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COMPUTER PROGRAM FOR CALCULATING LAMINAR, TRANSITIONAL, AND TURBULENT BOUNDARY LAYERS FOR A COMPRESSIBLE AXISYMMETRIC FLOW

by James A. Albers and John L. Gregg

Lewis Research Center
Cleveland, Ohio 44135

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SUMMARY

A finite-difference program is described for calculating the viscous compressible boundary layer flow over either planar or axisymmetric surfaces. The flow may be initially laminar and progress through a transitional zone to fully turbulent flow, or it may remain laminar, depending on the imposed boundary conditions, laws of viscosity, and numerical solution of the momentum and energy equations. The flow may also be forced into a turbulent flow at a chosen spot by the data input. The input may contain the factors of arbitrary Reynolds number, free-stream Mach number, free-stream turbulence, wall heating or cooling, longitudinal wall curvature, wall suction or blowing, and wall roughness. The solution may start from an initial Falkner-Skan similarity profile, an approximate equilibrium turbulent profile, or an initial arbitrary input profile. This program is an extension of the finite-difference program of H. J. Herring and G. L. Mellor.

INTRODUCTION

Accurate methods for calculating boundary layer growth and boundary layer separation are needed for the analysis and design of aircraft and propulsion system component Nacelles, turbomachinery blading, nozzles, ducts, splitter rings, and airfoils are examples of some of the aircraft components that require information on the properties of boundary layer flow. The ability to use boundary layer methods enables one to replace much testing with calculations that consume less time and result in more detailed information.

This report discusses a FORTRAN IV program for computing laminar, transitional, and turbulent boundary layers for compressible flow over planar or axisymmetric surfaces. The present program is an extension of the finite-difference program of H. J. Herring and G. L. Mellor of reference 1. The program of reference 1 was extended to include an internal mechanism to determine transition from laminar to turbulent flow. The transition subroutine was written by H. J. Herring under the partial sponsorship of the Gas Turbine Products Division of General Electric Company. The program has been extended in its flexibility by the authors of this report by giving (1) detailed documentation of the program, (2) additional input and output options, and (3) restructuring the program by breaking it into more subroutines. Some of the additional input and output options that have been included are (1) option to scale input data, (2) numerical routine to increase accuracy at the start of the boundary layer growth, and (3) printout options. The structure of this program has been modified for use on smaller storage computers. This program includes instructions for interfacing with other programs which require an additional subroutine to supply a solution of the boundary layer.

The equations of motion, boundary conditions, and method of solution are the same as contained in reference 1. The major equations are taken from reference 1 so that they can be cross referenced to the computer program. A modified Crank-Nicolson scheme is used to reduce the governing differential equations to finite-difference form. Since the momentum and energy equations are decoupled, a solution of the momentum equation can be obtained without solving the energy equation in many cases of interest. The decoupling thus may lead to shorter execution time. The solution may start from an initial Falkner-Skan similarity profile, an approximate equilibrium turbulent profile, or an initial arbitrary input profile. The flow may be initially laminar and progress through a transitional zone to fully turbulent flow, or it may remain laminar, depending on the imposed boundary conditions, laws of viscosity, and numerical solution of the momentum and energy equations. The program can calculate variable property flows with arbitrary pressure gradients and heat transfer. In addition, it can calculate flows with arbitrary Reynolds number, free-stream Mach number, free-stream turbulence, longitudinal wall curvature, wall suction or blowing, and wall roughness.

This report gives a detailed description of the computer program.[1] It describes the function of each subroutine along with a discussion of all the variables in COMMON. The computer program source listing contains many detailed comments throughout which identify the operations carried out by the program. This report also discusses the input and output variables and presents special instructions for preparing input. Sample test cases including input and output printout are described.

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[1] Inquiries concerning this program should be directed to COSMIC, Computer Center, Information Services, 112 Barrow Hall, University of Georgia, Athens, Georgia 30602, (Reference: LEW-12178).

PROBLEM FORMULATION AND METHOD OF SOLUTION

Basic Equations of Motion, Boundary Conditions, and Method of Solution

The techniques for solving the boundary layer equations can be divided into two general methods. The first includes the explicit integral method which requires a procedure for solving ordinary differential equations for "integral" properties of the boundary layer. Some of the more commonly used integral techniques are discussed in references 2 and 3. The second method of solution of boundary layers is the finite-difference method, which provides a procedure for solving the partial differential equations of mass, momentum, and energy. Three finite-difference boundary layer techniques for turbulent flow commonly used are those of (1) Herring and Mellor (ref. 1), (2) Patankar, et al. (ref. 4), and (3) Cebeci and Smith (ref. 5). This report uses the method of Herring and Mellor (ref. 1). A brief synopsis of the problem formulation and method of solution is presented. (All symbols are defined in appendix A.)

The equations of mass, momentum, and energy for a compressible boundary layer for axisymmetric bodies are

$$\frac{\partial r\rho u}{\partial \bar{x}} + \frac{\partial r\rho v}{\partial \bar{y}} = 0 \tag{1}$$

$$\rho u \frac{\partial u}{\partial \bar{x}} + \rho v \frac{\partial u}{\partial \bar{y}} = \rho_e U \frac{dU}{d\bar{x}} + \frac{1}{r} \frac{\partial (r\tau)}{\partial \bar{y}} \tag{2}$$

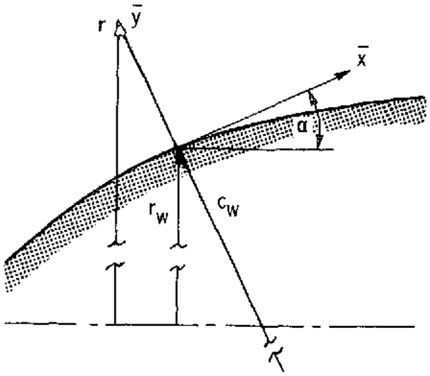
$$\rho u \frac{\partial h^o}{\partial \bar{x}} + \rho v \frac{\partial h^o}{\partial \bar{y}} = \frac{1}{r} \frac{\partial}{\partial \bar{y}} [r(q + u\tau)] \tag{3}$$

Equations (1), (2), and (3) apply to both laminar and turbulent flow if the definitions of τ/ρ and q/ρ are taken to be

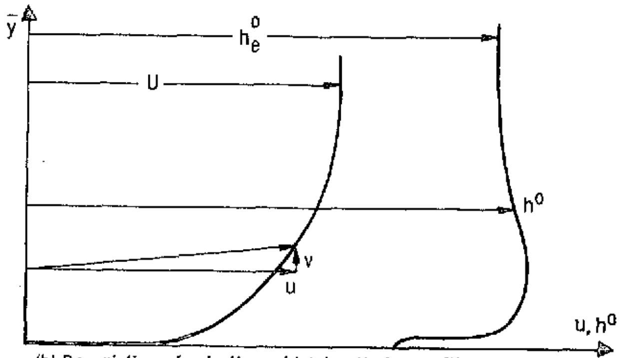
$$\frac{\tau}{\rho} = \nu_e \left(\frac{\partial u}{\partial \bar{y}}\right) \tag{4}$$

$$\frac{q}{\rho} = \nu_{eg} \left(\frac{\partial h}{\partial \bar{y}}\right) \tag{5}$$

where ν_e is the effective viscosity and ν_{eg} is the effective conductivity. For laminar flow, $\nu_e = \nu$ and $\nu_{eg} = \nu_g$, the molecular kinematic viscosity and conductivity, respectively. An illustration of the coordinate system used in the boundary layer equations is



(a) Coordinate system.



(b) Description of velocity and total enthalpy profiles.

Figure 1. - Illustration of coordinate system.

given in figure 1 where $\bar{x}$ and $\bar{y}$ are the untransformed coordinates.

The boundary conditions are

$$u(\bar{x}, 0) = 0 \tag{6}$$

$$v(\bar{x}, 0) = v_w(\bar{x}) \text{ or } \rho v(\bar{x}, 0) = \rho_w v_w(\bar{x}) \tag{7}$$

$$h^o(\bar{x}, 0) = h_w^o(\bar{x}) \text{ or } q(\bar{x}, 0) = q_w(\bar{x}) \tag{8}$$

$$\delta^* \rho_e U = \lim_{\bar{y} \to \infty} \int_0^{\bar{y}} \left[\rho_e U(\bar{x}) - \rho u(\bar{x}, \bar{y}')\right] \left(\frac{r}{r_w}\right) d\bar{y}' \text{ is bounded} \tag{9}$$

$$\psi\rho_e U(h_e^o - h_r) = \lim_{\bar{y}\to\infty} \int_0^{\bar{y}} \rho u \left[h_e^o - h^o(\bar{x}, \bar{y}')\right]\left(\frac{r}{r_w}\right) dy' \quad \text{is bounded} \tag{10}$$

Equation (6) is a general wall boundary condition. Equations (7) and (8) are general wall boundary conditions on v and h^o which include the effects of wall transpiration velocity v_w and the wall heat flux q_w. Equations (9) and (10) require that as $\bar{y} \to \infty$ the displacement thickness δ^* and the enthalpy thickness ψ be finite (ref. 6).

Mellor and Herring use a Probstein-Elliott transformation (ref. 7) to transform equations (1), (2), and (3) so they become closer to their planar form. For the calculation procedure a new set of variables is introduced. The velocity and enthalpy profiles are expressed in defect form according to the following transformations:

$$f'(x, \eta) = \frac{\rho_e U(x) - \rho u(x, y)}{\rho_e U(x)} = \frac{\partial f}{\partial \eta} \tag{11}$$

$$g'(x, \eta) = \frac{h_e^o - h^o(x, y)}{h_e^o - h_r} = \frac{\partial g}{\partial \eta} \tag{12}$$

where

$$\eta = \frac{y}{\delta^*(x)} \tag{13}$$

After these transformations have been introduced, the partial differential equations are still nonlinear and parabolic in the flow direction (see eqs. (II-14) and (II-15) of appendix B). Mellor and Herring linearize the partial differential equations by using finite differences for the x-derivatives resulting in a series of ordinary differential equations. The x-derivatives are represented by finite differences according to an adaptation of the Crank-Nicolson scheme (ref. 8). The momentum and energy equations are written in terms of average functions at a point halfway between the x-position of the known profile (x_{i-1}) and that of the profile to be calculated (x_i) as follows:

$$\overline{-\left\{(1 + C_a\eta)\frac{\Upsilon}{d}\left[d(1 - f')\right]'\right\}'} + \left\{(\bar{Q} + \bar{R})(\eta - \bar{f}) - \left(\frac{\bar{\rho}_w\bar{v}_w}{\bar{\rho}_e\bar{U}}\right) - \bar{\delta}^*\bar{f}_x\right\}\bar{d}\bar{f}''$$

$$+\left\{\left[(\bar{Q} + \bar{R})(\eta - \bar{f}) - \left(\frac{\bar{\rho}_w\bar{v}_w}{\bar{\rho}_e\bar{U}}\right) - \bar{\delta}^*\bar{f}_x\right]\bar{d}' - (\bar{P}\bar{d} + \bar{\delta}^*\bar{d}_x)(2 - \bar{f}')\right\}\bar{f}'$$

$$-\left[(\bar{Q} + \bar{R})(\eta - \bar{f}) - \left(\frac{\bar{\rho}_w\bar{v}_w}{\bar{\rho}_e\bar{U}}\right) - \bar{\delta}^*\bar{f}_x\right]\bar{d}' + \bar{P}(\bar{d} - 1) + \bar{\delta}^*\bar{d}_x$$

$$= (1 - \bar{f}')\bar{\delta}^*\bar{d}\bar{f}'_x \tag{14}$$

$$\overline{\left((1 + C_a\eta)\frac{\Upsilon_g}{d}\left\{g'' - \frac{\frac{1}{2}(k - 1)M_e}{H\left[1 + \frac{1}{2}(k - 1)M_e^2\right]}\left(\frac{\Upsilon}{\Upsilon_g} - 1\right)\left[d^2(1 - f')^2\right]'\right\}\right)'}$$

$$+\left[(\bar{Q} + \bar{R})(\eta - \bar{f}') - \left(\frac{\bar{\rho}_w\bar{v}_w}{\bar{\rho}_e\bar{U}}\right) - \bar{\delta}^*\bar{f}_x\right]\bar{g}'' = (\bar{1} - \bar{f}')\bar{\delta}^*\bar{g}'_x \tag{15}$$

where

$$d = \frac{\rho_e}{\rho}$$

Finally, the forms in which the momentum and energy equations are solved are

$$\left[b_4(f'' + b_5)\right]'_i = b_3 + b_2 f''_i + b_1 f'_i \tag{16}$$

$$\left[b_4(g''+b_5)\right]_i' = b_3 + b_2 g_i'' + b_1 g_i' \tag{17}$$

where the b coefficients are defined in equations (III-9) and (III-10) of appendix B. The solution of equations (16) and (17) is carried out iteratively because of their nonlinearity. The coefficients b_1 to b_5 are evaluated using the results of the previous iteration. The resulting linear equations are solved for f' and g' by applying a Gaussian elimination procedure. Then f'' and g'' are obtained by taking the first differences of f' and g'. The ordinary differential equations are then integrated numerically across the boundary layer at each x-location to get the integral momentum and energy relations.

In order to solve the partial differential equations for turbulent flow, an expression for the turbulent effective viscosity is required. Mellor and Herring, in formulating their effective viscosity hypothesis, divide the boundary layer in terms of an inner layer, an overlap layer, and an outer layer. The viscosity of each region is based on experimental data and is uniquely determined by values of a pressure gradient parameter and a displacement thickness Reynolds number (refs. 9 and 10). The effective viscosity hypothesis as used in the program includes the influence of longitudinal wall curvature (ref. 11).

Method of Predicting Transition

Theoretical investigations into the process of transition from laminar to turbulent flow are based on Reynolds' hypothesis that transition occurs as a consequence of an instability developed within the laminar boundary layer. The transition region is defined as the region between the instability point (or critical point) and the fully turbulent point. The instability point is the point on the surface at which amplification of an individual disturbance begins and proceeds downstream. The boundary layer becomes fully turbulent some distance downstream of the instability point since the disturbance takes time to be amplified to fully developed turbulent flow.

The basic formulation of the transition equations used herein was developed by H. J. Herring. The physical factors which influence the transition location that have been accounted for in this analysis include the pressure gradient parameter $\overline{K}$, surface roughness s_w, wall suction or blowing v_w, free-stream turbulence level $\overline{q^2}$, heat-transfer parameter S_t, and longitudinal radius of curvature parameter θ/c_w. The point of instability is determined from the critical Reynolds number R_{cr}, which is a function of the pressure gradient parameter $\overline{K}$ and the Stanton number S_t:

$$R_{cr} = f(\overline{K}, S_t) \tag{18}$$

where

$$\overline{K} = \frac{\theta^2}{\nu_w} \frac{dU}{dx} \tag{19}$$

The difference between the Reynolds number at the fully turbulent point R_{ft} and the critical Reynolds number R_{cr} is a function of both the pressure gradient parameter and free-stream turbulence level $\overline{q^2}/U^2$ where

$$R_{ft} - R_{cr} = R_\Delta(\overline{K}) f\left(\frac{\overline{q^2}}{U^2}\right) \tag{20}$$

If the effects of longitudinal radius of curvature θ/c_w and surface roughness $s_w/\delta*$ are included, the Reynolds number at the fully turbulent point becomes

$$R_{ft} = \left[R_{cr}(\overline{K}, S_t) + R_\Delta(\overline{K}) f\left(\frac{\overline{q^2}}{U^2}\right)\right] f\left(\frac{\theta}{c_w}\right) f\left(\frac{s_w}{\delta*}\right) \tag{21}$$

All the functional relations of equations (18) and (21) were obtained from reference 12, except the critical Reynolds number when heat transfer is considered. This functional relation was obtained by the method of Lees (ref. 13).

The effective viscosity in the transition region is determined from the kinematic viscosity ν, the intermittency factor γ, and the turbulent viscosity ν_t:

$$\nu_e = \nu + \gamma \nu_t \tag{22}$$

The intermittency factor is defined as that fraction of time during which the flow at a given position remains turbulent. It is calculated from the method of Dhawan and Narasimha (ref. 14).

PROGRAM DESCRIPTION

Program Calling Sequence and Operating Environment

A simplified functional flow diagram of the main supervisory program TUF is shown in figure 2. The program TUF is segmented into four principal parts: subroutines INIR, ITFR, ITSR, and NDIR. Subroutine INIR calls the input subroutine COTR. Subroutines ITFR, ITSR, and NDIR, in turn, call several other subroutines. All the subroutines and their relation are shown in figure 3. Subroutine INIR calls subroutines VIS, FILE, INTEG, and A6IR besides COTR. Subroutine ITFR calls subroutines VIS, FILE, PROFYL, INTEG, and A6IR. Subroutine ITSR calls subroutines TRANS, VIS, FILE, PROFYL, and INTEG. Subroutine NDIR calls subroutines VIS, FILE, and A6IR. Subroutine TRANS calls subroutine INDEX, and subroutine VIS calls subroutine INTEG.

Five of the subroutines in TUF use the same set of variables. These variables are all placed in labeled COMMON blocks which transmit information between subroutines. These variables are all defined in the Common Arrays and Single Word Common Stores sections. All subroutines using these variables are described in the Main Subroutines section. The remaining subroutines are described in the Auxiliary Subroutines section. Their major variables are described in the comment cards with each subroutine.

The program can handle as many as 99 points along the boundary layer surface and up to 300 points normal to the surface in the velocity profiles. The program is run at Lewis on the IBM-7094/7044 direct-coupled system with a 32768-word core ($77777_{(8)}$). The total program storage requirement is $67047_{(8)}$ of which $30117_{(8)}$ is used in storage of labeled common variables.

Main Subroutines

A brief description of the function of each subroutine will be discussed. Detailed comments are given throughout the source listing.

<u>COTR</u>. - Subroutine COTR reads, recomputes the starting data, and prints all the input data. Subroutine COTR reads in the x-station data from either cards or tape. Instructions for reading in data from the tape are given in the Special Instructions for Preparing Input section. Subroutine COTR calls subroutine A6IR to read and print comments that are a part of the data input.

<u>INIR</u>. - Subroutine INIR carries out some of the required initialization of the program and calls COTR for reading and listing the input data. Subroutine INIR calculates the x-station potential flow velocity U(X) if the Mach number M(X) is input, and

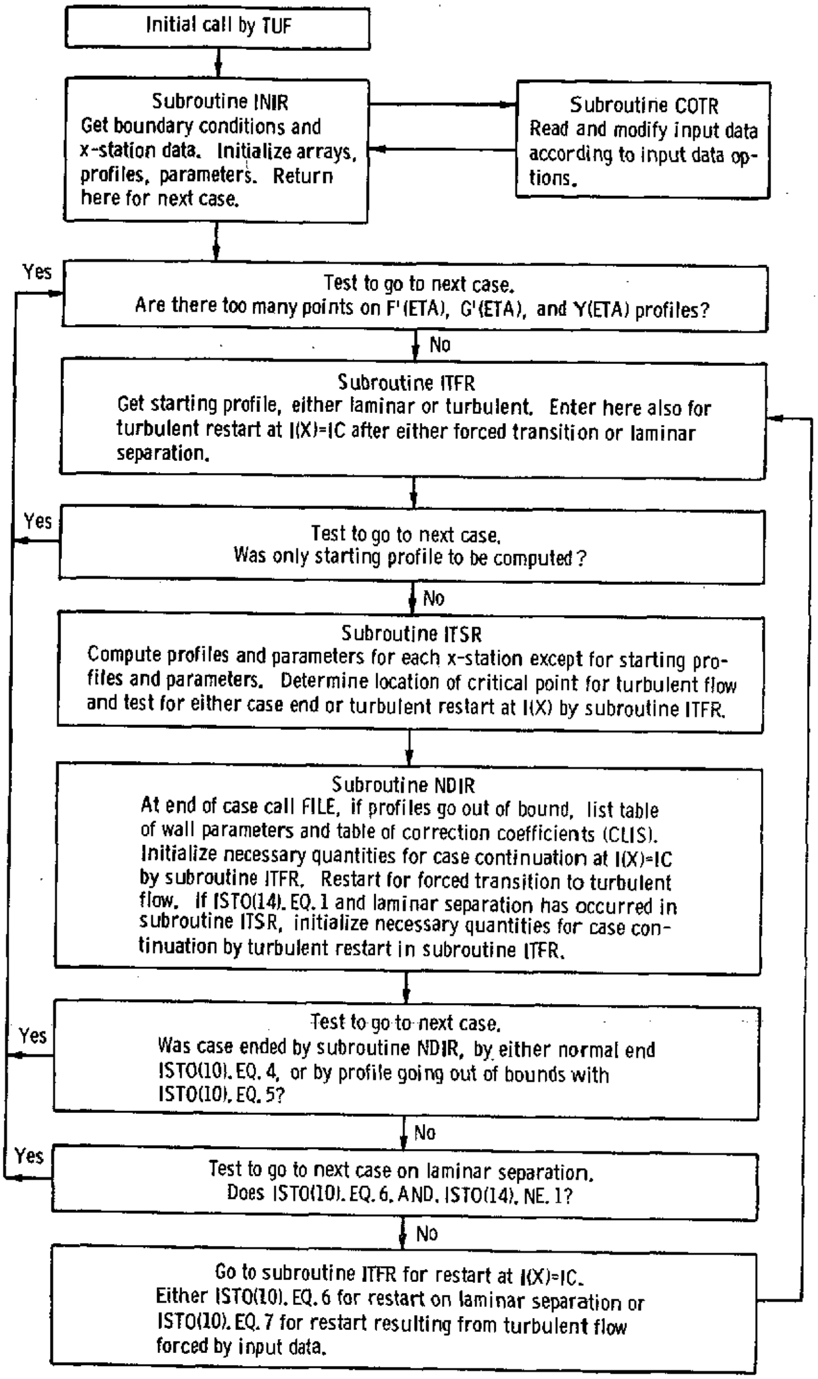


Figure 2. - Flow diagram for main supervisory routine TUF.

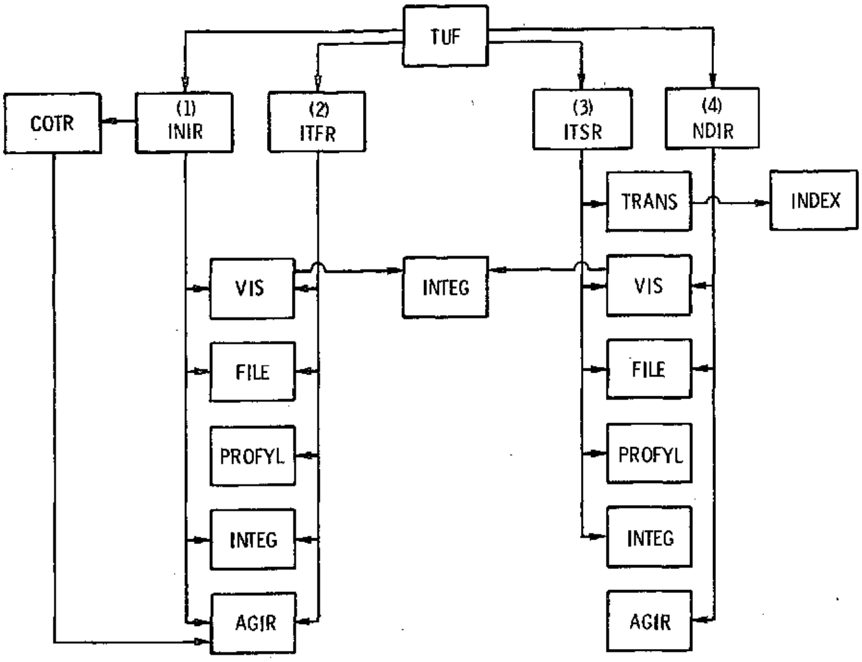


Figure 3. - Calling relation of program subroutines.

calculates the Mach number M(X) if the velocity U(X) is input. It nondimensionalizes the calculated U(X) by the value at the second x-station. It subdivides the initial intervals on the momentum and energy profiles (YY(J), $f'(\eta)$, and $g'(\eta)$) according to the input JDIV. It computes $f(\eta)$ by calling subroutine INTEG which uses the trapezoidal rule to calculate $f(\eta)$ from the $f'(\eta)$ profile. Subroutine INIR computes $f''(\eta)$ and $g''(\eta)$ by using forward differences. The computation of the secondary profiles of density D(J) and derivative of density DP(J) is followed by a call to subroutine VIS, which computes the effective voscisity VE(J) and effective conductivity VEG(J) from the input profile. Subroutine INIR then computes the local shear stress profile TAU(J).

ITFR. - Subroutine ITFR carries out the rest of the required initialization of the program. It calculates the momentum and energy starting profiles, except when the input profiles are used as the starting profiles. For variable property flow it recalculates the density D(J) and the x-derivative of the density DP(J). Subroutine ITFR calculates the parameters P, Q, R, etc., for laminar and turbulent flow. It calculates the coefficients of the momentum and energy equations and calls subroutine PROFYL for the $f'(\eta)$ and $g'(\eta)$ solution. The momentum and energy loops are iterated until convergence is obtained. For both the momentum and energy loops, the maximum number of iterations equals 15. Subroutine ITFR calculates δ^* and R_{δ^*} for option 4 and rescales P, Q, R, etc., for laminar flow. It prints the profiles and parameters by calling subroutine FILE.

ITSR. - The subroutine ITSR performs the calculations for the forward motion of the program for each x-station. The loop begins by moving the known profile into storage for the profile at the x-station before the one to be calculated. This is followed by an iterative loop to calculate a new set of profiles at the x-station. Within this loop, there is an inner loop to iterate for the $f'(\eta)$ profile. These calculations are very similar to the initialization part of the program. When these calculations have converged the integral parameters for the x-position are then calculated and used as a test for accuracy. The process continues until profiles have been calculated at all x-stations or the case is ended on (1) a profile out of bounds test or (2) a laminar separation. The subroutine ITSR calls subroutine TRANS (if type of flow is not specified by input), which determines whether flow is laminar, transitional, or turbulent.

NDIR. - Subroutine NDIR prepares for a turbulent restart calculation by resetting θ, δ^*, R_{δ^*}, etc.. It also calls subroutine FILE to list a summary of the principal boundary layer parameters at each x-station.

Auxiliary Subroutines

TRANS. - Subroutine TRANS computes the critical index IC for transition from laminar to turbulent flow. It computes the intermittency factor TURB(I) in the transition region which is used in subroutine VIS to compute the viscosity and conductivity. The subroutine itself was written by H. J. Herring under the sponsorship of General Electric Company for use with the Mellor-Herring Compressible Boundary Layer Program (ref. 1).

The input variable TOP governs the use of subroutine TRANS. If TOP = 0, transition is not predicted and the boundary layer program operates as specified by the TURB(I) values (see table VI). The range of the transition zone can be specified by changing TURB(I) from 0.0 to 1.0 either gradually or abruptly depending on the desired size of the transition region. If TOP = 1, the TRANS subroutine will be called and it will predict transition. For this operating mode TURB(I) values need not be specified. However, transition may be forced at an x-station by setting TURB(I) = 1.0 ahead of the predicted transition. At the specified location the boundary layer will be scaled up to a Reynolds number at which the current conditions would cause transition. In other words, the boundary layer is thickened enough so that transition can take place and the calculation continues downstream.

INDEX. - Subroutine INDEX is used to find the index or position of a value of a function S in a data table supplied by the TRANS subroutine.

VIS. - Subroutine VIS computes the effective viscosity VE(J) and effective conductivity VEG(J) using the viscosity and conductivity equations given by equations (IV-1A), (1B), (2), (3), and (4) of reference 1. The entire effective viscosity hypothesis for turbulent flow is contained in this routine with the exception of the recomputation of TURB(I+1) in subroutine TRANS under certain conditions.

PROFYL. - Subroutine PROFYL computes $f'(\eta)$ of the momentum equation using the b's from equations (III-9A) to (III-9E) of appendix B and computes $g'(\eta)$ of the energy equation using the b's from equations (III-10A) to (III-10E) of appendix B.

INTEG. -Subroutine INTEG is used to sum the input profile by a simple trapezoidal rule.

FILE. - Subroutine FILE lists the momentum and energy profiles and parameters at each x-station according to the input ISTO(k) and WSTO(1) list options. See the Input Variables section for these options.

A6IR. - Subroutine A6IR lists comment cards that accompany the data input. A detailed discussion of this routine is given in appendix C.

Common Arrays

This list is to be used with table I, the occurrence list of common arrays which shows in which subroutines each listed array is used (e.g., initialized, computed, employed in a computation, or listed). All arrays dimensioned 300 yield the ETA coordinate profile. All arrays dimensioned 100, except the JTR array, yield the x-coordinate profile. JTR, ISTO, and WSTO are general purpose arrays. The array B(300, 5) yields the five coefficient ETA profiles. All arrays shown by the table to be in subroutine INIR are initialized by subroutine INIR to either 0.0 or another constant.

In addition to the uses to be mentioned for the arrays as they are listed separately herein, the following functions are re-initialized in subroutine NDIR if a turbulent restart is required at the last critical point I(X)=IC. The re-initialization occurs if ISTO(14).EQ.1 to get a call of subroutine ITFR by TUF after a laminar separation occurs in subroutine ITSR. Otherwise, a re-initialization occurs when the input data TURB(I) forces a start of turbulent flow at I(X)=IC=IT. The single quantities MT(IC), DT(IC), DTK(IC), HT(IC), and RDT(IC) are re-initialized. The array TURB(IC) from I(X)=IC to IX is set equal to 1.0, and the profile of TAU(J) is recomputed. The ETA profiles of F(J), FP(J), FPP(J), GP(J), GPP(J), D(J), and DP(J) are shifted backward one x-station, and the coefficient CF(IC) is recomputed from the latest TAU(1).

The arrays X(I), U(I) or M(I) and TURB(I), GBC(I), RW(I), VW(I), SW(I), and CW(I) are read in together by subroutine COTR as the x-station data. In the present version of subroutine COTR, only the X(I), U(I) or M(I), and RW(I) can be read in from the tape. The remaining x-station data are set to 0.0 for the tape read in. The

TABLE I. - OCCURRENCE LIST OF COMMON ARRAYS

[Subroutines FILE, VIS, PROFYL, INTEG, TRANS, and INDEX have no common. An * indicates that the labeled store at the left occurs in the labeled subroutine above the *.]

		TUF	INIR	COTR	ITFR	ITSR	NDIR	FILE	VIS	PROFYL	INTEG	TRANS	INDEX
B	300, 5		*		*	*				*			
CAY	300		*			*							
CF	100		*		*	*	*	*					
CLIS	400		*			*	*						
CW	100		*	*	*	*	*	*	*			*	
D	300		*		*	*	*	*	*				
DB	300		*		*	*	*						
DBB	300		*		*	*	*						
DP	300		*		*	*	*	*	*				
DPB	300					*	*						
DT	100		*	*	*	*	*	*	*				
DTK	100				*	*	*					*	
F	300		*		*	*	*	*			*		
FB	300		*		*	*	*						
FBB	300		*			*							
FP	300		*	*	*	*	*	*	*	*	*		
FPB	300		*		*	*	*						
FPBB	300		*			*	*						
FPP	300		*		*	*	*	*	*			*	
FPPB	300		*			*	*						
GBC	100		*	*	*	*							
GP	300		*	*	*	*	*	*	*			*	
GPB	300		*		*	*	*						
GPBB	300		*			*	*						
GPP	300		*		*	*	*	*	*				
GPPB	300		*			*	*						
GPW	100		*		*	*	*						
HT	100		*		*	*	*	*					
ISTO	16	*	*	*	*	*	*	*				*	
JTR	100		*										
LABEL	132		*	*	*	*	*	*					
M REAL	100		*		*	*	*	*				*	
MT REAL	100		*		*	*	*	*				*	
RDT	100		*	*	*	*	*	*	*				
RW	100		*	*	*	*	*	*					
SF	100		*		*	*	*	*				*	
ST	100		*		*	*	*	*					
STR	100		*		*	*	*	*				*	
SW	100		*	*	*	*	*	*	*			*	
TAU	300		*		*	*	*	*	*				
TF	100		*		*	*	*	*	*			*	
TURB	100		*	*	*	*	*	*	*			*	
U	100		*	*	*	*	*	*				*	
VE	300		*		*	*	*	*	*				
VEG	300		*		*	*	*	*	*				
VH	300		*		*	*	*	*	*	*		*	
VHP	VHP		*		*	*	*	*	*	*		*	
VHPP	300		*		*	*	*	*	*	*		*	
VW	100		*	*	*	*	*	*					
WSTO	20	*	*	*	*	*	*	*				*	
X	100		*	*	*	*	*	*					*
Y	300		*		*	*	*			*	*	*	*
YY	300		*	*	*	*		*	*				

x-station data arrays near the origin are computed by a linear interpolation made by subroutine COTR on the integer switches ISTO(8) and ISTO(9).

B(300, 5)	Coefficient profiles (5) for the momentum equation (III-7) for computing F'(ETA) profile and for the energy equation (III-8) for computing G'(ETA). The B(J,K) profiles are computed in subroutines ITFR and ITSR just before the call of subroutine PROFYL for F'(ETA) and G'(ETA). B(J,K) in subroutine ITFR is computed from relations simplified in comparison with those used by subroutine ITSR.
CAY(300)	CAY(J).GE.-1. CAY(J)=CA*Y(J) in subroutine INIR is the scaled coordinate on 2/R(wall) normal to the axis of the body. CAY(J) is used in computing the TAU(J) profile which is computed from the same formula in all routines. CAY(J) is computed primarily to prevent a square root of a negative number from occurring in the function SQRT(1.+CA*Y(J)). In subroutine ITSR, CAY(J) is used to compute the YY(J) profile for subroutine VIS, the TAU(J) profile, and the B(J, 4) profile. CAY(J) is not computed in subroutine ITFR.
CF(100)	Profile of the skin friction coefficient defined in appendix A, computed in subroutines ITFR and ITSR, and listed by surboutines FILE and NDIR. CF(I) is initialized to 0.0 by subroutine INIR. CF(I) is recomputed in subroutines ITFR and ITSR after leaving the momentum-energy loop as CF(I)=2.*TAU(1).
CLIS(400)	General purpose array used by subroutine ITSR if ISTO(6).EQ.1 for storage of COF1, COF2, COG1, and COG2 of equations (II-21) and (II-23) and listed by subroutine NDIR.
CW(100)	Radius of longitudinal curvature profile at I(X) wall stations is in the same units as x, and is loaded by subroutine COTR together with the other x-station data. CW(I) is used by subroutine VIS which is called by subroutines INIR, ITFR, ITSR, and TRANS, which in turn is called by subroutine ITSR. CW(I) is listed by subroutines FILE, COTR, INIR, NDIR, and ITSR. CW(I) near the origin is computed by a linear interpolation made by subroutine COTR on the switches ISTO(8) and ISTO(9).
D(300)	Density ratio profile is initialized equal to 1.0 by subroutine INIR. Later, for MOP.GE.0, D(J) is determined before the call of subroutine VIS in the momentum loop of the calling subroutine and is computed from equation (II-16). D(J) is listed by subroutine FILE on an option.

DB(300)	Density ratio profile one station back upstream. DB(J) is used to compute the x-derivative DP(J) of the density ratio parameter profile. See DP(300) herein. For starting the flow DB(J) is computed by subroutine ITFR and is given by DELTA(*)*DP(J). See the density equation (II-16) and DELTA(*)*D(D(J))/DX by equation (II-32). Otherwise, DB(J) is loaded by subroutine ITSR at the nead of the I(X) loop. DB(J)=0.0 for MOP.LT.0.
DBB(300)	Density ratio profile two x-stations back upstream. DBB(J) is used to compute DP(J). See DP(300) herein. DBB(J) is loaded at the nead of the I(X) loop in subroutine ITSR.
DP(300)	Density ratio x-derivative parameter profile on ETA computed from equation (II-27). DP is initialized to 0.0 by subroutine INIR and remains 0.0 for MOP.LT.0. DP(J) is computed by subroutines INIR, ITFR, and ITSR in the same loop as D(J). DP(J) is used by subroutine VIS and by subroutines ITFR and ITSR in the computation of the B(J,K) profiles.
DPB(300)	Same as DP(J) but one x-station back upstream. DPB(J) is saved for the turbulent restart re-initialization by subroutine NDIR (possible working storage file for those NDIR decks which do not use the turbulent restart feature). DPB(J) is loaded at the head of the I(X) loop in subroutine ITSR.
DT(100)	Displacement thickness in the same units as x and is defined by appendix A (see DELTA(*)). DT(1) is initialized to 0.0 and later read in by subroutine COTR. For IOP.EQ.4 subroutine ITFR computes DT(2) and may reset DT(1)=DT(2) and starts the flow at I(X)=2. The remaining DT(I) are computed by subroutine ITSR initially before entering the momentum loop and recorrected in the output parameter section after the computation of COF1, COF2, COG1, and COG2 following the exit from the momentum-energy loop.
DTK(100)	Scaled value of DT(1) used only by subroutine TRANS, which is called only if TOP.EQ.1. ITSR also uses DTK(I) to compute RMTW for subroutine TRANS. DTK(I) is computed by subroutines ITFR and ITSR, and by subroutine NDIR in the turbulent restart re-initialization section.
F(300)	See FB(300). Used by subroutines INIR, ITFR, ITSR, and NDIR. F(J) is computed by subroutine INTEG by summing F'(ETA)=FP(J) and is used indirectly by subroutine VIS.

FB(300)	Subroutine ITFR loads FB(J) with F(J) for I(X).EQ.1,2 just before the return. Subroutine ITSR at the beginning of the loop on I(X) stores FB(J) in FBB(J) and loads FB(J) with F(J). F(J), FB(J), and FBB(J) are used to compute the coefficients for B(300, 5) for subroutine PROFYL.
FBB(300)	Used by subroutine ITSR. See FB(300).
FP(300)	F'(ETA) profile, used by subroutines INIR, COTR, ITFR, ITSR, NDIR, FILE, VIS, PROFYL, and INTEG. F'(ETA) is the velocity defect profile. Initial FP(J) profile is card read in and expanded by subroutine COTR, and then filled in by subroutine INIR on JY. If IABS(DOP).EQ.1.OR.MOP.GE.0, then FP(J) is later computed in subroutine INIR to become the initial profile for subroutine ITFR. F(J) is obtained from FP(J) by summing using subroutine INTEG, and FPP(J) is obtained from FP(J) by taking the first central differences in subroutines ITFR and ITSR and first forward differences in subroutine INIR. FP(J) is used in the computation of B(J,K) for subroutine PROFYL. FP(J) is also used by subroutine VIS to compute the effective viscosity and effective conductivity profiles, and by subroutines ITFR and ITSR to compute tht local shear stress TAU(J).
FPB(300)	FP(J) profile upstream one x-station. FPB(J) is loaded by subroutine ITFR just before the return and by subroutine ITSR at the head of the I(X) loop. FPB(J) excepting FPP(1) is used by subroutine ITSR, but not by subroutine ITFR, in the computation of the B(J,K) coefficients for subroutine PROFYL.
FPBB(300)	FP(J) profile upstream two I(X) stations. FPBB(J) is loaded at the head of the I(X) loop with FPB(J) in subroutine ITSR and is used in the computation of the B(J,3) profile for subroutine PROFYL.
FPP(300)	F''(ETA) profile obtained by first forward differences in subroutine INIR, and by first central differences in subroutines ITFR and ITSR excepting FPP(1). FPP(1)=FPP(1)*F(JE) in subroutine ITFR for IOP.EQ.1,5 where IOP.EQ.5 may initially be IOP.EQ.4. FPP(1) in subroutines ITFR and ITSR is obtained from first forward differences. FPP(J) is used in the computation of the TAU(J) profile and the B(J,K) coefficients for subroutine PROFYL. FPP(J) is used in computing the TAU(J) profile and the B(J,K) coefficients for subroutine PROFYL.

FPPB(300)	F''(ETA) profile upstream one x-station. FPPB(J) is used in subroutine ITSR in computing the B(J,K) coefficients for subroutine PROFYL but not in subroutine ITFR. ITSR loads FPPB(J) at the head of the I(X) loop.
GBC(100)	Wall boundary condition on the energy equation either G'(ETA) or G''(ETA). See equation (II-19D). GBC(I(X)) is read in by subroutine COTR as part of the x-station data and is used by subroutines ITFR and ITSR according to the integer switch MOP. GBC(I) near the origin is computed by a linear interpolation made by subroutine COTR on the switches ISTO(8) and ISTO(9).
GP(100)	Energy equation profile of G'(ETA) the total enthalpy defect ratio in appendix A (see G'(ETA)). GP(J) is initially read in and expanded by subroutine COTR on JDIV and then filled in by subroutine INIR. GP(J) is not later recomputed in subroutine INIR. The following GP(J) profiles are computed in either subroutine ITFR on a call of subroutine PROFYL for the starting profile on an option or in subroutine ITSR on a call of subroutine PROFYL. The GP(J) profile is used to compute the GPP(J)=G''(ETA) by first differences in subroutines INIR, ITFR, and ITSR in the same manner as for FPP(J). GP(J) is computed only once for each convergence of the momentum equation. GP(J=1) is used to determine the convergence of the set of momentum-energy equations. See also GPP(300).
GPB(300)	G'(ETA) profile is one x-station upstream and is stored just before the exit from subroutine ITFR and at the head of the I(X) loop in subroutine ITSR. GPBB(J) is loaded from GPB(J). GPB(J) is used to compute the B(J,K) coefficients in subroutine ITSR for subroutine PROFYL, also used to compute B1.
GPBB(300)	G'(ETA) profile is two x-stations upstream from I(X) and is loaded by subroutine ITSR at the head of the I(X) loop. See GPB(300). GPBB(J) is used only to compute the B(J,K) coefficients in subroutine ITSR for subroutine PROFYL.
GPP(300)	G''(ETA) profile obtained by taking the first differences of G'(ETA) after the exit from subroutine PROFYL in the energy section of the momentum-energy loop in subroutines ITFR and ITSR and after the computation of F''(ETA) in subroutine INIR. Both GPP(J) and FPP(J) are used in computing DP(J) in subroutines INIR, ITFR, and ITSR as well as by subroutine VIS for VE(J), VEG(J) in the effective viscosity and effective conductivity corrections from equation (IV-3). GPP(1) is

	used in the final convergence test for leaving the momentum-energy loop in subroutines ITFR and ITSR.
GPPB(300)	G''(ETA) profile is one x-station upstream from the current I(X) and is loaded by subroutines ITFR and ITSR like GPB(J). A storage array used only by subroutine NDIR.
GPW(100)	Value of GP(J)=G'(ETA) profile at the wall. GPW(I)=GBC(I) if IBC.EQ.2 but GPW(I)=GP(1) if IBC.EQ.3 where IBC=ABS(MOP). GPW(I) is used by subroutine PROFYL. For MOP, see the card input data of table VI.
HT(100)	Total enthalpy thickness is in the same units as x and is defined in appendix A (see PSI). HT(I) is computed in subroutines ITFR and ITSR after leaving the momentum-energy loop.
ISTO(16)	Set of integer switches read in by subroutine COTR. See the comments in the data input deck of table VI for the ISTO(K) usage. ISTO(K) is initialized to 0 by subroutine INIR.
JTR(100)	Standby set of integers not used in the current program of TUF.
LABEL(132)	Array in alphanumeric format used for a heading to identify the case at the time of the listing of the ETA profiles. Current version of TUF uses only 18 of these stores.
M(100)	Mach number at the x-station boundary layer edge, M(I(X)). M(I) is either loaded with U(I) from cards when U(I) on input is the Mach number, or computed from the U(I), SHR, and MR data when U(I) is the x-velocity input. See subroutine INIR after the exit from subroutine COTR. See also DOP in table VI.
MT(100)	Momentum thickness in the same units as x and is defined in appendix A (see THETA). Subroutines ITFR and ITSR compute MT(J) after the exit from the momentum-energy loop using the relation MT(I)=DT(I)/SF(I).
RDT(100)	Reynolds number based on the momentum thickness U*DELTA(*)/U(BLE). RDT(I) is computed by subroutine ITSR in each momentum loop and reset to match CF(I) after leaving the momentum-energy loop.
RW(100)	Radius of the body surface expressed in the same units as x. RW(I) is part of the x-station data read in by subroutine COTR from either cards or tape. RW(I) near the origin is computed by linear interpolation

	using ISTO(8) and ISTO(9) in subroutine COTR. RW(1) may be reset in subroutine INIR after the read in by subroutine COTR.
SF(100)	Ratio DELTA(*)/THETA where DELTA(*) is the displacement thickness and THETA is the integral momentum thickness of equation (II-22). SF(100) is computed in subroutines ITFR and ITSR after leaving the momentum-energy loop, but it is also computed in the momentum loop of subroutines ITFR and ITSR.
ST(100)	Stanton number is defined in appendix A and is based on the free stream to wall enthalpy differences. ST(I) is computed in subroutines ITFR and ITSR after leaving the momentum-energy loop. Either ST(I)=0.0 or if ABS(B1).GT.ZERO then ST(I)=STR(I)/B1.
STR(100)	Stanton number is defined in appendix A and is based on the free stream to reference enthalpy differences. STR(J) is computed in the energy section of the momentum-energy loop of subroutines ITFR and ITSR. In subroutine ITSR we have STR(I)=-VEG(1)*GPP(1)/D(1).
SW(100)	Nikuradse (ref. 16) sand grain roughness scale in the same units as x, and read in by subroutine COTR as part of the x-station data. SW(I) near the origin is computed by a linear interpolation made by subroutine COTR on the switches ISTO(8) and ISTO(9).
TAU(300)	Profile of the local nondimensional shear stress. TAU(J) is initially computed by subroutine INIR followed by the TAU(J) computation in the momentum section of the momentum-energy loop of subroutines ITFR and ITSR. Subroutine VIS uses TAU(J). Subroutines ITFR and ITSR compute CF(I)=2.*TAU(1).
TF(100)	x-Profile of the Mach number function T(total)/T(static). TF(I)=1.+(1./2.)*SHR-1.)*M(I)*M(I). TF(100) is computed along with either M(I) or U(I) in subroutine INIR.
TURB(100)	Intermittency factor .GE.0 and .LE.1. TURB(I) represents the amount of turbulence present in the flow. See comments on subroutines VIS and TRANS. TURB(I) is either card read in by subroutine COTR or computed by subroutine TRANS during the run. It is used in the computation of the effective viscosity VE(J) and the effective conductivity VEG(J) by subroutine VIS. TURB(I) near the origin is reset on (TOP.NE.1.AND.IOP.NE.7) during the linear interpolation of the x-station data by subroutine COTR on the switches ISTO(8) and ISTO(9). All TURB(I) are initialized to 0.0 by subroutine INIR before entering subroutine COTR.

U(100)	Free-stream velocity at the boundary layer edge is either read in by subroutine COTR from cards or tape or computed by subroutine INIR from the M(I) data read in by subroutine COTR as U(I). U(I) near the origin is computed by a linear interpolation made by subroutine COTR on the switches ISTO(8) and ISTO(9).
VE(300)	Nondimensional effective viscosity profile computed by subroutine VIS on call by subroutines INIR, ITFR, ITSR, and NDIR. Subroutine VIS is called by subroutines ITFR and ITSR from the momentum loop and by subroutine ITSR after the exit from the momentum-energy loop provided that TOP.EQ.1.
VEG(300)	Nondimensional effective conductivity profile computed together with VE(J) in subroutine VIS. See VE(300) and comment in subroutine VIS.
VH(300)	Working store array, temporary storage.
VHP(300)	Working store array, temporary storage.
VHPP(300)	Working store array, temporary storage.
VW(100)	Transpiration velocity in the same units as U(X) and read in by subroutine COTR together with the other x-station data. See table V for the density weighting. VW(I) is used by subroutines ITFR and ITSR in the computation of B(J,K) for use by subroutine PROFYL in computing F'(ETA) and G'(ETA). VW(I) near the origin is computed by a linear interpolation made by subroutine COTR on the switches ISTO(8) and ISTO(9).
WSTO(20)	General purpose working array read in by subroutine COTR. See the comments in the data input of table VI. WSTO(K) is initialized to 0.0 by subroutine INIR.
X(100)	x-Coordinate X(I). It is read in from either cards or tape by subroutine COTR. X(I) near the origin is computed by a linear interpolation made by subroutine COTR on the switches ISTO(8) and ISTO(9).
Y(300)	Independent variable Y/DELTA(*) normal to the wall is computed as Y(J)=YY(J)*(1.+YY(J)*CA/4.) in subroutine INIR to account for the nose angle of an axisymmetric body. It is not recomputed later during the run. The profile of YY(J) is both read in from either cards or tape and completed on the JDIV interval by subroutine COTR. Y(J) is used as the normal coordinate everywhere except by subroutine VIS which uses a YY(J) coordinate recomputed at each I(X) wall station. However, at

	the starting I(X), subroutine ITFR uses the initial YY(J) completed profile.
YY(300)	y-Untransformed coordinate normal to the body surface as divided by DELTA(*). YY(J) is used to obtain the transformed y of equation (II-7B). YY(J) profile is read in, spaced by subroutine COTR, and then filled in by subroutine INIR before being used to compute the Y(J) profile which includes the effect of the nose angle. Later, in subroutine ITSR, YY(J) is recomputed at each I(X) wall station using the displacement thickness which in turn is also computed at each I(X) wall station. YY(J) is recomputed only when ABS(RW(I)/DT(I)).GE. 1 so that the new YY(J) is YY(J)=2.*Y(J)/(1.+SQRT(1.+CAY(J)=CA*Y(J)) where CAY(J).GE. -1. CA is recomputed at each I(X) station. YY(J) is used by subroutines ITFR and ITSR to supply subroutine VIS with a normal coordinate. YY(J) as used by subroutine VIS at the origin, in both subroutines INIR and ITFR, is the initial complete YY(J) not corrected using CA.

Single Word Common Stores

This list is to be used with table II, the occurrence list of single word common stores which shows in which subroutines each listed word is used (e.g., initialized, computed, employed in a computation, or listed). The following abbreviations are used in the computer equations: enthalpy, H; boundary layer edge, BLE; at reference level, REF; total, TOT:

ATUF	Not used.
B1	Initially TF(I)-1. In both subroutines ITFR and ITSR, but is recomputed later in ITFR and ITSR as GPW(-TF(I)-1.)/BH/TF(I) to compute in turn ST(I)=STR(I)/B1 in ITFR and ITSR.
BH	Enthalpy ratio (H(BLE)TOT-H(REF))/H(BLE)TOT data constant read in by subroutine COTR.
BK	Clauser constant 0.016 set in subroutine INIR and used by VIS only.
BS	Input for initial pressure gradient from data read in by subroutine COTR. BS is the exponent in the power law for velocity =U(X)/U(L)=(X/L)**B at the boundary layer edge in wedge flow. See equation (II-28a). BS=1.0 for plane stagnation flow and BS=0.0 for Blasius flow.

TABLE II. - OCCURRENCE LIST OF SINGLE WORD COMMON STORES

[Subroutines FILE, VIS, PROFYL, INTEG, TRANS, INDEX have no common. An * indicates that the labeled store at the left occurs in a labeled subroutine above the *.]

	TUF	INIR	COTR	IFTR	ITSR	NDIR	FILE	VIS	PROFYL	INTEG	TRANS	INDEX
ATUF												
B1		*		*	*							
BH		*	*	*	*	*	*	*			*	
BK		*						*				
BS		*	*	*								
C		*		*								
CO				*	*							
COB					*							
CA		*		*	*	*						
CA1					*	*						
CMTF		*			*							
CMTG		*			*							
CMU		*		*		*						
COAL		*		*								
DI												
DJ												
DOP INTEGER		*	*	*	*							
DTM					*							
DTS					*	*						
DTXM				*	*							
DX				*	*							
DXB					*							
ET		*		*	*				*			
FPE				*	*				*			
FPPW				*	*				*			
FT		*	*									
FTU2		*			*							
FV		*		*	*							
GAM		*		*								
GAMX		*		*								
GPE				*	*							
GPPW				*	*							
I		*	*	*	*	*	*				*	*
IO												
IBC				*	*				*			
IC		*			*	*					*	
ID		*		*	*	*	*				*	
IOP		*	*	*		*						
IT		*	*		*	*						
IX		*	*	*	*	*						
IXA					*	*						
IXE												
IXF				*	*							
JD		*		*	*	*	*		*	*	*	
JDIV		*	*	*	*	*	*					
JE		*		*	*	*	*	*	*	*		
JEB					*	*						
JEF		*	*	*	*						*	
JEG		*	*	*	*							
JK		*		*	*	*		*				

	TUF	INIR	COTR	ITFR	ITSR	NDIR	FILE	VIS	PROFYL	INTEG	TRANS	INDEX
JM				*	*							
JTUF												
JY		*	*	*	*	*	*	*	*		*	
KR REAL		*			*						*	
KMI		*		*	*							
LOOP												
LOOPF												
ML REAL		*		*								
MOP		*	*	*	*							
MR		*	*			*						
NU				*								
OI		*		*	*							
P		*		*	*	*						
PR					*							
PM					*							
POP INTEGER		*	*	*	*	*						
PR		*		*	*	*	*	*				
PRT		*		*	*	*	*	*				
Q		*		*								
QB					*							
QM					*							
QRB					*							
QRM					*							
R		*		*	*	*						
RB					*							
RC		*			*	*					*	
RDF		*		*		*						
RDTK				*	*	*					*	
RL		*		*								
RM					*							
RMS												
RMT					*							
RMTW				*	*						*	
RX					*	*						
RXRDF												
SHR		*		*	*	*	*	*				
SK		*		*								
STC		*		*	*	*		*				
STRX		*		*								
STUF												
TO		*	*	*	*	*		*				
TFR		*				*						
TOP INTEGER		*	*		*	*					*	
UX					*	*						
VPB					*							
VPM					*							
XK		*			*						*	
XT		*		*	*							
ZERO		*		*	*							

C	Constant in the displacement thickness at DELTA(*) given by DELTA(*)/L=C*(X/L)**(1.-B)/2. (eq. (II-28b)). C is computed in subroutine INIR as C=SQRT(2./(BS+1.)/RL. If IOP.EQ.4, yielding laminar similar flow, C is recomputed in subroutine ITFR as C=F(JE)*C and is used in computing P, Q, VP, and CF.
C0	Coefficient used by subroutines ITFR and ITSR in computing the coefficient profiles B(J,K=1,5) used by subroutine PROFYL. See equation (III-6e).
C0B	First of five cofficient functions (C0B, C1B, C2B, C3B, and C4B) computed in subroutine ITSR from the (I-1) and (I-2) x-stations and used by equations (III-9a) and (III-9c) to compute B(J,K) for the F'(ETA) profile in subroutine PROFYL.
CA	Nose angle parameter (2.*(DELTA(*)/R(W))*(COS A)) used to compute the array CAY(J)=CA*Y(J). CA is used by subroutine INIR to compute Y(J) and YY(J). Computation of CA in subroutine INIR depends on the IOP option used. If IOP.EQ.4, subroutine ITFR resets CA to 0.0 and recomputes CA as 2.*OI*COAL*C*(X(2)-X(1))/RW(2) provided RWSL.GE.1.0E-08 where RWSL is the slope of RW(I) at the origin. In subroutine ITSR, CA is computed in the momentum loop and is given by CA=CA1*DT(I).
CA1	Function (2/R(W))*COSA. A function of RW(I) used to compute CA in both the momentum loop of subroutine ITSR and the initialization section of subroutine NDIR. CA=CA1*DT(I). CA1 is computed in subroutine ITSR before entering the momentum-energy loop. CA1=0.0 in planar flow.
CMU	Shear parameter. See equation (II-34). CMU is computed before the call of VIS. CMU is used by subroutine ITFR to compute STRX, a Stanton number gradient parameter for the starting profiles.
COAL	Cosine of the angle of the nose of an axisymmetric body for the starting profiles. COAL is computed equal to SQRT(1.-(D(RW(X)=1,2))/DX)**2) in subroutine INIR, and it is used by subroutines INIR and ITFR in the computation of CA.
CMTF	Function initialized to 1.0 in subroutine INIR and corrected by COF2/COF1 in subroutine ITSR at each succeeding I(X) wall station but not used in a further computation, an indicator of the history of the ratio COF1/COF2.
CMTG	Function initialized to 1.0 in subroutine INIR and corrected by COG2/COG1 in subroutine ITSR at each succeeding I(X) wall station but not used in a further computation, an indicator of the history of the ratio COG1/COG2.

DI	Not used.
DJ	Not used.
DOP	Integer switch read in by subroutine COTR and used by subroutines COTR and INIR to interpret the input data. See DOP in table VI.
DTM	Arithmetic mean value of DELTA(*)=(DELTA(*)(I(X))-DELTA(X)(I(X)-1))/2.
DTS	Convenient storage in subroutines ITSR and NDIR for the value of the displacement thickness DT(I) which is then altered to conform to the integral of the momentum equation. In the reset section of subroutine ITSR, after computing COF1, COF2, COG1, and COG2, DTS=DT(I).
DTXM	Arithmetic average value of DTX taken between the I(X) and I(X)-1 x-stations where DTX is defined as the x-derivative of the displacement thickness DELTA(*) at I(X). DTXM is computed in subroutines ITFR and ITSR. In subroutine ITFR, DTXM=Q-P*(1.-M(I)*M(I)) computed in the output parameter section only, after exit from the momentum-energy loop, for use by subroutine ITSR. Subroutine ITSR uses DTXM at the head of the I(X) loop to compute DT(I)=DT(IB)+DTXM*(DX=X(I)-X(I-1)). DTXM is then recomputed at the head of the momentum loop and is used to compute QM at the head of the momentum loop.
DX	First backward difference in x, computed and used in subroutine ITSR. In subroutine ITFR, DX is initialized to 0.0 just before the return to TUF. At the head of the I(X) loop in ITSR DXB=DX followed by DX=X(I)-X(IB=I-1).
DXB	Previous DX loaded at the head of the I(X) loop in subroutine ITSR.
ET	Convenient store now initialized in subroutine INIR to 1.0E-08. ET is now supplied to subroutine PROFYL by subroutines ITFR and ITSR but is not used in the current version of subroutine PROFYL.
FPE	PROFYL end value or outer boundary value of FP(J)=F'(ETA)=0.0 set by subroutine ITFR before calling subroutine PROFYL in which FP(JY)=FPE.
FPPW	Velocity gradient defect at the wall, F''(ETA=0.0) or the inner boundary value used by subroutine PROFYL. FPPW is used to compute F'(J=2) by subroutine PROFYL. FPPW is set to FPP(1) by subroutine ITFR before entering subroutine PROFYL.
FT	Fraction of the free-stream flow that is turbulent. It is read in by subroutine COTR and used by surroutine INIR to compute FTU2=FT*U(I)*U(I) for I=1,2. Subroutine ITSR recomputes FTE as FTE=FTU2/(U(I)*U(I)) for I=2,3,4.... Subroutine TRANS uses FTE as FT.

FTU2	Convenient store equal to FT*U(I)*U(I) in subroutine INIR and used by subroutine ITSR to get a scaled FT in subroutine TRANS. See FT.
FV	Convenient store for 1.-FP(J) in subroutines INIR, ITFR, and ITSR.
GAM	Square root of the ratio of the friction velocity to the free-stream velocity in the starting solution. GAM equals the SQRT(TAU(1)/(DENSITY(BLE)*VELOCITY(BLE SQUARED). GAM is initialized to 0.0 in surboutine INIR. GAM is recomputed to SQRT(ABS(TAU(1))) in subroutine ITFR in the momentum loop if IOP.EQ.3, 7 and is then used to compute GAMX.
GAMX	Shear stress gradient parameter in the starting solution. See also GAM.
GPE	Profile end value or outer boundary value of GP(J)=GP(JY)=0.0.
GPPW	Value of GP(ETA=0.0) obtained by subroutines ITFR and ITSR by taking the first differences of GP(ETA) following the return from subroutine PROFYL and computing the profile GPP(ETA). Then GPPW=GPP(1) is used as the inner boundary value when computing the GP(ETA) on the next momentum-energy loop iterate. GPPW is treated similarly to FPPW.
I	Integer or index of the I(X) wall station where final profiles at each x-station are computed.
IO	Input integer switch, read in by subroutine COTR. Subroutine INIR sets OI=IO. OI becomes a multiplying factor in computing CA in subroutines INIR, ITFR, and ITSR. IO.EQ.-1 for the inside surface of an axisymmetric body such as a jet engine nacelle. IO.EQ.0 for planar flow. IO.EQ.+1 for flow on the outside of an axisymmetric body. OI is also used in the computation of CA1.
IBC	Absolute value of the integer switch MOP, read in by subroutine COTR. IBC is used as a skip switch by subroutines ITFR and ITSR. If IBC.EQ.1, the computation of the GP(ETA) profile in the energy equation section of the momentum-energy loop. In subroutine ITFR, if IBC.EQ.2, then GPW(I)=GBC(I), GPPW/GPP(1), and STR(I)=-GPPW/D(1)*VEG(1). If IBC.EQ.3, then GPW/GP(1)=GPPW=-GBC(I)*D(1)/VEG(1) followed by GPPW=GPPW*C*RL if IOP.EQ.4. If IBC.EQ.3 and IOP.EQ.4, then STR(I)=GBC(I)/C/RL. Otherwise, STR(I)=0.0. In subroutine ITSR, STR(I) is always computed after the exit from the momentum-energy loop as STR(I)=-VEG(1)*GPP(1)/D(1), but GPPW is not recomputed when IOP.EQ.4 as in subroutine ITFR. Otherwise, GP(I) and GPPW are computed as in subroutine ITFR.

