REMTECH

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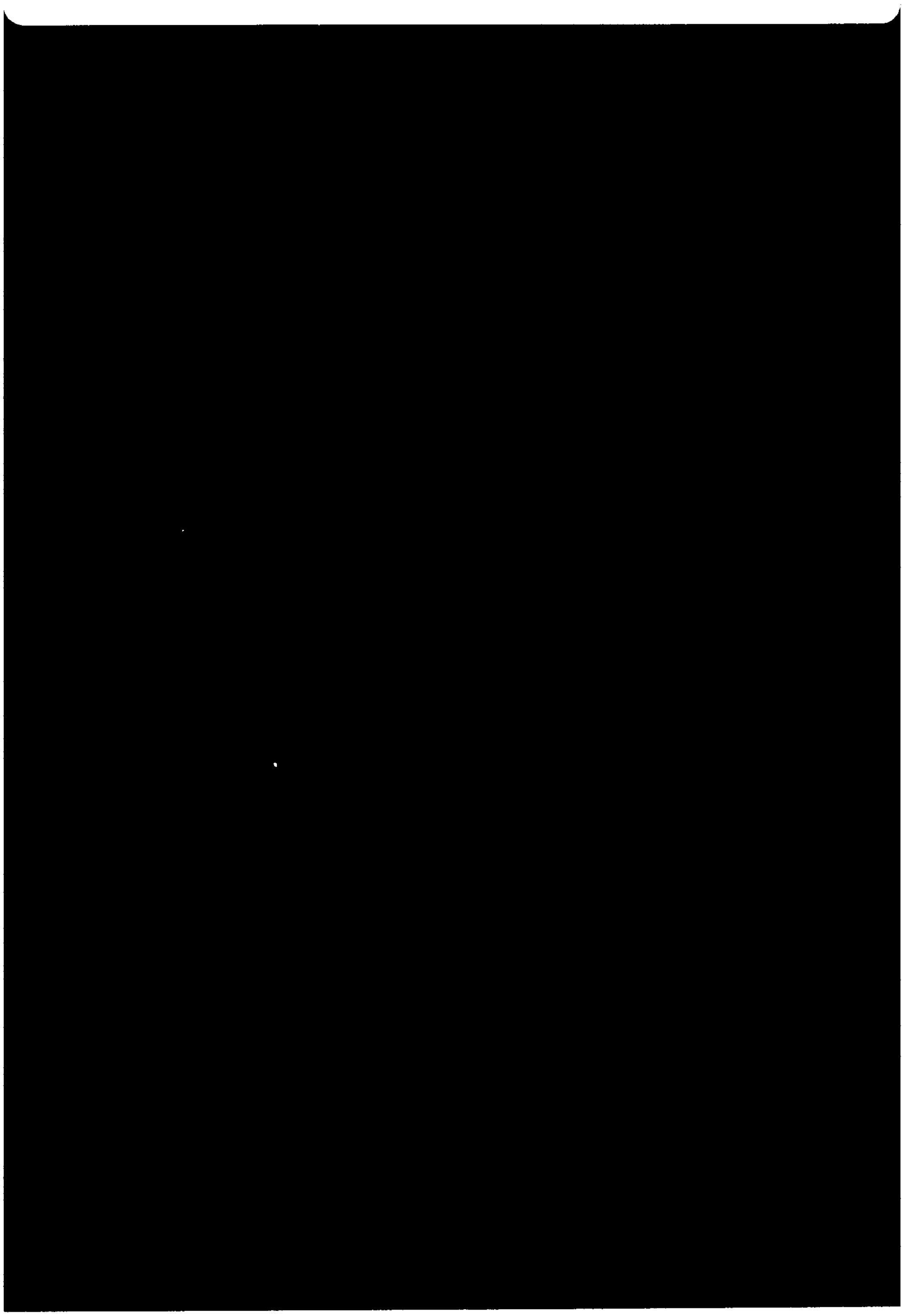

# FOREWORD

This document is Volume II of a two-volume report presenting the latest version of the Plume Impingement Computer Program (PLIMP). The theoretical bases of the program and recent changes are discussed in Volume I. This volume describes the user input necessary to run the program and outlines two sample problems.

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# Section 1
# INTRODUCTION

The Plume Impingement Program (PLIMP) is a computer code used to predict impact pressures, forces, moments, heating rates and contamination on surfaces due to direct impingement of flowfields. Typically, it has been used to analyze the effects of rocket exhaust plumes on nearby structures from ground level to the vacuum of space. The program normally uses flowfields generated by the MOC [1], RAMP2 [2], SPF/2 [3], or SFPGEN [4] computer programs. It is capable of analyzing gaseous and gas/particle flows. A number of simple subshapes are available to model the surfaces of any structure.

The original PLIMP program [5] has been modified many times over the last 20 years with Refs. [6,7] documenting the major changes. The theoretical bases for the referenced major changes, and additional undocumented changes and enhancements since 1988 are summarized in Volume I of this report. This volume is the User's Input Guide and should be substituted for all previous guides when running the latest version of the program. This version can operate on VAX and UNIX machines with NCAR graphics ability.

# Section 2
# INPUT GUIDE

This section describes the input necessary to use the 1991 version of PLIMP. Subsection 2.1 explains the input for the impingement calculations, Subsection 2.2 shows the files necessary to be opened and Subsection 2.3 explains the input for the new graphics program.

## 2.1 Input Instructions

RECORD 1: PROGRAM CONTROL INFORMATION
Format: (7I5,I3,2I1,7I5)

| Column | Variable | | Description |
|---|---|---|---|
| 5 | IGO | | Type of calculations desired |
| | | = 0 | Perform impingement analysis only |
| | | = 1 | Arrange data generated by RAMP2 or MOC program into a format used by PLIMP and perform an impingement analysis. |
| | | = 2 | Arrange data only |
| 10 | IRUN(4) | | Source of impingement data — Used to indicate if impingement calculations are to be made or if impingement data are to be read into the program from a prior execution. |
| | | = 0 | Impingement data was not previously calculated |
| | | = N | Fortran file number containing calculated impingement data from a previous PLIMP run. |
| NOTE: | If IRUN(4) > 0 only Record 1, NAMELIST INPT2 (see after Record 19), and Record 20 are used. | | |
| 15 | IRUN(6) | | Not used |
| 20 | IRUN(7) | | Output type (used if IRUN(4) > 0, Column 10) |
| | | = 0 | Do not print data |
| | | = 1 | Print data only |
| | | = 2 | Plot data only |
| | | = 3 | Print and plot data |
| 25 | LSOLID | | Not used |
| 30 | LRAMP | | Input flowfield type |
| | | = 0 | Any input flowfield file except RAMP2, MOC and SFPGEN |
| | | = 1 | RAMP2, MOC or SFPGEN input flowfield file |
| 35 | IAF(8) | | Type of flowfield chemistry |
| | | = 0 | Variable O/F, constant O/F, two-phase, ideal gas, variable enthalpy |

| Column | Variable | | Description |
|---|---|---|---|
| | | = 1 | Variable total enthalpy (single phase) |
| | | = 2 | Ideal gas with variable total enthalpy |
| 38 | ISPECI | | Debug flag for subroutines SPECIE and SPLOAD - Species mole fractions, O/F ratios, entropy level |
| | | = 0 | Normal output |
| | | = 1 | Extra output |
| 39 | IDSHAD | | Debug flag for subroutine SHADOW - Shading of subshapes |
| | | = 0 | Normal output |
| | | = 1 | Extra output |
| 40 | IMTRAN | | Debug flag for subroutine MTRAN - Transitional region calculations |
| | | = 0 | Normal output |
| | | = 1 | Extra output |
| 45 | IFRTAP | | Not used |
| 50 | ISORCG | | Gaseous source flowfield |
| | | = 0 | No gaseous source flowfield |
| | | = 1 | Gaseous source flowfield |
| 55 | ISORCP | | Particle source flowfield |
| | | = 0 | No particle source flowfield |
| | | = 1 | Particle source flowfield |
| 60 | METRIC | | Type of units |
| | | = 0 | Input and output files (units 5 and 6) English units |
| | | = 1 | Input and output files (units 5 and 6) SI units |
| NOTE: | Debug flags will output in English units only. | | |
| 65 | FORM | | Output format |
| | | = 0 | Output file (unit 6) in 132 column format |
| | | = 1 | Output file (unit 6) in 80 column format |
| 70 | NPLOT | | NCAR graphics data file for pre- or postprocessing |
| | | = 0 | Do not print impingement data to unit 9 |
| | | = 1 | Print impingement data to unit 9 |
| 75 | ICENT | | Not used if NPLOT = 0 |
| | | = 0 | Unit 9 data for postprocessor |
| | | = 1 | Preprocessor data (unit 9) do not run impingement analysis |

RECORD 2: CONTROL INFORMATION FOR THE ORDERING SECTION (used only when IGO > 0 Record 1, column 5)
Format: (16I5)

| Column | Variable | | Description |
|---|---|---|---|
| 5 | ISTART | | Beginning of flowfield ordering calculations |
| | | = N | Ordering the flowfield data will begin with this characteristic line number (MOC) or normal data surface (RAMP2) |
| 10 | ISIGN | | Location of flowfield quadrant (MOC runs) |
| | | = −1 | The flowfield was generated in the fourth quadrant |
| | | = 0 | The flowfield was generated in the first quadrant |
| 15 | KNUMBR | | Not used |
| 20 | IDEL | | Deletion of flowfield points |
| | | = 0 | Will not delete any flowfield points before ordering |
| | | = 1 | Will delete flowfield points (based on Record 3, Columns 21-30) |
| 25 | IPRINT | | Printout options |
| | | = 0 | No intermediate printout while ordering data |
| | | = 1 | Intermediate data are to be printed as the flowfield is ordered by distance from the engine exit plane |
| 30 | ITERM | | End of flowfield ordering calculations |
| | | = N | Characteristic line or normal number where ordering of flowfield data is to be terminated. [If 0, it is set to 1,000,000 . . . flowfield calculations (MOC, RAMP2) terminated properly] |
| 35 | ISEND | | Boundary determination |
| | | = 1 | Plume boundary is to be curve-fitted for use in the interpolation scheme |
| | | = 2 | Cutoff limits read as input data (Record 18) are to be used to see if a point is within a prescribed boundary (this option is usually used). |
| 40 | ISKIP | | Deletion of lines in boundary determination (used if ISEND = 1) |
| | | = 0 | Every line will be examined for a free boundary point |
| | | = N | Every Nth line will be examined for a free boundary point |
| 45 | ISKPL | | Deletion of characteristic lines in ordering process |
| | | = 0 | Read all characteristics |
| | | = N | Read every Nth + 1 characteristic |

RECORD 3: REFERENCE COORDINATES FOR THE ORDERING CALCULATIONS
(used only when IGO > 0 Record 1, column 5)
Format: (6E10.6)

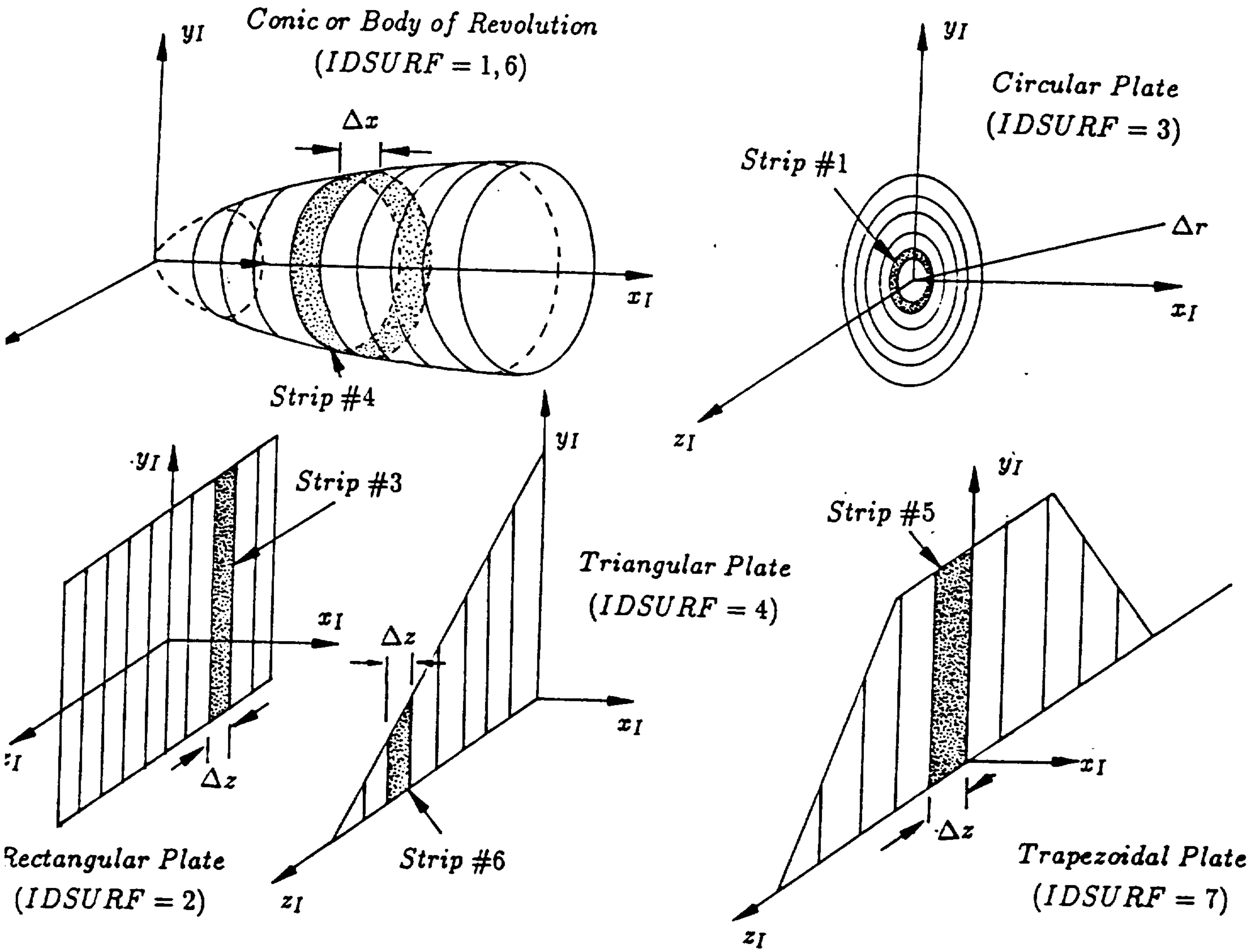
| Column | Variable | | Description |
|---|---|---|---|
| 1-10 | RREF | | Radial coordinate to which each flowfield data point will be referenced |
| 11-20 | XREF | | Axial coordinate to which each flowfield data point will be referenced |

NOTE: XREF and RREF are used to accomplish any desired coordinate system translation. This provides a simple means to move the origin; e.g., from the nozzle throat to the nozzle exit.) [X=(X-XREF)/DIAM, R=(R-RREF)/DIAM]

| Column | Variable | | Description |
|---|---|---|---|
| 21-30 | DELETE | | One of two points with a distance between them less than DELETE will be deleted from the flowfield data (used if IDEL = 0, Record 2, column 20) |
| 31-40 | DIAM | > 0.0 | Reference factor, units consistent with plume dimensions. Can be used to scale, etc., the local plume coordinates (use 1.0 for no scaling) |

RECORD 4: RUN IDENTIFICATION
Format: (18A4)

| Column | Variable | Description |
|---|---|---|
| 1-72 | HEADER | Title or heading |




*Strip numbers start at* $x_{min}$ $(IDSURF = 1,6)$, $z_{min}$ $(IDSURF = 2,4)$, $z_{max}$ $(IDSURF = 7)$, *or* $r_{min}$ $(IDSURF = 3)$

Figure 1: Elemental Strips

RECORD 5: INPUT OPTIONS NECESSARY TO CONTROL PROGRAM EXECUTION
Format: (16I5)

| Column | Variable | | Description |
|---|---|---|---|
| 5 | IOPT(1) | | Flowfield type |
| | | = 0 | Flowfield is two-dimensional |
| | | = 1 | Flowfield is axisymmetric |
| 10 | IOPT(2) | | Desired heating options |
| | | = 0 | Calculate continuum and free molecular heating |
| | | = 1 | Calculate continuum heating only |
| | | = 2 | Calculate free molecular heating only |
| | | = 3 | None |
| 15 | IOPT(3) | | Uniform flow assumptions (usually use 3) |
| | | = 0 | Composite vehicle in uniform flow |
| | | = 1 | Subshapes in uniform flow |
| | | = 2 | Elemental strips in uniform flow. (See Fig.1, page 6.) |
| | | = 3 | Elemental areas in uniform flow |
| 19-20 | IOPT(4) | = N | Number of subshapes in composite body (maximum of 50 subshapes) |
| 22 | IVAPN | = N | Number of species whose evaporation rate data as a function of surface temperature is to be input (5 max) [At present, data for $N_2H_4$, $H_2O$, $NH_3$, $CO_2$ and HCl are included. Use this option only if you want to add species and ISCTAM = 2 (this record, column 24).] |
| 23 | IPROP | | Indicates motor propellant type [Used only when net deposition rate output (ISCTAM=2) is selected.] |
| | | = 0 | ISCTAM < 2 |
| | | = 1 | Hydrazine - cold start |
| | | = 2 | Hydrazine - pulsed mode |
| | | = 3 | MMH/$N_2O_4$ bipropellant |
| | | = 4 | Solid propellant |
| | | = 5 | Other |
| 24 | ISCTAM | | Impingement gaseous contaminate species calculation (contaminant species that are impinging on the surfaces) |
| | | = 0 | Do not calculate and output species at surface |
| | | = 1 | Calculate and print out species which exist at the surface and are available to deposit on surface |
| | | = 2 | Calculate net deposition rates using model described in Section 3.3.4, Vol. I. |

| Column | Variable | | Description |
|---|---|---|---|
| 25 | IOPT(5) | | Type output desired |
| | | = 0 | Full output (data at each elemental area) |
| | | = 1 | Force and torque summary only |
| 30 | IOPT(6) | | Local flowfield chemistry |
| | | = 0 | Consider property variation with entropy |
| | | = 1 | Neglect entropy effects (use only one gas table) |
| 35 | IOPT(7) | | Boundary layer chemical species |
| | | = 0 | Use species on input flowfield file |
| | | = N | Number of species input (requires additional data from Record 10) (25 maximum) |
| 37 | IOPT(8) | | Forces and moment scaling (usually use 0) |
| | | = 0 | Do not scale forces and moment |
| | | = 1 | Multiply resultant forces and moment by PCRAT (Record 10, columns 61-70) |
| 38 | | = 0 | Plume loading only |
| | | = 1 | Subtract $P_{N_\infty}$ (Newtonian) from $P_{impact}$ for points within plume |
| | | = 2 | Calculate $P_{N_{\infty_{impact}}}$ for points outside plume |
| | | = 3 | Subtract $P_{N_\infty}$ over entire body surface |
| 39 | | = 0 | Zero pressure used for points in plume but shaded from flow |
| | | = 1 | External $P_\infty$ used for points in plume boundary but shaded from the flow |
| 40 | | = 0 | Single case being run |
| | | = 1 | Multiple cases with limited changes to input data (new cases input with NAMELIST CHNGE after Record 19). |
| 45 | IOPT(9) | | Type of local impact pressure calculation (continuum regime only, Section 3.2.3, Vol. I) |
| | | = 1 | Newtonian assumption ($K_{cp}$= 2.0) |
| | | = 2 | Modified Newtonian $[K_{cp} = (0.814 + \frac{6.88}{\alpha^{0.8}})\ C_{ps}]$ |
| | | = 3 | Isentropic expansion |
| | | = 4 | Oblique shock |
| | | = 5 | Limited modified Newtonian ($K_{cp} = C_{ps}$) |

| NOTE: | Record 14 provides opportunity to select a particular calculation method for each subshape. |
|---|---|

