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INTERIM USER'S MANUAL FOR BOUNDARY LAYER INTEGRAL MATRIX PROCEDURE

VERSION J

by

R. Michael Evans
Howard L. Morse

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LIST OF SYMBOLS

A	wall area
$C_{f/2}$	skin friction factor
C_p	specific heat at constant pressure
CM	mass transfer coefficient
G	total enthalpy
h	static enthalpy
K	mass fraction
k	thermal conductivity
MR	mixture ratio
$\dot{m}$	mass flux
P	pressure
Q	heat flux
q	heat flux per unit area
R,r	radius
St	Stanton number
s	wall length
T	temperature

u	velocity
x	axial coordinate
y	coordinate normal to wall
α	coordinate stretching parameter
δ^*	displacement thickness
δ_B^*	body displacement
η	normalized boundary layer coordinate
θ	momentum thickness
μ	molecular viscosity
ξ	normalized streamwise coordinate
ρ	density
τ	shear
ϕ	wall angle

<u>Subscripts</u>

e	edge value
i,j	species i,j
o	stagnation value
s	constant entropy
T	throat value
w	wall value

SECTION 1

INTRODUCTION

This report is intended to serve as an interim user's manual for Aerotherm's Boundary Layer Integral Matrix Procedure, Version J (BLIMPJ).* Details of the solution procedure can be found in Reference 1. BLIMPJ is intended to serve as rigorous boundary layer program in connection with existing JANNAF reference program such as ODK, DER, and TDK (Reference 2-4). 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.

Section 2 of this report contains a description of the revised input instructions. This version of the BLIMP program has been reoriented to rocket nozzle problems; therefore, many of the options available for other flow conditions do not apply and have been deleted from the input. In these cases the input instructions contain statements to this effect. Section 3 consists of several aids to usage of the program and two auxiliary subroutines provided with this version of BLIMP. The REFIT option is discussed in Section 4. Some features of the output are described in Section 5 and three sample cases are presented in Section 6.

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*A fully documented manual including program listing and Fortran variables description will be issued at a later date.

SECTION 2

INPUT

A comprehensive set of input instructions comprises the bulk of this section. Within these instructions are discussions of some of the options and helpful suggestions for selection of input. The primary selection of all code options is made in group one through the choice of the KR's. The input instructions, the discussion of code usage in Section 3, and the input for the sample cases of Section 6 should provide sufficient information for the average user to prepare input for rocket nozzle problems.

In accordance with JANNAF specifications, all units of input and output are in the International System of units (Reference 5). The internal units of the BLIMPJ code are primarily in the English Engineering system. Since other JANNAF codes have not converted to SI units, there is an option (KR(13)=1) to allow input and output in English units. This option does not, however, change the output headings. Appropriate I/O units for this option are discussed in Section 3.

The present version of BLIMPJ can use as input the nozzle contour and free stream pressure ratio provided by the namelist output of TDK. BLIMP output can provide punched card body contour coordinates in a form compatible with TDK input.

CARD GROUP IDENTIFICATION

ALL CARDS WITH THE EXCEPTION OF THE NAMELIST INPUT (GROUP 3) AND THE THERMOCHEMICAL DATA INPUT (GROUP 13) USE COLUMNS 73-80 FOR IDENTIFICATION (THIS IS OPTIONAL)

5 DIGIT NUMBER IN COLUMNS 73-77
- FIRST TWO DIGITS (73,74) - GROUP NUMBER
- THIRD DIGIT (75) - CARD OR CARD SET NUMBER
- LAST TWO DIGITS (76,77) - CARD NUMBER FOR CARDS WITHIN A CARD SET

COLUMN 80 - ALPHABETIC CHARACTER USED FOR CASE IDENTIFICATION

EX. 1) THIRD CARD OF CARD SET 2 IN GROUP 9, CASE A
09203 A

2) CARD 1 OF GROUP 12 (NOT A CARD SET), CASE B
12100 B

GROUP 1 CONTROL CARD, TITLE, AND IDENTIFICATION (CALLED FROM RECASE)

CARD 1,FORMAT(20I1,15A4),KR

FIELD 1 (COLUMNS 1-20) THIS IS THE VARIABLE KR(DIMENSIONED 20) WHICH IS USED TO CONTROL THE VARIOUS PROGRAM OPTIONS

COLUMN 1 DETERMINES WHETHER A NEW SET OF ETA VALUES IS TO BE INPUT FOR PRESENT CASE (SEE GROUP 4)

0 USES RESIDENT VALUES FROM PREVIOUS CASE

1 VALUES INPUT BY USER (MANDATORY FOR FIRST CASE OR FOR RESTART)

COLUMN 2 DESIGNATES TYPE OF FIRST GUESSES TO BE UTILIZED FOR PRIMARY VARIABLES (SEE GROUP 9)

0 USES BUILT-IN RELATIONS TO CALCULATE FIRST GUESSES (REQUIRES READING ONLY GUESS FOR ENTHALPY OF THE GAS AT THE WALL). RECOMMENDED FOR MOST SITUATIONS.

1 FIRST GUESSES INPUT BY USER

3 FIRST GUESSES INPUT BY USER ARE ACCEPTED AS SOLUTION AT FIRST TIME AND FIRST OR SUBSEQUENT (FOR RESTART) STATION.

COLUMN 3 DETERMINES TREATMENT OF STREAMWISE DERIVATIVES.

0 PERFORMS SIMILAR SOLUTION AT EACH STREAMWISE STATION

1 CONSIDERS TWO-POINT DIFFERENCE RELATIONS AT ALL STATIONS WITH THE FOLLOWING EXCEPTION (A SIMILAR SOLUTION IS PERFORMED AT THE FIRST STATION)

2 CONSIDERS THREE POINT DIFFERENCE RELATIONS AT ALL STATIONS WITH THE

FOLLOWING EXCEPTIONS (A SIMILAR SOLUTION IS PERFORMED AT THE FIRST STATION AND A TWO-POINT SOLUTION IS PERFORMED AT THE SECOND STATION AND A TWO-POINT SOLUTION IS PERFORMED FOR THE FIRST STATION AFTER A DISCONTINUITY OR A REFIT STATION, SEE CARD SET 4 OF GROUP 3)

3,4,5 SAME AS 0,1,2 EXCEPT A LINEAR CURVE FIT (SLOPL) IS USED INSTEAD OF A QUADRATIC CURVE FIT (SLOPQ) FOR EDGE CONDITIONS.

COLUMN 4 DETERMINES WHEN OUTPUT BLOCK IS TO BE PRINTED

0 OUTPUT BLOCK PRINTED FOR CONVERGED SOLUTION OR FOR NONCONVERGED SOLUTION AFTER 50 ITERATIONS (WITH APPROPRIATE COMMENT)

1 OUTPUT BLOCK PRINTED AFTER EACH ITERATION

COLUMN 5 DETERMINES TREATMENT OF ENTROPY LAYER

0 FOR ROCKET NOZZLE PROBLEMS

COLUMN 6 DESIGNATES BODY SHAPE
A DISCONTINUITY INTRODUCED AT A DOWNSTREAM STATION REVERTS TO INTEGRATION WITH RESPECT TO S STARTING AT THAT STATION. IT IS RECOMMENDED THAT THIS BE DONE AFTER AN APPRECIABLE CHANGE OF SURFACE INCLINATION WITH RESPECT TO THE FREE-STREAM VELOCITY FROM THAT AT THE TIP OR STAGNATION POINT. THE OPTIMUM SWITCH-OVER POINT DEPENDS ON THE SPECIFIC BODY SHAPE. IT IS LEFT TO THE USER TO ESTABLISH THIS FOR THE BODY SHAPE OF INTEREST. THE METHOD FOR IMPLEMENTING A DISCONTINUITY IS DISCUSSED UNDER CARD SET 4 OF GROUP 3).

3 PLANAR SHARP - BODY CONTOUR AND PRESSURE DISTRIBUTION INPUT IN NAMELIST FORM (CAN BE USED FOR BOUNDARY LAYER PREDICTIONS ALONG THE WALL OF A RECTANGULAR CROSS SECTION NOZZLE).

4 AXISYMMETRIC NOZZLE

6 AXISYMETRIC NOZZLE - NOZZLE SHAPE AND PRESSURE DISTRIBUTION IN NAMELIST FORM (EX. TDK OUTPUT) (USED WITH GROUP 3, CARD SETS 3, 4, 5)

7 SAME AS 6 WITH TRANSVERSE CURVATURE CONSIDERED.

8 AXISYMETRIC NOZZLE WITH TRANSVERSE CURVATURE (NOT RECOMMENDED)

*** NOTE *** TRANSVERSE CURVATURE SHOULD BE CONSIDERED ONLY WHEN THE BOUNDARY LAYER THICKNESS IS NOT MUCH LESS THAN THE NOZZLE RADIUS

COLUMN 7 DESIGNATES WHETHER OR NOT TURBULENT FLOW WILL BE CONSIDERED.

0 LAMINAR FLOW ONLY

2 TURBULENT FLOW WILL BE COMPUTED IF TRANSITION CRITERIA IS EXCEEDED (SEE GROUP 8).

COLUMN 8 DESIGNATES WHETHER OR NOT BODY SHAPE CORRECTED FOR DISPLACEMENT THICKNESS WILL BE OUTPUT

0 NO CORRECTED BODY CONTOUR

1 CORRECTED BODY CONTOUR AND PUNCH OF R-CORRECTION, THIS GIVES INVISID FLOW CONTOUR FOR THE GIVEN BODY CONTOUR (NOZZLE TO EXIT),

2 CORRECTED BODY CONTOUR AND PUNCH OF R+CORRECTION, THIS GIVES NEW BODY CONTOUR IF PRESENT CONTOUR IS THE DESIRED INVISID CONTOUR (NOZZLE TO EXIT),

3 CORRECTED BODY CONTOUR(R+-DELTA STAR) NO PUNCH

COLUMN 9 TOGETHER WITH COLUMN 11, THIS SPECIFIES THE TYPE OF WALL BOUNDARY CONDITIONS, (SEE APPENDIX A)

0 NOT USED,

1 NOT USED,

2 ASSIGNED COMPONENT MASS FLUXES AT THE WALL (MDOT EDGE GAS, MDOT PYROLYSIS GAS, MDOT CHAR-- REQUIRES KR(11) = 0, 1, OR 2),

3 NOT USED

4 WALL STEADY STATE ENERGY BALANCE WHILE SATISFYING WALL MASS BALANCES AND LIMITED SURFACE EQUILIBRIUM (USE KR(11) = 0, KR(7) = 0 OR 2,)

COLUMN 10 DETERMINES TYPE OF CURVE FITS EMPLOYED TO REPRESENT THE PRIMARY VARIABLES OF VELOCITY RATIO, TOTAL ENTHALPY, AND ELEMENTAL MASS FRACTIONS (KR(10)=1 IS STRONGLY RECOMMENDED FOR ACCURACY FOR MOST PROBLEMS,)

0 UTILIZES CONNECTED CUBICS

1 UTILIZES CONNECTED QUADRATICS EXCEPT FOR OUTERMOST SEGMENT WHERE CONNECTED CUBICS ARE EMPLOYED

2 UTILIZES CONNECTED QUADRATICS EVERYWHERE,

COLUMN 11 TOGETHER WITH COLUMN 9, THIS DESIGNATES THE TYPE OF WALL BOUNDARY CONDITION SEE GROUP 16,

0 ASSIGNED WALL TEMPERATURE, ALSO USED WITH KR(9)=4, THIS OPTION TOGETHER WITH KR(9)=2 WILL YIELD SURFACE EQUILIBRIUM IF THE ASSIGNED TEMPERATURE IS GREATER THAN THE ASSIGNED ABLATION TEMPERATURE (SEE GROUP 11, CARD 1, FIELD 7), THE PROGRAM WILL CALCULATE THE APPROPRIATE CHAR FLUX, ASSIGNED CHAR FLUX SHOULD BE SET TO ZERO (SEE GROUP 16, CARD SET 11),

1 ASSIGNED WALL ENTHALPY,

2 SURFACE EQUILIBRIUM WITH ASSIGNED COMPONENT MASS FLUXES (RE- QUIRES KR(9) = 2), THE PROBLEM IS WELL-POSED AND WILL CONVERGE ONLY IF THERE EXISTS A TEMPERATURE ABOVE 250K GIVING SURFACE EQUILIBRIUM FOR THE ASSIGNED COMPONENT MASS FLUXES, USE WITH CAUTION FOR ANALYSES OF MATERIALS WITH PLATEAU-LIKE BEHAVIOR,

*** USED FOR ASSIGNED BLOWING RATE ***

COLUMN 12 DETERMINES WHETHER OR NOT NEW DATA FOR THERMODYNAMIC AND

TRANSPORT PROPERTIES ARE TO BE USED

0 USER INPUTS NEW DATA FOR ELEMENTS AND MOLECULAR, ATOMIC, AND IONIC SPECIES. THERMOCHEMICAL DATA NOT PRINTED IN OUTPUT.

1 USES RESIDENT ELEMENTAL AND SPECIES DATA.

2 SAME AS KR(12)=0 EXCEPT THERMOCHEMICAL DATA ARE PRINTED IN OUTPUT

COLUMN 13

0 SI UNITS I/O

1 ENGLISH UNITS I/O-NO CHANGE TO HEADINGS

COLUMN 14 DETERMINES MODEL TO BE EMPLOYED FOR MULTICOMPONENT TRANSPORT PROPERTIES. CONSIDERING UNEQUAL DIFFUSION COEFFICIENTS CAN SUBSTANTIALLY INCREASE THE NUMBER OF ITERATIONS (AND SOMETIMES CONVERGENCE DOES NOT OCCUR IN THE ALLOWED NUMBER OF ITERATIONS) DUE TO THE USE OF INEXACT DERIVATIVES IN THE NEWTON-RAPHSON ITERATION PROCEDURE.

0 CONSIDERS UNEQUAL DIFFUSION AND THERMAL DIFFUSION COEFFICIENTS FOR ALL SPECIES

1 CONSIDERS UNEQUAL DIFFUSION COEFFICIENTS FOR ALL SPECIES BUT NEGLECTS THERMAL DIFFUSION

2 CONSIDERS EQUAL DIFFUSION COEFFICIENTS AND NEGLECTS THERMAL DIFFUSION

COLUMNS 15-20 FOR DEBUG PURPOSED ONLY. SHOULD ALL BE SET TO 0.

FIELD 2 (COLUMNS 21-72), CASE

TITLE OF CASE (ALPHANUMERIC). USED FOR IDENTIFICATION OF PRINTED OUTPUT.

GROUP 2 NUMBER OF ELEMENTS (CALLED FROM RECASE)

CARD 1, FORMAT(I2,8X,40I1)

FIELD 1 (COLUMNS 1-2, RIGHT-JUSTIFIED), NSP

NUMBER OF ELEMENTS IN THE SYSTEM NOT INCLUDING ELECTRONS (MAX. OF 9)

FIELDS 2-51 (COLUMNS (11-60), KS(M), M=1,NS ***** USED ONLY FOR KR(9) OR ANY OF THE KR9 = 2 OR 4 *****

(THIS INFORMATION IS USED ONLY FOR ABLATING WALL MATERIAL.) THE SURFACE MATERIAL IS SPECIFIED IN ADVANCE BY THE USER FOR KR(9) = 2 OR 4. UP TO THREE MATERIAL COMBINATIONS ARE ALLOWED. EACH

COMBINATION MAY HAVE A SEPARATE PYROLYSIS GAS AND CHAR MATERIAL SPECIFIED IN GROUP 11, FIELD 5. ENTER A 1, 2, OR 3 TO DENOTE MATERIAL COMBINATION 1, 2, OR 3 STARTING WITH THE STATION 1 ENTRY IN COLUMN 11, STATION 2 IN COLUMN 12, ETC. SEE ALSO GROUP 6, CARDS 1 AND 2.

GROUP 3 STATION INFORMATION (CALLED FROM RECASE)

CARD 1, FORMAT(I2,8X,40I1)

FIELD 1 (COLUMNS 1-2, RIGHT-JUSTIFIED), NS

NUMBER OF STREAMWISE STATIONS (MAXIMUM OF 40)

FIELD 2 (COLUMNS 11-50), KR9

VALUES TO BE ASSIGNED TO KR(9) WHEN WALL BOUNDARY CONDITIONS ARE TO BE CHANGED AT DOWNSTREAM STATIONS (SEE CARD 1 OF GROUP 1). COLUMN 11 CORRESPONDS TO STATION S(1), COLUMN 12 TO STATION S(2), AND SO ON. IF WALL BOUNDARY CONDITIONS ARE NOT TO BE CHANGED AT DOWNSTREAM STATIONS, THIS FIELD SHOULD BE LEFT BLANK. WHEN THE KR9( ) ARE EMPLOYED, KR(9) SHOULD BE GIVEN THE VALUE NECESSARY TO READ ALL APPROPRIATE WALL DATA (GROUP 16).
AT THE PRESENT TIME, IT IS POSSIBLE TO CONSIDER ANY COMBINATIONS OF KR9 OF 2, 3, AND 4 COMPRISING REGIONS OF AN ABLATION MATERIAL AND REGIONS WHERE THERE IS NO ABLATION (THESE NONABLATING REGIONS ARE OBTAINED BY USE OF KR9( ) = 2 WHILE ASSIGNING ZERO COMPONENT MASS FLUXES, SEE CARD SET 11 OF GROUP 16)

CARD SET 2, FORMAT(7E10.4)

FIELD 1 (COLUMNS 1-10) S(1)
S(1) IS NORMALIZED BY RTM. SEE GROUP 5, CARD 1.

FIELD 2 (COLUMNS 11-20),FIELD 3 (COLUMNS 21-30),ETC. 7 FIELDS PER CARD.
S(L), L=2,NS ***USED ONLY FOR KR(6)=4 OR 8***

STREAMWISE DISTANCE UPON WHICH BOUNDARY-LAYER SOLUTION IS BASED. S(L) IS ENTERED IN NORMALIZED FORM - THE NORMALIZING FACTOR BEING RTM INPUT IN GROUP 5, CARD 1. S(1) MUST NOT BE 0. THE VALUE OF S(1) SHOULD BE SELECTED TO REPRESENT THE PHYSICAL DISTANCE FROM THE START OF THE BOUNDARY-LAYER DEVELOPMENT TO THE FIRST SOLUTION STATION. THE BOUNDARY LAYER IS ASSUMED TO BE SIMILAR UP TO AND INCLUDING THIS FIRST STATION. A NEGATIVE ENTRY FOR S(L) SIGNIFIES A DISCONTINUITY AT THAT STATION. THIS PRODUCES A TWO-POINT DIFFERENCE SOLUTION AT THE FIRST STATION AFTER THE DISCONTINUITY AND THUS HAS AN EFFECT ONLY FOR THREE-POINT SOLUTIONS (KR(3)=2). (ALSO SEE CARD SET 4)

CARD 3 ,FORMAT (2I5) ***** USED ONLY FOR KR(6)=3,6,7 *****

FIELD 1 (COLUMNS 1-5) N

NUMBER OF THE LAST STATION OF NOZZLE CONTOUR DATA READ UNDER THE NAMELIST $INPUT OF CARD SET 5.

FIELD 2 (COLUMNS 6-10) NTH

THROAT STATION NUMBER IN THE NAMELIST INPUT.

CARD SET 4 ,FORMAT (14I5) ***** USED ONLY IF CARD 3 IS USED *****

FIELD 1 (COLUMNS 1-5), FIELD 2 (COLUMNS 6-10), ETC. 14 PER CARD, NP(I), I=1,NS (SEE CARD 1), RIGHT JUSTIFIED

THE STATION NUMBERS OF THE NS STATIONS OF NAMELIST INPUT TO BE USED AS BLIMP SOLUTION STATIONS. ENTER IN ASCENDING ORDER. A NEGATIVE ENTRY IDENTIFIES A DISCONTINUITY AT THAT STATION AND HAS THE SAME EFFECT AS A NEGATIVE ENTRY FOR S(L) AS DISCUSSED IN CARD SET 2, FIELD 2.

CARD SET 5 NAMELIST ($INPUT) FOR XITAB,YITAB,PITAB ***** USED ONLY IF CARD 3 IS USED *****

(TDK OUTPUT FOR XITAB, YITAB, AND PITAB (MAX OF 500 STATIONS) CAN BE INPUT HERE.)
XITAB, YITAB ARE THE COORDINATES OF THE BODY CONTOUR NORMALIZED BY RTM. (FOR A CIRCULAR CROSS SECTION NOZZLE YITAB IS THE RADIUS/RTM)
PITAB = PRESSURE AT EACH STATION, NORMALIZED BY THE STAGNATION PRESSURE.

*** NOTE *** THE NAMELIST CARDS ARE NOT SEQUENTIALLY IDENTIFIED.

GROUP 4 NODAL DATA (CALLED FROM RECASE) *** SKIP THIS GROUP FOR KR(1)=0 ***

CARD 1, FORMAT(I2) ***** USED ONLY IF KR(1)=1 *****

FIELD 1 (COLUMNS 1-2, RIGHT-JUSTIFIED), NETA

NUMBER OF NODAL POINTS ACROSS THE BOUNDARY LAYER INCLUDING WALL AND BOUNDARY LAYER EDGE (MAXIMUM OF 15).

CARD SET 2, FORMAT(7E10.4) ***** USED ONLY IF KR(1)=1 *****

FIELD 1 (COLUMNS 1-10), FIELD 2 (COLUMNS 11-20), ETC., 7 TO A CARD, ETA(I), I=1,NETA (SEE CARD 1 OF THIS GROUP)

ETA STATIONS ACROSS THE BOUNDARY LAYER, STARTING AT WALL (ETA=0.0). IT IS RECOMMENDED THAT THE VALUE OF ETA AT THE BOUNDARY-LAYER EDGE BE GIVEN A VALUE OF ABOUT 5.0 SO THAT THE STRETCHING PARAMETER WILL BE NEAR UNITY. ALSO, THERE SHOULD NOT BE MUCH MORE THAN A TWO-FOLD CHANGE IN DISTANCE BETWEEN TWO NEIGHBORING NODES. BEST ACCURACY FOR A GIVEN NUMBER OF NODES IS OBTAINED IF THE NODES ARE CLOSER TOGETHER NEAR THE WALL. FOR LAMINAR PROBLEMS, 7 NODES ARE OFTEN SUFFICIENT WITH A TYPICAL SPACING BEING 0.0, 0.5, 1.0, 1.5, 2.0, 3.0, 5.0 AND WITH KAPPA = 5, CBAR = 0.8 (SEE CARD 3, FIELDS 1 AND 2 OF THIS GROUP). FOR TURBULENT BOUNDARY LAYERS, MORE NODES ARE NEEDED CLOSE TO THE WALL DUE TO THE STEEP GRADIENTS THERE. A TYPICAL SPACING WOULD BE 0.0, 0.002, 0.006, 0.01, 0.025, 0.06, 0.15, 0.4, 0.7, 1.0, 1.5, 2.5, WITH KAPPA = 10 AND CBAR = 0.95. WHATEVER THE NODE SPACING THE

USER MUST EXAMINE THE SOLUTIONS TO BE SURE THAT A REASONABLE CURVEFIT IS OBTAINED NEAR THE WALL. THIS CAN BE A PROBLEM FOR LARGE STREAMWISE DISTANCES IN TURBULENT FLOWS. *** NOTE *** USE OF REFIT OPTION MAKES THE INITIAL SELECTION OF NODAL POINTS NON-CRITICAL.

CARD 3 FORMAT (I2,E10.4,2I2,F10.4,3I2) *****USED ONLY IF KR(1)=1*****

FIELD 1 (COLUMNS 1-2, RIGHT-JUSTIFIED), KAPPA

THE VARIABLE KAPPA IS ASSOCIATED WITH THE CONSTRAINT WHICH IS UTILIZED TO EFFECT A STRETCHING OF ETA, THE BOUNDARY-LAYER COORDINATE NORMAL TO THE SURFACE, IN ORDER TO EFFECTIVELY USE THE ASSIGNED NODAL SPACING (SEE CARDS 1 AND 2 OF THIS GROUP). KAPPA IS THE INDEX FOR THE NODAL POINT AT WHICH THE VELOCITY RATIO IS FIXED. TO ILLUSTRATE, IF KAPPA IS 5, THEN THE FIFTH NODAL POINT COUNTING FROM THE WALL AND INCLUDING THE WALL WILL HAVE A VALUE OF CBAR (A QUANTITY WHICH IS INPUT IN THE SECOND FIELD OF THIS CARD).

FIELD 2 (COLUMNS 3-12), CBAR

CBAR IS THE VALUE OF THE VELOCITY RATIO AT THE BOUNDARY-LAYER NODE DESIGNATED KAPPA (SEE DISCUSSION UNDER FIELD 1 OF THIS CARD).

FIELD 3 (COLUMNS 13-14, RIGHT-JUSTIFIED) KONRFT

THE VARIABLE KONRFT DETERMINES IF THE NODAL REFIT OPTION IS TO BE USED. FOR KONRFT=0, THE DEFAULT VALUE, REFIT IS NOT CALLED. IF THE REFIT OP- TION IS DESIRED, SET KONRFT = 1. THE REMAINING FIELDS ON CARD 3 ARE NOT REQUIRED IF KONRFT =0.

FIELD 4 (COLUMNS 15-16, RIGHT-JUSTIFIED) NPOINT

NPOINT IS THE NUMBER OF EXTRA DATA POINTS TO BE USED TO DEFINE EACH POLYNOMIAL SEGMENT DURING REFIT. SHOULD BE SET BETWEEN 1 AND 6- THE HIGHER THE NUMBER, THE GREATER THE DEFINITION OF THE CURVE PRIOR TO REFITTING. GENERALLY FROM 3 TO 5 APPEARS REASONABLE. IF NO VALUE OR 0 IS INPUT A DEFAULT VALUE OF 5 IS USED. IF A VALUE GREATER THAN 6 IS SELECTED, IT IS OVERRIDEN AND REPLACED BY 6.

FIELD 5 (COLUMNS 17-26) RATLIM

IN CONJUNCTION WITH THE VALUES OF F2FIX (SEE CARD 4 BELOW) RATLIM DETER- MINES HOW FAR AWAY FROM THE DESIRED VALUE THE VALUE OF F(2,I) IS ALLOWE- D TO DRIFT BEFORE REFIT IS CALLED. RATLIM IS EXPRESSED AS A RATIO OF THE DIFFERENCE BETWEEN THE DESIRED VALUES OF NEIGHBORING NODES. FOR EXAMPLE IF F2FIX(2)=0.1, F2FIX(3)=0.2 AND RATLIM=0.5, F(2,2) MAY DRIFT UPWARD OR F(2,3) DOWNWARD TO 0.15 BEFORE REFIT IS CALLED. RATLIM MUST BE SEL- ECTED BETWEEN 0.0 AND 1.0. OBVIOUSLY THE SMALLER THE VALUE, THE TIGHTER THE CONSTRAINT ON NODAL POSITIONING. A VALUE OF 0.0 WILL CAUSE REFIT TO BE CALLED AFTER EVERY CONVERGED SOLUTION.

FIELD 6 (COLUMNS 27-28 RIGHT-JUSTIFIED) KTURB

THE SWITCH KTURB DETERMINES IF THE NUMBER OF NODES ARE TO BE CHANGED UPON TRANSITION TO A TURBULENT BOUNDARY LAYER SOLUTION . FOR KTURB=0 (DEFAULT VALUE) NO CHANGE IS MADE. FOR KTURB =1 A SECOND SET OF KAPPA, CBAR, AND F2FIX VALUES ARE REQUIRED AND ARE NAMED, KAPPAT, NETAT, AND F2FIXT WHICH FUNCTION IDENTICALLY TO THEIR ORIGINAL COUNTERPARTS. CURRENTLY THIS OPTION IS LIMITED TO OCCURING SIMULTANEOUSLY WITH THE

TRANSITION TO TURBULENT FLOW. THE REMAINING FIELDS ON CARD 3 ARE NOT REQUIRED IF KTURB=0.

FIELD 7 (COLUMNS 29-30 RIGHT-JUSTIFIED) KAPPAT

KAPPAT HAS THE SAME MEANING AS KAPPA IN FIELD 1 OF THIS CARD AND IS USED IF A CHANGE IN THE NUMBER OF NODES IS TO BE MADE (KTURB=1).

FIELD 8 (COLUMNS 31-32 RIGHT-JUSTIFIED) NETAT

NETAT IS THE NEW NUMBER OF NODES ACROSS THE LAYER FOR KTURB=1.

CARD SET 4 FORMAT (8E10.4) *****USED ONLY IF KONRFT=1*****

FIELD1 (COLUMNS 1-10), FIELD 2 (COLUMNS 11-20), ETC. 8 TO A CARD, F2FIX(I), I=1,NETA (SEE CARD 1 OF THIS GROUP).

F2FIX(I) IS THE DESIRED DISTRIBUTION OF THE VELOCITY RATIO ACROSS THE BOUNDARY LAYER WHEN THE REFIT OPTION IS EMPLOYED. THE VALUES OF F2FIX MUST GO FROM 0.0 TO 1.0 AND THE VALUE OF F2FIX(KAPPA) MUST EQUAL CBAR.

CARD SET 5 FORMAT (8E10.4) *****USED ONLY IF KONRFT=1 AND KTURB=1*****

FIELD 1 (COLUMNS 1-10) FIELD 2 (COLUMNS 11-20), ETC., 8 TO A CARD. F2FIX(I), I=1,NETAT (SEE CARD 3 OF THIS GROUP).

F2FIXT(I) IS EQUIVALENT IN MEANING TO F2FIX(I) OF CARD 4 EXCEPT THAT IT APPLIES TO THE CHANGE IN THE NUMBER OF NODES. F2FIX(KAPPAT) MUST EQUAL CBAR.

GROUP 5 BODY SHAPE DATA (CALLED FROM RECASE)

CARD 1 ,FORMAT (E10.4)

FIELD 1 (COLUMNS 1-10) RTM

RTM (METERS) IS USED AS A NORMALIZING FACTOR FOR ALL LENGTH VARIABLES - S, ROKAP, YITAB. (RTM IS THROAT RADIUS FOR NOZZLES.)

CARD SET 2, FORMAT(7E10.4) ***** USED ONLY FOR KR(6) = 4 OR 8 *****

FIELD 1 (COLUMNS 1-10), FIELD 2 (COLUMNS 11-20), ETC., 7 TO A CARD, ROKAP(L), L=1, NS (SEE CARD 3 OF GROUP 3)

THIS IS THE LOCAL BODY RADIUS NORMAL TO THE BODY CENTERLINE NORMALIZED BY RTM.

GROUP 6 MATERIAL PROPERTY DATA NEEDED FOR WALL QUASI-STEADY ENERGY BALANCE (CALLED FROM RECASE) *****CONSIDER THIS GROUP ONLY IF KR(9) OR ANY OF THE KR9 IS EQUAL TO 3 OR GREATER*****

CARD 1, FORMAT(9E8.3) ** USED ONLY IF KR(9) OR ANY OF THE KR9 IS 3 OR 4 **

FIELDS 1,4,7 (COLUMNS 1-8, 25-32, 49-56), EMIV(I),I=1,3

SURFACE EMITTANCE OF THE MATERIAL COMBINATIONS BEING CONSIDERED UNDER KR(9) OR KR9 OF 3 OR 4.

FIELDS 2,5,8 (COLUMNS 9-16, 33-40, 57-64), HCARB(I),I=1,3

HEAT OF FORMATION (J/KG) OF THE VIRGIN STATE OF THE ABLATION MATERIALS BEING CONSIDERED UNDER KR(9) OR KR9 OF 3 OR 4.

FIELDS 3,6,9 (COLUMNS 17-24, 41-48, 65-72), HPYG(I),I=1,3

HEAT OF FORMATION (J/KG) OF THE TRANSPIRANTS BEING CONSIDERED UNDER KR(9) OR KR9 OF 3 OR 4.

CARD 2, FORMAT(6A4) ** USED ONLY WITH CARD 1 **

FIELDS 1,2, AND 3 (COLUMNS 1-8, 9-16, 17-24)

NAMES OF SURFACE SPECIES FOR MATERIAL COMBINATIONS 1,2, AND 3 EXACTLY AS THEY APPEAR IN THE THERMODYNAMIC DATA TABLES (GROUP 13), LEFT JUSTIFIED.

GROUP 7 STAGNATION DATA (CALLED FROM RECASE)

CARD 1 ,FORMAT (7E10.4)

FIELD 1 (COLUMNS 1-10)

LOCAL STAGNATION PRESSURE (N/M**2)

FIELD 2 (COLUMNS 11-20)

NORMALIZING FACTOR FOR THE EDGE PRESSURE READ IN UNDER NAMELIST FORM IF THOSE PRESSURES ARE NOT NORMALIXED TO THE STAGNATION PRESSURE, PRE= PRE/FACTOR

CARD 2 ,FORMAT (7E10.4)

FIELD 1 (COLUMNS 1-10)

STAGNATION ENTHALPY OF THE EDGE GAS (J/KG)

CARD 3 ,FORMAT (7E10.4)

FIELD 1 (COLUMNS 1-10)

INCIDENT RADIATION FLUX ABSORBED BY THE SURFACE AT STATION S(1), J/SEC-M**2. (IF A SURFACE ABSORPTIVITY LESS THAN UNITY IS TO BE CONSIDERED, THIS ENTRY SHOULD BE CORRECTED FOR SURFACE ABSORPTIVITY). THIS INFORMATION IS USED ONLY FOR KR(9) OR KR9 OF 4. INPUT BLANKS IN THIS FIELD FOR OTHER TYPES OF PROBLEMS. RADIATION FLUX AT OTHER STATIONS WILL BE INPUT AS RATIOS IN GROUP 15.

GROUP 8 TURBULENT FLOW PARAMETERS (CALLED FROM TREMBL) **** CONSIDER THIS GROUP ONLY IF KR(7)=2 *****

CARD 1, FORMAT(6E10.3)

FIELDS 1-6, (COLUMNS 1-10, 11-20, 21-30, 31-40, 41-50, 51-60) ELCON, YAP, CLNUM, SCT, PRT, RETR

ELCON IS THE PRANDTL MIXING LENGTH CONSTANT (0.44 IS A TYPICAL VALUE).

YAP IS A CONSTANT OF PROPORTIONALITY IN THE MIXING LENGTH EXPRESSION (11.823 IS A TYPICAL VALUE).

CLNUM IS THE CLAUSER CONSTANT OF PROPORTIONALITY IN OUTER WAKE REGION. (0.018 IS A TYPICAL VALUE)

SCT IS THE TURBULENT SCHMIDT NUMBER. (0.9 IS A TYPICAL VALUE)

PRT IS THE TURBULENT PRANDTL NUMBER. (0.9 IS A TYPICAL VALUE)

RETR IS THE TRANSITION REYNOLDS NUMBER BASED ON MOMENTUM THICKNESS. IF RETR IS EXCEEDED, TURBULENCE TERMS WILL BE INCLUDED IN THE GOVERNING EQUATIONS.

GROUP 9 FIRST GUESS OR RESTART INFORMATION (CALLED FROM FIRSTG) **** SKIP THIS GROUP FOR KR(2)=2. CONSIDER ONLY CARD 6 FOR KR(2)=0 ****

CARD 1 ,FORMAT (3E10.4,5X,I5,E10.4) **** USED ONLY IF KR(2)=1 OR 3 ****

FIELD 1 (COLUMN 1-10) ALPH

FIRST GUESS OR RESTART VALUE FOR BOUNDARY LAYER NORMALIZING PARAMETER (USE A 1.0 IF A BETTER GUESS IS NOT KNOWN).

FIELD 2 (COLUMNS 11-20) F(1,1)

FIRST GUESS OR RESTART VALUE FOR STREAM FUNCTION AT THE WALL.

FIELD 3 (COLUMNS 21-30) F(3,1)

FIRST GUESS OR RESTART VALUE FOR NORMALIZED VELOCITY GRADIENT AT THE WALL.

FIELD 4 (COLUMN 36-40, RIGHT JUSTIFIED) IST

STATION NUMBER FOR RESTART. MEANINGFUL ONLY FOR KR(2)=3.

CARD SET 2, FORMAT(7E10.4) **** USED ONLY FOR KR(2)=1 OR 3 ****

FIELD 1 (COLUMNS 1-10), FIELD 2 (COLUMNS 11-20), ETC., 7 TO A CARD, F(2,I), I=1,NETA.

FIRST GUESSES OR RESTART VALUES FOR VELOCITY RATIO U/U1 ACROSS THE BOUNDARY LAYER.

