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BOUNDARY LAYER SIMULATOR IMPROVEMENT

December 1984

REMTECH inc.
Huntsville, Alabama

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for

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FOREWORD

This final report presents work conducted for the Marshall Space Flight Center (MSFC) in response to the requirements of Contract NAS8-35976. The work presented here was performed by REMTECH, Inc., Hunstville, Alabama and is titled, "Boundary Layer Simulator Improvement".

The project manager for this project was Dr. Sarat C. Praharaj. The project was very much aided by the helpful technical support of the NASA contract monitor, Mr. Klaus Gross, and by Mr. A. Krebsbach, both of the Systems Performance Branch of the Mission Analysis Division.

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Section 1.0

INTRODUCTION

The primary goal of the work reported here was to improve the existing Boundary Layer Integral Matrix Procedure, Version J (BLIMPJ)[1]. BLIMPJ has been used in the industry as a rigorous boundary layer program in connection with the existing JANNAF reference programs such as ODE and TDK[2]. It is capable of treating two-dimensional and axisymmetric nozzles with a variety of wall boundary conditions which include regenerative and transpiration cooling as well as ablating wall materials. The improvements described herein have potential use in the design of the future Orbit Transfer Vehicle (OTV) engines.

The projected engine design for the OTV would utilize an expander cycle operation mode. In this mode, heat energy obtained through a regeneratively cooled wall is used to drive the turbines and pumps. O_2-H_2 propellant system is used to react in the combustion chamber at pressure levels of 1500-2000 psia at a mixture ratio of 6. The reaction products are expanded through a nozzle of large area ratio, ranging from 400 to 3000. Although the above chamber pressures and O/F ratio for a O_2-H_2 system are not uncommon for the currently operating Space Shuttle main engines (SSMEs), the area ratio is only of the order of 80. These high chamber pressure expander cycle engines depend primarily on the heat energy transmitted from the combustion products through the thrust chamber wall. The larger the regenerative heat transfer the higher the chamber pressure which in turn permits larger area ratio motors. These engines

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1. Evans, R., "Boundary Layer Integral Matrix Procedure, BLIMP-J User's Manual," Aerotherm Division/Acurex Corporation, July 1975, under Contract NAS8-30930.

2. Nickerson, G.R., Coats, D.E., and Bartz, J.L., "The Two-Dimensional Kinetic (TDK) Reference Computer Program," Engineering and Programming Manual, Ultrasystems, Inc., December 1973, under Contract NAS9-12652.

and the associated interior nozzle flowfields are outside the range of current engineering experience. The heat transfer to the nozzle wall is affected by such variables as wall roughness, relaminarization, and the presence of particles in the flow. The motor performance loss for these nozzles with thick boundary layers is inaccurate using the existing procedure coded in BLIMPJ. Flow expansion within large area ratio nozzles and associated low pressures and temperatures may produce two-phase flow conditions (liquid droplets or ice crystals) adjacent to the wall especially in connection with strongly cooled walls. The presence of such particles will have some effect on the friction and heat transfer mechanism within the boundary layer. Moreover, there are discussions in the technical community of replacing the nozzle wall around the throat by an ablative wall. This would reduce high heat-transfer to the nozzle throat because of ablation while introducing the ablation products in the nozzle boundary layer and the inviscid part of the nozzle flowfield. All these modifications and innovations require investigations and implementation in BLIMPJ code of the following simplified analytical formulations:

- Wall surface roughness simulation and its impact on heat transfer and shear effects.
- Prediction of relaminarization regions with approximations on heat transfer and friction along the wall.
- Presence of particles in the boundary layer and their impact on heat transfer and friction.
- Re-evaluation of the existing boundary layer thrust loss calculation method for nozzles with large area ratios, experiencing thick boundary layers at low density and high Mach number flow situations.

Various versions of BLIMPJ were received from Marshall Space Flight Center (MSFC). Apart from the version available at REMTECH, a total of three additional versions including the (i) Aerotherm, (ii) MSFC, and (iii) mini-versions was

TABLE 1.1 BLIMPJ SUBROUTINES

MINI	AERO THERM	MINI	AERO THERM	MINI	AERO THERM
ABMAX	ABMAX	ITERAT	ITERAT	SATEMP	
BLKDTA			KINET	SCRND	
BLMAIN	MAIN	LIAD	LIAD		SECOND
CHANGE		LIMIT		SETUP	SETUP
		LIMIL*			SHOMO
	CHOMO	LINCER	LINCER	SLOPE	
CRECT	CRECT	LINMAT	LINMAT		
	DATE	LOGPLT			SLOPL
	DUMCOM	LTCPHS			SLOPQ
EQUIL	EQUIL	MATER	MATER	STATE	STATE
ERF*	ERF	MATS1	MATS1	STATEN	STATEN
ERP	ERP	MATS2	MATS2	TAYLOR	TAYLOR
	ETIME*				
	ETIMEF	MINMAX		THERM	THERM
	FILQ3		MISCIN		TLEFT
	FILQ5	NICK			TOD
	FINEQ	NNNCER	NNNCER	TRANCR	TRANCR
FIRSTG	FIRSTG	NONCER*	OGLE	TRINT	TRINT
FISLEQ	FISLEQ	OUTPUT	OUTPUT	TRMBL	TRMBL
FUNXS	FUNXS	PLOT		TVCCOE*	TVCCOE*
GEOM	GEOM	POINTS	POINTS	TVCM1*	TVCM1*
	HHOMO	PROPS	PROPS	TVCI*	TVCI*
HISTXI	HISTXI	RECASE	RECASE	ROUGH	
ICOEFF	ICOEFF	REFCON	REFCON	PARTCL	
IMONE	IMONE	REFIT	REFIT		
INPUT	INPUT	RERAY	RERAY		
INTRP		RNLCER	RNLCER		
IONLY	IONLY	ROCOUT	ROCOUT		

*ENTRY POINT ROUTINE

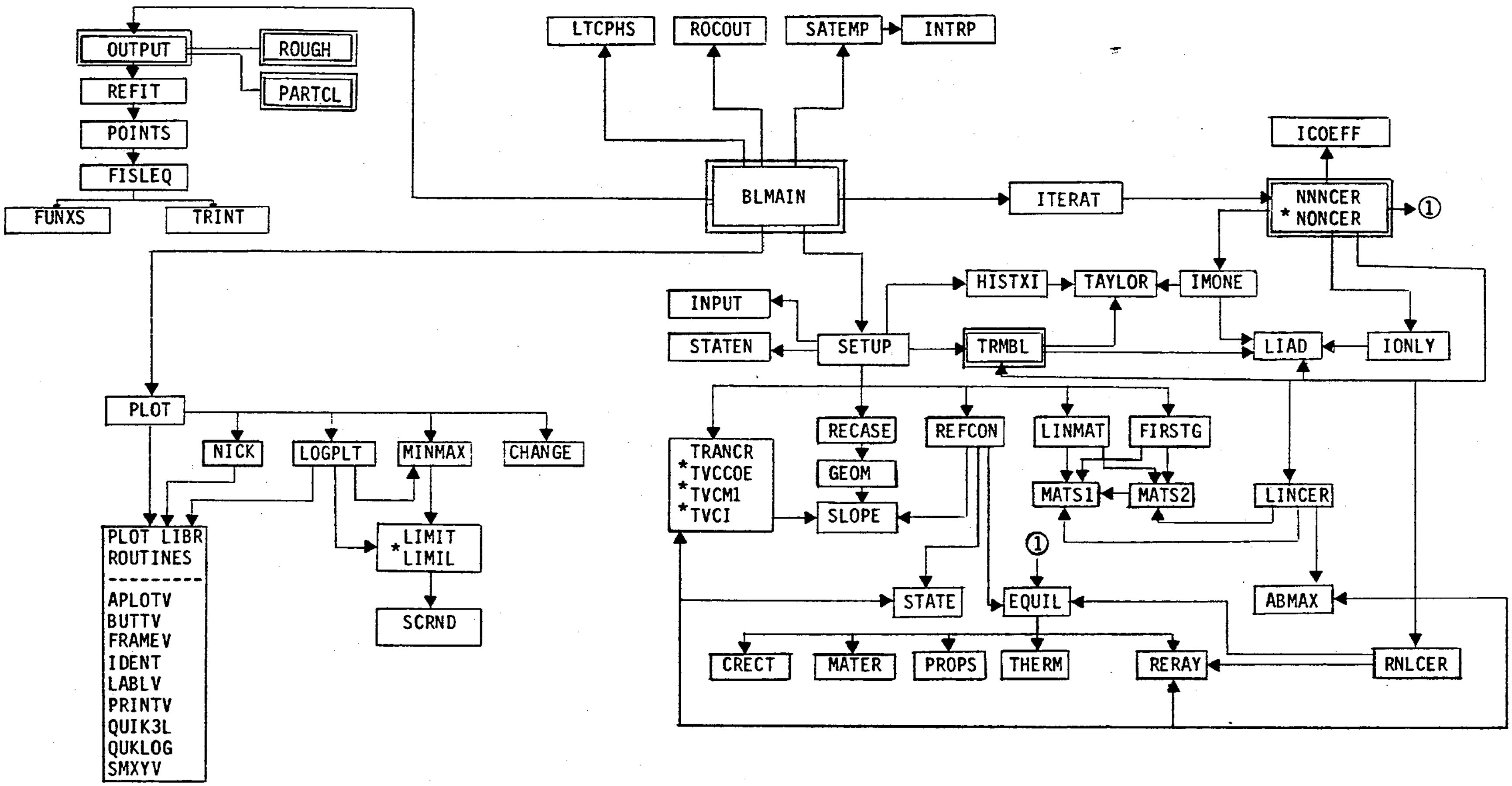
Routine Modified Or Added By REMTECH

obtained. It was recommended by MSFC to use the mini-version for making modifications to the code. The mini-version is a cleaner and shorter version of the code and has fewer subroutines when compared with the Aerotherm version in Table 1.1. In order to access the code at various subroutines for modifications, a macro flow diagram was prepared and is provided in Fig. 1.1.

The various tasks described earlier are discussed in the following sections. Section 2 discusses the effects of wall roughness on skin friction and heat transfer. Section 3 highlights the mechanism and effects of relaminarization, whereas Section 4 discusses the effects of particles on skin friction and heat transfer rate on the nozzle wall. Section 5, on the other hand, focuses on the re-evaluation of the existing boundary layer thrust loss calculation method for nozzles with large area ratios experiencing thick boundary layers. The last four sections described above are self-contained in that the technical discussion for each item along with the corresponding figures and list of references are contained in that section, independent of any other section. These sections also describe applications of the various modules in a composite fashion if more than one effect needs to be considered. Finally, Section 6 makes recommendations both in the areas of analytical and experimental techniques for future work.

BLKDTA — BLOCK DATA

ERP
ERF* — FUNCTIONS



* ENTRY POINT ROUTINES

[box] Routine Modified Or Added By REMTECH

Fig. 1.1 BLIMPJ Mini-Version Macro Flow Diagram

Section 2.0

WALL SURFACE ROUGHNESS EFFECTS

2.1 Background

The importance of wall surface roughness which increases the resistance to fluid flows has been recognized for many years. One of the principal parameters influencing the surface heat transfer to a rough wall is the roughness height, k.

The problem of modeling turbulent flow over rough surfaces has been divided into three regimes:

Regime I: Smooth - The roughness size is so small that the protrusions are contained within the laminar sublayer. The surface skin friction and heat transfer are not changed from smooth surface values.

Regime II: Transitional - Some of the roughness elements protrude outside of the laminar sublayer. The skin friction and heat transfer are increased above the smooth surface values.

Regime III: Fully Rough - All surface roughness elements protrude outside of the laminar sublayer. The increase in skin friction is primarily a result of form drag of the roughness elements.

H. Schlichting (Ref. 1) summarizes all the early work on rough wall measurements in turbulent flow and describes the evaluation of the "equivalent sand grain roughness height", K_s, which is based on the early work of Nikuradse (Ref. 2). Many theories and correlations, following Nikuradse, employ the parameter K_s. Defining K_s for a given surface condition is not a straightforward task. Schlichting (Ref. 1) describes procedures for a given array of roughness elements. Recently, Dirling (Ref. 3) has devised a correlation for K_s and has applied it to the prediction of nosetip shape change. In modeling the effects of roughness on skin friction, the velocity profile through the boundary layer has been correlated with surface roughness of sand. Data and empirical correlations have been developed for other types of roughness elements to obtain the equivalent sand roughness. That is, the sand roughness which yields the same velocity profile is the roughness of interest. There is considerable uncertainty in the determination of the equivalent sand roughness for roughness elements which are randomly shaped and spaced. Physical spacing, relating to the type of cavity flow that is established, the inclination of the roughness element surface to the flow direction, and the increased surface area are some of the important elements in the calculation of K_s. Figure 2.1 shows the correlation developed by Dirling (Ref. 3). The roughness density parameter Λ is defined as shown on the figure, where A_s is the windward surface area of the roughness, A_p is the projected area of the roughness in the flow direction and D is the inverse square root of the roughness elements per unit area. The correlation shown is derived from velocity measurements and is applicable for rough wall skin friction calculations. For the analysis given here, the K_s parameter is not investigated, but instead, it is assumed that K_s is given.

2.2 Roughness Options

The purpose of the task in this section is to determine which simplified correlations are appropriate for application in the BLIMPJ computer code. The correlations available in the literature, which perform "point" calculations based on local edge and wall quantities, were reviewed. The significance of "point" calculations lies in the fact that the history effects in the boundary layer at other points do not affect the calculation at the point under consideration. An excellent paper by Seidman (Ref. 4) reviewed some of these correlations and compared them with incompressible and compressible data. The appropriate options performing "point" calculations are given below:

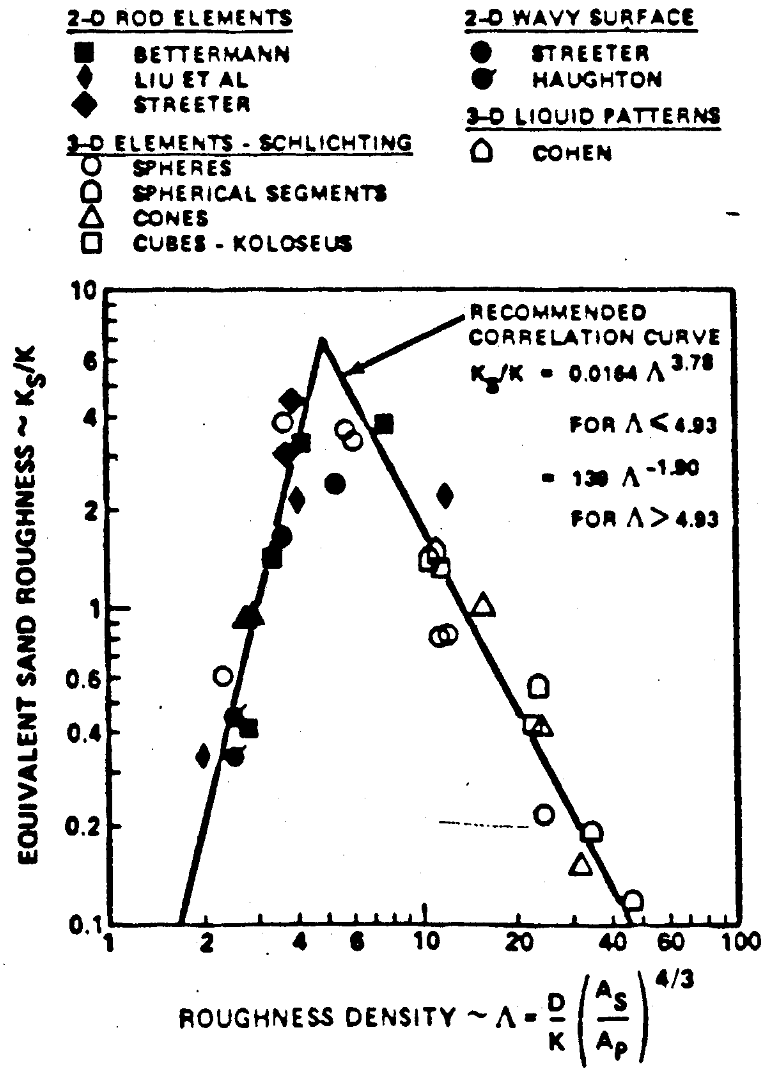


Fig. 2.1 Roughness Density Effect On Equivalent Sand Roughness Depth

Skin Friction Options	Heat Transfer Options
1. Prandtl-Schlichting	1. Seidman
2. Droblenkov	2. Hill

The mathematical expressions are given in Ref. 4. There are two options for calculating skin friction and four possible combinations that can be used to calculate heat transfer rate. For reasons described in the next subsection, Hill's correlation was not coded in BLIMPJ. As a result, only two combinations for heat-transfer rate calculation remained. The mathematical expressions for the above options were taken from Ref. 4 and are listed in Table 2.1 along with the input-output variable list that is used in the roughness subroutine. The expression (A.1) in Table 2.1 contain the calculation of a compressibility factor in terms of the enthalpy ratio. Although, in the original paper (Ref. 4) the corresponding temperature ratios are chosen, it is customary to use the enthalpy ratios instead of temperature ratio in order to include real gas effects. This would be appropriate for the O_2-H_2 reactive system to be used in the future OTV motor, where the combustion temperatures are in the order of 6000^{o}R and real gas effects exist.

Another option by Cebeci was selected to simulate the effects of a rough wall on the boundary layer and to account for "history" effects in the boundary layer. In Ref. 8, the turbulent mixing length of the eddy viscosity expression is modified for the inner region of a two-layer turbulence model to include the effects of surface roughness. Assuming that the velocity profiles for smooth and rough walls are similar, the expression for the mixing length given by

$$\ell = 0.4\, y \left\{1 - \exp\,(-y/A)\right\} \tag{2.1}$$

is modified and rewritten as,

TABLE 2.1

ROUGH WALL HEAT TRANSFER OPTIONS

Options 1 and 2:

Skin friction compressibility (Young)

$$\frac{C_f}{C_{fi}} = 0.365 \left(\frac{H_e}{H_{aw}}\right) + 0.635 \left(\frac{H_e}{H_w}\right) \quad (A.1)$$

Incompressible rough wall skin friction

Option (1) Prandtl-Schlichting

$$C_{fi} = \left[2.87 + 1.58 \log_{10}(X/k)\right]^{-2.5} \quad (A.2)$$

Option (2) Droblenkov

$$C_{fi} = 0.0139 \, (X/k)^{-1/7} \quad (A.3)$$

Rough surface turbulent Stanton Number (Seidman)

$$St = \frac{C_f}{2} \left[1 + A \left(\frac{C_f}{2}\right)^{0.725} (Re_k)^{0.45} (Pr)^{0.8}\right]^{-1} \quad (A.3)$$

where A = 0.52 nominal and range from 0.45 to 0.7 (Owen & Thomson), and C_f is obtained from Equ. (A.1).

Transition criterion (Fenter)

$$\eta_k = \frac{\rho_w U_\tau k}{\mu_w} \quad \text{where } U_\tau = U_e \sqrt{\frac{C_f}{2} \frac{\rho_e}{\rho_w}} \quad (A.4)$$

$\eta_k \leq 5$	Smooth
$5 \leq \eta_k \leq 100$	Transitionally rough
$100 \leq \eta_k$	Rough

TABLE 2.1 (Continued)

INPUT VARIABLES

X = Running length (ft)

k = Sand roughness height (ft)

H_{aw} = Aidabatic wall enthalpy (Btu/lbm)

H_e = B.L. edge enthalpy (Btu/lbm)

H_w = Wall enthalpy (Btu/lbm)

ρ_e = B.L. edge density (lbm/ft^3)

ρ_w = Wall density (lbm/ft^3)

μ_w = Wall viscosity (lbm/ft-sec)

μ_e = Edge viscosity (lbm/ft-sec)

Pr = Prandtl number (Edge)

ICF = Skin friction flag 1 ----> Prandtl-Schlichting
2 ----> Droblenkov

St_s = Smooth wall Stanton number

U_e = B.L. edge velocity (ft/sec)

OUTPUT

C_f = Rough wall sking friction coefficient

St = Rough wall Stanton number

PCT = Percent of transition to fully rough

$$\ell = 0.4\ (y + \Delta y)\ [1 - \exp\left\{-\ (y + \Delta y)/A\right\}] \quad (2.2)$$

where the coordinates are displaced by an amount Δy. He expresses Δy as a function of an equivalent sand-grain roughness parameter K_s^+ ($\equiv K_s U_\tau/\nu$), i.e.,

$$y = 0.9\ (\nu/U_\tau)\ \left\{\sqrt{K_s^+} - K_s^+\ \exp\ (-\ K_s^+/6)\right\} \quad (2.3)$$

This expression is valid for $4.535 < K_s^+ < 2000$, with the lower limit corresponding to the upper bound for a hydraulically smooth surface.

2.3 Examples

In order to illustrate the validity of the roughness options against measured data, first the skin-friction and heat-transfer data were collected from the original report by Pimenta, Moffat and Kays (Ref. 5). The two sets of data collected were for flat plates at moderate freestream velocities. Since BLIMPJ could not be run for external flow situations, BLIMPK (applicable for external flow) was modified to include the roughness options 1 and 2 and was run for an equivalent sand roughness of K_s = .002583 ft. employing the only-resident, Kendall's turbulence model. Figure 2.2 contains the two cases for which the two skin-friction options were used. It is seen that the two options bracket the data, although Droblenkov's approach is closer to the data. Figure 2.3, on the other hand, shows the heat-transfer computations based on Seidman's Stanton number correlation. Again, the two skin-friction options along with Seidman's heat transfer correlation bracket the heat-transfer data, although one combination seems to predict the data better than the other one. Another Stanton number correlation by Hill was checked out (Fig. 2.4a), by varying the value of A in Hill's correlation. It is found that Hill's correlation underpredicts the data considerably. Figure 2.4b, on the other hand, gives comparison of

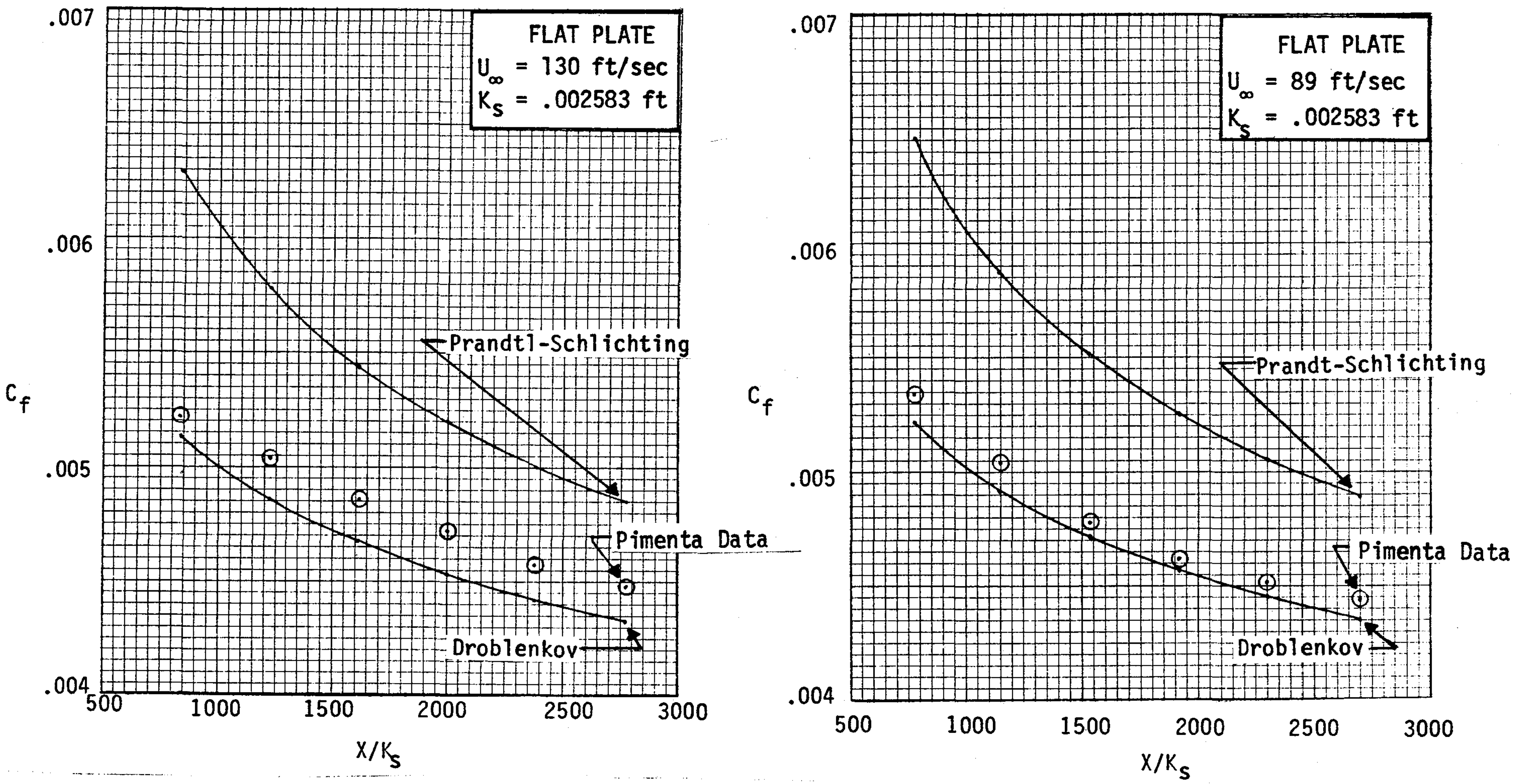


Fig. 2.2 Comparison Of Skin-Friction Correlation With Data

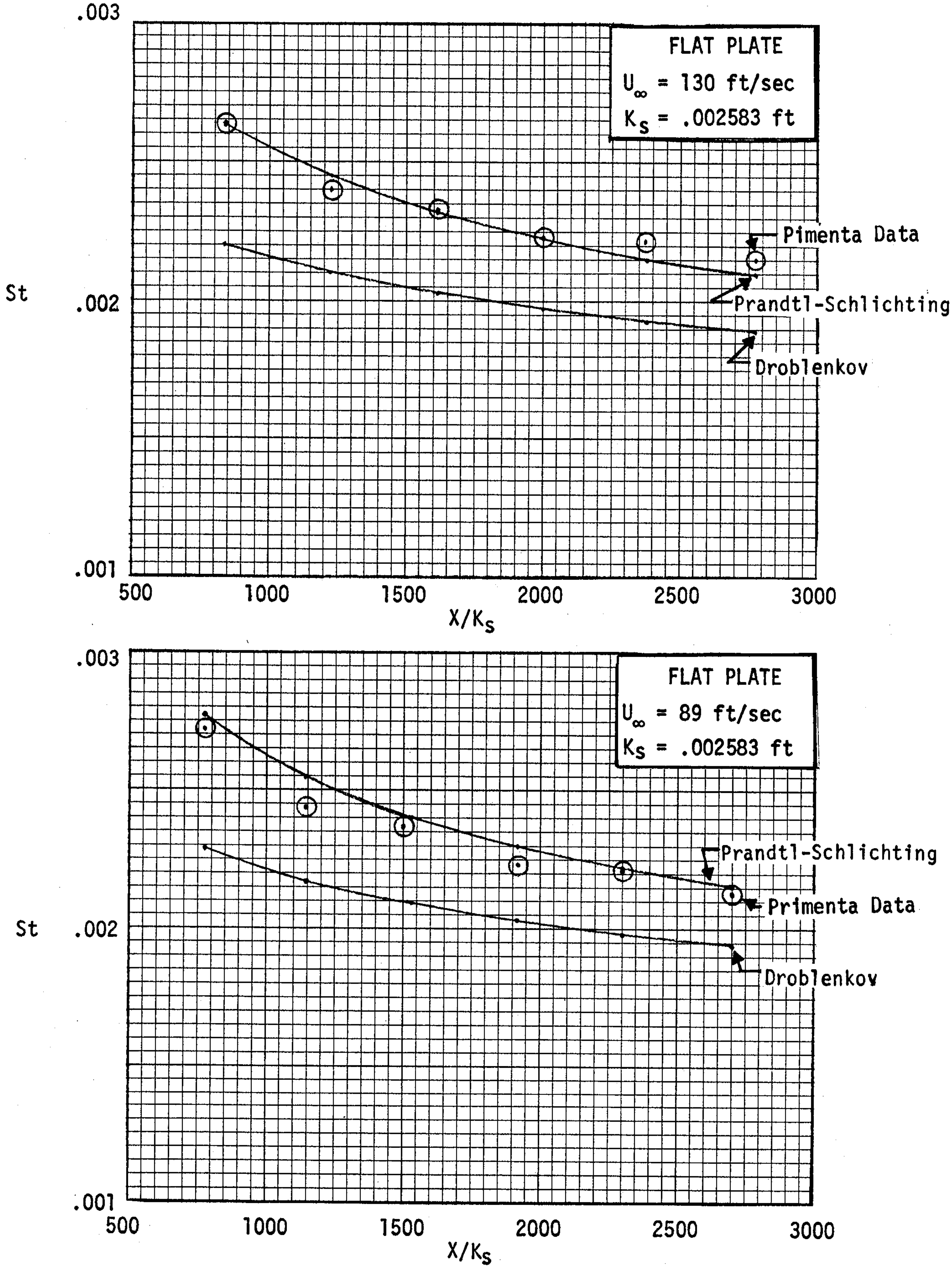


Fig. 2.3 Comparison Of Stanton Number Correlation With Data

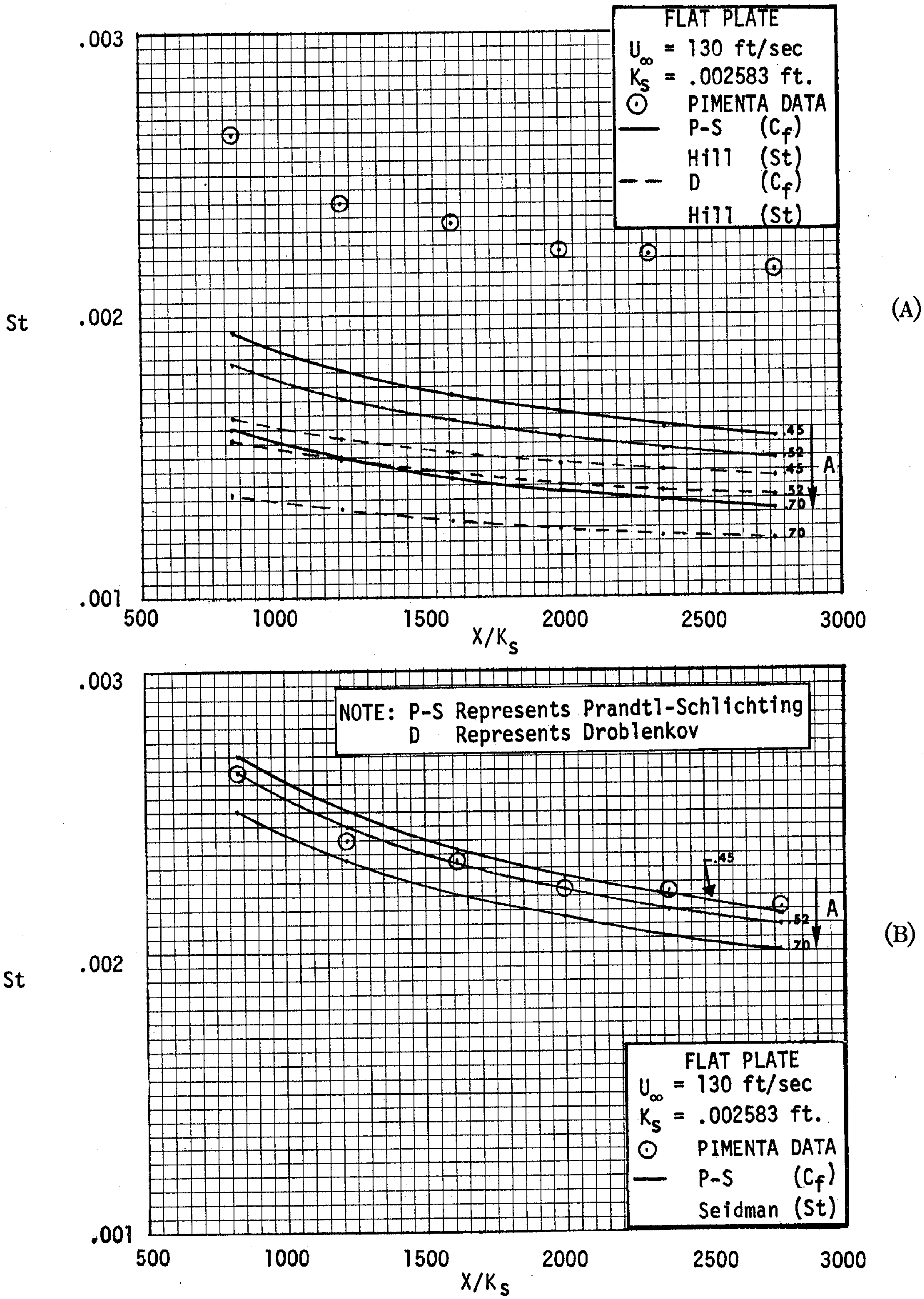


Fig. 2.4 Comparison Between Stanton Number Correlation And Data With Variable Parameter A

Seidman's correlation with heat-transfer data for three values of A. The nominal value of 0.52 for A seems to predict the data quite well.

The rationale for checking the roughness heat-transfer options against data in external flow is a result of little or no data being available for nozzles having rough walls. Some roughness data obtained in an MSFC test on a 40-K subscale regenatively cooled nozzle (Ref. 6) were communicated to the authors. On closer examination, it was found, however, that the nozzle was rough at the throat region only. In other words, the equivalent sand roughness is not constant throughout the nozzle and none of the roughness options described here applies to such a situation. Moreover, the concept of equivalent sand roughness breaks down, since similarity in the boundary layer can no longer be satisfied. Instead, to exercise the three roughness options in BLIMPJ, the code was modified to integrate all the options. In the meantime, the geometry package of a generic OTV nozzle was received (Ref. 7) along with the wall temperatures and wall pressures (given in Fig. 2.5). The code was first checked out for the OTV smooth wall situation using two different turbulence models including the Kendall and Cebeci-Smith models. The heat transfer distributions on the nozzle wall are given in Fig. 2.6. As noted by other investigators, the Cebeci-Smith model predicted lower heating rates. A fictitious value of the equivalent sand roughness of 0.00125 ft. was used to run BLIMPJ for the OTV nozzle using first the roughness option 3 (which used a modification to Cebeci-Smith turbulence model). An example of the namelist tape for BLIMPJ using a roughness option is given in Table 2.2. The heat-transfer results are plotted in Fig. 2.9 and compared with those for a smooth wall. Heat rates are approximately 3 times higher for the rough wall than for the smooth wall in the peak heating region occurring around the throat. Although the skin friction and heating rate values are quite high for a rough nozzle locally in the throat region, the integrated values of

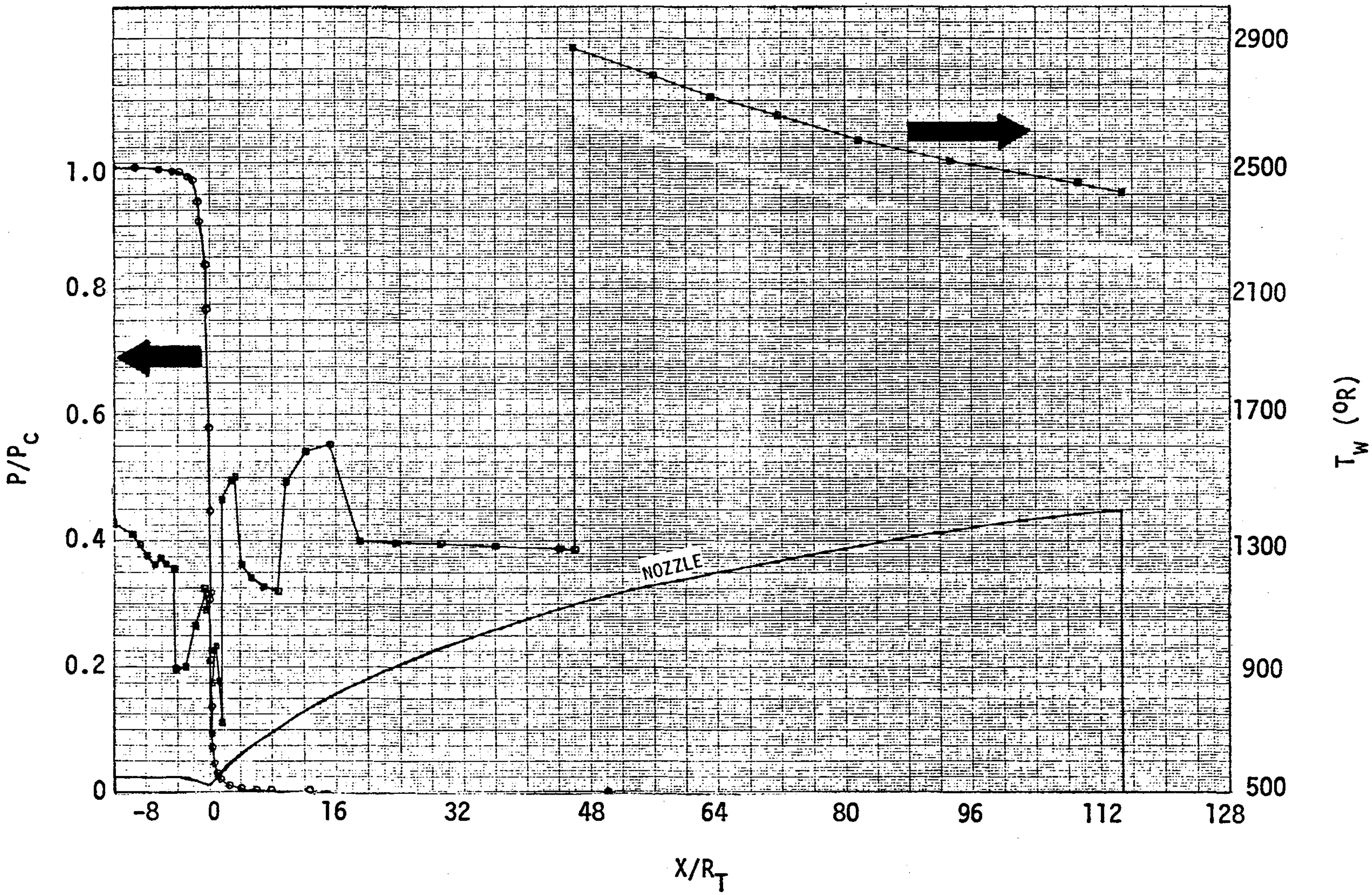


Fig. 2.5 Input Wall Pressure And Temperature Variation For A Typical OTV Nozzle

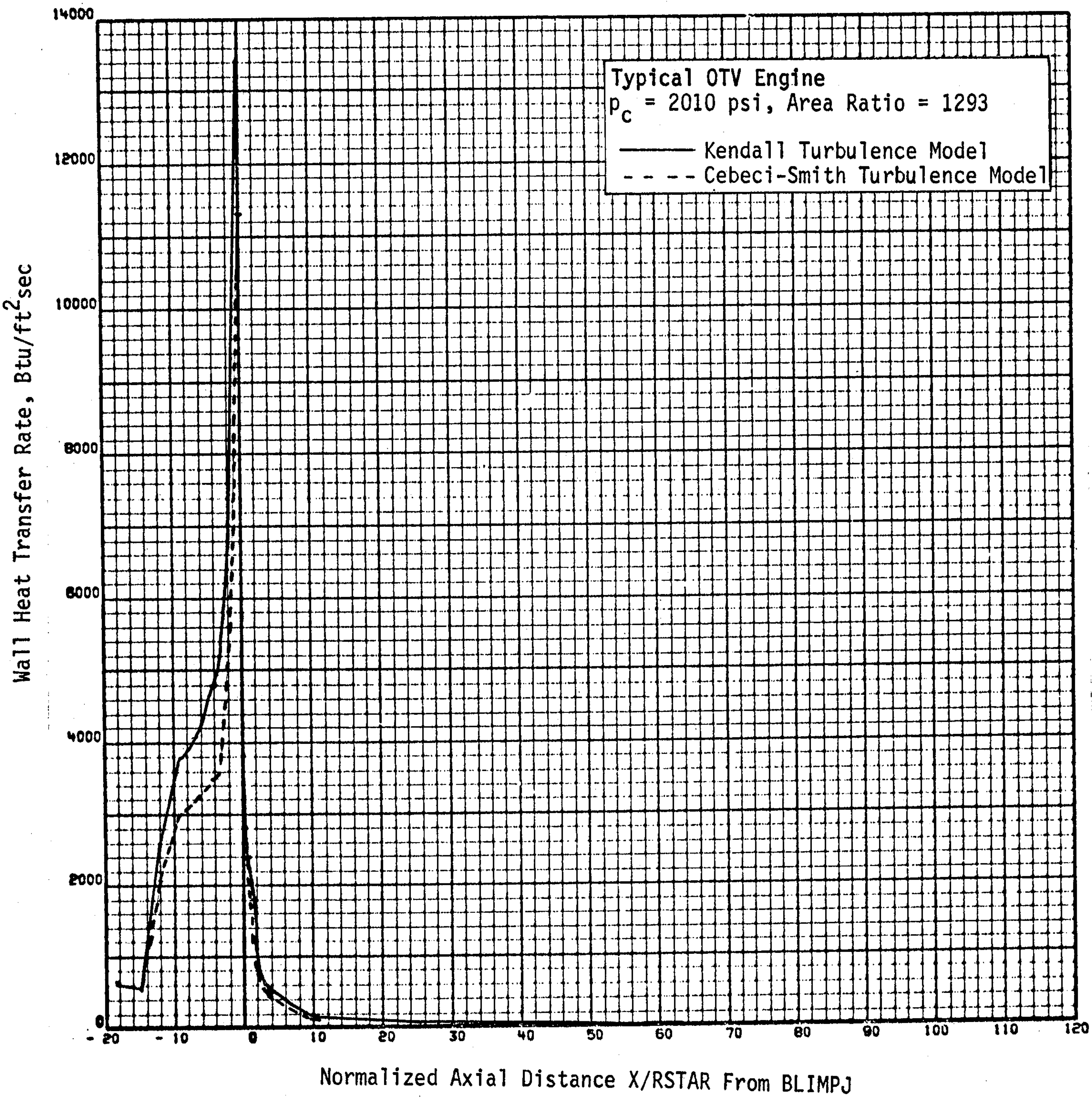


Fig. 2.6 Comparison Of Two Turbulence Models

TABLE 2.2 Example Of Namelist Input For Roughness Option

```
@ELT,DUL  SSME12,OTV
ELT 8P1 S7401C 12/06/84 21:52:08 (3-34)
   1.   NEW   04   ROCKETDYNE CTV ENGINE PC = 2010., AREA RATIO = 1293.0, ROUGHNESS OPTION - 2
   2.   -1    00   $DATA
   3.         01   ITOK = 0,
   4.         00   NSP = 2,
   5.         02   NEL = 2,
   6.   NEW   04   MR = 0.0, FUEL = 2.0,6*0.0, OX = 0.0,2.0,5*0.0,
   7.   NEW   04   NS=49,
   8.   NEW   04   IPLOT=1,
   9.   NEW   04   RK=.00125,ICF=2,
  10.   NEW   04   YAP=-11.823,
  11.   NEW   04   S=1.,
  12.   NEW   04   RTM=.0900633,
  13.   NEW   04   PCHAMB=2009.59,
  14.   NEW   04   GE=77.9558,GW=-5000.00,
  15.   -6    00   KAT = 2HH ,2HO , ATA = 4HHYDR,4H OXY, ATB = 4HOGEN,4HGEN , ATC = 2*4H    ,
  16.         00   WAT = 1.0080,16.0,
  17.   NEW   04   TKP = -1.0,-6.08,
  18.   NEW   04   TW=1445.,1375.,1340.,1305.,1234.,890.,895.,900.,900.,1031.,1088.,1095.,
  19.   NEW   04   1060.,1030.,1114.,1122.,1100.,1000.,790.,690.,740.,850.,870.,880.,910.,
  20.   NEW   04   920.,960.,950.,890.,880.,860.,850.,727.,1460.,1500.,1460.,1230.,1140.,
  21.   NEW   04   1520.,1298.,1275.,1272.,2670.,2740.,2590.,2540.,2430.,2407.,
  22.   NEW   04   N=353,NTH=36,
  23.   NEW   04   NP=1,2,3,4,5,-9,12,14,16,25,30,36,42,50,60,70,80,90,100,110,120,130,140,150,
  24.   NEW   04   160,170,160,190,200,210,220,235,255,-275,-266,267,288,-294,295,305,315,316,
  25.   NEW   04   -317,325,335,340,346,353,
  26.   -7    00   IP = 1,
  27.   NEW   04   IU = 0,
  28.   NEW   04   KTURB=0,
  29.   NEW   04   RETR=360.,
  30.   NEW   04   XITAB=-18.5014,-14.601,-12.026,-9.251,-6.475,
  31.   NEW   04   YITAB=5*2.,
  32.   NEW   04   PITAB=.9993,.99652,.99369,.99090,.98791,
  33.   NEW   04   VITAB=52.5,210.0,367.5,516.4,682.4,
  34.   NEW   04   XITAB( 6) =  -4.629640, -4.486464, -4.332684, -4.176904, -4.021124, -3.865344,
  35.   NEW   04    -3.709563, -3.553763, -3.398003, -3.242223, -3.066443, -2.930662, -2.774882,
  36.   NEW   04    -2.619102, -2.463322, -2.307542, -2.151761, -1.995981, -1.840201, -1.684421,
  37.   NEW   04    -1.528641, -1.372860, -1.217080, -1.061300,  -.905520,  -.749739,  -.593959,
  38.   NEW   04     -.438179,  -.282399,  -.126618,
  39.   NEW   04   XITAB( 36) =  .0000000,  .0026841,  .0054051,  .0081631,  .0109557,  .0137826,
  40.   NEW   04     .0166440,  .0195390,  .0224674,  .0254285,  .0284217,  .0314471,  .0345044,
  41.   NEW   04     .0375934,  .0407142,  .0438664,  .0470496,  .0502643,  .0535102,  .0567872,
  42.   NEW   04     .0600955,  .0634349,  .0668057,  .0702078,  .0736420,  .0771078,  .0806054,
  43.   NEW   04     .0841347,  .0876959,  .0912899,  .0949169,  .0985759,  .1022678,  .1059941,
  44.   NEW   04     .1097530,  .1135461,  .1173736,  .1212348,  .1251319,  .1290635,  .1330140,
  45.   NEW   04     .1370354,  .1410858,  .1451667,  .1492819,  .1534127,  .1576217,  .1618628,
  46.   NEW   04     .1661349,  .1704193,  .1747863,  .1791886,  .1835969,  .1880890,  .1926184,
  47.   NEW   04     .1971513,  .2017714,  .2064334,  .2110955,  .2158496,  .2206147,  .2254662,
  48.   NEW   04     .2303253,  .2352729,  .2402253,  .2452701,  .2503176,  .2554613,  .2606047,
  49.   NEW   04     .2658488,  .2710883,  .2764313,  .2817655,  .2871431,  .2926704,  .2982837,
  50.   NEW   04     .3039636,  .3096250,  .3151908,  .3208446,  .3265262,  .3321344,  .3378464,
  51.   NEW   04     .3435913,  .3492695,  .3550602,  .3608782,  .3666981,  .3724603,  .3783393,
  52.   NEW   04     .3842594,  .3901933,  .3960694,  .4020641,  .4061228,  .4141769,  .4202372,
  53.   NEW   04     .4263254,  .4324444,  .4385960,  .4447029,  .4509437,  .4572341,  .4635464,
  54.   NEW   04     .4698995,  .4762680,  .4826573,  .4890841,  .4955500,  .5020569,  .5086027,
  55.   NEW   04     .5151893,  .5218162,  .5285065,  .5352209,  .5419597,  .5487456,  .5555785,
```

(Arrow pointing to line 9:) Equivalent Sand Roughness, RK = .00125 ft.
Roughness Option, ICF = 2

and so on

these quantities over the whole nozzle in relation to the smooth wall values are much lesser in magnitude. Since this roughness option modifies the turbulence model due to the presence of roughness, Fig. 2.7a was prepared to compare the velocity profiles between the rough and smooth wall cases at the nozzle throat. Figure 2.7b, on the other hand, compares the velocity profiles given in normalized y-coordinates. It is clearly seen from both the plots that not only the boundary layer is thicker but is pushed upward as suggested by Cebeci. This phenomenon has also been observed experimentally be Voisinet (Ref. 9) and is reproduced in Fig. 2.7c as evidence.

The other two roughness options were also exercised for the same OTV nozzle with the above equivalent sand roughness height. Since the enthalpies in the expression (A1) in Table 2.1 are with respect to $T = 0^{o}R$ as the reference, the concept was modified in BLIMPJ to integrate C_p with respect to T from $T = 0^{o}R$ to either the wall or the edge temperature to calculate H_w or H_e, respectively. Noting that C_p is calculated as a function of T in the boundary layer, an extrapolation was made on C_p to a value down to $T = 0^{o}R$ as shown in Fig. 2.8 for the OTV nozzle throat location. A numerical intergration was performed within the code to calculate all the required enthalpies, and consequently, to compute skin friction and heat transfer rates. Figures 2.9, 2.10 and 2.11 compare heat flux, Stanton number and skin friction coefficient distribution using all the three available roughness options with $K_s = 0.00125$ ft. The comparison among the three options is quite reasonable near the throat and downstream of the throat. However, some disparities remain in Stanton number and skin friction in the subsonic contraction section of the nozzle, particulary for Options 1 and 2.

