     0.,    .002,  .0004, .004,  .0006, NOZPL045
 H         .006,  .0007, .008,    .0003, .012,  -.0008,.016,  -.0019,NOZPL046
 I         .02,   -.003, .024,    -.0041,.028,  -.0052,              NOZPL047
 J         20.,   .9,     0.,     0.,    .002,  .0008, .004,  .0015, NOZPL048
 K         .006,  .0019, .008,    .0011, .012,  -.0005,.016,  -.0019,NOZPL049
 L         .02,   -.0032,.024,    -.0045,.028,  -.0057  /            NOZPL050
  NOZERR= 0                                                          NOZPL051
  FLAG= 4.0                                                          NOZPL052
  CTID = 1.                                                          NOZPL053

***CONTINUING
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```
      GAMBO= (GAMMA+1.0)/(GAMMA-1.0)
      GAMBA= 1.0/GAMBO
      GAM1 = GAMMA-1.0
      GAP1 = GAMMA+1.0
      PRCRIT = (GAP1/2.)**(GAMMA/GAM1)
      IF(PTNPP .GT. PRCRIT)GO TO 10
      NOZERR= 1
      WRITE(6,9915)
      GO TO 90
 10   THETAP= THETAD*0.0174533
      RCOS1= COS(THETAP)
      RCOS2= COS(THETAP)**2
      RE= SQRT(APB/3.141592)
      R1= RE+ TAN(THETAP)*XE
      AE= AEAT*AT
      RS=(R1*RCOS1*(1.0-RCOS2)+SQRT(R1**2*RCOS2+AE/3.141592
     1    *RCOS1*(2.0-RCOS2)))/(RCOS1*(2.0-RCOS2))
      RT= RS-RCOS2*(RS-R1)
      XT= (R1-RT)/SIN(THETAP)
      S= (RS-RT)/RCOS1
      CS= RCOS1
      IF(OMODEL .GE. 2.)CS=CS-.007
      THETAR=-THETAP
      AME= 1.0001
      AEASK= 1.0
      IF(AEAT .EQ.1.0) GO TO 50
      ABE= 0.9
      AME= 1.0
      ICOUNT= 0
      AEAP= AEAT/CDN
   20 ICOUNT=ICOUNT+1
      IF(ICOUNT.LE. 200) GO TO 30
      WRITE(6,9900)
      NOZERR= 1
      RETURN
   30 AEASK=1.0/AME*((2.0/GAP1*(1.0+GAM1/2.0*AME**2))**(GAP1/(2.*GAM1)))
      IF(ABS(AEAP-AEASK).LT. 0.001) GO TO 50
      IF(AEAP-AEASK) 35,35,40
   35 AME= ABE+(AEAP-ASSE)/(AEASK-ASSE)*(AME-ABE)
      GO TO 20
   40 ASSE= AEASK
      ABE= AME
      AME= AME+0.1
      GO TO 20
   50 PEPTN= (1.0+GAM1/2.0*AME**2)**(-GAMMA/GAM1)
      FSAA= PEPTN*AEASK*(1.0+GAMMA*AME**2)
      PTPINV= 1.0/PTNPP
      XMOM = PEPTN*AEASK*GAMMA*AME**2*PTPINV*AT*CDN
      XMEXIT = AME
      FIPTA= GAMMA*SQRT(2.0/GAM1*(2.0/GAP1)**GAMBO*(1.0-PTPINV **
     1 (GAM1/GAMMA)))
      TID = FIPTA
      CTE= (CS*FSAA-PTPINV*AEASK)/FIPTA
      IF(AEASK.EQ. 1.0) CTE= CTE+ PTPINV*(1.0/CDN-1.0)/FIPTA
      IF(MO .LT. 1.)GO TO 95
      A=R1
      B= -TAN(THETAP)
```

***CONTINUING