CARD SET 3, FORMAT(7E10.4) **** USED ONLY FOR KR(2)=1 OR 3 ****

FIELD 1 (COLUMNS 1-10), FIELD 2 (COLUMNS 11-20), ETC., 7 TO A CARD, G(2,1), G(1,I), I=1,NETA

FIRST GUESSES OR RESTART VALUES FOR ENTHALPY GRADIENT AT THE WALL G(2,1) AND ENTHALPY G(1,I) ACROSS THE BOUNDARY LAYER, J/KG.

CARD SET 4, FORMAT(7E10.4) **** USED ONLY FOR KR(2)=1 OR 3 AND NSP GREATER THAN 1 ****

FIELD 1 (COLUMNS 1-10), FIELD 2 (COLUMNS 11-20), ETC., 7 TO A CARD, (SP(2,1,K), SP(1,I,K), I=1,NETA) K=1, NSP-1

FIRST GUESSES OR RESTART VALUES FOR ELEMENTAL MASS FRACTION GRADIENT AT THE WALL SP(2,1,K) AND ELEMENTAL MASS FRACTION VALUES SP(1,I,K) ACROSS THE BOUNDARY LAYER. READ IN WALL GRADIENT AND VALUES AT NODES FOR EACH ELEMENT BEFORE GOING ON TO NEXT ELEMENT. START EACH ELEMENT ON A NEW CARD.

CARD SET 5, FORMAT(36I2) **** USED ONLY FOR KR(2)=1 OR 3 AND NSP GREATER THAN 1 ****

FIELD 1 (COLUMNS 1-2, RIGHT JUSTIFIED), FIELD 2 (COLUMNS 3-4, RIGHT JUSTIFIED), ETC., (LEF(K), K=1,NSP) (SEE CARD 1 OF GROUP 2)

ENTRIES IN THESE FIELDS MUST INDIVIDUALLY CORRESPOND TO THE ELEMENTS AS THEY ARE SELECTED FROM THE THERMODYNAMIC DATA (SEE DISCUSSION UNDER GROUP 13) ACCORDING TO WHETHER, FOR THE FIRST, OR RESTART, STATION, THE ELEMENT IS

0 NOT PRESENT

1 PRESENT DUE TO LOCAL INJECTION

2 PRESENT DUE TO UPSTREAM INJECTION (NOT POSSIBLE AT FIRST STATION)

3 PRESENT FROM THE EDGE GAS

CARD 6, FORMAT(E10.4) ***** USED ONLY FOR KR(2)=0 *****

FIELD 1 (COLUMNS 1-10), GW

FIRST GUESS FOR ENTHALPY OF THE GAS AT THE WALL, J/KG. IF NO INFORMATION IS AVAILIABLE USE THE VALUE OF THE STAGNATION ENTHALPY (GROUP 7, CARD 2)

GROUP 10 ***** NOT USED FOR THIS VERSION *****

GROUP 11 ELEMENTAL DATA (CALLED FROM INPUT)
**** SKIP THIS GROUP FOR KR(12)=1 OR 6 OR FOR KR(7)=1 OR 3 ****

CARD 1, FORMAT(I3,F7.0,5F10.4) **** USED ONLY FOR KR(12)=0,2,5, OR 7

FIELD 1 (COLUMNS 1-3, RIGHT-JUSTIFIED), IS

NUMBER OF ELEMENTS IN THE SYSTEM INCLUDING ELECTRONS IF CONSIDERED (THIS ENTRY WILL BE THE SAME AS CARD 1 OF GROUP 2 (EXCEPT FOR THE DIFFERENT FORMAT) FOR SYSTEMS NOT CONTAINING ELECTRONS BUT WILL BE ONE GREATER FOR SYSTEMS CONTAINING ELECTRONS)

FIELDS 2 AND 3 (COLUMNS 4-10,11-20) FFAR, FITMOL

CONSTANTS IN THE CURVEFIT OF FF(J) IN TERMS OF MOLECULAR WEIGHT..

FF(J)=(WTM(J)/FITMOL)**FFAR

FFAR AND FITMOL ARE PRESUMED TO BE 0.431 AND 23.4 IF NO ENTRY IS MADE.

FIELDS 4, 5, AND 6 (COLUMNS 21-30, 31-40, 41-50) BASMOL, SIGMA, EPOVRK

*** NOTE FOR FIELDS 2-6 ***

THESE VARIABLES DEFINE THE REFERENCE SPECIES PROPERTIES FOR FF(J) - (AEROTHERM FINAL REPORT NO. 69-53, JULY 1969). BASMOL IS THE MOLECULAR WEIGHT OF THE REFERENCE SPECIES. SIGMA AND EPOVRK ARE THE SPECIES SIGMA AND EPSILON/K AS DEFINED BY SVEHLA ('ESTIMATED VISCOSITIES AND THERMAL CONDUCTIVITIES OF GASES AT HIGH TEMPERATURES', NASA TR-R-132, 1964). STANDARD VALUES DESCRIBED IN AEROTHERM REPORT 69-53 ARE USED IF NO ENTRIES ARE MADE.

FIELD 7 (COLUMNS 51-60) TF(N+1) **** USED ONLY FOR KR(9) = 2 WITH KR(11) = 0 ****

ABLATION TEMPERATURE (DEG K), ABOVE WHICH EQUILIBRIUM CHAR REMOVAL RATE WILL BE DETERMINED. BELOW THIS TEMPERATURE, SURFACE EQILIBRIUM IS SUPPRESSED. AUTOMATICALLY SET TO 50,000 K IF NO ENTRY. AN ABLATION TEMP-ERATURE MUST BE ENTERED IF SURFACE CHEMISTRY IS TO BE CONSIDERED.

CARD SET 2

CARDS 1,2,3...,IS (ONE FOR EACH ELEMENT, SEE CARD 1, FIELD 1 OF THIS GROUP), FORMAT (1X,A2,3A4,8F7.3) **** USED ONLY FOR KR(12)=0,2,5, OR 7 ***

FIELD 1 (COLUMNS 2-3 ***LEFT JUSTIFIED***) KAT(K)

ATOMIC SYMBOL OF ELEMENT (E FOR ELECTRON), WITH ELECTRON LAST (WHEN CONSIDERED).

FIELD 2, (COLUMNS 4-15) ATA(K), ATB(K), ATC(K)

NAME OF ELEMENT (USED FOR OUTPUT ONLY). FOR BEST LOOKING OUTPUT, ELEMENTS WITH 3 OR 4 LETTERS (EG., IRON) SHOULD START IN COLUMN 6, ELEMENTS WITH 5, 6, OR 7 LETTERS (EG., CARBON) SHOULD START IN COLUMN 5, AND ELEMENTS WITH 8 OR MORE LETTERS (EG., NITROGEN) SHOULD START IN COL. 4.

FIELD 3 (COLUMNS 16-22), WAT(K)

ATOMIC WEIGHT OF ELEMENT

FIELD 4 (COLUMNS 23-29) TK(K,1)

AMOUNT OF ELEMENT IN BOUNDARY-LAYER EDGE GAS. SEE BELOW FOR UNITS.

FIELDS 5 TO 10 (COLUMNS 30-36, 37-43, 44-50, 51-57, 58-64, 65-71) TK(K,J) J=2,7

AMOUNT OF ELEMENT IN PYROLYSIS GAS AND CHAR FOR EACH OF THE THREE ALLOWABLE MATERIALS. FIELDS 5 AND 6 ARE FOR MATERIAL 1, FIELDS 7 AND 8 FOR MATERIAL 2, ETC. NEGATIVE VALUES ARE USED TO DESIGNATE RELATIVE MASSES OF ELEMENTS, WHEREAS POSITIVE VALUES ARE USED TO DESIGNATE RELATIVE NUMBERS OF ATOMS. AS AN EXAMPLE OF THE LATTER, THE ENTRIES FOR A SILICA CHAR COULD BE 1. FOR THE ELEMENT SILICON AND 2. FOR OXYGEN.

GROUP 12 DIFFUSION FACTOR DATA (CALLED FROM INPUT)

**** SKIP THIS GROUP FOR KR(12)=1 OR IF IT IS DESIRED TO USE THE MOLECULAR WEIGHT APPROXIMATION FOR DIFFUSION FACTORS (SEE FIELDS 2 AND 3 OF CARD 1 OF GROUP 11).

CARD 1, FORMAT(I5) ***** USED ONLY FOR KR(12)=0 OR 2, AND THEN ONLY IF IT IS DESIRED TO READ IN DIFFUSION FACTOR DATA FOR ONE OR MORE SPECIES *****

FIELD 1 (COLUMNS 1-5, RIGHT-JUSTIFIED) NFF

NUMBER OF MOLECULES FOR WHICH DIFFUSION FACTOR DATA ARE TO BE READ (SEE FIELDS 2 AND 3 OF CARD 1 OF GROUP 11).

CARD SET 2

CARDS 1,2,3,..., AS REQUIRED (DIFFUSION FACTOR DATA REQUESTED BY CARD 1 OF THIS GROUP ARE ENTERED HERE 3 TO A CARD) FORMAT(3(2A4,E12.4))
***** USED ONLY FOR KR(12)=0 OR 2, AND THEN ONLY IF THE CONDITIONS OF CARD 1 OF THIS GROUP ARE MET *****

FIELDS 1, 3, 5, AND 7 (COLUMNS 1-8, 21-28, 41-48, AND 61-68, RESPECTIVELY) NFIA(J) AND NFIB(J) IN EACH FIELD

NAME OF MOLECULE AS IT APPEARS IN COLUMNS 73-80 ON FIRST CARD OF 4-CARD THERMODYNAMIC DATA SET FOR THE MOLECULE (SEE GROUP 13, CARD SETS 2,3, 4,..., CARD 1)

FIELDS 2, 4, 6, AND 8 (COLUMNS 9-20, 29-40, 49-60, AND 69-80 RESPECTIVELY) FFIN(J) IN EACH FIELD

A SET OF FF(J) ARE INCLUDED IN THE PROGRAM, IF ANY OF THESE ARE TO BE CHANGED, THE NEW VALUES FOR EACH OF THE SPECIES NAMED IN FIELDS 1,3,5 ETC, ARE ENTERED HERE UNDER THE VARIABLE NAME FFIN(J), THEY ARE THEN SORTED BY SPECIES NAME AND ENTERED INTO THE PROPER SLOTS IN THE FF(J) ARRAY. THESE DIFFUSION FACTORS ARE REFERENCED TO OXYGEN (O2) OR OTHER REFERENCE SPECIES INDICATED IN GROUP 11, TO OBTAIN ACCURATE VISCOSITY CALCULATIONS USE

```
FF(J)=(SIGMA(J)*WTM(J)**,25*EPOVRK(J)**,0795)/(SIGMA(REF)*WTM(REF)
          **,25*EPOVRK(REF)**,0795)
```

GROUP 13 THERMOCHEMICAL DATA (CALLED FROM INPUT)
***** SKIP THIS GROUP FOR KR(12)=1 *****

THERE ARE FOUR CARDS FOR EACH MOLECULAR, ATOMIC, CONDENSED, OR IONIC SPECIES, A TOTAL OF 70 SPECIES OF ALL TYPES ARE ALLOWED, THE NUMBER OF ALLOWABLE CONDENSED-PHASE MATERIALS WHICH CAN BE SIMULTANEOUSLY PRESENT IN ANY SOLUTION IS 4, ANY NUMBER OF CONDENSED PHASE SPECIES CAN BE INCLUDED IN THE THERMOCHEMICAL DATA DECK, (NOTE,,, CONDENSED SPECIES ARE REQUIRED IN SURFACE EQUILIBRIUM CALCULATIONS FOR CONSID- ERATION AS CANDIDATE SURFACE MATERIALS BUT ARE NOT PRESENTLY CONSID- ERED AS CANDIDATE SPECIES WITHIN THE BOUNDARY LAYER), A BLANK CARD AFTER THE LAST SET CONCLUDES THE THERMODYNAMIC DATA, THE ARRANGEMENT OF THESE CARD SETS IS OF CONSEQUENCE IN SO FAR AS IT DETERMINES THE BASE SPECIES UPON WHICH MASS BALANCES ARE PERFORMED, THE FIRST INDE- PENDENT SET OF BASE SPECIES BEING SELECTED, SINGULAR MATRICES CAN RE- SULT FROM CERTAIN SETS OF THEORETICALLY ACCEPTABLE BASE SPECIES DUE TO ROUND-OFF ERRORS, FURTHERMORE, MASS BALANCES, ETC, FOR THE (NSP)TH BASE SPECIES (SEE CARD 1 OF GROUP 2) IS OBTAINED BY DIFFERENCE, THEREFORE, THE ELEMENT REPRESENTED BY THIS BASE SPECIES SHOULD BE PRESENT IN APPRECIABLE QUANTITIES THROUGHOUT THE BOUNDARY LAYER, FOR EXAMPLE, FOR ABLATION IN AIR, MOLECULAR NITROGEN IS A GOOD CHOICE FOR THE (NSP)TH BASE SPECIES,
A MULTIPLE PHASE SPECIE SHOULD BE ENTERED TOGETHER IN ORDER OF AS- CENDING TEMPERATURE RANGES, THE GAS PHASE AND TWO PHASES OF ANY COMBINATION OF SOLID AND LIQUID ARE ALLOWED,
EXCEPT FOR THESE CONSIDERATIONS, ATOMIC, MOLECULAR, AND CONDENSED SPECIES CAN BE ARRANGED IN ANY ORDER, WHEN IONIZED FLOWS ARE CON- SIDERED, THE ATOMIC, MOLECULAR AND CONDENSED SPECIES DATA MUST APPEAR FIRST AND BE FOLLOWED BY, FIRST, ELECTRON SPECIES DATA, AND THEN THE IONIC SPECIES DATA (WHICH CAN BE IN ANY ORDER), THE DATA FORMAT ACCEPTED BY THE PROGRAM (DESCRIBED BELOW) IS AS GENERATED BY 'FORTRAN IV PROGRAM FOR CALCULATION OF THERMODYNAMIC DATA' DESCRIBED IN NASA TN D-4097, AUGUST 1967,

***** NOTE ***** THESE CARDS ARE NOT SEQUENTIALLY IDENTIFIED IN COLUMNS 73-80 WITH THE SYSTEM USED ELSEWHERE,

CARD 1 ,FORMAT (I5,3F10.3)

FIELD 2,3,4 (COLUMNS 6-15,16-25,26-31) TJ(I),I=1,3

TEMPERATURE RANGES FOR THE TEMPERATURE COEFFICIENTS, (DEG K)

TJ(1) = LOWER TEMPERATURE LIMIT
TJ(2) = COMMON TEMPERATURE
TJ(3) = UPPER TEMPERATURE LIMIT

CARD SETS 2,3,4,..., ONE FOR EACH MOLECULE

CARD 1 ,FORMAT (3A4,6X,2A3,4(A2,F3.0),A1,2F10.3,14X,I1)

FIELD 1 (COLUMNS 1-12)

SPECIES NAME EX. = H2O, USED FOR INPUT/OUTPUT ONLY.

FIELD 2 (COLUMNS 19-24)

DATE OF THE DATA USED FOR THE CURVE FIT.

FIELDS 3,4,5,6,..., (COLUMNS 25-26,27-29,30-31,32-34,35-36,37-39,40-41, 42-44) JAT(I),ALPT(I),I=1,4

JAT(I) = ATOMIC SYMBOL OF THE ELEMENTS IN THE MOLECULE (LEFT JUSTIFIED)
ALPT(I) = NUMBER OF ATOMS OF JAT(I) IN THE MOLECULE

FIELD 11 (COLUMN 45), JP

PHASE OF THE MOLECULE (S,L,G)
WHEN A SPECIES HAS SEVERAL PHASES THERE IS ONE 4-CARD SET FOR EACH PHASE. THE SETS ARE ORDERED WITH THE LOW TEMPERATURE PHASES FIRST. (SEE DISCUSSION AT THE BEGINNING OF THIS GROUP.)

FIELDS 12,13 (COLUMNS 46-55,56-65) SPL,SPU

SPL = LOWER TEMPERATURE LIMIT FOR THIS MOLECULE IN THIS PHASE
SPU = UPPER TEMPERATURE LIMIT FOR THIS MOLECULE IN THIS PHASE

FIELD 14 (COLUMN 80) IC1

ENTER A 1

CARD 2 ,FORMAT (5E15.8,I5)

FIELDS 1-5 (COLUMNS 1-15,16-30,31-45,46-60,61-75)

COEFFICIENTS A(I). I=1,5 FOR CP,H,S (SEE BELOW)

FIELD 6 (COLUMN 80)

ENTER A 2

CARD 3 ,FORMAT (5E15.8,I5)

FIELDS 1-5 (COLUMNS 1-15,16-30,31-45,46-60,61-75)

COEFFICIENTS A(I),I=6,7 B(I),I=1,3 FOR CP,H,S (SEE BELOW)

FIELD 6 (COLUMN 80)

ENTER A 3

CARD 4 FORMAT (5E15.8,I5)

FIELDS 1-4 (COLUMNS 1-15,16-30,31-45,46-60)

COEFFICIENTS B(I),I=4,7 FOR CP,H,S (SEE BELOW)

FIELD 5 (COLUMN 80)

ENTER A 4

THE A(I) APPLY TO THE UPPER TEMPERATURE RANGE AND THE B(I) APPLY TO THE LOWER TEMPERATURE RANGE IN THE EQUATIONS-

```
CP/R=A(1)+A(2)*T+A(3)*T**2+A(4)*T**3+A(5)*T**4

H/(R*T)=A(1)+A(2)*T/2+A(3)*T**2/3+A(4)*T**3/4+A(5)*T**4/5+A(6)/T

S/R=A(1)*ALOG(T)+A(2)*T+A(3)*T**2/2+A(4)*T**3/3+A(5)*T**4/4+A(7)
```

WHERE T IS IN DEGREES K.

AS MENTIONED BEFORE THE LAST CARD IN GROUP 13 IS A BLANK CARD (IDENTI- FIED AS 13LAST IN COLUMNS 73-78).

GROUP 14 ***** NOT USED FOR THIS VERSION *****

GROUP 15 STREAMWISE DISTRIBUTIONS FOR EDGE CONDITIONS (CALLED FROM REFCON)

CARD SET 1, FORMAT(7E10.4) ***** USED ONLY FOR KR(6)=4,8 *****

FIELD 1 (COLUMNS 1-10), FIELD 2 (COLUMNS 11-20), ETC., 7 TO A CARD,
PRE(L), L=1,NS (SEE CARD 3 OF GROUP 3)

RATIO OF LOCAL STATIC TO STAGNATION PRESSURE. IN ADDITION TO DEFINING THE LOCAL PRESSURE, THIS DATA IS USED TO FORM THE LOCAL VELOCITY GRAD- IENT AT OTHER BODY STATIONS.

CARD SET 2, FORMAT(7E10.4)

FIELD 1 (COLUMNS 1-10), FIELD 2 (COLUMNS 11-20), ETC., 7 TO A CARD,
RADR(L), L=1,NS (SEE CARD 3 OF GROUP 3)

RATIO OF LOCAL TO STAGNATION POINT INCIDENT RADIATION. THIS INFORMATION IS USED ONLY FOR KR(9) OR KR9 OF 4. INPUT BLANKS INTO THIS FIELD FOR OTHER TYPES OF PROBLEMS. (NOTE - NUMBER OF CARDS IN CARD SET 2=NC WHERE NC IS THE SMALLEST INTEGER SATISFYING 7*NC .GE. NS (CARD 1, GROUP3))

GROUP 16 STREAMWISE DISTRIBUTIONS FOR INPUT WALL CONDITIONS (CALLED FROM REFCON)

CARD SET 1, FORMAT(7E10.4) *** USED ONLY FOR KR(11)=1 AND KR(9)=0,1, OR 2 **

FIELD 1 (COLUMNS 1-10), FIELD 2 (COLUMNS 11-20), ETC., 7 TO A CARD, HW(L,1), L=1,NS (SEE CARD 3 OF GROUP 3)

ENTHALPY OF THE GAS AT THE WALL, J/KG.

CARD SET 2, FORMAT(7E10.4) ***** USED ONLY IF KR(11)=0 AND KR(9)=0,1, OR 2, IF KR(9)=3 OR IF ANY OF THE KR9=2 OR 3 ****

FIELD 1 (COLUMNS 1-10), FIELD 2 (COLUMNS 11-20), ETC., 7 TO A CARD, TW(L,1), L=1,NS (SEE CARD 3 OF GROUP 3)

WALL TEMPERATURE, DEG K

CARD SET 3, NOT USED IN THIS VERSION.

CARD SET 4, NOT USED IN THIS VERSION.

CARD SET 5, NOT USED IN THIS VERSION.

CARD SET 6, FORMAT(7E10.4) **** USED ONLY FOR KR(7)=0 OR 2 WITH KR(9)=2 AND KR(11)=0,1, OR 2, OR WITH ANY OF THE KR9=2

FIELD 1 (COLUMNS 1-10), FIELD 2 (COLUMNS 11-20), ETC., 7 TO A CARD, DO N=1,3 FLUXJ(N,L,1), L=1,NS (SEE CARD 3 OF GROUP 3)

WALL MASS FLUXES OF BOUNDARY-LAYER EDGE GAS, PYROLYSIS GAS, AND CHAR, RESPECTIVELY (SEE GROUP 11, CARD SET 2, FIELD 4), KG/SEC-M**2, POSITIVE FOR MASS INJECTION.
READ IN ALL EDGE GAS VALUES, THEN START PYROLYSIS GAS VALUES ON A NEW CARD AND READ ALL PYROLYSIS GAS VALUES, ETC.
*** NOTE *** IF NO MASS FLUXES, THE PROPER NUMBER OF BLANK CARDS MUST BE ENTERED HERE. (NUMBER OF CARDS=3 TIMES NUMBER OF CARDS IN CARD SET 1 OR CARD SET 2, WHICH EVER IS USED.)

*** TRANSPIRATION COOLING RATE CAN BE SPECIFIED HERE AS A PYROLYSIS GAS FLUX ***

GROUP 17 (CALLED FROM BLIMP)

CARD 1 FORMAT(A1)

FIELD 1 (COLUMN 1), JAST

THE PURPOSE OF THIS ENTRY IS TO PERMIT A TEST ON WHETHER OR NOT A NEW

CASE IS TO FOLLOW. IN THE EVENT A CASE DOES NOT CONVERGE IN THE ALLOTTED NUMBER OF ITERATIONS, ANY REMAINING CARDS FOR THAT CASE ARE READ AND THEN IGNORED UNTIL A COMMA (,) OR A PERIOD (.) IS ENCOUNTERED IN COLUMN 1. A COMMA SIGNIFIES ANOTHER CASE, WHILE A PERIOD SIGNIFIES THAT THERE ARE NO CASES TO FOLLOW.

SECTION 3

CODE USAGE

The BLIMP code has been fully documented in Reference 6 and Reference 7. Details of input, output, debug procedure, sample cases, code listing, and Fortran variables list for the BLIMP code can be found there. Most of that information also applies to BLIMPJ with the exceptions noted in this manual.

3.1 UNITS AND CONVERSION FACTORS

As pointed out in Section 2 , the internal units of BLIMPJ are primarily English Engineering and the input-output units are SI. The quantities of interest for BLIMPJ and the conversion factors used in the code are given in Table 3.1. If English unit input-output is specified (KR(13)=1), the following input changes are required:

- Group 5, card 1 - RTM (feet)
- Group 6, card 1 - HCARB, HPYG, (Btu/lbm)
- Group 7, card 1 - Stagnation Pressure (atm)
  card 2 - Stagnation Enthalpy (Btu/lbm)
  card 3 - Radiation Flux (Btu/sec-ft^3)
- Group 9, card 1 - Total Heat to Walls (Btu/sec)
  card set 3 - Enthalpy (Btu/lbm)
  card 6 - GW (Btu/lbm)
- Group 16, card set 1 - HW (Btu/lbm)
  card set 2 - TW (°R)
  card set 6 - FLUXJ (lbm/sec-ft^2)

The output headings will remain in SI units. Most of the quantities in the output will have the English units corresponding to the SI units shown in the output headings. The appropriate English units can be easily identified by referring to Table 3.1. The exceptions to this (for English unit output only) are given below:

- Pressure is in atmospheres
- The isentropic edge calculations are output in the following units

  C_p - cal/gm - °K

  Temperature - °K

  Pressure - atm

  Enthalpy - cal/gm

  Entropy - cal/gm-°K

  Velocity - ft/sec

  Density - lbm/ft³

TABLE 3-1

CONVERSION FACTORS

SI	Multiply By To Get	English Engineering
kg/m³	UCD(0.062427962)	lbm/ft³ (density)
joules/kg	UCE(4.3021-04)	Btu/lbm
meters	UCL(3.28084)	feet (length)
kg	UCM(2.2046226)	lbm (mass)
N/m²	UCP(9.86923-06)	atmospheres (pressure)
joules/m²	UCR(8.8114-05)	Btu/ft²
N/m²	UCS(0.020885434)	lbf/ft² (shear)
°K	UCT(1.8)	°R (temperature)
N-s/m²	UCV(0.671968995)	lbm/sec-ft (viscosity)
watts	9.4845-04	Btu/sec
N	0.224809	lbf

3.2 MACHINE REQUIREMENTS

Core usage:

Code: 20,059 (decimal words)

Data: 32,145 (decimal words)

Unit assignments:

Read 5

Write 6

Punch 7

Scratch 18 (3000 decimal words, drum)

Scratch 19 (3000 decimal words, drum)

This version of the BLIMP code has been checked out for execution on the Univac 1108 Exec 2 and Exec 8 systems. Other versions of BLIMP have been executed on CDC 6600. Primary sources of difficulty for conversion of this version to CDC 6600 are division by zero, zero core before execution, and the namelist feature.

3.3 SELECTION OF AXIAL SOLUTION STATIONS

The choice of how far to step in the axial direction between solution stations is cause for some concern. While there is no rigorous procedure for choosing the solution stations it is hoped that the following qualitative discussion will be helpful to the new user of BLIMPJ. As in many cases, experience is the best teacher.

In general there are three features of the flow which should influence the choice of stations.

- Discontinuities in geometry
- Discontinuities is wall conditions (ex. start of blowing or ablation)
- Pressure Distribution

3.3.1 Discontinuities in Geometry

Discontinuities in geometry arise primarily from abrupt changes in wall angle which lead to changes in free stream conditions (ex. the pressure gradient). These discontinuities can usually be treated by placing a solution station at the discontinuity and identifying that station with a minus sign as described in group 3 of the input instructions.

3.3.2 Discontinuities in Wall Conditions

The beginning and end of regions of blowing or ablation, or other drastic changes in wall conditions should be treated as discontinuities. They can best be treated by placing solution stations close together and on either side of the discontinuity and marking both stations with a minus sign. This has two effects. First, it stops the curve fit of edge conditions at the discontinuity; and second, in the case of KR(3) = 2, it shields the downstream solution in the new region from the solutions in the old region by restricting the backward differencing to the solutions at the discontinuity. If the stations are too close together, difficulty in convergency may occur. Sample case 6.3 is an example of this for a change in wall material.

3.3.3 Pressure Distribution

The selection of solution stations with respect to the pressure distribution influences the solution through the calculation of the streamwise derivatives of the pressure and the free stream velocity. (Both of these terms appear in the momentum equation.) The difficulty arises from the method of calculating these gradients. Presently there are two methods available. [See KR(3) options.]

Use of the linear option [KR(3) = 3, 4, or 5] is less likely to lead to trouble, but is also considerably less accurate in highly nonlinear regions. Derivatives at a station are computed as the average of the linear slopes to one station forward and to one station backward (Figure 3.1).

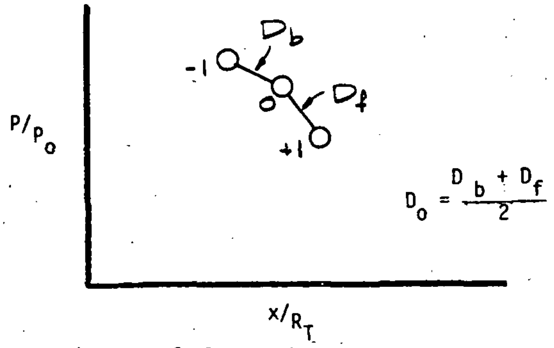

Figure 3-1. Linear Derivative

The quadratic option [KR(3) = 0, 1, or 2] is more accurate but can give erroneous results, particularly in regions of large curvature. The derivative at a station is the weighted average of the derivative calculated from a three point backward quadratic, a three point centered quadratic, and a three point forward quadratic (Figure 3.2). The derivative of each quadratic is

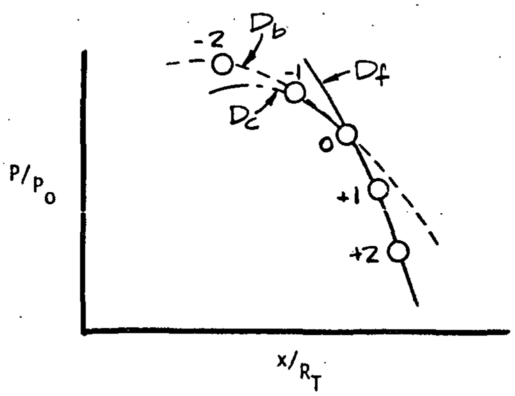

Figure 3-2. Quadratic Derivative

evaluated at the station in question (0 in Figure 3.2) and the derivative at the station calculated from

$$D_o = \frac{D_b + 2D_c + D_f}{4}$$

In regions of large curvature the forward or backward quadratic can be in error as shown by the example below.

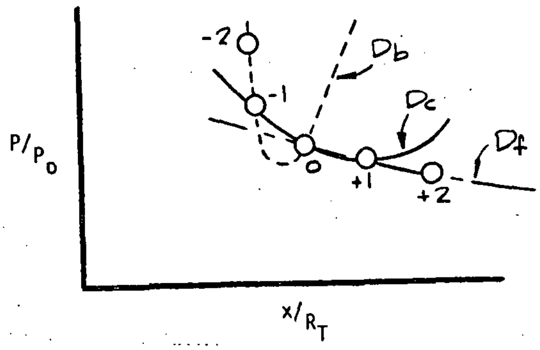

Figure 3-3. Quadratic Derivative With Error

In this case the large positive derivative from D_b would outweigh the contributions from D_f and D_c and lead to errors.

As a guide to the user the following suggestions are offered.

1. Select the distribution of solution stations by referring to a graph of P/P_o vs. $\frac{X}{R_T}$ (or S/R_T). (This is in additon to discontinuity considerations.)

2. Decrease the interval between points in regions of large

   $\left|\frac{dP}{dx}\right|$ and large $\left|\frac{d^2P}{dx^2}\right|$.

3. Check the output values of β (the streamwise derivative of edge velocity). For rocket nozzles it is expected that $\frac{du}{dx} > 0$ therefore, it is negative values of β where positive values are expected that indicate a poor selection of solution stations.

4. Use the linear option [KR(3) = 3, 4, or 5] and select the solution stations so that the average linear slope is a good approximation to the slope of the $\frac{dP}{dx}$ curve.

It should be stressed that accurate evaluation of the pressure gradient is of utmost importance to reliable solutions, and every effort should be made for a proper choice of the solution stations.

3.4 RESTART/FIRST GUESS OPTION

An option [KR(2) = 3] is available for restarting BLIMP at any solution station. This option is useful for continuing a solution which has been stopped during execution. (For example, exceeding the time limit or faulty data downstream of the selected station.) Restart should be used with care since there is some loss of accuracy at the restart station. It is important that the restart station be a valid solution station since the input is accepted as the solution. The card punch options (KR(8) = 1,2) should not be used with restart if the restart station is downstream of the throat since the normalizing factor, throat radius, would not be corrected for displacement thickness.

A potential problem associated with the restart option involves turbulent transition. This version of BLIMPJ has a transition length for the development of a fully turbulent boundary layer. This length is equal to the length upstream of the station at which the turbulent transition criterion (Re_θ) is exceeded. A RESTART should not be made at a station in this region. For restarting in the fully turbulent region the transition Reynolds number should be input as zero.

The option for inputting a first guess at the first station (KR(2) = 1) is useful for starting those problems which have well developed turbulent profiles. The built-in guess can lead to an excessive number of iterations for such cases. This option is also useful for starting those problems which have a large degree of nonsimilarity in streamwise solutions. However, it is very difficult to provide accurate profile information without careful calculations or output of a previous solution. A reasonable first guess frequently can be obtained from the output of a previous, similar problem (see sample case 6.2).

The additional input for restart or first guess is described in group 9 of the input instructions. For restart this information can be obtained from the output at the restart station. If the restart station is also a refit station, the values of ETA and the nodal distribution of F(2,I), G(1,I) and SP(1,I,K) are those of the refit output. The starred quantities on the sample output (Figure 3.3) that follows are those used in restart. The input ETA values must agree with those used for the solution station.

3.5 NAMELIST INPUT AND GEOMETRY CONVERSION (SUBROUTINE GEOM, CALLED BY RECASE)

In order to facilitate the input of various wall contours, subroutine GEOM is provided to accept a wall contour input as (X, Y) coordinates in namelist form. These coordinates are then used to calculate the wall distance, which BLIMP uses for its solution procedure. Up to 500 coordinates can be read in. The wall distance between pairs of points is calculated from the Pythagorean theorem.

$$\Delta S = \left[\Delta X^2 + \Delta Y^2\right]^{1/2}$$

In addition, the wall angle is calculated and those points selected as solution stations are passed back to calling program (RECASE). The entire geometry information is then written onto a scratch file (Unit 18) for later use, if necessary, in ROCOUT.