IC	Index of the critical point, which is the point at which disturbances in the laminar flow occur and begin to amplify toward the transition point to full turbulent flow. At and beyond IC TURB(I+1) is computed by subroutine TRANS if TOP.EQ.1. Otherwise, IC is determined as IC=I(X) at the laminar separation point on a test of F(JEF), WSTO(2), and FPP(1).GE.0.0 by subroutine ITSR. If laminar separation occurs, subroutine ITSR resets ITSO(10)=6, which causes a turbulent restart in subroutine ITFR provided in TUF ISTO(14).EQ.1. IC is initialized to IX+1 by subroutine INIR after the exit from subroutine COTR. All points after the first critical point and before points of fully developed turbulent flow are considered critical points. See also the single word common stores RC and IT.
ID	Number of stores available for the profiles on x. In the current version, ID is set equal to 100 by subroutine INIR.
IOP	Integer switch read in by subroutine COTR. IOP is used by subroutines INIR, COTR, and ITFR to set up the starting conditions, profiles, and parameters for various options such as laminar or turbulent starting flows. See table VI.
IT	Integer initialized to 100 by subroutine COTR and listed by subroutine COTR and also by subroutine INIR when POP.NE.1. IT is reset to I(X)+1 after the x-station data read in by subroutine COTR if TURB(I).GT.WSTO(13), which is followed in turn by a reset of ISTO(10)=7 by subroutine ITSR on completing the computations at I(X)=IT. Subroutine ITSR then exits to TUF and to subroutine NDIR in turn which re-initializes the necessary quantities for a turbulent restart at I(X)=IT by subroutine ITFR on the call by TUF. IT causes a relist of the profile at I(X)=IT by subroutine ITFR. In subroutine NDIR, IC is reset to IT for a forced fully developed turbulent flow beginning at I(X)=IT.
IX	I(X) of the last data station to be computed as determined by subroutine COTR. IX either is the number of x-stations whose data is either read in or linearly interpolated near the origin or IX=IS-1 when IS reaches 100. If (IX-I).LE.0 after the call of subroutine FILE in subroutine ITFR, then ITFR resets ISTO(10)=8, which causes a case end by the main routine TUF. Subroutine ITSR uses IX as the limit on the I(X) looping.
IXE	Convenient store. Not used.
IXF	Integer index. IXF=I+1 in subroutine ITFR. It is used by subroutine ITSR as the starting index of the I(X) loop.

JD	Dimension of the arrays used to store the profiles on ETA (normal to the x-direction). Subroutine INIR sets JD=300 in the current version of the TUF.
JDIV	Integer multiplier which is read in by subroutine COTR and used by subroutines COTR and INIR to increase the number of points on the YY(J), F(J), and GP(J) profiles. See table VI.
JE	Index of the ETA profile outer end point as used by subroutine FILE in listing the function profiles on ETA and by subroutine INTEG in summing the function profiles on ETA. In subroutine INIR, JE=MAX0(JEF, JEG) after JY, JEF, and JEG have been increased (by using JDIV) from the JY, JEF, and JEG read-in values. In the present versions of subroutines ITFR and ITSR, JE is reset to MAX0(JEF, JEG) following the return from subroutine PROFYL. Subroutine INIR resets JEF=JY if JEF.GT.JY. It also resets JEG=JY if JEG.GT.JY to prevent JE.GT.JY.
JEB	Last computed value of JE in subroutine ITFR on entering the I(X) loop of subroutine ITSR and the last computed value of JE at the previous I(X) station thereafter. JEB is reset at the head of the I(X) loop. JE=JEB in subroutine NDIR in preparation for a turbulent restart by subroutine ITFR.
JEF	JEF is initially the number of FP(J) points read in by subroutine COTR which then computes JEF using JDIV to increase the number of profile points. In the present versions of subroutines ITFR and INIR, JEF is used to recompute JE=MAX0(JEF, JEG) after the return from subroutine PROFYL.
JEG	Energy profile analogue of JEF. See JEF.
JK	Integer computed in subroutine VIS, and the index J of the VE(J) profile at which VE(J).GT.VR where VR is a constant value of the nondimensional effective viscosity in the outer part of the turbulent layer.
JM	Value J-1 in subroutines ITFR and ITSR during the computation of the FPP(J) profile. At J=1, subroutines ITFR and ITSR set JM=1 to get FPPW at the origin by the first forward difference. The remainder of the FPP(J) are by first central differences. The GPP(J) profile is computed similarly.
JTUF	Not used.
JY	Initially the number of the YY(J) profile points on ETA as read by subroutine COTR. Just before reading in the YY(J) subroutine COTR recomputes the program final JY by using JDIV. JY values are the preset

	boundary values of FP(J) and GP(J). The computed JY(MAX) must be JY(MAX).LE.300 to continue the case.
KB	Real function initialized to 0.0 by subroutine INIR. Subroutine TRANS recomputes KB before using subroutine INDEX to select the KF(RDF).GT.KB.
KMI	Upper index in the momentum and momentum-energy DO loops in subroutines ITFR and ITSR. Subroutine INIR sets KMI=15.
LOOP	Not used.
LOOPF	Not used.
ML	Free-stream Mach number at X=L. ML is set equal to MR in subroutine INIR after the return to subroutine INIR from subroutine COTR where MR is the result of either the MR card read in or a recomputation. Subroutine ITFR uses ML in the computation of Q, a parameter in equation (II-14). See DOP in table VI.
MOP	Integer switch read in by subroutine COTR. See table VI.
MR	Reference free-stream Mach number. MR is initially read in by subroutine COTR but may be recomputed. See the comment in table VI. See also ML.
NU	Nusselt number. If IOP.EQ.4, NU is computed in subroutine ITFR in the output parameter section as NU=RL*PR*ST(2). NU is not used in a computation.
OI	Multiplying factor. OI is set to IO by subroutine INIR. See IO, CA, and CA1. OI is used to compute CA in subroutines INIR and ITFR and also CA1 in subroutine ITSR.
P	Parameter in equation (II-14). P equals x-derivative of U(I)*DELTA(*)/U(I). Subroutine INIR sets P=BS. See BS. If IOP.EQ.4, P is recomputed in the laminar section of subroutine ITFR according to equation (II-29a) and used in the solution of equation (II-25). If IOP.EQ.2,6 (turbulent flow), subroutine ITFR resets P=TAU(1)*BS. If IOP.EQ.3,7 (also a turbulent flow), subroutine ITFR does not reset P. If ISTO(10).EQ.6,7, subroutine NDIR resets P=UX*DT(I) for a turbulent restart by subroutine ITFR.
PB	P parameter at I-1 x-station where PB=P at the head of the I(X) loop in subroutine ITSR. PB is used to compute PM (average P), which is used to compute C_2, which is used to compute B(J,1) and B(J,3). PM and RM are both arithmetic averages.

POP	Integer switch read in by subroutine COTR and used as a list switch. See POP in the input data sample, table VI. POP is used by all of the main subroutines.
PR	Prandtl number. PR is the same constant for all subroutines. Subroutine INIR initializes PR=0.78. If WSTO(15).NE.0.0, subroutine INIR resets PR=WSTO(15).
PRT	Turbulent Prandtl number. Subroutine INIR sets PRT=1. PRT is the same constant for all of the subroutines. If WSTO(14).NE.0.0, subroutine INIR resets PRT=WSTO(14).
Q	Product DELTA(*)*DENSITY(BLE)*U(I)/(DENSITY(BLE)*U(I)). Q is initialized to 0.0 by subroutine INIR for the laminar flow equation (II-25). See also equation (II-29b) for a recomputation in the laminar flow section of subroutine ITFR if IOP.EQ.4. Q is otherwise recomputed in subroutine ITFR as given by equation (II-41) for Q as an integrated function.
QB	Quantity Q at the I-1 x-station. QB is recomputed and used only in the momentum loop of subroutine ITSR. QB=DTXB+PB(1. -M(IB)*M(IB)) where DTXB is a corrected value of the displacement thickness.
QM	Mean value of Q and QB computed in the momentum loop of subroutine ITSR and used only in subroutine ITSR. (Not an arithmetic mean.) QM=DTXM+PM*(1. -. 5*(M(I)+M(IB))**2.
QRB	Quantity QB+RB at the I-1 x-station. Computed at the head of the momentum loop in subroutine ITSR.
QRM	Mean value of Q+R computed and used only in subroutine ITSR. QRM=QM+RM.
R	Radius parameter in equations (II-14) and (II-25) for laminar flow. R equals the (x-derivative of wall radius)*DELTA(*)/(wall radius) and is initialized to 0.0 by subroutine INIR. If IOP.EQ.4, R is recomputed in the similar laminar flow section of subroutine INIR from RL=RDT(1), C, the slope of RW at the origin, and from a slope multiplying function of RW. The radius parameter R is the R(*) of equation (II-29c). For IOP.EQ.1 or 5 and nonsimilar laminar flow, R is computed from DT(1), RDT(1), the slope of RW at the origin, and RW(1). For all other conditions R is recomputed in subroutine INIR if ABS(RW(1)/DT(1)).GE.1., where R(laminar)=R(turbulent)*RDT(1). For IOP.EQ.4, R is recomputed in subroutine ITFR after a reset to R=0.0 by the same formula as in subroutine INIR but with a changed value of C=F(JE)*C on a RW(I) slope

	test. Otherwise, R remains as computed in subroutine INIR. In subroutine ITSR, R is computed in the momentum loop R=RX*DT(I) where RX is computed ahead of the momentum-energy loop if ABS(RW(I)/DT(I)).GE.1. R is also recomputed in subroutine NDIR for a turbulent restart on ISTO(10).EQ.6, 7 with R=RX*DT(I).
RB	Value of R at the I-1 x-station, or RB=R in the transfer section ahead of the momentum-energy loop in subroutine ITSR.
RC	Critical Reynolds number or Reynolds number at the point of instability. Given by RC=DELTA(*)*(FREE STREAM VELOCITY)/(EFFECTIVE VISCOSITY AT THE WALL). RC is computed in subroutine TRANS. RC includes the effects of pressure gradient, heat transfer, surface roughness, and surface curvature. At the critical point IC the quantity RDTK.GE.RC where RDTK is computed in subroutine ITSR.
RDF	Quantity R(DELTA(*)) used in computing the starting profiles of both F'(ETA) and G'(ETA) is initialized to 0.0 by subroutine INIR. If IOP.EQ.4, subroutine INIR recomputes RDF/C*RL when RL=RDT(I), which is reset in subroutine COTR if IOP.EQ.4.AND.DOP.LT.0. That is, RDT(1)=X(2)*U(2)*WSTO(3). Here U(2)=M(2). If IOP.EQ.1, 5 (laminar flow), subroutine INIR resets RDF=RDT(I) for I=1. For turbulent flow (IOP.EQ.2, 3, 6, 7), subroutine INIR resets RDF to 1.0. RDF is used to compute Q in subroutine ITFR except for the IOP.EQ.4 option. If IOP.EQ.4, subroutine ITFR resets RDF=RDT(2), since the starting profile is at I(X)=2. Subroutine ITFR uses RDF to compute B(J, 4) for both F'(ETA) and G'(ETA).
RDTK	Local Reynolds number computed in subroutines ITFR and ITSR from the displacement thicknesses DTK(I) and DT(I) and the effective viscosity VE(1) at the wall. RDTK=1./VE(1)*DTK(I)/DT(I). RDTK is used by subroutines ITFR and ITSR to compute RMTW and by subroutine TRANS to compute the effect of surface roughness. If RDTK.LT.RC, in subroutine TRANS, TURB(I+1) remains as previously set by subroutine COTR. Otherwise, IC=I(X) and subroutine TRANS recomputes TURB(I+1) when RMTW.GE.RMC for all I(X) stations succeeding I(X).GE.IC.
RL	Reynolds number used in the laminar similarity solution IOP.EQ.4 initialized to 0.0 by subroutine INIR. On return from subroutine COTR, subroutine INIR resets RL=RDT(1) and uses RL in computing P, R, and RDF. Subroutine ITFR also uses RL on the IOP.EQ.4 option to compute P, Q, R, VP, and RDT(2).

RM	Arithmetic average of R and RB in subroutine ITSR. It is used to compute QRM, which in turn is used to compute C0 in the momentum loop and C7 in the energy section of the momentum-energy loop.
RMS	Not used.
RMT	Transition Reynolds number RMC+RD in subroutine TRANS where RD is the corrected Reynolds number and RMC is the critical Reynolds number based on the momentum thickness. Both RMC and RD are computed in subroutine TRANS. Subroutine TRANS computes TURB(I+1) by the method of Dhawan and Narasimha when RMTWF.LE.RMT and resets the remaining TURB(I+1)=1.0 and TOP=0 when RMTWF.GT.RMT. RMT is not tested unless first RMTW.GE.RMC.
RMTW	Local Reynolds number computed from RDTK, DTK(I), and the momentum thickness MT(I) where RMTW=RDTK/DTK(I)*MT(I). RMTW is computed in subroutines ITFR and ITSR for use by subroutine TRANS. RMTW is used by subroutine TRANS when I(X).GE.IC. If on testing RMTW the test results in RMTW.GE.RMC, all succeeding TURB(I+1) are recomputed. RMC is the critical Reynolds number based on the momentum thickness. RMTW is tested only if RDTK.GE.RC.
RX	x-Derivative of the body radius at the wall divided by the radius of the wall. RX is a function of RW(I) and X(I), where I=I, I-1, I+1, and used by subroutines ITSR and NDIR. Subroutine ITSR initializes RX=0.0 and then recomputes RX when ABS(RW(I)/DT(I)).GE.1. Subroutine ITSR lists RX each time RX is computed. Subroutine ITSR uses RX to compute CA1. Subroutine NDIR also computed R=RX*DT(I) in the re-initialization section.
RXRDF	Not used.
SHR	Specific heat ratio set to 1.4 by subroutine INIR and used by subroutine ITFR to compute DB(J) in subroutine ITFR by equation (II-32) and for B(J, 5) of the energy equation coefficient profiles. SHR is also supplied to subroutine VIS. Subroutine ITSR uses SHR to compute RDT(I) in the momentum loop, also COF1, COF2, COG1, and COG2 later. Subroutine NDIR uses SHR to recompute MT(IC) and CMU in the re-initialization section. Subroutine INIR uses SHR in computing TF(I).
SK	von Kármán constant in the empirical effective viscosity term. It is set to 0.41 by subroutine INIR and used by subroutine ITFR to compute GAMX and STRX before computing VH and VHP for Q and subroutine VIS.

STC	Sutherland viscosity constant in degrees Kelvin. Used in equation (II-18). STC is set to 110 by subroutine INIR and is used by subroutine VIS.
STRX	Stanton number gradient parameter in the starting solution (see eqs. (II-37) and (II-39)). STRX is initialized to 0. 0 by subroutine INIR and is used by subroutine ITFR in the solution of the approximate energy equation for turbulent similarity flow with variable properties. Subroutine ITFR computes STRX if GAM. GT. (ZERO=1. 0E -10) when GAM=SQRT(ABS(TAU(1))). STRX is also used by equations (II-32) and (II-42) for the DB(ETA) profile, which is used in the determination of Q for either laminar or turbulent flow.
STUF	Not used.
T0	Free-stream total temperature in degrees Kelvin.
TFR	Convenient store for the function 1. +((SHR-1.)/2.)*MR*MR where SHR is the specific heat ratio and MR the reference free-stream Mach number. TFR is computed by subroutine INIR and then used to compute the U(I) from the M(I) Mach number if MR. GE. 0. 0. OR. DOP. LE. 0. Subroutine INIR also uses TFR to compute CMU of equation (II-34). Subroutine NDIR uses TFR to recompute CMU for a following turbulent restart. See also TF(I) which uses M(I) in place of MR.
TOP	Integer switch. If TOP. EQ. 1 subroutine ITSR calls subroutine VIS followed by subroutine TRANS to compute the turbulence intermittency TURB(I+1) used by subroutine VIS to compute both the effective viscosity and conductivity. TOP is read in by subroutine COTR but is reset to 0 if IOP. EQ. 2, 3, 4, 6, 7 for the turbulent flow options in order to prevent a later reset in subroutine INIR of TURB(I) and a call of subroutine TRANS by subroutine ITSR. See the comment on TOP in the input data section, table VI.
UX	x-Derivative of U(I) divided by U(I), a function of X(I) and U(I) obtained by taking a central difference. UX is computed by subroutine ITSR and used by both subroutines ITSR and NDIR to compute P=DT(I)*UX in the momentum equation loop of subroutine ITSR and in the re-initialization section of subroutine NDIR.
VPB	Nondimensional aspiration flow at the I-1 x-station. It is similar to the VP of subroutine ITFR but at I(X). Subroutine ITSR computes VPB=VW(IB)/U(IB), where IB=I-1. If IABS(DOP). EQ. 1 subroutine ITSR recomputes VPB=VPB/DB(1) before entering the momentum loop.

VPM	Quantity similar to VPB and VP and computed as a mean value in the momentum loop before the call of subroutine PROFYL. VPM is recomputed as VPM*2.0/(C(1)+DB(1)) if IABS(DOP).EQ.1.
XT	Tolerance set to 0.005 by subroutine INIR for use by subroutine ITFR in testing for exit from momentum loop. To exit, ABS(F(JE(ETA))-1.).LT.XT. In subroutine ITSR, test ABS(F(JE)-1.) only if ABS((FPP(1)-FPPW)/FPPW).LE.XT. For the momentum-energy loop the final test for exit is on ZERO. However, in the convergence test section note the use of XT.
XK	Correcting factor used by subroutine TRANS. Subroutine INIR initializes XK=0.0. In subroutine TRANS, XK is used to compute KB=(KB*XK+DK*DX)/(XK+DX), which in turn is used in computing KK by subroutine INDEX. In the present version, BK=DK since XK=0.0.
ZERO	Tolerance initialized to 1.0E-10 by subroutine INIR. ZERO is used by subroutine ITFR as a tolerance to leave the momentum-energy loop if ABS((GP(1)-GPW(I)).LT.ZERO. XT is the tolerance in the subroutine ITFR momentum loop. ZERO is used by subroutine ITSR in conjunction with XT to exit the momentum-energy loop on tests of GP(1), GPW(I), GPPW, and GPP(1). XT alone is used in the subroutine ITSR momentum loop.

COMPLETE PROGRAM LISTING

A complete program source listing with detailed comments in each subroutine is given in this section. The subroutines are arranged in the order they would have if overlays were required. Otherwise, any order of the subroutines may be used.

Main Program TUF

```
$IBFTC TUF

C      TUF IS THE MAIN SUPERVISORY ROUTINE FOR THE SOLUTION OF THE
C      BOUNDARY LAYER EQUATION PROFILES AND PARAMETERS.

C      TUF, THE MAIN ROUTINE, CALLS SUBROUTINES INIR, ITFR,ITSR,NDIR.
```

```
C  * * * * * * * * * MAIN COMMON  V-3 TUF  * * * * * * * * * * * * * * * *
      COMMON  /TUFA/ATUF,
     1        B(300,5),
     2        B1,BH,BS,BK,
     3        CW(100),CF(100),CLIS(400),CAY(300),
     4        CA,CA1,CO,COB,CMTF,CMTG,C,COAL,CMU,
     5        DB(300),DBB(300),D(300),DP(300),DPB(300),
     6        DT(100),DTK(100),
     7        DX,DTXM,DOP,DI,DJ,DXB,DTM,DTS,
     8        ET,
     9        FB(300),FBB(300),FPBB(300),FPB(300),FP(300),F(300),
     A        FPP(300),FPPB(300),
     1        FPE,FPPW,FT,FV,FTU2,
     2        GPB(300),GPBB(300),GP(300),GPP(300),GPPB(300),
     3        GBC(100),GPW(100),
     4        GPPW,GPE, GAM,GAMX,
     5        HT(100),
     6        ISTO(16),
     7        I,IC,IO,IBC,IOP,IX,IXE,IT,IXA,ID,IXF
      COMMON  /TUFJ/ JTUF,
     1        JTR(100),
     2        JE,JK,JM,JY,JEF,JEG,JDIV,JEB,JD,
     3        KB,KMI,
     4        LABEL(132),
     5        LOOP,LOOPF,
     6        M(100),MT(100),
     7        MOP,MR,ML,
     8        NU,
     9        OI,
     A        P,PB,PM,POP,PR,PRT,
     1        QB,QM,QRB,QRM,Q,
     2        RW(100),RDT(100),
     3        RB,RM,RC,RMS,RMT,R,RDTK,RXRDF,RL,RMTW,RDF,RX
      COMMON  /TUFS/STUF,
     1        STR(100),SW(100),SF(100),ST(100),
     2        SHR,STC,SK,STRX,
     3        TAU(300),
     4        TURB(100),TF(100),
     5        TO,TOP,TFR,
     6        U(100),
     7        UX,
     8        VE(300),VEG(300),VH(300),VHP(300),VHPP(300),
     9        VW(100),
     A        VPB,VPM,
     1        WSTO(20),
     2        X(100),
     3        XT,XK,
     4        Y(300),YY(300),
     5        ZERO

      REAL    KB, M,ML,MR,MT,NU
      INTEGER     DOP,POP,TOP

C  * * * * * * * * *END OF MAIN COMMON TUF-V3* * * * * * * * * * * * * *

      DIMENSION     KSTOP(5)
      DIMENSION  XMAS(10)
```

```
C                    GET THE BOUNDARY CONDITIONS AND X-STATION DATA.
C                    INITIALIZE THE ARRAYS,PROFILES,PARAMETERS.
C                    RETURN TO HERE ALSO FOR THE NEXT CASE.
 101      WRITE  (6,99)
          CALL      INIR(KSTOP,XMAS)

C                    IF THE MODIFIED PROFILES OF EITHER F'(ETA),G'(ETA),
C                    Y(ETA) HAVE TUO MANY POINTS (JEF,JEG,JY)*JDIV.GT.300
C                    GO TO THE NEXT CASE.
          IF  ( ISTO(10).EQ.9 )    GO TO 101

C                    GET THE STARTING PROFILE, EITHER LAMINAR OR TURBULENT
C                    ENTER HERE ALSO FOR A TURBULENT RESTART AFTER AN EXIT
C                    FROM SUBR NDIR.
 134      WRITE  (6,99)
          CALL      ITFR

C                    IF I.LE.IX OR ONLY THE STARTING PROFILE IS TO BE
C                    COMPUTED GO TO THE NEXT CASE.
      IF  ( ISTO(10).EQ.8 )        GO TO 101

C                    COMPUTE ALL X-STATION PROFILES AND PARAMETERS EXCEPT
C                    THE STARTING PROFILES,PARAMETERS.
          CALL      ITSR

C                    LIST THE TABLE OF X-STATION WALL PARAMETERS, THE
C                    TABLE OF CORRECTION COEFFICIENTS (CLIS),AND
C                    RE-INITIALIZE THE NECESSARY QUANTITIES AT I(X)=IC
C                    ON EITHER A FORCED TRANSITION TO TURBULENT FLOW OR
C                    A LAMINAR SEPARATION WITH ISTO(14).EQ.1 FOR A
C                    TURBULENT RESTART IN SUBR ITFR CN A CALL FROM TUF.
          CALL      NDIR

C                    IF ISTO(10).EQ.4 GO TO THE NEXT CASE ON COMPLETING
C                    ALL X-STATIONS.
C                    IF ISTO(10).EQ.5 GO TO THE NEXT CASE AFTER A NON-
C                    SCHEDULED CASE END ON F(JEF).LT.0.0.OR.F(JEF).GT.
C                    WSTO(2) UNLESS TOP.EQ.1.AMD.I.LT.IX. (A CALL OF SUBR
C                    TRANS DID NOT OCCUR).
          IF   ( ISTO(10).EQ.4.OR.ISTO(10).EQ.5 )     GO TO 101
C                    TO PREVENT A TURBULENT RESTART AFTER A LAMINAR
C                    SEPARATION SET ISTO(14).NE.1.
          IF   ( ISTO(10).EQ.6.AND. ISTO(14).NE.1 )  GO TO 101

C                    ENTER SUBR ITFR FOR A TURBULENT RESTART ON EITHER
C                    A LAMINAR SEPARATION AT I(X)= IC OR A FORCED
C                    TRANSITION AT I(X)= IC.
      GO TO 134

   99 FORMAT (1H1)

          END
```

Subroutine A6IR

```
$IBFTC A6ID

      SUBROUTINE     A6IR

C     SUBR A6IR READS AND LISTS THE COMMENT ACCOMPANYING THE DATA INPUT.

C     SUBROUTINE A6IR IS CALLED BY SUBROUTINES INIR,COTR,ITFR,NDIR.

C     ABBREVIATIONS...
C     LHS  LEFT HAND SIDE.
C     RHS  RIGHT HAND SIDE.
C     CC   CARD COLUMN

      DIMENSION     ISOR (22)

C                   COUNTER FOR LINE NUMBERING.
      LCTR=  0

C                   ENTRANCE TO THE INITIAL LOOP,1ST MAIN, FOR CARDS  OF
C                   TYPE 0 TO BE LISTED CC1-72 WITH A LINE COUNT.
C                   ALSO FOR THE MAIN INDEX CARD WITH THE DISCRIMINATORS.
C                   CARDS READ-IN BY THIS LOOP ARE CALLED GROUP 1.
C                   THE 1ST 2 WORDS ARE USED BOTH AS LIST AND   TEST
C                   WORDS BY THE INITIAL LOOP.  THE 13TH WORD AS A
C                   DISCRIMINATOR WORD IS USED BY THE INITIAL LOOP ONLY.
C                   IF THE 2ND MAIN LOOP IS ENTERED THE 1ST 3 WORDS OF
C                   THE LAST CARD READ-IN BY THIS LOOP BECOME THE INDEX
C                   DISCRIMINATOR WORDS.
 104  READ  (5,997)  ( ISOR(K),  K=  1,14 )
      IROT=  ISOR(1)
      IVLS=  ISOR(2)
      IVLE=  ISOR(3)
C                   THE 4TH INDEX DISCRIMINATOR WORD. IRFT IS A TEST WORD
C                   TO LIST A FORTRAN IV CARD CC1-72 ON THE PAGE LHS WITH
C                   CARRIAGE CONTROL AND LINE NUMBERING.  A TYPE 0 CARD.
      IRFT=  ISOR(13)
C                   IF TRUE THIS CARD IS THE MAIN INDEX DISCRIMINATOR
C                   CARD FOR THE FOLLOWING GROUP 2 CARDS.
      IF  ( IRFT.EQ.IROT )     GO TO 106
 105  LCTR=  LCTR + 1
C                   LIST A TYPE 0 CARD.
      WRITE  (6,994)    (ISOR(K),  K=  1,12 ) , LCTR
      IF  ( IRFT.EQ.IVLS )     RETURN
C                   RETURN TO THE INITIAL LOOP READ.
      GO TO 104

C                   FOR A DECK TO READ AND WRITE ONLY TYPE 0 CARDS FOLLOW
C                   THIS CARD WITH THE 994 AND 997 FORMAT CARDS AND THEN
C                   THE END CARD.  DELETE THE REMAINDER OF THE DECK.
C     ***   ***    ENTER THE 2ND MAIN LOOP THE 1ST SUB LOOP    ***   ***
C                              LIV WHEN RESET TO 1 BY A CARD IN FRONT OF
C                   A SUB-DECK OF CARDS ENABLES THE DECK TO BE LISTED
C                   ON THE PAGE LHS WITHOUT CARRIAGE CONTROL PROVIDED
C                   ALL CARDS OF THE DECK HAVE CC1-6 NOT IDENTICAL WITH
C                   THE 3RD INDEX DISCRIMINATOR WORD.  THE 1ST CARD
C                   SUCCEEDING THE SUB-DECK RESETS LIV TO 0 PROVIDED
```

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C                     THE CARD 1ST WORD IS IDENTICAL WITH THE 3RD INDEX
C                     DISCRIMINATOR WORD.
C                     CARDS BELONGING TO THE SUB-DECK WHOSE 1ST WORDS MATCH
C                     EITHER THE 2ND OR 3RD INDEX DISCRIMINATOR WORDS
C                     WILL LIST ON THE PAGE LHS WITH CARRIAGE CONTROL.
C                     LIV MUST BE 0 TO ENABLE A RETURN TO THE CALLING
C                     ROUTINE, OR A TRANSFER TO THE 2ND SUB-LOOP WITH A
C                     RETURN TO THE 1ST SUB-LOOP ENTRANCE FOR A CARD READ.
C                     THE 1ST AND 13TH WORDS OF THIS READ-IN BECOME TEST
C                     WORDS IN THE 1ST SUB-LOOP.  HOWEVER, THE TEST FOR A
C                     RETURN PRECEEDS THE TEST ON THE 13TH WORD.  IF THE
C                     13TH WORD IS TESTED THEN A MATCH WITH THE 1ST INDEX
C                     DISCRIMINATOR WORD CAUSES A PICK UP OF A TYPE
C                     2 CARD TO COMPLETE A FULL LINE CF PRINT,122 COLUMNS.
C                     THERE IS NO RETURN TO THE INITIAL LOOP FROM THE
C                     2ND MAIN LOOP.  CARDS READ-IN BY THIS LOOP ARE
C                     CALLED GROUP 2 CARDS WHICH WITH THE EXCEPTION
C                     MENTIONED HAVE THE TEST WORD IN CC1-6.

C                     EXCEPTING THE RETURN CARD THE CARDS READ AT EFN 107
C                     LIST EITHER AS A TYPE1 CARD, CC1-42, OF A FULL LINE,
C                     OR AS A TYPE 4 OR 5 CARD LISTING ON THE PAGE LHS
C                     CC1-80 WITH OR WITHOUT CARRIAGE CONTROL.  ANY CARD
C                     READ-IN AT EFN 107 RETURNS CONTROL TO THE CALLING
C                     ROUTINE IF LIV= 0, AND CC1-6 IS NOT IDENTICAL WITH
C                     EITHER INDEX DISCRIMINATOR WORDS 2 OR 3 BUT IS
C                     IDENTICAL WITH THE INDEX DISCRIMINATOR WORD 1.
C                     NEITHER RETURN NOR TRANSFER CARDS ARE LISTED.
 106      LCTR=  0
          LIV=  0
C                     RE-ENTER HERE EITHER FROM THE 2ND SUB-LOOP ON A
C                     TRANSFER CARD OR AFTER LISTING CARDS OF TYPES 4,5.
 107      READ  (5,997)  (ISOR (K),   K=  1,14)
          IRIT= ISOR (1)
          IF  ( IRIT.NE.IVLS )      GO TO 115
 114      LIV=  1
C                     GO TO LIST PAGE LHS CC1-80 WITH CARRIAGE CONTROL, A
C                     TYPE 4 CARD,BEFORE RETURNING FOR ANOTHER CARD READ.
          GO TO 119
 115      IF  ( IRIT.NE.IVLE )      GO TO 117
C                     RESET THE SWITCH  TO EXIT FROM THE TYPE 5 LIST LOOP.
 116      LIV=  0
          GO TO 119
 117      IF  ( LIV.EQ.0 )      GO TO 118
          LCTR=  LCTR + 1
C                     LIST ON PAGE LHS CC1-80 BUT WITHOUT CARRIAGE CONTROL.
C                     LIST A TYPE 5 CARD.
 1171      WRITE  (6,995) (ISOR (K),   K=  1,14), LCTR
C                     RETURN TO THE 1ST SUB LOOP ENTRANCE FOR ANOTHER READ.
C                     THE NEXT CARD CAN BE EITHER A TYPE 4 OR 5 CARD.
          GO TO 107
C                     IF THE 1ST WORD OF THIS CARD,CC1-6, IS IDENTICAL WITH
C                     THE 1ST WORD,CC1-6, OF THE INDEX DISCRIMINATOR CARD
C                     THEN RETURN TO THE CALLING ROUTINE.  THIS IS THE
C                     EXIT FROM A6IR AFTER THE  2ND MAIN LOOP IS ENTERED.
C                     LIV MUST BE 0 TO MAKE THIS TEST.
 118      IF  ( IRIT.EQ.IROT )      RETURN
 1181     IRFT=  ISOR(13)
          IF  ( IRFT.EQ.IROT )      GO TO 121
```

```
C                    LIST THE LHS OF THE PAGE CC1-80 WITH CARRIAGE CONTROL
C                    AND THEN RETURN TO THE 1ST SUB LOOP ENTRANCE FOR
C                    ANOTHER CARD.  LIST A TYPE 4 CARD.
 119     LCTR=  LCTR + 1
 1191    WRITE  (6,999)  (ISOR (K),  K=  1,14 ), LCTR
C                    RETURN TO THE 1ST SUB LOOP ENTRANCE FOR A READ-IN.
C                    THE NEXT CARD MAY BE EITHER A TYPE 1 OR 4.
         GO TO 107
C                    READ-IN A CARD TO BE LISTED AS THE RHS OF A FULL LINE
C                    WITH CARRIAGE CONTROL.  A TYPE 2 CARD. LIV MUST BE 0.
 121     READ  ( 5,997)  (ISOR (K),  K=  8,21 )

         LCTR=  LCTR + 1
C                    LIST A FULL LINE WITH CARRIAGE CONTROL.
C                    LIST COLUMNS 1-42 ARE FROM A TYPE 1 CARD WHILE LIST
C                    COLUMNS 43-122 ARE FROM A TYPE 2 CARD.  LIV= 0.
 1211    WRITE  (6,996)  ( ISOR (K),  K=  1,21), LCTR
C     ***       ENTER THE 2ND SUB-LOOP OF THE 2ND MAIN LOOP      ***
C                    THIS LOOP CAN BE ENTERED ONLY IF LIV=  0.
 122     READ  (5,997)  (ISOR (K),  K=  1,14 )
         IRIT= ISOR (1)
C                    THE CARD JUST READ-IN IS CALLED THE TRANSFER CARD IF
C                    A MATCH OCCURS.
         IF  ( IRIT.EQ.IROT )      GO TO 107
         LCTR=  LCTR + 1
C                    LIST ON THE  PAGE RHS CC1-80.    A TYPE 3 CARD.
 1221    WRITE  (6,998)  (ISOR (K),  K=  1,14 ), LCTR
C                    THE NEXT CARD WILL EITHER BECOME A TRANSFER CARD OR
C                    LIST AS A TYPE 3 CARD.
         GO TO 122

 994     FORMAT  ( 12A6, 15X, I4 )
 995     FORMAT  (1X,13A6,A2,45X, I4 )
 996     FORMAT  ( 20A6,A2,4X,I4 )
 997     FORMAT  ( 13A6,A2)
 998     FORMAT  ( 42X,13A6,A2,4X,I4 )
  999     FORMAT  ( 13A6,A2,47X,I4 )

         END
```

Subroutine VIS

```
$IBFTC VISD

      SUBROUTINE VIS (JE, JY, JD, YY, FP, FPP, GP, GPP, D, DP, TAU,
     1   VH, VHP, TURB, SW, CW, SHR, BH, STC, TO, TF, RDT, DT, FJE,
     2   PR, PRT, JK, VE, VEG, ISTO )

C     SUBROUTINE VIS COMPUTES THE EFFECTIVE VISCOSITY AND CONDUCTIVITY
C     PROFILES FOR BOTH LAMINAR AND TURBULENT FLOWS.

C     SUBROUTINE VIS IS CALLED BY SUBROUTINES INIR,ITFR,ITSR,NDIR.

      DIMENSION  ISTO(16)

      DIMENSION YY(JD), FP(JD), FPP(JD), GP(JD), GPP(JD), D(JD), DP(JD)
      DIMENSION TAU(JD), VH(JD), VHP(JD), VE(JD), VEG(JD)

      DATA SIG3, SK, BK/ 328.51, 0.41, 0.016/
      DATA ZERO/ 1.0E-10/


      JK=JE
C                      SUTHERLAND VISCOSITY LAW EQUA II-18.
C                      THE LAMINAR VISCOSITY TERM IS GIVEN BY VH(J)/RDT.
      DO 100 J=1,JY
      VH(J)=D(J)**2.5*(1./TF+STC/TO)/(D(J)/TF+STC/TO)
  100 CONTINUE

C                      IF TURB(I) .LT.0 THEN THE EFFECTIVE VISCOSITY IS
C                      RESET=  THE LAMINAR VISCOSITY.
      IF (TURB.LT.ZERO) GO TO 400

C                      TEMPORARY STORAGE.
      DO 120 J=1, JE
      VHP(J)=1.-D(J)*(1.-FP(J))
  120 CONTINUE
      CALL INTEG (JE, JD, YY, VHP, 0.0, VHP)
      VR=VHP(JE)/FJE*BK
      GAM=SQRT(ABS(TAU(1))*D(1))
      YPS=SW/DT*RDT/VH(1)*GAM/30.0
     1   *(1.0+3.0*EXP(-SW/DT*RDT/VH(1)*GAM/150.0))

C                      COMPUTE THE TURBULENT VISCOSITY TERM,STORE IN VE(J).
C                      LOAD VEG(J) WITH THE TURBULENT CONDUCTIVITY TERM.
C                      SET THE VISCOSITY CORRECTION TERM,VHP(J), = 1.
      DO 200 J=1, JY
      JK=J
      CHI=SK*(RDT/VH(J)*YY(J)*SQRT(D(J)*ABS(TAU(J)))+YPS)
      CHI3=CHI*CHI*CHI
      VE(J)=VH(J)*(1.+CHI3*CHI/(CHI3+SIG3))/RDT
      VEG(J)=VE(J)/PRT+VH(J)*(1./PR-1./PRT)/RDT
      VHP(J)=1.0
      IF (VE(J).GT.VR) GO TO 210
  200 CONTINUE
      GO TO 300
```

```
C                  CONTINUE COMPUTING THE TURBULENT VISCOSITY AND
C                  CONDUCTIVITY TERMS FOR THE REMAINDER OF THE PROFILE.
  210 CONTINUE
      DO 220 J=JK, JY
      VE(J)=VR
      VEG(J)=VR/PRT
      VHP(J)=1.0
  220 CONTINUE
      IVEL=  1

C                  TO HERE ALSO IF THE OUTER FUNCTION IS SKIPPED.
  300 CONTINUE
C                  IF (ABS(CW).GE.1.0E-10) RECOMPUTE THE EFFECTIVE
C                  VISCOSITY CORRECTION , EQUA. IV-2.
  301 IF (ABS(CW).LT.ZERO) GO TO 370
C                  EFFECTIVE VISCOSITY CORRECTION  VHP(J).
      DO 310 J=1, JY


C                  RESET FROM VHP(J)=1.
      VHP(J)=0.0
C                  IF FPPV.LT.1.0E-10 THEN VHP(J) REMAINS= 0.0.
      FPPV=DP(J)*(1.-FP(J))-D(J)*FPP(J)
      IF (ABS(FPPV).LT.ZERO) GO TO 310
      FPV=D(J)*(1.-FP(J))
      BM=(TF-1.)/TF
      CU=(DT/CW)*FPV/FPPV
      B1=1.-CU
      DC=-FPV/FPPV*(BH*GPP(J)+2.*BM*FPPV*FPV)
     1   /(1.-BH*GP(J)-BM*FPV*FPV)/PRT
      B2=1.-CU*(1.+DC)*B1
      IF (ABS(B1*B2).LT.ZERO) GO TO 310
      B3=1.-CU*(1.+DC)
      B4=(1.-CU*(1.+DC))/B1
      IF (B4.LT.ZERO) GO TO 310
      B5=1.-4.0*(1.+CU)*(1.+DC)*CU/B2
      IF (B5.LT.ZERO) GO TO 310
C                  VHP(J)= EFFECTIVE VISCOSITY CORRECTION.
      VHP(J)=SQRT(B4)*B5**1.5*ABS(B1)
  310 CONTINUE
      IVEL=  2
C                  IF TO HERE FROM EFN 301 VHP(J)=1.
  370 CONTINUE
C                  TURB IS THE TURBULENT VISCOSITY FACTOR   AND = 0
C                  FOR FULLY LAMINAR FLOW.  TURB COMES FROM EITHER
C                  SUBR COTR OR SUBR TRANS.
C                  TURB(I) UNCORRECTED FOR THE LONGITUDINAL CURVATURE,
C                  VHP(J), IS GIVEN BY EQUA IV-4.
C                  EFFECTIVE VISCOSITY= TURB(I)*VISCOSITY(TURBULENT) +
C                  ( 1. - TURB(I))*VISCOSITY(LAMINAR).
C                  THE EFFECTIVE VISCOSITY = TURB*(VISCOSITY(TURBULENT)-
C                  VISCOSITY(LAMINAR)) + VISCOSITY (LAMINAR).
      DO 380 J=1, JY
C                  VE(J)= THE CORRECTED EFFECTIVE VISCOSITY FROM
C                  EQUAS  IV-2, IV-4 .
      VE(J)=TURB*VHP(J)*(VE(J)-VH(J)/ROT)+VH(J)/ROT
C                  VEG(J)= THE CORRECTED EFFECTIVE CONDUCTIVITY FROM
C                  EQUAS IV-2,IV-4 AND IS GOTTEN FROM THE VISCOSITY
C                  RELATIONS BY REPLACING VE(J) WITH VEG(J) AND THEN
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C                    DIVIDING BY RDT.
      VEG(J)=TURB*VHP(J)*(VEG(J)-VH(J)/PR/RDT)+VH(J)/PR/RDT
  380 CONTINUE
      IVEL=   2
      GO TO 421

C                    BOTH THE EFFECTIVE VISCOSITY AND CONDUCTIVITY BECOME
C                    LAMINAR IF TURB(I) HAS BECOME .LT.0.0.
  400 CONTINUE
      DO 420 J=1, JY
      VE(J)=VH(J)/RDT
      VEG(J)=VE(J)/PR
  420 CONTINUE
      IVEL=  3


 421     IF  (ISTO(5).EQ.0 )      RETURN
C                    EFFECTIVE VISCOSITY AT THE WALL.
      IF  ( VE(1).EQ.0.0 )      GO TO 423
C                    EFFECTIVE CONDUCTIVITY AT THE WALL.
      IF  (VEG(1).EQ.0.0 )      GO TO 423
C                    EFFECTIVE VISCOSITY CORRECTION AT THE WALL FROM THE
C                    RECOMPUTATION OF VHP(J). ABS(FPPV).LT.1.0E-10.
      IF  (VHP(1).EQ.0.0 )      GO TO 423
C                    LAMINAR VISCOSITY AT THE WALL.
      IF  ( VH(1).EQ.0.0 )      GO TO 423
      RETURN
 423  WRITE  (6,1) IVEL,VE(1),VEG(1),VHP(1),VH(1)

      RETURN

 1    FORMAT  (1H0,5HIVEL= I3, 3X, 7HVE(1)= 1PE9.2, 3X, 8HVEG(1)= E9.2,
     2        3X, 8HVHP(1)= E9.2, 3X, 7HVH(1)= E9.2 )

      END
```

Subroutine INTEG

```
$IBFTC SUMD

         SUBROUTINE INTEG (JE, JD, Y, SD, FIRST, S)

C     SUBROUTINE INTEG COMPUTES AND LOADS THE SUM OF SD(J) INTO S(J) BY
C     THE TRAPEZOIDAL RULE.
C     SD(J) AND S(J) HERE ARE DUMMY VARIABLES FOR THE FP,GP,VH,VHPP
C     AND OTHER PROFILE VARIABLES IN THE CALLING SUBROUTINES.


C     SUBROUTINE INTEG IS CALLED BY SUBROUTINES INIR,ITFR,ITSR,VIS.


      DIMENSION Y(JD), SD(JD), S(JD)


      JEM=JE-1
      SD2=  SD(1)
      S1=  FIRST
      S(1)=  S1

      DO 110 J=1, JEM
      SD1=  SD2
      SD2=  SD(J+1)
      S1=  S1 + (Y(J+1) - Y(J))  * (SD2 + SD1) / 2.
      S(J+1)=  S1
  110 CONTINUE

      IF (JE.GE.JD) RETURN

      DO 120 J=JE, JD
      S(J)=  S(JE)
  120 CONTINUE


      RETURN

      END
```

Subroutine FILE

```
$IBFTC DFILE


      SUBROUTINE FILE (LABEL, I, YY, F, FP, FPP, GP, GPP, D, DP,
     1   VH, VHP, VHPP, TAU, VE, VEG, SHR, BH, PR, PRT,
     2   X, U, M, TURB, RW, VW, SW, CW,
     3   RDT, DT, MT, HT, SF, CF, ST, STR, ID, JE, JY,JD,JDIV,ISTO,WSTO)


C     SUBR FILE LISTS THE MOMENTUM AND ENERGY EQUATION PROFILES ON Y AND
C     THE I(X) WALL STATION PARAMETERS AT EACH I(X) STATION ACCORDING
C     TO THE ISTO(K) AND WSTO(1) LIST OPTIONS.

C     SUBROUTINE FILE IS CALLED BY SUBROUTINES INIR,ITFR,ITSR,NDIR.


      REAL M, MT

      DIMENSION YY(JD), BB(13), LABEL(132), ISTO(16),WSTO(20)
      DIMENSION F(JD), FP(JD), FPP(JD), GP(JD), GPP(JD), D(JD), DP(JD)
      DIMENSION VH(JD), VHP(JD), VHPP(JD), VE(JD), VEG(JD), TAU(JD)
      DIMENSION X(ID), U(ID), M(ID), TURB(ID), RW(ID), VW(ID), SW(ID),
     1   CW(ID)
      DIMENSION DT(ID), MT(ID), HT(ID), SF(ID), RDT(ID)
      DIMENSION CF(ID), ST(ID), STR(ID)


C                  ISTO(7) IS EITHER CARD READ IN BY SUBR COTR OR SET
C                  AND THEN RESET BY SUBRS ITFR,ITSR.
         IF  ( I.NE.ISTO(7) )    GO TO 101
         GO TO 102


 101  IF  ( ISTO(2).EQ.-1 )     RETURN
C                  IF ISTO(4).EQ.1 THEN LIST THE SECONDARY PROFILES.
      IF  ( ISTO(4).NE.0 )  GO TO 111

C                  HEADING FOR EACH I(X) WALL STATION.
 102  WRITE (6,15) (LABEL(K), K=1,18)
      WRITE (6,16) X(I), U(I), M(I), RDT(I)
      WRITE (6,17) TURB(I), RW(I), VW(I), SW(I), CW(I)
      WRITE (6,18) DT(I), MT(I), HT(I), SF(I), CF(I), ST(I)
      WRITE (6,19) BH, PR, PRT, SHR

 111  XNOD= X(I)
      IF  ( WSTO(10).NE.0.0 )     XNOD=  X(I)/WSTO(10)
C                  XNOD IS X(I) NON-DIMENSIONAL.
      WRITE (6,20) X( I),XNOD,I,JE,ISTO(10)


C                  SET WORKING LIST SWITCH.
 112     IWSW=  ISTO(2)
C                  THE STANDARD LIST INTERVAL.
         JPTS=  ISTO(3)*JDIV
C                  TO LIST AT THE JDIV INTERVAL A SELECTED PROFILE
C                  FROM EITHER SUBR,ITFR,ITSR.
      IF  ( I.EQ.ISTO(7) )     IWSW=  3
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```
C                  TO LIST THE FINAL PROFILE OF THE CASE,AFTER THE CASE
C                  BECOMES TURBULENT (THE PROFILES GO OUT OF BOUNDS).
         IF  ( ISTO(10).EQ.5.OR.ISTO(10).EQ.6 )     IWSW=  3

C                  IWSE IS FOR THE LISTING OF THE END POINT OF THE
C                  SECONDARY PROFILES.
 113     IWSE=  JE

C                  INITIALIZE THE LIST COUNTER FOR EITHER INTERVAL OR
C                  POINT, HERE FOR POINT.
         LSPT=  1

C                  INITIALIZE THE COUNTER FOR THE STATIONS BEYOND
C                  THE IWSTO(1) PROFILE AMPLITUDE LIMIT.
         ILL=  0


C                  LIST THE PRIMARY PROFILES.

      DO 119 J=1, JE, JDIV

C                  SEE EQUA. II-7B, THE NORMAL COORDINATE.
      BB(1)=YY(J)

C                  X VELOCITY RATIO U(Y)/U(BLE).
      BB(2)=D(J)*(1.-FP(J))

C                  TO LIST THE PROFILES DURING THE VELOCITY OVERSHOOT.
         IF  ( ISTO(4).EQ.0.AND.BB(2).GT.1. )     IWSW=  3

C                  TO LIST AT ALL LSPT STATIONS TO JE,END OF PROFILE.
 114  IF  ( IWSW.EQ.0 )     GO TO 116

C                  TO LIST AT ALL JDIV STATIONS TO JE.
         IF  ( IWSW.EQ.3 )     GO TO 116

C                  TO LIST THE PROFILE INITIAL STATION.
      IF  ( J.EQ.1 )     GO TO 116

C                  IWSW HERE IS FROM ISTO(2) ONLY.  TEST FOR LIST
C                  CUT-OFF ON REACHING THE AMPLITUDE LIMIT.
      IF  ( BB(2).LT.WSTO(1).AND.IWSW.EQ.1 )     GO TO 119

C                  IWSW.EQ.2 IS FROM ISTO(2) ONLY.  TEST FOR LIST
C                  CUT-OFF ON REACHING THE AMPLITUDE LIMIT.
      IF  ( BB(2).LT.WSTO(1).AND.IWSW.EQ.2 )     GO TO 116


C                  TO BYPASS THE PROFILE AMPLITUDE  LIMIT COUNTER
C                  EXCEPT ON ISTO(2).EQ.2.
         IF  ( IWSW.NE.2 )     GO TO 115

C                  PROFILE LIST POINTS COUNTER FOR LISTING AFTER THE
C                  PROFILE AMPLITUDE LIMIT HAS BEEN EXCEEDED.
         ILL=  ILL + 1
C                  ISTO(4) IS THE SWITCH SET IN SUBR COTR TO LIMIT THE
         IF  ( ILL.GT.1.AND.ISTO(4).NE.0 )     GO TO 119

         GO TO 116
```

```
C                  INITIAL IWSE= JE.  TO HERE ON ISTO(2).NE.2.
 115     IF  ( IWSE.NE.JE )     GO TO 119

C                  RESET IWSE FOR THE LISTING OF THE SECONDARY PROFILE
C                  ON ISTO(4).NE.1 TO THE END POINT OF THE MAIN PROFILE.
      IWSE=  J
C                  BB(K), 5= 3,4,5 FOR  THE MOMENTUM PROFILES.
 116   BB(3)=F(J)
      BB(4)=FP(J)
      BB(5)=FPP(J)

C                  THE DENSITY PROFILE.
      BB(6)=D(J)

C                  BB(K), K= 7,8 FOR THE ENERGY EQUATION PROFILES.
      BB(7)=GP(J)
      BB(8)=GPP(J)

C                  LIST THE INITIAL POINT EXCEPT ON ISTO(2).EQ.-1.
      IF  ( J.EQ.1 )     GO TO 117

C                  TO LIST ON EACH Y DATA INPUT POINT (AT JDIV) INTERVAL
C                  SEE Y ARRAY IN SUBR COTR LISTING  OF INPUT DATA.
         IF  ( IWSW.EQ.3 )     GO TO 118

C                  TO LIST AT LEAST 1 PROFILE POINT BEYOND  THE POINT
C                  OF PROFILE AMPLITUDE .GT.WSTO(1).
         IF  ( ILL.EQ.1 )     GO TO 118
C                  LIST ONLY AT JPTS INTERVAL= ISTO(3)*JDIV.

      IF  ( J.NE.LSPT )     GO TO 119

C                  THE LIST Y STATION COUNTER.
 117     LSPT=  LSPT + JPTS

C                  ONE LINE OF DATA
 118  WRITE  (6,21)  J, (BB(K),  K=  1,8 )

C                  RETURN TO THE LOOP HEAD TO LIST ANOTHER LINE  OF
C                  THE PRINARY PROFILES.
 119  CONTINUE

C                  RETURN IF LIST  OF SECONDARY PROFILES IN NOT WANTED.
 121     IF  ( ISTO(4).EQ.1 )     RETURN


C                  FOR THE LISTING OF THE SECONDARY PROFILES.
      WRITE  (6,22)
      J2=  1

      IF  ( IWSW.EQ.+1 )     GO TO 131
      GO TO 132

C                  LIST ONLY THE END VALUES OF THE PROFILES WHEN IWSW=1.
 131  J2=  IWSE
C                  FOR THE 1ST POINT OF THE PROFILE TO BE LISTED.
C                  TO CONTINUE THE LIST ON POINT INTERVALS FROM THE
C                  1ST POINT LISTED.
 132  IWSW=  ISTO(2)
```

```
C                   INITIALIZE THE LIST COUNTER.
         LSPT=  1

C                   LIST SECONDARY PROFILES WITH THE INITIAL POINT AT
C                   EITHER 1 OR PROFILE LIST END POINT.
      DO  136 J= J2,IWSE,JDIV

C                   IF TRUE,LIST ON EACH JPTS ETA STATION TO JE= PROFILE
C                   END STATION.
      IF  ( IWSW.EQ.0 )     GO TO 133

C                   LIST THE INITIAL PROFILE STATION
      IF  ( J.EQ.1 )     GO TO 133

C                   IF TRUE,CONTINUE LISTING ON EACH JPTS ETA STATION.  .
      IF  ( IWSE.GE.J )     GO TO 133

C                   TO END THE PROFILE LIST AT CURRENT I(X) WALL STATION.
      IF  ( IWSW.EQ.-1 )      RETURN

C                   TO END PROFILE LIST ON THE NEXT ETA LIST ITERATE.
      IWSW=  -1

C                   NON-DIMENSIONAL SHEAR STRESS.
 133  BB(1)=  TAU(J)
C                   EFFECTIVE VISCOSITY.
      BB(2)=  VE(J)

C                   X DERIVATIVE OF THE DENSITY.
      BB(3)=  DP(J)

      BB(4)=  (1.-FP(J)) * DP(J)/D(J)

C                   ON CALL FROM SUBR ITSR AND IF TOP.EQ.1, THEN VH,VHP,
C                   VHPP ARE FROM SUBR TRANS.  OTHERWISE VH,VHP,VHPP ARE
C                   FROM SUBR INTEG..
C                    ON CALL FROM SUBR NDIR VH,VHP,VHPP ARE THE SAME AS
C                   FOR THE CALL OF FILE BY SUBR ITSR.
C                   ON CALL OF FILE BY SUBR ITFR VHP,VHPP ARE FROM
C                   SUBR INTEG AND VH IS FROM SUBR PROFYL.
C                   ON CALL OF FILE BY SUBR INIR VH,VHP ARE FROM SUBR VIS
C                   AND VHPP IS FROM SUBR INIR.

      BB(5)= VHPP(J)
      BB(6)=  VH(J)
      BB(7)=  VHP(J)
C                   CONDUCTIVITY.
      BB(8)=  VEG(J)

C                   IF TRUE,LIST THE INITIAL PROFILE POINT AND ADD TO
C                   THE  IST COUNTER.
      IF  ( J.EQ. 1 )     GO TO 134

C                   IF THIS INSTRUCTION IS REACHED LIST AT LEAST 1 ETA
C                   PROFILE STATION.
      IF  ( IWSW.EQ.-1 )     GO TO 135

C                   LIST ON THE LSPT ETA STATION AT JPTS INTERVAL.
      IF  ( J.NE.LSPT )     GO TO 136
```

```
C                      ADD TO THE LIST COUNTER.
 134      LSPT=  LSPT + JPTS

C                      LIST A LINE AT AN ETA STATION.
 135   WRITE  (6,21) J , (BB(K),  K=1,8)
C                      RETURN TO  THE LOOP HEAD TO LIST ANOTHER LINE.
 136   CONTINUE


       RETURN


 15    FORMAT ( A4, 44X,  27HBOUNDARY LAYER PROFILES FOR /1X,17A4 )

 16    FORMAT (1X,3HX =, F9.4, 35X,       3HU =, F9.3, 3X, 3HM =, F6.2,
     1   3X, 5HROT =, 1PE9.2)

 17    FORMAT (      24X, 6HTURB =, F5.3, 4X, 4HRW =, 1PE9.2, 4X,
     1   4HVW =, E9.2, 3X, 4HSW =, E9.2, 3X, 4HCW =, E9.2)

 18    FORMAT (      20X, 4HDT =, 1PE9.2, 1X,
     1   4HMT =, E9.2, 1X, 4HHT =, E9.2, 1X, 4HSF =, E9.2, 1X,
     2   4HCF =, E9.2, 1X, 4HST =, E9.2)

 19    FORMAT (      32X, 4HHR =, 1PE9.2, 3X, 4HPR =, E9.2, 3X,
     1   5HPRT =, E9.2, 3X, 5HSHR =, 0PF5.2)

 20    FORMAT  (1H0,3HX= F10.4,3X,6HXNOD= F10.4,3X,6HI(X)= I3,3X,4HJE=
     2          I4, 3X,10HISTO(10)= I3  /
     4           1X,3H J ,7X, 2HYY, 14X, 8HU/U(BLE),8X,1HF,15X,2HFP,14X,
     5          3HFPP, 13X, 1HD, 15X, 2HGP, 14X, 3HGPP )

 21    FORMAT  ( 1X, I3, 8(2X,1PE14.7 ) )

 22    FORMAT  ( 1X, 3HJ  , 7X, 3HTAU, 13X, 2HVE, 14X, 2HDP, 10X,
     2            12HDP/D*(1.-FP),  7X, 4HVHPP, 13X, 2HVH, 13X, 3HVHP,
     3            14X, 3HVEG )

       END
```

Subroutine PROFYL

```
$IBFTC APROF


      SUBROUTINE PROFYL (JE, JY, JD, Y, B, ET, FPW, FPPW, FPE, IBC,
     1   FP, VH, VHP, VHPP)


C     SUBR PROFYL OBTAINS F'(ETA) FROM THE MOMENTUM EQUATION
C        (8    * (F'' + B ))'  = B  + B  * F''  + B  * F'
C          4             5   I    3    2      I    1     I
C     OR G' FROM THE SIMILAR ENERGY EQUATION BY SUBSTITUTING CORRESPOND
C        ING VALUES OF THE G FUNCTIONS FOR THE F FUNCTIONS AND
C        LIKEWISE FOR THE COEFFICIENTS B(K).

C     SUBROUTINE PROFYL IS CALLED BY THE SUBROUTINES ITFR,ITSR.


      DIMENSION Y(JD), B(JD,5)
      DIMENSION FP(JD), VH(JD), VHP(JD), VHPP(JD)


      JE=JY
      VHPP(1)=0.0
      VH(1)=0.0
      VHP(1)=FPW

      IF (IBC.NE.3) GO TO 100
      VH(1)=1.0
      VHP(1)=-(FPPW+B(1,5))*(Y(2)-Y(1))

  100 CONTINUE

      JYM=JY-1
      DO 200 J=2, JYM
      VHPP(J)=VHPP(J-1)+(B(J,5)+B(J-1,5))/2.*(Y(J)-Y(J-1))
      DY=Y(J+1)-Y(J-1)
      ATP=-(B(J+1,4)+B(J,4))/(Y(J+1)-Y(J))/DY
      ATM=-(B(J,4)+B(J-1,4))/(Y(J)-Y(J-1))/DY
      A1=ATM-B(J,2)/DY
      A2=ATP+ATM-B(J,1)
      A3=ATP+B(J,2)/DY
      A4=B(J,3)-B(J,2)*B(J,5)-B(J,1)*VHPP(J)
      VH(J)=A3/(A2-A1*VH(J-1))
      VHP(J)=(A4+A1*VHP(J-1))/(A2-A1*VH(J-1))
  200 CONTINUE

      VHPP(JY)=VHPP(JY-1)+(B(JY,5)+B(JY-1,5))/2.*(Y(JY)-Y(JY-1))
      FP(JY)=FPE
      DO 250 JJ=1, JYM
      J=JY-JJ
C                  FP(J) BECOMES GP(J) DURING THE COMPUTATION OF THE
C                  ENERGY PROFILE.
      FP(J)=VH(J)*(FP(J+1)+VHPP(J+1))-VHPP(J)+VHP(J)
  250 CONTINUE
```

```
      DO 300 JJ=1, JYM
      J=JY-JJ
      IF (ABS(FP(J)).GT.1.E-8) GO TO 301
      JE=J
  300 CONTINUE

  301 CONTINUE
      RETURN
      END
```

```
$IBFTC INID

      SUBROUTINE     INIR(KSTOP,XMAS)

C     SUBROUTINE INIR INITIALIZES THE COMMON STORES, SETS UP THE
C     INITIAL BOUNDARY CONDITIONS, MODIFIES THE NORMAL COORDINATE
C     PROFILE Y(ETA), THE INPUT FIRST MOMENTUM EQUATION DERIVATIVE  ON
C     ETA F'(ETA), THE INPUT FIRST ENERGY EQUATION DERIVATIVE ON ETA
C     G'(ETA), AND COMPUTES THE INITIAL F''(ETA), G''(ETA) PROFILES.
C     THEN SUBR INIR COMPUTES THE INITIAL PROFILES ON ETA OF THE
C     DENSITY D(ETA), THE DENSITY X-DERIVATIVE DP(ETA), THE LOCAL
C     SHEAR STRESS TAU(ETA).  THE INITIAL VISCOSITY PROFILE VE(ETA) AND
C     CONDUCTIVITY PROFILE VEG(ETA) ARE GOTTEN FROM SUBR VIS.
C     THE INPUT DATA FOR SUBR INIR IS GOTTEN FROM SUBR COTR.
C     BEFORE THE EXIT TO THE MAIN ROUTINE TUF ALL  IMPORTANT QUANTITIES
C     ARE LISTED EITHER BY SUBR INIR OR SUBR FILE.

C     SUBROUTINE INIR IS CALLED BY THE MAIN ROUTINE TUF.
C     SUBROUTINE INIR CALLS SUBROUTINES...COTR,INTEG,VIS,FILE,A6IR.