```
      VE=SQRT(GAMBO)*ATAN(SQRT(1.0/GAMBO*(AME**2-1.0)))-ATAN(SQRT(       NOZPL111
     1    AME**2-1.0))                                                   NOZPL112
      AMEXP= SQRT(2.0/GAM1*(PTNPP**(GAM1/GAMMA)-1.0))                    NOZPL113
      AMVEXP= SQRT(GAMBO)*ATAN(SQRT(GAMBA*(AMEXP**2-1.0)))-ATAN(SQRT(    NOZPL114
     1          AMEXP**2-1.0))                                           NOZPL115
      AUEXP= ATAN(1.0/SQRT(AMEXP**2-1.0))                                NOZPL116
      THEXP= THETAR+AMVEXP-VE-AUEXP                                      NOZPL117
      THMAX= ATAN((RE-RS)/XE)                                            NOZPL118
      IF(THEXP .LE. THMAX) GO TO 60                                      NOZPL119
      THEXP= THMAX                                                       NOZPL120
      RMAX= SQRT(GAMBO*TAN(SQRT(1.0/GAMBO)*(THEXP-THETAR+VE+1.570796))**NOZPL121
     12 +1.0)                                                            NOZPL122
      AMVEXP= SQRT(GAMBO)*ATAN(SQRT(1.0/GAMBO*(RMAX**2-1.0)))-           NOZPL123
     1 ATAN(SQRT(RMAX**2-1.0))                                           NOZPL124
   60 BB= TAN(THEXP)                                                     NOZPL125
      AA= RS                                                             NOZPL126
      XI=-(A-AA)/(B-BB)                                                  NOZPL127
      RI= A+B*XI                                                         NOZPL128
      P1PTN= PEPTN                                                       NOZPL129
      RS1= RT                                                            NOZPL130
      NUM=(AMVEXP-VE)/.0174533                                           NOZPL131
      IF(NUM .LT. 5) NUM=5                                               NOZPL132
      RUM= NUM                                                           NOZPL133
      CTD= 0.0                                                           NOZPL134
      PSPTN= 0.0                                                         NOZPL135
      DO 80 J=1,NUM                                                      NOZPL136
      Q= J                                                               NOZPL137
      VL= VE+       Q/RUM *(AMVEXP-VE)                                   NOZPL138
      CALL  ITERAT(GAMBO,VL,AML,NOZERR)                                  NOZPL139
      IF(NOZERR.EQ.0)GO TO 65                                            NOZPL140
      WRITE(6,9905)                                                      NOZPL141
      GO TO 90                                                           NOZPL142
65    AUL= ATAN(1.0/SQRT(AML**2-1.0))                                    NOZPL143
      THETL= THETAR+VL-VE-AUL                                            NOZPL144
      BB= TAN(THETL)                                                     NOZPL145
      AA= RS                                                             NOZPL146
      XL=-(A-AA)/(B-BB)                                                  NOZPL147
      RL= A+B*XL                                                         NOZPL148
      VC= 2.0*VL                                                         NOZPL149
      CALL  ITERAT(GAMBO,VC,XMC,NOZERR)                                  NOZPL150
      IF(NOZERR.EQ.0)GO TO 70                                            NOZPL151
      WRITE(6,9905)                                                      NOZPL152
      GO TO 90                                                           NOZPL153
70    PCPTN= (1.0+GAM1/2.0*XMC**2) **(-GAMMA/GAM1)                       NOZPL154
      CTD= CTD+1.0/FIPTA*(0.5*(P1PTN+PCPTN)-PTPINV)*(RS1**2-RL**2)       NOZPL155
     1  *3.141592/(CDN*AT)                                               NOZPL156
      RS1= RL                                                            NOZPL157
      P1PTN= PCPTN                                                       NOZPL158
      IF(XL.EQ. XE) PSPTN= PCPTN                                         NOZPL159
   80 CONTINUE                                                           NOZPL160
      PBPTN= 4.312/PTNPP**1.975                                          NOZPL161
      PB1PTN= 0.517*PSPTN+ 0.0046                                        NOZPL162
      PB2PTN=PTPINV                                                      NOZPL163
      IF(PBPTN.GT. PB2PTN) PBPTN= PB2PTN                                 NOZPL164
      IF(PB1PTN.GT. PBPTN) PBPTN= PB1PTN                                 NOZPL165
      CTBD= (PBPTN-PTPINV)*APB/(CDN*AT*FIPTA)                            NOZPL166
      IF (PEPTN .GT. PTPINV) CTID = (FSAA-PTPINV*AEASK)/FIPTA+CTD+CTBD  NOZPL167
```

***CONTINUING

```
      CT= CTE+CTD+CTBD                                                  NOZPL 168
 90   RETURN                                                            NOZPL 169
 95   CALL XTRP(1.-CTID,DELDL,MO,K1CVL3)                                NOZPL 170
      CALL XTRP(1.-CTID,DELDS,MO,K1CVS3)                                NOZPL 171
      CALL XTRP(1.-CTID,DELCL,MO,K1DCL3)                                NOZPL 172
      CALL XTRP(1.-CTID,DELCS,MO,K1DCS3)                                NOZPL 173
      DELD = DELDS+(AT-ATMIN)*(DFLDL-DELDS)/(ATMAX-ATMIN)               NOZPL 174
      DELC = DELCS+(AT-ATMIN)*(DELCL-DELCS)/(ATMAX-ATMIN)               NOZPL 175
      CT = DELD + DELC + CTID                                           NOZPL 176
      GO TO 90                                                          NOZPL 177
 9900  FORMAT(* NOZZLE EXIT MACH NUMBER ITERATION FAILED*)              NOZPL 178
 9905 FORMAT(* NOZPLG--MACH ITERATION FAILED AT LOCAL EXPANSION ANGLE*) NOZPL 179
 9915 FORMAT(* NOZPLG--PLUG NOZZLE MUST BE CHOKED*)                     NOZPL 180
      END                                                               NOZPL 181