STATION 3 - - - - - - - - - - AXIAL POSITION -,20486+00 METERS - - - - - -17 DEC 73 22:43:15

ITERATED VALUES / DAMP / MAX,LIN ERROR / MAX,ERRORS IN CONSERVATION EQS,

ITS	TIME ALPH FPPW	DAMP	MAX,LIN ERROR	MOMENTUM	ENERGY	H	
1	1,40221,920 2,9411	,4999	8,-06	7 -4,0+01	4 -1,0+04	9 -9,6-05	0
2	2,49022,537 3,62031	,0000	4,-05	6 -2,4+01	3 -4,2+03	9 -7,8-05	0
3	3,50622,675 3,73411	,0000	3,-05	7 8,8+00	3 -1,4+03	9 -1,2-04	0
4	4,50822,689 3,74981	,0000	6,-06	5 -1,1+00	2 -1,5+02	9 -1,2-04	0
5	5,47722,690 3,75151	,0000	8,-06	5 -1,2-01	2 -1,6+01	9 1,7-05	0

ALPHA	RADIUS (METERS)	PRESSURE (N /M2)	EDGE VEL, M/SEC	BETA	HEAT FLUXES (WATTS/M2) DIFFUSIONAL	TOT ENTH	RERAD	QCOND
2,269+01	2,130-01	1,984+07	3,768+02	7,858-01	8,970+07	8,970+07	0,000	8,966+07

WALL SHEAR (N /M2)	MASS FLUXES (KG/SEC-M2) MECHANICAL REMOVAL	PYROL GAS	CHAR	TOTAL GAS	ELEMENTAL MASS DIFFUSIVE FLUXES (KG/SEC-M2) FOR HYDROGEN	OXYGEN
2,797+03	0,000	0,000	0,000	0,000	-8,573-06	8,573-06

MOM TRANS COEFF, CF/2	HEAT TRANS COEFF, ST NO,	BLOWING PARAMETERS (NORM, BY RHOE*UE*ST) FOR PYROL GAS	CHAR	TOTAL GAS	ELEMENTAL MASS TRANSFER COEFFICIENTS, CM, FOR HYDROGEN	OXYGEN
2,218-03	2,442-03	0,000	0,000	0,000	4,324-03	4,297-03

MOMENTUM THICKNESS, THETA (M)	DISPLACE, THICKNESS, DELSTAR (M)	EFFECTIVE BODY DISPLACE, (M)	ENTHALPY THICKNESS, LAMBDA (M)	REYNOLDS NUMBER PER METER	MASS THICKNESS (M) FOR HYDROGEN	OXYGEN
2,412-04	4,896-05	4,896-05	3,452-04	4,047+07	-1,579-01	-1,568-01

TOTAL HEAT TO WALL (WATTS)	THRUST LOSS (N)
1,290+07	-8,459+02

NODAL INFORMATION

ETA	DISTANCE FROM WALL (METERS)	F	U/UE	FPP	SHEAR (N /M2)	G, TOTAL ENTHALPY (J/KG)	GP (J/KG)	GPP (J/KG)	STATIC ENTHALPY (J/KG)	TEMP (DEG K)
0,000	0,000	0,000	0,000	3,751+00	2,797+03	-1,167+07	2,352+07	1,954+07	-1,167+07	8,250+02
1,266-03	5,164-07	1,526-03	1,055-01	3,594+00	2,794+03	-1,099+07	2,409+07	-2,079+08	-1,099+07	1,078+03
3,065-03	1,464-06	8,344-03	2,166-01	1,847+00	2,791+03	-1,018+07	1,560+07	-8,849+07	-1,018+07	1,358+03
7,889-03	4,721-06	4,059-02	3,497-01	5,851-01	2,778+03	-8,998+06	5,912+06	-1,823+07	-9,007+06	1,735+03
1,533-02	1,065-05	1,065-01	4,216-01	2,665-01	2,759+03	-8,260+06	2,833+06	-3,502+06	-8,272+06	1,961+03
3,615-02	2,955-05	3,294-01	5,097-01	1,067-01	2,708+03	-7,312+06	1,179+06	-3,957+05	-7,331+06	2,239+03
1,280-01	1,281-04	1,569+00	6,521-01	2,984-02	2,484+03	-5,714+06	3,538+05	-2,383+04	-5,745+06	2,678+03
3,903-01	4,554-04	5,895+00	7,878-01	1,576-02	1,910+03	-4,031+06	2,120+05	-3,271+03	-4,075+06	3,080+03
6,414-01	8,032-04	1,062+01	8,700-01	1,310-02	1,355+03	-2,876+06	1,934+05	-1,004+04	-2,930+06	3,307+03
1,000+00	1,340-03	1,806+01	9,500-01	6,570-03	5,888+02	-1,635+06	1,117+05	-1,051+03	-1,699+06	3,510+03
1,198+00	1,650-03	2,239+01	9,774-01	5,637-03	2,413+02	-1,145+06	1,070+05	-1,139+04	-1,213+06	3,580+03
2,500+00	3,767-03	5,201+01	1,000+00	0,000	0,000	-6,950+05	0,000	4,148+03	-7,659+05	3,640+03

DISTANCE FROM WALL (METERS)	DENSITY RHO (KG/M3)	VISCOSITY MU (N -S/M2)	SPECIFIC HEAT (J/KG-K)	THERMAL COND, (WATTS/M -K)	PRANDTL NUMBER	MODIFIED SCHMIDT NUMBER	MOLECULAR WEIGHT	MACH NUMBER
0,000	4,079+01	3,080-05	2,603+03	1,545-01	5,189-01	6,681-01	1,411+01	0,000
5,164-07	3,121+01	3,675-05	2,792+03	1,955-01	5,247-01	6,681-01	1,411+01	4,429-02
1,464-06	2,479+01	4,277-05	2,988+03	2,417-01	5,287-01	6,681-01	1,411+01	8,174-02
4,721-06	1,939+01	5,028-05	3,204+03	3,029-01	5,318-01	6,681-01	1,411+01	1,177-01
1,065-05	1,717+01	5,449-05	3,309+03	3,384-01	5,328-01	6,681-01	1,411+01	1,340-01
2,955-05	1,503+01	5,947-05	3,418+03	3,811-01	5,334-01	6,681-01	1,411+01	1,522-01
1,281-04	1,255+01	6,694-05	3,552+03	4,460-01	5,332-01	6,683-01	1,408+01	1,791-01
4,554-04	1,084+01	7,350-05	3,643+03	5,041-01	5,312-01	6,693-01	1,400+01	2,028-01
8,032-04	1,002+01	7,719-05	3,685+03	5,380-01	5,286-01	6,708-01	1,388+01	2,163-01
1,340-03	9,320+00	8,052-05	3,717+03	5,704-01	5,247-01	6,730-01	1,371+01	2,287-01
1,650-03	9,084+00	8,169-05	3,728+03	5,824-01	5,228-01	6,740-01	1,363+01	2,325-01
3,767-03	8,883+00	8,270-05	3,736+03	5,931-01	5,210-01	6,750-01	1,355+01	2,354-01

DISTANCE FROM WALL,METERS

0,000 5,164-07 1,464-06 4,721-06 1,065-05 2,955-05 1,281-04 4,554-04 8,032-04 1,340-03
1,650-03 3,767-03

```
ELEMENTAL FRACTIONS AND THEIR FIRST AND SECOND DERIVATIVES WITH RESPECT TO ETA

    H           1,429-01  1,429-01  1,429-01  1,429-01  1,429-01  1,429-01  1,429-01  1,429-01  1,429-01  1,429-01
                     1,429-01  1,429-01
              * -1,369-06 -1,469-06  2,919-07  2,548-09  1,478-08  8,914-09  8,178-09  3,260-08  2,496-08  4,120-08
                    -4,608-08  0,000
               -3,462-06  4,312-05 -2,643-06  7,242-08 -1,242-08 -3,530-10  4,103-09 -1,341-09  1,996-09 -1,946-08
                    -1,386-09  4,505-09
    O           8,571-01  8,571-01  8,571-01  8,571-01  8,571-01  8,571-01  8,571-01  8,571-01  8,571-01  8,571-01
                     8,571-01  8,571-01
                1,369-06  1,469-06 -2,919-07 -2,548-09 -1,478-08 -8,914-09 -8,178-09 -3,260-08 -2,496-08 -4,120-08
                     4,608-08  0,000
                3,462-06 -4,312-05  2,643-06 -7,242-08  1,242-08  3,530-10 -4,103-09  1,341-09 -1,996-09  1,946-08
                     1,386-09 -4,505-09

MOLE FRACTIONS

    H           2,792-13  5,577-10  9,359-08  7,175-06  4,346-05  2,455-04  1,835-03  7,025-03  1,305-02  2,127-02
                     2,490-02  2,838-02
    O           6,233-28  1,705-20  1,723-15  2,917-11  1,642-09  7,852-08  6,926-06  1,351-04  5,193-04  1,454-03
                     2,006-03  2,608-03
    O2          1,227-27  2,826-20  2,586-15  4,062-11  2,221-09  1,033-07  8,816-06  1,663-04  6,182-04  1,647-03
                     2,219-03  2,818-03
    H2          2,443-01  2,443-01  2,443-01  2,443-01  2,442-01  2,442-01  2,437-01  2,432-01  2,438-01  2,459-01
                     2,471-01  2,484-01
    OH          3,636-16  6,594-12  4,806-09  1,250-06  1,244-05  1,125-04  1,433-03  7,668-03  1,627-02  2,870-02
                     3,418-02  3,936-02
    H2O         7,557-01  7,557-01  7,557-01  7,557-01  7,557-01  7,555-01  7,530-01  7,418-01  7,258-01  7,011-01
                     6,896-01  6,784-01


   REFIT CALLED
```

I	*ETA(I)	*U/UE	*G(1,I)	*SP(1,I,1)	SP(1,I,2)	SP(1,I,3)	SP(1,I,4)	SP(1,I,5)	SP(1,I,6)	SP(1,I,7)	SP(1,I,8)
1	0,000	0,000	-1,167+07	1,429-01							
2	5,932-04	5,091-02	-1,135+07	1,429-01							
3	1,448-03	1,189-01	-1,089+07	1,429-01							
4	3,913-03	2,524-01	-9,881+06	1,429-01							
5	7,912-03	3,488-01	-9,002+06	1,429-01							
6	2,040-02	4,506-01	-7,955+06	1,429-01							
7	8,148-02	5,986-01	-6,325+06	1,429-01							
8	2,989-01	7,517-01	-4,504+06	1,429-01							
9	5,759-01	8,502-01	-3,162+06	1,429-01							
10	1,000+00	9,500-01	-1,635+06	1,429-01							
11	1,224+00	9,804-01	-1,088+06	1,429-01							
12	2,500+00	1,000+00	-6,950+05	1,429-01							

3.6 CORRECTED BODY CONTOUR (SUBROUTINE ROCOUT)

Available as an option (KR(8) = 1,2,3), this subroutine calculates a corrected body contour which can be output onto punched cards for use as input to TDK.

The KR(8) = 1 option calculates and punches the inviscid flow contour which should be used for TDK input for a specified, and different, nozzle contour (which has been input to BLIMPJ). The inviscid contour is calculated from

$$R_I = R_B - \delta_B^* \cos \phi$$

where R_I is the inviscid contour radius, R_B is the nozzle radius (input), δ_B^* is the body displacement thickness and ϕ is the wall angle (see Figure 3.1).

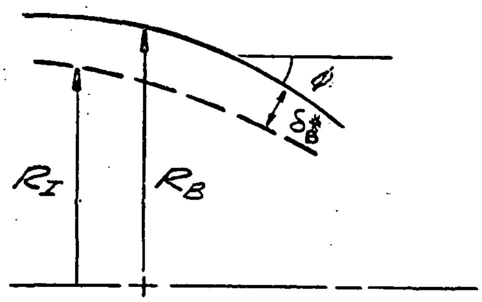

Figure 3.4. Corrected Contour KR(8) = 1

The KR(8) = 2 option calculates and punches the desired body contour if the input contour is the inviscid flow field contour. The body radius is calculated from

$$R_B = R_I + \delta_B^* \cos \theta$$

where the terms are the same as above except that R_I is the input contour to BLIMP.

In both cases the contour is normalized to the throat radius (the minimum radius) and the axial coordinate is zero at the throat. Also, the contour from the throat to the last BLIMP solution station is punched in a form suitable for TDK input.

The KR(8) = 3 option calculates both of the above quantities; however, there is no punched output and the input throat radius is used as a normalizing factor for the printed output.

3.7 NODES AND STATIONS

BLIMP is limited to 40 streamwise stations and 15 nodes at each station. The nature of the integral matrix solution procedure used in BLIMP does not require close spacing of nodes or stations, and it has been found that the above limits are more than adequate for almost all problems. In addition, the use of the REFIT option, described in Section 4, to maintain optimum nodal location eliminates the need for an excessive number of nodes to account for changes in boundary layer profile shape.

3.8 TRANSITION REYNOLDS NUMBER

The transition to turbulence is determined by comparing the momentum thickness Reynolds number, Re_θ, with an input transition value. It is not possible to give an appropriate transition value for compressible, highly accelerating flows. A flat plate, zero pressure gradient value of $Re_\theta = 360$ serves as a nominal guess. It is known that for accelerating flows the transition value increases. The value selected will depend on the particular problem under consideration.

3.9 DUMMY SUBROUTINES

There are several dummy subroutines included in the program which can be replaced with the appropraite system subroutines if it is desired. The easiest way to do this is to have the dummy routines call the appropriate system routines if the system routines have different call names. The dummy routines and their appropriate function are listed below.

Subroutine	Name	Function
B30D	TLEFT	Call the system to get time remaining for this job
B30E	DATA	Call the system for date
B30F	TOD	Call the system for time of day
B30G	SECOND	Call the system clock for elapsed run time in seconds

3.10 EXECUTION TIME

The primary contribution to the execution time of BLIMPJ is the inversion of the matrix for the nonlinear equations of the boundary layer. This is done once for each iteration and most solutions require three to five iterations. The biggest factors in the inversion time are the number of elements and the number of nodes. The effect on inversion time is shown below.

$$I_t \propto \left[(K + 1)N + 3\right]^m$$

where K is the number of elements, N is the number of nodes, and m is between 2 and 3. To economize execution time every effort should be made to eliminate elements that exist in trace amounts.

A second contributor to execution time is the number of chemical species input in group 13. The program will automatically eliminate those species which contain elements not identified in the elemental composition. However, the user should make every effort to eliminate those admissible species which will exist only in trace amounts.

SECTION 4

NODAL DISTRIBUTION REFIT OPTION

4.1 INTRODUCTION

A new option has been developed for the BLIMP code which will change the values of the independent variable, η, (ETA(I), the nodal distribution across the boundary layer) during code execution. The purpose of this option is to provide a means for maintaining an optimum nodal distribution for problems which include nonsimilar effects including transition to turbulence, blowing, pressure gradients, long streamwise running lengths, etc. This readjustment is accomplished while preserving the fundamental characteristics of each profile, namely, basic profile shape, wall and edge derivatives, and integral properties. Potentially a number of bases may be identified for selecting nodal distributions and for making decisions relative to changing the existing distribution, e.g., mapping of any one of the velocity, temperature, and specie profiles. However, since adequate mapping of the velocity profile is the most commonly encountered problem, a selection criterion based on this parameter has been implemented, and the identification, evaluation and implementation of any other possible criteria has not been pursued at this time. Initially the selection criterion has been based upon maintaining a desired (specified) velocity ratio distribution across the boundary layer. For nonsimilar turbulent flows, for example, the nodal distribution will change as a function of distance to account for the changes in velocity profile shape as the turbulent layer develops. The decision to refit is made following a converged solution and is based on whether or not the newly calculated velocities vary by more than a selected ratio from the desired values.

The REFIT procedure is currently valid for all forms of curve fitting across the boundary layer (KR (10)), i.e., all quadratics, quadratics with a final cubic and all cubics. Finally, as a result of the basic features of the REFIT option, it is possible to change the number of nodes used to describe the boundary layer. This latter capability has been programmed only for the case of transition from laminar to turbulent flow, as a means for eliminating the unnecessary and expensive extra nodes from laminar calculations. As such, this option is limited to this application; however, potentially it may be programmed for more general application. The REFIT option is limited to a maximum of 15 nodes; however, as might be anticipated, the ability to maintain a more optimum distribution of nodes makes it possible to solve most problems using fewer nodes than normally required without REFIT. For example, for some long streamwise length, turbulent flows, it is either very difficult or impossible to estimate in advance the best distribution for the entire length using all 15 nodes. With REFIT, it is possible to achieve good results with minimal selection of desired velocity ratios using 12 nodes. Since solution times vary roughly as the number of nodes squared, this represents a saving of 40 percent in computer time, some of which is used in the refitting operation.

4.2 BASIC PROCEDURE

A description of the basic procedure is as follows. A new input switch (KONRFT) is added to the BLIMP code (in RECASE). If KONRFT is greater than 0, the REFIT option will be used. In this event, a set of desired values of the velocity ratio, u/u_e (F2FIX(I)) must be read in. These represent the desired, fixed values of u/u_e as a function of node number. This set of values is selected based on such considerations as keeping nodes within the laminar sublayer for turbulent flows ($u/u_e < \sim 0.05$); maintaining good spacing in the middle velocity region where integral quantities are strongly affected; and, finally, defining and maintaining good spacing at the outer edge to prevent overshoot of the profile. (Note that this latter goal is one of the advantages of the REFIT method since the nodes between the fixed node (KAPPA) and outer nodes are tied to desired velocity ratios which are less than 1.0).

The capability to change the number of nodes (NETA) across the boundary layer has been added. Currently this is associated directly with the onset of transition from laminar to turbulent flow. The switch KTURB (also read in RECASE) determines if this suboption is to be employed. For KTURB = 1 the number of nodes will be changed following the first turbulent solution for transition based on Re_θ, momentum thickness Reynolds number. The BLIMP code assumes a finite transitional length which is equal to the streamwise length prior to onset of transition. Consequently, the first turbulent solution is still effectively a laminar solution because the transitional factor applied to the eddy viscosity is equal to zero. Thus the laminar nodal distribution is adequate for the "turbulent" part of the solution at the first turbulent station.

Following a converged solution (at the end of OUTPUT), the REFIT is called if KONRFT > 0 and either IS = 1, the ratio criterion is exceeded, or the number of nodes is being changed. At this point, the η values and all the primary boundary layer variables and their derivatives are passed to the main subroutine (REFIT) of the new option. This package first takes the existing distribution $u/u_e(I)$, consisting of ETA (I), F(2,I) and derivatives, generates the quadratic and cubic curve fit coefficients consistent with the curve fit option used in BLIMP (KR(10)) and then solves for the new locations of the ETA nodes based on the F2FIX values. Additional points are generated in each new polynomial segment (NPOINT per segment) and these data points, together with the following constraints, are generated in the subroutine POINTS.

1) Connecting curves must have equal function values at the new node.

2) Connecting curves must have equal first derivatives (spline fit) at the new node.

3) Connecting curves must have equal second derivatives at the new nodes if the curve option is all cubics, KR(10) = 0. The function value and the η value must be maintained at the first and last nodes.

4) The first derivative value must be maintained at the first and last node (except for all quadratics, KR(10) = 2, for which the outer derivative must float).

5) The function value and the η value must be maintained at their CBAR and KAPPA values.

These data points and constraints which define the old curve together with the new η values are then operated on by a series of subroutines (FISLEQ, FILQ3, FINEQ, and FILQ5) which perform a least squares curve fit. The results of this operation are returned to BLIMP as the new values of F(2,I), F(3,I) and F(4,I) at the new values of ETA(I). This process has been selected specifically to preserve the important characteristics of the profile, namely the derivatives at the wall and all integral quantities.

In identical manner, the other dependent variables, i.e., G(1,I) and SP(1,I,K), are adjusted to the new values of ETA(I). Note that the redistribution of η is based on an input u/u_e selection criterion; once this has been completed, all other variables are adjusted to this new distribution. This is the only selection criterion considered at this stage of development.

SECTION 5

OUTPUT

This section contains a description of the important and/or new output in BLIMPJ. Much of the output is self-explanatory, and a complete description of the output can be found in Reference 6 or Reference 7.

5.1 OUTPUT SUMMARY

In general the output consists of the following sections:

- Program heading, control options, input stagnation conditions, and turbulent parameters
- Edge gas composition and the input thermodynamic curve fit data
- A list of the elements, the associated base species, and transport property calculation procedures
- The one-dimensional, isentropic edge expansion for the stagnation conditions and each solution station
- Summary table of wall and edge conditions
- Boundary layer solution, station by station, nodal information in detail, and REFIT output
- Corrected contour summary for use in connection with TDK program.

It should be noted that the entire input data is not printed as part of the output. It is recommended that the input be listed for use in identifying errors and preserving the input details for later reference.

5.2 SPECIAL OUTPUT FOR BLIMPJ

5.2.1 Total Wall Area

The wall area calculation is an approximation to the actual wall area and is based on trapezoidal integration between BLIMP solution stations of

$$A = \int_{S_o}^{S_i} 2\pi r ds$$

where S_i is the wall length at station i and S_o is the wall length at the first, or restart, station. The wall area calculation is valid only for circular cross section nozzles.

5.2.2 Total Heat to the Wall

The total heat to the wall is calculated by trapezoidal integration between BLIMP solution stations of

$$Q_w = \int_{S_o}^{S_i} 2\pi rq\,ds$$

where S_i and S_o are defined in Section 5.2.1 and q is the net heat flux per unit area to the wall.

5.2.3 Thrust Loss (ΔF)

$$\Delta F = 2\pi r\rho_e u_e^2 \theta \cos\phi \left(1 - \frac{P\delta_B^*}{\theta\rho_e u_e^2}\right)$$

This represents the thrust loss due to boundary layer effects for a circular cross section nozzle. All of the terms in the equation above are taken from the BLIMP solution at the station of interest. The subscript e refers to edge gas values as calculated by the isentropic expansion performed by BLIMP. (Note that these edge values may not be the same as those calculated by TDK.)

5.2.4 Station Contour Summary

The option KR(8) $\neq$ 0 causes printout and punch of contours corrected for the effects of displacement thickness. Details of this option are contained in Section 3.6. The station numbers printed out refer to the input TDK contour station numbers.

5.3 ISENTROPIC EDGE EXPANSION

Most of the information presented in this output is self-explanatory, with the following possible exceptions.

- CP-FROZEN - Specific heat calculated from the mass fraction and specific heat of each specie at the specified temperature.

$$\text{CP-FROZEN} = \sum_i K_i Cp_i$$

- CP-EQUIL - Specific heat calculated from $\left.\frac{\partial h}{\partial T}\right)_p$ and allowing for changes in composition

$$Cp_{EQUAL} = \sum_i K_i Cp_i + \sum_i h_i \left.\frac{\partial K_i}{\partial T}\right)_p$$

- GAMMA = $\left(\frac{\partial \ell nP}{\partial \ell n\rho}\right)_s$

- MACH NUMBER = $U_e/\sqrt{(\partial P/\partial \rho)_s}$

5.4 SUMMARY TABLE FOR WALL AND EDGE CONDITIONS

The following quantities appear in the summary table and need some explanation:

- XI,(Kg/sec)**2 - The normalized internal streamwise coordinate defined by

$$\xi = \int_o^s u_e \rho_e \mu_e r^{2\kappa} ds$$

where κ is 0 for two-dimensional nozzles and 1 for circular cross section nozzles.

- RADIUS - Local nozzle radius except for KR(6) = 3 option which causes output of 0.3048 meters (= 1 foot).
- BETA - Representative of the pressure gradient,

$$\beta = 2 \frac{d\ell nu_e}{d\ell n\xi}$$

- COMP FLUX, KG/SM2 - Input wall flux of boundary layer edge gas, pyrolysis gas, and char gas.

5.5 BOUNDARY LAYER SOLUTION AT EACH STATION

For each solution station four groups of information are output:

- Iteration summary
- Integral properties and wall conditions
- Nodal information
- Refit information

5.5.1 Iteration Information

The iteration information shows the progression toward a solution. Most of this information is useful in locating convergence errors. For normal solution the values of ALPH (the coordinate stretching parameter) and FPPW (the normalized velocity gradient at the wall) should stabilize before convergence. The DAMP term reflects the allowable correction for each iteration and should have a value of 1.0. Very small or zero values of DAMP indicate that the error in the solution is very large and that convergence may not occur.

5.5.2 Integral Properties and Wall Conditions

The following definitions will be helpful in understanding this section of the output:

- ALPHA - Coordinate stretching parameters ALPHA(α), ETA(η), and y (the physical coordinate) are related through

$$\eta = \frac{r^{\kappa} u_e}{\alpha\sqrt{2\xi}} \int_o^y \rho dy$$

- Diffusional heat flux - heat flux to the wall due to diffusion, mass diffusion included
- Total enthalpy flux - net enthalpy flux to wall; diffusional heat flux less the energy convected away from the wall by blowing
- RERAD - reradiated heat flux
- QCOND - $- k \left.\frac{dT}{dy}\right|_{wall}$
- Blowing parameters defined by

$$B'_g = \frac{\dot{m}_g}{\rho_e u_e St}$$

  where $\dot{m}_g$ is the mass flux of pyrolysis gas, char gas, or total gas at the wall
- Transfer coefficients

$$C_{f/2} = \frac{\tau_w}{(\rho_e u_e) u_e}$$

$$St = \frac{\text{TOT ENTH}}{(\rho_e u_e)(G_e - G_w)}$$

$$CM_j = \frac{\text{MASS DIFFUSIVE FLUX}_j}{(\rho_e u_e)(K_{je} - K_{jw})}$$

where K_j is the mass fraction of element j

- Momentum thickness, enthalpy thickness, mass thickness

$$\text{Thickness} = \int_w^e \frac{\rho u}{\rho_e u_e} (P_e - P_w) dy \Big/ (P_e - P_w)$$

where P is either u, G, or K_i

- Displacement thickness $= \int_o^e (1 - \frac{\rho u}{\rho_e u_e})\, dy$

- Effective body displacement - same as displacement thickness for no blowing cases. In the case of blowing, this parameter gives the inviscid flow field displacement.

5.5.3 Nodal Information

The values of the primary variables, their derivatives, and several derived quantities are given at each node. First derivatives are denoted by P and second derivatives by PP. All derivatives are with respect to $\alpha\eta$. F is the stream function and G is the total enthalpy. The thermodynamic Prandtl number is based on frozen specific heat. The modified Schmidt number is a Schmidt number based on the self-diffusion coefficient for a fictitious species representative of the system as a whole. The term RHOSQ*EPS/RHO*MU is the ratio of the turbulent viscosity to the molecular viscosity.

5.5.4 REFIT Information

If the REFIT option is called, the new values of ETA and the primary variables are printed out. This information is particularly useful for RESTART input.

SECTION 6

SAMPLE CASES

6.1 SAMPLE CASE 1 - ROCKETDYNE 2-D NOZZLE

This problem is an O_2/H_2 rectangular cross section nozzle that was test fired by Rocketdyne. This problem is relatively straightforward and the input is typical of this type of problem. The real body contour, calculated pressure distribution, measured wall temperature, and stagnation conditions were provided. A complete listing of the input data is given and the pressure distribution and wall temperature are shown in Figure 6.1. The selected solution stations are also shown in Figure 6.1. Two point differencing with no discontinuities was used (KR(3) = 1). The corrected inviscid flow field contour was punched (KR(8) = 1) and a listing of the punched cards is provided. (Notice that the punch output starts at the nozzle throat.) The boundary layer was assumed to be fully turbulent at the first solution station. It was also assumed that the boundary layer upstream of the first solution station was developing over a combusting liquid layer. For this reason an artificially long starting length was selected to increase the boundary layer thickness at the first station.

Stagnation conditions for this case are:

$$P_o = 4.6182{+}06 \text{ N/m}^2$$

$$T_o = 3570°K \quad (H = 9.0948{+}04 \text{ J/hg})$$

$$MR = 6.15$$

Following the input data are parts of the program output. Included are the program heading, the thermochemical data for the species of interest, several of the free stream chemistry solutions, a summary of edge and wall conditions at each solution station, the boundary layer solutions at the first and last stations, the corrected body contour, and a listing of the punched card output. Since this is a two-dimensional nozzle, references to radius are, in fact, references to the contour coordinate y.

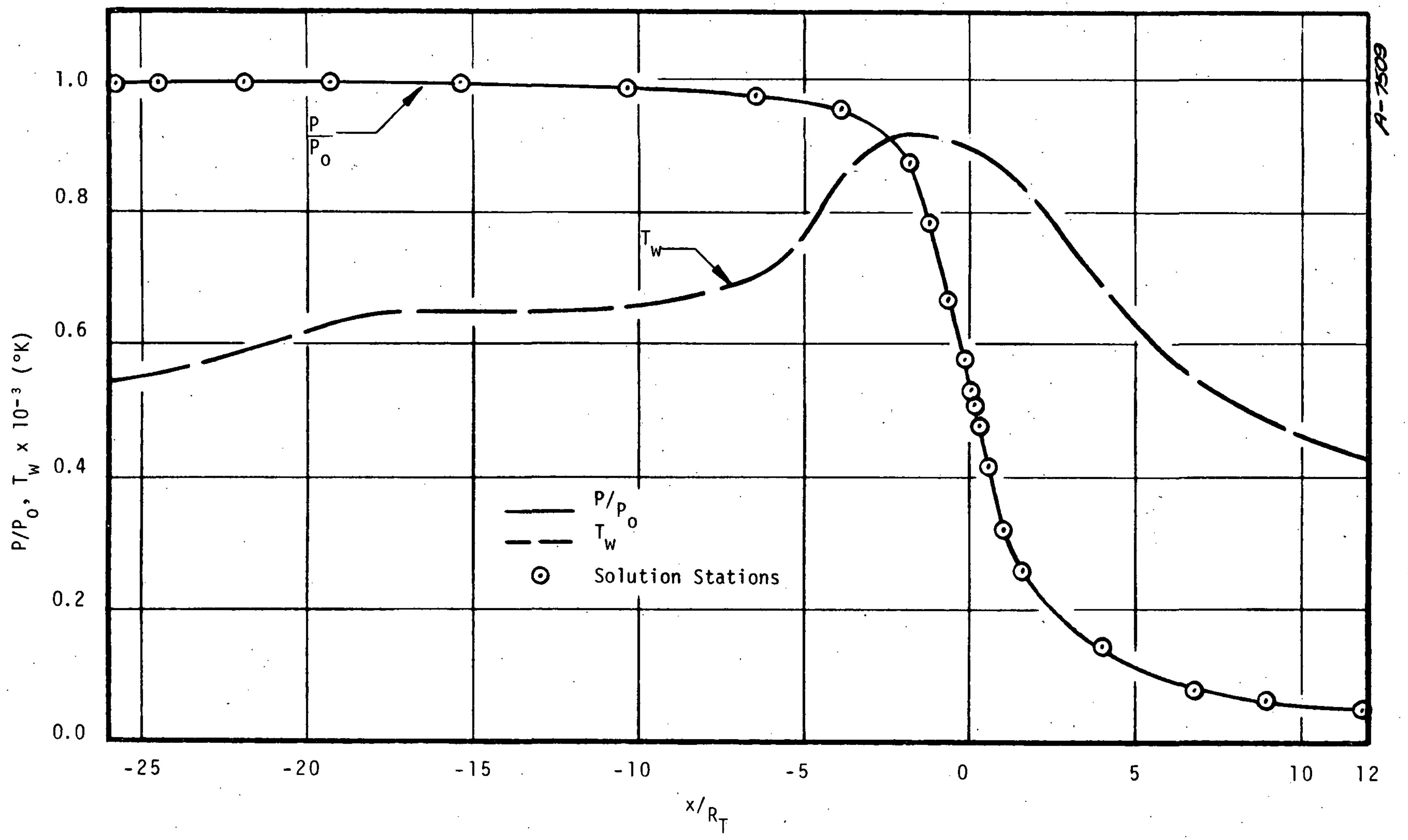

Figure 6-1. Case 1, Rocketdyne O_2/H_2 Nozzle: Pressure and Wall Temperature

LIST OF INPUT DATA

CASE 1

```
1010032121020200000  TEST CASE  ROCKETDYNE - PUNCH - R-DELTA*COS          01100  A
2                                                                         02100  A
19                                                                        03100  A
 14,25                                                                    03201  A
   49   30                                                                03300  A
    9   12    16    19    21    23    25    27    29    31    32    33    35    39 03401  A
   41   44    46    47    49                                              03402  A
 $INPUT
  XITAB=      0,0   ,    0,0   ,    0,0   , -25,806 , -24,516 , -23,226 , -21,935 ,
            -20,645 , -19,355 , -18,064 , -16,774 , -15,484 , -14,193 , -12,903 ,
 -11,600 , -10,322 ,  -8,645 ,  -7,742 ,  -6,452 ,  -5,161 ,  -3,871 ,  -2,181 ,
  -1,935 ,  -1,613 ,  -1,290 ,  -0,968 ,  -0,645 ,  -0,323 ,  -0,194 ,   0,0   ,
   0,0181,   0,1303,   0,2839,   0,4271,   0,5639,   0,7226,   0,880 ,   1,032 ,
   1,1232,   1,390 ,   1,553 ,   2,015 ,   3,007 ,   4,024 ,   5,007 ,   6,724 ,
   8,942 ,  10,720 ,  11,875 , YITAB=      0,0   ,   0,0   ,   0,0   ,   6,548 ,
   6,387 ,   6,219 ,   6,045 ,   5,864 ,   5,671 ,   5,471 ,   5,264 ,   5,039 ,
   4,807 ,   4,561 ,   4,297 ,   4,019 ,   3,716 ,   3,387 ,   3,032 ,   2,632 ,
   2,187 ,   1,484 ,   1,374 ,   1,258 ,   1,161 ,   1,090 ,   1,062 ,   1,013 ,
   1,006 ,   1,000 ,   1,0001,   1,0019,   1,0077,   1,0174,   1,0310,   1,0510,
   1,0761,   1,1039,   1,1239,   1,1903,   1,2342,   1,3858,   1,6239,   1,8961,
   2,160 ,   2,938 ,   3,217 ,   3,690 ,   4,000 , PITAB=      0,0   ,   0,0   ,
   0,0   ,   0,9953,   0,9951,   0,0   ,   0,9944,   0,0   ,   0,9934,   0,0   ,
   0,0   ,   0,9918,   0,0   ,   0,0   ,   0,0   ,   0,9875,   0,0   ,   0,0   ,
   0,9771,   0,0   ,   0,9565,   0,0   ,   0,8734,   0,0   ,   0,7806,   0,0   ,
   0,6653,   0,0   ,   0,577 ,   0,0   ,   0,531 ,   0,5071,   0,4774,   0,0   ,
   0,4151,   0,0   ,   0,0   ,   0,3204,   0,0   ,   0,0   ,   0,2564,   0,0   ,
   0,0   ,   0,1446,   0,0   ,   0,0750,   0,0609,   0,0   ,   0,0474
 $END
12                                                                        04100  A
0,0        ,002       ,006       ,01        ,025       ,06       ,15      04201  A
 ,4        ,7        1,0       1,5        2,5                             04202  A
10 0,95      1 3 0,5                                                      04300  A
  0,0      0,05      0,12      0,25      0,35      0,45      0,6          04401  A
 0,75      0,85      0,95      0,98      1,0                              04402  A
 ,003937                                                                  05100  A
4,6182E+06                                                                07100  A
9,0948E+04                                                                07200  A
                                                                          07300  A
 ,44     11,823     ,018      ,9        ,9                                08100  A
-12,18E+06                                                                09600  A
 2                                                                        11100  A
 H  HYDROGEN    1,008     -1,0                                            11201  A
 O   OXYGEN    16,0      -6,15                                            11202  A
    300,       1000,      5000,                                           13100  A
H                 J 9/65H 1,                  G  300,      5000,                 1
 0,25       E+01 0,              0,              0,              0,              2
 0,25471620E+05-0,46011763E+00 0,25       E+01 0,              0,                3
 0,              0,              0,25471627E+05-0,46011762E+00                   4
O                 J 6/620 1,                  G  300,      5000,                 1
 0,25420596E+01-0,27550619E-04-0,31028033E-08 0,45510674E-11-0,43680515E-15      2
 0,29230803E+05 0,49203080E+01 0,29464287E+01-0,16381665E-02+0,24210316E-05      3
-0,16028432E-08 0,38906964E-12 0,29147644E+05 0,29639949E+01                     4
O2                J 9,650 2,                  G  300,      5000,                 1
 0,36219535E+01 0,73618264E-03-0,19652228E-06 0,36201558E-10-0,28945627E-14      2
-0,12019825E+04 0,36150960E+01 0,36255985E+01-0,18782184E-02 0,70554544E-05      3
-0,67635137E-08 0,21555993E-11-0,10475226E+04 0,43052778E+01                     4
H2                J 3/61H 2,                  G  300,      5000,                 1
 0,31001901E+01 0,51119464E-03 0,52644210E-07-0,34909973E-10 0,36945345E-14      2
-0,87738042E+03-0,19629421E+01 0,30574451E+01 0,26765200E-02-0,58099162E-05      3
 0,55210391E-08-0,18122739E-11-0,98890474E+03-0,22997056E+01                     4
OH                J 3/660 1, H 1,             G  300,      5000,                 1
 0,29106427E+01 0,95931650E-03-0,19441702E-06 0,13756646E-10 0,14224542E-15      2
 0,39353815E+04 0,54423445E+01 0,38375943E+01-0,10778858E-02 0,96830378E-06      3
 0,18713972E-09-0,22571094E-12 0,36412823E+04 0,49370009E+00                     4
```

```
H2O                J 3/61H 2. O 1.          G  300.      5000.              1
 0.27167633E+01 0.29451374E-02-0.80224374E-06 0.10226682E-09-0.48472145E-14    2
-0.29905826E+05 0.66305671E+01 0.40701275E+01-0.11084499E-02 0.41521130E-05    3
-0.29637404E-08 0.80702103E-12-0.30279722E+05-0.32270046E+00                   4
                                                                      13LAST A
                                                                      15201  A
                                                                      15202  A
                                                                      15203  A
  630.      650.      658.       700.      861.      919.      911.   16201  A
  906.      900.       894.      888.9     886.      883.       869.  16202  A
  833.      708.       544.      488.      422.                       16203  A
                                                                      16601  A
                                                                      16602  A
                                                                      16603  A
                                                                      16604  A
                                                                      16605  A
                                                                      16606  A
                                                                      16607  A
                                                                      16608  A
                                                                      16609  A
                                                                      LAST   A
```