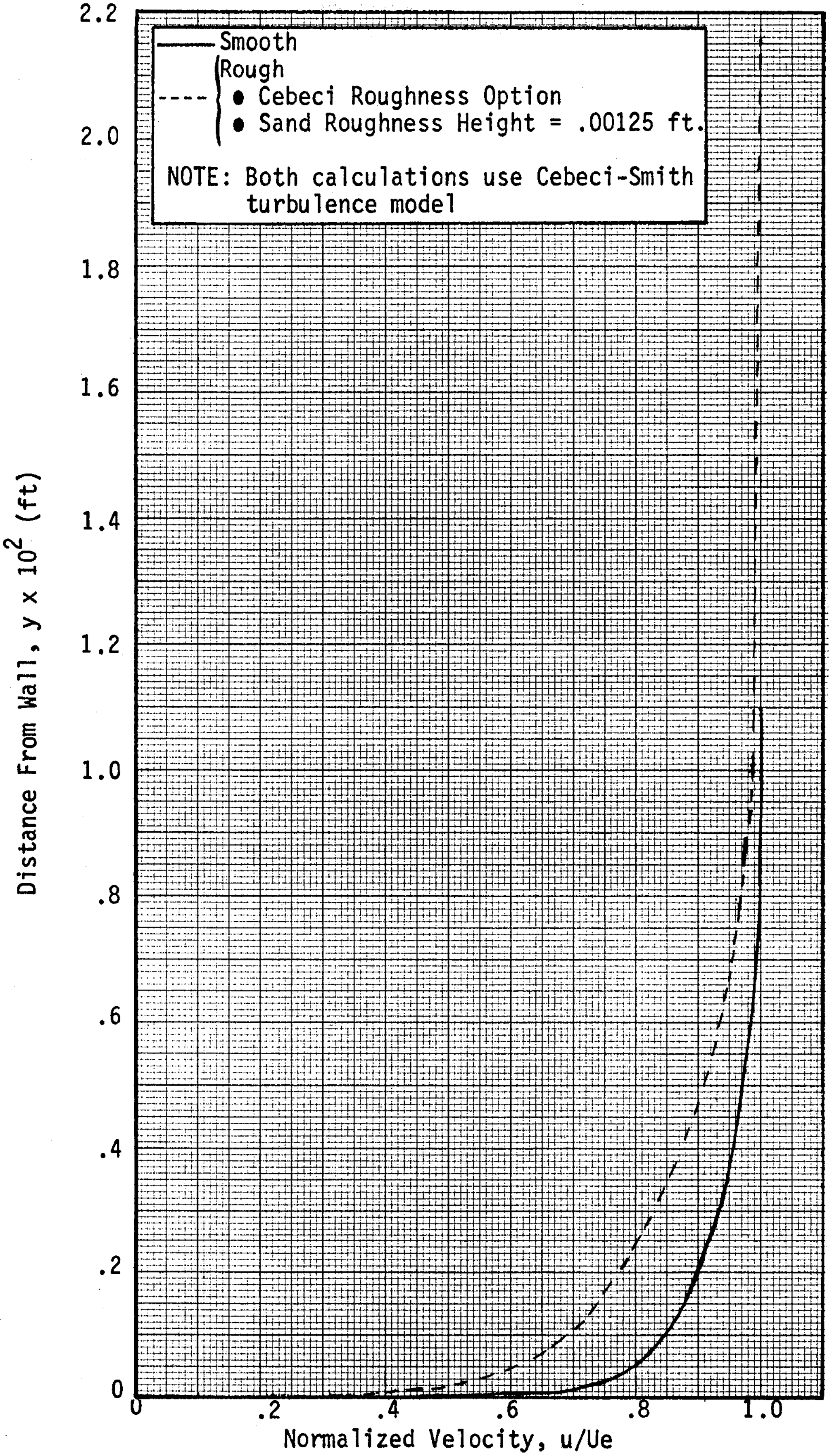


Fig. 2.7a Comparison Of Velocity Distribution Between Rough And Smooth Walls At The OTV Nozzle Throat

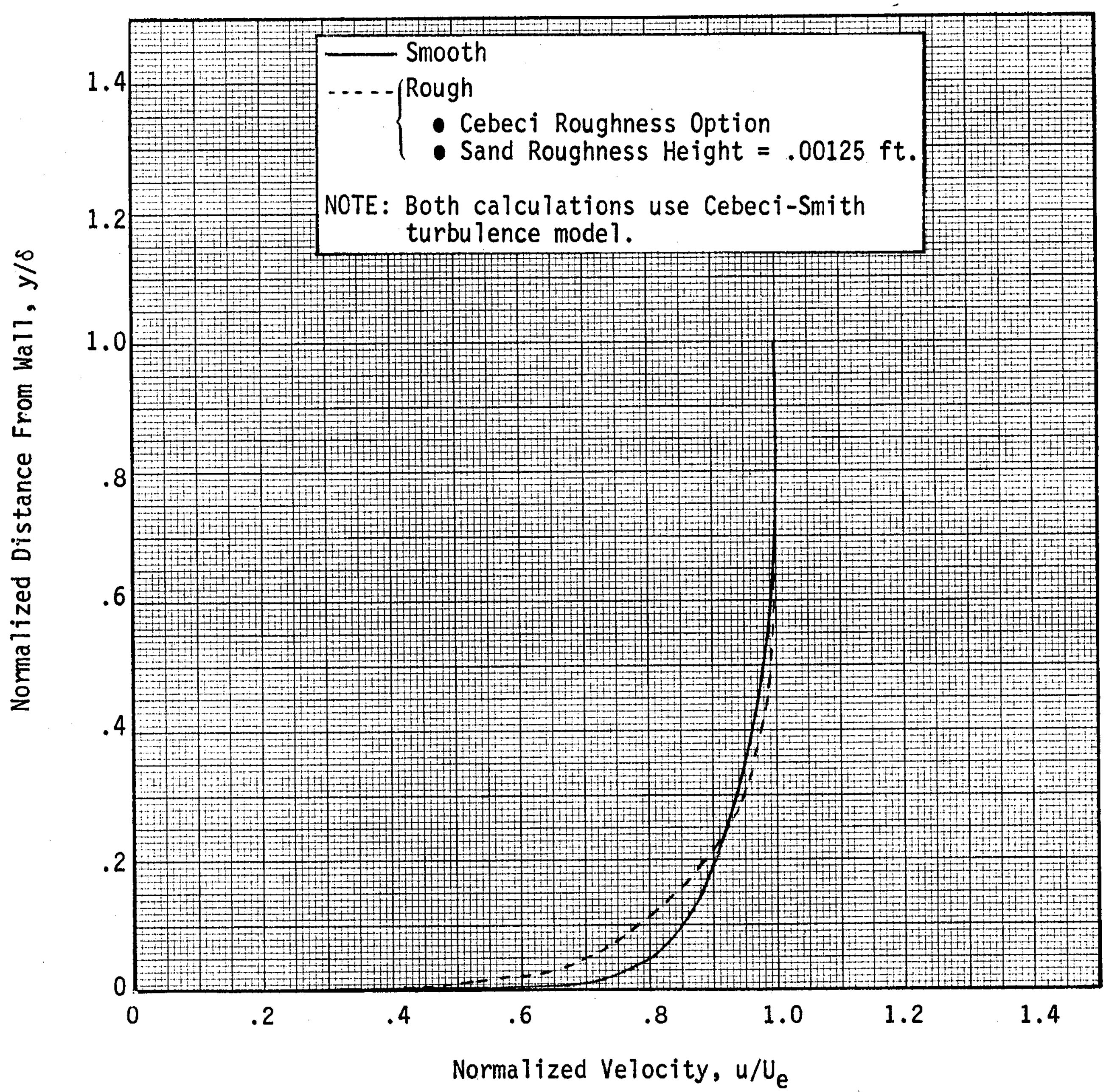
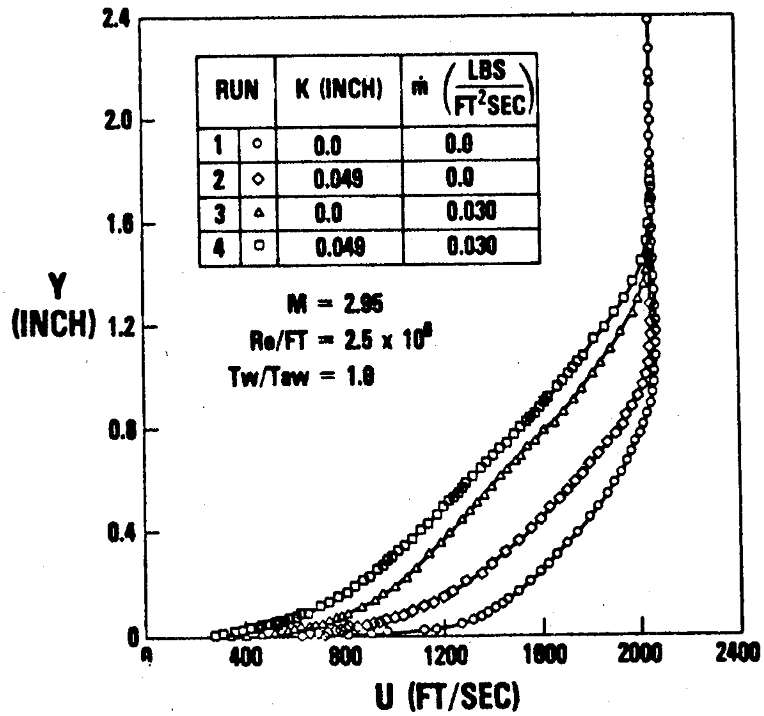


Fig. 2.7b Comparison Of Velocity Distribution Between Rough And Smooth Walls At The OTV Nozzle Throat



K = Equivalent Sand Roughness Height

ṁ = Mass Transfer Rate

Fig. 2.7c Typical Velocity Profiles Given By Voisinet (Ref. 9)

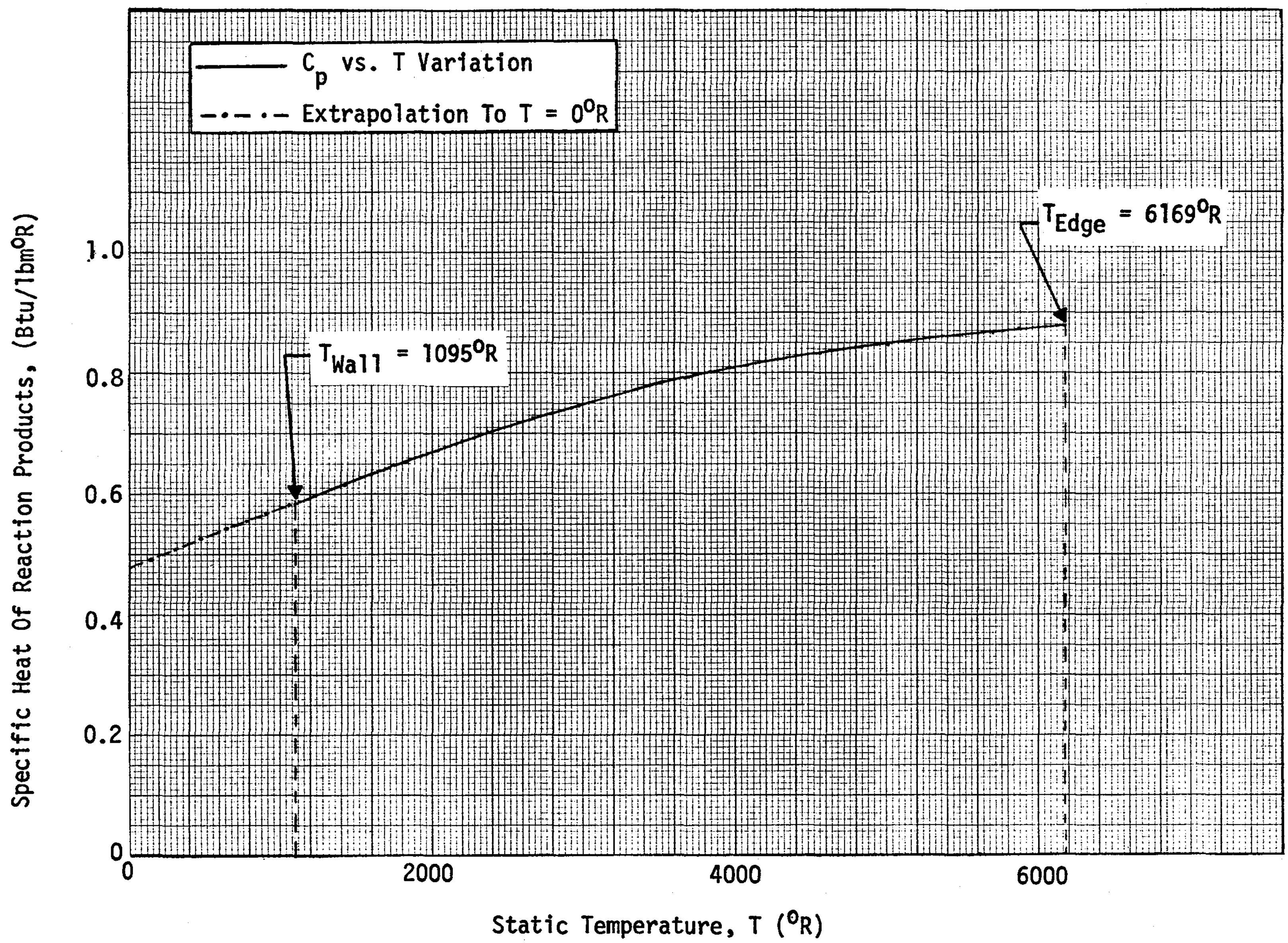


Fig. 2.8 Variation Of Specific Heat Of H_2/O_2 Reaction Products With Static Temperature At OTV Nozzle Throat

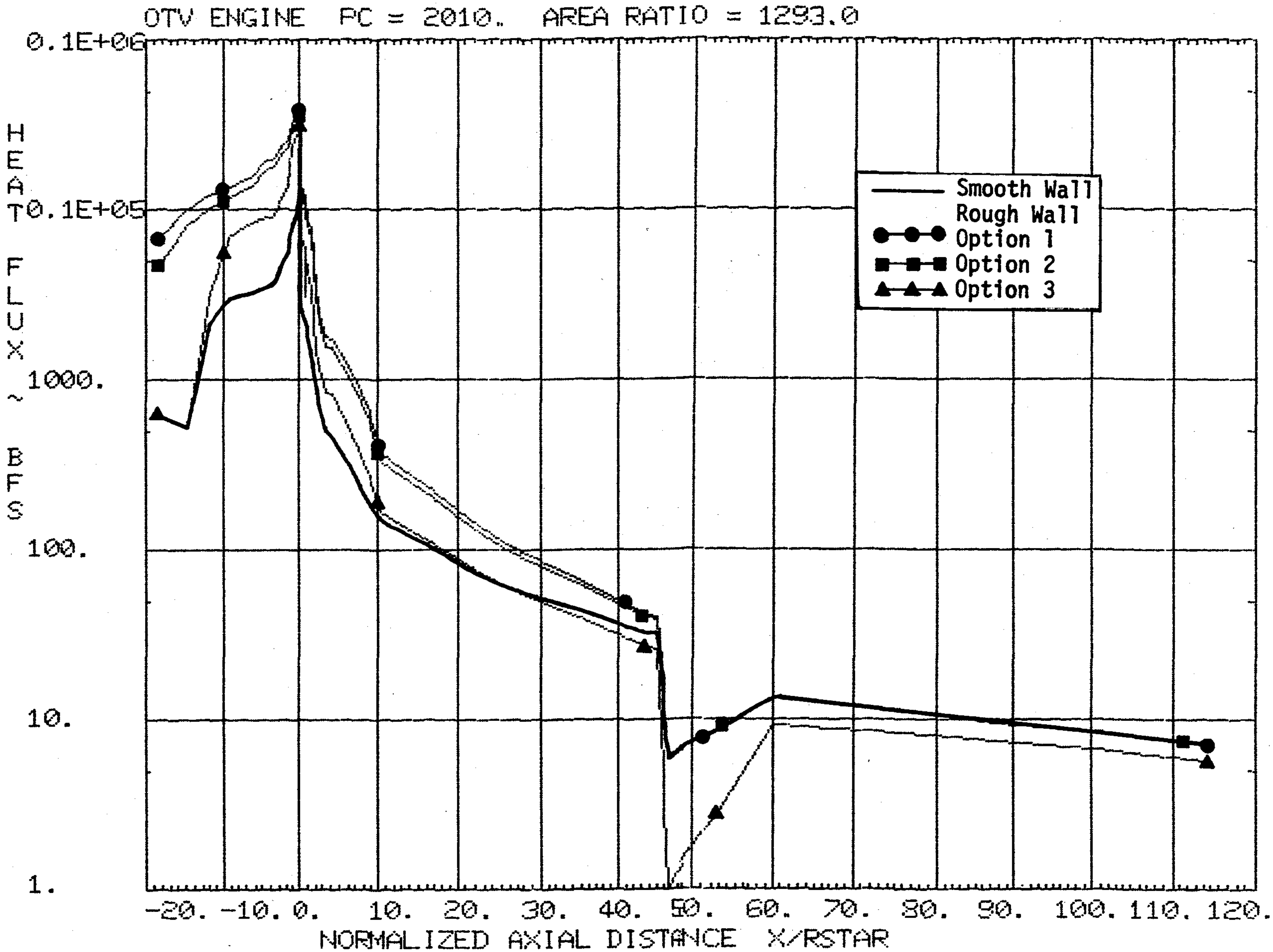


Fig. 2.9 Comparison Of Heat Flux Distribution On The Wall Of The OTV Nozzle Wall Using Various Roughness Options

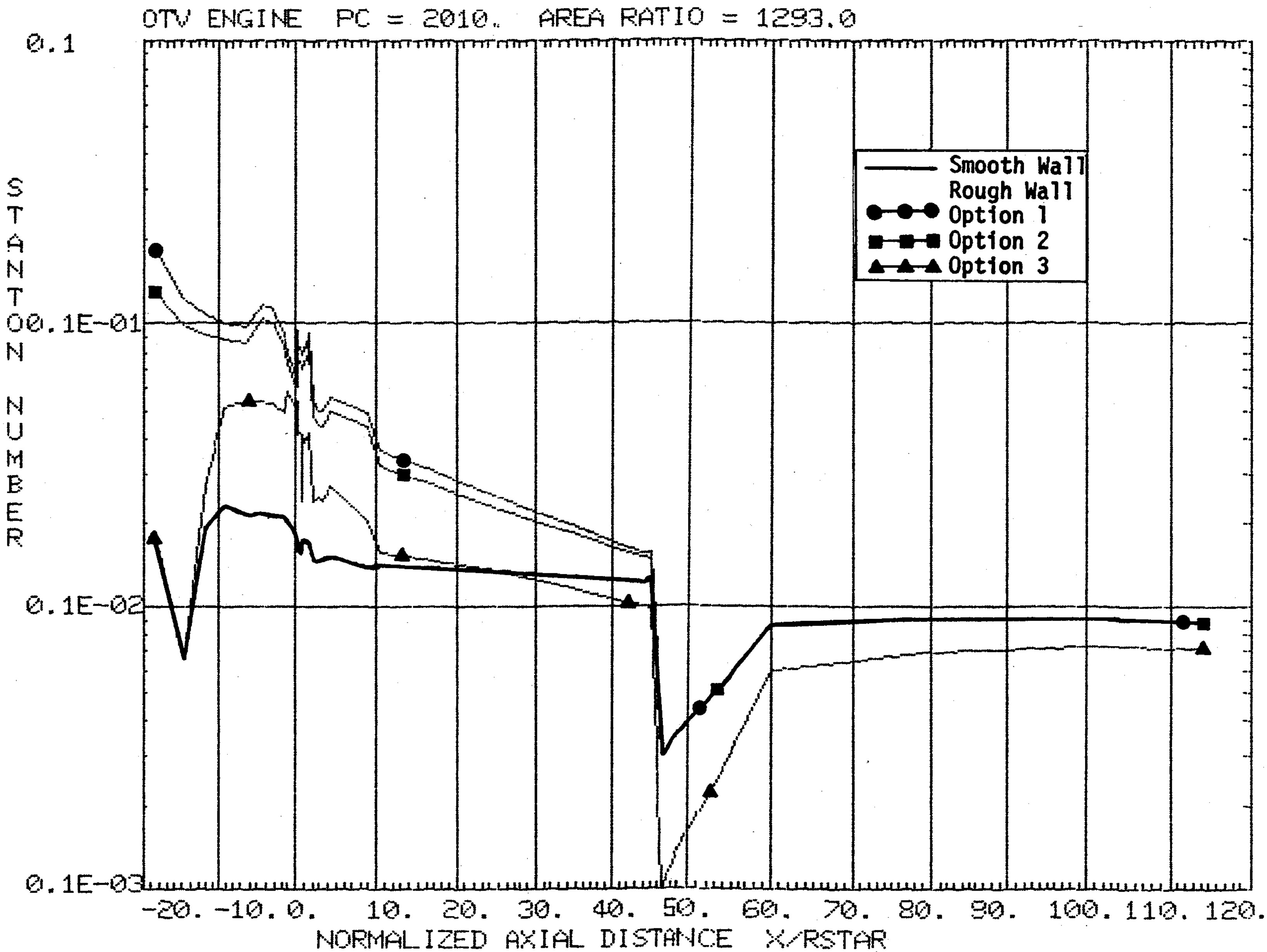


Fig. 2.10 Comparison Of Stanton Number Distribution On The OTV Nozzle Wall Using Various Roughness Options

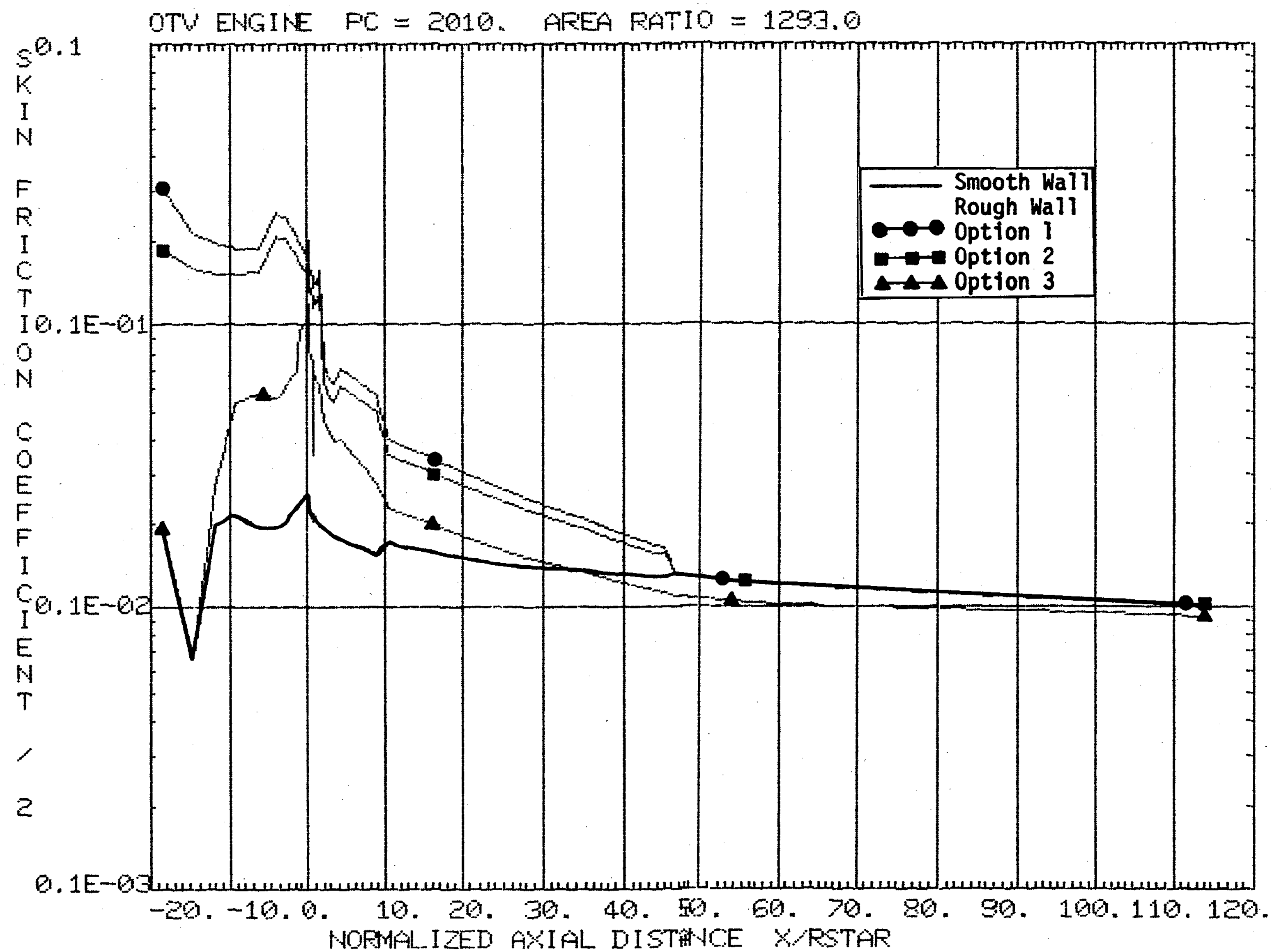


Fig. 2.11 Comparison Of Skin-Friction Coefficient Distribution On The OTV Nozzle Wall

2.4 Discussions

The correlations and modifications incorporated in BLIMPJ to account for roughness would be very good candidates for evaluating the thermal losses on the OTV nozzles. The results given in Figs. 2.9-2.11 for a fictitious sand roughness show that although the comparison of $\dot{q}$, St and C_{f_i} on the OTV wall between the three options is reasonable, there is still about 20 to 30 percent variation in the peak heating areas of the nozzle. It must be noted that certain engineering approximations have been incorporated in the evaluation of H in the calculation of the compressiblity factor, C_f/C_{f_i} in Options 1 and 2. The Option 3, on the other hand, is a more systematic modification of the turbulence model to account for wall surface roughness. It not only gives the heat transfer at the wall, but also provides the details of the turbulence scale change effects within the boundary layer. The effects of wall roughness on the law-of-the-wall results have been noted by others (Ref. 8) to cause a downward shift in the profiles with increased roughness. This meant that for the same value of the law-of-the-wall coordinate, y^+, the velocity is lower. The same phenomenon was observed in the work presented earlier. One item in the Cebeci roughness model (Ref. 8) is the upper limit of 2000 for the equivalent sand-grain roughness parameter, K_s for which the modification of the length scale is valid. In the code modification, a value of 4000 was used for running the case presented earlier. The validity of this limit must be examined experimentally. Suggestions for future work in this area appear in Sec. 6.

2.5 References

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Section 3.0

RELAMINARIZATION

3.1 Background

The prediction of relaminarization phenomena is one of the strongest tests of validity of the turbulence models. Relaminarization is basically a reversion from turbulent to laminar boundary layer. Relaminarization is principally caused by severe flow acceleration effects that typically occur internally in the convergent portion of nozzles where subsonic flow exists; in the divergent portion of nozzles where supersonic flow is dominant; and externally in expanding supersonic flows around bodies such as ogive-cylinder and sphere-cylinder configurations. Some of the theoretical and experimental work is reported in Refs. 1-5. Many of these works are experimental in nature. Patel and Head in Ref. 1 have shown experimentally that quite large departures occur from the universal inner-law velocity distribution in the presence of severe favorable pressure gradients in turbulent boundary layers. The work of such investigators as Launder in Ref. 2 has described investigations generally similar to that reported by Patel et al. (Ref. 1), but emphasizes the measurements of turbulence and mean velocity profiles, and covers the complete reversal transition process. In the measurements of Back, Cuffel and Massier (Ref. 3), a reduction in heat-transfer below values typical of a turbulent boundary layer was found when the values of the parameter, $K = (\mu_e/\rho_e U_e)(dU_e/dx)$ exceeded about 2 to 3 x 10^6. One of the best documented experimental investigations of compressible boundary layer relaminarization is that reported by Nash-Webber (Ref. 4). In this work, an instrumented flat plate was tested in the presence of a variety of upper-wall profiles. The profiles were chosen to impose various pressure gradients on the flat-plate turbulent boundary layer. He deduced a comprehensive criterion for relaminarization, which will be discussed in detail in the following subsection. It was noticed that acceleration effects tend to keep flow laminar beyond the normally-prescribed transition value.

3.2 Relaminarization Criterion

The various turbulence models in BLIMPJ were derived based on zero to moderate pressure gradients existing in the flow direction and thus, would not be able to predict laminarization for severe favorable pressure gradients. However, a treatment done by Adams et al. (Ref. 5) using the IKET (Integral form of the Kinetic Energy of Turbulence) approach was able to predict laminarization on the shoulder of a sphere-cylinder configuration tested at $M_\infty = 9$ in Tunnel F at AEDC. It was also pointed out by Adams that BLIMP could not predict either the onset of relaminarization or the degree of relaminarization.

The acceleration parameter which is a potential candidate for relaminarization and chosen for this study is that due to Nash-Webber (Ref. 4). According to Ref. 4, the acceleration parameter is defined as,

$$K = \frac{\bar{\mu}_w}{\bar{\rho}_w U_e} \cdot \frac{dU_e}{dx} \qquad (3.1)$$

Where the subscript 'w' denotes wall conditions, the subscript 'e' denotes boundary-layer edge conditions, and the barred quantities are time-averaged values. The importance of this parameter is illustrated in Ref. 4 and is reproduced here in Fig. 3.1 for completeness. According to this, the numerical value of K can be used as an indicator for probable occurrence of relaminarization provided that the momentum thickness Reynolds number based on edge conditions is sufficiently low. The recommended boundary value for the onset of relaminarization in Fig. 3.1 seems to be somewhat lower than the threshold recommended by Launder

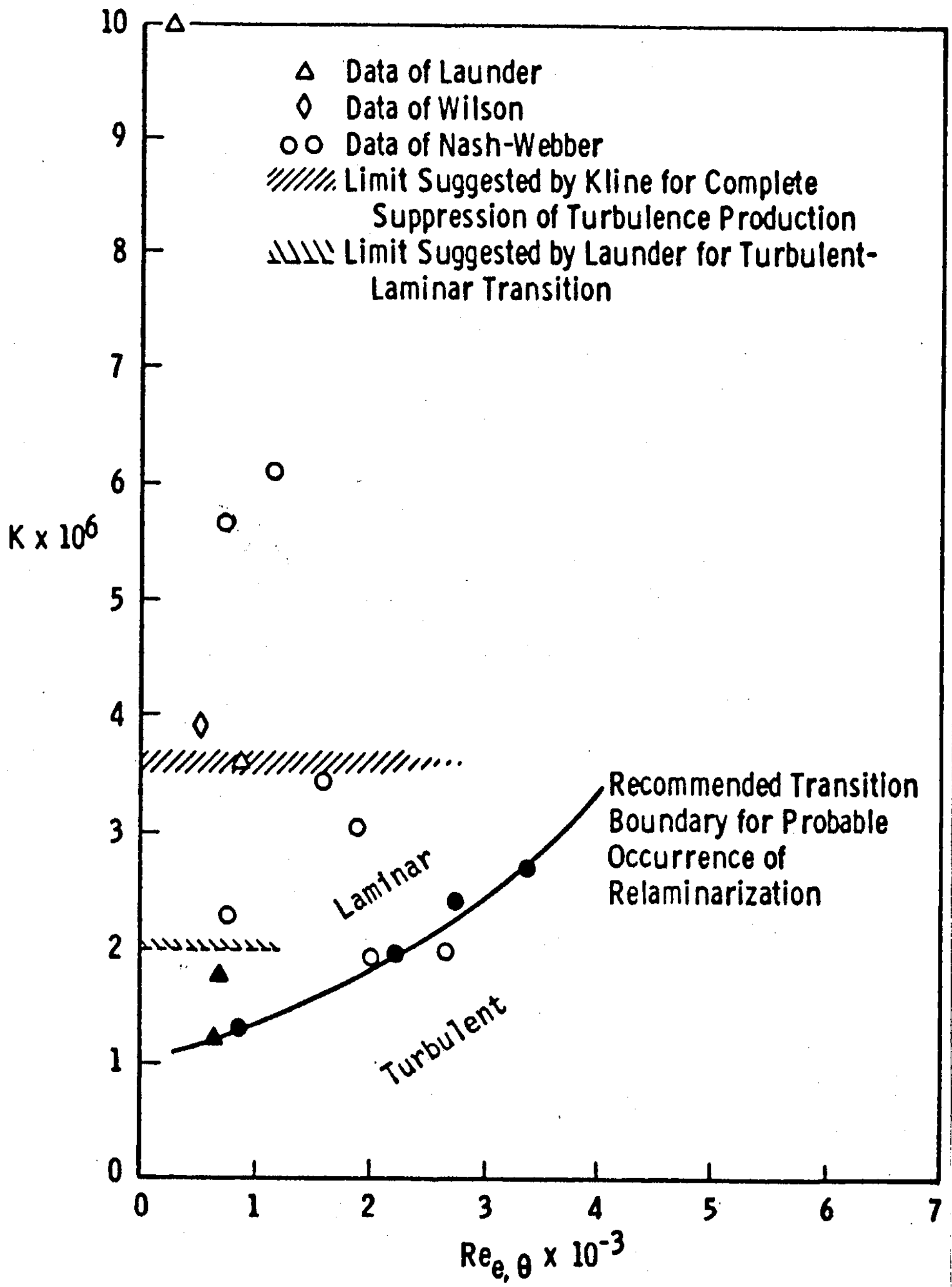

Fig. 3.1 Turbulent-Laminar Transition Boundary

(Ref. 2) and was curve-fitted by a quadratic polynominal given by

$$K = aR^2 + bR + C \qquad (3.2)$$

where

$$a = 8.935 \times 10^{-14}$$
$$b = 2.239 \times 10^{-10}$$
$$c = 1.0248 \times 10^{-6}$$

The end of relaminarization (complete laminar condition) is the limit (Fig. 3.1) suggested by Kline (given in Ref. 4) where there is complete suppression of turbulence production.

Currently, BLIMPJ contains a criterion for transition where a specified or input value of $Re_{e,\theta}$ is used to trigger transition. When the prescribed $Re_{e,\theta}$ is exceeded, the turbulent transport properties are introduced into the calculations. In order to simulate a transition zone, these transport properties are reduced by a factor varying between 0 and 1 for complete laminar and complete turbulent flow respectively. A linear relationship that is used for varying ε_m(eddy viscosity) is given by

$$\varepsilon_m = I(S) \cdot \varepsilon_m\,(ref) \qquad (3.3)$$

where ε_m(ref) is the reference value for complete by turbulent flow and

$$I(S) = \frac{S}{S_t} - 1.0, \quad S_t < S < 2S_t$$

with

$$I(S) = 0 \text{ for } S \leq S_t$$
$$I(S) = 1 \text{ for } S \geq 2S_t$$

where S is the running length and S_t is the running lenght up to the point of transition on the body. It is suggested by Ref. 6 that a flat plate zero pressure gradient value of $R_{e,\theta} = 360$ serves as a nominal estimate. Now, in order to account for flow acceleration effects, the recommended transition boundaries described in the previous paragraph and given in Fig. 3.1 has been coded in BLIMPJ. For acceleration parameters K less than 1×10^{-6}, Eq.(3.3) is used to check the state of the boundary layer. However, for acceleration parameter greater than 1×10^{-6}, the new criterion given in Fig. 3.1 and described in the previous paragraph is used. In order to simulate a relaminarization zone, the values of K are used instead of S in Eq. (3.3). K_1 and K_2 at any $Re_{e,\theta}$ corresponding to the beginning and the end of relaminarization have been coded in BLIMPJ according to the following formula:

$$\varepsilon_m = \left(\frac{K - K_1}{K_2 - K_1} \right) \cdot \varepsilon_m \text{ (ref)} \tag{3.4}$$

It should be observed that ε_m linearly varies with K from a turbulent ε_m (ref) value to a value of zero for completely laminar flow. Incidentally, the percent relaminarization value is

$$PCT = \left(\frac{K - K_1}{K_2 - K_1} \right) \times 100 \tag{3.5}$$

This additional logic in BLIMPJ only applies for turbulent flow. Depending on the value K, a value of turbulent eddy viscosity is calculated and fed into the boundary layer calculations.

3.3 Examples

In order to check the limits of relaminarization, an example of flow over the Shuttle clean ET configuration was considered. The aeroheating data were measured on a 0.0175 scale clean ET model tested at $M_\infty = 7.3$ in the Ames HWT facility. The measured data had been compared against turbulent and laminar calculations made by other aeroheating codes in Fig. 3.2. Because of tripping of the boundary layer due to the ET triple-cone nose, the boundary layer becomes turbulent over the ogive. The flow remains turbulent up to X/L = 0.2, becomes fully laminar at X/L = 0.25, and finally turbulent again beyond X/L = 0.4. The acceleration parameter in Eq. (3.2) was examined after calculating the pressure gradient from the method-of-characteristics procedure and then the acceleration parameter, and was plotted in Fig. 3.3 as a function of X/L. It is evident that the parameter peaks at X/L = 0.2 and drops off very rapidly as X/L is increased. Another way of plotting this information is shown in Fig. 3.4, where K is plotted vs. $Re_{e,\theta}$. From both the figures, it is obvious that the peak value is not higher than the threshold value of K($\cong 1.58 \times 10^{-6}$) at $Re_{e,\theta} = 1550$. This indicates that the acceleration parameter is not high enough to trigger relaminarization, even though the data seem to suggest it. A similar observation was made by Adams (Ref. 5) for the sphere-cylinder case. Even though his IKET approach as well as the measured data seemed to show relaminarization, the Nash-Webber correlation did not strongly suggest that.

In order to examine the validity of this correlation for nozzle boundary layers, the relevant data taken on a 10^0 - 10^0 half angle conical nozzle by Back et al. (Ref. 3) were examined in Fig. 3.5. Wall pressures calculated by TDK (Ref. 7) were input to the REMTECH version of BLIMPJ, and the heat-transfer (Fig. 3.5.B) along with the acceleration parameter distributions (Fig. 3.5.C) were calculated. The acceleration parameter based on edge quantities, K_e, compared quite well with Back's calculations. The K_e peak occuring upstream of the nozzle throat was not predicted by BLIMPJ because of inadequate wall pressure definition in this region. The heat-transfer calculations were made by using the coded relaminarization criterion. The momentum thickness Reynolds number, $Re_{e,\theta}$ distribution compared well with Back's calculations. The K_w

vs. $R_{e,\theta}$ correlation for relaminarization [Eq. (3.2)] suggested that the turbulent boundary layer was on the verge of relaminarization at the tangency point located at the juncture of the conical and curved portions of the nozzle contraction section. It is seen from Fig. 3.5.B, however, that the prediction is consistently higher than the measured data and that the boundary layer is predicted to be turbulent throughout the contraction section of the nozzle, but not partially relaminarized as evident from the measured data and as pointed out by Back's analysis. Back et al. point out in their paper that if K_e is higher than 2 to 3 x 10^{-6} relaminarization occurs. Since K_e satisfies this criterion in the contraction portion of the nozzle as evident from Fig. 3.5.C, it suggests that relaminarization occurs. The currently coded criterion, which is different from the above criterion and is more definite in structure, is not able to quantify the degree of laminarization as well as suggested by Nash-Webber (Ref. 4).

An example of the name list input to turn on the relaminarization flag is given in Table 3.1.

3.4 Discussions

The Nash-Webber criterion for relaminarization worked only marginally for the external flow situations, whereas for the limited measured data available on nozzles where relaminarization occurs in the boundary layer, this criterion seems to be only approximate. Without going through an extensive analysis such as the IKET-type model (Ref. 5), the current approach needs to be modified somewhat for engineering calculations. In addition, relaminarization can be predicted in the presence of roughness. In order to accomplish this, the roughness option 3 due to Cebeci must be input (RK = ..., ICF = 3) along with the relaminarization option (ILAMIN = 1). The occurence of relaminarization will tend to reduce the turbulence length scales whereas the presence of wall rough-

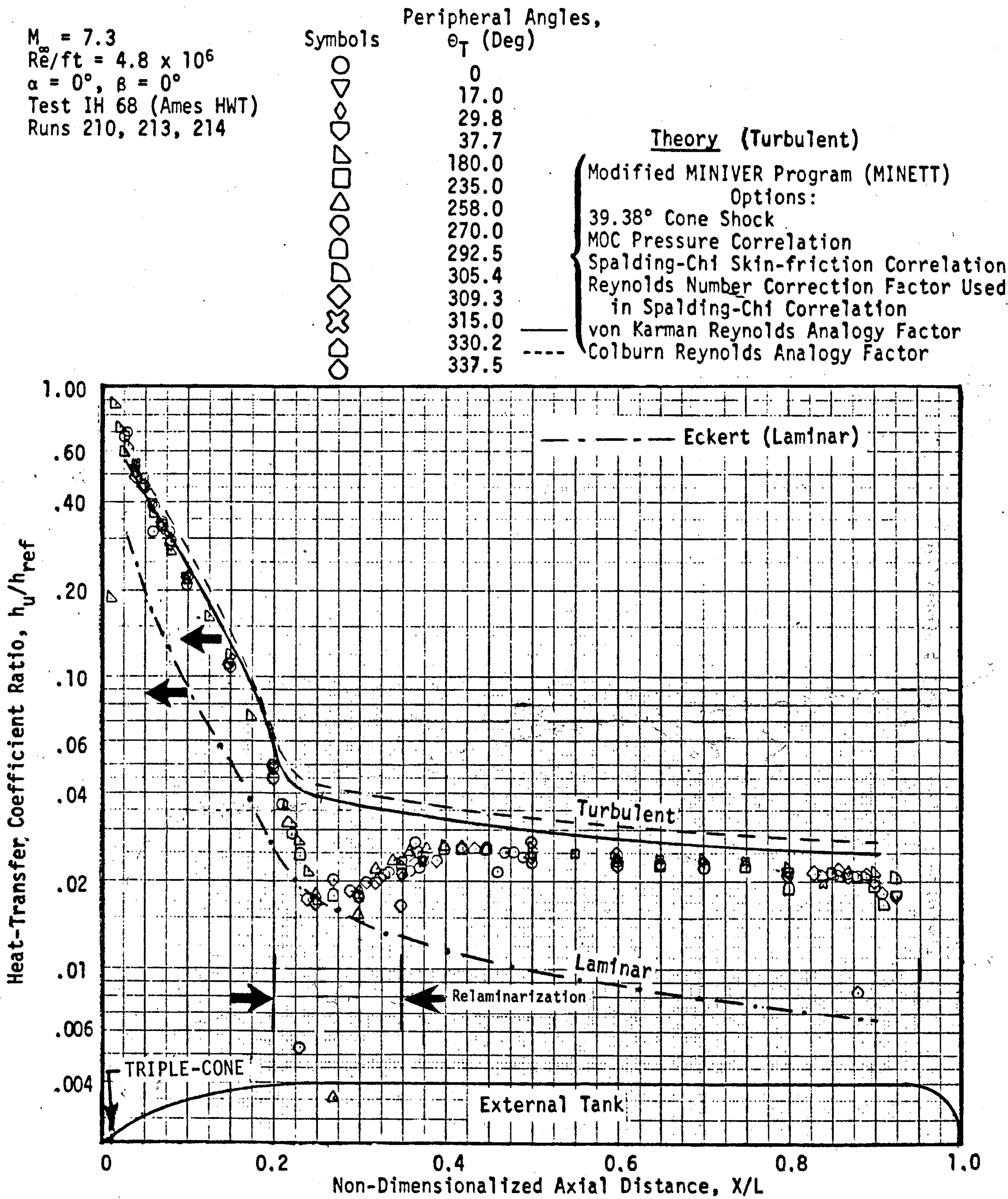

Fig. 3.2 1.75% Model Space Shuttle External Tank Heat-Transfer Distribution.

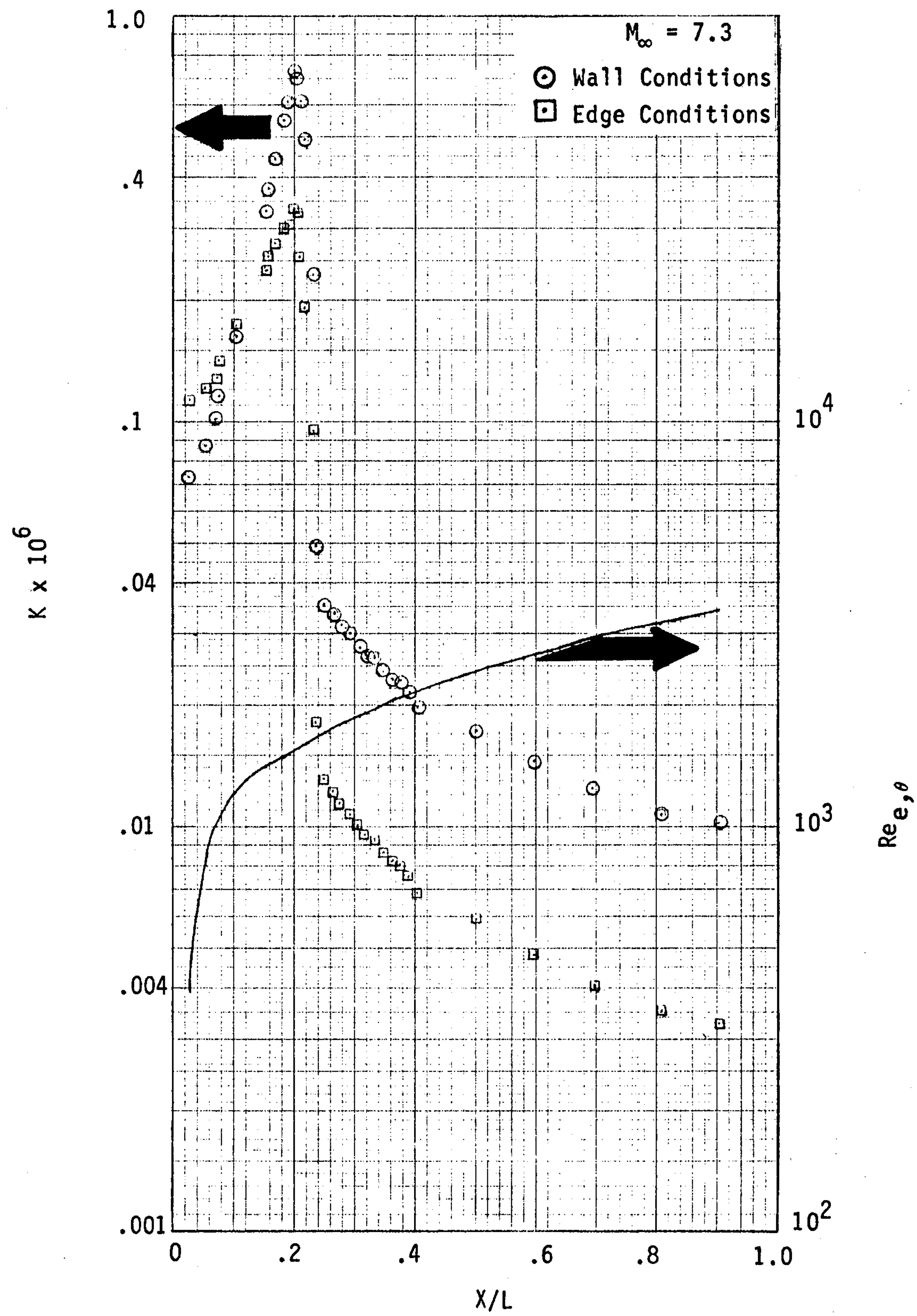

Fig. 3.3 Plot Of Acceleration Parameters Based On Edge And Wall Conditions And Momentum Thickness Reynolds Number Vs. X/L For The Shuttle ET Model

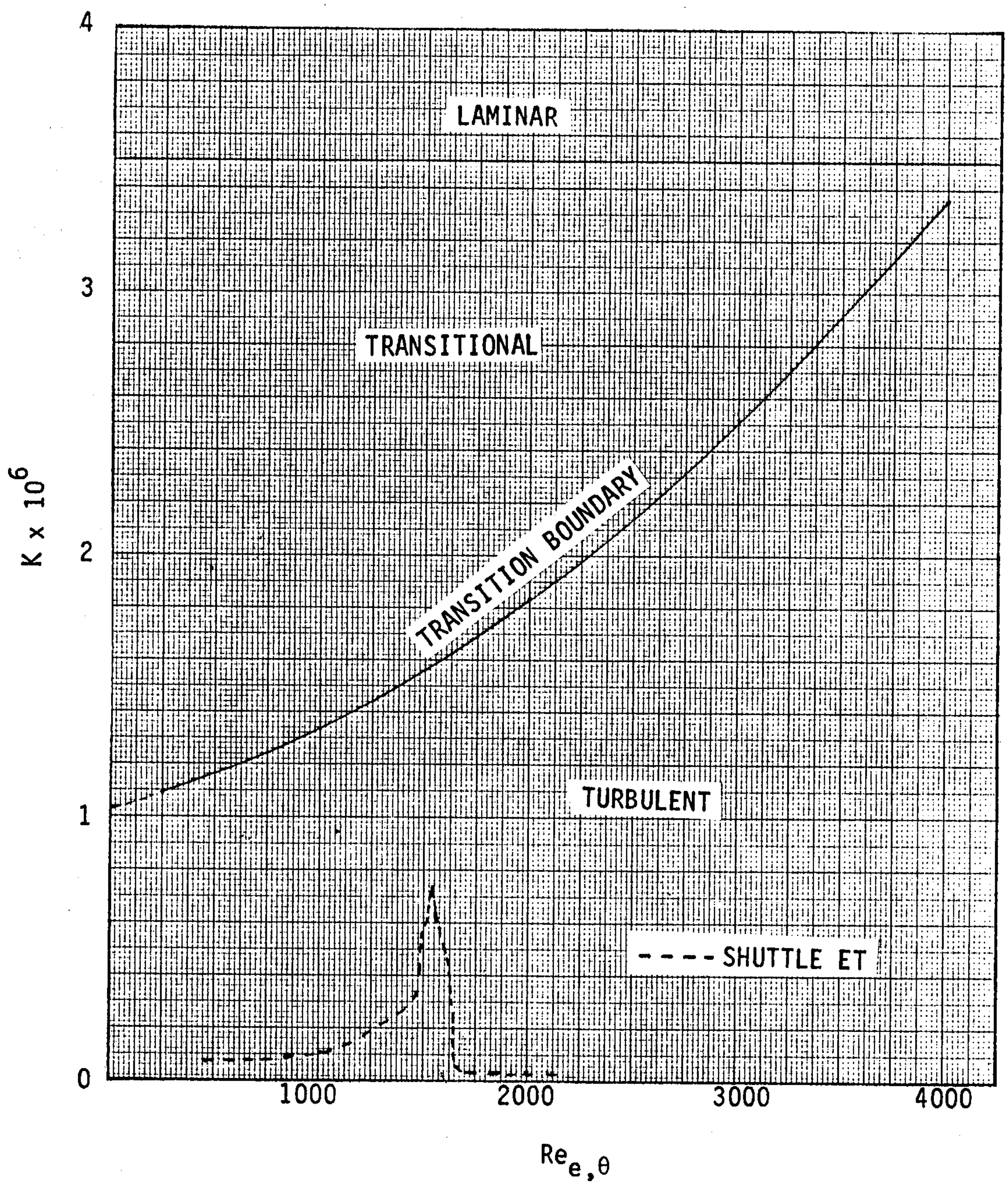

Fig. 3.4 Acceleration Parameter Vs. $Re_{e,\theta}$ for the Shuttle ET Shoulder Region

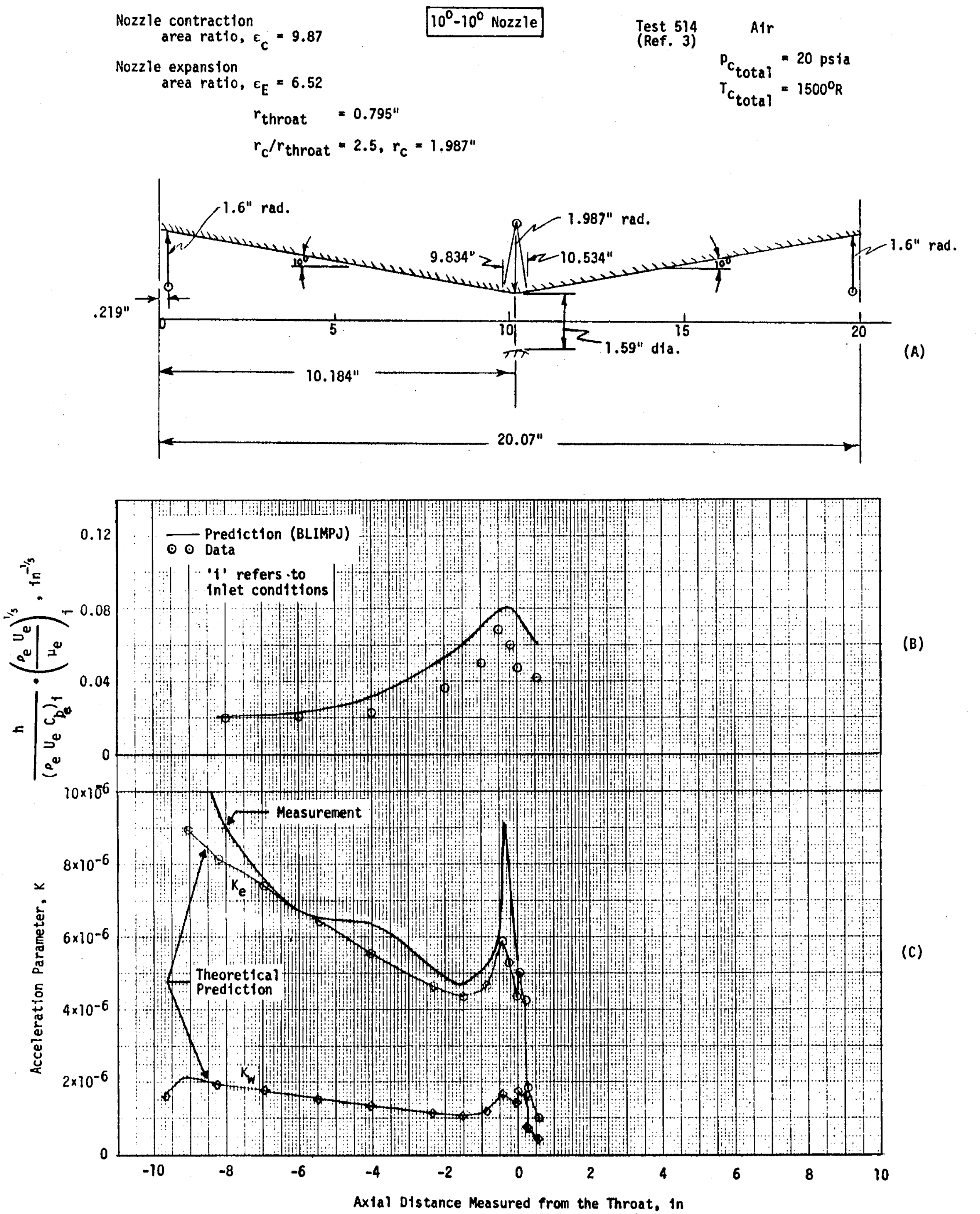

Fig. 3.5 Relaminarization Analysis Of The Boundary Layer Flow In Back Et Al. 10° - 10° Half Cone Angle Nozzle

TABLE 3.1 Example Of Namelist Input For Relaminarization

```
●ELT.DUL  SSME1Z.OTV
ELT 8R1 S74Q1C 12/10/84 22:24:19 (3->4)
   1.   NEW  04   ROCKETDYNE OTV ENGINE PC = 2010., AREA RATIO = 1293.0  PARTICLE OPTION = 1
   2.    -1  00    $DATA
   3.        01    ITDK = 0,
   4.        00    NSP = 2,
   5.        02    NEL = 2,
   6.   NEW  04    MR = 0.0, FUEL = 2.0,6*0.0, OX = 0.0,2.0,5*0.0,
   7.   NEW  04    NS=48,
   8.   NEW  04    IPLOT=1,
   9.   NEW  04    RK=.00125,ICF=0,
  10.   NEW  04    RP=1.E-5,RHOPA=169.,CPART=0.208,WP=4.0,IPART=1,
  11.   NEW  04    ILAMIN=1,
  12.   NEW  04    YAP=-11.823,
  13.   NEW  04    S=1.,
  14.   NEW  04    RTM=.0900833,
  15.   NEW  04    PCHAMB=2009.59,
  16.   NEW  04    GE=77.9558,GW=-5000.00,
  17.    -6  00    KAT = 2HH ,2HO , ATA = 4HHYDR,4H OXY, ATB = 4HOGEN,4HGEN , ATC = 2*4H    ,
  18.        00    WAT = 1.0080,16.0,
  19.   NEW  04    TKP = -1.0,-6.08,
  20.   NEW  04    TW=1445.,1375.,1340.,1305.,1234.,890.,895.,900.,900.,1031.,1088.,1095.,
  21.   NEW  04    1060.,1030.,1114.,1122.,1100.,1000.,790.,690.,740.,850.,870.,880.,910.,
  22.   NEW  04    920.,960.,950.,890.,880.,860.,850.,727.,1460.,1500.,1460.,1230.,1140.,
  23.   NEW  04    1520.,1298.,1275.,1272.,2870.,2740.,2590.,2540.,2430.,2407.,
  24.   NEW  04    N=353,NTH=36,
  25.   NEW  04    NP=1,2,3,4,5,-9,12,14,16,25,30,36,42,50,60,70,80,90,100,110,120,130,140,150,
  26.   NEW  04    160,170,180,190,200,210,220,235,255,-275,-286,287,288,-294,295,305,315,316,
  27.   NEW  04    -317,325,335,340,346,353,
  28.    -7  00    IP = 1,
  29.   NEW  04    IU = 0,
  30.   NEW  04    KTURB=0,
  31.   NEW  04    RETR=360.,
  32.   NEW  04    XITAB=-18.5014,-14.801,-12.026,-9.251,-6.475,
  33.   NEW  04    YITAB=5*2.,
  34.   NEW  04    PITAB=.9993,.99652,.99369,.99090,.98791,
  35.   NEW  04    VITAB=52.5,210.0,367.5,518.4,682.4,
  36.   NEW  04    XITAB( 6) =  -4.629640, -4.488464, -4.332684, -4.176904, -4.021124, -3.865344,
  37.   NEW  04     -3.709563, -3.553783, -3.398003, -3.242223, -3.086443, -2.930662, -2.774882,
  38.   NEW  04     -2.619102, -2.463322, -2.307542, -2.151761, -1.995981, -1.840201, -1.684421,
  39.   NEW  04     -1.528641, -1.372860, -1.217080, -1.061300,  -.905520,  -.749739,  -.593959,
  40.   NEW  04      -.438179,  -.282399,  -.126618,
  41.   NEW  04    XITAB( 36) =   .0000000,  .0026841,  .0054051,  .0081631,  .0109557,  .0137826,
  42.   NEW  04       .0166440,  .0195390,  .0224674,  .0254285,  .0284217,  .0314471,  .0345044,
  43.   NEW  04       .0375934,  .0407142,  .0438664,  .0470496,  .0502643,  .0535102,  .0567872,
  44.   NEW  04       .0600955,  .0634349,  .0668057,  .0702078,  .0736420,  .0771078,  .0806054,
  45.   NEW  04       .0841347,  .0876959,  .0912899,  .0949169,  .0985759,  .1022678,  .1059941,
  46.   NEW  04       .1097530,  .1135461,  .1173736,  .1212348,  .1251319,  .1290635,  .1330140,
  47.   NEW  04       .1370354,  .1410858,  .1451667,  .1492819,  .1534127,  .1576217,  .1618628,
  48.   NEW  04       .1661349,  .1704193,  .1747863,  .1791886,  .1835969,  .1880890,  .1926184,
  49.   NEW  04       .1971513,  .2017714,  .2064334,  .2110955,  .2158496,  .2206147,  .2254662,
  50.   NEW  04       .2303253,  .2352729,  .2402253,  .2452701,  .2503176,  .2554613,  .2606047,
  51.   NEW  04       .2658488,  .2710883,  .2764313,  .2817655,  .2871431,  .2926704,  .2982837,
  52.   NEW  04       .3039638,  .3096250,  .3151908,  .3208446,  .3265262,  .3321344,  .3378464,
  53.   NEW  04       .3435913,  .3492695,  .3550602,  .3608782,  .3666981,  .3724603,  .3783393,
  54.   NEW  04       .3842594,  .3901933,  .3960694,  .4020641,  .4081228,  .4141769,  .4202372,
  55.   NEW  04       .4263254,  .4324444,  .4385960,  .4447029,  .4509437,  .4572341,  .4635464,
  56.   NEW  04       .4698995,  .4762680,  .4826573,  .4890841,  .4955500,  .5020569,  .5086027,
  57.   NEW  04       .5151893,  .5218162,  .5285065,  .5352209,  .5419597,  .5487456,  .5555785,
  58.   NEW  04       .5624576,  .5693844,  .5763592,  .5833812,  .5904729,  .5975959,  .6047506,
```

Relaminarization Flag, ILAMIN = 1

and so on.

ness will tend to increase it. Although the code has not been exercised extensively for both being present in a nozzle, it is believed that the code would handle it adequately.

3.5 References

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Section 4.0

PARTICLE EFFECTS

4.1 Background

The study of the boundary layer flow containing particles (in the fluid-particle systems) is of special interest because of the influence of the particles on the wall shear and heat transfer, the possible tendency of particles to collect near a wall, and the problem of particle impingement on the wall. Typical data (Ref. 1) in the chemical engineering literature correlated in terms of voidage show that there is negligible effect caused by solid particles until the volume percent of solids reaches 0.05 percent, but a very marked increase occurred in heat transfer for higher solids loading. In fact, Nusselt number increases by factors as high as eight have been reported for the addition of particles to a flowing gas (Ref. 1). Material deposited on the nozzle wall also represents a loss in performance, because the resulting rough surface causes increased skin friction losses.

Correlation of gas-particle heat transfer in terms of solids loading and, sometimes, tube diameter (for pipe flow) is not entirely satisfactory, since such correlations ignore the effect of particle size. The differences in the data reported by Leva (Refs. 2 and 3) suggest that the enhancement in heat transfer is at least partially associated with disturbance of the laminar sublayer by particles, causing a local increase in heat transfer. On the other hand, reduction in heat transfer and shear stress have been reported in Ref. 4 for large populations of the smallest particles, less than 1μ, by primarily displacing the boundary layer and thereby reducing thermal gradients.