***END
```

```
***BEGIN

      SUBROUTINE NOZZLE(AT,ATFLOW,AEAT,GAMMA,PTTPFS,QMODEL,NT,FL,CDN,CT,NOZZL000
     1 FLAG,NOZERR  ,TID,CS,XMOM,CTID,A,XMEXIT)                         NOZZL001
      DIMENSION FIGB1A(157), FIGB1B(40)  , FIGB1(197)                   NOZZL002
      DIMENSION             FIG11A(157)  , FIG11B(112)  , FIG11(269)    NOZZL003
      EQUIVALENCE (FIG11A(1),FIG11(1)), (FIG11B(1),FIG11(158)),         NOZZL004
     1 (FIGB1A(1),FIGB1(1)), (FIGB1B(1),FIGB1(158))                     NOZZL005
      DATA FIG11A /  5.,     1.,     0.,     24.,    11.,               NOZZL006
     A         14.,    0.,     1.025, .997,  1.1,    .997,  1.2,   .997,   NOZZL007
     B         1.3,    .997,   1.4,   .997,  1.5,    .997,  1.56,  .997,   NOZZL008
     C         0.,     0.,     0.,    0.,    0.,     0.,    0.,    0.,     NOZZL009
     D         14.,    2.,     1.025, .997,  1.1,    .997,  1.2,   .997,   NOZZL010
     E         1.2,    .997,   1.25,  .996,  1.3,    .995,  1.3,   .995,   NOZZL011
     F         0.,     0.,     0.,    0.,    0.,     0.,    0.,    0.,     NOZZL012
     G         20.,    4.,     1.025, .997,  1.1,    .997,  1.2,   .997,   NOZZL013
     H         1.3,    .997,   1.33,  .997,  1.33,   .997,  1.4,   .9965,  NOZZL014
     I         1.5,    .996,   1.6,   .9952, 1.63,   .995,  0.,    0.,     NOZZL015
     J         22.,    6.,     1.025, .997,  1.1,    .997,  1.2,   .997,   NOZZL016
     K         1.4,    .997,   1.5,   .997,  1.56,   .997,  1.56,  .997,   NOZZL017
     L         1.6,    .996,   1.7,   .9945, 1.8,    .993,  2.0,   .9928,  NOZZL018
     M         22.,    8.,     1.025, .997,  1.06,   .997,  1.06,  .997,   NOZZL019
     N         1.1,    .9955,  1.2,   .9945, 1.3,    .995,  1.4,   .9955,  NOZZL020
     O         1.5,    .996,   1.6,   .9965, 1.8,    .996,  2.0,   .994,   NOZZL021
     P         22.,    10.,    1.025, .997,  1.045,  .997,  1.045, .997,   NOZZL022
     Q         1.1,    .993,   1.2,   .991,  1.3,    .991,  1.4,   .9915,  NOZZL023
     R         1.5,    .992,   1.6,   .9925, 1.8,    .9935, 2.0,   .994,   NOZZL024
     S         22.,    12.,    1.025, .997,  1.032,  .997,  1.032, .997/   NOZZL025
      DATA FIG11B   /                                                   NOZZL026
     A         1.1,    .9915,  1.2,   .9875, 1.3,    .986,  1.4,   .9862,  NOZZL027
     B         1.5,    .9865,  1.6,   .9875, 1.8,    .989,  2.0,   .990,   NOZZL028
     C         22.,    14.,    1.025, .997,  1.032,  .997,  1.032, .997,   NOZZL029
     D         1.1,    .990,   1.2,   .9835, 1.3,    .9815, 1.4,   .981,   NOZZL030
     E         1.5,    .981,   1.6,   .9812, 1.8,    .982,  2.0,   .9835,  NOZZL031
     F         22.,    16.,    1.025, .997,  1.025,  .997,  1.1,   .988,   NOZZL032
     G         1.2,    .9815,  1.3,   .978,  1.4,    .976,  1.5,   .975,   NOZZL033
     H         1.6,    .9753,  1.7,   .9756, 1.8,    .976,  2.0,   .977,   NOZZL034
     I         22.,    18.,    1.025, .997,  1.1,    .986,  1.2,   .978,   NOZZL035
     J         1.3,    .973,   1.4,   .971,  1.5,    .969,  1.6,   .968,   NOZZL036
     K         1.7,    .968,   1.8,   .968,  1.9,    .9685, 2.0,   .969,   NOZZL037
     L         22.,    20.,    1.025, .997,  1.1,    .9845, 1.2,   .976,   NOZZL038
     M         1.3,    .970,   1.4,   .966,  1.5,    .963,  1.6,   .9622,  NOZZL039
     N         1.7,    .9618,  1.8,   .9615, 1.9,    .9612, 2.0,   .9612 / NOZZL040
      DATA FIGB1A /  4.,     1.,     0.,     24.,    8.,                NOZZL041
     A         22.,    0.,     1.0,   0.,    1.05,   .001,  1.1,   .002,   NOZZL042
     B         1.2,    .004,   1.3,   .008,  1.4,    .011,  1.6,   .019,   NOZZL043
     C         1.8,    .026,   2.2,   .04,   3.0,    .062,  3.8,   .076,   NOZZL044
     D         22.,    3.,     1.0,   0.,    1.05,   .001,  1.1,   .002,   NOZZL045
     E         1.2,    .004,   1.3,   .008,  1.4,    .011,  1.6,   .019,   NOZZL046
     F         1.8,    .026,   2.2,   .04,   3.0,    .062,  3.8,   .076,   NOZZL047
     G         22.,    5.,     1.0,   0.,    1.05,   .002,  1.1,   .004,   NOZZL048
     H         1.2,    .007,   1.3,   .011,  1.4,    .015,  1.6,   .026,   NOZZL049
     I         1.8,    .037,   2.2,   .057,  3.0,    .09,   3.8,   .11,    NOZZL050
     J         22.,    7.5,    1.0,   0.,    1.05,   .0025, 1.1,   .005,   NOZZL051
     K         1.2,    .01,    1.3,   .016,  1.4,    .024,  1.6,   .041,   NOZZL052
     L         1.8,    .057,   2.2,   .086,  3.0,    .136,  3.8,   .164,   NOZZL053

***CONTINUING
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```
     M    22.,   10.,   1.0,   0.,    1.05,  .004,  1.1,   .0075,
     N    1.2,   .012,  1.3,   .022,  1.4,   .032,  1.6,   .053,
     O    1.8,   .074,  2.2,   .113,  3.0,   .18,   3.8,   .216,
     P    22.,   15.,   1.0,   0.,    1.05,  .006,  1.1,   .012,
     Q    1.2,   .025,  1.3,   .04,   1.4,   .058,  1.6,   .094,
     R    1.8,   .130,  2.2,   .202,  3.0,   .315,  3.8,   .38,
     S    22.,   20.,   1.0,   0.,    1.05,  .008,  1.1,   .014/
      DATA FIGB1B /
     A    1.2,   .028,  1.3,   .048,  1.4,   .07,   1.6,   .124,
     B    1.8,   .18,   2.2,   .268,  3.0,   .375,  3.25,  .40,
     C    22.,   90.,   1.0,   0.,    1.05,  .009,  1.1,   .017,
     D    1.2,   .034,  1.3,   .057,  1.4,   .082,  1.5,   .111,
     E    1.6,   .14,   1.8,   .195,  2.2,   .302,  2.77,  .40   /
      RAD = .0174533
      G12GM1 = (GAMMA+1)/(2.*(GAMMA-1.))
      PI = 3.1415927
      GRAV = 32.174
      RRR = 1716.5
      FLG220 = 0.
      NOZERR = 0
      LOOP = 0
      CTID= 1.0
 5    QMT = 1.
      ATFLAT = CDN
      PTPFS = PTTPFS
      PFSPTT = 1./PTPFS
      FLAGAT=0.
      IF(PTPFS .LT. ((GAMMA+1.)/2.)**(GAMMA/(GAMMA-1.))) FLAGAT=1.
      FLAGMT=0.
      DMT=.1
      FPTATS = GAMMA*SQRT((2./(GAMMA-1.))*(2./(GAMMA+1.))**(2.*G12GM1)
     1 *(1.-PFSPTT**((GAMMA-1.)/GAMMA)))
      AE = AEAT*AT
      IF(NT  .EQ. 1) GO TO 75
      RT = SQRT(AT/PI)
      RE = SQRT(AE/PI)
      THET = ATAN((RE-RT)/SQRT( FL-(RE-RT)**2 ))
      THETA = THET/RAD
      GO TO 80
 42   FSAATS = PEPTT*AEATS*(1.+GAMMA*QME**2)
      CALL XTRP(AEATS, CS, THETA, FIG11)
      IF(QMODEL .EQ. 2.)CS = CS-.007
      XMEXIT = QME
      XMOM = PEPTT*AEATS*GAMMA*QME**2*PTTPFS*ATFLOW
      IF (PEPTT .GT. PFSPTT) CTID = (FSAATS-PFSPTT*AEATS)/FPTATS
      TID = FPTATS
      CT =(CS*FSAATS- PFSPTT*AEATS)/FPTATS
      FLAG=4.
      GO TO 500
 75   IF(FLAGAT .EQ. 1) GO TO 162
C***  CONVERGENT NOZZLE -- CHOKED
      CS = .997
      IF(QMODEL .EQ. 2.)CS = CS-.007
      ATFATS = 1.
      AEATS = 1./ATFLAT
      PEPTT = ((GAMMA+1.)/2.)**(-GAMMA/(GAMMA-1.))
      PMAX  = ((GAMMA+1.)/2.)**( GAMMA/(GAMMA-1.))
```

***CONTINUING