CASE 1 OUTPUT

ROCKETDYNE RECTANGULAR NOZZLE WITH ARTIFICIAL START LENGTH

```
           BOUNDARY LAYER INTEGRAL MATRIX PROGRAM (BLIMP)

      ACUREX CORP.-AEROTHERM DIV.,MT.VIEW,CALIF. (RMK,EPB)  17 FEB 74 11:37:15

CASE:  TEST CASE  ROCKETDYNE - PUNCH - R-DELTA*COS        01100  A

      CONTROL NUMBERS  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20

                       1  0  1  0  0  3  2  1  2  1  0  2  0  2  0  0  0  0  0  0

   U/UE TO       NODAL PT.                          ETA VALUES
  NORM. ETA      AT WHICH
                 ETA NORM.
   9.500-01         10        0.000     2.000-03  6.000-03  1.000-02  2.500-02  6.000-02  1.500-01  4.000-01  7.000-01
                              1.000+00  1.500+00  2.500+00

CASE:                   1.00000+00

TOTAL ENTHALPY,J/KG     9.09480+04

TOTAL PRESSURE, N/M2    4.61820+06

INCIDENT RAD FLUX,J/SM2  0.00000

    MIXING LENGTH CONSTANT  =  4.4000-01
    SUBLAYER CONSTANT, YA+  =  1.1823+01
    CLAUSER NUMBER          =  1.8000-02
    TURBULENT SCHMIDT NUMBER=  9.0000-01
    TURBULENT PRANDTL NUMBER=  9.0000-01
    TRANSITION MOM.THICK,RE =  0.0000
        CASE  1 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -  17 FEB 74 11:37:15

RELATIVE ELEMENTAL COMPOSITIONS, ATOMIC WTS/UNIT MASS
   SYMBOL  ELEMENT    ATOMIC WT    EDGE GAS   PYRO.GAS 1    CHAR 1    PYRO.GAS 2    CHAR 2    PYRO.GAS 3    CHAR 3
     H     HYDROGEN     1.00800    .1387501    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
     O     OXYGEN      16.00000    .0537587    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000

   THERMODYNAMIC PROPERTY CURVE-FIT DATA (SEE MANUAL FOR FORMAT)

H              J 9/65H  1.   0.   0.   0.G   300.000  5000.000              1
  1000.00     .25000000+01    .00000000     .00000000     .00000000     .00000000     .25471627+05   -.46011762+00
  5000.00     .25000000+01    .00000000     .00000000     .00000000     .00000000     .25471620+05   -.46011763+00
      .00     .00000000       .00000000     .00000000     .00000000     .00000000     .00000000      .00000000
O              J 6/62O  1.   0.   0.   0.G   300.000  5000.000              1
  1000.00     .29464287+01   -.16381665-02   .24210316-05  -.16028432-08   .38906964-12   .29147644+05   .29639949+01
  5000.00     .25420596+01   -.27550619-04  -.31028033-08   .45510674-11  -.43680515-15   .29230803+05   .49203080+01
      .00     .00000000       .00000000     .00000000     .00000000     .00000000     .00000000      .00000000
O2             J 9.65O  2.   0.   0.   0.G   300.000  5000.000              1
  1000.00     .36255985+01   -.18782184-02   .70554544-05  -.67635137-08   .21555993-11  -.10475226+04   .43052778+01
  5000.00     .36219535+01    .73618264-03  -.19652228-06   .36201558-10  -.28945627-14  -.12019825+04   .36150960+01
      .00     .00000000       .00000000     .00000000     .00000000     .00000000     .00000000      .00000000
H2             J 3/61H  2.   0.   0.   0.G   300.000  5000.000              1
  1000.00     .30574451+01    .26765200-02  -.58099162-05   .55210391-08  -.18122739-11  -.98890474+03  -.22997056+01
  5000.00     .31001901+01    .51119464-03   .52644210-07  -.34909973-10   .36945345-14  -.87738042+03  -.19629421+01
      .00     .00000000       .00000000     .00000000     .00000000     .00000000     .00000000      .00000000
OH             J 3/66O  1.H  1.   0.   0.G   300.000  5000.000              1
  1000.00     .38375943+01   -.10778858-02   .96830378-06   .18713972-09  -.22571094-12   .36412823+04   .49370009+00
  5000.00     .29106427+01    .95931650-03  -.19441702-06   .13756646-10   .14224542-15   .39353815+04   .54423445+01
      .00     .00000000       .00000000     .00000000     .00000000     .00000000     .00000000      .00000000
H2O            J 3/61H  2.O  1.   0.   0.G   300.000  5000.000              1
  1000.00     .40701275+01   -.11084499-02   .41521180-05  -.29637404-08   .80702103-12  -.30279722+05  -.32270046+00
  5000.00     .27167633+01    .29451374-02  -.80224374-06   .10226682-09  -.48472145-14  -.29905826+05   .66305671+01
      .00     .00000000       .00000000     .00000000     .00000000     .00000000     .00000000      .00000000
THE INTERPRETATION OF MEANINGLESS INPUT WAS ATTEMPTED.
THE FOLLOWING RECORD IS ERRONEOUS OR DOES NOT CORRESPOND TO FORMAT SPECIFICATIONS:
                                                                            13LAST A
  I/O  CALLED  AT  SEQUENCE  NUMBER 000360  OF  INPUT


    ELEMENT   HYDROGEN     OXYGEN
    BASE SP      H           O
```

```
MOLECULAR TRANSPORT PROPERTIES
 VISCOSITY ....., BUDDENBERG - WILKE MIXTURE FORMULA WITH MU(I) CALCULATED ON
                  THE BASIS OF D(I,I) = DBAR/G(I)**2

 THERMAL CONDUCTIVITY ....., MASON - SAXENA MIXTURE FORMULA WITH EUCKEN CORRECTION

 DIFFUSION COEFFICIENTS ....., D(I,J) = DBAR/(F(I)*F(J)) WITH DBAR BASED ON
                  SIGMA =  3,4670, EPOVRK =  106,7000, AND MREF =  32,0000

 METHODS EMPLOYED

  0 CONDENSED PHASE, VALUES FOR F(I) AND G(I) SET EQUAL TO 1,E+10

  1 VALUES FOR F(I) (OR G(I)) INPUT DIRECTLY

  2 VALUES FOR F(I) (OR G(I)) CALCULATED BY  F(I) =(M(I)/FITMOL)**FFA AND
    G(I) = (M(I)/FITGMW)**GGA WHERE M(I) IS SPECIES MOLECULAR WEIGHT,
    FITMOL =  26,7000, AND FFA =  ,4890, FITGMW =  24,3000, AND GGA =  ,4540

  3 VALUES FOR G(I) CALCULATED BY G(I) = SQRT(DBAR/D(I,I)) = (SIGMA(I)/SIGMA)
    * (EPS(I)/EPOVRK) **0,0795 * (M(I)/MREF) **0,25 WHERE SIGMA(I) AND EPS(I)
    ARE GIVEN WITH THERMODYNAMIC DATA

 SPECIES   F(I) METHOD G(I) METHOD        SPECIES   F(I) METHOD G(I) METHOD
 H          ,201   2    ,236   2          O          ,778   2    ,827   2
 O2        1,093   2   1,133   2          H2         ,283   2    ,323   2
 OH         ,802   2    ,850   2          H2O        ,825   2    ,873   2

STAGNATION SOLUTION FOLLOWED BY BOUNDARY-LAYER EDGE EXPANSION

       CP-FROZEN      CP-EQUIL       GAMMA
      (J/KG-DEG-K)   (J/KG-DEG-K)
        ,36763+04     ,11226+05     ,11350+01
                TEMP = 3570,0611 DEG-K      PRES =  ,4618+07  N/M2    MOL WT = 13,3659437
   RELATIVE MASSES OF COMPONENTS 1,2 AND 3     ,00000         ,00000          ,00000
      ENTHALPY =    ,9094789+05 J/KG     ENTROPY =   ,18169+05 J/KG-DEG-K
      DENSITY =    ,207925+01KG/M3
   VEL =  0,000     M/SEC    MACH =   0,000

   SPECIES   MOLE FR,         SPECIES   MOLE FR,        SPECIES   MOLE FR,
   H          ,49768-01       O          ,77499-02      O2         ,80802-02
   H2         ,23978+00       OH         ,64046-01      H2O        ,63058+00

STATION NO,  1

       CP-FROZEN      CP-EQUIL       GAMMA
      (J/KG-DEG-K)   (J/KG-DEG-K)
        ,36760+04     ,11219+05     ,11350+01
                TEMP = 3567,8442 DEG-K      PRES =  ,4588+07  N/M2    MOL WT = 13,3681673
   RELATIVE MASSES OF COMPONENTS 1,2 AND 3     ,00000         ,00000          ,00000
      ENTHALPY =    ,7625105+05 J/KG     ENTROPY =   ,18169+05 J/KG-DEG-K
      DENSITY =    ,206716+01KG/M3
   VEL =  1,715+02 M/SEC    MACH =   1,080-01

   SPECIES   MOLE FR,         SPECIES   MOLE FR,        SPECIES   MOLE FR,
   H          ,49686-01       O          ,77241-02      O2         ,80598-02
   H2         ,23972+00       OH         ,63911-01      H2O        ,63090+00

STATION NO,  2

       CP-FROZEN      CP-EQUIL       GAMMA
      (J/KG-DEG-K)   (J/KG-DEG-K)
        ,36759+04     ,11218+05     ,11350+01
                TEMP = 3567,3040 DEG-K      PRES =  ,4580+07  N/M2    MOL WT = 13,3687080
   RELATIVE MASSES OF COMPONENTS 1,2 AND 3     ,00000         ,00000          ,00000
      ENTHALPY =    ,7267309+05 J/KG     ENTROPY =   ,18169+05 J/KG-DEG-K
      DENSITY =    ,206422+01KG/M3
   VEL =  1,912+02 M/SEC    MACH =   1,205-01

   SPECIES   MOLE FR,         SPECIES   MOLE FR,        SPECIES   MOLE FR,
   H          ,49666-01       O          ,77179-02      O2         ,80549-02
   H2         ,23970+00       OH         ,63879-01      H2O        ,63098+00
```

STATION NO. 19

CP-FROZEN (J/KG-DEG-K) .34931+04 CP-EQUIL (J/KG-DEG-K) .59276+04 GAMMA .11482+01

TEMP = 2637.3442 DEG-K PRES = .2189+06 N/M2 MOL WT = 14.2113023

RELATIVE MASSES OF COMPONENTS 1,2 AND 3 .00000 .00000 .00000

ENTHALPY = -.5595774+07 J/KG ENTROPY = .18169+05 J/KG-DEG-K

DENSITY = .141850+00KG/M3

VEL = 3.373+03 M/SEC MACH = 2.534+00

SPECIES	MOLE FR.	SPECIES	MOLE FR.	SPECIES	MOLE FR.
H	.14235-01	O	.48128-03	O2	.67052-03
H2	.22245+00	OH	.11641-01	H2O	.75052+00

AXIAL DISTANCE,METERS	-.76201-01	-.60961-01	-.40638-01	-.25402-01	-.15240-01	-.76181-02	-.50787-02	-.25394-02
	-.76378-03	.71260-04	.51299-03	.11177-02	.22201-02	.40630-02	.61142-02	.15842-01
	.26472-01	.35205-01	.46752-01					
WALL LENGTH,METERS	.56102-01	.71545-01	.92262-01	.10802+00	.11872+00	.12698+00	.12966+00	.13223+00
	.13402+00	.13486+00	.13530+00	.13591+00	.13701+00	.13888+00	.14099+00	.15107+00
	.16250+00	.17130+00	.18325+00					
RADIUS,METERS	.30480+00	.30480+00	.30480+00	.30480+00	.30480+00	.30480+00	.30480+00	.30480+00
	.30480+00	.30480+00	.30480+00	.30480+00	.30480+00	.30480+00	.30480+00	.30480+00
	.30480+00	.30480+00	.30480+00					
XI,(KG/SEC)**2	.15181-03	.19595-03	.26424-03	.33177-03	.39274-03	.46229-03	.49423-03	.52979-03
	.55571-03	.56776-03	.57406-03	.58259-03	.59768-03	.62101-03	.64420-03	.72884-03
	.79221-03	.82617-03	.86554-03					
PRESSURE RATIO	.99340+00	.99180+00	.98760+00	.97710+00	.95650+00	.87340+00	.78060+00	.66530+00
	.57700+00	.53100+00	.50710+00	.47740+00	.41510+00	.32040+00	.25640+00	.14460+00
	.75000-01	.60900-01	.47400-01					
STATIC PRESSURE, N/M2	.45877+07	.45803+07	.45609+07	.45124+07	.44173+07	.40335+07	.36050+07	.30725+07
	.26647+07	.24523+07	.23419+07	.22047+07	.19170+07	.14797+07	.11841+07	.66779+06
	.34636+06	.28125+06	.21890+06					
EDGE VELOCITY,M/SEC	.17148+03	.19122+03	.23536+03	.32060+03	.44392+03	.77238+03	.10414+04	.13295+04
	.15380+04	.16461+04	.17026+04	.17736+04	.19262+04	.21753+04	.23637+04	.27721+04
	.31495+04	.32545+04	.33731+04					
BETA	.59805+00	.65028+00	.18790+01	.21366+01	.41020+01	.88253+01	.79376+01	.63095+01
	.62219+01	.62927+01	.57530+01	.58799+01	.67594+01	.55236+01	.35809+01	.22397+01
	.24786+01	.97154+00	.15247+01					
INCID RAD.FLUX.WATTS/M2	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000					
WALL TEMPERATURE,DEG K	.63000+03	.65000+03	.65800+03	.70000+03	.86100+03	.91900+03	.91100+03	.90600+03
	.90000+03	.89400+03	.88890+03	.88600+03	.88300+03	.86900+03	.83300+03	.70800+03
	.54400+03	.48800+03	.42200+03					
COMP FLUX,KG/SM2	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000					
COMP FLUX,KG/SM2	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000					
COMP FLUX,KG/SM2	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000					

STATION 1 - - - - - - - - - - AXIAL POSITION -,76201-01 METERS - - - - - -17 FEB 74 11:37:15

ITERATED VALUES . DAMP MAX.LIN MAX,ERRORS IN CONSERVATION EQS,

ITS.	TIME	ALPH	FPPW	DAMP	MAX,LIN ERROR		MOMENTUM		ENERGY		H	
1	3,000	4,400	,7826	,0723	9,+00	10	-2,4+01	7	-3,4+04	3	-1,0-05	0
2	3,000	5,133	,8624	,1449	9,+00	10	-2,3+01	8	3,2+04	8	-1,6-05	0
3	6,000	5,999	,9473	,2068	7,+00	10	-2,0+01	8	3,1+04	8	-1,9-05	0
4	6,000	7,017	1,0386	,3048	6,+00	11	1,6+01	8	2,6+04	8	1,6-05	0
5	6,000	8,196	1,1419	,4821	4,+00	11	1,2+01	8	2,0+04	3	-2,9-06	0
6	6,000	9,502	1,2744	,9188	2,+00	11	7,3+00	8	1,2+04	8	-1,6-05	0
7	10,000	9,826	1,3756	1,0000	2,-01	8	-3,9+00	8	2,2+03	3	-6,8-06	0
8	10,000	9,930	1,4020	1,0000	4,-06	9	9,9-01	6	4,1+02	9	1,6-05	0
9	10,000	9,956	1,4081	1,0000	2,-06	7	-1,9-01	6	7,0+01	3	6,5-06	0
10	10,000	9,962	1,4095	1,0000	2,-06	7	-4,0-02	4	-1,5+01	9	-3,5-05	0

ALPHA	RADIUS (METERS)	PRESSURE (N /M2)	EDGE VEL, M/SEC	BETA	HEAT FLUXES (WATTS/M2) DIFFUSIONAL	TOT ENTH	RERAD	QCOND
9,962+00	3,048-01	4,588+06	1,715+02	5,980-01	1,721+07	1,721+07	0,000	1,718+07

WALL SHEAR (N /M2)	MASS FLUXES (KG/SEC-M2) MECHANICAL REMOVAL	PYROL GAS	CHAR	TOTAL GAS	ELEMENTAL MASS DIFFUSIVE FLUXES (KG/SEC-M2) FOR HYDROGE	OXYGEN
2,358+02	0,000	0,000	0,000	0,000	-2,102-06	2,102-06

MOM TRANS COEFF, CF/2	HEAT TRANS COEFF, ST NO,	BLOWING PARAMETERS (NORM, BY RHOE*UE*ST) FOR PYROL GAS	CHAR	TOTAL GAS	ELEMENTAL MASS TRANSFER COEFFICIENTS, CM, FOR HYDROGE	OXYGEN
3,880-03	3,942-03	0,000	0,000	0,000	-8,845-02	-7,960-02

MOMENTUM THICKNESS, THETA (M)	DISPLACE, THICKNESS, DELSTAR (M)	EFFECTIVE BODY DISPLACE, (M)	ENTHALPY THICKNESS, LAMBDA (M)	REYNOLDS NUMBER PER METER	MASS THICKNESS (M) FOR HYDROGE	OXYGEN
2,721-04	1,135-05	1,135-05	4,420-04	4,314+06	4,357+00	3,922+00

TOTAL HEAT TO WALL (WATTS)	THRUST LOSS (N)	TOTAL WALL AREA (M2)
2,544+05	-6,802+01	1,479-02

NODAL INFORMATION

ETA	DISTANCE FROM WALL (METERS)	F	U/UE	FPP	SHEAR (N /M2)	G, TOTAL ENTHALPY (J/KG)	GP (J/KG)	GPP (J/KG)	STATIC ENTHALPY (J/KG)	TEMP (DEG K)
0,000	0,000	0,000	0,000	1,409+00	2,358+02	-1,222+07	9,192+06	2,036+07	-1,222+07	6,300+02
2,000-03	5,579-07	2,834-04	2,862-02	1,463+00	2,357+02	-1,204+07	9,598+06	1,339+07	-1,204+07	7,063+02
6,000-03	1,867-06	2,597-03	8,779-02	1,506+00	2,353+02	-1,164+07	1,013+07	-7,506+06	-1,164+07	8,616+02
1,000-02	3,433-06	7,256-03	1,451-01	1,370+00	2,348+02	-1,125+07	9,832+06	-2,585+07	-1,125+07	1,012+03
2,500-02	1,120-05	4,154-02	2,958-01	6,472-01	2,324+02	-1,006+07	5,970+06	-1,002+07	-1,007+07	1,426+03
6,000-02	3,602-05	1,755-01	4,484-01	2,280-01	2,256+02	-8,592+06	2,477+06	-1,685+06	-8,595+06	1,898+03
1,500-01	1,174-04	6,493-01	5,862-01	7,946-02	2,080+02	-7,049+06	9,658+05	-1,159+05	-7,054+06	2,354+03
4,000-01	3,938-04	2,321+00	7,425-01	4,610-02	1,586+02	-5,003+06	6,773+05	-2,813+02	-5,011+06	2,868+03
7,000-01	7,836-04	4,732+00	8,664-01	3,680-02	9,691+01	-2,980+06	6,764+05	-7,549+04	-2,991+06	3,225+03
1,000+00	1,220-03	7,460+00	9,500-01	1,914-02	4,257+01	-1,295+06	4,508+05	-7,643+04	-1,309+06	3,433+03
1,500+00	2,003-03	1,235+01	9,993-01	6,589-04	6,840-01	2,011+03	7,008+04	-2,276+04	-1,266+04	3,560+03
2,500+00	3,611-03	2,232+01	1,000+00	0,000	0,000	9,095+04	0,000	8,692+03	7,625+04	3,568+03

DISTANCE FROM WALL (METERS)	DENSITY RHO (KG/M3)	VISCOSITY MU (N -S/M2)	SPECIFIC HEAT (J/KG-K)	THERMAL COND, (WATTS/M -K)	PRANDTL NUMBER	MODIFIED SCHMIDT NUMBER	MOLECULAR WEIGHT	MACH NUMBER	RHOSQ*EPS /RHO*MU
0,000	1,262+01	2,577-05	2,428+03	1,200-01	5,213-01	6,674-01	1,441+01	0,000	0,000
5,579-07	1,126+01	2,779-05	2,478+03	1,315-01	5,237-01	6,674-01	1,441+01	6,734-03	1,232-03
1,867-06	9,230+00	3,168-05	2,586+03	1,552-01	5,280-01	6,674-01	1,441+01	1,882-02	6,639-02
3,433-06	7,857+00	3,522-05	2,697+03	1,787-01	5,314-01	6,674-01	1,441+01	2,887-02	3,330-01
1,120-05	5,575+00	4,416-05	2,986+03	2,454-01	5,373-01	6,674-01	1,441+01	5,022-02	2,660+00
3,602-05	4,190+00	5,331-05	3,233+03	3,190-01	5,403-01	6,674-01	1,441+01	6,661-02	1,001+01
1,174-04	3,375+00	6,145-05	3,408+03	3,870-01	5,411-01	6,675-01	1,440+01	7,876-02	2,874+01
3,938-04	2,751+00	7,010-05	3,547+03	4,614-01	5,389-01	6,686-01	1,430+01	9,125-02	3,824+01
7,836-04	2,398+00	7,609-05	3,619+03	5,174-01	5,322-01	6,721-01	1,402+01	1,004-01	2,907+01
1,220-03	2,199+00	7,973-05	3,654+03	5,563-01	5,237-01	6,762-01	1,368+01	1,058-01	2,443+01
2,003-03	2,075+00	8,202-05	3,675+03	5,840-01	5,162-01	6,795-01	1,339+01	1,082-01	1,088+01
3,611-03	2,067+00	8,217-05	3,676+03	5,858-01	5,156-01	6,797-01	1,337+01	1,080-01	0,000

DISTANCE FROM WALL,METERS

0,000 5,579-07 1,867-06 3,433-06 1,120-05 3,602-05 1,174-04 3,938-04 7,836-04 1,220-03
2,003-03 3,611-03

ELEMENTAL FRACTIONS AND THEIR FIRST AND SECOND DERIVATIVES WITH RESPECT TO ETA

H
1,399-01 1,399-01 1,399-01 1,399-01 1,399-01 1,399-01 1,399-01 1,399-01 1,399-01 1,399-01
1,379-01 1,399-01
8,124-07 6,530-07 1,311-06 -2,065-07 5,114-08 1,498-09 -4,646-10 2,029-11 5,243-10 -7,269-11
9,269-10 0,000
-8,003-06 1,651-05 -3,808-05 1,724-06 -1,424-07 -2,189-09 1,947-10 1,687-10 -1,998-10 2,007-10
-4,331-10 2,470-10

O
8,601-01 8,601-01 8,601-01 8,601-01 8,601-01 8,601-01 8,601-01 8,601-01 8,601-01 8,601-01
8,601-01 8,601-01
-8,124-07 -6,530-07 -1,311-06 2,065-07 -5,114-08 -1,498-09 4,646-10 -2,029-11 -5,243-10 7,269-11
-9,269-10 0,000
8,003-06 -1,651-05 3,808-05 -1,724-06 1,424-07 2,189-09 -1,947-10 -1,687-10 1,998-10 -2,007-10
4,331-10 -2,470-10

MOLE FRACTIONS

H	2,652-17	2,493-15	2,191-12	2,193-10	4,878-07	5,487-05	8,937-04	7,242-03	2,117-02	3,610-02	4,879-02	4,969-02
O	5,368-37	1,513-32	6,566-26	2,114-21	7,159-14	2,937-09	1,443-06	1,502-04	1,496-03	4,304-03	7,478-03	7,724-03
O2	1,529-36	3,805-32	1,392-25	4,036-21	1,175-13	4,301-09	2,093-06	2,079-04	1,908-03	4,949-03	7,853-03	8,060-03
H2	2,251-01	2,251-01	2,251-01	2,251-01	2,251-01	2,251-01	2,248-01	2,240-01	2,270-01	2,334-01	2,393-01	2,397-01
OH	2,100-21	7,452-19	4,731-15	1,804-12	3,660-08	1,542-05	5,353-04	7,426-03	2,671-02	4,719-02	6,297-02	6,391-02
H2O	7,749-01	7,749-01	7,749-01	7,749-01	7,749-01	7,749-01	7,738-01	7,609-01	7,217-01	6,741-01	6,337-01	6,309-01

REFIT CALLED

I	ETA(I)	U/UE	G(1,I)	SP(1,I,1)	SP(1,I,2)	SP(1,I,3)	SP(1,I,4)	SP(1,I,5)	SP(1,I,6)	SP(1,I,7)	SP(1,I,8)
1	0,000	0,000	-1,222+07	1,399-01							
2	3,459-03	4,980-02	-1,190+07	1,399-01							
3	8,201-03	1,202-01	-1,142+07	1,399-01							
4	1,917-02	2,485-01	-1,046+07	1,399-01							
5	3,419-02	3,515-01	-9,553+06	1,399-01							
6	6,073-02	4,496-01	-8,576+06	1,399-01							
7	1,677-01	6,029-01	-6,850+06	1,399-01							
8	4,163-01	7,499-01	-4,895+06	1,399-01							
9	6,560-01	8,502-01	-3,270+06	1,399-01							
10	1,000+00	9,500-01	-1,295+06	1,399-01							
11	1,194+00	9,779-01	-5,949+05	1,399-01							
12	2,500+00	1,000+00	9,095+04	1,399-01							

STATION 19 - - - - - - - - - - AXIAL POSITION ,46752-01 METERS - - - - - -17 FEB 74 11:38:57

ITERATED VALUES / DAMP / MAX,LIN / MAX,ERRORS IN CONSERVATION EQS,

ITS	TIME	ALPH	FPPW	DAMP	MAX,LIN ERROR		MOMENTUM		ENERGY		H	
1	4,000	11,332	3,3761	,4999	2,-06	13	1,6+01	10	4,9+03	10	-4,7-05	0
2	4,000	11,530	3,3762	1,0000	4,-06	13	7,8+00	10	2,5+03	10	-2,3-04	0
3	4,000	11,533	3,4388	1,0000	4,-06	6	-2,6+00	3	-8,0+02	3	2,0-05	0
4	7,000	11,534	3,4483	1,0000	4,-06	6	-3,4-01	3	-1,1+02	10	1,3-04	0
5	7,000	11,534	3,4498	1,0000	4,-06	6	-4,8-02	3	-1,7+01	10	-2,0-04	0

ALPHA	RADIUS (METERS)	PRESSURE (N /M2)	EDGE VEL, M/SEC	BETA	HEAT FLUXES (WATTS/M2) DIFFUSIONAL	TOT ENTH	RERAD	QCOND
1,153+01	3,048-01	2,189+05	3,373+03	1,525+00	1,720+07	1,720+07	0,000	1,719+07

WALL SHEAR (N /M2)	MASS FLUXES (KG/SEC-M2) MECHANICAL REMOVAL	PYROL GAS	CHAR	TOTAL GAS	ELEMENTAL MASS DIFFUSIVE FLUXES (KG/SEC-M2) FOR HYDROGE	OXYGEN
5,117+03	0,000	0,000	0,000	0,000	-2,254-07	2,254-07

MOM TRANS COEFF, CF/2	HEAT TRANS COEFF, ST NO,	BLOWING PARAMETERS (NORM, BY RHOE*UE*ST) FOR PYROL GAS	CHAR	TOTAL GAS	ELEMENTAL MASS TRANSFER COEFFICIENTS, CM, FOR HYDROGE	OXYGEN
3,171-03	2,608-03	0,000	0,000	0,000	1,012-03	1,020-03

MOMENTUM THICKNESS, THETA (M)	DISPLACE, THICKNESS, DELSTAR (M)	EFFECTIVE BODY DISPLACE, (M)	ENTHALPY THICKNESS, LAMBDA (M)	REYNOLDS NUMBER PER METER	MASS THICKNESS (M) FOR HYDROGE	OXYGEN
5,014-04	-1,728-04	-1,728-04	9,376-04	7,206+06	-9,563-03	-9,986-03

TOTAL HEAT TO WALL (WATTS)	THRUST LOSS (N)	TOTAL WALL AREA (M2)
7,126+06	1,567+03	2,435-01

NODAL INFORMATION

ETA	DISTANCE FROM WALL (METERS)	F	U/UE	FPP	SHEAR (N /M2)	G, TOTAL ENTHALPY (J/KG)	GP (J/KG)	GPP (J/KG)	STATIC ENTHALPY (J/KG)	TEMP (DEG K)
0,000	0,000	0,000	0,000	3,450+00	5,117+03	-1,272+07	2,016+07	1,905+08	-1,272+07	4,220+02
1,716-03	1,074-06	6,964-04	7,138-02	3,761+00	5,113+03	-1,228+07	2,395+07	-5,017+07	-1,231+07	5,950+02
4,130-03	3,166-06	4,037-03	1,649-01	2,961+00	5,105+03	-1,163+07	2,253+07	-1,656+08	-1,179+07	8,055+02
9,393-03	9,388-06	1,850-02	2,950-01	1,324+00	5,081+03	-1,057+07	1,248+07	-7,177+07	-1,106+07	1,079+03
1,593-02	1,877-05	4,389-02	3,711-01	6,955-01	5,048+03	-9,834+06	7,068+06	-2,348+07	-1,062+07	1,238+03
2,830-02	3,886-05	1,027-01	4,456-01	3,488-01	4,983+03	-9,064+06	3,718+06	-4,246+06	-1,019+07	1,384+03
7,730-02	1,302-04	3,979-01	5,767-01	1,152-01	4,709+03	-7,641+06	1,318+06	-4,381+05	-9,532+06	1,602+03
2,430-01	4,819-04	1,662+00	7,210-01	3,573-02	3,868+03	-5,921+06	4,814+05	1,873+04	-8,877+06	1,810+03
5,085-01	1,105-03	4,030+00	8,228-01	3,079-02	2,697+03	-4,359+06	5,388+05	-2,202+04	-8,208+06	2,013+03
1,000+00	2,444-03	9,100+00	9,500-01	1,407-02	8,666+02	-1,558+06	4,139+05	-3,100+04	-6,789+06	2,396+03
1,266+00	3,260-03	1,207+01	9,843-01	8,309-03	2,260+02	-5,356+05	3,189+05	-7,106+04	-6,044+06	2,556+03
2,500+00	7,340-03	2,633+01	1,000+00	0,000	0,000	9,095+04	0,000	2,626+04	-5,594+06	2,638+03

DISTANCE FROM WALL (METERS)	DENSITY RHO (KG/M3)	VISCOSITY MU (N -S/M2)	SPECIFIC HEAT (J/KG-K)	THERMAL COND, (WATTS/M -K)	PRANDTL NUMBER	MODIFIED SCHMIDT NUMBER	MOLECULAR WEIGHT	MACH NUMBER	RHOSQ*EPS /RHO*MU
0,000	8,992-01	1,979-05	2,308+03	8,865-02	5,152-01	6,674-01	1,441+01	0,000	0,000
1,074-06	6,377-01	2,482-05	2,405+03	1,148-01	5,202-01	6,674-01	1,441+01	3,583-01	5,117-02
3,166-06	4,711-01	3,030-05	2,546+03	1,466-01	5,265-01	6,674-01	1,441+01	7,177-01	6,803-01
9,388-06	3,518-01	3,673-05	2,748+03	1,895-01	5,326-01	6,674-01	1,441+01	1,121+00	3,517+00
1,877-05	3,064-01	4,023-05	2,864+03	2,153-01	5,351-01	6,674-01	1,441+01	1,323+00	7,936+00
3,886-05	2,742-01	4,328-05	2,959+03	2,386-01	5,368-01	6,674-01	1,441+01	1,509+00	1,693+01
1,302-04	2,368-01	4,767-05	3,087+03	2,732-01	5,387-01	6,674-01	1,441+01	1,825+00	5,085+01
4,819-04	2,096-01	5,167-05	3,193+03	3,055-01	5,399-01	6,674-01	1,441+01	2,155+00	1,367+02
1,105-03	1,884-01	5,542-05	3,283+03	3,366-01	5,406-01	6,674-01	1,441+01	2,342+00	1,105+02
2,444-03	1,577-01	6,220-05	3,422+03	3,943-01	5,399-01	6,680-01	1,435+01	2,507+00	7,739+01
3,260-03	1,470-01	6,498-05	3,471+03	4,190-01	5,382-01	6,688-01	1,428+01	2,529+00	3,363+01
7,340-03	1,418-01	6,640-05	3,493+03	4,322-01	5,367-01	6,695-01	1,421+01	2,534+00	0,000

DISTANCE FROM WALL,METERS

0,000 1,074-06 3,166-06 9,388-06 1,877-05 3,886-05 1,302-04 4,819-04 1,105-03 2,444-03
3,260-03 7,340-03

ELEMENTAL FRACTIONS AND THEIR FIRST AND SECOND DERIVATIVES WITH RESPECT TO ETA

H
1,399-01 1,399-01 1,399-01 1,399-01 1,399-01 1,399-01 1,399-01 1,399-01 1,399-01 1,399-01
1,399-01 1,399-01
-5,424-06 -1,819-06 5,796-07 2,166-08 2,557-08 1,205-08 1,966-08 2,807-08 8,010-08 8,610-08
-4,616-08 0,000
1,821-04 8,617-05 -9,190-06 5,179-08 -9,474-08 1,346-08 4,405-09 1,699-08 1,059-09 -4,316-08
-2,100-08 2,749-08

O
8,601-01 8,601-01 8,601-01 8,601-01 8,601-01 8,601-01 8,601-01 8,601-01 8,601-01 8,601-01
8,601-01 8,601-01
5,424-06 1,819-06 -5,796-07 -2,166-08 -2,557-08 -1,205-08 -1,966-08 -2,807-08 -8,010-08 -8,610-08
4,616-08 0,000
-1,821-04 -8,617-05 9,190-06 -5,179-08 9,474-08 -1,346-08 -4,405-09 -1,699-08 -1,059-09 4,316-08
2,100-08 -2,749-08

MOLE FRACTIONS

```
H      1,324-25  1,028-17  1.168-12  5,124-09  1,267-07  1,246-06  1,788-05  1,251-04  5,709-04  4,997-03
            1,023-02  1,425-02
O      1,000-30  4,293-38  1,081-26  1,740-18  2,376-15  4,045-13  1,598-10  1,250-08  3,733-07  4,748-05
            2,332-04  4,823-04
O2     1,000-30  1,311-37  2,413-26  3,209-18  4,112-15  6,708-13  2,530-10  1,917-08  5,587-07  6,854-05
            3,299-04  6,719-04
H2     2,251-01  2,251-01  2,251-01  2,251-01  2,251-01  2,251-01  2,251-01  2,250-01  2,248-01  2,234-01
            2,226-01  2,225-01
OH     2,525-32  3,953-22  1,348-15  6,752-11  4,200-09  7,921-08  2,411-06  2,901-05  2,010-04  3,156-03
            7,752-03  1,166-02
H2O    7,749-01  7,749-01  7,749-01  7,749-01  7,749-01  7,749-01  7,749-01  7,748-01  7,744-01  7,683-01
            7,588-01  7,505-01
```

STATION SUMMARY FOR TEST CASE ROCKETDYNE - PUNCH - R-DELTA*COS 01100 A

NEW CONTOUR INFORMATION-NORMALIZED BY
THROAT RADIUS = 3,97644-03 METERS

STATION NO.	AXIAL COORDINATE	CONTOUR CORRECTION	INPUT CONTOUR	INVISCID CONTOUR
1	0,00000	0,00000	0,00000	0,00000
2	0,00000	0,00000	0,00000	0,00000
3	0,00000	0,00000	0,00000	0,00000
4	-2,55501+01	3,80517-03	6,48306+00	6,47925+00
5	-2,42729+01	3,61495-03	6,32366+00	6,32004+00
6	-2,29957+01	3,42474-03	6,15732+00	6,15390+00
7	-2,17175+01	3,23438-03	5,98505+00	5,98181+00
8	-2,04403+01	3,04416-03	5,80584+00	5,80289+00
9	-1,91630+01	2,85395-03	5,61476+00	5,61190+00
10	-1,78848+01	2,98220-03	5,41674+00	5,41376+00
11	-1,66076+01	3,14128-03	5,21179+00	5,20865+00
12	-1,53304+01	3,29541-03	4,98903+00	4,98573+00
13	-1,40522+01	1,23612-03	4,75933+00	4,75809+00
14	-1,27750+01	-8,16989-04	4,51577+00	4,51658+00
15	-1,14850+01	-2,88182-03	4,25438+00	4,25727+00
16	-1,02196+01	-4,89413-03	3,97914+00	3,98404+00
17	-8,55926+00	-6,03505-03	3,67915+00	3,68519+00
18	-7,66522+00	-6,33099-03	3,35341+00	3,35974+00
19	-6,38801+00	-7,33035-03	3,00193+00	3,00925+00
20	-5,10982+00	-8,53456-03	2,60590+00	2,61443+00
21	-3,83261+00	-9,70462-03	2,16531+00	2,17501+00
22	-2,15937+00	-1,00709-02	1,46928+00	1,47935+00
23	-1,91581+00	-1,00426-02	1,36037+00	1,37042+00
24	-1,59700+00	-9,87231-03	1,24552+00	1,25540+00
25	-1,27721+00	-9,56247-03	1,14949+00	1,15905+00
26	-9,58400-01	-9,51104-03	1,07919+00	1,08370+00
27	-6,38603-01	-9,45841-03	1,05147+00	1,06093+00
28	-3,19797-01	-9,51721-03	1,00295+00	1,01247+00
29	-1,92076-01	-9,66580-03	9,96023-01	1,00567+00
30	0,00000	-9,91755-03	9,90082-01	1,00000+00
31	1,79205-02	-9,94474-03	9,90181-01	1,00013+00
32	1,29008-01	-1,00971-02	9,91964-01	1,00206+00
33	2,81084-01	-1,03471-02	9,97706-01	1,00805+00
34	4,22864-01	-1,07687-02	1,00731+00	1,01803+00
35	5,58307-01	-1,11577-02	1,02078+00	1,03193+00
36	7,15434-01	-1,17306-02	1,04058+00	1,05231+00
37	8,71273-01	-1,22740-02	1,06543+00	1,07770+00
38	1,02177+00	-1,28017-02	1,09295+00	1,10575+00
39	1,11206+00	-1,29919-02	1,11275+00	1,12575+00
40	1,37621+00	-1,37205-02	1,17850+00	1,19222+00
41	1,53760+00	-1,41471-02	1,22196+00	1,23611+00
42	1,99502+00	-1,48717-02	1,37206+00	1,38693+00
43	2,97718+00	-1,73089-02	1,60779+00	1,62510+00
44	3,98409+00	-1,93231-02	1,87730+00	1,89662+00
45	4,95734+00	-2,44536-02	2,13858+00	2,16303+00
46	6,65731+00	-3,15205-02	2,90886+00	2,94033+00
47	8,85332+00	-3,69115-02	3,18510+00	3,22201+00
48	1,06137+01	-3,96183-02	3,65340+00	3,69302+00
49	1,17572+01	-4,19752-02	3,96033+00	4,00230+00

PUNCH OUTPUT

CASE 1

```
PW(1)=   ,10000000+01,  ,00000000   ,  ,10001262+01,  ,17920492-01,
         ,10020607+01,  ,12900774+00,  ,10080532+01,  ,28103441+00,
         ,10180786+01,  ,42286121+00,  ,10319327+01,  ,55830749+00,
         ,10523073+01,  ,71543358+00,  ,10777018+01,  ,87127256+00,
         ,11057537+01,  ,10217651+01,  ,11257455+01,  ,11120606+01,
         ,11922156+01,  ,13762146+01,  ,12361069+01,  ,15375980+01,
         ,13869279+01,  ,19950161+01,  ,16251037+01,  ,29771779+01,
         ,18966184+01,  ,39840918+01,  ,21630317+01,  ,49573429+01,
         ,29403827+01,  ,66573144+01,  ,32220067+01,  ,88533173+01,
         ,36930225+01,  ,10613684+02,  ,40023050+01,  ,11757229+02,
0,0 , 0,0 $END
```

6.2 SAMPLE CASE 2 - SPACE SHUTTLE MAIN ENGINE

This sample problem is an O_2/H_2 circular cross section nozzle typical of the space shuttle main engine. A first guess (KR(2) = 1) at the first station was made from a previous problem at different conditions. The data taken from the previous problem is all of group 9 and cards 1 and 2 in card set 2 of group 4 of the input data. This was done to reduce the number of iterations at the first station, where a well developed turbulent profile was expected. The nozzle contour and pressure distributions were provided from the output of a single zone TDK run using the same contour and fuel. The solution stations were selected by the process discussed in Section 3.3. Wall temperatures and stagnation conditions were also provided. Figure 6.2 shows the pressure distribution and the wall temperature variation. The solution stations are shown and those stations selected as discontinuities are labelled with a D. These stations were selected to correspond to the wall temperature jumps and to the region of rapid change in curvature of P/P_o near $x/R_T = 2$. The stagnation conditions are:

$$P_o = 2.0477+07 \text{ N/m}^2$$

$$T_o = 3653°\text{K} \ (-6.9501+05 \text{ J/kg})$$

$$MR = 6$$

A complete listing of the input, the program output heading and station summary, and the first and last solution stations are shown. (Run time on a Univac 1108 was 195 seconds.)

