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SRB-IIID SOLID ROCKET BOOSTER PERFORMANCE PREDICTION PROGRAM

VOLUME I

ENGINEERING DESCRIPTION/USERS INFORMATION MANUAL

Submitted To:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
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Under Contract NAS8-31644

Submitted By:

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SRB-IIID SOLID ROCKET BOOSTER PERFORMANCE PREDICTION PROGRAM VOLUME I – ENGINEERING DESCRIPTION/USERS INFORMATION MANUAL

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Under Contract NAS8–31644

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FOREWORD

This document presents work performed by Northrop Services, Inc., Huntsville, Alabama, while under contract to the Science and Engineering Directorate of Marshall Space Flight Center (NAS8-31644). This task was conducted in response to the requirements of Schedule Order 1.7.5, Amendment No. 1, Task No. 1. Mr. J. R. Redus, EL-24, is the Technical Coordinator.

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Section I

INTRODUCTION

This document is the combined Engineering/Users Manual for the modified Solid Rocket Booster Performance Evaluation Model (SRB-IIID). The SRB-IIID model was developed as an extension to the internal ballistics module (IBM) of the Boeing developed SRB-II performance program. Because of the similarities of the two models, this manual has been prepared to supplement the original Boeing documentation (References 1 and 2). The reader, therefore, is requested to refer to these documents for the understanding of the general program flow.

Part I of this manual contains the engineering description of SRB-IIID which describes the approach used to develop the IIID concept and an explanation of the modifications which were necessary to implement these concepts. Part II of this manual contains program user information and describes the revised options available to the user of the SRB-IIID program.

This document contains Volume I of three volumes, which describe the SRB-IIID model. Volume II contains a sample SRB-IIID prediction case, and Volume III is the programmers manual containing a brief description of some of the major subroutines, a detailed listing of the program and a cross reference of variables used in the SRB-IIID model.

Section II

PART I - SRB-IIID ENGINEERING DESCRIPTION

2.1 SRB-IIID CONCEPT

The motor configuration upon which the SRB-IIID program calculations are based is divided into three sections (see Figure 2-1): the head end section, the cylindrical section and the aft-end section. The geometry of both the head and aft-end sections is modeled exclusively through the use of tables of burn area as a function of burn distance. The grain geometry in the cylindrical section is defined at several planes which are perpendicular to the motor longitudinal axis. These planes are called reference planes and are used to define propellant grain cross-sectional changes along the length of the cylindrical section of a motor. The propellant surface contained between adjacent pairs of reference planes is then assumed to vary in a linear manner.

The cylindrical section is further divided by the program into a number of increments or mass addition regions by the location of increment dividing planes along the longitudinal axis as shown in Figure 2-2. Values of cross-sectional geometry are determined at the increment dividing planes during the burn modeling by linear interpolation between adjacent pairs of reference planes.

The cylindrical section is usually the longest single portion of a motor and the division of this portion in the manner described above provides a more accurate analytical description of the motor being simulated. The use of increment dividing planes to define mass addition regions allows the program to calculate propellant mass generation times as a function of the burning rate which varies along the length of the cylindrical section.

The purpose of developing the SRB-IIID model was to provide the capability of modeling asymmetrical grain conditions which are likely to exist in large solid rocket motors (such as the Space Shuttle SRB), and to be able to predict the effects of these asymmetries on the resulting performance. Examples of the types of asymmetries include initial geometry dispersions caused by such things