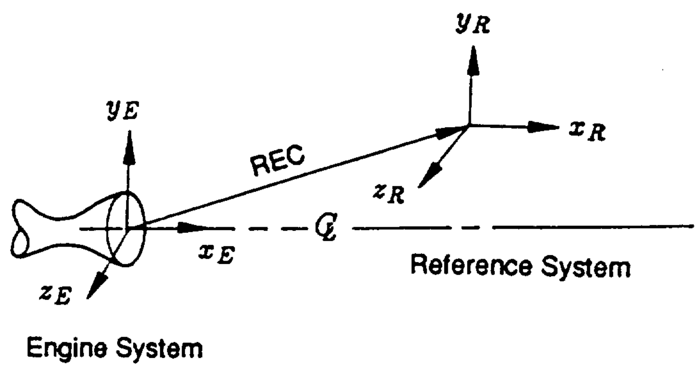
| Column | Variable | | Description |
|---|---|---|---|
| 46-50 | IOPT(10) | | Debug Flag. |
| | | = 0 | No debug printout |
| | | = N | Number of desired subshapes in debug printout. (Look out! starts with subshape 1 and continues through N subshapes.) |
| 51-55 | IOPT(11) | | Plot control for SC 4020 plot program (Not NCAR graphics) |

> NOTE: It may be necessary for user to update PLIMP FORTRAN file to output parameters in the format necessary for his particular plot program.

| Column | Variable | | Description |
|---|---|---|---|
| 51 | | = 0 | Do not connect plotted data points |
| | | = 1 | Connect plotted data points |
| 52-53 | | = N | Number of file unit on which impingement plot data will be written, usually 14 |
| 54-55 | ITPLOT | = N | Number of parameters to be plotted |
| 56-60 | IOPT(12) | = N | Case number |
| 65 | IOPT(13) | | Dimensions of input |
| | | = 0 | Impingement program dimensions in inches |
| | | = 1 | Impingement program dimensions in feet (meters if METRIC = 1, Record 1, column 60) |
| 70 | IOPT(14) | | Dimensions of ordered flowfield |
| | | = 0 | Flowfield dimensions in inches |
| | | = 1 | Flowfield dimensions in feet |
| 75 | IOPT(15) | | Local property printout |
| | | = 0 | No intermediate printout of properties |
| | | = 1 | Print local properties |
| | | = 8 | Intermediate printouts in heating routines |
| 80 | IOPT(16) | | Body-on-body shading |
| | | = 0 | No body-on-body shading calculations to be performed |
| | | = 1 | Body-on-body surface shading to be considered. (Input additional shading data after each subshape geometry, Record 14c) |

RECORD 6: REFERENCE COORDINATE SYSTEM POSITION VECTOR (Position vector defining the relative positions of the engine and reference coordinate systems.)

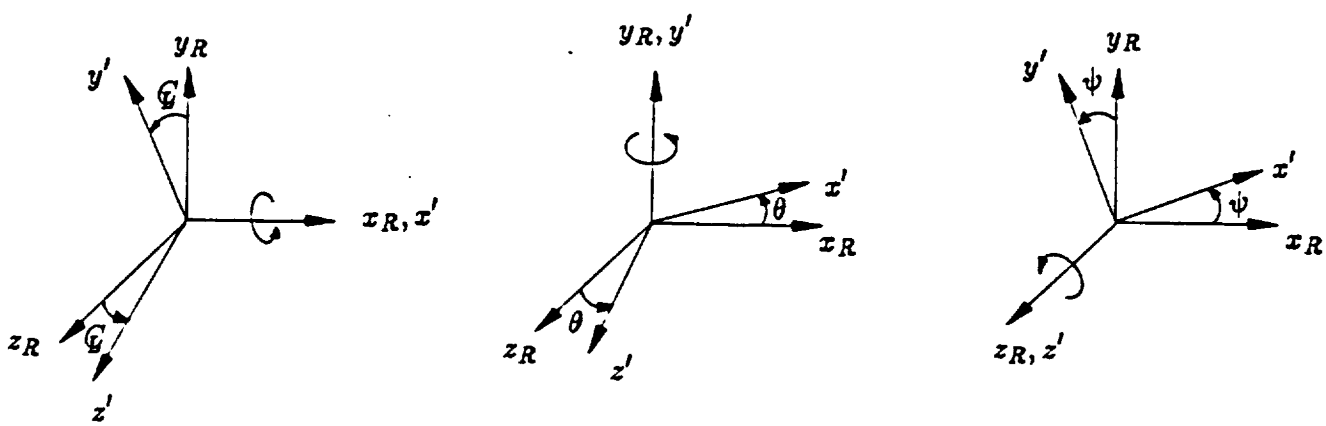
This record contains values for an engine position vector, REC, a moment transfer vector, RECT, and three control flags, ITU, ITV, ITW. These flags control the use of the position vector and its transformation matrix, and the moment transfer vector. REC and RECT are measured in inches, feet, or meters consistent with IOPT(13) (Record 5, column 65).




Engine coordinates may be defined from reference system, or reference system may be defined by engine system.

Sketch of Coordinate System Convention

NOTE: Rotations are always from the reference coordinate system toward the engine coordinate system. All coordinate rotations discussed in this report obey the right-hand rule for positive rotation notation. See sketch below.




Right-Hand Convention for Positive Angles of Rotation

Format: ( 6E10.6,3I5)

| Column | Variable | | Description |
|---|---|---|---|
| 1-10 | REC(x) | | Components of engine position vector |
| 11-20 | REC(y) | | |
| 21-30 | REC(z) | | |
| 31-40 | RECT(x) | | Components of moment transfer vector written in reference system (RECT = 0 if ITW = 0, column 75) |
| 41-50 | RECT(y) | | |
| 51-60 | RECT(z) | | |
| 65 | ITU | | Engine position vector control flag |
| | | = 0 | The engine position vector, REC, is measured in the engine system and locates the reference with respect to the engine. (Vector points from the engine to the reference system.) |
| | | = 1 | The position vector, REC, is measured in the reference coordinate system and locates the engine system with respect to the reference system. (Vector points from the reference to the engine system.) |
| 68-70 | ITV | | Engine reference system transformation matrix control flag (Input is right adjusted.) |
| | | = 0 | The components of the $i$ and $j$ unit vectors of the transformation matrix will be read from Record 7, columns 1-60. |
| | | >0 | The three axes angles of rotation will be read from Record 7. The program will compute the transformation matrix. User must specify order of rotation(s) with this flag, ITV, as a three-digit coded number using the following (rotate reference to engine system): |
| | | = 1 | x-axis rotation, $\phi$ deg |
| | | = 2 | y-axis rotation, $\theta$ deg |
| | | = 3 | z-axis rotation, $\psi$ deg |
| 75 | ITW | | Moment reference point control. |

NOTE: PLIMP will normally calculate moments in the reference system. However, the reference system origin is typically chosen for convenient subshape description. It may not be the point about which the surface would rotate if a moment were applied. This option allows the user to define that point (e.g., the surface's center of gravity). PLIMP will now calculate all moments in this coordinate system.

| | | | |
|---|---|---|---|
| | | = 0 | The resultant moments are referenced to reference coordinate system |
| | | = 1 | The resultant moments are to be referenced to the point defined by RECT |

RECORD 7: REFERENCE COORDINATE SYSTEM DIRECTION COSINES OR AXES ROTATION ANGLES

This record contains values for the direction cosines of the reference system unit vectors, IC and JC. The unit vectors are measured in the engine, E, coordinate system. If the control variable, ITV (Record 6, columns 68–70), is greater than zero, the axis rotation angles, $\phi$, $\theta$, $\psi$, are input and the cosines computed by the program.

Format: (6E10.6, I5)

| Column | Variable | Description | |
|---|---|---|---|
| | | Direction cosines of $x_R$ in E system if ITV=0. If ITV greater than zero, then $\phi$, $\theta$, $\psi$ are input. | |
| 1-10 | IC(x) | Direction cosine from $x_E$ or $\phi$ (deg) | (Angles read in this order |
| 11-20 | IC(y) | Direction cosine from $y_E$ or $\theta$ (deg) | regardless of the order of |
| 21-30 | IC(z) | Direction cosine from $z_E$ or $\psi$ (deg) | rotation(s), ITV) |
| | | x, y, z direction cosines of $y_R$ in E system if ITV = 0. Not used if ITV greater than zero. | |
| 31-40 | UNITIC | Direction cosine from $x_E$ | |
| 41-50 | UNITJC | Direction cosine from $y_E$ | |
| 51-60 | UNITKC | Direction cosine from $z_E$ | |
| 61-65 | IFL | Must match ITV, Record 6, columns 68-70 | |

## RECORD 8: PLOT IDENTIFICATION PARAMETERS

Format: (16I5)

If IOPT(11) > 0 (Record 5, columns 51–55) the following impingement parameters can be plotted by the SC4020 or user plotting routine inserting the correct number (right justified). (Again, the user will need to adapt his program to PLIMP format or vice versa.)

| Column | Variable | | Description |
|---|---|---|---|
| 1- 5 | IPLSYM(1) | = 1 | Turbulent convective heating rate |
| ⋮ | | = 2 | Laminar convective heating rate |
| | | = 3 | Transitional flow convective heating rate |
| 66-70 | IPLSYM(14) | = 4 | Free molecular flow convective heating rate |
| | | = 5 | Local Reynolds number based on momentum thickness |
| | | = 6 | Impact pressure |
| | | = 7 | Impact pressure/chamber pressure ratio |
| | | = 8 | Impact force |
| | | = 9 | Incident mass flow rate |
| | | = 10 | Free-stream Mach number |
| | | = 11 | Local Mach number |
| | | = 12 | Local plume impingement angle |
| | | = 13 | Local temperature |
| | | = 14 | O/F ratio |
| 75 | N | | Point deletion criterion. Every Nth output point will be plotted. |
| 80 | N | | Line deletion criterion. Every Nth output line will be plotted. |

NOTE: The numbers input in columns 1-5 ... 66-70 do not have to be in numerically ascending order; however, these columns, in blocks of five, should be filled from left to right. Blanks should be used through 70, i.e,

| Column = | (1 5) | (6 10) | (11 15) | (16 20) ... | (61 65) | (66 70) | (71 75) | (76 80) |
|---|---|---|---|---|---|---|---|---|
| Number = | 6 | 1 | 8 | | | | 1 | 1 |

RECORD 9: SPECIES CONCENTRATION CARDS [used when IOPT(7) > 0 (Record 5, column 35)].

This record specifies the mole fractions of the flowfield gas composition. It is input if the flowfield was generated by the MOC program using thermodynamic data input by file (ICON(1) = 1) or the RAMP2 program using the ideal gas and variable total enthalpy option (ICON(1) = 32). Input only the 25 most dominant species. Do not input if heating rate or contamination option is not chosen; i.e., IOPT(2) = 3 or ISCTAM = 0 (Record 5, columns 10 and 24, respectively) or using SFPGEN or SPF/2 flowfields.

Format: 3(2A4,2X,E10.6)

| Column | Variable | Description |
|---|---|---|
| 1-8 | XPNAME(1) | Chemical species name; i.e., H2, CO2, etc. (See Table 1, page 15.) The species names are left justified. |
| 11-20 | XP(1) | Mole fraction associated with chemical species 1 |
| 21-28 | XPNAME(2) | Species name 2 |
| 31-40 | XP(2) | Mole fraction associated with chemical species 2 |
| 41-48 | XPNAME(3) | Species name 3 |
| 51-60 | XPNAME(4) | Mole fraction associated with chemical species 3 |

Use additional records as necessary.

Table 1: Chemical Systems in PLIMP

| | | | |
|---|---|---|---|
| *Al | *$CF_4$ | *$H_2S$ | $Na_2$ |
| AlCl | CH | He | *Ne |
| $AlClH_3$ | $ICH_4$ | I | O |
| AlF | CN | *$I_2$ | OH |
| $AlF_3$ | *CO | *Li | $O_2$ |
| AlN | *COS | *LiCl | P |
| AlO | *$CO_2$** | *LiF | $PCl_3$ |
| *Ar | CP | LiO | PF |
| B | CS | *$Li_2$ | $PH_3$ |
| BCl | $C_2$ | $Li_3O$ | PN |
| $BCl_2$ | *$C_2H_2$ | *Mg | PO |
| *$BCl_3$ | *$C_2H_4$ | MgCl | PS |
| BF | *$C_2N_2$ | *$MgCl_2$ | $P_2$ |
| $BF_2$ | Cl | MgF | $P_4$ |
| *$BF_3$ | ClCN | MgF2 | *S |
| BO | *ClF | N | *$SF_6$ |
| $B_2$ | *$ClF_3$ | *$N_2$ | SO |
| $B_2O_3$ | *ClO | $NF_3$ | *$SO_2$ |
| Be | *$Cl_2$ | NH | $S_2$ |
| BeCl | *F | *$NH_3$** | *Si |
| *$BeCl_2$ | FCN | *NO | SiCl |
| BeF | *$F_2$ | *NOCl | $SiCl_4$ |
| $BeF_2$ | H | *$N_2O$ | SiF |
| *C | *HCN** | *Na | $SiF_4$ |
| CCl | *HCl** | *NaCl | $SiH_4$ |
| CF | HF | *NaF | SiO |
| $CF_2$ | *$H_2$ | NaO | *$SO_2$ |
| $CF_3$ | *$H_2O$** | *NaOH | SiS |
| | | | $SI_2$ |
| | | | *UA (unreacting ammonia) |

*Vapor Pressure Data Available
**Evaporation Rate Data Available

RECORD 10: ENGINE REFERENCE AND NON-DIMENSIONALIZING PARAMETERS
Format: (8E10.6)

| Column | Variable | Description |
|---|---|---|
| 1-10 | XTE | Transfer distance from engine gimbal to exit plane (inches, feet, or meters consistent with IOPT(13), Record 5, column 65). This option used primarily when the orientation of the engine coordinate system with respect to the reference system is about the engine gimbal point. |
| 11-20 | XMIN | Minimum distance from engine reference system at which impingement calculations are to start. (This eliminates useless calculations.) |
| 21-30 | | Not used |
| 31-40 | REFERN | Engine scale factor if plume coordinates are non-dimensional, or to be scaled (units consistent with IOPT(14), Record 5, column 70). |
| 41-50 | RICH | Diameter of nozzle at exit plane for use in non-dimensionalizing program output (units consistent with IOPT(13) Record 5, column 65). (Usually 1.0) |
| 51-60 | PC | Engine chamber pressure (psi or pascals), non-dimensionalizes pressure output. (Input 1.0 for no non-dimensionalization.) |
| 61-70 | PCRAT | Ratio of desired plume chamber pressure for which heating rates, forces and moments are desired to the chamber pressure at which the plume flowfield was generated. (Usually 1.0) |
| 71-80 | DELPHI | Constant angular increment off stagnation line (deg) at which impingement calculations are desired. |

RECORD 11: CONDITIONS EXTERNAL TO FLOWFIELD
Format: (6E10.6)

| Column | Variable | Description |
|---|---|---|
| 1-10 | PAMB | Static pressure, psfa, pascals |
| 11-20 | TAMB | Static temperature, °R or °K |
| 21-30 | EMAMB | Mach number |
| 31-40 | GAMAMB | Ratio of specific heats, $\gamma$ |
| 41-50 | RAMB | Gas constant, $ft^2/sec^2$-R or $m^2/sec^2$-K |
| 51-60 | CPINF | Newtonian pressure coefficient, $C_{ps}$ |

RECORD 12: HEATING RATE REFERENCE PARAMETERS

This record must be input. [The record should be blank if no heating rates are to be calculated; i.e., IOPT(2) = 3 (Record 5, column 10)]

Format: (7E10.6,1X,A4)

| Column | Variable | | Description |
|---|---|---|---|
| 1-10 | CPS | | Specific heat of solid particles BTU/lbm or kJ/kg(use 0.33 for $Al_2O_3$) |
| 11-20 | TAME | | Trajectory time if surface temperature calculations are to be made. |
| 21-30 | XSTAG | | Axial distance from subshape origin to stagnation point. Units consistent with IOPT(13), (Record 5, column 65) |
| 31-40 | TD | | Temperature of the gas in the boundary layer at the stagnation point at onset of dissociation, °R or °K |
| 41-50 | RB | | The reference radius (r*) at the stagnation point for use in velocity gradient calculation. (Units for r*, consistent with columns 51-60 this record.) |
| 51-60 | FUDGE | = 1 | r* input in feet or meters |
| | | = 12 | r* input in inches |
| | | (any numerical value input other than 1 or 12 defaults to 1) | |
| 61-70 | ACOMCF | | Accommodation coefficient for solid particle impingement (0.0 - 1.0) (usually 0.5) |
| 72-75 | SHAP | | Nose shape of surface |
| | | = 3DHM, Hemisphere | |
| | | = 2DHM, Cylinder | |
| | | = 3DDS, Circular disk | |
| | | = 2DFP, Rectangular flat plate | |
| | | = 3DCN, Cone | |

RECORD 13a: SUBSHAPE SURFACE TEMPERATURE [Input only if heating or contamination desired (IOPT(2) < 3 or ISCTAM > 0)] (Record 5, columns 10 and 24, respectively)

This record contains the surface temperature of each of the N subshapes to be used in the heating rate calculation. N = IOPT(4) (Record 5, columns 19–20).