C * * * * * * * * * MAIN COMMON  V-3 TUF  * * * * * * * * * * * * * * *

      COMMON  /TUFA/ATUF,
     1        B(300,5),
     2        B1,BH,BS,BK,
     3        CW(100),CF(100),CLIS(400),CAY(300),
     4        CA,CA1,CO,COB,CMTF,CMTG,C,COAL,CMU,
     5        DB(300),DBB(300),D(300),DP(300),DPB(300),
     6        DT(100),DTK(100),
     7        DX,DTXM,DOP,DI,DJ,DXB,DTM,DTS,
     8        ET,
     9        FB(300),FBB(300),FPBB(300),FPB(300),FP(300),F(300),
     A        FPP(300),FPPB(300),
     1        FPE,FPPW,FT,FV,FTU2,
     2        GPB(300),GPBB(300),GP(300),GPP(300),GPPB(300),
     3        GBC(100),GPW(100),
     4        GPPW,GPE, GAM,GAMX,
     5        HT(100),
     6        ISTO(16),
     7        I,IC,IO,IBC,IOP,IX,IXE,IT,IXA,ID,IXF
      COMMON  /TUFJ/ JTUF,
     1        JTR(100),
     2        JE,JK,JM,JY,JEF,JEG,JDIV,JEB,JD,
     3        KB,KMI,
     4        LABEL(132),
     5        LOOP,LOOPF,
     6        M(100),MT(100),
     7        MOP,MR,ML,
     8        NU,
     9        OI,
     A        P,PB,PM,POP,PR,PRT,
     1        QB,QM,QRB,QRM,Q,
     2        RW(100),RDT(100),
     3        RB,RM,RC,RMS,RMT,R,RDTK,RXRDF,RL,RMTW,RDF,RX
```

```
      COMMON   /TUFS/STUF,
     1         STR(100),SW(100),SF(100),ST(100),
     2         SHR,STC,SK,STRX,
     3         TAU(300),
     4         TURB(100),TF(100),
     5         TO,TOP,TFR,
     6         U(100),
     7         UX,
     8         VE(300),VEG(300),VH(300),VHP(300),VHPP(300),
     9         VW(100),
     A         VPB,VPM,
     1         WSTO(20),
     2         X(100),
     3         XT,XK,
     4         Y(300),YY(300),
     5         ZERO

      REAL     KB, M,ML,MR,MT,NU

      INTEGER      DOP,POP,TOP

C  * * * * * * * * *END OF MAIN COMMON TUF-V3* * * * * * * * * * * * * * *


      DIMENSION  KSTOP(5),XMAS(10)


      RB=  0.0
      RM=  0.0
      RC=  0.0
      RMS= 0.0
      RMT= 0.0
      R =  0.0
      RDTK= 0.0
      RXRDF= 0.0
      RL=  0.0
      RMTW= 0.0
      RDF= 0.0
      RX=  0.0
      RDT(2)=  0.0

         DO  1  K=  1,16
 1       ISTO(K)=  0
         DO  2  K=  1,20
 2       WSTO(K)=  0.0


C             TAPE 1 SUPPLIES X STATION DATA ON USING THE TAPE OPTION.
         REWIND  1

C                  IN SUBR COTR WE HAVE ( TO NONDIMENSIONALIZE X(I).)
C     IF  ( WSTO(10).EQ.0.0.AND.ISTO(12).EQ.1.AND.WSTO(5).NE.0.0 )
C    2    WSTO(10)=  XMAS(1)*WSTO(5)
      XMAS(1)=  ABS(XMAS(1) )

C                  THE DIMENSION OF THE I(X) WALL STATION ARRAYS.
         ID=  100
C                  THE DIMENSION OF THE J(Y) ARRAYS.
```

```
        GPW(K)=  0.0
         GBC(K)=  0.0
         HT(K)=  0.0
         JTR(K)=  0.0
           M(K)=  0.0
         MT(K)=  0.0
        RDT(K)=  0.0
          RW(K)=  0.0
        STR(K)=  0.0
         ST(K)=  0.0
         SF(K)=  0.0
          SW(K)=  0.0
         TF(K)=  0.0
        TURB(K)=  0.0
           U(K)=  0.0
          VW(K)=  0.0
           X(K)=  0.0
  8     CONTINUE


C                   VON KARMAN CONSTANT IN EMPIRICAL EFFECTIVE VISCOSITY
C                   IN SUBR VIS.
        SK=  .41
C                   CLAUSER CONSTANT FOR THE OUTER VISCOSITY LAW.
        BK=  .016
C                   A POSSIBLE TOLERANCE.
        ET=  1.0E-08
C                 CONSECUTIVE ITERATE CONVERGENCE ALLOWANCE IN ITFR,ITSR.
        XT=  .005


C                   COEFFICIENT PROFILES FOR BOTH MOMENT AND ENERGY
C                   EQUATIONS IN SUBR PROFYL.
        DO  7  J=  1,5
        DO  6  I=  1,300
  6     B(I,J)=  0.0
  7     CONTINUE


C                   COTR READS IN DATA CARDS OR TAPE, CALLS A6IR.
      CALL     COTR(KSTOP,XMAS)


        IF  ( JY.LE.300.OR.JEF.LE.300.OR.JEG.LE.300 )      GO TO 10

        ISTO(10)= 9
        WRITE  (6,63)  ISTO(10)
        CALL  A6IR

C                   GO TO THE NEXT CASE
        RETURN

C                   TO PREVENT JE FROM BECOMING .GT.JY.
C                   JY= ( JY(READ-IN) - 1 ) * JDIV + 1
C                   JEF=  ( JEF(READ-IN) - 1 ) * JDIV + 1
 10   IF  ( JEF.GT.JY )      JEF=  JY
      IF  ( JEG.GT.JY )      JEF=  JY
C                   SONIC VELOCITY CONSTANT.
C                   THE SONIC VELOCITY= SQRT(SHR*GR*T(DEG K) )
```

```
         JD=  300
C                         INITIALIZE THE PROFILE END POINTS.
         JY=  300
         JEF=  300
         JEG=  300
         JE=  300
C                         THE MAXIMUM NUMBER OF ITERATES FOR THE CONVERGENCE
C                         OF THE MOMENTUM EQUATION PROFILES.  ALSO THE MAXIMUM
C                         NUMBER OF ITERATES OF THE OUTER MOMENTUM-ENERGY LOOP.
      KMI=  15

         DO  90  K=  1,400
         CLIS(K)=  0.0
 90      CONTINUE
         DO  9  K=  1,300
         CAY(K)=  0.0
            D(K)=  1.0
           DP(K)=  0.0
           DB(K)=  0.0
          DBB(K)=  0.0
      FB(K)=0.0
            F(K)=  0.0
           FP(K)=  0.0
          FPP(K)=  0.0
           GP(K)=  0.0
         FBB(K)=  0.0
         FPBB(K)=  0.0
           FB(K)=  0.0
          FPB(K)=  0.0
         FPPB(K)=  0.0
          GPB(K)=  0.0
         GPBB(K)=  0.0
          GPP(K)=  0.0
         GPPB(K)=  0.0
          TAU(K)=  .001
           VH(K)=  0.0
          VHP(K)=  0.0
         VHPP(K)=  0.0
           VE(K)=  0.0
          VEG(K)=  0.0
            Y(K)=  0.0
           YY(K)=  0.0
 9       CONTINUE

C                         THE SPECIFIC HEAT RATIO.
         SHR=  1.4
C                         SUTHERLAND CONSTANT.
         STC=  110.0
C                         PRANDTL NUMBER.
          PR=  .78
C                         TURBULENT PRANDTL NUMBER, USED PY SUBR VIS.
         PRT=  1.0
C                         TOLERANCE, ESPECIALLY IN SUBRS ITFR,ITSR.
         ZERO=  1.0E-10

         DO  8  K=  1,100
          CF(K)=  0.0
          CW(K)=  0.0
          DT(K)=  0.0
```

```
C                 FOR AN INPUT VELOCITY IN FT/SEC AND TEMPERATURE DEG K
      GR= 1116.45*1116.45/SHR/288.15
C                 INITIALIZE THE VELOCITY OF SOUND AT MR.
C                 COMPUTE THE G*R FACTOR FOR THE SONIC VELOCITY.
      IF   ( WSTO(18).NE.0.0.AND.WSTO(19).NE.0.0 )
     2        GR=  WSTO(18)*WSTO(18)/SHR/WSTO(19)
      RL=ROT(1)
      ML=MR
      TFR=1.+(SHR-1.)/2.*MR*MR
      IF   ( WSTO(14).NE.0.0)      PRT= WSTO(14)
      IF   ( WSTO(15).NE.0.0 )      PR= WSTO(15)

      IS=1
      IF (IOP.EQ.4) IS=2

C                 EITHER U(I) OR M(I) IS READ-IN AT THE SAME LOCATION
C                 ON THE X-STATION DATA CARDS. IF U(X) IS READ IN
C                 COMPUTE M(X).  IF M(X) IS READ IN COMPUTE U(X).
      IF (MR.LT.ZERO.OR.DOP.GT.0) GO TO 105
C                 COMPUTE U(X) FROM M(X).
      DO 104 I=1, IX
C                 MACH NUMBER FROM EITHER CARDS OR TAPE.
      M(I)=U(I)
C                 IN COTR IF WSTO(8).NE.0.0 THEN U(I)=WSTO(8)*U(I).
      IF   ( WSTO(8).NE.0.0 )      M(I)= M(I)/WSTO(8)
C                 A TEMPERATURE FUNCTION.  T(TOTAL)/T(STATIC).
      TF(I)=1.+(SHR-1.)/2.*M(I)*M(I)
C                 COMPUTE THE X VELOCITY  FROM THE INPUT MACH NUMBER.
      U(I)=M(I)/MR*SQRT(TFR/TF(I))
C                 WSTO(8) IS A MODEL SCALING FACTOR
      IF   ( WSTO(8).NE.0.0 )      U(I)= WSTO(8)*U(I)
  104 CONTINUE

      WRITE  (6,58)  WSTO(8)
      GO TO 107

C                 COMPUTE M(X) FROM U(X).
  105 CONTINUE
C                 INITIALIZE M(1).
      M(1)=  MR
C                 IX IS FROM SUBR COTR AND IX.LE.99.
C                 ALTERNATE MACH NUMBER COMPUTATION AT THE X STATION.
      DO 106 I=1, IX
      UNS= U(I)
      IF   ( WSTO(16).NE.0.0 )      UNS= UNS / WSTO(16)
      IF   ( WSTO(8).NE.0.0 )      UNS= UNS / WSTO(8)
      IF   ( I.NE.1 )       GO TO 1056
      DO   1055  K= 1,5
C                 T(STATIC) OF MR= T(TOTAL)/(1.+((SHR-1.)/2.)*MR*MR).
C                 VELOCITY OF SOUND AT THE MR STATIC TEMPERATURE DEG K.
C                 GR IS HEREIN BASED ON AN INPUT OF FT/SEC UNLESS BOTH
C                 WSTO(18) AND WSTO(19) .NE.0.0.
      VSMR= SQRT(SHR*GR*TO/(1.+((SHR-1.)/2.)*M(1)*M(1) )   )
 1055 M(1)= UNS / VSMR
C                 MACH NUMBER BASED ON THE VELOCITY OF SOUND AT X(1).
 1056 M(I)=  UNS / VSMR
C                 A TEMPERATURE FUNCTION.
      TF(I)=1.+(SHR-1.)/2.*M(I)*M(I)
  106 CONTINUE
```

```
C                  RESET MR,ML,TFR.
      MR= M(1)
      ML= MR
      TFR= 1. + ((SHR-1.)/2.)*MR*MR
      WRITE  (6,67)  MR,TFR, WSTO(8)

C                  SKIP EFN 105 WHEN U(X) IS COMPUTED FROM M(X).
  107 CONTINUE

C                  FILL IN THE VACANCIES ON THE YY(J),F'(ETA),
C                  G'(ETA) PROFILES AND COMPUTE THE F(ETA),F''(ETA),
C                  G''(ETA), D(ETA), AND DP(ETA) PROFILES.
      DIVJ=JDIV
C                  JY IS THE EXPANDED JY FROM SUBR COTR.
      DO 108 J=2, JY
C                  JF(MAX)= JY
      JF=((J-1)/JDIV)*JDIV+1
C                  JL(MAX)= JY
      JL=((J+JDIV-2)/JDIV)*JDIV+1
C                  NORMAL COORDINATE.
      YY(J)=YY(JF)+(YY(JL)-YY(JF))/DIVJ*FLOAT(J-JF)
C                  F'(ETA).
      FP(J)=FP(JF)+(FP(JL)-FP(JF))/DIVJ*FLOAT(J-JF)
C                  G'(ETA).
      GP(J)=GP(JF)+(GP(JL)-GP(JF))/DIVJ*FLOAT(J-JF)
  108 CONTINUE

C                  JEF AND JEG HAVE BEEN EXPANDED IN SUBR COTR.
C                  JEF(MAX)= JY,  JEG(MAX)= JY.
      JE=MAX0(JEF,JEG)
      CMTF=1.0
      CMTG=1.0
      P=BS
      OI=IO
      RT=0.0
      RC=0.0
C                  REAL.
      KB=0.0
      XK=0.0
C                  THE CRITICAL I(X) STATION FOR TURBULENT FLOW IS
C                  INITIALIZED = 1 MORE THAN THE LAST STATION.
      IC=IX+1
      CA=0.0
      SC=1.0
C                  THE FIRST I(X) STATION IS INITIALIZED TO 1.
C                  I IS RESET= 2 ON IOP.EQ.4 FOLLOWING EFN 112.
      I=1

C                  IF IO.NE.0 WE HAVE AXISYMMETRIC FLOW.
C                  DR/DX AT THE ORIGIN
      IF (IO.NE.0) SC=0.5

C                  SLOPE OF THE TANGENT TO THE AXISYMMETRIC BODY.
         RWSL=     (RW(2)-RW(1) ) / ( X(2)-X(1) )
         WSTO(19)= RWSL*RWSL
         IF   (WSTO(19).GT.1.0.AND.RW(1).LT.RW(2) )  RW(1)=  RW(2)-X(2)
         IF   (WSTO(19).GT.1.0.AND.RW(1).LT.RW(2) )     RWSL=  1.
         IF   (WSTO(19).GT.1.0.AND.RW(1).GT.RW(2) )  RW(1)=  RW(2)+X(2)
         IF   (WSTO(19).GT.1.0.AND.RW(1).GT.RW(2) )  RWSL=  -1.
```

```
         WSTO(19)=  RWSL*RWSL
         COAL=  SQRT(1.-WSTO(19) )
 111  GO TO (113,114,114,112,113,114,114), IOP

C                  THE STARTING FLOW IS SIMILAR LAMINAR.  HERE THE
C                  STARTING PROFILE IS ONE STATION DOWN FROM THE ORIGIN.
  112 CONTINUE
C                  RESET I FOR THE STARTING PROFILES IN SUBR ITFR.
      I=2
C                  DISPLACEMENT THICKNESS.
      DT(1)=0.0
C                  REYNOLDS NUMBER BASED ON DISPLACEMENT THICKNESS.
      RDT(1)=0.0
C                  A CONSTANT IN EQUA II-28B FOR THE DISPLACEMENT
C                  DERIVED FROM THE WEDGE POWER LAW OF BOUNDARY LAYER
C                  WEDGE VELOCITY.
      C=SQRT(2./(BS+1.)/RL)
C                  PARAMETER OF EQUA II-14.
C                  HERE RL= RDT(1) FROM A RESET IN SUBR COTR.
      P=C*C*RL*BS
C                  RDF=0 FOR LAMINAR STARTING FLOW AND = 1 FOR TURBULENT
C                  STARTING FLOW.
      RDF=C*RL
C                    COMPUTED REYNOLDS NUMBER AT STATION I(X)= 2.
      RDT(2)=RDF

         IF  (ABS(RWSL).LT.1.0E-8)     GO TO 115
C                  PARAMETER IN EQUA II-14.
      R=RL*C*C*(RW(3)-RW(1))/(X(3)-X(1))*(X(2)-X(1))/(RW(3)+RW(1))
C                  COSINE OF ANGLE OF NOSE OF THE AXISYMMETRICAL BODY.
      CA=2.*OI*COAL*C*(X(2)-X(1))/RW(2)
      GO TO 115

C                  TO HERE FROM EFN 111 ON IOP.EQ.1,5 LAMINAR FLOW.
  113 CONTINUE
      RDF=RDT(I)
      IF (ABS(RW(1)/DT(1)).LT.0.1) GO TO 115
C                  SEE EQUA II-14, THE R PARAMETER.
         R=  RWSL*DT(1)/RW(1)*RDT(1)
         CA=  2.*OI*DT(1)/RW(1)*COAL
      GO TO 115

C                  TO HERE FOR TURBULENT FLOW FROM EFN 111.
  114 CONTINUE
      RDF=1.0
      IF (ABS(RW(1)/DT(1)).LT.0.1) GO TO 115
         R=  RWSL*DT(1)/RW(1)
         CORW=  R/DT(1)*RW(1)
         CORS=  CORW*CORW
         IF  ( CORS.GT.1.0 )     CORS=  1.
         CORT=  SQRT(1.-CORS)
C                  THE SCALED NOSE ANGLE OF THE AXISYMMETRIC BODY.
C                  TO HERE ALSO FOR LAMINAR FLOW.
         CA=  2.*OI*DT(1)/RW(1)*CORT

C                  TO HERE ON A SKIP.
  115 CONTINUE
C                  TO BE USED IN SUBR ITSR FOR SUBR TRANS, FOR A
C                  SCALING OF FT DOWNSTREAM FROM THE ORIGIN.
```

```
      FTU2=FT*U(I)*U(I)
C                        MODIFY Y(J) TO ACCOUNT FOR THE NOSE ANGLE OF AN
C                        AXISYMMETRIC BODY.
      DO 120 J=1, JD
      Y(J)=YY(J)*(1.+YY(J)*CA/4.)
  120 CONTINUE

      IF (IABS(DOP).NE.1.OR.MOP.LT.0) GO TO 123
C                        RECOMPUTE THE F'(ETA) PROFILE ON DOP.EQ.1.OR.MOP.GE.0
C                        FOR BOTH LAMINAR AND TURBULENT FLOW.
      DO 122 J=1, JE
      FV=1.-FP(J)

      FP(J)=1.-FV/(TF(I)*(1.-GP(J)*BH)-(TF(I)-1.)*FV*FV)
  122 CONTINUE


C                        COMPUTE F(ETA) BY USING THE TRAPEZOIDAL RULE.
C                        TO HERE ON SKIPPING THE PRECEEDING FP(J) COMPUTATION.
 123  CALL INTEG (JE, JD, Y, FP, 0.0, F)

      DO 125 J=1, JY
      DY=Y(J+1)-Y(J)
C                        F''(ETA) PROFILE BY 1ST DIFFERENCES.
      FPP(J)=(FP(J+1)-FP(J))/DY
C                        G''(ETA PROFILE BY 1ST DIFFERENCES.
      GPP(J)=(GP(J+1)-GP(J))/DY
C                        THE DENSITY IS A CONSTANT FOR THIS PROFILE.
      D(J)=1.0
C                        THE R(DELTA)*DELTA(*)*(X-DERIVATIVE OF THE LOCAL
C                        DENSITY) PARAMETER.
      DP(J)=0.0
C                        THE DELTA(*)*(X-DERIVATIVE OF THE LOCAL DENSITY)
C                        PARAMETER.
      DB(J)=0.0
C                        THE PROFILE OF THE LOCAL SHEAR STRESS IS A CONSTANT.
      TAU(J)=0.001
C                        THE DENSITY, DENSITY X-DERIVATIVE LOOP END.
  125 CONTINUE

C                        RESET THE END VALUES TO THE BOUNDARY CONDITIONS.
      FPP(JY)=0.0
      GPP(JY)=0.0
C                        TEST TO RECOMPUTE THE DENSITY AND X-DERIVATIVE
C                        OF DENSITY PARAMETER PROFILES.
      IF (MOP.LT.0) GO TO 127
      B1=TF(I)-1.
      DO 126 J=1, JY
      FV=1.-FP(J)
C                        LOCAL DENSITY PROFILE
      D(J)=2.*TF(I)*(1.-BH*GP(J))/(1.+SQRT(1.+4.*B1*FV*FV*TF(I)
     1   *(1.-BH*GP(J))))
C                        LOCAL X- DERIVATIVE OF DENSITY PARAMETER.
      DP(J)=(2.*B1*D(J)*D(J)*FV*FPP(J)-TF(I)*BH*GPP(J))
     1   /(1.+2.*B1*D(J)*FV*FV)
  126 CONTINUE

C                        SET X DERIVATIVE OF DENSITY TO THE BOUNDARY VALUE.
      DP(JY)=0.0
```

```
C                       SKIP TO HERE IF MOP.LE.0 (FOR CONSTANT DENSITY FLOW).
  127 CONTINUE
C                       QUANTITIES FOR THE SUBR VIS COMPUTATION OF THE
C                       EFFECTIVE VISCOSITY = VE(ETA) AND EFFECTIVE
C                       CONDUCTIVITY = VEG(ETA) PROFILES.
      DO 128 J=1, JE
      FV=1.-FP(J)
      VH(J)=FV*(1.-D(J)*FV)
  128 CONTINUE

C                       SEE EQUA II-22.
C                       INTEGRAL MOMENTUM THICKNESS BASED ON DELT(*).
      CALL INTEG (JE, JD, Y, VH, D.D, VH)
C                       DELTA(*)/THETA.
      SF(1)=1./VH(JE)
C                       MOMENTUM THICKNESS.
      MT(1)=DT(1)/SF(1)
      Q=0.0
C                       SKIN FRICTION COEFFICIENT.
      CF(1)=0.0
      CF(2)=0.0
C                       STANTON NUMBER BASED ON FREESTREAM TO REFERENCE
C                       ENTHALPY DIFFERENCE.
      STR(1)=0.0
      STR(2)=0.0
C                       SHEAR PARAMETER C(MU).  SEE II-34.
      CMU=(1.5-1./(1.+STC/TO*TFR))*(SHR-1.)*MR*MR
      GAM=0.0
      GAMX=0.0
      STRX=0.0
C                       COMPUTE VE(ETA),VEG(ETA) IN VIS AND FOLLOW WITH
C                       THE TAU(ETA) PROFILE, ALL PROFILES TO BE ITERATED
C                       WHEN TURB(I).EQ.1.
      KC=5
C                       TURB(I).GE.0.0.AND..LE.1.
      IF (TURB(I).LT.1.0) KC=1

      DO 132 K=1, KC

C                       COMPUTE 1 EACH VE(ETA)=EFFECTIVE VISCOSITY AND
C                       VEG(ETA)= EFFECTIVE CONDUCTIVITY PROFILES.
C                       THE VISCOSITY AND CONDUCTIVITY PROFILES ARE
C                       COMPUTED FOR BOTH COMPRESSIBLE AND CONSTANT DENSITY
C                       FLOWS.

      CALL VIS (JE, JY, JD, YY, FP, FPP, GP, GPP, D, DP, TAU, VH, VHP,
     1   TURB(I), SW(I), CW(I), SHR, BH, STC, TO, TF(I), RDT(I), DT(I),
     2   F(JY), PR, PRT, JK, VE, VEG, ISTO )

C                       COMPUTE A PROFILE OF TAU(ETA).
      LCAY= 0
      DO 131 J=1, JY
      CAY(J)=  CA*Y(J)
      IF  (CAY(J).GE.-1. )      GO TO 129
      LCAY=  LCAY + 1
      IF  ( LCAY.EQ.1 )      WRITE  (6,62)  CA,Y(J)
         TAU(J)=  0.0
      GO TO 131
```

```
C                   THE LOCAL NON-DIMENSIONAL SHEAR STRESS.
 129  TAU(J)=VE(J)*(DP(J)/D(J)*(1.-FP(J))-FPP(J))*SQRT(1.+CAY(J) )
  131 CONTINUE
C                   END SUBR VIS AND TAU(ETA) PROFILE LOOP.
  132 CONTINUE


      IF (TURB(I).GT.0.999) CF(I)=2.*TAU(I)



C **** PRINT OUT THE INPUT VARIABLES AND PARAMETERS ****
C     WRITE  (6,48)      I
C                   LIST HEADING AND INITIAL PROFILES.  IF IOP.LE.3 THE
C                   INITIAL F'(ETA),G'(ETA) PROFILES ARE THE STARTING
C                   PROFILES.
      CALL FILE (LABEL, 1, YY, F, FP, FPP, GP, GPP, D, DP,
     1   VH, VHP, VHPP, TAU, VE, VEG, SHR, BH, PR, PRT,
     2   X, U, M, TURB, RW, VW, SW, CW,
     3   RDT, DT, MT, HT, SF, CF, ST,STR,ID,JE,JY,JD,JDIV,ISTO,WSTO )

      IF  (ISTO(1).EQ.2)      GO TO 133

      IF (POP.EQ.1)      RETURN

 133  WRITE  (6,49)      ISTO(10)
      WRITE  (6,50)    LABEL(1), (LABEL(K),  K=  2,18)
      WRITE (6,52) JDIV , JY, JEF, JEG, JE
      WRITE (6,53) SHR, PR, PRT, GR, VSMR
      WRITE (6,54) ET, XT
      WRITE (6,55) IOP, MOP, DOP, IO, TOP, POP
      WRITE (6,56) M(1), DT(1), RDT(1), BS, TO, BH, FT
      WRITE (6,60) X(1), U(1), M(1), TURB(1), GBC(1), RW(1), VW(1),
     1   SW(1), CW(1)

      IF (IOP.EQ.4)
     1   WRITE (6,60) X(2), U(2), M(2), TURB(2), GBC(2), RW(2), VW(2),
     2   SW(2), CW(2)


      WRITE  (6,59)  ( IL,  M(IL),   IL=  1,IX )
      WRITE  (6,64)  ( IL, TF(IL),   IL=  1,IX )
      WRITE  (6,65)  ( IL,  U(IL),   IL=  1,IX )
      WRITE  (6,66)  I, CF(I), SF(I), MT(I), STR(I), TF(I), VH(1),
     2               TAU(1), TAU(2), VE(1),P,R,CMU,RDT(2)

         RETURN



 48   FORMAT  (1H1,5X, 5HI(X)=  I3,
     2        54HTHE INITIAL PROFILES FOR BOTH MOMENTUM AND ENERGY ARE-)

 49   FORMAT  (1H1,10HISTO(10)= I3 )
 50   FORMAT  ( A4, 9X, 20HINPUT VARIABLES FOR , 17A4 )

   52 FORMAT (10X, 6HJDIV =, I2, 5X,3HJY=I4,5X,4HJEF=I4,5X,4HJEG=I4,5X,
     2        3HJE=I4 )
```

```
  53 FORMAT (10X, 5HSHR =, F6.3, 2X, 4HPR =, F6.2, 2X, 5HPRT =, F6.2,
    2          2X, 4HGR= E15.8, 2X, 6HVSMR= E15.8 )
  54 FORMAT (10X, 4HET =, 1PE11.4, 2X, 4HXT=   , E11.4 )

  55 FORMAT (10X, 5HIOP =, I2, 2X, 5HMOP =, I2, 2X, 5HDOP =, I2, 2X,
    1   4HIO =, I2, 2X, 5HTOP =, I2, 2X, 5HPOP =, I2)

  56 FORMAT (10X, 3HM =, F7.3, 2X, 4HDT =, 1PE11.4,2X, 5HRDT =, E11.4,
    1   2X, 3HB =, E11.4,2X, 4HTO =, E11.4,2X, 4HBH =, E11.4,2X,
    2   4HFT =, E11.4 )

58     FORMAT (1H0, 41HSUBR INIR HAS COMPUTED THE U(I) FROM THE
    2                48HM(I)=U(I) INPUT AND THEN SCALED U(I) ON WSTO(8)
    3                19HIF WSTO(8).NE.0.0. 2X, 9HWSTO(8)= 1PE10.3 )

59    FORMAT   ( 1H0, 5HM(I)=  /  5(4X,I3,2X,1PE14.7 ) )

  60 FORMAT (1H0, 9X, 3HX =, 1PE11.4, 1X,
    1   3HU =, E11.4,1X, 3HM =, E11.4,1X, 6HTURB =, 0PF6.3, 1X,
    2   5HGBC =, 1PE11.4 /
    3          10X,4HRW=  E11.4,1X, 4HVW=  E11.4, 1X, 4HSW=  E11.4, 1X,
    4          4HCW=  E11.4 )

62    FORMAT   ( 1H0, 42HCA*Y(J) OUT OF BOUNDS.  RESET TAU(J)=  0.0,
    2          5X, 3HCA= 1PE12.5, 5X, 5HY(J)= E12.5 )


63    FORMAT   (1H0, 35HCOMPUTED JY .OR.JEF.OR.JEG.GT.300.
    2          23HGO TO THE NEXT CASE. , 10HISTO(10)= I2)

64    FORMAT   ( 1H0, 6HTF(I)= /  5(4X,I3,2X,1PE14.7 ) )
65    FORMAT   ( 1H0, 5HU(I)=  /  5(4X,I3,2X,1PE14.7 ) )

66    FORMAT   ( 1H0, 2HI= I3, 3X, 7HCF(I)= 1PE12.5, 3X, 7HSF(I)= E12.5,
    2          3X, 7HMT(I)= E12.5, 3X, 8HSTR(I)= E12.5, 3X, 7HTF(I)=
    3          E12.5/ 9X, 7HVH(1)= E12.5, 3X, 8HTAU(1)= E12.5, 3X,
    4          8HTAU(2)= E12.5, 3X, 7HVE(1)=  E12.5 /
    5          13X, 3HP= E12.5,      8X, 3HR= E12.5, 6X, 5HCMU= E12.5,
    6           3X, 8HROT(2)= E12.5 )

67    FORMAT   (1H0, 46HSUBR INIR HAS COMPUTED THE M(I) FROM THE U(I)
    2                39HDATA INPUT,AND MR FROM U(1),MR, AND TO /
    3                 10X,  4HMR= F8.4, 5X, 5HTFR= F8.4, 5X,  9HWSTO(8)=
    4                 1PE10.3 )

      END
```

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$IBFTC COTD

      SUBROUTINE    COTR(KSTOP,XMAS)

C     SUBROUTINE COTR READS IN ALL OF THE INPUT DATA EXCEPTING THE
C     COMMENT DATA WHICH IS READ IN BY SUBR A6IR.

C     SUBROUTINE COTR IS CALLED BY SUBROUTINE INIR.
C     SUBROUTINE COTR CALLS SUBROUTINE A6IR BEFORE EACH SUBSET OF DATA
C     FOR COMMENT.  IN ORDER TO INCLUDE SOME GENERAL COMMENT SUBR COTR
C     ALSO CALLS SUBR A6IR JUST BEFORE THE EXIT TO THE CALLING ROUTINE
C     SUBR INIR.

C     SUBR COTR WILL READ IN ALL X STATIONS BUT INIR WILL COMPUTE A
C     MAXIMUM OF 99 STATIONS.  FOR ALL STATIONS .GE.100 THE DATA IS
C     STORED IN THE 100TH DATA STATION.  HOWEVER, IF CARD READING
C     OF X STATION DATA IS USED, THEN NOT MORE THAN 200 CARDS CAN BE
C     READ IN.  CARDS THAT FOLLOW THE 200TH CARD WILL BE READ BY A6IR.
C     X(I) FOR THE LAST STATION DATA CARD IS TO BE EITHER 0,BLANK OR
C     .LT. X(I-1).  THE LAST STATION DATA CARD IS FOLLOWED BY AT LEAST
C     1 CARD OF COMMENT TO BE READ IN BY SUBR A6IR.
C     FOR CARD READ-IN NC IS LISTED AFTER ALL CARDS ARE READ IN AND
C     STATIONS ARE LISTED ON ISTO(1).NE.0, AND IS THE TOTAL NUMBER OF
C     CARDS READ -IN PROVIDED THE NUMBER OF CARDS IS .LE.200.
C     ON TAPE READ-IN OF THE STATION DATA NC IS THE NUMBER OF TAPE
C     STATIONS ACTUALLY READ IN.
C     FOR TAPE READ-IN THE NUMBER OF STATION POINTS AVAILABLE FOR
C     READING-IN IS LISTED AS KEND AT THE TIME OF READ-IN.
C     IF KEND.GT.100 THEN, AFTER LISTING, COTR RESETS KEND TO 100, THE
C     NUMBER OF POINTS TO BE READ IN FROM THE TAPE.  KEND WILL BE LISTED
C     AS 100 ON ANY LATER LISTING OF KEND.  ON CARD READ IN KEND=0.
C     ON THE X STATION TAPE READ IN OPTION KEND IS THE NUMBER OF X DATA
C     POINTS READ IN PROVIDED KEND.LE.98.  FOR BOTH CARD OR TAPE READ IN
C     IF IS=100 THEN THE X STATION DATA LISTED IS FOR THE LAST DATA
C     STATION READ-IN WHICH MAY BE LATER THAN FOR THE X(100) CARD OR THE
C     X(100)  POINT FROM THE TAPE.


C  * * * * * * * * * MAIN COMMON  V-3 TUF  * * * * * * * * * * * * * * *

      COMMON  /TUFA/ATUF,
     1        B(300,5),
     2        B1,BH,BS,BK,
     3        CW(100),CF(100),CLIS(400),CAY(300),
     4        CA,CA1,CO,COB,CMTF,CMTG,C,COAL,CMU,
     5        DB(300),DBB(300),D(300),DP(300),DPB(300),
     6        DT(100),DTK(100),
     7        DX,DTXM,DOP,DI,DJ,DXB,DTM,DTS,
     8        ET,
     9        FB(300),FBB(300),FPBB(300),FPB(300),FP(300),F(300),
     A        FPP(300),FPPB(300),
     1        FPE,FPPW,FT,FV,FTU2,
     2        GPB(300),GPBB(300),GP(300),GPP(300),GPPB(300),
     3        GBC(100),GPW(100),
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```
     4          GPPW,GPE, GAM,GAMX,
     5          HT(100),
     6          ISTO(16),
     7          I,IC,IO,IBC,IOP,IX,IXE,IT,IXA,ID,IXF
      COMMON    /TUFJ/ JTUF,
     1          JTR(100),
     2          JE,JK,JM,JY,JEF,JEG,JDIV,JEB,JD,
     3          KB,KMI,
     4          LABEL(132),
     5          LOOP,LOOPF,
     6          M(100),MT(100),
     7          MOP,MR,ML,
     8          NU,
     9          OI,
     A          P,PB,PM,POP,PR,PRT,
     1          QB,QM,QRB,QRM,Q,
     2          RW(100),RDT(100),
     3          RB,RM,RC,RMS,RMT,R,RDTK,RXRDF,RL,RMTW,RDF,RX
      COMMON    /TUFS/STUF,
     1          STR(100),SW(100),SF(100),ST(100),
     2          SHR,STC,SK,STRX,
     3          TAU(300),
     4          TURB(100),TF(100),
     5          TO,TOP,TFR,
     6          U(100),
     7          UX,
     8          VE(300),VEG(300),VH(300),VHP(300),VHPP(300),
     9          VW(100),
     A          VPB,VPM,
     1          WSTO(20),
     2          X(100),
     3          XT,XK,
     4          Y(300),YY(300),
     5          ZERO

      REAL      KB, M,ML,MR,MT,NU

      INTEGER      DOP,POP,TOP

 * * * * * * * * *END OF MAIN COMMON TUF-V3* * * * * * * * * * * * *

      DIMENSION  KSTOP(5),XTAP(100), UTAP(100), RTAP(100),XMAS(10)


C                   BEGIN A NEW CASE BY READING IN SOME COMMENT CARDS.
      CALL      A6IR

      KEND=  0
      NC=  0
      ISTU=  0
C                   READ IN THE INTEGER SWITCH ARRAY.
      READ  (5,2)  ( ISTO(K),  K=  1,15 )
         ISTO(10)=  1
      IF  ( ISTO(1).NE.0 )      WRITE  (6,21)  (ISTO(K),  K= 1,15)

      CALL      A6IR
      READ  (5,5)  (WSTO(K),  K=  1,20 )
```

```
C                 THE RESET VALUE OF WSTO(11) IS IN ENGLISH UNITS.
      IF  ( WSTO(11).EQ.0.0 )     WSTO(11)=  .1564000E-03
      IF  ( ISTO(1).NE.0 )     WRITE  (6,51) (WSTO(K),  K=  1,20)


C                 READ IN THE LABEL(K) ARRAY FOR THE X-STATION HEADING.
      CALL     A6IR
      READ (5,1) (LABEL(K), K=1,18)
      IF  ( ISTO(1).NE.0 )     WRITE  (6,1)  (LABEL(K),  K=  1,18 )

C                 READ IN THE INITIAL YY(J),FP(J),GP(J) PROFILES.
      CALL     A6IR
      READ (5,2) JDIV
      IF  ( ISTO(1).NE.0 )     WRITE  (6,21)  JDIV

      CALL A6IR
      READ  (5,2)  JY
        JYC=  JY
C                 THE FOLLOWING JY IS NOT MODIFIED AGAIN.
      JY=(JY-1)*JDIV+1
      READ (5,3) (YY(J), J=1, JY, JDIV)
      IF  ( ISTO(1).NE.0 )  WRITE  (6,31)  JYC,JY,JDIV,
     2                      (YY(J),  J=  1,JY,JDIV )

      CALL A6IR
      READ  (5,2)  JEF
      JEFC=  JEF
      JEF=(JEF-1)*JDIV+1
      READ (5,3) (FP(J), J=1, JEF, JDIV)
      IF  ( ISTO(1).NE.0 )  WRITE  (6,31)  JEFC,JEF,JDIV,
     2                      ( FP(J),  J=  1,JEF,JDIV )

      CALL A6IR
      READ  (5,2)  JEG
      JEGC=  JEG
      JEG=(JEG-1)*JDIV+1
      READ (5,3) (GP(J), J=1, JEG, JDIV)
      IF  ( WSTO(9).EQ.0.0 )     GO TO 70
      DO  69  J=  1,JEG,JDIV
 69   GP(J)=  WSTO(9)*GP(J)
 70   IF  ( ISTO(1).NE.0 )  WRITE  (6,31)  JEGC,JEG,JDIV,
     2                      ( GP(J),  J=  1,JEG,JDIV )
C                 READ IN THE PROGRAM OPTION SWITCHES.
      CALL A6IR
      READ (5,2) IOP, MOP, DOP, IO, TOP, POP
      IF  ( IOP.EQ.2.OR.IOP.EQ.3.OR.IOP.EQ.6.OR.IOP.EQ.7 )     TOP=  0
      IF  (ISTO(1).NE.0)  WRITE  (6,21) IOP,MOP,DOP,IO,TOP,POP

C                 READ IN THE CASE INITIAL PARAMETERS.
      CALL A6IR
      READ (5,4) MR, DT(1), RDT(1), BS, TO, BH, FT
        IF  ( IOP.EQ.7.AND.DT(1).EQ.0.0 )     DT(1)=  .001
      IF  (ISTO(1).NE.0)  WRITE (6,40) MR,DT(1),RDT(1),BS,TO,BH,FT

      CALL A6IR

C     ***         X-STATION DATA READ-IN AND RECOMPUTATION SECTION. ***
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```
C                     TEST FOR CARD OR TAPE READ IN OF STATION PARAMETERS.
      IF  ( ISTO(15).NE.0 )      GO TO 711
C                     TAPE READ IN TO INTERMEDIATE STORAGE.
C                     KRS= CLOCK STATION NUMBER.
         KRS=  ISTO(11)
         DO  71  K=  1,KRS
         READ  (1)     KEND
         WRITE  (6,67)     KEND
         IF  ( KEND.GT.100 )     KEND=  100
         READ  (1)             (XTAP(I),UTAP(I),RTAP(I),  I=  1,KEND)
 71      CONTINUE

C                     TO HERE ON EITHER CARD OR TAPE READ IN.
 711  IT=100
         IS=  0
      IX=  0
C                     LINE IS RESET = 1 WHEN THE SLOPE TEST RESULTS IN A
C                     LINEAR INTERPOLATION, AND PREVENTS FURTHER TESTING.
         LINE=  0
C                     IPS IS TESTED AGAINST IS TO START THE LINEAR
C                     INTERPOLATION TEST.
      IPS=  ISTO(9) + 2
C                     ISS IS USED AS A STORE FOR THE NUMBER OF POINTS
C                     THE PROFILES ARE STRETCHED AS THE RESULT OF THE
C                     LINEAR INTERPOLATION.
      ISS=0
C                     EITHER READ IN OR RE-STORE, AND MODIFY THE X-STATION
C                     DATA.
      DO 102 I=1, 200
C                     TOTAL NUMBER OF STATION POINTS READ IN.
      NC=  I
C                     STATION COUNTER INCLUDING INTERPOLATED POINTS.
      IF  (IS.LT.100)     IS=  IS + 1
C                     IF ISTO(8).NE.0 ISS BECOMES ISTO(8) + 1 AFTER THE
C                     INTERPOLATION.
      ISN=  IS- ISS

C                     SKIP TO 712 ON TAPE READ IN OF STATION DATA.
      IF  ( ISTO(15).EQ.0 )      GO TO 712
      READ  (5,4)
     2        X(IS),U(IS),TURB(IS),GBC(IS),RW(IS),VW(IS),SW(IS),CW(IS)
      GO TO 713


C                     TRANSFER FROM INTERMEDIATE STORAGE THE TAPE DATA.
 712     X(IS)=  XTAP(ISN)
         U(IS)=  UTAP(ISN)
         TURB(IS)=  0.0
         GBC(IS)=  0.0
         RW(IS)=  RTAP(ISN)
         VW(IS)=  0.0
         SW(IS)=  0.0
         CW(IS)=  0.0
C                     AN INSTRUCTION TO CHANGE THE X-STATION DATA CAN BE
C                     INSERTED HERE.

C                     TO HERE ON EITHER CARD OR TAPE READ OF STATION DATA.
 713  IF  ( IOP.EQ.2.OR.IOP.EQ.3.OR.IOP.EQ.6.OR.IOP.EQ.7 )  TURB(IS)=1.0
         IF  ( WSTO(5).NE.0.0 )      X(IS)=  WSTO(5)*X(IS)
```

```
      IF  ( WSTO(5).NE.0.0 )    RW(IS)=  WSTO(5)*RW(IS)
         IF  ( WSTO(16).NE.0.0 )     U(I)=  WSTO(16)*U(I)
         IF  ( WSTO(8).NE.0.0 )     U(IS)=  WSTO(8)*U(IS)
         IF  ( TOP.EQ.1 )      TURB(IS)= 0.0
         IF  ( TURB(IS).GE.1. )      ISTU=  1
         IF  ( ISTU.EQ.1  )      TURB(IS)= 1.
         IF  ( WSTO(17).NE.0.0 )     GBC(I)=  WSTO(17)*GBC(I)
         IF  ( ID.EQ.0 )      RW(IS)= 0.0
         IF  ( X(IS).NE.0.0 )   GO TO 714
      IF  (IOP.EQ.4.AND.BS.EQ.1.0)     U(IS)=0.0
         GO TO 15
C                  LINE IS RESET = 1 AFTER DUX.GT.DUZ.
 714     IF  ( LINE.EQ.1 )     GO TO 15
      IF  ( ISTO(8) .EQ.0 )      GO TO 15


C            * * * BEGIN THE LINEAR INTERPOLATION SECTION OF POINTS.
         IF  ( IS.LE.IPS )     GO TO 15
         DUX=  ( U(IS)-U(IS-1) ) / ( X(IS)-X(IS-1) )
      DUZ=  ( U(IS-1) - U(1) ) / X(IS-1)
      IF  ( DUX.LE.DUZ )     GO TO 15
         IF  ( ISTO(1).NE.0 )     WRITE  (6,41)
     2     X(IS),U(IS),TURB(IS),GBC(IS),RW(IS),VW(IS),SW(IS),CW(IS),IS
      ISX=  ISTO(8)  + IS
      IFIN=  ISX-1
      FIN=  IFIN
      LINE=  1
 72      X(ISX+1)=  X(IS)
         U(ISX+1)=  U(IS)
         TURB(ISX+1)=  TURB(IS)
         GBC(ISX+1)=  GBC(IS)
         RW(ISX+1)= RW(IS)
         VW(ISX+1)=  VW(IS)
         SW(ISX+1)=  SW(IS)
         CW(ISX+1)=  CW(IS)
         ISM=  IS-1
         X(ISX)=  X(ISM)
         U(ISX)=  U(ISM)
         TURB(ISX)=  TURB(ISM)
         GBC(ISX)=  GBC(ISM)
         RW(ISX)= RW(ISM)
         VW(ISX)= VW(ISM)
         SW(ISX)=  SW(ISM)
         CW(ISX)=  CW(ISM)
         IF  ( ISTO(1).NE.0 )     WRITE  (6,42)
     2       X(ISM),U(ISM),TURB(ISM),GBC(ISM),RW(ISM),VW(ISM),
     3       SW(ISM),CW(ISM),ISM
         X(2)=  X(ISM)/FIN
         DOU=  ( U(ISM)-U(1) ) / FIN
         U(2)=  U(1) + DOU
         DOT=  (TURB(ISM)-TURB(1))/FIN
         TURB(2)=  TURB(1) + DOT
         DOR=  ( RW(ISM)-RW(1) ) / FIN
         DOG=  (GBC(ISM)-GBC(1)) / FIN
         GBC(2)=  GBC(1) + DOG
         RW(2)= RW(1) + DOR
      IS=  2
         DOV=  (VW(ISM)-VW(1)) / FIN
         VW(2)=  VW(1) + DOV
```

```
         DOS=  (SW(ISM)-SW(1)) / FIN
         SW(2)=  SW(1) + DOS
         DOC=  (CW(ISM)-CW(1)) / FIN
         CW(2)=  CW(1) + DOC
         IF  ( ISTO(1).NE.0 )     WRITE  (6,41)
     2            X(2),U(2),TURB(2),GBC(2),RW(2),VW(2),SW(2),CW(2),IS
C                  INSERTION OF THE INTERPOLATION POINTS.
         DO  13  KX=  3,IFIN
         IX=  KX
         X(KX)=  X(KX-1) + X(2)
         U(KX)=  U(KX-1) + DOU
         TURB(KX)=  TURB(KX-1) + DOT
         GBC(KX)=    GBC(KX-1) + DOG
         RW(KX)= RW(KX-1) + DOR
         VW(KX)=  VW(KX-1) + DOV
         SW(KX)=  SW(KX-1) + DOS
         CW(KX)=  CW(KX-1) + DOC
      IF  ( TOP.EQ.1 )     TURB(KX)=  0.0
      IF  ( IOP.EQ.7 )     TURB(KX)=  1.0
      IF  ( TOP.NE.1.AND. IOP.NE.7 )     TURB(KX)=  TURB(KX-1)
      IF  ( TOP.NE.1 )     GO TO 11
 11      IF  ( ISTO(1).NE.0 )  WRITE  (6,41)
     2     X(KX),U(KX),TURB(KX),GBC(KX),RW(KX),VW(KX),SW(KX),CW(KX),KX
 13      CONTINUE
         IX=  ISX
 141     IF  ( ISTO(1).NE.0 )  WRITE  (6,41)
     2  X(ISX),U(ISX),TURB(ISX),GBC(ISX),RW(ISX),VW(ISX),SW(ISX),CW(ISX)
     3  ,ISX
         IS=  ISX + 1

      IF  ( ISTO(15).NE.0 )     GO TO 15
      ISS=  ISTO(8) + 1

C             * * * END OF THE LINEAR INTERPOLATION SECTION OF POINTS.

C                  SKIP TO HERE AFTER COMPLETING THE LINEAR SECTION.
 15      IF  ( ISTO(1).NE.0 )  WRITE  (6,41)
     2     X(IS),U(IS),TURB(IS),GBC(IS),RW(IS),VW(IS),SW(IS),CW(IS),IS
C                  AT THE END OF THE STATION DATA READ IN IX= THE COUNT
C                  OF THE LAST STATION TO BE COMPUTED.
         IX=  IS
         IF  ( IS.EQ.1 )     GO TO 102
C                  TO PERMIT ALL STATIONS .LE.200 TO BE READ IN.
         IF  ( IS.GE.100 )     GO TO 1011
C                  TEST FOR THE LAST STATION TO BE READ IN.
         IF  ( (X(IS)-X(IS-1)).GT.0.0 )     GO TO 102
C                  DELAY THE END OF STATION DATA READ IN TEST UNTIL
C                  I(X).GT.IPS ON TAPE READ IN OF STATION DATA.
      IF  ( ISTO(15).EQ.0.AND.IS.LE.IPS )     GO TO 102
C                  THE COUNT OF THE LAST X STATION TO BE COMPUTED IS
C                  MADE HERE WHEN IS.EQ.100
 101     IX=  IS - 1
      GO TO 1030
C                  TEST FOR THE LAST X STATION TO BE READ IN.
 1011    IF  ( (X(IS)-X(IS-1)).LE.0.0 )     GO TO 101
C                  END OF THE STATION DATA READ IN LOOP.
  102 CONTINUE
```

```
 1030     IF  ( IOP.EQ.1.OR.WSTO(13).EQ.0.0 )   GO TO 1032
          DO  1031  I=  1,100
          IF  (TURB(I).LE.WSTO(13) )     GO TO 1031
C                        RESET IT FOR THE FORCED TURBULENT RESTART AT IT.
          IT=  I + 1
          GO TO 1032
 1031     CONTINUE
 1032 IF  ( IOP.EQ.4.AND.RDT(1).EQ.0.0 )      RDT(1)= X(2)*U(2)*WSTO(3)
      IF  ( IOP.EQ.7.AND.DOP.GT.0.AND.RDT(1).EQ.0.0 )
     2                   RDT(1)= U(1)*DT(1) / WSTO(11)
C                        IF MR IS COMPUTED IT IS ASSUMED THAT
C                        U(I) IS THE MACH NUMBER = M(I).  AFTER THE EXIT FROM
C                        SUBR COTR THEN IF MR.LE.(ZERO).OR DOP.LE.0 SUBR INIR
C                        COMPUTES THE U(I) FROM THE M(I)=U(I) INPUT.
      IF  ( IOP.EQ.4.AND.MR.EQ.0.0.AND.DOP.LE.0 )      GO TO 1033
      IF  ( IOP.NE.4.AND.MR.EQ.0.0.AND.DOP.LE.0 )      GO TO 1034
C                        MR= .001 MAY OVERWRITE THE PRECEEDING VALUE.
      IF  ( IOP.EQ.7.AND.U(1).EQ.0.0.AND.MR.EQ.0.0.AND.DOP.LE.0 )
     2   GO TO 1035

      GO TO 1036

C                        THE INPUT U(2) IS A MACH NUMBER
 1033 MR= U(2)
      IF  ( WSTO(8).NE.0.0 )      MR= MR/WSTO(8)
      GO TO 1036

C                        THE INPUT U(1) IS A MACH NUMBER
 1034 MR= U(1)
      IF  ( WSTO(8).NE.0.0 )      MR= MR/WSTO(8)
      GO TO 1036

C                        WSTO(8) IS A MODEL SCALE NUMBER.
 1035 MR= .001
      IF  ( WSTO(8).NE.0.0 )      MR= MR/WSTO(8)
C                        RECOMPUTE BS IF IOP.EQ.7
 1036     IF  ( IOP.NE.7 )    GO TO 1037
          DUDX=  ( U(2)-U(1)) / (X(2)-X(1))
          UAV=  (U(1)+U(2)) / 2.
          BS=  ( DUDX/UAV ) * DT(1)


C                        WSTO(10) IS A NON-DIMENSIONALIZING NUMBER.
 1037 IF  ( WSTO(10).EQ.0.0.AND.ISTO(12).EQ.0 )  WSTO(10)=X(IX)
      IF  ( WSTO(10).EQ.0.0.AND.ISTO(12).EQ.1.AND.WSTO(5).NE.0.0 )
     2     WSTO(10)=  XMAS(1)*WSTO(5)
C
C                        ISS IS USED IN THE LINEAR INTERPOLATION SECTION TO
C                        COMPUTE ISN= IS-ISS WHERE ISS IS RESET AFTER THE
C                        FINAL INTERPOLATED FUNCTION IS COMPUTED.
      IF  ( ISTO(8).NE.0 )       ISS= ISTO(8) + 1
         WRITE  (6,57)  IX,X(IX),X(IS),MR,DT(1),RDT(1),BS,IT,NC,KEND,
     2                       WSTO(10), ISS
      CALL  A6IR
      IF  (ISTO(1).NE.0)  WRITE  (6,99)


C     END OF CARD OR  TAPE INPUT DATA FOR THIS CASE.  SUBR NDIR CALLS
C     SUBR A6IR FOR FURTHER COMMENT.  SUBR INIR CALLS A6IR FOR CASE END
```

```
C       ON ARRAY OVERFLOW.  SUBR ITFR CALLS SUBR A6IR FOR COMMENT IF THE
C       CASE ENDS WITH THE STARTING PROFILES.

        RETURN


 1      FORMAT  (18A4)
    2 FORMAT (15I5)
    3 FORMAT (6F10.5)
    4 FORMAT (8F10.5)
 5      FORMAT  (5E15.8)
 21     FORMAT  (1X,15I5)

 31     FORMAT  (1X,I5,10X, 2(I4,1H,) / (1X,6F14.8) )

 40     FORMAT  (1X,F9.6,F10.7,F10.2,4(F10.4) )

 41     FORMAT  ( 1X,8F10.5,5X,4HIS= I4 )
 42     FORMAT  ( 1H0,8F10.5, 5X, 4HIS= I4  / 1X )
 51     FORMAT  (1X,5E15.8)

 57     FORMAT  ( 17HXEND OF CARD READ, 5X, 18HNO. OF X STATIONS= I3,3X,
     2         22HLAST X TO BE COMPUTED= E15.8, 5X, 7HLAST X= E15.8  /
     3          1HK, 4HMR= 1PE14.7, 5X, 7HDT(1)= E14.7, 5X, 8HRDT(1)=
     4          E14.7, 5X, 4HBS= E14.7, 5X, 3HIT= I4, 2X, 3HNC= I3,2X,
     5          6HKEND= I4  /  61X, 10HWSTO(10)= E14.7, 5X,
     7          34HNO. OF X-STATION POINTS INCREASE=  I3 )

 58     FORMAT  ( 1H0,22HRESCALED U(X) BY UKX=  1PE14.7 )

 67     FORMAT  (1H0, 6HKEND= I4, )
   99 FORMAT (1H1)

        END
```

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$IBFTC ITFD


      SUBROUTINE    ITFR

C     SUBROUTINE ITFR GENERATES THE STARTING PROFILES F'(ETA) OR FP(J),
C     G'(ETA) OR GP(J), AND LISTS THE STARTING STATION PARAMETERS WHEN
C     THE INPUT PROFILES ARE UNCHANGED.
C     FOR LAMINAR FLOW ITFR RESCALES P*,Q*,R*,VP* AND COMPUTES DTX,MT,
C     CF,HT,ST.  SUBR ITFR ENDS THE CASE IF IX.LE.I(X) AND SENDS
C     CONTROL TO SUBR INIR FOR THE NEXT CASE ON ISTO(10).EQ.8.  ON A
C     NORMAL EXIT FROM ITFR ISTO(10).EQ.2.  SUBR ITFR IS RE-ENTERED
C     AFTER THE EXIT FROM SUBR NDIR ON ISTO(14).EQ.1 TO MAKE A TURBULENT
C     RE-START AFTER A LAMINAR SEPARATION OCCURS IN SUBR ITSR.
C     SUBR ITFR IS ALSO RE-ENTERED WHEN A FORCED TRANSITION TO
C     TURBULENT FLOW OCCURS IN SUBR ITSR.


C     SUBROUTINE ITFR IS CALLED BY THE MAIN ROUTINE TUF.
C     SUBROUTINE ITFR CALLS SUBROUTINES INTEG,VIS,PROFYL,FILE,A6IR.


C     THE ASSUMED CONVERGENCE OF THE MOMENTUM EQUATION PROFILES AND
C     THE DENSITY, DENSITY X-DERIVATIVE, EFFECTIVE VISCOSITY, EFFECTIVE
C     CONDUCTIVITY, AND LOCAL SHEAR STRESS PROFILES IS DETERMINED BY
C     TESTS ON ABS(F(JE)-1.).LT.XT WHERE XT IS INITIALIZED IN SUBR INIR
C                 TO .005.
C     HOWEVER, IN SUBR ITSR, IN ORDER TO TEST F(JE) THEN
C     ABS((F''(J=1)-FPPW)/FPPW).LE.XT OR F''(J=1) ON 2 SUCCESSIVE
C     ITERATES OF THE MOMENTUM EQUATION PROFILE AT THE WALL MUST MEET A
C     CONVERGENCE TEST CRITERION.

C     IF THE ENERGY EQUATION PROFILES G'(ETA),G''(ETA) ARE COMPUTED THEN
C     CONVERGENCE OF THE MOMENTUM-ENERGY PROFILES IS DETERMINED BY
C     THE CONVERGENCE OF G''(ETA=0.0) WHICH IS CHECKED AFTER THE
C     CONVERGENCE OF G'(ETA=0.0).
C     EXIT FROM THE MOMENTUM-ENERGY LOOP IS MADE ONLY AFTER THE TESTS
C     OF G''(ETA=0.0) ARE EITHER MADE OR BYPASSED ON THE IOP AND
C     MOP OPTIONS.


C * * * * * * * * * MAIN COMMON  V-3 TUF  * * * * * * * * * * * * * * *

      COMMON  /TUFA/ATUF,
     1        B(300,5),
     2        B1,BH,BS,BK,
     3        CW(100),CF(100),CLIS(400),CAY(300),
     4        CA,CA1,CO,COB,CMTF,CMTG,C,COAL,CMU,
     5        DB(300),DBB(300),D(300),DP(300),DPB(300),
     6        DT(100),DTK(100),
     7        DX,DTXM,DOP,DI,DJ,DXB,DTM,DTS,
     8        ET,
     9        FB(300),FBB(300),FPBB(300),FPB(300),FP(300),F(300),
     A        FPP(300),FPPB(300),
     1        FPE,FPPW,FT,FV,FTU2,
     2        GPB(300),GPBB(300),GP(300),GPP(300),GPPB(300),
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```
     3          GBC(100),GPW(100),
     4          GPPW,GPE, GAM,GAMX,
     5          HT(100),
     6          ISTO(16),
     7          I,IC,IO,IBC,IOP,IX,IXE,IT,IXA,ID,IXF
      COMMON    /TUFJ/ JTUF,
     1          JTR(100),
     2          JE,JK,JM,JY,JEF,JEG,JDIV,JEB,JD,
     3          KB,KMI,
     4          LABEL(132),
     5          LOOP,LOOPF,
     6          M(100),MT(100),
     7          MOP,MR,ML,
     8          NU,
     9          OI,
     A          P,PB,PM,POP,PR,PRT,
     1          QB,QM,QRB,QRM,Q,
     2          RW(100),RDT(100),
     3          RB,RM,RC,RMS,RMT,R,RDTK,RXRDF,RL,RMTW,RDF,RX
      COMMON    /TUFS/STUF,
     1          STR(100),SW(100),SF(100),ST(100),
     2          SHR,STC,SK,STRX,
     3          TAU(300),
     4          TURB(100),TF(100),
     5          TO,TOP,TFR,
     6          U(100),
     7          UX,
     8          VE(300),VEG(300),VH(300),VHP(300),VHPP(300),
     9          VW(100),
     A          VPB,VPM,
     1          WSTO(20),
     2          X(100),
     3          XT,XK,
     4          Y(300),YY(300),
     5          ZERO

      REAL      KB, M,ML,MR,MT,NU

      INTEGER       DOP,POP,TOP

C  * * * * * * * * *END OF MAIN COMMON TUF-V3* * * * * * * * * * * * * * *

         ISTO(10)=  2
         LST2=  0

      IF  ( ISTO(5).NE.1.OR.POP.EQ.1 )      GO TO 140
      WRITE (6,70)
      WRITE (6,71)  I, ISTO(10)

C                       RETURN TO HERE TO RECOMPUTE THE F'(ETA) PROFILE ON
C                       IOP.EQ.5 RESET FROM IOP=4 IF 2.*ABS(DU/DX).LT..3 AT
C                       EFN-421.
  140 CONTINUE
C                       BEGINNING OF THE LOOP TO GENERATE THE STARTING
C                       PROFILES FP(J)= F'(ETA) OF THE MOMENTUM EQUATION
C                       AND GP(J)= G'(ETA) OF THE ENERGY EQUATION TOGETHER
C                       WITH THE EFFECTIVE VISCOSITY,CONDUCTIVITY, AND
C                       DENSITY PROFILES AND OTHER MOMENTUM AND ENERGY
C                       PROFILES.
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C                     THE MOMENTUM-ENERGY LOOP.
      DO 399  MAE=  1,KMI

      IF  ( ISTO(5).NE.1.OR.POP.EQ.1 )     GO TO 141
      WRITE  (6,98)  I, ISTO(10), MAE

C                     THE MOMENTUM EQUATION LOOP.
C                     HEAD OF LOOP FOR THE F'(ETA) PROFILE . (INNER LOOP.)
 141  DO  349  MOM=  1,KMI
C                     FOR A CONSTANT DENSITY FLOW MOP.LT.0.
      IF (MOP.LT.0) GO TO 305
C                     FOR VARIABLE PROPERTY FLOW, RECOMPUTE D(J)=DENSITY,
C                     DP(J)= THE R(DELTA(*)*DELTA(*)*(X-DERIVATIVE OF
C                     DENSITY).
C                     AND DB(J)=(X DERIVATIVE OF DENSITY TERM)*DELTA(*).
      B1=TF(I)-1.
      DO 304 J=1, JY
      FV=1.-FP(J)
C                     DENSITY RATIO PROFILE.  SEE EQUA II-16.
      D(J)=2.*TF(I)*(1.-BH*GP(J))/(1.+SQRT(1.+4.*B1*FV*FV*TF(I)
     1   *(1.-BH*GP(J))))
C                     SEE EQUA II-27.
      DP(J)=(2.*B1*D(J)*D(J)*FV*FPP(J)-TF(I)*BH*GPP(J))
     1   /(1.+2.*B1*D(J)*FV*FV)
C                     SEE EQUA II-32.
      DB(J)=(P*(SHR-1.)*M(I)*M(I)*TF(I)
     1   *(1.-BH*GP(J)-D(J)*D(J)*FV*FV)
     2   +(SHR-1.)*M(I)*M(I)*D(J)*D(J)*FV*GAMX*(FP(J)+Y(J)*FPP(J))
     3   -TF(I)*BH*(STRX*GP(J)+GAMX*GPP(J)*Y(J)))
     4   /(1.+(SHR-1.)*M(I)*M(I)*D(J)*FV*FV)
  304 CONTINUE

  305 CONTINUE

C                     TEST IOP TO SET THE PARAMETERS FOR EITHER LAMINAR
C                     OR TURBULENT STARTING FLOW.
C                     IF  IOP= 1,4,5 THE STARTING FLOW IS LAMINAR.
C                     IF  IOP= 2,3,6,7 THE STARTING FLOW IS TURBULENT.