```
      PEPFS = PEPTT*PTTPFS                                              NOZZL 111
      FSAAS = ATFATS*PEPTT*(1.+GAMMA)                                   NOZZL 112
      PVARB = PEPTT                                                     NOZZL 113
      FLAG=4.                                                           NOZZL 114
      IF (PTTPFS .GE. A) GO TO 77                                       NOZZL 115
      FLAG = 5.                                                         NOZZL 116
      PVARB = PFSPTT + (PEPTT-PFSPTT)*(PTTPFS-PMAX)/(A-PMAX)            NOZZL 117
   77 XMOM = GAMMA*PTPFS*PVARB*AE                                       NOZZL 118
      TID = FPTATS                                                      NOZZL 119
      XMEXIT = 1.                                                       NOZZL 120
      CT =   (CS*(FSAAS+PVARB*(AEATS-ATFATS) - PFSPTT*AEATS))/FPTATS    NOZZL 121
      IF(PTTPFS .GT. PVARB)CTID = (FSAAS + PVARB*(AEATS-ATFATS) - PFSPTTNOZZL 122
     1 * AEATS)/FPTATS                                                  NOZZL 123
      GO TO 500                                                         NOZZL 124
   80 CALL XTRP(AEAT , DPTQT, THETA, FIGB1)                             NOZZL 125
      QMT = 1.                                                          NOZZL 126
   90 IF(LOOP .GT. 50)GO TO 480                                         NOZZL 127
      LOOP = LOOP + 1                                                   NOZZL 128
      PTTQT =  2.*( 1.+.5*(GAMMA-1.)*QMT**2)**(GAMMA/(GAMMA-1.))/(GAMMA* NOZZL 129
     1 QMT**2)                                                          NOZZL 130
      PTEQT = PTTQT - DPTQT                                             NOZZL 131
      PTEPTT = PTEQT/PTTQT                                              NOZZL 132
      QMCALC = GRAV*SQRT(GAMMA/RRR)*QMT*(1.+.5*(GAMMA-1.)*QMT**2)**(-G12NOZZL 133
     1GM1)                                                              NOZZL 134
      QMEXIT = SQRT(2.*(PFSPTT**((1.-GAMMA)/GAMMA)-1.)/(GAMMA-1.))      NOZZL 135
      IF(FLAGAT.EQ.0.)QMEXIT=1.                                         NOZZL 136
      QMID = GRAV*SQRT(GAMMA/RRR)*QMEXIT*(1.+.5*(GAMMA-1.)*QMEXIT**2)**(NOZZL 137
     1-G12GM1)                                                          NOZZL 138
      CDN   = QMCALC/QMID*ATFLAT                                        NOZZL 139
      ATSAT =                                                           NOZZL 140
     1     ATFLAT*QMT*((2.+(GAMMA-1.)*QMT **2)/(GAMMA+1.))**(-G12GM1)   NOZZL 141
      AESAT = ATSAT/PTEPTT                                              NOZZL 142
      AESAE = AESAT/AEAT                                                NOZZL 143
      AEAES = 1./AESAE                                                  NOZZL 144
      IF (AEAES .LT. 1.) GO TO 485                                      NOZZL 145
  110 QMEE = .5                                                         NOZZL 146
      KT = 0                                                            NOZZL 147
  120 FUNC2 = AEAES- ((2.+(GAMMA-1.)*QMEE**2)/(GAMMA+1.))**G12GM1/QMEE  NOZZL 148
      SVQMEE = QMEE                                                     NOZZL 149
      CALL ITRATE(QMEE, FUNC2, 0., KT)                                  NOZZL 150
      IF (ABS(FUNC2) .LE. 1.E-4) GO TO 140                              NOZZL 151
      IF (KT .GT. 25) GO TO 475                                         NOZZL 152
      IF (KT .EQ. 1) QMEE = .51                                         NOZZL 153
      IF (SVQMEE - QMEE .GT. 0.)QMEE = AMAX1(QMEE, .8*SVQMEE)           NOZZL 154
      IF (SVQMEE - QMEE .LT. 0.)QMEE = AMIN1(QMEE, .5*(SVQMEE+1.))      NOZZL 155
      GO TO 120                                                         NOZZL 156
  140 PEPTE = (1.+.5*(GAMMA-1.)*QMEE**2)**(-GAMMA/(GAMMA-1.))           NOZZL 157
      PEPTT = PEPTE * PTEPTT                                            NOZZL 158
      PTTPE = 1./PEPTT                                                  NOZZL 159
      IF (ABS(PTPFS -PTTPE) .LE. 5.E-3) GO TO 161                       NOZZL 160
      IF (PTTPFS .GE. PTTPE) GO TO 150                                  NOZZL 161
      IF(FLAGMT.NE.1.) GO TO 145                                        NOZZL 162
      DMT=DMT/2.                                                        NOZZL 163
      FLAGMT=0.                                                         NOZZL 164
  145 QMT = QMT-DMT                                                     NOZZL 165
      GO TO 90                                                          NOZZL 166
  150 IF (QMT .GE. 1.) GO TO 163                                        NOZZL 167
```

***CONTINUING