Format: (8E10.4)

| Column | Variable | Description |
|---|---|---|
| 1-10 | TWAL(1) | Wall temperature (°R or °K) of subshape 1 |
| 11-20 | TWAL(2) | Wall temperature (°R or °K) of subshape 2 |
| 21-30 | TWAL(3) | Wall temperature (°R or °K) of subshape 3 |
| ⋮ | ⋮ | |
| 71-80 | TWAL(8) | Wall temperature (°R or °K) of subshape 8 |

Use additional records as necessary

RECORD 13b: EVAPORATION RATE CONTROL (Input only if ISCTAM = 2 and IVAPN > 0, Record 5, column 22)
Format: (2A4,I2)

| Column | Variable | Description |
|---|---|---|
| 1-8 | AME | Species name (consistent with Table 1 and left adjusted). |
| 15 | IN | Number of evaporation rates vs. temperature points to be read in on Record 13c. |

RECORD 13c: SURFACE EVAPORATION RATES AS FUNCTION OF TEMPERATURE [Input data from lowest to highest temperature. Input only if IVAPN = 0 and ISCTAM = 2 (Record 5, columns 22 and 24, respectively).]
Format: (8E10.6)

| Column | Variable | Description |
|---|---|---|
| EVPRAT(1) = T(1) + EVP(1) | | |
| 1-10 | T(1) | Temperature - °R or °K — Lowest temperature point |
| 11-20 | EVP(1) | Evaporation rate - lbm/ft$^2$-sec or kg/m$^2$-sec — Matches lowest temperature |
| 21-30 | T(2) | Temperature - °R or °K — Next lowest temperature point |
| 31-40 | EVP(2) | Evaporation rate - lbm/ft$^2$-sec or kg/m$^2$-sec — Matches next lowest temperature |

Continue until IN data sets have been input using additional records as necessary.

NOTE: Records 13b and 13c are required only if the user has selected the deposition model (ISCTAM = 2, Record 5, column 2) and has indicated that there are additional surface evaporation rate data for species that are not already included in the internal program data. Input as many sets of Records 13b, c as IVAPN (maximum of 5).

RECORD 14a: REFERENCE DIMENSIONS

This record contains N subshape reference dimensions to be used in determining the local flow regime. N = IOPT(4), Record 5, columns 19–20.

Format: (6E10.6)

| Column | Variable | Description |
|---|---|---|
| 1-10 | REFDLT(1,1) | Subshape reference length (inches, feet, or meters consistent with IOPT(13), Record 5, column 65). |
| 11-20 | REFDLT(2,1) | Subshape 1 reference diameter (inches, feet, or meters) |
| 21-30 | REFDLT(1,2) | Subshape 2 reference length |
| 31-40 | REFDLT(2.2) | Subshape 2 reference diameter |
| 41-50 | REFDLT(1,3) | Subshape 3 reference length |
| 51-60 | REFDLT(2,3) | Subshape 3 reference diameter |

Use additional records as necessary.

RECORD 14b: SUBSHAPE GEOMETRY CARD

These records identify the type of surface (conic, rectangular plate, circular plate, etc.) and the coefficients of the surface equation. There will be as many of these records as there are subshapes (maximum of 10). Records 14b, 14c, 14d are read as a set for each subshape.

Format: (I1,I9,7E10.6)

| Column | Variable | | Description |
|---|---|---|---|
| 1 | IDSURF | | Surface identification |
| | | = 1 | Conic |
| | | = 2 | Rectangular plate |
| | | = 3 | Circular plate |
| | | = 4 | Right triangular plate |
| | | = 5 | Not used |
| | | = 6 | Body of revolution described by a polynomial |
| | | = 7 | Trapezoid |
| 2-4 | NPHI | = N | Surface integration control |
| 5-7 | NX | = N | Surface integration control. These are applied as follows: |

| Subshape | NPHI | NX |
|---|---|---|
| 1. Conic | Angular (60 max) | X (unlimited) |
| 2. R. Plate | Z (unlimited) | Y (80 maximum) |
| 3. C. Plate | Angular (unlimited) | Radial (60 max) |
| 4. T. Plate | Z (same as Y) | Y (60 max) |
| 5. Not used | | |
| 6. Polynomial | Angular (60 max) | X (unlimited) |
| 7. Trapezoid | Z (unlimited) | Y (60 max) |

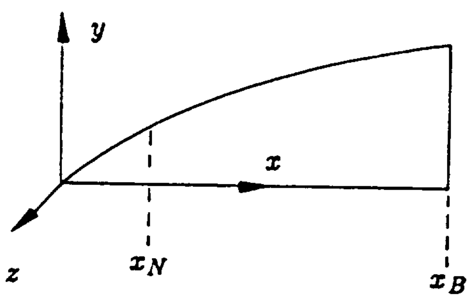
NOTE: The NPHI increment applies to the rectangular portion of the trapezoidal plate. Each triangular portion of the plate will have the same number of Z increments as there are Y increments.

| Column | Variable | | Description |
|---|---|---|---|
| 8 | | = N | The type of impingement pressure calculation for the subshape if different from option specified by IOPT(9) (Record 5, column 45). If left blank, the option specified by IOPT(9) will be used. |
| 9 | | = 0 | Calculate heating rates on all surface strips (Fig.1, page 6) |
| | | = 1 | Heating rate calculations or data output on specified subshape strip numbers, if IOPT(5) = 1 (Record 5, column 25), strip numbers specified by Record 14d. |
| | | = 2 | No heating rate calculations on subshape |

| Column | Variable | Description |
|---|---|---|
| | = 3 | Surface temperature calculations on selected strips specified by Record 14d. |
| 10 | IHT | Continuum regime heat transfer rate method |
| | = 1 | Eckert Reference Enthalpy method for unyawed cones |
| | = 2 | Eckert Reference Enthalpy method for flat plates |
| | = 3 | Yawed cone heating rates using swept infinite cylinder theory |
| | = 4 | Stagnation point heating rates using Marvin and Deiwert Method (requires input data on Record 12) |
| | = 5 | Cylinder heating rates using yawed infinite cylinder theory |
| 11-20 | A | |
| 21-30 | B | Coefficients of subshape equations, subshape coordinate system. Refer to sketches below for definitions of coefficients; units of coefficients are consistent with IOPT(13), Record 5, column 65. Subshape coordinate system orientations must be located as shown. |
| 31-40 | C | |
| 41-50 | D | |
| 51-60 | E | |
| 61-70 | XN | |
| 71-80 | XB | |

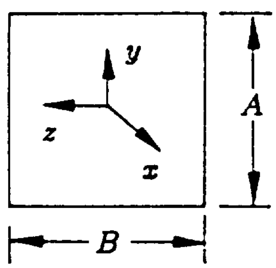
NOTE: For flat plates (rectangular, triangular, circular, trapezoidal), the X axis must be oriented in a general direction toward the engine. (Impingement assumed on side with +X axis.)

Conic , IDSURF = 1




Surface Equation:
$R = A\left(\sqrt{B + CX + DX^2} + E\right)$, for $XN \leq X \leq XB$
(E must = 0 for proper shading calculation.)

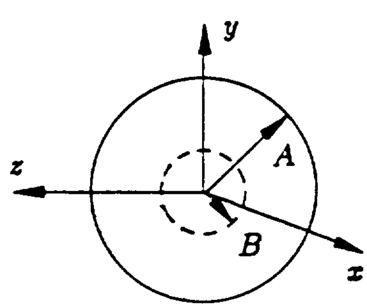
Rectangular Plate, IDSURF = 2




Coordinate system origin is located at the geometric center. The X axis is normal to the plane of the plate. The Y axis should be oriented in the general direction of flow if heating rate calculations are made.

A = $2Y_{max}$
B = $2Z_{max}$
(C, D, E, XN, XB unused.)

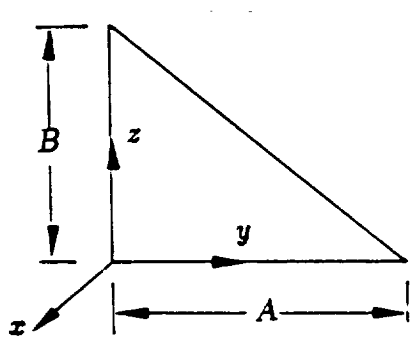
Circular Plate, IDSURF = 3




Coordinate system origin is located at the geometric center. The X axis is normal to the plane of the circular plate. Orientation of the Y, Z axes directions are established by the user.

A = outer radius of circular plate, $R_o$
B = inner radius of circular plate, $R_i$
(C, D, E, XN, XB unused.)

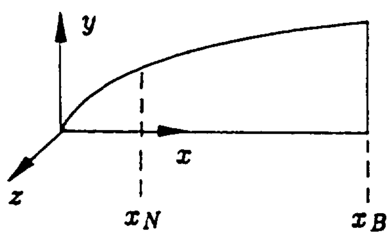
Right Triangular Plate,
IDSURF = 4




Coordinate system origin is located at the vertex of the right angle. The X axis is normal to plane of the plate. Orientation of the Y,Z axis should be in general direction of flow.

A = $Y_{max}$
B = $Z_{max}$
(C, D, E, XN, XB unused.)

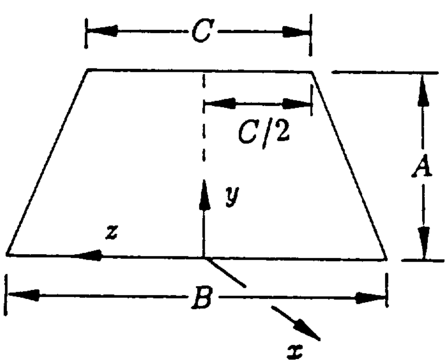
Body of Revolution, IDSURF = 6




Surface Equation

$R = A + BX + CX^2 + DX^3 + EX^4,\ XN \leq X \leq XB$

Trapezoidal Plate, IDSURF = 7




The coordinate system origin is at the base in the middle of the rectangle. The program will work from the +Z toward −Z direction. (The trapezoid must be symmetric about the Y-zxis.)

| | | |
|---|---|---|
| A | = | $Y_{max}$ |
| B | = | Base length |
| C | = | Top length |
| D | = 1 | Flow is from +X direction (impinges on front side) |
| | = −1 | Flow is from −X direction (impinges on back side) |
| E | = 0 | Complete trapezoid |
| | = 1 | +Z side of trapezoid |
| | = −1 | −Z side of trapezoid |
| | = 2 | Triangle on +Z side only |
| | = −2 | Triangle on −Z side only |
| | = −3 | Rectangular part only |

(XN and XB unused.)

NOTE: The trapezoid routine can analyze a triangular plate and a rectangular plate; however, a substantial amount of execution time may be conserved if these simple subshapes are analyzed with their respective routines. The reason for this is due to the more complex computer logic involved in the trapezoid routine.

RECORD 14c: BODY SHADING DATA (input only if shading option is flagged, IOPT(16) = 1, Record 5, column 80)
Format: (10I2)

| Column | Variable | Description |
|---|---|---|
| 1-2 | ICHEK(1) | |
| 3-4 | ICHEK(2) | Relative number(s) of the body(s) according to the order in which they are input which are to be checked for its shading on the body currently being input. (Input body numbers right justified.) |
| 5-6 | ICHEK(3) | |
| ⋮ | ⋮ | |
| 19-20 | ICHEK(10) | |
| NOTE: | A maximum of 10 surface numbers may be input. Scan for surfaces to check is terminated by reading a zero if less than 10 surfaces are input. | |

RECORD 14d: SURFACE TEMPERATURE IDENTIFICATION (input only if flagged on Record 14b, column 9 = 1 or 3) This option allows a simple thermal analysis of five points on a surface so that the surface temperature can vary with time.

Format: (5I6,5E10.6)

| Column | Variable | Description |
|---|---|---|
| 1-6 | ISELT(1) | First point |
| 1-2 | N | Strip number for first point (Fig.1, page 6) |
| 3-4 | N | Node number on strip for first point (node numbers start at $Y_{min}$) |
| 5-6 | | Surface material |
| | = 1 | Titanium |
| | = 2 | Carbon/Carbon |
| | = 3 | Aluminum |
| 7-12 | ISELT(2) | Second point |
| ⋮ | ⋮ | Repeat until all points are identified (5 maximum) |
| 25-30 | ISELT(5) | |
| 31-40 | THK(1) | Material thickness [units consistent with IOPT(13) Record 5, column 65] for first point |
| 41-50 | THK(2) | Material thickness for second point |
| ⋮ | ⋮ | Repeat until material thicknesses for all points are read in. |
| 71-80 | THK(5) | |

RECORD 15: SUBSHAPE POSITION VECTOR

These records contain the position vectors, RCI, from the reference system to the subshape origins. RCI is measured in the reference system and "points" to the subshape origin. There will be as many of these records as there are subshapes which are read successively. The units are consistent with IOPT(13), Record 5, column 65. These records are read in the same order as the subshape geometry data (Record 14).

Format: (3E10.6,I5)

| Column | Variable | | Description |
|---|---|---|---|
| 1-10 | RCI(x) | | x component of position vector |
| 11-20 | RCI(y) | | y component of position vector |
| 21-30 | RCI(z) | | z component of position vector |
| 33-35 | ITA | | Reference-Subshape system status flag |
| | | = 0 | Matrix of direction cosines will be read |
| | | > 0 | Angles of axes rotations are to be read. Program will compute transformation matrix. User must specify order of rotation(s) using the following code:<br>= 1 Rotation about x axis, $\phi$<br>= 2 Rotation about y axis, $\theta$ deg<br>= 3 Rotation about z axis, $\psi$ deg |

NOTE: The rotation is always from the reference to the subshape coordinate system.

## RECORD 16: SUBSHAPE DIRECTION COSINES OR AXES ROTATION ANGLES

These records contain either the subshape direction cosines of the unit vectors, II and JI, or the axes angles of rotation, depending on the value of ITA (Record 15, columns 33–35). There will be one of these records for each subshape. These parameters are measured in the composite system reference frame. If the control variable ITA is greater than zero, the axis rotation angles, $\phi$, $\theta$, $\psi$, are input and the cosines computed by the program. These records are read in the same order as the geometry data (Record 14) immediately after Record 15.

Format: (6E10.6,I5)

| Column | Variable | Description | |
|---|---|---|---|
| | | Direction cosines of $x_I$ in the reference coordinate system if ITA = 0. If ITA is greater than zero, then $\phi$, $\theta$, and $\psi$ are input. | |
| 1-10 | II(X) | Direction cosine from $x_R$ or $\phi$ (deg) | (Angles read in this order regardless of the order of rotation(s), ITA) |
| 11-20 | II(Y) | Direction cosine from $y_R$ or $\theta$ (deg) | |
| 21-30 | II(Z) | Direction cosine from $z_R$ or $\psi$ (deg) | |
| | | Direction cosines of $y_I$ in the reference coordinate system if ITA = 0. Not used if ITA is greater than zero. | |
| 31-40 | JI(X) | Direction cosine from $x_R$ | |
| 41-50 | JI(Y) | Direction cosine from $y_R$ | |
| 51-60 | JI(Z) | Direction cosine from $z_R$ | |
| 61-65 | IFL | Must match ITA, Record 15, columns 33-35 | |

## RECORD 17: ANGULAR INTEGRATION CONTROL

These records enable the program to limit the calculations to the area of interest on a conic, a general body of revolution, and a circular plate by limiting the angular surface integration. For all other bodies, blank cards should be used. There are as many of these cards as there are subshapes and read in order immediately after the subshape direction cosines or axes rotation angles (Record 16).

The choice of PHIM1 and PHIM2 values provides a method of centering the calculation nodes such that output data are printed on desired angular locations. The PHIM1 and PHIM2 angular values are measured in the subshape coordinate system. This does not limit the size of the subshape which is always 360 deg. It only limits the areas of calculation, thus reducing computer execution time.