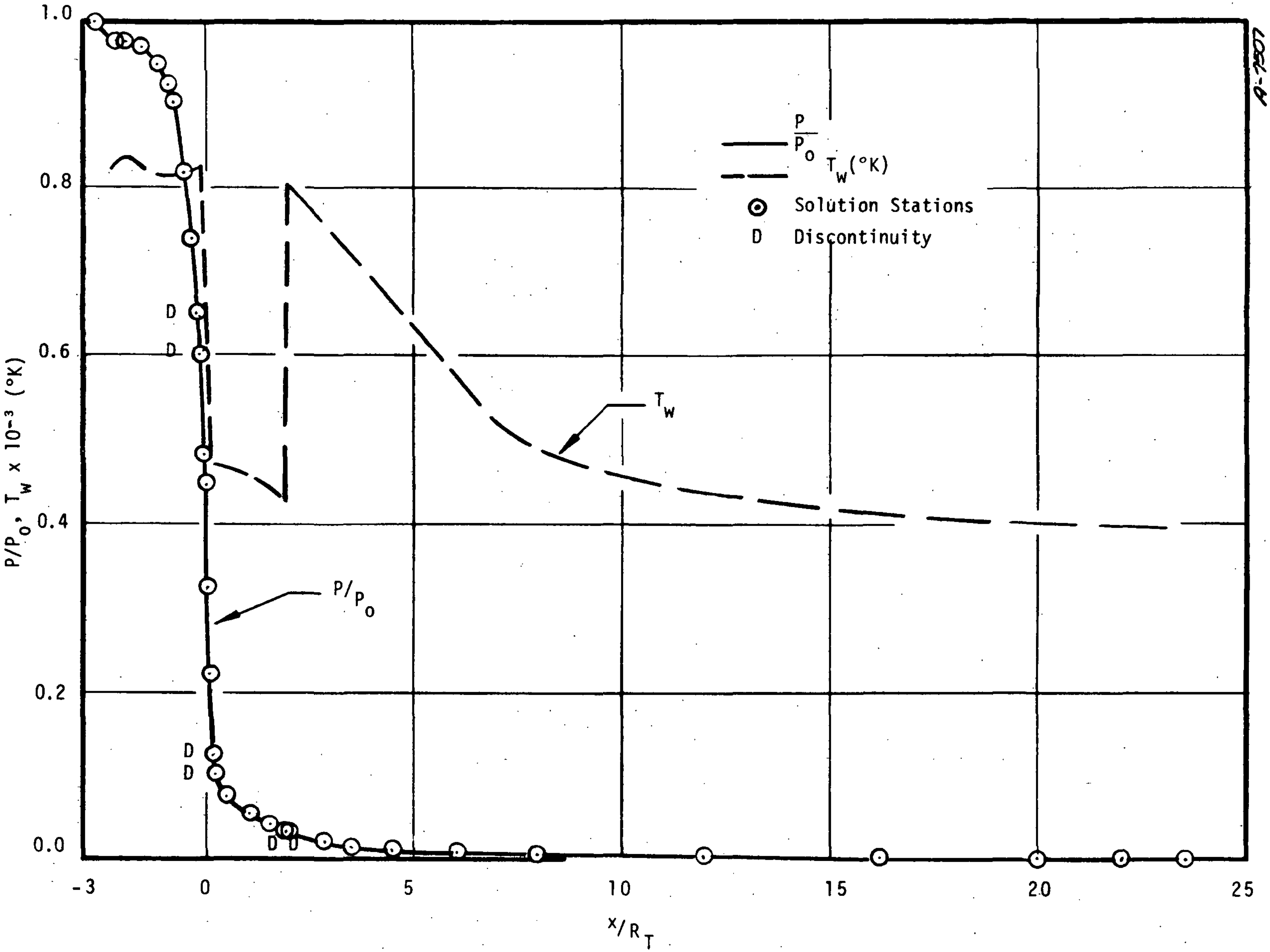

Figure 6-2. Case 2, SSME-NPL: Pressure and Wall Temperature

LIST OF INPUT DATA
CASE 2

```
1120062021020200000  SSME-NPL  (FIRST GUESS FROM MPL SOLUTION)         01100  N
 2                                                                     02100  N
31                                                                     03100  N
 ,194                                                                  03201  N
  393    31                                                            03300  N
    2     4    10    15    18    20    24    26   -28   -29    30    31    38    47  03401  N
  -53   -55    83   140   180  -211  -213   265   280   298   317   334   357   373  03402  N
  384   389   393                                                      03403  N
 $INPUT
 XITAB = -2,717022143,
 XITAB( 2) = -2,158263+00,-2,084139+00,-2,010015+00,-1,935891+00,-1,861766+00,
 -1,787642+00,-1.713517+00,-1,639393+00,-1,565268+00,-1,491144+00,-1,417019+00,
 -1.342895+00,-1,268770+00,-1,194646+00,-1,120522+00,-1.046397+00,-9,722726-01,
 -8,981482-01,-8,240237-01,-7,498993-01,-6,757748-01,-6,016504-01,-5,275259-01,
 -4,534014-01,-3,792768-01,-3,051523-01,-2,310278-01,-1,569032-01,-3,376257-02,
 XITAB(31) =  0,000000    , 7,301470-03, 1.480773-02, 2,248320-02, 3,035240-02,
  3,839005-02, 4,655763-02, 5,487080-02, 6,331403-02, 7,188499-02, 8,057737-02,
  8,939333-02, 9,832679-02, 1,073762-01, 1,165444-01, 1,258282-01, 1,352258-01,
  1,447381-01, 1,543664-01, 1,641102-01, 1,739715-01, 1,839499-01, 1,940455-01,
  2,042591-01, 2,145957-01, 2,250502-01, 2,356269-01, 2.464870-01, 2,571494-01,
  2,676082-01, 2,780790-01, 2,885548-01, 2,989977-01, 3,094342-01, 3,197972-01,
  3,301202-01, 3,404461-01, 3,507206-01, 3,609625-01, 3,711967-01, 3,813872-01,
  3,915503-01, 4,016734-01, 4,117679-01, 4,218635-01, 4,321029-01, 4,421489-01,
  4,521438-01, 4,620973-01, 4,720099-01, 4,819380-01, 4,918356-01, 5,016912-01,
  5,115829-01, 5,214410-01, 5,318231-01, 5,421098-01, 5,523693-01, 5,626000-01,
  5,728096-01, 5,830457-01, 5,932676-01, 6,034578-01, 6,136905-01, 6,239089-01,
  6,340935-01, 6,443033-01, 6,545275-01, 6,647377-01, 6,749371-01, 6,851697-01,
  6,953991-01, 7,055998-01, 7,158182-01, 7,260608-01, 7.363012-01, 7,465105-01,
  7,567564-01, 7,670198-01, 7,772841-01, 7,875275-01, 7,978002-01, 8,080852-01,
  8,183716-01, 8,286478-01, 8,389705-01, 8,492908-01, 8,595882-01, 8,699128-01,
  8,802965-01, 8,906735-01, 9,010085-01, 9,113905-01, 9,218289-01, 9,322654-01,
  9,426602-01, 9,531054-01, 9,635785-01, 9,740826-01, 9,845947-01, 9,950968-01,
  1,005645+00, 1,016230+00, 1,026838+00, 1,037423+00, 1,048058+00, 1,058743+00,
  1,069428+00, 1,080102+00, 1,090814+00, 1,101596+00, 1.112398+00, 1,123156+00,
  1,133972+00, 1,144836+00, 1,155729+00, 1,166644+00, 1,177561+00, 1,188519+00,
  1,199540+00, 1,210586+00, 1.221615+00, 1,232694+00, 1,243838+00, 1,255024+00,
  1,266164+00, 1,277356+00, 1,288631+00, 1,299893+00, 1,311229+00, 1,322551+00,
  1,333927+00, 1,345376+00, 1,356861+00, 1,368309+00, 1,379825+00, 1,391401+00,
  1,403013+00, 1,414673+00, 1,426313+00, 1,438029+00, 1,449814+00, 1,461640+00,
  1.473431+00, 1,485295+00, 1,497217+00, 1,509186+00, 1,521200+00, 1,533212+00,
  1,545280+00, 1,557436+00, 1,569644+00, 1,581815+00, 1,594050+00, 1,606344+00,
  1.618703+00, 1,631109+00, 1,643501+00, 1,655969+00, 1,668528+00, 1,681135+00,
  1,693686+00, 1,706319+00, 1,719039+00, 1,731799+00, 1,744615+00, 1,757420+00,
  1,770315+00, 1,783289+00, 1,796325+00, 1,809308+00, 1,822383+00, 1,835511+00,
  1,848721+00, 1,861971+00, 1,875216+00, 1,888525+00, 1,901951+00, 1,915432+00,
  1,928857+00, 1,942360+00, 1,955945+00, 1,969594+00, 1,983300+00, 1,996984+00,
  2,010762+00, 2,024642+00, 2,038590+00, 2,052464+00, 2,066424+00, 2,080470+00,
  2,094577+00, 2,108742+00, 2,122895+00, 2,137126+00, 2,151483+00, 2,165896+00,
  2,180235+00, 2,194661+00, 2,209183+00, 2,223752+00, 2,238402+00, 2,253021+00,
  2,267734+00, 2,282540+00, 2,297421+00, 2,312224+00, 2,327134+00, 2,342127+00,
  2,357161+00, 2,372277+00, 2,387358+00, 2,402533+00, 2,417826+00, 2,433179+00,
  2,448450+00, 2,463840+00, 2,479372+00, 2,494980+00, 2,510441+00, 2,526017+00,
  2,541671+00, 2,557418+00, 2,573240+00, 2,588988+00, 2,604861+00, 2,620877+00,
  2,636924+00, 2,677363+00, 2,710983+00, 2,745303+00, 2,779791+00, 2,815088+00,
  2,850751+00, 2,887245+00, 2,924102+00, 2,961821+00, 2,999905+00, 3,038866+00,
  3,078239+00, 3,118460+00, 3,159123+00, 3,200663+00, 3,242597+00, 3,285441+00,
  3,328774+00, 3,372992+00, 3,418005+00, 3,463434+00, 3,509776+00, 3,556600+00,
  3,604941+00, 3,653065+00, 3,701893+00, 3,751925+00, 3,802548+00, 3,854022+00,
  3,906147+00, 3,959293+00, 4,013382+00, 4,068083+00, 4,123805+00, 4,180349+00,
  4,237946+00, 4,296925+00, 4,356728+00, 4,417886+00, 4,480667+00, 4,544530+00,
  4,610106+00, 4,677761+00, 4,747077+00, 4,818067+00, 4,891428+00, 4,966935+00,
  5,044267+00, 5,123662+00, 5,205269+00, 5,289058+00, 5,374611+00, 5,462202+00,
  5,551555+00, 5,642443+00, 5,735165+00, 5,829753+00, 5,925968+00, 6,023916+00,
  6,123277+00, 6,224261+00, 6,326940+00, 6,431439+00, 6,537526+00, 6,645595+00,
  6,755391+00, 6,867253+00, 6,980977+00, 7,097068+00, 7,215089+00, 7,335826+00,
  7,458969+00, 7,583819+00, 7,711083+00, 7,841360+00, 7,974671+00, 8,111135+00,
  8,250457+00, 8,392641+00, 8,538094+00,
 8,686774,8,838667,8,993873,9,152518,9,314894,9,480435,9,649603,9,822585,
 9,999484,10,179860,10,364607,10,553176,10,745641,10,942437,11,143385,11,348369,
 11,558386,11,77240,11,991338,12,214441,12,442866,12,675662,12,913938,13,156592,
 13,405260,13,65860,13,917562,14,182350,14,451863,14,727825,15,009371,15,296731,
 15,590478,15,890424,16,196485,16,508911,16,828265,17,154032,17,486682,
 17,826637,18,172746,18,526305,18,887276,19,255961,19,632308,20,016557,
 20,408671,20,808905,21,217218,21,633897,22,058882,22,492796,22,936060,
 23,388284,23,517697,
```

```
      YITAB(1) = 2*1,732051+00, 1.730471+00, 1.725721+00, 1,717776+00, 1,706591+00,
       1,692103+00, 1,674225+00, 1,652848+00, 1,627836+00, 1,599017+00, 1,566184+00,
       1,530971+00, 1,495748+00, 1,460524+00, 1,425301+00, 1,390078+00, 1,354854+00,
       1,319631+00, 1,284408+00, 1,249184+00, 1,213961+00, 1,178738+00, 1,143514+00,
       1,108291+00, 1,074717+00, 1,047696+00, 1,027053+00, 1,012386+00, 1,000570+00,
      YITAB(31) =  1,000000+00, 1,000068+00, 1,000280+00, 1,000645+00, 1,001177+00,
       1,001884+00, 1,002775+00, 1,003859+00, 1,005147+00, 1,006647+00, 1,008371+00,
       1,010329+00, 1,012532+00, 1,014993+00, 1,017725+00, 1,020744+00, 1,024063+00,
       1,027699+00, 1,031674+00, 1,036006+00, 1,040720+00, 1,045840+00, 1,051397+00,
       1,057422+00, 1,063956+00, 1,071038+00, 1,078721+00, 1,086885+00, 1,094900+00,
       1,102756+00, 1,110620+00, 1,118485+00, 1,126324+00, 1,134155+00, 1,141905+00,
       1,149624+00, 1,157332+00, 1,164990+00, 1,172625+00, 1,180237+00, 1,187816+00,
       1,195371+00, 1,202883+00, 1,210373+00, 1,217858+00, 1,225437+00, 1,232873+00,
       1,240264+00, 1,247611+00, 1,254928+00, 1,262251+00, 1,269535+00, 1,276789+00,
       1,284068+00, 1,291301+00, 1,298920+00, 1,306468+00, 1,313976+00, 1,321460+00,
       1,328929+00, 1,336404+00, 1,343858+00, 1,351289+00, 1,358747+00, 1,366175+00,
       1,373579+00, 1,381001+00, 1,388416+00, 1,395815+00, 1,403205+00, 1,410616+00,
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$END
12                                                                      04100  N
  0.0        2.808-03  6.808-03  1.557-02  2.703-02  4.835-02  1.465-01  04201  N
  4.154-01   7.219-01  1.0       1.203     2.5                           04202  N
10  .95       1 3   .5                                                  04300  N
   0.0        .05       .12       .25       .35       .45       .6       04401  N
    .75       .85       .95       .98      1.0                           04402  N
 .13087858                                                              05100  N
 2.0477+07                                                              07100  N
-6.9501+05                                                              07200  N
                                                                        07300  N
    .44      11.823     .018      .9        .9       0.0                 08100  N
 10.86       0.0       2.39               1                             09100  N
  0.0        .0692     .161      .297      .381      .46       .614      09201  N
   .766      .881      .95       .98      1.0                            09202  N
  1.244+07 -1.178+07 -1.139+07 -1.088+07 -9.930+06 -9.232+06 -8.511+06  09301  N
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-7,004+06 -5,200+06 -3,416+06 -2,034+06 -1,261+06 -6,272+06             09302  N
-1,194-06  1,429-01  1,429-01  1,429-01  1,429-01  1,429-01  1,429-01  09401  N
 1,429-01  1,429-01  1,429-01  1,429-01  1,429-01  1,429-01            09402  N
 3 3                                                                    09501  N
  2                                                                     11100  N
 H HYDROGEN      1,008 -1,0                                             11201  N
 O  OXYGEN      16,0   -6,0                                             11202  N
      300,      1000,      5000,                                        13100  N
H                   J 9/65H 1,                G  300,      5000,               1
 0,25       E+01 0,              0,              0,             0,             2
 0,25471620E+05-0,46011763E+00 0,25       E+01 0,               0,             3
 0,              0,              0,25471627E+05-0,46011762E+00                 4
O                   J 6/620 1,                G  300,     5000,                1
 0,25420596E+01-0,27550619E-04-0,31028033E-08 0,45510674E-11-0,43680515E-15    2
 0,29230803E+05 0,49203080E+01 0,29464287E+01-0,16381665E-02+0,24210316E-05    3
-0,16028432E-08 0,38906964E-12 0,29147644E+05 0,29639949E+01                   4
O2                  J 9,650 2,                G  300,     5000,                1
 0,36219535E+01 0,73618264E-03-0,19652228E-06 0,36201558E-10-0,28945627E-14    2
-0,12019825E+04 0,36150960E+01 0,36255985E+01-0,18782184E-02 0,70554544E-05    3
-0,67635137E-08 0,21555993E-11-0,10475226E+04 0,43052778E+01                   4
H2                  J 3/61H 2,                G  300,      5000,               1
 0,31001901E+01 0,51119464E-03 0,52644210E-07-0,34909973E-10 0,36945345E-14    2
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 0,55210391E-08-0,18122739E-11-0,98890474E+03-0,22997056E+01                   4
OH                  J 3/660 1, H 1,           G  300,      5000,               1
 0,29106427E+01 0,95931650E-03-0,19441702E-06 0,13756646E-10 0,14224542E-15    2
 0,39353815E+04 0,54423445E+01 0,38375943E+01-0,10778858E-02 0,96830378E-06    3
 0,18713972E-09-0,22571094E-12 0,36412823E+04 0,49370009E+00                   4
H2O                 J 3/61H 2, O 1,           G  300,      5000,               1
 0,27167633E+01 0,29451374E-02-0,80224374E-06 0,10226682E-09-0,48472145E-14    2
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-0,29637404E-08 0,80702103E-12-0,30279722E+05-0,32270046E+00                   4
                                                                        13 LAST
                                                                        15201  N
                                                                        15202  N
                                                                        15203  N
                                                                        15204  N
                                                                        15205  N
833,      838,      825,      817,      816,      816,      819,          16201  N
828,      828,      805,      700,      650,      575,      490,          16202  N
466,7     466,      465,      455,      440,      422,      805,6         16203  N
755,      717,      665,      575,      492,      437,      410,          16204  N
400,      395,      394,4                                                 16205  N
                                                                        16601  N
                                                                        16602  N
                                                                        16603  N
                                                                        16604  N
                                                                        16605  N
                                                                        16606  N
                                                                        16607  N
                                                                        16608  N
                                                                        16609  N
                                                                        16610  N
                                                                        16611  N
                                                                        16612  N
                                                                        16613  N
                                                                        16614  N
                                                                        16615  N
                                                                        LAST   N
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OUTPUT CASE 2

BOUNDARY LAYER INTEGRAL MATRIX PROGRAM (BLIMP)

ACUREX CORP.-AEROTHERM DIV.,MT.VIEW,CALIF. (RMK,EPB) 17 DEC 73 22:42:46

CASE SSME-NPL (FIRST GUESS FROM MPL SOLUTION) 01100 N

CONTROL NUMBERS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	1	1	2	0	0	6	2	0	2	1	0	2	0	2	0	0	0	0	0	0

U/UE TO NORM. ETA	NODAL PT. AT WHICH ETA NORM.	ETA VALUES								
9.500-01	10	0.000	2.808-03	6.808-03	1.557-02	2.703-02	4.835-02	1.465-01	4.154-01	7.219-0
		1.000+00	1.203+00	2.500+00						

CASE 1.00000+00

TOTAL ENTHALPY,J/KG -6.95010+05

TOTAL PRESSURE,N /M2 2.04770+07

INCIDENT RAD FLUX,J/SM2 0.00000

MIXING LENGTH CONSTANT = 4.4000-01
SUBLAYER CONSTANT, YA+ = 1.1823+01
CLAUSER NUMBER = 1.8000-02
TURBULENT SCHMIDT NUMBER= 9.0000-01
TURBULENT PRANDTL NUMBER= 9.0000-01
TRANSITION MOM.THICK.RE = 0.0000

AXIAL DISTANCE,METERS	-.28247+00	-.26307+00	-.20486+00	-.15635+00	-.12725+00	-.10785+00	-.69042-01	-.49639-01
	-.30237-01	-.20535-01	-.44186-02	.00000	.71814-02	.17698-01	.25396-01	.28086-01
	.65661-01	.14276+00	.20224+00	.25421+00	.25778+00	.37788+00	.45935+00	.58642+00
	.78840+00	.10437+01	.15694+01	.21198+01	.26197+01	.28870+01	.30780+01	
WALL LENGTH,METERS	.25390-01	.44815-01	.10458+00	.15782+00	.19005+00	.21153+00	.25449+00	.27588+00
	.29628+00	.30617+00	.32236+00	.32678+00	.33398+00	.34465+00	.35335+00	.35650+00
	.40327+00	.49812+00	.57017+00	.63241+00	.63665+00	.77806+00	.87235+00	.10171+01
	.12423+01	.15202+01	.20757+01	.26424+01	.31497+01	.34191+01	.36111+01	
RADIUS,METERS	.22669+00	.22586+00	.21305+00	.19115+00	.17732+00	.16810+00	.14966+00	.14066+00
	.13442+00	.13250+00	.13095+00	.13088+00	.13138+00	.13403+00	.13761+00	.13925+00
	.16710+00	.22233+00	.26300+00	.29724+00	.29954+00	.37418+00	.42162+00	.49092+00
	.59050+00	.70007+00	.87911+00	.10135+01	.10989+01	.11326+01	.11521+01	
XI,(KG/SEC)**2	.31395-03	.55432-03	.12994-02	.19748-02	.23896-02	.26685-02	.32343-02	.35148-02
	.37745-02	.38964-02	.40887-02	.41389-02	.42148-02	.43080-02	.43637-02	.43808-02
	.46329-02	.52840-02	.58955-02	.64691-02	.65095-02	.79018-02	.86678-02	.10388-01
	.12821-01	.15918-01	.22330-01	.29053-01	.35119-01	.38302-01	.40535-01	
PRESSURE RATIO	.97670+00	.97625+00	.96878+00	.94836+00	.92633+00	.90408+00	.81798+00	.73996+00
	.64945+00	.60086+00	.48369+00	.44647+00	.32484+00	.19596+00	.12534+00	.10473+00
	.76277-01	.55609-01	.42513-01	.33951-01	.33607-01	.21202-01	.16478-01	.11899-01
	.80510-02	.56426-02	.35064-02	.25956-02	.21512-02	.19737-02	.18727-02	
STATIC PRESSURE,N /M2	.20000+08	.19991+08	.19838+08	.19420+08	.18968+08	.18513+08	.16750+08	.15152+08
	.13299+08	.12304+08	.99045+07	.91424+07	.66518+07	.40127+07	.25665+07	.21445+07
	.15619+07	.11387+07	.87053+06	.69522+06	.68817+06	.43415+06	.33741+06	.24366+06
	.16486+06	.11554+06	.71800+05	.53151+05	.44050+05	.40416+05	.38348+05	
EDGE VELOCITY,M/SEC	.32494+03	.32808+03	.37678+03	.48678+03	.58438+03	.67030+03	.94313+03	.11510+04
	.13722+04	.14870+04	.17634+04	.18534+04	.21666+04	.25671+04	.28569+04	.29608+04
	.31299+04	.32828+04	.34019+04	.34950+04	.34991+04	.36724+04	.37586+04	.38620+04
	.39753+04	.40692+04	.41828+04	.42482+04	.42867+04	.43038+04	.43140+04	
BETA	.22811-03	.64757-01	.78582+00	.16525+01	.21852+01	.27574+01	.44420+01	.49793+01
	.50297+01	.49894+01	.62940+01	.12524+02	.17759+02	.15389+02	.17597+02	.19093+02
	.11666+01	.53573+00	.62948+00	.55597+00	.37538+00	.43243+00	.37083+00	.30785+00
	.23760+00	.18734+00	.13019+00	.98188-01	.90099-01	.88554-01	.79975-01	
INCID RAD.FLUX,WATTS/M2	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	
WALL TEMPERATURE,DEG K	.83300+03	.83800+03	.82500+03	.81700+03	.81600+03	.81600+03	.81900+03	.82800+03
	.82800+03	.80500+03	.70000+03	.65000+03	.57500+03	.49000+03	.46670+03	.46600+03
	.46500+03	.45500+03	.44000+03	.42200+03	.80560+03	.75500+03	.71700+03	.66500+03
	.57500+03	.49200+03	.43700+03	.41000+03	.40000+03	.39500+03	.39440+03	

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COMP FLUX,KG/SM2        ,00000     ,00000     ,00000     ,00000     ,00000     ,00000     ,00000     ,00000
                        ,00000     ,00000     ,00000     ,00000     ,00000     ,00000     ,00000     ,00000
                        ,00000     ,00000     ,00000     ,00000     ,00000     ,00000     ,00000     ,00000
                        ,00000     ,00000     ,00000     ,00000     ,00000     ,00000     ,00000

COMP FLUX,KG/SM2        ,00000     ,00000     ,00000     ,00000     ,00000     ,00000     ,00000     ,00000
                        ,00000     ,00000     ,00000     ,00000     ,00000     ,00000     ,00000     ,00000


     STATION   1 - - - - - - - - - - AXIAL POSITION  -,28247+00 METERS - - - - - -17 DEC 73 22142146

ITERATED VALUES                DAMP  MAX,LIN   MAX,ERRORS IN CONSERVATION EQS,
ITS   TIME   ALPH   FPPW              ERROR  MOMENTUM     ENERGY      H
 1     6,99711,889 2,3098 ,1597  2,+00 11  6,2+01  8 -5,3+04  8 -7,7-05  0
 2     8,14913,078 2,2822 ,0247  2,+00 11  6,5+01  8 -5,4+04  8 -9,2-05  0
 3     9,27114,386 2,2352 ,0491  2,+00 11  6,9+01  8 -5,7+04  8 -1,1-04  0
 4    10,39815,825 2,1774 ,0932  2,+00 11  6,9+01  8 -5,7+04  8 -1,1-04  0
 5    11,57117,407 2,0443 ,2751  2,+00 11  6,9+01  8 -5,5+04  8 -9,5-05  0
 6    12,75019,148 1,9293 ,5074  1,+00 11  5,0+01  8 -4,1+04  8 -9,8-05  0
 7    13,89520,575 1,88431,0000  6,-01 11  2,5+01  8 -2,2+04  8 -3,0-05  0
 8    14,93620,653 1,91681,0000  1,-05  7  2,0+00  8 -1,5+03  9  3,0-05  0
 9    15,89920,676 1,91941,0000  8,-06  5 -2,2-01  2 -3,8+01  9 -3,8-05  0
10    16,85320,681 1,92001,0000  1,-06  5 -4,3-02  2 -6,8+00  2 -2,7-06  0

     ALPHA      RADIUS    PRESSURE  EDGE VEL,   BETA               HEAT FLUXES (WATTS/M2)
               (METERS)   (N /M2)    M/SEC               DIFFUSIONAL TOT ENTH  RERAD      QCOND
     2,068+01  2,267-01  2,000+07  3,249+02  2,281-04  9,551+07  9,551+07  0,000      9,546+07

     WALL       MASS FLUXES (KG/SEC-M2)              ELEMENTAL MASS DIFFUSIVE FLUXES (KG/SEC-M2) FOR
     SHEAR    MECHANICAL  PYROL       CHAR    TOTAL GAS  HYDROGEN     OXYGEN
    (N /M2)   REMOVAL      GAS
     2,316+03  0,000      0,000      0,000     0,000     -6,425-06  6,425-06

    MOM TRANS HEAT TRANS     BLOWING PARAMETERS          ELEMENTAL MASS TRANSFER COEFFICIENTS,
     COEFF,    COEFF,    (NORM, BY RHOE*UE*ST) FOR                CM,  FOR
     CF/2       ST NO,   PYROL GAS    CHAR    TOTAL GAS  HYDROGEN     OXYGEN
     2,451-03  2,999-03  0,000      0,000      0,000      1,187-01  1,483-01


    MOMENTUM  DISPLACE, EFFECTIVE ENTHALPY  REYNOLDS  MASS THICKNESS (M) FOR
   THICKNESS,THICKNESS,   BODY   THICKNESS,  NUMBER
    THETA     DELSTAR   DISPLACE,  LAMBDA  PER METER   HYDROGEN     OXYGEN
     (M)        (M)        (M)       (M)
    1,251-04  4,823-05  4,823-05  1,522-04  3,513+07 -9,318+00 -1,165+01

    TOTAL HEAT    THRUST
     TO WALL       LOSS
     (WATTS)       (N )        (THIS CASE WAS RUN PRIOR TO ADDITION OF WALL AREA CALCULATION.)
    1,321+06   -1,205+03

NODAL INFORMATION
     ETA      DISTANCE     F          U/UE       FPP       SHEAR     G, TOTAL     GP        GPP      STATIC      TEMP
              FROM WALL                                               ENTHALPY                        ENTHALPY
              (METERS)                                    (N /M2)     (J/KG)     (J/KG)    (J/KG)     (J/KG)    (DEG K)
    0,000     0,000     0,000     0,000     1,920+00  2,316+03 -1,165+07  1,336+07  9,264+06 -1,165+07  8,330+02
    2,808-03  5,703-07  3,212-03  1,102-01  1,874+00  2,316+03 -1,086+07  1,390+07 -5,662+07 -1,086+07  1,124+03
    6,808-03  1,648-06  1,773-02  2,287-01  9,911-01  2,315+03 -9,901+06  9,211+06 -2,856+07 -9,904+06  1,449+03
    1,557-02  4,673-06  7,204-02  3,519-01  3,681-01  2,311+03 -8,701+06  4,036+06 -7,834+06 -8,707+06  1,828+03
    2,703-02  9,309-06  1,641-01  4,179-01  1,894-01  2,306+03 -7,964+06  2,179+06 -2,292+06 -7,974+06  2,050+03
    4,835-02  1,890-05  3,639-01  4,815-01  9,912-02  2,294+03 -7,226+06  1,168+06 -3,857+05 -7,239+06  2,265+03
    1,465-01  7,026-05  1,499+00  6,146-01  3,202-02  2,218+03 -5,649+06  3,856+05 -2,382+04 -5,669+06  2,698+03
    4,154-01  2,344-04  5,354+00  7,610-01  2,061-02  1,884+03 -3,873+06  2,531+05 -6,773+03 -3,903+06  3,116+03
    7,219-01  4,448-04  1,056+01  8,782-01  1,639-02  1,238+03 -2,404+06  2,102+05 -1,581+04 -2,445+06  3,392+03
    1,000+00  6,504-04  1,584+01  9,500-01  8,574-03  5,830+02 -1,457+06  1,193+05 -6,165+03 -1,504+06  3,539+03
    1,203+00  8,058-04  1,990+01  9,807-01  6,036-03  1,983+02 -1,010+06  9,342+04 -1,130+04 -1,061+06  3,601+03
    2,500+00  1,828-03  4,682+01  1,000+00  0,000     0,000     -6,950+05  0,000     4,337+03 -7,478+05  3,643+03
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DISTANCE FROM WALL (METERS)	DENSITY RHO (KG/M3)	VISCOSITY MU (N -S/M2)	SPECIFIC HEAT (J/KG-K)	THERMAL COND, (WATTS/M -K)	PRANDTL NUMBER	MODIFIED SCHMIDT NUMBER	MOLECULAR WEIGHT	MACH NUMBER
0,000	4,073+01	3,100-05	2,609+03	1,558-01	5,191-01	6,681-01	1,411+01	0,000
5,703-07	3,018+01	3,777-05	2,826+03	2,031-01	5,255-01	6,681-01	1,411+01	3,913-02
1,648-06	2,342+01	4,464-05	3,045+03	2,566-01	5,297-01	6,681-01	1,411+01	7,222-02
4,673-06	1,856+01	5,203-05	3,249+03	3,176-01	5,323-01	6,681-01	1,411+01	9,965-02
9,309-06	1,655+01	5,612-05	3,346+03	3,523-01	5,331-01	6,681-01	1,411+01	1,122-01
1,890-05	1,497+01	5,994-05	3,428+03	3,851-01	5,335-01	6,681-01	1,410+01	1,233-01
7,026-05	1,255+01	6,727-05	3,558+03	4,489-01	5,332-01	6,683-01	1,408+01	1,451-01
2,344-04	1,079+01	7,410-05	3,650+03	5,095-01	5,309-01	6,695-01	1,399+01	1,680-01
4,448-04	9,801+00	7,858-05	3,699+03	5,513-01	5,272-01	6,716-01	1,382+01	1,858-01
6,504-04	9,297+00	8,101-05	3,721+03	5,753-01	5,240-01	6,734-01	1,368+01	1,962-01
8,058-04	9,087+00	8,205-05	3,731+03	5,861-01	5,222-01	6,743-01	1,361+01	2,004-01
1,828-03	8,946+00	8,275-05	3,737+03	5,936-01	5,209-01	6,750-01	1,355+01	2,029-01

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                                  DISTANCE FROM WALL,METERS
            0,000     5,703-07  1,648-06  4,673-06  9,309-06  1,890-05  7,026-05  2,344-04  4,448-04  6,504-04
                 8,058-04  1,828-03

ELEMENTAL FRACTIONS AND THEIR FIRST AND SECOND DERIVATIVES WITH RESPECT TO ETA

   H        1,429-01  1,429-01  1,429-01  1,429-01  1,429-01  1,429-01  1,429-01  1,429-01  1,429-01  1,429-01
                 1,429-01  1,429-01
            6,096-07  5,663-07 -7,330-08 -2,679-08 -1,552-08 -9,978-09 -3,573-09 -2,336-09 -1,621-09 -1,023-09
                -5,549-10  0,000
           -7,455-07 -7,732-06  2,566-07  4,754-08  1,257-08  3,156-09  2,224-10  1,128-10  1,041-10  1,114-10
                 7,013-11 -2,876-11
   O        8,571-01  8,571-01  8,571-01  8,571-01  8,571-01  8,571-01  8,571-01  8,571-01  8,571-01  8,571-01
                 8,571-01  8,571-01
           -6,096-07 -5,663-07  7,330-08  2,679-08  1,552-08  9,978-09  3,573-09  2,336-09  1,621-09  1,023-09
                 5,549-10  0,000
            7,455-07  7,732-06 -2,566-07 -4,754-08 -1,257-08 -3,156-09 -2,224-10 -1,128-10 -1,041-10 -1,114-10
                -7,013-11  2,876-11

MOLE FRACTIONS

   H        3,790-13  1,527-09  3,250-07  1,582-05  7,947-05  2,824-04  1,971-03  7,780-03  1,606-02  2,265-02
                 2,600-02  2,846-02
   O        1,243-27  1,647-19  2,826-14  1,714-10  6,333-09  1,073-07  8,128-06  1,692-04  8,090-04  1,655-03
                 2,191-03  2,624-03
   O2       2,429-27  2,675-19  4,148-14  2,356-10  8,482-09  1,409-07  1,033-05  2,074-04  9,462-04  1,858-03
                 2,406-03  2,833-03
   H2       2,443-01  2,443-01  2,443-01  2,443-01  2,442-01  2,441-01  2,437-01  2,432-01  2,444-01  2,463-01
                 2,475-01  2,485-01
   OH       5,402-16  2,416-11  2,378-08  3,433-06  2,686-05  1,345-04  1,569-03  8,705-03  2,081-02  3,081-02
                 3,587-02  3,952-02
   H2O      7,557-01  7,557-01  7,557-01  7,557-01  7,557-01  7,554-01  7,528-01  7,399-01  7,170-01  6,967-01
                 6,860-01  6,781-01
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REFIT CALLED

I	ETA(I)	U/UE	G(1,I)	SP(1,I,1)	SP(1,I,2)	SP(1,I,3)	SP(1,I,4)	SP(1,I,5)	SP(1,I,6)	SP(1,I,7)	SP(1,I,
1	0,000	0,000	-1,165+07	1,429-01							
2	1,266-03	5,057-02	-1,129+07	1,429-01							
3	3,065-03	1,193-01	-1,079+07	1,429-01							
4	7,889-03	2,518-01	-9,694+06	1,429-01							
5	1,533-02	3,487-01	-8,730+06	1,429-01							
6	3,615-02	4,503-01	-7,595+06	1,429-01							
7	1,280-01	5,980-01	-5,847+06	1,429-01							
8	3,903-01	7,501-01	-4,007+06	1,429-01							
9	6,414-01	8,504-01	-2,758+06	1,429-01							
10	1,000+00	9,500-01	-1,457+06	1,429-01							
11	1,198+00	9,802-01	-1,017+06	1,429-01							
12	2,500+00	1,000+00	-6,950+05	1,429-01							

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      STATION  31 - - - - - - - - - - AXIAL POSITION    ,30780+01 METERS - - - - - -17 DEC 73 22:46:22

ITERATED VALUES              DAMP  MAX,LIN   MAX,ERRORS IN CONSERVATION EQS,
ITS   TIME   ALPH    FPPW           ERROR  MOMENTUM     ENERGY      H
 1    1,44837,428 4,2421 ,4999  6,-05 13  9,2+00 10 -2,2+03 10 -2,0-03  0
 2    2,50837,475 4,26011,0000  3,-05 13  4,6+00 10 -1,1+03 10 -3,7-03  0
 3    3,50337,476 4,26561,0000  3,-05  6 -5,2-01 10  1,2+02 10  1,7-04  0
 4    4,51937,476 4,26641,0000  6,-05  6 -6,9-02 10  6,5+01 10 -1,6-04  0
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ALPHA	RADIUS (METERS)	PRESSURE (N /M2)	EDGE VEL. M/SEC	BETA	HEAT FLUXES (WATTS/M2) DIFFUSIONAL	TOT ENTH	RERAD	QCOND
3,748+01	1,152+00	3,835+04	4,314+03	7,998-02	2,920+06	2,920+06	0,000	2,919+06

WALL SHEAR (N /M2)	MASS FLUXES (KG/SEC-M2) MECHANICAL REMOVAL	PYROL GAS	CHAR	TOTAL GAS	ELEMENTAL MASS DIFFUSIVE FLUXES (KG/SEC-M2) FOR HYDROGEN	OXYGEN
1,004+03	0,000	0,000	0,000	0,000	-7,272-07	7,272-07

MOM TRANS COEFF, CF/2	HEAT TRANS COEFF, ST NO,	BLOWING PARAMETERS (NORM, BY RHOE*UE*ST) FOR PYROL GAS	CHAR	TOTAL GAS	ELEMENTAL MASS TRANSFER COEFFICIENTS, CM, FOR HYDROGEN	OXYGEN
1,176-03	1,226-03	0,000	0,000	0,000	1,386-03	1,386-03

MOMENTUM THICKNESS, THETA (M)	DISPLACE, THICKNESS, DELSTAR (M)	EFFECTIVE BODY DISPLACE, (M)	ENTHALPY THICKNESS, LAMBDA (M)	REYNOLDS NUMBER PER METER	MASS THICKNESS (M) FOR HYDROGEN	OXYGEN
6,443-03	8,113-03	8,113-03	9,057-03	4,496+06	9,972-02	9,831-02

TOTAL HEAT TO WALL (WATTS)	THRUST LOSS (N)
1,479+08	3,741+04

NODAL INFORMATION

ETA	DISTANCE FROM WALL (METERS)	F	U/UE	FPP	SHEAR (N /M2)	G, TOTAL ENTHALPY (J/KG)	GP (J/KG)	GPP (J/KG)	STATIC ENTHALPY (J/KG)	TEMP (DEG K)
0,000	0,000	0,000	0,000	4,266+00	1,004+03	-1,273+07	2,710+07	4,401+08	-1,273+07	3,944+02
2,310-04	3,389-06	1,637-04	3,828-02	4,578+00	1,004+03	-1,248+07	3,091+07	1,819+08	-1,249+07	4,949+02
5,671-04	9,656-06	1,003-03	9,453-02	4,353+00	1,004+03	-1,207+07	3,320+07	-3,516+08	-1,216+07	6,325+02
1,547-03	3,478-05	6,886-03	2,114-01	2,011+00	1,003+03	-1,109+07	2,029+07	-1,628+08	-1,151+07	8,865+02
3,450-03	9,798-05	2,601-02	3,103-01	7,628-01	1,003+03	-1,006+07	8,677+06	-2,658+07	-1,095+07	1,089+03
9,222-03	3,267-04	1,069-01	4,192-01	2,442-01	9,999+02	-8,804+06	2,928+06	-2,026+06	-1,044+07	1,270+03
3,873-02	1,666-03	6,811-01	5,845-01	5,489-02	9,828+02	-6,804+06	6,884+05	-1,136+05	-9,982+06	1,423+03
1,612-01	7,504-03	3,792+00	7,391-01	1,246-02	9,067+02	-4,841+06	1,672+05	-5,561+03	-9,921+06	1,443+03
4,582-01	2,152-02	1,268+01	8,473-01	6,992-03	7,214+02	-3,325+06	1,053+05	-2,362+03	-1,000+07	1,416+03
1,000+00	4,658-02	3,106+01	9,500-01	3,123-03	3,323+02	-1,674+06	5,732+04	-2,296+02	-1,007+07	1,395+03
1,274+00	5,925-02	4,098+01	9,801-01	2,732-03	1,430+02	-1,097+06	5,496+04	-3,642+03	-1,003+07	1,407+03
2,500+00	1,167-01	8,694+01	1,000+00	0,000	0,000	-6,950+05	0,000	1,249+03	-9,994+06	1,419+03

DISTANCE FROM WALL (METERS)	DENSITY RHO (KG/M3)	VISCOSITY MU (N -S/M2)	SPECIFIC HEAT (J/KG-K)	THERMAL COND, (WATTS/M -K)	PRANDTL NUMBER	MODIFIED SCHMIDT NUMBER	MOLECULAR WEIGHT	MACH NUMBER
0,000	1,650-01	1,894-05	2,338+03	8,746-02	5,062-01	6,681-01	1,411+01	0,000
3,389-06	1,315-01	2,199-05	2,389+03	1,033-01	5,087-01	6,681-01	1,411+01	2,654-01
9,656-06	1,029-01	2,585-05	2,472+03	1,246-01	5,131-01	6,681-01	1,411+01	5,828-01
3,478-05	7,339-02	3,230-05	2,648+03	1,643-01	5,205-01	6,681-01	1,411+01	1,112+00
9,798-05	5,971-02	3,700-05	2,800+03	1,974-01	5,249-01	6,681-01	1,411+01	1,484+00
3,267-04	5,124-02	4,092-05	2,930+03	2,272-01	5,276-01	6,681-01	1,411+01	1,868+00
1,666-03	4,573-02	4,411-05	3,029+03	2,524-01	5,294-01	6,681-01	1,411+01	2,471+00
7,504-03	4,509-02	4,452-05	3,041+03	2,557-01	5,296-01	6,681-01	1,411+01	3,104+00
2,152-02	4,593-02	4,398-05	3,025+03	2,513-01	5,293-01	6,681-01	1,411+01	3,590+00
4,658-02	4,665-02	4,354-05	3,012+03	2,478-01	5,291-01	6,681-01	1,411+01	4,054+00
5,925-02	4,624-02	4,379-05	3,019+03	2,498-01	5,293-01	6,681-01	1,411+01	4,165+00
1,167-01	4,586-02	4,403-05	3,026+03	2,517-01	5,294-01	6,681-01	1,411+01	4,233+00

DISTANCE FROM WALL,METERS

0,000	3,389-06	9,656-06	3,478-05	9,798-05	3,267-04	1,666-03	7,504-03	2,152-02	4,658-02	5,925-02	1,167-01

ELEMENTAL FRACTIONS AND THEIR FIRST AND SECOND DERIVATIVES WITH RESPECT TO ETA

H	1,429-01	1,429-01	1,429-01	1,429-01	1,429-01	1,429-01	1,429-01	1,429-01	1,429-01	1,429-01	1,429-01	1,429-01
	1,523-05	-5,577-06	2,059-06	4,382-07	-4,483-08	-8,356-09	-1,161-08	-1,526-08	-3,567-08	-5,457-08	-7,745-08	0,000
	-2,403-03	6,062-04	-4,412-05	-6,775-06	1,686-07	-2,947-09	-7,948-10	-1,833-09	-9,308-10	-2,227-09	4,508-09	-1,136-09
O	8,571-01	8,571-01	8,571-01	8,571-01	8,571-01	8,571-01	8,571-01	8,571-01	8,571-01	8,571-01	8,571-01	8,571-01
	-1,523-05	5,577-06	-2,059-06	-4,382-07	4,483-08	8,356-09	1,161-08	1,526-08	3,567-08	5,457-08	7,745-08	0,000
	2,403-03	-6,062-04	4,412-05	6,775-06	-1,686-07	2,947-09	7,948-10	1,833-09	9,308-10	2,227-09	-4,508-09	1,136-09

MOLE FRACTIONS

H	4,206-27	3,237-21	3,567-16	5,962-11	1,635-08	5,394-07	5,295-06	6,901-06	4,859-06	3,614-06	4,279-06	5,016-06
O	1,000-30	1,000-30	8,391-35	5,023-23	1,561-17	4,073-14	6,905-12	1,252-11	5,692-12	2,928-12	4,279-12	6,115-12
O2	1,000-30	1,000-30	2,137-34	9,373-23	2,574-17	6,269-14	1,019-11	1,839-11	8,416-12	4,353-12	6,341-12	9,037-12
H2	2,443-01	2,443-01	2,443-01	2,443-01	2,443-01	2,443-01	2,443-01	2,443-01	2,443-01	2,443-01	2,443-01	2,443-01
OH	2,021-34	8,119-27	2,665-20	1,491-13	2,080-10	1,873-08	3,522-07	4,947-07	3,154-07	2,157-07	2,679-07	3,286-07
H2O	7,557-01	7,557-01	7,557-01	7,557-01	7,557-01	7,557-01	7,557-01	7,557-01	7,557-01	7,557-01	7,557-01	7,557-01

6.3 SAMPLE CASE 3 - SOLID PROPELLANT ROCKET NOZZLE

To aid the user of BLIMPJ this sample problem of a solid propellant rocket motor with two ablative wall materials is presented. The primary differences in this case and the liquid propellant cases are:

- Time varying stagnation conditions
- More elements and chemical species
- Ablative wall materials
- Solid particles in the flow (Al_2O_3)

BLIMP cannot accommodate time varying stagnation conditions or solid particles in the gas. Average values of the stagnation condition are assumed. Since the solid particles tend to leave the boundary layer region and reside in the free stream, the amount of Al_2O_3 condensate at M = 1.0 was calculated using the Aerotherm Chemical Equilibrium program and this amount was removed from the elemental composition of the boundary layer gas. The elemental composition of the fuel, which is primarily ammonium perchlorate and aluminum, and the elemental composition of the boundary layer edge gas are shown in Table 6-1.

Element Element	Percent By Weight Fuel	Percent By Weight Gas
H	3.738	5.267
C	11.474	16.171
N	8.694	12.254
O	38.987	35.675
Al	16.045	.949
Cl	21.062	29.684

TABLE 6-1

Elemental Composition of the Fuel and the Assumed Boundary Layer Gas (29.047 Percent (Weight) of the Fuel Condensed as Al_2O_3)

The two ablative wall materials are silicon phenolic tape (MX2600) and carbon phenolic tape (MX4926). The specified wall temperature was always less than the fail temperature of the wall material. In the absence of any other information it was assumed that the wall was in steady state ablation. In this case the pyrolysis gas and char gas are leaving the surface at a fixed ratio. The combined ablation gas is then assumed to have the elemental composition of the wall material and is accounted for in BLIMP as char gas. (See input cards in group 11 for the composition of the two wall materials.) The BLIMP options which use assigned wall temperature and ablation gas composition, and calculate the required blowing rate are KR(9) = 2, KR(11) = 0, assigned wall temperature, and assigned blowing rate of zero. The change in wall material at station 22 is specified on card 02100 of the input. Discontinuities were also specified at the juncture of the two materials. (Notice that these points are not forced to be extremely close together.)

A complete list of the input, the output heading and summary page, and the first and twenty-sixth solution stations are shown. The execution time on a Univac 1108 was approximately 30 minutes. This is primarily a result of having seven elements (see Section 3.10). Two suggestions which would reduce the execution time are to remove all the aluminum, and remove the silicon and run up to station 22, then restart at station 22 and include silicon. This would probably save ten minutes.

Another feature of this run is that the linear curve fit option for the edge pressure was used. This was done primarily to eliminate any problems with curve fit. If a more exact solution is desired, the option KR(3) = 2 should be used and a time limited case executed to insure that the Betas are correct before investing in the entire solution.

This case was run in two parts using the restart option. For this reason the total wall area and the total heat to wall given as the station 26 output apply only to that portion of the nozzle from the restart station (20).

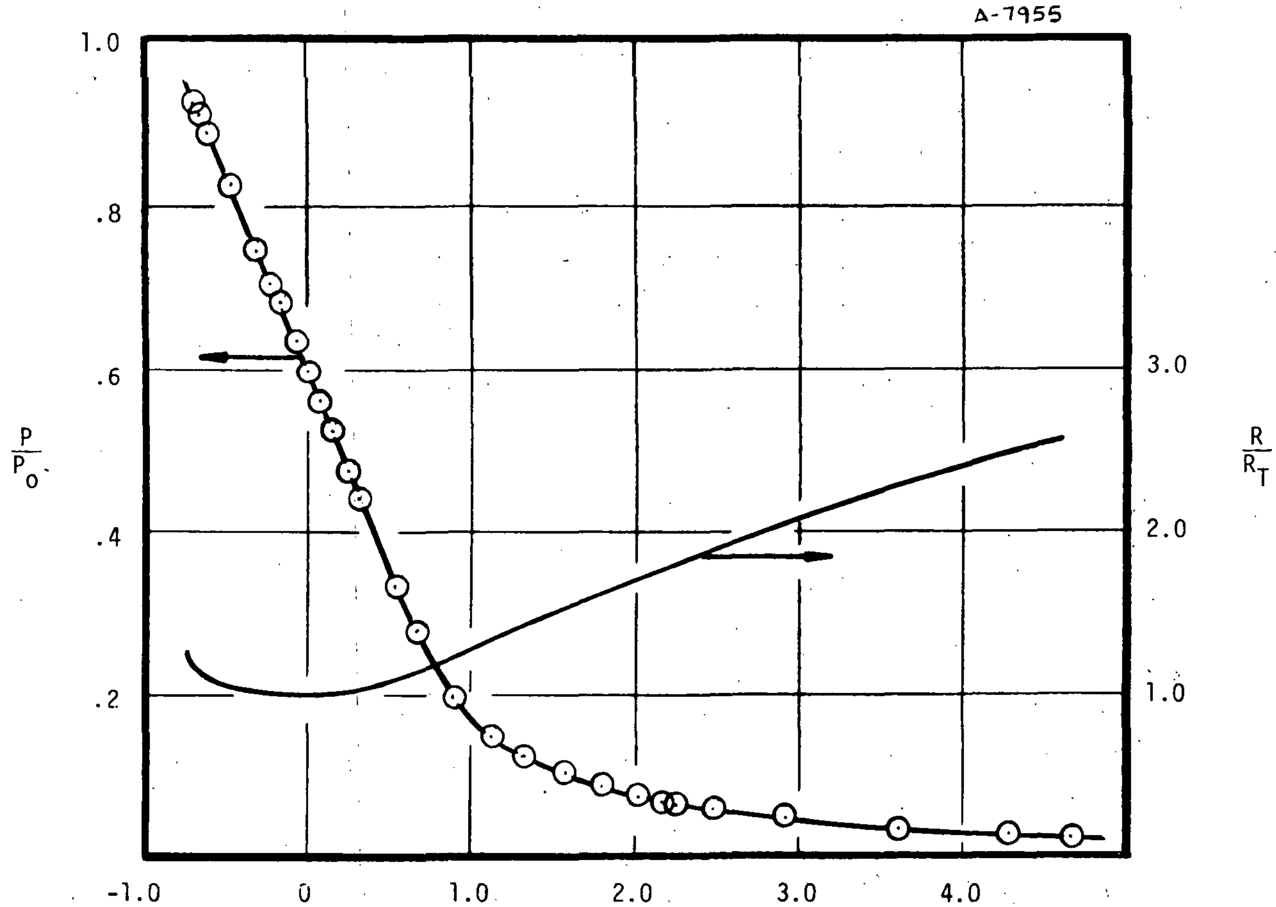

Figure 6-3. Case 3, Pressure Distribution and Nozzle Contours

INPUT

SAMPLE CASE 3