The laminar particle-gas boundary layer has been investigated by Marble (Ref. 5), Soo (Ref. 6), Tabakoff and Hamed (Ref. 7) using momentum integral techniques. In all these studies, analytical expressions have been found relating wall heat transfer and shear with particles to those without the particles. These investigations have determined that the introduction of particles leads to an increase in the gas boundary layer thickness. In addition, it was found that the gas boundary layer characteristics are more sensitive to particle concentration than any other particulate flow parameter. It has been shown that for gas-particle flow systems, the wall heat transfer and skin friction are related to non-particle flow by a non-dimensional parameter called the "momentum range" which depends on particle size, the fluid viscosity, the fluid velocity and the distance from the leading edge, and another quantity called the "particle momentum interaction parameter", which depends on the ratio of particle mass density to fluid mass density.

Particulate-laden turbulent boundary layer flows in nozzles have not been understood completely and substantial empiricism must be employed to estimate the effects of particle concentration, particle size, density, pressure and entropy gradients on wall shear and heat transfer rate. Tien (Ref. 8) analyzed the increase in heat transfer due to differences in the gas and particle temperatures in boundary layer regions, under the assumptions of incompressible, constant property flow with no radiation or velocity lag effects and no effect of the particles on the gas flowfield. In this case, there is an increase in heat transfer rate while the flow is developing in the pipe. Soo and Tien (Ref. 9) considered particle motion in a turbulent fluid stream with emphasis on the effect of wall interference. The high particle intensity in wall regions increases the heat transfer by increasing the particle to gas heat transfer rates. Disruption of the gas laminar sublayer by particle motion further increases the local heat transfer. Also, if temperatures are high enough for radiation to occur, the radiation from particles to colder walls causes additional heat transfer. Farbar and Morley (Ref. 10) also concluded from their experimental work on flowing gas-solids mixtures in a circular tube that the use of solids in gaseous heat transfer systems may prove to be advantageous when an increase in the heat transfer rate is desired without any increase in the heat transfer area. It was concluded from this study that the gas-side heat transfer factor increases rapidly for solids loading ratios greater than unity. The solids affect both the gas boundary layer and the heat capacity of the flowing mixture. On the other hand, for solids loading ratios of unity or less, a transitional region exists in which the effect is primarily one of increased heat capacity.

4.2 Particle Options

The various options integrated in BLIMPJ fall into the following two categories:

4.2.1 Laminar Boundary Layer-Particulate Flow

The approach used in the modification of BLIMPJ to account for the presence of particles and their effect on wall shear and heat transfer is taken from the work of Marble (Ref. 10). Marble developed an expression for the shear coefficient from an integral momemtum solution of the laminar boundary layer equations, particle continuity and momentum equations for an incompressible flat plate flow. The final expression for the case where $\lambda_v/x < 1$ is given in Table 4.1. The applicable momentum range, λ_v, in the OTV-type nozzles would fall basically in this category. We recognize in Eq. (B.1) of Table 4.1 C_{f_0} as the shear coefficient for the fluid boundary layer without particles. In his original paper, Marble used

$$C_{f_o}/2 = 0.332/\sqrt{R_x} \tag{4.1}$$

Since BLIMPJ provides a shear coefficient for clean flow, that value was used as reference instead to calculate the shear coefficient for the gas-particle system. The quantity, λ_v, represents a distance, x, which describes the particle motion relative to the fluid. For $x < \lambda_v$, there is a high degree of fluid-particle slip, whereas for $x > \lambda_v$, the particles tend to take on the motions of the gas. The heat transfer characteristics are more complex in the high "particle-slip" regime in that the initial conditions become quite important in such a calculation. Since there is very litter work in the literature for this regime, this was not coded in BLIMPJ.

Returning our attention to the expression for shear, the factor $\sqrt{1 + K}$ multiplying the usual shear coefficient gives the result for no particle slip and represents a minimum value for shearing stress. The first order correction $0.49\ (\lambda_v/x\ .\ K/1 + K)$ gives shear stress due to particle slip reduction along the flow path.

Heat transfer through the boundary layer was treated in a similar manner as given in Eq. (B.2).

4.2.2 Turbulent Boundary Layer-Particulate Flow

The approach for modification of the heat transfer and skin friction calculations in BLIMPJ for a turbulent boundary layer is based on the analytical results of Tien (Ref. 8) and the empirical expressions of Farbar and Morley (Ref. 10). Tien solved the turbulent gas-particle energy equations for flow in a pipe and found that the qualitative effect of particle concentration is to flatten the temperature profile and consequently to increase the heat transfer. He has theoretically confirmed the test results of Farbar and Morley that

TABLE 4.1

GAS-PARTICLE SKIN FRICTION AND HEAT TRANSFER

Laminar Boundary Layer (Marble)

$$C_f = C_{f_o} \sqrt{1 + K} \left(1 + 0.49 \frac{K\lambda_{v/x}}{1 + K}\right), \quad \frac{\lambda_v}{X} \ll 1 \qquad \text{(B.1)}$$

and

$$\dot{q} = \dot{q}_o \sqrt{1 + K} \left(1 + 0.49 \frac{K\lambda_{v/x}}{1 + K}\right), \quad \frac{\lambda_v}{X} \ll 1 \qquad \text{(B.2)}$$

where

$$K = \rho_p/\rho_e$$

$$\lambda_v = \frac{mU_e}{6\pi a\mu_e}$$

TABLE 4.1 (Continued)

Turbulent Boundary Layer

For $\frac{W_p}{W_f} < 1$ (Tien)

$$C_f = C_{f_o}(1 + \beta_5)$$

and

$$\dot{q} = \dot{q}_o(1 + \beta_5) \qquad \text{(B.3)}$$

where $\beta_5 = \frac{C_p W_p}{C_f W_f}$

For $\frac{W_p}{W_f} > 1$ (Farbar and Morley)

$$Nu = 0.14\, Re_D^{0.6}\, (W_p/W_f)^{0.45} \qquad \text{(B.4)}$$

$$\dot{q} = \frac{Nu \,.\, K_g}{D} \cdot (T_{aw} - T_w)$$

Particle Factor = $\dot{q}/\dot{q}_o$

$$C_f = \left(\frac{\dot{q}}{\dot{q}_o}\right) \cdot C_{f_o} \qquad \text{(B.6)}$$

TABLE 4.1 (Continued)

Nomenclature

m	= average particle mass, lbm
U_e	= boundary layer edge velocity, ft/sec
σ	= Stokes drag coefficient ($= 6\pi\mu_e a$)
a	= radius of spherical particle, ft.
μ	= gas viscesity, lbm/ft.sec
λ_v	= momentum range, ft.
K	= Particle momentum interaction parameter
ρ_p	= particle mass density of the gas, lbm/ft^3
ρ_e	= gas density, lbm/ft^3
Re_D	= edge Reynolds number based on diameter
X	= running length, ft.
τ	= shear stress, lbf/ft^2
C_{f_o}	= friction coefficient calculated by BLIMPJ
C_f	= modified friction coefficient
$\dot{q}_o$	= heat transfer rate calculated by BLIMPJ, Btu/ft^{2}sec.
$\dot{q}$	= modified heat transfer rate, Btu/ft^{2}sec.
c_p	= specific heat of the solid particle, Btu/lb.degF
W_p	= mass flow of particles, lb/sec.ft^2
c_f	= specific heat at constant pressure of fluid, Btu/lb.degF
W_f	= mass flow of fluid, lb/sec.ft^2
Kg	= thermal conductivity of the gas, Btu/sec.ft^{o}K
D	= diameter of the tube, ft.
Nu	= Nusselt's number

suspended solids, having a solids-to-gas loading ratio of less than 1.0, have a negligible effect on heat transfer. As pointed out earlier, Tien's analysis is valid for the entrance region of a pipe. Since the flow is not fully developed in this region of the pipe, the boundary layers do not merge. This flow situation is similar to what happens in a nozzle, where the boundary layers develop near the nozzle wall and do not merge. Consequently, the expressions developed by Tien for the pipe may be applicable to a nozzle. The expressions for particle-to-fluid loading ratio of less than 1 are given in Eq. (B.3) of Table 4.1.

For higher particulate loading where interactions and collisions among particles become important, the above expression is no longer valid. For the case, where the particle-to-fluid loading ratio is more than 1, the experimental results of Farbar and Morley (Ref. 10) have been correlated and are given in Eq. (B.4) of Table 4.1. This expression is valid for a limited Reynolds number range of $13{,}500 < R_e < 27{,}000$ which were the limits in the test conditions. It has further been noted by Farbar and Morley that for loading ratios up to unity, the Nusselt number varies as the 0.03 power of the loading ratio, while that above unity varies as the 0.45 power of the loading ratio, except that for the lowest Reynolds number which indicates a variation to the 0.5 power. The expressions for Nu in Eq. (B.4) was used to calculate a particle factor which was then used to calculate skin friction coefficient from Eq. (B.5). The above expressions were coded in BLIMPJ and checked with a few examples.

4.3 EXAMPLES

In order to illustrate the effect of particles in the fluid boundary layer on skin friction and heat transfer rate, the following hypothetical example was chosen. Aluminum particles of 10 μradius (density of Al = 169 lbm/ft^3) and particles-to-fluid loading ratio of 0.5 was chosen. Thus,

$$r = 10\mu = 10^{-5}\ m$$

$$\rho_{al} = 169\ lbm/ft^3$$

$$C_{p_{al}} = 0.208\ Btu/lbm.^oF$$

An example of the namelist input in BLIMPJ for particles-in-flow is given in Table 4.2. The OTV nozzle was used for testing the effects of these particles. The relative magnitudes of the resultant skin friction and heat flux are plotted in Figs. 4.1-4.3. Since the OTV nozzle contains both laminar and turbulent boundary layer flow regimes, both laminar and turbulent expressions for particles-in-flow could be checked out simultaneously.

4.4 Discussions

The particle options chosen in the present work are designed to perform "point" calculations and are not capable of taking into account the "history" effects. The particle option can either be used independently or used along with one or both of the roughness and relaminarization options. The reference value for the particle factor will be obtained either from the smooth wall value or from the relaminarization or rough wall value and then be enhanced by the particle factor. It has been pointed out previously that the particle factor expressions for turbulent flow were derived from tube data and do not represent a rocket nozzle case, and in that sense are only approximate in nature. However, they will provide relative values of wall skin friction and heat flux for various particle sizes and particle loadings. Some relevant suggestions for future work for gas-particle flows in rocket nozzles are given in Sec. 6.

TABLE 4.2 Example Of Namelist Input Particle Option

```
@ELT,DUL   SSME1Z.OTV
ELT 8R1 S74Q1C 12/10/84 22:24:19 (3->4)
      NEW   04              OTV ENGINE PC = 2010., AREA RATIO = 1293.0  PARTICLE OPTION = 1
       -1   00        $DATA
            01        ITDK = 0,
            00        NSP = 2,
            02        NEL = 2,
      NEW   04        MR = 0.0, FUEL = 2.0,6*0.0, OX = 0.0,2.0,5*0.0,
      NEW   04        NS=48,
      NEW   04        IPLOT=1,
      NEW   04        RK=.00125,ICF=0,
      NEW   04        RP=1.E-5,RHOPA=169.,CPART=0.208,WP=0.5,IPART=1,
      NEW   04        ILAMIN=0,
      NEW   04        YAP=-11.823,
      NEW   04        S=1.,
      NEW   04        RTM=.0900833,
      NEW   04        PCHAMB=2009.59,
      NEW   04        GE=77.9558,GW=-5000.00,
       -6   00        KAT = 2HH ,2HO , ATA = 4HHYDR,4H OXY, ATB = 4HOGEN,4HGEN , ATC = 2*4H    ,
            00        WAT = 1.0080,16.0,
      NEW   04        TKP = -1.0,-6.08,
      NEW   04        TW=1445.,1375.,1340.,1305.,1234.,890.,895.,900.,900.,1031.,1088.,1095.,
      NEW   04        1060.,1030.,1114.,1122.,1100.,1000.,790.,690.,740.,850.,870.,880.,910.,
      NEW   04        920.,960.,950.,890.,880.,860.,850.,727.,1460.,1500.,1460.,1230.,1140.,
      NEW   04        1520.,1298.,1275.,1272.,2870.,2740.,2590.,2540.,2430.,2407.,
      NEW   04        N=353,NTH=36,
      NEW   04        NP=1,2,3,4,5,-9,12,14,16,25,30,36,42,50,60,70,80,90,100,110,120,130,140,150,
      NEW   04        160,170,180,190,200,210,220,235,255,-275,-286,287,288,-294,295,305,315,316,
      NEW   04        -317,325,335,340,346,353,
       -7   00        IP = 1,
      NEW   04        IU = 0,
      NEW   04        KTURB=0,
      NEW   04        RETR=360.,
      NEW   04        XITAB=-18.5014,-14.801,-12.026,-9.251,-6.475,
      NEW   04        YITAB=5*2.,
      NEW   04        PITAB=.9993,.99652,.99369,.99090,.98791,
      NEW   04        VITAB=52.5,210.0,367.5,518.4,682.4,
      NEW   04        XITAB( 6) =  -4.629640, -4.488464, -4.332684, -4.176904, -4.021124, -3.865344,
      NEW   04         -3.709563, -3.553783, -3.398003, -3.242223, -3.086443, -2.930662, -2.774882,
      NEW   04         -2.619102, -2.463322, -2.307542, -2.151761, -1.995981, -1.840201, -1.684421,
      NEW   04         -1.528641, -1.372860, -1.217080, -1.061300,  -.905520,  -.749739,  -.593959,
      NEW   04          -.438179,  -.282399,  -.126618,
      NEW   04        XITAB( 36) =  .0000000,  .0026841,  .0054051,  .0081631,  .0109557,  .0137826,
      NEW   04          .0166440,  .0195390,  .0224674,  .0254285,  .0284217,  .0314471,  .0345044,
      NEW   04          .0375934,  .0407142,  .0438664,  .0470496,  .0502643,  .0535102,  .0567872,
      NEW   04          .0600955,  .0634349,  .0668057,  .0702078,  .0736420,  .0771078,  .0806054,
      NEW   04          .0841347,  .0876959,  .0912899,  .0949169,  .0985759,  .1022678,  .1059941,
      NEW   04          .1097530,  .1135461,  .1173736,  .1212348,  .1251319,  .1290635,  .1330140,
      NEW   04          .1370354,  .1410858,  .1451667,  .1492819,  .1534127,  .1576217,  .1618628,
      NEW   04          .1661349,  .1704193,  .1747863,  .1791886,  .1835969,  .1880890,  .1926184,
      NEW   04          .1971513,  .2017714,  .2064334,  .2110955,  .2158496,  .2206147,  .2254662,
      NEW   04          .2303253,  .2352729,  .2402253,  .2452701,  .2503176,  .2554613,  .2606047,
      NEW   04          .2658488,  .2710883,  .2764313,  .2817655,  .2871431,  .2926704,  .2982837,
      NEW   04          .3039638,  .3096250,  .3151908,  .3208446,  .3265262,  .3321344,  .3378464,
      NEW   04          .3435913,  .3492695,  .3550602,  .3608782,  .3666981,  .3724603,  .3783393,
      NEW   04          .3842594,  .3901933,  .3960694,  .4020641,  .4081228,  .4141769,  .4202372,
      NEW   04          .4263254,  .4324444,  .4385960,  .4447029,  .4509437,  .4572341,  .4635464,
      NEW   04          .4698995,  .4762680,  .4826573,  .4890841,  .4955500,  .5020569,  .5086027,
      NEW   04          .5151893,  .5218162,  .5285065,  .5352209,  .5419597,  .5487456,  .5555785,
      NEW   04          .5624576,  .5693844,  .5763592,  .5833812,  .5904729,  .5975959,  .6047506,
```

Radius of the particle, RP = 1.E-05
Density of the particle, RHOPA = 169 lbm/ft^3
Specific heat of the particle, CPART = .208,Btu/lb
Particle loading (W_p/W_f) WP = 0.5
Particle Option, IPART = 1

↓ and so on.

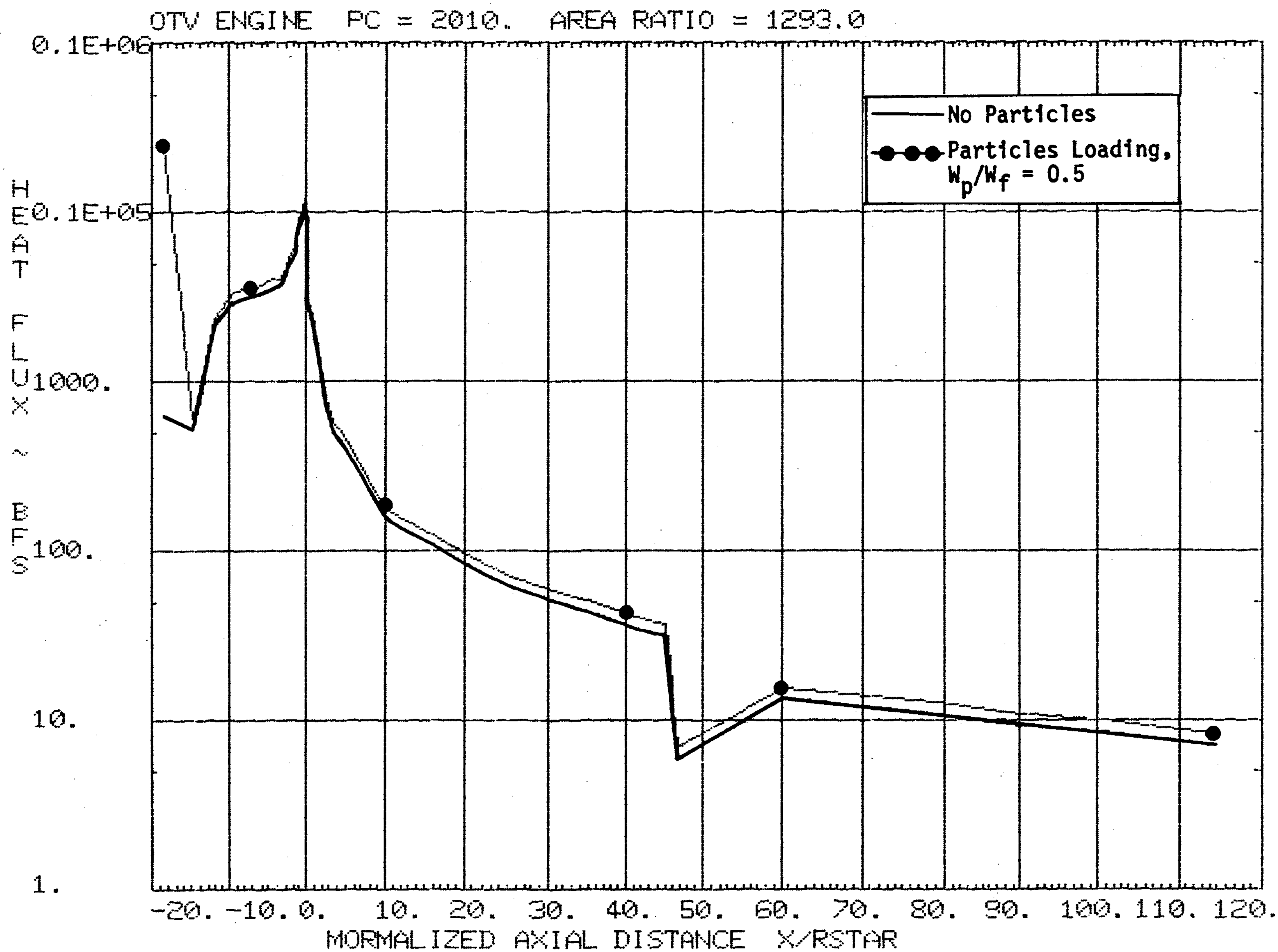

Fig. 4.1 Comparison Of Heat Flux Distribution Over The OTV Nozzle Wall For With And Without Particles In Flow

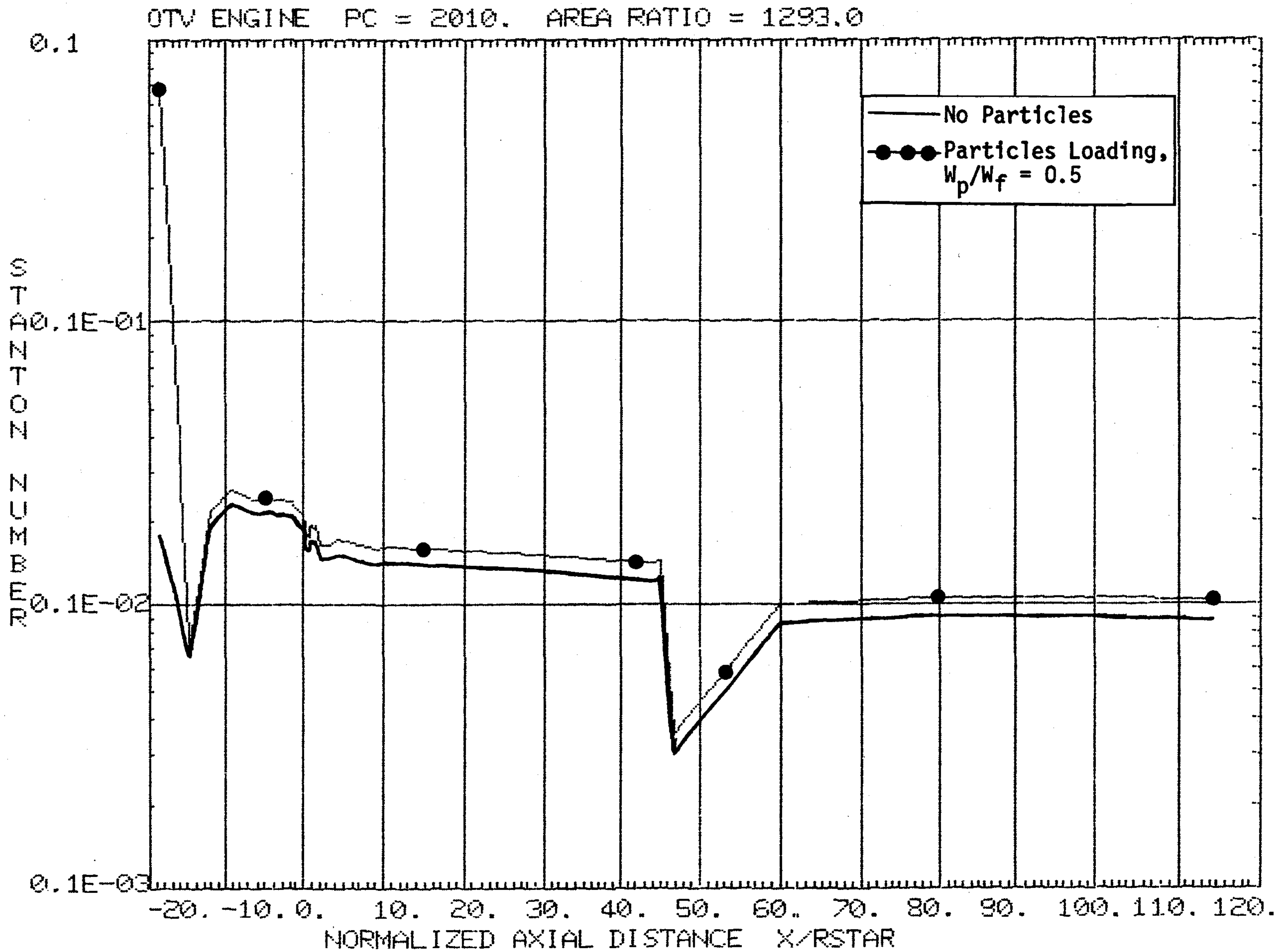

Fig. 4.2 Comparison Of Stanton Number Distribution Over The OTV Nozzle Wall For With And Without Particles In Flow

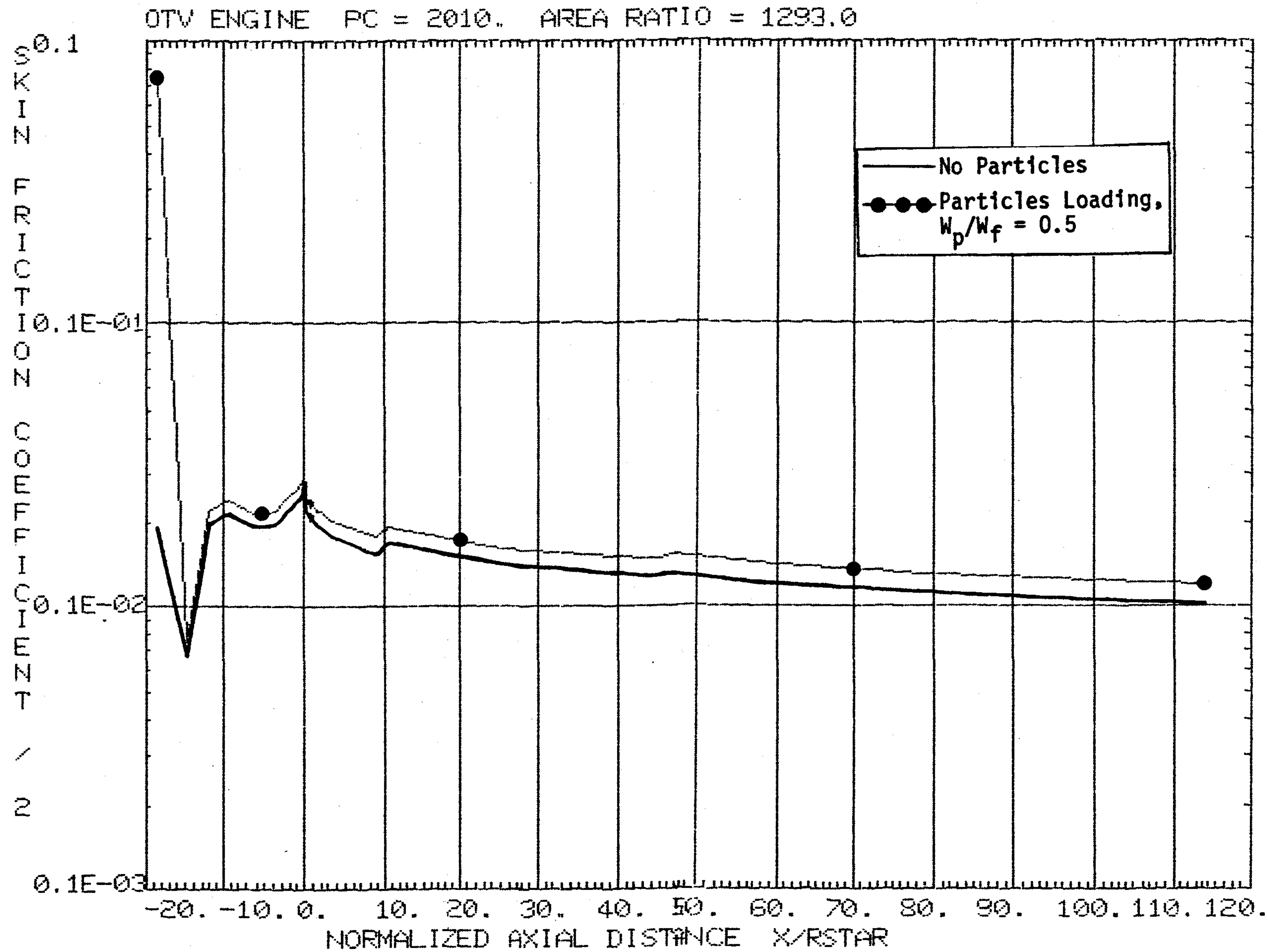

Fig. 4.3 Comparison Of Skin Friction Coefficient Distribution Over The OTV Nozzle Wall For With And Without Particles In Flow

4.5 References

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Section 5.0

THRUST LOSS RE-EVALUATION

5.1 Background

A thrust loss calculation method which has been previously implemented in BLIMPJ code is given in Ref. 1. The thrust loss due to the boundary layer effects for a circular cross-section nozzle is given at a specified cross-section by (for vacuum ambient conditions)

$$\Delta F = 2\pi r_e \cos\phi_e (\rho_e U_e^2 \theta - P\delta_B^*) \tag{5.1}$$

where

r_e = Body radius at the station of interest

ϕ_e = Wall angle

ρ_e = Boundary layer edge density

U_e = Boundary layer edge velocity

θ = Momentum thickness

P = Static pressure in the boundary layer

δ_B^* = Body displacement thickness

The assumptions used in deriving the above expression are the following:

(i) The boundary layer is thin, i.e., the thickness of the boundary layer is small compared to the radius of the nozzle at any cross-section.

(ii) The inviscid values of density and velocity do not change within the thickness of the boundary layer. In other words, if there was no viscosity (i.e. for inviscid flow), there would be no variation of the inviscid values between the edge location and the nozzle wall.

(iii) The pressure is constant across the boundary layer. This assumption is consistent with the derivation of the usual boundary layer equations.

(iv) The definitions of body displacement thickness and momentum thickness are given by

$$\delta_B^* = \int_0^e \left(1 - \frac{\rho U}{\rho_e U_e}\right) dy \tag{5.2}$$

and

$$\theta = \int_0^e \frac{\rho U}{\rho_e U_e} \left(1 - \frac{U}{Ue}\right) dy \qquad (5.3)$$

where e and o refer to edge and wall conditions respectively.

As the nozzles grow in area ratio, the boundary layers grow in size, and the above assumptions may not hold. The proposed OTV nozzles such as the one given in Fig. 2.5 will utilize an expander cycle operations mode in which the walls will be regenerately cooled and the heat energy will be used to drive the turbines and pumps. So, while the regenratively cooled walls will help in reducing the size of the boundary layers to some extent, the large area ratio nozzles will produce thick boundary layers. Consequently, depending on the reservoir and exit conditions, and the geometry of the nozzle, it is possible and very likely that boundary layer thicknesses will vary from small to large values. The displacement and transverse curvature effects become important for thick boundary layers and must be included in the boundary layer calculations. In addition, as the flow expands in the nozzle, it will create low density and high Mach number flows. If the flow passes from the continuum to a non-continuum regime, velocity slip and temperature jump (STJ) may become important.

Similar boundary layer solutions are not applicable for such an investigation, since similarity cannot be satisfied for any specified set of reservoir conditions, nozzle geometry and wall temperature distributions. Fortunately, the boundary layer procedure in BLIMPJ does not assume similarity. Furthermore, it takes into account transverse curvature effects (TVC) in the derivation. It also calculates the displacement effects for thin boundary layers. As far as the STJ effects are concerned, it has been pointed out by previous investigations (Ref. 2) that they are generally small compared to the other effects discussed above and thus, will be ignored in the present approach.

5.2 Thrust Loss Reevaluation Procedure For Thick Boundary Layers

In accordance with the above discussions, the expression for thrust loss for thick boundary layers has been modified. The assumptions made in deriving Eq. (5.2) and (5.3) are no more strictly valid. The u-component of the velocity in the inviscid flow will vary to some extent between the nozzle wall to the edge location. Consequently, the definitions for δ^*_B and θ are

$$\delta^*_{Bt} = \int_0^e \left[1 - \frac{\rho U}{\rho_i(y) \cdot U_i(y)}\right] dy \tag{5.4}$$

and

$$\theta_t = \int_0^e \frac{\rho U}{\rho_i(y) \cdot U_i(y)} \left[1 - \frac{U}{U_i(y)}\right] dy \tag{5.5}$$

The expression for the thrust loss calculation given in Eq. (5.1) will also have to be modified in its derivation where the edge quantities, (ρ_e, U_e) and pressure will no more be constants but would be replaced by local inviscid values $\rho_i(y)$, $U_i(y)$ and $P(y)$. However, it was decided that the whole procedure of thrust loss calculation will be much more simple and adapted a lot easier in the BLIMPJ algorithm, if the pressure is replaced by an average value of the pressure distribution within the thickness of the boundary layer. As a result, averaged inviscid edge values of velocity and density will automatically be calculated from the BLIMPJ algorithm and could be used in the thrust loss calculation in the existing algorithm in BLIMPJ. In the above calculations, the location of the boundary layer edge is not precisely known and has to be determined by iterating upon the inviscid and viscous flowfields.

There are two different problems to be solved when one attempts to calculate performance for a rocket nozzle having thick boundary layers:

<u>Case 1</u> - The potential nozzle contour is given and the objective is to define the hardware wall contour and calculate the rocket nozzle performance. For details, see Attachment 5.1.

<u>Case 2</u> - The hardware wall contour is given and the objective is to define the potential contour and calculate the rocket nozzle performance. For details, see Attachment 5.2.

Attachment 5.1

In the case, where the potential contour is given, the objective is to define the wall contour for thick boundary layer situations. The suggested iteration procedure is given below: (Also see Fig. 5.1).

(i) Run the inviscid code (TDK and RAMP) to define the distribution of pressure on the potential wall and everywhere else in the nozzle, particularly near the potential wall.

(ii) Run BLIMPJ with the given pressure distribution on the potential wall. This calculates δ and δ^*. Then, the body radius is calculated from

$$R_B = R_P + \delta^* \cos \phi$$

This is the first iteration.

(iii) Calculate an average inviscid pressure for the height between the potential wall and the boundary layer edge, which was obtained from the previous calculation at each station. Use these pressures to run BLIMPJ again, and calculate δ_2 and δ^*_2. Then, calculate R_B. This is the second iteration.

(iv) Iterations stop when convergence on δ^* is achieved within a specified accuracy.

Attachment 5.2

In the case where the hardware wall contour is given, the objective is to define the inviscid edge for thick boundary layer situations. The suggested iteration procedure is given below: (also see Fig. 5.2)

(i) Run the inviscid code (TDK or RAMP) to calculate the distribution of pressure on the hardware wall in the nozzle.

(ii) Run BLIMPJ with the calculated wall pressure distribution on the hardware wall. This calculates δ and δ^* as a function of the nozzle axial coordinate. Then, the radius of the potential wall is calculated from

$$R_P = R_B - \delta^* \cos \phi$$

This is the first itertation.

(iii) Calculate the pressures again by using the inviscid code (TDK or RAMP) on the new potential wall and everywhere else in the nozzle, particularly near the potential wall.

(iv) Calculate the average pressure for the height between the boundary layer edge, which was obtained previously, and the hardware wall. Use the pressures on the hardware wall to run BLIMPJ again and calculate δ_2 and δ_2^*. Then calculate R_P. This is the second iteration.

(v) Go back to (iii) and iterate until a prescribed convergence criterion on δ^* is achieved. If it is found that the pressure calculations in (iii) in the first two iterations are very close, do not go back to (iii), instead go back to the beginning of (iv).

Once the iterations are completed, the thrust loss will automatically have been calculated by BLIMPJ to yield the final answer.

NOTES:

1. The potential contour is given; the objective is to define the wall contour.
2. Subscript refers to iteration number.
3. δ^* refers to displacement thickness.
4. δ refers to boundary layer thickness.

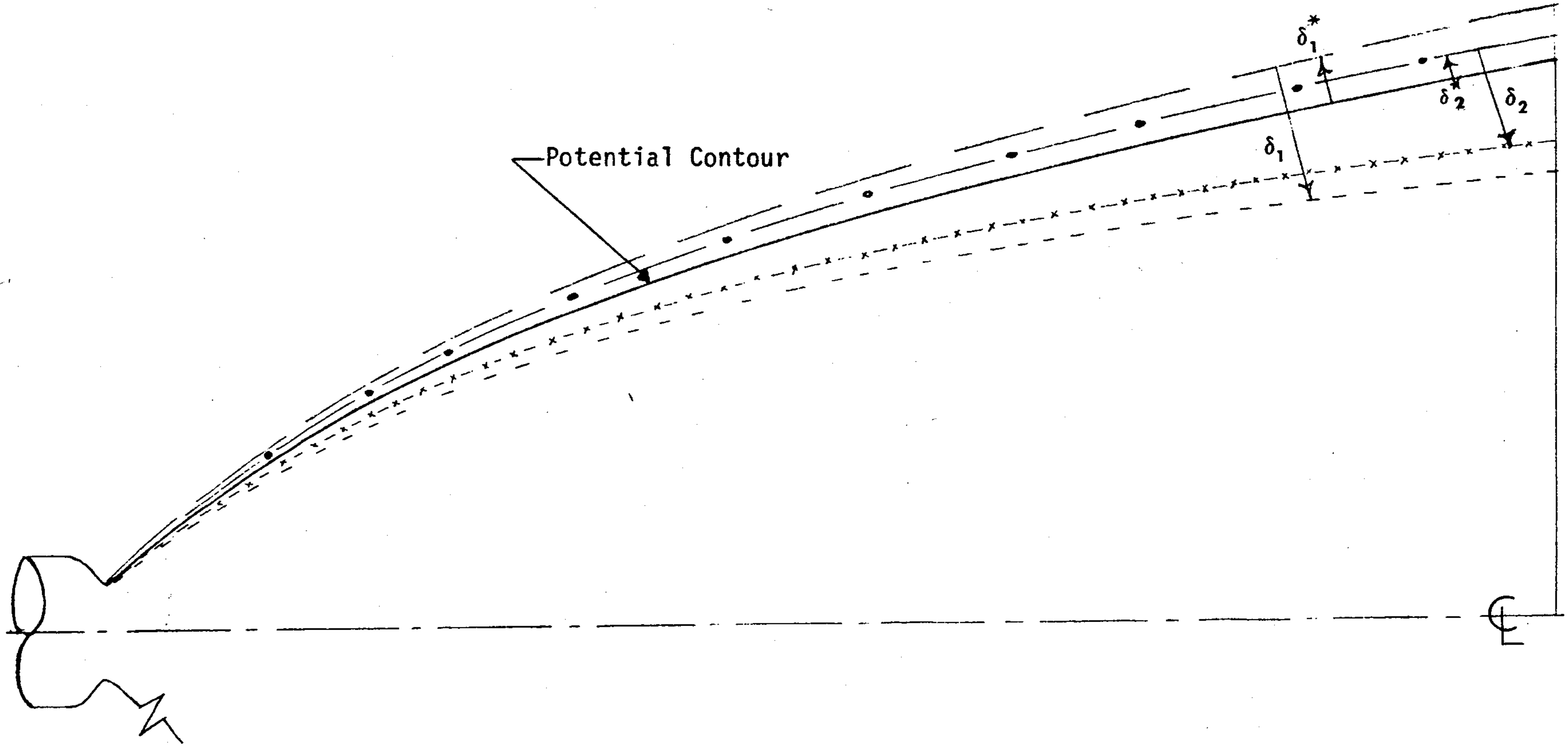


Fig. 5.1 Suggested Iteration Procedure For Nozzles With Thick Boundary Layer (Potential Contour Given)

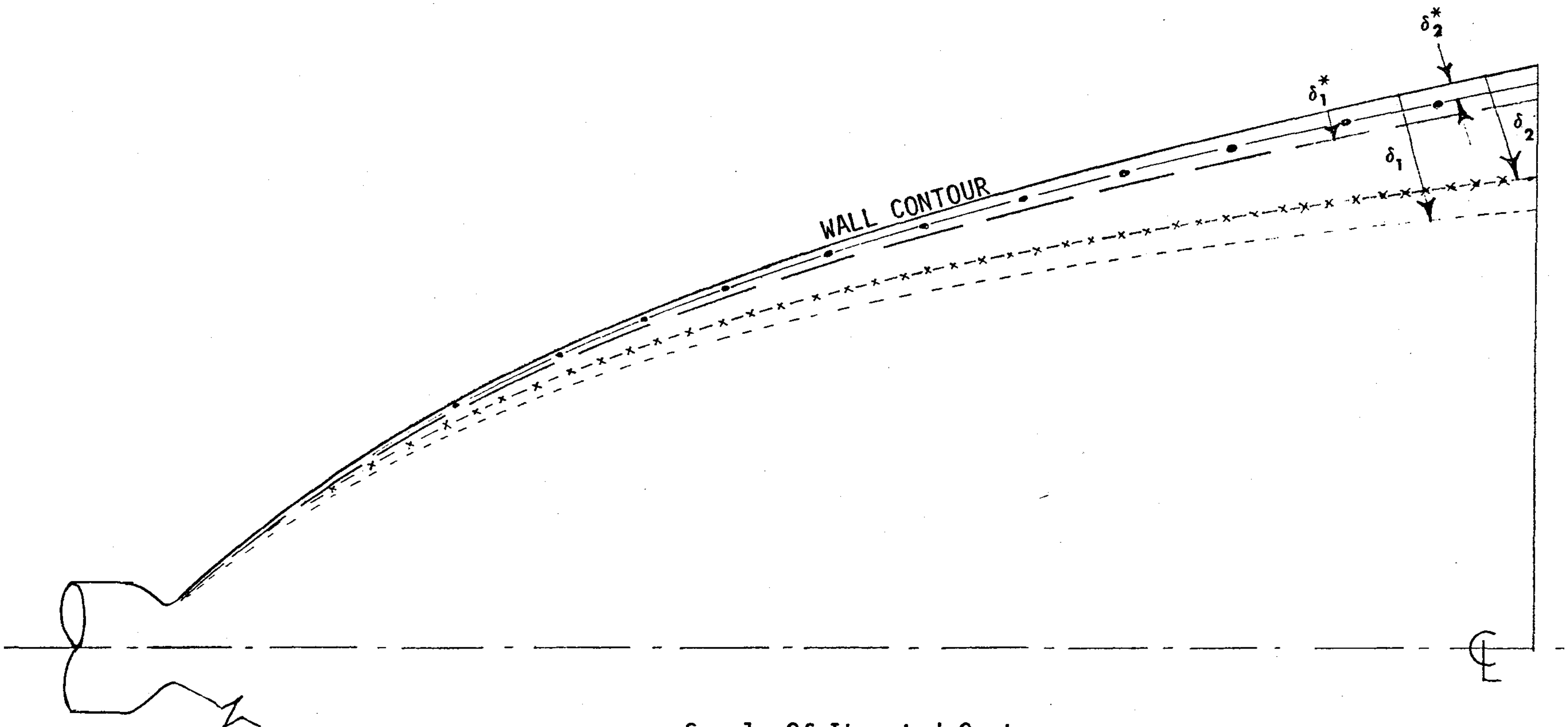
NOTES:

1. The wall contour is given; the objective is to define the inviscid edge.

2. **Subscript refers to iteration number.**

3. δ_* refers to displacement thickness.

4. δ refers to boundary layer thickness.



Sample Of Iterated Contours

Fig. 5.2 Suggested Iteration Procedure For Nozzle With Thick Boundary Layer (Wall Contour Given)

5.3 Example

For illustrating the procedure given above for calculating thrust loss for thick boundary layer situations, the OTV nozzle given earlier in Sec. 2.3 was used. Furthermore, since the given wall coordinates represent a generic class of OTV nozzles, these coordinates were assumed to represent the potential wall contour of the OTV nozzle. Consequently, the iterations were performed based on the procedure shown in Attachment 5.1.

Since REMTECH did not have the information to run TDK for computing and storing the pressures for the interior points away from the wall, another available code called RAMP (Ref. 3) was run for the OTV nozzle contour to compute the pressure fields both on the wall and near the wall. Figure 5.3 gives a comparison of wall pressure distributions from TDK and RAMP on the nozzle wall. The comparison is quite good. A comparison of δ^* calculations based on results from both codes is given in Fig. 5.4 showing a close agreement. The pressure distribution near the potential contour obtained from RAMP is given in Fig. 5.5 along with δ and δ^* from the first iteration. It is obvious that there is a distribution of pressure through the thickness of the boundary layer and as a result, the shown inviscid edge of the boundary layer is not accurate. Going through the step (iii) in Attachment 5.1 yields a new average pressure distribution given in Fig. 5.6, which is distinctly different from the first iteration both in the high pressure region near the throat and in the low pressure region near the exit plane. The BLIMPJ calculation yielded a δ^* distribution which was compared with the original distribution in Fig. 5.7. Again, the two iterations are somewhat different. A third iteration was done when it was found that the average pressure and δ^* distributions were very close to the second iteration (Figs. 5.6 and 5.7). The thrust loss in the successive iterations is given in Fig. 5.8.

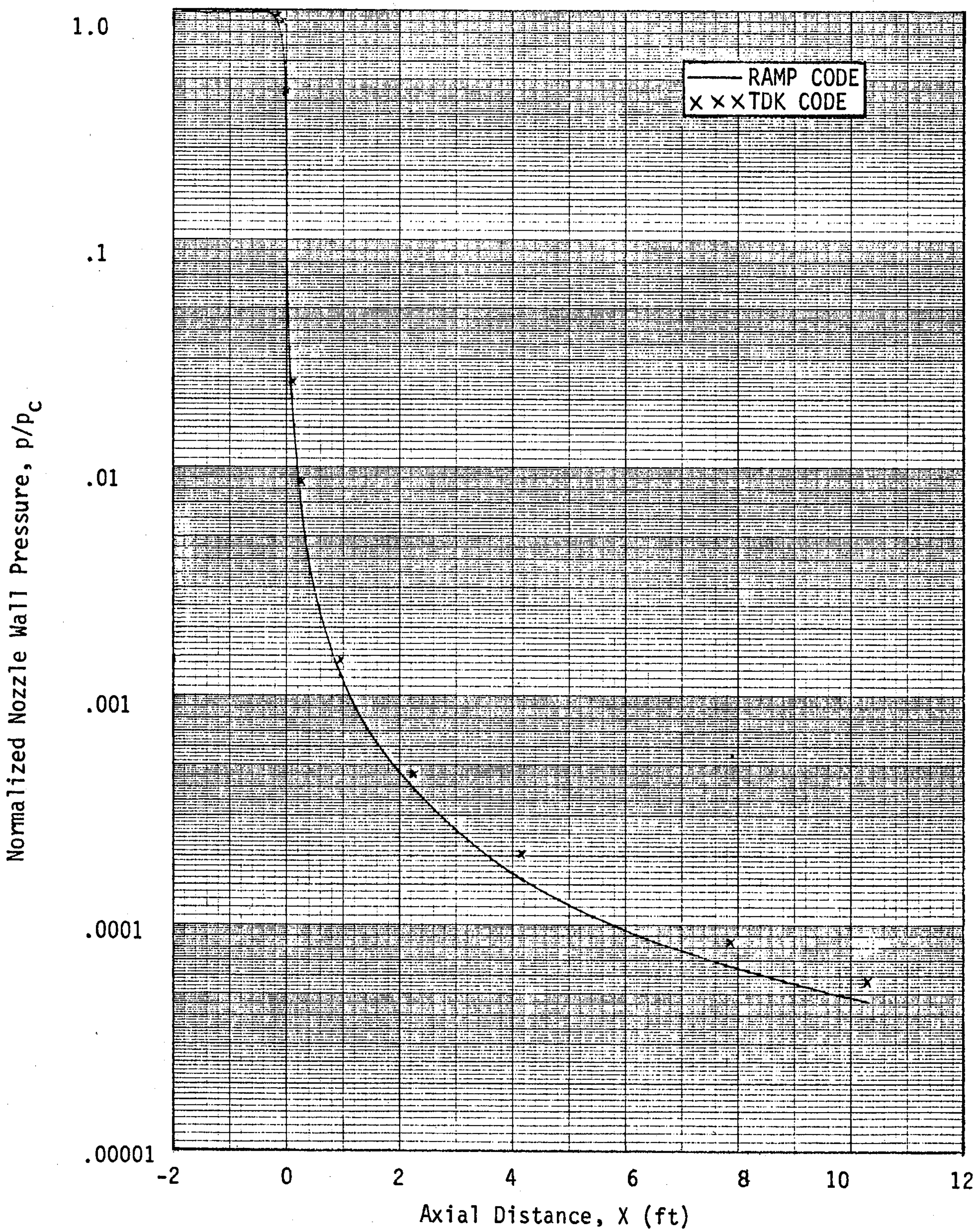


Fig. 5.3 Comparison Of OTV Nozzle Wall Pressure Distribution Using Two Different Codes

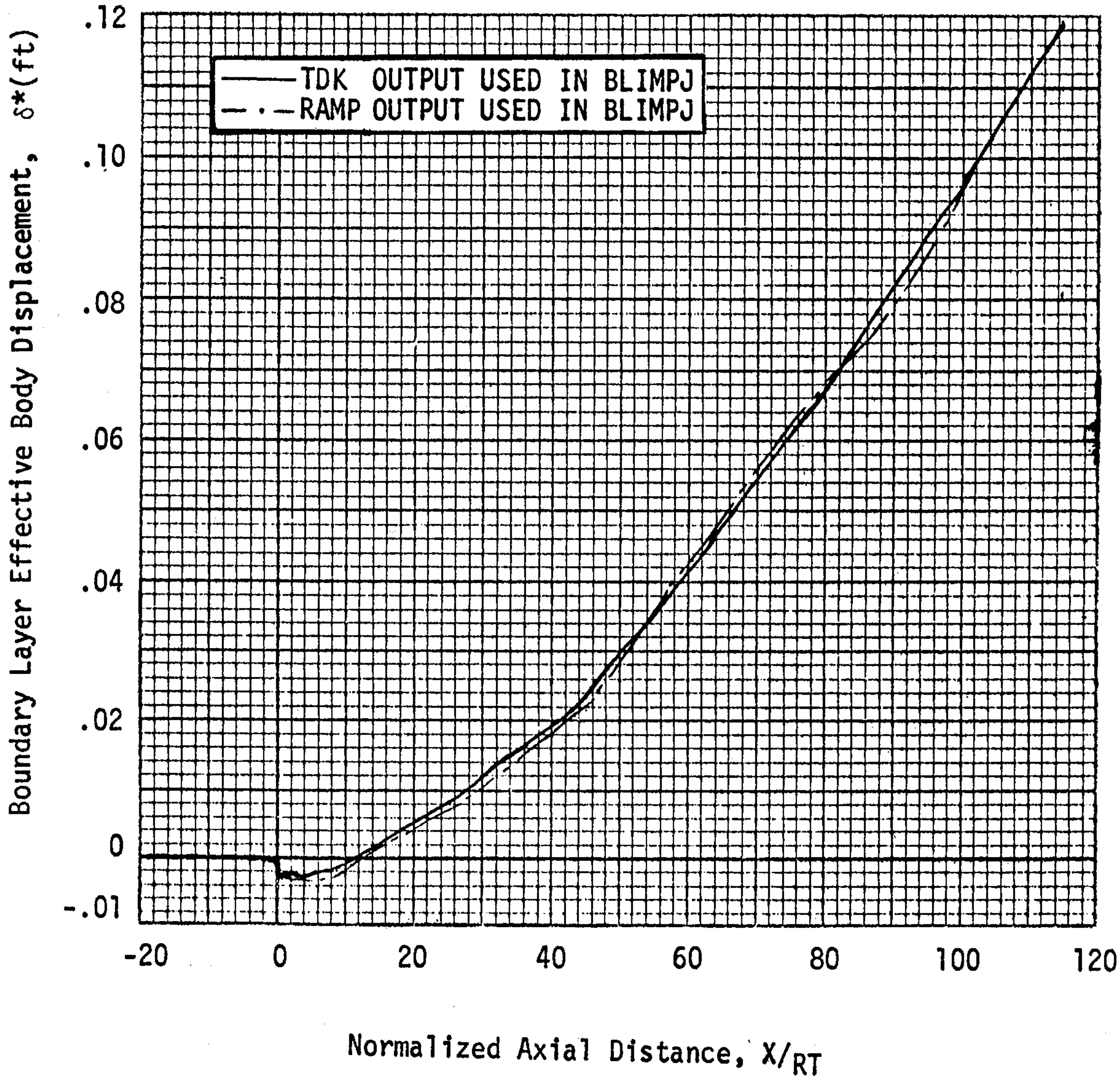


Fig. 5.4 Comparison Between TDK And RAMP Output For The Boundary Layer Effective Displacement For First Iteration

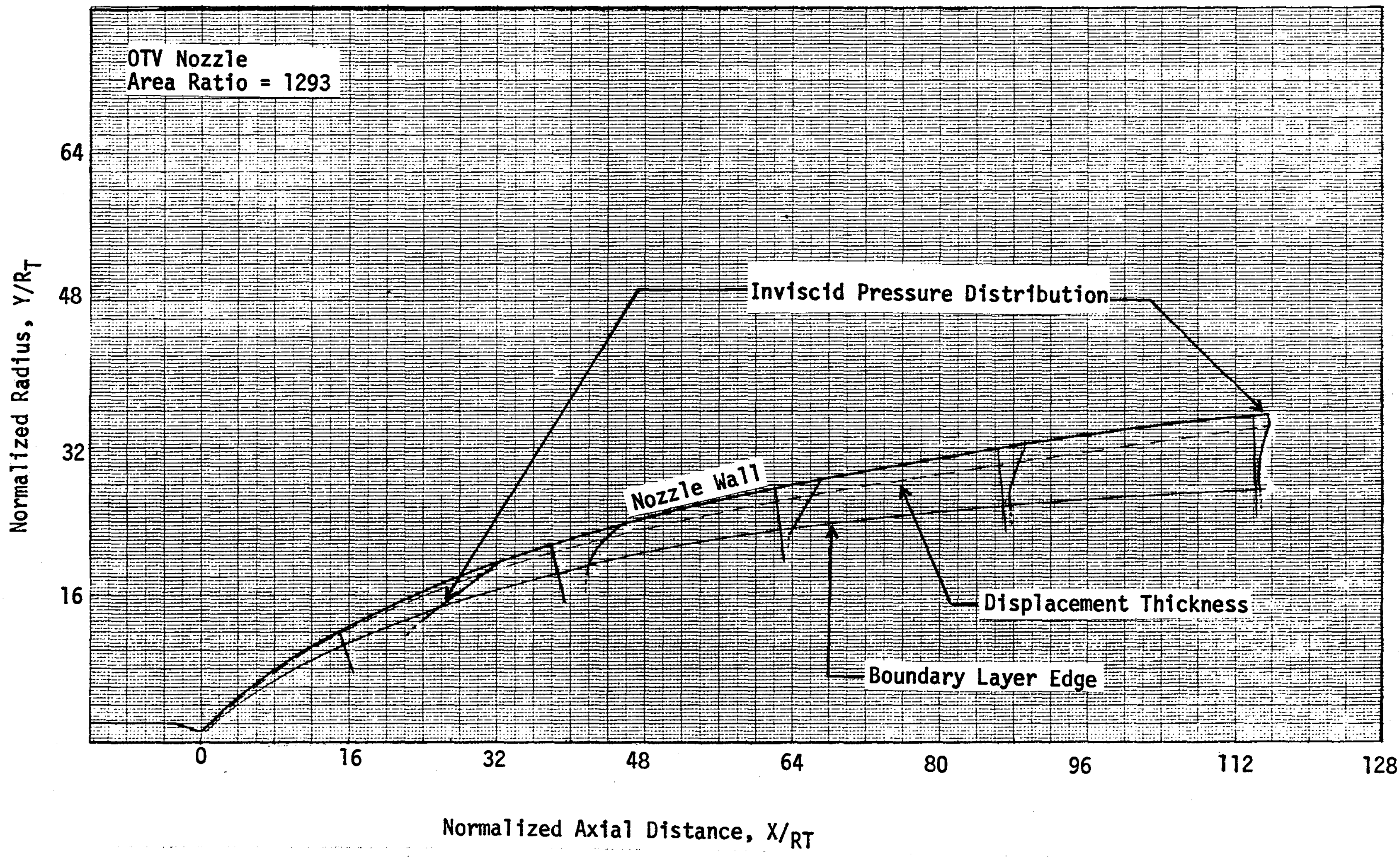


Fig. 5.5 Inviscid Pressure Distribution At Various Wall Locations Within The Boundary Layer Thickness