```
      IF(FLAGMT.NE.0.) GO TO 155
      DMT=DMT/2.
      FLAGMT=1.
 155  QMT = QMT+DMT
      GO TO 90
 161  CS = .995
      IF(QMODEL .EQ. 2.)CS = CS-.007
      AEATS = AEAT/ATSAT
      QMXX=SQRT(2./(GAMMA-1.)*((1./PEPTE)**((GAMMA-1.)/GAMMA)-1.))
      FSAAS =PEPTT*AEATS *(1.+GAMMA*QMXX**2)
      XMOM = PEPTT*AEATS*GAMMA*QMXX**2*PTTPFS*ATFLOW
      TID = FPTATS
      XMEXIT = QMXX
      CT =(CS*FSAAS - PEPTT*AEATS)/FPTATS
      FLAG=1.
      GO TO 500
 162  CS = .997
      IF(QMODEL .EQ. 2.)CS = CS-.007
      QMT = SQRT(2.*(PFSPTT**((1.-GAMMA)/GAMMA ) -1. )/ (GAMMA-1.))
      ATFATS = ((2. + (GAMMA-1.)*QMT**2) /(GAMMA+1.))**G12GM1/ QMT
      PEPFS = 1.
      FSAAS = ATFATS*PFSPTT* (1.+GAMMA*QMT**2)
      AEATS = ATFATS/ATFLAT
      TID = FPTATS
      PTPE = ((GAMMA+1.)/2.)**(GAMMA/(GAMMA-1.))
      XMOM = GAMMA*PTPFS/PTPE*AE*QMT**2
      XMEXIT = QMT
      CT = (CS*(FSAAS +PFSPTT*(AEATS-ATFATS))- PFSPTT*AEATS)/FPTATS
      FLAG=1.
      GO TO 500
 163  AEATS=AEAT/ATSAT
      QME = 1.
      KT = 0
 165  FUNC1 = AEATS -((2.+(GAMMA-1.)*QME**2)/(GAMMA+1))**G12GM1/QME
      SVQMEE = QME
      CALL ITRATE(QME, FUNC1, 0., KT)
      IF (ABS(FUNC1) .LE. 1.E-4) GO TO 170
      IF (KT .GT. 25) GO TO 475
      IF (KT .EQ. 1) QME = 1.01
      IF (SVQMEE - QME  .GT. 0.)QME  = AMAX1(QME , .5*(1.+SVQMEE))
      IF (SVQMEE - QME  .LT. 0.)QME  = AMIN1(QME , 1.2*SVQMEE)
      GO TO 165
 170  PEPTT = (1. + .5* QME**2 *(GAMMA-1.))**(-GAMMA/(GAMMA-1.))
 175  WSWP = 0.
      PREPFS = .63 +.04*ALOG(WSWP+.01)
      PREPTT = PREPFS/PTTPFS
      IF(FLG220 .EQ. 1.) PREPTT=PECUPT*PREPFS
      IF(PREPTT .LE. PEPTT)GO TO 42
      QMX =SQRT(2./(GAMMA-1.)*((PREPTT  )**((1.-GAMMA)/GAMMA)-1.))
      QMI=QMX
      AREATS =        ((2.+QMX**2*(GAMMA-1.))/(GAMMA+1.))**(G12GM1)/QMX
 200  CALL XTRP(AREATS,CS, THETA, FIG11)
      IF(QMODEL .EQ. 2.)CS = CS-.007
      PECUSP = .1*(10.**(.0332*THETA+.72)) * (10.*(AEAT-1.))**(-.77)
      PIPTT = PREPTT
      PETPTT = PEPTT
      P2PTT = PEPTT/PREPFS
```

***CONTINUING