 306  GO TO (315,320,321,310,315,320,321), IOP

C                     THE PROGRAM SECTION TO RECOMPUTE THE INITIAL PROFILE
C                     FOR SIMILAR LAMINAR STARTING FLOW.
  310 CONTINUE
C **** SET P*, Q* AND R* ****
C                     SEE EQUA II-25.
      C=F(JE)*C
      P=C*C*RL*BS
C                     PARAMETER IN EQUA II-14.
      Q=P*(1.-ML*ML)+C*C*RL*(1.-BS)/2.
      VP = VW(I)/U(I)*C*RL
      IF(IABS(DOP).EQ.1) VP=VP/D(1)
      RDT(2)=C*RL
      RDF=RDT(2)
      CA=0.0
      R=0.0
      IF (ABS(RW(2)/(X(2)-X(1))).LT.1.E-8) GO TO 313
C                     A PARAMETER CONTAINING ( D R(W)/DX).  EQUA II-14.
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      R=RL*C*C*(RW(3)-RW(1))/(X(3)-X(1))*(X(2)-X(1))/(RW(3)+RW(1))
C                     A PARAMETER OF COS A WHERE A IS THE ANGLE BETWEEN THE
C                     WALL AND THE SYMMETRICAL BODY AXIS.
      CA=2.*OI*COAL*C*(X(2)-X(1))/RW(2)
C                     Y(J) IS RECOMPUTED FROM THE ORIGINAL YY(J).
      DO 312 J=1, JY
C                     YY(J) HERE IS THE COMPLETED PROFILE.
      Y(J)=YY(J)*(1.+YY(J)*CA/4.)
  312 CONTINUE

  313 CONTINUE
C                     QR IS USED IN EQUA III-6E.
      QR=Q+R
C ****                END OF THE SIMILAR LAMINAR PARAMETER RECOMPUTATION.
 314  GO TO 330

C                     SKIP TO HERE FROM EFN-306 ON IOP.EQ.1,5.  IOP MAY
C                     HAVE BEEN RESET= 5 FROM 4 AT EFN-421.  LAMINAR FLOW.
  315 CONTINUE

      FPP(1)=FPP(1)*F(JE)
      CF(I)=2.*TAU(I)
      VP = VW(I)/U(I)*RDT(I)

      IF(IABS(DOP).EQ.1) VP=VP/D(1)
 316  GO TO 325

C                     SKIP TO HERE FROM EFN -306 IF IOP.EQ.2,6.
C                     TURBULENT STARTING FLOW.
  320 CONTINUE
C                     SET P AND Q
      P=-TAU(1)*BS
C                     SKIP TO HERE FROM EFN-306 IF IOP.EQ.3,7.
C                     TURBULENT STARTING FLOW.
  321 CONTINUE
      CF(I)=2.*TAU(1)
      GAM=SQRT(ABS(TAU(1)))
      GAMX=-GAM/SK*(Q+CMU*P)
C                     IF TRUE RECOMPUTE THE STANTON NUMBER GRADIENT
C                     PARAMETER.
      IF (GAM.GT.ZERO) STRX=-(GAM+STR(I)/GAM)/SK*(Q+CMU*P)
      VP = VW(I)/U(I)
      IF(IABS(DOP).EQ.1) VP=VP/D(1)

C                     ENTER HERE FROM EFN-316 IF IOP.EQ.1,5.
C                     LAMINAR STARTING FLOW.
  325 CONTINUE
C                     TO COMPUTE Q AND QR
      DO 326 J=1, JE
      VH(J)=((R*D(J)*(Y(J)-F(J))+GAM/SK*CMU*P*Y(J)*D(J)-VP)*FPP(J)
     1   +(R*DP(J)*(Y(J)-F(J))-(P*D(J)+DB(J))*(2.-FP(J))
     2   +(1.-FP(J))*(D(J)-Y(J)*DP(J))*GAM/SK*CMU*P-VP*DP(J))*FP(J)
     3   +R*DP(J)*F(J)+P*(D(J)-1.)-R*Y(J)*DP(J)+DB(J)+VP*DP(J))
      VHP(J)=(D(J)*(Y(J)-F(J))+GAM/SK*Y(J)*D(J))*FPP(J)
     1   +(DP(J)*(Y(J)-F(J))
     2   +(1.-FP(J))*(D(J)-Y(J)*DP(J))*GAM/SK)*FP(J)
     3   -(Y(J)-F(J))*DP(J)
  326 CONTINUE
```

```
C                  SUM BY THE TRAPEZOIDAL RULE.
      CALL INTEG (JE, JD, Y, VH, 0.0, VH)
      CALL INTEG (JE, JD, Y, VHP, 0.0, VHP)
C                  FOR BOTH LAMINAR, EXCEPT WHEN IOP.EQ.4, AND
C                  TURBULENT FLOW.  SEE EQUA II-41.
      Q=-(CF(I)/2.*RDF+VH(JE)/F(JE))/VHP(JE)*F(JE)
      QR=Q+R
C                  IF ISTO(5).EQ.0 SKIP LISTING OF VE,VEG,VH,VHP AT
C                  EXIT OF SUBR VIS.
C                  SKIP TO HERE FROM EFN-314 IF IOP.EQ.4, LAMINAR FLOW.
C                  TO HERE ON ALL IOP.
  330 CONTINUE

C                  CALCULATE VE* OR VE, THE EFFECTIVE VISCOSITY PROFILE
C                  AND VEG* OR VEG THE EFFECTIVE CONDUCTIVITY PROFILE.
C                  THE CALL OF SUBR VIS IS NOT SKIPPED.
      CALL VIS (JE, JY, JD, YY, FP, FPP, GP, GPP, D, DP, TAU, VH, VHP,
     1   TURB(I), SW(I), CW(I), SHR, BH, STC, TO, TF(I), RDT(I), DT(I),
     2   F(JY), PR, PRT, JK, VE, VEG, ISTO )

C                  IF THE INPUT PROFILES ARE CONSIDERED CORRECT THEN
C                  LEAVE THE MOMENTUM LOOP.
C                  (SKIP THE FP=F'(ETA), F(ETA),TAU(ETA) AND SF(I)
C                  PROFILE RECOMPUTATIONS.)
 331  IF (IOP.LE.3) GO TO 350

C                  COMPUTE THE COEFFICIENT PROFILES AND CALL SUBR
C                  PROFYL FOR THE F'(ETA) PROFILE.
      FPPW=FPP(1)
      FPE=0.0
      DO 335 J=1, JY
C                  SEE EQUA III-6E.
      CO=QR*(Y(J)-F(J))-VP
C                  SEE EQUA III-9A.
      B(J,1)=CO*DP(J)-(P*D(J)+DB(J))*(2.-FP(J))
     1   -(1.-FP(J))*(D(J)-Y(J)*DP(J))*GAMX
C                  SEE EQUA III-9B.
      B(J,2)=(CO-Y(J)*GAMX)*D(J)
C                  SEE EQUA III-9C.
      B(J,3)=-CO*DP(J)+P*(D(J)-1.)+DB(J)
C                  SEE EQUA III-9D.
      B(J,4)=-(1.+CA*Y(J))*VE(J)*RDF
C                  SEE EQUA III-9.
      B(J,5)=-DP(J)/D(J)*(1.-FP(J))
  335 CONTINUE

C                  SOLVE THE MOMENTUM EQUA. FOR F'(ETA).
C                  SEE EQUA III-7.
      CALL PROFYL (JEF, JY, JD, Y, B, ET, 1.0, FPPW, FPE, 2,
     1   FP, VH, VHP, VHPP)

      JE=MAX0(JEF,JEG)
C                  COMPUTE THE F''(ETA) PROFILE BY 1ST DIFFERENCES OF
C                  THE F'(ETA) PROFILE.
C                  COMPUTE THE SHEAR STRESS PROFILE TAU(J), AND VH(J).
      JM=1
      JYM=JY-1
      DO 340 J=1, JYM
C                  F''(ETA) PROFILE.
```

```
      FPP(J)=(FP(J+1)-FP(JM))/(Y(J+1)-Y(JM))
      JM=J
C                    THE LOCAL SHEAR STRESS.
      TAU(J)=VE(J)*(DP(J)/D(J)*(1.-FP(J))-FPP(J))*SQRT(1.+CA*Y(J))
      VH(J)=(1.-FP(J))*(1.-D(J)*(1.-FP(J)))
  340 CONTINUE

      FPP(JY)=0.0
      TAU(JY)=0.0
      VH(JY)=0.0

C                    SUM F'(ETA) FOR F(ETA) BY THE TRAPEZOIDAL RULE.
      CALL INTEG (JE, JD, Y, FP, 0.0, F)
C                    COMPUTE THETA FOR SF= DELTA(*)/THETA.  SEE
C                    EQUA II-22.
      CALL INTEG (JE, JD, Y, VH, 0.0, VH)
      SF(I)=F(JE)/VH(JE)

C **** PRINT OUT INTERMEDIATE FP PARAMETERS AND VARIABLES ****
      IF  ( ISTO(5).NE.1.OR.POP.EQ.1 )      GO TO 341
         WRITE (6,72) I, JK, JEF, F(JEF), FPP(1), SF(I), P, Q, R,TF(I),
     2            M(I),VE(1),VEG(1),VH(1),VHP(1),D(1),D(JY),DP(1),DP(JY)

C **** TEST FOR CONVERGENCE OF FP ****
 341  IF (MOM  .GT.1.AND.ABS(F(JE)-1.).LT.XT) GO TO 350
C                    EFN 349 IS THE LOOPF= 1,KMI END FOR F'(ETA).
C                    END OF THE MOMENTUM LOOP.
  349 CONTINUE
C                    THE INTERMEDIATE LOOP FOR THE F'(ETA) PROFILE ENDS.


C                    IF IOP.LE.3 SKIP TO HERE FROM EFN 331, THE
C                    RECOMPUTATION OF  THE MOMENTUM PROFILE.
  350 CONTINUE
C **** SET BOUNDARY CONDITIONS ON GP OR GPP ****
C                    SKIP THE COMPUTATION OF THE G'(ETA) PROFILE IF
C                    ABS(MOP).EQ.1
      IBC=IABS(MOP)
 351  GO TO (400,352,353), IBC
352   CONTINUE
      GPW(I)=GBC(I)
      GPPW=GPP(1)
      STR(I)=-GPPW/D(I)*VEG(1)
      GO TO 354
C                    IBC= 3
 353  CONTINUE
      GPW(I)=GP(1)
      GPPW=-GBC(I)*D(1)/VEG(1)
      IF (IOP.EQ.4) GPPW=GPPW*C*RL
      IF  (IOP.EQ.4)      STR(I)= GBC(I)/C/RL
 354  CONTINUE
C                    IF THE INPUT PROFILES ARE CONSIDERED CORRECT SKIP
C                    THE G'(ETA) PROFILE RECOMPUTATION AND GO TO LIST.
 355  IF (IOP.LE.3) GO TO 410

C                    COMPUTE THE COEFFICIENT PROFILES AND CALL SUBR
C                    PROFYL FOR THE GP=G'(ETA) PROFILE.
C                    SEE EQUAS III-10A TO III-10E FOR TURBULENT FLOW AND
C                    III-12A TO III-12E FOR SIMILAR LAMINAR FLOW.,
```

```
      GPE=0.0
 356  DO 360 J=1, JY
      B(J,1)=-(1.-FP(J))*STRX
      B(J,2)=QR*(Y(J)-F(J))-VP-GAMX*Y(J)
      B(J,3)=0.0
      B(J,4)=-(1.+CA*Y(J))*VEG(J)/D(J)*RDF
      B(J,5)=-(SHR-1.)*M(I)*M(I)/BH/TF(I)*(VE(J)/VEG(J)-1.)
     1   *D(J)*(1.-FP(J))*(DP(J)*(1.-FP(J))-D(J)*FPP(J))
  360 CONTINUE

C                    COMPUTE G'(ETA) BY EQUA III-8.
      CALL PROFYL (JEG, JY, JD, Y, B, ET, GPW(I), GPPW, GPE, IBC,
     1   GP, VH, VHP, VHPP)

      JE=MAX0 (JEF,JEG)
      JM=1
      JYM=JY-1
C                    EXCEPTING GPP(1) COMPUTE G''(ETA) BY 1ST CENTRAL
C                    DIFFERENCES.
      DO 365 J=1, JYM
      GPP(J)=(GP(J+1)-GP(JM))/(Y(J+1)-Y(JM))
      JM=J
  365 CONTINUE

      IF (IBC.EQ.3) GPP(1)=GPPW

C****                LIST EACH MAIN LOOP=1,KMI LOOP VALUE AT THE WALL.
      IF  ( ISTO(5).NE.1.OR.POP.EQ.1 )     GO TO 366
         WRITE (6,76) I, JEG, GP(1), GPP(1), C, RL

C                    FOR CONSTANT DENSITY FLOW LEAVE THE MOMENTUM-ENERGY
C                    LOOP.

C               * * * THE STARTING STATION OUTPUT PARAMETER SECTION. * * *

 366  IF (MOP.LT.0) GO TO 400

C                    TEST G' OR G'' AT THE WALL ON EACH MAIN LOOP=1,KMI
C                    LOOP.
      IF (MAE .LT.2) GO TO 399
      IF (ABS(GPW(I)).GT.ZERO) GO TO 396
      IF (ABS(GP(1)-GPW(I)).LT.ZERO) GO TO 397
      GO TO 399

  396 CONTINUE
      IF (ABS((GP(1)-GPW(I))/GP(1) ).GT.XT)  GO TO 399

  397 CONTINUE
      IF (ABS(GPPW).GT.ZERO) GO TO 398
      IF (ABS(GPP(1)-GPPW).LT.ZERO) GO TO 400
      GO TO 399

  398 CONTINUE

      IF (ABS((GPP(1)-GPPW)/GPPW).LT.XT) GO TO 400
C                    EFN 399 IS THE LOOP END OF THE MAIN LOOP TO GENERATE
C                    STARTING PROFILES OF F'(ETA) AND G'(ETA).
  399 CONTINUE
```

```
C                     SKIP TO HERE FROM EFN 351 TO BYPASS THE G'(ETA)
C                     PROFILE SECTION ON ABS(MOP).EQ.1.
  400 CONTINUE
      GO TO 415
C                     TO HERE FROM EFN 355 TO SKIP RECOMPUTATION OF THE
C                     INPUT G'(ETA) PROFILE WHEN IOP.EQ.3.  ALSO THE
C                     RECOMPUTATION OF THE F'(ETA),F''(ETA),TAU(ETA)
C                     PROFILES AND SF(I) BY SUBR ITFR WAS SKIPPED IN THE
C                     MOMENTUM LOOP.
  410 CONTINUE

      IF (POP.EQ.1) GO TO 415
C **** PRINT OUT PARAMETERS (IF INPUT PROFILES ARE UNCHANGED) ****
      WRITE (6,72) I, JK, JEF, F(JEF), FPP(1), SF(I), P, Q, R
      WRITE (6,76) I, JEG, GP(1), GPP(1), D(1), TF(I)

  415 CONTINUE
C                     SUBR ITSR SETS THE LOOP STARTING INDEX=  IXF.
      IXF=I+1
 416  GO TO (425,430,430,420,425,430,430), IOP
C                     IOP.EQ.4 ONLY.
C                     ABS(2.*(DU/DX).LT..3) TO USE THE PRESENT PROFILE AT
C                     I(X)=2 AS THE STARTING PROFILE..  OTHERWISE RECOMPUTE
C                     ON IOP = 5 RESET.
  420 CONTINUE
C **** FOR OPTION 4, CALCULATE DT(2), RDT(2) AND PRINT EXPLANATION ****
      SF(1)=SF(2)
      DT(2)=(X(2)-X(1))*SQRT(Q/RL/(BS*(1.-ML*ML)+(1.-BS)/2.))
      RDT(2)=RL*DT(2)/(X(2)-X(1))
      IF (ABS(BS-1.0).LT.ZERO) DT(1)=DT(2)
      MT(1)=DT(1)/SF(1)
C                     THE SLOPE AT THE ORIGIN.
      UX2=(U(2)-U(1))/(X(2)-X(1))
C                     THE FORWARD SLOPE AT I(X)= 2.
      UX3=(U(3)-U(2))/(X(3)-X(2))
C                     TEST TO RESET IOP.EQ.5 FOR A RECOMPUTATION OF THE
C                     F'(ETA) PROFILE.
      IF  ((UX3+UX2 ).EQ.0.0 )      GO TO 4211
C                     A TEST TO SKIP THE RESET OF IOP TO 5.
 421  IF (2.*ABS((UX3-UX2)/(UX3+UX2)).LT.0.3) GO TO 422
 4211 IOP=5
      P=UX3/U(2)*DT(2)*RDT(2)
      WRITE (6,77) I, X(2), IOP, UX2,UX3
C                     RETURN TO EFN 140 TO RECOMPUTE THE F'(ETA) PROFILE.
      GO TO 140
C                     SKIP RESET OF IOP= 5
  422 CONTINUE

         WRITE (6,78) I, X(2), X(1), DT(1), TF(I)
C                     SKIP TO HERE FROM EFN-416 IF IOP.EQ.1,5.
  425 CONTINUE

      WRITE  (6,97)  I,IXF,IOP,RDT(I)

C **** FOR LAMINAR FLOW, RESCALE P*, Q*, R*, QR* AND VP*
      P=P/RDT(I)
      Q=Q/RDT(I)
      R=R/RDT(I)
      QR=QR/RDT(I)
      VP=VP/RDT(I)
```

```
C                  SKIP FROM EFN-416 ON IOP.EQ.2,3,6,7  TURBULENT FLOWS.
  430 CONTINUE
C **** CALCULATE DTXM,MT, CF, HT AND ST FOR BOTH LAMINAR AND TURBULENT
C                  STARTING FLOW.
      DTXM=Q-P*(1.-M(I)*M(I))
      MT(I)=DT(I)/SF(I)
      CF(I)=2.*TAU(1)
      B1=GPW(I)-(TF(I)-1.)/BH/TF(I)
      ST(I)=0.0
      IF (ABS(B1).GT.ZERO) ST(I)=STR(I)/B1
      DO 440 J=1, JE
      VHP(J)=1.-D(J)*(1.-FP(J))
      VHPP(J)=GP(J)*(1.-FP(J))
  440 CONTINUE

      CALL INTEG (JE, JD, Y, VHP, 0.0, VHP)
      CALL INTEG (JE, JD, Y, VHPP, 0.0, VHPP)
      DTK(I)=VHP(JE)*DT(I)
      RDTK=1./VE(1)*DTK(I)/DT(I)
      RMTW=RDTK/DTK(I)*MT(I)
      HT(I)=VHPP(JE)*DT(I)

      IF (IOP.NE.4) GO TO 445
      HT(1)=HT(2)
      NU=RL*PR*ST(2)
      WRITE (6,79)  X(I), NU, HT(2)
  445 CONTINUE

         LST2=  ISTO(7)
         ISTO(7)=  I
C                  IF THE INITIAL IOP.EQ.4 ITFR MAY RESET IOP=5.
      IF  ( ISTO(1).NE.0.AND.IOP.GT.3 )      GO TO 446

      IF  ( ISTO(5).NE.1.OR.POP.EQ.1 )     GO TO 450
C **** PRINT PROFILES AND PARAMETERS WITH $FILE ****
 446  WRITE (6,99)
      CALL FILE (LABEL, I, YY, F, FP, FPP, GP, GPP, D, DP,
     1   VH, VHP, VHPP, TAU, VE, VEG, SHR, BH, PR, PRT,
     2   X, U, M, TURB, RW, VW, SW, CW,
     3   RDT, DT, MT, HT, SF, CF, ST,STR,ID,JE,JY,JD,JDIV,ISTO,WSTO )
  450 CONTINUE
      ISTO(7)=  LST2
C                  IX= LAST I(X) WALL STATION TO BE COMPUTED.
C                  GO TO THE NEXT CASE IF THERE ARE NOT MORE THAN 2
C                  X-STATIONS ON AN INITIAL IOP=4, AND NOT MORE THAN 1
C                  X-STATION ON AN INITIAL IOP= 1,2,3,5,6,7.
      IF (IX-I.LE.0) GO TO 481
C                  THE INITIAL LOAD FOR TRANSFER IN SUBR ITSR TO FBB(J),
C                  ETC.  IX IS COMPUTED IN SUBR COTR.
      DX=0.0
      DO 480 J=1, JY
      FB(J)=F(J)
      FPB(J)=FP(J)
      GPB(J)=GP(J)
      DB(J)=D(J)
  480 CONTINUE
         RETURN
```

```
481     WRITE  (6,69)
     ISTO(10)=  8
     CALL  A6IR
     RETURN


69      FORMAT  (1H0, 40HEND THIS CASE IN SUBR ITFR ON IX.LE.I.
    2             34HGO TO SUBR INIR FOR THE NEXT CASE.  )

70   FORMAT (1H0,  4X,   15HENTER SUBR ITFR, 5X,
    1   48HVALUES OF IMPORTANT VARIABLES FOR EACH ITERATION)

71   FORMAT  ( 1H0, 3HI= I3, 5X, 9HISTO(10)=  I3  /
    1         1X,7HF-EQ...,9X,2HJK,1X,3HJEF,5X,3HFJE,6X,4HFPPW,
    1   6X, 2HSF, 9X, 1HP, 9X, 1HQ, 9X, 1HR, 9X, 5HTF(I), 7X,4HM(I)  /
    1   28X,5HVE(1),4X,6HVEG(1),4X,5HVH(1),6X,6HVHP(1),4X,4HD(1),6X,
    1   5HD(JY),5X,5HDP(1),7X,6HDP(JY) /
    1         1X, 7HG-EQ... , 12X,
    2   3HJEG, 5X, 3HGPW, 6X, 4HGPPW, 6X, 1HC, 6X, 2HRL  / 1H0 )

72   FORMAT  (1H0, 3HI= I3, 2X, 7HF-EQ..., 2(1X,I3), 8(1X,1PE9.2))

 76   FORMAT  (1H0, 3HI= I3, 2X,7HG-EQ... , 2X, I3, 8(1X,2PE9.2) )

77   FORMAT  (1H0/
    1   1X,3HI= I3,3X, 45HFREE STREAM VELOCITY DISTRIBUTION IS NOT WELL
    1   1X, 19HDESCRIBED NEAR X = , F10.5, 1X, 9HWITH IOP=  I3, 2X,
    2   5HUX2= 1PE9.2, 2X, 5HUX3= E9.2 /
    2   10X,
    3   54HIOP IS RESET TO 5, P IS RECOMPUTED AND THE PROFILE IS
    4   21HRECOMPUTED AS LISTED.  / 1H2  )

 78  FORMAT  (1H0, 6HI(X)=  I3, 1H.     /
    1   5X,        29HTHE FOLLOWING PROFILE AT X = , F10.6, 1X,
    1   60HIS A STARTING LAMINAR PROFILE, AND IS TAKEN TO BE IDENTICAL
    2   21HTO THE PROFILE AT X=    F10.6/ 5X, 10HWHERE DT=  1PE11.4, 5X
    3   7HTF(I)= E14.7)

 79  FORMAT  (1H0,  28HTHE NUSSELT NUMBER AT X(I)=  1PE9.2, 4H IS ,
    2              1PE9.2, 5X,  24HTHE ENTHALPY THICKNESS= E9.2)

 97  FORMAT (1H0,6HI(X)= I3,3X,5HIXF= I3,3X,5HIOP= I2,3X 8HRDT(I)=
    2          1PE14.7)

 98  FORMAT  (1H0, 3HI= I3, 3X, 9HISTO(10)=  I3, 5X, 5HMAE= I3 / 1X)
 99  FORMAT (1H1)

     END
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Subroutine ITSR

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$IBFTC ITSD

           SUBROUTINE ITSR
C      SUBROUTINE ITSR IS THE MAIN SUBROUTINE FOR THE COMPUTATION OF THE
C      MOMENTUM AND ENERGY PROFILES TOGETHER WITH THE WALL PARAMETERS AT
C      EACH I(X) WALL STATION.  ITSR INITIALIZES ISTO(10)= 3.  ON EXIT
C      FROM SUBR ITSR ISTO(10) = 4,5,6,7.  ON A NORMAL END OF CASE AT
C      I(X)= IX ISTO(10).EQ.4.  SUBR ITSR EXITS TO TUF WHICH CALLS SUBR
C      NDIR TO END THE CASE.  IF ISTO(10) BECOMES 5 ON THE PROFILE
C      LIMIT TEST THEN SUBR ITSR ENDS THE CASE  BY EXITING TO TUF WHICH
C      CALLS SUBR NDIR FOR THE CASE END LISTING.  IF ISTO(10) BECOMES 6
C      SUBR ITSR EXITS TO TUF WHICH CALLS SUBR NDIR FOR A LISTING AND
C      A RE-INITIALIZATION TO CONTINUE THE RUN, AND A CALL OF SUBR ITFR
C      IF ISTO(14).EQ.1 FOR A TURBULENT RE-START AT I(X).
C      IF ISTO(10) BECOMES 7 SUBR ITSR EXITS TO TUF WHICH CALLS SUBR NDIR
C      FOR A RE-INITIALIZATION AND THEN CALLS SUBR ITFR FOR A FORCED
C      TURBULENT RE-START AT I(X).

C      SUBROUTINE ITSR IS CALLED BY THE MAIN ROUTINE TUF.
C      SUBROUTINE ITSR CALLS SUBROUTINES VIS,PROFYL,INTEG,TRANS,FILE.


C  * * * * * * * * * MAIN COMMON  V-3 TUF  * * * * * * * * * * * * * * *

       COMMON  /TUFA/ATUF,
      1        B(300,5),
      2        B1,BH,BS,BK,
      3        CW(100),CF(100),CLIS(400),CAY(300),
      4        CA,CA1,CO,COB,CMTF,CMTG,C,COAL,CMU,
      5        DB(300),DBB(300),D(300),DP(300),DPB(300),
      6        DT(100),DTK(100),
      7        DX,DTXM,DOP,DI,DJ,DXB,DTM,DTS,
      8        ET,
      9        FB(300),FBB(300),FPBB(300),FPB(300),FP(300),F(300),
      A        FPP(300),FPPB(300),
      1        FPE,FPPW,FT,FV,FTU2,
      2        GPB(300),GPBB(300),GP(300),GPP(300),GPPB(300),
      3        GBC(100),GPW(100),
      4        GPPW,GPE, GAM,GAMX,
      5        HT(100),
      6        ISTO(16),
      7        I,IC,IO,IBC,IOP,IX,IXE,IT,IXA,ID,IXF
       COMMON  /TUFJ/ JTUF,
      1        JTR(100),
      2        JE,JK,JM,JY,JEF,JEG,JDIV,JEB,JD,
      3        KB,KMI,
      4        LABEL(132),
      5        LOOP,LOOPF,
      6        M(100),MT(100),
      7        MOP,MR,ML,
      8        NU,
      9        OI,
      A        P,PB,PM,POP,PR,PRT,
      1        QB,QM,QRB,QRM,Q,
```

```
     2        RW(100),ROT(100),
     3        RB,RM,RC,RMS,RMT,R,RDTK,RXRDF,RL,RMTW,RDF,RX
      COMMON  /TUFS/STUF,
     1        STR(100),SW(100),SF(100),ST(100),
     2        SHR,STC,SK,STRX,
     3        TAU(300),
     4        TURB(100),TF(100),
     5        TO,TOP,TFR,
     6        U(100),
     7        UX,
     8        VE(300),VEG(300),VH(300),VHP(300),VHPP(300),
     9        VW(100),
     A        VPB,VPM,
     1        WSTO(20),
     2        X(100),
     3        XT,XK,
     4        Y(300),YY(300),
     5        ZERO

      REAL    KB, M,ML,MR,MT,NU

      INTEGER     DOP,POP,TOP

C  * * * * * * * * *END OF MAIN COMMON TUF-V3* * * * * * * * * * * * * *


         ISTO(10)=  3
C
C                  IXF IS SET= I+1 IN SUBR ITFR AFTER THE TEST FOR
C                  CONVERGENCE OF THE STARTING PROFILE.  IXF=2 UNLESS
C                  THE INITIAL IOP.EQ.4 FOR WHICH IXF BECOMES 3.
C                  IX IS SET IN SUBR COTR.
      DO 899 I=IXF, IX
C                  A CONVENIENT STORE TO SAVE I FOR THE SUBR NDIR LIST.
      IXA=I
C **** MOVE FP, GP, AND D BACK TO MOVE FORWARD IN X ****
      DO 510 J=1, JY
      FBB(J)=FB(J)
      FB(J)=F(J)
      FPBB(J)=FPB(J)
      FPB(J)=FP(J)
      FPPB(J)=FPP(J)
      GPBB(J)=GPB(J)
      GPB(J)=GP(J)
      GPPB(J)=GPP(J)
      DBB(J)=DB(J)
      DB(J)=D(J)
      DPB(J)=DP(J)
  510 CONTINUE

      JEB=JE
      CAB=CA
      PB=P
      RB=R
      IB=I-1
      DXB=DX
      DX=X(I)-X(IB)
      DT(I)=DT(IB)+DTXM*DX
      DTBB=DT(IB)
```

```
      IF (IB.GT.1) DTBB=DT(I-2)
      VPB=VW(IB)/U(IB)
      IF (IABS(DOP).EQ.1) VPB=VPB/DB(1)
C                     TEST FOR LAST I(X) WALL STATION .
      IF (I.GE.IX) GO TO 520
      UX=U(I-1)/U(I)*(X(I)-X(I+1))/(X(I-1)-X(I))/(X(I-1)-X(I+1))
     1   +(2.*X(I)-X(I-1)-X(I+1))/(X(I)-X(I-1))/(X(I)-X(I+1))
     2   +U(I+1)/U(I)*(X(I)-X(I-1))/(X(I+1)-X(I-1))/(X(I+1)-X(I))
      RX=0.0
      CA1=0.0
      IF (ABS(RW(I)/DT(I)).LT.0.1) GO TO 520
      RX=RW(I-1)/RW(I)*(X(I)-X(I+1))/(X(I-1)-X(I))/(X(I-1)-X(I+1))
     1   +(2.*X(I)-X(I-1)-X(I+1))/(X(I)-X(I-1))/(X(I)-X(I+1))
     2   +RW(I+1)/RW(I)*(X(I)-X(I-1))/(X(I+1)-X(I-1))/(X(I+1)-X(I))

      WSTO(18)=  RX*RW(I)
      WSTO(19)=  WSTO(18)*WSTO(18)
      IF  ( WSTO(19).GE.1.0 )      GO TO 511
      CA1=  2.*OI*SQRT(1.-WSTO(19)) / RW(I)
      GO TO 520
 511  CA1= WSTO(4) + WSTO(6)*X(I) + WSTO(7)*X(I)*X(I)
         RWX=  1. / RX
      WRITE  (6,52)  RX,RW(I),WSTO(18),CA1,RWX

  520 CONTINUE
      IF (POP.EQ.1) GO TO 530
C                     LIST THE INPUT PARAMETERS FOR THE NEXT X-STATION.
      WRITE  (6,51)  LABEL(1), (LABEL(K),  K=  2,18 )
      WRITE (6,60) I,X(I),U(I),M(I), TURB(I), GBC(I), RW(I),
     1   VW(I), SW(I), CW(I)
         IF  ( ISTO(5).NE.1 )     GO TO 530
      WRITE (6,70)
      WRITE (6,81)
  530 CONTINUE

C **** BEGINNING OF ITERATIVE LOOP TO CALCULATE FP AND GP PROFILES ****
      DO 799 MAE=  1,KMI
      ITME=  MAE

C **** BEGINNING OF INNER LOOP TO CALCULATE THE F'(ETA) PROFILE.
      DO 670 MOM=  1,KMI
      ITP=  MOM
C **** RECALCULATE DT, RDT, P, Q, AND R ****
C                     DT AND RDT ARE RECOMPUTED AFTER THE EXIT FROM THE
C                     MOMENTUM-ENERGY LOOP.
      DT(I)=DT(I)*F(JE)
      RDT(I)=RDT(IB)*U(I)/U(IB)*DT(I)/DT(IB)
     1   *(TF(I)/TF(IB))**(1.5-1./(SHR-1.))
     2   *(1./TF(I)+STC/TO)/(1./TF(IB)+STC/TO)
      DTXM=(DT(I)-DT(IB))/DX
      DTXB=(DT(I)-DTBB)/(DX+DXB)
      P=DT(I)*UX
      PM=(P+PB)/2.
      QM=DTXM+PM*(1.-(0.5*(M(I)+M(IB)))**2)
      QB=DTXB+PB*(1.-M(IB)*M(IB))
      R=RX*DT(I)
      RM=(R+RB)/2.
      QRM=QM+RM
      QRB=QB+RB
      CA=CA1*DT(I)
```

```
C                    SCALE THE Y(J) COORDINATES TO THE YY(J) COORDINATES
C                    FOR USE BY SUBR VIS.
      DO 605 J=1, JY
      CAY(J)=  CA*Y(J)
      IF  ( CAY(J).LT.-1.0 )      CAY(J)=  -1.0
      IF (ABS(RW(I)/DT(I)).LT.0.1) GO TO 605
      YY(J)=2.*Y(J)/(1.+SQRT(1.+ CAY(J) ) )
  605 CONTINUE

C                    FOR CONSTANT DENSITY FLOW MOP.LT.0.
 607  IF (MOP.LT.0) GO TO 611

C                    COMPUTE THE DENSITY PROFILE= D(J).  COMPUTE ALSO THE
C                    DERIVATIVE TERM OF THE MOMENTUM EQUATION = DP(J).
C                    SEE EQUAS II-27 AND II-32.
      B1=TF(I)-1.
      DO 610 J=1, JY
      FV=1.-FP(J)
      D(J)=2.*TF(I)*(1.-BH*GP(J))/(1.+SQRT(1.+4.*B1*FV*FV*TF(I)
     1   *(1.-BH*GP(J))))
      DP(J)=(2.*B1*D(J)*D(J)*FV*FPP(J)-TF(I)*BH*GPP(J))
     1   /(1.+2.*B1*D(J)*FV*FV)
  610 CONTINUE

C                    ALSO SKIP TO HERE FROM EFN-607
C                    TO COMPUTE THE EFFECTIVE VISCOSITY AND CONDUCTIVITY
C                    PROFILES FOR THE MOMENTUM EQUATION.
  611 CONTINUE

C                    COMPUTE THE EFFECTIVE VISCOSITY AND CONDUCTIVITY
C                    PROFILES  VE(J) AND VEG(J) FOR BOTH CONSTANT CENSITY
C                    AND COMPRESSIBLE FLOWS.
      CALL VIS (JE, JY, JO, YY, FP, FPP, GP, GPP, D, DP, TAU, VH, VHP,
     1   TURB(I), SW(I), CW(I), SHR, BH, STC, TO, TF(I), RDT(I), DT(I),
     2   F(JY), PR, PRT, JK, VE, VEG, ISTO )

C                    COMPUTE THE FP=F'(ETA) EQUATION COEFFICIENT PROFILES
C                    AND CALL SUBR PROFYL FOR THE F'(ETA) PROFILE.
      DTM=(DT(I)+DT(IB))/2.
      VPM=(VW(I)+VW(IB))/(U(I)+U(IB))
      IF(IABS(DOP).EQ.1) VPM=VPM*2./(D(1)+DB(1))
      FPE=0.0
      FPPW=FPP(1)
      DO 650 J=1, JY
      FPM=(FP(J)+FPB(J))/2.
      DM=(D(J)+DB(J))/2.
      DPM=(DP(J)+DPB(J))/2.
      DDXM=(D(J)-DB(J))/DX
      DDXB=(D(J)-DBB(J))/(DX+DXB)
      C0=QRM*(Y(J)-(F(J)+FB(J))/2.)-VPM-DTM*(F(J)-FB(J))/DX
      C1=C0*DM
      C2=C0*DPM-(PM*DM+DTM*DDXM)*(2.-FPM)
      C3=-C0*DPM+PM*(DM-1.)+DTM*DDXM
      C4=DM*(1.-FPM)*DTM/DX
      C0B=QRB*(Y(J)-FB(J))-VPB-DT(IB)*(F(J)-FBB(J))/(DX+DXB)
      C1B=C0B*DB(J)
      C2B=C0B*DPB(J)-(PB*DB(J)+DT(IB)*DDXB)*(2.-FPB(J))
      C3B=-C0B*DPB(J)+PB*(DB(J)-1.)+DT(IB)*DDXB
      C4B=(1.-FPB(J))*DB(J)*DT(IB)/(DX+DXB)
```

```
C                    THE F'(ETA) EQUATION COEFFICIENT PROFILES.
      B(J,1)=C2-2.*C4+C4B
      B(J,2)=C1
      B(J,3)=2.*C3-C3B+(C1-C1B)*FPPB(J)+(C2+2.*C4-C2B)*FPB(J)
     1   -C4B*FPBB(J)
      B(J,4)=-(1.+CAY(J) )*VE(J)
      B(J,5)=-DP(J)/D(J)*(1.-FP(J))
  650 CONTINUE

C                    TO COMPUTE THE F'(ETA) PROFILE FOR THE MOMENTUM
C                    EQUATION.
      CALL PROFYL (JEF, JY, JD, Y, B, ET, 1.0, FPPW, FPE, 2,
     1   FP, VH, VHP, VHPP)

      JE=MAX0(JEF,JEG)
C                    FPP(J)= THE F''(ETA) OF THE MOMENTUM EQUATION.
C                    COMPUTE THE LOCAL SHEAR STRESS= TAU(J).
      JYM=JY-1
      JM=1
      DO 660  J=1, JYM
C                    GET THE F''(ETA) PROFILE BY 1ST CENTRAL DIFFERENCES.
      FPP(J)=(FP(J+1)-FP(JM))/(Y(J+1)-Y(JM))
      JM=J
C                    COMPUTE TAU(J)= LOCAL SHEAR STRESS PROFILE.
      TAU(J)=VE(J)*(DP(J)/D(J)*(1.-FP(J))-FPP(J))*SQRT(1.+CAY(J) )
  660 CONTINUE
      FPP(JY)=0.0
      TAU(JY)=0.0
      VH(JY)=0.0

C                    COMPUTE F(ETA) OF THE MOMENTUM EQUATION.
      CALL INTEG (JE, JD, Y, FP, 0.0, F)

         IF  ( ISTO(5).NE.1 )      GO TO 661
C                    LIST INNER LOOP BOUNDARY VALUES AND PARAMETERS.
      IF (POP.EQ.1)      GO TO 661
         WRITE (6,82) JK, JEF, F(JEF), FPP(1), DT(1), DTXM, PM, QM, RM

C                    TEST TO SKIP END OF CASE TEST.
 661  IF (TOP.EQ.1.AND.I.LT.IX) GO TO 663
C                    TEST TO END CASE.
      IF (F(JEF).LT.0.0.OR.F(JEF).GT.WSTO(2) )     GO TO 662
      GO TO 664

C                    END CASE.
 662     ISTO(10)=  5
         RETURN

  663 CONTINUE
C                    TEST TO EXIT FROM ITSR ON A LAMINAR SEPARATION.
      IF (F(JEF).GT.0.0.AND.F(JEF).LT.WSTO(2).AND.FPP(1).LT.0.0)
     2   GO TO 664
C                    ENTER SUBR ITFR FROM TUF FOR A TURBULENT RESTART
C                    IF ISTO(14).EQ.1.
      IC=I
         ISTO(10)=  6
         RETURN

  664 CONTINUE
```

```
C                     TEST F''(ETA=0.0) AND F(J=JE) FOR CONVERGENCE. BOTH
C                     MUST CONVERGE.
      IF (MOM  .EQ.1) GO TO 670
      IF (ABS((FPP(1)-FPPW)/FPPW).GT.XT) GO TO 670
      IF (ABS(F(JE)-1.).LT.XT) GO TO 749
C                     END OF INNER LOOP TO COMPUTE THE MOMENTUM PROFILES.
  670 CONTINUE

 749  CONTINUE
C                     INDEX FOR TEST TO ENTER THE ENERGY EQUATION SECTION
C                     OF THE MAIN LOOP.
      IBC=IABS(MOP)
C                     TEST FOR ENTRY INTO THE ENERGY EQUATION SECTION.
C                     IF IBC.EQ.1 ENTER THE MOMENTUM EQUATION LOOP ONLY
C                     ONCE FOR EACH I(X) WALL STATION AND SKIP THE ENERGY
C                     PROFILE COMPUTATIONS.
 750  GO TO (800,751,752), IBC
  751 CONTINUE
      GPW(I)=GBC(I)
      GPPW=GPP(1)
      GO TO 753

  752 CONTINUE
      GPW(I)=GP(1)
      GPPW=-GBC(I)*D(1)/VEG(1)

  753 CONTINUE

C                     COMPUTE G'(ETA) COEFFICIENT PROFILES.
      GPE=0.0
      DO 760 J=1, JY
      C7=QRM*(Y(J)-(F(J)+FB(J))/2.)-DTM*(F(J)-FB(J))/DX-VPM
      C8=(1.-(FP(J)+FPB(J))/2.)*DTM/DX
      C7B=QRB*(Y(J)-FB(J))-VPB-DT(IB)*(F(J)-FBB(J))/(DX+DXB)
      C8B=(1.-FPB(J))*DT(IB)/(DX+DXB)
      B(J,1)=-2.*C8+C8B
      B(J,2)=C7
      B(J,3)=(C7-C7B)*GPPB(J)+2.*C8*GPB(J)-C8B*GPBB(J)
      B(J,4)=-(1.+CAY(J) )*VEG(J)/D(J)
      B(J,5)=-(SHR-1.)*M(I)*M(I)/BH/TF(I)*(VE(J)/VEG(J)-1.)
     1   *D(J)*(1.-FP(J))*(DP(J)*(1.-FP(J))-D(J)*FPP(J))
  760 CONTINUE

C                     TO COMPUTE THE G'(ETA) PROFILE FOR THE ENERGY
C                     EQUATION.
      CALL PROFYL (JEG, JY, JD, Y, B, ET, GPW(I), GPPW, GPE, IBC,
     1   GP, VH, VHP, VHPP)

C                     GPP(J)= THE G ''(ETA) OF THE ENERGY EQUATION.
      JE=MAX0(JEF,JEG)
      JM=1
      JYM=JY-1
      DO 765 J=1, JYM
      GPP(J)=(GP(J+1)-GP(JM))/(Y(J+1)-Y(JM))
      JM=J
  765 CONTINUE
      IF (IBC.EQ.3) GPP(1)=GPPW

         IF  ( ISTO(5).NE.1 )     GO TO 766
```

```
C                   LIST G'(ETA=0.0), G''(ETA=0.0), AND D(ETA=0.0).
C                   IF THE FLUID PROPERTIES ARE CONSTANT, EXIT THE MAIN
C                   LOOP AT THE CURRENT I(X) WALL STATION.
     IF (POP.EQ.1)      GO TO 766
        WRITE (6,86) JEG, GP(1), GPP(1), D(1)

C **** IF FLOW HAS CONSTANT FLUID PROPERTIES, LEAVE LOOP ****
C    IF ABS(MOP).EQ.1 THE ENERGY SECTION OF THE MOMENTUM-ENERGY LOOP
C    IS BYPASSED.
C    FOR MOP.GE.0 LEAVE THE MOMENTUM-ENERGY LOOP ONLY IF THE SUCCESSIVE
C    G''(ETA=0.0) ARE INSIDE THE TOLERANCE CRITERIA.
 766 IF (MOP.LT.0) GO TO 800

C                   TEST G'(ETA=0.0) AND G''(ETA=0.0) IN ORDER FOR
C                   CONVERGENCE ON CONSECUTIVE ITERATES OF THE MAIN
C                   LOOP AT I(X).  IF THE ENERGY PROFILES ARE CONVERGENT
C                   EXIT FROM THE MOMENTUM-ENERGY EQUATION LOOP FOR
C                   THE FINAL COMPUTATION OF THE STATION PARAMETERS.
     IF (MAE .EQ.1) GO TO 799
     IF (ABS(GPW(I)).GT.ZERO) GO TO 796
     IF (ABS(GP(1)-GPW(I)).LT.ZERO) GO TO 797
     GO TO 799
  796 CONTINUE
     IF (ABS((GP(1)-GPW(I))/GP(1) ).GT.XT)     GO TO 799
  797 CONTINUE
     IF (ABS(GPPW).GT.ZERO) GO TO 798
     IF (ABS(GPP(1)-GPPW).LT.ZERO) GO TO 800
     GO TO 799
  798 CONTINUE
     IF (ABS((GPP(1)-GPPW)/GPPW).LT.XT) GO TO 800
C                   END OF THE LOOP TO COMPUTE BOTH MOMENTUM AND ENERGY
C                   EQUATION PROFILES.
  799 CONTINUE


C                   SEE EFN 750 FOR THE SKIP OF THE ENERGY EUIATION.
  800 CONTINUE
C **** COMPUTE SF, MT, HT, CF AND ST ****
     DO 840 J=1, JE
     FV=1.-FP(J)
C                   FOR DTK(I)
     VH(J)=1.-D(J)*FV
C                   FOR SF(I)
     VHP(J)=FV*(1.-D(J)*FV)
C                   FOR HT(I).
     VHPP(J)=GP(J)*FV
  840 CONTINUE

C                   SUM FOR DTK(I).
     CALL INTEG (JE, JD, Y, VH, 0.0, VH)
C                   SUM FOR SF(I).
     CALL INTEG (JE, JD, Y, VHP, 0.0, VHP)
C                   SUM FOR HT(I).
     CALL INTEG (JE, JD, Y, VHPP, 0.0, VHPP)

C                   MT(I),DT(I),HT(I),RDT(I),DTK(2) ARE LATER RESET AFTER
C                   COMPUTING COF1,COF2,COG1,COG2 AND BEFORE TESTING
C                   TOP.EQ.1 TO CALL SUBRS VIS AND TRANS.
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C           MODIFIED DISPLACEMENT THICKNESS FOR RMTW FOR SUBR TRANS.
      DTK(I)=VH(JE)*DT(I)
C                 SEE AUXILIARY RELATION          DELTA(*) / THETA.
      SF(I)=1./VHP(JE)
C                 MOMENTUM THICKNESS.
      MT(I)=DT(I)/SF(I)
C                 TOTAL ENTHALPY THICKNESS.
      HT(I)=VHPP(JE)*DT(I)
C                 SKIN FRICTION COEFFICIENT.
      CF(I)=2.*TAU(1)
C                 STANTON NUMBER BASED ON THE REFERENCE ENTHALPY.
      STR(I)=-VEG(1)*GPP(1)/D(1)
C                 FOR SUBR TRANS QUANTITIES.  SEE RMTW,
      B1=GPW(I)-(TF(I)-1.)/BH/TF(I)
C                 STANTON NUMBER BASED ON FREE STREAM TO WALL ENTHALPY
C                 DIFFERENCE.
      ST(I)=0.0
      IF (ABS(B1).GT.ZERO) ST(I)=STR(I)/B1

C  * * * COMPUTE THE INTEGRALS OF THE MOMENTUM AND ENERGY EQUATIONS. *
C                 SEE EQUA II-21 FOR THE MOMENTUM EQUATION AND
C                 EQUA II-23 FOR THE ENERGY EQUATION.
      HB=(SF(I)+SF(IB))/2.
      COF1=(U(I)/U(IB))**(2.+HB)*(TF(IB)/TF(I))**(1./(SHR-1.))
     1   *MT(I)/MT(IB)
      IF (RW(IB)/DT(IB).GT.0.1) COF1=COF1*RW(I)/RW(IB)
      COF2=EXP(DX*((CF(IB)+CF(I))/2.+2.*VPM)
     1   /(MT(IB)+MT(I)))
      COG1=1.0
      IF (ABS(HT(IB)).GT.ZERO) COG1=U(I)/U(IB)
     1   *(TF(IB)/TF(I))**(1./(SHR-1.))*HT(I)/HT(IB)
      IF (RW(IB)/DT(IB).GT.0.1) COG1=COG1*RW(I)/RW(IB)
      COG2=1.0
      B1=0.0
      B2=HT(I)+HT(IB)
      IF (ABS(B2).GT.ZERO) B1=(STR(I)+STR(IB)+VPM*(GP(1)+GPB(1)))*DX/B2
      IF (ABS(B1).LT.88.0) COG2=EXP(B1)
      CMTF=CMTF*COF2/COF1
      CMTG=CMTG*COG2/COG1

         IF   ( ISTO(6).NE.1 )     GO TO 841
         CLIS(4*I-3)=  COF1
         CLIS(4*I-2)=  COF2
         CLIS(4*I-1)=  COG1
         CLIS(4*I  )=  COG2

 841     IF   ( COF1.NE.0.0 )      R21F=  COF2/COF1
         IF   ( COF1.EQ.0.0 )      R21F=  0.0
         IF   ( COG1.NE.0.0 )      R21G=  COG2/COG1
         IF   ( COG1.EQ.0.0 )      R21G=  0.0

C  * * *          LIST THE RESULTS AS AN INDICATION OF ACCURACY. * * *
      IF  ( POP.EQ.1 )      GO TO 842
      WRITE  (6,89)  COF1,COF2,R21F,COG1,COG2,R21G,ITP,WSTO(18),XCF,SCF,
     2               ITME

C **** RESET MT, DT, HT, AND RDT TO MATCH CF ****
 842  DTS=DT(I)
      MT(I)=MT(I)*COF2/COF1
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      DT(I)=SF(I)*MT(I)
      DTK(I)=DTK(I)*DT(I)/DTS
      RDT(I)=RDT(I)/DTS*DT(I)
      HT(I)=HT(I)*DT(I)/DTS
      DTXM=(DT(I)-DT(IB))/DX

      IF (I.GE.IX)    GO TO 880
      DT(I+1)=DT(I)+DTXM*(X(I+1)-X(I))
      MT(I+1)=DT(I+1)/SF(I)
  880 CONTINUE

C                    IF TOP.NE.1 SKIP BOTH SUBR VIS AND SUBR TRANS.
      IF (TOP.NE.1) GO TO 898
      RDTKB=RDTK

C                    TO COMPUTE THE EFFECTIVE VISCOSITY AND CONDUCTIVITY
C                    PROFILES VE(J) AND VEG(J) FOR SUBR TRANS.
      CALL VIS (JE, JY, JD, YY, FP, FPP, GP, GPP, D, DP, TAU, VH, VHP,
     1   TURB(I), SW(I), CW(I), SHR, BH, STC, TO, TF(I), RDT(I), DT(I),
     2   F(JY), PR, PRT, JK, VE, VEG, ISTO )

      RDTK=1./VE(1)*DTK(I)/DT(I)
      RMTWB=RMTW
      RMTW=RDTK/DTK(I)*MT(I)
      FTE=  FTU2/U(I)/U(I)

C                    TO COMPUTE TURB(I+1) FOR SUBR VIS, AND IC, THE
C                    CRITICAL POINT.
      CALL TRANS (I, ID, JEF, JY, JD, Y, FP, FPP, GP, VH, VHP, VHPP,
     1   SF(I), SW(I), CW(I), STR(I), DTK(I), MT, TF(I), M(I), BH,
     2   RDTK, RC, RMC, IC, KB, XK, FTE, DX, RMTW, RMTWB, U, TURB,
     3   RMT, TOP,ISTO,WSTO)

      IF  ( ISTO(5).EQ.0 )     GO TO 898

      RRCD=  100.
      IF  ( RMTW.NE.0.0 )     RRCD=  RMC/RMTW
      DRDC= RDTK -  RC
      DRM1= RMTW- RMC
      DRM2=  100.
      IF  ( MT(I).NE.0.0 )     DRM2=  RMTW*MT(I+1)/MT(I) - RMT
      RRFT=  100.
      IF  ( RMT.NE.0.0 )     RRFT=  RMC/RMT

      IF (POP.EQ.1)      GO TO 898
      WRITE (6,96)  RRCD,RRFT,RMC,RMTW,RMT,RC,RDTK,DRDC,DRM1,DRM2
C                    SKIP SUBRS VIS AND TRANS IF TOP.NE.1.
  898 CONTINUE


C                    TO LIST THE PROFILES NEAR THE ZERO SHEAR POINT RESET
C                    ISTO(7).  XCF,SCF ARE LISTED TOGETHER WITH COF1,ETC
C                    BY SUBR ITSR ON POP.NE.1.
      ISAV= ISTO(7)
      SCF=  -( CF(I)-CF(I-1) ) / ( X(I)-X(I-1) )
      IF  ( SCF.NE.0.0 )     XCF=  X(I) + CF(I) / SCF
      IXI=  I + ISTO(13)
      IF  ( XCF.GT.X(IXI) )     GO TO 901
      IF  ( XCF.LT.X(I) )     GO TO 901
      ISTO(7)=  I
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C                     TO LIST THE MOMENTUM,ENERGY AND RELATED PROFILES.
 901  CALL FILE (LABEL, I, YY, F, FP, FPP, GP, GPP, D, DP,
     1   VH, VHP, VHPP, TAU, VE, VEG, SHR, BH, PR, PRT,
     2   X, U, M, TURB, RW, VW, SW, CW,
     3   ROT, DT, MT, HT, SF, CF, ST,STR,ID,JE,JY,JD,JDIV,ISTO,WSTO )

      ISTO(7)=  ISAV

C                     IT IS RESET= IT+1 IN SUBR COTR IF TURB(I).GT.WSTO(13)
C                     IN SUBR COTR AFTER EXITING FROM THE I(X) STATION
C                     READING LOOP.  SUBR NDIR SETS ALL SUCCEEDING
C                     TURB(I) = 1. IN TE RE-INITIALIZATION SECTION.
 911  IF  ( I.NE.IT )       GO TO 899
         ISTO(10)=  7
         RETURN

C                     RETURN TO THE HEAD OF THE I(X) LOOP.
  899 CONTINUE
C ***                 END FORWARD MOTION ON X.


C                     SUBR ITSR HAS REACHED A NORMAL END OF THE CASE.
 912     ISTO(10)=  4
         RETURN


 51   FORMAT  (A4,5X,20HINPUT VARIABLES FOR  ,17A4 )

 52   FORMAT  ( 1H0, 17HLIMIT ON RX*RW(I) ,2X, 3HRX= 1PE14.7,2X,
     2        7HRW(I)= E14.7, 2X,10HWSTO(18)= E14.7,2X,4HCA1= E14.7,
     3        2X, 4HRWX= E14.7 )

 60      FORMAT  (1H0, 6HI(X)= I3, 2X, 2HX= 1PE9.2, 1X,
     1   3HU =, E9.2, 1X, 3HM =, E9.2, 1X, 6HTURB =, 0PF5.2, 1X,
     2   5HGBC =, 1PE9.2, 1X, 4HRW =, E9.2, 1X, 4HVW =, E9.2,
     3   1X, 4HSW =, E9.2, 1X, 4HCW =, E9.2)

 70   FORMAT (1H0, 40X,
     1   48HVALUES OF IMPORTANT VARIABLES FOR EACH ITERATION)

   81 FORMAT (1H0, 1HF, 2X, 2HJK, 1X, 3HJEF, 5X, 3HFJE, 6X, 4HFPPW, 6X,
     1   2HDT, 7X, 4HDTXM, 7X, 2HPM, 8X, 2HQM, 8X, 2HRM/
     2   1X, 1HG, 5X, 3HJEG, 5X, 3HGPW, 6X, 4HGPPW, 6X, 2HDW/ 1H0)

   82 FORMAT (1H0,1HF, 2(1X, I3), 7(1X, 1PE9.2))
   86 FORMAT (1X, 1HG, 5X, I3, 3(1X, 1PE9.2))

 89   FORMAT (1H0,15X, 42HINTEGRALS OF MOMENTUM AND ENERGY EQUATIONS
     1     /18X, 8HMOMENTUM, 45X, 5HENERGY/
     2        13X, F7.4, 4H  =  F7.4, 5X, 5HR21F= F8.4, 10X F7.4, 4H  =
     3        F7.4, 5X, 5HR21G= F8.4,10X,5HITP= I3 /  45X,
     4       10HWSTO(18)= 1PE14.7, 3X,5HXCF= E14.7,3X,5HSCF= E14.7 ,
     5        5X, 6HITME= I3 )
```

```
96   FORMAT  (1H0, 25HTRANSITION STATISTICS... 6HRRCD= 1PE9.2, 3X,
   2               6HRRFT=  E9.2, 4X, 5HRMC= E9.2, 3X, 6HRMTW= E9.2, 3X,
   3               5HRMT= E9.2, 3X, 4HRC= E9.2  /
   4               26X, 6HRDTK= E9.2, 3X, 6HDRDC= E9.2, 3X,  6HDRM1=
   5               E9.2, 3X, 6HDRM2= E9.2 )

  98 FORMAT (1H0)

       END
```

Subroutine TRANS

```
$IBFTC CTRAN


      SUBROUTINE TRANS (I, ID, JEF, JY, JD, Y, FP, FPP, GP,
     1   VH, VHP, VHPP, SF, SW, CW, STR, DTK, MT, TF, M, BH,
     2   RDTK, RC, RMC, IC, KB, XK, FT, DX, RMTW, RMTWB, U, TURB,
     3   RMT, TOP, ISTO,WSTO )


C     SUBROUTINE TRANS COMPUTES THE CRITICAL X-STATION INDEX I(X)=IC
C     FOR THE CHANGE FROM LAMINAR TO TURBULENT FLOW, AND THE TURBULENCE
C     OR INTERMITTENCY FACTOR TURB(I+1) USED BY SUBR VIS TO COMPUTE
C     THE VISCOSITY AND CONDUCTIVITY PROFILES.

C     SUBROUTINE TRANS IS CALLED BY SUBROUTINE ITSR IF TOP.EQ.1.
C     SUBROUTINE TRANS CALLS THE FUNCTION SURBOUTINE ...INDEX.



C     COMMENT...
C     TRANSITION MAY BE EITHER CALCULATED OR SPECIFIED.  TRANSITION IS
C     SPECIFIED BY CHANGING TURB(I) ( THE INTERMITTENCY FACTOR) FROM
C     0.0 TO 1.0 EITHER GRADUALLY OR ABRUPTLY DEPENDING ON THE SIZE
C     OF THE TRANSITION REGION.
C
C     SUBR TRANS FINDS THE TRANSITION ZONE BY COMPUTING AND TESTING THE
C     CRITICAL REYNOLDS NUMBER RC.
C     SUBR TRANS MAY RECOMPUTE THE EFFECTIVE INTERMITTENCY FACTOR
C     TURB(I+1) AFTER COMPUTING AND TESTING THE TRANSITIONAL REYNOLDS
C     NUMBERS.  THE CRITICAL REYNOLDS NUMBER  IS COMPUTED AT  ALL
C     I.LE.IC WHERE IC IS INITIALIZED =  IX+1 BY SUBR INIR AND WHERE
C     IX IS THE LAST X STATION TO BE COMPUTED.
C     IF TOP.EQ.1 SUBR COTR RESETS TURB(I)=0.0 BEFORE THE DATA LIST.
C     IF IOP.EQ.7 SUBR COTR RESETS TURB(I)=1. BEFORE THE DATA LIST.

C
C     SUBR TRANS CALLS FUNCTION INDEX(Z,S,NDIM,MIN,MAX,IGUESS)
C     TO FIND THE INDEX OR POSITION OF A VALUE OF A FUNCTION S IN ONE OF
C     THE DATA TABLES IN SUBR TRANS WHEN THE VALUE OF THE S SOUGHT IS
C     THE LEAST VALUE OF S THAT EXCEEDS    A GIVEN VALUE Z OF ANOTHER
C     FUNCTION.
C     SUBR TRANS CONTAINS THE SETS OF CURVE DATA...
C                   (1)-SFF ON RCH. (2)-SWF ON RSF, (3)-KF ON RDF,
C                   (4)-FTF ON RTF, (5)-CWF ON RRF.
C     THE INDEX FROM FUNCTION INDEX(Z,S,NDIM,MIN,MAX,IGUESS) IS EITHER
C                   (1)-KH(SF,SFF(RCH)) FOR SF VS SFF(RCH),
C                   (2)-KS(SWR,SWF(RSF)) FOR SWR VS SWF(RSF),
C                   (3)-KK(KB,KF(RDF)) FOR KB VS KF(RDF),
C                   (4)-KFT(FT,FTF(RTF)) FOR FT VS FTF(RTF),
C                   (5)-KR(CWR,CWF(RRF)) FOR CWR VS CWF(RRF).
C     THE INDEX KH(SF,SFF), KS(SWR,SWF), KK(KB,KF), KFT(FT,FTF),
C     KR(CWR,CWF) IS THE INTEGER OF THE PLACE IN THE TABLE OF SFF,SWF,
C     KF,FTF,CWF SUCH THAT SF,SWR,KB,FT,CWR  IS JUST .LT. SFF(RCH),
C     SWF(RSF),KF(RDF),FTF(RTF),CWF(RRF).