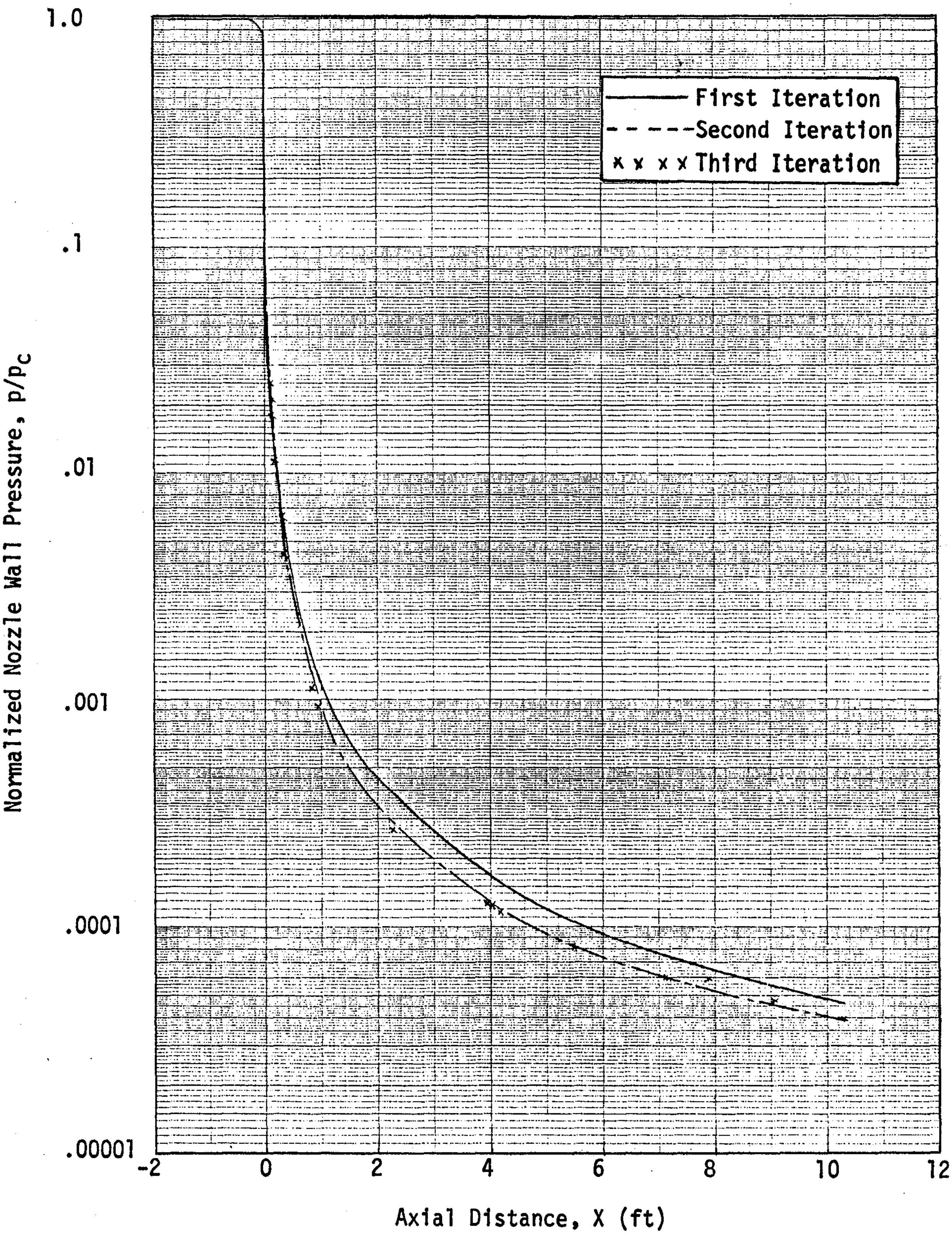


Fig. 5.6 Iterations Of The Wall Pressure Distribution For The OTV Nozzle With Thick Boundary Layer

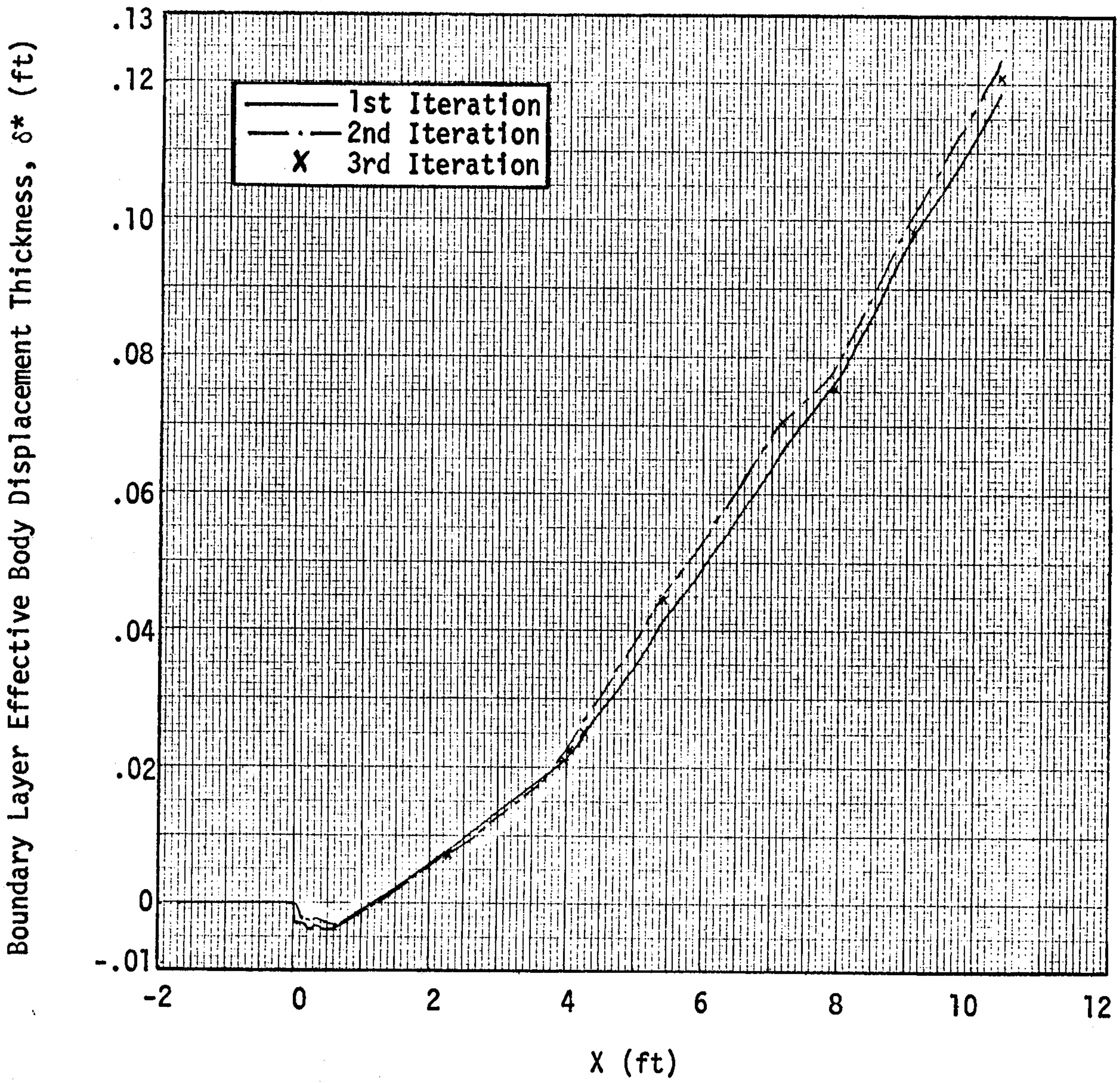


Fig. 5.7 Iterations Of δ^* Distribution For The OTV Nozzle With Thick Boundary Layer

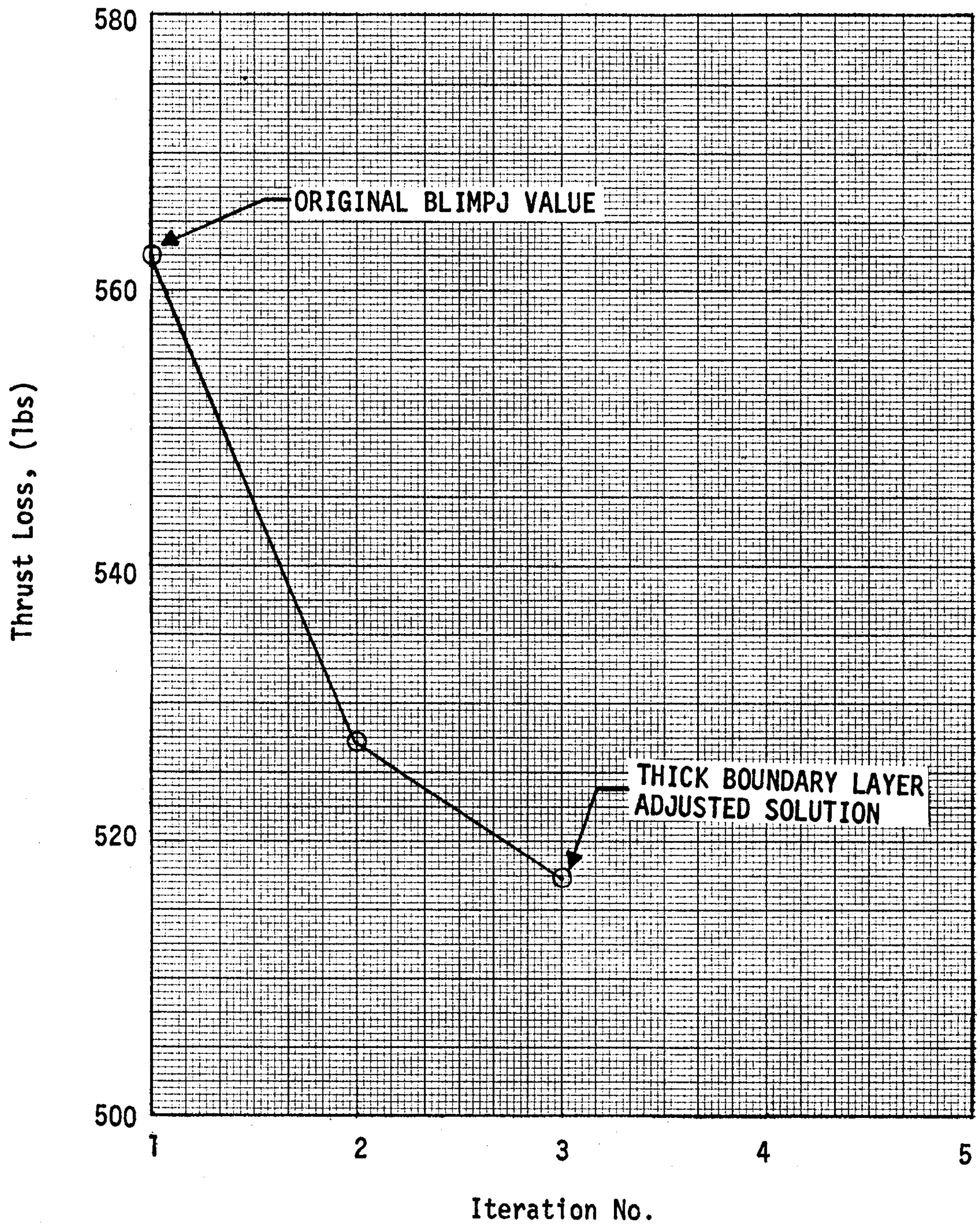


Fig. 5.8 Thrust Loss In The OTV Nozzle As A Function Of Iterations

5.4 Discussions

The procedures described before and the example given in Subsection 5.3 are engineering procedures which could be used for thrust loss calculation in nozzles with thick boundary layers. The calculations performed at the time were not all computerized and as a result, could contain some inaccuracies in the various steps of the calculation. Even though the convergence was observed in the pressure distribution in Fig. 5.6 in the third iteration, it was not absolutely so in the convergence of δ^* in Fig. 5.7 and thrust loss in Fig. 5.8. However, the difference between the second and third iteration for the thrust loss in the OTV nozzle is around 10 lbs and it might be even less between the third and a fourth iteration. The thrust loss for thick boundary layers has not been programmed, since TDK cannot presently provide the necessary data away from the nozzle wall. However, a number of suggestions are made in Sec. 6 for future work.

5.5 References

1. Evans, M., "BLIMPJ User's Manual," Aerotherm/Acurex Corporaton, July 1975, under Contract NAS8-30930.

2. Whitfield, D.L., and Lewis, C.H., "Boundary-Layer Analysis of Low-Density Nozzles, Including Displacement, Slip, and Transverse Curvature," Journal of Spacecraft, April 1970, pp. 462-468.

3. Smith, Sheldon D., "High Altitude Chemically Reacting Gas-Particle Mixture, Volume I - A Theoretical Analysis and Development of Numerical Solution," August 1984, LMSC-HREC TRD867400-I.

Section 6.0

RECOMMENDATIONS

Future work in the OTV research and development areas described in the previous sections may be categorized into three broad areas;

- Analytical
- Numerical
- Experimental

6.1 Analytical

The future analytical work on OTV-class nozzles, with reference to the four modules that have been addressed in the previous sections of this report, consists of the following recommendations:

6.1.1 Wall Roughness Effects

1. Roughness module in BLIMPJ needs to be checked out further with other available data for any size nozzle. This would enhance confidence in the usability of the various roughness options incorporated in BLIMPJ. The modules should also be exercised with the data to be taken on the future OTV model or flight tests.

2. Effects of partially smooth and partially rough nozzle wall on wall skin friction and heat transfer rate need to be examined. This problem does not lend itself to the assumption of an equivalent sand roughness, because the concept of equivalent sand roughness which is based on similarity assumptions breaks down. Some related developments appear in works by T.C. Lin, J.C. Adams, etc.

6.1.2 Relaminarization

1. The relaminarization module needs to be checked out with any other available data for internal flow situations.

2. Questions remain as to whether the relaminarization criterion using wall quantities rather than edge quantities is valid for OTV-type nozzles. What happens to this criterion when wall roughness is present?

3. It is well known that freestream turbulence is present in the inviscid flow inside the nozzle. The question, then, is what role does the freestream turbulence play in the turbulence length scales and thus, in the relaminarization process?

6.1.3 Particle Effects

1. Check the options in BLIMPJ with available data both in laminar and turbulent flows.

2. For the case of replaceable and ablating nozzle inserts, the particles or debris in boundary layer flow will enhance heat transfer at the nozzle wall. If the particle loading could be determined, the effects of ablating nozzle wall could be determined.

3. Modify the turbulent mixing length due to the presence of particles in the flow.

6.1.4 Thrust Loss Reevaluation

1. Check the predicted performance with available nozzle data having large area ratios, and consequently, thick boundary layers.

2. A procedure which consists of a combination of machine and hand calculations has been given in Sec. 5 for computing final performance calculations for large area ratio nozzles. This procedure should be considered approximate. A special software using a flow diagram involving TDK and BLIMPJ needs to be written for smooth calculation of high area ratio nozzles.

3. An optimization procedure needs to be developed to design a nozzle with length and area ratio constraints for minimizing thrust loss in large area ratio nozzles.

6.2 Numerical

Computational fluid dynamics (CFD) procedures should be examined to evaluate the nozzle wall thermal losses due to relaminarization, the presence of wall roughness and particles in flow. Without going into too many details, the following concerns should be borne in mind:

1. The turbulence models in the existing codes need to be examined. The problems of modifying the turbulence models for roughness, particles and relaminarization remain.

2. Acceptable chemistry packages have to be integrated in the CFD codes.

3. On the positive side, the iteration procedure necessary for calculating the thrust loss for thick boundary layers is eliminated in the CFD procedure, since the code defines both the inviscid and viscous flowfields in the nozzle at the same time. However, the thrust loss formula for nozzles needs to be integrated with the CFD code, if the boundary layer effects need to be singled-out.

6.3 Experimental

It is the opinion of the authors that not enough applicable experimental data is available for the OTV-class nozzles. In order to validate the modules described in this report, measurements need to be made to support them. The parameters that need to be measured, the size of the models, the kind of flow to be tested and the accuracies involved in conducting these tests are the items described in modular form in Table 6.1. This table presents a number of choices and possibilities from which any combinations could be selected for future experimental programs to support the OTV nozzle development.

TABLE 6.1 Recommendations For OTV Experimental Programs

STUDY ITEMS ITEMS TO EXPLORE	WALL ROUGHNESS EFFECTS	RELAMINARIZATION EFFECTS	PARTICLE EFFECTS	THICK BOUNDARY LAYER ISP LOSSES
EXISTING DATA BASE FOR NOZZLES	• NO OTV NOZZLE DATA • ROCKETDYNE 40K SUBSCALE CHAMBER TEST AT MSFC • FOR SSME, NO INTERNAL NOZZLE DATA	• BACK AND CUFFEL 10° - 10° HALF ANGLE CONE DATA • NASH-WEBBER VARIABLE NOZZLE WHICH STUDIED RELAMINARIZATION EFFECTS	• NO OTV NOZZLE OR ANY OTHER NOZZLE BOUNDARY LAYER DATA • THE AVAILABLE DATA BASE IS FOR TUBES AND PIPES	• NO OTV THICK BOUNDARY LAYER DATA
MODEL TESTS - SHORT DURATION	• STEADY STATE TEST TIMES 10 MSEC - 100 MSEC • TEST TIME DEPENDENT ON ALTITUDE CHAMBER SIZE AND/OR DIFFUSER CAPACITY • USE DIFFERENT NOZZLES OR NOZZLE INSERTS FOR ROUGHNESS EFFECTS STUDY	• TEST ARRANGEMENT SAME AS WITH WALL ROUGHNESS	• VERY DIFFICULT IF NOT IMPOSSIBLE TO INJECT KNOWN PARTICLES INTO FLOWS ON SHORT DURATION BASIS	
COLD, HOT OR REACTIVE FLOW	• EXACT SIMULATION OF HOT FLOWING H_2/O_2 @ O/F = 6 AND P_{CH} = 2000 PSI • USE OF COLD/NON-REACTING GASES	• SAME AS WITH WALL ROUGHNESS	• COMBUSTION OF SOLID PROPELLANT - THE PROBLEM IS THE LACK OF CONTROL OR KNOWLEDGE OF PARTICLE SIZE AND CONCENTRATION	
PARAMETERS TO BE MEASURED	• WALL ROUGHNESS • NOZZLE WALL HEAT TRANSFER AS A FUNCTION OF TIME • NOZZLE WALL PRESSURES • NOZZLE WALL TEMPERATURES • EXIT VELOCITY/TEMPERATURE PROFILES	• WALL HEAT TRANSFER • WALL TEMPERATURES • WALL PRESSURES	• WALL HEAT TRANSFER • WALL TEMPERATURES • WALL PRESSURES	
INSTRUMENTS TO BE USED; SPECIAL INNOVATIVE PROBES THAT COULD BE USED	• FAST-RESPONSE PIEZO-ELECTRIC PRESSURE TRANSDUCERS • THIN FILM SHORT DURATION HEAT TRANSFER GAGES • CO-AXIAL SURFACE HEAT TRANSFER GAGES • MINIATURE THIN WIRE/T.C. GAGES • MECHANICAL MEASUREMENTS OF WALL ROUGHNESS	• SAME AS WITH WALL ROUGHNESS	• SAME AS WITH WALL ROUGHNESS	
ACCURACY OF MEASUREMENTS	• ±5% TO ±10% FOR THIN-FILM AND CO-AXIAL GAGES • ±0.5% ON TEMPERATURE • ±2% ON PRESSURE	• ±5% TO ±10% ON HEAT TRANSFER • ±0.5% ON TEMPERATURE • ±2% ON PRESSURE	• ±5% TO 10% ON HEAT TRANSFER • ±0.5% ON TEMPERATURE • ±2% ON PRESSURE	
MODEL SCALE PROBLEMS, IF ANY	• CHEMISTRY, THERMODYNAMICS AND TRANSPORT PROPERTIES ARE REALISTIC IN NOZZLE • SMALL THROAT AREAS AND IMPERFECTIONS MAY OBSCURE EFFECTS BEING SOUGHT	• SAME AS WITH WALL ROUGHNESS	• PARTICLE SIZE AND CONCENTRATIONS VERY DIFFICULT TO SCALE FOR SMALL TEST RIG	
FACILITIES TO BE USED	• IMPULSE BASE FLOW FACILITY (IBFF) AT MSFC • PLUMBROOK SPACE POWER FACILITY AT NASA LEWIS • CHAMBER A AT JOHNSON SPACE CENTER • LUDWIG TUBE AT CALSPAN, BUFFALO	• SAME AS FOR WALL ROUGHNESS EFFECTS	• SAME FACILITIES AS FOR WALL ROUGHNESS STUDIES	

TABLE 6.1 (Continued)

STUDY ITEMS ITEMS TO EXPLORE	WALL ROUGHNESS EFFECTS	RELAMINARIZATION EFFECTS	PARTICLE EFFECTS	THICK BOUNDARY LAYER ISP LOSSES
MODEL TESTS - LONG DURATION	• DEPENDING ON MODEL SIZE AND TEST DURATION, COSTS CAN BE A FACTOR OF 10 LARGER THAN SHORT DURATION • ALLOWS MORE THAN ONE MEASUREMENT PER RUN • SCALE PROBLEMS ARE ALLEVIATED • HIGH ALTITUDE SIMULATION REQUIRES VERY LARGE FACILITY	• SAME AS FOR WALL ROUGHNESS EFFECTS	• LONG DURATION ALLOWS FOR POSSIBLE UTILIZATION OF PARTICLE INJECTION TECHNIQUES IN COLD/WARM GAS FLOW • REACTIVE FLOWS STILL HAVE UNKNOWN PARTICLE SIZE/CONCENTRATION	• LARGE OTV MODELS SHOULD BE USED • CAN MAKE BETTER THRUST MEASUREMENTS THAN SHORT DURATION TEST • BOUNDARY LAYER PROBING IS POSSIBLE
COLD, HOT OR REACTIVE FLOW	• COLD/WARM FLOWS SIMPLEST AND LEAST COSTLY • HOT OR REACTIVE FLOWS REQUIRE COMPLEX FACILITY AND MODEL COOLING	• SAME AS FOR WALL ROUGHNESS EFFECTS	• COLD, HOT OR REACTIVE FLOW SIMULATION IS NOW COMPLICATED BY THE NEED FOR PARTICLES • PARTICLE INJECTION SCHEME CAN BE UNRELIABLE	• HOT/REACTIVE FLOWS SIMULATING H_2/O_2 SYSTEM ARE PREFERABLE
PARAMETERS TO BE MEASURED	• WALL ROUGHNESS • WALL PRESSURE AND TEMPERATURE MEASUREMENTS • EXIT VELOCITY/TEMPERATURE PROFILES • WALL HEAT TRANSFER RATE • PROBE THE BOUNDARY LAYER INSIDE NOZZLE	• SAME AS FOR WALL ROUGHNESS EFFECTS	• PARTICLE DENSITY AND SIZE • NOZZLE PROBES TO MEASURE PRESSURE AND TEMPERATURE • WALL PRESSURE AND TEMPERATURE MEASUREMENTS	• THRUST MEASUREMENT • BOUNDARY LAYER PRESSURE AND TEMPERATURE MEASUREMENTS, BOTH INSIDE AND AT EXIT PLANE OF NOZZLE
INSTRUMENTS AND PROBES TO BE USED	• THERMOCOUPLES FOR TEMPERATURE • PRESSURE TANSDUCERS • LASER DOPPLER VELOCIMETER (PARTICLES) • FOR HOT/REACTIVE FLOW MEASUREMENTS, SYSTEMS/PROBES REQUIRE SPECIAL PROTECTION • OPTICAL SCHLIEREN AT EXIT PLANE • PHASE CHANGE PAINT	• SAME AS FOR WALL ROUGHNESS EFFECTS	• LDV VERY ADAPTABLE TO PARTICLE FLOWS • PARTICLE MEASUREMENT TECHNIQUES ARE GENERALLY UNRELIABLE EXCEPT IN SPECIAL FLOW SITUATIONS	• THRUST/STRAIN GAGE - MEASUREMENTS FOR ISP DETERMINATION • INTRUSIVE TECHNIQUES SUCH AS HOT-WIRE ANENOMETERS AND PRESSURE PROBES • NON-INTRUSIVE TECHNIQUE SUCH AS LDV
ACCURACY OF MEASUREMENTS	• SAME AS FOR SHORT DURATION • LDV ±15% DUE TO PARTICLE LAG	• SAME AS FOR SHORT DURATION	• SAME AS FOR SHORT DURATION • LDV ±15% DUE TO PARTICLE LAG • PARTICLE - UNKNOWN	• SAME AS FOR SHORT DURATION • HOT WIRE ±15%
MODEL SCALE PROBLEMS, IF ANY	• SCALE PROBLEMS ARE ALLEVIATED TO SOME EXTENT ASSUMING THAT MODELS ARE LARGER ON LONG DURATION • THROAT MUST BE PROTECTED AGAINST HIGH q RESULTING IN WALL TEMPERATURE DISCONTINUITY WHERE MATERIALS CHANGE	• SCALE PROBLEMS ARE ALLEVIATED IF MODEL SIZES ARE INCREASED	• SCALE PROBLEMS ARE ALLEVIATED IF MODEL SIZES ARE INCREASED	• SCALE PROBLEMS ARE ALLEVIATED IF MODEL SIZES ARE INCREASED
FACILITIES TO BE USED	• ENGINE TEST FACILITY AT AEDC CAN SIMULATE ALTITUDE • ENGINE TEST FACILITY AT MSFC HAS NO ALTITUDE SIMULATION • LEWIS TEST FACILITY ALTITUDE SIMULATION NOT KNOWN	• SAME FACILITIES AS FOR WALL ROUGHNESS STUDIES	• SAME FACILITIES AS FOR WALL ROUGHNESS STUDIES	• SAME FACILITIES AS FOR WALL ROUGHNESS STUDIES

APPENDIX

A LISTING OF THE UPDATED SUBROUTINES IN BLIMPJ

```
0001   000565 411G        0001   001023 42L         0001   001042 447G        0001   001057 452G        0001   001072 464G
0001   001107 500G        0001   001124 513G        0001   001131 520G        0001   001172 533G        0001   001246 65L
0001   001252 70L         0006 I 000000 ADARY       0005 I 000000 CASE        0005   000015 CBAR        0004   000000 DUB
0006 I 000026 ESPER       0006 I 000027 FLDP        0007 I 000000 FLDX        0006 I 000313 FLDY        0000 I 000000 I
0006 I 001077 IAXIS       0000 I 000003 IERR        0006 I 001100 INJ         0000   000071 INJP$       0006 I 001101 INKI
0003   000000 IPLOT       0007 I 000030 IPP         0005 I 000020 IS          0005   000021 ISH         0003 I 000001 IUNIT
0006 I 001102 IWALL       0000 I 000001 IX          0006 I 001103 J           0006 I 001104 K           0006 I 001105 KELVIN
0006 I 001106 KGDE        0006 I 001107 L           0006 I 026161 LA          0006 I 001110 LANK        0006 I 026162 LB
0006 I 026163 LC          0006 I 001111 LOGRAM      0006 I 001112 LWXO        0006 I 001126 LWYO        0006 I 001142 LXIN
0006 I 001156 LXIV        0006 I 001172 LYIN        0006 I 001206 LYIV        0006 I 026164 M           0006 I 001222 METER
0007 I 000031 MS          0004 I 000006 N           0005 I 000114 NETA        0006 I 001223 NJOUL       0005   000115 NNLEQ
0006 I 026165 NOGRID      0007 I 000032 NPCON       0007 I 000033 NPLOT       0005 I 000120 NS          0007 I 000072 NSTAT
0007 I 000154 NSTP        0000 I 000002 NUMBR       0006 I 001224 OULES       0006 R 020266 Q           0006 R 023222 R
0006 R 026156 RCIRC       0006 R 026157 RSQAR       0006 R 026160 RSTAR       0006 I 001225 S           0006 I 001226 SECON
0006 I 001227 SPER        0006 I 001230 SQUARE      0006 R 001231 U           0006 R 004165 V           0006 R 007121 W
0006 I 012055 WATTS       0006 R 012056 X           0006 R 012224 XL          0006 R 012222 XMAX        0006 R 012223 XMIN
0006 R 012225 XR          0006 R 012226 Y           0006 R 015244 YB          0006 R 015245 YMAX        0006   015246 YMIN
0006 R 015247 YT          0006 R 015250 Z           0006 I 020204 ZS
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00101          SUBROUTINE PLOT                                                     000000
00101     C                                                                        000000
00101     C    BLIMP PLOT SUBROUTINE FOR PLOTTING BLIMP DATA STORED ON DRUM        000000
00101     C    ORDER OF PARAMETERS TO BE PLOTTED: 1 PRESSURE, 2 EDGE TEMPERATURE,  000000
00101     C    3 VELOCITY, 4 MACH NUMBER, 5 DENSITY, 6 TOTAL ENTHALPY, 7 TOTAL HEAT, 000000
00101     C    8 TOTAL WALL AREA, 9 MOMENTUM THICKNESS, 10 DISPLACEMENT THICKNESS, 000000
00101     C    11 THRUST LOSS, 12 WALL TEMPERATURE, 13 SHEAR AT WALL,              000000
00101     C    14 ACCELERATION PARAMETER, 15 VISCOSITY, 16 SPECIFIC HEAT,          000000
00101     C    17 THERMAL CONDUCTIVITY, 18 WALL LENGTH, 19 CONDUCTIVE HEAT FLUX,   000000
00101     C    20 INVISID MASS FLOW, 21 TOTAL MASS FLOW, 22 BETAP, 23 BETAV,       000000
00101     C    24 MOMENTUM TRANSFER COEFFICIENT, 25 HEAT TRANSFER COEFFICIENT,     000000
00101     C    26 XI, 27 TOTAL GAS FLUX, 28 TOTAL GAS BLOWING PARAMETER.           000000
00101     C    ORDER OF PROFILE PLOTS: 1 TEMPERATURE, 2 VELOCITY RATIO, 3 MACH NUMBER, 000000
00101     C    4 DENSITY, 5 VISCOSITY, 6 SPECIFIC HEAT, 7 STATIC ENTHALPY,         000000
00101     C    8 TOTAL ENTHALPY, 9 THERMAL CONDUCTIVITY, 10 EPSA (RHOSQ*EPS/RHO/MU), 000000
00101     C    11 SHEAR, 12 ETA, 13 GAMMA, 14 PITOT TUBE PRESSURE.                 000000
00101     C    NOTE FOR PLOTTING PURPOSES THE FOLLOWING VALUES OF IP AND THEIR     000000
00101     C    CORRESPONDING CHARACTERS ARE GIVEN: 35 = (PLOTTING DOT), 43 = (SMALL 000000
00101     C    CIRCLE), 34 = +, 5 = (BLANK), 40 = *, 20 = 0, 48 = O, 39 = $, 23 = Q, 000000
00101     C    62 = (SMALL SQUARE), 61 = (PERIOD), 46 = ,(COMMA), 33 = -, 58 = ',  000000
00101     C    36 = =, 3 AND 4 GIVE SMALL CIRCULAR SYMBOLS.                        000000
00101     C                                                                        000000
00103          COMMON /AL/ IPLOT,IUNIT                                     /AL/    000000
00104          COMMON /CARDS/ DUB(6),N                                     /CARDS/ 000000
00105          COMMON /INTCOM/ CASE(13),CBAR(3),IS,ISH(59),NETA,NNLEQ(3),NS   /INTCOM/ 000000
00106          COMMON /NONCOM/ ADARY(22),ESPER,FLDP(12,15),FLDY(12,31),IAXIS,INJ,/NONCOM/ NEW000000
00106         1 INKI,IWALL,J,K,KELVIN,KGDE,L,LANK,LOGRAM,LWXO(12),LWYO(12),   /NONCOM/ -01000000
00106        2 LXIN(12),LXIV(12),LYIN(12),LYIV(12),METER,NJOUL,OULES,S,SECON,  /NONCOM/  000000
00106        3 SPER,SQUARE,U(1500),V(1500),W(1500),WATTS,X(100),XMAX,XMIN,XL,  /NONCOM/  000000
00106        4 XR,Y(50,31),YB,YMAX,YMIN,YT,Z(1500),ZS(50),Q(1500),R(1500)      /NONCOM/ NEW000000
00106        5 ,RCIRC,RSQAR,RSTAR,LA,LB,LC,M,NOGRID                          /NONCOM/ -01000000
00107          COMMON /PLOTS/FLDX(12,2),IPP,MS,NPCON,NPLOT(31),NSTAT(50),NSTP(15) /PLOTS/ NEW000000
00107     C                                                                   -01000000
00110          INTEGER ADARY,CASE,ESPER,FLDP,FLDX,FLDY,OULES,S,SECON,SPER,SQUARE,  000000
00110         1          WATTS,ZS                                                  000000
00111          DATA ADARY/22*6H      /,ZS/1H1,1H2,1H3,1H4,                ANK 3/83 000000
00111         1 1H5,1H6,1H7,1H8,1H9,2H10,2H11,2H12,2H13,2H14,2H15,2H16,2H17,2H18,  000000
00111        2 2H19,2H20,2H21,2H22,2H23,2H24,2H25,2H26,2H27,2H28,2H29,2H30,2H31,   000000
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00111   3 2H32,2H33,2H34,2H35,2H36,2H37,2H38,2H39,2H40,2H41,2H42,2H43,2H44,          000000
00111   & 2H45,2H46,2H47,2H48,2H49,2H50/,SPER/6HS PER /,                            000000
00111   4 KELVIN/6HKELVIN/,INKI/6H IN KI/,LOGRAM/6HLOGRAM/,METER/6HMETER /,        000000
00111   5 WATTS/6HWATTS//,SQUARE/6HSQUARE/,S/6HS     /,LANK/6H      /,              000000
00111   6 SECON/6H SECON/,NJOUL/6HN JOUL/,ESPER/6HES PER/,KGDE/6H KG DE/,          000000
00111   7 INJ/6HE IN J/,OULES/6HOULES//,FLDX/'NORMALIZED AXIAL DISTANCE X/R        000000
00111   8STAR FROM BLIMP     ',4*6H       ,'DISTANCE FROM WALL TO BOUNDARY LA      000000
00111   9YER  EDGE  IN  INCHES AT STATION 1     '/,LXIN/'NORMALIZED INPUT AANK 7/83 000000
00111   AXIAL DISTANCE X/RSTAR IN BLIMP     ',3*6H      /,LYIN/'NORMALIZED         000000
00111   BINPUT NOZZLE CONTOUR WALL RADIUS R/RSTAR   ',3*6H      /,                 000000
00111   C LWXO/'ADJUSTED NORMALIZED AXIAL DISTANCE X/RSTAR FOR NEW WALL CON        000000
00111   DTOUR          '/,LWYO/'ADJUSTED NORMALIZED NOZZLE WALL CONTOUR RADI        000000
00111   EUS R/RSTAR',3*6H      /,LXIV/'ADJUSTED NORMALIZED AXIAL DISTANCE X        000000
00111   F/RSTAR FOR NEW INVISCID CONTOUR     '/,LYIV/'ADJUSTED NORMALIZED I        000000
00111   GNVISCID NOZZLE CONTOUR RADIUS R/RSTAR  ',2*6H      /                      000000
00142    DATA ((FLDY(I,J),I=1,12),J=1,17)/'PRESSURE AT THE EDGE OF THE BOUN        000000
00142   ADARY LAYER  IN  POUNDS  PER SQUARE INCH ','TEMPERATURE AT THE EDGE        000000
00142   B OF THE BOUNDARY  LAYER  IN  DEGREES RANKINE     ', 'VELOCITY AT T        000000
00142   CHE EDGE OF THE BOUNDARY LAYER  IN  FEET   PER SECOND        ',            000000
00142   D 'MACH NUMBER AT THE EDGE OF THE BOUNDARY LAYER   ',4*6H       ,          000000
00142   E 'DENSITY AT THE EDGE OF THE BOUNDARY LAYER  IN   POUNDS PER CUBIC        000000
00142   F FOOT  ', 'TOTAL ENTHALPY FROM THE BOUNDARY LAYER TO THE WALL IN B        000000
00142   GTU PER SEC FT**2 ', 'TOTAL HEAT FROM THE BOUNDARY LAYER TO THE WAL        000000
00142   HL IN BTU PER SECOND          ', 'TOTAL WALL  AREA  IN  SQUARE  FEET        000000
00142   I ', 6*6H       , 'BOUNDARY LAYER  MOMENTUM  THICKNESS  THETA  IN  F        000000
00142   JEET  ', 3*6H       , 'BOUNDARY LAYER EFFECTIVE BODY  DISPLACEMENT         000000
00142   KTHICKNESS  IN  FEET         ', 'BOUNDARY LAYER THRUST LOSS IN POUND        000000
00142   LS', 6*6H       , 'NOZZLE WALL TEMPERATURE IN  DEGREES RANKINE     '        000000
00142   M , 4*6H       , 'BOUNDARY LAYER SHEAR ALONG THE NOZZLE WALL  IN  PO        000000
00142   NUNDS  PER SQUARE FOOT ', 'BOUNDARY LAYER ACCELERATION PARAMETER MU        000000
00142   OLTIPLIED BY ONE MILLION         ', 'VISCOSITY AT THE BOUNDARY LAYE        000000
00142   PR EDGE  IN  POUNDS PER FOOT SECOND            ', 'SPECIFIC HEAT AT THE        000000
00142   Q BOUNDARY LAYER EDGE IN BTU PER POUND DEGREE RANKINE', 'THERMAL CO        000000
00142   RNDUCTIVITY AT THE BOUNDARY LAYER EDGE IN BTU/FT SECOND DEG. R '/          000000
00144    DATA ((FLDY(I,J),I=1,12),J=18,28)/'NOZZLE WALL LENGTH  IN  FEET  '        000000
00144   A , 7*6H       , 'HEAT CONDUCTED FROM THE BOUNDARY LAYER TO THE WALL        000000
00144   B IN BTU PER SEC FT**2 ', 'BOUNDARY LAYER INVISCID MASS FLOW IN  PO        000000
00144   CUNDS  PER  SECOND    ', 2*6H       , 'BOUNDARY LAYER TOTAL MASS FLOW        000000
00144   D  IN   POUNDS PER SECOND', 3*6H       , 'STREAMWISE PRESSURE GRADIE        000000
00144   ENT PARAMETER BETAP     ', 4*6H       , 'STREAMWISE VELOCITY GRADIENT        000000
00144   F PARAMETER BETAV     ', 4*6H       , 'MOMENTUM TRANSFER COEFFICIENT         000000
00144   G', 7*6H       , 'HEAT TRANSFER COEFFICIENT BASED ON ENTHALPY POTENT        000000
00144   HIAL ', 3*6H       , 'TRANSFORMED STREAMWISE COORDINATE XI  IN  POU        000000
00144   INDS**2 PER SECOND**2         ', ' TOTAL  GAS  MASS  FLUX  IN  POUND        000000
00144   JS PER SQUARE FOOT  SECOND           ', 'TOTAL GAS BLOWING PARAMETE        000000
00144   KR  ', 7*6H       /                                                        000000
00146    DATA((FLDY(I,J),I=1,12),J=29,31)/'MOMENTUM TRANSFER COEFFICIENT ',     NEW000000
00146   $ 7*6H       ,'HEAT TRANSFER COEFFICIENT       ',7*6H       ,           NEW000000
00146   $ 'HEAT FLUX   ',10*6H       /                                          NEW000000
00150    DATA FLDP/'TEMPERATURE FROM THE WALL TO BOUNDARY LAYER EDGE IN DEG        000000
00150   AREES RANKINE      ', 'RATIO OF BOUNDARY LAYER VELOCITY TO EDGE VELO        000000
00150   BCITY FROM WALL TO EDGE      ', 'MACH NUMBER FROM THE WALL TO THE BO        000000
00150   CUNDARY LAYER EDGE  ', 3*6H       , 'DENSITY FROM THE WALL TO THE BO        000000
00150   DUNDARY LAYER EDGE  IN   POUNDS/CUBIC FOOT', 'VISCOSITY FROM WALL T        000000
00150   EO B. L. EDGE TIMES 100,000 POUNDS PER FOOT SECOND  ', 'SPECIFIC HEANK 7/83 000000
00150   FAT FROM WALL TO BOUNDARY LAYER EDGE IN BTU PER POUND DEGREE R',          000000
00150   G 'STATIC ENTHALPY FROM WALL TO BOUNDARY LAYER  EDGE IN BTU PER POU        000000
00150   HND       ', 'TOTAL ENTHALPY FROM THE WALL TO THE BOUNDARY LAYER EDG        000000
00150   IE IN BTU PER POUND', 'THERMAL CONDUCTIVITY FROM WALL TO BL EDGE TIANK 7/83 000000
00150   JMES 1.0E5 IN BTU/FT SEC DG R', 'EPSA ARRAY KINEMATIC EDDY VISCOSITANK 7/83 000000
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00150           KY FROM THE WALL TO BOUNDARY LAYER EDGE', 'SHEAR FROM THE WALL TO B              000000
00150           LOUNDARY LAYER EDGE  IN  POUNDS PER  SQUARE FOOT ', 'ETA ARRAY FROM              000000
00150           M THE WALL TO THE BOUNDARY LAYER EDGE     ', 3*6H       ,'SPECIFIC HE              000000
00150           NAT RATIO GAMMA FROM THE WALL TO THE BOUNDARY LAYER EDGE      ',                 000000
00150           O 'PITOT TUBE PRESSURE ACROSS THE BOUNDARY LAYER IN POUNDS PER SQUA              000000
00150           PRE INCH ',12*6H       /                                                         000000
00150     C                                                                                      000000
00152            CALL IDENT (105,ADARY)                                                          000000
00153            REWIND 3                                                                        000003
00154            DO 10 I = 1,NS                                                                  000006
00157        10  READ (3) X(I),Y(I,2),Y(I,12),Y(I,18),Y(I,22),Y(I,23),Y(I,26)                    000016
00171            IAXIS = 31                                                                   NEW000031
00172            WRITE (10) IS,IAXIS                                                          -01000033
00176            DO 20 I = 1,IS                                                                  000054
00201            READ (3) Y(I,3),Y(I,6),Y(I,1),Y(I,19)                                           000054
00207            READ (3) Y(I,13),Y(I,27)                                                        000063
00213            READ (3) Y(I,24),Y(I,25),Y(I,28)                                                000071
00220            READ(3)Y(I,29),Y(I,30),Y(I,31)                                               NEW000100
00225            READ (3) Y(I,9),Y(I,10)                                                         000107
00231            READ (3) Y(I,7),Y(I,8),Y(I,11),Y(I,14),Y(I,20),Y(I,21)                          000115
00241            READ (3) Y(I,5),Y(I,15),Y(I,16),Y(I,17),Y(I,4)                                  000127
00250        20  WRITE (10) X(I),(Y(I,J), J = 1,IAXIS)                                           000140
00260            CALL MINMAX (IS,1,1,IS,X,XR,XL)                                                 000156
00261            IF (IUNIT .EQ. 1)  CALL CHANGE                                                  000167
00263            DO 30 J = 1,IAXIS                                                               000174
00266            IF (NPLOT(J) .EQ. 0)  GO TO 30                                                  000203
00270            IF (NPLOT(J) .EQ. 2)  GO TO 26                                                  000205
00272            CALL MINMAX (IS,2,1,1,Y(1,J),YT,YB)                                             000210
00272     C      SKIP PLOT IF ALL DATA IS ZERO                                                   000210
00273            IF (ABS(YB) + ABS(YT) .LE. 0.0)  GO TO 30                         ANK 7/83      000223
00275            GO TO 27                                                                        000230
00276        26  CALL LOGPLT (FLDX(1,1),FLDY(1,J),IPP,IS,X,XL,XR,Y(1,J))           ANK 5/83      000232
00277            GO TO 28                                                                        000247
00300        27  CALL QUIK3L (-1,XL,XR,YB,YT,5,FLDX(1,1),FLDY(1,J),-IS,X,Y(1,J))   ANK 3/83      000251
00301        28  CALL PRINTV (78,CASE,30,1023)                                     ANK 7/83      000274
00302            IX = MAX0 (IS/MS,1)                                               ANK 3/83      000301
00303            NUMBR = IS/IX                                                     ANK 3/83      000311
00304            CALL APLOTV (NUMBR,X,Y(1,J),IX,IX,1,IPP,IERR)                     ANK 5/83      000315
00305        30  CONTINUE                                                                        000335
00307            REWIND 2                                                                        000335
00310            WRITE (10) N                                                                    000340
00313            READ (2) RSTAR,(Q(I),R(I), I = 1,N)                                             000350
00323            WRITE (10) RSTAR,(Q(I),R(I), I = 1,N)                                           000363
00333            READ (2) RCIRC,RSQAR,(Z(I),W(I),U(I),V(I), I = 1,N)                             000376
00333     C      NORMALIZE CORRECTED CONTOURS TO ORIGINAL THROAT RADIUS FOR PLOTTING             000376
00346            DO 31 J = 1,N                                                                   000417
00351            Z(J) = Z(J)*RCIRC/RSTAR                                                         000417
00352            W(J) = W(J)*RCIRC/RSTAR                                                         000422
00353            U(J) = U(J)*RSQAR/RSTAR                                                         000426
00354        31  V(J) = V(J)*RSQAR/RSTAR                                                         000432
00356            WRITE (10) RCIRC,RSQAR,(Z(I),W(I),U(I),V(I), I = 1,N)                           000437
00371            IF (NPCON .EQ. 0)  GO TO 42                                                     000455
00371     C      FORCE A BLANK FRAME ON THE MICROFICHE                                           000455
00373            CALL FRAMEV (2)                                                   ANK 7/83      000457
00374            XMIN = AMIN1 (Q(1),U(1),Z(1))                                                   000462
00375            XMAX = AMAX1(Q(N),U(N),Z(N))                                                    000474
00376            YMAX = AMAX1 (R(N),V(N),W(N))                                                   000507
00377            XMIN = SIGN(AINT(ABS(XMIN)*10.0)/10.0 + 0.10,XMIN)                              000521
00400            NOGRID = IFIX((XMAX - XMIN)/YMAX) + 1                                           000532
00401            CALL BUTTV(1)                                                                   000544
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00402          YB = 0.0                                                              000547
00403          YT = YMAX                                                             000550
00404          XR = XMIN                                                             000552
00405          LA = 1                                                                000554
00406          LB = 1                                                                000556
00407          LC = 1                                                                000557
00410          DO 35 M = 1,NOGRID                                                    000565
00413          XL = XR                                                               000565
00414          XR = XR + YT                                                          000567
00415          CALL NICK (1,-1,N,LA,LXIN,XL,XR,YB,YT,Q,R)                 ANK 3/83   000571
00416          IF (M .NE. 1)  GO TO 32                                               000606
00420          CALL PRINTV (8,8HRSTAR = ,100,1005)                        ANK 8/83   000611
00421          CALL LABLV (RSTAR,215,1005,7,1,2)                                     000617
00422          CALL PRINTV (11,11HR CIRCLE = ,420,1005)                   ANK 8/83   000627
00423          CALL LABLV (RCIRC,574,1005,7,1,2)                                     000635
00424          CALL PRINTV (11,11HR SQUARE = ,775,1005)                   ANK 8/83   000645
00425          CALL LABLV (RSQAR,930,1005,7,1,2)                                     000653
00426       32 CALL NICK (2,0,N,LB,LWXO,XL,XR,YB,YT,Z,W)                  ANK 3/83   000664
00427          IF(MOD(M,2).EQ.1.AND.MOD(M,3).EQ.1)  CALL PRINTV(72,LYIN,30,1023) ANK 8/83   000700
00431          IF(MOD(M,2).EQ.0.AND.MOD(M,3).EQ.1)  CALL PRINTV(72,LWYO,30,1023) ANK 8/83   000726
00433          IF(MOD(M,2).EQ.1.AND.MOD(M,3).EQ.0)  CALL PRINTV(72,LYIV,30,1023) ANK 8/83   000753
00435       35 CALL NICK (3,0,N,LC,LXIV,XL,XR,YB,YT,U,V)                  ANK 3/83   001000
00437          CALL BUTTV(0)                                                         001017
00440       42 IWALL = 14                                                            001023
00441          WRITE (10) NETA,IWALL                                                 001024
00445          REWIND 4                                                              001034
00446          DO 70 L = 1,IS                                                        001042
00451          DO 45 I = 1,NETA                                                      001057
00454       45 READ (4) Y(I,12),Y(I,2),Y(I,13),Y(I,11)                               001057
00463          DO 50 I = 1,NETA                                                      001072
00466       50 READ (4) X(I),Y(I,4),Y(I,3),Y(I,14),Y(I,7),Y(I,8)                     001072
00477          DO 52 I = 1,NETA                                                      001107
00502       52 READ (4) Y(I,5),Y(I,6),Y(I,9),Y(I,1),Y(I,10)                          001107
00512          DO 55 I = 1,NETA                                                      001124
00515       55 WRITE (10) X(I),(Y(I,K), K = 1,IWALL)                                 001124
00525          IF (NSTAT(L) .EQ. 0)  GO TO 70                                        001141
00527          CALL MINMAX (NETA,1,1,NETA,X,XR,XL)                                   001143
00530          IF (L .GT. 1) FLDX(12,2) = ZS(L)                                      001157
00532          DO 65 J = 1,IWALL                                                     001172
00535          IF (NSTP(J) .EQ. 0)  GO TO 65                                         001172
00537          CALL MINMAX (NETA,2,1,1,Y(1,J),YT,YB)                                 001174
00537    C     SKIP PLOT IF ALL DATA IS ZERO                                         001174
00540          IF (ABS(YB) + ABS(YT) .LE. 0.0)  GO TO 65                  ANK 7/83   001207
00542          CALL QUIK3L(-1,YB,YT,XL,XR,IPP,FLDP(1,J),FLDX(1,2),-NETA,Y(1,J),X)ANK 5/83   001214
00543          CALL PRINTV (78,CASE,30,1023)                              ANK 7/83   001237
00544       65 CONTINUE                                                              001253
00546       70 CONTINUE                                                              001253
00550          WRITE (6,2) IS,N,NETA                                                 001253
00555        2 FORMAT (///10X,'BLIMP PLOT TAPE COMPLETED IS =',I3,'   N =',I4,       001263
00555         1       '   NETA =',I3//)                                              001263
00556          CALL ENDJOB                                                           001263
00557          RETURN                                                                001265
00560          END                                                                   001322

      END OF COMPILATION:        NO  DIAGNOSTICS.
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@SYS$*MSFCFOR$.FOR,IS ROUGH
HSA  E3 -12/10/84-22:23:44 (,0)

   SUBROUTINE ROUGH      ENTRY POINT 000172

   STORAGE USED: CODE(1) 000176; DATA(0) 000034; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003    RUF     000022
    0004    RUF3    000002

   EXTERNAL REFERENCES (BLOCK, NAME)

    0005    ALOG10
    0006    XPRR
    0007    SQRT
    0010    NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001   000041 10L        0001   000163 100L       0001   000052 20L        0003 R 000021 CF         0000 R 000000 CFCFI
    0000 R 000001 CFI        0000 R 000002 CFR        0003 R 000000 CFS        0004   000001 DEACY      0000 R 000004 ETAK
    0003 R 000016 FMF        0003 R 000004 HAW        0003 R 000003 HE         0003 R 000005 HW         0003 I 000015 ICF
    0000   000025 INJP$      0003 R 000011 MUE        0003 R 000010 MUW        0003 R 000020 PCT        0003 R 000012 PR
    0000 R 000005 REK        0003 R 000006 RHOE       0003 R 000007 RHOW       0003 R 000014 RK         0003 R 000017 ST
    0000 R 000006 STR        0003 R 000001 STS        0003 R 000013 UE         0004   000000 UTAU       0000 R 000003 UTAU1
    0003 R 000002 X
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00101                 SUBROUTINE ROUGH(A)                                                          000000
00103                 REAL MUW,MUE                                                                 000000
00104                 COMMON/RUF/CFS,STS,X,HE,HAW,HW,RHOE,RHOW,MUW,MUE,PR,UE,RK,ICF,               000000
00104                $ FMF,ST,PCT,CF                                                               000000
00105                 COMMON/RUF3/UTAU,DEACY                                                       000000
00105           C                                                                                  000000
00105           C     INPUT VARIABLES                                                              000000
00105           C                                                                                  000000
00105           C   CFS  - SMOOTH WALL SKIN FRICTION COEFFICIENT                                   000000
00105           C   STS  - SMOOTH WALL STANTON NUMBER                                              000000
00105           C   X    - RUNNING LENGTH              (FT)                                        000000
00105           C   HE   - B.L. EDGE ENTHALPY          (BTU/LBM)                                   000000
00105           C   HAW  - ADIABATIC WALL ENTHALPY     (BTU/LBM)                                   000000
00105           C   HW   - WALL ENTHALPY               (BTU/LBM)                                   000000
00105           C   RHOE - B.L. EDGE DENSITY           (LBM/CU.FT.)                                000000
00105           C   RHOW - WALL DENSITY                (LBM/CU.FT.)                                000000
00105           C   MUW  - WALL VISCOSITY              (LBM/FT.-SEC)                               000000
00105           C   MUE  - EDGE VISCOSITY              (LBM/FT.-SEC)                               000000
00105           C   PR   - PRANDTL NUMBER (EDGE)                                                   000000
00105           C   UE   - B.L. EDGE VELOCITY          (FT/SEC)                                    000000
00105           C   RK   - SAND ROUGHNESS HEIGHT       (FT)                                        000000
00105           C   ICF  - SKIN FRICTION FLAG          1 - PRANDTL - SCHLICHTING                   000000
00105           C                                      2 - DROBLENKOV                              000000
00105           C   FMF  - MANGLER FACTOR              1.00 - 2D OPTION                            000000
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00105   C                         1.15 - AXISYMETRIC                          000000
00105   C                                                                     000000
00105   C                                                                     000000
00105   C       OUTPUT VARIABLES                                              000000
00105   C                                                                     000000
00105   C     ST    - ROUGH WALL STANTON NUMBER                               000000
00105   C     PCT   - PERCENT OF TRANSITION TO FULLY ROUGH                    000000
00105   C     CF    - ROUGH WALL SKIN FRICTION COEFFICIENT                    000000
00105   C                                                                     000000
00106           IF(ICF.EQ.3)GO TO 100                                         000000
00106   C     SKIN FRICTION COMPRESSIBILITY (YOUNG)                           000000
00110           CFCFI=(0.365*HE/HAW)+(0.635*HE/HW)                            000002
00111           IF(CFCFI.LE.0.0)CFCFI=0.0                                     000012
00111   C     INCOMPRESSIBLE ROUGH WALL SKIN FRICTION                         000012
00113           IF(ICF.NE.1)GO TO 10                                          000016
00113   C     OPTION(1)  PRANDTL - SCHLICHTING                                000016
00115           CFI=(2.87+1.58*ALOG10(X/RK))**-2.5                            000021
00116           GO TO 20                                                      000037
00117     10    CONTINUE                                                      000041
00117   C     OPTION(2)  DROBLENKOV                                           000041
00120           CFI=0.0139*(X/RK)**-(1.0/7.0)                                 000041
00121     20    CONTINUE                                                      000052
00122           CFR=CFCFI*CFI*FMF                                             000052
00122   C     TRANSITION CRITERION (FENTER)                                   000052
00123           UTAU1=UE*SQRT((CFR/2.0)*(RHOE/RHOW))                          000055
00124           ETAK=RHOW*UTAU1*RK/MUW                                        000070
00124   C     ROUGH SURFACE TURBULENT STANTON NUMBER                          000070
00124   C     A=0.52 NOMINAL , RANGE OF 0.45 TO 0.7   (OWEN - THOMSON)        000070
00125           REK=RHOE*UE*RK/MUE                                            000074
00126           STR=CFR/2.*(1.+A*(CFR/2.)**.725*REK**.45*PR**.8)**-1. @ (SEIDMAN)      000101
00126   C       STR=CFR/2.*(1.+A*((CFR/2.)*(HW/HE))**.5*REK**.45*PR**.8)**-1. @ (HILL) 000101
00126   C                                                                     000101
00126   C     100 USED BY FENTER , 70 USED BY HILL , 65 USED BY PIMENTA       000101
00126   C       PIMENTA VALUE CURRENTLY USED FOR TRANSITION                   000101
00126   C              ETAK .LE.   5.0    SMOOTH                              000101
00126   C     5.0 .LE. ETAK .LE.  65.0    TRANSITIONALLY ROUGH                000101
00126   C    65.0 .LT. ETAK               ROUGH                               000101
00126   C                                                                     000101
00127           PCT=(ETAK-5.0)/(65.0-5.0)                                     000126
00130           IF(PCT.LT.0.0)PCT=0.0                                         000132
00132           IF(PCT.GT.1.0)PCT=1.0                                         000136
00134           CF=(PCT*CFR)+((1.0-PCT)*CFS)                                  000144
00135           ST=(PCT*STR)+((1.0-PCT)*STS)                                  000154
00136    100    CONTINUE                                                      000163
00137           RETURN                                                        000163
00140           END                                                           000175

        END OF COMPILATION:        NO  DIAGNOSTICS.
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@SYS$*MSFCFOR$.FOR,IS PARTCL
HSA  E3 -12/10/84-22:23:46 (,0)

   SUBROUTINE PARTCL    ENTRY POINT 000165

   STORAGE USED: CODE(1) 000170; DATA(0) 000026; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003    PARTI   000020
    0004    RUF     000022

   EXTERNAL REFERENCES (BLOCK, NAME)

    0005    SQRT
    0006    XPRR
    0007    NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001    000041 100L       0001    000075 105L       0001    000110 110L       0001    000152 120L       0001    000155 160L
    0000 R 000003 BETA5       0003 R 000006 CF          0004 R 000021 CFR         0004 R 000000 CFRO        0003 R 000004 CP
    0000 R 000005 D           0004    000012 DUMM11     0004    000020 DUMM17     0004    000003 DUMM4      0004 R 000004 DUMM5
    0004 R 000005 DUMM6       0004    000007 DUMM8      0004    000010 DUMM9      0004    000016 FMF        0004    000015 ICF
    0003 I 000013 ILT         0000    000016 INJP$      0003    000017 IPART      0003 R 000015 K           0003 R 000010 KG
    0003 R 000001 LAMBV       0003 R 000000 M           0004 R 000011 MUE         0000 R 000000 NU          0000 R 000001 PI
    0003 R 000014 Q           0000 R 000006 QDOT        0003 R 000003 RED         0004 R 000006 RHOE        0003 R 000002 RHOP
    0004    000014 RK         0003    000016 RP         0004 R 000017 STR         0004 R 000001 STS         0003 R 000011 TAW
    0003 R 000012 TW          0004 R 000013 UE          0000 R 000004 W           0003 R 000007 WF          0003 R 000005 WP
    0004 R 000002 X           0000 R 000002 Y


00101       1*            SUBROUTINE PARTCL                                                    000000
00103       2*            REAL K,KG,LAMBV,M,MUE,NU                                             000000
00104       3*            COMMON /PARTI/M,LAMBV,RHOP,RED,CP,WP,CF,WF,KG,TAW,TW,                000000
00104       4*           $ ILT,Q,K,RP,IPART                                                    000000
00105       5*            COMMON/RUF/CFRO,STS,X     ,DUMM4,DUMM5,DUMM6,RHOE,DUMM8,             000000
00105       6*             1  DUMM9,MUE,DUMM11,UE,RK,ICF,FMF,STR,DUMM17,CFR                    000000
00105       7*      C                                                                          000000
00105       8*      C  INPUT VARIABLES                                                         000000
00105       9*      C                                                                          000000
00105      10*      C  M - AVERAGE PARTICLE MASS                     (LBM)                     000000
00105      11*      C  UE - BOUNDARY LAYER EDGE VELOCITY             (FT/SEC)                  000000
00105      12*      C  SIGMA - STOKERS DRAG COEFFICIENT              (LBM/SEC)                 000000
00105      13*      C  A - RADIUS OF SPHERICAL PARTICLE              (FT)                      000000
00105      14*      C  MUE - GAS VISCOSITY                           (LBM/FT SEC)              000000
00105      15*      C  LAMBV - MOMENTUM RANGE                        (FT)                      000000
00105      16*      C  RHOP - PARTICLE MASS DENSITY OF THE GAS       (LBM/FT3)                 000000
00105      17*      C  RHOE - GAS DENSITY                            (LBM/FT3)                 000000
00105      18*      C  RED - EDGE REYNOLDS NUMBER BASED ON D                                   000000
00105      19*      C  X - RUNNING LENGTH                            (FT)                      000000
00105      20*      C  TAU - SHEAR STRESS                            (LBF/FT2)                 000000
00105      21*      C  CFRO - FRICTION COEFFICIENT                                             000000
00105      22*      C  STS - SMOOTH STANTON NUMBER                                             000000
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00105    C  CP - SPECIFIC HEAT OF THE SOLID PARTICLE       (BTU/LB DEG F)            000000
00105    C  WP - MASS FLOW OF PARTICLES                    (LB/FT2 SEC)              000000
00105    C  CF - SPECIFIC HEAT AT CONSTANT PRESSURE OF FLUID  (BTU/LB DEG F)         000000
00105    C  WF - MASS FLOW OF FLUID                        (LB/FT2 SEC)              000000
00105    C  K- RATIO OF PARTICLE DENSITY TO FLUID MASS DENSITY AT EDGE               000000
00105    C  KG - THERMAL CONDUCTIVITY OF THE GAS           (BTU/SEC FT DEG K)        000000
00105    C  D - DIAMETER OF THE TUBE                       (FT)                      000000
00105    C  NU - NUSSELT'S NUMBER                                                    000000
00105    C  TAW - ADIABATIC WALL TEMPERATURE               DEG. R                    000000
00105    C  TW - WALL TEMPERATURE                          DEG. R                    000000
00105    C  ILT - FLOW TYPE FLAG 1 - LAMINAR                                         000000
00105    C                       2 - TURBULENT                                       000000
00105    C  OUTPUT VARIABLES                                                         000000
00105    C                                                                           000000
00105    C  CFR - MODIFIED FRICTION COEFFICIENT                                      000000
00105    C  STR - PARTICLE STANTON NUMBER                                            000000
00105    C                                                                           000000
00106          PI=3.1415927                                                          000000
00107          IF(ILT.EQ.2) GOTO 100                                                 000001
00107    C IF ILT = 2 THE FLOW IS TURBULENT                                          000001
00111          K=RHOP/RHOE                                                           000004
00112          Y=LAMBV/X                                                             000007
00112    C THE EQUATIONS USED TO COMPUTE QDOT AND CFR ARE DIFFERENT WHEN             000007
00112    C  LAMBDA/X IS LESS THAN 1. THAT THE EQUATIONS USED WHEN LAMBDA/X           000007
00112    C  IS GREATER THAN 1. HERE ONLY LAMBDA/X LESS THAN 1 CASE IS USED.          000007
00113     10   CFR=CFRO*SQRT(1.+K)*(1.+(.49*(Y*K  /(1.+K))))                         000012
00114          STR = STS*SQRT(1.+K)*(1.+(.49*(Y*K  /(1.+K))))                        000031
00115          Q =STR/STS                                                            000035
00116          GOTO 160                                                              000037
00117     100  BETA5=(WP*CP)/(WF*CF)                                                 000041
00120          W=WP/WF                                                               000046
00121          IF(W.LT.1..OR.ABS(W-1.).LT..001) GO TO 105                            000051
00123          IF(W.GT.1.) GOTO 110                                                  000070
00123    C THIS IF STATEMENT SERVES THE SAME PURPOSE AS THE IF STATEMENT FOR         000070
00123    C  THE LAMINAR CASE                                                         000070
00125     105  CFR=CFRO*(1.+BETA5)                                                   000075
00126          STR =STS *(1.+BETA5)                                                  000101
00127          Q =STR/STS                                                            000104
00130          GOTO 120                                                              000106
00131     110  NU=.14*(RED**.6)*(W**.45)                                             000110
00132          D=RED/(RHOE*UE/MUE)                                                   000123
00133          QDOT=((NU*KG)/D)*(TAW-TW)                                             000131
00134          STR=QDOT/((DUMM5-DUMM6)*RHOE*UE)                                      000137
00135          Q =STR/STS                                                            000145
00136          CFR=Q*CFRO                                                            000147
00137     120  CONTINUE                                                              000152
00140          RETURN                                                                000152
00141     160  CONTINUE                                                              000155
00142          RETURN                                                                000155
00143          END                                                                   000167

      END OF COMPILATION:        NO  DIAGNOSTICS.
```

```
@SYS$*MSFCFOR$.FOR,WUS BLKDTA
HSA  E3 -12/10/84-22:23:49 (22,23)
-21
      COMMON/RUF/DUMM1,DUMM2,DUMM3,DUMM4,DUMM5,DUMM6,DUMM7,DUMM8,DUMM9,
     $ DUMM10,DUMM11,DUMM12,RK,ICF,FMF,DUMM16,DUMM17,DUMM18
      COMMON/PARTI/PARTM,DUMM24,RHOPA,DUMM23,CPART,WP,DUMM19,WF,
     $ DUMM22,DUMM20,DUMM21,ILT,PF,AK,RP,IPART
      COMMON /LAM/ ILAMIN
-92
C     DEFAULT VALUES FOR ROUGHNESS OPTION
      DATA FMF/1.15/,ICF/0/,RK/0.0/
C     DEFAULT VALUES FOR PARTICLE OPTION
      DATA IPART/0/,RP/0./,WP/0./,WF/1./,CPART/0./,RHOPA/0./
C     DEFAULT VALUES FOR RELAMINARIZATION OPTION
      DATA ILAMIN/0/

   BLOCK DATA

   STORAGE USED: CODE(1) 000000; DATA(0) 000000; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003    AL     000002
    0004    CARDS  000003
    0005    CONSTS 000010
    0006    CRBCOM 000111
    0007    EPSCOM 000045
    0010    EQPCOM 000435
    0011    ETACOM 000017
    0012    HOLLER 000060
    0013    INPUTI 000015
    0014    INTCOM 000115
    0015    LOWTH  001372
    0016    NZERO  000001
    0017    PLOTS  000172
    0020    PRMALS 000154
    0021    RFTCOM 000045
    0022    RUF    000022
    0023    PARTI  000020
    0024    LAM    000001
    0025    SAHA   000066
    0026    TEMCOM 000162
    0027    UNICOM 000011
    0030    WALTEM 000715


   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0020    000000 A          0023    000015 AK         0030    000000 ALTAB      0012 I  000000 AREA       0006    000000 ASU
    0010    000000 ATA        0010 R  000030 BASMOL     0014    000000 CASE       0014 R  000015 CBAR       0007 R  000000 CLNUM
    0023 R  000004 CPART      0005 R  000000 CPFL       0025    000000 CPH        0015 R  000000 CPL        0012 I  000002 CQ
    0012 I  000006 DENS       0012 I  000010 DIST       0007    000001 DL         0005 R  000001 DPR        0004    000000 DUB8
    0022    000000 DUMM1      0022    000011 DUMM10     0022    000012 DUMM11     0022    000013 DUMM12     0022    000017 DUMM16
    0022    000020 DUMM17     0022    000021 DUMM18     0023    000006 DUMM19     0022    000001 DUMM2      0023    000011 DUMM20
    0023    000012 DUMM21     0023    000010 DUMM22     0023    000003 DUMM23     0023    000001 DUMM24     0022    000002 DUMM3
    0022    000003 DUMM4      0022    000004 DUMM5      0022    000005 DUMM6      0022    000006 DUMM7      0022    000007 DUMM8
    0022    000010 DUMM9      0007 R  000020 ELCON      0012 I  000012 ENERGY     0010 R  000031 EPOVRK     0007    000021 EPSA
    0011 R  000000 ETA        0010    000032 FF         0004 R  000001 FFAR       0004 R  000002 FITMOL     0017    000000 FLDX
    0012 I  000014 FLUX       0022 R  000016 FMF        0021 R  000000 F2FIX      0021    000017 F2FIXT     0005 R  000002 GC
    0012 I  000016 HEAT       0015 R  000226 HL         0012 I  000022 HWALL      0014    000016 I          0015 I  000454 IADD
```

```
0013 I 000000 IBODY     0022 I 000015 ICF       0025 I 000062 ICON      0030 I 000231 ICOOL     0026 I 000000 IDAT
0013 I 000001 IDERIV    0013 I 000002 IDIFF     0026 I 000001 IED       0030   000232 IENH      0013 I 000003 IETA
0013 I 000004 IFIT      0013 I 000005 IFLOW     0013 I 000006 IGUESS    0024 I 000000 ILAMIN    0015 I 000455 ILSP
0023   000013 ILT       0026 I 000002 IND       0015 I 000537 INEW      0026 I 000003 IOR       0026 I 000004 IOUT
0023 I 000017 IPART     0025 I 000063 IPASS     0003 I 000000 IPLOT     0017 I 000030 IPP       0020 I 000146 IPUNCH
0026 I 000005 IRE       0025 I 000064 IRITE     0026 I 000006 IROC      0026 I 000007 ISAV      0026 I 000010 ITA
0013 I 000007 ITDK      0026 I 000011 ITE       0013 I 000010 ITHERM    0025 I 000065 ITRCNT    0003 I 000001 IUNIT
0013 I 000011 IWALL     0020   000147 J         0013 I 000012 JWALL     0014 I 000023 KAPPA     0013 I 000013 KEDGP
0014 I 000024 KONRFT    0014   000025 KR9       0026 I 000012 LIF       0026 I 000014 LLA       0026 I 000015 LLAW
0026 I 000016 LOT       0026 I 000017 MAIN      0012 I 000024 MASS      0026 I 000020 MOEG      0017 I 000031 MS
0026 I 000021 MURD      0026 I 000022 NCH       0014 I 000114 NETA      0026 I 000023 NIT       0015 I 000551 NLTSP
0017 I 000032 NPCON     0017 I 000033 NPLOT     0021 I 000043 NPOINT    0017 I 000071 NSTAT     0017 I 000153 NSTP
0026 I 000024 NTOR      0013 I 000014 NTROPY    0016 I 000000 NUL       0026 I 000026 NW        0023   000000 PARTM
0005 R 000003 PATM      0023   000014 PF        0005 R 000004 PI        0020 R 000153 PNORM     0012 I 000030 PRESS
0007 R 000040 PRT       0012 I 000032 RAD       0021 R 000044 RATLIM    0005 R 000005 RBAR      0007 R 000041 RETR
0012 I 000034 REY       0023 R 000002 RHOPA     0007   000042 RHOVS     0022 R 000014 RK        0023 R 000016 RP
0005 R 000006 RVAR      0007 R 000043 SCT       0012 I 000036 SHEAR     0010 R 000434 SIGMA     0005 R 000007 SIPSF
0015 R 000552 SL        0006 R 000110 STEF      0015 I 001000 SUBLT     0012 I 000040 TCON      0012 I 000044 TEMP
0012 I 000046 THRUST    0015 R 001144 TL        0030 R 000714 TOLQW     0027 R 000000 UCD       0027 R 000001 UCE
0027 R 000002 UCL       0027 R 000003 UCM       0027 R 000004 UCP       0027 R 000005 UCR       0027 R 000006 UCS
0027 R 000007 UCT       0027 R 000010 UCV       0012 I 000050 VEL       0012 I 000052 VIS       0023 R 000007 WF
0023 R 000005 WP        0012 I 000056 XIPR      0007 R 000044 YAP
```

```
00101          BLOCK DATA                                                              000000
00101    C                                                                             000000
00102          COMMON /AL/ IPLOT,IUNIT                                          /AL/     000000
00103          COMMON /CARDS/ DUB8,FFAR,FITMOL                                /CARDS/    000000
00104          COMMON /CONSTS/ CPFL,DPR,GC,PATM,PI,RBAR,RVAR,SIPSF            /CONSTS/   000000
00105          COMMON /CRBCOM/ ASU(72),STEF                                   /CRBCOM/   000000
00106          COMMON /EPSCOM/ CLNUM,DL(15),ELCON,EPSA(15),PRT,RETR,RHOVS,SCT,YAP/EPSCOM/ 000000
00107          COMMON /EQPCOM/ ATA(24),BASMOL,EPOVRK,FF(258),SIGMA            /EQPCOM/   000000
00110          COMMON /ETACOM/ ETA(15)                                        /ETACOM/   000000
00111          COMMON /HOLLER/ AREA(2),CQ(2,2),DENS(2),DIST(2),ENERGY(2),FLUX(2),/HOLLER/ 000000
00111         1 HEAT(2,2),HWALL(2),MASS(2,2),PRESS(2),RAD(2),REY(2),SHEAR(2),  /HOLLER/   000000
00111         2 TCON(2,2),TEMP(2),THRUST(2),VEL(2),VIS(2,2),XIPR(2)           /HOLLER/   000000
00112          COMMON /INPUTI/ IBODY,IDERIV,IDIFF,IETA,IFIT,IFLOW,IGUESS,ITDK,  /INPUTI/   000000
00112         1                ITHERM,IWALL,JWALL,KEDGP,NTROPY               /INPUTI/   000000
00113          COMMON /INTCOM/ CASE(13),CBAR,I(5),KAPPA,KONRFT,KR9(55),NETA   /INTCOM/   000000
00114          COMMON /LOWTH/ CPL(3,50),HL(3,50),IADD,ILSP(50),INEW(10),NLTSP,  /LOWTH/   000000
00114         1               SL(3,50),SUBLT(50,2),TL(50,3)                   /LOWTH/   000000
00115          COMMON /NZERO/ NUL                                             /NZERO/    000000
00116          COMMON/PLOTS/ FLDX(12,2),IPP,MS,NPCON,NPLOT(30),NSTAT(50),NSTP(15) /PLOTS/ 000000
00117          COMMON /PRMALS/ A(102),IPUNCH,J(4),PNORM                       /PRMALS/   000000
00120          COMMON /RFTCOM/ F2FIX(15),F2FIXT(20),NPOINT,RATLIM             /RFTCOM/   000000
00121          COMMON/RUF/DUMM1,DUMM2,DUMM3,DUMM4,DUMM5,DUMM6,DUMM7,DUMM8,DUMM9,        NEW000000
00121         $ DUMM10,DUMM11,DUMM12,RK,ICF,FMF,DUMM16,DUMM17,DUMM18                   NEW000000
00122          COMMON/PARTI/PARTM,DUMM24,RHOPA,DUMM23,CPART,WP,DUMM19,WF,               NEW000000
00122         $ DUMM22,DUMM20,DUMM21,ILT,PF,AK,RP,IPART                                NEW000000
00123          COMMON /LAM/ ILAMIN                                                      NEW000000
00124          COMMON /SAHA/ CPH(50),ICON,IPASS,IRITE,ITRCNT                   /SAHA/    000000
00125          COMMON /TEMCOM/ IDAT,IED,IND,IOR,IOUT,IRE,IROC,ISAV,ITA,ITE,    /TEMCOM/   000000
00125         1 LIF(2),LLA,LLAW,LOT,MAIN,MOEG,MURD,NCH,NIT,NTOR(2),NW(92)      /TEMCOM/   000000
00126          COMMON /UNICOM/ UCD,UCE,UCL,UCM,UCP,UCR,UCS,UCT,UCV            /UNICOM/   000000
00127          COMMON /WALTEM/ ALTAB(153),ICOOL,IENH(306),TOLQW               /WALTEM/   000000
00127    C                                                                             000000
00130          INTEGER AREA,CQ,DENS,DIST,ENERGY,FLUX,HEAT,HWALL,PRESS,RAD,REY,  ANK 5/83  000000
00130         1        SHEAR,SUBLT,TCON,TEMP,THRUST,VEL,VIS,XIPR                          000000
```

```
00130     C                                                                                000000
00131          DATA IDAT/5HDATA)/,IED/5HEDGE /,IND/6HREWIND/,IOR/2HOR/,IOUT      ANK 7/83   000000
00131         1 /6HOUTPUT/,IRE/5HREAD(/,IROC/6HROCOUT/,ISAV/5HSAVE /,ITA/6HTAPE) ANK 7/83   000000
00131         2/,ITE/6HWRITE(/,LIF/4HPROF,4HILE /,LLA/3HALL/,LLAW/5HWALL /,      ANK 7/83   000000
00131         3 LOT/6H PLOT /,MAIN/6HBLMAIN/,MOEG/6HGEOM [/,MURD/6H(DRUM /,      ANK 7/83   000000
00131         4 NCH/6HPUNCH /,NIT/6H UNIT /,NTOR/4HCONT,4HOUR /,NW/6H(1H1,3,     ANK 7/83   000000
00131         5 60H7X, 'THE FOLLOWING STORAGE UNITS ARE USED IN THE BLIMP PROGR, ANK 7/83   000000
00131         6 60HAM'///A6,'2 ',A6,A2,1X,   A6,1X, A6,' [', A6, '];  ', 2A6,  , ANK 7/83   000000
00131         7 60H2A5,', ',A6,'];  ',A6,' [',3A5,', ',A6,', ',A6,2A4,A5,'];'/ , ANK 7/83   000000
00131         8 60H23X,A6,'[',A6,', ',A5, 2A4, A5,']'//A6,'3 ',A6,A2,1X,A6,1X, , ANK 7/83   000000
00131         9 60HA6,' [',A6,'];  ',A6,' [',A6,2A5,']; ',A6,'[',A6,', ',3A5,  , ANK 7/83   000000
00131         A 60H']'// A6, '4 ',A6,A2,1X,A6,1X,A6,' [', A6, '];  ', A6,' [', , ANK 7/83   000000
00131         B 60HA6, 2A4, A5, ']; ', A6, '[',A6, ', ', A5, 2A4, A5, ']'// A6,, ANK 7/83   000000
00131         C 60H'10 ',A6, A2, A6, A5, 2A6, '[', A6, A3, A6, A5, ']'// A6,   , ANK 7/83   000000
00131         D 60H'15 ', A6, A2,1X, A6, A5, A6, 1X, A6,' [', A6,A3,1X, A6, A5,, ANK 7/83   000000
00131         E 6H']'/ )/                                                        ANK 7/83   000000
00157          DATA NPCON,NSTP,NPLOT,IPLOT,NSTAT,IUNIT,IPUNCH,NPOINT,IPP/16*1,5* ANK 7/83   000000
00157         12,7*1,2,2,16*1,0,1,49*0,2,3,3,40/,ELCON,ETA/.44,0.,.002,.006,.01, ANK 7/83   000000
00157         4 0.025,0.06,0.15,0.35,0.60,0.80,1.0,1.35,1.75,2.05,2.50/,                    000000
00157         5 F2FIX/0.0,0.05,0.12,0.25,0.35,0.45,0.60,0.68,0.77,0.86,0.95,0.97,           000000
00157         6 0.98,0.99,1.0/,MS/30/,PNORM/1.0/,YAP/11.8230/,                   ANK 3/83   000000
00157         1 CLNUM/0.0180/,SCT,PRT/2*0.90/,RETR/0.0/,RATLIM/0.50/                        000000
00204          DATA IBODY/4/,IDERIV,IDIFF/2,2/,IETA,IFIT/1,1/,IFLOW/2/,IGUESS/0/,ANK 4/83   000000
00204         1     ITHERM,IWALL/2,2/,JWALL,KEDGP,NTROPY/0,1,0/                  ANK 8/83   000000
00221          DATA FITMOL/26.70/,BASMOL/32.0/,NETA/15/,FFAR/0.4890/,            ANK 8/83   000000
00221         3 SIGMA/3.4670/,EPOVRK/106.70/,KAPPA/11/,CBAR/0.950/,TOLQW/1.0E-4/,           000000
00221         J ICON,ICOOL,IPASS,ITRCNT,ITDK,NUL,IRITE,KONRFT/6*0,1,1/,          ANK 5/83   000000
00221         K STEF/4.7589105E-13/                                              ANK 5/83   000000
00244          DATA AREA/12HSQ. M SQ. FT/,CQ/24H(J/KG DEG K)BTU/LB DEG R/,DENS/12ANK 5/83   000000
00244         1HKG/M3 LB/FT3/,DIST/12HMETERS(FEET)/,ENERGY/12H(J/KG)BTU/LB/,FLUX/           000000
00244         3 12HKG/SM2LB/SF2/,HEAT/24H (WATTS/M2) BTU/SEC FT2 /,HWALL/12HWATTS           000000
00244         4 BTU/S /,MASS/24H(KG/SEC-M2) LB/SEC SQ FT/,PRESS/12H(N/M2)(ATM) /,           000000
00244         5 RAD/12HJ/S-M2B/SFT2/,REY/12H METER FOOT /,SHEAR/12H(N/M2)LB/FT2/,           000000
00244         6 TCON/24H(WATTS/M-K) BTU/SEC FT R/,TEMP/12HDEG. KDEG. R/,THRUST/             000000
00244         7 12HNEWTONPOUNDS/,VEL/12HM/SEC FT/SEC/,VIS/24H (N-SEC/M2) (LBM/SEC           000000
00244         8 FT)/,XIPR/12H(KG/SE(LB/SE/                                                  000000
00244     C    CONVERSION FACTORS SI UNITS TO BLIMP UNITS                                   000000
00270          DATA UCD/6.2427962E-2/,UCE/4.3021E-4/,UCL/3.280839895/,UCM/2.20462           000000
00270         A26/,UCP/9.8692327E-6/,UCR/8.8114E-5/,UCS/2.0885434E-2/,UCT/1.80/,            000000
00270         B UCV/0.671968995/,CPFL/777.64867981/,DPR/57.2957795/,GC/32.174/,  ANK 4/83   000000
00270         C PATM/14.696006/,PI/3.1415926536/,RBAR/1.987165/,RVAR/1545.12/,   ANK 4/83   000000
00270         D SIPSF/144.0/                                                     ANK 4/83   000000
00270     C    COMPOUNDS IN LOW TEMPERATURE EXTENSION ARRAY ARE: 1 = OH, 2 = H,             000000
00270     C    3 = HO2, 4 = H2, 5 = H2O2, 6 = O, 7 = O2, 8 = H2O, 9 = N2, 10 = AR           000000
00312          DATA CPL/3.6484136,3.9241834,3.701756,2.5010504,2*2.5000943,                 000000
00312         1 3.995642,4.000171,4.0273454,3.6081553,3.3857279,3.3011853,                  000000
00312         2 4.0057066,4.0323777,4.4349613,2.6545354,2.8510969,2.7345992,                000000
00312         3 3.4924125,3.5014706,3.5029803,3.9553836,4.0062098,4.0102356,                000000
00312         4 3.4909028,3.5004642,3.5009674,2.5005472,2*2.500943,120*0.0/,                000000
00312         5 SL/1.7978376,17.978376,20.62486,1.1052932,11.052932,12.786054,              000000
00312         6 2.2956322,22.956322,25.732639,1.2102165,12.102165,14.349588,                000000
00312         7 2.2422898,22.422898,25.320494,1.6337344,16.337344,18.286352,                000000
00312         8 2.0831184,20.831184,23.258259,1.8315539,18.315539,21.093366,                000000
00312         9 1.9208269,19.208269,21.634841,1.5879808,15.879808,17.612729,120*            000000
00312         A0.0/,HL/3589.6616,39.508546,21.65648,25476.983,257.24587,                    000000
00312         B 129.87094,1317.4245,17.129931,10.570335,-1014.9283,-6.577209,               000000
00312         C -1.6682057,-17671.426,-172.74861,-84.05693,29164.349,294.27148,             000000
00312         D 148.53824,-1040.7087,-6.949599,-1.7235609,-30272.845,-298.81263,            000000
00312         E -147.40094,-1039.3515,-6.937521,-1.7185286,-742.9332,-4.9537909,            000000
00312         F -1.2268734,120*0.0/,TL/50*1.0,50*100.0,50*200.0/,ILSP/50*3/,                000000
```

```
00312          G SUBLT/6HOH    ,6HH     ,6HHO2   ,6HH2    ,6HH2O2  ,6HO     ,         000000
00312          H 6HO2    ,6HH2O   ,6HN2    ,6HAR    ,90*6H      /,NLTSP/10/,        000000
00312          I IADD,INEW/11*0/                                                    000000
00312     C      DEFAULT VALUES FOR ROUGHNESS OPTION                             NEW000000
00324            DATA FMF/1.15/,ICF/0/,RK/0.0/                                   NEW000000
00324     C      DEFAULT VALUES FOR PARTICLE OPTION                              NEW000000
00330            DATA IPART/0/,RP/0./,WP/0./,WF/1./,CPART/0./,RHOPA/0./          NEW000000
00330     C      DEFAULT VALUES FOR RELAMINARIZATION OPTION                      NEW000000
00337            DATA ILAMIN/0/                                                  NEW000000
00341            END                                                                000000

      END OF COMPILATION:        NO  DIAGNOSTICS.
```

```
@SYS$*MSFCFOR$.FOR,WUS BLMAIN
HSA  E3 -12/10/84-22:23:51 (22,23)
-34
       COMMON/ACCN/ACCPK,ILAM,SPCT
       COMMON/RETH/RETHMO
       COMMON/RUF/DUMM1,DUMM2,DUMM3,DUMM4,DUMM5,DUMM6,DUMM7,DUMM8,DUMM9,
      $ DUMM10,DUMM11,DUMM12,RK,ICF,FMF,DUMM16,DUMM17,DUMM18
       COMMON/PARTI/PARTM,DUMM24,RHOPA,DUMM23,CPART,WP,DUMM19,WF,
      $ DUMM22,DUMM20,DUMM21,ILT,PF,AK,RP,IPART
       COMMON /LAM/ ILAMIN
       COMMON/RUF3/UTAU,DEACY
-97
      $ IPART,RP,WP,WF,RHOPA,CPART,ILAMIN,
-98,98-
/ZP            /ZP,FMF,ICF,RK/

   MAIN PROGRAM

   STORAGE USED: CODE(1) 000576; DATA(0) 002046; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   AL      000002
    0004   BLQCOM  002043
    0005   CARDS   000077
    0006   COEFFS  002354
    0007   CRBCOM  000111
    0010   EDGCOM  001217
    0011   EPSCOM  000045
    0012   EQPCOM  002433
    0013   EQTCOM  000243
    0014   ETACOM  002631
    0015   INPUTI  000015
    0016   INTCOM  000123
    0017   INTERI  000007
    0020   LOWTH   001372
    0021   NONCOM  035230
    0022   PLOTS   000172
    0023   PRMALS  000243
    0024   PRMORG  000455
    0025   RFTCOM  000045
    0026   ACCN    000003
    0027   RETH    000001
    0030   RUF     000022
    0031   PARTI   000020
    0032   LAM     000001
    0033   RUF3    000002
    0034   SAHA    000151
    0035   SAVE    000010
    0036   SAVEQL  000005
    0037   SAVHIS  000475
    0040   SAVMAT  000056
    0041   SAVNCR  000175
    0042   SAVOUT  000021
    0043   SAVTBL  000067
    0044   SAVTRM  000020
    0045   STTCOM  000044
    0046   TEMCOM  000162
    0047   VARCOM  000645
    0050   WALL    001212
```