Format: (2E10.6)

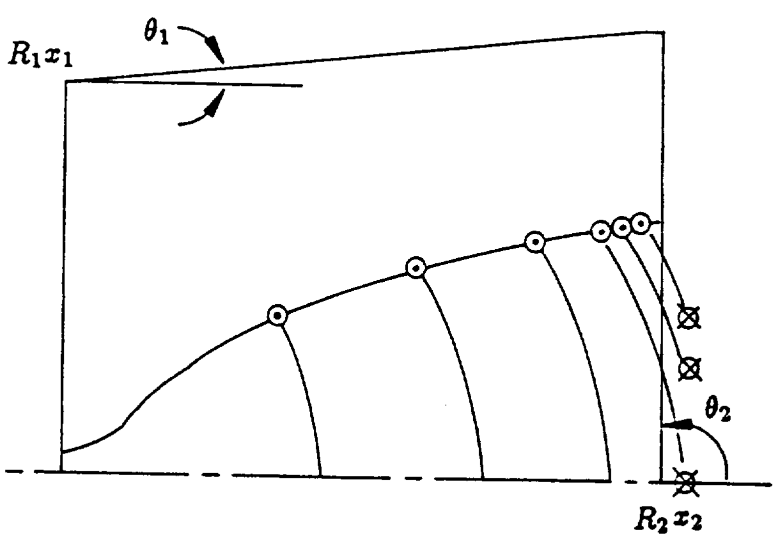
| Column | Variable | Description |
|---|---|---|
| 1-10 | PHIM1 | Angle in degrees measured in the y-z plane from the +y axis at which calculations are to be started. |
| 11-20 | PHIM2 | Angle measured same as PHIM1 at which calculations are to be terminated. |

RECORD 18: FLOWFIELD LIMITS

This record contains the necessary information to limit the calculations to those areas of interest in the flowfield. This scheme is employed in order to make the program efficient for the many problem orientations which are possible (see sketch below). Units are consistent with IOPT(14), Record 5, column 70.

Format: (6E10.6)

| Column | Variable | Description |
|---|---|---|
| 1-10 | CUTDAT(1) | Radial coordinate defining upper cutoff. |
| 11-20 | CUTDAT(2) | Axial coordinate defining upper cutoff |
| 21-30 | CUTDAT(3) | Angle cutoff line makes with horizontal |
| 31-40 | CUTDAT(4) | Radial coordinate defining downstream cutoff |
| 41-50 | CUTDAT(5) | Axial coordinate defining downstream cutoff |
| 51-60 | CUTDAT(6) | Angle cutoff line makes with horizontal |




$R_1$ CUTDAT(1)
$X_1$ CUTDAT(2)
$\theta_1$ CUTDAT(3)
$R_2$ CUTDAT(4)
$X_2$ CUTDAT(5)
$\theta_2$ CUTDAT(6)
⊗ Normal termination by downstream cutoffs.
⊙ Normal termination by plume boundary.

RECORD 19: EXTERNAL FLOWFIELD DIRECTION COSINES OR AXES ROTATION ANGLES

This record contains either the direction cosines of the unit vectors or the three axes angles of rotation written in the reference coordinate system for the plume external approach flow (EF). (This record is needed only if Record 5, column 38 = 0.)

Format: (6E10.6,I5)

| Column | Variable | Description | |
|---|---|---|---|
| | | Direction cosines of $x_{EF}$ in the reference system if ITA = 0, columns 63-65. If ITA is greater than zero, then $\phi$, $\theta$, and $\psi$ are input | |
| 1-10 | II(X) | Direction cosine from $x_R$ or $\phi$ deg | (Angles read in this order regardless of the order of rotation(s), ITA) |
| 11-20 | II(Y) | Direction cosine from $y_R$ or $\theta$ deg | |
| 21-30 | II(Z) | Direction cosine from $z_R$ or $\psi$ deg | |
| | | Direction cosines of $y_{EF}$ in the reference coordinate system if ITA= 0. Not used if ITA is greater than zero. | |
| 31-40 | JI(X) | Direction cosine from $x_R$ | |
| 41-50 | JI(Y) | Direction cosine from $y_R$ | |
| 51-60 | JI(Z) | Direction cosine from $z_R$ | |
| 63-65 | IFL | Must match ITA on Record 15, columns 33-35 | |

If additional cases are to follow in which a limited number of records are changed, Record 5, column 40 = 1, the data are read into the program via a NAMELIST entitled CHNGE. The variables contained in the NAMELIST are described in the input cards. They are as follows: ICONIC, IOPT, TEC, REC, HEADER, ICON, IRUN, PCRAT, TAME, IOUT, PAMB, TAMB, ENAMB, GAMAMB, RAMB, CPINF, UNITIC, UNITJC, UNITKC, ITU, ITV, ITW, IPLSYM, ISELT, RCI, PC. The program will continue to read cages until the last digit in IOPT(8) = 0, Record 5, column 40 or Record 20 'END' is encountered.

NOTE: The variable, ICONIC, contains the information read in on Record 14b, Columns 2-10.

NOTE: UNITIC, UNITJC, and UNITKC are input on Record 7. If the angles of rotation are being input, all three must be reset through the CHNGE input.

If IRUN(4) > 0, Record 1, column 10, Records 2–19 are not used and the impingement run previously made and now being input through IRUN(4) data file is updated via a NAMELIST entitled INPT2. This allows plotting of the impingement data using the following variables in the name list: IOPT, IPLSYM, PRATIO, RICH, PCRAT, ITPLOT, TUNIT, IRUN, ICON.

RECORD 20: PROGRAM END

End of input record. The program will analyze as many cases as the user desires for each computer run. The program execution is terminated by end of case card.

Format: (A4)

| Column | Variable | Description |
|---|---|---|
| 1-4 | = END | Causes program execution to terminate |

## 2.2 Input and Output Files

The modified PLIMP code operates on VAX/VMS and SUN Workstations (UNIX operating systems). Before any input or output can take place between a file and a program, the file must be connected to a unit number. This task can be accomplished with the aid of ASSIGN statements in COMMAND files on the VAX system. In keeping with ANSI Standard FORTRAN 77 and due to the fact that ASSIGN statements are not easily implemented on UNIX, units/files should be connected before use by means of OPEN statements. These OPEN statements are located in the FORTRAN file - OPEN.FOR (on tape, Ref. [8]). The file names are read using a namelist entitled FILES. The names may be input in the data file FILES.DAT.

The data file, FILES.DAT, is presented in Table 2 along with a description of the input variables, and the program magnetic tape assignments are given in Table 3.

Table 2: Input File to Establish NAMELIST Files

```
&FILES

ORD = 'N',          ORDER DATA ONLY -- INPUT Y
IMP = 'N',          PERFORM IMPINGEMENT ANALYSIS ONLY -- INPUT Y
ORD_IMP = 'N',      ORDER DATA AND PERFORM AN IMPINGEMENT ANALYSIS
                    -- INPUT Y
SORFL = 'Y',        PERFORM AN IMPINGEMENT ANALYSIS USING AN SFPGEN
                    PLUME -- INPUT Y

ORD_2 = ' file name for unit 2',   IF ORD = 'Y' ENTER FILE NAMES FOR
ORD_5 = ' file name for unit 5',                LOGICAL UNITS
ORD_6 = ' file name for unit 6',                2,5,6,8,10
ORD_8 = ' file name for unit 8',
ORD_10 = ' file name for unit 10',


IMP_2 = ' file name for unit 2',   IF IMP = 'Y' ENTER FILE NAMES FOR
IMP_5 = ' file name for unit 5',                LOGICAL UNITS
IMP_6 = ' file name for unit 6',                2,5,6,8
IMP_8 = ' file name for unit 8',


ORD_IMP_2 = ' file name for unit 2', IF ORD_IMP = 'Y' ENTER FILE NAMES
ORD_IMP_5 = ' file name for unit 5',                  FOR LOGICAL UNITS
ORD_IMP_6 = ' file name for unit 6',                  2,5,6,8,10
ORD_IMP_8 = ' file name for unit 8',
ORD_IMP_10 = ' file name for unit 10',
```

Table 2: (Continued) Input File to Establish NAMELIST Files

```
SOR_5 = ' file name for unit 5',       IF SOR = 'Y' ENTER FILE NAMES FOR
SOR_6 = ' file name for unit 6',                    LOGICAL UNITS 5,6,16
SOR_16 = ' file name for unit 16',
&END
```

If the user wishes, this option may be removed by commenting out the `CALL OPEN` statement in `MAIN.FOR` and using `ASSIGN` statements to name the different logical units on the VAX system.

Table 3: Program Magnetic Tape Assignments

| PLIMP | Logical Unit Number | File Function |
|---|---|---|
| IGO = 2<br>(Arrange MOC or RAMP2 data only) | 2<br>3<br>5<br>6<br>8<br>10 | Limits of ordered flowfield (output)<br>Scratch file<br>PLIMP input file (user supplied)<br>PLIMP output file<br>Ordered flowfield data file (output)<br>Flowfield file generated by MOC or RAMP2 (input) |
| IGO = 0<br>(Perform an impingement analysis ... flowfield has been previously ordered) | 2<br>3<br>5<br>6<br>8<br>9<br>11<br>13<br>15<br>18<br>IUNIT | Limits of ordered flowfield (input)<br>Scratch file<br>PLIMP input file (user supplied)<br>PLIMP output file<br>Ordered flowfield data (input)<br>NCAR graphics data file (output)<br>Scratch file (used by plot package)<br>Coefficients data used in heating analysis<br>Scratch file<br>Scratch file<br>Variable file unit number on which impingement data are to be stored |
| IGO = 1<br>(Order flowfield and perform an impingement analysis in a single execution) | 2<br>3<br>5<br>6<br>8 | Limits of ordered flowfield (input)<br>Scratch file<br>PLIMP input file (user supplied)<br>PLIMP output file<br>Ordered flowfield data file (input) |

Table 3: (Continued) Program Magnetic Tape Assignments

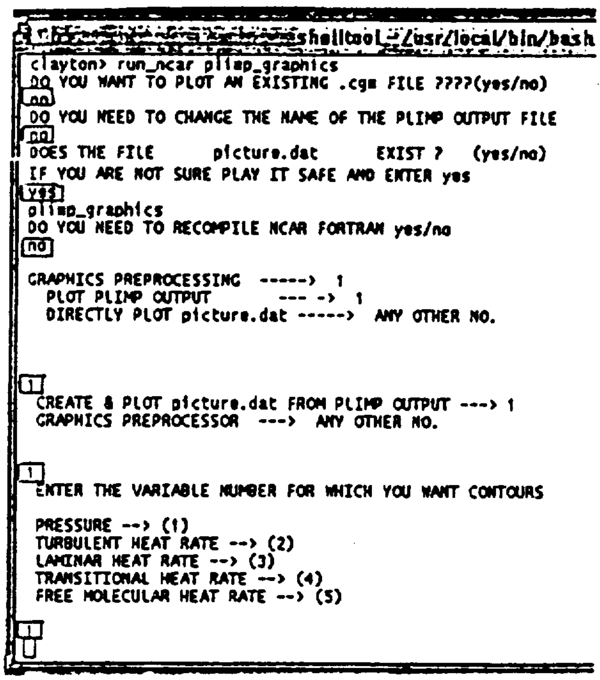
| PLIMP | Logical Unit Number | File Function |
|---|---|---|
| | 9 | NCAR graphics data file (output) |
| | 10 | Flowfield file generated by MOC or RAMP2 (input) |
| | 11 | Scratch file (used by plot package) |
| | 13 | Coefficients data used in heating analysis |
| | 15 | Scratch file |
| | 18 | Scratch file |
| | IUNIT | Variable file unit number on which impingement data are to be stored |
| IGO = 0; ISORCG = 1 or ISORCP = 1 (Perform an impingement analysis using an SFPGEN generated flowfield) | 3 | Scratch file |
| | 5 | PLIMP input file (user supplied) |
| | 6 | PLIMP output file |
| | 9 | NCAR graphics data file (output) |
| | 11 | Scratch file (used by plot package) |
| | 13 | Coefficients data used in heating analysis |
| | 15 | Scratch file |
| | 16 | SFPGEN plume flowfield file (input) |
| | 18 | Scratch file |
| | IUNIT | Variable file unit number on which impignement data are to be stored |
| IRUN4 > 0 | IUNIT | Variable file unit number on which impingement data are stored |
| | 11 | Scratch file (used by plot package) |

## 2.3 Pre- and Postprocessing Graphics

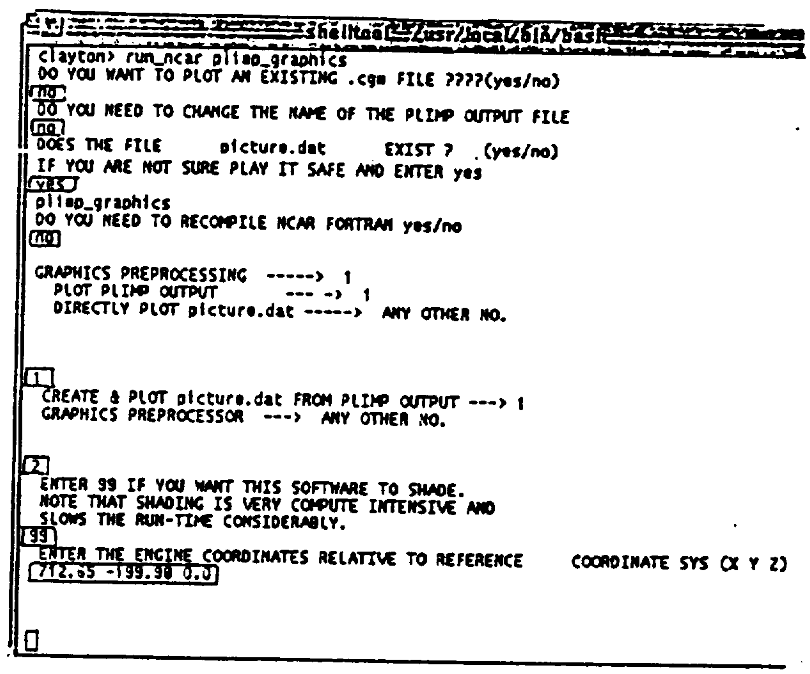
Table 4 shows two examples of run sequences for the PLIMP pre- and postprocessor NCAR graphics routine. The first example is the interactive prompts/responses for a postprocessing run assuming Record 1, column 70, NPLOT = 1 and Unit 9 has been opened. The second example is a preprocessing run where shading was requested and engine coordinates relative to the reference system were given. In both cases the user's response is shown boxed. The icon labeled 'idt' appears on the screen after the program is finished and the picture is ready for display. The mouse should be clicked in the 'display' box of the icon for viewing the picture. Questions regarding the meaning of the prompts are answered in Section 3.3.5.3 of Volume I. That section also contains a sample input for the preprocessing file using the stand-alone NCAR graphics program without using PLIMP. Creation of that file is not interactive and is explained in Section 3.3.5.2 of Volume I.

Table 4: NCAR Graphics Run Sequences

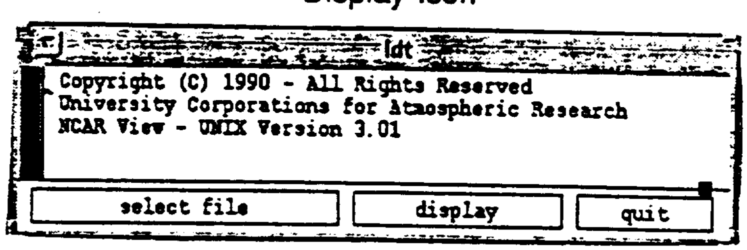
Postprocessing




Preprocessing




Display Icon



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# Section 3
# SAMPLE PROBLEMS

This section describes two sample problems and carefully discusses the inputs necessary for PLIMP to solve them.

## 3.1 Sample Case 1

This section contains a sample case involving the STS-7 mission of June 1983. It will aid the user in familiarization and preparation of input data for the modified PLIMP code. An RCS plume impingement test was performed to provide force and moment data for the Shuttle Pallet Satellite (SPAS-01) due to a single orbiter RCS firing [9]. The SPAS-01 was positioned at different orientations relative to the orbiter with the forward upward facing RCS engine impinging upon its surface. This test case was previously used as an impingement validation case [10]. However a comparison with the experimental data will not be performed at this time. The RCS plume flowfield was calculated using the RAMP2 computer code. This plume is one of the flowfields generated for the plume database described in Volume I.

The nozzle solution was performed assuming equilibrium/frozen thermochemistry, variable oxidizer to fuel ratio distribution. BLIMPJ execution was also required since the effects of the boundary layer were important.

The RAMP2 code cannot perform a plume calculation considering both variable O/F ratio distribution and total enthalpy gradients (due to boundary layer effects); therefore, the RCS plume flowfield was generated utilizing the ideal gas variable total enthalpy option of the code. An SFPGEN plume flowfield was then generated using the RAMP2 plume file. All the relevant information to perform these tasks is presented in Volume I.

During the test, the SPAS-01 satellite was positioned at eight different locations relative to the orbiter as shown in Fig. 2. The RCS engine was fired while the satellite was at each position. There are many options in setting up the coordinate systems in this sample problem; Fig. 3 shows the engine and composite (reference) coordinate systems chosen. The SPAS-01 structure was divided into 10 subshapes and is presented in Fig. 4. The reference coordinate system in Fig. 4 corresponds to the axis and is located at the Center of Gravity (CG) of the vehicle. Table 5 lists the PLIMP input for this sample case and should be referred to while reading the following details for each record.