      DIMENSION  ISTO(16), WSTO(20)
```

```
C                  SUBR INIR SETS JD= 100.
      DIMENSION Y(JD), FP(JD), FPP(JD), GP(JD)
      DIMENSION VH(JD), VHP(JD), VHPP(JD)
      DIMENSION MT(ID), U(ID), TURB(ID)

C                  FOR SUBR TRANS ONLY.
      DIMENSION SFF(15), RCH(15), SWF(9), RSF(9)
      DIMENSION KF(15), RDF(15), FTF(14), RTF(14), CWF(4), RRF(4)

      REAL M, MT, KB, KF

      DATA ZERO/ 1.0E-10/
      DATA IH, IS, IK, IT, IR/ 15, 9, 15, 14, 4/

C                  DATA CURVE..SHAPE FACTOR (SFF) VERSUS CRITICAL
C                  REYNOLDS NUMBER (RCH),- AN EXTENSION OF FIG. 17.19
C                  OF SCHLICHTING.
C                  TABLE OF CURVE DATA SET NO. 1.
      DATA SFF/2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0,
     1   3.2, 3.4, 3.6, 5.0/

      DATA RCH/42000.0, 20000.0, 15000.0, 7000.0, 3150.0, 1000.0, 425.0,
     1   200.0, 145.0, 115.0, 90.0, 70.0, 60.0, 45.0, 10.0/

C                  DATA CURVE...SURFACE ROUGHNESS,SWF, VERSUS
C                  TRANSITION  REYNOLDS NUMBER,RSF,- OBTAINED BY USING
C                  FIG. 17.38 OF SCHLICHTING.
C                  TABLE OF CURVE DATA SET NO. 2.
C

      DATA SWF/0.0, 120.0, 150.0, 200.0, 250.0, 300.0, 350.0, 400.0,
     1   1000.0/

      DATA RSF/1.0, 1.0, 0.955, 0.695, 0.418, 0.216, 0.060, 0.0, 0.0/

C                  DATA CURVE...PRESSURE GRADIENT PARAMETER,KF, VERSUS
C                               RDF FROM FIG. 17.9 OF SCHLICHTING.
C                  TABLE OF CURVE DATA SET NO. 3.
      DATA KF/-1.0, -0.04, -0.03, -0.02, -0.015, -0.01, -0.005, 0.0,
     1   0.005, 0.01, 0.015, 0.02, 0.025, 0.04, 1.0/

      DATA RDF/400.0, 440.0, 450.0, 500.0, 540.0, 600.0, 700.0, 820.0,
     1   1000.0, 1200.0, 1420.0, 1720.0, 2060.0, 3200.0, 64000.0/

C                  DATA CURVE...FREE STREAM TURBULENCE ,FTF, VERSUS
C                  REYNOLDS NUMBER,TRANS-CRITICAL, RTF FROM FIG. 16.21
C                  OF SCHLICHTING.
C                  TABLE OF CURVE DATA SET NO. 4.
      DATA FTF/ 0.0, 0.003, 0.006, 0.0084, 0.012, 0.021, 0.0296, 0.036,
     1   0.048, 0.060, 0.072, 0.084, 0.100, 1.000/

      DATA RTF/ 1.130, 1.130, 0.865, 0.740, 0.662, 0.495, 0.370, 0.291,
     1   0.148, 0.071, 0.032, 0.018, 0.0, 0.0/

C                  DATA CURVE...SURFACE CURVATURE, CWF,VERSUS TRANSITION
C                  REYNOLDS NUMBER,RRF, FROM FIG. 17.33 OF SCHLICHTING.
C                  TABLE OF CURVE DATA SET NO. 5.
      DATA CWF/0.0002, 0.00008, 0.0, -0.00008/
```

```
      DATA RRF/ 1.04, 1.04, 1.0, 0.81/

C                       SUCCEEDING X-STATION NUMBER.
      IP=I+1
         KS=  1
         KR=  1
         KH=  1
         KK=  1
         KFT=  1
      CWR= 1.0E-19
      RTR= 1.0E-19
      RD= 1.0E-19

C                       COMPUTE THE EFFECT OF SURFACE ROUGHNESS.
      SWR=SW*RDTK/DTK
C                       INITIALIZE A MULTIPLIER OF RC=CRITICAL REYNOLDS NO.
      RSR=1.0

      IF (SWR.LT.0.01) GO TO 150

C                       FOR SWF(RSF) TABLE OF CURVE DATA.
      KS=INDEX (SWR, SWF, IS, 1, IS, IS/2)

C                       RSR= A FUNCTION CHARACTERISTIC OF ROUGHNESS ELEMENTS
C                       DIVIDED BY THE DISPLACEMENT THICKNESS.
      RSR=(RSF(KS)-RSF(KS-1))/(SWF(KS)-SWF(KS-1))*(SWR-SWF(KS-1))
     1   +RSF(KS-1)

C                       COMPUTE THE EFFECT OF SURFACE CURVATURE.
  150 CONTINUE
C                       INITIALIZE A MULTIPLIER OF RC=CRITICAL REYNOLDS NO.
      RRR=1.0

      IF (ABS(CW).LT.ZERO) GO TO 170

      CWR=MT(I)/CW
      IF (CWR.GT.-0.00008) GO TO 160
      RRR=0.73/SQRT(ABS(CWR))
      GO TO 161

C                       RRR= MOMENTUM THICKNESS / RADIUS OF CURVATURE.
  160 CONTINUE
C                       FOR CWF(RRF) TABLE OF CURVE DATA.
      KR=INDEX (CWR, CWF, IR, 1, IR, IR/2)
      RRR=(RRF(KR)-RRF(KR-1))/(CWF(KR)-CWF(KR-1))*(CWR-CWF(KR-1))
     1   +RRF(KR-1)

  161 CONTINUE
  170 CONTINUE
C                       RC IS NOT RECOMPUTED AFTER I.GE.IC.  IC=IX+1 IN INIR.
 171  IF (I.GE.IC) GO TO 600
      IF (ABS(STR).GT.ZERO) GO TO 300

C                       COMPUTE THE EFFECT OF THE PRESSURE GRADIENT
C                       PARAMETER ON THE CRITICAL REYNOLDS NUMBER.
C                       RC= THE CRITICAL REYNOLDS NUMBER= A FUNCTION OF THE
C                       SHAPE FACTOR.
C                       FOR SFF(RCH) TABLE OF CURVE DATA.
```

```
      KH=INDEX (SF, SFF, IH, 1, IH, IH/2)
      RC=(RCH(KH)-RCH(KH-1))/(SFF(KH)-SFF(KH-1))*(SF-SFF(KH-1))
     1   +RCH(KH-1)

      GO TO 500

  300 CONTINUE
C                   COMPUTE THE HEAT TRANSFER EFFECT ON THE CRITICAL
C                   REYNOLDS NUMBER RC.  (METHOD TAKEN FROM LEES).

      JC=1
      JCP=1
      VHPP(1)=0.0

      TTFW=(1.-BH*GP(1))*TF-(1.-FP(1))*(1.-FP(1))*(TF-1.)
      TTF=TTFW

      TTFP=(1.-BH*GP(2))*TF-(1.-FP(2))*(1.-FP(2))*(TF-1.)

      IF (ABS(TTFW).LT.1.E-20) GO TO 351
      JEM=JEF-1

      DO 350 J=2, JEM
      TTFB=TTF
      TTF=TTFP
      VF=1.-FP(J)
      VFP=1.-FP(J+1)
      TTFP=(1.-BH*GP(J+1))*TF-VFP*VFP*(TF-1.)

      IF (ABS(FPP(J)*VF*TTFP*TTFB*TTFW).LT.1.E-20) GO TO 349

      VH(J)=3.14159*VF/TTFW*FPP(1)
     1   *(TTF*TTF/FPP(J)**3*(FPP(J+1)/TTFP-FPP(J-1)/TTFB)
     2   /(Y(J+1)-Y(J-1)))

      VHP(J)=-FPP(1)*Y(J)/VF-1.
      VHPP(J)=(1.-2.*VHP(J))*VH(J)

      IF (VHPP(J).GT.0.58) GO TO 351
      JC=J+1

  349 CONTINUE
  350 CONTINUE

  351 CONTINUE

      VFC=(1.-FP(JC-1))+(FP(JC-1)-FP(JC))/(VHPP(JC)-VHPP(JC-1))
     1   *(0.58-VHPP(JC-1))

      GPC=GP(JC-1)+(GP(JC)-GP(JC-1))/(VHPP(JC)-VHPP(JC-1))
     1   *(0.58-VHPP(JC-1))

C                   THE CRITICAL REYNOLDS NUMBER BEFORE INCLUDING
C                   SURFACE ROUGHNESS AND SURFACE CURVATURE EFFECTS.
      RC=-25.0*FPP(1)*((1.-BH*GPC)*TF-VFC*VFC*(TF-1.))**1.76
     1   /VFC**4/SQRT(1.-M*M*(1.-VFC)*(1.-VFC))

C                   RC= CRITICAL REYNOLDS NUMBER=FUNCTION OF STANTON NO.
C                   RMC=CRITICAL REYNOLDS NUMBER FRCM MOMENTUM THICKNESS.
```

```
  500 CONTINUE
C                      INCLUDE THE SURFACE ROUGHNESS AND CURVATURE EFFECTS.
      RC=RC*RSR*RRR
      RMC=RC/DTK*MT(I)

C                      RDTK= LOCAL REYNOLDS NUMBER FROM MOMENTUM THICKNESS.
C                      RC= CRITICAL REYNOLDS NUMBER FROM DISPLACEMTNT
C                      THICKNESS.
C                      IF TRUE THEN TURB(I+1) REMAINS AS SET IN SUBR COTR.
      IF (RDTK.LT.RC)      GO TO 999
C                      RESET IC=I TO SKIP THE RECOMPUTATION OF RC AT
C                      SUCCEEDING X STATIONS.   SEE EFN 171.

      IC=I

C                      EFFECT OF PRESSURE GRADIENT PARAMETER ON
C                      TRANS-CRITICAL REYNOLDS NUMBER.
  600 CONTINUE
      DK=(RMTW+RMTWB)/2.*(MT(I)+MT(I-1))/(U(I)+U(I-1))
     1   *(U(I)-U(I-1))/DX

      KB=(KB*XK+DK*DX)/(XK+DX)

C                      FOR KF(RDF) TABLE OF CURVE DATA.
      KK=INDEX (KB, KF, IK, 1, IK, IK/2)

C                      RD= REYNOLDS NUMBER = FUNCTION OF PRESSURE GRADIENT
C                      PARAMETER.
      RD=(RDF(KK)-RDF(KK-1))/(KF(KK)-KF(KK-1))*(KB-KF(KK-1))+RDF(KK-1)

C                      COMPUTE THE EFFECT OF THE FREE STREAM TURBULENCE.
C                      FOR FTF(RTF) TABLE OF CURVE DATA.
      KFT=INDEX (FT, FTF, IT, 1, IT, IT/2)

C                      RTR= TRANSITIONAL REYNOLDS NUMBER=FUNCTION OF FREE
C                      STREAM TURBULENCE.
      RTR=(RTF(KFT)-RTF(KFT-1))/(FTF(KFT)-FTF(KFT-1))*(FT-FTF(KFT-1))
     1   +RTF(KFT-1)
C                        CORRECTED VALUE OF RD.
      RD=RD*RTR*RRR*RSR

      RMT=RMC+RD
C                      RMTW= LOCAL REYNOLDS NUMBER FROM THE MOMENTUM
C                      THICKNESS.  RMTW IS COMPUTED IN SUBR ITSR AFTER
C                      TESTING FOR TOP.EQ.1 AND JUST BEFORE CALLING TRANS.
      RMTWF=RMTW/MT(I)*MT(I+1)

C                      RMC= CRITICAL REYNOLDS NUMBER FROM THE MOMENTUM
C                      THICKNESS.
C                      IF RMTW.GE.RMC.AND.RMTWF.LE.RMT THEN COMPUTE AN INTER
C                      MEDIATE VALUE OF TURB(I+1).GT.0.0 AND .LE.1.
C                      IF RMTW.GE.RMC.AND.RMTWF.GT.RMT SET THE REMAINING
C                      TURB(I+1)=1. , AND RESET TOP=0 TO SKIP SUBR TRANS
C                      FOR THE REMAINING I(X) STATIONS OF THE CASE.
C                      NOTE THAT RMT.GT.RMC BY RD AND RMTWF.GT.RMTW.
      IF (RMTW.LT.RMC)  GO TO 999

C                      RMTWF= LOCAL REYNOLDS NUMBER FROM THE MOMENTUM
C                      THICKNESS.
```

```
C                      RMT= TRANSITION  REYNOLDS NUMBER FROM THE MOMENTUM
C                      THICKNESS.
C                      IF TRUE THEN THE SUCCEEDING TURB(I+1)= 1.
      IF (RMTWF.GT.RMT) GO TO 700
      XI=2.*(RMTWF-RMC)/RD
C                      TURB(I)= INTERMITTENCY FACTOR COMPUTED BY THE
C                      METHOD OF DHAWAN AND NARASIMHA.  TURB(I+1) IS USED BY
C                      SUBR VIS.
      TURB(I+1)=1.-EXP(-0.412*XI*XI)
      GO TO 999

  700 CONTINUE
      TOP=0
C                      TURB(II) IS USED BY SUBR VIS.
      DO 701 II=IP, ID
      TURB(II)=1.0
  701 CONTINUE


  999 IF  ( ISTO(5).EQ.0 )      RETURN

      WRITE  (6,998)  I,IC,
     2                  RSR,RRR,RMC,RD,RMT,FT,RTR,TURB(IP)

      RETURN

  998 FORMAT  ( 1H0, 44HTRANSITIONAL STATISTICS LISTED BY TRANS...
     2                6HI(X)= I3, 5X, 4HIC= I3  /
     3                1X,5HRSR= E10.3,2X,5HRRR= E10.3,2X,5HRMC= E10.3,2X
     4                4HRD= E10.3,2X,5HRMT= E10.3,2X,4HFFT= E10.3,2X,5HRTR=
     5                E10.3 /      1X, 11HTURB(I+1)= E10.3 )

      END
```

Subroutine INDEX

```
      FUNCTION INDEX(Z,S,NDIM,MIN,MAX,IGUESS)
C     FUNCTION SUBROUTINE  INDEX IS CALLED BY SUBROUTINE TRANS
C     COMMENT...
C     THE OBJECTIVE OF THE SUBROUTINE FUNCTION INDEX IS TO FIND THE
C     INDEX OR POSITION OF A VALUE OF A FUNCTION S IN A DATA TABLE WHERE
C     S= S(K) AND S(K)= S(FN(K)) WHEN THE VALUE OF THE S SOUGHT IS THE
C     LEAST VALUE OF S THAT EXCEEDS A GIVEN VALUE Z OF ANOTHER FUNCTION
C     SUPPLIED BY SUBROUTINE TRANS.
C     SUBR TRANS CONTAINS A SET OF TABLES FOR S(K) VS FN(K).
C     THE PORTION OF THE TABLE OF S TO BE USED LIES BETWEEN THE INDICES
C     MIN AND MAX WHICH MARK A PORTION OF THE FUNCTION S  THAT IS
C     MONOTONIC INCREASING WITH S(MAX).GT.S(MIN).
C     THE VALUE OF MIN MUST BE SUCH THAT AT LEAST THERE EXISTS AN S AT
C     MIN+1.
C     A GUESSED  TABLE OR ARRAY INDEX OF THE FUNCTION S REQUIRED TO
C     SATISFY THE OBJECTIVE OF THE ROUTINE IS GIVEN AS IGUESS.
C     IF NO S EXCEEDS Z THEN MAX WILL BE GIVEN BY FUNCTION ROUTINE
C     INDEX AS THE CORRECT INDEX.
C     IF S(MIN+1) EXCEEDS Z THEN MIN+1 WILL BE GIVEN BY THE FUNCTION
C     ROUTINE INDEX AS THE CORRECT INDEX ALTHO S(MIN) COULD BE .GT.Z AND
C     YET NOT BE GIVEN BY FUNCTION INDEX AS THE CORRECT INDEX.
C     NDIM IS NOT USED IN THIS DECK.


      DIMENSION S(82)


      I=IGUESS

      IF (S(MIN+1)-Z) 2, 1, 1
    1 CONTINUE
      I=MIN+1
      GO TO 6
    2 CONTINUE
      IF (S(MAX)-Z) 3, 3, 4
    3 CONTINUE
      I=MAX
      GO TO 6
    4 CONTINUE
      IF (S(I)-Z) 5, 6, 7
    5 CONTINUE
      I=I+1
      IF (S(I)-Z) 5, 6, 6
    7 CONTINUE
      I=I-1
      IF (S(I)-Z) 8, 6, 7
    8 CONTINUE
      I=I+1

    6 CONTINUE
      INDEX=I

      RETURN

      END
```

```
$IBFTC NDID

          SUBROUTINE NDIR

C     SUBROUTINE NDIR LISTS THE SUMMARY OF THE PRINCIPAL BOUNDARY
C     LAYER PARAMETERS AT THE CASE END.    SUBROUTINE NDIR ALSO TESTS
C     ISTO(10).EQ.4,5,6,7,SET BY SUBR ITSR, TO DETERMINE WHETHER THE
C     CASE  IS TO BE ENDED OR THE NECESSARY QUANTITIES ARE TO BE
C     RE-INITIALIZED FOR A POSSIBLE RESTART AT I(X)= IC BY SUBR ITFR
C     ON A CALL BY THE MAIN ROUTINE TUF.

C     SUBROUTINE NDIR IS CALLED BY THE MAIN ROUTINE TUF.
C     SUBROUTINE NDIR CALLS SUBROUTINES FILE,VIS,A6IR.


C  * * * * * * * * * MAIN COMMON  V-3 TUF  * * * * * * * * * * * * * * * * *

      COMMON   /TUFA/ATUF,
     1         B(300,5),
     2         B1,BH,BS,BK,
     3         CW(100),CF(100),CLIS(400),CAY(300),
     4         CA,CA1,CO,COB,CMTF,CMTG,C,COAL,CMU,
     5         DB(300),DBB(300),D(300),DP(300),DPB(300),
     6         OT(100),OTK(100),
     7         DX,DTXM,DOP,DI,DJ,DXB,DTM,DTS,
     8         ET,
     9         FB(300),FBB(300),FPBB(300),FPB(300),FP(300),F(300),
     A         FPP(300),FPPB(300),
     1         FPE,FPPW,FT,FV,FTU2,
     2         GPB(300),GPBB(300),GP(300),GPP(300),GPPB(300),
     3         GBC(100),GPW(100),
     4         GPPW,GPE, GAM,GAMX,
     5         HT(100),
     6         ISTO(16),
     7         I,IC,IO,IBC,IOP,IX,IXE,IT,IXA,ID,IXF
      COMMON   /TUFJ/ JTUF,
     1         JTR(100),
     2         JE,JK,JM,JY,JEF,JEG,JDIV,JEB,JD,
     3         KB,KMI,
     4         LABEL(132),
     5         LOOP,LOOPF,
     6         M(100),MT(100),
     7         MOP,MR,ML,
     8         NU,
     9         OI,
     A         P,PB,PM,POP,PR,PRT,
     1         QB,QM,QRB,QRM,Q,
     2         RW(100),RDT(100),
     3         RB,RM,RC,RMS,RMT,R,RDTK,RXRDF,RL,RMTW,RDF,RX
      COMMON   /TUFS/STUF,
     1         STR(100),SW(100),SF(100),ST(100),
     2         SHR,STC,SK,STRX,
     3         TAU(300),
     4         TURB(100),TF(100),
     5         TO,TOP,TFR,
```

```
     6          U(100),
     7          UX,
     8          VE(300),VEG(300),VH(300),VHP(300),VHPP(300),
     9          VW(100),
     A          VPB,VPM,
     1          WSTO(20),
     2          X(100),
     3          XT,XK,
     4          Y(300),YY(300),
     5          ZERO

      REAL      KB, M,ML,MR,MT,NU

      INTEGER        DOP,POP,TOP

C  * * * * * * * * *END OF MAIN COMMON TUF-V3* * * * * * * * * * * * * *


C                      SEE FORMATS 93,94,95,96.
         IF   ( ISTO(10).EQ.5 )        GO TO 901
         IF   ( ISTO(10).EQ.6 )        GO TO 920
         IF   ( ISTO(10).EQ.7 )        GO TO 921
      GO TO 905

C                      CALL SUBR PROFILE FOR A LIST IF THE PROFILE OF F(ETA)
C                      GOES OUT OF BOUNDS.
  901 CONTINUE
         WRITE  (6,95)
      WRITE (6,99)
      CALL FILE (LABEL, I, YY, F, FP, FPP, GP, GPP, D, DP,
     1   VH, VHP, VHPP, TAU, VE, VEG, SHR, BH, PR, PRT,
     2   X, U, M, TURB, RW, VW, SW, CW,
     3   RDT, DT, MT, HT, SF, CF, ST, STR, ID, JE, JY,JD,JDIV,ISTO,WSTO)

C                      ALSO, IF ISTO(14).NE.1.AND. ISTO(10).EQ.6 RETURN TO
C                      HERE BY WAY OF EFN 920,936 TO END THE CASE.
  905 CONTINUE

C **** PRINT OUT SUMMARY OF PRINCIPAL BOUNDARY LAYER PARAMETERS ****
      LP=  60
      DO 910 I=1, IXA
      IF   ( LP.GE.60 )       GO TO 906
      GO TO 907
 906  WRITE  (6,99)
      WRITE (6,90) (LABEL(K), K=2,18)
      WRITE (6,91)
      LP=  8

 907  IF   ( WSTO(10).NE.0.0 )        X(I)=  X(I)/WSTO(10)

      WRITE (6,92) X(I), DT(I), MT(I), HT(I), SF(I), CF(I), ST(I),
     1   GPW(I), RDT(I), U(I), M(I), TURB(I), RW(I), VW(I), SW(I), CW(I)
      LP=  LP + 2
  910 CONTINUE

         IF   ( ISTO(6).EQ.1 )       GO TO 911
         GO TO 913
 911     WRITE  (6,99)
         DO  912  I=  1,IXA
```

```
         COF1=  CLIS(4*I-3)
         COF2=  CLIS(4*I-2)
         IF  ( COF1.NE.0.0 )      R21F=  COF2/COF1
         IF  ( COF1.EQ.0.0 )      R21F=  0.0
         COG1=  CLIS(4*I-1)
         COG2=  CLIS(4*I)
         IF  ( COG1.NE.0.0 )      R21G=  COG2/COG1
         IF  ( COG1.EQ.0.0 )      R21G=  0.0
         WRITE  (6,98)  I,X(I),COF1,COF2,R21F,COG1,COG2,R21G
 912     CONTINUE

 913     CALL A61R
         RETURN

C              ENTER HERE IF AND ONLY IF F(JEF).LE.0.0.OR.
C              F(JEF).GE.WSTO(2). .AND.FPP(1).GE.0.0 IN SUBR ITSR.  ALSO
C              TOP.EQ.1.AND.I.LT.IX.

C                    IF ISTO(14).EQ.1.AND.ISTO(10).EQ.6 THEN TUF
C                    CALLS SUBR ITFR FOR A TURBULENT RESTART AFTER A
C                    LAMINAR SEPARATION.
 920  IF  ( ISTO(14).NE.1 )       GO TO 936
         WRITE  (6,96)
      MT(IC)=(U(IC-1)/U(IC))**(2.+SF(IC-1))
     1   *(TF(IC)/TF(IC-1))**(1./(SHR-1.))*MT(IC-1)
      DT(IC)=MT(IC)*SF(IC-1)
      DTK(IC)=DTK(IC-1)/DT(IC-1)*DT(IC)
      HT(IC)=0.0
      IF (ABS(HT(IC-1)).GT.ZERO)
     1   HT(IC)=U(IC-1)/U(IC)*(TF(IC)/TF(IC-1))**(1./(SHR-1.))*HT(IC-1)
      IF (RW(IC-1)/DT(IC-1).GT.0.1)
     1   HT(IC)=HT(IC)*RW(IC-1)/RW(IC)
      RDT(IC)=RDT(IC-1)*U(IC)/U(IC-1)*DT(IC)/DT(IC-1)
     1   *(TF(IC)/TF(IC-1))**(1.5-1./(SHR-1.))
     2   *(1./TF(IC)+STC/TO)/(1./TF(IC-1)+STC/TO)
      IF (POP.NE.1) WRITE (6,93) IC,RC,RDTK
      GO TO 922

C              ENTER HERE(SKIPPING EFN 920) IF AND CNLY IF I.EQ.IT IN
C              SUBR ITSR.
  921 CONTINUE
         WRITE  (6,97)  I
      IC=IT
      IF (POP.NE.1) WRITE (6,94)  IC, RC, RDTK

C              ISTO(10).EQ.6.OR.ISTO(10).EQ.7.
  922 CONTINUE
      DTS=DT(IC)
      DT(IC)=RC/RDTK*DT(IC)
      DTK(IC)=DTK(IC)/DTS*DT(IC)
      MT(IC)=MT(IC)/DTS*DT(IC)
      HT(IC)=HT(IC)/DTS*DT(IC)
      RDT(IC)=RDT(IC)/DTS*DT(IC)
      DO 925 II=IC, IX
      TURB(II)=1.0
  925 CONTINUE
      TOP=0
      IOP=7
      MR=M(IC)
```

```
      TFR=TF(IC)
      I=IC
      CA=CA1*DT(I)
      R=RX*DT(I)
      P=UX*DT(I)
      RDF=1.0
      JE=JEB
      DO 930 J=1, JY
      F(J)=FB(J)
      FP(J)=FPB(J)
      FPP(J)=FPPB(J)
      GP(J)=GPB(J)
      GPP(J)=GPPB(J)
      D(J)=DB(J)
      DP(J)=DPB(J)
      TAU(J)=0.001
  930 CONTINUE
      CMU=(1.5-1./(1.+STC/TO*TFR))*(SHR-1.)*MR*MR
      DO 935 K=1, 5
      CALL VIS (JE, JY, JD, YY, FP, FPP, GP, GPP, D, DP, TAU, VH, VHP,
     1   TURB(I), SW(I), CW(I), SHR, BH, STC, TO, TF(I), RDT(I), DT(I),
     2   F(JY), PR, PRT, JK, VE, VEG, ISTO )
      DO 934 J=1, JY
      TAU(J)=VE(J)*(DP(J)/D(J)*(1.-FP(J))-FPP(J))*SQRT(1.+CA*Y(J))
  934 CONTINUE
  935 CONTINUE
      CF(IC)=2.*TAU(1)

          RETURN


 936  WRITE  (6,93)  RC,RDTK,RRCD,JE
      WRITE  (6,96)
      WRITE  (6,99)
      CALL FILE (LABEL, I, YY, F, FP, FPP, GP, GPP, D, DP,
     1   VH, VHP, VHPP, TAU, VE, VEG, SHR, BH, PR, PRT,
     2   X, U, M, TURB, RW, VW, SW, CW,
     3   RDT, DT, MT, HT, SF, CF, ST, STR, ID, JE, JY,JD,JDIV,ISTO,WSTO)
C                    GO TO PRINT OUT THE SUMMARY OF THE PARAMETERS.
      GO TO 905

   90 FORMAT (  45X, 39HPRINCIPAL BOUNDARY LAYER PARAMETERS FOR/
     1   26X, 17A4)
   91 FORMAT (//5X, 1HX, 8X, 2HDT, 7X, 2HMT, 7X, 2HHT, 5X,
     1   2HSF, 5X, 2HCF, 6X, 2HST, 7X, 3HGPW, 5X,
     2   3HRDT, 7X, 1HU, 7X, 1HM, 4X, 4HTURB, 5X, 2HRW,
     3   8X, 2HVW, 7X, 2HSW, 4X, 2HCW/)
   92 FORMAT (/1X, F8.5, 1X, 3(F8.6, 1X), F5.3, 1X,
     1   2(F7.5, 1X), F8.5, 1X, F8.0, 1X, F8.3, 1X,
     2   F6.3, 1X, F5.3, 1X, F8.3, 1X, F9.4, 1X, F8.5, 1X, F5.1)
 93   FORMAT  (1H2,30X,4HIC= I4 /
     1              1H0, 30X, 41HLAMINAR SEPARATION HAS OCCURED WITH RC =
     2   1PE9.2, 1X, 11HAND RDTK = , 1PE9.2,5X,6HRRCD= E9.2,5X,3HJE=I4
     3   ////53X, 17HTURBULENT RESTART///)
 94   FORMAT (1H0/1H0, 42HFORCED TRANSITION HAS OCCURED WITH IC=IT= ,I3,
     1          3X, 4HRC= 1PE9.2, 1X, 11HAND RDTK = , E9.2
     2   ////53X, 17HTURBULENT RESTART///)
 95   FORMAT  ( 1X, 46HF(JEF).LT.0.0.OR.F(JEF).GT.WSTO(2) ) IS TRUE,
     2          13HISTO(10).EQ.5 ,5X, 20HTHE PROFILE FOLLOWS.  )
```

```
96    FORMAT (1X,41HF(JEF).GT.0.0.AND.F(JEF).LT.WSTO( 2).AND.
    2          40HFPP(1).LT.0.0 IS FALSE.    ISTO(10).EQ.6, 5X,
    3          41HTHE PROFILE FOLLOWS UNLESS ISTO(14).EQ.1. )
97    FORMAT (1X, 24HI.EQ.IT ON ISTO(10).EQ.7, 5X, 2HI=  I4 )
98        FORMAT (1X,2HI= I3,2X,6HX(I)=    1PE12.5,5X,6HCOF1=  0PF8.4,
    2          2X,6HCOF2=  F8.4,3X,6HR21F=  F8.4,5X,6HCOG1=  F8.4,2X,
    3              6HCOG2=  F8.4,3X,6HR21G=  F8.4 )
  99 FORMAT (1H1)


          END
```

OPERATING INSTRUCTIONS

The description of the input of the program is described in the Input Variables section. Further explanation of input preparation is given in the Special Instructions for Preparing Input section. This is followed by a description of the output variables and test cases with sample input and output.

Input Variables

Table III shows the input variables as they are punched on the data cards. The "Star Cards" in the table are used to separate the input variables from data comment cards. Since the program does not use any constants which depend on the system of units (except the free-stream total temperature), any consistent set of units may be used.

The ISTO and WSTO arrays are described after the other input variables. The ISTO and WSTO arrays are used to indicate various program options on the input and output. If more details are needed to determine the value of the input variables than are contained in the succeeding discussion, refer to the comments in table VI.

JDIV	Number of subintervals between consecutive values of the $f'(\eta)$ and $g'(\eta)$ input profiles.
JY	Total number of η values of $f'(\eta)$ and $g'(\eta)$ input profiles, maximum value of JDIV JY is 300.
YY(I)	Array of η profile values.
JEF	Total number of $f'(\eta)$ values on the input profile.
FP(I)	Array of $f'(\eta)$ profile values.
JEG	Total number of $g'(\eta)$ values on input profile.
GP(I)	Array of $g'(\eta)$ profile values.
IOP	Initialization option number: If IOP.EQ.1,2,3, the input profile is the starting profile. If IOP.EQ.4,5,6,7, the starting profile is calculated using the input profile as a rough guess If IOP.EQ.1, the starting flow is laminar and $(dU/dx)\delta^{*2}/\nu_\infty$ is known. If IOP.EQ.2, the starting flow is turbulent and $\delta^*(dp/dx)\tau_w$ is known. If IOP.EQ.3, the starting flow is turbulent and $(dU/dx)\delta^*/U$ is known.

TABLE III. - INPUT FORM FOR PROGRAM

1 2 3 4 5	6	7 8 9 10 11 12	13 14 15 16 17 18	19 20 21 22 23 24	25 26 27 28 29 30	31 32 33 34 35 36	37 38 39 40 41 42	43 44 45 46 47 48	49 50 51 52 53 54	55 56 57 58 59 60	61 62 63 64 65 66	67 68 69 70 71 72	73 74 75 76 77 78 79 80
*													
I STO		ARRAY											
*													
WSTO		ARRAY											
*													
TITLE DESCRIBING CASE													
*													
JDIV													
*													
J Y													
YY ARRAY													

TABLE III. - Continued. INPUT FORM FOR PROGRAM

1 2 3 4 5	6	7 8 9 10 11 12	13 14 15 16 17 18	19 20 21 22 23 24	25 26 27 28 29 30	31 32 33 34 35 36	37 38 39 40 41 42	43 44 45 46 47 48	49 50 51 52 53 54	55 56 57 58 59 60	61 62 63 64 65 66	67 68 69 70 71 72	73 74 75 76 77 78 79 80
*													
JEF													
FP ARRAY													
*													
JEG													
GP ARRAY													
*													
IOP		MOP	DOP	IO	TOP	POP							
*													
MR			DT(1)	RDT(1)		BS		TO		BH	FT		
*													

TABLE III. - Concluded. INPUT FORM FOR PROGRAM

1 2 3 4 5	6	7 8 9 10 11 12	13 14 15 16 17 18	19 20 21 22 23 24	25 26 27 28 29 30	31 32 33 34 35 36	37 38 39 40 41 42	43 44 45 46 47 48	49 50 51 52 53 54	55 56 57 58 59 60	61 62 63 64 65 66	67 68 69 70 71 72	73 74 75 76 77 78 79 80
X ARRAY		U ARRAY		TURB ARRAY		GB ARRAY		RW ARRAY		VW ARRAY	SW ARRAY		CW ARRAY
*													

	If IOP.EQ.4, the starting flow is similar laminar. Only on this option do calculations start from the beginning of the boundary layer growth. If IOP.EQ.5, the starting flow is laminar and $(dU/dx)\delta^{*2}/\nu_\infty$ is known. If IOP.EQ.6, the starting flow is turbulent and $\delta^*(dp/dx)/\tau_W$ is known. If IOP.EQ.7, the starting flow is turbulent and $(dU/dx)\delta^*/U$ is known.
MOP	Designated options on the $g'(\eta)$ profile. The option number is determined from the desired method of obtaining the $g'(\eta)$ profile whether the flow properties are variable or not (see table IV).
DOP	Controls the interpretation of either the input velocity or the Mach number input data. The option number is determined from table V.
IO	Determines type of flow: IO.EQ.-1 for axisymmetric flow on inside surface formed from radii drawn from body axis. IO.EQ.1 for axisymmetric flow on outside surface formed from radii drawn from body axis. IO.EQ.0 or blank for planar flow.
TOP	If TOP.EQ.1, transition is to be calculated by the program.
POP	Print option for listing data. If TOP.EQ.1, skip detailed list of output (see table VI).
MR	Reference free-stream Mach number generally equal to the potential flow Mach number at start of boundary layer calculation: If IOP.EQ.4, MR=M(2), and if IOP.NE.4, MR=M(1). If IOP.EQ.7 and M(1).EQ.0.0, MR is reset to 0.001.
DT(1)	Displacement thickness at start of boundary layer calculation: If IOP.EQ.7 and DT(1).EQ.0.0, DT(1)=0.001 in the program.
RDT(1)	Reynolds number based on displacement thickness at the start of the boundary layer calculation: If IOP.EQ.4, RDT(1) becomes $(x_2-x_1)U(x_2)/\nu_\infty$ and can be calculated in the program (see WSTO(3) input).
BS	Input for initial pressure gradient: If IOP.EQ.1, BS is $(dU/dx)\delta^{*2}/\nu_\infty$. If IOP.EQ.2, BS is $\delta^*(dp/dx)/\tau_W$. If IOP.EQ.3, BS is $(dU/dx)\delta^*/U$.

TABLE IV. - ALTERNATIVE VALUES OF MOP

Flow properties		Method of obtaining $g'(\eta)$ profile
Not variable	Variable	
-1	1	h^o assumed constant and equal to h_e^o throughout the layer; $g'(\eta) = 0.0$.
-2	2	$g'_w = GBC = \left[h_e^o - h_w(x)\right] \Big/ \left(h_e^o - h_r\right)$ is the wall boundary condition imposed on the energy equation.
-3	3	$g''_w = -(GBC)d_w/\Upsilon_w = -\underset{\sim}{S}_{tr} d_w/\Upsilon_w$ is the wall boundary condition imposed on the energy equation where $\underset{\sim}{S}_{tr} = R_L S_{tr} = L g_w \Big/ \left[\rho_e \nu_\infty \left(h_e^o - h_r\right)\right]$ for laminar similarity starting solutions and $\underset{\sim}{S}_{tr} = S_{tr} = g_w \Big/ \left[\rho_e U \left(h_e^o - h_r\right)\right]$ for all others.

TABLE V. - ALTERNATIVE VALUES OF DOP

Interpretation of input $U_{in}(I)$		Interpretation of input, $f'_{in}(\eta)$ profile
Mach number input, $^a U_{in}(I) \rightarrow M(I)$	Velocity input, $^a U_{in} \rightarrow U(I)$	
-1	1	$^a f'_{in}(\eta) \rightarrow (U - u)/U$ $V_{w_{in}} = V_w$
-2	2	$^a f'_{in}(\eta) \rightarrow (\rho_e U - \rho u)/(\rho_e U)$ $V_{w_{in}} = (\rho_w/\rho_e)/V_w$

[a] These interchanges take place at the beginning of the program and thereafter U(I) and $f'(\eta)$ have their conventional meanings, whereas VW(I) represents $(\rho_w/\rho_e)V_w$ throughout the calculation for DOP = ±2.

	If IOP.EQ.4, BS=1.0 for Falkner-Skan stagnation point flow and BS=0.0 for Blasius flat plate flow. If IOP.EQ.5, BS is $(dU/dx)\delta^{*2}/\nu_\infty$. If IOP.EQ.6, BS is $\delta^*(dp/dx)/\tau_w$. If IOP.EQ.7, BS is $(dU/dx)\delta^*/U$.
TO	Free-stream total temperature in degrees Kelvin.
BH	Enthalpy ratio, $(h_e^o - h_r)/h_e^o$.
FT	Free-stream turbulence, fraction of time during which the flow at a given position remains turbulent.
X(I)	Wall station locations (see Special Instructions for Preparing Input section).
U(I)	Free-stream velocity corresponding to each x-location. The arrays of X(I), U(I), etc., are specified along the boundary surface for the downstream calculations. The maximum number of x-stations that can be computed is 99. The last station data card should be followed by an x-card with an x less than the previous x to switch out of the card read in loop.
TURB(I)	Indicates fraction of flow that is turbulent. For laminar flow, TURB(I)=0.0; for turbulent flows, TURB(I)=1.0. By changing TURB(I) from 0.0 to 1.0, either abruptly or gradually over a distance of several x-stations, the effect of transition can be simulated. Also see WSTO(13). If the transition option is used (i.e., TOP.EQ.1), a TURB(I) input is not needed. If flow is all laminar, TURB(I) input is not needed. If flow is turbulent, set TURB(I)=1.0 at desired X(I) location. All other TURB(I) at locations GT.X(I) will be set to 1.0 by the program.
GBC(I)	Wall boundary condition on the energy equation, either g'(wall) or g''(wall).
RW(I)	Radius of body surface in the same units as x. If IO=0, RW=0.0.
VW(I)	Transpiration velocity in the same units as U.
SW(I)	Nikuradse sandgrain roughness scale in the same units as x.

CW(I)	Longitudinal wall radius of curvature in the same units as x.

The ISTO and WSTO arrays are now described.

ISTO(1)	If ISTO(1).NE.0, then the program lists input data. ISTO(2), ISTO(3), ISTO(4), and ISTO(7) are options used to list boundary layer velocity profiles.
ISTO(2)	If ISTO(1).EQ.-1, skip listing the profiles except at the x-location denoted by ISTO(7), or at the last x-location calculated if separation occurs. If ISTO(2).EQ.0, the profiles are listed on each profile point to the profile end provided there is no u/U.GT.1 overshoot. On overshoot with WSTO(1).LE.1 each succeeding JDIV point is listed unless ISTO(4).NE.0. If ISTO(2).EQ.1, FILE lists only the profile end values at the wall and boundary layer edge (provided ISTO(4).NE.0 to bypass the possible profile overshoot). If ISTO(2).EQ.2, the profiles are listed on each profile point to the first point greater than WSTO(1). If ISTO(2).EQ.3, the profiles are listed on each profile point at the JDIV interval to the profile end. If ISTO(2).GE.3 or .LT.-1, only the value of each profile at the wall is listed unless overshoot (u/U.GT.1) occurs. Overshoot is suppressed if ISTO(4).NE.0.
ISTO(3)	Used to compute the profile point list interval. List internal = ISTO(3)* JDIV.
ISTO(4)	If ISTO(4).NE.0, the list for the overshoot (u/U.GT.1) portion of the profile is suppressed.
ISTO(5)	If ISTO(5).EQ.1, the program lists the momentum and energy equation boundary values for each iteration if POP.EQ.0. If ISTO(5).EQ.0, the program does not list transition statistics or viscosity functions VE, VEG, etc., at the wall.
ISTO(6)	If ISTO(6).EQ.1, the energy and momentum balances COF1, COF2, etc., together with their ratio are listed for all computed x-stations.
ISTO(7)	x-Location number that a profile list is required.
ISTO(8)	Used to include a linear section of x-station data from x = 0 to some x-location specified by slope test. ISTO(8) must be greater than or equal

to 1 to include linear section. The end point of the linear section after the interpolation of new x points equals ISTO(8) plus the x-station number of the last station read in before the interpolation. The total number of x-station points will be increased by ISTO(8)+1. This option should be used only when the slope of the input data increases somewhere between x = 0 and the first maximum.

ISTO(9)	Determines the end point of the linear section. If the x-station data read in is greater than ISTO(9)+2, begin the slope test.
ISTO(10)	Input is not used by program. However, ISTO(10) can be used as an identification of the input data decks, such as EQ. 1 for first case, EQ. 2 for second case, etc.
ISTO(11)	If ISTO(11).EQ.1, one set of station data read in on tape. If ISTO(11).EQ.2, more than one set of station data read in on tape.
ISTO(12)	Nondimensionlizes x-station data after computations. If ISTO(12).EQ.0 and WSTO(10).EQ.0, x-station data are nondimensionalized with the last x-station to be computed.
ISTO(13)	Used to list full profile near zero shear.
ISTO(14)	If ISTO(14).EQ.1, turbulent restart occurs at the point of laminar separation.
ISTO(15)	If ISTO(15).EQ.0, station data are read in from tape. If ISTO(15).NE.0, station data are read in from cards.
WSTO(1)	Used to set amplitude list limit for the profile u/U usually taken as 0.9999.
WSTO(2)	Used to limit amplitude of profiles u/U for calculations.
WSTO(3)	Used to recalculate RDT(1). If IOP.EQ.4, WSTO(3)=1/ν(1).
WSTO(K)	k = 4, 6, 7 are used only if ((RX*RW(I))**2).GE.1 where CA1=WSTO(4)+WSTO(6)*X(I)+WSTO(7)*X(I)*X(I). See subroutine ITSR.
WSTO(5)	Used as a scale factor for X(I) before computations. If WSTO(5).NE.0, then X(I)=WSTO(5)*X(I) on read in. Likewise for RW(I).
WSTO(8)	Used as a scale factor for U(I) before the boundary layer computations. If WSTO(8).NE.0, then U(I)=WSTO(8)*U(I).
WSTO(9)	If WSTO(9).NE.0.0, COTR sets GP(I)=WSTO(9)*GP(I) on read in.
WSTO(10)	If WSTO(10).EQ.0 and ISTO(12).EQ.0, the program sets WSTO(10)=X(IX) where IX is the station number of the last x-station to be computed. If

	WSTO(10).NE.0 x is nondimensionalized after computations and X(I) is scaled X(I)=X(I)/WSTO(10).
WSTO(11)	Used to compute RDT(1). If IOP.EQ.7 and DOP.GT.0, RDT(1)=U(1)*DT(1)/WSTO(11). WSTO(11)=ν(1). If WSTO(11).EQ.0, the program sets WSTO(11)=0.1564*10**-3.
WSTO(12)	Not used.
WSTO(13)	Value of TURB(I) in the transition region for which turbulent restart will be allowed.
WSTO(14)	If WSTO(14).EQ.0, turbulent Prandtl number (PRT).EQ.1.0. If WSTO(14).NE.0, PRT=WSTO(14).
WSTO(15)	If WSTO(15).EQ.0, molecular Prandtl number (PR).EQ.0.78. If WSTO(15).NE.0, PR=WSTO(15).
WSTO(16)	Used as a conversion factor for U(I) before boundary layer computations. If WSTO(16).NE.0, U(I)=WSTO(16)*U(I).
WSTO(17)	Used as a multiplier for GBC. If WSTO(17).NE.0, GBC=WSTO(17)*GBC(I).
WSTO(18)	Sonic velocity corresponding to static temperature at start of boundary layer calculation.
WSTO(19)	Static temperature at start of boundary layer calculation.
WSTO(20)	Not used.

A master input data sample with comments of the input variables is shown in table VI. Table VI illustrates the use of subroutine A6IR to read in and list comment cards in the input deck.

Special Instructions for Preparing Input

Specification of profiles. - The input intervals of η are subdivided by the input JDIV. For a laminar calculation the η step need not vary appreciably across the layer, and the product of JY and JDIV equal to 150 is usually adequate to define a profile. However, in a turbulent portion of the x-profiles a smaller step size should be prescribed close to the wall than is specified further out to improve the accuracy in the "law-of-the-wall" region. The η step size although variable from wall to boundary layer edge, remains fixed throughout the boundary layer calculations. The input step sizes should be specified for accurate results in both laminar and turbulent portions of the flow. The outer edge of the boundary layer in the η coordinate will not

TABLE VI. - MASTER INPUT DATA SAMPLE

```
$DATA
 *                 A TEST CASE FOR THE TUF PROGRAM.......               *
 *                                                                      *
 *          IF ISTO(15).EQ.0 FOR TAPE READ OF THE X-STATION DATA THEN   *
 *          THE X-STATION DATA CARDS ARE TO BE DELETED.  ALSO ISTO(K),  *
 *          K= 11,12 MUST BE PROPERLY SET.                              *
 *                                                                      *
 *          ISTO(K),  K=1,15                          FORMAT (15I5)     *
 *                                     ISTO(1)                          *
 *          IF ISTO(1).NE.0 THEN SUBR COTR LISTS EITHER THE INPUT DATA  *
 *          OR THE MODIFIED INPUT DATA.  IF ISTO(1).EQ.2 THEN SUBR INIR *
 *          LISTS ALSO THE MAJOR BOUNDARY PARAMETERS INCLUDING U(I),    *
 *          M(I), TF(I).  SEE POP HEREIN.                               *
 *                           ISTO(K),  K=  2,3,4,7.                     *
 *          SUBR FILE USES ISTO(K), K= 2,3,4,7 TO LIST AT I(X) THE      *
 *          PROFILES ON Y AS FOLLOWS...                                 *
 *         *ASSUME THAT WSTO(1).LT.1...                                 *
 *          SUBR FILE ALWAYS INITIALIZES THE LIST SHITCH IWSW= ISTO(2)  *
 *          AND THE TEST FOR U(X) OVERSHOOT FOLLOWS IMMEDIATELY.        *
 *          SUBR INIR RESETS JE= MAXO(JEF,JEG) AFTER EXPANDING THE      *
 *          NUMBER OF POINTS ON THE YY(J),FP(J),GP(J) PROFILES BEFORE   *
 *          COMPUTING THE Y(J).  SUBRS ITFR,ITSR RESET JE= MAXO(JEF,JEG)*
 *          AFTER THE EXIT FROM SUBR PROFYL.                            *
 *          JE= MAXO(JEF,JEG) AFTER THE EXIT FROM SUBR PROFYL.          *
 *         *ISTO(2).EQ.-1...                                            *
 *          IF ISTO(2).EQ.-1 THEN FILE SKIPS ALL LISTING EXCEPT TO LIST *
 *          A FULL PROFILE ON EITHER ISTO(7).EQ.I(X) OR AN END OF CASE  *
 *          ON ISTO(10).EQ.5,6 IN SUBR ITSR WHICH IS FOLLOWED BY A CALL *
 *          OF FILE BY SUBR NDIR.  SEE ISTO(7).                         *
 *         *ISTO(2).EQ. 0...                                            *
 *          IF ISTO(2).EQ.0 THEN FILE LISTS ON EACH                     *
 *          LSPT= LSPT + (JPTS= ISTO(3)*JDIV)  PROFILE POINT TO THE     *
 *          PROFILE END JE PROVIDED THERE IS NO U(Y)/U(BLE) .GT.1       *
 *          OVERSHOOT.  ON OVERSHOOT WITH WSTO(1).LE.1 EACH SUCCEEDING  *
 *          JDIV POINT IS LISTED UNLESS ISTO(4).NE.0.                   *
 *         *ISTO(2).EQ. 1...                                            *
 *          IF ISTO(2).EQ.1 THEN FILE LISTS ONLY THE PROFILE END VALUES *
 *          AT THE WALL AND BOUNDARY LAYER EDGE (BLE) J= JE PROVIDED    *
 *          ISTO(4).NE.0 TO BYPASS THE POSSIBLE U OVERSHOOT.            *
 *         *ISTO(2).EQ. 2...                                            *
 *          IF ISTO(2).EQ.2 THEN FILE LISTS AS FOR 0 EXCEPT THE LISTING *
 *          IS ENDED ON THE 1ST LISTED POINT AFTER U(Y)/U(BLE) .GT.     *
 *          WSTO(1).  TO LIST THE FULL PROFILE ON ISTO(2).EQ.2, AND AT  *
 *          EACH LSPT POINT ON AN EXPECTED OVERSHOOT, SET WSTO(1)= 10.  *
 *          FOR EXAMPLE, AND SET ISTO(4).NE.0.                          *
 *         *ISTO(2).EQ. 3...                                            *
 *          IF  ISTO(2).EQ.3 FILE LISTS EACH PROFILE POINT AT THE JDIV  *
 *          INTERVAL TO THE PROFILE END AT JE.  THE ISTO(4) SWITCH IS   *
 *          INEFFECTIVE.  IWSW MAY BE RESET = 3 AFTER IWSW= ISTO(2).    *
 *         *ISTO(2).GT.3 OR .LT.-1...                                   *
 *          IF ISTO(2).GT.3 OR .LT.-1, SAY 4 OR -2, THEN FILE LISTS ONLY*
 *          THE WALL VALUE OF EACH PROFILE UNLESS OVERSHOOT ON U(Y)     *
 *          OCCURS.  ON OVERSHOOT LISTING IS SUPPRESSED IF ISTO(4).NE.0.*
 *                                     ISTO(3)                          *
 *          ISTO(3) IS USED TO GET THE STANDARD LIST INTERVAL OR        *
```

TABLE VI. - Continued. MASTER INPUT DATA SAMPLE

```
*          JPTS=ISTO(3)*JDIV FOR THE LIST ON LSPT= LSPT + JPTS.        *
*                                     ISTO(4)                          *
*          IF ISTO(4).NE.0 THEN FILE SUPPRESSES THE RESET OF THE IWSW  *
*          LIST SWITCH= 3 ON U(Y)/U(BLE).GT.1., AND, ALSO SKIPS THE    *
*          LISTING OF THE HEADING.                                     *
*          IF ISTO(4).EQ.1 THEN FILE SKIPS THE LISTING OF ALL SECONDARY*
*          PROFILE POINTS SUCH AS TAU...                               *
*                                     ISTO(5)                          *
*          ISTO(5) IS TESTED ONLY IN SUBRS ITFR,ITSR,VIS,TRANS.        *
*          IF ISTO(5).NE.1 THEN SUBR ITFR BYPASSES BOTH TEST AND LIST  *
*          ON POP.                                                     *
*          IF ISTO(5).NE.1 THEN SUBR ITSR BYPASSES THE TEST OF POP     *
*          TO LIST THE MOMENTUM AND ENERGY EQUATION BOUNDARY VALUES    *
*          FOR EACH ITERATION.  THE TEST OF POP TO LIST SOME IMPORTANT *
*          INPUT PARAMETERS BY SUBR INIR IS UNAFFECTED BY ISTO(5).     *
*          NEITHER ISTO(5) NOR POP AFFECTS THE CALL OF SUBR FILE BY    *
*          SUBR ITSR.                                                  *
*          IF ISTO(5).EQ.0 SUBR VIS BYPASSES THE LISTING AT THE WALL   *
*          OF THE VISCOSITY FUNCTIONS VE,VEG,VHP,VH WHEN AT LEAST ONE  *
*          OF THE FUNCTIONS = 0.0 AT THE WALL.                         *
*          IF ISTO(5).EQ.0 SUBR ITSR BYPASSES THE LISTING OF THE       *
*          TRANSITIONAL STATISTICS.                                    *
*          IF ISTO(5).EQ.0 SUBR TRANS SKIPS LISTING OF MISCELLANEOUS   *
*          TRANSITIONAL STATISTICS.                                    *
*          IN ITFR THE STARTING PROFILES OF THE MOMENTUM AND ENERGY    *
*          EQUATIONS TOGETHER WITH THE BOUNDARY CONDITIONS AT I(X)=1,2 *
*          ARE ALWAYS LISTED IF ISTO(1).NE.0.AND.IOP.GT.3.  OTHERWISE  *
*          IF ISTO(5).EQ.1.AND.POP.NE.1 THE STARTING PROFILES WILL BE  *
*          LISTED.  FOR IOP.LE.3 THE INITIAL PROFILES LISTED BY SUBR   *
*          FILE IN SUBR INIR ARE THE STARTING PROFILES.                *
*                                     ISTO(6)                          *
*          IF ISTO(6).EQ.1 SUBR ITSR LOADS CLIS(J) WITH A TABLE OF     *
*          COF1,COF2,COG1,COG2 FOR ALL COMPUTED X-STATIONS AND SUBR    *
*          NDIR LISTS CLIS(J) TOGETHER WITH THE RATIOS R21F,R21G WHERE *
*          R21F= COF2/COF1 AND R21G= COG2/COG1.                        *
*                                     ISTO(7)                          *
*          ISTO(7) IS A SWITCH USED BY SUBR FILE TO OVER RIDE THE      *
*          NORMAL LIST OPTION AT I(X) IN ORDER TO LIST A SET OF FULL   *
*          PROFILES ON THE SUBR FILE SWITCH IWSW= 3.                   *
*          THE VALUE OF ISTO(7) AT THE TIME OF READ-IN ALWAYS YIELDS A *
*          SUBR FILE LISTING AT I(X)= ISTO(7)  IF SUBR FILE IS CALLED. *
*          IF ISTO(7).EQ.I (X-STATION NUMBER) SUBR FILE RESETS         *
*          IWSW= 3 AND LISTS AS FOR ISTO(2)= 3 TO JE= MAXO(JEF,JEG)    *
*          WHICH IS A RESET IN BOTH ITFR AND ITSR AFTER THE EXIT FROM  *
*          SUBR PROFYL.                                                *
*          SUBR INIR RESETS JEF,JEG AFTER EXTENDING THE PROFILES       *
*          ON JDIV.  LATER SUBR PROFYL RESETS JE= J WHEN               *
*          ABS(FP(J)).LE.1.*E-08, BUT AGAIN SUBRS ITFR,ITSR RESET JE.  *
*          ISTO(7) IS RESET= I(X) BY SUBR ITFR BEFORE MAKING THE TEST  *
*          IF ISTO(1).NE.0.AND.IOP.GT.3 CALL FILE,FOLLOWED BY THE TEST *
*          IF ISTO(5).EQ.1.OR.POP.NE.1 CALL FILE.     ISTO(7) IS       *
*          ALSO RESET TO (I) AT I(X) BY SUBR ITSR FOR A DETAIL LIST ON *
*          COMING CLOSE TO TURBULENT FLOW FROM LAMINAR FLOW.  SEE      *
*          ISTO(13).                                                   *
*          BOTH SUBRS ITFR, ITSR RESET ISTO(7) TO THE SUBR COTR READ-IN*
*          VALUE AFTER LEAVING SUBR FILE.                              *
*                                     ISTO(8)                          *
*          IF ISTO(8).NE.0 THEN ISTO(8) IS USED TO INCLUDE A LINEAR    *
*          SECTION OF X-STATION DATA BETWEEN X= 0.0 AND X(I)= X(IS-1)  *
*          BASED ON A SLOPE TEST.  THE TOTAL NUMBER OF X STATION POINTS*
```

TABLE VI. - Continued. MASTER INPUT DATA SAMPLE

```
*          WILL BE INCREASED BY ISTO(8) + 1.                            *
*          TO INCLUDE THE LINEAR SECTION ISTO(8) MUST BE .GE.1.  THEN   *
*          I(X) AT THE END POINT OF THE LINEAR SECTION AFTER THE        *
*          INTERPOLATION = ISX= ISTO(8)+IS(L) WHERE IS(L) IS THE X      *
*          STATION NUMBER OF THE LAST STATION READ IN BEFORE THE        *
*          INTERPOLATION.  THEN IS(L).GE.3 AND BECOMES .GE.5 OR AFTER   *
*          THE INTERPOLATION (IS) BECOMES = ISTO(8) + IS(L) + 1.  THE   *
*          TOTAL NUMBER OF STATIONS TO BE COMPUTED = IX = TOTAL         *
*          NUMBER OF X STATIONS READ IN, PLUS,IF ISTO(8).NE.0 THE       *
*          ADDITIONAL POINTS ISTO(8)+1, BUT IX IS CUT TO BE .LE.99.     *
*                                    ISTO(9)                            *
*          ISTO(9) IS USED BY SUBR COTR TO DELAY THE SLOPE TEST UNTIL   *
*          I(X).GT.(ISTO(9)+2).  THE SLOPE TEST CAUSES AN INSERTION     *
*          OF A LINEAR SECTION FROM X= 0.0 TO X(ISX) ONLY IF THE SLOPE  *
*          DUX OF THE DATA AT THE U(X) PLACE IN THE X-STATION DATA      *
*          FROM X(I-1) TO X(I) .GT. THE SLOPE DUZ FROM X= 0.0 TO X(I-1)*
*          .OR. (IOP.EQ.4.AND.BS.EQ.1) .OR. LINE.EQ.1 WHERE LINE IS     *
*          SET = 1 AFTER DUX.GT.DUZ.                                    *
*          U(1) NEED NOT BE ZERO FOR THE SLOPE TEST, AND IS USED        *
*          TOGETHER WITH U(I-1) TO COMPUTE THE SLOPE OF THE LINEAR      *
*          PORTION OF THE U(X) CURVE WHERE U(X) IS M(X) IF DOP.LT.0.    *
*          HOWEVER, U(1) IS RESET TO 0.0 BEFORE THE INTERPOLATION IF    *
*          IOP.EQ.4.                                                    *
*          THE TEST FOR ENDING THE STATION DATA READ IN ON              *
*          ( X(I) - X(I-1) ) .LE. 0.0 BEGINS ONLY WHEN I(X).GT.IPS      *
*          WHERE  IPS= ISTO(9) + 2 WHEN THE X-STATION DATA IS READ IN   *
*          FROM THE TAPE.                                               *
*                                    ISTO(10)                           *
*          ISTO(10) IS USED BOTH AS A TELL-TALE AND AS A SWITCH.        *
*          SUBR NDIR USES ISTO(10) AS A SWITCH TO RE-INITIALIZE THE     *
*          NECESSARY PARAMETERS FOR A RESTART IN SUBR ITFR ON A CALL BY*
*          TUF. ISTO(10) IS ALSO USED BY TUF TO GO TO THE NEXT CASE     *
*          ON A CALL OF SUBR INIR AFTER AN EXIT FROM EITHER INIR ON     *
*          ISTO(10).EQ.9 OR ITFR ON ISTO(10).EQ.8.  IF EITHER JEF,JEG,  *
*          JY IS .GT.300 ON THE RETURN FROM SUBR COTR THEN SUBR INIR    *
*          RESETS ISTO(10)=9.   IF ONLY THE STARTING PROFILE IS TO BE   *
*          COMPUTED, IX.EQ.1,2 THEN SUBR ITFR RESETS ISTO(10)=8 BEFORE  *
*          EXITING TO TUF.                                              *
*          ISTO(10) IS INITIALIZED = 0 BY SUBR INIR AND RESET = 1 BY    *
*          SUBR COTR AFTER THE ISTO(K) READ-IN, =2 BY ITFR, =3 BY ITSR,*
*          AND IS RESET = 4,5,6,7 BY SUBR ITSR BEFORE THE EXIT TO TUF.  *
*          SUBR ITSR RESETS ISTO(10)= 4 BEFORE EXITING ON I= IX.        *
*          SUBR ITSR RESETS ISTO(10)= 5 FOR A NON-SCHEDULED CASE END IF*
*          F(JEF).LT.0.0.OR.F(JEF).GT.WSTO(2) UNLESS TOP=1.AND.I.LT.IX.*
*          HENCE ISTO(10).EQ.5 DOES NOT OCCUR WHEN SUBR TRANS IS CALLED*
*          EXCEPT POSSIBLY AT THE LAST OR IX POINT.                     *
*          SUBR ITSR RESETS ISTO(10)= 6 WHEN LAMINAR SEPARATION OCCURS  *
*          WHICH IS FOLLOWED BY A RE-INITIALIZATION IN SUBR NDIR AND    *
*          A TURBULENT RESTART IN SUBR ITFR PROVIDED ISTO(14).EQ.1.     *
*          LAMINAR SEPARATION OCCURS IF TOP.EQ.1.AND I.LT.IX.AND. IF    *
*          F(JEF).LE.0.0.OR.F(JEF).GE.WSTO(2).OR.FPP(1).GE.0.0.         *
*          SUBR ITSR RESETS ISTO(10)= 7 ON A FORCED TURBULENT RESTART   *
*          BY SUBR ITFR WHEN SUBR ITSR REACHES I(X).EQ.IT.  SEE         *
*          WSTO(13) HEREIN AND IX,IT IN THE COMMENT ON THE SINGLE WORD  *
*          COMMON.                                                      *
*                                    ISTO(11)                           *
*          ISTO(11) IS THE NUMBER OF SETS OF STATION DATA READ IN FROM  *
*          THE TAPE BY SUBR COTR. THE LAST SET OF DATA READ IN IS THE   *
*          SET OF DATA USED AS THE INPUT DATA SINCE THE TAPE IS REWOUND*
*          EACH TIME SUBR INIR IS ENTERED.                              *
```

TABLE VI. - Continued. MASTER INPUT DATA SAMPLE