EXTERNAL REFERENCES (BLOCK, NAME)

0052	LTCPHS
0053	SETUP
0054	ITERAT
0055	OUTPUT
0056	SATEMP
0057	ROCOUT
0060	PLOT
0061	EXIT
0062	NINTR$
0063	NWDU$
0064	NIO3$
0065	NIO1$
0066	NIO2$
0067	NRDU$
0070	NRNL$
0071	NWNL$
0072	NREW$
0073	NWBU$
0074	NSTOP$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000		002000	1F	0001		000533	15L	0000		002016	2F	0001		000236	25L	0000		002001	3F
0001		000334	30L	0001		000262	347G	0001		000371	35L	0001		000310	361G	0001		000443	41L
0001		000445	43L	0001		000401	45L	0001		000137	46L	0001		000550	50L	0026		000000	ACCPK
0031		000015	AK	0047	R	000000	ALPH	0051	R	000000	ALTAB	0000	R	000033	AMNFS	0000	R	000030	AMNO
0000	R	000032	AMNOS	0000	R	000031	AMWP	0000		001677	ARRAYS	0007	I	000000	ASU	0012	I	000000	ATA
0012	I	000010	ATB	0012	I	000020	ATC	0012	R	000030	BASMOL	0014		000321	BA1	0014		001727	BA2
0044		000000	BC	0040		000000	BE	0044		000010	BLNK	0014		000072	BONE	0007	I	000003	BSU
0040		000010	BY	0036		000000	B1	0014		000110	B2	0016	I	000000	CASE	0016	R	000015	CBAR
0043		000000	CL	0011	R	000000	CLNUM	0000	R	000034	CMR	0006	R	000000	COEF	0051	R	000062	COEFCL
0041		000000	CORMA	0023		000000	COSALF	0031	R	000004	CPART	0034		000000	CPH	0020	R	000000	CPL
0051	R	000063	CPLTAB	0000		000075	DATA	0043		000001	DCLNUM	0014		000054	DCU	0033		000001	DEACY
0043		000002	DELCON	0023		000062	DELTBD	0043		000003	DEPC	0014		000017	DETA	0011		000001	DL
0037		000000	DLX2	0021	R	000000	DPDX	0043		000004	DPI	0010	R	000000	DSIP	0014		000036	DSQ
0005	R	000000	DUB8	0021	R	002734	DUDX	0010		000062	DUEDGE	0021		005670	DUM	0030		000000	DUMM1
0030		000011	DUMM10	0030		000012	DUMM11	0030		000013	DUMM12	0030		000017	DUMM16	0030		000020	DUMM17
0030		000021	DUMM18	0031		000006	DUMM19	0030		000001	DUMM2	0031		000011	DUMM20	0031		000012	DUMM21
0031		000010	DUMM22	0031		000003	DUMM23	0031		000001	DUMM24	0030		000002	DUMM3	0030		000003	DUMM4
0030		000004	DUMM5	0030		000005	DUMM6	0030		000006	DUMM7	0030		000007	DUMM8	0030		000010	DUMM9
0041		000001	DVNL	0043		000042	DVS	0021		010624	DXDS	0040		000020	EB	0040		000030	EBL
0040		000040	EESE	0011	R	000020	ELCON	0007		000006	EMIS	0007		000007	EMISC	0007	R	000010	EMIST
0007	R	000011	EMIV	0051	R	000145	ENHTAB	0042		000000	ENTHAL	0040		000050	EP	0012	R	000031	EPOVRK
0011		000021	EPSA	0043		000043	EPS1	0014	R	000000	ETA	0047	R	000001	F	0012	R	000032	FF
0005	R	000001	FFAR	0005	R	000002	FITMOL	0000	R	000026	FK	0045		000000	FLD	0022	I	000000	FLDX
0051	R	000227	FLMASS	0050	R	000000	FLUXJ	0030	R	000016	FMF	0004		000000	FR	0000	R	000000	FUEL
0050		000226	FW	0025	R	000000	F2FIX	0025	R	000017	F2FIXT	0047	R	000075	G	0045		000025	GAM1
0023	R	000144	GE	0010		000063	GEP	0012	R	000126	GG	0047	R	000075	GW	0037		000001	HALPH
0007		000014	HCARB	0036		000001	HCH	0007	R	000015	HCHAR	0010		000064	HE	0000	R	000023	HFU
0037		000002	HGP	0020	R	000226	HL	0000	R	000024	HOX	0007		000020	HPG	0007	R	000021	HPYG
0037		000057	HSP	0007	R	000024	HTEF	0050	R	000310	HW	0016		000016	I	0020	I	000454	IADD
0051	I	000230	IAREA	0015	I	000000	IBODY	0030	I	000015	ICF	0034	I	000062	ICON	0051	I	000231	ICOOL
0041		000174	ICORM	0024		000000	ID	0046	I	000000	IDAT	0015	I	000001	IDERIV	0015	I	000002	IDIFF
0046	I	000001	IED	0051	I	000232	IENH	0015	I	000003	IETA	0012		000222	IFC	0040		000051	IFCJC

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0015 I 000004 IFIT      0015 I 000005 IFLOW     0005 I 000003 IFRAC     0015 I 000006 IGUESS    0026   000001 ILAM
0032 I 000000 ILAMIN    0020 I 000455 ILSP      0031   000013 ILT       0046 I 000002 IND       0020 I 000537 INEW
0035   000000 INT       0046 I 000003 IOR       0046 I 000004 IOUT      0023 I 000145 IP        0031 I 000017 IPART
0034 I 000063 IPASS     0003 I 000000 IPLOT     0022 I 000030 IPP       0023 I 000146 IPUNCH    0016 I 000017 IQ
0012   000316 IR        0046 I 000005 IRE       0034 I 000064 IRITE     0046 I 000006 IROC      0016 I 000020 IS
0046 I 000007 ISAV      0016 I 000021 ISH       0013 I 000000 ISN       0023 I 000147 IST       0007   000025 ISU
0046 I 000010 ITA       0051 I 000233 ITCOOL    0015 I 000007 ITDK      0046 I 000011 ITE       0005 I 000004 ITEMP
0036   000002 ITFF      0015 I 000010 ITHERM    0051 I 000234 ITHICK    0051 I 000235 ITLINP    0034   000065 ITRCNT
0016   000022 ITS       0023 I 000150 IU        0003 I 000001 IUNIT     0015 I 000011 IWALL     0000 I 000027 J
0040   000052 JJ        0015 I 000012 JWALL     0016 I 000023 KAPPA     0025   000036 KAPPAL    0025 I 000037 KAPPAT
0012 I 000326 KAT       0017   000000 KBC       0017   000001 KCC       0015 I 000013 KEDGP     0016 I 000024 KONRFT
0017 I 000003 KQ10      0017   000002 KQ9       0036   000003 KR2       0016 I 000025 KR9       0007 I 000026 KS
0017   000004 KSB       0017   000005 KSOL      0025 I 000040 KTURB     0017   000006 KT8       0005 I 000005 KU
0051 R 000236 LAMDAW    0012   000336 LAMI      0051 R 000237 LAMTAB    0014   000126 LAR       0004 I 001606 LEF
0004   001616 LEFS      0004   001626 LEFT      0004   001636 LEFW      0046 I 000012 LIF       0046 I 000014 LLA
0046 I 000015 LLAW      0046 I 000016 LOT       0000 L 000016 LOWT      0004   001604 L2        0004   001605 L3
0046 I 000017 MAIN      0016   000107 MAT1I     0016   000110 MAT1J     0016   000111 MAT2I     0004   001646 MOA
0004   001742 MOB       0046 I 000020 MOEG      0000 R 000017 MR        0022 I 000031 MS        0046 I 000021 MURD
0016 I 000112 MWE       0005 I 000006 N         0016   000113 NAM       0045 I 000026 NC        0000 I 000020 NCASE
0046 I 000022 NCH       0036   000004 NCV       0012 I 000432 NEL       0016 I 000114 NETA      0025   000041 NETAL
0025 I 000042 NETAT     0005 I 000007 NFF       0046 I 000023 NIT       0020   000551 NLTSP     0016   000115 NNLEQ
0016 I 000116 NON       0005 I 000010 NP        0022 I 000032 NPCON     0022 I 000033 NPLOT     0025 I 000043 NPOINT
0016   000117 NRNL      0016 I 000120 NS        0034 I 000066 NSJ       0016 I 000121 NSP       0004   002036 NSPEC
0016   000122 NSPM1     0022 I 000071 NSTAT     0022 I 000153 NSTP      0000 I 000021 NTAL      0023 I 000151 NTH
0046 I 000024 NTOR      0015 I 000014 NTROPY    0046 I 000026 NW        0000 R 000025 OK        0000   001106 OUT
0000 R 000007 OX        0012   000433 P         0031   000000 PARTM     0023 R 000152 PCHAMB    0010   000065 PE
0031   000014 PF        0004   002037 PIEASE    0043   000044 PIM       0021 R 013560 PITAB     0043   000045 PM
0023 R 000153 PNORM     0045 R 000027 PRA       0045 R 000030 PRB       0045 R 000031 PRC       0045 R 000032 PRD
0045 R 000033 PRDUM     0024 R 000063 PRE       0011 R 000040 PRT       0013   000074 PVMW      0013   000120 PVOL
0034   000067 QWG       0023 R 000156 RADFL     0024 R 000145 RADR      0024   000227 RADS      0023   000154 RAD5
0023   000155 RAD6      0025 R 000044 RATLIM    0051 R 000321 RECOFT    0043   000046 RED       0027   000000 RETHMO
0011 R 000041 RETR      0010   000147 RHOE      0031 R 000002 RHOPA     0011   000042 RHOVS     0050 R 000372 RHOVW
0030 R 000014 RK        0024 R 000311 ROKAP     0031 R 000016 RP        0023 R 000157 RTM       0024 R 000373 S
0011 R 000043 SCT       0035   000001 SDRHOH    0035   000002 SDRHOK    0012 R 000434 SIGMA     0020 R 000552 SL
0047 R 000152 SP        0026   000002 SPCT      0010   000231 SPE       0005   000072 SPL       0005   000073 SPU
0050 R 000454 SPW       0007   000110 STEF      0020 I 001000 SUBLT     0023   000160 SUMQG     0012   000435 T
0010   000705 TE        0012 R 001006 TF        0051 R 000322 THITAB    0051   000404 TI        0013 R 000144 TJ
0005 R 000074 TJA       0012 R 000436 TKP       0013 R 000147 TKT       0020 R 001144 TL        0051 R 000466 TLINP
0051 R 000632 TLTAB     0051 R 000714 TOLQW     0012   000526 TQ        0045   000034 TR        0043   000047 TREF
0010   000767 TTVC      0012   000616 TU        0051 R 000715 TUBEN     0010   000770 TVCC      0050 R 001130 TW
0010   001052 UE        0042   000001 UKAPPA    0033   000000 UTAU      0021   016514 VA        0043   000050 VINTR
0021 R 021450 VITAB     0045 R 000037 VMUA      0045 R 000040 VMUB      0045 R 000041 VMUC      0045 R 000042 VMUD
0010   001134 VMUE      0045   000043 VMWD      0010   001216 VMWE      0012   001102 VN        0012   001176 VNU
0021   024404 VS        0004   002040 W         0042   000020 WALLA     0012 R 002136 WAT       0031 R 000007 WF
0012   002146 WM        0013 R 000217 WMS       0031 R 000005 WP        0012   002147 WTM       0051 R 000716 XAREA
0051 R 001000 XENH      0021 R 027340 XITAB     0051 R 001062 XLTAB     0023   000161 XST       0051 R 001226 XTHIK
0012   002243 Y         0011 R 000044 YAP       0021 R 032274 YITAB     0012   002337 YW        0051 R 001310 ZMUTAB
0000 R 000022 ZP
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00100     1*     CBLIMP                              BOUNDARY LAYER INTEGRAL MATRIX PROCEDURE   BLIM 001    000000
00100     2*     C                                                                                          000000
00101     3*           COMMON /AL/ IPLOT,IUNIT                                                  /AL/        000000
00103     4*           COMMON /BLQCOM/ FR(60,15),L2,L3,LEF(8),LEFS(8),LEFT(8),LEFW(8),          /BLQCOM/    000001
00103     5*          1                MOA(60),MOB(60),NSPEC,PIEASE,W(3)                        /BLQCOM/    000001
00104     6*           COMMON /CARDS/ DUB8,FFAR,FITMOL,IFRAC,ITEMP,KU,N,NFF,NP(50),SPL,         /CARDS/     000001
00104     7*          1               SPU,TJA(3)                                                /CARDS/     000001
00105     8*           COMMON /COEFFS/ COEF(7,3,60)                                             /COEFFS/    000001
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00106           COMMON /CRBCOM/ ASU(3),BSU(3),EMIS,EMISC,EMIST,EMIV(3),HCARB,     /CRBCOM/     000001
00106          1                HCHAR(3),HPG,HPYG(3),HTEF,ISU,KS(50),STEF         /CRBCOM/     000001
00107           COMMON /EDGCOM/ DSIP(50),DUEDGE,GEP,HE,PE(50),RHOE(50),SPE(6,50), /EDGCOM/     000001
00107          1                TE(50),TTVC,TVCC(50),UE(50),VMUE(50),VMWE         /EDGCOM/     000001
00110           COMMON /EPSCOM/ CLNUM,DL(15),ELCON,EPSA(15),PRT,RETR,RHOVS,SCT,YAP/EPSCOM/     000001
00111           COMMON /EQPCOM/ ATA(8),ATB(8),ATC(8),BASMOL,EPOVRK,FF(60),GG(60), /EQPCOM/     000001
00111          1 IFC(60),IR(8),KAT(8),LAMI(60),NEL,P,SIGMA,T,TKP(8,7),TQ(8,7),    /EQPCOM/     000001
00111          2 TU(60,3),VN(60),VNU(60,8),WAT(8),WM,WTM(60),Y(60),YW(60)         /EQPCOM/     000001
00112           COMMON/EQTCOM/ISN(3,20),PVMW(20),PVOL(20),TJ(3),TKT(20,2),WMS(20) /EQTCOM/     000001
00113           COMMON /ETACOM/ ETA(15),DETA(15),DSQ(14),DCU(14),BONE(14),B2(14), /EATCOM/     000001
00113          1                LAR(123),BA1(43,18),BA2(30,15)                    /EATCOM/     000001
00114           COMMON /INPUTI/ IBODY,IDERIV,IDIFF,IETA,IFIT,IFLOW,IGUESS,ITDK,   /INPUTI/     000001
00114          1                ITHERM,IWALL,JWALL,KEDGP,NTROPY                   /INPUTI/     000001
00115           COMMON /INTCOM/ CASE(13),CBAR,I,IQ,IS,ISH,ITS,KAPPA,KONRFT,KR9(50)/INTCOM/     000001
00115          1        ,MAT1I,MAT1J,MAT2I,MWE,NAM,NETA,NNLEQ,NON,NRNL,NS,NSP,NSPM1/INTCOM/     000001
00116           COMMON /INTERI/ KBC,KCC,KQ9,KQ10,KSB,KSOL,KT8                     /INTERI/     000001
00117           COMMON /LOWTH/ CPL(3,50),HL(3,50),IADD,ILSP(50),INEW(10),NLTSP,    /LOWTH/     000001
00117          1               SL(3,50),SUBLT(50,2),TL(50,3)                       /LOWTH/     000001
00120           COMMON /NONCOM/ DPDX(1500),DUDX(1500),DUM(1500),DXDS(1500),PITAB( /NONCOM/     000001
00120          1 1500),VA(1500),VITAB(1500),VS(1500),XITAB(1500),YITAB(1500)      /NONCOM/     000001
00121           COMMON/PLOTS/ FLDX(12,2),IPP,MS,NPCON,NPLOT(30),NSTAT(50),NSTP(15) /PLOTS/     000001
00122           COMMON /PRMALS/ COSALF(50),DELTBD(50),GE,IP,IPUNCH,IST,IU,NTH,    /PRMALS/     000001
00122          1                PCHAMB,PNORM,RAD5,RAD6,RADFL,RTM,SUMQG,XST(50)    /PRMALS/     000001
00123           COMMON /PRMORG/ ID(51),PRE(50),RADR(50),RADS(50),ROKAP(50),S(50)  /PRMORG/     000001
00124           COMMON /RFTCOM/ F2FIX(15),F2FIXT(15),KAPPAL,KAPPAT,KTURB,NETAL,   /RFTCOM/     000001
00124          1                NETAT,NPOINT,RATLIM                               /RFTCOM/     000001
00125           COMMON/ACCN/ACCPK,ILAM,SPCT                                          NEW000001
00126           COMMON/RETH/RETHMO                                                   NEW000001
00127           COMMON/RUF/DUMM1,DUMM2,DUMM3,DUMM4,DUMM5,DUMM6,DUMM7,DUMM8,DUMM9,    NEW000001
00127          $ DUMM10,DUMM11,DUMM12,RK,ICF,FMF,DUMM16,DUMM17,DUMM18                NEW000001
00130           COMMON/PARTI/PARTM,DUMM24,RHOPA,DUMM23,CPART,WP,DUMM19,WF,           NEW000001
00130          $ DUMM22,DUMM20,DUMM21,ILT,PF,AK,RP,IPART                             NEW000001
00131           COMMON /LAM/ ILAMIN                                                  NEW000001
00132           COMMON/RUF3/UTAU,DEACY                                               NEW000001
00133           COMMON /SAHA/ CPH(50),ICON,IPASS,IRITE,ITRCNT,NSJ,QWG(50)          /SAHA/     000001
00134           COMMON /SAVE/ INT,SDRHOH,SDRHOK(6)                                /SAVE/      000001
00135           COMMON /SAVEQL/ B1,HCH,ITFF,KR2,NCV                               /SAVEQL/     000001
00136           COMMON /SAVHIS/ DLX2,HALPH,HGP(15,3),HSP(15,3,6)                  /SAVHIS/     000001
00137           COMMON /SAVMAT/ BE(8),BY(8),EB(8),EBL(8),EESE(8),EP,IFCJC,JJ(4)   /SAVMAT/     000001
00140           COMMON /SAVNCR/ CORMA,DVNL(123),ICORM                             /SAVNCR/     000001
00141           COMMON /SAVOUT/ ENTHAL,UKAPPA(15),WALLA                           /SAVOUT/     000001
00142           COMMON /SAVTBL/ CL,DCLNUM,DELCON,DEPC,DPI(15,2),DVS,EPS1,PIM,PM,  /SAVTBL/     000001
00142          1                RED,TREF,VINTR(15)                                /SAVTBL/     000001
00143           COMMON /SAVTRM/ BC(8),BLNK(8)                                     /SAVTRM/     000001
00144           COMMON /STTCOM/ FLD(7,3),GAM1,NC,PRA,PRB,PRC,PRD,PRDUM,TR(3),     /STTCOM/     000001
00144          1                VMUA,VMUB,VMUC,VMUD,VMWD                          /STTCOM/     000001
00145           COMMON /TEMCOM/ IDAT,IED,IND,IOR,IOUT,IRE,IROC,ISAV,ITA,ITE,      /TEMCOM/     000001
00145          1 LIF(2),LLA,LLAW,LOT,MAIN,MOEG,MURD,NCH,NIT,NTOR(2),NW(92)        /TEMCOM/     000001
00146           COMMON /VARCOM/ ALPH,F(15,4),G(15,3),SP(15,3,7)                   /VARCOM/     000001
00147           COMMON /WALL/ FLUXJ(3,50),FW(50),HW(50),RHOVW(50),SPW(6,50),TW(50) /WALL/     000001
00150           COMMON /WALTEM/ ALTAB(50),COEFCL,CPLTAB(50),ENHTAB(50),FLMASS,    /WALTEM/     000001
00150          1 IAREA,ICOOL,IENH,ITCOOL,ITHICK,ITLINP,LAMDAW,LAMTAB(50),RECOFT,  /WALTEM/     000001
00150          2 THITAB(50),TI(50),TLINP(100),TLTAB(50),TOLQW,TUBEN,XAREA(50),    /WALTEM/     000001
00150          3 XENH(50),XLTAB(100),XTHIK(50),ZMUTAB(50)                         /WALTEM/     000001
00150     C                                                                                000001
00150     C     ORDER OF PARAMETERS TO BE PLOTTED: 1 PRESSURE, 2 EDGE TEMPERATURE,              000001
00150     C     3 VELOCITY, 4 MACH NUMBER, 5 DENSITY, 6 TOTAL ENTHALPY, 7 TOTAL HEAT,           000001
00150     C     8 TOTAL WALL AREA, 9 MOMENTUM THICKNESS, 10 DISPLACEMENT THICKNESS,             000001
00150     C     11 THRUST LOSS, 12 WALL TEMPERATURE, 13 SHEAR AT WALL,                          000001
00150     C     14 ACCELERATION PARAMETER, 15 VISCOSITY, 16 SPECIFIC HEAT,                      000001
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00150  C      17 THERMAL CONDUCTIVITY, 18 WALL LENGTH, 19 CONDUCTIVE HEAT FLUX,              000001
00150  C      20 INVISID MASS FLOW, 21 TOTAL MASS FLOW, 22 BETAP, 23 BETAV,                  000001
00150  C      24 MOMENTUM TRANSFER COEFFICIENT, 25 HEAT TRANSFER COEFFICIENT,                000001
00150  C      26 XI, 27 TOTAL GAS FLUX, 28 TOTAL GAS BLOWING PARAMETER.                      000001
00150  C      ORDER OF PROFILE PLOTS: 1 TEMPERATURE, 2 VELOCITY RATIO, 3 MACH NUMBER,        000001
00150  C      4 DENSITY, 5 VISCOSITY, 6 SPECIFIC HEAT, 7 STATIC ENTHALPY,                    000001
00150  C      8 TOTAL ENTHALPY, 9 THERMAL CONDUCTIVITY, 10 EPSA (RHOSQ*EPS/RHO/MU),          000001
00150  C      11 SHEAR, 12 ETA, 13 GAMMA, 14 PITOT TUBE PRESSURE.                            000001
00150  C      NOTE FOR PLOTTING PURPOSES THE FOLLOWING VALUES OF IP AND THEIR                000001
00150  C      CORRESPONDING CHARACTERS ARE GIVEN: 35 = (PLOTTING DOT), 43 = (SMALL           000001
00150  C      CIRCLE), 34 = +, 5 = (BLANK), 40 = *, 20 = 0, 48 = O, 39 = $, 23 = Q,          000001
00150  C      62 = (SMALL SQUARE), 61 = (PERIOD), 46 = ,(COMMA), 33 = -, 58 = ',             000001
00150  C      36 = =, 3 AND 4 GIVE SMALL CIRCULAR SYMBOLS.                                   000001
00150  C      COMPOUNDS IN LOW TEMPERATURE EXTENSION ARRAY ARE: 1 = OH, 2 = H,               000001
00150  C      3 = HO2, 4 = H2, 5 = H2O2, 6 = O, 7 = O2, 8 = H2O, 9 = N2, 10 = AR             000001
00150  C                                                                                     000001
00151         DIMENSION FUEL(7),OX(7),TF(60)                                  ANK 5/83      000001
00152         EQUIVALENCE (G,GW),(TU(121),TF)                                 ANK 4/83      000001
00153         INTEGER ASU,ATA,ATB,ATC,BSU,CASE,FLDX,SUBLT                                   000001
00154         LOGICAL LOWT                                                                  000001
00155         REAL LAMDAW,LAMTAB,MR                                           ANK 4/83      000001
00156         DATA FUEL,MR,OX/15*0.0/,LOWT/F/,NCASE,NTAL/0,0/,ZP/-1.0/        ANK 7/83      000001
00156  C                                                                                    000001
00166         NAMELIST /DATA/ ALPH,ALTAB,ASU,ATA,ATB,ATC,BASMOL,BSU,CBAR,CLNUM,  /DATA/     000001
00166        1         COEF,COEFCL,CPL,CPLTAB,DPDX,DSIP,DUB8,DUDX,ELCON,EMIST,   /DATA/     000001
00166        2         EMIV,ENHTAB,EPOVRK,ETA,F,FF,FFAR,FITMOL,FLDX,FLMASS,      /DATA/     000001
00166        3    FLUXJ,FUEL,F2FIX,F2FIXT,G,GE,GG,GW,HCHAR,HFU,HL,HOX,HPYG,HTEF, /DATA/     000001
00166        4         HW,IADD,IAREA,IBODY,ICOOL,IDERIV,IDIFF,IENH,IETA,IFIT,    /DATA/     000001
00166        5         IFLOW,IFRAC,IGUESS,ILSP,INEW,IP,IPLOT,IPP,IPUNCH,ISN,     /DATA/     000001
00166        6         IST,ITCOOL,ITDK,ITEMP,ITHERM,ITHICK,ITLINP,IU,IUNIT,      /DATA/     000001
00166        7         IWALL,JWALL,KAPPA,KAPPAT,KAT,KEDGP,KONRFT,KR9,KS,KTURB,   /DATA/     000001
00166        8     KU,LAMDAW,LAMTAB,LEF,LOWT,MR,MS,N,NC,NEL,NETA,NETAT,NFF,NP,   /DATA/     000001
00166        9         NPCON,NPLOT,NPOINT,NS,NSP,NSTAT,NSTP,NTAL,NTH,NTROPY,OX,  /DATA/     000001
00166        A         PCHAMB,PITAB,PNORM,PRA,PRB,PRC,PRD,PRDUM,PRE,PRT,RADFL,   /DATA/     000001
00166        B         RADR,RATLIM,RECOFT,RETR,RHOVW,ROKAP,RTM,S,SCT,SIGMA,SL,   /DATA/     000001
00166        C         SP,SPW,SUBLT,TF,THITAB,TJ,TJA,TKP,TKT,TL,TLINP,TLTAB,     /DATA/     000001
00166        D         TOLQW,TUBEN,TW,VITAB,VMUA,VMUB,VMUC,VMUD,WAT,WMS,XAREA,   /DATA/     000001
00166        $ IPART,RP,WP,WF,RHOPA,CPART,ILAMIN,                                        NEW000001
00166        E         XENH,XITAB,XLTAB,XTHIK,YAP,YITAB,ZMUTAB,ZP,FMF,ICF,RK     /DATA/  NEW000001
00167         NAMELIST /OUT/ ALPH,BASMOL,CBAR,CLNUM,COEFCL,DUB8,ELCON,EMIST,     /OUT/    -01000001
00167        1         EMIV,EPOVRK,ETA,F,FFAR,FITMOL,FLMASS,FUEL,F2FIX,F2FIXT,   /OUT/      000001
00167        2         G,GE,GW,HCHAR,HFU,HOX,HPYG,HTEF,HW,IADD,IAREA,IBODY,      /OUT/      000001
00167        3         ICOOL,IDERIV,IDIFF,IENH,IETA,IFIT,IFLOW,IFRAC,IGUESS,     /OUT/      000001
00167        4         INEW,IP,IPLOT,IPP,IPUNCH,IST,ITCOOL,ITDK,ITEMP,ITHERM,    /OUT/      000001
00167        5         ITHICK,ITLINP,IU,IUNIT,IWALL,JWALL,KAPPA,KAPPAT,KEDGP,    /OUT/      000001
00167        6         KONRFT,KR9,KS,KTURB,KU,LAMDAW,LEF,LOWT,MR,MS,N,NC,NEL,    /OUT/      000001
00167        7         NETA,NETAT,NFF,NP,NPCON,NPLOT,NPOINT,NS,NSP,NSTAT,NSTP,   /OUT/      000001
00167        8         NTAL,NTH,NTROPY,OX,PCHAMB,PNORM,PRA,PRB,PRC,PRD,PRDUM,    /OUT/      000001
00167        9         PRE,PRT,RADFL,RADR,RATLIM,RECOFT,RETR,RHOVW,ROKAP,RTM,    /OUT/      000001
00167        A         S,SCT,SIGMA,TJ,TJA,TKP,TOLQW,TUBEN,TW,VMUA,VMUB,VMUC,     /OUT/      000001
00167        B         VMUD,WAT,WMS,YAP,ZP                                       /OUT/      000001
00170         NAMELIST /ARRAYS/ ALTAB,CPL,CPLTAB,DSIP,ENHTAB,FLUXJ,HL,ILSP,    /ARRAYS/    000001
00170        1         LAMTAB,SL,SP,TF,THITAB,TKT,TL,TLINP,XAREA,XENH,XLTAB,   /ARRAYS/    000001
00170        2         XTHIK,ZMUTAB                                            /ARRAYS/    000001
00170  C                                                                                    000001
00171         WRITE (6,NW) NIT,MURD,IOR,ITA,MAIN,IND,MOEG,ITE,LLAW,IDAT,IND,   ANK 7/83    000001
00171        1 IROC,IRE,LLAW,IDAT,IND,ITE,NTOR,IDAT,LOT,IND,IRE,NTOR,IDAT,NIT,   ANK 7/83    000001
00171        2 MURD,IOR,ITA,MAIN,IND,IOUT,ITE,IED,IDAT,LOT,IND,IRE,IED,IDAT,NIT,ANK 7/83    000001
00171        3     MURD,IOR,ITA,MAIN,IND,IOUT,ITE,LIF,IDAT,LOT,IND,IRE,          ANK 7/83    000001
00171        4     LIF,IDAT,NIT,MURD,IOR,LOT,ISAV,ITA,LOT,ITE,LLA,LOT,           ANK 7/83    000001
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00171          5     IDAT,NIT,MURD,IOR,NCH,ISAV,ITA,IROC,ITE,LLA,NCH,IDAT         ANK 7/83     000001
00307         46  MWE = -1                                                                    000137
00310             READ (5,1,END=50) CASE                                                      000140
00313          1  FORMAT (13A6)                                                               000151
00314             READ (5,DATA,END=50)                                                        000151
00317             IF (ZP .GT. 0.0)  WRITE (6,ARRAYS)                              ANK 3/83     000156
00323             IF (ZP .GE. 0.0)  WRITE (6,OUT)                                 ANK 3/83     000165
00327             IF (NEL .LE. 8 .AND. NSP .LE. 7)  GO TO 25                      ANK 8/83     000174
00331             WRITE (6,3) NEL,NSP                                             ANK 8/83     000212
00335          3  FORMAT (//10X,'NEL MUST BE .LE. 8, NEL =',I2,                   ANK 8/83     000221
00335            1 '     NSP MUST BE .LE. 7, NSP =',I2//)                         ANK 8/83     000221
00336             NEL = MIN0(NEL,8)                                               ANK 8/83     000221
00337             NSP = MIN0(NSP,7)                                               ANK 8/83     000227
00340         25  IF (MR .LE. 0.0)  GO TO 30                                      ANK 8/83     000236
00342             IF (NTAL .GT. 0)  GE = (MR*HOX + HFU)/(MR + 1.0)                ANK 4/83     000240
00342       C     CALCULATE RELATIVE NUMBER OF ATOMS FROM THE MIXTURE RATIO AND THE           000240
00342       C     NUMBER OF EACH ELEMENT IN THE OXIDIZER AND FUEL                             000240
00344             OK = 0.0                                                        ANK 5/83     000255
00345             FK = 0.0                                                        ANK 5/83     000256
00346             DO 10 J = 1,NSP                                                 ANK 5/83     000262
00351             FK = FK + FUEL(J)*WAT(J)                                        ANK 5/83     000262
00352         10  OK = OK + OX(J)*WAT(J)                                          ANK 5/83     000265
00354             AMNO = MR*FK/OK                                                 ANK 5/83     000272
00355             AMWP = FK + AMNO*OK                                             ANK 5/83     000275
00356             AMNOS = AMNO/AMWP                                               ANK 5/83     000300
00357             AMNFS = 1.0/AMWP                                                ANK 5/83     000302
00360             DO 20 J = 1,NSP                                                 ANK 5/83     000310
00363         20  TKP(J,1) = AMNOS*OX(J) + AMNFS*FUEL(J)                          ANK 5/83     000310
00365             CMR = AMNOS*OK/(AMNFS*FK)                                       ANK 5/83     000316
00366             WRITE (6,2) CMR,MR                                              ANK 5/83     000324
00372          2  FORMAT (//10X,'COMPUTED MIXTURE RATIO =',F10.6,'   INPUT MIXTURE',ANK 5/83     000334
00372            1        ' RATIO =',F10.6//)                                     ANK 5/83     000334
00373         30  NCASE = NCASE + 1                                               ANK 5/83     000334
00374             NSJ = 15 + NSP                                                              000336
00374       C     IF LOW TEMPERATURE EXTENSION DATA HAS BEEN READ IN, CONVERT IT              000336
00374       C     TO INTERNALLY REQUIRED UNITS                                                000336
00375             IF (LOWT)  CALL LTCPHS                                                      000341
00377             IF (NCASE .GT. 1)  REWIND 2                                     ANK 7/83     000345
00401             IF (IPLOT .EQ. 0)  GO TO 45                                                 000354
00403             IF (NCASE .LE. 1)  GO TO 35                                     ANK 7/83     000356
00405             REWIND 3                                                                    000362
00406             REWIND 4                                                                    000365
00407         35  NSTAT(NS) = 1                                                   ANK 7/83     000371
00410             IF (IWALL .NE. 7)  GO TO 45                                     ANK 4/83     000373
00412             NPLOT(7) = 0                                                                000376
00413             NPLOT(12) = 0                                                               000377
00414         45  IS = 1                                                          ANK 5/83     000401
00415             IQ = 1                                                                      000402
00416             IF (ICOOL .NE. 0 .AND. ICON .EQ. 0)  IRITE = 0                              000404
00420             IF (IPLOT .EQ. 0 .OR. ICOOL .NE. 0)  IPASS = 1                              000415
00422             IF (ICON .EQ. 1 .AND. IPLOT .NE. 0)  IPASS = 0                              000427
00424         41  CALL SETUP                                                                  000443
00425          43 CALL ITERAT                                                     BLIM 031     000445
00426             CALL OUTPUT                                                     BLIM 032     000446
00427             IF (NON)  43,44,15                                                          000450
00432         44  ISH = IS                                                        ANK 5/83     000454
00433             IQ = IQ + 1                                                                 000456
00434             IS = IS + 1                                                     ANK 5/83     000461
00435             IF (NP(IS) .EQ. NTH)  NSTAT(IS) = 1                             ANK 5/83     000464
00437             IF (KQ10 + IS .EQ. -10)  KQ10 = 1                               ANK 5/83     000474
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```
00441              IF (IS .EQ. NS)  IRITE = 1                        ANK 5/83    000502
00443              IF (IS .LE. NS)  GO TO 41                         ANK 5/83    000507
00445              IS = NS                                           ANK 5/83    000513
00446              IF (ICOOL .EQ. 0 .OR. ICON .EQ. 1)  GO TO 15                  000515
00450              CALL SATEMP                                                   000527
00451              GO TO 45                                                      000531
00452          15  IF (NP(IS) .LE. NTH)  GO TO 46                    ANK 8/83    000533
00454              CALL ROCOUT                                       ANK 8/83    000537
00455              IF (IPLOT .GT. 0)  CALL PLOT                                  000541
00457              GO TO 46                                                      000546
00460          50  IF (IPUNCH .NE. 1 .AND. IPUNCH .NE. 2)  CALL EXIT  ANK 8/83   000550
00462              J = 0                                             ANK 8/83    000565
00463              WRITE (15) J                                      ANK 8/83    000566
00466              END                                               BLIM 038    000575