**Record 1** — Record 1 of the input data concerns the program control information. The variable IGO determines the type of calculation required. RAMP2 flowfields have to be arranged into a specific format acceptable to PLIMP. If the flowfield has been previously ordered and an impingement analysis is required, a value of 0 is entered for IGO, if not, the data may be arranged into this format and an impingement analysis performed in the same execution (IGO = 1) or during a later execution (IGO = 2). SFPGEN flowfield files are ordered flowfields, therefore, a value of 0 was entered

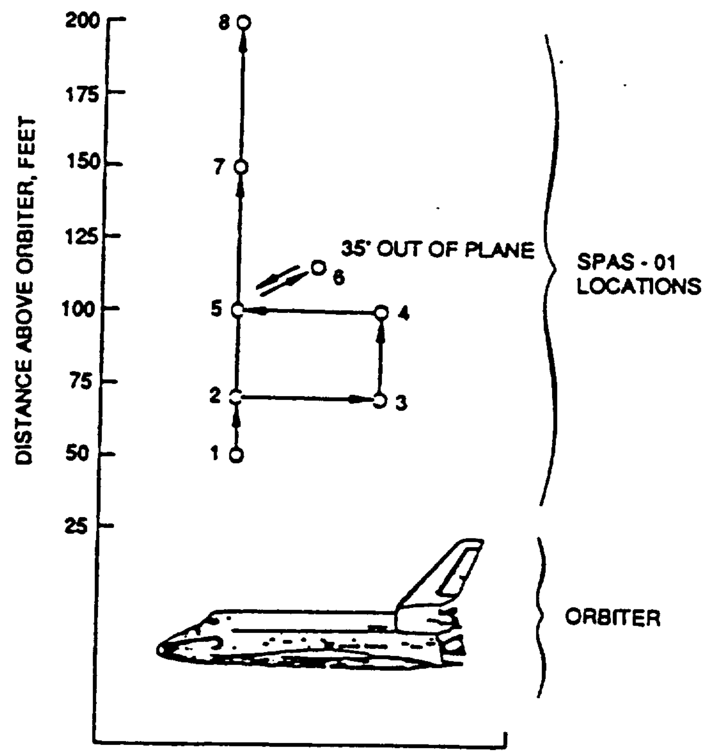


Figure 2: Relative Location of SPAS and Orbiter for Plume Impingement Test

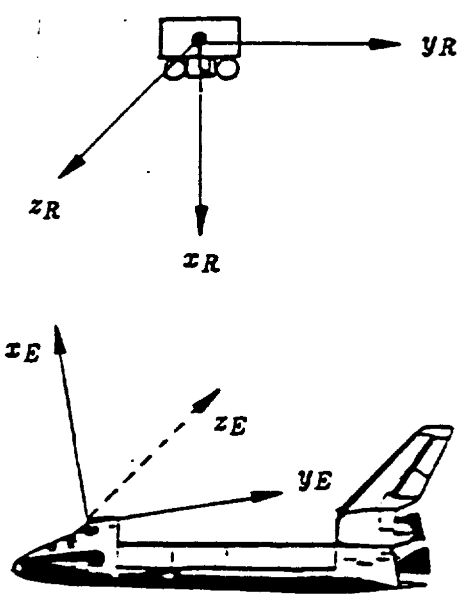


Figure 3: Orientation of Engine and Composite Coordinate System for SPAS/RCS Impingement Calculation

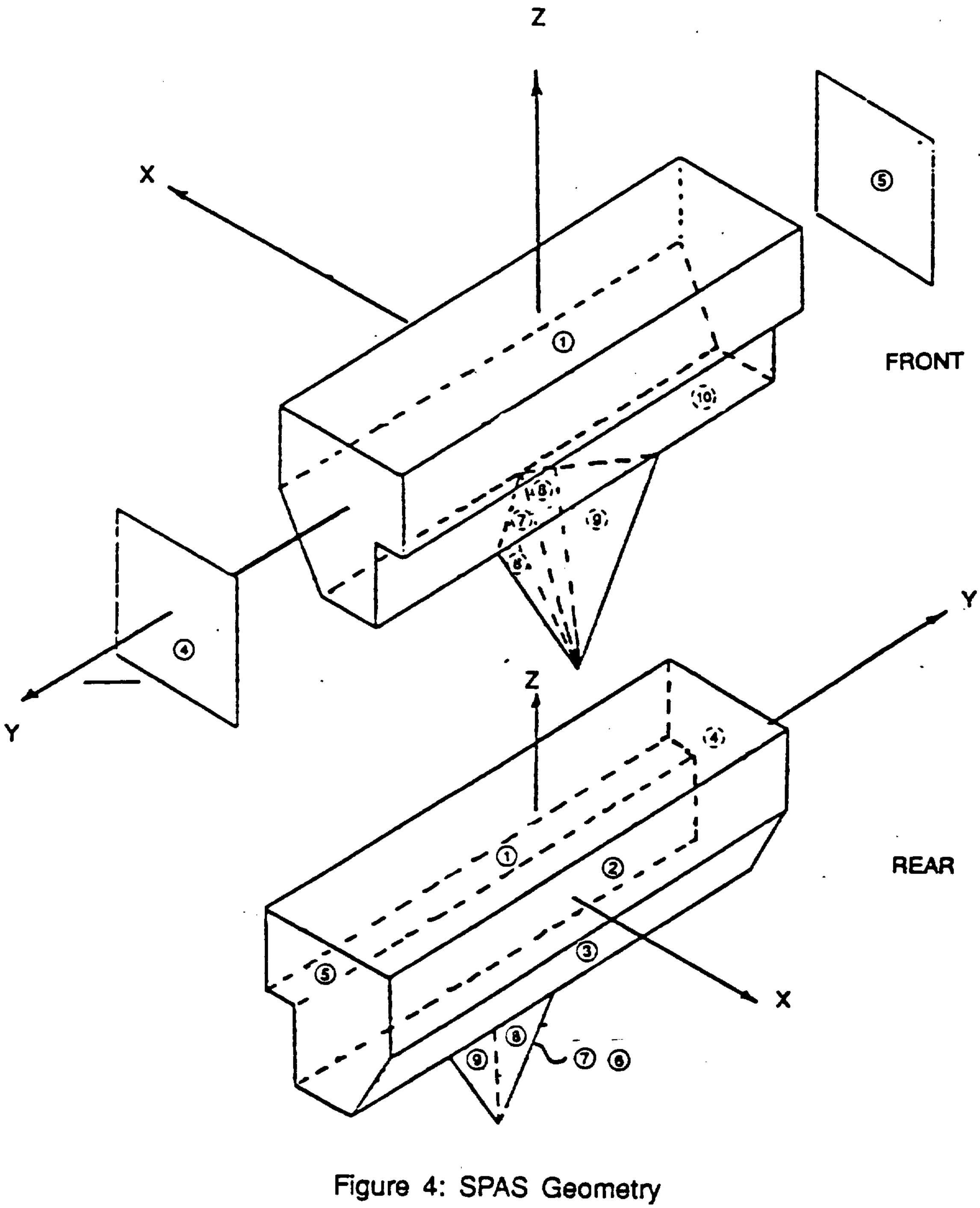


Figure 4: SPAS Geometry

Table 5: Input File for Sample Case 1

```
    0    0         0    0    1    2   000        1    0    0    0    1    0
 SPAS-01 RCS Plume Impingement Test
    1    0    3   10   10    1    0   000   2    000000  1    0    1    0    1
712.65     -199.98   0.0                                          1  231
0.0        180.0     -2.00
0.         0.                  1.        1.        1.        1.        0.
0.1     -06250.      0.0       1.4       1716.     2.
0.0        0.0       0.0       2500.     1.0       12.                 2DFP
500.       500.      500.      500.      500.      500.      500.      500.
500.       500.
166.       46.       166.      28.       166.      25.6
46.        52.       46.       52.       56.3      32.5
11.9       56.53     56.53     11.9      32.5      56.53
166.       23.
2003003000 46.       166.
00
2015015002 166.      28.0
00
2015015002 166.      25.6
00
2003003002 46.       52.
00
2015015002 46.       52.
00
4010010002 56.53     32.5
 3 8
4010010002 11.9      56.53
 3 8 9
4010010002 56.53     11.9
 3 7 9
4010010002 32.5      56.53
 3 6 7 8
2003003002 23.       166.
 0
3.68       -.18      14.57       132
26.18      -.18      .57         123
21.67      -.18      -25.43      213
3.18       82.82     -11.43      312
3.18       -83.18    -11.43      312
11.0       10.02     -37.43      123
11.0       10.02     -37.43      132
11.0       -10.38    -37.43      123
11.0       -10.38    -37.43      132
5.68       -.18      -37.43      213
90.0       0.0       90.
0.0        0.0       0.0
0.0        20.6      0.0
0.0        0.0       90.
```

Table 5: (Continued) Input File for Sample Case 1

```
0.0        0.0        -90.
-90.       -31.2      23.45
180.0      -23.45     -31.2
-90.       25.0       23.45
180.0      -23.45     25.0
-90.       90.        0.0
.
.
.
10 blank lines (1 per subshape) for Record 17
.
.
.
100.       -100.      0.0        0.0        100.       90.
END
```

in column 5. The second input variable, IRUN(4) was set to 0 since impingement calculations are desired. Therefore IRUN(7) is left blank. Since PLIMP can now perform two-phase impingement analyses in a single execution LSOLID is no longer required. LRAMP is set to 1 as the plume flowfield was generated using the SFPGEN computer code. The RAMP2 plume flowfield was generated using the ideal gas with variable total enthalpy option, therefore IAF(8) is equal to 2. ISPECI, IDSHAD, and IMTRAN are set to 0 respectively as extra output is not required. The next two variables, ISORCG and ISORCP, are 1 and 0, respectively (gaseous SFPGEN flowfield.) English units are used to prepare the input file (METRIC = 0) and 132 column format is desired (FORM = 0). The variable NPLOT determines if data for the 3-D NCAR pre/post processing graphics package will be output on unit 9. NPLOT was assigned a value of 1 to enable this option. If the user wishes to check the input geometry without performing an impingement analysis i.e., use the NCAR graphics preprocessor option, ICENT is input as 1. If the post processor option is desired (as in this case), ICENT is assigned a value of 0. ICENT is not required if NPLOT is less than 1.

**Records 2 and 3** — Records 2 and 3 are not required as IGO = 0.

**Note: Sample case 2 in this section demonstrates how to order a RAMP2 flowfield.**

**Record 4** — The problem title is input on Record 4 and may be any 72-character alphanumeric name.

**Record 5** — This record contains the input options necessary to control program execution. The flowfield type is specified by IOPT(1) and for this case is input as 1 for axisymmetric flow. Continuum and free molecular heating rate calculations are desired, thus IOPT(2) is 0. The limit of uniform flow assumptions is given by IOPT(3). It is assumed that the elemental areas are in uniform flow (IOPT(3) = 3). The SPAS-01 satellite was divided into 10 subshapes (IOPT(4) = 10). IVAPN and IPROP are both set to 0 since ISCTAM is 1. IOPT(5) indicates the type of output desired. In this case IOPT(5) = 0 as data for each elemental area and full distribution information is required on each subshape. A value of 0 for IOPT(7) indicates the number of species to be input for boundary layer calculations.

**Note: The number of species and their mole fractions can be obtained from the RAMP2 output file. Not required if using an SFPGEN plume flowfield.**

IOPT(8) is required to scale the desired chamber pressure to that actually used to generate the flowfield. No scaling is needed, therefore IOPT(8) is 0. Columns 38 and 39 determine the method used to calculate the pressure force on the impinged body. The plume loading only option is desired. Zero was input in column 38 (therefore, column 39 is left blank). A zero is also input in column 40 as one case is being executed. The type of local impact pressure is specified using IOPT(9). The modified Newtonian option is used (IOPT(9) = 2) in this sample case.

**Note: Record 14 provides an opportunity to override this selection for each individual subshape.**

A detailed printout of the intermediate steps used in the calculation procedure at each subshape may be obtained by inserting into IOPT(10) the number of subshapes for which the printout is desired. Since this produces a large amount of data, IOPT(10) was input as 0. IOPT(11) is the plot control flag. Columns 51-55 determine the number of parameters and the way they would be presented on the plots. No plots are required for this case, therefore columns 51-55 are left blank. The number of the computer execution is inserted in IOPT(12) and is 1. The units for PLIMP are defined by IOPT(13). Inches were used in setting up the input file for this sample problem (IOPT(13) = 0). The units used to generate the flowfield are feet (IOPT(14) = 1).

IOPT(15) provides the opportunity to print out local intermediate properties during the pressure and heating rate calculations. This is set to 0 as printout is not desired. Whether the shading option is enabled or not depends on the value of IOPT(16). Shading is required so a value of 1 is inserted in column 80.

**Record 6** — This record defines the relative positions of the engine and reference coordinate systems. The engine position was defined by a vector from the reference coordinate system to the engine coordinate system. Thus, column 65 (ITU) is set to 1. Table 6 outlines the relative location of the engine coordinate system with respect to the composite coordinate system (SPAS-01 CG) for the eight locations presented in Fig. 2. Position 1 was chosen for this case. The $X_{ref}$ axis points towards the engine and results in a value of 712.65 for REC(X). The $Y_{ref}$ axis points away from the engine coordinate system, REC(Y) is −199.98. The value for REC(Z) is 0.0. Since no transfer of moments is required, RECT(X), RECT(Y), and RECT(Z) are left blank. As a result of this, PLIMP will use the integrated impingement forces to calculate the resultant moments about the reference coordinate system. The engine-reference transformation control flag is input in columns 68-70 (ITV). This variable will determine which procedure will be used to transform the reference coordinate system to the engine coordinate system.

**Note: The transformation is always from the reference system to the engine system regardless of the value of ITU (column 65).**

If the three axes angles of rotation are to be specified on Record 7, the value inserted for ITV is the order of this rotation. In this sample problem, ITV = 231, the reference

Table 6: Relative Location of Engine Coordinate System with Respect to the Composite Coordinate System (SPAS-CG)

| Position Number | X (in) | Y (in) | Z (in) |
|---|---|---|---|
| 1 | 712.65 | −199.98 | 0.0 |
| 2 | 952.65 | −199.98 | 0.0 |
| 3 | 952.65 | −919.98 | 0.0 |
| 4 | 1312.65 | −919.98 | 0.0 |
| 5 | 1312.65 | −199.98 | 0.0 |
| 6 | 1312.65 | −199.98 | −420.0 |
| 7 | 1912.65 | −199.98 | 0.0 |
| 8 | 2512.65 | −199.98 | 0.0 |

coordinate is first rotated about the Y axis, then about the Z axis and finally about the X axis.

**Record 7** — The numerical values of the three axes angles of rotation are inserted on this record. The X axis rotation is 0.0 deg, the Y and Z axes rotations are 180 deg and -2.0 deg, respectively. Figure 5 demonstrates these rotations in pictorial form. The values are input in order of X, Y, Z regardless of the rotational order specified by ITV Record 6.

**Record 8** — This record is used to identify the parameters for which plots are desired. It is input only if ITPLOT > 0 (IOPT(11)) on Record 5. In this case, this record is not input.

**Record 9** — Record 9 is the species concentration record. It specifies the mole fractions of the flowfield gas composition when the species are not in the input flowfield file (Unit 8). It is input when IOPT(7) > 0 and IOPT(2) < 2 on Record 5. This record was not used in this case because the input flowfield was generated by SFPGEN.

**Record 10** — Engine references and parameters for non-dimensionalizing are given on Record 10. XTE is the transfer distance from the engine gimbal to the exit plane. This is primarily used when the orientation of the engine coordinate system with respect to the reference system is about the engine gimbal point. The units must be consistent with the units of the ordered flowfield (IOPT(14)). Since no transfer was desired, XTE was input as 0.0. XMIN is the minimum distance from the engine reference system at which impingement calculations are to start. This variable is used to reduce computer execution time. If it is known that no impingement will take place for some distance from the nozzle exit, this distance may be inserted thus eliminating unnecessary calculations. A value of 0.0 was used for XMIN. The engine scale factor (REFERN) can be used to convert a non-dimensionalized plume to dimensional units or to scale the plume. A value of 1.0 was input as neither option was desired. The diameter of the nozzle at the exit plane, RICH, can be used to non-dimensionalize the program output. A value of 1.0 was input to avoid non-dimensionalization. The pressure output can be non-dimensionalized by

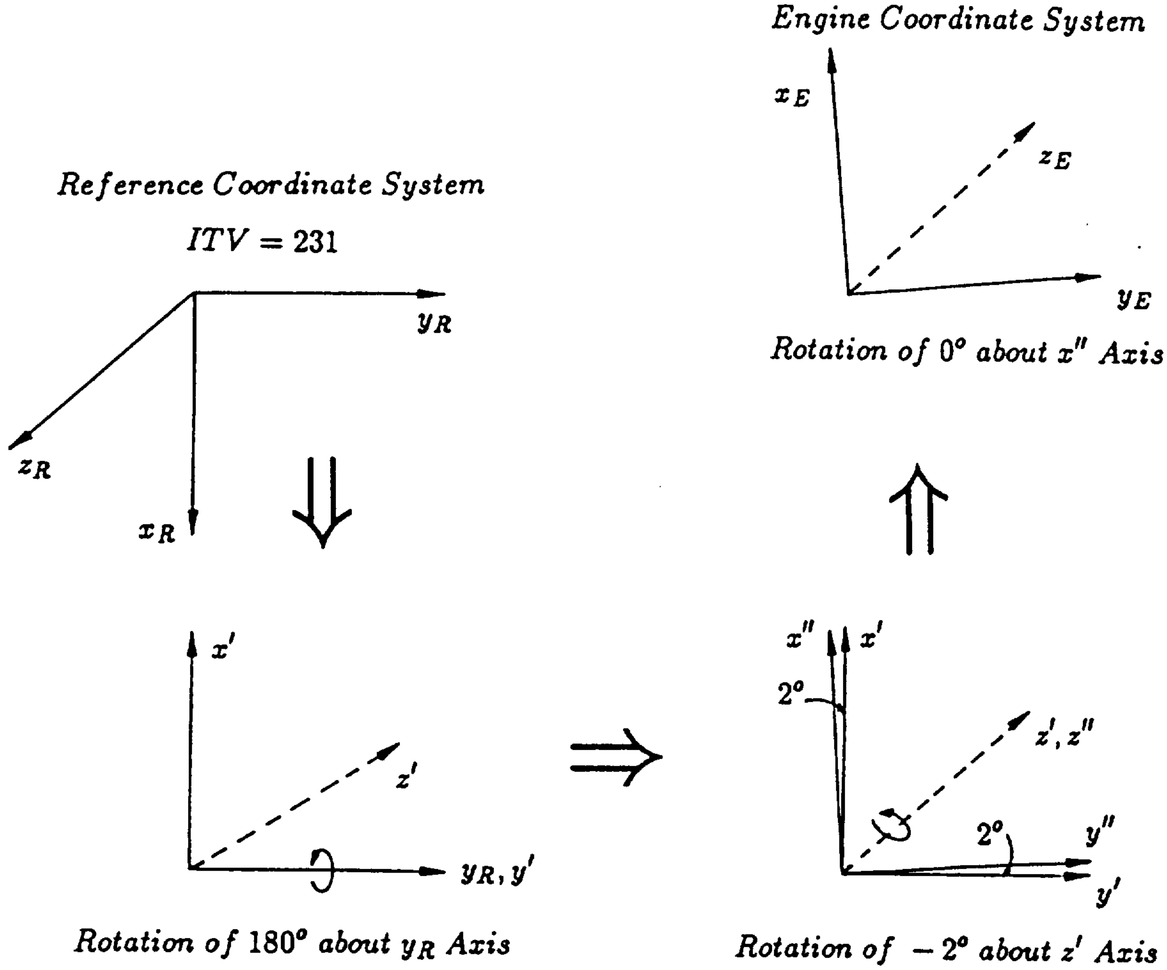


Figure 5: Rotation of the Reference Coordinate System into Alignment with the Engine Coordinate System

the variable PC (engine chamber pressure). PC was assigned a value of 1.0 since non-dimensionalization was not desired. PCRAT is used to change the heating rate values, forces and moments to correspond to a desired plume chamber pressure instead of the actual chamber pressure used to generate the plume flowfield. PCRAT was input as 1.0 as no change is needed. DELPHI allows impingement calculations to be started away from the stagnation line; 0.0 deg was input.