```
      PECUPT = PEPTT/PECUSP                                             NOZZL 225
      IF(PECUPT .GT. PETPTT) GO TO 219                                  NOZZL 226
      IF(PECUPT .GT. P2PTT) GO TO 218                                   NOZZL 227
      PREPTT = PEPTT                                                    NOZZL 228
      AREATS = AEATS                                                    NOZZL 229
      QMI = QME                                                         NOZZL 230
      PECUPT = P2PTT                                                    NOZZL 231
      GO TO 220                                                         NOZZL 232
  218 IF (PTTPFS .LE. 1./PECUPT) GO TO 220                              NOZZL 233
  219 FSAAS = PIPTT*     (1.+GAMMA*QMI **2)*AREATS                      NOZZL 234
      QI = PFSPTT*(6.+PTTPFS*PREPTT )*(AEATS-AREATS)/7.                 NOZZL 235
      XMOM = PIPTT*AREATS*GAMMA*QMI **2 *PTTPFS*ATFLOW                  NOZZL 236
      TID = FPTATS                                                      NOZZL 237
      XMEXIT = QMI                                                      NOZZL 238
      CT =(CS*FSAAS - AEATS   /PTTPFS + QI)/FPTATS                      NOZZL 239
      FLAG=3.                                                           NOZZL 240
      GO TO 500                                                         NOZZL 241
  220 PTTQT = 2.*(1.+.5*(GAMMA-1.))**(GAMMA/(GAMMA-1.))                 NOZZL 242
      PTEQT = PTTQT - DPTQT                                             NOZZL 243
      PTEPTT = PTEQT/PTTQT                                              NOZZL 244
      PTEPE = PTEPTT/PETPTT                                             NOZZL 245
      PTTPET = 1./PETPTT                                                NOZZL 246
      QMEE=SQRT(2.*(PTTPET **((GAMMA-1.)/GAMMA)-1.)/(GAMMA-1.))         NOZZL 247
      QMEX=SQRT(2.*(PTEPE  **((GAMMA-1.)/GAMMA)-1.)/(GAMMA-1.))         NOZZL 248
      AEATS =((2.+(GAMMA-1.)*QMEE **2)/(GAMMA+1.))**G12GM1/QMEE         NOZZL 249
      FSAAS =        AEATS*(1.+GAMMA*QMEX**2)/PTTPET                    NOZZL 250
      FPTATS = GAMMA*SQRT((2./(GAMMA-1.))*(2./(GAMMA+1.))**(2.*G12GM1)  NOZZL 251
     1 *(1.-PETPTT**((GAMMA-1.)/GAMMA)))                                NOZZL 252
      XMOM1 = PETPTT*AEATS*GAMMA*QMEX**2*PTTPFS*ATFLOW                  NOZZL 253
      FPTAT1 = FPTATS                                                   NOZZL 254
      CS = .995                                                         NOZZL 255
      IF(QMODEL .EQ. 2.)CS = CS-.007                                    NOZZL 256
      CTSUBP =(CS  *FSAAS -PETPTT*AEATS)/FPTATS                         NOZZL 257
      IF(FLG220.EQ.1.)GO TO 225                                         NOZZL 258
      FLG220 = 1.                                                       NOZZL 259
      GO TO 175                                                         NOZZL 260
  225 QI = PECUPT*((6.+PREPTT/PECUPT)/7.)*(AEATS-AREATS)                NOZZL 261
      FSAAS2= PREPTT*AREATS*(1.+GAMMA*QMI **2)                          NOZZL 262
      FPTATS = GAMMA*SQRT((2./(GAMMA-1.))*(2./(GAMMA+1.))**(2.*G12GM1)  NOZZL 263
     1 *(1.-PECUPT**((GAMMA-1.)/GAMMA)))                                NOZZL 264
      CALL XTRP(AREATS,CS, THETA, FIG11)                                NOZZL 265
      IF(QMODEL .EQ. 2.)CS = CS-.007                                    NOZZL 266
      XMOM2 = PREPTT*AREATS*GAMMA *QMI **2*PTTPFS*ATFLOW                NOZZL 267
      CTCUSP =(CS*FSAAS2-AEATS *PECUPT + QI)/FPTATS                     NOZZL 268
      XMOM = (XMOM2-XMOM1)*(PTPFS-PTEPE)/(1./PECUPT-PTEPE) + XMOM1      NOZZL 269
      TID = (FPTATS - FPTAT1) * (PTPFS-PTEPE)/(1./PECUPT - PTEPE)+FPTAT1NOZZL 270
      XMEXIT=(QMI-QMEX)*(PTPFS-PTEPE)/(1./PECUPT-PTEPE)+QMI             NOZZL 271
      CT = (CTCUSP-CTSUBP)*(PTPFS-PTEPE)/(1./PECUPT-PTEPE) + CTSUBP     NOZZL 272
      FLAG=2.                                                           NOZZL 273
      GO TO 500                                                         NOZZL 274
  475 WRITE(6,630)                                                      NOZZL 275
      GO TO 490                                                         NOZZL 276
  480 WRITE(6,620)                                                      NOZZL 277
      GO TO 490                                                         NOZZL 278
  485 WRITF(6,610)                                                      NOZZL 279
  490 NOZERR = 1                                                        NOZZL 280
      WRITE(6,600)                                                      NOZZL 281
```

***CONTINUING

```
 500   RETURN                                                          NOZZL 282
 600   FORMAT(1H1,*----ERROR IN NOZZLE----*)                           NOZZL 283
 610   FORMAT(1H ,*COMPUTED NOZZLE DIVERGENCE AREA LESS THAN 1.*)      NOZZL 284
 620   FORMAT(1H ,*NOZZLE THROAT AREA ITERATION FAILED*)               NOZZL 285
 630   FORMAT(1H ,*NOZZLE EXIT MACH NUMBER ITERATION FAILED*)          NOZZL 286
       END                                                             NOZZL 287

***END
```

***BEGIN

```
      SUBROUTINE XTRP(X,Y,Z,CV)
C    CURVE  INTERPOLATION AND EXTRAPOLATION
C  SAME EXCEPT TRAP ADDED TO CALL EXIT WHEN A CURVE IS MISSING
C     QUADRATIC FIT ON BIVARIANT INTERPOLATION
C     MINIMUM STORAGE VERSION, X MUST INCREASE
      DIMENSION CV(10)
      AX=X
      AZ=Z
      CV(3)=0.0
      ICV=CV(1)+0.1
      IF( ICV.EQ.5 ) ICV=4
      IF( ICV.GT.0 .AND. ICV.LT.5 ) GO TO 901
      WRITE(6,900) ICV
 900  FORMAT(45H CURVE MISSING OR WRONG IN A CALL TO XTRP, ID ,I4)
      RELLIM=-5.0
      HTLIHP=SQRT(RELLIM)
      FFOEG=CV(1000000)
      CALL  EXIT
 901  CONTINUE
      GO TO (1000,2000,3000,4000) ,ICV
C     UNIVARIATE LINEAR
 1000 N= CV(4)+ 4.0
      IF (AX-CV(5)) 1080,1050,1017
 1017 DO 1025     I=7,N,2
      IF (AX-CV(I)) 1040,1040,1025
 1025 CONTINUE
      GO TO 1060
C     COMPUTE
 1040 LRET=3
      GO TO 3900
 1050 A=CV(6)
 1045 Y=A
      GO TO 9999
C     EXTRAPOLATION
 1060 CV(3)=1.0
      I=N-1
      IF (CV(2))          1040,9999,1040
 1080 CV(3)=1.0
      I=7
      IF (CV(2))          1040,9999,1040
C     UNIVARIATE QUADRATIC
 2000 N=CV(4)+4.0
      IF (CV(5)-AX) 2010,1050,2200
 2010 DO 2015    I= 9,N,2
      IF (CV(I)-AX) 2015,2020,2020
 2015 CONTINUE
      GO TO 2225
 2020 IF (CV(I-2)-CV(I-4)) 2025,2250,2025
 2025 LRET=4
      GO TO 5000
C     EXTRAPOLATION
 2200 CV(3)=1.0
      I=9
      IF (CV(2))          2025,9999,2025
```

***CONTINUING