```
1050062021020200000O  SOLID PROPELLANT  SAMPLE CASE                            01100  S
 7          1111111111111111111112222222                                         02100  S
28                                                                               03100  S
6.78222-03                                                                       03201  S
 .43   15                                                                        03300  S
   3    6     7     9    11    12    13    14    15    16    17    18    20    22  03401  S
  24   25    26    27    28    29   -30   -31    32    33    35    38    41    43  03402  S
 $INPUT
 XITAB(1)= -1.0      , -.7392   , -.731    , -.716    , -.701    , -.678    ,
  -.603    , -.528   , -.452    , -.377    , -.301    , -.226    , -.151    ,
  -.075    ,  .00    ,  .075    ,  .151    ,  .226    ,  .301    ,  .377    ,
   .452    ,  .528   ,  .603    ,  .678    ,  .904    , 1.130    , 1.356    ,
  1.583    , 1.809   , 2.035    , 2.1628   , 2.261    , 2.487    , 2.713    ,
  2.939    , 3.165   , 3.391    , 3.617    , 3.843    , 4.069    , 4.295    ,
  4.521    , 4.648   ,
 YITAB(1)=  1.268    , 1.258    , 1.23     , 1.205    , 1.191    , 1.177    ,
  1.139    , 1.105   , 1.076    , 1.052    , 1.033    , 1.019    , 1.008    ,
  1.002    , 1.0     , 1.001    , 1.006    , 1.016    , 1.029    , 1.046    ,
  1.066    , 1.089   , 1.119    , 1.153    , 1.253    , 1.352    , 1.450    ,
  1.545    , 1.635   , 1.724    , 1.7728   , 1.812    , 1.901    , 1.988    ,
  2.072    , 2.152   , 2.228    , 2.298    , 2.367    , 2.428    , 2.482    ,
  2.529    , 2.555   ,
 PITAB(1)=  1.0      ,  .949    ,  .934    ,  .925    ,  .918    ,  .909    ,
   .885    ,  .859   ,  .828    ,  .797    ,  .762    ,  .730    ,  .681    ,
   .637    ,  .598   ,  .5588   ,  .525    ,  .483    ,  .441    ,  .402    ,
   .365    ,  .331   ,  .297    ,  .265    ,  .199    ,  .154    ,  .125    ,
   .103    ,  .087   ,  .075    ,  .06912  ,  .065    ,  .057    ,  .051    ,
   .045    ,  .040   ,  .037    ,  .034    ,  .031    ,  .029    ,  .028    ,
   .027    ,  .027   ,
 $END
12.                                                                              04100  S
 0.0          .002         .006         .01         .025         .06        .15  04201  S
  .4          .7          1.0          1.5         2.5                           04202  S
10     .95     1 3    .5                                                         04300  S
 0.0          .05          .12          .25         .35          .45        .6   04401  S
  .75         .85          .95          .98        1.0                           04402  S
  .674116                                                                        05100  S
 4.1341+06                                                                       07100  S
 1.7968+06                                                                       07200  S
 0.0                                                                             07300  S
  .44     11.823         .018         .9          .9          200.               08100  S
 6.482 +05                                                                       09600  S
  7                                                           1900.              11100  S
 H HYDROGEN        1.008-.05267         -.0253          -.0242                   11201  S
 C  CARBON         12.    -.15171       -.8584          -.2092                   11202  S
 N NITROGEN        14.008-.12254        -.0000           .0000                   11203  S
 O  OXYGEN         16.    -.35675       -.1163          -.462                    11204  S
 ALALUMINUM        26.97 -.00949         .0000           .0000                   11205  S
 SI SILICON        28.06 -.00000         .0000          -.3046                   11206  S
 CLCHLORINE        65.457-.29684         .0000           .0000                   11207  S
      300.         1000.      5000.                                              13100  S
H2                   J 3/61H    20    00    00    0G    300.000   5000.000              1
 0.31001901E 01 0.51119464E-03 0.52644210E-07-0.34909973E-10 0.36945345E-14          2
-0.87738042E 03-0.19629421E 01 0.30574451E 01 0.26765200E-02-0.58099162E-05          3
 0.55210391E-08-0.18122739E-11-0.98890474E 03-0.22997056E 01                         4
CO                   J 9/65C    10   100   000    0G    300.000   5000.000              1
 0.29840696E 01 0.14891390E-02-0.57899684E-06 0.10364577E-09-0.69353550E-14          2
-0.14245228E 05 0.63479156E 01 0.37100928E 01-0.16190964E-02 0.36923594E-05          3
-0.20319674E-08 0.23953344E-12-0.14356310E 05 0.29555351E 01                         4
AL                   J12/65AL  100   000   000    0G    300.000   5000.000              1
 0.25450650E 01-0.75157512E-04 0.48674178E-07-0.14045399E-10 0.15219285E-14          2
 0.38498957E 05 0.53100256E 01 0.27964983E 01-0.12468495E-02 0.20733316E-05          3
-0.15487769E-08 0.43185442E-12 0.38456100E 05 0.41365426E 01                         4
H2O                  J 3/61H    20   100   000    0G    300.000   5000.000              1
```

```
 0.27167633E 01 0.29451374E-02-0.80224374E-06 0.10226682E-09-0.48472145E-14    2
-0.29905826E 05 0.66305671E 01 0.40701275E 01-0.11084499E-02 0.41521180E-05    3
-0.29637404E-08 0.80702103E-12-0.30279722E 05-0.32270046E 00                   4
HCL                 J 9/64H   1CL  100  000  0G   300.000  5000.000            1
 0.27665884E 01 0.14381883E-02-0.46993000E-06 0.73499408E-10-0.43731106E-14    2
-0.11917468E 05 0.64583540E 01 0.35248171E 01 0.29984862E-04-0.86221891E-06    3
 0.20979721E-08-0.98658191E-12-0.12150509E 05 0.23957713E 01                   4
SIO                 J 9/67SI  10   100  000  0G   300.000  5000.000            1
 0.37478835E 01 0.81991943E-03-0.32525396E-06 0.57324962E-10-0.35108944E-14    2
-0.13317430E 05 0.36478404E 01 0.32528276E 01 0.41823126E-03 0.37806202E-05    3
-0.51024483E-08 0.19471317E-11-0.13090340E 05 0.66485803E 01                   4
N2                  J 9/65N   20   00   00   0G   300.000  5000.000            1
 0.28963194E 01 0.15154866E-02-0.57235277E-06 0.99807393E-10-0.65223555E-14    2
-0.90586184E 03 0.61615143E 01 0.36748261E 01-0.12081500E-02 0.23240102E-05    3
-0.63217559E-09-0.22577253E-12-0.10611588E 04 0.23580424E 01                   4
ALCL                J 9/64AL  1CL  100  000  0G   300.000  5000.000            1
 0.43754335E 01 0.18702767E-03-0.49869033E-07 0.85147171E-11-0.53213024E-15    2
-0.69880112E 04 0.23323888E 01 0.33327027E 01 0.44047734E-02-0.65385801E-05    3
 0.44387437E-08-0.11170643E-11-0.67755002E 04 0.73643189E 01                   4
ALCL2               J 9/64AL  1CL  200  000  0G   300.000  5000.000            1
 0.66933063E 01 0.33723139E-03-0.14321882E-06 0.26838301E-10-0.18532160E-14    2
-0.39836262E 05-0.38121903E 01 0.43363468E 01 0.99563726E-02-0.15049433E-04    3
 0.10272735E-07-0.26037172E-11-0.39361237E 05 0.75382417E 01                   4
ALCL3               J 3/64AL  1CL  300  000  0G   300.000  5000.000            1
 0.93982905E 01 0.67170780E-03-0.29024817E-06 0.55354910E-10-0.38875822E-14    2
-0.73283478E 05-0.16564590E 02 0.53451521E 01 0.16916668E-01-0.25004302E-04    3
 0.16718989E-07-0.41452873E-11-0.72452431E 05 0.30263715E 01                   4
ALO                 J 9/65AL  10   100  000  0G   300.000  5000.000            1
 0.39717174E 01 0.63202200E-03-0.25846015E-06 0.49488774E-10-0.33027949E-14    2
 0.95752335E 04 0.32492563E 01 0.29297104E 01 0.31210445E-02-0.13586470E-05    3
-0.11939557E-08 0.89331277E-12 0.98709961E 04 0.86985845E 01                   4
ALOCL               J 9/64AL  10   1CL  100  0G   300.000  5000.000            1
 0.67805200E 01 0.79662822E-03-0.34233355E-06 0.65022648E-10-0.45519197E-14    2
-0.44080832E 05-0.93132976E 01 0.32444409E 01 0.14117005E-01-0.19322038E-04    3
 0.11962798E-07-0.27069180E-11-0.43312343E 05 0.79922149E 01                   4
ALOH                J12/67AL  10   1H   10   0G   300.000  5000.000            1
 0.36860674E 01 0.33636822E-02-0.12466244E-05 0.21382205E-09-0.13898319E-13    2
-0.23046105E 05 0.36769913E 01 0.26132211E 01 0.27716894E-02 0.74157830E-05    3
-0.11354602E-07 0.45569559E-11-0.22586797E 05 0.10062166E 02                   4
ALO2H               J12/68AL  10   2H   10   0G   300.000  5000.000            1
 0.64264346E 01 0.32230362E-02-0.12139348E-05 0.21074500E-09-0.13828000E-13    2
-0.57626154E 05-0.74707565E 01 0.24800456E 01 0.16149264E-01-0.16033524E-04    3
 0.64466166E-08-0.40994769E-12-0.56682759E 05 0.12293907E 02                   4
C                   J 3/61C   100  000  000  0G   300.000  5000.000            1
 0.25810663E 01-0.14696202E-03 0.74388084E-07-0.79481079E-11 0.58900977E-16    2
 0.35216294E 05 0.43128879E 01 0.25328705E 01-0.15887641E-03 0.30682082E-06    3
-0.26770064E-09 0.87488827E-13 0.85240422E 05 0.46062374E 01                   4
CO2                 J 9/65C   10   200  000  0G   300.000  5000.000            1
 0.44608041E 01 0.30981719E-02-0.12392571E-05 0.22741325E-09-0.15525954E-13    2
-0.48961442E 05-0.98635982E 00 0.24007797E 01 0.87350957E-02-0.66070878E-05    3
 0.20021861E-08 0.63274039E-15-0.48377527E 05 0.96951457E 01                   4
CL                  J 3/61CL  100  000  000  0G   300.000  5000.000            1
 0.29595315E 01-0.41899860E-03 0.15980973E-06-0.28102717E-10 0.18673826E-14    2
 0.13659143E 05 0.30350159E 01 0.20888310E 01 0.28675912E-02-0.41905834E-05    3
 0.22408564E-08-0.33258769E-12 0.13836331E 05 0.72655033E 01                   4
H                   J 9/65H   100  000  000  0G   300.000  5000.000            1
 0.25000000E 01 0.              0.              0.              0.             2
 0.25471627E 05-0.46011763E 00 0.25000000E 01 0.              0.             3
 0.              0.              0.25471627E 05-0.46011762E 00                  4
HCO                 J 3/61H   1C   10   100  0G   300.000  5000.000            1
 0.33366720E 01 0.33912031E-02-0.12957629E-05 0.22679230E-09-0.14952372E-13    2
-0.26430557E 04 0.69479829E 01 0.37929190E 01-0.47861919E-04 0.57306920E-05    3
-0.54606603E-08 0.16288628E-11-0.26288218E 04 0.52070412E 01                   4
N                   J 3/61N   100  000  000  0G   300.000  5000.000            1
```

```
 0.24502682E 01 0.10661458E-03-0.74653373E-07 0.18796524E-10-0.10259839E-14    2
 0.56116040E 05 0.44487581E 01 0.25030714E 01-0.21800181E-04 0.54205287E-07    3
-0.56475602E-10 0.20999044E-13 0.56098904E 05 0.41675764E 01                   4
NO                J 6/63N   1O  100  000  0G   300.000  5000.000                1
 0.31890000E 01 0.13382281E-02-0.52899318E-06 0.95919332E-10-0.64847932E-14    2
 0.98283290E 04 0.67458126E 01 0.40459521E 01-0.34181783E-02 0.79819190E-05    3
-0.61139316E-08 0.15919076E-11 0.97453934E 04 0.29974988E 01                   4
O                 J 6/62O   100  000  000  0G   300.000  5000.000                1
 0.25420596E 01-0.27550619E-04-0.31028033E-08 0.45510674E-11-0.43680515E-15    2
 0.29230803E 05 0.49203080E 01 0.29464287E 01-0.16381665E-02 0.24210316E-05    3
-0.16028432E-08 0.38906964E-12 0.29147644E 05 0.29639949E 01                   4
OH                J 3/66O   1H  100  000  0G   300.000  5000.000                1
 0.29106427E 01 0.95931650E-03-0.19441702E-06 0.13756646E-10 0.14224542E-15    2
 0.39353815E 04 0.54423445E 01 0.38375943E 01-0.10778858E-02 0.96830378E-06    3
 0.18713972E-09-0.22571094E-12 0.36412823E 04 0.49370009E 00                   4
O2                J 9/65O   20   00   00   0G   300.000  5000.000                1
 0.36219535E 01 0.73618264E-03-0.19652228E-06 0.36201558E-10-0.28945627E-14    2
-0.12019825E 04 0.36150760E 01 0.36255985E 01-0.18782184E-02 0.70554544E-05    3
-0.67635137E-08 0.21555993E-11-0.10475226E 04 0.43052778E 01                   4
SICL2             J12/69SI  1CL  20   00   0G   300.000  5000.000                1
 0.66562009E 01 0.39225514E-03-0.16975920E-06 0.30024021E-10-0.14765027E-14    2
-0.21865180E 05-0.43502099E 01 0.42340627E 01 0.10291978E-01-0.15513731E-04    3
 0.10572099E-07-0.26771636E-11-0.21378628E 05 0.73084885E 01                   4
SI                J 3/67SI  100  000  000  0G   300.000  5000.000                1
 0.26506014E 01-0.35763852E-03 0.29592293E-06-0.72804829E-10 0.57963329E-14    2
 0.53437054E 05 0.52204057E 01 0.31793537E 01-0.27646992E-02 0.44784038E-05    3
-0.32833177E-08 0.91213631E-12 0.53339032E 05 0.27273204E 01                   4
SIC               J 3/67SI  1C  100  000  0G   300.000  5000.000                1
 0.55799033E 01-0.13409344E-02 0.75483047E-06-0.16543778E-09 0.12663345E-13    2
 0.85046120E 05-0.56633593E 01-0.21924696E 01 0.41342700E-01-0.78274113E-04    3
 0.60694120E-07-0.16729207E-10 0.85953143E 05 0.28756080E 02                   4
SICL              J 9/67SI  1CL 100  000  0G   300.000  5000.000                1
 0.44179424E 01 0.13137080E-03-0.30789013E-07 0.47802942E-11-0.24135145E-15    2
 0.21650362E 05 0.33226348E 01 0.38247525E 01 0.24969130E-02-0.36640266E-05    3
 0.25169051E-08-0.65148061E-12 0.21774076E 05 0.61967573E 01                   4
SICL3             J12/69SI  1CL  30   00   0G   300.000  5000.000                1
 0.73913634E 01 0.67983523E-03-0.29385989E-06 0.56056340E-10-0.39374882E-14    2
-0.51298469E 05-0.15758539E 02 0.51253419E 01 0.17938812E-01-0.26825402E-04    3
 0.18160893E-07-0.45701854E-11-0.50431048E 05 0.48235054E 01                   4
SICL4             J 9/67SI  1CL 400  000  0G   300.000  5000.000                1
 0.12089655E 02 0.10190735E-02-0.44167865E-06 0.84481573E-10-0.59491580E-14    2
-0.82936052E 05-0.29940086E 02 0.61040010E 01 0.24933114E-01-0.36703263E-04    3
 0.24448748E-07-0.60370155E-11-0.81705075E 05-0.98955289E 00                   4
SIH               J12/69SI  1H   10   00   0G   300.000  5000.000                1
 0.30911184E 01 0.14689347E-02-0.56349951E-06 0.10071335E-09-0.63679401E-14    2
 0.44302447E 05 0.57808348E 01 0.41309782E 01-0.35619084E-02 0.76432635E-05    3
-0.53797081E-08 0.12582731E-11 0.44159598E 05 0.10358455E 01                   4
SIN               J 3/67SI  1N  100  000  0G   300.000  5000.000                1
 0.39858621E 01-0.87927056E-05 0.54269539E-06-0.17951017E-09 0.16337069E-13    2
 0.43524809E 05 0.31615156E 01 0.31051955E 01 0.14852449E-02 0.18561060E-05    3
-0.37734883E-08 0.16835331E-11 0.43785709E 05 0.78753961E 01                   4
SI2               J 3/67SI  200  000  000  0G   300.000  5000.000                1
 0.50474139E 01 0.53990034E-03-0.43078376E-06 0.11355206E-09-0.96262871E-14    2
 0.69133185E 05-0.19234578E 01 0.38155393E 01-0.19096542E-03 0.59233416E-05    3
-0.57649603E-08 0.14775004E-11 0.69784655E 05 0.57275556E 01                   4
                                                                       13 LAST
                                                                       15201  S
                                                                       15202  S
                                                                       15203  S
                                                                       15204  S
 2977.     2972.     2968.     2956.     2939.     2930.     2919.     16201  S
 2914.     2897.     2893.     2875.     2859.     2826.     2788.     16202  S
 2738.     2673.     2617.     2562.     2514.     2472.     2431.     16203  S
 2015.     2015.     2012.     2009.     2005.     2003.     2002.     16204  S
```

16601	S
16602	S
16603	S
16604	S
16605	S
16606	S
16607	S
16608	S
16609	S
16610	S
16611	S
16612	S
LAST	S

OUTPUT

SAMPLE CASE 3