**Record 11** — Conditions external to the flowfield are input on this record. The ambient static pressure, PAMB, is 0.1E-06 psf. The ambient static temperature, TAMB, is 250.0 R. These conditions correspond to an altitude of approximately 300,000 ft. EMAMB is 0.0. The ratio of specific heats (GAMAMB) and the gas constant (RAMB) for the ambient air are 1.4 and 1716.0 $ft^2/sec^2/R$. The Newtonian pressure coefficient, CPN, was input as 2.0.

**Record 12** — Record 12 contains the heating rate reference parameters. A value of 0.0 BTU/lbm was input for CPS (the specific heat for solid particles) since there are no solid particles in this plume. The trajectory time, TAME, is input if surface temperature calculations are to be made. TAME was set to 0.0 seconds. The axial distance (XSTAG) from the subshape origin to the stagnation point is 0.0 in. The temperature (TD) of the gas in the boundary layer at the stagnation point at onset of dissociation is assumed to be 2500 R. The reference radius, RS was input as 1.0 in.; therefore, FUDGE was input as 12.0. The nose shape (SHAP) of the vehicle is a rectangular flat plate (2DFP).

**Records 13a, 13b, and 13c** — Record 13a, the subshape surface temperatures, are input only if heating rate and/or impingement gaseous contaminant calculations are to be performed. The wall temperature, TWAL, for each subshape was set to 500 R. Records 13b and 13c are required only if the user has selected the deposition model (ISCTAM = 2) and has indicated that there is additional surface evaporation rate data for species that are not already included in the internal program data. These records were not used.

**Records 14a, 14b, 14c, and 14d** — Record 14a contains the body reference dimensions, REFL and REFD (reference length and diameter), used to determine the local flow regime for the N subshapes. The properties for three subshapes may be listed on each line. In this sample problem, ten subshapes were listed. Records 14b, 14c and 14d are input in succession for each subshape.

The type of subshape (conic, rectangular plate, circular plate, etc.) are outlined on Record 14b. The SPAS-01 structure was defined using 10 subshapes. Six of these subshapes are rectangular flat plates, the remaining four are triangular subshapes. The 10 subshapes are outlined in Fig. 4 of the SPAS-01 geometry. The first subshape was a flat plate of dimensions 46.0 in. and 166.0 in. Therefore, IDSURF in column 1 is 2. The surface integration controls were selected with three divisions in the Z direction (NPHI = 3) and three divisions in the Y direction (NX = 3). The values chosen for the integration controls are dependent on the problem. The flat plate is composed of 9 (3 x 3) elemental areas as a result of assigning these values to NPHI and NX. The total number of elemental areas per subshape will effect computation time, therefore unnecessary calculations should be avoided.

The type of impingement pressure calculation (if different from the option specified by IOPT(9) on Record 5) is recorded in column 8. For this case column 8 was input as 0, thus the option previously chosen will be used for this subshape i.e., modified Newtonian pressure distribution. Column 9 indicates the heating rate option for each subshape. Since heating rate calculations are not required for this subshape, columns 9 and 10 are both input as 0. The reasoning behind this decision is straightforward. A visual inspection of Fig. 4 shows that this subshape is shaded from the flow by all other subshapes when the engine is located in position 1. The coefficients of the subshape equations are input in columns 11 - 60. The coefficients are defined in the subshape coordinate systems. The value of A is 46.0 in. and B is 166.0 in. Since this subshape is a flat plate; there are no values for C, D, E, XN or XB.

The shading option [IOPT(16)] was flagged on Record 5, therefore Record 14c is required. Zero is input in column 2 of this record. This informs PLIMP that no other subshape will be checked to see if it is shading this one. Although each elemental area comprising this subshape will be checked to determine whether or not it is pointing in the direction of the flow. If they are pointing away from the flow (as in this case), the subshape shades itself.

The final record (in this set) for subshape 1 is a surface temperature identification record. Record 14d was not input for this sample problem.

Subshape 2 is also a flat plate of dimensions 166.0 in. and 28.0 in. The surface integration controls were selected with 15 divisions in the Z direction (NPHI = 15) and 15 divisions in the Y direction (NX = 15). Column 9 was assigned a value of 0 to indicate that heating rate calculations (using the Eckert Reference Enthalpy method, IHT = 2) are to be performed on all elemental areas of this subshape. Again only coefficients A and B are input (A = 166.0, B = 28.0). Subshape 2 is facing the flow direction and the flow impinging upon it is not impeded by any other subshape; therefore, column 2 of Record 14c is 0. Record 14d was not used for this subshape. Records 14b, 14c and 14d are similar for subshapes 3, 4 and 5 as they are also flat plates and are not shaded by other subshapes.

Subshape 6 is a triangular plate (IDSURF = 4). NPHI and NX were both assigned identical values of 10. Therefore the plate was divided into 55 elemental areas. The method used to calculate the impingement pressure remains as input on Record 5. Eckert Reference Enthalpy was chosen as the desired heat transfer method. A and B for subshape 6 were entered as 56.53 in. and 32.5 in., respectively. There are no values for C, D, E, XN or XB.

The flow to subshape 6 may be blocked by subshapes 3, and 8; therefore, 3 was inserted in column 6 of Record 14c, and 8 in column 4. This specifies that subshapes 3 and 8 will be checked to see if they block flow impinging on subshape 6. Record 14d was not used for this subshape.

Subshapes 7, 8 and 9 have similar inputs regarding record 14b. Impingement on subshape 7 may be blocked by subshapes 3, 8 and 9. Therefore, Record 14c for subshape 7 is input as 3 in column 2, 8 in column 4, and 9 in column 6. Similar observation shows that subshape 8 may be impeded by subshapes 3, 7 and 9, while subshape 8 is screened by 3, 6, 7 and 8.

**Note: If the vehicle were comprised of subshapes generated using the conic, circular plate, body of revolution, or trapezoid equations, the coefficients of these subshapes would be input according to the instructions outlined in this input guide (Record 14b).**

**Record 15** — There are 10 subshape position vector records (Record 15) input as a group immediately after Record 14. The origin of each subshape is located by a vector (RCI) from the reference coordinate system to the subshape origin. The units are consistent with IOPT(13) and these records are input in the same order as the subshape geometry data (Record 14). For subshape 1 of the sample problem, the X component of the position vector was input as 3.68. The Y component was input as -0.18 and the Z component as 14.57. All of these distances are in inches. The position vector components indicate the location of the subshape origin. A system of axis rotations must be chosen to define the subshape axis positions and inclinations. A reference-subshape system flag (ITA) is located in columns 33-35 of this record. If column 33 is 0, the direction cosines defining the orientation of the two coordinate systems are input. If ITA is greater than 0, the input is the order of rotation needed to align the axes of the reference system to that of the subshape. It is important at this moment to discuss the significance of subshape coordinate placement. Continuum heating rate results are highly dependent on the proper placement of the subshape origin. Referring to the different subshape descriptions on pages 24–25:

1. The X coordinate must be placed along the body centerline in the general direction of the flow for conic bodies and bodies of revolution.
2. For rectangular flat plates, the coordinate system is located at the geometrical center. It is located at the vertex of the right angle for right triangular plates. For both, the X coordinate must be placed perpendicular to the surface and must be pointing toward the general direction of flow.
3. Circular plates have the coordinate system at the geometric center. The X axis is normal to the plane of the plate. Orientation of the Y, Z axes directions are established by the user.
4. The trapezoid subshape coordinate system must be correctly orientated as shown on page 25 of this guide. The X axis is normal to the surface. The Y and Z axis directions are defined by the user.

**Record 16** — This record contains the subshape direction cosines or the axes angles of rotation. There is one of these records for each subshape. In this problem, the rotation angles have been input for all ten subshapes. It is important to note that no matter in which order the individual rotations are to occur (specified by ITA on Record 15), the angles of rotation are input always in the following order:

1. Rotation about the X axis (columns 1-10)
2. Rotation about the Y axis (columns 11-20)
3. Rotation about the Z axis (columns 21-30)

The rotations for subshape 1 are as follows: the rotation about the X axis was input as 90.0 deg; the Y axis rotation was 0.0 deg; the final rotation is 90.0 deg about the Z axis. Since ITA was 132, the reference coordinate axes are first rotated 90.0 deg about the X axis. The second rotation is also 90.0 deg but about the Z axis this time. The reference coordinate system is now identically oriented with the axes of this subshape. Therefore, the Y axis rotation was specified as 0.0 deg since no more rotations are necessary. The input for subshape 2 was 0.0 in columns 1-10, 11-20, and 21-30. This implies that the reference coordinate axes are aligned with those of subshape 2. ITA (column 33-35 on Record 15) was input regardless of this fact. The angles of rotation for the remaining six subshapes were input according to the order specified on Record 14. The numerical values may be identified from Table 5.

**Record 17** — This is the angular integration control record. This enables PLIMP to limit the calculations to the area of interest on conical subshapes, general bodies of revolution and circular plates. PHIM1 and PHIM2 are defined in the subshape coordinate system. PLIMP calculations will only be performed between these limits. The angle is input in degrees measured in the Y-Z plane from the +Y axis. PHIM1 specifies the angular location at which calculations are to begin, PHIM2 specifies where calculations are terminated. There are as many of these records as there are subshapes. Since the SPAS-01 was described using rectangular flat plates and right triangular plates, 10 blank records are inserted into the input file. It is important to remember that, regardless of the fact that only impingement parameters in the area between PHIM1 and PHIM2 are calculated, the entire 360 deg is used for shading calculation.

**Record 18** — The necessary information to limit the calculations to the areas of interest in the flowfield is input on Record 18. The calculation limits are used to create a box either about the entire flowfield (as in this case) or about a particular portion of the flowfield. PLIMP checks for possible impingement only within the specified limits of this box. This option is important, particularly for high altitude plumes (large plumes). If a subshape is located far downstream from the nozzle exit, these limits would allow PLIMP to avoid the search through unnecessary portions of the flowfield for impingement. For the sample problem the following input was used: columns 1-10 = 100.0, columns 11-20 = −100.0, columns 21-30 = 0.0, columns 31-40 = 0.0, columns 41-50 = 100.0, and columns 41-60 = 90.0. These limits are similar to those used to calculate the RAMP2 plume, the only difference being the downstream cutoff limit (X2) was 25.0 ft. for the RAMP2 calculation. Since the SPAS-01 and the RCS engine are 59.8 ft. apart at position 1, the RAMP2 flowfield is too short for this analysis. The SFPGEN flowfield was used. (Refer to Volume I about SFPGEN flowfield length limitations).

**Record 19** — This record describes the external flow coordinate system, but is not used in this case since column 38 of Record 5 is equal to zero.

**Record 20** — Record 20 was input in columns 1-3 as END. This is used to identify the completion of the input data.

This completes the input file for this sample problem. Selected sample pages of the output are in Appendix A.

## 3.2 Sample Case 2

In order to perform an impingement calculation using a RAMP2 flowfield, the flowfield file (unit 3) must be ordered into a format acceptable to PLIMP. The PLIMP code must be executed using the first 3 records in Table 7. The PLIMP output files, unit 2 and unit 8 can then be saved and used as input for all subsequent PLIMP executions involving this particular flowfield.

Table 7: Sample Case 2 Input

```
      2    0             0    0    1    2  000             0    0    0    0    0    0
    121    0             0    0  346    2    0    0
0.0     .775                  1.0
SPAS-01 RCS Plume Impingement Test - file to create an ordered flowfield
                                    of RCSVOF.UN3
```

**Record 1** — Record 1 of the input data concerns the program control information. The variable IGO determines the type of calculation required. It is set to 2. This informs PLIMP to arrange the RAMP2 flowfield file, but not to perform an impingement analysis. The second input variable, IRUN(4), was set to 0, with IRUN(7) left blank. LRAMP is set to 1 (RAMP2 flowfield file). The RAMP2 plume flowfield was generated using the ideal gas with variable total enthalpy option, therefore IAF(8) is equal to 2. ISPECI, IDSHAD, and IMTRAN are set to 0 respectively as extra output is not required. The next two variables, ISORCG and ISORCP, are set to 0. English units are used to prepare the input file (METRIC = 0) and 132 column format is desired (FORM = 0). The variable NPLOT determines if data for the 3-D NCAR pre/post processing graphics package will be output on unit 9. This option is not required, NPLOT was input as 0. ICENT is not required if NPLOT is less than 1, therefore ICENT is 0.

**Record 2** — Since IGO was set to 2, Record 3 must be input to control the ordering of the plume flowfield. ISTART on column 5 determines the characteristic line number in the flowfield at which the data ordering process will begin. This corresponds to the characteristic line number of the nozzle exit plane and the value is determined by examining the RAMP2 output file (unit 6). ISTART is input as 121. ISIGN concerns MOC generated flowfields and is set to 0 for this case. Points may be deleted from the flowfield by setting IDEL to a value greater than zero. This option was not chosen. No intermediate data is to be printed, so IPRINT is 0. ITERM is the characteristic line number at which the ordering process is to terminate. This value is determined from the RAMP2 output file. It is input as 346 for this flowfield. The cutoff limits specified in the RAMP2 input file (unit 5) are to be used to check if a point is within a prescribed boundary; therefore, ISEND is 2. ISKIP is set to zero since ISEND = 2. No deletion of characteristic lines is required, ISKPL on column 45 is 0.

**Record 3** — Record 3 is used to make any desired coordinate system translations. The variables RREF and XREF were used to move the origin of the flowfield from the nozzle throat to the nozzle exit. RREF was input as 0.0 ft and XREF as 0.775 ft. The units are consistent with the plume dimensions.

Since IDEL (Record 2, column 20) is zero, DELETE is left blank. No points will be deleted from the flowfield. The last variable on this record, DIAM is set to 1.0 (no scaling).

No more data is required to order RAMP2 flowfield files. Although (as in this case) additional information, such as the problem title, may be input as a reminder.

**Note: If IGO = 1 (Record 1, column 5) i.e., arrange the data and perform an impingement analysis, Records 4-20 would be input (according to the particular problem) immediately following the data in this file.**

**Record 20** — END is put in columns 1–3 to end the run.

This completes the input for this sample case. Selected pages of the output are shown in Appendix B.

# Section 4
# REFERENCES


[1] Smith, S. D. and Ratliff, A. W., "Rocket Exhaust Plume Computer Program Improvement," Lockheed Missiles and Space Co. Report, LMSC-HREC D16220, June 1971.

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[3] Dash, S. M., Pergament, H. S., Wolf, D. E., Sinha, N., and Taylor, M. W., "The JANNAF Standardized Plume Flowfield Code Version II (SPF-II)," U. S. Army Missile Command Report CR-RD-SS-90–4, July 1990.

[4] Smith, S. D., "Plume Modeling in Support of Space Station Contamination Model Development," Plumetech Report PT-R004, May 1989.

[5] Wojciechowski, C. J. and Penny, M. M., "Development of High Altitude Plume Impingement Analysis for Calculating Heating Rates, Forces and Moments," Lockheed Missiles and Space Co. Report, LMSC-HREC D162867, March 1971.

[6] Audeh, B. J. and Murph, J. E., "Input Guide for the Plume Impingement Computer Program (PLIMP)," Lockheed Missiles and Space Co. Report, LMSC-HEC TRF225888, June 30, 1988.

[7] Smith, S. D., Burke, R. W., Xiques, K. E., and Freeman, J. A., "Space Station Plume Impingement and Contamination Control Study," Lockheed Missiles and Space Co. Report, LMSC-HEC TRF225887, Dec. 30, 1988.

[8] UNIX Tar Computer Tape of PLIMP and NCAR Grpahics Source Code

[9] Lazaron, M. P. and Alred, J. W., "Results of the SPAS-01RCS Plume Impingement Test," AIAA Paper No. 85-0407, AIAA 23rd Aerospace Sciences Meeting, Reno, NV, Jan. 14-17, 1985.

[10] Smith, S. D., "Development of a Nozzle/Plume and Plume Impingement Code," Final Report Contract No. NAS9-17318, CI-FR-0089, Continuum Inc., Huntsville, AL 35816-3495.