```
 2225 CV(3)=1.0                                                            XTRP 054
      I=N-1                                                                XTRP 055
      IF (CV(2))          2025,9999,2025                                   XTRP 056
 2250 I= I+2                                                               XTRP 057
      GO TO 2025                                                           XTRP 058
C     BIVARIATE LINEAR                                                     XTRP 059
 3000 K000FX=CV(4)                                                         XTRP 060
 3035 IF (CV(7)-AZ) 3040,3040,3200                                         XTRP 061
 3040 NZ=CV(5)-1.0                                                         XTRP 062
      DO 3045   J=1,NZ                                                     XTRP 063
      LCZ=7+J*K000FX                                                       XTRP 064
      IF (CV(LCZ)-AZ) 3045,3050,3050                                       XTRP 065
 3045 CONTINUE                                                             XTRP 066
      GO TO 3400                                                           XTRP 067
 3050 NX=CV(LCZ-1)                                                         XTRP 068
      KX1=LCZ+1                                                            XTRP 069
      JX=KX1+NX-1                                                          XTRP 070
 3100 IF (CV(KX1)-AX) 3105,3105,3352                                       XTRP 071
 3105 DO 3110     I=KX1,JX,2                                               XTRP 072
      IF (CV(I)-AX) 3110,3115,3115                                         XTRP 073
 3110 CONTINUE                                                             XTRP 074
      LRET=1                                                               XTRP 075
      GO TO 3375                                                           XTRP 076
 3115 LRET=2                                                               XTRP 077
      GO TO 3900                                                           XTRP 078
 3120 Y2=A                                                                 XTRP 079
      IF( AZ.NE.CV(LCZ) ) GO TO 8801                                       XTRP 080
      Y = Y2                                                               XTRP 081
      GO TO 9999                                                           XTRP 082
 8801 LCZ=LCZ-K000FX                                                       XTRP 083
      KX1=LCZ+1                                                            XTRP 084
      IF (CV(KX1)-AX) 3125,3125,3353                                       XTRP 085
 3125 NX=CV(LCZ-1)                                                         XTRP 086
      JX=KX1+NX-1                                                          XTRP 087
      DO  3130     I=KX1,JX,2                                              XTRP 088
      IF (CV(I)-AX) 3130,3135,3135                                         XTRP 089
 3130 CONTINUE                                                             XTRP 090
      LRET=2                                                               XTRP 091
      GO TO 3375                                                           XTRP 092
 3135 LRET=1                                                               XTRP 093
      GO TO 3900                                                           XTRP 094
 3085 Y1=A                                                                 XTRP 095
      IF( AZ.NE.CV(LCZ) ) GO TO 3950                                       XTRP 096
      Y = Y1                                                               XTRP 097
      GO TO 9999                                                           XTRP 098
C     EXTRAPOLATION                                                        XTRP 099
 3200 CV(3)=1.0                                                            XTRP 100
      LCZ=7+K000FX                                                         XTRP 101
      IF (CV(2))          9999,9999,3050                                   XTRP 102
 3352 LRET=1                                                               XTRP 103
      GO TO 3355                                                           XTRP 104
 3353 LRET=2                                                               XTRP 105
 3355 CV(3)=1.0                                                            XTRP 106
      IF (CV(2))          3360,9999,3360                                   XTRP 107
 3360 I=KX1+2                                                              XTRP 108
      GO TO (3115,3135),LRET                                               XTRP 109
 3375 CV(3)=1.0                                                            XTRP 110
```

***CONTINUING

```
      IF (CV(2))          3380,9999,3380                                 XTRP 111
 3380 I=JX-1                                                             XTRP 112
      GO TO (3115,3135),LRET                                             XTRP 113
 3400 CV(3)=1.0                                                          XTRP 114
      LCZ=7+NZ*K000FX                                                    XTRP 115
      IF (CV(2))          9999,9999,3050                                 XTRP 116
C     COMPUTE                                                            XTRP 117
 3900 A= (AX-CV(I-2))*(CV(I+1)-CV(I-1))/(CV(I)-CV(I-2))+CV(I-1)          XTRP 118
      GO TO (      3065,3120,1045),LRET                                  XTRP 119
 3950 LZIN = LCZ+ K000FX                                                 XTRP 120
      Y= (AZ-CV(LCZ))*(Y2-Y1)/(CV(LZIN)-CV(LCZ))+Y1                      XTRP 121
      GO TO 9999                                                         XTRP 122
C     BIVARIATE QUADRATIC                                                XTRP 123
 4000 K000FX=CV(4)                                                       XTRP 124
 4015 IF (CV(7)-AZ) 4020,4020,4100                                       XTRP 125
 4020 NZ=CV(5)-1.0                                                       XTRP 126
      DO 4025  J=2,NZ                                                    XTRP 127
      LCZ=7+J*K000FX                                                     XTRP 128
      IF (CV(LCZ)-AZ) 4025,4030,4030                                     XTRP 129
 4025 CONTINUE                                                           XTRP 130
      GO TO 4200                                                         XTRP 131
 4030 LCZM1K = LCZ - 1*K000FX                                            XTRP 132
      LCZM2K = LCZ - 2*K000FX                                            XTRP 133
      IF( CV(LCZM1K) - CV(LCZM2K) ) 4040,4035,4040                       XTRP 134
 4035 LCZ    = LCZ + K000FX                                              XTRP 135
 4040 NE = CV(LCZ-1)                                                     XTRP 136
      KX1=LCZ+1                                                          XTRP 137
      KX3=LCZ+5                                                          XTRP 138
      JX=LCZ+NE-1                                                        XTRP 139
      Z3=CV(LCZ)                                                         XTRP 140
 4300 IF (CV(KX1)-AX) 4310,4310,4450                                     XTRP 141
 4310 DO 4320    I=KX3,JX,2                                              XTRP 142
      IF (CV(I)-AX) 4320,4325,4325                                       XTRP 143
 4320 CONTINUE                                                           XTRP 144
      LRET=1                                                             XTRP 145
      GO TO 4500                                                         XTRP 146
 4325 IF (CV(I-2)-CV(I-4))     4330,4630,4330                            XTRP 147
 4330 LRET=2                                                             XTRP 148
      GO TO 5000                                                         XTRP 149
 4340 Y3=A                                                               XTRP 150
      IF( Z3.NE.AZ  ) GO TO 8802                                         XTRP 151
      Y = Y3                                                             XTRP 152
      GO TO 9999                                                         XTRP 153
 8802 LCZ=LCZ-K000FX                                                     XTRP 154
      KX1=KX1-K000FX                                                     XTRP 155
      KX3=KX3-K000FX                                                     XTRP 156
      NE=CV(LCZ-1)                                                       XTRP 157
      Z2=CV(LCZ)                                                         XTRP 158
      IF (CV(KX1)-AX) 4350,4350,4460                                     XTRP 159
 4350 JX=LCZ+NE-1                                                        XTRP 160
      DO 4360    I=KX3,JX,2                                              XTRP 161
      IF (CV(I)-AX) 4360,4365,4365                                       XTRP 162
 4360 LRET=2                                                             XTRP 163
      GO TO 4500                                                         XTRP 164
 4365 IF (CV(I-2)-CV(I-4))     4370,4640,4370                            XTRP 165
 4370 LRET=3                                                             XTRP 166
      GO TO 5000                                                         XTRP 167
```

***CONTINUING