     END OF COMPILATION:        NO  DIAGNOSTICS.
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```
@SYS$*MSFCFOR$.FOR,WUS NNNCER
HSA  E3 -12/10/84-22:23:55 (31,32)
-20
     $ ,HF(15,5),XI(50)
-28,28-
/251),S(50)                        /151),RADS(50),ROKAP(50),S(50)/
-30,30-
/30),RHOP(15),TP          /15),RHO(15),RHOP(15),TP/
-34
      COMMON/ACCN/ACCPK,ILAM,SPCT
      COMMON/ACPK/ACCPK1,ACCPK2
      COMMON/RETH/RETHMO
      COMMON/RUF/DUMM1,DUMM2,DUMM3,DUMM4,DUMM5,DUMM6,DUMM7,DUMM8,DUMM9,
     $ DUMM10,DUMM11,DUMM12,RK,ICF,FMF,DUMM16,DUMM17,DUMM18
      COMMON/PARTI/PARTM,DUMM24,RHOPA,DUMM23,CPART,WP,DUMM19,WF,
     $ DUMM22,DUMM20,DUMM21,ILT,PF,AK,RP,IPART
      COMMON /LAM/ ILAMIN
-313
      RETHMO=-C3M(IS)*RHOE(IS)*UE(IS)*CTE*VMUE(IS)/VMU(NETA)
      ACCP=BETAV(IS)*VMUE(IS)**2*ROKAP(IS)**2/2.0/XI(IS)
      ACCPK=ACCP*RHOE(IS)*VMU(1)/(VMUE(IS)*RHO(1))
      IF(ILAMIN.EQ.0)GO TO 79
      ILAM=0
      IF(S(IS).GT.2.*STURB.AND.ACCPK.GT.1.1E-06)GO TO 69
      GO TO 79
69    IF(RETHMO.LT.250.)GO TO 79
      ILAM=1
      AA=8.935E-14
      BB=2.239E-10
      CC=1.0247E-06
      ACCPK1=AA*RETHMO**2+BB*RETHMO+CC
      IF(RETHMO.LT.4100.)GO TO 98
      ILAM=0
      GO TO 99
 98   ACCPK2=3.5E-06
 99   IF(ACCPK.LT.ACCPK1)ILAM=0
      IF(ACCPK.GT.ACCPK2)ILAM=1
 79   CONTINUE
-320
      IF(RETHMO.GT.RETR)ILT=2
-321
      IF(RETHMO.LT.RETR)ILT=1


   SUBROUTINE NNNCER     ENTRY POINT 002554
              NONCER     ENTRY POINT 002557


   STORAGE USED: CODE(1) 002562; DATA(0) 000142; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003    BLQCOM 002043
    0004    BUMCOM 000004
    0005    COECOM 000014
    0006    COECON 000247
    0007    CONSTS 000003
    0010    CRBCOM 000110
    0011    EDGCOM 001216
    0012    EPSCOM 000042
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0013    EQPCOM 000433
0014    EQTCOM 001427
0015    ERRCOM 000622
0016    ETACOM 002631
0017    FLXCOM 000020
0020    HISCOM 000426
0021    INPUTI 000015
0022    INTCOM 000123
0023    INTERI 000006
0024    NONCOM 035532
0025    NZERO  000001
0026    PRMALS 000145
0027    PRMORG 000455
0030    PRPCOM 000303
0031    PRPNPT 000076
0032    SAVNCR 000175
0033    TURB   000001
0034    VARCOM 000645
0035    WALL   000226
0036    ACCN   000003
0037    ACPK   000002
0040    RETH   000001
0041    RUF    000022
0042    PARTI  000020
0043    LAM    000001


 EXTERNAL REFERENCES (BLOCK, NAME)

0044    EQUIL
0045    STATE
0046    LINCER
0047    TRMBL
0050    IMONE
0051    TVCM1
0052    ICOEFF
0053    TVCCOE
0054    IONLY
0055    TVCI
0056    LIAD
0057    ABMAX
0060    RERAY
0061    RNLCER
0062    NERR3$


 STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001    000067 10L       0001    000626 100L      0001    001141 1001L     0001    000163 11L       0001    000157 12L
0001    000642 120L      0001    001022 145L      0001    000056 167G      0001    000113 202G      0001    000137 216G
0001    000204 230G      0001    000206 234G      0001    001163 244L      0001    000247 251G      0001    000345 270G
0001    000346 273G      0001    000025 3L        0001    000364 302G      0001    000417 317G      0001    000426 325G
0001    000435 331G      0001    000501 354G      0001    000504 360G      0001    000513 364G      0001    000030 4L
0001    000604 417G      0001    000671 441G      0001    000672 444G      0001    001002 470G      0001    001033 500G
0001    001114 512G      0001    001117 516G      0001    001134 526G      0001    000373 53L       0001    001173 535G
0001    000401 54L       0001    001274 560G      0001    001304 565G      0001    001324 574G      0001    000424 58L
0001    000544 60L       0001    001350 605G      0001    001204 605L      0001    001376 614G      0001    001407 621G
0001    001445 629L      0001    001425 630G      0001    001472 642G      0001    001474 645G      0001    001512 654G
0001    001520 660G      0001    001663 665L      0001    001545 671G      0001    001703 673L      0001    001720 675L
0001    002320 69L       0001    001572 701G      0001    001617 704G      0001    001624 710G      0001    001646 717G
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0001 002022 740L	0001 002005 747G	0001 002077 760G	0001 002121 765L	0001 002127 770L
0001 002163 775G	0001 002366 79L	0001 002406 850L	0001 000612 95L	0001 002351 98L
0001 002353 99L	0014 R 000044 A	0000 R 000020 AA	0000 R 000017 ACCP	0036 R 000000 ACCPK
0037 R 000000 ACCPK1	0037 R 000001 ACCPK2	0042 000015 AK	0034 R 000000 ALPH	0020 R 000000 ALPHD
0024 R 000000 AM	0010 I 000000 ASU	0013 000000 ATA	0016 R 000321 BA1	0016 R 001727 BA2
0000 R 000021 BB	0020 R 000001 BETAP	0020 R 000063 BETAV	0010 I 000003 BSU	0004 R 000000 BUMP
0022 000000 CASE	0022 R 000015 CBAR	0000 R 000022 CC	0006 000000 CK1	0006 R 000006 CK6
0012 000000 CLNUM	0024 R 000000 CORAR	0032 R 000000 CORMA	0026 000000 COSALF	0042 000004 CPART
0007 R 000000 CPFL	0000 R 000015 CTE	0020 R 000145 C1	0005 R 000005 C10	0005 000006 C12
0005 R 000007 C13	0005 000010 C14	0020 000146 C2	0020 R 000147 C3M	0005 R 000013 C32
0005 R 000000 C5	0005 R 000001 C6	0005 R 000002 C7	0005 R 000003 C8	0005 R 000004 C9
0030 000255 DCAPCH	0024 R 035431 DLPH	0024 R 035441 DLPK	0007 000001 DPR	0030 R 000000 DRHOH
0030 R 000001 DRHOK	0015 R 000612 DRNL	0011 000000 DSIP	0030 R 000254 DTH	0024 R 035521 DTHW
0030 R 000037 DTK	0024 R 035522 DTKW	0000 R 000012 DUB	0011 R 000062 DUEDGE	0000 R 000014 DUM
0041 000000 DUMM1	0041 000011 DUMM10	0041 000012 DUMM11	0041 000013 DUMM12	0041 000017 DUMM16
0041 000020 DUMM17	0041 000021 DUMM18	0042 000006 DUMM19	0041 000001 DUMM2	0042 000011 DUMM20
0042 000012 DUMM21	0042 000010 DUMM22	0042 000003 DUMM23	0042 000001 DUMM24	0041 000002 DUMM3
0041 000003 DUMM4	0041 000004 DUMM5	0041 000005 DUMM6	0041 000006 DUMM7	0041 000007 DUMM8
0041 000010 DUMM9	0032 R 000001 DVNL	0004 R 000001 EASE	0015 R 000375 ELMM	0010 R 000007 EMISC
0010 000010 EMIST	0010 R 000011 EMIV	0015 R 000376 ENL	0015 R 000571 ELNM	0015 R 000601 ENLMM
0012 R 000021 EPSA	0014 R 000000 EQT	0016 R 000000 ETA	0034 R 000001 F	0015 R 000000 FLE
0035 R 000000 FLUXJ	0041 000016 FMF	0003 000000 FR	0034 R 000075 G	0007 R 000002 GC
0026 R 000144 GE	0011 R 000063 GEP	0015 R 000053 GLE	0031 R 000000 HB	0010 R 000014 HCARB
0010 R 000015 HCHAR	0011 R 000064 HE	0020 000231 HF	0031 R 000017 HP	0010 R 000020 HPG
0010 R 000021 HPYG	0022 I 000016 I	0021 000000 IBODY	0041 000015 ICF	0032 I 000174 ICORM
0027 000000 IDISC	0015 I 000602 IENLM	0021 I 000005 IFLOW	0021 I 000006 IGUESS	0021 000007 IH
0036 I 000001 ILAM	0043 I 000000 ILAMIN	0042 I 000013 ILT	0000 000077 INJP$	0042 000017 IPART
0022 I 000017 IQ	0022 I 000020 IS	0022 000021 ISH	0014 I 000016 ISP	0010 I 000025 ISU
0022 I 000022 ITS	0021 I 000011 IWALL	0000 I 000010 IX	0004 I 000002 I777	0000 I 000001 J
0000 I 000013 JJ	0021 000012 JW	0000 I 000004 K	0022 I 000023 KAPPA	0023 000000 KBC
0023 I 000001 KCC	0000 I 000000 KK	0022 000024 KONRFT	0023 I 000003 KQ10	0023 I 000002 KQ9
0022 I 000025 KR9	0010 I 000026 KS	0023 000004 KSB	0023 I 000005 KSOL	0000 I 000005 L
0016 I 000126 LAR	0003 I 001606 LEF	0003 I 001616 LEFS	0000 I 000016 LPI	0003 I 001604 L2
0003 I 001605 L3	0000 I 000002 M	0022 I 000107 MAT1I	0022 I 000110 MAT1J	0022 I 000111 MAT2I
0000 I 000006 MM	0003 I 001646 MOA	0003 I 001742 MOB	0022 000112 MWE	0000 I 000003 MX
0000 I 000007 N	0022 I 000113 NAM	0013 I 000432 NEL	0022 I 000114 NETA	0022 I 000115 NNLEQ
0022 000116 NON	0022 I 000117 NRNL	0022 000120 NS	0022 I 000121 NSP	0003 I 002036 NSPEC
0022 I 000122 NSPM1	0021 I 000014 NTROPY	0025 I 000000 NUL	0014 000017 P	0042 000000 PARTM
0011 R 000065 PE	0042 000014 PF	0003 R 002037 PIEASE	0030 R 000000 PREQ	0031 000020 QR
0017 R 000007 QW	0014 000350 R	0027 000227 RADS	0040 R 000000 RETHMO	0012 R 000041 RETR
0031 R 000037 RHO	0011 R 000147 RHOE	0031 R 000056 RHOP	0042 000002 RHOPA	0041 000014 RK
0027 R 000311 ROKAP	0042 000016 RP	0027 R 000373 S	0000 R 000011 SFE	0034 R 000152 SP
0036 000002 SPCT	0015 R 000111 SPLE	0033 R 000000 STURB	0014 R 001237 TC	0024 R 035530 TCW
0031 R 000075 TP	0017 R 000017 TPWALL	0011 R 000767 TTVC	0011 000770 TVCC	0011 R 001052 UE
0017 R 000010 VJKW	0014 R 001333 VLNK	0024 R 035531 VLNKW	0030 R 000264 VMU	0011 R 001134 VMUE
0003 R 002040 W	0017 R 000001 WALLJ	0017 R 000000 WALLQ	0004 R 000003 WDOT	0042 000007 WF
0042 000005 WP	0020 R 000344 XI	0006 R 000242 XM		

```
00101      1*          SUBROUTINE NNNCER                                                        000000
00101      2*    C                                                                              000000
00103      3*          COMMON /BLQCOM/ FR(900),L2,L3,LEF(8),LEFS(24),MOA(60),MOB(60),   /BLQCOM/   000000
00103      4*         1                NSPEC,PIEASE,W(3)                               /BLQCOM/   000000
00104      5*          COMMON /BUMCOM/ BUMP,EASE,I777,WDOT                              /BUMCOM/   000000
00105      6*          COMMON /COECOM/ C5,C6,C7,C8,C9,C10,C12,C13,C14(3),C32            /COECOM/   000000
00106      7*          COMMON /COECON/ CK1(6),CK6(156),XM(5)                            /COECON/   000000
00107      8*          COMMON /CONSTS/ CPFL,DPR,GC                                      /CONSTS/   000000
00110      9*          COMMON /CRBCOM/ ASU(3),BSU(4),EMISC,EMIST,EMIV(3),HCARB,HCHAR(3), /CRBCOM/  000000
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00110        1               HPG,HPYG(4),ISU,KS(50)                                    /CRBCOM/      000000
00111         COMMON /EDGCOM/ DSIP(50),DUEDGE,GEP,HE,PE(50),RHOE(400),TTVC,            /EDGCOM/      000000
00111        1               TVCC(50),UE(50),VMUE(50)                                  /EDGCOM/      000000
00112         COMMON /EPSCOM/ CLNUM(17),EPSA(16),RETR                                  /EPSCOM/      000000
00113         COMMON /EQPCOM/ ATA(282),NEL                                             /EQPCOM/      000000
00114         COMMON /EQTCOM/ EQT(14),ISP,P(21),A(14,14),R(439),TC(60),VLNK(60) /EQTCOM/      000000
00115         COMMON /ERRCOM/ FLE(43),GLE(30),SPLE(30,6),ELMM,ENL(123),ENLM(8),  /ERRCOM/      000000
00115        1               ENLMM,IENLM(8),DRNL(8)                                    /ERRCOM/      000000
00116         COMMON /ETACOM/ ETA(86),LAR(123),BA1(43,18),BA2(30,15)                   /ETACOM/      000000
00117         COMMON /FLXCOM/ WALLQ,WALLJ(6),QW,VJKW(7),TPWALL                         /FLXCOM/      000000
00120         COMMON /HISCOM/ ALPHD,BETAP(50),BETAV(50),C1,C2,C3M(50)                  /HISCOM/      000000
00120        $ ,HF(15,5),XI(50)                                                                 NEW000000
00121         COMMON /INPUTI/ IBODY(5),IFLOW,IGUESS,IH(2),IWALL,JW(2),NTROPY           /INPUTI/      000000
00122         COMMON /INTCOM/CASE(13),CBAR,I,IQ,IS,ISH,ITS,KAPPA,KONRFT,KR9(50),/INTCOM/      000000
00122        1 MAT1I,MAT1J,MAT2I,MWE,NAM,NETA,NNLEQ,NON,NRNL,NS,NSP,NSPM1              /INTCOM/      000000
00123         COMMON /INTERI/ KBC,KCC,KQ9,KQ10,KSB,KSOL                                /INTERI/      000000
00124         COMMON/NONCOM/AM(123,123),DLPH(8),DLPK(6,8),DTHW,DTKW(6),TCW,VLNKW/NONCOM/      000000
00125         COMMON /NZERO/ NUL                                                       /NZERO/       000000
00126         COMMON /PRMALS/ COSALF(100),GE                                           /PRMALS/      000000
00127         COMMON /PRMORG/ IDISC(151),RADS(50),ROKAP(50),S(50)                      /PRMORG/ NEW000000
00130         COMMON /PRPCOM/ DRHOH,DRHOK(30),DTK(141),DTH,DCAPCH(7),VMU(15)           /PRPCOM/ -01000000
00131         COMMON /PRPNPT/ HB(15),HP,QR(15),RHO(15),RHOP(15),TP                     /PRPNPT/ NEW000000
00132         COMMON /SAVNCR/ CORMA,DVNL(123),ICORM                                    /SAVNCR/ -01000000
00133         COMMON /TURB/ STURB                                                      /TURB/        000000
00134         COMMON /VARCOM/ ALPH,F(15,4),G(15,3),SP(15,3,7)                          /VARCOM/      000000
00135         COMMON /WALL/ FLUXJ(3,50)                                                /WALL/        000000
00136         COMMON/ACCN/ACCPK,ILAM,SPCT                                                       NEW000000
00137         COMMON/ACPK/ACCPK1,ACCPK2                                                         NEW000000
00140         COMMON/RETH/RETHMO                                                                NEW000000
00141         COMMON/RUF/DUMM1,DUMM2,DUMM3,DUMM4,DUMM5,DUMM6,DUMM7,DUMM8,DUMM9,                 NEW000000
00141        $ DUMM10,DUMM11,DUMM12,RK,ICF,FMF,DUMM16,DUMM17,DUMM18                             NEW000000
00142         COMMON/PARTI/PARTM,DUMM24,RHOPA,DUMM23,CPART,WP,DUMM19,WF,                        NEW000000
00142        $ DUMM22,DUMM20,DUMM21,ILT,PF,AK,RP,IPART                                          NEW000000
00143         COMMON /LAM/ ILAMIN                                                               NEW000000
00143  C                                                                                           000000
00144         DIMENSION CORAR(1),PREQ(1)                                               ANK 4/83      000000
00145         EQUIVALENCE (AM,CORAR),(DRHOH,PREQ)                                      ANK 4/83      000000
00146         INTEGER ASU,BSU                                                                      000000
00146  C                                                                                           000000
00147         EASE=AMIN1(EASE*2.,1.0)                                                              000000
00150         IF (ITS .NE. 1)  GO TO 11                                                            000006
00152         EASE = 1.0/3.0                                                           ANK 8/83      000011
00153         BUMP = 1.0                                                               B05A0740      000013
00154         IF (IQ .LE. 1)  GO TO 3                                                  ANK 5/83      000015
00156         IF (WDOT .LT. 0.0)  GO TO 4                                                          000021
00160       3 WDOT=-.12/C1                                                                         000025
00161       4 PIEASE=1.                                                                            000030
00162         ICORM = 1                                                                B05A0760      000031
00163         CORMA = 1.E + 10                                                         B05A0770      000033
00164         IF (KR9(IS) .GT. 0)  IWALL = KR9(IS)                                     ANK 4/83      000035
00166         DO 17 I = 1,NETA                                                                     000056
00171      17 EPSA(I)=0.                                                                           000056
00173         IF (IWALL - 2)  11,10,9                                                  ANK 4/83      000057
00176       9 FLUXJ(3,IS) = -1.0                                                                   000063
00177      10 ISP = NEL + 1                                                            ANK 5/83      000067
00200         KK=MAXO(1,KS(IS))                                                                    000071
00201         DO 13 J = 1,3                                                            ANK 6/83      000104
00204      13 W(J) = FLUXJ(J,IS)                                                       ANK 6/83      000113
00206         L2=2*KK                                                                              000115
00207         L3=L2+1                                                                              000120
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```
00210          IF (IWALL .LE. 2)  GO TO 11                                   ANK 4/83    000122
00212          HPG = HPYG(KK)                                                            000126
00213          EMISC=EMIV(KK)                                                            000130
00214          HCARB=HCHAR(KK)                                                           000132
00215          DO 12 J=ISP,NSPEC                                                         000137
00220          IF (MOA(J) .NE. ASU(KK) .OR. MOB(J) .NE. BSU(KK))  GO TO 12               000137
00222          ISU = J                                                                   000153
00223          GO TO 11                                                                  000155
00224       12 CONTINUE                                                                  000160
00226          ISU=ISP                                                                   000160
00226    C     INITIALIZE AM MATRIX AND ENL ARRAY; COMPUTE COEFF. FOR NONLINEAR EQUATIONS 000160
00227     11   DO 15 I = 1,123                                               ANK 4/83    000163
00232          ENL(I)=0.                                                                 000204
00233          DO 15 J=1,NNLEQ                                               B05A0860    000206
00236       15 AM(I,J) = 0.                                                  B05A0870    000206
00236    C     EVAL. GROUPINGS WHICH CHANGE DURING ITERATION BUT ARE NOT F(ETA) B05A0880 000206
00241          C5 = 1.0/ALPH                                                             000214
00242          C6 = ALPH**2*BETAP(IS)                                        ANK 7/83    000217
00243          C7 = -UE(IS)**2/ALPH**2/(CPFL*GC)                             ANK 4/83    000222
00244          C8 = ALPHD * C5                                               B05A0980    000231
00245          C9 = BETAV(IS) + C1 - C8                                      ANK 8/83    000234
00245    C     FINALLY, EVAL CONTRIBUTIONS TO AM AND ERRORS FROM OTHER COEFFS B05A1140   000234
00245    C---- START OF MAJOR DO LOOP FOR EVAL OF COEFFS AND ERRORS AT EACH ETA B05A1290  000234
00246          KCC = 2                                                       ANK 4/83    000240
00247          KSOL = 0                                                      ANK 4/83    000242
00250          DO 49 I=1,NETA                                                            000247
00253          M = MAT1J + I - NETA                                          ANK 8/83    000247
00254          MX = NETA - 1                                                 ANK 8/83    000253
00255          HB(I) = G(I,1) + C7*F(I,2)**2/2.0                             ANK 5/83    000256
00256          HP = G(I,2) + C7*F(I,2)*F(I,3)                                            000264
00257          IF (IFLOW .LE. 0)  CALL EQUIL (HB(I),PE(IS))                  ANK 5/83    000271
00261          IF (IFLOW .GT. 0)  CALL STATE                                 ANK 4/83    000307
00263          IF (I .GT. 1)  GO TO 54                                                   000314
00265          IF (NSPM1 .LE. 0)  GO TO 53                                               000330
00267          DO 52 K = 1,NSPM1                                                         000333
00272          DO 31 KK = 1,NEL                                              ANK 5/83    000346
00275       31 DLPK(K,KK) = A(KK+2, K+2)                                                 000346
00277       52 DTKW(K)= DTK(K)                                                           000350
00301          DO 32 KK = 1,NEL                                              ANK 5/83    000364
00304       32 DLPH(KK)= A(KK+2,1)                                                       000364
00306          VLNKW=VLNK(ISU)                                                           000366
00307          TCW=TC(ISU)                                                               000370
00310       53 DTHW=DTH                                                                  000373
00311          M=116                                                                     000374
00312          MX=1                                                                      000376
00313       54 RHOP(I)=DRHOH*HP                                                          000401
00314          IF (NSPM1 .LE. 0)  GO TO 58                                               000405
00316          DO 57 K = 1,NSPM1                                                         000410
00321     57   RHOP(I) = RHOP(I) + DRHOK(K)*SP(I,2,K)                                    000417
00323       58 L=0                                                                       000424
00323    C-----UPPER LIMIT IS MAX NUMBER OF SPECIES (MXNSP) =LAST DIM ON SP              000424
00324          DO 49 MM=1, 7                                                             000426
00327          M=M+MX                                                                    000426
00327    C-----UPPER LIMIT CORRESPONDS TO DIMENSIONS ON AM ARRAY                         000426
00327    C     LOWER LIMIT IS UPPER LIMIT (123) MINUS (2*7 + 11 + 4/7 OR 25) (123 - 25)  000426
00330          DO 49 N=98,123                                                            000430
00333          L=L+1                                                                     000435
00334       49 AM(M,N)=PREQ(L)                                                           000440
00340          RETURN                                                                    000447
00340    C                                                                               000447
```

```
00341              ENTRY NONCER                                                            000452
00342              DUEDGE=0.                                                               000452
00343              GEP=0.                                                                  000453
00344              HE = GE                                                  ANK 4/83       000454
00345              CALL LINCER                                                             000456
00346              IF (KQ10 .GT. 0)  CALL TRMBL(2)                          ANK 4/83       000460
00350              TTVC=1.0                                                                000466
00351              M=116                                                                   000470
00352              MX=1                                                                    000472
00353              DO 120 I=1,NETA                                          B05A1300       000501
00356              L=0                                                                     000501
00357              DO 59 MM=1, 7                                            B05B           000504
00362              M=M+MX                                                                  000504
00363              DO 59 N= 98,123                                          B05B           000506
00366              L=L+1                                                                   000513
00367              PREQ(L)=AM(M,N)                                                         000515
00370           59 AM(M,N)=0.                                                              000520
00370        C     TEST TO BYPASS COMMANDS THAT CANNOT BE PERFORMED AT ETA(1)   B05A1310   000520
00373              IF (I .LE. 1)  GO TO 60                                                 000523
00375              CALL IMONE                                                              000527
00376              IF (KQ9 .NE. 0)  CALL TVCM1                              ANK 4/83       000531
00400              IF (KQ10 .GT. 0)  CALL TRMBL(4)                          ANK 4/83       000535
00400        C     COMPUTE STATIC ENTHALPY AND DETERMINE STATE OF GAS      B05A1340       000535
00402           60 C10 = C7*F(I,2)                                                         000544
00403              C13 = C7*F(I,3)                                                         000546
00404              HP = C13*F(I,2) + G(I,2)                                                000551
00404        C---- EVAL GROUPINGS WHICH ARE USED AT I-1 AS WELL AS AT I     B05A1460       000551
00405              CALL ICOEFF                                                             000554
00406              IF (KQ9 .NE. 0)  CALL TVCCOE                             ANK 4/83       000556
00410              IF (KQ10 .GT. 0)  CALL TRMBL(3)                          ANK 4/83       000562
00412              IF (I .NE. 1)  GO TO 100                                                000570
00412        C     DLPK,TCW,VLNKW,DLPH, AND Y1 NEEDED ONLY FOR CARBON PROBLEM   B05A1490   000570
00414              IF (NSPM1 .LE. 0)  GO TO 95                                             000574
00416              DO 90 K = 1,NSPM1                                                       000577
00421              WALLJ(K) = CK6(K)                                        B05A1520       000604
00422           90 VJKW(K) = CK6(K)/C3M(IS)                                 ANK 8/83       000605
00424           95 WALLQ = C32                                              B05A1620       000612
00425              QW = C32/C3M(IS)                                         ANK 8/83       000614
00426              TPWALL = TP                                                             000617
00427              MX = NETA - 1                                            ANK 8/83       000621
00430              GO TO 120                                                ANK 4/83       000624
00430        C---- BACK TO CONSERVATION EQUATIONS                           B05A1650       000624
00431          100 CALL IONLY                                               B05A1660       000626
00432              IF (KQ10 .GT. 0)  CALL TRMBL(5)                          ANK 4/83       000627
00434              IF (KQ9 .NE. 0)  CALL TVCI                               ANK 4/83       000635
00436          120 M=MAT1J+I-MX                                                            000642
00440              DO 122 I=2,4                                                            000647
00443              DO 122 J=1,NNLEQ                                                        000672
00446          122 AM(I,J)=0.                                                              000672
00451              ENL(4)= F(NETA,2) - ALPH                                 ANK 4/83       000677
00452              AM(4,1) = 1.0                                            ANK 4/83       000702
00453              AM(4,MAT1J)=-1.                                                         000704
00454              ENL(3) = - F(1,2)                                                       000707
00455              AM(3,4)=1.                                                              000711
00456              ENL(2) = CBAR*(F(NETA,2) - (ETA(NETA) - ETA(KAPPA))*F(NETA,3)) -   ANK 4/83   000713
00456            1              F(KAPPA,2)                                  ANK 4/83       000713
00457              IF (NTROPY .EQ. 0)  ENL(2) = CBAR*F(NETA,2) - F(KAPPA,2) ANK 4/83       000724
00461              AM(2,KAPPA+3)=1.                                                        000734
00462              AM(2,MAT1J)=-CBAR                                                       000737
00463              IF (NTROPY .EQ. 5)  CALL LIAD (-1,2,2*NETA-2,(ETA(NETA) -   ANK 4/83    000742
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00463              1                         ETA(KAPPA))*CBAR)          ANK 4/83    000742
00465               IF (ITS .GT. 1)  GO TO 145                          ANK 5/83    000771
00467               DO 140 K = 1,NSP                                                001002
00472          140  IF (LEFS(K) .LE. 0 .AND. LEF(K) .GT. 0)  EASE = 0.050           001002
00475          145  M = 2                                               ANK 4/83    001022
00476               MM=MAT1J-1                                                      001023
00477               DO 200 I=1,NRNL                                                 001033
00502               CALL ABMAX(MM-1,ENL(M),ENLM(I),IENLM(I))                        001034
00503               IENLM(I) = IENLM(I)+1                                           001053
00504               M=M+MM                                                          001056
00505          200  MM = NETA - 1                                       ANK 8/83    001061
00505       C       SOLVE REDUCED SET OF EQUATIONS                      B05A2070    001061
00507               IF (IGUESS .LT. 0)  RETURN                          ANK 4/83    001066
00507       C       SCRUNTCH DEFINED ROWS OF AM MATRIX TO THE TOP       B05A2090    001066
00511               DO 240 M=1,NAM                                      B05A2130    001074
00514               ENL(M)=ENL(M+1)                                                 001114
00515               DO 240 J=1,NNLEQ                                                001117
00520          240  AM(M,J)=AM(M+1,J)                                               001117
00523               IF (KQ10 .LE. 0)  GO TO 1001                        ANK 4/83    001126
00525               DO 1000 M = 4,NAM                                               001134
00530         1000  AM(M,3) = AM(M,3) + ENL(M)/F(1,3)                               001134
00530       C       THE FOLLOWING ROUTINE REARRANGES COLUMNS OF THE NOW RECTANGULAR   B05A2250    001134
00530       C       AM MATRIX,ACCORDING TO LAR,INVERTS((AM(I,J),J=2,NAM),I=1,NAM) AND B05A2260    001134
00530       C       MULTIPLIES THE INVERSE TIMES THE REMAINING COLUMNS OF AM MATRIX   B05A2270    001134
00530       C       AND TIMES THE ENL.                                  B05A2280    001134
00532         1001  CALL RERAY (NAM,AM,NSP+1,ENL,1,LAR,IX,123,EQT,EQT(106),EQT(219),  ANK 4/83    001141
00532              1           EQT(332),EQT(445))                       ANK 4/83    001141
00532       C       TREAT SURFACE OPTIONS IN RNLCER WITH REDUCED NONLINEAR SET      001141
00533          244  CALL RNLCER                                         ANK 4/83    001163
00533       C       DETERMINE MAXIMUM NONLINEAR ERRORS                  B05A4010    001163
00534               DO 605 I = 1,NRNL                                               001164
00537               IF (ABS(ENLM(I)) .GE. ABS(DRNL(I)))  GO TO 605                  001173
00541               ENLM(I) = DRNL(I)                                               001177
00542               IENLM(I) = 1                                                    001201
00543          605  CONTINUE                                                        001205
00545               SFE = ALPH*AMAX1(ABS(BETAP(IS)),0.10)               ANK 7/83    001205
00546               DUB = AMAX1(ABS(G(NETA,1) - G(1,1)),1.0E3)                      001214
00547               ENLM(1) = ENLM(1)/SFE                                           001224
00550               ENLM(2) = ENLM(2)/DUB                                           001227
00551               CALL ABMAX (NRNL,ENLM,ENLMM,M)                                  001232
00552               ENLMM = ENLMM/10.                                               001240
00553               ENLM(1) = ENLM(1)*SFE                                           001243
00554               ENLM(2) = ENLM(2)*DUB                                           001246
00555               ELMM = ABS(ELMM)                                    B05A4160    001251
00556               ENLMM = ABS(ENLMM)                                  ANK 4/83    001253
00556       C       EVALUATE NONLINEAR CORRECTIONS FROM THE REDUCED SET B05A4180    001253
00557               DO 615 I=1,NAM                                      B05A4190    001274
00562               L = LAR(I)                                          B05A4200    001274
00563               DVNL(L) = ENL(I)                                    B05A4210    001276
00564               DO 615 K=1,NRNL                                     B05A4220    001304
00567               J = K + NAM                                         B05A4230    001304
00570          615  DVNL(L) = DVNL(L) - DRNL(K) * AM(I,J)               B05A4240    001307
00573               DO 620 K=1,NRNL                                     B05A4250    001324
00576               I = NAM + K                                         B05A4260    001324
00577               J = LAR(I)                                          B05A4270    001327
00600          620  DVNL(J) = DRNL(K)                                   B05A4280    001332
00600       C-----RECYCLE IF ALPH WANTS TO GO NEGATIVE                              001332
00602               IF (DVNL(1) .GT. -0.90*ALPH)  GO TO 629                         001337
00604               DO 627 K=NUL,NSPM1                                              001350
00607               WALLJ(K) = VJKW(K)*C3M(IS)                          ANK 8/83    001350
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00610        627 ENL(K+117)=0.                                                             001352
00612            JJ = NAM + 1                                                              001354
00613            DO 628 I=2,NNLEQ                                                          001357
00616            DUM=AM(I,1)/AM(1,1)                                                       001376
00617            ENL(I)=ENL(I)-ENL(1)*DUM                                                  001400
00620            DO 628 J = JJ,NNLEQ                                                       001407
00623        628 AM(I,J)=AM(I,J)-DUM*AM(1,J)                                               001407
00626            ENL(1)=0.                                                                 001420
00627            DO 631 J = JJ,NNLEQ                                                       001425
00632        631 AM(1,J)=0.                                                                001425
00634            ITS=ITS+1                                                                 001426
00635            EASE = AMIN1(EASE,0.2)                                                    001431
00636            IF (ITS - 101)  244,244,850                                               001437
00636       C-----EVALUATE LINEAR CORRECTIONS                                  B05A4300    001437
00641        629  DO 630 I = 1,MAT1I                                                       001445
00644            DO 630 J=1,MAT1J                                              B05A4320    001474
00647        630 FLE(I) = FLE(I) - DVNL(J) * BA1(I,J)                          B05A4330    001474
00652            JJ = MAT1J                                                    B05A4340    001505
00653            DO 635 J = 1,NETA                                             ANK 8/83    001512
00656            JJ = JJ + 1                                                   B05A4360    001512
00657            DO 635 I=1,MAT2I                                              B05A4370    001514
00662        635 GLE(I) = GLE(I) - DVNL(JJ) * BA2(I,J)                         B05A4380    001520
00665            CORAR(1)=DVNL(1)/ALPH*0.5                                                 001530
00666            L=NETA                                                                    001534
00667            J=MAT1J+2                                                                 001536
00670            DO 640 I=2,NETA                                                           001545
00673            CORAR(I) = DVNL(J)/AMAX1(G(NETA,1),1.0E4)                                 001546
00674        640 J=J+1                                                                     001556
00676            IF (NSPM1 .LE. 0)  GO TO 665                                              001562
00700            DO 655 K = 1,NSPM1                                                        001565
00703            DO 650 J = 1,NETA                                             ANK 8/83    001617
00706            JJ = JJ + 1                                                   B05A4460    001617
00707            DO 650 I=1,MAT2I                                              B05A4470    001621
00712        650 SPLE(I,K) = SPLE(I,K) - DVNL(JJ) * BA2(I,J)                   B05A4480    001624
00715            J = MAT1J + K*NETA + 2                                        ANK 8/83    001637
00716            DO 655 I=2,NETA                                               B05A4510    001646
00721            L = L + 1                                                     B05A4520    001646
00722            CORAR(L)=DVNL(J)                                                          001652
00723        655 J=J+1                                                                     001654
00726        665  IF (EASE .LT. 0.20)  GO TO 673                                           001663
00730            IF (CORAR(ICORM)/CORMA .LT. -0.330)  BUMP = 2.0*BUMP                      001666
00732            GO TO 675                                                                 001701
00733        673  IF (ABS(1.0 - CORAR(ICORM)/CORMA) .LE. 0.250)  BUMP = BUMP/2.0           001703
00735        675 CALL ABMAX(L,CORAR,CORMA,ICORM)                               B05A4580    001720
00735       C    CORRECT PRIMARY VARIABLES                                                 001720
00736            DUM = 0.050/BUMP                                              ANK 4/83    001725
00737            EASE=AMIN1(1.5*EASE,1.0,DUM/ABS(CORMA))                                   001730
00740            IF(ITS.EQ.2) BUMP=AMAX1(BUMP,.02/ABS(CORMA))                              001745
00742            IF (KQ10 .GT. 0) EASE=AMIN1(ABS(F(1,3)/(DVNL(3)+1.E-30)/2.),EASE) ANK 6/83    001760
00744            IF (EASE .GE. 1.0)  GO TO 740                                 ANK 4/83    001776
00746            DO 730 I = 1,253                                                          002005
00751            IF (I .LE. 123)  DVNL(I) = DVNL(I)*EASE                       ANK 7/83    002005
00753        730 FLE(I) = FLE(I) * EASE                                        B05A4800    002014
00755        740  PIEASE = PIEASE*(1.0 - EASE)                                             002022
00756            CTE = F(NETA,1) - F(1,1) - XM(5)/F(NETA,2)                                002025
00757            DO 785 I = 1,NETA                                                         002077
00762            F(I,2) = F(I,2) + DVNL(I+3)                                               002077
00763            F(I,4) = F(I,4) + FLE(2*NETA+I-2)                                         002102
00764            IF (I .GT. 1)  GO TO 765                                                  002105
00766            F(1,1) = F(1,1) + DVNL(2)                                                 002111
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00767            F(1,3) = F(1,3) + DVNL(3)                                               002114
00770            GO TO 770                                                               002117
00771       765  F(I,1) = F(I,1) + FLE(I-1)                                              002121
00772            F(I,3) = F(I,3) + FLE(NETA+I-2)                                         002123
00773       770 LPI=MAT1J+I+1                                                            002127
00774            DO 785 K=NUL,NSPM1                                                      002132
00777            IF (I .EQ. NETA)  SP(I,1,K) = SP(I,1,K) + SPLE(1,K)                     002165
01001            IF (I .NE. NETA)  SP(I,1,K) = SP(I,1,K) + DVNL(LPI)                     002172
01003            SP(I,3,K) = SP(I,3,K) + SPLE(NETA+I,K)                                  002201
01004            IF (I .LE. 1)  SP(1,2,K) = SP(1,2,K) + DVNL(LPI-1)                      002210
01006            IF (I .GT. 1)  SP(I,2,K) = SP(I,2,K) + SPLE(I,K)                        002216
01010       785  LPI = LPI + NETA                                          ANK 8/83      002223
01013            ALPH=ALPH+DVNL(1)                                                       002242
01014            RETHMO=-C3M(IS)*RHOE(IS)*UE(IS)*CTE*VMUE(IS)/VMU(NETA)               NEWO02245
01015            ACCP=BETAV(IS)*VMUE(IS)**2*ROKAP(IS)**2/2.0/XI(IS)                   NEWO02255
01016            ACCPK=ACCP*RHOE(IS)*VMU(1)/(VMUE(IS)*RHO(1))                         NEWO02266
01017            IF(ILAMIN.EQ.O)GO TO 79                                              NEWO02274
01021            ILAM=0                                                               NEWO02276
01022            IF(S(IS).GT.2.*STURB.AND.ACCPK.GT.1.1E-06)GO TO 69                   NEWO02277
01024            GO TO 79                                                             NEWO02316
01025      69    IF(RETHMO.LT.250.)GO TO 79                                           NEWO02320
01027            ILAM=1                                                               NEWO02323
01030            AA=8.935E-14                                                         NEWO02325
01031            BB=2.239E-10                                                         NEWO02327
01032            CC=1.0247E-06                                                        NEWO02331
01033            ACCPK1=AA*RETHMO**2+BB*RETHMO+CC                                     NEWO02333
01034            IF(RETHMO.LT.4100.)GO TO 98                                          NEWO02342
01036            ILAM=0                                                               NEWO02346
01037            GO TO 99                                                             NEWO02347
01040      98    ACCPK2=3.5E-06                                                       NEWO02351
01041      99    IF(ACCPK.LT.ACCPK1)ILAM=0                                            NEWO02353
01043            IF(ACCPK.GT.ACCPK2)ILAM=1                                            NEWO02357
01045      79    CONTINUE                                                             NEWO02366
01046            IF (ITS .NE. 99 .OR. I777 .EQ. 777)  GO TO 850                          002366
01050            I777 = 777                                                              002401
01051            ITS = 60                                                                002403
01052      850   IF (KQ10 .GT. -1 .OR. KQ10 .LT. -10)  RETURN              ANK 4/83      002406
01054            RETHMO = -C3M(IS)*RHOE(IS)*UE(IS)*CTE*VMUE(IS)/VMU(NETA)  ANK 8/83      002426
01055            IF (RETHMO.GT.RETR) STURB = S(IS)                                       002440
01057            IF (RETHMO .GT. RETR)  KQ10 = -10                         ANK 4/83      002447
01061            IF(RETHMO.GT.RETR)ILT=2                                              NEWO02455
01063            IF (RETHMO .LT. RETR)  KQ10 = -1                          ANK 4/83      002463
01065            IF(RETHMO.LT.RETR)ILT=1                                              NEWO02471
01067            RETURN                                                    BO5A5350      002477
01070            END                                                       BO5A5360      002561

        END OF COMPILATION:        NO  DIAGNOSTICS.
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@SYS$*MSFCFOR$.FOR,WUS OUTPUT
HSA  E3 -12/10/84-22:24:00 (39,40)
-8,8
      COMMON/EDGCOM/DSP(53),PE(50),RHOE(350),TE(51),TVCC(50),UE(50),
     $ VMUE(50)
-30
      COMMON/RUF/DUMM1,DUMM2,DUMM3,DUMM4,DUMM5,DUMM6,DUMM7,DUMM8,DUMM9,
     $ DUMM10,DUMM11,DUMM12,RK,ICF,FMF,DUMM16,DUMM17,DUMM18
      COMMON/PARTI/PARTM,DUMM24,RHOPA,DUMM23,CPART,WP,DUMM19,WF,
     $ DUMM22,DUMM20,DUMM21,ILT,PF,AK,RP,IPART
      COMMON /LAM/ ILAMIN
-37
      COMMON/ACCN/ACCPK,ILAM,SPCT
      COMMON/RETH/RETHMO
      DIMENSION DM1(15),DM2(15)
-99,99-
\///\/\
-196
      IF(IPART.EQ.1)GO TO 40
      IF(ICF.GT.O.AND.ICF.LT.3)GO TO 40
      GO TO 41
 40   DUMM1=DER(11)*2.
      DUMM2=DER(12)
      DUMM3=S(IS)
      AM=F(NETA,2)/ALPH*UE(IS)/SQRT(GMR(NETA)/VMW(NETA)*TT(NETA)*49732.)
      REFF=(1.+(GMR(NETA)-1.)/2.*PR(NETA)**.333*AM**2)/
     $ (1.+(GMR(NETA)-1.)/2.*AM**2)
      DO 42 I=1,NETA
      DM1(I)=CPBAR(I)*UCT/UCE
      DM2(I)=TT(I)/UCT
42    CONTINUE
      DZERO=DM1(1)-(DM1(2)-DM1(1))/(DM2(2)-DM2(1))*DM2(1)
      AINT=O.5*(DZERO+DM1(1))*DM2(1)
      DUMM6=AINT
      DO 43 I=2,NETA
      AINT=AINT+O.5*(DM1(I-1)+DM1(I))*(DM2(I)-DM2(I-1))
43    CONTINUE
      DUMM4=AINT
      DUMM5=(DUMM4+(G(NETA,1)-HB(NETA)/UCE))*REFF
      DUMM7=RHO(NETA)
      DUMM8=RHO(1)
      DUMM9=VMU(1)
      DUMM10=VMUE(IS)
      DUMM11=PR(NETA)
      DUMM12=UE(IS)
      IF(IPART.EQ.1.AND.(ICF.EQ.O.OR.ICF.EQ.3))GO TO 41
      AFACT=O.52
      CALL ROUGH(AFACT)
      CF=DUMM18/2.
      ST=DUMM16
      WALLQ=ST*(G(NETA,1)-G(1,1))*RHOE(IS)*UE(IS)
 41   CONTINUE
      IF(IPART.EQ.1)GO TO 45
      GO TO 44
 45   IF(ICF.EQ.O.OR.ICF.EQ.3)GO TO 46
      DUMM1=DUMM18
      DUMM2=DUMM16
 46   CONTINUE
      DUMM5=G(NETA,1)
      DUMM6=G(1,1)
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      DUMM19=CPBAR(NETA)*UCT/UCE
      DUMM20=REFF*TE(1)/UCT
      DUMM21=TT(1)/UCT
      DUMM22=DUMM19*VMU(NETA)/UCV/DUMM11
      DUMM23=(DUMM7*DUMM12*2.*ROKAP(IS)/RAD5)/DUMM10
      PARTM=(4./3.)*(22./7.)*((RP/12.)**3)*RHOPA
      DUMM24=PARTM*DUMM12/((22./7.)*6.*RP/12.*DUMM10)
      CALL PARTCL
      CF=DUMM18/2.
      ST=DUMM16
      WALLQ=ST*(G(NETA,1)-G(1,1))*RHOE(IS)*UE(IS)
 44   CONTINUE
-204
      IF(IPASS.EQ.0) WRITE(3)CF,CH,WALLQ
-235
      ACCPK=ACCP*RHOE(IS)*VMU(1)/(VMUE(IS)*RHO(1))
-240
      IF(ICF.EQ.0)GO TO 1111
      WRITE(6,1009)
1009  FORMAT(/,1X,56('*'),' REMTECH INC. 11-84 ',56('*'))
1010  FORMAT(/,1X,132('*'))
      WRITE(6,1000)ICF,RK
1000  FORMAT(/,2X,'ROUGHNESS MODULE USED  -  OPTION ',I2,/,
     $ 6X,'EQUIVALENT SAND ROUGHNESS HEIGHT,   RK = ',E10.3,'(FEET)')
      IF(ICF.EQ.3)GO TO 1112
      RFACT=DUMM16/DUMM2
      IF(DUMM17.EQ.0.0)WRITE(6,1001)RFACT
      IF(DUMM17.GT.0.0.AND.DUMM17.LT.1.0)WRITE(6,1002)RFACT
      IF(DUMM17.EQ.1.0)WRITE(6,1003)RFACT
1001  FORMAT(6X,'SMOOTH',14X,20X,'ROUGHNESS FACTOR = ',F7.3)
1002  FORMAT(6X,'TRANSITIONALLY ROUGH',20X,'ROUGHNESS FACTOR = ',F7.3)
1003  FORMAT(6X,'ROUGH',15X,20X,'ROUGHNESS FACTOR = ',F7.3)
      WRITE(6,1008)CF,ST,WALLQ
1008  FORMAT(1X,'          CF/2=',1PE10.3,5X,'  ST NO. =',1PE10.3,5X,
     $ 'HEAT FLUX=',1PE10.3)
      GO TO 1111
1112  CONTINUE
      IF(ABS(DUMM17).LE.0.001)WRITE(6,1004)
      IF(ABS(DUMM17-1.).LE.0.001)WRITE(6,1005)
      IF(ABS(DUMM17-2.).LE.0.001)WRITE(6,1006)
1004  FORMAT(6X,'SMOOTH')
1005  FORMAT(6X,'ROUGH')
1006  FORMAT(6X,'RKS BEYOND UPPER LIMIT - EQUATION BECOMES INVALID - ',
     $ 'THEREFORE RKS = 0.0 WAS USED.')
      WRITE(6,1010)
1111  CONTINUE
      IF(IPART.EQ.1)GO TO 1301
      GO TO 1302
1301  WRITE(6,1009)
      IF(ILT.EQ.1)WRITE(6,1303)RP,AK,PF
1303  FORMAT(/,2X,'PARTICLE MODULE USED',/,6X,'LAMINAR FLOW',5X,
     $ 'PARTICLE SIZE RP=',E10.3,'IN RADIUS',/,1X,'PARTICLE LOADING =',
     $ F10.2,10X,'PARTICLE FACTOR =',F10.4)
      IF(ILT.EQ.2)WRITE(6,1305)RP,WP,PF
1305  FORMAT(/,2X,'PARTICLE MODULE USED',/,6X,'TURBULENT FLOW',5X,
     $ 'PARTICLE SIZE RP=',E10.3,'IN RADIUS',/,1X,'PARTICLE LOADING =',
     $ F10.2,10X,'PARTICLE FACTOR =',F10.4)
      WRITE(6,1008)CF,ST,WALLQ
      WRITE(6,1010)
1302  CONTINUE
```

```
      IF(ILAMIN.EQ.O.OR.ILAM.EQ.O)GO TO 1211
      WRITE(6,1009)
      WRITE(6,1200)SPCT
1200  FORMAT(/,2X,'RELAMINARIZATION  OCCURED',/,
     $ 2X,'DEGREE OF RELAMINARIZATION = ',E10.3,' PERCENT')
      WRITE(6,1010)
1211  CONTINUE
      WRITE(6,1007)RETHMO,ACCP,ACCPK
1007  FORMAT(/,1X,'      RETHMO  ACCN PARA ACCN PARA',/,1X,
     $ '               (EDGE)    (WALL)',/, 3X,1P3E10.3)
```