```
          BOUNDARY LAYER INTEGRAL MATRIX PROGRAM (BLIMP)

     ACUREX CORP.-AEROTHERM DIV.,MT.VIEW,CALIF. (RMK,EPB)  23 FEB 74 10:55:05

ASE  SOLID PROPELLANT  SAMPLE CASE                        01100  S

     CONTROL NUMBERS  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20

                      1  0  5  0  0  6  2  0  2  1  0  2  0  2  0  0  0  0  0  0

 U/UE TO          NODAL PT.                          ETA VALUES
 NORM. ETA        AT WHICH
                  ETA NORM.
  9.500-01          10        0.000     4.796-04  1.168-03  2.720-03  4.837-03  9.585-03  3.177-02  1.265-01  3.781-01
                              1.000+00  1.348+00  2.500+00

ASE                    1.00000+00

OTAL ENTHALPY,J/KG     1.79680+06

OTAL PRESSURE, N/M2    4.13410+06

NCIDENT RAD FLUX,J/SM2  0.00000

   MIXING LENGTH CONSTANT  =  4.4000-01
   SUBLAYER CONSTANT, YA+  =  1.1823+01
   CLAUSER NUMBER          =  1.8000-02
   TURBULENT SCHMIDT NUMBER=  9.0000-01
   TURBULENT PRANDTL NUMBER=  9.0000-01
   TRANSITION MOM.THICK.RE =  0.0000

       CASE  1 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - 23 FEB 74 10:55:05
```

RELATIVE ELEMENTAL COMPOSITIONS, ATOMIC WTS/UNIT MASS

SYMBOL	ELEMENT	ATOMIC WT	EDGE GAS	PYRO.GAS 1	CHAR 1	PYRO.GAS 2	CHAR 2	PYRO.GAS 3	CHAR 3
H	HYDROGEN	1.00800	.0522520	.0000000	.0250992	.0000000	.0240079	.0000000	.0000000
C	CARBON	12.00000	.0134758	.0000000	.0715333	.0000000	.0174333	.0000000	.0000000
N	NITROGEN	14.00800	.0087479	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
O	OXYGEN	16.00000	.0222969	.0000000	.0072687	.0000000	.0288750	.0000000	.0000000
AL	ALUMINUM	26.97000	.0003519	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
SI	SILICON	28.06000	.0000000	.0000000	.0000000	.0000000	.0108553	.0000000	.0000000
CL	CHLORINE	65.45700	.0045349	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

THERMODYNAMIC PROPERTY CURVE-FIT DATA (SEE MANUAL FOR FORMAT)

```
H2            J 3/61H  2.0  0.0  0.0  0.G    300.000  5000.000                 1
  1000.00    .30574451+01    .26765200-02   -.58099162-05    .55210391-08   -.18122739-11   -.98890474+03   -.22997056+01
  5000.00    .31001901+01    .51119464-03    .52644210-07   -.34909973-10    .36945345-14   -.87738042+03   -.19629421+01
      .00    .00000000       .00000000       .00000000       .00000000       .00000000       .00000000       .00000000
CO            J 9/65C  1.O  1.00 0.00 0.G    300.000  5000.000                 1
  1000.00    .37100928+01   -.16190964-02    .36923594-05   -.20319674-08    .23953344-12   -.14356310+05    .29555351+01
  5000.00    .29840696+01    .14891390-02   -.57897684-06    .10364577-09   -.69353550-14   -.14245228+05    .63479156+01
      .00    .00000000       .00000000       .00000000       .00000000       .00000000       .00000000       .00000000
AL            J12/65AL 1.00 0.00 0.00 0.G    300.000  5000.000                 1
  1000.00    .27964983+01   -.12468495-02    .20733316-05   -.15487769-08    .43185442-12    .38456100+05    .41365426+01
  5000.00    .25450650+01   -.75157512-04    .48674178-07   -.14045399-10    .15219285-14    .38498957+05    .53100256+01
      .00    .00000000       .00000000       .00000000       .00000000       .00000000       .00000000       .00000000
H2O           J 3/61H  2.O  1.00 0.00 0.G    300.000  5000.000                 1
  1000.00    .40701275+01   -.11084497-02    .41521180-05   -.29637404-08    .80702103-12   -.30279722+05   -.32270046+00
  5000.00    .27167633+01    .29451374-02   -.80224374-06    .10226682-09   -.48472145-14   -.29905826+05    .66305671+01
      .00    .00000000       .00000000       .00000000       .00000000       .00000000       .00000000       .00000000
HCL           J 9/64H  1.CL 1.00 0.00 0.G    300.000  5000.000                 1
  1000.00    .35248171+01    .29984832-04   -.86221891-06    .20979721-08   -.98658191-12   -.12150509+05    .23957713+01
  5000.00    .27665884+01    .14381883-02   -.46993000-06    .73479408-10   -.43731106-14   -.11917468+05    .64583540+01
      .00    .00000000       .00000000       .00000000       .00000000       .00000000       .00000000       .00000000
SIO           J 9/67SI 1.O  1.00 0.00 0.G    300.000  5000.000                 1
  1000.00    .32528276+01    .41823126-03    .37806202-05   -.51024483-08    .19471317-11   -.13090340+05    .66485803+01
  5000.00    .37478835+01    .81991943-03   -.32525396-06    .57324962-10   -.35108944-14   -.13317430+05    .36478404+01
      .00    .00000000       .00000000       .00000000       .00000000       .00000000       .00000000       .00000000
N2            J 9/65N  2.0  0.0  0.0  0.G    300.000  5000.000                 1
  1000.00    .36748261+01   -.12081500-02    .23240102-05   -.63217559-09   -.22577253-12   -.10611588+04    .23580424+01
  5000.00    .28963194+01    .15154866-02   -.57235277-06    .99807393-10   -.65223555-14   -.90586184+03    .61615148+01
      .00    .00000000       .00000000       .00000000       .00000000       .00000000       .00000000       .00000000
ALCL          J 9/64AL 1.CL 1.00 0.00 0.G    300.000  5000.000                 1
  1000.00    .33327027+01    .44047734-02   -.65385801-05    .44387437-08   -.11170643-11   -.67755002+04    .73643189+01
  5000.00    .43754335+01    .10702767-03   -.49869033-07    .85147171-11   -.53213024-15   -.69880112+04    .23323888+01
      .00    .00000000       .00000000       .00000000       .00000000       .00000000       .00000000       .00000000
ALCL2         J 9/64AL 1.CL 2.00 0.00 0.G    300.000  5000.000                 1
  1000.00    .43363468+01    .99563726-02   -.15049433-04    .10272735-07   -.26037172-11   -.39361237+05    .75382417+01
  5000.00    .66933063+01    .33723139-03   -.14321882-06    .26838301-10   -.18532160-14   -.39836262+05   -.38121908+01
      .00    .00000000       .00000000       .00000000       .00000000       .00000000       .00000000       .00000000
ALCL3         J 3/64AL 1.CL 3.00 0.00 0.G    300.000  5000.000                 1
  1000.00    .53451521+01    .16916668-01   -.25004302-04    .16718989-07   -.41452878-11   -.72452431+05    .30263715+01
  5000.00    .93982905+01    .67170780-03   -.29024817-06    .55354910-10   -.38875822-14   -.73283478+05   -.16564590+02
      .00    .00000000       .00000000       .00000000       .00000000       .00000000       .00000000       .00000000
ALO           J 9/65AL 1.O  1.00 0.00 0.G    300.000  5000.000                 1
```

1000.00	.29297104+01	.31210445-02	-.13586470-05	-.11939557-08	.89331277-12	.98709961+04	.86985846+01
5000.00	.39717174+01	.63202200-03	-.25846015-06	.49488774-10	-.33027949-14	.95752335+04	.32492568+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
ALOCL	J 9/64AL 1.0	1.CL 1.00 0.G	300.000 5000.000	1			
1000.00	.32444409+01	.14117005-01	-.19322038-04	.11962798-07	-.27069180-11	-.43312343+05	.79922149+01
5000.00	.67805200+01	.79662822-03	-.34233355-06	.65022648-10	-.45519197-14	-.44080832+05	-.93132976+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
ALOH	J12/67AL 1.0	1.H 1.0 0.G	300.000 5000.000	1			
1000.00	.26132211+01	.27716894-02	.74157830-05	-.11354602-07	.45569559-11	-.22586797+05	.10062166+02
5000.00	.36860674+01	.33636822-02	-.12466244-05	.21382205-09	-.13898319-13	-.23046105+05	.36769913+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
ALO2H	J12/68AL 1.0	2.H 1.0 0.G	300.000 5000.000	1			
1000.00	.24800456+01	.16149264-01	-.16033524-04	.64466166-08	-.40994769-12	-.56682759+05	.12293907+02
5000.00	.64264346+01	.32230362-02	-.12139348-05	.21074500-09	-.13828000-13	-.57626154+05	-.74707565+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
C	J 3/61C 1.00	0.00 0.00 0.G	300.000 5000.000	1			
1000.00	.25328705+01	-.15887641-03	.30682082-06	-.26770064-09	.87488827-13	.85240422+05	.46062374+01
5000.00	.25810663+01	-.14696202-03	.74388084-07	-.79481079-11	.58900977-16	.85216294+05	.43128879+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
CO2	J 9/65C 1.0	2.00 0.00 0.G	300.000 5000.000	1			
1000.00	.24007797+01	.87350957-02	-.66070878-05	.20021861-08	.63274039-15	-.48377527+05	.96951457+01
5000.00	.44608041+01	.30981719-02	-.12392571-05	.22741325-09	-.15525954-13	-.48961442+05	-.98635982+00
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
CL	J 3/61CL 1.00	0.00 0.00 0.G	300.000 5000.000	1			
1000.00	.20838310+01	.28675912-02	-.41905834-05	.22408564-08	-.33258769-12	.13836331+05	.72655033+01
5000.00	.29595315+01	-.41899860-03	.15980973-06	-.28102717-10	.18673826-14	.13659143+05	.30350159+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
H	J 9/65H 1.00	0.00 0.00 0.G	300.000 5000.000	1			
1000.00	.25000000+01	.00000000	.00000000	.00000000	.00000000	.25471627+05	-.46011762+00
5000.00	.25000000+01	.00000000	.00000000	.00000000	.00000000	.25471627+05	-.46011763+00
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
HCO	J 3/61H 1.C	1.0 1.00 0.G	300.000 5000.000	1			
1000.00	.37929190+01	-.47861919-04	.57306920-05	-.34606603-08	.16288628-11	-.26288218+04	.52070412+01
5000.00	.33366729+01	.33912031-02	-.12957629-05	.22579230-09	-.14952372-13	-.26430557+04	.69479829+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
N	J 3/61N 1.00	0.00 0.00 0.G	300.000 5000.000	1			
1000.00	.25030714+01	-.21800181-04	.54205287-07	-.56475602-10	.20999044-13	.56098904+05	.41675764+01
5000.00	.24502682+01	.10661458-03	-.74653373-07	.18796524-10	-.10259839-14	.56116040+05	.44487581+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
NO	J 6/63N 1.0	1.00 0.00 0.G	300.000 5000.000	1			
1000.00	.40459521+01	-.34181783-02	.79819190-05	-.61139316-08	.15919076-11	.97453934+04	.29974968+01
5000.00	.31890000+01	.13382281-02	-.52899318-06	.95919332-10	-.64847932-14	.98283290+04	.67458126+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
O	J 6/62O 1.00	0.00 0.00 0.G	300.000 5000.000	1			
1000.00	.29464287+01	-.16381665-02	.24210316-05	-.16028432-08	.38906964-12	.29147644+05	.29639949+01
5000.00	.25420596+01	-.27550619-04	-.31028033-08	.45510674-11	-.43680515-15	.29230803+05	.49203080+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
OH	J 3/66O 1.H	1.00 0.00 0.G	300.000 5000.000	1			
1000.00	.38375943+01	-.10778858-02	.96830378-06	.18713972-09	-.22571094-12	.36412823+04	.49370009+00
5000.00	.29106427+01	.95931650-03	-.19441702-06	.13756646-10	.14224542-15	.39353815+04	.54423445+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
O2	J 9/65O 2.0	0.0 0.0 0.G	300.000 5000.000	1			
1000.00	.36255985+01	-.18782184-02	.70554544-05	-.67635137-08	.21555993-11	-.10475226+04	.43052778+01
5000.00	.36219535+01	.73618264-03	-.19652228-06	.36201558-10	-.28945627-14	-.12019825+04	.36150960+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
SI	J 3/67SI 1.00	0.00 0.00 0.G	300.000 5000.000	1			
1000.00	.31793537+01	-.27646992-02	.44784038-05	-.32833177-08	.91213631-12	.53339032+05	.27273204+01
5000.00	.26506014+01	-.35763852-03	.29592293-06	-.72804829-10	.57963329-14	.53437054+05	.52204057+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
SIC	J 3/67SI 1.C	1.00 0.00 0.G	300.000 5000.000	1			
1000.00	-.21924696+01	.41342700-01	-.78274113-04	.60694120-07	-.16729207-10	.85953143+05	.28756080+02
5000.00	.55799033+01	-.13409344-02	.75483047-06	-.16543778-09	.12663345-13	.85046120+05	-.56633593+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
SICL	J 9/67SI 1.CL	1.00 0.00 0.G	300.000 5000.000	1			
1000.00	.38247525+01	.24969130-02	-.36640266-05	.25169051-08	-.65148061-12	.21774076+05	.61967573+01
5000.00	.44179424+01	.13137080-03	-.30789013-07	.47802942-11	-.24135145-15	.21650362+05	.33226348+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
SICL2	J12/69SI 1.CL	2.0 0.0 0.G	300.000 5000.000	1			
1000.00	.42340627+01	.10291978-01	-.15513731-04	.10572099-07	-.26771636-11	-.21378628+05	.73084885+01
5000.00	.66562009+01	.39225514-03	-.16975920-06	.30024021-10	-.14765027-14	-.21865180+05	-.43502099+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
SICL3	J12/69SI 1.CL	3.0 0.0 0.G	300.000 5000.000	1			
1000.00	.51253419+01	.17938812-01	-.26825402-04	.18160893-07	-.45701854-11	-.50431048+05	.48235054+01
5000.00	.93913634+01	.67983523-03	-.29385989-06	.56056340-10	-.39374882-14	-.51298469+05	-.15758539+02
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
SICL4	J 9/67SI 1.CL	4.00 0.00 0.G	300.000 5000.000	1			
1000.00	.61040010+01	.24933114-01	-.36703263-04	.24448748-07	-.60370155-11	-.81705075+05	-.98955289+00
5000.00	.12089655+02	.10190735-02	-.44167865-06	.84481573-10	-.59491580-14	-.82936052+05	-.29940086+02
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
SIH	J12/69SI 1.H	1.0 0.0 0.G	300.000 5000.000	1			
1000.00	.41309782+01	-.35619084-02	.76432635-05	-.53797081-08	.12582731-11	.44159598+05	.10358455+01
5000.00	.30911184+01	.14689347-02	-.56349951-06	.10071335-09	-.63679401-14	.44302447+05	.57808348+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
SIN	J 3/67SI 1.N	1.00 0.00 0.G	300.000 5000.000	1			
1000.00	.31051955+01	.14852449-02	.18561060-05	-.37734883-08	.16835331-11	.43785709+05	.78753961+01
5000.00	.39858621+01	-.87927056-05	.54269539-06	-.17951017-09	.16337069-13	.43524809+05	.31615156+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
SI2	J 3/67SI 2.00	0.00 0.00 0.G	300.000 5000.000	1			
1000.00	.38155393+01	-.19096542-03	.59233416-05	-.57549603-08	.14775004-11	.69784655+05	.57275556+01
5000.00	.50474139+01	.53990034-03	-.43078376-06	.11355206-09	-.96262871-14	.69133185+05	-.19234578+01
.00	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