```
 4375 Y2=A
      IF( Z2.NE.AZ ) GO TO 8803
      Y = Y2
      GO TO 9999
 8803 LCZ=LCZ-KOOOFX
      KX1=KX1-KOOOFX
      KX3=KX3-KOOOFX
      NE=CV(LCZ-1)
      Z1=CV(LCZ)
      IF (CV(KX1)-AX) 4380,4380,4470
 4380 JX=LCZ+NE-1
      DO 4385     I=KX3,JX,2
      IF (CV(I)-AX) 4385,4390,4390
 4385 CONTINUE
      LRET=3
      GO TO 4500
 4390 IF (CV(I-2)-CV(I-4))     4395,4650,4395
 4395 LRET=1
      GO TO 5000
 4099 Y1=A
      IF( Z1.NE.AZ ) GO TO 5500
      Y = Y1
      GO TO 9999
C     EXTRAPOLATION
 4100 CV(3)=1.0
      LCZ=7+2*KOOOFX
      IF(CV(2))          9999,9999,4030
 4200 CV(3)=1.0
      LCZ=7+NZ*KOOOFX
      IF (CV(2))         9999,9999,4030
 4450 LRET=1
      GO TO 4480
 4460 LRET=2
      GO TO 4480
 4470 LRET=3
 4480 CV(3)=1.0
      I=KX3
      IF(CV(2))          4490,9999,4490
 4490 GO TO  (              4325,4365,4390),LRET
 4500 CV(3)=1.0
      I=JX
      IF (CV(2))         4510,9999,4510
 4510 GO TO (              4325,4365,4390),LRET
 4630 I=I+2
      GO TO 4330
 4640 I=I+2
      GO TO 4370
 4650 I=I+2
      GO TO 4395
C     COMPUTE
 5000 CONTINUE
      A=CV(I-3)+(AX-CV(I-4))*((CV(I-1)-CV(I-3))/(CV(I-2)-CV(I-4))+(AX-CV
     1(I-2))/(CV(I)-CV(I-4))*((CV(I+1)-CV(I-1))/(CV(I)-CV(I-2))-(CV(I-1
     2)-CV(I-3))/(CV(I-2)-CV(I-4))))
      GO TO (4099,4340,4375,1045),LRET
 5500 IF( CV(1).NE.5.0 ) GO TO 5502
      IF( AZ.LT.Z2 ) GO TO 5501
```

***CONTINUING

```
      Z1 = Z2                                                           XTRP 225
      Z2 = Z3                                                           XTRP 226
      Y1 = Y2                                                           XTRP 227
      Y2 = Y3                                                           XTRP 228
 5501 Y = (AZ-Z1) * (Y2-Y1)/(Z2-Z1) + Y1                                XTRP 229
      RETJRN                                                            XTRP 230
 5502 Y=Y1+(AZ-Z1)*((Y2-Y1)/(Z2-Z1)+(AZ-Z2)/(Z3-Z1)*                    XTRP 231
     1 ((Y3-Y2)/(Z3-Z2)-(Y2-Y1)/(Z2-Z1)))                               XTRP 232
 9999 RETURN                                                            XTRP 233
      END                                                               XTRP 234

***END
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13. ABSTRACT

A computer program has been developed for predicting twin-nozzle/aftbody drag and internal nozzle performance for fighter type aircraft having twin buried engines and dual nozzles. The program is capable of generating the installed thrust-minus-drag data required for conducting mission analysis studies of aircraft of this type. The configuration variables which can be analyzed include (1) nozzle type (convergent flap and iris, convergent-divergent with and without secondary flow, and shrouded and unshrouded plug), (2) nozzle lateral spacing, (3) interfairing type (horizontal and vertical wedge), (4) interfairing length, and (5) vertical stabilizer type (single and twin).

The performance prediction methods incorporated in the program are based almost entirely on empirical correlations. Specifically, correlations used in conjunction with one-dimensional flow relationships are employed for the prediction of the nozzle thrust and discharge coefficients, and correlations of the test data obtained during the contracted effort are employed for prediction of the aft-end drag. The prediction methods account for the effects of nozzle pressure ratio and flow separation on both internal and external nozzle surfaces.

This manual describes the operation of the computer program in terms of program input requirements, performance prediction methods, and output format and includes a presentation of sample input/output cases and a complete computer listing of the program. The program has been developed for use on the CDC 6600 computer.

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Design Criteria and Guidelines						
Turbojet/Turbofan						