# Appendix A
# SAMPLE CASE 1 OUTPUT

This appendix presents selected pages from the complete output file (UNIT 6) for sample case 1. The program output is organized sot hat the initial pages contain the input data. Impingement data for each subshape is then listed in input order. The calculations were performed in English units. The complete output is 212 pages.

```
1PLIMP INPUT DATA RECORDS ECHOED BELOW:

0RECORD COLUMNS ...
 1   5    10   15   20   25   30   35   40   45   50   55   60   65   70   75
 |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
     0    0         0    0    1    2   000        1    0    0    0    1    0
  SPAS-01 RCS Plume Impingement Test
     1    0    3   10   10    1    0   000   2    000000   1    0    1    0    1
 712.65    -199.98   0.0                                       1  231
 0.0        180.0    -2.00
 0.         0.                 1.        1.        1.        1.        0.
 0.1      -06250.    0.0       1.4       1716.     2.
 0.0        0.0      0.0       2500.     1.0       12.                  2DFP
 500.       500.     500.      500.      500.      500.      500.      500.
 500.       500.
 166.       46.      166.      28.       166.      25.6
 46.        52.      46.       52.       56.3      32.5
 11.9       56.53    56.53     11.9      32.5      56.53
 166.       23.
 2003003000 46.      166.
 00
 2015015002 166.     28.0
 00
 2015015002 166.     25.6
 00
 2003003002 46.      52.
 00
 2015015002 46.      52.
 00
 4010010002 56.53    32.5
  3 8
 4010010002 11.9     56.53
  3 8 9
 4010010002 56.53    11.9
  3 7 9
 4010010002 32.5     56.53
  3 6 7 8
 2003003002 23.      166.
  0
 3.68       -.18     14.57       132
 26.18      -.18     .57         123
 21.67      -.18     -25.43      213
 3.18       82.82    -11.43      312
 3.18       -83.18   -11.43      312
 11.0       10.02    -37.43      123
 11.0       10.02    -37.43      132
 11.0       -10.38   -37.43      123
 11.0       -10.38   -37.43      132
 5.68       -.18     -37.43      213
```

```
90.0      0.0       90.
0.0       0.0       0.0
0.0       20.6      0.0
0.0       0.0       90.
0.0       0.0       -90.
-90.      -31.2     23.45
180.0     -23.45    -31.2
-90.      25.0      23.45
180.0     -23.45    25.0
-90.      90.       0.0
```

```
100.      -100.     0.0       0.0       100.      90.
END
|   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
1   5    10   15   20   25   30   35   40   45   50   55   60   65   70   75

1     LOCKHEED-HUNTSVILLE
```

```
PPPPPPPP    LL            IIIIII   MM       MM  PPPPPPPP
PPPPPPPP    LL            IIIIII   MM       MM  PPPPPPPP
PP      PP  LL              II     MMMM   MMMM  PP      PP
PP      PP  LL              II     MMMM   MMMM  PP      PP
PP      PP  LL              II     MM  MM   MM  PP      PP
PP      PP  LL              II     MM  MM   MM  PP      PP
PPPPPPPP    LL              II     MM       MM  PPPPPPPP
PPPPPPPP    LL              II     MM       MM  PPPPPPPP
PP          LL              II     MM       MM  PP
PP          LL              II     MM       MM  PP
PP          LL              II     MM       MM  PP
PP          LL              II     MM       MM  PP        LMSC
PP          LLLLLLLLLL    IIIIII   MM       MM  PP        /HEC
PP          LLLLLLLLLL    IIIIII   MM       MM  PP        1985

                               A
                         COMPUTER CODE
                            FOR THE
```

```
                         DEFINITION
                             OF
                        ENVIRONMENTS
                          RESULTING
                            FROM

                          PL    IMP
                   EXHAUST PLUME IMPINGEMENT



     ROCKET EXHAUST PLUME IMPINGEMENT ANALYSIS USING
 THE LOCKHEED/HUNTSVILLE PLUME IMPINGEMENT COMPUTER PROGRAM

0   INPUT INSTRUCTIONS:
    IGO= 0   IRUN(4)= 0   IRUN(6)= 0   IRUN(7)= 0
  LRAMP= 1    IAF(8)= 2    ISPECI= 0    IDSHAD= 0
 IMTRAN= 0   IFRTAP= 0    ISOLGS= 1    ISOLGP= 0
 METRIC= 0     FORM= 0      NPLOT= 1      ICENT= 0
1                                                          PAGE    1
 ROCKET EXHAUST PLUME IMPINGEMENT ANALYSIS USING
 THE LOCKHEED/HUNTSVILLE PLUME IMPINGEMENT COMPUTER PROGRAM
0  SPAS-01 RCS Plume Impingement Test
+


 OPTIONS:===>       (1)  (2)  (3)  (4)  (5)  (6)  (7)  (8)  (9) (10) (11) (12) (13) (14) (15) (16)
                     1    0    3   10   10    1    0    0    2    0    0    1    0    1    0    1
0  YOU THE USER HAVE JUDICIOUSLY CHOSEN TO INPUT THE
   ENGINE-REFERENCE SYSTEM POSITION VECTOR IN THE REFERENCE COORDINATE SYSTEM.

0  VECTOR FROM REFERENCE TO ENGINE SYSTEM IN THE REFERENCE COORDINATE SYSTEM.

      RCE(X)         RCE(Y)         RCE(Z)
      0.71265E+03   -0.19998E+03    0.00000E+00

0  THE PROGRAM ASSUMES THE ABOVE VECTOR IS WRITTEN IN THE ENGINE SYSTEM
   THE FOLLOWING TRANSFORMATION IS MADE.
0  VECTOR FROM ENGINE TO REFERENCE SYSTEM IN THE ENGINE COORDINATE SYSTEM :

       REC(X)         REC(Y)         REC(Z)
      0.70524E+03    0.22473E+03    0.00000E+00

0TRANSFORMATION MATRIX FROM THE REFERENCE COORDINATE SYSTEM TO THE ENGINE COORDINATE SYSTEM:
      I(X)          I(Y)          I(Z)          J(X)          J(Y)          J(Z)          K(X)          K(Y)          K(Z)
  -0.99939E+00 -0.34899E-01  0.00000E+00 -0.34899E-01  0.99939E+00  0.00000E+00  0.00000E+00  0.00000E+00 -0.10000E+01

0IPEEP=  1 ITPLOT=  0 FILE UNIT =  0

 PARAMETERS FOR LOADS AND HEATING CALCULATIONS:
```

```
     XTE= 0.00000E+00     XMIN= 0.00000E+00    MOL D= 0.00000E+00    ENG D= 0.10000E+01    NOZ D= 0.10000E+01
      PC= 0.10000E+01    PCRAT= 0.10000E+01   DELPHI= 0.00000E+00

 CONDITIONS EXTERNAL TO PLUME:
    PAMB= 0.10000E-06     TAMB= 0.25000E+03    EMAMB= 0.00000E+00   GAMAMB= 0.14000E+01
    RAMB= 0.17160E+04    CPINF= 0.20000E+01

 HEATING RATE REFERENCE PARAMETERS:
     CPS= 0.00000E+00     TIME= 0.00000E+00    XSTAG= 0.00000E+00       TD= 0.25000E+04
   RSTAG= 0.10000E+01    UNITS= 0.12000E+02   ACOMCF= 0.00000E+00 NZ SHAP= 2DFP
+
1                                                     PAGE    2
+                                           CASE NO.   1
 ROCKET EXHAUST PLUME IMPINGEMENT ANALYSIS USING
 THE LOCKHEED/HUNTSVILLE PLUME IMPINGEMENT COMPUTER PROGRAM
0  SPAS-01 RCS Plume Impingement Test
+
```

WALL TEMPERATURE FOR EACH SUBSHAPE ARE

| SUBSHAPE | TEMPERATURE |
|---|---|
| 1 | 0.50000E+03 |
| 2 | 0.50000E+03 |
| 3 | 0.50000E+03 |
| 4 | 0.50000E+03 |
| 5 | 0.50000E+03 |
| 6 | 0.50000E+03 |
| 7 | 0.50000E+03 |
| 8 | 0.50000E+03 |
| 9 | 0.50000E+03 |
| 10 | 0.50000E+03 |

0THE CHARACTERISTIC LENGTHS TO BE USED TO DETERMINE THE FLOW REGIME WITH RESPECT TO THE SUBSHAPES ARE:

| BODY NO. | REFD | REFL |
|---|---|---|
| 1 | 0.16600E+03 | 0.46000E+02 |
| 2 | 0.16600E+03 | 0.28000E+02 |
| 3 | 0.16600E+03 | 0.25600E+02 |
| 4 | 0.46000E+02 | 0.52000E+02 |
| 5 | 0.46000E+02 | 0.52000E+02 |
| 6 | 0.56300E+02 | 0.32500E+02 |
| 7 | 0.11900E+02 | 0.56530E+02 |
| 8 | 0.56530E+02 | 0.11900E+02 |
| 9 | 0.32500E+02 | 0.56530E+02 |
| 10 | 0.16600E+03 | 0.23000E+02 |

THE FOLLOWING DEFINITIONS MAY BE USEFUL:
IHT = HEATING OPTION.
IS  = SUBSHAPE STRIP HEATING SELECTION OPTION.

```
                                                                   IP  - IMPACT PRESSURE OPTION.
0
                                              COEFFICIENTS OF SUBSHAPE
 BODY NO  TYPE      A          B          C          D          E          XNOSE        XBASE      NPHI  NX IHT IS IP
    1     PLAT 0.46000E+02 0.16600E+03 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00   3    3   0  0  2
               BODY SHADOWING CODE = 0 0 0 0 0 0 0 0 0 0
    2     PLAT 0.16600E+03 0.28000E+02 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00  15   15   2  0  2
               BODY SHADOWING CODE = 0 0 0 0 0 0 0 0 0 0
1                                                      PAGE    3
+                                              CASE NO.    1
 ROCKET EXHAUST PLUME IMPINGEMENT ANALYSIS USING
 THE LOCKHEED/HUNTSVILLE PLUME IMPINGEMENT COMPUTER PROGRAM
0  SPAS-01 RCS Plume Impingement Test
+

0
                                              COEFFICIENTS OF SUBSHAPE
 BODY NO  TYPE      A          B          C          D          E          XNOSE        XBASE      NPHI  NX IHT IS IP
    3     PLAT 0.16600E+03 0.25600E+02 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00  15   15   2  0  2
               BODY SHADOWING CODE = 0 0 0 0 0 0 0 0 0 0
    4     PLAT 0.46000E+02 0.52000E+02 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00   3    3   2  0  2
               BODY SHADOWING CODE = 0 0 0 0 0 0 0 0 0 0
    5     PLAT 0.46000E+02 0.52000E+02 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00  15   15   2  0  2
               BODY SHADOWING CODE = 0 0 0 0 0 0 0 0 0 0
    6     TRIA 0.56530E+02 0.32500E+02 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00  10   10   2  0  2
               BODY SHADOWING CODE = 3 8 0 0 0 0 0 0 0 0
    7     TRIA 0.11900E+02 0.56530E+02 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00  10   10   2  0  2
               BODY SHADOWING CODE = 3 8 9 0 0 0 0 0 0 0
    8     TRIA 0.56530E+02 0.11900E+02 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00  10   10   2  0  2
               BODY SHADOWING CODE = 3 7 9 0 0 0 0 0 0 0
    9     TRIA 0.32500E+02 0.56530E+02 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00  10   10   2  0  2
               BODY SHADOWING CODE = 3 6 7 8 0 0 0 0 0 0
   10     PLAT 0.23000E+02 0.16600E+03 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00   3    3   2  0  2
               BODY SHADOWING CODE = 0 0 0 0 0 0 0 0 0 0
1                                                      PAGE    4
+                                              CASE NO.    1
 ROCKET EXHAUST PLUME IMPINGEMENT ANALYSIS USING
 THE LOCKHEED/HUNTSVILLE PLUME IMPINGEMENT COMPUTER PROGRAM
0  SPAS-01 RCS Plume Impingement Test
+

 POSITIONS OF SUBSHAPES WITH RESPECT TO REFERENCE COORDINATE SYSTEM:
                                  BODY NO       RCI(X)          RCI(Y)          RCI(Z)
                                     1        0.36800E+01    -0.18000E+00     0.14570E+02
                                     2        0.26180E+02    -0.18000E+00     0.57000E+00
                                     3        0.21670E+02    -0.18000E+00    -0.25430E+02
                                     4        0.31800E+01     0.82820E+02    -0.11430E+02
                                     5        0.31800E+01    -0.83180E+02    -0.11430E+02
                                     6        0.11000E+02     0.10020E+02    -0.37430E+02
                                     7        0.11000E+02     0.10020E+02    -0.37430E+02
                                     8        0.11000E+02    -0.10380E+02    -0.37430E+02
                                     9        0.11000E+02    -0.10380E+02    -0.37430E+02
```

10 0.56800E+01 -0.18000E+00 -0.37430E+02

0TRANSFORMATION MATRICES FROM THE SUBSHAPES TO REFERENCE COORDINATE SYSTEM:

| BODY NO | I(X) | I(Y) | I(Z) | J(X) | J(Y) | J(Z) | K(X) | K(Y) | K(Z) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.00000E+00 | 0.00000E+00 | 0.10000E+01 | -0.10000E+01 | 0.00000E+00 | 0.00000E+00 | 0.00000E+00 | -0.10000E+01 | 0.00000E+00 |
| 2 | 0.10000E+01 | 0.00000E+00 | 0.00000E+00 | 0.00000E+00 | 0.10000E+01 | 0.00000E+00 | 0.00000E+00 | 0.00000E+00 | 0.10000E+01 |
| 3 | 0.93606E+00 | 0.00000E+00 | -0.35184E+00 | 0.00000E+00 | 0.10000E+01 | 0.00000E+00 | 0.35184E+00 | 0.00000E+00 | 0.93606E+00 |
| 4 | 0.00000E+00 | 0.10000E+01 | 0.00000E+00 | -0.10000E+01 | 0.00000E+00 | 0.00000E+00 | 0.00000E+00 | 0.00000E+00 | 0.10000E+01 |
| 5 | 0.00000E+00 | -0.10000E+01 | 0.00000E+00 | 0.10000E+01 | 0.00000E+00 | 0.00000E+00 | 0.00000E+00 | 0.00000E+00 | 0.10000E+01 |
| 6 | 0.78472E+00 | 0.47524E+00 | -0.39795E+00 | -0.34039E+00 | -0.20615E+00 | -0.91741E+00 | -0.51803E+00 | 0.85536E+00 | 0.00000E+00 |
| 7 | 0.78472E+00 | 0.47524E+00 | -0.39795E+00 | 0.51803E+00 | -0.85536E+00 | 0.00000E+00 | -0.34039E+00 | -0.20615E+00 | -0.91741E+00 |
| 8 | 0.83145E+00 | -0.38771E+00 | -0.39795E+00 | -0.36066E+00 | 0.16818E+00 | -0.91741E+00 | 0.42262E+00 | 0.90631E+00 | 0.00000E+00 |
| 9 | 0.83145E+00 | -0.38771E+00 | -0.39795E+00 | -0.42262E+00 | -0.90631E+00 | 0.00000E+00 | -0.36066E+00 | 0.16818E+00 | -0.91741E+00 |
| 10 | 0.00000E+00 | 0.00000E+00 | -0.10000E+01 | -0.10000E+01 | 0.00000E+00 | 0.00000E+00 | 0.00000E+00 | 0.10000E+01 | 0.00000E+00 |

WHERE APPLICABLE THE ANALYSIS IS BETWEEN THE INCLUDED ANGLES FOR THE FOLLOWING SUBSHAPES:

| BODY NO | PHI1 | PHI2 |
|---|---|---|
| 1 | 0.00000E+00 | 0.00000E+00 |
| 2 | 0.00000E+00 | 0.00000E+00 |
| 3 | 0.00000E+00 | 0.00000E+00 |
| 4 | 0.00000E+00 | 0.00000E+00 |
| 5 | 0.00000E+00 | 0.00000E+00 |
| 6 | 0.00000E+00 | 0.00000E+00 |
| 7 | 0.00000E+00 | 0.00000E+00 |
| 8 | 0.00000E+00 | 0.00000E+00 |
| 9 | 0.00000E+00 | 0.00000E+00 |
| 10 | 0.00000E+00 | 0.00000E+00 |