```
*                                    ISTO(12)                           *
*        ISTO(12) IS USED TO SELECT THE X NON-DIMENSIONALIZING          *
*        NUMBER.  SEE WSTO(10) HEREIN.                                  *
*                               ISTO(12) , WSTO(10)                     *
*        IN SUBR COTR WE HAVE,FOR TESTING AND LISTING BY SUBR NDIR,..*
*        IF WSTO(10).EQ.0.0 AND ISTO(12).EQ.0 THEN  COTR SETS           *
*        WSTO(10)=  X(IX). IX IS THE STATION NUMBER OF THE LAST X       *
*        STATION TO BE COMPUTED.                                        *
*        IF WSTO(10).EQ.0.0 AND ISTO(12).EQ.1.AND.WSTO(5).NE.0          *
*        THEN COTR SETS WSTO(10)= XMAS(1)*WSTO(5) WHERE XMAS(1) IS      *
*        SOME X-DISTANCE SUPPLIED BY THE MAIN SUPERVISORY ROUTINE       *
*        TUF FOR NON-DIMENSIONALIZING PURPOSES WHEN THE X-STATION       *
*        DATA IS READ IN FROM TAPE.  THE XMAS(K) QUANTITIES, IF USED,*
*        ARE SUPPLIED TO THE ROUTINE TUF BY THE ROUTINE WHICH CALLS     *
*        TUF ON THE CONVERSION OF TUF TO A SUBROUTINE. SEE TABLE VII.*
*        WSTO(10) IS USED IN SUBRS FILE,NDIR.                           *
*                                    ISTO(13)                           *
*        IF ISTO(13).LT.0 AND ABS(ISTO(13)).GT.ANY I(X) SKIP FULL       *
*        PROFILE LIST IN SUBR FILE ON X(I) BASED ON THE TEST FOR NEAR*
*        ZERO SHEAR IN SUBR ITSR.                                       *
*        IF THE X INTERCEPT OF CF(I(X)) IS EITHER.GT.(X(I)+ISTO(13))    *
*        .OR.LT.X(I) SKIP THE SUBR FILE LISTING ON THE IWSW= 3 RESET.*
*                                    ISTO(14)                           *
*        IF ISTO(14).EQ.1 THEN SUBR NDIR PREPARES FOR A TURBULENT       *
*        RESTART IN SUBR ITFR WHEN LAMINAR SEPARATION OCCURS            *
*        WITHIN SUBR ITSR WHICH THEN SETS ISTO(10)= 6.                  *
*                                    ISTO(15)                           *
*        IF ISTO(15).EQ.0 THE X-STATION DATA IS READ IN FROM TAPE.      *
*        IF ISTO(15).NE.0 THEN READ IN THE X-STATION DATA FROM CARDS.*
*        IF ISTO(15).NE.0 THEN THE SWITCH ISTO(11) IS BYPASSED.         *
*        IF ISTO(15).EQ.0 THE CARDS OF STATION DATA MUST BE DELETED.    *
*        ISTO(16) IS NOT READ IN.  NOR USED.                            *
*                                                                       *
*        ISTO(K),  K=  1,15                        FORMAT  ( 15I5 )     *
*
    1    2    2    1   -1    1    1    2    2    1    2    1                  1
*        WSTO(K), K=1,20.                          FORMAT(5E15.8)       *
*                                    WSTO(1)                            *
*        WSTO(1) IS USED BY SUBR FILE AS THE U/U(BLE) AMPLITUDE         *
*        LIST LIMIT.                                                    *
*        IF U/U(E).GT.WSTO(1).AND.ISTO(2).EQ.2 SUBR FILE ENDS FURTHER*
*        PROFILE LISTING ON Y AT X(I).                                  *
*                                    WSTO(2)                            *
*        WSTO(2) IS USED BY SUBR ITSR TO LIMIT THE AMPLITUDE OF THE     *
*        F(ETA) PROFILE OUTER END POINT JEF.  SEE ISTO(10) HEREIN.      *
*                                    WSTO(3)                            *
*        WSTO(3) MAY BE USED BY SUBR COTR TO RECOMPUTE RDT(1).     SEE*
*        RDT(1).  ALSO SEE IOP.EQ.4 HEREIN.                             *
*                              WSTO(K), K= 4,6,7                        *
*        WSTO(K), K=4,6,7, ARE USED BY SUBR ITSR IF (RX*RW(I))**2       *
*        .GE.1.TO COMPUTE CA1=WSTO(4)+WSTO(6)*X(I)+WSTO(7)*X(I)*X(I).*
*                                    WSTO(5)                            *
*        SEE ALSO WSTO(10),ISTO(12).                                    *
*        IF WSTO(5).NE.0.0 COTR SETS X(I)= WSTO(5)*X(I) ON READ-IN.     *
*        IF WSTO(5).NE.0.0 COTR SETS RW(I)= WSTO(5)*RW(I) ON READ-IN.*
*                                    WSTO(8)                            *
*        WSTO(8) IS USED AS A RESCALING PARAMETER.                      *
*        IF WSTO(8).NE.0.0 THEN SUBR COTR RESCALES THE QUANTITY         *
*        IN THE U(I) STORE, WHICH WILL BE TREATED LATER AS EITHER       *
*        U(I) OR M(I) ACCORDING TO THE VALUES OF MR AND DOP AS TESTED*
```

TABLE VI. - Continued. MASTER INPUT DATA SAMPLE

```
*         BY SUBR INIR.  AT THE TIME OF RESCALING BY SUBR COTR THE    *
*         QUANTITY IN U(I) IS THE READ-IN QUANTITY IF WSTO(16).EQ.0.0 *
*         BUT IS U(I)= WSTO(16)*U(I) OTHERWISE WHERE WSTO(16) IS USED *
*         TO CONVERT THE UNIT OF MEASUREMENT OF THE INPUT.  FOR THE   *
*         COMPUTATION OF M(I) FROM THE INPUT SEE SWITCH DOP HEREIN.   *
*                                     WSTO(9)                         *
*         IF WSTO(9).NE.0.0 COTR SETS GP(I)= WSTO(9)*GP(I) ON READ IN.*
*                                     WSTO(10)                        *
*         IF WSTO(10).EQ.0.0 AND ISTO(12).EQ.0 THEN  COTR SETS        *
*         WSTO(10)=  X(IX). IX IS THE STATION NUMBER OF THE LAST X    *
*         LAST STATION TO BE COMPUTED.                                *
*         IF WSTO(10).EQ.0.0 AND ISTO(12).EQ.1.AND.WSTO(5).NE.0       *
*         THEN COTR SETS WSTO(10)= XMAS(1)*WSTO(5) WHERE XMAS(1) IS   *
*         SOME X-DISTANCE SUPPLIED BY THE SUPERVISORY ROUTINE TUF, SEE*
*         TABLE VII, AND GOTTEN IN TURN FROM THE SUPERVISORY ROUTINE  *
*         OF TUF WHEN TUF IS CONVERTED TO A SUBROUTINE.  WSTO(10) IS  *
*         USED IN SUBRS FILE,NDIR FOR SCALING PURPOSES TO LIST A      *
*         NON-DIMENSIONALIZED X(I).                                   *
*         IF WSTO(10).NE.0.0 SUBR FILE, AND SUBR NDIR IF THE CASE IS  *
*         ENDED, SCALES X(I)= X(I) / WSTO(10). HENCE IF WSTO(10).EQ.1.*
*         X(I) IS NOT NON-DIMENSIONALIZED AND XNOD= X(I).             *
*         IF WSTO(10).EQ.0.0 IN SUBR FILE THEN XNOD= X(I).            *
*         IF WSTO(10).EQ.0.0 IN SUBR NDIR THEN X(I)= X(I).            *
*                                     WSTO(11)                        *
*         IF IOP.EQ.7.AND.DOP.GT.0.AND.RDT(1).EQ.0.0 SUBR COTR        *
*         COMPUTES  ROT(1)=U(1)*DT(1)/WSTO(11).  IF WSTO(11).EQ.0.0   *
*         SUBR COTR RESETS WSTO(11)= .1564*10**-3  (ENGLISH UNITS).   *
*                                     WSTO(12)                        *
*         WSTO(12) IS NOT USED.  (AT LERC  WSTO(12) IS AN EXECUTION   *
*         TIME LIMITER.)                                              *
*                                     WSTO(13)                        *
*         IF WSTO(13).NE.0.AND.TOP.NE.1 THEN SUBR COTR AFTER ALL      *
*         X-STATION DATA READ-IN RESETS IT= I+1 WHEN                  *
*         TURB(I).GT.WSTO(13).  THEN, LATER, A FORCED TURBULENT       *
*         RESTART OCCURS IN SUBR ITFR FOLLOWING A RESET OF ISTO(10)= 7*
*         IN SUBR ITSR AFTER SUBR ITSR HAS COMPUTED THE X-STATION     *
*         PROFILES FOR I= IT.                                         *
*         SUBR ITFR ON A RESET OF ISTO(10)= 7 IN SUBR ITSR AFTER      *
*         SUBR ITSR HAS COMPUTED THE X-STATION PROFILES FOR I= IT.    *
*                                                                     *
*                                     WSTO(14)                        *
*         IF WSTO(14).NE.0.0 THEN SUBR INIR RESETS PRT= WSTO(14)      *
*                                     WSTO(15)                        *
*         IF WSTO(15).NE.0.0 THEN SUBR INIR RESETS PR= WSTO(15)       *
*                                     WSTO(16)                        *
*         IF WSTO(16).NE.0.0 THEN SUBR COTR RESETS THE QUANTITY IN    *
*         U(I)=  WSTO(16)*U(I) BEFORE A POSSIBLE RESCALING OF THE     *
*         QUANTITY BY WSTO(8).  SEE WSTO(8).                          *
*                                     WSTO(17)                        *
*         IF WSTO(17).NE.0.0 THEN SUBR COTR RESETS                    *
*         GBC(2)= WSTO(17)*GBC(I).                                    *
*                                     WSTO(18)                        *
*         IF WSTO(18).NE.0.0.AND.WSTO(19).NE.0.0 THEN WSTO(18) IS THE *
*         SONIC VELOCITY READ IN CORRESPONDING TO THE TEMPERATURE     *
*         READ IN TO WSTO(19), AND WSTO(18),WSTO(19) ARE USED TO      *
*         COMPUTE GR= G*R OF THE EQUATION                             *
*         VELOCITY(SONIC)= SQRT( SHR*GR*T(STATIC) ).  GR IS COMPUTED  *
*         AND USED BY SUBR INIR TO COMPUTE THE M(I) WHEN THE U(I)     *
*         READ IN BY SUBR COTR IS THE VELOCITY.                       *
*         WSTO(18) IS USED LATER BY SUBR ITSR AS CONVENIENT STORAGE.  *
```

TABLE VI. - Continued. MASTER INPUT DATA SAMPLE

```
 *                                          WSTO(19)                          *
 *          SEE  WSTO(18) HEREIN.                                             *
 *          SUBRS INIR,ITSR ALSO USE WSTO(19) AS CONVENIENT STORAGE.          *
 *                                          WSTO(20)                          *
 *          WSTO(20) IS NOT USED.                                             *
 *                                                                            *
 *          WSTO(K),  K=  1,20                                FORMAT  ( 5E15.8 )*
 *
  .99990000E+00  .20000000E+02  .62200000E+06                                      WSTO
+0.00000000E+00                                                     .10000000E+01 WSTO
0.15640000E-03   .17500000E+03                                                    WSTO
+0.00000000E+00                                                                   WSTO
 *                                                                            *
 *          LABEL(K), K=1,18 ON FORMAT (18A4) THE X-STATION HEADING CARD*
 *          IS THE NEXT DATA CARD.                                            *
 *
L***...DIFFUSER STUDY......................................DIFFUSER STUDY...
 *          JDIV IS USED BY SUBRS COTR,INIR FOR INCREASING THE NUMBER OF*
 *          POINTS ON THE INPUT YY(J),FP(J),GP(J) PROFILES.                   *
 *          JDIV                                              FORMAT  ( 15I5 )  *
 *
    3
 *          THREE SETS OF DATA FOLLOW FOR THE PROFILES OF YY(J),FP(J),  *
 *          GP(J).  THE NUMBER OF POINTS ON EACH PROFILE IS INCREASED   *
 *          BY SUBR COTR.  SUBR INIR LATER COMPUTES THE EXPANDED        *
 *          INITIAL PROFILES OF YY(J),FP(J),GP(J).                      *
 *          IF LISTED THEN GET FOR EACH PROFILE NO. OF WORDS INPUT,     *
 *          NO. LAST STORE OF PROFILE, AND JDIV FOLLOWED BY THE CARD    *
 *          INPUT.                                                      *
 *          YY(J) IS THE COORDINATE FOR THE INPUT F°(ET),G°(ETA) DATA.  *
 *          SUBR PROFYL RESETS JE=J(Y) WHEN ABS(FP(J)).LE.1.*10**-8.    *
 *          BUT SUBRS INIR,ITFR,ITSR RESET JE= MAX0(JEF,JEG) AFTER EXIT *
 *          FROM PROFYL.                                                *
 *                                                                      *
 *          JY ON FORMAT (15I5) THEN YY(J), J=1,JY ON FORMAT (6F10.5)   *
 *
   48                                                                     JY
0.0         0.002      0.005      0.01       0.02       0.05              YY06
.7            .8         .9         1.0        1.2        1.4             YY18
 .1           .2         .3          .4         .5          .6             YY1
1.6         1.8        2.0        2.5         3.0       3.5               YY24
4.0         4.5        5.0        5.5        6.0        6.5               YY30
7.0          7.5       8.0         8.5       9.0         9.5              YY36
10.         11.        12.        13.        14.        16.               YY42
18.          20.       22.         24.       26.        28.               YY48
 *                                                                      *
 *          FP(J) = F°(ETA) IS THE MOMENTUM EQUATION INITIAL PROFILE.   *
 *          THE CARD DATA INPUT PROFILE F°(ETA) VS YY(ETA) IS CLOSE TO A*
 *          SIMILAR LAMINAR PROFILE ON A CYLINDER ( U(X=0.0)= 0.0).     *
 *                                                                      *
 *          JEF ON FORMAT (15I5). THEN FP(J), J=1,JEF ON FORMAT (6F10.5)*
 *
   36                                                                     JEF
1.          .998       .996       .992        .985      .962              FP06
.926        .855       .78        .726       .666       .60               FP12
.555         .505      .457       .413       .333      .265               FP18
.208        .161       .123       .0588      .0261     .0108              FP24
.00427      .00162     .000607    .000229    .0000895  .0000366           FP30
.0000157    .00000696 .00000316 .00000144 .00000062 .00000023             FP36
 *                                                                      *
```

TABLE VI. - Continued. MASTER INPUT DATA SAMPLE

```
*          GP(J)= G'(ETA) IS THE ENERGY EQUATION INITIAL PROFILE.        *
*                                                                        *
*          JEG ON FORMAT (15I5). THEN GP(J), J=1,JEG ON FORMAT (6F10.5)*
*
    6                                                                          GP
0.0        0.0       0.0       0.0       0.0       0.0                       GP06
*                                                                        *
*          IOP,MOP,DOP,IO,TOP,POP ON FORMAT (15I5) IS THE NEXT DATA      *
*          CARD.                                                         *
*          IOP HAS OPTIONS 1,2,3,4,5,6,7 LISTED IN THE DISCUSSION OF     *
*          INPUT VARIABLES.  SEE ALSO REF. 1.                            *
*          IF IOP.EQ.1,2,3 THE INPUT PROFILE IS THE STARTING PROFILE.    *
*          IF IOP.EQ.EITHER 1,5 THE STARTING FLOW IS LAMINAR.            *
*          IF IOP.EQ. EITHER 2,3 THE STARTING FLOW IS TURBULENT.         *
*          IF IOP.EQ.4 THE STARTING FLOW IS SIMILAR LAMINAR.             *
*          IF IOP.EQ. EITHER 6,7 THE STARTING FLOW IS TURBULENT.         *
*          IF IOP.EQ.4 SUBR INIR RESETS IS=2 AND THE STARTING PROFILE    *
*          IS AT I(X)= IS= 2.  ONLY ON IOP.EQ.4 DO CALCULATIONS START    *
*          FROM THE BEGINNING OF THE BOUNDARY LAYER GROWTH.              *
*          IF IOP.EQ.4.AND.BS.EQ1 THEN SUBR COTR RESETS U(X=0.0)=0.0.    *
*          IF IOP.EQ.2.3,6,7 SUBR COTR RESETS TOP=0 AND TURB(IS)=1.0     *
*          IF IOP.EQ.EITHER 4,7 SUBR COTR MAY RECOMPUTE RDT(1) AND MR.   *
*          IF IOP.EQ.7 SUBR COTR RECOMPUTES BS, ALSO RESETS DT(1)=.001   *
*          WHEN DT(1).EQ.0.0  ON THE DT(1) READ-IN.                      *
*                                    MOP                                 *
*          MOP.EQ.-1,-2,-3,+1,+2,+3 FOR OPTIONS ON THE G'(ETA), GBC(I)   *
*          PROFILES IN SUBRS ITFR, ITSR. IBC= ABS(MOP) IN ITFR,ITSR.     *
*          FOR BOTH SUBRS ITFR AND ITSR...                               *
*          IF ABS(MOP).EQ.1.OR.MOP.LT.0 COMPUTE THE PROFILES IN THE      *
*          MOMENTUM EQUATION LOOP TO CONVERGENCE ONLY ONCE AT EACH       *
*          I(X) WALL STATION.  FOR ABS(MOP).EQ.1 THEN BYPASS THE         *
*          ENERGY EQUATION SECTION AND EXIT TO THE STATION PARAMETER     *
*          SECTION.  IF THE ENERGY EQUATION SECTION IS ENTERED AND IF    *
*          MOP.LT.0 COMPUTE THE ENERGY PROFILES ONCE AND EXIT TO THE     *
*          STATION PARAMETER SECTION.  FOR MOP.LT.0 THE DENSITY PROFILE*
*          D(J) IS INITIALIZED = 1., AND THE X-DERIVATIVES OF THE        *
*          DENSITY PROFILES DP(J),DB(J) ARE INITIALIZED = 0.0 IN SUBR    *
*          INIR AND REMAIN UNCHANGED FOR ALL SUCCEEDING X-STATIONS.      *
*          SEE ALSO TABLE IV, AND THE IBC ENTRY IN THE SINGLE WORD       *
*          COMMON DISCUSSION.                                            *
*                                    DOP                                 *
*          DOP IS FOR THE INTERPRETATION OF INPUT...SEE TABLE V.         *
*          BEFORE THE TESTS ON DOP AND MR IN SUBR INIR THE DATA INPUT    *
*          BY SUBR COTR IN THE U(I) PLACE OF THE X-STATION DATA IS       *
*          MODIFIED ACCORDING TO THE VALUES OF WSTO(K), K= 8,16.         *
*          IF MR AFTER SUBR COTR.LT.0.OR.DOP.GT.0 THEN SUBR INIR         *
*          COMPUTES M(I) AND TF(I) FROM THE U(I)= THE MODIFIED           *
*          VELOCITIES.                                                   *
*          IF MR.GE.0.OR.DOP.LE.0 THEN SUBR INIR COMPUTES TF(I) AND      *
*          U(I) FROM THE MODIFIED U(I)= THE MODIFIED MACH NUMBERS.       *
*          IF DOP.GT.0.OR.MR.LE.0 THEN SUBR INIR COMPUTES UNS= THE       *
*          READ-IN VALUE OF U(I) IN ORDER TO COMPUTE M(I), TF(I), AND    *
*          THEN RESETS MR= M(1), ML=MR, AND TFR IS RECOMPUTED.           *
*          IF DOP.LE.0.OR.MR.GE.0.0 THEN M(I) IS RESET (DIVIDED BY       *
*          WSTO(8) IF WSTO(8).NE.0.0) TO THE VALUE OF M(I) AFTER THE     *
*          MULTIPLICATION BY WSTO(16) IF WSTO(16).NE.0.0.  THEN          *
*          TF(I) AND U(I) ARE COMPUTED FOLLOWED BY A RESCALING OF U(I) *
*          BY A MULTIPLICATION BY WSTO(8) IF WSTO(8).NE.0.0.             *
*          FOR DOP EITHER +2,-2 VW(I) (INPUT)=  V(WALL)*DENSITY(WALL) /*
*          (DENSITY(BLE)) = VW(I) ALWAYS, AND                            *
```

TABLE VI. - Continued. MASTER INPUT DATA SAMPLE

```
*        F'(ETA)= (DENSITY(BLE)*U(BLE)-DENSITY(ETA)*U(ETA) /          *
*        (DENSITY(BLE)*U(BLE).                                        *
*        FOR DOP EITHER +1,-1  VW(I)(INPUT) = V(WALL) AND             *
*        F'(INPUT)(ETA) =  ( U(BLE)-U(ETA) ) / U(BLE). SEE TABLE V.   *
*        HOWEVER, IF IABS(DOP).EQ.1.AND.MOP.GE.0 THEN SUBR INIR       *
*        ALWAYS RECOMPUTES F'(ETA)= FP(J) FROM THE TF(J) AND THE      *
*        FP(J),GP(J) PROFILES BEFORE COMPUTING THE FPP(J) PROFILE.    *
*        THE ALTERED PROFILES ARE THEN USED TO COMPUTE THE VE(J),     *
*        VEG(J) BY SUBR VIS  AND THE TAU(J) PROFILE LATER BY INIR.    *
*                                 IO                                  *
*        IO.EQ.-1 FOR AXISYMMETRIC FLOW ON THE INSIDE SURFACE FORMED  *
*        BY RADII DRAWN FROM THE BODY AXIS.                           *
*        IO.EQ.+1 FOR AXISYMMETRIC FLOW ON THE OUTSIDE SURFACE FORMED*
*        BY RADII DRAWN FROM THE BODY AXIS.                           *
*        IF IO.EQ.0 SUBR COTR RESETS RW(IS)= 0.0                      *
*                                 TOP                                 *
*        IF TOP.EQ.1 IN SUBR ITSR THEN ITSR CALLS SUBR TRANS TO       *
*        INCLUDE THE TRANSITION ZONE.                                 *
*        TOP IS RESET=0 IF IOP.EQ.2,3,6,7 AT THE TIME OF TOP READ-IN.*
*        IF TOP AT THE TIME OF THE X-STATION DATA READ-IN = 1, THEN   *
*        SUBR COTR RESETS TURB(I)= 0.0.                               *
*        IF TOP.NE.1.AND.WSTO(13).NE.0.0 SEE COMMENT ON WSTO(13).     *
*                                 POP                                 *
*        EXCEPTING SUBR ITFR, POP DOES NOT AFFECT THE CALL OF         *
*        SUBR FILE.                                                   *
*                                                                     *
*        IN SUBR INIR...                                              *
*        IF EITHER ISTO(1).EQ.2 OR POP.NE.1                           *
*        THE FOLLOWING LISTINGS OCCUR AFTER THE EXIT FROM SUBR FILE   *
*        WHICH IS ALWAYS CALLED BY SUBR INIR AND WHICH LISTS          *
*        ACCORDING TO ISTO(K), K= 2,3,4,7.  THE FOLLOWING LISTINGS    *
*        OCCUR JUST BEFORE THE EXIT TO THE CALLING ROUTINE TUF.       *
*        IF POP.NE.1 WRITE (6,49), WRITE (6,50) LABEL(K), FOLLOW      *
*        WITH WRITE (6,K), K= 52,53,54,55,56,60 THE INITIAL           *
*        PARAMETERS AND THE X-STATION DATA AT THE STARTING STATION    *
*        I(X)= 1, AND, IF IOP.EQ.4 THE STARTING X-STATION DATA AT     *
*        I(X)= 2.                                                     *
*        ALSO WRITE THE PROFILES  OF M(I),TF(I),U(I) AND THE INITIAL  *
*        WALL PARAMETERS AT I= 1,2.                                   *
*                                                                     *
*        IN SUBR ITFR...                                              *
*        IF ISTO(5).EQ.1.AND.POP.NE.1 WRITE (6,70),(6,71) I,ISTO(10).*
*        IF POP.GT.3...                                               *
*        AT THE HEAD OF THE MOMENTUM-ENERGY LOOP IF ISTO(5).EQ.1.AND.*
*        POP.NE.1 THEN WRITE (6,98) I, ISTO(10).  IN THE MOMENTUM     *
*        LOOP IF ISTO(5).EQ.1.AND.POP.NE.1 WRITE (6,72) I,JK,JEF,     *
*        F(JEF),FPP(1),SF(I),P,Q,R,TF(I),M(I),VE(1),VEG(1),VH(1),     *
*        VHP(1),D(1),D(JY),DP(1),DP(JY) ON EACH MOM INDEX.  IN THE    *
*        ENERGY SECTION OF THE MOMENTUM-ENERGY LOOP IF ISTO(5).EQ.1   *
*        .AND.POP.NE.1 WRITE (6,76) I,JEG,GP(1),GPP(1),C,RL ON EACH   *
*        MAE INDEX.                                                   *
*        IF IOP.LE.3...                                               *
*        USE THE SUBRS INIR, COTR PROFILES AS THE STARTING PROFILES   *
*        EXCEPTING THE D(ETA),DP(ETA),DP(ETA) PROFILES ON MOP.GE.0    *
*        AND THE VE(ETA),VEG(ETA) PROFILES BY SUBR VIS, SKIP THE      *
*        LISTINGS FOR IOP.EQ.4,5,6,7 IN THE MOMENTUM-ENERGY LOOP AND  *
*        TEST POP AFTER THE MOMENTUM-ENERGY LOOP EXIT.  IF POP.NE.1   *
*        WRITE (6,72) I,JK,JEF,F(JEF),FPP(1),SF(I),P,Q,R. THEN WRITE  *
*        (6,76) I,JEG,GP(1),GPP(1),D(1),TF(I).                        *
*        BEFORE THE EXIT, IF ISTO(1).NE.0.AND.IOP.GT.3 CALL FILE FOR  *
```

TABLE VI. - Continued. MASTER INPUT DATA SAMPLE

```
*          THE STARTING PROFILES LISTING.  OTHERWISE, IF ISTO(5).EQ.1  *
*          .AND.POP.NE.1 CALL FILE.                                     *
*                                                                      *
*          IN SUBR ITSR...                                              *
*          FOR THE X-STATION HEADING IN THE I(X) LOOP...                *
*          IF POP.NE.1 WRITE (6,51), LABEL(K), WRITE (6,60), THEN IF    *
*          ISTO(5).EQ.1 WRITE (6,70), WRITE (6,81).                     *
*          IF ISTO(5).EQ.1, THEN IF POP.NE.1...                         *
*          FOR EACH VALUE OF THE MOMENTUM LOOP INDEX WRITE (6,82) JK,   *
*          JEF,F(JEF),FPP(1),DT(I),DTXM,PM,QM,RM.  FOR EACH VALUE OF    *
*          THE MOMENTUM-ENERGY LOOP INDEX,MAE,  WRITE (6,86) JFG,GP(1),*
*          GPP(1),D(1) UNLESS IBC.EQ.1 FOR WHICH THE ENERGY EQUATION    *
*          SECTION IS SKIPPED.                                          *
*          THEN IF POP.NE.1 WRITE (6,89) COF1,COF2,R21F,COG1,COG2       *
*          R21G,ITP,WSTO(18),XCF,SCF,ITME.  FOLLOWING THE LISTING OF    *
*          DISPLACEMENT CORRECTION FACTORS, IF ISTO(5).NE.0.AND.        *
*          POP.NE.1 WRITE (6,96) RRCD,RRFT,RMC,RMTW,RMT,RC,RDTK,DRDC,   *
*          DRM1,DRM2  WHICH ARE THE TRANSITION STATISTICS.              *
*                                                                      *
*          IN SUBR NDIR...                                              *
*          IF ISTO(10).EQ.5.AND.ISTO(14).EQ.1.AND.POP.NE.1 THEN         *
*          WRITE (6,93) IC,RC,RDTK.                                     *
*          IF ISTO(10).EQ.7.AND.POP.NE.1 THEN WRITE (6,94) IC,RC,RDTK.  *
*                                                                      *
*          INTEGER PROGRAM SWITCHES.                  FORMAT  (15I5)    *
*                                                                      *
* IOP MOP   DOP   IO  TOP  POP                                         *
*
   4    1   -1    0    1    0
*          MR,DT(1),RDT(1),BS,TO,BH,FT ON FORMAT (8F10.5) IS THE NEXT   *
*          DATA CARD.                                                   *
*          IF IOP.EQ.4 THEN MR,DT(1),RDT(1) CAN BE LEFT BLANK UNDER     *
*          SOME OPTIONS.                                                *
*                                     MR                               *
*    MR...REFERENCE FREE STREAM MACH NUMBER.                           *
*          IF MR.GE.0.OR.DOP.LE.0 SUBR INIR COMPUTES ALL U(I) FROM      *
*          THE M(I) DATA INPUT AT THE U(I) PLACE IN THE X-STATION DATA *
*          AFTER THE RETURN FROM SUBR COTR.  IF ISTO(1).EQ.2 THEN SUBR *
*          INIR SKIPS THE TEST TO RETURN ON POP.EQ.1 BEFORE THE LISTING*
*          IN ORDER TO LIST THE HEADING, PARAMETERS, M(I),TF(I),U(I).   *
*          UNDER THE FOLLOWING CONDITIONS SUBR COTR WILL RESET MR AFTER*
*          THE X-STATION DATA READ-IN...                                *
*          IF IOP.EQ.4.AND.MR.EQ.0.0.AND.DOP.LE.0  THEN MR= U(2).       *
*          IF IOP.NE.4.AND.MR.EQ.0.0.AND.DOP.LE.0 THEN MR= U(1).        *
*          IF IOP.EQ.7.AND.U(1).EQ.0.0,AND.MR.EQ.0.0.AND.DOP.LE.0 THEN *
*          MR= .001                                                     *
*                                     DT(1)                            *
*    DT(1)...DISPLACEMENT THICKNESS OR DELTA(*) IN THE SAME UNITS AS X.*
*          IF IOP.EQ.4 DT(1) IS LATER RESET=0.0 AND MT(1)=0.0 IN THE    *
*          IOP.EQ.4 SECTION OF SUBR INIR.                               *
*          IF IOP.EQ.7.AND.DT(1).EQ.0.0 ON READ-IN SUBR COTR RESETS     *
*          DT(1)= .001                                                  *
*                                     RDT(1)                           *
*    RDT(1)...REYNOLDS NUMBER BASED ON DISPLACEMENT THICKNESS.         *
*          IF IOP.EQ.4.AND.RDT(1).EQ.0.0 THEN SUBR COTR RECOMPUTES AND *
*          RE-LISTS RDT(1)= X(2)*U(2)*WSTO(3).                          *
*          IF IOP.EQ.7.AND.DOP.GT.0.AND RDT(1).EQ.0.0 THEN SUBR COTR    *
*          RECOMPUTES AND RELISTS  RDT(1)= U(1)*DT(1)/WSTO(11).         *
*          IF IOP.EQ.4 RDT(1) IS LATER RESET=0 IN THE IOP.EQ.4 SECTION *
*          OF SUBR INIR AFTER THE RETURN FROM SUBR COTR.  RL=RDT(1)     *
```

TABLE VI. - Continued. MASTER INPUT DATA SAMPLE

```
*          BEFORE THE RESET.                                           *
*                                     BS                               *
*    BS...INPUT FOR THE INITIAL PRESSURE GRADIENT.  SEE BS IN THE      *
*          DISCUSSION OF INPUT VARIABLES.                              *
*          IF IOP.EQ.4.AND.X.EQ.0.0.AND.BS.EQ.1.THEN SUBR COTR SETS    *
*          U(X=0.0)= 0.0.                                              *
*          SUBR COTR RECOMPUTES AND LISTS BS IF IOP.EQ.7.              *
*          SUBR INIR RESETS P= BS.                                     *
*                                     TO                               *
*    TO...FREE STREAM TOTAL TEMPERATURE IN DEG. K.                     *
*                                     BH                               *
*    BH= ENTHALPY RATIO...(H(BLE)TOT-H(REF) ) / H(BLE)TOT              *
*                                                                      *
*          7 WORDS.                                  FORMAT  (8F10.5)  *
*                                                                      *
*    MR  *  DT(1)  *  RDT(1) *   BS    *   TO    *   BH    *   FT    * *
*
                                1.0000  289.0000    1.0000
*         IF ISTO(15).EQ.1 THE X-STATION DATA ARE READ IN BY CARDS     *
*         WITH I(X)= 1,2,3...200 ON FORMAT (8F10.5).                   *
*         IF ISTO(15).EQ.0 THE X-STATION DATA ARE READ IN BY TAPE 1    *
*         AND THE CARD READ-IN INSTRUCTION IS SKIPPED.  FOR TAPE 1     *
*         READ-IN THE NUMBER OF X-STATIONS READ IN = KEND.LE.100.      *
*         NOTE THAT BEFORE LISTING WE MAY HAVE RESETS OF X,RW ON       *
*         WSTO(5) AND U ON WSTO(16),WSTO(8).                           *
*         IF LINEAR INTERPOLATION AT THE ORIGIN IS USED SOME OF THE    *
*         DATA, (X(I),U(I),RW(I)), IS REPLACED AND THE NUMBER OF       *
*         X-STATIONS IS INCREASED BY ISTO(8)+1, BUT                    *
*         IF IOP.EQ.2.3,6,7 SUBR COTR RESETS TOP=0 AND TURB(IS)=1.0.   *
*         THE NUMBER OF X-STATIONS THAT WILL BE COMPUTED IS .LE.99.    *
*         IF TOP.EQ.1 AT THE TIME OF THE X-STATION DATA READ-IN THEN   *
*         ALL TURB(I) ARE RESET = 0.0.                                 *
*         IF TURB(I).GE.1 THEN ALL TURB(K) FOR K.GE.I ARE RESET = 1.   *
*         IF IO.EQ.0 THEN ALL RW(I) ARE RESET = 0.0.                   *
*         THE ORDER OF READ-IN OF 1 LINE OF DATA IS...                 *
*         X(I),U(I),TURB(I),GBC(I),RW(I),VW(I),SW(I),CW(I).            *
*                                                                      *
*                                     X(I)                             *
*         X(I)= X INPUT AT THE WALL STATION IN AN ARBITRARY UNIT.      *
*         X(I) ON THE LAST X-STATION READ-IN MUST BE .LE.X(I-1).       *
*                                     U(I)                             *
*         U(I)= FREE STREAM VELOCITY AT X IN AN ARBITRARY UNIT.        *
*         IF MR.GE.0.OR.DOP.LE.0 SUBR INIR COMPUTES U(I) FROM THE M(I)*
*         DATA INPUT AND THE COMPUTED TF(I) AS DISCUSSED UNDER MR      *
*         HEREIN.                                                      *
*                                     TURB(I)                          *
*         TURB(I)= 0.0 TO 1.... INDICATES THE FRACTION OF EFFECTIVE    *
*           VISCOSITY THAT IS TURBULENT. IF TURB(I)=0.0 THE EFFECTIVE *
*           VISCOSITY IS ALL LAMINAR.                                  *
*           SUBR COTR SETS TURB(K)=1.FOR ALL K.GT.I WHERE TURB(I)=1.   *
*                                     GBC(I)                           *
*         GBC(I)= WALL BOUNDARY CONDITION ON THE ENERGY EQUA, EITHER   *
*         G'(WALL) OR G''(WALL)...SEE TABLE IV, ALSO MOP HEREIN.       *
*                                     RW(I)                            *
*         RW(I)= RADIUS OF BODY SURFACE R(WALL) IN THE SAME UNIT AS X.*
*                                     VW(I)                            *
*         VW(I)= TRANSPIRATION VELOCITY IN THE SAME UNIT AS U(X).      *
*         SEE TABLE IV.                                                *
*                                     SW(I)                            *
*         SW(I)= NIKURADSE (REF 15) SANDGRAIN ROUGHNESS SCALE IN THE   *
```

TABLE VI. - Continued. MASTER INPUT DATA SAMPLE

```
*          SAME UNIT AS X.                                          *
*                                        CW(I)                      *
*          CW(I)= LONGITUDINAL WALL RADIUS OF CURVATURE IN THE SAME *
*          UNIT AS X.                                               *
*                                     X(I) = 0 CARD                 *
*          WHEN THE X-STATION DATA IS READ IN BY CARDS, THE LAST CARD *
*          IS KEY PUNCHED FOR THE TEST TO SWITCH OUT FROM THE DATA  *
*          READ IN-LOOP.                                            *
*                                                                   *
*                                                                   *
*          X-STATION DATA CARDS...WITH 8 WORDS...ON FORMAT (8F10.5) *
*                                                                   *
     0*    0 *   THE A6IR DISCRIMINATOR CARD, 1ST OF 7 FOR SUBR A6IR.
0*
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
 *X(I)    *    U(I)  * TURB(I) *  GBC(I) *  RW(I)   *  VW(I)   *  SW(I)   *  CW(I)   *
0 *
                    RETURNS TO INIR FROM A6IR.
   0.        0.        0.
   0.1181    0.0185    0.
   0.1910    0.0371    0.
   0.2475    0.0556    0.
   0.2921    0.0741    0.
   0.3310    0.0927    0.
   0.3660    0.1112    0.
   0.3980    0.1297    0.
   0.4278    0.1483    0.
   0.4537    0.1668    0.
   0.4753    0.1853    0.
   0.4939    0.2039    0.
   0.5105    0.2224    0.
   0.5257    0.2409    0.
   0.5397    0.2595    0.
   0.5528    0.2780    0.
   0.5652    0.2965    0.
   0.5769    0.3151    0.
   0.5881    0.3336    0.
   0.5988    0.3521    0.
   0.6091    0.3707    0.
   0.6190    0.3892    0.
   0.6286    0.4077    0.
   0.6379    0.4263    0.
   0.6470    0.4448    0.
   0.6572    0.4633    0.
   0.6677    0.4819    0.
   0.6787    0.5004    0.
   0.6903    0.5189    0.
   0.7023    0.5375    0.
   0.7151    0.5560    0.
   0.7287    0.5745    0.
   0.7432    0.5931    0.
   0.7590    0.6116    0.
   0.7763    0.6301    0.
   0.7959    0.6487    0.
   0.8187    0.6672    0.
   0.8476    0.6857    0.
   0.8865    0.7043    0.
   0.9293    0.7228    0.
   0.9761    0.7413    0.
```

TABLE VI. - Continued. MASTER INPUT DATA SAMPLE

```
      1.0285     0.7599     0.
      1.1073     0.7784     0.
      1.2552     0.7969     0.
      1.6701     0.8155     0.
      1.8764     0.7980     0.
      2.0310     0.7804     0.
      2.3831     0.7280     0.
      2.7353     0.6846     0.
      3.0875     0.6501     0.
      3.4397     0.6242     0.
      3.7918     0.6028     0.
      4.1440     0.5860     0.
      4.4962     0.5738     0.
      4.8484     0.5582     0.
      5.2005     0.5407     0.
      5.5527     0.5237     0.
      5.9049     0.5073     0.
      6.2571     0.4915     0.
      6.6093     0.4761     0.
      6.9614     0.4609     0.
      7.3136     0.4458     0.
      7.6658     0.4313     0.
      8.0180     0.4177     0.
      8.3701     0.4047     0.
      8.7223     0.3923     0.
      9.0745     0.3805     0.
      9.4267     0.3695     0.
      9.7788     0.3592     0.
     10.1310     0.3498     0.
     10.4832     0.3412     0.
     10.8354     0.3332     0.
     11.1875     0.3258     0.
     11.5397     0.3193     0.
     11.8919     0.3135     0.
     12.2441     0.3087     0.
     12.5962     0.3041     0.
     12.9484     0.3001     0.
     13.3006     0.2968     0.
     13.6528     0.2943     0.
     14.0049     0.2921     0.
     14.3571     0.2905     0.
     14.7093     0.2895     0.
     15.0615     0.2891     0.
     15.4137     0.2893     0.
     15.7658     0.2910     0.
     16.1180     0.2952     0.
     16.4702     0.3019     0.
     16.8224     0.3110     0.
     17.1745     0.3226     0.
     17.5267     0.3366     0.
+0.0        +0.0
 *     A6IR. END CASE DATA READ. THE NEXT CARD IS READ IN AT CASE END.   A6IR.
 *           TO ELIMINATE THE COMMENTS CARDS REMOVE ALL CARDS WITH STARS *
 *           IN CARD COLUMN TWO (*) EXCEPT THOSE IMMEDIATELY PRECEEDING  *
 *           A SET OF DATA CARDS WITH THE EXCEPTION THAT THE SEVEN CARDS *
 *           IMMEDIATELY PRECEEDING THE X STATION PARAMETER SET OF DATA  *
 *           CARDS ARE TO BE REPLACED BY A STAR CARD (A * IN CC 2 ONLY)  *
 *           AND AT LEAST ONE STAR CARD MUST SUCCEED THE STATION DATA    *
 *           SET.  STAR CARDS WILL ALWAYS LIST SINCE COMMENTS CARDS ARE  *
 *           READ BY SUBR A6IR.  OTHERWISE THE INPUT DECK WILL NOT BE    *
```

TABLE VI. - Concluded. MASTER INPUT DATA SAMPLE

```
*           LISTED UNLESS ISTO(1).NE.0.  THE SIMPLEST CARD THAT CAN BE  *
*           USED AS A MARKER CARD IS ONE WITH AN * IN CC2, OR CC1.       *
*           NC IS THE NUMBER OF X DATA STATIONS READ IN,CARD OR TAPE, BY*
*           SUBR COTR.  NC.LE.200.                                      *
*           KEND IS THE NUMBER OF X DATA STATION POINTS READ IN FROM    *
*           TAPE BY SUBR COTR WHICH RESETS KEND=100 IF KEND AS READ FROM*
*           THE TAPE.GT.100.                                            *
*           TOP IS RESET=C IF IOP.EQ.2,3,6,7.                           *
*           NOTE THAT ISTO(8)=  2 TO INCLUDE A LINEAR SECTION.          *
*           END OF CASE.
```

change appreciably as the calculations proceed downstream since η is normalized with δ^*. Smaller η spacing will be required throughout the layer if a very small x step size is used.

The specification of the $f'(\eta)$ and $g'(\eta)$ profiles depends on whether these profiles are used as the starting profiles or the input profiles are recalculated. If the input profiles are to be used as specified, they should be compatible with the initial pressure gradient. For turbulent flow the profiles must be well defined in the "law-of-the-wall" region. This region can often be specified by using some empirical "law of the wall". If the input profiles are recalculated, the initial profiles need not be very accurate since the calculated profiles usually converge very rapidly to their final value for almost any reasonable input profile.

Specification of x-step size. - The sequence of the x-values defines the x-spacing at which calculations will be performed. The x-step size depends on the input station Mach number or velocity distribution. The x-step size should be inversely proportional to the magnitude of the slope of the velocity distribution. For large velocity gradients the x-steps must be very small. The numerical examples illustrate realistic x-step sizes for accurate results.

The x-step size is most sensitive at the start of the boundary layer growth. However, if the slope of the U(X) as a function of x curve is linear, larger x-step sizes can be taken. The input options ISTO(8) and ISTO(9) can be used to modify input x-station data to include a linear section at the start of the boundary layer growth.

Instructions for linking with another program. - The TUF set of decks headed by the main routine TUF can be tied to another program to be titled TRIR(XMAS) which will compute and store on tape 1 the x-station data to be used by the TUF set of routines. To tie in the TUF set of decks, the main program of TUF remains the same except that a card containing subroutine TUFL(KSTOP, XMAS) is placed behind the $IBFTC card of the main routine TUF. Let the main routine using both supervisory subroutines TUFL(KSTOP, XMAS) and TRIR(XMAS) be titled COSY. Then COSY can have a blank common which is set equivalent to the KSTOP array of subroutine TUFL(KSTOP, XMAS) where the blank common of COSY is also the blank common of subroutine TRIR(XMAS). The array XMAS is dimensioned the same for COSY, TRIR,

TABLE VII. - EXAMPLE OF LINKING TUF TO ANOTHER PROGRAM

```
$IBFTC COSD     DECK,LIST
C       COSY IS THE MAIN ROUTINE FOR  THE MAIN SUPERVISORY SUBROUTINES...
C       TRIR WHICH PROVIDES X(I),U(I) OR M(I), AND RW(I) FOR THE
C       BOUNDARY LAYER SUBROUTINE TUFL, AND
C       SUBR TUFL WHICH USES THE BLANK COMMON OF COSY AS THE KSTOP ARRAY.


        CCMMON  NTO(2),NPO(2),NHBMXO

        DIMENSION  KSTOP(5),XMAS(10)

        EQUIVALENCE  (KSTOP(5),NHBMXO)


C       TFE OUTPUT DATA OF SUBR TRIR IS PUT ON TAPE 1.
        REWIND  1

        CALL TRIR(XMAS)

C       TFE BOUNDARY LAYER SUBROUTINE.
        CALL   TUFL(KSTOP,XMAS)


        CALL   EXIT
        STOP

        ENC
```

and TUFL. The main routine COSY then calls subroutine TRIR(XMAS) followed by a COSY call of subroutine TUFL(KSTOP,XMAS) to get the boundary layer solution. If storage is limited, the same overlay origin can be used before both the subroutine TRIR and the subroutine TUFL sets of decks. A second overlay origin can be placed before each of the decks of the subroutines INIR, ITFR, ITSR, and NDIR which are loaded in the order shown in the program listing. Also, such blank common not needed for both sets of decks TRIR and TUFL can be labeled. An example of the COSY kind of routine is shown in table VII.

Output Variables

The primary output from the calculations is a list of the calculated profiles and parameters that is printed out at each x-station. Most of the output is optional and is controlled by the input ISTO array. Definitions of the output variables that are not defined elsewhere are given here.

Principal boundary layer parameters. - The following principal boundary layer parameters are listed in the program output: X, DT, MT, HT, SF, CF, ST, GPW, RDT, U, M, TURB, RW, VW, SW, and CW. These parameters are all defined in the

Common Arrays section. The output of the x-station dimensional variables are in the same units as the input x-station variables.

Profile parameters. - The following momentum and energy profile parameters are listed in the program output: J, YY, U/U(BLE), F, FP, FPP, D, GP, and GPP. All of these variables are defined in the Common Arrays section except J and U/U(BLE), which are as follows:

J	Index of eta profile point.
U/U(BLE)	Ratio of velocity in boundary layer to velocity at boundary layer edge, D(J)*(1. -FP(J)).

Transition parameters. - The transition parameters that are printed out and defined in the Common Arrays section are IC, RC, FT, RMX, RMTW, RMT, and RDTK. The other transition parameters are defined as follows:

RSR	Function characteristic of effect of surface roughness.
RRR	Function characteristic of effect of surface curvature.
RTR	Function characteristic of effect of free-stream turbulence.
RD	Final value of RD is a function characteristic of effects of pressure gradient, surface roughness, surface curvature, and free-stream turbulence.
RRCD	RMC/RMTW
RRFT	RMC/RMT
DRDC	RDTK-RC
DRMI	RMTW-RMC
DRM2	RMTW*MT(I+1)/MT(I)-RMT

Momentum and energy balance parameters. - Under the output heading INTEGRALS OF MOMENTUM AND ENERGY are listed the values of COF1 and COF2 for the momentum balance and the values of COG1 and COG2 for the energy balance. Both COF1 and COF2 are defined by equation (II-21), and COG1 and COG2 are defined by equation (II-23). The other balance parameters are defined as follows:

R21F	COF2/COF1
R21G	COG2/COG1
ITP	Number of iterations in momentum and energy loops.

General parameters. - The general parameters that are listed in the output are IVEL, VE(1), VEG(1), VHP(1), VH(1), HR, PR, PRT, SHR, XNOD, I(X), JE, and ISTO(10). The parameters VE, VEG, VHP, and VH are defined in the Common

Arrays section. The parameters JE, PR, PRT, SHR, I(X), and JE are defined in the Single Word Common Stores section. The other variables are defined as follows:

IVEL	Code to tell what correction is included in calculation of effective viscosity.
XNOD	If XNOD.NE.X, XNOD=X(I)/WSTO(10).
ISTO(10)	Code number to indicate in which subroutine the profiles are last computed.

Numerical Examples

To illustrate the use of the program and the results obtained, two numerical examples are given. The first example is a flat plate, and the second is an inlet diffuser. For both examples the boundary layer is calculated in the laminar, transitional, and turbulent portions of the flow.

Flat plate. - The first example is a flat plate with a slightly tapered leading edge. The input for the example is given in table VIII. The boundary layer is calculated from the stagnation point at the leading edge of the plate to an x of 6.9 centimeters (2.7 in.). The starting velocity profile in table VIII is used by the program to calculate a Blasius profile at the leading edge (BS = 0.01). The index for the x-station data is denoted by IS. There is a total of 80 x-locations for this example.

Sample output for this example is given in table IX. Most of the output is optional and is controlled by the input ISTO ARRAY. The output that is illustrated corresponds to the following description:

(1) Profiles and parameters at a nondimensional x = 0.0025
(2) Transition statistics and profiles at nondimensional x = 0.80 and x = 0.85
(3) Summary of boundary layer parameters
(4) Momentum and energy balance ratios

Examination of the summary output indicates transition to fully turbulent flow occurs at a nondimensional x value of 0.42. The fully turbulent point corresponds to the first x-value where TURB(I)=1.0. The experimental transition was found to occur at a nondimensional x of 0.46. In general, good momentum and energy balances were obtained for the chosen x-stations for this example.

Execution time for this example was 2 minutes on an IBM-7094/7044 direct-coupled system.

Inlet diffuser. - The second example is an inlet diffuser. The geometry is described in detail in reference 16 (diffuser identification number, 10). The input for the diffuser example is given in table X. The boundary layer is calculated from the stagnation point on the inlet lip (x = 0) to the diffuser exit at an x of 44.6 centimeters (17.52 in.). The starting velocity profile in table X is used by the program to calculate a Falkner-Skan laminar wedge flow solution for a starting profile (BS = 1.0). For this example a linear section of x-station data was calculated by the program. (Note ISTO(8) and ISTO(9) both equal two). There is a total of 95 x-locations for this example. There is a small x-step size in the region of large Mach number gradients to improve the accuracy of the computations.

Sample output for the inlet diffuser example is given in table XI. The output that is illustrated corresponds to the following description:

(1) Profiles and parameters at a nondimensional x = 0.0412
(2) Transition statistics and profiles at a nondimensional x = 0.7287 and x = 0.7432
(3) Summary of boundary layer parameters
(4) Momentum and energy balance ratios

Execution time for this example was 2 minutes on an IBM-7094/7044 direct-coupled system.

Discussion of Problem Difficulties

The main accessary source of information when either a difficulty appears or an unexpected transition to turbulent flow occurs is table VI. Table VI can be used as an input data deck. If so used, it contains both comment, which is always listed, and the case numerical data, which is listed when ISTO(1).NE.0. Hence, table VI when used as an input deck can become a convenient diagnostic aid when the case being computed is aborted. If a difficulty appears, which may not end the case with a machine diagnostic, then the comment on ISTO(10) in table VI can be used to connect the case listing with the source program. After the probable location of the difficulty is located, subroutine FILE can be used to list complete profiles by setting ISTO(7)=I(X) the index of the desired x-station to be listed.

If it is desired to study the viscosity and conductivity profile wall values of subroutine VIS and the transition statistics of subroutine ITSR and of subroutine TRANS on TOP.EQ.1, then set ISTO(5).NE.0. The telltale word IVEL, which appears in the subroutine VIS listing, can be used as a diagnostic aid to determine the sequence of formulas used in computing the viscosity and conductivity profiles. Unlike ISTO(7), which causes a list for only the selected x-station, ISTO(5).NE.0 causes a list at each x-station succeeding the first. To differentiate the listing by subroutine TRANS from that of subroutine ITSR, the heading of the subroutine TRANS listing carries the label TRANS. Also ISTO(5) with the integer printout switch POP lists additional information as summarized by table VI.

TABLE VIII. - INPUT FOR FLAT PLATE

```
ENTER INIR AT       0.     SEC.
*          ISTO(K),  K=  1,15                                 FORMAT  ( 15I5 )                  1
    1    2    4    1    1    1    1    0    0    1    0    0    0    0    1
*          WSTO(K),  K=  1,20                                 FORMAT  ( 5E15.8 )                1
 0.99990000E+00 0.30000000E+03-0.             -0.            -0.
-0.            -0.            -0.             -0.            -0.
 0.15640000E-03 0.            -0.              0.90000000E+00-0.
 0.            -0.            -0.             -0.            -0.
*          LABEL(K), K=1,18, ON FORMAT (18A4), THE X-STATION HEADING.                           1
   FLAT PLATE                                               FLAT PLATE
*          JDIV                                               FORMAT  ( 15I5 )                  1
    4
*          JY ON FORMAT (15I5) THEN YY(J), J=1,JY ON FORMAT (6F10.5)                            1
   42          165.    4.
    0.         0.01000000   0.02000000   0.04000000   0.05999999   0.08000000
    0.09999999 0.12000000   0.14000000   0.16000000   0.18000000   0.20000000
    0.22000000 0.23999999   0.26000000   0.28000000   0.30000000   0.32000000
    0.34000000 0.36000000   0.38000000   0.40000000   0.44000000   0.48000000
    0.52000000 0.56000000   0.60000000   0.64000000   0.68000000   0.72000000
    0.80000000 0.90000000   1.00000000   1.20000000   1.40000001   1.59999999
    1.80000000 2.19999999   2.59999999   3.00000000   3.59999999   4.19999999
*          JEF ON FORMAT (15I5). THEN FP(J), J=1,JEF ON FORMAT (6F10.5)                         1
   36          141.    4.
    1.00000000 0.99800000   0.99600000   0.99200000   0.98500000   0.96200000
    0.92600000 0.85500000   0.78900000   0.72600000   0.66600000   0.60900000
    0.55500000 0.50500000   0.45699999   0.41300000   0.33300000   0.26500000
    0.20800000 0.16100000   0.12300000   0.05880000   0.02609999   0.01080000
    0.00426999 0.00161999   0.00060700   0.00022899   0.00008950   0.00003660
    0.00001570 0.00000656   0.00000316   0.00000144   0.00000062   0.00000022
*          JEG ON FORMAT (15I5). THEN GP(J), J=1,JEG ON FORMAT (6F10.5)                         1
    6           21.    4.
   -0.         -0.          -0.          -0.          -0.          -0.
* IOF   MOP   DOP    IO   TOP   POP                                                             1
    4     1     1     0     1     1
*    MR   *  DT(1)  *  RCT(1) *   BS    *    TO    *    BH    *    FT    *                      1
 0.696000-0.         1004.00   0.0100  295.2300   1.0000   -0.
*          X-STATION DATA CARDS...WITH 8 WORDS...ON FORMAT (8F10.5)                             1
   0.        752.60000  0.        -0.        0.        -0.        -0.        -0.          IS=    1
   0.00250   753.68000  0.        -0.        0.        -0.        -0.        -0.          IS=    2
   0.00500   754.76000  0.        -0.        0.        -0.        -0.        -0.          IS=    3
   0.00750   755.84000  0.        -0.        0.        -0.        -0.        -0.          IS=    4
   0.01000   756.91000  0.        -0.        0.        -0.        -0.        -0.          IS=    5
   0.01500   759.07000  0.        -0.        0.        -0.        -0.        -0.          IS=    6
   0.02000   761.23000  0.        -0.        0.        -0.        -0.        -0.          IS=    7
   0.03000   765.54000  0.        -0.        0.        -0.        -0.        -0.          IS=    8
   0.04000   769.85000  0.        -0.        0.        -0.        -0.        -0.          IS=    9
   0.05000   774.17000  0.        -0.        0.        -0.        -0.        -0.          IS=   10
   0.06000   778.48000  0.        -0.        0.        -0.        -0.        -0.          IS=   11
   0.07000   782.79000  0.        -0.        0.        -0.        -0.        -0.          IS=   12
   0.08000   787.11000  0.        -0.        0.        -0.        -0.        -0.          IS=   13
   0.09000   791.42000  0.        -0.        0.        -0.        -0.        -0.          IS=   14
   0.10000   795.73000  0.        -0.        0.        -0.        -0.        -0.          IS=   15
   0.11000   800.05000  0.        -0.        0.        -0.        -0.        -0.          IS=   16
   0.12000   804.36000  0.        -0.        0.        -0.        -0.        -0.          IS=   17
   0.13000   808.67000  0.        -0.        0.        -0.        -0.        -0.          IS=   18
   0.14000   812.99000  0.        -0.        0.        -0.        -0.        -0.          IS=   19
   0.15000   817.30000  0.        -0.        0.        -0.        -0.        -0.          IS=   20
   0.16000   821.61000  0.        -0.        0.        -0.        -0.        -0.          IS=   21
   0.17000   825.93000  0.        -0.        0.        -0.        -0.        -0.          IS=   22
   0.18000   830.24000  0.        -0.        0.        -0.        -0.        -0.          IS=   23
```

TABLE VIII. - Concluded. INPUT FOR FLAT PLATE

```
 0.19000 834.55000     0.          -0.          0.          -0.         -0.         -0.               IS=    24
 0.20000 838.87000     0.          -0.          0.          -0.         -0.         -0.               IS=    25
 0.21000 843.18000     0.          -0.          0.          -0.         -0.         -0.               IS=    26
 0.22000 847.49000     0.          -0.          0.          -0.         -0.         -0.               IS=    27
 0.23000 851.81000     0.          -0.          0.          -0.         -0.         -0.               IS=    28
 0.24000 856.12000     0.          -0.          0.          -0.         -0.         -0.               IS=    29
 0.25000 860.43000     0.          -0.          0.          -0.         -0.         -0.               IS=    30
 0.26000 864.75000     0.          -0.          0.          -0.         -0.         -0.               IS=    31
 0.27000 869.06000     0.          -0.          0.          -0.         -0.         -0.               IS=    32
 0.28000 873.37000     0.          -0.          0.          -0.         -0.         -0.               IS=    33
 0.29000 877.69000     0.          -0.          0.          -0.         -0.         -0.               IS=    34
 0.30000 882.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    35
 0.32000 886.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    36
 0.34000 889.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    37
 0.36000 892.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    38
 0.38000 894.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    39
 0.40000 897.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    40
 0.42000 898.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    41
 0.44000 900.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    42
 0.46000 902.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    43
 0.48000 904.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    44
 0.50000 905.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    45
 0.52000 904.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    46
 0.54000 903.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    47
 0.56000 902.50000     0.          -0.          0.          -0.         -0.         -0.               IS=    48
 0.58000 902.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    49
 0.60000 901.50000     0.          -0.          0.          -0.         -0.         -0.               IS=    50
 0.62000 901.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    51
 0.64000 900.50000     0.          -0.          0.          -0.         -0.         -0.               IS=    52
 0.66000 900.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    53
 0.68000 896.50000     0.          -0.          0.          -0.         -0.         -0.               IS=    54
 0.70000 898.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    55
 0.75000 895.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    56
 0.80000 890.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    57
 0.85000 886.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    58
 0.90000 882.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    59
 0.95000 877.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    60
 1.00000 872.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    61
 1.05000 867.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    62
 1.10000 862.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    63
 1.15000 857.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    64
 1.20000 851.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    65
 1.30000 842.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    66
 1.40000 833.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    67
 1.50000 826.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    68
 1.60000 821.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    69
 1.70000 817.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    70
 1.80000 815.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    71
 1.90000 812.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    72
 2.00000 810.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    73
 2.10000 808.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    74
 2.20000 806.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    75
 2.30000 805.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    76
 2.40000 806.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    77
 2.50000 808.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    78
 2.60000 811.50000     0.          -0.          0.          -0.         -0.         -0.               IS=    79
 2.70000 815.00000     0.          -0.          0.          -0.         -0.         -0.               IS=    80
 0.         -0.        0.          -0.          0.          -0.         -0.         -0.               IS=    81

END OF CARD READ      NO. OF X STATIONS= 80   LAST X TO BE COMPUTED= 0.27000000E+01      LAST X= 0.
PR=   6.9600000E-01        DT(1)= -0.                  ROT(1)=  1.0040000E+03      BS=  1.0000000E-02      IT= 100  NC= 81  KIND=     0
                                                                 WSTO(10)=  2.7000000E+00      NO. OF X-STATION POINTS INCREASE=   0
0                                                                                             1
```

TABLE IX. - OUTPUT FOR FLAT PLATE

(a) Profiles and parameters at X = 0. 0025

```
                                                    BOUNDARY LAYER PROFILES FOR
FLAT PLATE                                           FLAT PLATE
X =    0.0025                                       U =   753.680    M =   0.70    RDT = 6.01E+01
                              TURB =0.        RW = 0.              VW =-0.           SW =-0.           CW =-0.
                        DT = 1.50E-04 MT = 5.14E-05 HT = 0.          SF = 2.91E+00 CF = 2.19E-02 ST =-0.
                                       HR = 1.00E+00    PR = 7.80E-01    PRT = 9.00E-01    SHR = 1.40

X=       0.0025    XNOD=        0.0009    I(X)=    2    JE=   165    ISTO(10)=     2
 J         YY              U/U(BLE)             F                 FP               FPP                D                    GP                 GPP
  1   0.                0.                0.                1.0000000E+00  -5.5712460E-01   1.0976166E+00   -0.                 -0.
  5   1.0000000E-02     6.1136492E-03     9.9721473E-03     9.9443004E-01  -5.5682659E-01   1.0976130E+00   -0.                 -0.
  9   2.0000000E-02     1.2223565E-02     1.9888612E-02     9.8886338E-01  -5.5648385E-01   1.0976024E+00   -0.                 -0.
 13   4.0000000E-02     2.4433409E-02     3.9554613E-02     9.7773842E-01  -5.5598615E-01   1.0975598E+00   -0.                 -0.
 17   6.0000000E-02     3.6630092E-02     5.8998218E-02     9.6662372E-01  -5.5549369E-01   1.0974889E+00   -0.                 -0.
 21   8.0000000E-02     4.8813628E-02     7.8219623E-02     9.5551842E-01  -5.5503840E-01   1.0973898E+00   -0.                  0.
 25   1.0000000E-01     6.0983763E-02     9.7219011E-02     9.4442190E-01  -5.5462197E-01   1.0972627E+00    0.                  0.
 29   1.2000000E-01     7.3140562E-02     1.1599655E-01     9.3333328E-01  -5.5424566E-01   1.0971075E+00    0.                  0.
 33   1.4000000E-01     8.5283803E-02     1.3455239E-01     9.2225188E-01  -5.5389777E-01   1.0969244E+00    0.                  0.
 37   1.6000000E-01     9.7413199E-02     1.5288666E-01     9.1117717E-01  -5.5357591E-01   1.0967136E+00    0.                  0.
 41   1.8000000E-01     1.0952828E-01     1.7099951E-01     9.0010872E-01  -5.5327491E-01   1.0964750E+00    0.                  0.
 45   2.0000000E-01     1.2162671E-01     1.8889104E-01     8.8904603E-01  -5.5299178E-01   1.0962088E+00    0.                  0.
 49   2.2000000E-01     1.3371376E-01     2.0656138E-01     8.7798895E-01  -5.5272058E-01   1.0959152E+00    0.                  0.
 53   2.4000000E-01     1.4578288E-01     2.2401063E-01     8.6693715E-01  -5.5245907E-01   1.0955942E+00    0.                  0.
 57   2.6000000E-01     1.5783527E-01     2.4123890E-01     8.5589056E-01  -5.5220042E-01   1.0952459E+00    0.                  0.
 61   2.8000000E-01     1.6987010E-01     2.5824628E-01     8.4484915E-01  -5.5194263E-01   1.0948706E+00    0.                  0.
 65   3.0000000E-01     1.8188650E-01     2.7503288E-01     8.3381292E-01  -5.5167739E-01   1.0944684E+00    0.                  0.
 69   3.2000000E-01     1.9388340E-01     2.9159882E-01     8.2278205E-01  -5.5140619E-01   1.0940394E+00    0.                  0.
 73   3.4000000E-01     2.0585971E-01     3.0794419E-01     8.1175679E-01  -5.5112084E-01   1.0935838E+00    0.                  0.
 77   3.6000000E-01     2.1781440E-01     3.2406912E-01     8.0073730E-01  -5.5082430E-01   1.0931018E+00    0.                  0.
 81   3.8000000E-01     2.2974619E-01     3.3997372E-01     7.8972400E-01  -5.5050393E-01   1.0925936E+00    0.                  0.
 85   4.0000000E-01     2.4165379E-01     3.5565811E-01     7.7871734E-01  -5.5011736E-01   1.0920593E+00    0.                  0.
 89   4.4000000E-01     2.6539112E-01     3.8636687E-01     7.5672585E-01  -5.4938496E-01   1.0909138E+00    0.                  0.
 93   4.8000000E-01     2.8901411E-01     4.1619663E-01     7.3476847E-01  -5.4845289E-01   1.0896673E+00    0.                  0.
 97   5.2000000E-01     3.1250946E-01     4.4514889E-01     7.1285200E-01  -5.4733185E-01   1.0883219E+00    0.                  0.
101   5.6000000E-01     3.3566268E-01     4.7322546E-01     6.9098470E-01  -5.4598813E-01   1.0868804E+00    0.                  0.
105   6.0000000E-01     3.5905820E-01     5.0042846E-01     6.6917615E-01  -5.4438776E-01   1.0853456E+00    0.                  0.
109   6.4000000E-01     3.8207941E-01     5.2676047E-01     6.4743737E-01  -5.4249419E-01   1.0837207E+00    0.                  0.
113   6.8000000E-01     4.0490870E-01     5.5222453E-01     6.2578073E-01  -5.4027243E-01   1.0820092E+00    0.                  0.
117   7.2000000E-01     4.2752742E-01     5.7682421E-01     6.0422011E-01  -5.3734230E-01   1.0802151E+00    0.                  0.
121   7.5999999E-01     4.7205648E-01     6.2344770E-01     5.6144727E-01  -5.3107835E-01   1.0763962E+00    0.                  0.
125   8.5999999E-01     5.2617480E-01     6.7695264E-01     5.0881729E-01  -5.2070694E-01   1.0712405E+00    0.                  0.
129   1.0000000E+00     5.7825975E-01     7.2525312E-01     4.5741109E-01  -5.0478814E-01   1.0657419E+00    0.                  0.
133   1.2000000E+00     6.7458842E-01     8.0683897E-01     3.5966368E-01  -4.6780932E-01   1.0541155E+00    0.                  0.
137   1.4000000E+00     7.5964748E-01     8.6976047E-01     2.7124645E-01  -4.1364118E-01   1.0423928E+00    0.                  0.
141   1.6000000E+00     8.3031873E-01     9.1617612E-01     1.9500052E-01  -3.4692429E-01   1.0314525E+00    0.                  0.
145   1.8000000E+00     8.8616383E-01     9.4873656E-01     1.3292519E-01  -2.6424579E-01   1.0220154E+00    0.                  0.
149   2.2000000E+00     9.5686984E-01     9.8393947E-01     5.1599835E-02  -1.3887432E-01   1.0089305E+00    0.                  0.
153   2.6000000E+00     9.8725189E-01     9.9627755E-01     1.5496790E-02  -5.2265570E-02   1.0027920E+00    0.                  0.
157   3.0000000E+00     9.9709867E-01     9.9962748E-01     3.5701907E-03  -1.3469152E-02   1.0006713E+00    0.                  0.
161   3.6000000E+00     9.9982672E-01     1.0004143E+00     2.1745425E-04  -1.2616695E-03   1.0000442E+00    0.                  0.
165   4.2000000E+00     1.0000000E+00     1.0004515E+00     0.              0.               1.0000000E+00    0.                  0.