```
ELEMENT  HYDROGEN    CARBON    NITROGEN    OXYGEN    ALUMINUM    SILICON

ELEMENT  CHLORINE
BASE SP     H2          CO          N2          H2O         AL          SIO
HCL
```

MOLECULAR TRANSPORT PROPERTIES

VISCOSITY ..... BUDDENBERG - WILKE MIXTURE FORMULA WITH MU(I) CALCULATED ON THE BASIS OF D(I,I) = DBAR/G(I)**2

THERMAL CONDUCTIVITY ..... MASON - SAXENA MIXTURE FORMULA WITH EUCKEN CORRECTION

DIFFUSION COEFFICIENTS ..... D(I,J) = DBAR/(F(I)*F(J)) WITH DBAR BASED ON SIGMA = 3.4670, EPOVRK = 106.7000, AND MREF = 32.0000

METHODS EMPLOYED

0 CONDENSED PHASE, VALUES FOR F(I) AND G(I) SET EQUAL TO 1.E+10

1 VALUES FOR F(I) (OR G(I)) INPUT DIRECTLY

2 VALUES FOR F(I) (OR G(I)) CALCULATED BY F(I) =(M(I)/FITMOL)**FFA AND G(I) = (M(I)/FITGMW)**GGA WHERE M(I) IS SPECIES MOLECULAR WEIGHT, FITMOL = 26.7000, AND FFA = .4890, FITGMW = 24.3000, AND GGA = .4540

3 VALUES FOR G(I) CALCULATED BY G(I) = SQRT(DBAR/D(I,I)) = (SIGMA(I)/SIGMA) * (EPS(I)/EPOVRK) **0.0795 * (M(I)/MREF) **0.25 WHERE SIGMA(I) AND EPS(I) ARE GIVEN WITH THERMODYNAMIC DATA

SPECIES	F(I)	METHOD	G(I)	METHOD	SPECIES	F(I)	METHOD	G(I)	METHOD
H2	.283	2	.323	2	CO	1.024	2	1.066	2
AL	1.005	2	1.048	2	H2O	.825	2	.873	2
HCL	1.562	2	1.579	2	SIO	1.278	2	1.310	2
N2	1.024	2	1.067	2	ALCL	1.835	2	1.834	2
ALCL2	2.385	2	2.339	2	ALCL3	2.825	2	2.738	2
ALO	1.262	2	1.295	2	ALOCL	1.984	2	1.972	2
ALOH	1.276	2	1.309	2	ALO2H	1.486	2	1.507	2
C	.676	2	.726	2	CO2	1.277	2	1.309	2
CL	1.550	2	1.568	2	H	.201	2	.236	2
HCO	1.041	2	1.084	2	N	.729	2	.779	2
NO	1.059	2	1.101	2	O	.778	2	.827	2
OH	.802	2	.850	2	O2	1.093	2	1.133	2
SI	1.025	2	1.067	2	SIC	1.219	2	1.255	2
SICL	1.846	2	1.844	2	SICL2	2.393	2	2.346	2
SICL3	2.832	2	2.744	2	SICL4	3.210	2	3.082	2
SIH	1.042	2	1.085	2	SIN	1.249	2	1.283	2
SI2	1.438	2	1.462	2					

STAGNATION SOLUTION FOLLOWED BY BOUNDARY-LAYER EDGE EXPANSION

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    CP-FROZEN       CP-EQUIL       GAMMA
   (J/KG-DEG-K)   (J/KG-DEG-K)
    .19238+04      .35717+04      .11854+01
          TEMP = 3358.7743 DEG-K      PRES =  .4134+07  N/M2   MOL WT = 20.9817495
RELATIVE MASSES OF COMPONENTS 1,2 AND 3    .00000        .00000        .00000
     ENTHALPY =   .1796800+07 J/KG     ENTROPY =   .11239+05 J/KG-DEG-K
     DENSITY =    .310565+01KG/M3
VEL =  0.000     M/SEC    MACH =  0.000.
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SPECIES	MOLE FR.	SPECIES	MOLE FR.	SPECIES	MOLE FR.
H2	.32765+00	CO	.26630+00	AL	.15009-03
H2O	.15625+00	HCL	.81471-01	SIO	.00000
N2	.91498-01	ALCL	.30009-02	ALCL2	.15555-02
ALCL3	.26257-04	ALO	.80879-04	ALOCL	.11507-02
ALOH	.57631-03	ALO2H	.83226-03	C	.31974-08
CO2	.16294-01	CL	.63179-02	H	.37711-01
HCO	.14979-03	N	.51854-05	NO	.54480-03
O	.53155-03	OH	.77830-02	O2	.10117-03
SI	.00000	SIC	.00000	SICL	.00000
SICL2	.00000	SICL3	.00000	SICL4	.00000
SIH	.00000	SIN	.00000	SI2	.00000

STATION NO. 1

CP-FROZEN (J/KG-DEG-K)	CP-EQUIL (J/KG-DEG-K)	GAMMA
.19217+04	.35192+04	.11861+01

TEMP = 3327.2873 DEG-K   PRES = .3861+07 N/M2.   MOL. WT = 21.0085418

RELATIVE MASSES OF COMPONENTS 1,2 AND 3   .00000   .00000   .00000

ENTHALPY = .1706417+07 J/KG   ENTROPY = .11239+05 J/KG-DEG-K

DENSITY = .293187+01KG/M3

VEL = 4.253+02 M/SEC   MACH = 3.402-01

SPECIES	MOLE FR.	SPECIES	MOLE FR.	SPECIES	MOLE FR.
H2	.32855+00	CO	.26654+00	AL	.14027-03
H2O	.15693+00	HCL	.81770-01	SIO	.00000
N2	.91636-01	ALCL	.29892-02	ALCL2	.15995-02
ALCL3	.27413-04	ALO	.75424-04	ALOCL	.11613-02
ALOH	.56995-03	ALO2H	.82929-03	C	.26200-08
CO2	.16431-01	CL	.60699-02	H	.36139-01
HCO	.14044-03	N	.45583-05	NO	.50302-03
O	.47943-03	OH	.73245-02	O2	.91502-04
SI	.00000	SIC	.00000	SICL	.00000
SICL2	.00000	SICL3	.00000	SICL4	.00000
SIH	.00000	SIN	.00000	SI2	.00000

STATION NO. 2

CP-FROZEN (J/KG-DEG-K)	CP-EQUIL (J/KG-DEG-K)	GAMMA
.19208+04	.34984+04	.11863+01

TEMP = 3314.8021 DEG-K   PRES = .3758+07 N/M2.   MOL. WT = 21.0190399

RELATIVE MASSES OF COMPONENTS 1,2 AND 3   .00000   .00000   .00000

ENTHALPY = .1670770+07 J/KG   ENTROPY = .11239+05 J/KG-DEG-K

DENSITY = .285557+01KG/M3

VEL = 5.022+02 M/SEC   MACH = 4.026-01

SPECIES	MOLE FR.	SPECIES	MOLE FR.	SPECIES	MOLE FR.
H2	.32891+00	CO	.26663+00	AL	.13548-03
H2O	.15719+00	HCL	.81887-01	SIO	.00000
N2	.91690-01	ALCL	.29843-02	ALCL2	.16133-02
ALCL3	.27897-04	ALO	.73317-04	ALOCL	.11654-02
ALOH	.56734-03	ALO2H	.82796-03	C	.24187-08
CO2	.16485-01	CL	.59720-02	H	.35520-01
HCO	.13687-03	N	.43277-05	NO	.48705-03
O	.45980-03	OH	.71464-02	O2	.87847-04
SI	.00000	SIC	.00000	SICL	.00000
SICL2	.00000	SICL3	.00000	SICL4	.00000
SIH	.00000	SIN	.00000	SI2	.00000

STATION NO. 26

CP-FROZEN (J/KG-DEG-K)	CP-EQUIL (J/KG-DEG-K)	GAMMA
.17712+04	.19317+04	.12573+01

TEMP = 1880.0520 DEG-K   PRES = .1406+06 N/M2   MOL WT = 21.6243002

RELATIVE MASSES OF COMPONENTS 1,2 AND 3   .00000   .00000   .00000

ENTHALPY = -.1623419+07 J/KG   ENTROPY = .11239+05 J/KG-DEG-K

DENSITY = .194421+00KG/M3

VEL = 2.616+03 M/SEC   MACH = 2.744+00

SPECIES	MOLE FR.	SPECIES	MOLE FR.	SPECIES	MOLE FR.
H2	.36210+00	CO	.26274+00	AL	.46524-07
H2O	.16131+00	HCL	.82582-01	SIO	.00000
N2	.94583-01	ALCL	.45911-03	ALCL2	.50171-02
ALCL3	.14816-02	ALO	.16753-07	ALOCL	.48285-03
ALOH	.50025-04	ALO2H	.11823-03	C	.24855-15
CO2	.28662-01	CL	.60827-04	H	.34647-03
HCO	.19403-05	N	.37216-10	NO	.18062-06
O	.88067-08	OH	.12128-04	O2	.17313-08
SI	.00000	SIC	.00000	SICL	.00000
SICL2	.00000	SICL3	.00000	SICL4	.00000
SIH	.00000	SIN	.00000	SI2	.00000

STATION NO. 27

CP-FROZEN (J/KG-DEG-K)	CP-EQUIL (J/KG-DEG-K)	GAMMA
.17596+04	.19230+04	.12584+01

TEMP = 1807.5427 DEG-K PRES = .1158+06 N/M2 MOL WT = 21.6346047
RELATIVE MASSES OF COMPONENTS 1,2 AND 3 .00000 .00000 .00000
ENTHALPY = -.1760994+07 J/KG ENTROPY = .11239+05 J/KG-DEG-K
DENSITY = .165613+00KG/M3
VEL = 2.668+03 M/SEC MACH = 2.853+00

SPECIES	MOLE FR.	SPECIES	MOLE FR.	SPECIES	MOLE FR.
H2	.36408+00	CO	.26136+00	AL	.17561-07
H2O	.16008+00	HCL	.81800-01	SIO	.00000
N2	.94628-01	ALCL	.31947-03	ALCL2	.48407-02
ALCL3	.19676-02	ALO	.60508-08	ALOCL	.36945-03
ALOH	.33249-04	ALO2H	.82126-04	C	.56270-16
CO2	.30188-01	CL	.37464-04	H	.21420-03
HCO	.13758-05	N	.11983-10	NO	.91725-07
O	.28781-08	OH	.63046-05	O2	.56375-09
SI	.00000	SIC	.00000	SICL	.00000
SICL2	.00000	SICL3	.00000	SICL4	.00000
SIH	.00000	SIN	.00000	SI2	.00000

STATION NO. 28

CP-FROZEN (J/KG-DEG-K)	CP-EQUIL (J/KG-DEG-K)	GAMMA
.17575+04	.19220+04	.12585+01

TEMP = 1794.2504 DEG-K PRES = .1116+06 N/M2 MOL WT = 21.6365263
RELATIVE MASSES OF COMPONENTS 1,2 AND 3 .00000 .00000 .00000
ENTHALPY = -.1786160+07 J/KG ENTROPY = .11239+05 J/KG-DEG-K
DENSITY = .161868+00KG/M3
VEL = 2.677+03 M/SEC MACH = 2.874+00

SPECIES	MOLE FR.	SPECIES	MOLE FR.	SPECIES	MOLE FR.
H2	.36447+00	CO	.26108+00	AL	.14496-07
H2O	.15983+00	HCL	.81647-01	SIO	.00000
N2	.94637-01	ALCL	.29671-03	ALCL2	.47592-02
ALCL3	.20710-02	ALO	.49521-08	ALOCL	.34946-03
ALOH	.30610-04	ALO2H	.76250-04	C	.42306-16
CO2	.30490-01	CL	.34118-04	H	.19523-03
HCO	.12885-05	N	.96353-11	NO	.70140-07
O	.23195-08	OH	.55570-05	O2	.45396-09
SI	.00000	SIC	.00000	SICL	.00000
SICL2	.00000	SICL3	.00000	SICL4	.00000
SIH	.00000	SIN	.00000	SI2	.00000

AXIAL DISTANCE, METERS	-.49278+00	-.45705+00	-.40649+00	-.30470+00	-.20291+00	-.15235+00	-.10179+00	-.50559-01
	.00000	.50559-01	.10179+00	.15235+00	.25414+00	.35593+00	.45705+00	.60940+00
	.76175+00	.91410+00	.10671+01	.12195+01	.13718+01	.14580+01	.15242+01	.16765+01
	.19812+01	.24383+01	.28953+01	.31333+01				
WALL LENGTH, METERS	.45720-02	.56209-01	.11289+00	.22323+00	.32913+00	.38056+00	.43166+00	.48305+00
	.53363+00	.58419+00	.63553+00	.68654+00	.79035+00	.89621+00	.10062+01	.11728+01
	.13391+01	.15052+01	.16710+01	.18350+01	.19988+01	.20910+01	.21623+01	.23260+01
	.26518+01	.31336+01	.36073+01	.38503+01				
RADIUS, METERS	.82916+00	.79343+00	.76782+00	.72535+00	.69636+00	.68692+00	.67951+00	.67546+00
	.67412+00	.67479+00	.67816+00	.68490+00	.70513+00	.73411+00	.77726+00	.84467+00
	.91140+00	.97747+00	.10415+01	.11022+01	.11622+01	.11951+01	.12215+01	.12815+01
	.13968+01	.15491+01	.16732+01	.17224+01				
XI, (KG/SEC)**2	.32520-03	.40976-02	.84165-02	.17128-01	.25737-01	.29969-01	.34204-01	.38492-01
	.42719-01	.46940-01	.51222-01	.55475-01	.64093-01	.72792-01	.81726-01	.95088-01
	.10817+00	.12101+00	.13367+00	.14598+00	.15813+00	.16491+00	.17012+00	.18201+00
	.20537+00	.23924+00	.27208+00	.28910+00				
PRESSURE RATIO	.93400+00	.90900+00	.88500+00	.82800+00	.76200+00	.73000+00	.68100+00	.63700+00
	.59800+00	.55880+00	.52500+00	.48300+00	.40200+00	.33100+00	.26500+00	.19900+00
	.15400+00	.12500+00	.10300+00	.87000-01	.75000-01	.69120-01	.65000-01	.57000-01
	.45000-01	.34000-01	.28000-01	.27000-01				
STATIC PRESSURE, N/M2	.38612+07	.37579+07	.36587+07	.34230+07	.31502+07	.30179+07	.28153+07	.26334+07
	.24722+07	.23101+07	.21704+07	.19958+07	.16619+07	.13684+07	.10955+07	.82269+06
	.63665+06	.51676+06	.42581+06	.35967+06	.31006+06	.28575+06	.26872+06	.23564+06
	.18603+06	.14056+06	.11575+06	.11152+06				
EDGE VELOCITY, M/SEC	.42525+03	.50215+03	.56763+03	.70370+03	.84173+03	.90420+03	.99632+03	.10766+04
	.11467+04	.12167+04	.12772+04	.13528+04	.15029+04	.16427+04	.17845+04	.19450+04
	.20721+04	.21660+04	.22466+04	.23123+04	.23669+04	.23957+04	.24169+04	.24607+04
	.25350+04	.26159+04	.26680+04	.26775+04				
BETA	.32025-01	.28779+00	.45743+00	.76712+00	.93779+00	.12130+01	.13869+01	.12614+01
	.12350+01	.11850+01	.12793+01	.14411+01	.14270+01	.14157+01	.12767+01	.10610+01
	.89303+00	.76363+00	.69739+00	.62199+00	.60305+00	.55835+00	.54504+00	.50656+00
	.45130+00	.36571+00	.21954+00	.11786+00				
INCID RAD. FLUX, WATTS/M2	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000				
WALL TEMPERATURE, DEG K	.29770+04	.29720+04	.29680+04	.29550+04	.29390+04	.29300+04	.29190+04	.29140+04
	.28970+04	.28930+04	.28750+04	.28590+04	.28260+04	.27880+04	.27380+04	.26730+04
	.26170+04	.25620+04	.25140+04	.24720+04	.24310+04	.20150+04	.20150+04	.20120+04
	.20090+04	.20050+04	.20030+04	.20020+04				
COMP FLUX, KG/SM2	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000				
COMP FLUX, KG/SM2	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000				
COMP FLUX, KG/SM2	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	.00000	.00000	.00000	.00000				

STATION 1 - - - - - - - - - - AXIAL POSITION -,49278+00 METERS - - - - - -27 JAN 74 10:36:39

ITERATED VALUES — DAMP MAX.LIN — MAX.ERRORS IN CONSERVATION EQS.

ITS	TIME	ALPH	FPPW	DAMP	MAX.LIN ERROR	MOMENTUM	ENERGY	H2	CO	AL	H2O	HCL	SIO
1	21,507	3,600	,6456	,3233	7,+00	13 -1,3+00	8 3,7+02	1 6,3-09	1 2,2-08	1 2,1-09	1 8,9-08	1 7,8-08	2 0,0
0													
2	29,372	3,240	,5640	,4433	5,+00	13 -8,5-01	8 2,6+02	1 2,4-08	1 3,0-07	8 -1,9-09	11 2,4-07	11 8,0-08	2 0,0
0													
3	37,233	2,916	,4926	,7218	3,+00	13 -4,6-01	8 1,6+02	11 1,2-07	8 -5,3-07	11 8,3-09	11 -3,7-07	1 -7,6-08	2 0,0
0													
4	45,059	2,779	,4843	1,0000	7,-01	13 -1,3-01	8 5,1+01	3 6,0-08	5 -1,9-06	11 9,8-09	11 -1,1-06	7 1,8-07	2 0,0
0													
5	52,555	2,777	,4865	1,0000	9,-08	11 -4,0-03	8 5,5+00	3 -3,1-07	11 -4,2-06	3 1,2-07	11 3,4-06	3 4,0-06	2 0,0
0													
6	60,068	2,777	,4865	1,0000	3,-08	11 2,9-05	8 7,9-01	4 2,5-07	11 -4,2-06	11 -1,3-07	5 -2,0-06	11 -4,3-06	2 0,0
0													

ALPHA	RADIUS (METERS)	PRESSURE (N /M2)	EDGE VEL, M/SEC	BETA	HEAT FLUXES (WATTS/M2) DIFFUSIONAL	TOT ENTH	RERAD	QCOND
2,777+00	8,292-01	3,861+06	4,252+02	3,202-02	3,020+06	3,020+06	0,000	2,515+06

WALL SHEAR (N /M2)	MASS FLUXES (KG/SEC-M2) MECHANICAL REMOVAL	PYROL GAS	CHAR	TOTAL GAS	ELEMENTAL MASS DIFFUSIVE FLUXES (KG/SEC-M2) FOR HYDROGEN	CARBON	NITROGEN	OXYGEN	ALUMINUM	SILICON	CHLORINE
7,352+02	0,000	0,000	1,193-06	1,193-06	9,421-09	-6,384-07	2,489-07	1,582-07	4,877-09	0,000	2,171-07

MOM TRANS COEFF, CF/2	HEAT TRANS COEFF, ST NO.	BLOWING PARAMETERS (NORM, BY RHOE*UE*ST) FOR PYROL GAS	CHAR	TOTAL GAS	ELEMENTAL MASS TRANSFER COEFFICIENTS, CM, FOR HYDROGEN	CARBON	NITROGEN	OXYGEN	ALUMINUM	SILICON	CHLORINE
1,387-03	2,109-03	0,000	4,538-07	4,538-07	6,031-04	1,263-03	3,152-03	8,603-04	7,149-04	0,000	1,010-03

MOMENTUM THICKNESS, THETA (M)	DISPLACE. THICKNESS, DELSTAR (M)	EFFECTIVE BODY DISPLACE. (M)	ENTHALPY THICKNESS, LAMBDA (M)	REYNOLDS NUMBER PER METER	MASS THICKNESS (M) FOR HYDROGEN	CARBON	NITROGEN	OXYGEN	ALUMINUM	SILICON	CHLORINE
1,151-05	2,504-05	2,504-05	1,928-05	1,502+07	-6,192-03	6,000-04	2,045-02	-3,561-03	-2,549-03	0,000	-2,533-03

TOTAL HEAT TO WALL (WATTS)	THRUST LOSS (N)	TOTAL WALL AREA (M2)
4,062+05	-4,719+02	1,345-01

NODAL INFORMATION

ETA	DISTANCE FROM WALL (METERS)	F	U/UE	FPP	SHEAR (N /M2)	G, TOTAL ENTHALPY (J/KG)	GP (J/KG)	GPP (J/KG)	STATIC ENTHALPY (J/KG)	TEMP (DEG K)
0,000	0,000	-3,548-07	0,000	4,865-01	7,352+02	6,482+05	3,708+05	4,428+04	6,482+05	2,977+03
2,000-03	1,205-07	7,145-06	2,701-03	4,864-01	7,350+02	6,503+05	3,711+05	4,425+04	6,503+05	2,978+03
6,000-03	3,616-07	6,714-05	8,102-03	4,862-01	7,345+02	6,544+05	3,716+05	4,421+04	6,544+05	2,979+03
1,000-02	6,028-07	1,871-04	1,350-02	4,860-01	7,341+02	6,585+05	3,721+05	4,405+04	6,585+05	2,981+03
2,500-02	1,509-06	1,171-03	3,373-02	4,853-01	7,324+02	6,740+05	3,739+05	4,336+04	6,739+05	2,987+03
6,000-02	3,630-06	6,737-03	8,080-02	4,835-01	7,282+02	7,106+05	3,781+05	3,955+04	7,100+05	3,000+03
1,500-01	9,134-06	4,196-02	2,008-01	4,768-01	7,145+02	8,063+05	3,880+05	1,127+04	8,027+05	3,035+03
4,000-01	2,478-05	2,918-01	5,129-01	4,224-01	6,245+02	1,078+06	3,958+05	-7,375+04	1,055+06	3,124+03
7,000-01	4,418-05	8,476-01	7,999-01	2,666-01	3,887+02	1,382+06	3,344+05	-1,532+05	1,325+06	3,213+03
1,000+00	6,412-05	1,586+00	9,500-01	9,380-02	1,354+02	1,608+06	2,068+05	-1,246+05	1,526+06	3,275+03
1,500+00	9,807-05	2,961+00	1,005+00	-1,408-02	-2,016+01	1,775+06	3,383+04	-3,166+04	1,684+06	3,321+03
2,500+00	1,665-04	5,736+00	1,000+00	0,000	0,000	1,797+06	0,000	7,291+03	1,706+06	3,327+03

DISTANCE FROM WALL (METERS)	DENSITY RHO (KG/M3)	VISCOSITY MU (N -S/M2)	SPECIFIC HEAT (J/KG-K)	THERMAL COND. (WATTS/M -K)	PRANDTL NUMBER	MODIFIED SCHMIDT NUMBER	MOLECULAR WEIGHT	MACH NUMBER	RHOSQ*EPS /RHO*MU
0,000	3,334+00	7,711-05	1,895+03	3,841-01	3,805-01	7,109-01	2,137+01	0,000	0,000
1,205-07	3,333+00	7,712-05	1,895+03	3,842-01	3,805-01	7,109-01	2,137+01	9,700-04	0,000
3,616-07	3,331+00	7,715-05	1,895+03	3,843-01	3,804-01	7,109-01	2,137+01	2,909-03	0,000
6,028-07	3,329+00	7,717-05	1,895+03	3,845-01	3,804-01	7,109-01	2,137+01	4,846-03	0,000
1,509-06	3,322+00	7,727-05	1,896+03	3,852-01	3,804-01	7,110-01	2,137+01	1,210-02	0,000
3,630-06	3,305+00	7,751-05	1,897+03	3,867-01	3,802-01	7,110-01	2,136+01	2,892-02	0,000
9,134-06	3,264+00	7,809-05	1,900+03	3,905-01	3,799-01	7,110-01	2,133+01	7,148-02	0,000
2,478-05	3,159+00	7,960-05	1,907+03	4,007-01	3,788-01	7,110-01	2,125+01	1,801-01	0,000
4,418-05	3,058+00	8,108-05	1,913+03	4,110-01	3,775-01	7,111-01	2,116+01	2,771-01	0,000
6,412-05	2,989+00	8,211-05	1,918+03	4,184-01	3,764-01	7,112-01	2,108+01	3,259-01	0,000
9,807-05	2,939+00	8,287-05	1,921+03	4,241-01	3,755-01	7,112-01	2,102+01	3,424-01	0,000
1,665-04	2,932+00	8,298-05	1,922+03	4,249-01	3,753-01	7,112-01	2,101+01	3,402-01	0,000

DISTANCE FROM WALL, METERS

0.000	1.205-07	3.616-07	6.028-07	1.509-06	3.630-06	9.134-06	2.478-05	4.418-05	6.412-05	9.807-05	1.665-04

ELEMENTAL FRACTIONS AND THEIR FIRST AND SECOND DERIVATIVES WITH RESPECT TO ETA

H2	3.032-02	3.032-02	3.032-02	3.032-02	3.032-02	3.032-02	3.032-02	3.032-02	3.032-02	3.032-02	3.032-02	3.032-02
	-3.169-08	-3.163-08	-3.164-08	-3.154-08	-3.173-08	-3.171-08	-3.178-08	-3.008-08	-2.230-08	-1.070-08	1.207-10	0.000
	9.218-09	-8.877-10	9.705-09	-4.553-09	1.397-10	-2.692-10	2.455-09	9.332-09	1.392-08	7.797-09	9.641-11	-1.833-10
CO	3.773-01	3.773-01	3.773-01	3.773-01	3.773-01	3.773-01	3.773-01	3.773-01	3.773-01	3.773-01	3.773-01	3.773-01
	-3.968-07	-3.963-07	-3.964-07	-3.951-07	-3.973-07	-3.963-07	-3.984-07	-3.754-07	-2.809-07	-1.367-07	5.682-09	0.000
	8.328-08	-5.716-10	1.120-07	-5.286-08	1.076-08	-8.309-09	3.300-08	1.135-07	1.731-07	1.026-07	4.434-10	-4.536-09
AL	9.490-03	9.490-03	9.490-03	9.490-03	9.490-03	9.490-03	9.490-03	9.490-03	9.490-03	9.490-03	9.490-03	9.490-03
	2.161-09	2.152-09	2.202-09	1.911-09	2.211-09	1.868-09	2.099-09	1.911-09	1.823-09	8.630-10	1.076-10	0.000
	-1.540-09	4.499-09	-2.621-08	7.210-09	-3.532-09	9.242-10	-2.709-10	-1.056-10	-1.153-09	-5.442-10	-2.240-10	1.466-10
H2O	1.589-01	1.589-01	1.589-01	1.589-01	1.589-01	1.589-01	1.589-01	1.589-01	1.589-01	1.589-01	1.589-01	1.589-01
	3.126-07	3.129-07	3.133-07	3.136-07	3.132-07	3.143-07	3.149-07	2.985-07	2.226-07	1.144-07	2.320-09	0.000
	5.603-08	3.190-08	3.359-08	-1.152-08	1.172-08	2.406-09	-2.360-08	-9.114-08	-1.298-07	-8.077-08	-3.426-09	1.754-09
HCL	3.014-01	3.014-01	3.014-01	3.014-01	3.014-01	3.014-01	3.014-01	3.014-01	3.014-01	3.014-01	3.014-01	3.014-01
	6.693-08	6.559-08	6.544-08	6.426-08	6.697-08	6.418-08	6.596-08	6.156-08	5.164-08	2.805-08	2.146-09	0.000
	-2.419-07	-1.294-08	-1.070-07	6.523-08	-2.881-08	7.131-09	-6.333-09	-1.192-08	-2.832-08	-1.866-08	4.541-09	-6.087-09
SIO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N2	1.225-01	1.225-01	1.225-01	1.225-01	1.225-01	1.225-01	1.225-01	1.225-01	1.225-01	1.225-01	1.225-01	1.225-01
	4.681-08	4.734-08	4.709-08	4.685-08	4.670-08	4.765-08	4.717-08	4.352-08	2.711-08	4.066-09	-1.038-08	0.000
	9.487-08	-2.200-08	-2.209-08	-3.498-09	9.715-09	-1.883-09	-5.260-09	-1.970-08	-2.766-08	-1.040-08	-1.431-09	8.905-09

MOLE FRACTIONS

H2	3.421-01	3.421-01	3.420-01	3.420-01	3.418-01	3.414-01	3.403-01	3.373-01	3.338-01	3.311-01	3.289-01	3.286-01
CO	2.698-01	2.697-01	2.697-01	2.697-01	2.697-01	2.696-01	2.695-01	2.688-01	2.680-01	2.673-01	2.666-01	2.665-01
AL	3.371-05	3.383-05	3.409-05	3.434-05	3.530-05	3.761-05	4.397-05	6.456-05	9.204-05	1.162-04	1.371-04	1.403-04
H2O	1.651-01	1.650-01	1.650-01	1.650-01	1.649-01	1.647-01	1.642-01	1.626-01	1.605-01	1.587-01	1.572-01	1.569-01
HCL	8.526-02	8.525-02	8.525-02	8.524-02	8.521-02	8.515-02	8.496-02	8.430-02	8.337-02	8.257-02	8.187-02	8.177-02
SIO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N2	9.343-02	9.342-02	9.342-02	9.341-02	9.339-02	9.335-02	9.322-02	9.284-02	9.238-02	9.200-02	9.168-02	9.164-02
ALCL	2.436-03	2.438-03	2.441-03	2.444-03	2.457-03	2.486-03	2.555-03	2.718-03	2.854-03	2.932-03	2.983-03	2.989-03
ALCL2	2.731-03	2.728-03	2.722-03	2.716-03	2.693-03	2.642-03	2.513-03	2.201-03	1.920-03	1.740-03	1.616-03	1.599-03
ALCL3	9.408-05	9.382-05	9.329-05	9.276-05	9.082-05	8.649-05	7.648-05	5.574-05	4.081-05	3.288-05	2.804-05	2.741-05
ALO	1.745-05	1.751-05	1.765-05	1.778-05	1.830-05	1.954-05	2.296-05	3.412-05	4.911-05	6.229-05	7.369-05	7.543-05
ALOCL	1.108-03	1.109-03	1.109-03	1.110-03	1.113-03	1.118-03	1.131-03	1.156-03	1.166-03	1.166-03	1.162-03	1.161-03
ALOH	4.253-04	4.257-04	4.265-04	4.272-04	4.301-04	4.367-04	4.532-04	4.935-04	5.297-04	5.525-04	5.679-04	5.700-04
ALO2H	6.746-04	6.751-04	6.761-04	6.771-04	6.807-04	6.889-04	7.089-04	7.556-04	7.938-04	8.150-04	8.277-04	8.293-04
C	2.181-10	2.195-10	2.222-10	2.250-10	2.357-10	2.622-10	3.417-10	6.612-10	1.231-09	1.865-09	2.513-09	2.620-09
CO2	1.818-02	1.817-02	1.816-02	1.816-02	1.813-02	1.806-02	1.789-02	1.745-02	1.701-02	1.670-02	1.647-02	1.643-02
CL	2.380-03	2.385-03	2.397-03	2.408-03	2.452-03	2.554-03	2.827-03	3.635-03	4.593-03	5.358-03	5.978-03	6.070-03

H	1,386-02	1,389-02	1,396-02	1,403-02	1,428-02	1,489-02	1,650-02	2,130-02	2,707-02	3,174-02	3,557-02	3,614-02
HCO	9,642-05	9,652-05	9,670-05	9,689-05	9,760-05	9,924-05	1,034-04	1,145-04	1,258-04	1,337-04	1,396-04	1,404-04
N	5,904-07	5,934-07	5,996-07	6,057-07	6,293-07	6,872-07	8,551-07	1,473-06	2,457-06	3,452-06	4,406-06	4,559-06
NO	1,192-04	1,197-04	1,205-04	1,214-04	1,248-04	1,328-04	1,551-04	2,280-04	3,268-04	4,146-04	4,913-04	5,030-04
O	5,527-05	5,558-05	5,618-05	5,680-05	5,915-05	6,493-05	8,187-05	1,457-04	2,501-04	3,579-04	4,626-04	4,794-04
OH	2,210-03	2,217-03	2,231-03	2,244-03	2,296-03	2,419-03	2,754-03	3,798-03	5,124-03	6,242-03	7,183-03	7,325-03
O2	1,081-05	1,087-05	1,099-05	1,111-05	1,156-05	1,269-05	1,597-05	2,828-05	4,825-05	6,869-05	8,835-05	9,151-05
SI	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
SIC	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
SICL	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
SICL2	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
SICL3	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
SICL4	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
SIH	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
SIN	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
SI2	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

REFIT CALLED

I	ETA(I)	U/UE	G(1,I)	SP(1,I,1)	SP(1,I,2)	SP(1,I,3)	SP(1,I,4)	SP(1,I,5)	SP(1,I,6)	SP(1,I,7)	SP(1,I,8)
1	0,000	0,000	6,482+05	3,032-02	3,773-01	9,490-03	1,589-01	3,014-01	0,000		
2	3,708-02	4,999-02	6,866+05	3,032-02	3,773-01	9,490-03	1,589-01	3,014-01	0,000		
3	8,926-02	1,200-01	7,414+05	3,032-02	3,773-01	9,490-03	1,589-01	3,014-01	0,000		
4	1,875-01	2,500-01	8,468+05	3,032-02	3,773-01	9,490-03	1,589-01	3,014-01	0,000		
5	2,658-01	3,499-01	9,315+05	3,032-02	3,773-01	9,490-03	1,589-01	3,014-01	0,000		
6	3,471-01	4,503-01	1,021+06	3,032-02	3,773-01	9,490-03	1,589-01	3,014-01	0,000		
7	4,780-01	5,996-01	1,162+06	3,032-02	3,773-01	9,490-03	1,589-01	3,014-01	0,000		
8	6,365-01	7,506-01	1,323+06	3,032-02	3,773-01	9,490-03	1,589-01	3,014-01	0,000		
9	7,735-01	8,493-01	1,447+06	3,032-02	3,773-01	9,490-03	1,589-01	3,014-01	0,000		
10	1,000+00	9,500-01	1,608+06	3,032-02	3,773-01	9,490-03	1,589-01	3,014-01	0,000		
11	1,137+00	9,763-01	1,674+06	3,032-02	3,773-01	9,490-03	1,589-01	3,014-01	0,000		
12	2,500+00	1,000+00	1,797+06	3,032-02	3,773-01	9,490-03	1,589-01	3,014-01	0,000		

STATION 26 - - - - - - - - - - AXIAL POSITION ,24383+01 METERS - - - - - -23 FEB 74 11:00:03

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ITERATED VALUES               DAMP  MAX.LIN   MAX.ERRORS IN CONSERVATION EQS.
ITS.  TIME   ALPH   FPPW             ERROR  MOMENTUM      ENERGY       H2             CO            AL            H2O           HCL           SIO
1    11.00021,137 6,9386 ,4999   6,-05 13  3,6+01 10   6,5+03 11 -5,0-01 11 -6,7-01 10  1,6-03 11  6,4-01 11 -5,1-01  9 -3,2-02
0
2.   21,00021,796 6,87071,0000   3,-05 13  1,7+01 10   3,1+03 11 -2,8-01 11 -3,6-01 11 -8,9-04 11  3,5-01 11 -2,8-01  9 -1,8-02
0
3    32,00021,812 6,81821,0000   3,-05  7 -6,6-01 10  -1,2+02 10 -1,6-02 10 -1,9-02  1 -2,8-04 10  2,1-02 10 -1,9-02  1  1,4-02
0
4    42,00021,808 6,75691,0000   3,-05  6  2,0+00  4   1,5+02 10  1,7-04 10  2,4-03 10 -5,5-05 10 -2,0-03  4  1,1-03  4 -1,9-03
0
5    49,00021,807 6,75291,0000   3,-05  6  1,4-01  3   1,1+01 10  1,3-04 10 -7,3-04 10 -5,4-05 10 -5,2-04 10 -4,5-04  3 -1,2-04
0
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ALPHA	RADIUS (METERS)	PRESSURE (N /M2)	EDGE VEL, M/SEC	BETA	HEAT FLUXES (WATTS/M2) DIFFUSIONAL	TOT ENTH	RERAD	QCOND
2,181+01	1,549+00	1,406+05	2,616+03	3,657-01	1,907+06	1,951+06	0,000	1,815+06

WALL SHEAR (N /M2)	MASS FLUXES (KG/SEC-M2) MECHANICAL REMOVAL	PYROL GAS	CHAR	TOTAL GAS	ELEMENTAL MASS DIFFUSIVE FLUXES (KG/SEC-M2) FOR HYDROGEN	CARBON	NITROGEN	OXYGEN	ALUMINUM	SILICON	CHLORINE
1,277+03	0,000	0,000	2,530-02	2,530-02	4,066-04	-1,296-03	3,660-03	-2,464-03	2,300-04	-7,435-03	6,898-03

MOM TRANS COEFF, CF/2	HEAT TRANS COEFF, ST NO.	BLOWING PARAMETERS (NORM. BY RHOE*UE*ST) FOR PYROL GAS	CHAR	TOTAL GAS	ELEMENTAL MASS TRANSFER COEFFICIENTS, CM, FOR HYDROGEN	CARBON	NITROGEN	OXYGEN	ALUMINUM	SILICON	CHLORINE
9,597-04	1,058-03	0,000	4,703-02	4,703-02	6,466-05	-5,685-04	-3,220-04	6,283-04	1,186-03	1,442-03	5,736-04

MOMENTUM THICKNESS, THETA (M)	DISPLACE. THICKNESS, DELSTAR (M)	EFFECTIVE BODY DISPLACE. (M)	ENTHALPY THICKNESS, LAMBDA (M)	REYNOLDS NUMBER PER METER	MASS THICKNESS (M) FOR HYDROGEN	CARBON	NITROGEN	OXYGEN	ALUMINUM	SILICON	CHLORINE
2,574-03	3,965-03	4,023-03	3,314-03	8,927+06	3,401-02	5,906-02	4,374-02	2,167-02	5,994-03	7,380-04	2,133-02

TOTAL HEAT TO WALL (WATTS)	THRUST LOSS (N)	TOTAL WALL AREA (M2)
6,502+06	2,658+04	2,430+00

NODAL INFORMATION

ETA	DISTANCE FROM WALL (METERS)	F	U/UE	FPP	SHEAR (N /M2)	G, TOTAL ENTHALPY (J/KG)	GP (J/KG)	GPP (J/KG)	STATIC ENTHALPY (J/KG)	TEMP (DEG K)
0,000	0,000	-6,587-02	0,000	6,753+00	1,277+03	-1,748+06	1,158+07	1,902+08	-1,748+06	2,005+03
4,796-04	8,789-06	-6,550-02	7,082-02	6,790+00	1,281+03	-1,516+06	1,357+07	3,836+07	-1,633+06	2,070+03
1,168-03	2,185-05	-6,372-02	1,646-01	5,700+00	1,286+03	-1,408+06	1,414+07	-1,785+08	-1,501+06	2,144+03
2,720-03	5,252-05	-5,550-02	3,027-01	2,464+00	1,293+03	-1,032+06	8,103+06	-8,741+07	-1,345+06	2,228+03
4,837-03	9,558-05	-3,937-02	3,855-01	1,123+00	1,295+03	-7,507+05	4,068+06	-2,258+07	-1,259+06	2,274+03
9,585-03	1,939-04	5,373-03	4,672-01	4,545-01	1,294+03	-4,506+05	1,729+06	-2,633+06	-1,197+06	2,306+03
3,177-02	6,585-04	2,713-01	6,047-01	1,139-01	1,272+03	7,785+04	4,556+05	-1,671+05	-1,173+06	2,321+03
1,265-01	2,627-03	1,701+00	7,489-01	2,571-02	1,165+03	6,623+05	1,103+05	-1,100+04	-1,256+06	2,286+03
3,781-01	7,735-03	6,122+00	8,491-01	1,081-02	9,125+02	1,102+06	4,993+04	-2,313+03	-1,364+06	2,249+03
1,000+00	1,994-02	1,843+01	9,500-01	4,070-03	3,725+02	1,566+06	1,856+04	-3,923+02	-1,520+06	2,220+03
1,348+00	2,661-02	2,575+01	9,784-01	3,414-03	1,595+02	1,696+06	1,558+04	-1,520+03	-1,577+06	2,149+03
2,500+00	4,860-02	5,078+01	1,000+00	0,000	0,000	1,797+06	0,000	2,794+02	-1,623+06	1,880+03

DISTANCE FROM WALL (METERS)	DENSITY RHO (KG/M3)	VISCOSITY MU (N -S/M2)	SPECIFIC HEAT (J/KG-K)	THERMAL COND. (WATTS/M -K)	PRANDTL NUMBER	MODIFIED SCHMIDT NUMBER	MOLECULAR WEIGHT	MACH NUMBER	RHOSQ*EPS /RHO*MU
0,000	2,065-01	5,972-05	1,615+03	2,271-01	4,247-01	7,125-01	2,450+01	0,000	0,000
8,789-06	1,999-01	6,098-05	1,623+03	2,327-01	4,254-01	7,125-01	2,448+01	1,983-01	1,031-02
2,185-05	1,929-01	6,240-05	1,632+03	2,391-01	4,261-01	7,125-01	2,446+01	4,534-01	2,424-01
5,252-05	1,853-01	6,401-05	1,643+03	2,464-01	4,267-01	7,125-01	2,443+01	8,197-01	2,019+00
9,558-05	1,815-01	6,487-05	1,648+03	2,504-01	4,269-01	7,125-01	2,441+01	1,035+00	5,729+00
1,939-04	1,788-01	6,548-05	1,652+03	2,533-01	4,270-01	7,125-01	2,440+01	1,247+00	1,572+01
6,585-04	1,776-01	6,576-05	1,654+03	2,546-01	4,272-01	7,124-01	2,439+01	1,609+00	6,475+01
2,627-03	1,808-01	6,510-05	1,649+03	2,507-01	4,281-01	7,125-01	2,446+01	2,008+00	2,658+02
7,735-03	1,856-01	6,443-05	1,634+03	2,437-01	4,320-01	7,126-01	2,470+01	2,304+00	4,964+02
1,994-02	1,932-01	6,392-05	1,599+03	2,304-01	4,437-01	7,128-01	2,537+01	2,630+00	5,381+02
2,661-02	1,951-01	6,254-05	1,621+03	2,342-01	4,329-01	7,126-01	2,480+01	2,714+00	2,742+02
4,860-02	1,944-01	5,697-05	1,771+03	2,649-01	3,810-01	7,110-01	2,162+01	2,743+00	0,000

```
                                   DISTANCE FROM WALL,METERS
          0,000     8,789-06  2,185-05  5,252-05  9,558-05  1,939-04  6,585-04  2,627-03  7,735-03  1,994-02
              2.651-02  4.860-02

ELEMENTAL FRACTIONS AND THEIR FIRST AND SECOND DERIVATIVES WITH RESPECT TO ETA

   H2     1,743-02  1,742-02  1,740-02  1,737-02  1,735-02  1,732-02  1,725-02  1,703-02  1,611-02  1,353-02
              1,578-02  3,032-02
         -1,393-03 -1,406-03 -1,238-03 -6,278-04 -3,309-04 -1,736-04 -1,027-04 -1,115-04 -2,251-04 -1,549-04
              7,432-04  0.000
         -1,230-03  1,121-02  1,802-02  6,431-03  1,519-03  1,467-04 -4,286-06 -2,071-05  5,182-06  1,190-04
              1,909-05 -7,865-05
   CO     3,684-01  3,681-01  3,677-01  3,670-01  3,666-01  3,661-01  3,654-01  3,645-01  3,628-01  3,583-01
              3.602-01  3.773-01
         -2,987-02 -3,007-02 -2,615-02 -1,256-02 -5,993-03 -2,486-03 -6,614-04 -2,423-04 -3,556-04 -3,090-04
              7,970-04  0.000
         -1,886-02  2,610-01  4,015-01  1,422-01  3,387-02  3,772-03  2,028-04 -2,065-05  3,440-06  1,457-04
              3.606-05 -9,951-05
   AL     9,109-03  9,132-03  9,164-03  9,214-03  9,247-03  9,279-03  9,334-03  9,385-03  9,408-03  9,418-03
              9,432-03  9.490-03
          2,272-03  2,287-03  1,987-03  9,510-04  4,505-04  1,831-04  4,264-05  7,036-06  1,190-06  2,511-07
              3,543-06  0,000
          1,402-03 -1,996-02 -3,062-02 -1,084-02 -2,583-03 -2,903-04 -1,723-05 -1,065-06 -6,921-08  4,338-07
             -1,228-08 -2,698-07
   H2O    1,668-01  1,672-01  1,678-01  1,686-01  1,692-01  1,697-01  1,707-01  1,718-01  1,735-01  1,777-01
              1,758-01  1.589-01
          3,897-02  3,923-02  3,411-02  1,637-02  7,797-03  3,219-03  8,304-04  2,657-04  3,432-04  2,793-04
             -8.005-04  0,000
          2,452-02 -3,410-01 -5,242-01 -1,857-01 -4,422-02 -4,936-03 -2,734-04  1,413-05 -4,710-06 -1,423-04
             -3.283-05  9,656-05
   HCL    2,774-01  2,781-01  2,791-01  2,806-01  2,816-01  2,826-01  2,842-01  2,856-01  2,855-01  2,834-01
              2,860-01  3,014-01
          6,920-02  6,954-02  6,050-02  2,892-02  1,367-02  5,518-03  1,227-03  1,153-04 -1,684-04 -1,282-04
              8.132-04  0,000
          4,230-02 -6,088-01 -9,332-01 -3,304-01 -7,872-02 -8,868-03 -5,383-04 -5,171-05  2,964-06  1,240-04
              1,632-05 -8,126-05
   SIO    1,592-02  1,471-02  1,309-02  1,056-02  8,918-03  7,252-03  4,475-03  1,840-03  5,911-04  1,216-05
              1,225-06  0,000
         -1,153-01 -1,161-01 -1.009-01 -4,828-02 -2,288-02 -9,304-03 -2,178-03 -3,726-04 -8,280-05 -2,587-06

             -2,943-07  0,000
         -7,120-02  1,013+00  1,554+00  5,503-01  1,311-01  1,473-02  8,738-04  5,282-05  5,914-06  3,021-07
              3,519-08 -1,177-08
   N2     1,449-01  1,453-01  1,458-01  1,466-01  1,471-01  1,477-01  1,486-01  1,498-01  1,521-01  1,576-01
              1.528-01  1,226-01
          3,616-02  3,640-02  3,167-02  1,523-02  7,286-03  3,044-03  8,414-04  3,384-04  4,876-04  3,150-04
             -1,551-03  0,000
          2,307-02 -3,154-01 -4,857-01 -1,721-01 -4,097-02 -4,553-03 -2,435-04  2,719-05 -1,272-05 -2,472-04
             -3,836-05  1,631-04
```

MOLE FRACTIONS

H2	2.633-01	2.614-01	2.594-01	2.570-01	2.557-01	2.547-01	2.538-01	2.530-01	2.464-01	2.259-01	2.454-01	3.621-01
CO	2.797-01	2.805-01	2.812-01	2.816-01	2.816-01	2.814-01	2.808-01	2.798-01	2.792-01	2.780-01	2.756-01	2.627-01
AL	1.871-07	4.019-07	8.806-07	1.963-06	2.909-06	3.794-06	4.253-06	3.150-06	2.222-06	1.525-06	8.519-07	4.669-08
H2O	1.824-01	1.836-01	1.849-01	1.864-01	1.873-01	1.880-01	1.891-01	1.906-01	1.931-01	1.996-01	1.954-01	1.613-01
HCL	8.715-02	8.818-02	8.926-02	9.041-02	9.098-02	9.142-02	9.201-02	9.249-02	9.308-02	9.461-02	9.275-02	8.258-02
SIO	8.854-03	8.175-03	7.264-03	5.855-03	4.941-03	4.015-03	2.477-03	1.022-03	3.314-04	7.001-06	6.875-07	0.000
N2	1.268-01	1.270-01	1.273-01	1.279-01	1.282-01	1.286-01	1.294-01	1.308-01	1.341-01	1.427-01	1.333-01	9.462-02
ALCL	7.453-04	9.590-04	1.216-03	1.515-03	1.671-03	1.780-03	1.829-03	1.709-03	1.563-03	1.395-03	1.205-03	4.598-04
ALCL2	5.122-03	4.867-03	4.468-03	3.944-03	3.655-03	3.455-03	3.381-03	3.644-03	3.926-03	4.201-03	4.603-03	5.017-03
ALCL3	9.639-04	6.812-04	4.564-04	2.884-04	2.257-04	1.901-04	1.774-04	2.196-04	2.777-04	3.551-04	4.895-04	1.480-03
ALO	1.099-07	2.450-07	5.584-07	1.300-06	1.970-06	2.513-06	2.970-06	2.201-06	1.598-06	1.227-06	6.019-07	1.681-08
ALOCL	1.033-03	1.249-03	1.484-03	1.727-03	1.843-03	1.922-03	1.969-03	1.918-03	1.886-03	1.953-03	1.625-03	4.833-04
ALOH	9.383-05	1.246-04	1.635-04	2.115-04	2.380-04	2.570-04	2.660-04	2.450-04	2.217-04	1.984-04	1.652-04	5.010-05
ALO2H	3.160-04	4.088-04	5.223-04	6.573-04	7.304-04	7.831-04	8.126-04	7.690-04	7.366-04	7.544-04	5.849-04	1.184-04
C	1.732-15	5.109-15	1.618-14	5.512-14	1.025-13	1.568-13	1.885-13	1.165-13	6.798-14	3.947-14	1.550-14	2.497-16
CO2	4.266-02	4.133-02	3.997-02	3.862-02	3.797-02	3.757-02	3.754-02	3.854-02	4.084-02	4.669-02	4.342-02	2.865-02
CL	1.826-04	2.814-04	4.466-04	7.309-04	9.383-04	1.116-03	1.213-03	1.021-03	8.604-04	7.781-04	4.917-04	6.093-05
H	7.293-04	1.113-03	1.747-03	2.824-03	3.603-03	4.260-03	4.593-03	3.820-03	3.104-03	2.523-03	1.759-03	3.471-04
HCO	2.574-06	3.077-06	3.718-06	4.542-06	5.023-06	5.379-06	5.532-06	5.098-06	4.628-06	4.119-06	3.601-06	1.942-06
N	2.917-10	7.189-10	1.882-09	5.253-09	8.841-09	1.267-08	1.494-08	1.022-08	6.863-09	5.011-09	2.079-09	3.736-11
NO	1.271-06	2.453-06	4.947-06	1.047-05	1.532-05	1.996-05	2.269-05	1.752-05	1.377-05	1.253-05	5.959-06	1.811-07
O	1.033-07	2.712-07	7.602-07	2.283-06	3.990-06	5.870-06	7.035-06	4.731-06	3.190-06	2.497-06	9.098-07	8.839-09
OH	5.085-05	8.836-05	1.593-04	2.987-04	4.110-04	5.127-04	5.697-04	4.559-04	3.657-04	3.209-04	1.801-04	1.215-05
O2	3.110-08	8.230-08	2.325-07	7.049-07	1.239-06	1.832-06	2.214-06	1.509-06	1.062-06	9.399-07	3.093-07	1.737-09
SI	3.846-10	6.207-10	1.001-09	1.520-09	1.767-09	1.789-09	1.212-09	3.871-10	9.300-11	1.398-12	8.924-14	0.000
SIC	5.031-19	1.033-18	2.152-18	4.282-18	5.701-18	6.323-18	4.428-18	1.252-18	2.574-19	3.102-21	1.724-22	0.000
SICL	3.572-09	4.271-09	4.998-09	5.397-09	5.276-09	4.744-09	3.061-09	1.127-09	3.187-10	5.743-12	4.638-13	0.000
SICL2	7.007-07	5.236-07	3.711-07	2.350-07	1.753-07	1.309-07	7.807-08	3.559-08	1.280-08	2.949-10	3.537-11	0.000
SICL3	8.060-08	4.770-08	2.639-08	1.285-08	8.392-09	5.725-09	3.293-09	1.679-09	6.883-10	1.850-11	2.631-12	0.000
SICL4	1.415-09	6.409-10	2.666-10	9.592-11	5.379-11	3.306-11	1.823-11	1.055-11	5.009-12	1.592-13	2.773-14	0.000
SIH	1.638-10	2.273-10	3.118-10	3.984-10	4.241-10	4.040-10	2.660-10	9.036-11	2.293-11	3.493-13	2.679-14	0.000
SIN	4.333-11	6.025-11	8.290-11	1.065-10	1.138-10	1.087-10	7.192-11	2.461-11	6.408-12	1.052-13	7.534-15	0.000
SI2	5.087-17	7.375-17	1.026-16	1.216-16	1.172-16	9.519-17	3.931-17	5.151-18	3.883-19	1.099-22	7.798-25	0.000

APPENDIX A

WALL BOUNDARY CONDITIONS

Wall boundary conditions for the BLIMP program have been generalized to include surface thermochemistry considerations. These wall boundary conditions are flagged by various combinations of the KR(9) and KR(11) flags. The purpose of this appendix is to explain the types of options that are available.

For typical engineering problems, there are several sets of boundary conditions which are used most often. These are typically combinations of the following conditions.

- Chemical equilibrium between the gaseous boundary layer and the surface material
- Assigned surface temperature
- Assigned surface mass flux
- Energy balance between the surface material and the gaseous boundary layer assuming steady state ablation.

Of course, these four conditions cannot be used in all possible combinations and do not constitute a complete list. Five combinations which can be used in the BLIMP program and the control card punches necessary to flag them are summarized below. The reader should also note that a procedure for varying KR(9) as a function of body station (denoted KR9( ) in this manual) is described under card 1, field 2 of group 3. This procedure allows the user to change the type of boundary conditions at various points along the body.

a. Assigned temperature and mass flux

   Use KR(9) = 2, KR(11) = 0. This combination is often used when experimental data or data from separate analyses are available to describe T and MDOT as functions of streamwise location. No surface material-boundary layer gas interaction chemistry is considered in the resulting solutions.

b. Assigned temperature and surface equilibrium

   Use KR(9) = 2, KR(11) = 0. This option is obtained when the program compares the assigned temperature to the ablation temperature (group 11, card 1) for the surface material in question. If the assigned temperature is larger, a surface equilibrium analysis is performed. The assigned MDOT should be zero. With the surface equilibrium chemistry package called in, the program automatically chooses the correct surface material and calculates the correct mass loss rate at the assigned temperature.

c. Assigned mass flux and surface equilibrium

Use KR(9) = 2, KR(11) = 2. This option also uses the surface equilibrium chemistry package mentioned in (b) above. The program will automatically choose the correct surface material and temperature to coincide with the assigned mass flux.

d. Steady state energy balance and surface equilibrium

Use KR(9) = 4, KR(11) = 0. Whenever KR(9) is greater than or equal to 3, a special surface chemistry package based on vapor pressures is called. The special chemistry package does not allow fail temperatures and the surface material must be specified in advance. Within these limitations, the program will calculate the correct mass loss rate of specified surface material necessary to satisfy the steady state energy balance equation.

In the steady state energy balance, the pyrolysis front and the exposed material surface are assumed to be receding at identical rates. This special situation eliminates the need for an in-depth conduction analysis and allows ablation calculations to be performed as a subroutine to the boundary layer analysis. The steady state assumption is good for large ablation rates or small thermal diffusivity of the ablation material. For charring materials it is also necessary that the ratio of pyrolysis gas to char mass removal rate approach the steady state ratio, which can be found from the virgin material composition.

e. Assigned flux of transpirant with steady state energy balance

Use KR(9) = 2, KR(11) = 0, and assign KR9( ) = 4, as required. This option allows an assigned flux of transpiring gas into the boundary layer through an ablating surface while maintaining surface equilibrium. The local surface condition is determined by the steady state energy balance. The flux of transpirant gas is input on card set 11 of group 16 as a pyrolysis gas. The fields for boundary layer edge gas and char fluxes must also be input in accordance with KR(9) = 2 but blank cards may be used. Card set 3 of group 16 for assigned wall temperature is also required in accordance with KR(11) = 0 but blank fields may be used. The boundary layer calculations use the KR9( ) = 4 value, the KR(9) = 2 option affecting only the reading of the transpiration flux. The heat of formation of the transpirant gas must be input in field 3 of card 1 of group 6.

The above combinations of boundary conditions are used in nearly all ablating and nonablating boundary layer flow analyses; however, other combinations are possible.

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