SUBROUTINE OUTPUT   ENTRY POINT 003775

STORAGE USED: CODE(1) 004015; DATA(0) 001251; BLANK COMMON(2) 000000

COMMON BLOCKS:

0003	AL	000002
0004	BLQCOM	002043
0005	COECON	000317
0006	CONSTS	000010
0007	CRBCOM	000111
0010	EDGCOM	001216
0011	EPSCOM	000040
0012	EQPCOM	002243
0013	ETACOM	000017
0014	FLXCOM	000020
0015	HISCOM	000426
0016	HOLLER	000056
0017	INPUTI	000015
0020	INTCOM	000123
0021	INTERI	000004
0022	PRMALS	000243
0023	PRMORG	000455
0024	PRPCOM	000303
0025	PRPERT	000151
0026	PRPIOP	000016
0027	PRPNPT	000056
0030	RFTCOM	000045
0031	RUF	000022
0032	PARTI	000020
0033	LAM	000001
0034	SAHA	000151
0035	SAVOUT	000021
0036	TEMCOM	000201
0037	TURB	000020
0040	UNICOM	000011
0041	VARCOM	000645
0042	WALL	000454
0043	ACCN	000003
0044	RETH	000001

EXTERNAL REFERENCES (BLOCK, NAME)

0045	ROUGH
0046	PARTCL
0047	REFIT

```
0050    ATAN2
0051    COS
0052    NWDU$
0053    NIO1$
0054    NIO3$
0055    NIO2$
0056    NWBU$
0057    SQRT
0060    XPRR
0061    NERR3$

STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000    000111 1F         0000    000413 1000F      0000    000437 1001F      0000    000450 1002F      0000    000463 1003F
0000    000512 1004F      0000    000515 1005F      0000    000520 1006F      0000    000650 1007F      0000    000474 1008F
0000    000377 1009F      0000    000410 1010F      0001    002343 1111L      0001    002277 1112L      0001    002544 1155G
0001    002552 1163G      0000    000722 12F        0000    000630 1200F      0001    002447 1211L      0001    002641 1220G
0001    002653 1231G      0000    001070 13F        0001    002347 1301L      0001    002417 1302L      0000    000540 1303F
0000    000574 1305F      0001    003101 1307G      0001    003107 1313G      0001    003115 1317G      0001    003127 1330G
0000    001122 14F        0001    003255 1406G      0001    003273 1417G      0001    003302 1425G      0001    003313 1434G
0001    003324 1442G      0001    003363 1453G      0001    003364 1456G      0001    003423 1472G      0000    001134 15F
0001    003432 1500G      0001    003554 1537G      0001    003562 1544G      0001    003603 1553G      0001    003614 1561G
0001    003654 1577G      0000    001141 16F        0001    003667 1605G      0001    003707 1615G      0001    000041 166G
0000    001145 17F        0000    000215 18F        0001    003035 184L       0001    003173 185L       0000    000151 2F
0000    001002 20F        0001    000541 2021L      0001    000123 204G       0001    003377 2041L      0001    001041 2071L
0001    001047 2074L      0001    001224 2078L      0000    000330 21F        0001    000260 2103L      0001    000246 2104L
0001    000271 2105L      0001    000317 2106L      0001    000556 2135L      0001    000625 2137L      0000    000374 22F
0000    000205 23F        0000    000326 24F        0000    001103 25F        0001    000334 262G       0000    000212 3F
0001    000371 30L        0001    000047 3051L      0001    000433 314G       0001    000436 316G       0001    000444 323G
0001    003460 325L       0001    003744 327L       0001    000477 336G       0001    000513 347G       0001    000707 35L
0001    000516 352G       0001    000574 373G       0000    000263 4F         0001    001334 40L        0001    000604 400G
0001    000457 400L       0001    003623 4002L      0001    003700 4012L      0001    003534 4019L      0001    003565 4021L
0001    003630 4022L      0001    000607 404G       0001    001543 41L        0001    000661 423G       0001    000673 431G
0001    001657 44L        0001    001547 45L        0001    000776 455G       0001    001565 46L        0001    001007 463G
0000    001062 5F         0001    002074 50L        0001    001070 502G       0001    001205 514G       0001    001275 525G
0001    002477 55L        0001    001415 551G       0001    001444 563G       0000    000671 6F         0001    003227 60L
0001    001707 642G       0001    003343 65L        0001    001745 664G       0001    001763 674G       0000    000726 7F
0001    001775 704G       0001    002023 717G       0001    002040 730G       0001    002070 746G       0000    001010 8F
0015    000000 A          0000 R  000062 ACCP       0043 R  000000 ACCPK      0000 R  000055 ACH        0000 R  000047 ADR
0000 R  000101 AFACT      0000 R  000000 AINT       0032 R  000015 AK         0041 R  000000 ALPH       0000 R  000076 AM
0016 I  000000 AREA       0000 R  000057 ARET       0007    000000 ASU        0012 I  000000 ATA        0012 I  000010 ATB
0015 R  000001 BETAP      0015 R  000063 BETAV      0000 R  000073 BLOW       0015    000146 C          0025 R  000000 CAPC
0020    000000 CASE       0000 R  000064 CF         0000 R  000063 CH         0005    000000 CK         0011    000000 CLNUM
0036 R  000000 CM         0000 R  000106 COND       0022 R  000000 COSALF     0000 R  000044 COSOR      0032    000004 CPART
0025 R  000017 CPBAR      0006    000000 CPFL       0034 R  000000 CPH        0016 I  000002 CQ         0026 R  000000 CRHO
0015 R  000145 C1         0015 R  000147 C3M        0000 R  000045 C89        0000 R  000072 DELBD      0000 R  000067 DELST
0022 R  000062 DELTBD     0016 I  000006 DENS       0036 R  000007 DER        0000 R  000075 DF         0016 I  000010 DIST
0011 R  000001 DL         0000 R  000001 DM1        0000 R  000020 DM2        0024    000000 DRHOH      0010    000000 DSP
0036 R  000071 DUDS       0031 R  000000 DUMM1      0031 R  000011 DUMM10     0031 R  000012 DUMM11     0031 R  000013 DUMM12
0031 R  000017 DUMM16     0031 R  000020 DUMM17     0031 R  000021 DUMM18     0032 R  000006 DUMM19     0031 R  000001 DUMM2
0032 R  000011 DUMM20     0032 R  000012 DUMM21     0032 R  000010 DUMM22     0032 R  000003 DUMM23     0032 R  000001 DUMM24
0031 R  000002 DUMM3      0031 R  000003 DUMM4      0031 R  000004 DUMM5      0031 R  000005 DUMM6      0031 R  000006 DUMM7
0031 R  000007 DUMM8      0031 R  000010 DUMM9      0000 R  000066 DUM3       0000 R  000074 DUZ        0000 R  000105 DW
0000 R  000054 DX         0000 R  000100 DZERO      0007 R  000006 EMIS       0007    000007 EMISC      0016 I  000012 ENERGY
0035 R  000000 ENTHAL     0011 R  000021 EPSA       0013 R  000000 ETA        0041 R  000001 F          0000 I  000037 FLOW
0042    000000 FLUXJ      0031    000016 FMF        0004 R  000000 FR         0030 R  000000 F2FIX      0030 R  000017 F2FIXT
0041 R  000075 G          0006 R  000002 GC         0025 R  000036 GMR        0027 R  000000 HB         0000 R  000056 HEAD
0016 I  000016 HEAT       0015 R  000231 HF         0016 I  000022 HWALL      0000 I  000051 I          0017    000000 IB
0031 I  000015 ICF        0023    000000 IDISC      0017 I  000005 IFLOW      0017    000006 IG         0043 I  000001 ILAM
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0033 I 000000 ILAMIN     0032 I 000013 ILT        0000   001211 INJP$      0032 I 000017 IPART      0034 I 000063 IPASS
0003   000000 IPLOT      0034 I 000064 IRITE      0020 I 000020 IS         0020   000021 ISH        0022 I 000147 IST
0007 I 000025 ISU        0017 I 000007 ITDK       0017   000010 ITH        0034   000065 ITRCNT     0022   000150 IU
0003 I 000001 IUNIT      0017 I 000011 IWALL      0000 I 000060 J          0017   000012 JW         0000 I 000046 K
0020 I 000023 KAPPA      0030 I 000036 KAPPAL     0030 I 000037 KAPPAT     0021   000000 KBC        0020 I 000024 KONRFT
0021 I 000003 KQ10       0021 I 000002 KQ9        0020   000025 KR9        0007   000026 KS         0030 I 000040 KTURB
0004   001604 L2         0000 I 000110 M          0016 I 000024 MASS       0004 I 001646 MOA        0004 I 001742 MOB
0012 I 000432 NEL        0020 I 000114 NETA       0030 I 000041 NETAL      0030 I 000042 NETAT      0020   000115 NNLEQ
0020 I 000116 NON        0030   000043 NPOINT     0020   000117 NRNL       0020 I 000120 NS         0034 I 000066 NSJ
0020 I 000121 NSP        0004 I 002036 NSPEC      0020 I 000122 NSPM1      0017 I 000014 NTROPY     0000 I 000043 NUM
0012   000433 P          0032 R 000000 PARTM      0006 R 000003 PATM       0010 R 000065 PE         0032 R 000014 PF
0006   000004 PI         0004   002037 PIEASE     0000 R 000104 PITOT      0000 R 000061 POUT       0025 R 000055 PR
0000 I 000041 PRES       0016 I 000030 PRESS      0000 R 000053 QDIFU      0034 R 000067 QWG        0022   000156 RADFL
0023 R 000227 RADS       0022 R 000154 RAD5       0022 R 000155 RAD6       0030 R 000044 RATLIM     0000 R 000077 REFF
0044 R 000000 RETHMO     0016 I 000034 REY        0000 R 000103 RFACT      0027 R 000037 RHO        0010 R 000147 RHOE
0032 R 000002 RHOPA      0042 R 000372 RHOVW      0031 R 000014 RK         0023 R 000311 ROKAP      0032 R 000016 RP
0022 R 000157 RTM        0006 R 000006 RVAR       0023 R 000373 S          0025 R 000074 SC         0000 R 000052 SHEAD
0016 I 000036 SHEAR      0000 R 000050 SHFAC      0006 R 000007 SIPSF      0041 R 000152 SP         0043 R 000002 SPCT
0000 R 000102 ST         0007 R 000110 STEF       0037   000000 STURB      0022 R 000160 SUMQG      0016 I 000040 TCON
0010 R 000705 TE         0016 I 000044 TEMP       0036 R 000153 THELEM     0000 R 000070 THENGY     0000 R 000071 THMOM
0016 I 000046 THRUST     0014 R 000017 TPWALL     0025 R 000113 TT         0037 R 000001 TURPR      0010 R 000770 TVCC
0040 R 000000 UCD        0040 R 000001 UCE        0040 R 000002 UCL        0040 R 000003 UCM        0000 R 000065 UCMF
0040 R 000004 UCP        0040 R 000005 UCR        0040 R 000006 UCS        0040 R 000007 UCT        0040 R 000010 UCV
0010 R 001052 UE         0035 R 000001 UKAPPA     0016 I 000050 VEL        0016 I 000052 VIS        0000 R 000107 VISC
0014 R 000010 VJKW       0024 R 000264 VMU        0010 R 001134 VMUE       0025 R 000132 VMW        0012 R 001176 VNU
0004 R 002040 W          0035 R 000020 WALLA      0014 R 000001 WALLJ      0014 R 000000 WALLQ      0012 R 002136 WAT
0032   000007 WF         0032 R 000005 WP         0012 R 002147 WTM        0005 R 000247 XG         0015 R 000344 XI
0005 R 000242 XM         0005 R 000254 XSP        0022 R 000161 XST        0036 R 000162 Y
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00101        SUBROUTINE OUTPUT                                                      B11A 002     000000
00101    C                                                                                       000000
00103        COMMON /AL/ IPLOT,IUNIT                                                 /AL/        000000
00104        COMMON /BLQCOM/ FR(60,15),L2(34),MOA(60),MOB(60),NSPEC,PIEASE,W(3)/BLQCOM/          000000
00105        COMMON /COECON/ CK(162),XM(5),XG(5),XSP(5,7)                           /COECON/     000000
00106        COMMON /CONSTS/ CPFL(2),GC,PATM,PI(2),RVAR,SIPSF                       /CONSTS/     000000
00107        COMMON /CRBCOM/ ASU(6),EMIS,EMISC(14),ISU,KS(50),STEF                  /CRBCOM/     000000
00110        COMMON/EDGCOM/DSP(53),PE(50),RHOE(350),TE(51),TVCC(50),UE(50),                   NEW000000
00110       $ VMUE(50)                                                                        NEW000000
00111        COMMON /EPSCOM/ CLNUM,DL(16),EPSA(15)                                  /EPSCOM/  -01000000
00112        COMMON/EQPCOM/ATA(8),ATB(274),NEL,P(355),VNU(60,8),WAT(9),WTM(60) /EQPCOM/         000000
00113        COMMON /ETACOM/ ETA(15)                                                /ETACOM/     000000
00114        COMMON /FLXCOM/ WALLQ,WALLJ(7),VJKW(7),TPWALL                          /FLXCOM/     000000
00115        COMMON /HISCOM/ A,BETAP(50),BETAV(50),C1,C,C3M(50),HF(15,5),XI(50)/HISCOM/          000000
00116        COMMON /HOLLER/ AREA(2),CQ(2,2),DENS(2),DIST(2),ENERGY(4),HEAT(2, /HOLLER/          000000
00116       1 2),HWALL(2),MASS(2,2),PRESS(4),REY(2),SHEAR(2),TCON(2,2),TEMP(2),/HOLLER/          000000
00116       2 THRUST(2),VEL(2),VIS(2,2)                                             /HOLLER/     000000
00117        COMMON /INPUTI/ IB(5),IFLOW,IG,ITDK,ITH,IWALL,JW(2),NTROPY             /INPUTI/     000000
00120        COMMON /INTCOM/ CASE(16),IS,ISH(2),KAPPA,KONRFT,KR9(55),               /INTCOM/     000000
00120       1                NETA,NNLEQ,NON,NRNL,NS,NSP,NSPM1                       /INTCOM/     000000
00121        COMMON /INTERI/ KBC(2),KQ9,KQ10                                        /INTERI/     000000
00122        COMMON /PRMALS/ COSALF(50),DELTBD(53),IST,IU(4),                       /PRMALS/     000000
00122       1                RAD5,RAD6,RADFL,RTM,SUMQG,XST(50)                      /PRMALS/     000000
00123        COMMON /PRMORG/ IDISC(151),RADS(50),ROKAP(50),S(50)                    /PRMORG/     000000
00124        COMMON /PRPCOM/ DRHOH(180),VMU(15)                                     /PRPCOM/     000000
00125        COMMON /PRPERT/ CAPC(15),CPBAR(15),GMR(15),PR(15),SC(15),TT(15),       /PRPERT/     000000
00125       1                VMW(15)                                                /PRPERT/     000000
00126        COMMON /PRPIOP/ CRHO(14)                                               /PRPIOP/     000000
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00127         COMMON /PRPNPT/ HB(31),RHO(15)                                      /PRPNPT/     000000
00130         COMMON /RFTCOM/ F2FIX(15),F2FIXT(15),KAPPAL,KAPPAT,KTURB,NETAL,     /RFTCOM/     000000
00130        1              NETAT,NPOINT,RATLIM                                   /RFTCOM/     000000
00131         COMMON/RUF/DUMM1,DUMM2,DUMM3,DUMM4,DUMM5,DUMM6,DUMM7,DUMM8,DUMM9,               NEW000000
00131        $ DUMM10,DUMM11,DUMM12,RK,ICF,FMF,DUMM16,DUMM17,DUMM18                           NEW000000
00132         COMMON/PARTI/PARTM,DUMM24,RHOPA,DUMM23,CPART,WP,DUMM19,WF,                      NEW000000
00132        $ DUMM22,DUMM20,DUMM21,ILT,PF,AK,RP,IPART                                        NEW000000
00133         COMMON /LAM/ ILAMIN                                                             NEW000000
00134         COMMON /SAHA/ CPH(51),IPASS,IRITE,ITRCNT,NSJ,QWG(50)                  /SAHA/     000000
00135         COMMON /SAVOUT/ ENTHAL,UKAPPA(15),WALLA                             /SAVOUT/     000000
00136         COMMON /TEMCOM/ CM(7),DER(50),DUDS(50),THELEM(7),Y(15)              /TEMCOM/     000000
00137         COMMON /TURB/ STURB,TURPR(15)                                         /TURB/     000000
00140         COMMON /UNICOM/ UCD,UCE,UCL,UCM,UCP,UCR,UCS,UCT,UCV                 /UNICOM/     000000
00141         COMMON /VARCOM/ ALPH,F(15,4),G(15,3),SP(15,3,7)                     /VARCOM/     000000
00142         COMMON /WALL/ FLUXJ(250),RHOVW(50)                                    /WALL/     000000
00143         COMMON/ACCN/ACCPK,ILAM,SPCT                                                     NEW000000
00144         COMMON/RETH/RETHMO                                                              NEW000000
00145         DIMENSION DM1(15),DM2(15)                                                       NEW000000
00145   C                                                                                    000000
00146         DIMENSION FLOW(2),PRES(2)                                           ANK 5/83     000000
00147         INTEGER AREA,CQ,DENS,DIST,ENERGY,FLOW,HEAT,HWALL,PRES,PRESS,REY,    ANK 8/83     000000
00147        1        SHEAR,TCON,TEMP,THRUST,VEL,VIS,ATA,ATB                      ANK 8/83     000000
00150         DATA FLOW/12HKG/SECLB/SEC/,NUM/6HNUMBER/,PRES/12H(N/M2)LB/IN2/                   000000
00150   C                                                                                    000000
00154         TVCF(X)=(SQRT(AMAX1(0.,1.+2.*COSOR*X))-1.)/COSOR                                 000000
00154   C                                                                                    000000
00155         IF (IWALL .GT. 2)  RHOVW(IS) = C1*F(1,1) + HF(1,5)                  ANK 4/83     000000
00157         C89 = -ALPH*C3M(IS)*VMUE(IS)                                        ANK 8/83     000012
00160         WALLQ = -WALLQ/C3M(IS)                                              ANK 8/83     000017
00161         DER(3) = WALLQ - RHOVW(IS)*G(1,1)/C3M(IS)                           ANK 8/83     000022
00162         WALLJ(NSP)=0.                                                       B11A 149     000027
00163         IF (NSPM1 .LE. 0)  GO TO 3051                                                    000031
00165         DO 305 K = 1,NSPM1                                                               000034
00170         WALLJ(K)=VJKW(K)                                                    B11A 151     000041
00171     305 WALLJ(NSP)=WALLJ(NSP)-WALLJ(K)                                      B11A 152     000042
00173    3051 DER(1) = W(2)/C3M(IS)                                               ANK 8/83     000047
00174         DER(2) = W(3)/C3M(IS)                                               ANK 8/83     000052
00175         ADR = (W(2) + W(3) - RHOVW(IS))/C3M(IS)                             ANK 8/83     000055
00176         IF (ADR*100.0 .LT. RHOVW(IS)/C3M(IS))  ADR = 0.0                    ANK 8/83     000063
00200         Y(1) = 0.0                                                                       000074
00201         SHFAC = -UE(IS)/(ALPH**2*C3M(IS)*GC)                                ANK 8/83     000075
00202         DUDS(1) = F(1,3)*SHFAC*(CAPC(1) + EPSA(1))                                       000105
00203         DO 182 I=2,NETA                                                     B11A 162     000123
00206         DUDS(I) = F(I,3)*SHFAC*(CAPC(I) + EPSA(I))                                       000123
00207     182 Y(I)=Y(I-1)+C89*CRHO(I-1)                                           B11A 163     000130
00211         SHEAD = DUDS(1)                                                     ANK 8/83     000135
00212         IF (IWALL .LT. 3)  EMIS = 0.0                                       ANK 4/83     000140
00214         QDIFU = -CAPC(1)/ALPH*CPBAR(1)/PR(1)*TPWALL/C3M(IS)                 ANK 8/83     000145
00215         CPH(IS) = CPBAR(NETA)                                               ANK 5/83     000155
00216         QWG(IS) = QDIFU                                                                  000160
00217         DER(11)=ALPH                                                        EV 10/73     000161
00220         DER(12) = ROKAP(IS)/RAD5                                                         000163
00221         DER(13) = PE(IS)/UCP                                                             000166
00222         DER(14)=UE(IS)/UCL                                                  EV 10/73     000171
00223         DX = UE(IS)**2*RHOE(IS)/GC                                          ANK 4/83     000174
00224         ACH = DER(12)*RAD6                                                               000201
00225         DER(15) = BETAP(IS)                                                 ANK 7/83     000204
00226         DER(16) = BETAV(IS)                                                              000206
00227         DER(17) = WALLQ/UCR                                                              000210
00230         DER(18) = DER(3)/UCR                                                             000213
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00231            DER(19) = STEF*TT(1)**4*EMIS/UCR                        ANK 5/83    000216
00232            DER(20) = QDIFU/UCR                                                 000224
00233            HEAD = ACH*DER(18)                                      ANK 8/83    000226
00234            IF (IWALL .LE. 2)  GO TO 2104                           ANK 4/83    000230
00236            HEAD = 0.0                                              ANK 8/83    000234
00237            IF (RADS(IS) .LT. -1.0E-4)  HEAD = - RADS(IS)/UCR       ANK 8/83    000235
00241     2104   IF (IS .NE. 1)  GO TO 2103                                          000246
00243            ARET = 0.0                                              ANK 8/83    000250
00244            IF (ITDK .GT. 0)  COSALF(1) = 1.0                       ANK 4/83    000251
00246            GO TO 2106                                              EV 10/73    000256
00247     2103   ARET = (S(IS) - S(IS-1))/UCL                            ANK 8/83    000260
00250            IF (IST .EQ. 0)  GO TO 2105                                         000264
00252            ARET = 0.0                                              ANK 8/83    000266
00253            IST = 0                                                             000267
00254     2105   IF (ITDK .GT. 0)  COSALF(IS) = COS(ATAN2((ROKAP(IS) - ROKAP(IS-1))ANK 4/83    000271
00254            1                                ,UCL*(XST(IS) - XST(IS-1))))       000271
00256     2106   IF (IRITE .EQ. 0)  GO TO 30                                         000317
00260            WRITE (6,1) (HEAT(J,IUNIT), J = 1,2),DIST(IUNIT),PRESS(IUNIT),    ANK 8/83    000320
00260            1             VEL(IUNIT),(DER(J), J = 11,20)                        000320
00272        1   FORMAT(/6X,5HALPHA,7X,6HRADIUS,6X,8HPRESSURE,4X,9HEDGE VEL.,6X,    NEW000346
00272           1 5HBETAP,8X,5HBETAV,17X,'HEAT FLUXES '2A6/18X,A6,7X,A6,6X,A6,31X,  -01000346
00272           2 'DIFFUSIONAL',4X,8HTOT ENTH,7X,5HRERAD,8X,5HQCOND/1X,1P10E13.6)  000346
00273            POUT = DER(13)*PATM                                     ANK 5/83    000346
00274            IF (IUNIT .EQ. 1)  POUT = DER(13)                         PLOT      000351
00274      C     STORE ON DRUM FOR PLOTTING: VELOCITY,ENTHALPY,PRESSURE,HEAT FLUX   PLOT      000351
00276            IF (IPASS .EQ. 0)  WRITE (3) DER(14),DER(18),POUT,DER(20)  ANK 7/83    000356
00305       30   ACCP = RHO(NETA)/VMU(NETA)*UE(IS)/ALPH*F(NETA,2)                    000371
00306            CH = WALLQ/(G(NETA,1) - G(1,1))                                     000400
00307            CF = CAPC(1)/ALPH*VMUE(IS)/C89*F(1,3)                               000405
00310            IF (IRITE .EQ. 0)  GO TO 400                                        000413
00312            WRITE (6,2) ((MASS(J,IUNIT),J=1,2),K=1,2),(ATA(K),ATB(K),K=1,NSP)   000423
00330        2   FORMAT(//5X,4HWALL 12X,12HMASS FLUXES ,2A6,9X,32HELEMENTAL MASS DI  000450
00330           1FFUSIVE FLUXES ,2A6,1X,3HFOR/4X,5HSHEAR,3X,17HMECHANICAL  PYROL,    000450
00330           2 6X,4HCHAR,3X,'TOTAL GAS ',8(1X,2A4,1X))                            000450
00331            WRITE (6,23) SHEAR(IUNIT)                               ANK 8/83    000450
00334       23   FORMAT (4X,A6,3X,7HREMOVAL,5X,3HGAS)                                000457
00335      400   DO 203 I = 1,NETA                                                   000457
00340            SP(I,1,NSP) = 1.0                                                   000477
00341            SP(I,2,NSP) = 0.0                                                   000500
00342      203   SP(I,3,NSP) = 0.0                                                   000501
00344            IF (NSPM1 .LE. 0)  GO TO 2021                                       000503
00346            DO 202 K = 1,NSPM1                                                  000506
00351            DO 202 I=1,NETA                                         B11A 191    000516
00354            SP(I,1,NSP) = SP(I,1,NSP) - SP(I,1,K)                               000516
00355            SP(I,2,K) = SP(I,2,K)/ALPH                                          000520
00356            SP(I,2,NSP) = SP(I,2,NSP) - SP(I,2,K)                               000523
00357            SP(I,3,K) = SP(I,3,K)/ALPH**2                                       000525
00360      202   SP(I,3,NSP) = SP(I,3,NSP) - SP(I,3,K)                               000530
00363     2021   XSP(5,NSP) = F(NETA,1) - F(1,1)                                     000541
00364            IF (NSPM1 .GT. 0)  GO TO 2135                                       000546
00366            VJKW(1) = 0.0                                                       000551
00367            CM(1)=0.                                                            000552
00370            THELEM(1)=0.                                                        000553
00371            GO TO 2137                                                          000554
00372     2135   DO 2136 I=1,NSPM1                                       B11A        000556
00375     2136   XSP(5,NSP)=XSP(5,NSP)-XSP(5,I)                          B11A 199    000574
00377            DO 2131 I=1,NSP                                         B11A 200    000604
00402            VJKW(I)=0.                                              B11A 201    000604
00403            DO 2132 K=1,NSP                                         B11A 202    000607
00406     2132   VJKW(I) = VJKW(I) - WALLJ(K)/WTM(K)*VNU(I,K)            ANK 4/83    000607
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00410    2131 VJKW(I)=VJKW(I)*WAT(I)                                          B11A 204     000614
00412   2137  UCMF = UCE/UCR                                                               000625
00413         IF (IRITE .EQ. O)  GO TO 35                                                  000627
00415         DER(11) = SHEAD/UCS                                             ANK 8/83     000631
00416         DER(12) = ADR*UCMF                                                           000634
00417         DER(13)=DER(1)*UCMF                                             EV 10/73     000636
00420         DER(14)=DER(2)*UCMF                                             EV 10/73     000641
00421         DER(15) = RHOVW(IS)*UCMF/C3M(IS)                                ANK 8/83     000644
00422         DO 2237 I=1,NSP                                                 EV 10/73     000661
00425    2237 DER(I+15)=VJKW(I)*UCMF                                          EV 10/73     000661
00427         WRITE (6,3) (DER(J), J = 11,NSJ)                                             000664
00435       3 FORMAT (2X,1P13E10.3)                                                        000676
00435   C     STORE ON DRUM FOR PLOTTING: WALL SHEAR,TOTAL GAS FLUX             PLOT       000676
00436         IF (IPASS .EQ. O) WRITE (3) DER(11),DER(15)                     ANK 7/83     000676
00443      35 ADR = C89/F(NETA,2)*RHOE(IS)/RHO(NETA)                                       000707
00444         DUM3 = ADR*(F(NETA,1) - F(1,1))                                              000715
00445         DELST=Y(NETA)-DUM3                                              B11A 208     000721
00446         THENGY = (DUM3*G(NETA,1) - ADR*XG(5))/(G(NETA,1) - G(1,1))                   000723
00447         THMOM = DUM3 - ADR*XM(5)/F(NETA,2)                                           000734
00450         DELBD = Y(NETA) - ADR*F(NETA,1)                                              000741
00451         BLOW = RHOVW(IS)/C3M(IS)/CH                                     ANK 8/83     000745
00452         IF (NSPM1 .LE. O)  GO TO 2074                                                000751
00454         DO 2071 I = 1,NSP                                                            000776
00457         THELEM(I)=O.                                                    B11A 221     000776
00460         CM(I)=O.                                                                     000776
00461         DUZ=O.                                                                       000777
00462         DO 2072 K=1,NSP                                                 B11A 223     001007
00465         DUZ = DUZ + (DUM3*SP(NETA,1,K)-C89/ALPH*XSP(5,K))/WTM(K)*VNU(I,K) ANK 4/83   001007
00466   2072  THELEM(I) = THELEM(I) + (SP(NETA,1,K) - SP(1,1,K))/WTM(K)*VNU(I,K)ANK 4/83   001017
00470         IF (ABS(THELEM(I)) .LE. 0.0)  GO TO 2071                                     001026
00472         CM(I) = VJKW(I)/(THELEM(I)*WAT(I))                                           001031
00473         THELEM(I)=DUZ/THELEM(I)                                                      001036
00474    2071 CONTINUE                                                                     001047
00476   2074  IF (KQ9 .EQ. O)  GO TO 2078                                     ANK 4/83     001047
00476   C     TRANSVERSE CURVATURE CALLED FOR BY IBODY INPUT AS 8                          001047
00500         COSOR = TVCC(IS)/VMUE(IS)*0.50/C3M(IS)                          ANK 4/83     001050
00501         DO 2076 I=1,NETA                                                             001062
00504         Y(I)=TVCF(Y(I))                                                              001070
00505    2076 DUDS(I)=DUDS(I)*(1.+COSOR*Y(I))                                              001105
00507         DELST=TVCF(DELST)                                                            001112
00510         DELBD=TVCF(DELBD)                                                            001130
00511         THMOM=TVCF(THMOM)                                                            001146
00512         THENGY=TVCF(THENGY)                                                          001164
00513         DO 2077 K=1,NSP                                                              001205
00516    2077 THELEM(K)=TVCF(THELEM(K))                                                    001205
00520   2078  IF (IRITE .EQ. O)  GO TO 50                                                  001224
00520   C     CALCULATE THE BOUNDARY LAYER THRUST LOSS                                     001224
00522         DF = 2.0*COSALF(IS)/(UCL*UCS)*(ACH*DX*THMOM - ACH*PE(IS)*DELBD*  ANK 5/83    001225
00522        1     PATM*SIPSF + RAD6*SQRT(XI(IS)*2.0)*F(1,1)*UE(IS)/GC/UCL)   ANK 5/83     001225
00523         WRITE (6,18) (ATA(K),ATB(K), K = 1,NEL)                         ANK 5/83     001265
00532      18 FORMAT (//3X,20HMOM TRANS HEAT TRANS,5X,18HBLOWING PARAMETERS,7X,            001301
00532        1 36HELEMENTAL MASS TRANSFER COEFFICIENTS/4X,2(6HCOEFF.,4X),25H(NOR           001301
00532        2M. BY RHOE*UE*ST) FOR,14X,8HCM,  FOR/5X,4HCF/2,5X,38HST NO.   PYRO           001301
00532        3L GAS   CHAR   TOTAL GAS ,8(1X,2A4,1X))                                      001301
00533         DER(10) = RHOE(IS)*UE(IS)                                                    001301
00534         DER(11)=CF/DER(10)                                              EV 10/73     001304
00535         DER(12)=CH/DER(10)                                              EV 10/73     001307
00536         IF(IPART.EQ.1)GO TO 40                                                   NEW001312
00540         IF(ICF.GT.O.AND.ICF.LT.3)GO TO 40                                        NEW001315
00542         GO TO 41                                                                 NEW001332
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00543      40  DUMM1=DER(11)*2.                                                      NEWO01334
00544          DUMM2=DER(12)                                                         NEWO01336
00545          DUMM3=S(IS)                                                           NEWO01340
00546          AM=F(NETA,2)/ALPH*UE(IS)/SQRT(GMR(NETA)/VMW(NETA)*TT(NETA)*49732.)    NEWO01343
00547          REFF=(1.+(GMR(NETA)-1.)/2.*PR(NETA)**.333*AM**2)/                     NEWO01361
00547         $ (1.+(GMR(NETA)-1.)/2.*AM**2)                                         NEWO01361
00550          DO 42 I=1,NETA                                                        NEWO01415
00553          DM1(I)=CPBAR(I)*UCT/UCE                                               NEWO01415
00554          DM2(I)=TT(I)/UCT                                                      NEWO01420
00555      42  CONTINUE                                                              NEWO01424
00557          DZERO=DM1(1)-(DM1(2)-DM1(1))/(DM2(2)-DM2(1))*DM2(1)                   NEWO01424
00560          AINT=0.5*(DZERO+DM1(1))*DM2(1)                                        NEWO01434
00561          DUMM6=AINT                                                            NEWO01440
00562          DO 43 I=2,NETA                                                        NEWO01444
00565          AINT=AINT+0.5*(DM1(I-1)+DM1(I))*(DM2(I)-DM2(I-1))                     NEWO01444
00566      43  CONTINUE                                                              NEWO01454
00570          DUMM4=AINT                                                            NEWO01454
00571          DUMM5=(DUMM4+(G(NETA,1)-HB(NETA)/UCE))*REFF                           NEWO01455
00572          DUMM7=RHO(NETA)                                                       NEWO01463
00573          DUMM8=RHO(1)                                                          NEWO01465
00574          DUMM9=VMU(1)                                                          NEWO01467
00575          DUMM10=VMUE(IS)                                                       NEWO01471
00576          DUMM11=PR(NETA)                                                       NEWO01473
00577          DUMM12=UE(IS)                                                         NEWO01475
00600          IF(IPART.EQ.1.AND.(ICF.EQ.0.OR.ICF.EQ.3))GO TO 41                     NEWO01477
00602          AFACT=0.52                                                            NEWO01520
00603          CALL ROUGH(AFACT)                                                     NEWO01522
00604          CF=DUMM18/2.                                                          NEWO01525
00605          ST=DUMM16                                                             NEWO01530
00606          WALLQ=ST*(G(NETA,1)-G(1,1))*RHOE(IS)*UE(IS)                           NEWO01532
00607      41  CONTINUE                                                              NEWO01543
00610          IF(IPART.EQ.1)GO TO 45                                                NEWO01543
00612          GO TO 44                                                              NEWO01545
00613      45  IF(ICF.EQ.0.OR.ICF.EQ.3)GO TO 46                                      NEWO01547
00615          DUMM1=DUMM18                                                          NEWO01560
00616          DUMM2=DUMM16                                                          NEWO01562
00617      46  CONTINUE                                                              NEWO01565
00620          DUMM5=G(NETA,1)                                                       NEWO01565
00621          DUMM6=G(1,1)                                                          NEWO01567
00622          DUMM19=CPBAR(NETA)*UCT/UCE                                            NEWO01571
00623          DUMM20=REFF*TE(1)/UCT                                                 NEWO01575
00624          DUMM21=TT(1)/UCT                                                      NEWO01601
00625          DUMM22=DUMM19*VMU(NETA)/UCV/DUMM11                                    NEWO01604
00626          DUMM23=(DUMM7*DUMM12*2.*ROKAP(IS)/RAD5)/DUMM10                        NEWO01610
00627          PARTM=(4./3.)*(22./7.)*((RP/12.)**3)*RHOPA                            NEWO01620
00630          DUMM24=PARTM*DUMM12/((22./7.)*6.*RP/12.*DUMM10)                       NEWO01630
00631          CALL PARTCL                                                           NEWO01637
00632          CF=DUMM18/2.                                                          NEWO01641
00633          ST=DUMM16                                                             NEWO01644
00634          WALLQ=ST*(G(NETA,1)-G(1,1))*RHOE(IS)*UE(IS)                           NEWO01646
00635      44  CONTINUE                                                              NEWO01657
00636          DER(13) = DER(1)/CH                                                      001657
00637          DER(14) = DER(2)/CH                                                      001661
00640          DER(15)=BLOW                                                  EV 10/73   001664
00641          DO 2139 I=1,NSP                                               EV 10/73   001707
00644    2139  DER(I+15)=CM(I)/DER(10)                                       EV 10/73   001707
00644     C    STORE ON DRUM FOR PLOTTING: MOMENTUM TRANSFER COEFFICIENT, HEAT          001707
00644     C    TRANSFER COEFFICIENT, TOTAL GAS BLOWING PARAMETER                        001707
00646          IF (IPASS .EQ. 0)  WRITE (3) DER(11),DER(12),BLOW                PLOT    001714
00654          IF(IPASS.EQ.0) WRITE(3)CF,CH,WALLQ                                    NEWO01725
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00662              WRITE (6,3) (DER(J), J = 11,NSJ)                                             001736
00670              WRITE (6,4) DIST(IUNIT),REY(IUNIT),(ATA(K),ATB(K), K = 1,NEL)    ANK 5/83    001750
00701          4   FORMAT(//3X,68HMOMENTUM  DISPLACE. EFFECTIVE ENTHALPY  REYNOLDS  M           001767
00701             1ASS THICKNESS IN ,A6,4H FOR/2X,48HTHICKNESS  THICKNESS   BODY    TH          001767
00701             2ICKNESS   NUMBER/4X,5HTHETA,4X,33HDELSTAR   DISPLACE.  LAMBDA    PE          001767
00701             3R,A6,8(1X,2A4,1X))                                                           001767
00702              WRITE (6,24) (DIST(IUNIT), K = 1,4)                                          001767
00710         24   FORMAT (4(4X,A6))                                                            002000
00711              THMOM = THMOM/UCL                                                            002000
00712              DELTBD(IS) = DELBD/UCL                                                       002003
00713              DER(13) = DELST/UCL                                                          002007
00714              DER(14) = THENGY/UCL                                                         002012
00715              DER(15) = ACCP*UCL                                                           002015
00716              DO 2140 I=1,NSP                                                  EV 10/73    002023
00721       2140   DER(I+15) = THELEM(I)/UCL                                                    002023
00723              WRITE (6,3) THMOM,DER(13),DELTBD(IS),(DER(K), K = 14,NSJ)                    002026
00723        C     STORE ON DRUM FOR PLOTTING: MOMENTUM THICKNESS, EFFECTIVE DISPLACEMENT       002026
00734              IF (IPASS .EQ. 0)  WRITE (3) THMOM,DELTBD(IS)                      PLOT      002043
00741              WRITE (6,21) HWALL(IUNIT),THRUST(IUNIT),AREA(IUNIT),(FLOW(IUNIT), ANK 8/83   002055
00741             1            K = 1,2)                                                         002055
00752         21   FORMAT (//5X,'TOTAL HEAT',7X,6HTHRUST,9X,5HTOTAL,7X,'ACCELERATION'           002074
00752             1,5X,8HINVISCID,9X,5HTOTAL,7X,'AREA RATIO'/6X,7HTO WALL,10X,4HLOSS,           002074
00752             A 8X,9HWALL AREA,                                                             002074
00752             25X,'PARAMETER-K',5X,2(9HMASS FLOW,7X)/7X,A6,2(9X,A6),15X,2(9X,A6))           002074
00753         50   WALLA = WALLA + (ROKAP(IS-1) + ROKAP(IS))*RAD6*ARET/RAD5         ANK 8/83    002074
00754              SUMQG = SUMQG + (ENTHAL + HEAD)*ARET                             ANK 8/83    002103
00755              ENTHAL = HEAD                                                    ANK 8/83    002110
00755        C     ENTHAL IS PI*ROKAP(I)*QWALL, SUMQG IS THE TOTAL HEAT TO THE WALL,            002110
00755        C     AND WALLA IS THE ACCUMULATED WALL AREA                                       002110
00756              IF (IRITE .EQ. 0)  GO TO 60                                                  002112
00760              ACCP = BETAV(IS)*VMUE(IS)**2*ROKAP(IS)**2/2.0/XI(IS)                         002114
00761              ACCPK=ACCP*RHOE(IS)*VMU(1)/(VMUE(IS)*RHO(1))                              NEW002125
00762              THENGY = 2.0*SQRT(XI(IS)*2.0)*RAD6/UCM*F(NETA,1)                             002133
00763              THMOM = 2.0*SQRT(XI(IS)*2.0)*RAD6/UCM*(F(NETA,1) - F(1,1))                   002150
00764              ARET = (ROKAP(IS)/RAD5/RTM)**2                                   ANK 8/83    002154
00765              WRITE (6,22) SUMQG,DF,WALLA,ACCP,THENGY,THMOM,ARET               ANK 8/83    002161
00776         22   FORMAT (1X,1P7E15.6)                                                         002175
00777              IF(ICF.EQ.0)GO TO 1111                                                    NEW002175
01001              WRITE(6,1009)                                                             NEW002177
01003       1009   FORMAT(/,1X,56('*'),' REMTECH INC. 11-84 ',56('*'))                       NEW002204
01004       1010   FORMAT(/,1X,132('*'))                                                     NEW002204
01005              WRITE(6,1000)ICF,RK                                                       NEW002204
01011       1000   FORMAT(/,2X,'ROUGHNESS MODULE USED  -  OPTION ',I2,/,                     NEW002213
01011             $ 6X,'EQUIVALENT SAND ROUGHNESS HEIGHT,   RK = ',E10.3,'(FEET)')           NEW002213
01012              IF(ICF.EQ.3)GO TO 1112                                                    NEW002213
01014              RFACT=DUMM16/DUMM2                                                        NEW002216
01015              IF(DUMM17.EQ.0.0)WRITE(6,1001)RFACT                                       NEW002221
01021              IF(DUMM17.GT.0.0.AND.DUMM17.LT.1.0)WRITE(6,1002)RFACT                     NEW002231
01025              IF(DUMM17.EQ.1.0)WRITE(6,1003)RFACT                                       NEW002254
01031       1001   FORMAT(6X,'SMOOTH',14X,20X,'ROUGHNESS FACTOR = ',F7.3)                    NEW002265
01032       1002   FORMAT(6X,'TRANSITIONALLY ROUGH',20X,'ROUGHNESS FACTOR = ',F7.3)          NEW002265
01033       1003   FORMAT(6X,'ROUGH',15X,20X,'ROUGHNESS FACTOR = ',F7.3)                     NEW002265
01034              WRITE(6,1008)CF,ST,WALLQ                                                  NEW002265
01041       1008   FORMAT(1X,'       CF/2=',1PE10.3,5X,'  ST NO. =',1PE10.3,5X,              NEW002275
01041             $ 'HEAT FLUX=',1PE10.3)                                                    NEW002275
01042              GO TO 1111                                                                NEW002275
01043       1112   CONTINUE                                                                  NEW002277
01044              IF(ABS(DUMM17).LE.0.001)WRITE(6,1004)                                     NEW002277
01047              IF(ABS(DUMM17-1.).LE.0.001)WRITE(6,1005)                                  NEW002307
01052              IF(ABS(DUMM17-2.).LE.0.001)WRITE(6,1006)                                  NEW002322
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01055        1004  FORMAT(6X,'SMOOTH')                                                                      NEWO02335
01056        1005  FORMAT(6X,'ROUGH')                                                                       NEWO02335
01057        1006  FORMAT(6X,'RKS BEYOND UPPER LIMIT - EQUATION BECOMES INVALID - ',                       NEWO02335
01057             $ 'THEREFORE RKS = 0.0 WAS USED.')                                                        NEWO02335
01060              WRITE(6,1010)                                                                            NEWO02335
01062        1111  CONTINUE                                                                                 NEWO02343
01063              IF(IPART.EQ.1)GO TO 1301                                                                 NEWO02343
01065              GO TO 1302                                                                               NEWO02345
01066        1301  WRITE(6,1009)                                                                            NEWO02347
01070              IF(ILT.EQ.1)WRITE(6,1303)RP,AK,PF                                                        NEWO02353
01076        1303  FORMAT(/,2X,'PARTICLE MODULE USED',/,6X,'LAMINAR FLOW',5X,                               NEWO02366
01076             $ 'PARTICLE SIZE RP=',E10.3,'IN RADIUS',/,1X,'PARTICLE LOADING =',                        NEWO02366
01076             $ F10.2,10X,'PARTICLE FACTOR =',F10.4)                                                    NEWO02366
01077              IF(ILT.EQ.2)WRITE(6,1305)RP,WP,PF                                                        NEWO02366
01105        1305  FORMAT(/,2X,'PARTICLE MODULE USED',/,6X,'TURBULENT FLOW',5X,                             NEWO02401
01105             $ 'PARTICLE SIZE RP=',E10.3,'IN RADIUS',/,1X,'PARTICLE LOADING =',                        NEWO02401
01105             $ F10.2,10X,'PARTICLE FACTOR =',F10.4)                                                    NEWO02401
01106              WRITE(6,1008)CF,ST,WALLQ                                                                 NEWO02401
01113              WRITE(6,1010)                                                                            NEWO02411
01115        1302  CONTINUE                                                                                 NEWO02417
01116              IF(ILAMIN.EQ.0.OR.ILAM.EQ.0)GO TO 1211                                                   NEWO02417
01120              WRITE(6,1009)                                                                            NEWO02426
01122              WRITE(6,1200)SPCT                                                                        NEWO02433
01125        1200  FORMAT(/,2X,'RELAMINARIZATION  OCCURED',/,                                               NEWO02441
01125             $ 2X,'DEGREE OF RELAMINARIZATION = ',E10.3,' PERCENT')                                    NEWO02441
01126              WRITE(6,1010)                                                                            NEWO02441
01130        1211  CONTINUE                                                                                 NEWO02447
01131              WRITE(6,1007)RETHMO,ACCP,ACCPK                                                           NEWO02447
01136        1007  FORMAT(/,1X,'      RETHMO  ACCN PARA ACCN PARA',/,1X,                                    NEWO02456
01136             $ '               (EDGE)     (WALL)',/, 3X,1P3E10.3)                                      NEWO02456
01137              IF (IPASS .EQ. 1)  GO TO 55                                             PLOT              002456
01141              ACCP = 1.0E6*ACCP                                                                         002461
01141        C     STORE ON DRUM FOR PLOTTING: TOTAL HEAT TO WALL, WALL AREA, THRUST LOSS,                   002461
01141        C     ACCELERATION PARAMETER, INVISCID MASS FLOW, AND TOTAL MASS FLOW                           002461
01142              WRITE (3) SUMQG,WALLA,DF,ACCP,THENGY,THMOM                              PLOT              002464
01152          55  WRITE (6,6) SHEAR(IUNIT),(ENERGY(IUNIT), K = 1,2)                      ANK 8/83           002477
01161           6  FORMAT (1H1,5X,'NODAL INFORMATION'//1X,2HNO,7X,3HETA,10X,4HU/UE,                          002552
01161             1 8X,5HGAMMA,8X,6HSHEAR ,A6,3X,'STREAM FUNCTION F',8X,'FPP',12X,                           002552
01161             2 'GP 'A6,8X,'GPP ',A6)                                                                    002552
01162              DO 183 I=1,NETA                                                         B11A 240          002552
01165              DER(1) = F(I,2)/ALPH                                                                      002552
01166              DER(2) = DUDS(I)/UCS                                                                      002555
01167              DER(3) = F(I,3)/ALPH**2                                                                   002560
01170              DER(4) = G(I,2)/(ALPH*UCE)                                                                002563
01171              DER(5) = G(I,3)/(ALPH**2*UCE)                                                             002566
01171        C     STORE ON DRUM FOR PLOTTING: ETA VALUES, VELOCITY RATIO, GAMMA, AND SHEAR.                 002566
01172              IF (IPASS .NE. 1)  WRITE (4) ETA(I),DER(1),GMR(I),DER(2)               PLOT               002571
01201         183  WRITE (6,12) I,ETA(I),DER(1),GMR(I),DER(2),F(I,1),(DER(J),J=3,5)                          002603
01213          12  FORMAT (1X,I2,3F13.7,1P5E18.7)                                                            002623
01214              WRITE (6,7) DIST(IUNIT),DENS(IUNIT),(ENERGY(IUNIT), K = 1,2),                             002623
01214             1            PRES(IUNIT),NUM,NUM                                                           002623
01227           7  FORMAT (//1X,2HNO,5X,'DISTANCE FROM',8X,'DENSITY',7X,'STATIC ENTHA                        002653
01227             1LPY',4X,'TOTAL ENTHALPY',6X,'PITOT TUBE',7X,'MACH',7X,'MOLECULAR',                        002653
01227             2 5X,'PRANDTL'/ 9X,'WALL ',A6,8X,'RHO ',A6,8X,'H  ',A6,9X,'G.  ',                          002653
01227             3 A6,5X,'PRESSURE ',A6,4X,A6,7X,'WEIGHT',7X,A6)                                            002653
01230              DO 184 I=1,NETA                                                         B11A 259          002653
01233              GMR(I)=ABS(GMR(I))                                                                        002657
01234              ACH = F(I,2)/ALPH*UE(IS)/SQRT(GMR(I)/VMW(I)*TT(I)*GC*RVAR)             ANK 5/83           002661
01235              DER(2)=RHO(I)/UCD                                                       EV 10/73          002676
01236              DX = GMR(I) - 1.0                                                                         002701
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01237            ADR = GMR(I) + 1.0                                                            002704
01240            IF (ACH .GE. 1.0)  PITOT = POUT*(ACH**2*ADR/2.0)**(GMR(I)/DX)/                002707
01240           1                 ((2.0*GMR(I)*ACH**2 - DX)/ADR)**(1.0/DX)                     002707
01242            DX = (UE(IS)/UCL*F(I,2)/ALPH)**2                                              002752
01243            IF (IUNIT .EQ. 2)  DX = DX/(GC*SIPSF)                              ANK 4/83   002755
01245            IF (ACH .LT. 1.0)  PITOT = POUT + (1.0 + ACH**2/4.0)*DER(2)*DX/2.0            002762
01247            Y(I) = Y(I)/UCL                                                               002777
01250            DER(1) = HB(I)/UCE                                                 ANK 5/83   003002
01251            DER(6) = G(I,1)/UCE                                                           003005
01252            IF (IPASS .EQ. 1)  GO TO 184                                       ANK 7/83   003010
01252      C     CONVERT DISTANCE FROM WALL TO CENTIMETERS OR INCHES                           003010
01254            DW = 100.0*Y(I)                                                    ANK 7/83   003012
01255            IF (IUNIT .EQ. 2)  DW = 12.0*Y(I)                                  ANK 7/83   003014
01255      C     STORE ON DRUM FOR PLOTTING: DISTANCE FROM WALL, DENSITY, MACH NUMBER,         003014
01255      C     PITOT TUBE PRESSURE, STATIC ENTHALPY, AND TOTAL ENTHALPY.                     003014
01257            WRITE (4) DW,DER(2),ACH,PITOT,DER(1),DER(6)                        ANK 7/83   003022
01267        184 WRITE (6,20) I,Y(I),DER(2),DER(1),DER(6),PITOT,ACH,VMW(I),PR(I)               003035
01303         20 FORMAT (1X,I2,1P5E18.7,0PF13.8,F13.6,F13.8)                                   003054
01304            WRITE (6,8) DIST(IUNIT),(VIS(J,IUNIT), J = 1,2),(TCON(J,IUNIT),               003054
01304           1            J = 1,2),(CQ(J,IUNIT), J = 1,2),TEMP(IUNIT),NUM,NUM    ANK 5/83   003054
01326          8 FORMAT (//1X,2HNO,5X,'MIXING LENGTH',6X,'VISCOSITY MU',5X,'THERMAL            003127
01326           1 COND.',5X,'SPECIFIC HEAT',4X,'KINEMATIC EDDY',2X,'TEMPERATURE',2X            003127
01326           2,'SCHMIDT',5X,'TURBULENT'/11X,A6,10X,2A6,6X,2A6,6X,2A6,4X,'VISCOSI            003127
01326           3TY EPSA',4X,A6,5X,A6,4X,'PRANDTL ',A6)                                        003127
01327            DO 185 I = 1,NETA                                                             003127
01332            DER(1) = DL(I)/C89/ALPH/UCL                                        ANK 5/83   003127
01333            DER(3)=VMU(I)/UCV                                                  EV 10/73   003134
01334            DER(4)=CPBAR(I)*UCT/UCE                                            EV 10/73   003137
01335            DER(5)=DER(4)*DER(3)/PR(I)                                         EV 10/73   003143
01336            DER(6) = TT(I)/UCT                                                 ANK 5/83   003146
01337            IF (IPASS .EQ. 1)  GO TO 185                                       ANK 7/83   003151
01341            COND = 1.0E5*DER(5)                                                ANK 7/83   003153
01342            VISC = 1.0E5*DER(3)                                                ANK 7/83   003156
01342      C     STORE ON DRUM FOR PLOTTING: VISCOSITY, SPECIFIC HEAT, THERMAL                 003156
01342      C     CONDUCTIVITY, TEMPERATURE, AND KINEMATIC EDDY VISCOSITY.                      003156
01343            WRITE (4) VISC,DER(4),COND,DER(6),EPSA(I)                          ANK 7/83   003161
01352        185 WRITE (6,5) I,DER(1),DER(3),DER(5),DER(4),EPSA(I),DER(6),SC(I),               003173
01352           1            TURPR(I)                                                          003173
01366          5 FORMAT (1X,I2,1P5E18.7,0PF11.3,F12.8,F13.8)                                   003212
01366      C     STORE ON DRUM FOR PLOTTING: EDGE DENSITY,VISCOSITY, SPECIFIC HEAT,            003212
01366      C                                 THERMAL CONDUCTIVITY, AND MACH NUMBER             003212
01367            IF (IPASS .NE. 1)  WRITE (3) DER(2),DER(3),DER(4),DER(5),ACH          PLOT    003212
01377         60 IF (IFLOW .EQ. 1)  GO TO 325                                       ANK 4/83   003227
01401            IF (IRITE .EQ. 0)  GO TO 65                                                   003231
01403            WRITE (6,13) DIST(IUNIT),(Y(I), I = 1,NETA)                                   003242
01412         13 FORMAT (1H1,45X,22HDISTANCE FROM WALL IN ,A6/(12X,1P10E12.4/18X,              003260
01412           1       9E12.4))                                                               003260
01413            WRITE (6,25)                                                                  003260
01415         25 FORMAT(//1X,78HELEMENTAL FRACTIONS AND THEIR FIRST AND SECOND DERI            003273
01415           1VATIVES WITH RESPECT TO ETA/)                                                 003273
01416            DO 201 K=1,NSP                                                     B11A 265   003273
01421            WRITE (6,14) MOA(K),MOB(K),(SP(I,1,K), I = 1,NETA)                            003273
01431         14 FORMAT (2X,2A6,1X,1P9E13.5/21X,8E13.5/(15X,9E13.5/21X,8E13.5))                003305
01432            WRITE (6,15) (SP(I,2,K), I = 1,NETA)                                          003305
01440        201 WRITE (6,15) (SP(I,3,K), I = 1,NETA)                                          003316
01447         15 FORMAT (12X,1P10E12.4/18X,9E12.4)                                             003343
01450         65 IF (NSPM1 .LE. 0)  GO TO 2041                                                 003343
01452            DO 204 K = 1,NSPM1                                                            003345
01455            DO 204 I=1,NETA                                                    B11A 270   003364
01460            SP(I,2,K) = SP(I,2,K)*ALPH                                                    003364
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01461      204  SP(I,3,K) = SP(I,3,K)*ALPH**2                                    003366
01464     2041  IF (IRITE .EQ. 0)  GO TO 325                                     003377
01466           WRITE (6,16)                                                     003400
01470       16  FORMAT (/2X14HMOLE FRACTIONS,/)                        B11A 130  003405
01471           DO 196 J=1,NSPEC                                       B11A 274  003405
01474      196  WRITE (6,14) MOA(J),MOB(J),(FR(J,I), I = 1,NETA)                 003423
01505           IF (IWALL .EQ. 4)  WRITE (6,17) MOA(ISU),MOB(ISU)      ANK 4/83  003443
01512       17  FORMAT (/4X,'SURFACE SPECIES IS ',2A6)                           003460
01513      325  WALLQ = -WALLQ*C3M(IS)                                 ANK 8/83  003460
01514           IF (NON.LT.0) RETURN                                             003463
01516           J = NETA - 1                                                     003471
01517           M = KAPPA - 1                                                    003474
01520           K = KAPPA + 1                                                    003477
01521           NETAL=NETA                                                       003502
01522           KAPPAL=KAPPA                                                     003504
01523           IF (KONRFT.EQ.0) RETURN                                          003506
01525           IF (KQ10 .GT. 0 .AND. KTURB .GT. 0)  GO TO 4019        ANK 4/83  003513
01527           IF (IS - 1)  4002,4021,4002                                      003527
01527       C   TRANSITION TO TURBULENCE - CHANGE NODE DATA                      003527
01532     4019  KTURB=-1                                                         003534
01533           Y(I)=Y(I)*UCL                                          EV 10/73  003535
01534           NETA=NETAT                                                       003541
01535           KAPPA=KAPPAT                                                     003543
01536           DO 4020 I=1,NETA                                                 003554
01541     4020  F2FIX(I)=F2FIXT(I)                                               003554
01543           DO 4018 I = NETAL,J                                              003562
01546     4018  TT(I+1) = -1.0                                         ANK 5/83  003562
01550     4021  IF (NTROPY .EQ. 0)  GO TO 4002                         ANK 4/83  003565
01550       C   SPECIAL ENTROPY OPTION NTROPY = 5                                003565
01552           DO 4000 I = 1,M                                                  003566
01555     4000  UKAPPA(I)=F2FIX(I)/F2FIX(KAPPA)                                  003603
01557           UKAPPA(KAPPA)=1.0                                                003606
01560           DO 4001 I = K,J                                                  003614
01563     4001  UKAPPA(I)=(F2FIX(I)-F2FIX(KAPPA))/(F2FIX(NETA)-F2FIX(KAPPA))       ANK 8/83  003614
01565           UKAPPA(NETA)=1.0                                                 003620
01566     4002  IF (KTURB .NE. -1)  GO TO 4022                                   003623
01570           KTURB = 0                                                        003625
01571           GO TO 327                                                        003626
01572     4022  IF (IS .EQ. NS)  RETURN                                          003630
01574           IF (NTROPY .EQ. 0)  GO TO 4012                         ANK 4/83  003635
01574       C   SPECIAL ENTROPY OPTION NTROPY = 5                                003635
01576           DO 4010 I = 1,M                                                  003654
01601     4010  F2FIX(I) = UKAPPA(I)*F(KAPPA,2)/ALPH                             003654
01603           F2FIX(KAPPA) = F(KAPPA,2)/ALPH                                   003660
01604           DO 4011 I = K,J                                                  003667
01607     4011  F2FIX(I) = (F(KAPPA,2) + (F(NETA,2) - F(KAPPA,2))*UKAPPA(I))/ALPH ANK 8/83  003667
01611           F2FIX(NETA) = F(NETA,2)/ALPH                                     003674
01612     4012  IF (IS .EQ. 1)  GO TO 327                                        003700
01614           DO 326 I = 2,J                                                   003702
01617           M=I                                                              003707
01620           IF (F(I,2) - F2FIX(I)*ALPH .LT. 0.0)  M = I + 1        ANK 8/83  003711
01622      326  IF(ABS((F(I,2)-F2FIX(I)*ALPH)/(F(M,2)-F(M-1,2))).GT.RATLIM)GOTO327ANK 8/83  003721
01625           KONRFT=1                                                         003736
01626           RETURN                                                           003740
01627      327  CALL REFIT                                                       003744
01630           KONRFT=2                                                         003745
01631           RETURN                                                           003747
01632           END                                                    B11A 307  004014
```

END OF COMPILATION: NO DIAGNOSTICS.