IVEL=  3    VE(1)=  1.31E-02   VEG(1)=  1.68E-02   VHP(1)=  0.          VH(1)=  1.18E+00

IVEL=  3    VE(1)=  1.56E-02   VEG(1)=  2.00E-02   VHP(1)=  0.          VH(1)=  1.18E+00

TRANSITIONAL STATISTICS LISTED BY TRANS...  I(X)=    3      IC=  81
RSR=  0.100E+01  RRR=  0.100E+01  RMC=  0.401E+02  RD=   0.100E-18  RMT=  0.           FT= -0.           RTR=  0.100E-18
TURB(I+1)=  0.
```

TABLE IX. - Continued. OUTPUT FOR FLAT PLATE

(b) Transition statistics and profile at X = 0.80 and X = 0.85

```
X=      0.7500   XNOD=      0.2778   I(X)=  56    JE=  165    ISTO(10)=    3
 J         YY                U/U(BLE)          F                 FP                FPP               D                    GP                       GPP
  1   0.                 0.                0.                1.0000000E+00   -7.2791873E-01    1.1376562E+00  -0.                      -0.
 17   6.0000000E-02     4.9996259E-02     5.8684219E-02     9.5603986E-01   -7.3782952E-01    1.1373091E+00  -0.                      -0.
 33   1.4000000E-01     1.1759075E-01     1.3279146E-01     8.9646298E-01   -7.5112210E-01    1.1357363E+00   0.                       0.
 49   2.2000000E-01     1.8573124E-01     2.0209530E-01     8.3605194E-01   -7.5705947E-01    1.1328664E+00   0.                       0.
 65   3.0000000E-01     2.5305860E-01     2.6656350E-01     7.7580926E-01   -7.4519874E-01    1.1287648E+00   0.                       0.
 81   3.8000000E-01     3.1745833E-01     3.2627572E-01     7.1747985E-01   -7.0892411E-01    1.1236662E+00   0.                       0.
 97   5.2000000E-01     4.1731604E-01     4.2009212E-01     6.2521989E-01   -6.0405013E-01    1.1134957E+00   0.                       0.
113   6.8000000E-01     5.0846577E-01     5.1293597E-01     5.3852105E-01   -4.8441916E-01    1.1018179E+00   0.                       0.
129   1.0000000E+00     6.3879799E-01     6.6338441E-01     4.0915177E-01   -3.4185795E-01    1.0811541E+00   0.                       0.
145   1.8000000E+00     8.4885640E-01     8.9505113E-01     1.8222655E-01   -2.3096508E-01    1.0380093E+00   0.                       0.
161   3.6000000E+00     9.9682800E-01     1.0001016E+00     3.9878553E-03   -1.3175434E-02    1.0008191E+00   0.                       0.
165   4.2000000E+00     1.0000000E+00     1.0010149E+00     0.                0.               1.0000000E+00   0.                       0.

TRANSITICNAL STATISTICS LISTED BY TRANS...  I(X)=  57      IC=   7
RSR=  0.100E+01  RRR=  0.100E+01  RMC=  0.416E+02  RD=  0.505E+03  RMT=  0.546E+03  FT= -0.            RTR=  0.113E+01
TURB(I+1)=  0.451E+00

X=      0.8000   XNOD=      0.2963   I(X)=  57    JE=  165    ISTO(10)=    3
 J         YY                U/U(BLE)          F                 FP                FPP               D                    GP                       GPP
  1   0.                 0.                0.                1.0000000E+00   -8.5380970E-01    1.1361224E+00  -0.                      -0.
 17   6.0000000E-02     5.8572496E-02     5.8456454E-02     9.4842386E-01   -8.6609647E-01    1.1356511E+00  -0.                      -0.
 33   1.4000000E-01     1.3783371E-01     1.3153902E-01     8.7840115E-01   -8.8380650E-01    1.1335117E+00   0.                       0.
 49   2.2000000E-01     2.1753573E-01     1.9897329E-01     8.0742546E-01   -8.8555888E-01    1.1296184E+00   0.                       0.
 65   3.0000000E-01     2.9464580E-01     2.6076400E-01     7.3790401E-01   -8.4307253E-01    1.1241904E+00   0.                       0.
 81   3.8000000E-01     3.6443300E-01     3.1718869E-01     6.7399440E-01   -7.4728491E-01    1.1178735E+00   0.                       0.
 97   5.2000000E-01     4.6082221E-01     4.0489839E-01     5.8370600E-01   -5.4785413E-01    1.1069634E+00   0.                       0.
113   6.8000000E-01     5.3825049E-01     4.9200928E-01     5.0905819E-01   -4.0098385E-01    1.0963631E+00   0.                       0.
129   1.0000000E+00     6.4334349E-01     6.3711585E-01     4.0394548E-01   -2.9125674E-01    1.0793367E+00   0.                       0.
145   1.8000000E+00     8.3886702E-01     8.7227045E-01     1.9306508E-01   -2.1972705E-01    1.0395721E+00   0.                       0.
161   3.6000000E+00     9.9431994E-01     9.9469053E-01     7.0295217E-03   -1.9761088E-02    1.0013590E+00   0.                       0.
165   4.2000000E+00     1.0000000E+00     9.9645135E-01     0.                0.               1.0000000E+00   0.                       0.

TRANSITICNAL STATISTICS LISTED BY TRANS...  I(X)=  58      IC=   7
RSR=  0.100E+01  RRR=  0.100E+01  RMC=  0.416E+02  RD=  0.507E+03  RMT=  0.549E+03  FT= -0.            RTR=  0.113E+01
TURB(I+1)=  0.502E+00

X=      0.8500   XNOD=      0.3148   I(X)=  58    JE=  165    ISTO(10)=    3
 J         YY                U/U(BLE)          F                 FP                FPP               D                    GP                       GPP
  1   0.                 0.                0.                1.0000000E+00   -1.0345429E+00    1.1349016E+00  -0.                      -0.
 17   6.0000000E-02     7.0792766E-02     5.8131295E-02     9.3758456E-01   -1.0468543E+00    1.1342189E+00  -0.                      -0.
 33   1.4000000E-01     1.6606336E-01     1.2976964E-01     8.5318999E-01   -1.0598995E+00    1.1311448E+00   0.                       0.
 49   2.2000000E-01     2.5577423E-01     1.9464919E-01     7.6923538E-01   -1.0260783E+00    1.1257108E+00   0.                       0.
 65   3.0000000E-01     3.4510516E-01     2.5301260E-01     6.9151087E-01   -9.0176150E-01    1.1186948E+00   0.                       0.
 81   3.8000000E-01     4.1516316E-01     3.0563559E-01     6.2647555E-01   -7.2174880E-01    1.1114752E+00   0.                       0.
 97   5.2000000E-01     5.0128341E-01     3.8720240E-01     5.4462335E-01   -4.7095857E-01    1.1008105E+00   0.                       0.
113   6.8000000E-01     5.6534173E-01     4.6904213E-01     4.8209180E-01   -3.2918168E-01    1.0915868E+00   0.                       0.
129   1.0000000E+00     6.5101873E-01     6.0880861E-01     3.9580024E-01   -2.4898478E-01    1.0774892E+00   0.                       0.
145   1.8000000E+00     8.2737800E-01     8.4737104E-01     2.0610176E-01   -2.0614336E-01    1.0421714E+00   0.                       0.
161   3.6000000E+00     9.9042084E-01     9.9257669E-01     1.1978264E-02   -2.9484999E-02    1.0024282E+00   0.                       0.
165   4.2000000E+00     1.0000000E+00     9.9573436E-01     0.                0.               1.0000000E+00   0.                       0.

TRANSITICNAL STATISTICS LISTED BY TRANS...  I(X)=  59      IC=   7
RSR=  0.100E+01  RRR=  0.100E+01  RMC=  0.416E+02  RD=  0.501E+03  RMT=  0.543E+03  FT= -0.            RTR=  0.113E+01
TURB(I+1)=  0.592E+00

X=      0.9000   XNOD=      0.3333   I(X)=  59    JE=  165    ISTO(10)=    3
 J         YY                U/U(BLE)          F                 FP                FPP               D                    GP                       GPP
  1   0.                 0.                0.                1.0000000E+00   -1.1603534E+00    1.1336862E+00  -0.                      -0.
```

TABLE IX. - Continued. OUTPUT FOR FLAT PLATE

(c) Summary of boundary layer parameters

```
                                          PRINCIPAL BOUNDARY LAYER PARAMETERS FOR
                     FLAT PLATE                                              FLAT PLATE

    X          DT         MT          HT       SF       CF        ST         GPW         ROT       U        M     TURB       RW        VW        SW      CW
0.        0.        0.          0.           2.908 0.        0.         0.             0.   752.600  0.698 0.         0.       -0.       -0.      -0.
0.00093 0.000150 0.000051 0.           2.908 0.02190 0.         0.            60.   753.680  0.699 0.         0.       -0.       -0.      -0.
0.00185 0.000189 0.000065 0.           2.918 0.00560 0.         0.            76.   754.760  0.700 0.         0.       -0.       -0.      -0.
0.00278 0.000230 0.000078 0.           2.925 0.01369 0.         0.            93.   755.840  0.701 0.         0.       -0.       -0.      -0.
0.00370 0.000275 0.000094 0.           2.921 0.01190 0.         0.           111.   756.910  0.702 0.         0.       -0.       -0.      -0.
0.00556 0.000347 0.000119 0.           2.909 0.00935 0.         0.           140.   759.070  0.704 0.         0.       -0.       -0.      -0.
0.00741 0.000404 0.000139 0.           2.902 0.00802 0.         0.           163.   761.230  0.706 0.         0.       -0.       -0.      -0.
0.01111 0.000497 0.000172 0.           2.894 0.00662 0.         0.           202.   765.540  0.710 0.001      0.       -0.       -0.      -0.
0.01481 0.000572 0.000198 0.           2.882 0.00580 0.         0.           233.   769.850  0.714 0.001      0.       -0.       -0.      -0.
0.01852 0.000637 0.000221 0.           2.884 0.00529 0.         0.           261.   774.170  0.718 0.001      0.       -0.       -0.      -0.
0.02222 0.000694 0.000241 0.           2.881 0.00491 0.         0.           285.   778.480  0.722 0.002      0.       -0.       -0.      -0.
0.02593 0.000743 0.000258 0.           2.876 0.00462 0.         0.           306.   782.790  0.726 0.002      0.       -0.       -0.      -0.
0.02963 0.000787 0.000275 0.           2.865 0.00439 0.         0.           325.   787.110  0.730 0.002      0.       -0.       -0.      -0.
0.03333 0.000826 0.000289 0.           2.854 0.00421 0.         0.           343.   791.420  0.734 0.002      0.       -0.       -0.      -0.
0.03704 0.000862 0.000303 0.           2.847 0.00405 0.         0.           359.   795.730  0.738 0.003      0.       -0.       -0.      -0.
0.04074 0.000897 0.000316 0.           2.842 0.00392 0.         0.           375.   800.050  0.742 0.003      0.       -0.       -0.      -0.
0.04444 0.000929 0.000327 0.           2.837 0.00381 0.         0.           390.   804.360  0.746 0.003      0.       -0.       -0.      -0.
0.04815 0.000958 0.000338 0.           2.831 0.00371 0.         0.           404.   808.670  0.750 0.003      0.       -0.       -0.      -0.
0.05185 0.000986 0.000349 0.           2.826 0.00363 0.         0.           417.   812.990  0.754 0.003      0.       -0.       -0.      -0.
0.05556 0.001012 0.000359 0.           2.822 0.00355 0.         0.           429.   817.300  0.758 0.003      0.       -0.       -0.      -0.
0.05926 0.001037 0.000368 0.           2.818 0.00348 0.         0.           441.   821.610  0.762 0.003      0.       -0.       -0.      -0.
0.06296 0.001061 0.000377 0.           2.814 0.00342 0.         0.           453.   825.930  0.766 0.003      0.       -0.       -0.      -0.
0.06667 0.001083 0.000385 0.           2.811 0.00336 0.         0.           464.   830.240  0.770 0.003      0.       -0.       -0.      -0.
0.07037 0.001105 0.000393 0.           2.808 0.00331 0.         0.           475.   834.550  0.774 0.003      0.       -0.       -0.      -0.
0.07407 0.001125 0.000401 0.           2.805 0.00326 0.         0.           485.   838.870  0.778 0.003      0.       -0.       -0.      -0.
0.07778 0.001145 0.000408 0.           2.802 0.00322 0.         0.           495.   843.180  0.782 0.002      0.       -0.       -0.      -0.
```

TABLE IX. - Continued. OUTPUT FOR FLAT PLATE

(c) Continued. Summary of boundary layer parameters

```
                                          PRINCIPAL BOUNDARY LAYER PARAMETERS FOR
                       FLAT PLATE                                           FLAT PLATE

    X        DT        MT        HT     SF      CF      ST       GPW      RDT      U        M    TURB     RW       VW       SW       CW
0.08148 0.001163 0.000416 0.        2.860 0.00318 0.        0.        505.  847.490  0.786 0.002    0.       -0.      -0.      -0.
0.08519 0.001181 0.000422 0.        2.798 0.00314 0.        0.        514.  851.810  0.790 0.002    0.       -0.      -0.      -0.
0.08889 0.001199 0.000429 0.        2.796 0.00311 0.        0.        524.  856.120  0.794 0.002    0.       -0.      -0.      -0.
0.09259 0.001216 0.000435 0.        2.794 0.00307 0.        0.        533.  860.430  0.798 0.002    0.       -0.      -0.      -0.
0.09630 0.001232 0.000441 0.        2.793 0.00304 0.        0.        541.  864.750  0.802 0.002    0.       -0.      -0.      -0.
0.10000 0.001247 0.000447 0.        2.791 0.00301 0.        0.        550.  869.060  0.806 0.002    0.       -0.      -0.      -0.
0.10370 0.001262 0.000452 0.        2.790 0.00298 0.        0.        558.  873.370  0.810 0.002    0.       -0.      -0.      -0.
0.10741 0.001277 0.000458 0.        2.789 0.00296 0.        0.        566.  877.690  0.814 0.002    0.       -0.      -0.      -0.
0.11111 0.001292 0.000463 0.        2.791 0.00287 0.        0.        575.  882.000  0.818 0.002    0.       -0.      -0.      -0.
0.11852 0.001370 0.000481 0.        2.848 0.00257 0.        0.        611.  886.000  0.821 0.002    0.       -0.      -0.      -0.
0.12593 0.001426 0.000499 0.        2.858 0.00241 0.        0.        637.  889.000  0.824 0.010    0.       -0.      -0.      -0.
0.13333 0.001483 0.000515 0.        2.879 0.00229 0.        0.        664.  892.000  0.827 0.013    0.       -0.      -0.      -0.
0.14074 0.001541 0.000533 0.        2.893 0.00222 0.        0.        691.  894.000  0.829 0.014    0.       -0.      -0.      -0.
0.14815 0.001583 0.000547 0.        2.897 0.00213 0.        0.        711.  897.000  0.831 0.020    0.       -0.      -0.      -0.
0.15556 0.001634 0.000565 0.        2.892 0.00205 0.        0.        734.  898.000  0.832 0.013    0.       -0.      -0.      -0.
0.16296 0.001681 0.000580 0.        2.900 0.00201 0.        0.        757.  900.000  0.834 0.032    0.       -0.      -0.      -0.
0.17037 0.001719 0.000594 0.        2.894 0.00198 0.        0.        775.  902.000  0.836 0.021    0.       -0.      -0.      -0.
0.17778 0.001754 0.000608 0.        2.886 0.00192 0.        0.        792.  904.000  0.838 0.021    0.       -0.      -0.      -0.
0.18519 0.001811 0.000623 0.        2.905 0.00177 0.        0.        818.  905.000  0.839 0.021    0.       -0.      -0.      -0.
0.19259 0.001890 0.000644 0.        2.936 0.00165 0.        0.        853.  904.000  0.838 0.037    0.       -0.      -0.      -0.
0.20000 0.001908 0.000663 0.        2.876 0.00169 0.        0.        860.  903.000  0.837 0.115    0.       -0.      -0.      -0.
0.20741 0.001926 0.000682 0.        2.823 0.00177 0.        0.        868.  902.500  0.837 0.119    0.       -0.      -0.      -0.
0.21481 0.001946 0.000702 0.        2.774 0.00179 0.        0.        877.  902.000  0.836 0.100    0.       -0.      -0.      -0.
0.22222 0.001988 0.000721 0.        2.757 0.00178 0.        0.        895.  901.500  0.836 0.109    0.       -0.      -0.      -0.
0.22963 0.002021 0.000741 0.        2.729 0.00178 0.        0.        910.  901.000  0.835 0.121    0.       -0.      -0.      -0.
0.23704 0.002054 0.000760 0.        2.702 0.00179 0.        0.        925.  900.500  0.835 0.129    0.       -0.      -0.      -0.
```

TABLE IX. - Continued. OUTPUT FOR FLAT PLATE

(c) Continued. Summary of boundary layer parameters

```
                                                PRINCIPAL BOUNDARY LAYER PARAMETERS FOR
                 FLAT PLATE                                                  FLAT PLATE

    X        DT       MT      HT      SF      CF     ST      GPW     RDT       U        M    TURB     RW      VW      SW      CW
0.24444 0.002084 0.000780 0.       2.673 0.00176 0.      0.        938.  900.000  0.834 0.138   0.     -0.     -0.     -0.
0.25185 0.002132 0.000803 0.       2.657 0.00177 0.      0.        959.  898.500  0.833 0.148   0.     -0.     -0.     -0.
0.25926 0.002104 0.000823 0.       2.556 0.00198 0.      0.        946.  898.000  0.832 0.268   0.     -0.     -0.     -0.
0.27778 0.002242 0.000882 0.       2.542 0.00183 0.      0.       1006.  895.000  0.830 0.156   0.     -0.     -0.     -0.
0.29630 0.002291 0.000951 0.       2.409 0.00211 0.      0.       1025.  890.000  0.825 0.333   0.     -0.     -0.     -0.
0.31481 0.002334 0.001026 0.       2.276 0.00250 0.      0.       1041.  886.000  0.821 0.451   0.     -0.     -0.     -0.
0.33333 0.002438 0.001108 0.       2.200 0.00269 0.      0.       1084.  682.000  0.818 0.502   0.     -0.     -0.     -0.
0.35185 0.002563 0.001201 0.       2.134 0.00287 0.      0.       1136.  877.000  0.813 0.592   0.     -0.     -0.     -0.
0.37037 0.002702 0.001301 0.       2.077 0.00305 0.      0.       1193.  872.000  0.808 0.668   0.     -0.     -0.     -0.
0.38889 0.002659 0.001406 0.       2.034 0.00317 0.      0.       1258.  867.000  0.804 0.732   0.     -0.     -0.     -0.
0.40741 0.003028 0.001516 0.       1.997 0.00328 0.      0.       1328.  862.000  0.799 0.792   0.     -0.     -0.     -0.
0.42593 0.003187 0.001634 0.       1.950 0.00366 0.      0.       1393.  857.000  0.794 1.000   0.     -0.     -0.     -0.
0.44444 0.003401 0.001767 0.       1.924 0.00370 0.      0.       1480.  851.000  0.789 1.000   0.     -0.     -0.     -0.
0.48148 0.003821 0.002020 0.       1.891 0.00362 0.      0.       1652.  842.000  0.780 1.000   0.     -0.     -0.     -0.
0.51852 0.004267 0.002278 0.       1.870 0.00353 0.      0.       1830.  833.000  0.772 1.000   0.     -0.     -0.     -0.
0.55556 0.004670 0.002523 0.       1.851 0.00347 0.      0.       1994.  826.000  0.766 1.000   0.     -0.     -0.     -0.
0.59259 0.005050 0.002750 0.       1.837 0.00342 0.      0.       2148.  821.000  0.761 1.000   0.     -0.     -0.     -0.
0.62963 0.005412 0.002968 0.       1.824 0.00339 0.      0.       2295.  817.000  0.757 1.000   0.     -0.     -0.     -0.
0.66667 0.005736 0.003163 0.       1.814 0.00336 0.      0.       2428.  815.000  0.755 1.000   0.     -0.     -0.     -0.
0.70370 0.006090 0.003371 0.       1.806 0.00333 0.      0.       2572.  812.000  0.753 1.000   0.     -0.     -0.     -0.
0.74074 0.006412 0.003567 0.       1.798 0.00329 0.      0.       2703.  810.000  0.751 1.000   0.     -0.     -0.     -0.
0.77778 0.006740 0.003761 0.       1.792 0.00326 0.      0.       2837.  808.000  0.749 1.000   0.     -0.     -0.     -0.
0.81481 0.007063 0.003957 0.       1.785 0.00323 0.      0.       2968.  806.000  0.747 1.000   0.     -0.     -0.     -0.
0.85185 0.007353 0.004136 0.       1.778 0.00323 0.      0.       3088.  805.000  0.746 1.000   0.     -0.     -0.     -0.
0.88889 0.007583 0.004282 0.       1.771 0.00324 0.      0.       3187.  806.000  0.747 1.000   0.     -0.     -0.     -0.
0.92593 0.007784 0.004410 0.       1.765 0.00326 0.      0.       3277.  808.000  0.749 1.000   0.     -0.     -0.     -0.
```

TABLE IX. - Continued. OUTPUT FOR FLAT PLATE

(c) Concluded. Summary of boundary layer parameters

```
                                       PRINCIPAL BOUNDARY LAYER PARAMETERS FOR
                FLAT PLATE                                               FLAT PLATE

     X          DT        MT        HT        SF     CF        ST         GPW      ROT       U        M     TURB      RW          VW          SW       CW

0.56296 0.007941 0.004512 0.         1.760 0.00327 0.         0.         3352.  811.500  0.752 1.000     0.        -0.        -0.         -0.

1.00000 0.008106 0.004614 0.         1.757 0.00328 0.         0.         3431.  815.000  0.755 1.000     0.        -0.        -0.         -0.
```

TABLE IX. - Continued. OUTPUT FOR FLAT PLATE

(d) Momentum and energy balance ratios

```
I=  1  X(I)=  0.                 COF1=   0.      COF2=   0.       R21F=   0.          COG1=   0.       COG2=   0.       R21G=   0.
I=  2  X(I)=  9.25926E-04        COF1=   0.      COF2=   0.       R21F=   0.          COG1=   0.       COG2=   0.       R21G=   0.
I=  3  X(I)=  1.85185E-03        COF1=   2.2737  COF2=   1.2649   R21F=   0.5563      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I=  4  X(I)=  2.77778E-03        COF1=   1.2516  COF2=   1.2224   R21F=   0.9767      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I=  5  X(I)=  3.70370E-03        COF1=   1.1857  COF2=   1.2057   R21F=   1.0169      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I=  6  X(I)=  5.55556E-03        COF1=   1.2761  COF2=   1.2839   R21F=   1.0061      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I=  7  X(I)=  7.40741E-03        COF1=   1.1829  COF2=   1.1829   R21F=   1.0000      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I=  8  X(I)=  1.11111E-02        COF1=   1.2608  COF2=   1.2658   R21F=   1.0040      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I=  9  X(I)=  1.48148E-02        COF1=   1.1814  COF2=   1.1828   R21F=   1.0011      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 10  X(I)=  1.85185E-02        COF1=   1.1397  COF2=   1.1415   R21F=   1.0016      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 11  X(I)=  2.22222E-02        COF1=   1.1150  COF2=   1.1169   R21F=   1.0017      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 12  X(I)=  2.59259E-02        COF1=   1.1004  COF2=   1.1001   R21F=   0.9998      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 13  X(I)=  2.96296E-02        COF1=   1.0880  COF2=   1.0882   R21F=   1.0002      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 14  X(I)=  3.33333E-02        COF1=   1.0795  COF2=   1.0792   R21F=   0.9998      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 15  X(I)=  3.70370E-02        COF1=   1.0731  COF2=   1.0722   R21F=   0.9991      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 16  X(I)=  4.07407E-02        COF1=   1.0676  COF2=   1.0665   R21F=   0.9990      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 17  X(I)=  4.44444E-02        COF1=   1.0627  COF2=   1.0619   R21F=   0.9992      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 18  X(I)=  4.81481E-02        COF1=   1.0588  COF2=   1.0581   R21F=   0.9993      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 19  X(I)=  5.18519E-02        COF1=   1.0557  COF2=   1.0548   R21F=   0.9992      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 20  X(I)=  5.55556E-02        COF1=   1.0529  COF2=   1.0520   R21F=   0.9991      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 21  X(I)=  5.92593E-02        COF1=   1.0505  COF2=   1.0495   R21F=   0.9991      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 22  X(I)=  6.29630E-02        COF1=   1.0483  COF2=   1.0474   R21F=   0.9991      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 23  X(I)=  6.66667E-02        COF1=   1.0463  COF2=   1.0455   R21F=   0.9992      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 24  X(I)=  7.03704E-02        COF1=   1.0446  COF2=   1.0438   R21F=   0.9992      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 25  X(I)=  7.40741E-02        COF1=   1.0431  COF2=   1.0422   R21F=   0.9991      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 26  X(I)=  7.77778E-02        COF1=   1.0417  COF2=   1.0408   R21F=   0.9992      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 27  X(I)=  8.14815E-02        COF1=   1.0404  COF2=   1.0396   R21F=   0.9992      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 28  X(I)=  8.51852E-02        COF1=   1.0393  COF2=   1.0384   R21F=   0.9992      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 29  X(I)=  8.88889E-02        COF1=   1.0381  COF2=   1.0374   R21F=   0.9993      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 30  X(I)=  9.25926E-02        COF1=   1.0372  COF2=   1.0364   R21F=   0.9992      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 31  X(I)=  9.62963E-02        COF1=   1.0363  COF2=   1.0355   R21F=   0.9992      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 32  X(I)=  1.00000E-01        COF1=   1.0354  COF2=   1.0347   R21F=   0.9993      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 33  X(I)=  1.03704E-01        COF1=   1.0346  COF2=   1.0339   R21F=   0.9993      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 34  X(I)=  1.07407E-01        COF1=   1.0339  COF2=   1.0332   R21F=   0.9992      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 35  X(I)=  1.11111E-01        COF1=   1.0339  COF2=   1.0321   R21F=   0.9983      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 36  X(I)=  1.18519E-01        COF1=   1.0582  COF2=   1.0593   R21F=   1.0010      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
I= 37  X(I)=  1.25926E-01        COF1=   1.0476  COF2=   1.0523   R21F=   1.0045      COG1=   1.0000   COG2=   1.0000   R21G=   1.0000
```

TABLE IX. - Concluded. OUTPUT FOR FLAT PLATE

(d) Concluded. Momentum and energy balance ratios

```
I= 38  X(I)=  1.33333E-01    COF1=  1.0489  COF2=  1.0474  R21F=  0.9986   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 39  X(I)=  1.40741E-01    COF1=  1.0406  COF2=  1.0440  R21F=  1.0032   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 40  X(I)=  1.48148E-01    COF1=  1.0444  COF2=  1.0410  R21F=  0.9967   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 41  X(I)=  1.55556E-01    COF1=  1.0314  COF2=  1.0384  R21F=  1.0068   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 42  X(I)=  1.62963E-01    COF1=  1.0406  COF2=  1.0360  R21F=  0.9956   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 43  X(I)=  1.70370E-01    COF1=  1.0343  COF2=  1.0346  R21F=  1.0003   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 44  X(I)=  1.77778E-01    COF1=  1.0332  COF2=  1.0330  R21F=  0.9998   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 45  X(I)=  1.85185E-01    COF1=  1.0332  COF2=  1.0304  R21F=  0.9973   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 46  X(I)=  1.92593E-01    COF1=  1.0241  COF2=  1.0274  R21F=  1.0032   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 47  X(I)=  2.00000E-01    COF1=  1.0215  COF2=  1.0259  R21F=  1.0043   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 48  X(I)=  2.07407E-01    COF1=  1.0278  COF2=  1.0260  R21F=  0.9982   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 49  X(I)=  2.14815E-01    COF1=  1.0282  COF2=  1.0260  R21F=  0.9978   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 50  X(I)=  2.22222E-01    COF1=  1.0273  COF2=  1.0254  R21F=  0.9981   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 51  X(I)=  2.29630E-01    COF1=  1.0267  COF2=  1.0247  R21F=  0.9980   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 52  X(I)=  2.37037E-01    COF1=  1.0259  COF2=  1.0240  R21F=  0.9982   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 53  X(I)=  2.44444E-01    COF1=  1.0267  COF2=  1.0233  R21F=  0.9966   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 54  X(I)=  2.51852E-01    COF1=  1.0222  COF2=  1.0226  R21F=  1.0004   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 55  X(I)=  2.59259E-01    COF1=  1.0233  COF2=  1.0233  R21F=  1.0000   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 56  X(I)=  2.77778E-01    COF1=  1.0528  COF2=  1.0575  R21F=  1.0045   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 57  X(I)=  2.96296E-01    COF1=  1.0476  COF2=  1.0554  R21F=  1.0074   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 58  X(I)=  3.14815E-01    COF1=  1.0563  COF2=  1.0601  R21F=  1.0037   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 59  X(I)=  3.33333E-01    COF1=  1.0578  COF2=  1.0629  R21F=  1.0048   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 60  X(I)=  3.51852E-01    COF1=  1.0560  COF2=  1.0623  R21F=  1.0059   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 61  X(I)=  3.70370E-01    COF1=  1.0542  COF2=  1.0611  R21F=  1.0066   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 62  X(I)=  3.88889E-01    COF1=  1.0513  COF2=  1.0594  R21F=  1.0077   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 63  X(I)=  4.07407E-01    COF1=  1.0477  COF2=  1.0570  R21F=  1.0089   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 64  X(I)=  4.25926E-01    COF1=  1.0459  COF2=  1.0569  R21F=  1.0105   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 65  X(I)=  4.44444E-01    COF1=  1.0415  COF2=  1.0560  R21F=  1.0139   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 66  X(I)=  4.81481E-01    COF1=  1.0770  COF2=  1.1029  R21F=  1.0240   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 67  X(I)=  5.18519E-01    COF1=  1.0622  COF2=  1.0880  R21F=  1.0243   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 68  X(I)=  5.55556E-01    COF1=  1.0543  COF2=  1.0765  R21F=  1.0210   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 69  X(I)=  5.92593E-01    COF1=  1.0486  COF2=  1.0682  R21F=  1.0187   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 70  X(I)=  6.29630E-01    COF1=  1.0402  COF2=  1.0621  R21F=  1.0210   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 71  X(I)=  6.66667E-01    COF1=  1.0416  COF2=  1.0570  R21F=  1.0149   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 72  X(I)=  7.03704E-01    COF1=  1.0308  COF2=  1.0531  R21F=  1.0216   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 73  X(I)=  7.40741E-01    COF1=  1.0313  COF2=  1.0493  R21F=  1.0175   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 74  X(I)=  7.77778E-01    COF1=  1.0278  COF2=  1.0461  R21F=  1.0178   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 75  X(I)=  8.14815E-01    COF1=  1.0239  COF2=  1.0433  R21F=  1.0190   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 76  X(I)=  8.51852E-01    COF1=  1.0214  COF2=  1.0411  R21F=  1.0193   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 77  X(I)=  8.88889E-01    COF1=  1.0222  COF2=  1.0395  R21F=  1.0168   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 78  X(I)=  9.25926E-01    COF1=  1.0188  COF2=  1.0384  R21F=  1.0193   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 79  X(I)=  9.62963E-01    COF1=  1.0203  COF2=  1.0376  R21F=  1.0169   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 80  X(I)=  1.00000E+00    COF1=  1.0176  COF2=  1.0369  R21F=  1.0189   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
*          CASE END                                                                  1
```

TABLE X. - INPUT FOR INLET DIFFUSER

```
ENTER INIR AT       0.0   SEC.
*          ISTO(K),  K=  1,15                         FORMAT  ( 15I5 )                   1
    1    2    2    1    1    1    1    2    2    1    0    1   -0   -0    1
*          WSTO(K),  K=  1,20                         FORMAT  ( 5E15.8 )                 1
 0.99990000E+00 0.20000000E+02 0.62200000E+06-0.            -0.
-0.            -0.            -0.            -0.             0.10000000E+01
 0.15640000E-30 0.            -0.            -0.            -0.
-0.            -0.            -0.            -0.            -0.
*          LABEL(K), K=1,18, ON FORMAT (18A4), THE X-STATION HEADING.                    1


***...DIFFUSER STUDY.................................DIFFUSER STUDY...
*          JDIV                                       FORMAT  ( 15I5 )                   1
    3
*          JY ON FORMAT (15I5) THEN YY(J), J=1,JY ON FORMAT (6F10.5)                     1
   48          142,   3.
    0.           0.00200000    0.00500000    0.01000000    0.02000000    0.05000000
    0.09999999   0.20000000    0.30000000    0.40000000    0.50000000    0.60000000
    0.70000000   0.80000000    0.90000000    1.00000000    1.20000000    1.40000000
    1.59999999   1.80000000    2.00000000    2.50000000    3.00000000    3.50000000
    4.00000000   4.50000000    5.00000000    5.50000000    6.00000000    6.50000000
    7.00000000   7.50000000    8.00000000    8.50000000    9.00000000    9.50000000
   10.00000000  11.00000000   12.00000000   13.00000000   14.00000000   16.00000000
   18.00000000  20.00000000   22.00000000   24.00000000   26.00000000   28.00000000
*          JEF ON FORMAT (15I5). THEN FP(J), J=1,JEF ON FORMAT (6F10.5)                  1
   36          106.   3.
    1.00000000   0.99800000    0.99600000    0.99200000    0.98500000    0.96200000
    0.92600000   0.85500000    0.78000000    0.72600000    0.66600000    0.60000000
    0.55500000   0.50500000    0.45699999    0.41300000    0.33300000    0.26500000
    0.20800000   0.16100000    0.12300000    0.05880000    0.02609999    0.01080000
    0.00426999   0.00161999    0.00060700    0.00022899    0.00008950    0.00003660
    0.00001570   0.00000656    0.00000316    0.00000144    0.00000062    0.00000022
*          JEG ON FORMAT (15I5). THEN GP(J), J=1,JEG ON FORMAT (6F10.5)                  1
    6           16.   3.
    0.           0.            0.            0.            0.            0.
* IOP  MOP  DOP   IO  TOP  POP                                                           1
    4    1   -1    0    1    1
*   MR  *  DT(1)  *  RDT(1) *   BS   *   TO   *   BH   *   FT   *                        1
-0.     -0.            -0.       1.0000  289.0000   1.0000   -0.
*          X-STATION DATA CARDS...WITH 8 WORDS...ON FORMAT (8F10.5)                      1
   0.         0.         0.        -0.          0.        -0.        -0.        -0.          IS=    1
   0.11810    0.01850    0.        -0.          0.        -0.        -0.        -0.          IS=    2
   0.19100    0.03710    0.        -0.          0.        -0.        -0.        -0.          IS=    3
   0.24750    0.05560    0.        -0.          0.        -0.        -0.        -0.          IS=    4
   0.29210    0.07410    0.        -0.          0.        -0.        -0.        -0.          IS=    5

   0.24750    0.05560    0.        -0.          0.        -0.        -0.        -0.          IS=    4

   0.04125    0.00927    0.        -0.          0.        -0.        -0.        -0.          IS=    2
   0.08250    0.01853    0.        -0.          0.        -0.        -0.        -0.          IS=    3
   0.12375    0.02780    0.        -0.          0.        -0.        -0.        -0.          IS=    4
   0.16500    0.03707    0.        -0.          0.        -0.        -0.        -0.          IS=    5
   0.20625    0.04633    0.        -0.          0.        -0.        -0.        -0.          IS=    6
   0.24750    0.05560    0.        -0.          0.        -0.        -0.        -0.          IS=    7
   0.29210    0.07410    0.        -0.          0.        -0.        -0.        -0.          IS=    8
   0.33100    0.09270    0.        -0.          0.        -0.        -0.        -0.          IS=    9
   0.36600    0.11120    0.        -0.          0.        -0.        -0.        -0.          IS=   10
   0.39800    0.12970    0.        -0.          0.        -0.        -0.        -0.          IS=   11
   0.42780    0.14830    0.        -0.          0.        -0.        -0.        -0.          IS=   12
   0.45370    0.16680    0.        -0.          0.        -0.        -0.        -0.          IS=   13
```

TABLE X. - Continued. INPUT FOR INLET DIFFUSER

```
  0.47530    0.18530    0.       -0.       0.       -0.       -0.       -0.          IS=   14
  0.49390    0.20390    0.       -0.       0.       -0.       -0.       -0.          IS=   15
  0.51050    0.22240    0.       -0.       0.       -0.       -0.       -0.          IS=   16
  0.52570    0.24090    0.       -0.       0.       -0.       -0.       -0.          IS=   17
  0.53970    0.25950    0.       -0.       0.       -0.       -0.       -0.          IS=   18
  0.55280    0.27800    0.       -0.       0.       -0.       -0.       -0.          IS=   19
  0.56520    0.29650    0.       -0.       0.       -0.       -0.       -0.          IS=   20
  0.57690    0.31510    0.       -0.       0.       -0.       -0.       -0.          IS=   21
  0.58810    0.33360    0.       -0.       0.       -0.       -0.       -0.          IS=   22
  0.59880    0.35210    0.       -0.       0.       -0.       -0.       -0.          IS=   23
  0.60910    0.37070    0.       -0.       0.       -0.       -0.       -0.          IS=   24
  0.61900    0.38920    0.       -0.       0.       -0.       -0.       -0.          IS=   25
  0.62860    0.40770    0.       -0.       0.       -0.       -0.       -0.          IS=   26
  0.63790    0.42630    0.       -0.       0.       -0.       -0.       -0.          IS=   27
  0.64700    0.44480    0.       -0.       0.       -0.       -0.       -0.          IS=   28
  0.65720    0.46330    0.       -0.       0.       -0.       -0.       -0.          IS=   29
  0.66770    0.48190    0.       -0.       0.       -0.       -0.       -0.          IS=   30
  0.67870    0.50040    0.       -0.       0.       -0.       -0.       -0.          IS=   31
  0.69030    0.51890    0.       -0.       0.       -0.       -0.       -0.          IS=   32
  0.70230    0.53750    0.       -0.       0.       -0.       -0.       -0.          IS=   33
  0.71510    0.55600    0.       -0.       0.       -0.       -0.       -0.          IS=   34
  0.72870    0.57450    0.       -0.       0.       -0.       -0.       -0.          IS=   35
  0.74320    0.59310    0.       -0.       0.       -0.       -0.       -0.          IS=   36
  0.75900    0.61160    0.       -0.       0.       -0.       -0.       -0.          IS=   37
  0.77630    0.63010    0.       -0.       0.       -0.       -0.       -0.          IS=   38
  0.79590    0.64870    0.       -0.       0.       -0.       -0.       -0.          IS=   39
  0.81870    0.66720    0.       -0.       0.       -0.       -0.       -0.          IS=   40
  0.84760    0.68570    0.       -0.       0.       -0.       -0.       -0.          IS=   41
  0.88650    0.70430    0.       -0.       0.       -0.       -0.       -0.          IS=   42
  0.92930    0.72280    0.       -0.       0.       -0.       -0.       -0.          IS=   43
  0.97610    0.74130    0.       -0.       0.       -0.       -0.       -0.          IS=   44
  1.02850    0.75990    0.       -0.       0.       -0.       -0.       -0.          IS=   45
  1.10730    0.77840    0.       -0.       0.       -0.       -0.       -0.          IS=   46
  1.25520    0.79690    0.       -0.       0.       -0.       -0.       -0.          IS=   47
  1.67010    0.81550    0.       -0.       0.       -0.       -0.       -0.          IS=   48
  1.87640    0.79800    0.       -0.       0.       -0.       -0.       -0.          IS=   49
  2.03100    0.78040    0.       -0.       0.       -0.       -0.       -0.          IS=   50
  2.38310    0.72800    0.       -0.       0.       -0.       -0.       -0.          IS=   51
  2.73530    0.68460    0.       -0.       0.       -0.       -0.       -0.          IS=   52
  3.08750    0.65010    0.       -0.       0.       -0.       -0.       -0.          IS=   53
  3.43970    0.62420    0.       -0.       0.       -0.       -0.       -0.          IS=   54
  3.79180    0.60280    0.       -0.       0.       -0.       -0.       -0.          IS=   55
  4.14400    0.58600    0.       -0.       0.       -0.       -0.       -0.          IS=   56
  4.49620    0.57380    0.       -0.       0.       -0.       -0.       -0.          IS=   57
  4.84840    0.55820    0.       -0.       0.       -0.       -0.       -0.          IS=   58
  5.20050    0.54070    0.       -0.       0.       -0.       -0.       -0.          IS=   59
  5.55270    0.52370    0.       -0.       0.       -0.       -0.       -0.          IS=   60
  5.90490    0.50730    0.       -0.       0.       -0.       -0.       -0.          IS=   61
  6.25710    0.49150    0.       -0.       0.       -0.       -0.       -0.          IS=   62
  6.60930    0.47610    0.       -0.       0.       -0.       -0.       -0.          IS=   63
  6.96140    0.46090    0.       -0.       0.       -0.       -0.       -0.          IS=   64
  7.31360    0.44580    0.       -0.       0.       -0.       -0.       -0.          IS=   65
  7.66580    0.43130    0.       -0.       0.       -0.       -0.       -0.          IS=   66
  8.01800    0.41770    0.       -0.       0.       -0.       -0.       -0.          IS=   67
  8.37010    0.40470    0.       -0.       0.       -0.       -0.       -0.          IS=   68
  8.72230    0.39230    0.       -0.       0.       -0.       -0.       -0.          IS=   69
  9.07450    0.38050    0.       -0.       0.       -0.       -0.       -0.          IS=   70
  9.42670    0.36950    0.       -0.       0.       -0.       -0.       -0.          IS=   71
  9.77880    0.35920    0.       -0.       0.       -0.       -0.       -0.          IS=   72
 10.13100    0.34980    0.       -0.       0.       -0.       -0.       -0.          IS=   73
```

TABLE X. - Concluded. INPUT FOR INLET DIFFUSER

```
 10.48320   0.34120   0.        -0.        0.        -0.       -0.       -0.          IS=   74
 10.83540   0.33320   0.        -0.        0.        -0.       -0.       -0.          IS=   75
 11.18750   0.32580   0.        -0.        0.        -0.       -0.       -0.          IS=   76
 11.53970   0.31930   0.        -0.        0.        -0.       -0.       -0.          IS=   77
 11.89190   0.31350   0.        -0.        0.        -0.       -0.       -0.          IS=   78
 12.24410   0.30870   0.        -0.        0.        -0.       -0.       -0.          IS=   79
 12.59620   0.30410   0.        -0.        0.        -0.       -0.       -0.          IS=   80
 12.94840   0.30010   0.        -0.        0.        -0.       -0.       -0.          IS=   81
 13.30060   0.29680   0.        -0.        0.        -0.       -0.       -0.          IS=   82
 13.65280   0.29430   0.        -0.        0.        -0.       -0.       -0.          IS=   83
 14.00490   0.29210   0.        -0.        0.        -0.       -0.       -0.          IS=   84
 14.35710   0.29050   0.        -0.        0.        -0.       -0.       -0.          IS=   85
 14.70930   0.28950   0.        -0.        0.        -0.       -0.       -0.          IS=   86
 15.06150   0.28910   0.        -0.        0.        -0.       -0.       -0.          IS=   87
 15.41370   0.28930   0.        -0.        0.        -0.       -0.       -0.          IS=   88
 15.76580   0.29100   0.        -0.        0.        -0.       -0.       -0.          IS=   89
 16.11800   0.29520   0.        -0.        0.        -0.       -0.       -0.          IS=   90
 16.47020   0.30190   0.        -0.        0.        -0.       -0.       -0.          IS=   91
 16.82240   0.31100   0.        -0.        0.        -0.       -0.       -0.          IS=   92
 17.17450   0.32260   0.        -0.        0.        -0.       -0.       -0.          IS=   93
 17.52670   0.33660   0.        -0.        0.        -0.       -0.       -0.          IS=   94
  0.        0.        0.        -0.        0.        -0.       -0.       -0.          IS=   95

END OF CARD READ      NO. OF X STATIONS= 94   LAST X TO BE COMPUTED= 0.17526700E+02      LAST X= 0.

MR=  9.2666665E-03      DT(1)= -0.                  ROT(1)=  2.3775949E+02      BS=  1.0000000E+00      IT= 100  NC= 92  KEND=     0
                                                              WSTO(10)=  1.0000000E+00      NO. OF X-STATION POINTS INCREASE=    3
*                                                                                           1
```

TABLE XI. - OUTPUT FOR INLET DIFFUSER

(a) Profiles and parameters at X = 0.0412

```
***                                                      BOUNDARY LAYER PROFILES FOR
...DIFFUSER STUDY..................................... ..DIFFUSER STUDY...
X =    0.0412                                        U =      1.000    M =   0.01    RDT = 9.99E+00
                              TURB =0.          RW = 0.            VW =-0.           SW =-0.           CW =-0.
                  DT = 1.73E-03 MT = 7.82E-04 HT = 0.          SF = 2.22E+00 CF = 1.60E-01 ST =-0.
                                   HR = 1.00E+00   PR = 7.80E-01   PRT = 1.00E+00   SHR = 1.40

X=      0.0412    XNOD=      0.0412    I(X)=    2    JE=   102    ISTO(10)=    2
 J        YY                U/U(BLE)          F                 FP              FPP               D                     GP                GPP
  1   0.               0.                0.                1.0000000E+00  -7.9657369E-01   1.0000172E+00   0.                 0.
  4   2.0000000E-03   1.5933563E-03    1.9984064E-03    9.9840666E-01  -7.9613328E-01   1.0000172E+00   0.                 0.
  7   5.0000000E-03   3.9800939E-03    4.9900454E-03    9.9601997E-01  -7.9480557E-01   1.0000172E+00   0.                 0.
 10   1.0000000E-02   7.9495707E-03    9.9602176E-03    9.9205056E-01  -7.9247056E-01   1.0000172E+00   0.                 0.
 13   2.0000000E-02   1.5856888E-02    1.9841156E-02    9.8414338E-01  -7.8721494E-01   1.0000172E+00   0.                 0.
 16   4.9999999E-02   3.9326894E-02    4.9012573E-02    9.6067377E-01  -7.7463061E-01   1.0000171E+00   0.                 0.
 19   1.0000000E-01   7.7605252E-02    9.6085441E-02    9.2239606E-01  -7.5160906E-01   1.0000171E+00   0.                 0.
 22   2.0000000E-01   1.5103090E-01    1.8462299E-01    8.4897163E-01  -7.1347978E-01   1.0000168E+00   0.                 0.
 25   3.0000000E-01   2.2031886E-01    2.6602536E-01    7.7968473E-01  -6.7238386E-01   1.0000163E+00   0.                 0.
 28   4.0000000E-01   2.8553068E-01    3.4070336E-01    7.1447383E-01  -6.3199661E-01   1.0000158E+00   0.                 0.
 31   5.0000000E-01   3.4674594E-01    4.0906073E-01    6.5325931E-01  -5.9248812E-01   1.0000152E+00   0.                 0.
 34   6.0000000E-01   4.0406007E-01    4.7149248E-01    5.9594576E-01  -5.5400555E-01   1.0000144E+00   0.                 0.
 37   7.0000000E-01   4.5758227E-01    5.2838330E-01    5.4242398E-01  -5.1667668E-01   1.0000137E+00   0.                 0.
 40   7.9999999E-01   5.0743347E-01    5.8010642E-01    4.9257304E-01  -4.8060908E-01   1.0000129E+00   0.                 0.
 43   8.5599999E-01   5.5374453E-01    6.2702245E-01    4.4626212E-01  -4.4589263E-01   1.0000120E+00   0.                 0.
 46   1.0000000E+00   5.9665436E-01    6.6947851E-01    4.0335231E-01  -4.0719780E-01   1.0000112E+00   0.                 0.
 49   1.2000000E+00   6.7284730E-01    7.4234559E-01    3.2715912E-01  -3.5053357E-01   1.0000096E+00   0.                 0.
 52   1.4000000E+00   7.3723368E-01    8.0117301E-01    2.6277222E-01  -2.9460767E-01   1.0000080E+00   0.                 0.
 55   1.6000000E+00   7.9105965E-01    8.4819758E-01    2.0894555E-01  -2.4492592E-01   1.0000066E+00   0.                 0.
 58   1.8000000E+00   8.3556659E-01    8.8540691E-01    1.6443787E-01  -2.0137986E-01   1.0000053E+00   0.                 0.
 61   2.0000000E+00   8.7195910E-01    9.1454359E-01    1.2804461E-01  -1.5532593E-01   1.0000043E+00   0.                 0.
 64   2.5000000E+00   9.3468245E-01    9.6157224E-01    6.5319676E-02  -9.3026770E-02   1.0000023E+00   0.                 0.
 67   3.0000000E+00   9.6898407E-01    9.8484401E-01    3.1017021E-02  -4.8854768E-02   1.0000011E+00   0.                 0.
 70   3.5000000E+00   9.8634386E-01    9.9555124E-01    1.3656638E-02  -2.3690476E-02   1.0000005E+00   0.                 0.
 73   4.0000000E+00   9.9444499E-01    1.0001148E+00    5.5551977E-03  -1.0570188E-02   1.0000002E+00   0.                 0.
 76   4.5000000E+00   9.9791933E-01    1.0019103E+00    2.0807233E-03  -4.3256084E-03   1.0000001E+00   0.                 0.
 79   5.0000000E+00   9.9928459E-01    1.0025605E+00    7.1541023E-04  -1.6188995E-03   1.0000000E+00   0.                 0.
 82   5.5000000E+00   9.9977483E-01    1.0027765E+00    2.2516360E-04  -5.5268394E-04   1.0000000E+00   0.                 0.
 85   6.0000000E+00   9.9993528E-01    1.0028421E+00    6.4701582E-05  -1.7171125E-04   1.0000000E+00   0.                 0.
 88   6.5000000E+00   9.9998306E-01    1.0028603E+00    1.6933835E-05  -4.8445033E-05   1.0000000E+00   0.                 0.
 91   7.0000000E+00   9.9999596E-01    1.0028649E+00    4.0274760E-06  -1.2386682E-05   1.0000000E+00   0.                 0.
 94   7.5000000E+00   9.9999912E-01    1.0028660E+00    8.6858196E-07  -2.8647655E-06   1.0000000E+00   0.                 0.
 97   8.0000000E+00   9.9999982E-01    1.0028662E+00    1.6950736E-07  -5.9821420E-07   1.0000000E+00   0.                 0.
100   8.5000000E+00   9.9999995E-01    1.0028662E+00    2.9873490E-08  -1.1258605E-07   1.0000000E+00   0.                 0.

IVEL=  3    VE(1)=  4.99E-02    VEG(1)=  6.40E-02    VHP(1)=  0.           VH(1)=  1.00E+00

IVEL=  3    VE(1)=  3.97E-02    VEG(1)=  5.09E-02    VHP(1)=  0.           VH(1)=  1.00E+00

TRANSITIONAL STATISTICS LISTED BY TRANS...  I(X)=    3     IC=  95
RSR=  0.100E+01   RRR=  0.100E+01   RMC=  0.613E+04   RC=  0.100E-18   RMT=  0.          FT= -0.          RTR=  0.100E-18
TURB(I+1)=  0.

X=      0.0825    XNOD=      0.0825    I(X)=    3    JE=   102    ISTO(10)=    3
 J        YY                U/U(BLE)          F                 FP              FPP               D                     GP                GPP
  1   0.               0.                0.                1.0000000E+00  -8.0014764E-01   1.0000687E+00   0.                 0.
  7   5.0000000E-03   3.9959835E-03    4.9900061E-03    9.9600428E-01  -7.9789290E-01   1.0000687E+00   0.                 0.
 13   2.0000000E-02   1.5919594E-02    1.9840534E-02    9.8408149E-01  -7.9027936E-01   1.0000687E+00   0.                 0.
```

TABLE XI. - Continued. OUTPUT FOR INLET DIFFUSER

(b) Transition statistics and profiles at X = 0.7287 and X = 0.7432

```
IVEL=  3   VE(1)=  4.54E-03   VEG(1)=  5.82E-03   VHP(1)=  0.          VH(1)=  1.12E+00

IVEL=  3   VE(1)=  4.53E-03   VEG(1)=  5.81E-03   VHP(1)=  0.          VH(1)=  1.12E+00

TRANSITIONAL STATISTICS LISTED BY TRANS...  I(X)=  35     IC=  95
RSR=  0.100E+01  RRR=  0.100E+01  RMC=  0.102E+04  RC=  0.100E-18  RMT=  0.          FT= -0.          RTR=  0.100E-18
TURB(I+1)=  0.

X=       0.7287    XNOD=        0.7287    I(X)=  35     JE=  100    ISTO(10)=    3
 J         YY                   U/U(BLE)             F                    FP                 FPP                  D                       GP                    GPP
  1    0.                  0.                  0.                  1.0000000E+00  -7.5640528E-01   1.0660100E+00   0.                     0.
  7    5.0000000E-03   4.0269484E-03   4.9905518E-03   9.9622240E-01  -7.5440480E-01   1.0660090E+00   0.                     0.
 13    2.0000000E-02   1.6046302E-02   1.9849220E-02   9.8494709E-01  -7.4761547E-01   1.0659930E+00   0.                     0.
 19    1.0000000E-01   7.8619547E-02   9.6280781E-02   9.2622046E-01  -7.1654767E-01   1.0656011E+00   0.                     0.
 25    3.0000000E-01   2.2390734E-01   2.6760960E-01   7.8930179E-01  -6.5054912E-01   1.0626922E+00   0.                     0.
 31    5.0000000E-01   3.5354433E-01   4.1290417E-01   6.6575426E-01  -5.8539558E-01   1.0577377E+00   0.                     0.
 37    7.0000000E-01   4.6790693E-01   5.3477678E-01   5.5501959E-01  -5.2219667E-01   1.0515226E+00   0.                     0.
 43    8.9999959E-01   5.6748645E-01   6.3575769E-01   4.5679826E-01  -4.6022496E-01   1.0447066E+00   0.                     0.
 49    1.2000000E+00   6.9064802E-01   7.5348203E-01   3.3236939E-01  -3.7018860E-01   1.0344763E+00   0.                     0.
 55    1.6000000E+00   8.1112409E-01   8.5988563E-01   2.0676470E-01  -2.6059406E-01   1.0225517E+00   0.                     0.
 61    2.0000000E+00   8.9060659E-01   9.2434022E-01   1.2138473E-01  -1.6064502E-01   1.0136480E+00   0.                     0.
 67    3.0000000E+00   9.7756288E-01   9.8753680E-01   2.5308310E-02  -4.4049273E-02   1.0029458E+00   0.                     0.
 73    4.0000000E+00   9.9654634E-01   9.9933988E-01   3.9139394E-03  -7.9691955E-03   1.0004621E+00   0.                     0.
 79    5.0000000E+00   9.9959710E-01   1.0010015E+00   4.5749125E-04  -1.0686920E-03   1.0000546E+00   0.                     0.
 85    6.0000000E+00   9.9996498E-01   1.0011788E+00   3.9816834E-05  -1.0631467E-04   1.0000048E+00   0.                     0.

IVEL=  3   VE(1)=  4.32E-03   VEG(1)=  5.53E-03   VHP(1)=  0.          VH(1)=  1.13E+00

IVEL=  3   VE(1)=  4.32E-03   VEG(1)=  5.53E-03   VHP(1)=  0.          VH(1)=  1.13E+00

TRANSITIONAL STATISTICS LISTED BY TRANS...  I(X)=  36     IC=  95
RSR=  0.100E+01  RRR=  0.100E+01  RMC=  0.798E+03  RC=  0.100E-18  RMT=  0.          FT= -0.          RTR=  0.100E-18
TURB(I+1)=  0.

X=       0.7432    XNOD=        0.7432    I(X)=  36     JE=   99    ISTO(10)=    3
 J         YY                   U/U(BLE)             F                    FP                 FPP                  D                       GP                    GPP
  1    0.                  0.                  0.                  1.0000000E+00  -7.5018032E-01   1.0703535E+00   0.                     0.
  7    5.0000000E-03   4.0102050E-03   4.9906294E-03   9.9625337E-01  -7.4825807E-01   1.0703524E+00   0.                     0.
 13    2.0000000E-02   1.5980957E-02   1.9850449E-02   9.8506920E-01  -7.4164701E-01   1.0703355E+00   0.                     0.
 19    1.0000000E-01   7.8328199E-02   9.6310117E-02   9.2679063E-01  -7.1143776E-01   1.0699206E+00   0.                     0.
 25    3.0000000E-01   2.2328457E-01   2.6784287E-01   7.9070375E-01  -6.4742390E-01   1.0668350E+00   0.                     0.
 31    5.0000000E-01   3.5288266E-01   4.1346683E-01   6.6758289E-01  -5.8421652E-01   1.0615659E+00   0.                     0.
 37    7.0000000E-01   4.6743099E-01   5.3571691E-01   5.5691178E-01  -5.2267902E-01   1.0549389E+00   0.                     0.
 43    8.9999999E-01   5.6734655E-01   6.3705731E-01   4.5846000E-01  -4.6196817E-01   1.0476540E+00   0.                     0.
 49    1.2000000E+00   6.9113214E-01   7.5518231E-01   3.3333013E-01  -3.7292546E-01   1.0366932E+00   0.                     0.
 55    1.6000000E+00   8.1233829E-01   8.6174614E-01   2.0661928E-01  -2.6313253E-01   1.0238947E+00   0.                     0.
 61    2.0000000E+00   8.9217994E-01   9.2596723E-01   1.2044006E-01  -1.6188820E-01   1.0143481E+00   0.                     0.
 67    3.0000000E+00   9.7868640E-01   9.8797556E-01   2.4225620E-02  -4.3374442E-02   1.0029843E+00   0.                     0.
 73    4.0000000E+00   9.9691117E-01   9.9906132E-01   3.5279330E-03  -7.4444478E-03   1.0004407E+00   0.                     0.
 79    5.0000000E+00   9.9966762E-01   1.0005227E+00   3.8041640E-04  -9.2529720E-04   1.0000481E+00   0.                     0.
 82    5.5000000E+00   9.9990292E-01   1.0006343E+00   1.1122529E-04  -2.8979034E-04   1.0000142E+00   0.                     0.