//////////////////// PROBLEM LIMITS INFORMATION \\\\\\\\\\

UPPER BOUNDARY: R= 0.10000E+03 X= -0.10000E+03 THETA= 0.00000E+00

LOWER BOUNDARY: R= 0.00000E+00 X= 0.10000E+03 THETA= 0.90000E+02

0 ALL INPUT DATA CARDS HAVE BEEN READ !
+

*** UNITS FOR FINAL PRINTOUT ***

| | |
|---|---|
| DIMENSIONS | FEET OR INCHES |
| ANGLES | DEGREES |
| PRESSURES OR STRESSES | PSIA |
| TEMPERATURES | DEGREES R |
| FLOWRATES | LBM/SEC |
| FORCES | LBF |
| HEAT OR ENERGY RATES | BTU/SEC-FT2 |

```
        NOTE: INPUT PC .NE. 1.0 NON-DIMENS  P IMPACT.


 THE SOURCE FLOW PLUME IS IDENTIFIED AS
    RCS VARIABLE O/F TRANSONIC NOZZLE SOLUTION



 THE GAS THERMODYNAMIC TABLES ARE :
0 GAS PROPERTIES :
         O/F
              S
                     V            R            GAMMA         T             P
   0.00000E+00
          0.00000E+00
                0.00000E+00  0.24986E+04  0.13020E+01  0.60702E+04  0.14422E+05
  THE SPECIE CONCENTRATIONS FROM SOURCE PLUME ARE
  FOR CO        THE MOLE FRACTION IS 0.1190
  THE SPECIE CONCENTRATIONS FROM SOURCE PLUME ARE
  FOR CO2       THE MOLE FRACTION IS 0.0495
  THE SPECIE CONCENTRATIONS FROM SOURCE PLUME ARE
  FOR H         THE MOLE FRACTION IS 0.0095
  THE SPECIE CONCENTRATIONS FROM SOURCE PLUME ARE
  FOR H2        THE MOLE FRACTION IS 0.1637
  THE SPECIE CONCENTRATIONS FROM SOURCE PLUME ARE
  FOR H2O       THE MOLE FRACTION IS 0.3312
  THE SPECIE CONCENTRATIONS FROM SOURCE PLUME ARE
  FOR N2        THE MOLE FRACTION IS 0.3097
  THE SPECIE CONCENTRATIONS FROM SOURCE PLUME ARE
  FOR O         THE MOLE FRACTION IS 0.0012
  THE SPECIE CONCENTRATIONS FROM SOURCE PLUME ARE
  FOR OH        THE MOLE FRACTION IS 0.0113
  THE SPECIE CONCENTRATIONS FROM SOURCE PLUME ARE
  FOR O2        THE MOLE FRACTION IS 0.0027

***  DELETED PAGES 5-8 ***

1                                                              PAGE    9
+                                                    CASE NO.    1
 ROCKET EXHAUST PLUME IMPINGEMENT ANALYSIS USING
 THE LOCKHEED/HUNTSVILLE PLUME IMPINGEMENT COMPUTER PROGRAM
0  SPAS-01 RCS Plume Impingement Test
+
 SUBSHAPE  IY     IZ    SHAPE      X (SUBSHAPE)  Y (SUBSHAPE)  Z (SUBSHAPE)    PLUME X       PLUME R     MACH NO-PLUME
    IN PLUME  SHADED    REGIME       P IMPACT    IMPACT ANGLE  PRESS. FORCE  MASS FLUX-PLM  P-STAT-PLM       ----
     RAD. CIRV.       Q LAMINAR     Q-TURBULENT  REY NO. (FT)   Q TRANSIT    Q FREE MOLEC  SHEAR STRESS    M-LOCAL
 SFLUX(LBM/FT2/SEC)      CO            CO2            H            H2            H2O           N2            O
                         OH            O2
0    2      1      1    PLAT       0.00000E+00  -0.77467E+02  -0.13067E+02  0.68178E+03  0.14675E+03  0.17468E+02
```

```
      YES        NO    CONT        0.14998E-02   0.79250E+02   0.30982E-01   0.63840E-03   0.40814E-05   0.00000E+00
     0.00000E+00   0.28381E+00   0.42793E-01   0.21253E+01   0.00000E+00   0.00000E+00   0.14688E-04   0.14355E+00
                   0.10048E-03   0.65696E-04   0.28926E-06   0.99529E-05   0.17999E-03   0.26174E-03   0.59030E-06
                   0.58175E-05   0.26436E-05
0    2     2     1    PLAT         0.00000E+00  -0.66400E+02  -0.13067E+02   0.68140E+03   0.15777E+03   0.17579E+02
      YES        NO    CONT        0.14599E-02   0.78350E+02   0.30159E-01   0.62400E-03   0.39401E-05   0.00000E+00
     0.00000E+00   0.18203E+00   0.38680E-01   0.66737E+01   0.00000E+00   0.00000E+00   0.10991E-04   0.16755E+00
                   0.97912E-04   0.64015E-04   0.28186E-06   0.96982E-05   0.17539E-03   0.25504E-03   0.57519E-06
                   0.56686E-05   0.25759E-05
0    2     3     1    PLAT         0.00000E+00  -0.55333E+02  -0.13067E+02   0.68101E+03   0.16880E+03   0.17692E+02
      YES        NO    CONT        0.14200E-02   0.77455E+02   0.29334E-01   0.60970E-03   0.38016E-05   0.00000E+00
     0.00000E+00   0.14991E+00   0.37736E-01   0.11746E+02   0.00000E+00   0.00000E+00   0.10159E-04   0.18814E+00
                   0.95348E-04   0.62338E-04   0.27448E-06   0.94442E-05   0.17079E-03   0.24836E-03   0.56013E-06
                   0.55202E-05   0.25084E-05
0    2     4     1    PLAT         0.00000E+00  -0.44267E+02  -0.13067E+02   0.68062E+03   0.17983E+03   0.17808E+02
      YES        NO    TRAN        0.13800E-02   0.76565E+02   0.28509E-01   0.59552E-03   0.36660E-05   0.00000E+00
     0.00000E+00   0.13340E+00   0.37684E-01   0.17264E+02   0.13342E+00   0.15373E+01   0.10027E-04   0.20876E+00
                   0.92797E-04   0.60671E-04   0.26714E-06   0.91915E-05   0.16622E-03   0.24171E-03   0.54514E-06
                   0.53725E-05   0.24413E-05

***  DELETED PAGE 10 ***

1                                                               PAGE   11
+                                                    CASE NO.    1
 ROCKET EXHAUST PLUME IMPINGEMENT ANALYSIS USING
 THE LOCKHEED/HUNTSVILLE PLUME IMPINGEMENT COMPUTER PROGRAM
0  SPAS-01 RCS Plume Impingement Test
+
 SUBSHAPE  IY     IZ     SHAPE     X (SUBSHAPE)   Y (SUBSHAPE)   Z (SUBSHAPE)    PLUME X        PLUME R      MACH NO-PLUME
    IN PLUME  SHADED    REGIME       P IMPACT     IMPACT ANGLE   PRESS. FORCE  MASS FLUX-PLM   P-STAT-PLM        ----
     RAD. CIRV.       Q LAMINAR    Q-TURBULENT    REY NO. (FT)    Q TRANSIT     Q FREE MOLEC   SHEAR STRESS     M-LOCAL
 SFLUX(LBM/FT2/SEC)      CO            CO2              H              H2            H2O             N2             O
                         OH            O2
0    2     15    1    PLAT         0.00000E+00   0.77467E+02  -0.13067E+02   0.67638E+03   0.30131E+03   0.19603E+02
      YES        NO    TRAN        0.89894E-03   0.67052E+02   0.18570E-01   0.42485E-03   0.21462E-05   0.00000E+00
     0.00000E+00   0.99350E-01   0.48650E-01   0.11245E+03   0.10605E+00   0.10234E+01   0.21767E-04   0.61097E+00
                   0.62679E-04   0.40979E-04   0.18043E-06   0.62083E-05   0.11227E-03   0.16326E-03   0.36821E-06
                   0.36288E-05   0.16490E-05

***  DELETED PAGES 12-53 ***

1                                                               PAGE   54
+                                                    CASE NO.    1
 ROCKET EXHAUST PLUME IMPINGEMENT ANALYSIS USING
 THE LOCKHEED/HUNTSVILLE PLUME IMPINGEMENT COMPUTER PROGRAM
0  SPAS-01 RCS Plume Impingement Test
+
 RESULTANT GASEOUS PRESSURE FORCE LOCATION FOR BODY NO.   2 ARE
    CPX =  0.21816669E+01 CPY = -0.62863332E+00 CPZ =  0.47451694E-01
0                                      THE INTEGRATED HEATING RATES ON SUBSHAPE NO.   2 ARE
                                     Q LAMINAR      Q TURBULENT      Q TRANSITION     Q FREE
                                     0.40397E+01    0.13082E+01      0.27850E+01      0.00000E+00
```

0 THE PORTION OF SUBSHAPE NO. 2 EXAMINED IS 0.00000E+00 PERCENT SHADED FROM THE PLUME.

THE RESULTANT GASEOUS FORCES AND TORQUES ON SUBSHAPE NO. 2 ARE:

0

| PRESSURE FORCE COMPONENTS | | | TORQUE COMPONENTS | | |
|---|---|---|---|---|---|
| FORCE (X) | FORCE (Y) | FORCE (Z) | TORQUE (X) | TORQUE (Y) | TORQUE (Z) |
| -0.56139E+01 | 0.00000E+00 | 0.00000E+00 | 0.00000E+00 | -0.26639E+00 | -0.35291E+01 |

0

| SHEAR FORCE COMPONENTS | | | TORQUE COMPONENTS | | |
|---|---|---|---|---|---|
| FORCE (X) | FORCE (Y) | FORCE (Z) | TORQUE (X) | TORQUE (Y) | TORQUE (Z) |
| 0.00000E+00 | 0.60616E-01 | 0.12501E-03 | -0.20937E-02 | -0.27273E-03 | 0.13224E+00 |

0

| TOTAL GASEOUS FORCE COMPONENTS | | | TORQUE COMPONENTS | | |
|---|---|---|---|---|---|
| FORCE (X) | FORCE (Y) | FORCE (Z) | TORQUE (X) | TORQUE (Y) | TORQUE (Z) |
| -0.56139E+01 | 0.60616E-01 | 0.12501E-03 | -0.20937E-02 | -0.26666E+00 | -0.33968E+01 |

0 THE GASEOUS NORMAL AND SHEAR FORCES ON SUBSHAPE NO. 2 ARE

NORMAL FORCE= 0.56139E+01 SHEAR FORCE= 0.60616E-01 LBF OR N

*** DELETED PAGES 55-210 ***

1 PAGE 211

\+ CASE NO. 1

ROCKET EXHAUST PLUME IMPINGEMENT ANALYSIS USING
THE LOCKHEED/HUNTSVILLE PLUME IMPINGEMENT COMPUTER PROGRAM

0 SPAS-01 RCS Plume Impingement Test

\+

THE INTEGRATED HEATING RATES FOR THE BODY OF CASE NO. 1 ARE

| Q LAMINAR | Q TURBULENT | Q TRANSITION | Q FREE | Q PART |
|---|---|---|---|---|
| 0.15450E+02 | 0.56274E+01 | 0.14748E+02 | 0.00000E+00 | 0.00000E+00 |

THE RESULTANT FORCES AND TORQUES ON BODY OF CASE NO. 1 IN THE REFERENCE COORDINATE SYSTEM ARE:

0

| PRESSURE FORCE COMPONENTS | | | TORQUE COMPONENTS | | |
|---|---|---|---|---|---|
| FORCE (X) | FORCE (Y) | FORCE (Z) | TORQUE (X) | TORQUE (Y) | TORQUE (Z) |
| -0.10912E+02 | 0.38347E+00 | 0.21179E+01 | -0.22077E+00 | 0.11193E+02 | -0.66786E+01 |

0

| SHEAR FORCE COMPONENTS | | | TORQUE COMPONENTS | | |
|---|---|---|---|---|---|
| FORCE (X) | FORCE (Y) | FORCE (Z) | TORQUE (X) | TORQUE (Y) | TORQUE (Z) |
| -0.64117E+00 | 0.35381E+00 | -0.31120E+00 | 0.10487E+00 | 0.16130E+01 | -0.21421E+01 |

```
0                    TOTAL GASEOUS FORCE COMPONENTS                                          TORQUE COMPONENTS
                     FORCE(X)        FORCE(Y)        FORCE(Z)         TORQUE(X)        TORQUE(Y)        TORQUE(Z)
                   -0.11554E+02    0.73728E+00    0.18067E+01     -0.11591E+00     0.12805E+02     -0.88207E+01
1                                                                  PAGE     1
+                                                    CASE NO.      1
 ROCKET EXHAUST PLUME IMPINGEMENT ANALYSIS USING
 THE LOCKHEED/HUNTSVILLE PLUME IMPINGEMENT COMPUTER PROGRAM
0 END
+

         ***  UNITS FOR FINAL PRINTOUT  ***

         DIMENSIONS               FEET OR INCHES
         ANGLES                          DEGREES
         PRESSURES OR STRESSES              PSIA
         TEMPERATURES                  DEGREES R
         FLOWRATES                       LBM/SEC
         FORCES                              LBF
         HEAT OR ENERGY RATES       BTU/SEC-FT2

         NOTE: INPUT PC .NE. 1.0 NON-DIMENS  P IMPACT.
```

# Appendix B
# SAMPLE CASE 2 OUTPUT

The following section lists the complete output file (UNIT 6) for sample case 2.

```
1PLIMP INPUT DATA RECORDS ECHOED BELOW:

0RECORD COLUMNS ...
 1   5   10   15   20   25   30   35   40   45   50   55   60   65   70   75
 |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |
     2   0         0    0    1    2  000    0    0    0    0    0    0    0
   121   0         0    0  346    2    0    0
 0.0       .775              1.0
 SPAS-01 RCS Plume Impingement Test  -  file to create an ordered flowfield
                                        of RCSVOF.UN3
 |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |
 1   5   10   15   20   25   30   35   40   45   50   55   60   65   70   75

1      LOCKHEED-HUNTSVILLE


  PPPPPPPP     LL             IIIIII    MM        MM   PPPPPPPP
  PPPPPPPP     LL             IIIIII    MM        MM   PPPPPPPP
  PP       PP  LL               II      MMMM    MMMM   PP       PP
  PP       PP  LL               II      MMMM    MMMM   PP       PP
  PP       PP  LL               II      MM   MM   MM   PP       PP
  PP       PP  LL               II      MM   MM   MM   PP       PP
  PPPPPPPP     LL               II      MM        MM   PPPPPPPP
  PPPPPPPP     LL               II      MM        MM   PPPPPPPP
  PP           LL               II      MM        MM   PP
  PP           LL               II      MM        MM   PP
  PP           LL               II      MM        MM   PP
  PP           LL               II      MM        MM   PP         LMSC
  PP           LLLLLLLLLL     IIIIII    MM        MM   PP         /HEC
  PP           LLLLLLLLLL     IIIIII    MM        MM   PP         1985


                                 A
                           COMPUTER CODE
                              FOR THE
                             DEFINITION
                                 OF
                           ENVIRONMENTS
                             RESULTING
                               FROM

                             PL    IMP
                      EXHAUST PLUME IMPINGEMENT
```

```
     ROCKET EXHAUST PLUME IMPINGEMENT ANALYSIS USING
 THE LOCKHEED/HUNTSVILLE PLUME IMPINGEMENT COMPUTER PROGRAM

0   INPUT INSTRUCTIONS:
    IGO= 2   IRUN(4)= 0   IRUN(6)= 0   IRUN(7)= 0
  LRAMP= 1    IAF(8)= 2   ISPECI= 0    IDSHAD= 0
 IMTRAN= 0   IFRTAP= 0    ISOLGS= 0    ISOLGP= 0
 METRIC= 0     FORM= 0     NPLOT= 0      ICENT= 0


 CONTROLS FOR DATA ORDERING SECTION:
ISTART =121     ISIGN =  1    KNUMBR =300
  IDEL =  0    IPRINT =  0     ITERM =    346
 ISEND =  2     ISKIP =  1
0THE ORDERING OF DATA POINTS WILL BEGIN WITH LINE 121 OF THE FLOW FIELD,
THE VALUES OF R AND THETA WILL BE MULTIPILIED BY  1,
 AND THE DATA WILL BE ARRANGED IN BLOCKS OF 300 POINTS,
  IDEL =  0   INTERMEDIATE PRINT FLAG =  0.
 THE LAST CHARACTERISTIC LINE TO BE CONSIDERED FOR ORDERING
 IS NUMBERED     346.
 THE BOUNDARY SEARCH FLAG IS   2, AND EVERY  1 CHARACTERISTIC LINES WILL BE EXAMINED FOR BOUNDARY PTS.


 FLOWFIELD REFERENCE VALUES:
 RREF  = 0.00000E+00     XREF = 0.77500E+00     DELETE = 0.00000E+00     DIAM = 0.10000E+01
0 THE DATA POINTS WILL BE REFERENCED TO THE POINT DESCRIBED BY THE COORDINATES: R= 0.00000E+00, X= 0.77500E+00
 DELETE= 0.00000E+00 THE FLOW FIELD NON-DIMENSIONAL FACTOR IS  0.10000E+01


 THE FLOWFIELD IS IDENTIFIED BY THE HEADING:
       RCS VARIABLE O/F TRANSONIC NOZZLE SOLUTION
+      ___________________________________________________________
1THERE ARE 25 GROUPS OF DATA WITH A MAXIMUM OF 300 POINTS PER DATA SET.
 RECORD=  1 DMIN= 0.52661419E-01 DMAX= 0.12256330E+00
 RECORD=  2 DMIN= 0.12266330E+00 DMAX= 0.27026173E+00
 RECORD=  3 DMIN= 0.27036172E+00 DMAX= 0.37631851E+00
 RECORD=  4 DMIN= 0.37641850E+00 DMAX= 0.40057245E+00
 RECORD=  5 DMIN= 0.40067244E+00 DMAX= 0.40330794E+00
 RECORD=  6 DMIN= 0.40340793E+00 DMAX= 0.40614972E+00
 RECORD=  7 DMIN= 0.40624970E+00 DMAX= 0.40900537E+00
 RECORD=  8 DMIN= 0.40910536E+00 DMAX= 0.41179702E+00
 RECORD=  9 DMIN= 0.41189700E+00 DMAX= 0.41513333E+00
 RECORD= 10 DMIN= 0.41523331E+00 DMAX= 0.42336410E+00
 RECORD= 11 DMIN= 0.42346409E+00 DMAX= 0.45202675E+00
 RECORD= 12 DMIN= 0.45212674E+00 DMAX= 0.52875483E+00
 RECORD= 13 DMIN= 0.52885485E+00 DMAX= 0.76123536E+00
 RECORD= 14 DMIN= 0.76133537E+00 DMAX= 0.13981986E+01
 RECORD= 15 DMIN= 0.13982986E+01 DMAX= 0.20920904E+01
 RECORD= 16 DMIN= 0.20921903E+01 DMAX= 0.33621724E+01
 RECORD= 17 DMIN= 0.33622723E+01 DMAX= 0.56806517E+01
```

```
RECORD= 18 DMIN= 0.56807518E+01 DMAX= 0.81087122E+01
RECORD= 19 DMIN= 0.81088123E+01 DMAX= 0.10498075E+02
RECORD= 20 DMIN= 0.10498175E+02 DMAX= 0.12829650E+02
RECORD= 21 DMIN= 0.12829750E+02 DMAX= 0.15254921E+02
RECORD= 22 DMIN= 0.15255021E+02 DMAX= 0.17879171E+02
RECORD= 23 DMIN= 0.17879271E+02 DMAX= 0.20145775E+02
RECORD= 24 DMIN= 0.20145874E+02 DMAX= 0.22824936E+02
RECORD= 25 DMIN= 0.22825035E+02 DMAX= 0.24153494E+02
```