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@SYS$*MSFCFOR$.FOR,WUS TRMBL
HSA  E3 -12/10/84-22:24:09 (31,32)
-23
      COMMON/ACPK/ACCPK1,ACCPK2
      COMMON/ACCN/ACCPK,ILAM,SPCT
      COMMON/RETH/RETHMO
      COMMON/RUF/DUMM1,DUMM2,DUMM3,DUMM4,DUMM5,DUMM6,DUMM7,DUMM8,DUMM9,
     $ DUMM10,DUMM11,DUMM12,RK,ICF,FMF,DUMM16,DUMM17,DUMM18
      COMMON /LAM/ ILAMIN
-80
      IF(ILAMIN.EQ.0)GO TO 39
      IF(ILAM.EQ.1)GO TO 29
      GO TO 39
29    SALPH=1.-(ACCPK-ACCPK1)/(ACCPK2-ACCPK1)
      SPCT=SALPH*100. (1. - SALPH) *100.
39    CONTINUE
-304
C
C   ROUGHNESS OPTION (3)       ICF = 3
C
      IF(ICF.EQ.3)GO TO 201
      GO TO 202
201   CONTINUE
      RKS=RK*UTAU*RHO(I)/VMU(I)
      IF(RKS.LE.4.535)PCT=0.0
      IF(RKS.GT.4.535.AND.RKS.LE.4000.)PCT=1.0
      IF(RKS.GT.4000.)PCT=2.0
      DUMM17=PCT
      IF(ABS(PCT).LE..001)GO TO 203
      DEACY=.9*(VMU(I)/(RHO(I)*UTAU))*(RKS**.5-RKS*EXP(-RKS/6.))
203   CONTINUE
      ACY=ALPH*DEL*CAPY+DEACY
202   CONTINUE

   SUBROUTINE TRMBL      ENTRY POINT 004622

   STORAGE USED: CODE(1) 004637; DATA(0) 000631; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003    COECOM 000017
    0004    COECON 000014
    0005    EDGCOM 001216
    0006    EPSCOM 000045
    0007    ERRCOM 000571
    0010    ETACOM 000036
    0011    HISCOM 000344
    0012    INPUTI 000006
    0013    INTCOM 000123
    0014    INTERI 000004
    0015    NONCOM 035431
    0016    NZERO  000001
    0017    PRMORG 000455
    0020    PRPCOM 000303
    0021    PRPERT 000074
    0022    PRPNPT 000076
    0023    SAVTBL 000067
    0024    TURB   000020
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0025	VARCOM	000645
0026	ACPK	000002
0027	ACCN	000003
0030	RETH	000001
0031	RUF	000022
0032	LAM	000001

EXTERNAL REFERENCES (BLOCK, NAME)

0033	LIAD
0034	TAYLOR
0035	ERP
0036	ERF
0037	NERR2$
0040	NWDU$
0041	NIO2$
0042	SQRT
0043	EXP
0044	XPRR
0045	TANH
0046	COSH
0047	NERR3$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001		002617	1000G	0001		000012	1001L	0001		000213	1002L	0001		001402	1003L	0001		004232	1004L
0001		004245	1005L	0001		001534	103L	0001		003114	1036G	0001		001576	104L	0001		003454	1100G
0001		003565	1122G	0001		003661	1136G	0001		003716	1150G	0001		004051	1177G	0001		004074	1210G
0001		004167	1226G	0001		004310	1255G	0001		004434	1275G	0001		004511	1307G	0001		004556	1317G
0001		000577	15L	0001		000074	2003L	0001		000123	2004L	0001		000155	2005L	0001		002456	201L
0001		002560	202L	0001		002553	203L	0001		000227	247G	0001		000264	29L	0001		001651	305L
0001		001127	32L	0001		001702	320L	0001		000415	321G	0001		000432	324G	0001		000752	33L
0001		001712	330L	0001		001742	331L	0001		002022	350L	0001		002111	362L	0001		000275	39L
0001		000710	400G	0001		003773	400L	0001		004027	401L	0001		004063	405L	0001		003770	406L
0001		004133	415L	0000		000360	42F	0001		000064	43L	0001		001065	431G	0000		000437	44F
0000		000407	45F	0001		001215	456G	0000		000417	46F	0001		001220	461G	0000		000351	47F
0001		001336	477G	0000		000457	48F	0000		000516	49F	0001		002143	505L	0001		002216	525L
0001		002317	532L	0001		002664	547L	0001		002701	550L	0001		003253	554L	0001		003203	555L
0001		001656	561G	0001		001675	573G	0001		004252	600L	0001		001706	601G	0001		001775	616G
0001		002101	636G	0001		004600	650L	0001		002206	663G	0001		002213	670G	0001		003257	700L
0001		003650	703L	0001		002273	711G	0001		001204	75L	0003		000000	A	0000	R	000321	ABECK
0027	R	000000	ACCPK	0026	R	000000	ACCPK1	0026	R	000001	ACCPK2	0000	R	000341	ACEB	0000	R	000325	ACY
0000	R	000311	AF	0025	R	000000	ALPH	0011		000000	ALPHD	0015	R	000000	AM	0000	R	000301	BBECK
0011	R	000001	BETAP	0000	R	000312	BF	0003		000003	C	0021	R	000000	CAPC	0000	R	000307	CAPY
0013		000000	CASE	0013	R	000015	CBAR	0000	R	000300	CBECK	0000	R	000275	CCEB	0005		000000	CG
0004		000000	CK1	0004	R	000006	CK6	0023	R	000000	CL	0006	R	000000	CLNUM	0021	R	000017	CPBAR
0000	R	000324	CRD	0011	R	000145	C1	0003	R	000005	C10	0003	R	000007	C13	0011		000146	C2
0003	R	000011	C26	0003	R	000012	C28	0011	R	000147	C3M	0003	R	000013	C32	0003	R	000015	C53
0003	R	000016	C56	0003	R	000002	C7	0003		000006	D	0000	R	000320	DADA	0000	R	000313	DADPP
0000	R	000306	DADVP	0000	R	000277	DB	0020	R	000255	DCAPCH	0020	R	000067	DCAPCK	0000	R	000000	DCAPCW
0023	R	000001	DCLNUM	0000	R	000344	DEACY	0000	R	000304	DEL	0023	R	000002	DELCON	0000	R	000007	DELTA
0023	R	000003	DEPC	0010	R	000017	DETA	0006	R	000001	DL	0000	R	000346	DLDA	0023	R	000004	DPI
0020		000256	DPRH	0020	R	000000	DRHOH	0000	R	000331	DRHOI	0020	R	000001	DRHOK	0000	R	000332	DUM
0031		000000	DUMM1	0031		000011	DUMM10	0031		000012	DUMM11	0031		000013	DUMM12	0031		000017	DUMM16
0031	R	000020	DUMM17	0031		000021	DUMM18	0031		000001	DUMM2	0031		000002	DUMM3	0031		000003	DUMM4
0031		000004	DUMM5	0031		000005	DUMM6	0031		000006	DUMM7	0031		000007	DUMM8	0031		000010	DUMM9
0000	R	000326	DUM1	0000	R	000327	DUM2	0023	R	000042	DVS	0000	R	000071	DYA	0003		000010	E
0006	R	000020	ELCON	0007	R	000376	ENL	0000	R	000330	EPI	0000	R	000322	EPS	0006	R	000021	EPSA

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0023 R 000043 EPS1     0036 R 000000 ERF      0035 R 000000 ERP      0010 R 000000 ETA      0000 R 000345 EXPA
0025 R 000001 F        0007   000000 FLE      0000 R 000264 FM       0031   000016 FMF      0025 R 000075 G
0022   000000 HB       0011 R 000231 HF       0022 R 000017 HP       0013 I 000016 I        0012   000000 IBODY
0031 I 000015 ICF      0017   000000 IDISC    0012 I 000005 IFLOW    0027 I 000001 ILAM     0032 I 000000 ILAMIN
0000   000574 INJP$    0000 I 000334 INK      0000 I 000274 IPRT     0013   000017 IQ       0013 I 000020 IS
0013   000021 ISH      0000 I 000302 IWK      0000 I 000335 J        0000 I 000316 K        0013 I 000023 KAPPA
0014   000000 KBC      0013   000024 KONRFT   0014 I 000003 KQ10     0013   000025 KR9      0000 I 000315 L
0013 I 000110 MAT1J    0013   000111 MAT2I    0000 I 000347 MINK     0000 I 000333 MPJ      0013 I 000114 NETA
0013 I 000115 NNLEQ    0013   000116 NON      0013 I 000121 NSP      0013 I 000122 NSPM1    0016 I 000000 NUL
0003   000014 O        0000 R 000323 ONK      0000 R 000343 PCT      0023 R 000044 PIM      0023 R 000045 PM
0000 R 000317 PPL      0021 R 000055 PR       0006 R 000040 PRT      0022   000020 QR       0000 R 000305 RC
0023 R 000046 RED      0030   000000 RETHMO   0006 R 000041 RETR     0022 R 000037 RHO      0005 R 000147 RHOE
0022 R 000056 RHOP     0006 R 000042 RHOVS    0031 R 000014 RK       0000 R 000342 RKS      0017 R 000373 S
0000 R 000303 SALPH    0006 R 000043 SCT      0025 R 000152 SP       0027 R 000002 SPCT     0000 R 000350 SQPI
0024 R 000000 STURB    0000 R 000336 TAUW     0022 R 000075 TP       0000 R 000276 TPCON    0023 R 000047 TREF
0005 R 000767 TTVC     0024 R 000001 TURPR    0005   000770 TVCC     0005 R 001052 UE       0000 R 000337 UTAU
0000 R 000314 VA       0023 R 000050 VINTR    0020 R 000264 VMU      0005 R 001134 VMUE     0000 R 000340 VWP
0000 R 000270 XP       0006 R 000044 YAP      0000 R 000310 YDI
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00101          SUBROUTINE TRMBL(ILK)                                                    000000
00101     C                                                                             000000
00103          COMMON /COECOM/ A(2),C7,C(2),C10,D,C13,E,C26,C28,C32,O,C53,C56  /COECOM/   000000
00104          COMMON /COECON/ CK1(6),CK6(6)                                   /COECON/   000000
00105          COMMON /EDGCOM/ CG(103),RHOE(400),TTVC,TVCC(50),UE(50),VMUE(50) /EDGCOM/   000000
00106          COMMON /EPSCOM/ CLNUM,DL(15),ELCON,EPSA(15),PRT,RETR,RHOVS,SCT,YAP/EPSCOM/ 000000
00107          COMMON /ERRCOM/ FLE(254),ENL(123)                               /ERRCOM/   000000
00110          COMMON /ETACOM/ ETA(15),DETA(15)                                /ETACOM/   000000
00111          COMMON /HISCOM/ ALPHD,BETAP(100),C1,C2,C3M(50),HF(15,5)         /HISCOM/   000000
00112          COMMON /INPUTI/ IBODY(5),IFLOW                                  /INPUTI/   000000
00113          COMMON /INTCOM/ CASE(13),CBAR,I,IQ,IS,ISH(2),KAPPA,KONRFT,KR9(51),/INTCOM/ 000000
00113         1                MAT1J,MAT2I(3),NETA,NNLEQ,NON(3),NSP,NSPM1      /INTCOM/   000000
00114          COMMON /INTERI/ KBC(3),KQ10                                     /INTERI/   000000
00115          COMMON /NONCOM/ AM(123,123)                                     /NONCOM/   000000
00116          COMMON /NZERO/ NUL                                              /NZERO/    000000
00117          COMMON /PRMORG/ IDISC(251),S(50)                                /PRMORG/   000000
00120          COMMON /PRPCOM/ DRHOH,DRHOK(54),DCAPCK(118),DCAPCH,DPRH(6),VMU(15)/PRPCOM/ 000000
00121          COMMON /PRPERT/ CAPC(15),CPBAR(30),PR(15)                       /PRPERT/   000000
00122          COMMON /PRPNPT/ HB(15),HP,QR(15),RHO(15),RHOP(15),TP            /PRPNPT/   000000
00123          COMMON /SAVTBL/ CL,DCLNUM,DELCON,DEPC,DPI(15,2),DVS,EPS1,PIM,PM, /SAVTBL/  000000
00123         1                RED,TREF,VINTR(15)                              /SAVTBL/   000000
00124          COMMON /TURB/ STURB,TURPR(15)                                   /TURB/     000000
00125          COMMON /VARCOM/ ALPH,F(15,4),G(15,3),SP(15,3,7)                 /VARCOM/   000000
00126          COMMON/ACPK/ACCPK1,ACCPK2                                               NEW000000
00127          COMMON/ACCN/ACCPK,ILAM,SPCT                                             NEW000000
00130          COMMON/RETH/RETHMO                                                      NEW000000
00131          COMMON/RUF/DUMM1,DUMM2,DUMM3,DUMM4,DUMM5,DUMM6,DUMM7,DUMM8,DUMM9,       NEW000000
00131         $ DUMM10,DUMM11,DUMM12,RK,ICF,FMF,DUMM16,DUMM17,DUMM18                   NEW000000
00132          COMMON /LAM/ ILAMIN                                                     NEW000000
00132     C                                                                             000000
00133          DIMENSION DCAPCW(7),DELTA(50),DYA(123),FM(4),XP(4)              ANK 4/83   000000
00133     C                                                                             000000
00134          GO TO (1001,1002,1003,1004,1005),ILK                                      000000
00135     1001 IPRT = 0                                                        ANK 8/83   000012
00136          IF(YAP)2002,2003,2004                                                     000012
00136     C    CEBECI-SMITH TURBULENCE MODEL                                             000012
00141     2002 YAP = - YAP                                                               000015
00142          CCEB = 26.0                                                               000016
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```
00143              WRITE (6,47)                                                           000020
00145           47 FORMAT (/1X,'CEBECI-SMITH TURBULENCE MODEL')                           000025
00146              WRITE (6,42) ELCON,YAP,CLNUM                                           000025
00153           42 FORMAT (/1X,'MIXING LENGTH CONSTANT ELCON =',1PE13.6/1X,'SUBLAYER      000035
00153             1CONSTANT YAP',8X,'=',E13.6/1X,'CLAUSER NUMBER CLNUM',9X,'=',E13.6)     000035
00154              IF (PRT .GT. 0.0)  WRITE (6,45) PRT                                    000035
00160           45 FORMAT (/1X,'TURBULENT PRANDTL NUMBER PRT =',1PE13.6)                  000046
00161              IF (PRT .GT. 0.0)  GO TO 43                                            000046
00163              IPRT = 1                                                               000051
00164              TPCON=-PRT                                                             000053
00165              WRITE (6,46) TPCON                                                     000055
00170           46 FORMAT (/1X,'VARIABLE TURBULENT PRANDTL NUMBER IN USE'/1X,             000064
00170             1          'TURBULENT PRANDTL CONSTANT   =',1PE13.6)                    000064
00171           43 WRITE (6,44) SCT,RETR                                                  000064
00175           44 FORMAT (/1X,'TURBULENT SCHMIDT NUMBER SCT =',1PE13.6/1X,               000072
00175             1          'TRANSITION MOM. THICK. RETR  =',E13.6)                      000072
00176              GO TO 2005                                                             000072
00176        C     BECKWITH-BUSHNELL TURBULENCE MODEL                                     000072
00177        2003  DB = ELCON/CLNUM                                                       000074
00200              CBECK = 26.0                                                           000076
00201              BBECK=CLNUM                                                            000100
00202              WRITE (6,48) BBECK,ELCON,PRT                                           000102
00207           48 FORMAT (/1X,'BECKWITH-BUSHNELL TURBULENCE MODEL'//1X,'BECKWITH CON     000112
00207             1STANT BBECK',6X,'=',1PE13.6/1X,'MIXING LENGTH CONSTANT ELCON =',       000112
00207             2 E13.6/1X,'TURBULENT PRANDTL NUMBER PRT =',E13.6)                      000112
00210              WRITE (6,44) SCT,RETR                                                  000112
00214              GO TO 2005                                                             000121
00214        C     KENDALL TURBULENCE MODEL                                               000121
00215        2004  WRITE (6,49)                                                           000123
00217           49 FORMAT (/1X,'KENDALL TURBULENCE MODEL')                                000127
00220              WRITE (6,42) ELCON,YAP,CLNUM                                           000127
00225              WRITE (6,45) PRT                                                       000137
00230              WRITE (6,44) SCT,RETR                                                  000145
00234        2005  DELCON = ELCON                                                         000155
00235              DCLNUM = CLNUM                                                         000156
00236              IFLOW = IFLOW - 2                                          ANK 4/83    000160
00237              KQ10 = 1                                                   ANK 4/83    000163
00240              IF (RETR .GT. 0.0)  KQ10 = -1                              ANK 4/83    000165
00242              IF (RETR .LT. -1.999)  KQ10 = RETR - 10.010                ANK 4/83    000172
00244              RETURN                                                                 000207
00244        C**** CALCULATES EPS2/NUE AND ITS DERIVITIVES AS DVS AND AM(1,...)           000207
00245        1002  IWK = 0                                                                000213
00245        C     INTERMITTANCY CORRECTIONS                                              000213
00246              DO 13 I = 1,NETA                                                       000213
00251              VINTR(I) = 1.0                                                         000227
00252           13 IF (CBECK .LE. 0.0 .AND. I .GT. KAPPA)  VINTR(I) = 1.0 - (ETA(I) -     000231
00252             1    ETA(KAPPA))/(ETA(NETA) - ETA(KAPPA))                               000231
00255              SALPH = 1.0                                                            000253
00256              IF(ILAMIN.EQ.0)GO TO 39                                             NEW000255
00260              IF(ILAM.EQ.1)GO TO 29                                               NEW000257
00262              GO TO 39                                                            NEW000262
00263        29    SALPH=1.-(ACCPK-ACCPK1)/(ACCPK2-ACCPK1)                             NEW000264
00264              SPCT=SALPH*100. (1.- SALPH)*100.                                    NEW000272
00265        39    CONTINUE                                                            NEW000275
00266              IF (S(IS) .LT. 2.0*STURB)  SALPH = S(IS)/STURB - 1.0                   000275
00270              ELCON = DELCON*SQRT(SALPH)                                             000310
00271              TPCON = TPCON*SQRT(SALPH)                                              000316
00272              BBECK = DCLNUM*SQRT(SALPH)                                             000321
00273              CLNUM = DCLNUM*SALPH                                                   000324
00273        COMMENT  ..  C3=-DEL/VMUE  , RHOVS=-DEL/VMUE*RHOV=-RED*RHOV/(RHOE*UE)        000324
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00274    99*           DEL = -C3M(IS)*VMUE(IS)                                ANK 8/83    000327
00275   100*           RED = -C3M(IS)*RHOE(IS)*UE(IS)                         ANK 8/83    000333
00276   101*           RC=RED*CLNUM                                                       000337
00277   102*           PM = 0.0                                               ANK 5/83    000341
00300   103*           EPS1=0.                                                            000342
00301   104*           DEPC=0.                                                            000343
00302   105*           RHOVS=C1*F(1,1)+HF(1,5)                                            000344
00303   106*           IF (RC .LT. 0.0)  GO TO 75                                         000350
00305   107*           DADVP = RHOE(IS)/RHO(1)                                            000361
00306   108*           CAPY = DADVP/RHO(1)*RHOP(1)                                        000364
00307   109*           YDI=0.                                                             000367
00310   110*           AF = 0.0                                                           000370
00311   111*           BF = 0.0                                                           000371
00312   112*           AM(1,1)=0.                                                         000372
00313   113*           DADPP = (0.995 - CBAR)/(1.0 - CBAR)                                000373
00314   114*           SALPH = 0.0                                                        000401
00315   115*           VA = 0.0                                                           000402
00316   116*           DVS=0.                                                             000403
00317   117*           L = 117                                                            000404
00320   118*           DO 66 I=1,NETA                                                     000415
00323   119*           DO 3  K=1,NSP                                                      000432
00326   120*         3 DRHOK(K-1) = AM(L,K+97)                                            000432
00330   121*           PPL = - CAPY                                                       000434
00331   122*           DADA = DADVP                                                       000436
00332   123*           ABECK = YDI                                                        000440
00333   124*           EPS = BF                                                           000442
00334   125*           ONK = RHOE(IS)/RHO(I)**2                                           000444
00335   126*           C10 = C7*F(I,2)                                                    000452
00336   127*           C56 = F(I,2)/ALPH                                                  000455
00337   128*           CRD=DRHOH*C10                                                      000460
00340   129*           ACY = - VA                                                         000462
00341   130*           IF (I .GE. NETA)  GO TO 15                                         000464
00343   131*           DADVP = RHOE(IS)/RHO(I+1)                                          000470
00344   132*           CAPY = DADVP/RHO(I+1)*RHOP(I+1)                                    000474
00345   133*           PPL = PPL + CAPY                                                   000477
00346   134*           YDI = DETA(I)/2.0*(DADVP + DADA + DETA(I)/6.0*PPL)                 000501
00347   135*           SALPH = SALPH + YDI                                                000513
00350   136*           DUM1 = YDI*(F(I,3)/DADA - F(I+1,3)/DADVP)/6.0                      000515
00351   137*           DUM2 = F(NETA,2) - (F(I,2) + F(I+1,2))/2.0                         000525
00352   138*           DVS=DVS+YDI*(DUM2-DUM1/2.)                                         000532
00353   139*           VA = YDI**2                                                        000537
00354   140*           ACY = ACY + VA                                                     000542
00355   141*           AF = AF + DETA(I)/2.0*(DUM2 - DUM1)                                000544
00356   142*           ABECK = ABECK + YDI                                                000552
00357   143*           BF = ALPH*DEL*DETA(I)/2.0                                          000555
00360   144*           IF (I .EQ. KAPPA)  EPI = BF*DADPP                                  000562
00362   145*           IF (I .NE. KAPPA)  EPS = EPS + BF                                  000570
00364   146*        15 DRHOI = - AF*DADA/RHO(I) - F(I,3)/12.0*ACY/RHOE(IS)                000577
00365   147*           IF(CBECK.GT.0.) GO TO 33                                           000611
00367   148*           DUM = AM(L,98)*DRHOI*RC                                            000613
00370   149*           AM(1,I+3) = AM(1,I+3) - RC*ABECK/2.0 + C7*DUM*F(I,2)               000616
00371   150*           IF (I .LE. 1)  AM(1,3) = AM(1,3) - RC/DADA*ACY/12.0                000626
00373   151*           IF (I .GT. 1)  CALL LIAD (-1,1,NETA-2+I,-RC/DADA*ACY/12.0)         000640
00375   152*           AM(1,1) = AM(1,1) - C7*DUM*F(I,2)**2/ALPH                          000663
00376   153*           MPJ=MAT1J+1+I                                                      000700
00377   154*           DO 60 K=NUL, NSPM1                                                 000710
00402   155*           IF (K .GT. 0)  DUM = AM(L,K+98)*DRHOI*RC                           000713
00404   156*           IF (I .EQ. NETA)  CALL LIAD (K,1,1,DUM)                            000722
00406   157*           IF (I .NE. NETA)  AM(1,MPJ) = AM(1,MPJ) + DUM                      000733
00410   158*        60 MPJ = MPJ + NETA                                       ANK 8/83    000742
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00412             GO TO 32                                                        000750
00412       C     BECKWITH-BUSHNELL MODEL                                         000750
00413          33 IF (I .LT. KAPPA)  AM(1,1) = AM(1,1) + DEL*YDI + CRD*C56*ONK*EPS 000752
00415             IF (I .EQ. KAPPA)  AM(1,1) = AM(1,1)+CRD*C56*ONK*EPS+DADPP*DEL*YDI 000777
00417             IF (I .GE. KAPPA)  AM(1,1) = AM(1,1) + EPI*ONK*CRD*C56          001013
00421             INK=I+3                                                         001024
00422             AM(1,INK) = - CRD*EPS*ONK                                       001030
00423             IF (I .EQ. KAPPA)  AM(1,INK) = AM(1,INK) - CRD*EPI*ONK          001035
00425             IF (I .EQ. KAPPA + 1)  AM(1,INK) = - CRD*BF*ONK                 001046
00427             INK=INK+1                                                       001057
00430             DO 68  K=1,NSP                                                  001065
00433             INK = INK + NETA                                  ANK 8/83      001065
00434             AM(1,INK) = - EPS*ONK*DRHOK(K-1)                                001071
00435             IF (I .EQ. KAPPA)  AM(1,INK) = AM(1,INK) - EPI*ONK*DRHOK(K-1)   001075
00437          68 IF (I .EQ. NETA)  CALL LIAD (K-1,1,1,-EPI*ONK*DRHOK(K-1))       001105
00442          32 IF (I .EQ. KAPPA - 1)  DELTA(IS) = SALPH                        001127
00444          66 L = MAT1J + I                                                   001137
00446             DVS=AMAX1(O.,RC*DVS)                                            001145
00447             IF (CBECK .LE. O.O)  AM(1,MAT1J) = AM(1,MAT1J) + SALPH*RC       001154
00451             DELTA(IS) = ALPH*DEL*(DELTA(IS) + (SALPH - DELTA(IS))*DADPP)    001167
00452             RETURN                                                          001200
00453          75 RC=-RC                                                          001204
00454             DVS=O.                                                          001205
00455             DO 80 I=2,NETA                                                  001220
00460             DO 76 J = 1,3                                     ANK 6/83      001220
00463          76 FM(J) = F(I,J+1)                                  ANK 6/83      001220
00465             FM(4) = F(I-1,4)                                                001222
00466             CALL TAYLOR (DETA(I-1),FM(2),FM,XP)                             001224
00467             DVS = DVS+F(I,2)*XP(1)+F(I,3)*XP(2)+F(I,4)*XP(3)+F(I-1,4)*XP(4) 001234
00470             AM(1,I+3) = AM(1,I+3) + XP(1)                                   001251
00471             CALL LIAD (-1,1,NETA+I-2,XP(2))                                 001254
00472             CALL LIAD (-1,1,2*NETA+I-2,XP(3))                               001266
00473          80 CALL LIAD (-1,1,2*NETA+I-3,XP(4))                               001301
00475             DVS = DVS*RC/F(NETA,2)                                          001321
00476             DO 85 I=1,NNLEQ                                                 001326
00501          85 AM(1,I) = - 2.0*AM(1,I)*RC/F(NETA,2)                            001336
00503             AM(1,2)=AM(1,2)-RC                                              001343
00504             AM(1,MAT1J) = AM(1,MAT1J) + DVS/F(NETA,2)                       001346
00505             CALL LIAD(-1,1,NETA-1,RC)                                       001353
00506             DVS = AMAX1(RC*(F(NETA,1) - F(1,1)) - DVS,0.0)                  001364
00507             RETURN                                                          001376
00510        1003 TURPR(I) = PRT                                                  001402
00511             TURPR(1)=O.                                                     001404
00512             IF(ELCON.LE.0.00001) GO TO 401                                  001405
00514             IF(IPRT.EQ.1) GO TO 505                                         001411
00516             IF(IWK.EQ.1) GO TO 401                                          001414
00520             IF(CCEB.GT.O..OR.CBECK.GT.O.) GO TO 505                         001417
00520       C**** CALCULATES MIXING LENGTH AND ITS DERIVITIVES FOR KENDALL MODEL  001417
00522             PIM = PM                                          ANK 5/83      001433
00523             PM = SQRT(ABS(RED/C26*(CAPC(1)*F(1,3) - ALPH*RHOVS*F(I,2))))/   ANK 5/83      001435
00523            1   (CAPC(I)*YAP)                                                001435
00524             IF (I .LE. 1)  GO TO 305                                        001457
00526             EPI = EXP(-(PM + PIM)/2.0*DETA(I-1))              ANK 5/83      001463
00527             ONK = PM - PIM                                    ANK 5/83      001474
00530             IF (ONK/PM .GT. 1.0E-4)  GO TO 103                ANK 5/83      001477
00532             PM = AMAX1(PM,PIM)                                ANK 5/83      001503
00533             ONK = 1.0                                                       001511
00534             AF=1.0                                                          001513
00535             BF = 1.0/PM                                       ANK 5/83      001514
00536             DADA = -2.0/PM**2                                 ANK 5/83      001516
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00537            CRD = 1.0/PIM                                                    001522
00540            EPS = -2.0/PIM**2                                                001525
00541            GO TO 104                                                        001532
00542       103  AF = SQRT(2.0*DETA(I-1)/ONK)                                     001534
00543            BF = ERP(AF*PM/2.0)                                  ANK 5/83    001544
00544            DADA = 1.0 - AF*PM*BF                                ANK 5/83    001553
00545            CRD = ERP(AF*PIM/2.0)                                            001560
00546            EPS = 1.0 - AF*PIM*CRD                                           001570
00547       104  BF = BF - EPI*CRD                                                001576
00550            DUM1 = EPI*(AF*CRD - CL)*DETA(I-1)/2.0                           001601
00551            CL=CL*EPI+AF*BF                                                  001611
00552            DL(I) = ALPH*ELCON*(ETA(I) - CL)                     ANK 5/83    001616
00553            DUM2 = AF/ONK*(BF/2.0 + DADA*AF*PM/4.0 - EPI*EPS*AF*PIM/4.0)   ANK 5/83    001623
00554            IF(I-2) 305,330,320                                              001644
00557       305  DL(1) = 0.0                                          ANK 5/83    001651
00560            DO 307 J=1,NNLEQ                                                 001651
00563       307  AM(2,J)=0.                                                       001656
00565            CL=0.                                                            001657
00566            DPI(1,2)= CAPC(1)                                                001660
00567            DPI(3,1) = F(1,3)*DCAPCH                                         001662
00570            IF (NSPM1 .LE. 0)  GO TO 350                                     001665
00572            DO 315 K = 1,NSPM1                                               001670
00575       315  DPI(K+3,1) = F(1,3)*DCAPCK(K)                                    001675
00577            GO TO 350                                                        001700
00600       320  DO 325 J=1,NNLEQ                                                 001702
00603       325  AM(2,J) = AM(2,J)*EPI                                            001706
00605       330  DUM = -ALPH*ELCON*(DUM1 + DUM2 - EPI*EPS*AF**2/2.0)*TREF          001712
00606            AM(2,1) = AM(2,1) + (DL(I) - EPI*DL(I-1))/ALPH       ANK 5/83    001727
00607            L=I-1                                                            001736
00610       331  AM(2,1)= AM(2,1)+DPI(1,1)*DUM                                    001742
00611            AM(2,2)= AM(2,2) + DPI(2,1)* DUM                                 001745
00612            AM(2,3)= AM(2,3) + DPI(1,2)*DUM                                  001751
00613            AM(2,L+3)= AM(2,L+3)+DPI(2,2)*DUM                                001755
00614            J=MAT1J+2                                                        001764
00615            DO 340 K=NUL,NSPM1                                               001775
00620            AM(2,J)= AM(2,J) + DPI(K+3,1) * DUM                              002001
00621            AM(2,J+L-1) = AM(2,J+L-1) + DPI(K+3,2)*DUM                       002005
00622       340  J = J + NETA                                         ANK 8/83    002011
00624            IF (L .GE. I)  GO TO 400                                         002015
00626       350  TREF= RED/C26 /(2.*CAPC(I)*YAP*PM*YAP*CAPC(I))       ANK 5/83    002022
00627            DPI(3,2) = -PM/TREF*(DCAPCH/CAPC(I)-DRHOH/(2.*RHO(I)))   ANK 5/83    002034
00630            DPI(2,2)= C10*DPI(3,2)-RHOVS*ALPH                                002047
00631            DPI(1,1) = - C10*C56*DPI(3,2) - F(I,2)*RHOVS                     002054
00632            DPI(2,1) = - ALPH*C1*F(I,2)                                      002063
00633            IF (NSPM1 .LE. 0)  GO TO 362                                     002067
00635            DO 360 K = 1,NSPM1                                               002072
00640       360  DPI(K+3,2)=-PM/TREF*(DCAPCK(K)/CAPC(I)-DRHOK(K)/(2.*RHO(I)))   ANK 5/83    002101
00642       362  L=I                                                              002111
00643            DUM = - ALPH*ELCON*(DUM1 - DUM2 + DADA*AF**2/2.0)*TREF           002112
00644            IF (I .LE. 1)  RETURN                                            002126
00646            IF (I - NETA)  331,400,400                                       002135
00646     C      CEBECI-SMITH AND BECKWITH-BUSHNELL MODELS                        002135
00651       505  DEL = -C3M(IS)*VMUE(IS)                              ANK 8/83    002143
00652            INK=I-1                                                          002146
00653            ONK = - 12.0                                                     002151
00654            IF (I .GT. 1)  GO TO 525                                         002153
00656            INK = 1                                                          002157
00657            ONK=ABS(ONK)                                                     002161
00660            TAUW = -AMAX1(C28,1.0E-4)*UE(IS)/ALPH/C3M(IS)        ANK 8/83    002163
00661            DCAPCW(1)=DCAPCH                                                 002174
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00662          DO 515 K=1,NSPM1                                              002206
00665      515 DCAPCW(K+1)=DCAPCK(K)                                         002206
00667          DO 520 J=1,NNLEQ                                              002213
00672      520 DYA(J)=0.                                                     002213
00674          CAPY=0.                                                       002214
00675    525   VA = DETA(INK)*C26*(0.50 - C53*DETA(INK)/ONK)                 002216
00676          CAPY=CAPY+VA                                                  002226
00677          DYA(1)=DYA(1)+VA*DEL                                          002230
00700          IF(I.EQ.NETA) GO TO 532                                       002234
00702          DADA = - DETA(INK)/2.0*C26/RHO(I)*ALPH*DEL                    002237
00703          VA = DADA*DRHOH*C10                                           002247
00704          DYA(1)=DYA(1)-VA*C56                                          002252
00705          INK=I+3                                                       002255
00706          DYA(INK)=DYA(INK)+VA                                          002260
00707          INK=INK+1                                                     002264
00710          DO 530 K=1,NSP                                                002273
00713          INK = INK + NETA                                 ANK 8/83     002273
00714      530 DYA(INK) = DYA(INK) + DADA*DRHOK(K-1)                         002275
00716          IF(I.EQ.1) RETURN                                             002303
00720          IF(ONK.GT.0.) GO TO 406                                       002311
00722          ONK=ABS(ONK)                                                  002314
00723      532 UTAU = SQRT(TAUW/RHO(I))                                      002317
00724          IF(CBECK.GT.0.) GO TO 700                                     002326
00724     C ************************ CEBECI-SMITH MODEL ************************  002326
00726          VWP = (HF(1,5) + F(1,1)*C1)/(C3M(IS)*RHO(1)*UTAU)  ANK 8/83   002331
00727          EPI = EXP(YAP*VWP)                                            002342
00730          PPL=0.                                                        002350
00731          IF (ABS(BETAP(IS)) .GE. 1.0E-7)  PPL = -BETAP(IS)*RHOE(IS)*UE(IS) ANK 8/83   002351
00731         1 /C3M(IS)**2*CAPC(I)/(RHO(I)*UTAU)**3            ANK 8/83     002351
00733          EPS = EPI - 1.0                                               002400
00734          IF (ABS(VWP) .LT. 1.0E-7)  AF = YAP                           002403
00736          IF (ABS(VWP) .GE. 1.0E-7)  AF = EPS/VWP                       002411
00740          BF = AF*PPL                                                   002420
00741          SALPH = BF + EPI                                              002423
00742          IF (SALPH .LE. 0.0)  SALPH = 1.0E-30                          002425
00744          SALPH = SQRT(SALPH)                                           002432
00745          ACEB = CCEB*VMU(I)/RHO(I)/UTAU/SALPH                          002436
00746          ACY=ALPH*DEL*CAPY                                             002445
00746     C                                                            NEW002445
00746     C   ROUGHNESS OPTION (3)      ICF = 3                        NEW002445
00746     C                                                            NEW002445
00747          IF(ICF.EQ.3)GO TO 201                                   NEW002451
00751          GO TO 202                                               NEW002454
00752     201  CONTINUE                                                NEW002456
00753          RKS=RK*UTAU*RHO(I)/VMU(I)                               NEW002456
00754          IF(RKS.LE.4.535)PCT=0.0                                 NEW002464
00756          IF(RKS.GT.4.535.AND.RKS.LE.4000.)PCT=1.0                NEW002471
00760          IF(RKS.GT.4000.)PCT=2.0                                 NEW002511
00762          DUMM17=PCT                                              NEW002517
00763          IF(ABS(PCT).LE..001)GO TO 203                           NEW002521
00765          DEACY=.9*(VMU(I)/(RHO(I)*UTAU))*(RKS**.5-RKS*EXP(-RKS/6.))  NEW002525
00766     203  CONTINUE                                                NEW002553
00767          ACY=ALPH*DEL*CAPY+DEACY                                 NEW002553
00770     202  CONTINUE                                                NEW002560
00771          VA = ACY/ACEB                                                 002560
00772          EXPA = EXP(-VA)                                               002562
00773          DL(I)=ELCON*ACY*(1.-EXPA)                        ANK 5/83     002567
00774          DADA = ELCON*(1.0 - (1.0 - VA)*EXPA)                          002575
00775          IF(IWK.EQ.1) GO TO 555                                        002603
00777          DO 545  J=1,NNLEQ                                             002617
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01002          545  AM(2,J) = DYA(J)*DADA                                                      002617
01004               DLDA = - ELCON*EXPA*VA**2                                                  002622
01005               IF(ABS(VWP).LT.1.E-07) GO TO 547                                           002630
01007               DADPP = - ACEB/2.0/VWP/(PPL/VWP + EPI/EPS)                                 002634
01010               DADVP = - ACEB/2.0*(- BF/VWP + YAP*(1.0 + PPL/VWP)*EPI)/(BF + EPI)         002646
01011               GO TO 550                                                                  002662
01012           547 DADPP=-ACEB/2./(PPL+1./YAP)                                                002664
01013               DADVP=DADPP*(1.+YAP*PPL/2.)                                                002672
01014          550  BF = - C10*C56*DRHOH                                                       002701
01015               AF = - C10*C56*DCAPCH                                                      002705
01016               DADA = DADPP*PPL*(AF/CAPC(I) - 1.50*BF/RHO(I) + 3.0/ALPH) - 1.50*          002710
01016              1 ACEB*BF/RHO(I) + ACEB/ALPH + DADVP*VWP*(BF/RHO(I)/2.0 + 1.0/ALPH)         002710
01016              2 + AF*ACEB/CAPC(I)                                                         002710
01017               AM(2,1)=AM(2,1)+DLDA*DADA                                                  002755
01020               AM(2,2) = AM(2,2) + DLDA*DADVP*C1/C3M(IS)/RHO(1)/UTAU          ANK 8/83    002760
01021               DADA = (- ACEB/2.0 - 1.50*DADPP*PPL - DADVP*VWP/2.0)/F(1,3)                002771
01022               AM(2,3) = AM(2,3) + DLDA*DADA                                              003005
01023               INK=I+3                                                                    003010
01024               DADA = C10*((ACEB + DADPP*PPL)*(DCAPCH/CAPC(I) - 1.50*DRHOH/RHO(I)         003013
01024              1 ) + DADVP*VWP*DRHOH/RHO(I)/2.0)                                           003013
01025               AM(2,INK) = AM(2,INK) + DLDA*DADA                                          003034
01026               INK = INK + NETA + 1                                           ANK 8/83    003040
01027               MINK=MAT1J+2                                                               003044
01030               AM(2,MINK) = AM(2,MINK) + DLDA*DCAPCW(1)/CAPC(1)*(- ACEB/2.0 -             003047
01030              1 1.50*DADPP*PPL - DADVP*VWP/2.0)                                           003047
01031               IF (I .NE. NETA)  AM(2,INK) = AM(2,INK) + DADA*DLDA/C10                    003057
01033               IF (I .EQ. NETA)  CALL LIAD (0,2,1,DLDA*DADA/C10)                          003072
01035               DO 553 K = 2,NSP                                                           003107
01040               INK = INK + NETA                                               ANK 8/83    003115
01041               MINK = MINK + NETA                                             ANK 8/83    003120
01042               AF = (ACEB + DADPP*PPL)*(DCAPCK(K-1)/CAPC(I) - 1.50*DRHOK(K-1)/            003123
01042              1 RHO(I)) + DADVP*VWP*DRHOK(K-1)/RHO(I)/2.0                                 003123
01043               AM(2,MINK) = AM(2,MINK) + DLDA*DCAPCW(K)/CAPC(1)*(-ACEB/2.0 - 1.50         003140
01043              1 *DADPP*PPL - DADVP*VWP/2.0)                                               003140
01044               IF (I .NE. NETA)  AM(2,INK) = AM(2,INK) + DLDA*AF                          003151
01046          553  IF (I .EQ. NETA)  CALL LIAD (K-1,2,1,DLDA*AF)                              003161
01046          CALCULATE THE TURBULENT PRANDTL NUMBER ................................         003161
01051           555 IF(IPRT.NE.1) GO TO 554                                                    003203
01053               AF = ACY*UTAU*RHO(I)/VMU(I)/CCEB/SALPH                                     003205
01054               BF = ACY*UTAU*RHO(I)/VMU(I)*SQRT(PR(I))/34.0/SALPH                         003216
01055               PRT = ELCON/TPCON*(1.0 - EXP(-AF))/(1.0 - EXP(-BF))                        003227
01056           554 TURPR(I)=PRT                                                               003253
01057               GO TO 703                                                                  003255
01057          C ********************** BECKWITH-BUSHNELL MODEL **********************          003255
01060          700  SQPI = 1.772453851                                                         003257
01061               ABECK=CBECK/RHO(I)*VMU(I)/UTAU                                             003260
01062               ACY=ALPH*DEL*CAPY                                                          003266
01063               VA = DB*ACY/DELTA(IS)                                                      003273
01064               EPI = 5.0*ACY/DELTA(IS) - 3.90                                             003277
01065               EXPA = EXP(-ACY/ABECK)                                                     003304
01066               AF = 1.0 - EXPA                                                            003313
01067               BF = TANH(VA)                                                              003315
01070               CRD = SQRT(0.50 - ERF(EPI)/2.0)                                            003321
01071               DL(I) = BBECK*DELTA(IS)*AF*BF*CRD                              ANK 5/83    003333
01072               DRHOI = 1.50*DRHOH/RHO(I)                                                  003343
01073               EPS = EXP(-EPI**2)                                                         003347
01074               DADA = BBECK*(DELTA(IS)/ABECK*BF*CRD*EXPA + DB*AF*CRD/COSH(VA)**2          003356
01074              1 - 2.50/SQPI*AF*BF/CRD*EPS)                                                003356
01075               DLDA = -BBECK*DELTA(IS)*BF*CRD*ACY/ABECK**2*EXPA                           003406
01076               DADPP = BBECK*(AF*BF*CRD - DB*ACY/DELTA(IS)*AF*CRD/COSH(VA)**2 +           003420
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01076            1         2.50/SQPI*AF*BF/CRD*ACY/DELTA(IS)*EPS)                          003420
01077              DO 701  J=1,NNLEQ                                                       003454
01102         701  AM(2,J) = DYA(J)*DADA + AM(1,J)*DADPP                                   003454
01104              DADA = ABECK*(C10*C56*(-DCAPCH/CAPC(I) + DRHOI) + 1.0/ALPH)             003462
01105              AM(2,1)=AM(2,1)+DLDA*DADA                                               003472
01106              AM(2,3) = AM(2,3) - DLDA*ABECK/2.0/F(1,3)                               003475
01107              INK=I+3                                                                 003502
01110              AM(2,INK) = AM(2,INK) + DLDA*ABECK*C10*(DCAPCH/CAPC(I) - DRHOI)         003505
01111              INK = INK + NETA + 1                                        ANK 8/83    003513
01112              MINK=MAT1J+2                                                            003517
01113              DADA = ABECK*(DCAPCH/CAPC(I) - DRHOI)                                   003522
01114              AM(2,MINK) = AM(2,MINK) - DLDA*ABECK*DCAPCW(1)/CAPC(1)/2.0              003525
01115              IF (I .NE. NETA)  AM(2,INK) = AM(2,INK) + DADA*DLDA                     003534
01117              IF (I .EQ. NETA)  CALL LIAD (0,2,1,DADA*DLDA)                           003547
01121              DO 708 K = 2,NSP                                                        003560
01124              INK = INK + NETA                                            ANK 8/83    003566
01125              MINK = MINK + NETA                                          ANK 8/83    003572
01126              DADA = ABECK*(DCAPCK(K-1)/CAPC(I) - 1.50*DRHOK(K-1)/RHO(I))             003576
01127              AM(2,MINK) = AM(2,MINK) - ABECK*DCAPCW(K)*DLDA/CAPC(1)/2.0              003606
01130              IF (I .NE. NETA)  AM(2,INK) = AM(2,INK) + DADA*DLDA                     003616
01132         708  IF (I .EQ. NETA)  CALL LIAD (K-1,2,1,DADA*DLDA)                         003626
01132       C      CEBECI-SMITH AND BECKWITH-BUSHNELL MODELS                               003626
01135         703  DO 704 J = 1,NNLEQ                                                      003650
01140          704 AM(2,J)=AM(2,J)/C26/DEL                                                 003661
01142              EPI = DL(I)/RHOE(IS)/DEL                                    ANK 5/83    003665
01143              AM(2,1) = AM(2,1) - C10*C56*DRHOH*EPI                                   003671
01144              INK=I+3                                                                 003677
01145              AM(2,INK) = AM(2,INK) + C10*DRHOH*EPI                                   003702
01146              INK=INK+1                                                               003710
01147              DO 706 K = 1,NSP                                                        003716
01152              INK = INK + NETA                                            ANK 8/83    003716
01153              IF (I .NE. NETA)  AM(2,INK) = AM(2,INK) + DRHOK(K-1)*EPI                003723
01155         706  IF (I .EQ. NETA)  CALL LIAD (K-1,2,1,DRHOK(K-1)*EPI)                    003733
01160              DL(I) = DL(I)/C26/DEL                                       ANK 5/83    003754
01161              IF(I.EQ.NETA) GO TO 406                                                 003761
01163              INK=I                                                                   003764
01164              GO TO 525                                                               003766
01164       C      CALCULATES EPS AND EPS DERIVATIVES                                      003766
01164       C      CEBECI-SMITH AND BECKWITH-BUSHNELL MODELS                               003766
01165          406 IF(IWK.EQ.1) GO TO 401                                                  003770
01165       C      KENDALL TURBULENCE MODEL                                                003770
01167         400  DUM1 = DL(I)**2/ALPH**2*RED/C26                             ANK 5/83    003773
01170              EPS1 = DUM1*ABS(F(I,3))                                                 004003
01171              IF (CBECK .GT. 0.0 .OR. EPS1 .LT. DVS/C26**2)  GO TO 405                004006
01173         401  EPS = VINTR(I)*DVS/C26**2                                               004027
01174              IWK = 1                                                                 004035
01175              ENL(3) = ENL(1)*VINTR(I)/C26**2                                         004037
01176              DO 402 J=1,NNLEQ                                                        004051
01201         402  AM(3,J) = AM(1,J)*VINTR(I)/C26**2                                       004051
01203              DUM1=2.0*EPS/RHO(I)                                                     004055
01204              GO TO 415                                                               004061
01204       C      BECKWITH-BUSHNELL MODEL                                                 004061
01205          405 EPS=EPS1*VINTR(I)                                                       004063
01206              ENL(3)=0.                                                               004066
01207              DO 410 J=1,NNLEQ                                                        004074
01212         410  AM(3,J) = 2.0*AM(2,J)*EPS/DL(I)                             ANK 5/83    004074
01214              AM(3,1)=AM(3,1)-2.0/ALPH*EPS                                            004101
01215              CALL LIAD (-1,3,NETA+I-2,SIGN(1.0,F(I,3))*VINTR(I)*DUM1)                004106
01216              DUM1=EPS/RHO(I)                                                         004126
01217          415 DUM=DUM1*DRHOH                                                          004133
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01220             EPSA(I)=EPS                                            004135
01221             AM(3,1)=AM(3,1)-C56*C10*DUM                            004140
01222             AM(3,I+3)= AM(3,I+3)+DUM*C10                           004145
01223             J=MAT1J+I+1                                            004154
01224             L=MAT1J                                                004160
01225             DO 420 K=NUL,NSPM1                                     004167
01230             IF (I .LT. NETA)  AM(3,J) = AM(3,J) + DUM              004172
01232             IF (I .GE. NETA)  CALL LIAD (K,3,1,DUM)                004202
01234             J = J + NETA                                ANK 8/83   004214
01235         420 DUM=DUM1*DRHOK(K+1)                                    004217
01237             DEPC=ENL(3)                                            004224
01240             RETURN                                                 004226
01240       C**** MODIFIES ENL AND AM AFTER IMONE                        004226
01241        1004 L = I - 1                                              004232
01242             SALPH=-ALPH/TTVC                                       004234
01243             IF(I-2) 650,650,600                                    004237
01243       C**** MODIFIES ENL AND AM AFTER IONLY                        004237
01246        1005 L = I                                                  004245
01247             SALPH= ALPH/TTVC                                       004246
01250         600 DUM = F(L,3)/SALPH                                     004252
01251             ENL(I+3)=ENL(I+3)-DUM*(EPS-DEPC)                       004255
01252             AM(I+3,1)=AM(I+3,1)-DUM*EPS/ALPH                       004263
01253             C28=C28+DUM*EPS                                        004271
01254             DO 605 J=1,NNLEQ                                       004310
01257         605 AM(I+3,J)=AM(I+3,J)+DUM*AM(3,J)                        004310
01261             CALL LIAD (-1,I+3,L+NETA-2,EPS/SALPH)                  004314
01262             MPJ=MAT1J+I-1                                          004331
01263             EPI = 1.0 - 1.0/PRT                                    004335
01264             DEL = - C13*F(L,2)*EPI/SALPH                           004342
01265             AF = G(L,2)/(SALPH*PRT)                                004347
01266             CRD = DEL*EPS                                          004354
01267             DEL = DEL + AF                                         004356
01270             BF = EPS/SALPH*(1.0/SCT - 1.0/PRT)*(HP - CPBAR(L)*TP)  004360
01271             ENL(MPJ) = ENL(MPJ) - AF*(EPS - DEPC) - BF - CRD       004371
01272             C32 = C32 + AF*EPS + BF + CRD                          004401
01273             AM(MPJ,1) = AM(MPJ,1) - AF/ALPH*EPS - 3.0/ALPH*CRD     004407
01274             DO 610 J=1,NNLEQ                                       004434
01277         610 AM(MPJ,J) = AM(MPJ,J) + DEL*AM(3,J)                    004434
01301             AM(MPJ,L+3) = AM(MPJ,L+3) - EPI*C13/SALPH*EPS          004440
01302             CALL LIAD (-1,MPJ,NETA+L-2,-EPI*C10/SALPH*EPS)         004447
01303             CALL LIAD (0,MPJ,L,EPS/(SALPH*PRT))                    004466
01304             IF (NSPM1 .LE. 0)  GO TO 650                           004501
01306             DO 630 K = 1,NSPM1                                     004504
01311             DUM = SP(L,2,K)/(SALPH*SCT)                            004520
01312             MPJ = MPJ + NETA - 1                        ANK 8/83   004526
01313             CK6(K)=CK6(K)+DUM*EPS                                  004534
01314             ENL(MPJ)=ENL(MPJ)-DUM*(EPS-DEPC)                       004537
01315             AM(MPJ,1)=AM(MPJ,1)-DUM/ALPH*EPS                       004544
01316             DO 620 J=1,NNLEQ                                       004556
01321         620 AM(MPJ,J)=AM(MPJ,J)+DUM*AM(3,J)                        004556
01323         630 CALL LIAD (K,MPJ,L,EPS/(SALPH*SCT))                    004562
01325         650 RETURN                                      ANK 4/83   004600
01326             END                                                    004636

      END OF COMPILATION:       NO  DIAGNOSTICS.
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