IVEL=  3   VE(1)=  4.11E-03   VEG(1)=  5.27E-03   VHP(1)=  0.          VH(1)=  1.14E+00

IVEL=  3   VE(1)=  4.10E-03   VEG(1)=  5.26E-03   VHP(1)=  0.          VH(1)=  1.14E+00

TRANSITIONAL STATISTICS LISTED BY TRANS...  I(X)=  37     IC=  95
RSR=  0.100E+01  RRR=  0.100E+01  RMC=  0.590E+03  RC=  0.100E-18  RMT=  0.          FT= -0.          RTR=  0.100E-18
TURB(I+1)=  0.
```

TABLE XI. - Continued. OUTPUT FOR INLET DIFFUSER

(c) Summary of boundary layer parameters

```
                                 PRINCIPAL BOUNDARY LAYER PARAMETERS FOR
                    ...DIFFUSER STUDY..................................DIFFUSER STUDY...

    X         DT         MT      HT      SF     CF        ST        GPW       ROT      U        M     TURB       RW        VW        SW      CW
 0.       0.001733 0.000782 0.        2.217 0.        0.        0.            0.     0.      0.     0.         0.       -0.       -0.      -0.
 0.04125  0.001733 0.000782 0.        2.217 0.15953  0.        0.           10.     1.000   0.009  0.         0.       -0.       -0.       0.
 0.08250  0.002185 0.000985 0.        2.218 0.07989  0.        0.           25.     2.000   0.019  0.         0.       -0.       -0.      -0.
 0.12375  0.001609 0.000745 0.        2.160 0.05037  0.        0.           28.     3.000   0.028  0.         0.       -0.       -0.      -0.
 0.16500  0.001807 0.000812 0.        2.225 0.04176  0.        0.           42.     3.999   0.037  0.         0.       -0.       -0.      -0.
 0.20625  0.001776 0.000802 0.        2.214 0.03134  0.        0.           51.     4.999   0.046  0.         0.       -0.       -0.      -0.
 0.24750  0.001852 0.000853 0.        2.171 0.03029  0.        0.           64.     5.998   0.056  0.         0.       -0.       -0.       0.
 0.29210  0.001212 0.000577 0.        2.101 0.02591  0.        0.           56.     7.992   0.074  0.         0.       -0.       -0.       0.
 0.33100  0.001240 0.000567 0.        2.187 0.02489  0.        0.           71.     9.995   0.093  0.         0.       -0.       -0.      -0.
 0.36600  0.001184 0.000543 0.        2.180 0.02032  0.        0.           81.    11.985   0.111  0.         0.       -0.       -0.      -0.
 0.39800  0.001124 0.000512 0.        2.194 0.01828  0.        0.           90.    13.973   0.130  0.         0.       -0.       -0.      -0.
 0.42780  0.001085 0.000496 0.        2.187 0.01697  0.        0.           99.    15.969   0.148  0.         0.       -0.       -0.      -0.
 0.45370  0.001034 0.000475 0.        2.175 0.01611  0.        0.          106.    17.950   0.167  0.         0.       -0.       -0.      -0.
 0.47530  0.000967 0.000447 0.        2.162 0.01563  0.        0.          110.    19.928   0.185  0.         0.       -0.       -0.       0.
 0.49390  0.000909 0.000420 0.        2.162 0.01519  0.        0.          113.    21.913   0.204  0.         0.       -0.       -0.      -0.
 0.51050  0.000862 0.000399 0.        2.160 0.01472  0.        0.          117.    23.882   0.222  0.         0.       -0.       -0.      -0.
 0.52570  0.000829 0.000382 0.        2.168 0.01423  0.        0.          121.    25.847   0.241  0.         0.       -0.       -0.      -0.
 0.53970  0.000800 0.000367 0.        2.181 0.01375  0.        0.          125.    27.817   0.259  0.         0.       -0.       -0.      -0.
 0.55280  0.000776 0.000355 0.        2.187 0.01329  0.        0.          130.    29.771   0.278  0.         0.       -0.       -0.      -0.
 0.56520  0.000757 0.000345 0.        2.197 0.01286  0.        0.          134.    31.719   0.296  0.         0.       -0.       -0.      -0.
 0.57690  0.000740 0.000335 0.        2.208 0.01244  0.        0.          139.    33.671   0.315  0.         0.       -0.       -0.      -0.
 0.58810  0.000726 0.000328 0.        2.215 0.01207  0.        0.          144.    35.606   0.334  0.         0.       -0.       -0.      -0.
 0.59880  0.000715 0.000321 0.        2.226 0.01170  0.        0.          148.    37.534   0.352  0.         0.       -0.       -0.      -0.
 0.60910  0.000705 0.000315 0.        2.236 0.01137  0.        0.          153.    39.465   0.371  0.         0.       -0.       -0.      -0.
 0.61900  0.000696 0.000310 0.        2.245 0.01106  0.        0.          158.    41.378   0.389  0.         0.       -0.       -0.      -0.
 0.62860  0.000690 0.000306 0.        2.255 0.01076  0.        0.          163.    43.283   0.408  0.         0.       -0.       -0.      -0.
```

TABLE XI. - Continued. OUTPUT FOR INLET DIFFUSER

(c) Continued. Summary of boundary layer parameters

```
                                          PRINCIPAL BOUNDARY LAYER FARAMETERS FOR
                         ...DIFFUSER STUDY..................................DIFFUSER STUDY...

      X        DT        MT       HT      SF      CF      ST      GPW     RDT       U       M    TURB     RW       VW       SW      CW
 0.63790 0.000684 0.000302 0.          2.267 0.01047 0.       0.          167.   45.190  0.426 0.       0.       -0.      -0.      -0.
 0.64700 0.000678 0.000298 0.          2.276 0.01002 0.       0.          172.   47.078  0.445 0.       0.       -0.      -0.      -0.
 0.65720 0.000695 0.000300 0.          2.317 0.00946 0.       0.          182.   48.957  0.463 0.       0.       -0.      -0.      -0.
 0.66770 0.000705 0.000302 0.          2.335 0.00897 0.       0.          191.   50.837  0.482 0.       0.       -0.      -0.      -0.
 0.67870 0.000717 0.000305 0.          2.351 0.00850 0.       0.          200.   52.697  0.500 0.       0.       -0.      -0.      -0.
 0.69030 0.000735 0.000310 0.          2.374 0.00807 0.       0.          211.   54.547  0.519 0.       0.       -0.      -0.      -0.
 0.70240 0.000753 0.000314 0.          2.398 0.00766 0.       0.          222.   56.398  0.538 0.       0.       -0.      -0.      -0.
 0.71510 0.000774 0.000320 0.          2.416 0.00726 0.       0.          234.   58.227  0.556 0.       0.       -0.      -0.      -0.
 0.72870 0.000798 0.000327 0.          2.436 0.00686 0.       0.          247.   60.047  0.575 0.       0.       -0.      -0.      -0.
 0.74320 0.000824 0.000335 0.          2.459 0.00648 0.       0.          262.   61.865  0.593 0.       0.       -0.      -0.      -0.
 0.75900 0.000856 0.000345 0.          2.482 0.00609 0.       0.          277.   63.662  0.612 0.       0.       -0.      -0.      -0.
 0.77630 0.000893 0.000356 0.          2.507 0.00570 0.       0.          295.   65.448  0.630 0.       0.       -0.      -0.      -0.
 0.79590 0.000937 0.000370 0.          2.535 0.00528 0.       0.          316.   67.232  0.649 0.       0.       -0.      -0.      -0.
 0.81870 0.000993 0.000387 0.          2.567 0.00483 0.       0.          341.   68.995  0.667 0.       0.       -0.      -0.      -0.
 0.84760 0.001074 0.000412 0.          2.606 0.00432 0.       0.          375.   70.745  0.686 0.       0.       -0.      -0.      -0.
 0.88650 0.001193 0.000448 0.          2.661 0.00384 0.       0.          424.   72.493  0.704 0.       0.       -0.      -0.      -0.
 0.92930 0.001283 0.000481 0.          2.668 0.00349 0.       0.          463.   74.219  0.723 0.000   0.       -0.      -0.      -0.
 0.97610 0.001384 0.000512 0.          2.702 0.00322 0.       0.          507.   75.933  0.741 0.000   0.       -0.      -0.      -0.
 1.02850 0.001486 0.000544 0.          2.729 0.00295 0.       0.          551.   77.643  0.760 0.000   0.       -0.      -0.      -0.
 1.10730 0.001666 0.000601 0.          2.772 0.00253 0.       0.          626.   79.331  0.778 0.001   0.       -0.      -0.      -0.
 1.25520 0.002020 0.000713 0.          2.834 0.00202 0.       0.          769.   81.007  0.797 0.003   0.       -0.      -0.      -0.
 1.67010 0.002815 0.000943 0.          2.985 0.00108 0.       0.         1083.   82.678  0.815 0.021   0.       -0.      -0.      -0.
 1.87640 0.003488 0.001129 0.          3.090 0.00083 0.       0.         1328.   81.106  0.798 0.040   0.       -0.      -0.      -0.
 2.03100 0.003182 0.001328 0.          2.396 0.00177 0.       0.         1198.   79.513  0.780 0.399   0.       -0.      -0.      -0.
 2.38310 0.004584 0.001990 0.          2.304 0.00130 0.       0.         1661.   74.702  0.728 0.241   0.       -0.      -0.      -0.
 2.73530 0.005228 0.002845 0.          1.837 0.00307 0.       0.         1825.   70.642  0.685 1.000   0.       -0.      -0.      -0.
```

TABLE XI. - Continued. OUTPUT FOR INLET DIFFUSER

(c) Continued. Summary of boundary layer parameters

```
                          PRINCIPAL BOUNDARY LAYER PARAMETERS FOR
               ...DIFFUSER STUDY..................................DIFFUSER STUDY...

    X        DT       MT      HT     SF     CF     ST    GPW      RDT      U       M   TURB    RW      VW     SW     CW

 3.08750 0.006846 0.003941 0.       1.737 0.00328 0.      0.      2313.  67.366 0.650 1.000   0.     -0.    -0.    -0.
 3.43970 0.008635 0.005059 0.       1.707 0.00313 0.      0.      2839.  64.880 0.624 1.000   0.     -0.    -0.    -0.
 3.75180 0.010384 0.006202 0.       1.674 0.00302 0.      0.      3333.  62.809 0.603 1.000   0.     -0.    -0.    -0.
 4.14400 0.012097 0.007315 0.       1.654 0.00294 0.      0.      3805.  61.172 0.586 1.000   0.     -0.    -0.    -0.
 4.49620 0.013608 0.008330 0.       1.634 0.00285 0.      0.      4216.  59.978 0.574 1.000   0.     -0.    -0.    -0.
 4.84840 0.015664 0.009585 0.       1.634 0.00270 0.      0.      4756.  58.444 0.558 1.000   0.     -0.    -0.    -0.
 5.20050 0.018000 0.011677 0.       1.625 0.00255 0.      0.      5337.  56.715 0.541 1.000   0.     -0.    -0.    -0.
 5.55270 0.020672 0.012712 0.       1.626 0.00240 0.      0.      5982.  55.026 0.524 1.000   0.     -0.    -0.    -0.
 5.90490 0.023621 0.014502 0.       1.629 0.00227 0.      0.      6668.  53.388 0.507 1.000   0.     -0.    -0.    -0.
 6.25710 0.026905 0.016464 0.       1.634 0.00213 0.      0.      7408.  51.803 0.491 1.000   0.     -0.    -0.    -0.
 6.60930 0.030619 0.018641 0.       1.643 0.00199 0.      0.      8218.  50.252 0.476 1.000   0.     -0.    -0.    -0.
 6.96140 0.034907 0.021093 0.       1.655 0.00185 0.      0.      9124.  48.714 0.461 1.000   0.     -0.    -0.    -0.
 7.31360 0.039932 0.023889 0.       1.672 0.00169 0.      0.     10155.  47.180 0.446 1.000   0.     -0.    -0.    -0.
 7.66580 0.045675 0.026996 0.       1.692 0.00154 0.      0.     11299.  45.701 0.431 1.000   0.     -0.    -0.    -0.
 8.01800 0.052106 0.030376 0.       1.715 0.00139 0.      0.     12545.  44.309 0.418 1.000   0.     -0.    -0.    -0.
 8.37010 0.059703 0.034116 0.       1.750 0.00123 0.      0.     13991.  42.975 0.405 1.000   0.     -0.    -0.    -0.
 8.72230 0.068150 0.038251 0.       1.782 0.00108 0.      0.     15547.  41.698 0.392 1.000   0.     -0.    -0.    -0.
 9.07450 0.077908 0.042811 0.       1.820 0.00093 0.      0.     17306.  40.480 0.380 1.000   0.     -0.    -0.    -0.
 9.42670 0.088876 0.047737 0.       1.862 0.00079 0.      0.     19240.  39.341 0.369 1.000   0.     -0.    -0.    -0.
 9.77880 0.101275 0.053067 0.       1.908 0.00065 0.      0.     21383.  38.272 0.359 1.000   0.     -0.    -0.    -0.
10.13100 0.114858 0.058668 0.       1.958 0.00053 0.      0.     23684.  37.295 0.350 1.000   0.     -0.    -0.    -0.
10.48320 0.130316 0.064541 0.       2.019 0.00041 0.      0.     26278.  36.399 0.341 1.000   0.     -0.    -0.    -0.
10.83540 0.147042 0.070775 0.       2.078 0.00030 0.      0.     29024.  35.564 0.333 1.000   0.     -0.    -0.    -0.
11.18750 0.165773 0.077330 0.       2.144 0.00021 0.      0.     32063.  34.791 0.326 1.000   0.     -0.    -0.    -0.
11.53970 0.184262 0.083827 0.       2.198 0.00014 0.      0.     34991.  34.111 0.319 1.000   0.     -0.    -0.    -0.
11.89190 0.202215 0.090290 0.       2.240 0.00011 0.      0.     37763.  33.504 0.313 1.000   0.     -0.    -0.    -0.
```

TABLE XI. - Continued. OUTPUT FOR INLET DIFFUSER

(c) Concluded. Summary of boundary layer parameters

```
                                  PRINCIPAL BOUNDARY LAYER PARAMETERS FOR
                ...DIFFUSER STUDY..................................DIFFUSER STUDY...

     X          CT        MT        HT       SF      CF        ST        GPW       RDT        U         M     TURB      RW        VW        SW        CW

  12.24410  0.217865  0.096171  0.          2.265  0.00009  0.          0.        40115.    33.000    0.309  1.000     0.       -0.       -0.        -0.
  12.59620  0.233459  0.102297  0.          2.282  0.00008  0.          0.        42398.    32.517    0.304  1.000     0.       -0.       -0.        -0.
  12.94840  0.246777  0.108044  0.          2.284  0.00010  0.          0.        44274.    32.097    0.300  1.000     0.       -0.       -0.        -0.
  13.30060  0.254541  0.113085  0.          2.251  0.00016  0.          0.        45203.    31.751    0.297  1.000     0.       -0.       -0.        -0.
  13.65280  0.258605  0.117081  0.          2.209  0.00022  0.          0.        45567.    31.488    0.294  1.000     0.       -0.       -0.        -0.
  14.00490  0.260120  0.120718  0.          2.155  0.00029  0.          0.        45517.    31.256    0.292  1.000     0.       -0.       -0.        -0.
  14.35710  0.258248  0.123440  0.          2.092  0.00038  0.          0.        44961.    31.088    0.291  1.000     0.       -0.       -0.        -0.
  14.70930  0.253488  0.125193  0.          2.025  0.00049  0.          0.        43991.    30.983    0.289  1.000     0.       -0.       -0.        -0.
  15.06150  0.246331  0.125558  0.          1.956  0.00062  0.          0.        42694.    30.941    0.289  1.000     0.       -0.       -0.        -0.
  15.41370  0.236369  0.125754  0.          1.880  0.00078  0.          0.        40994.    30.962    0.289  1.000     0.       -0.       -0.        -0.
  15.76580  0.219677  0.123226  0.          1.783  0.00103  0.          0.        38306.    31.141    0.291  1.000     0.       -0.       -0.        -0.
  16.11800  0.198116  0.117253  0.          1.690  0.00135  0.          0.        35008.    31.582    0.295  1.000     0.       -0.       -0.        -0.
  16.47020  0.174578  0.108662  0.          1.607  0.00171  0.          0.        31494.    32.286    0.302  1.000     0.       -0.       -0.        -0.
  16.82240  0.150404  0.098518  0.          1.527  0.00209  0.          0.        27883.    33.241    0.311  1.000     0.       -0.       -0.        -0.
  17.17450  0.127876  0.087597  0.          1.460  0.00248  0.          0.        24512.    34.457    0.323  1.000     0.       -0.       -0.        -0.
  17.52670  0.108177  0.076712  0.          1.410  0.00279  0.          0.        21549.    35.919    0.337  1.000     0.       -0.       -0.        -0.
```

TABLE XI. - Continued. OUTPUT FOR INLET DIFFUSER

(d) Momentum and energy balance ratios

```
I=  1  X(I)=  0.              COF1=   0.      COF2=   0.      R21F=  0.       COG1=  0.      COG2=  0.      R21G=  0.
I=  2  X(I)=  4.12500E-02     COF1=   0.      COF2=   0.      R21F=  0.       COG1=  0.      COG2=  0.      R21G=  0.
I=  3  X(I)=  8.25000E-02     COF1=  18.6346  COF2=  23.4303  R21F=  1.2574   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I=  4  X(I)=  1.23750E-01     COF1=   5.0415  COF2=   4.1295  R21F=  0.8191   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I=  5  X(I)=  1.65000E-01     COF1=   3.2552  COF2=   3.6401  R21F=  1.1182   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I=  6  X(I)=  2.06250E-01     COF1=   2.5592  COF2=   2.5320  R21F=  0.9894   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I=  7  X(I)=  2.47500E-01     COF1=   1.9744  COF2=   2.2821  R21F=  1.1558   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I=  8  X(I)=  2.92100E-01     COF1=   2.7816  COF2=   2.2125  R21F=  0.7954   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I=  9  X(I)=  3.31000E-01     COF1=   2.2360  COF2=   2.4799  R21F=  1.1091   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 10  X(I)=  3.66000E-01     COF1=   2.0321  COF2=   2.0434  R21F=  1.0056   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 11  X(I)=  3.98000E-01     COF1=   1.8098  COF2=   1.7895  R21F=  0.9888   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 12  X(I)=  4.27800E-01     COF1=   1.6646  COF2=   1.6899  R21F=  1.0152   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 13  X(I)=  4.53700E-01     COF1=   1.5412  COF2=   1.5578  R21F=  1.0108   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 14  X(I)=  4.75300E-01     COF1=   1.4520  COF2=   1.4496  R21F=  0.9984   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 15  X(I)=  4.93900E-01     COF1=   1.3978  COF2=   1.3905  R21F=  0.9948   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 16  X(I)=  5.10500E-01     COF1=   1.3548  COF2=   1.3538  R21F=  0.9993   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 17  X(I)=  5.25700E-01     COF1=   1.3250  COF2=   1.3253  R21F=  1.0002   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 18  X(I)=  5.39700E-01     COF1=   1.3016  COF2=   1.2984  R21F=  0.9975   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 19  X(I)=  5.52800E-01     COF1=   1.2777  COF2=   1.2782  R21F=  1.0005   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 20  X(I)=  5.65200E-01     COF1=   1.2597  COF2=   1.2610  R21F=  1.0010   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 21  X(I)=  5.76900E-01     COF1=   1.2452  COF2=   1.2429  R21F=  0.9981   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 22  X(I)=  5.88100E-01     COF1=   1.2286  COF2=   1.2301  R21F=  1.0012   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 23  X(I)=  5.98800E-01     COF1=   1.2165  COF2=   1.2164  R21F=  0.9999   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 24  X(I)=  6.09100E-01     COF1=   1.2057  COF2=   1.2053  R21F=  0.9996   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 25  X(I)=  6.19000E-01     COF1=   1.1941  COF2=   1.1943  R21F=  1.0002   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 26  X(I)=  6.28600E-01     COF1=   1.1848  COF2=   1.1854  R21F=  1.0005   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 27  X(I)=  6.37900E-01     COF1=   1.1776  COF2=   1.1764  R21F=  0.9990   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 28  X(I)=  6.47000E-01     COF1=   1.1736  COF2=   1.1677  R21F=  0.9950   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 29  X(I)=  6.57200E-01     COF1=   1.1772  COF2=   1.1811  R21F=  1.0033   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 30  X(I)=  6.67700E-01     COF1=   1.1733  COF2=   1.1746  R21F=  1.0011   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 31  X(I)=  6.78700E-01     COF1=   1.1699  COF2=   1.1717  R21F=  1.0015   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 32  X(I)=  6.90300E-01     COF1=   1.1675  COF2=   1.1693  R21F=  1.0016   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 33  X(I)=  7.02300E-01     COF1=   1.1642  COF2=   1.1632  R21F=  0.9991   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 34  X(I)=  7.15100E-01     COF1=   1.1598  COF2=   1.1626  R21F=  1.0024   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 35  X(I)=  7.28700E-01     COF1=   1.1585  COF2=   1.1599  R21F=  1.0012   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 36  X(I)=  7.43200E-01     COF1=   1.1571  COF2=   1.1571  R21F=  1.0000   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 37  X(I)=  7.59000E-01     COF1=   1.1552  COF2=   1.1573  R21F=  1.0019   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 38  X(I)=  7.76300E-01     COF1=   1.1557  COF2=   1.1566  R21F=  1.0008   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 39  X(I)=  7.95900E-01     COF1=   1.1583  COF2=   1.1599  R21F=  1.0014   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 40  X(I)=  8.18700E-01     COF1=   1.1630  COF2=   1.1647  R21F=  1.0014   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 41  X(I)=  8.47600E-01     COF1=   1.1757  COF2=   1.1805  R21F=  1.0041   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 42  X(I)=  8.86500E-01     COF1=   1.1923  COF2=   1.2037  R21F=  1.0095   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 43  X(I)=  9.29300E-01     COF1=   1.1824  COF2=   1.1838  R21F=  1.0011   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 44  X(I)=  9.76100E-01     COF1=   1.1733  COF2=   1.1710  R21F=  0.9980   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 45  X(I)=  1.02850E+00     COF1=   1.1680  COF2=   1.1650  R21F=  0.9975   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 46  X(I)=  1.10730E+00     COF1=   1.2041  COF2=   1.2075  R21F=  1.0028   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 47  X(I)=  1.25520E+00     COF1=   1.2729  COF2=   1.2944  R21F=  1.0169   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 48  X(I)=  1.67010E+00     COF1=   1.5890  COF2=   1.4429  R21F=  0.9081   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 49  X(I)=  1.87640E+00     COF1=   1.0829  COF2=   1.1007  R21F=  1.0164   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 50  X(I)=  2.03100E+00     COF1=   1.1103  COF2=   1.0842  R21F=  0.9765   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 51  X(I)=  2.38310E+00     COF1=   1.1231  COF2=   1.1832  R21F=  1.0535   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 52  X(I)=  2.73530E+00     COF1=   1.1864  COF2=   1.1712  R21F=  0.9872   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 53  X(I)=  3.08750E+00     COF1=   1.1554  COF2=   1.1819  R21F=  1.0229   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 54  X(I)=  3.43970E+00     COF1=   1.1403  COF2=   1.1331  R21F=  0.9937   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 55  X(I)=  3.79180E+00     COF1=   1.1004  COF2=   1.1009  R21F=  1.0005   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 56  X(I)=  4.14400E+00     COF1=   1.0806  COF2=   1.0809  R21F=  1.0002   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 57  X(I)=  4.49620E+00     COF1=   1.0828  COF2=   1.0668  R21F=  0.9852   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 58  X(I)=  4.84840E+00     COF1=   1.0567  COF2=   1.0560  R21F=  0.9994   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 59  X(I)=  5.20050E+00     COF1=   1.0439  COF2=   1.0458  R21F=  1.0018   COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
```

TABLE XI. - Concluded. OUTPUT FOR INLET DIFFUSER

(d) Concluded. Momentum and energy balance ratios

```
I= 60  X(I)=  5.55270E+00    COF1=  1.0397  COF2=  1.0372  R21F=  0.9977    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 61  X(I)=  5.90490E+00    COF1=  1.0323  COF2=  1.0306  R21F=  0.9984    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 62  X(I)=  6.25710E+00    COF1=  1.0276  COF2=  1.0253  R21F=  0.9978    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 63  X(I)=  6.60930E+00    COF1=  1.0235  COF2=  1.0209  R21F=  0.9974    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 64  X(I)=  6.96140E+00    COF1=  1.0200  COF2=  1.0171  R21F=  0.9972    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 65  X(I)=  7.31360E+00    COF1=  1.0153  COF2=  1.0139  R21F=  0.9987    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 66  X(I)=  7.66580E+00    COF1=  1.0122  COF2=  1.0112  R21F=  0.9990    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 67  X(I)=  8.01800E+00    COF1=  1.0112  COF2=  1.0090  R21F=  0.9979    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 68  X(I)=  8.37010E+00    COF1=  1.0095  COF2=  1.0072  R21F=  0.9977    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 69  X(I)=  8.72230E+00    COF1=  1.0076  COF2=  1.0056  R21F=  0.9980    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 70  X(I)=  9.07450E+00    COF1=  1.0063  COF2=  1.0044  R21F=  0.9981    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 71  X(I)=  9.42670E+00    COF1=  1.0059  COF2=  1.0033  R21F=  0.9974    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 72  X(I)=  9.77880E+00    COF1=  1.0040  COF2=  1.0025  R21F=  0.9985    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 73  X(I)=  1.01310E+01    COF1=  1.0038  COF2=  1.0019  R21F=  0.9981    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 74  X(I)=  1.04832E+01    COF1=  1.0044  COF2=  1.0013  R21F=  0.9970    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 75  X(I)=  1.08354E+01    COF1=  1.0033  COF2=  1.0009  R21F=  0.9976    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 76  X(I)=  1.11875E+01    COF1=  1.0010  COF2=  1.0006  R21F=  0.9996    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 77  X(I)=  1.15397E+01    COF1=  1.0023  COF2=  1.0004  R21F=  0.9981    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 78  X(I)=  1.18919E+01    COF1=  0.9989  COF2=  1.0003  R21F=  1.0014    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 79  X(I)=  1.22441E+01    COF1=  1.0036  COF2=  1.0032  R21F=  0.9966    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 80  X(I)=  1.25962E+01    COF1=  0.9988  COF2=  1.0002  R21F=  1.0014    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 81  X(I)=  1.29484E+01    COF1=  0.9968  COF2=  1.0002  R21F=  1.0033    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 82  X(I)=  1.33006E+01    COF1=  0.9965  COF2=  1.0002  R21F=  1.0037    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 83  X(I)=  1.36528E+01    COF1=  1.0006  COF2=  1.0003  R21F=  0.9997    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 84  X(I)=  1.40049E+01    COF1=  0.9974  COF2=  1.0004  R21F=  1.0029    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 85  X(I)=  1.43571E+01    COF1=  0.9986  COF2=  1.0005  R21F=  1.0019    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 86  X(I)=  1.47093E+01    COF1=  0.9988  COF2=  1.0006  R21F=  1.0018    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 87  X(I)=  1.50615E+01    COF1=  0.9990  COF2=  1.0008  R21F=  1.0018    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 88  X(I)=  1.54137E+01    COF1=  0.9951  COF2=  1.0010  R21F=  1.0059    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 89  X(I)=  1.57658E+01    COF1=  0.9977  COF2=  1.0013  R21F=  1.0035    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 90  X(I)=  1.61180E+01    COF1=  1.0031  COF2=  1.0017  R21F=  0.9986    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 91  X(I)=  1.64702E+01    COF1=  1.0027  COF2=  1.0024  R21F=  0.9997    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 92  X(I)=  1.68224E+01    COF1=  1.0036  COF2=  1.0032  R21F=  0.9996    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 93  X(I)=  1.71745E+01    COF1=  1.0051  COF2=  1.0043  R21F=  0.9993    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000
I= 94  X(I)=  1.75267E+01    COF1=  1.0159  COF2=  1.0056  R21F=  0.9899    COG1=  1.0000  COG2=  1.0000  R21G=  1.0000

*01* UNIT05. EOF.                                                         REC=  00000 FIL=  00002
```

If POP.NE.1, then subroutine ITSR lists the number of cycles to converge in the momentum loop (ITP=MOM) and in the momentum-energy loop (ITME=MAE) together with other case sensitive variables such as COF1, COF2, COG1, and COG2. The ratios R21F=COF2/COF1 and R21G=COG2/COG1 are listed by subroutine ITSR together with COF2, COF1, COG2, and COG1 at each x-station and also as a table by subroutine NDIR when ISTO(6).EQ.1. The ratios R21F and R21G both equal 1.0 when the integral momentum and energy equations are well balanced. As a result, no corrections based on the displacement thickness are made. Hence, if either ratio deviates much from 1.0 a difficulty may appear. The sensitivity of the wall parameters to variations of the ratios R21F and R21G is smaller for large pressure gradients than for small pressure gradients.

To obtain more detailed statistics on the convergence of the wall parameters and boundary values in both MAE and MOM loops of subroutines ITFR and ITSR, the switch ISTO(5) can be set equal to 1, and the switch POP can be set not equal to 1. If the proper values of ISTO(7), ISTO(5), POP, and ISTO(1), which list the input data, are used, then information sufficient to locate the source of the difficulty can usually be obtained. If, in addition, the case should not be aborted, then the subroutine NDIR end profiles and tables will be listed and can be used as a further aid to the diagnosis. Also, subroutine FILE has a variety of ways of listing profiles to get sufficient data without listing excessively. For the subroutine FILE listing capabilities, see ISTO(2) in table VI.

If the functions U(X) or M(X) lead to an early transition to turbulent flow, then, by using ISTO(8) and ISTO(9), a linear section can be inserted at the origin. In most cases the use of a linear section starting at the origin and using the original starting values will either delay or remove the transition to turbulent flow provided the input function, either U(X) or M(X), has a section concave upward between the origin and the first maximum. When either U(I) or M(I) is modified by subroutine COTR by the insertion of a linear section, the corresponding values of the other x-station data input are modified similarly. Subroutine INIR also later modifies the values of RW(I) at the origin to satisfy the criterion d(RW(I)/dx.LE.1.0 at ETA=0.0. Later, in subroutines ITFR and ITSR a substitute value of d(RW(I)/dx is used to prevent a case abort for some sections of the input RW(I) curve when otherwise a negative square root would occur.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, December 27, 1973,
501-24.

APPENDIX A

SYMBOLS

The number in parenthesis following some of the definitions is the number of the equation in appendix B which defines the variable. The quantity in square brackets is the equivalent notation used in the computer program.

B	exponent in expression for free-stream velocity variation in laminar similarity solution (II-28), [BS]
$b_1, \ldots, b_5$	coefficients in eqs. (III-7, 8), [B]
C	constant of proportionality in expression for δ^* in laminar similarity solution (II-28), [C]
C_a	parameter related to axisymmetric flow appearing in eq. (II-14), $2(\delta^*/r_w) \cos \alpha$, [CA]
C_f	coefficient of skin friction, $\tau_w/(\rho_e U^2/2)$, [CF]
C_p	specific heat at constant pressure
C_u	longitudinal curvature parameter in eq. (IV-2), $(\delta^*/c_w)(u/U)/[(\partial(u/U)/\partial\eta]$, [CU]
C_μ	parameter in skin friction relation (II-34), [CMU]
c_w	radius of longitudinal curvature in the same units as x, [CW]
$c_0, \ldots, c_8$	coefficients in eq. (III-6), [CO. . . C8]
d	density ratio, ρ_e/ρ, [D]
f'	velocity defect variable, $(\rho_e U - \rho u)/\rho_e U$, [FP]
g'	enthalpy defect variable, $(h_e^o - h^o)/(h_e^o - h_r)$, [GP]
H	$(h_e^o - h_r)/h_e^o$, [BH]
h	static enthalpy
h_r	arbitrary reference enthalpy
h^o	total enthalpy, $h + u^2/2$
i, j	indices of variables in the x- and y-directions, respectively, [I, J]
$\overline{K}$	pressure gradient parameter, $(\theta^2/\nu_w)(dU/dx)$, [KF]
k	specific heat ratio, [SHR]

L	position at which R_L is defined in laminar similarity (II-28), $x_2 - x_1$
M_e	free-stream Mach number, [M]
P	parameter in eq. (II-14), $\delta^* U_x/U$, [P]
P*	parameter in laminar similarity flow, $R_{\delta*}P$, [P]
P_r	Prandtl number, ν/ν_g, [PR]
P_{rt}	turbulent Prandtl number, $(\nu_e - \nu)/(\nu_{eg} - \nu_g)$, [PRT]
p	static pressure
Q	parameter in eq. (II-14), $(\rho_e U\delta^*)_x/\rho_e U$, [Q]
Q*	$R_{\delta*}Q$, parameter in laminar similarity flow, [Q]
$\overline{q^2}/U^2$	turbulence intensity, [FTE]
q	local heat flux
R	$r_{w_x}\delta^*/r_w$, [R]
R*	parameter in laminar similarity flow, $R_{\delta*}R$, [R]
R_{cr}	critical Reynolds number, [RMC]
R_{ft}	fully turbulent Reynolds number,]RMT]
R_L	Reynolds number in laminar similarity solution, $(x_2 - x_1)U/\nu$, [RL]
$R_{\delta*}$	Reynolds number based on displacement thickness, $\delta^* U/\nu$, [RDT]
r	radius of a point in the boundary layer in the same units as x, $r_w(\bar{x}) + \bar{y}\cos\alpha(\bar{x})$
r_w	radius of surface in the same units as x, [RW]
S_c	Sutherland constant, eq. (II-18), [STC]
S_t	Stanton number, $q_w/[\rho_e U(h_e^o - h_w)]$, [ST]
S_{tr}	reference Stanton number, $q_w/(\rho_e U(h_e^o - h_r)]$, [STR]
s_w	characteristic sice of roughness elements in the same units as x, [SW]
T	proportion of turbulence viscosity in effective viscosity, eq. (IV-4), [TURB]
U	free-stream velocity, arbitrary dimensional units, [U]
U_L	free-stream velocity at x_2 in laminar similarity solution, same units as U, [U(2)]
u, v	time average velocities in x- and y-directions, respectively

u_τ	skin friction velocity, $\sqrt{\tau_w/\rho_w}$, same units as U
V_c	correction factor which accounts for influence of longitudinal wall curvature on the effective viscosity, [VHP]
$-\overline{v'h'}$	Reynolds heat flux
$-\overline{v'u'}$	Reynolds stress
v_w	wall transpiration velocity, same units as U, [VW]
x	streamwise coordinate, arbitrary dimensional units, [X]
$\bar{x}$	untransformed x-coordinate
Δx	$x_{i+1} - x_i$, numerical integration step in the streamwise direction, [DX]
y	coordinate normal to wall
$\bar{y}$	untransformed y-coordinate
α	angle of tangent to surface with respect to axis of symmetry
γ	ratio of skin friction velocity to freestream velocity, $\sqrt{\tau_w/\rho U^2}$, [GAM]
δ^*	displacement thickness, $\int_0^\infty \left(\rho_e U - \rho u\right)\Big/\left(\rho_e U\right)(r/r_w)d\bar{y}$, same units as $\bar{x}$, [DT]
δ_k^*	kinematic displacement thickness, $\int_0^\infty \left(U - u\right)\Big/U(r/r_w)d\bar{y}$, same units as $\bar{x}$
η	nondimensional coordinate normal to wall, y/δ^*, [Y]
θ	momentum thickness, $\int_0^\infty \rho u\left(U - u\right)\Big/\left(\rho_e U^2\right)(r/r_w)d\bar{y}$, same units as $\bar{x}$, [MT]
κ	von Kármán constant, 0.41, [SK]
ν	molecular kinematic viscosity
ν_e	effective kinematic viscosity
ν_{eg}	effective kinematic conductivity
ρ	density
$\bar{\tau}$	local shear stress

Υ	nondimensional effective viscosity, eq. (II-17a), $\nu_e/U\delta^*$, [VE]
Υ^*	nondimensional effective viscosity in laminar starting flow, $R_{\delta^*}\Upsilon$, [VE]
Υ_g	nondimensional effective conductivity, eq. (II-17b), $\nu_{eg}/U\delta^*$, [VEG]
ψ	integral enthalpy thickness, $\int_0^\infty \left(\rho u/\rho_e U\right)\left(h_e^o - h^o\right)\Big/\left(h_e^o - h_r\right)(r/r_w)d\bar{y}$, [HT]
φ, Φ	inner and outer effective viscosity functions

Subscripts:

cr	critical point
e	evaluated at edge of layer (except for $\nu_e(\eta = \eta_e) \equiv \nu_{e\infty}$); also used to denote equilibrium f' and g' functions
ft	fully turbulent point
w	evaluated at wall, [( )W]
x	differentiation with respect to x
1	evaluated at initial x-station
∞	evaluated at the edge of the layer, $\eta \to \infty$, [( )E]
$\sim$	denotes quantity in similarity starting equations which have different interpretation in laminar and turbulent flows
Δ	fully turbulent point minus critical point

Superscripts:

	differentiation with respect to $\eta = y/\delta^*$, [( )P]
$\overline{}$	when used with x and y denotes untransformed coordinates; also denotes average value, $[(\ )_{i+1} + (\ )_i]/2$

APPENDIX B

EQUATIONS USED BY COMPUTER PROGRAM

The pertinent equations are given herein as a cross reference to the discussion of the common program variables and the comments contained in the computer program. The equations and equation numbers are taken from reference 1. The symbols are defined in appendix A.

Transformed momentum and energy equations:

$$
\begin{aligned}
-\left\{(1 + C_a\eta)\frac{\Upsilon}{d}[d(1 - f')]'\right\}' &+ \left[(Q + R)(\eta - f) - \frac{\rho_w v_w}{\rho_e U} - \delta^* f_x\right] df'' \\
&+ \left\{\left[(Q + R)(\eta - f) - \frac{q_w v_w}{\rho_e U} - \delta^* f_x\right] d' - (Pd + \delta^* d_x)(2 - f')\right\} f' \\
&- \left[(Q + R)(\eta - f) - \frac{\rho_w v_w}{\rho_e U} - \delta^* f_x\right] d' + P(d - 1) + \delta^* d_x \\
&= (1 - f')\delta^* df'_x \qquad \text{(II-14)}
\end{aligned}
$$

$$
\begin{aligned}
\left((1 + C_a\eta)\frac{\Upsilon_g}{d}\left\{g'' - \frac{\frac{k - 1}{2} M_e^2}{H\left(1 + \frac{k - 1}{2} M_e^2\right)}\left(\frac{\nu_g}{\nu_{eg}} - 1\right)\left[d^2(1 - f')^2\right]'\right\}\right)' \\
+ \left[(Q + R)(\eta - f) - \delta^* f_x - \frac{\rho_w v_w}{\rho_e U}\right] g'' = (1 - f')\delta^* g'_x \qquad \text{(II-15)}
\end{aligned}
$$

$$d = \frac{2\left(1 + \frac{k - 1}{2} M_e\right)(1 - Hg')}{1 + \sqrt{1 + 2(k - 1)M_e^2(1 - f')\left(1 + \frac{k - 1}{2} M_e^2\right)(1 - Hg')}} \tag{II-16}$$

Effective viscosity and effective conductivity:

$$\Upsilon = \frac{\delta_k^*}{\delta^*}\left[\frac{\varphi(X\underset{\sim}{R})}{\underset{\sim}{R}} + \Phi(X) - X\right] \tag{II-17a}$$

and

$$\Upsilon_g = \frac{\frac{\nu}{\nu_\infty}}{R_{\delta^*} P_r} + \frac{1}{P_{rt}}\left(\Upsilon - \frac{\frac{\nu}{\nu_\infty}}{R_{\delta^*}}\right) \tag{II-17b}$$

where

$$X = \frac{\kappa y \sqrt{\frac{\bar{\tau}}{\rho}}}{\delta_k^* U}, \quad \underset{\sim}{R} = \frac{U\delta_k^*}{\nu(\eta)}$$

Sutherland molecular viscosity relation:

$$\frac{\nu}{\nu_\infty} = \left(\frac{h}{h_e}\right)^{5/2} \frac{\left(\frac{h_e}{C_p}\right) + S_c}{\left(\frac{h}{C_p}\right) + S_c} \qquad (S_c = 110\text{ K for air}) \tag{II-18}$$

Transformed boundary conditions:

$$f(x, 0) = 0 \tag{II-19a}$$

$$f'(x, 0) = 0 \tag{II-19b}$$

$$\lim_{\eta \to \infty} f(x, \eta) \to 1 \qquad \text{(II-19c)}$$

$$g'(x, 0) = \frac{h_e^o - h_w(x)}{h_e^o - h_r} \quad \text{or} \quad g''(x, 0) = - \frac{\delta^* q_w(x)}{\rho_w \nu_w \left(h_e^o - h_r\right)} \qquad \text{(II-19d)}$$

$$\lim_{\eta \to \infty} g(x, \eta) \text{ is bounded} \qquad \text{(II-19e)}$$

Momentum integral equation:

$$\frac{\left(\theta r_w \rho_e U^{2+H}\right)_i}{\left(\theta r_w \rho_e U^{2+H}\right)_{i-1}} = \exp\left[\int_{x_{i-1}}^{x_i} \left(\frac{\overline{C}_f}{2} + \frac{\overline{\rho_w v_w}}{\overline{\rho_e U}}\right) d\left(\frac{x}{\theta}\right)\right] \qquad \text{(II-21)}$$

where θ, the integral momentum thickness, is defined as

$$\theta = \int_0^\infty \frac{\rho u}{\rho_e U} \left(1 - \frac{u}{U}\right) dy \qquad \text{(II-22)}$$

Energy integral equation:

$$\frac{\left[r_w \rho_e U \left(h_e^o - h_r\right) \psi\right]_i}{\left[r_w \rho_e U \left(h_e^o - h_r\right) \psi\right]_{i-1}} = \exp\left\{\int_{x_{i-1}}^{x_i} \left[\overline{S}_{tr} + \left(\frac{\overline{\rho_w v_w}}{\rho_e U}\right)\left(\frac{\overline{h_e^o - h_w}}{h_e^o - h_r}\right) d\left(\frac{x}{\psi}\right)\right]\right\} \qquad \text{(II-23)}$$

where ψ, the integral enthalpy thickness, is defined as

$$\psi = \int_0^\infty \frac{\rho u}{\rho_e U} \left(\frac{h_e^o - h^o}{h_e^o - h_r}\right) dy \qquad \text{(II-24)}$$

The left and right sides of equation (II-23), are COG1 and COG2, respectively.

Momentum and energy equations for laminar similarity flow:

$$
\begin{aligned}
-\left\{(1 + C_a\eta)\,\frac{\Upsilon^*}{d}\,[d(1 - f')]'\right\}' &+ \left[(Q^* + R^*)d(\eta - f) - d\,\frac{\rho_w v_w}{\rho_e U}\,R_{\delta^*}\right]f'' \\
&+ \left[(Q^* + R^*)d'(\eta - f) - (P^*d + R_{\delta^*}\delta^* d_x)(2 - f') - \frac{\rho_w v_w}{\rho_e U}\,R_{\delta^*}d'\right]f' \\
&+ (Q^* + R^*)d'f + P^*(d - 1) - (Q^* + R^*)\eta d' \\
&+ R_{\delta^*}\delta^* d_x + \frac{\rho_w v_w}{\rho_e U}\,R_{\delta^*}d' = 0
\end{aligned}
\tag{II-25}
$$

$$
\begin{aligned}
&\left((1 + C_a\eta)\,\frac{\Upsilon_g^*}{d}\left\{g'' - \frac{\frac{k - 1}{2}M_e^2}{H\left(1 + \frac{k - 1}{2}M_e^2\right)}\left(\frac{\Upsilon^*}{\Upsilon_g^*} - 1\right)\left[d^2(1 - f')^2\right]'\right\}\right)' \\
&\qquad + \left[(Q^* + R^*)(\eta - f)\,\frac{\rho_w v_w}{\rho_e U}\,R_{\delta^*}\right]g'' = 0
\end{aligned}
\tag{II-26}
$$

where

$$
R_{\delta^*}\delta^* d_x = \frac{P^*(k - 1)M_e^2\left(1 - \frac{k - 1}{2}M_e^2\right)\left[1 - Hg' - d^2(1 - f')^2\right]}{1 + (k - 1)M_e^2 d(1 - f')^2}
\tag{II-27}
$$

Laminar similarity parameters:

$$
\frac{U(x)}{U_L} = \left(\frac{x}{L}\right)^B
\tag{II-28a}
$$

$$\frac{\delta^*(x)}{L} = C\left(\frac{x}{L}\right)^{[(1-B)/2]} \qquad \text{(II-28b)}$$

$$P^* = C^2 R_L B \qquad \text{(II-29a)}$$

$$Q^* = C^2 R_L \left[B\left(1 - M_e^2\right) + \frac{1}{2}(1 - B)\right] \qquad \text{(II-29b)}$$

$$R^* = C^2 R_L L \frac{r_{w_x}}{r_w} \qquad \text{(II-29c)}$$

Turbulent similarity parameters:

$$\delta^* d_x = \frac{P(k-1)M_e^2\left(1 + \frac{k-1}{2}M_e^2\right)\left[(1 - Hg') - d^2(1 - f')^2\right]}{1 + (k-1)M_e^2 d(1 - f')^2}$$

$$+ \frac{(k-1)M_e^2 d^2 (1 - f')\eta^* f'_x - \left(1 + \frac{k-1}{2}M_e^2\right)H\delta^* g'_x}{1 + (k-1)M_e^2 d(1 - f')^2} \qquad \text{(II-32)}$$

$$\frac{\gamma'_x \delta^*}{\gamma} = -\left(\frac{\gamma}{\kappa}\right)(Q + C_\mu P) \qquad \text{(II-34)}$$

where

$$C_\mu = \left\{1.5 - \left[1 + \left(\frac{S_c C_p}{h_e^o}\right)\left(1 + \frac{k-1}{2}M_e^2\right)\right]^{-1}\right\}(k-1)M_e^2 \qquad \text{(II-35)}$$

$$\frac{\delta^* S_{tr_x}}{S_{tr}} = -\frac{\gamma + \frac{S_{tr}}{\gamma}}{\kappa}(Q + C_\mu P) \qquad \text{(II-37)}$$

Momentum and energy equations for turbulent similarity flow:

$$- \left\{(1 + C_a\eta) \frac{\Upsilon}{d} \left[d(1 - f')\right]'\right\}' + \left[(Q + R)d(\eta - f) - \frac{\delta^*\gamma_x}{\gamma} \eta d - d\frac{\rho_w v_w}{\rho_e U}\right] f''$$

$$+ \left[(Q + R)d'(\eta - f) - (Pd + \delta^* d_x)(2 - f') - (1 - f')(d - \eta d') \frac{\delta^*\gamma_x}{\gamma} \frac{\rho_w v_w}{\rho_e U} d'\right] f'$$

$$+ (Q + R)d'f + P(d - 1) - (Q + R)\eta d' + \delta^* d_x + \frac{\rho_w v_w}{\rho_e U} d' = 0 \qquad \text{(II-38)}$$

and

$$\left((1 + C_a\eta) \frac{\Upsilon_g}{d} \left\{g'' - \frac{\frac{k - 1}{2} M_e^2}{H\left(1 + \frac{k - 1}{2} M_e^2\right)} \left(\frac{\Upsilon}{\Upsilon_g} - 1\right) \left[d^2(1 - f')^2\right]'\right\}\right)'$$

$$+ \left[(Q + R)(\eta - f) - \frac{\delta^*\gamma_x}{\gamma} \eta - \frac{\rho_w v_w}{\rho_e U}\right] g'' - (1 - f') \frac{\delta^* {S_{tr}}_x}{S_{tr}} g' = 0 \qquad \text{(II-39)}$$

In both laminar and turbulent flow the resulting expression for Q is:

$$Q = - \frac{\dfrac{C_f}{2} + \displaystyle\int_0^\infty \left\{ \begin{aligned} &\left[\underset{\sim}{R}d(\eta - f) + \left(\frac{\underset{\sim}{\gamma}}{\kappa}\right)C_\mu \underset{\sim}{P}\eta d - d\left(\frac{\rho_w v_w}{\rho_e U}\right)\right] f'' \\ &+ \left[\underset{\sim}{R}d'(\eta - f) - \left(\underset{\sim}{P}d + \delta^* d_x\right)(2 - f') \right. \\ &\left. + (1 - f')(d - \eta d')\left(\frac{\underset{\sim}{\gamma}}{\kappa}\right)C_\mu P - \left(\frac{\rho_w v_w}{\rho_e U}\right) d'\right] f' \\ &+ \left[\underset{\sim}{R}d'f + \underset{\sim}{P}(d - 1) - \underset{\sim}{R}\eta d' + \delta^* d_x + \left(\frac{\rho_w v_w}{\rho_e U}\right) d'\right] \end{aligned} \right\} d\eta}{\displaystyle\int_0^\infty \left\{ \begin{aligned} &\left[d(\eta - f) + \left(\frac{\underset{\sim}{\gamma}}{\kappa}\right)\eta d\right] f'' - (\eta - f)d' \\ &+ \left[d'(\eta - f) + (1 - f')(d - \eta d')\left(\frac{\underset{\sim}{\gamma}}{\kappa}\right)\right] f' \end{aligned} \right\} d\eta} \qquad \text{(II-41)}$$

$$\begin{aligned} \delta^* d_x = &\frac{\underset{\sim}{P}(k - 1)M_e^2 \left(1 + \frac{k - 1}{2} M_e^2\right)\left[1 - Hg' - d^2(1 - f')^2\right]}{1 + (k - 1)M_e^2 d(1 - f')^2} \\ &+ \frac{(k - 1)M_e^2 d^2 (1 - f') \dfrac{\delta^* \underset{\sim}{\gamma}_x}{\underset{\sim}{\gamma}} (f' + \eta f'')}{1 + (k - 1)M_e^2 d(1 - f')^2} \\ &- \frac{\left(1 + \frac{k - 1}{2} M_e^2\right) H \left(\dfrac{\delta^* \underset{\sim}{S}_{tr_x}}{\underset{\sim}{S}_{tr}} g' + \dfrac{\delta^* \underset{\sim}{\gamma}_x}{\underset{\sim}{\gamma}} g'' \eta\right)}{1 + (k - 1)M_e^2 d(1 - f')^2} \end{aligned} \qquad \text{(II-42)}$$

Equations used in method of solution:

$$\tau_i' = -\left\{(1 + C_a\eta)\Upsilon\left[f'' - \left(\frac{d'}{d}\right)(1 - f')\right]\right\}_i' \qquad \text{(III-6a)}$$

$$g_i' = -\left((1 + C_a\eta)\,\frac{\Upsilon_g}{d}\left\{g'' - \frac{(k - 1)M_e^2}{H\left[1 + \frac{1}{2}(k - 1)M_e^2\right]}\left(\frac{\Upsilon}{\Upsilon_g} - 1\right)d(1 - f')[d'(1 - f') - df'']\right\}\right)_i' \qquad \text{(III-6b)}$$

$$\tau_{i-1} = c_{1_{i-1}}f_{i-1}'' + c_{2_{i-1}}f_{i-1}' + c_{3_{i-1}} - c_{4_{i-1}}(f_i' - f_{i-2}') \qquad \text{(III-6c)}$$

$$g_{i-1}' = c_{7_{i-1}}g_{i-1}'' - c_{8_{i-1}}(g_i' - g_{i-2}') \qquad \text{(III-6d)}$$

and

$$c_0 = (Q + R)(\eta - f) - \left(\frac{\rho_w v_w}{\rho_e U}\right) - \delta^* f_x \qquad \text{(III-6e)}$$

$$c_1 = c_0 d \qquad \text{(III-6f)}$$

$$c_2 = c_2 d' - (Pd + \delta^* d_x)(2 - f') \qquad \text{(III-6g)}$$

$$c_3 = -c_0 d' + P(d - 1) + \delta^* d_x \qquad \text{(III-6h)}$$

$$c_4 = d(1 - f')\,\frac{\delta^*}{\Delta x} \qquad \text{(III-6i)}$$

$$c_7 = c_0 \qquad \text{(III-6j)}$$

$$c_8 = (1 - f')\,\frac{\delta^*}{\Delta x} \qquad \text{(III-6k)}$$

Finally, the form in which these equations are solved is

$$\left[b_4(f'' + b_5)\right]_i' = b_3 + b_2 f_i'' + b_1 f_i' \tag{III-7}$$

$$\left[b_4(g'' + b_5)\right]_i' = b_3 + b_2 g_i'' + b_1 g_i' \tag{III-8}$$

where the coefficients for the f' equation are

$$b_1 = \bar{c}_2 - 2\bar{c}_4 + c_{4_{i-1}} \tag{III-9a}$$

$$b_2 = \bar{c}_1 \tag{III-9b}$$

$$b_3 = (\bar{c}_i - c_{i-1}) f_{i-1}'' + \left(\bar{c}_2 + 2\bar{c}_4 - c_{2_{i-1}}\right) f_{i-1}' + 2\bar{c}_3 - c_3 - c_4 f_{i-2}' \tag{III-9c}$$

$$b_4 = -\left[(1 + C_a \eta)\Upsilon\right]_i \tag{III-9d}$$

$$b_5 = -\left[\left(\frac{d'}{d}\right)(1 - f')\right]_i \tag{III-9e}$$

and for the g' equation,

$$b_1 = \bar{c}_7 \tag{III-10a}$$

$$b_2 = -2\bar{c}_8 + c_{8_{i-1}} \tag{III-10b}$$

$$b_3 = \left(\bar{c}_7 - c_{7_{i-1}}\right) g_{i-1}'' + 2\bar{c}_8 g_{i-1}' - c_{8_{i-1}} g_{i-2}' \tag{III-10c}$$

$$b_4 = -\left[(1 - C_a \eta) \frac{\Upsilon_g}{d}\right]_i \tag{III-10d}$$

$$b_5 = -\left\{\frac{(k-1)M_e^2}{H\left[1 + \frac{1}{2}(k-1)M_e^2\right]}\left(\frac{\Upsilon}{\Upsilon_g} - 1\right) d(1 - f')[d'(1 - f') - df'']\right\} \tag{III-10e}$$

For the similarity starting flows, the corresponding coefficients of equation (III-7) are

$$b_1 = c_0 d' - \left(\underset{\sim}{P}d + \delta^* d_x\right)(2 - f') - (1 - f')(d - \eta d')\left(\frac{\delta^* \underset{\sim}{\gamma}_x}{\underset{\sim}{\gamma}}\right) \tag{III-11a}$$

$$b_2 = \left[c_0 - \eta\left(\frac{\delta^* \underset{\sim}{\gamma}_x}{\underset{\sim}{\gamma}}\right)\right] d \tag{III-11b}$$

$$b_3 = -c_0 d' + \underset{\sim}{P}(d - 1) + \delta^* d_x \tag{III-11c}$$

$$b_4 = (1 + C_a \eta)\underset{\sim}{\Upsilon} \tag{III-11d}$$

$$b_5 = -\left(\frac{d'}{d}\right)(1 - f') \tag{III-11e}$$

where

$$c_0 = \left(\underset{\sim}{Q} + \underset{\sim}{R}\right)(\eta - f) - \left(\frac{\underset{\sim}{\rho}_w \underset{\sim}{v}_w}{\rho_e U}\right)$$

$$b_1 = -(1 - f')\left(\frac{\delta^* \underset{\sim}{S}_{tr_x}}{\underset{\sim}{S}_{tr}}\right) \tag{III-12a}$$

$$b_2 = c_0 - \eta\left(\frac{\delta^* \underset{\sim}{\gamma}_x}{\underset{\sim}{\gamma}}\right) \tag{III-12b}$$

$$b_3 = 0.0 \tag{III-12c}$$

$$b_4 = -(1 + C_a\eta)\,\frac{\Upsilon_g}{d} \qquad \text{(III-12d)}$$

$$b_5 = -\frac{(k-1)M_e^2}{H\left[1 + \frac{1}{2}(k-1)M_e^2\right]}\left(\frac{\Upsilon}{\Upsilon_g} - 1\right) d(1 - f')[d'(1 - f') - df''] \qquad \text{(III-12e)}$$

Effective viscosity correction:

$$V_c = \left[\frac{1 - c_u\left(1 + \frac{\overline{\rho v'u'}}{\overline{\rho u'v'}}\right)}{1 - c_u}\right]^{1/2} \left\{1 - 4.0\,\frac{c_u(1 + c_u)\left(1 + \frac{\overline{\rho' v' u}}{4\overline{\rho u'v'}}\right)}{\left[1 - c_u\left(1 + \frac{\overline{\rho' v' u}}{\overline{\rho u'v'}}\right)(1 - c_u)\right]}\right\}^{3/2} |1 - c_u| \qquad \text{(IV-2)}$$

where the term $(\overline{\rho' v' u})/(\overline{\rho u'v'})$ evaluated using Reynolds analogy is

$$\frac{\overline{\rho' v' u}}{\overline{\rho u'v'}} = \frac{u}{h}\,\frac{1}{P_{rt}}\,\frac{\left(\frac{\partial h}{\partial y}\right)}{\left(\frac{\partial u}{\partial y}\right)} \qquad \text{(IV-3)}$$

Turbulent viscosity relation:

$$\Upsilon = T\Upsilon_{turbulent} + (1 - T)\Upsilon_{laminar}, \; (0 < T < 1) \qquad \text{(IV-4)}$$

APPENDIX C

DISCUSSION OF SUBROUTINE A6IR

A6IR is a reading and listing program that comprises two separate main loops for reading, testing, listing, and returning to the calling routine. If the second main loop is entered, it is entered following the exit from the first main loop. Subroutine A6IR has no internal switches to prevent listing on an external switch option. Listing and/or switching data is carried on each card and can be a part of the listed text.

Cards read in by the first main loop are designated as type 0 cards. The last type 0 card read in either causes a return to the calling routine or becomes a main index discriminator card for the following second main loop. Except for the return and transfer cards, the second main loop lists the remaining cards.

If only type 0 cards are to be listed, A6IR may be simplified. Except for the 994 and 997 format cards and the end card, delete all cards after the card containing the GO TO 104 instruction.

The main index discreiminator card contains the following test words:

Card column	
1 to 6	First index discriminator word
7 to 12	Second index discriminator word
13 to 18	Third index discriminator word (Any index discriminator word may be a blank.)
73 to 78	Test word for main loop only

The first main loop lists type 0 cards only. Type 0 cards list on the left side card columns 1 to 72 with carriage control and line numbering if card columns 1 to 6, first word, and card columns 73 to 78, thirteenth word or the list test word, have a mismatch. Then following the listing of the card, if card columns 7 to 12, second word, and card columns 73 to 78, thirteenth word, do match, subroutine A6IR exits to the calling routine. Otherwise, another type 0 card is read in for testing. The first type 0 card which fails to be listed becomes the discriminator card and the second main loop is entered.

The second main loop lists only cards of types 1 to 5. Cards of type 1, 2, and 3 can be listed only if the switch LIV equals 0. LIV is set equal to 0 on entering the second main loop and later reset to 1 and 0 by type 4 cards.

Type 1 cards list as the page left side card columns 1 to 42 of a full line of 122 columns with carriage control. For a card to become a type 1 card, the thirteenth word (card columns 73 to 78) must be identical with the first main index discriminator word. Otherwise, it becomes a type 4 card. A type 1 card is always followed by a type 2 card.

A type 1 card can follow either a type 0, 4, or 5 card of a type 3 card which becomes a transfer card. Type 2 cards list as the page right side card columns 1 to 80 of a full line with card columns 1 to 42 of a type 1 card as the left side. Type 2 cards follow only type 1 cards, and any card which follows a type 1 card is a type 2 card.

Type 3 cards list as the page right side card columns 1 to 80 of a partial line starting with carriage column 43 and with no carriage control. Type 3 cards succeed either type 3 or 2 cards.

Type 4 cards list on the page left side card columns 1 to 80 with carriage control. A type 4 card can succeed either a card of type 0, 4, or 5, or a type 3 transfer card.

Type 5 cards list on the page left side card columns 1 to 80 without carriage control. A type 5 card can succeed a card of type 0, 4, or 5.

A transfer card is a possible type 3 card and succeeds only a card of type 2 or 3. A transfer card is read in by the second main loop (second subloop), and it transfer control from the second subloop to the first subloop entrance without being listed. Except for the last card which may be a type 3 card, a blank transfer card becomes the marker card after each set of two cards when a block of full width lines is to be listed and the first discriminator word is a blank.

A return card if read in by the first main loop is listed as a type 0 card before it is tested for a return to the calling routine. A return card if read in by the second main loop is a possible type 1 card, but it returns control to the calling routine before reaching the test for a type 1 card.

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