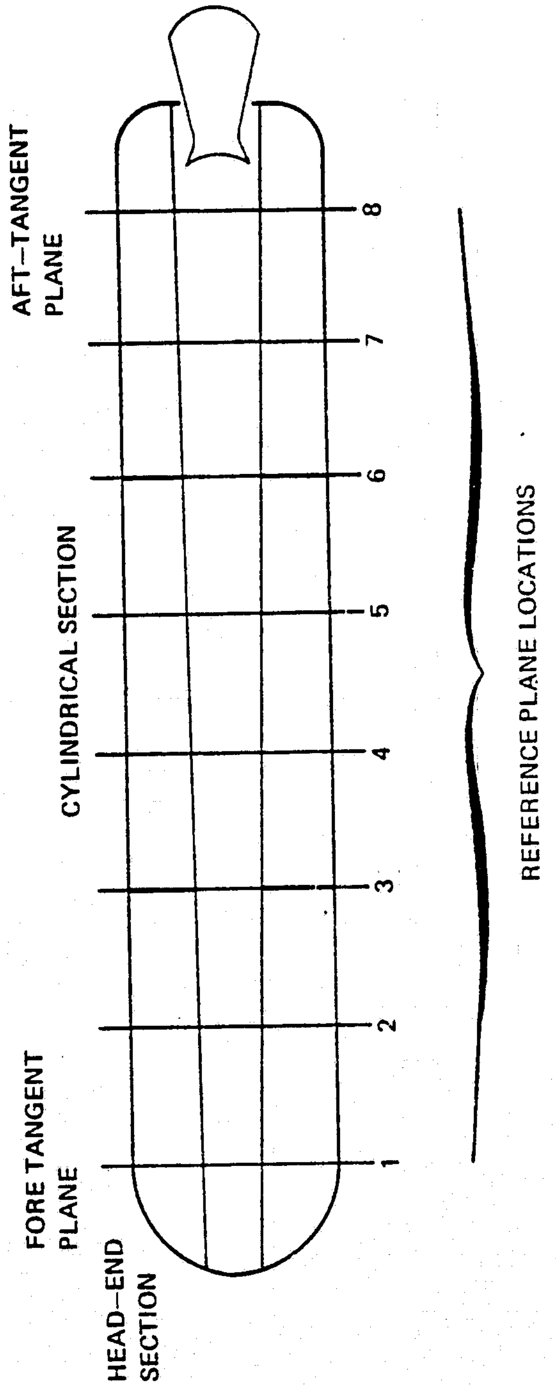


Figure 2-1. MOTOR SIMULATION CONFIGURATION

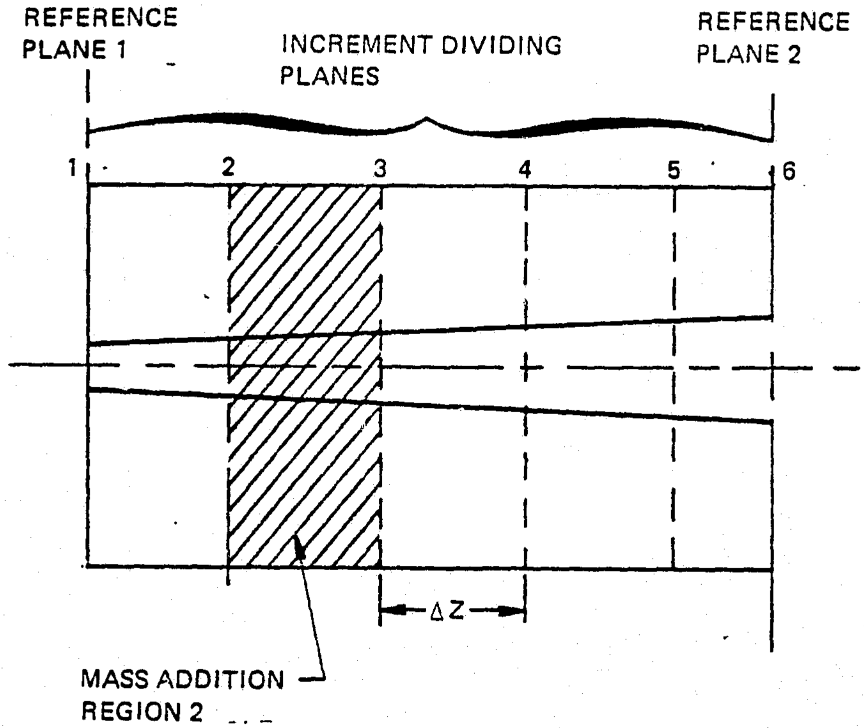


Figure 2-2. INCREMENT DIVIDING PLANE PLACEMENT

as abnormal curing of the grain, mandrel offsets, and so forth; and asymmetrical radial temperature gradients which occur due to a motor's exposure to a particular environment.

The basic method used to model these eccentricities is to further divide the propellant grain in the cylindrical section into circumferential sectors. These sectors are equally spaced subtending angles of $2\pi/n$ (where n is the number of sectors) and the vertex of each sector is on the longitudinal axis of the motor. Each sector is allowed to have discrete local propellant properties which are not necessarily continuous between sectors. Initial sector properties are defined at each input reference plane and are assumed to vary linearly between adjacent reference planes. During the propellant burn modeling, sector properties and their resulting effect on the grain regression are monitored at each reference plane and subsequently at each increment dividing plane.

2.2 SRB-IIID MODELING ASSUMPTIONS

Subsection 2.1 describes how the initial geometry of the motor being simulated is defined for input and subsequently monitored during the burn simulation. Prior to describing the program method of solution, several assumptions which were necessary to translate the physical system into the analytical model contained in SRB-IIID are listed below.

(1) Propellant burning during ignition and steady-state operation occurs normal to the exposed grain surface.

(2) The burn rate in the fore and aft head sections is assumed to be constant over the burning surface of the entire region in the two sections respectively.

(3) Mass addition occurs instantaneously with no velocity component along the motors longitudinal axis.

(4) Pressure and other thermodynamic properties are constant at any increment dividing plane despite discontinuous sector geometry.

(5) No burning occurs at discontinuous (circumferential) sector faces.

(6) The products of combustion obey the perfect gas law.

(7) The gas flow is one-dimensional and adiabatic.

(8) For a given cross-section perpendicular to the motor longitudinal axis, the combustion temperature is constant.

(9) The heat capacity of the combustion gasses is constant.

(10) The friction forces of the combustion gasses in the port cavity are negligible.

2.3 SRB-IIID METHOD OF SOLUTION

The initial grain geometry within the cylindrical section of the motor is described for each sector by defining sector values at the input reference planes. The program reads these input values along with other propellant variables and end section geometry arrays to start the simulation. The program divides the cylindrical section into a number of increments or mass addition regions by the location of increment dividing planes along the longitudinal axis of the motor as mentioned earlier. These increment dividing planes are automatically placed at each input reference plane and then at specified intervals (ΔZ) down the length of the cylindrical section until either a segment slot face (the gap formed when two grain segments are joined) or the next reference plane is passed. During the time solution of the burn simulation the sector port perimeter and sector port area are determined for each sector of each increment dividing plane by linear interpolation between adjacent reference planes. Mass addition is assumed to occur as a step process calculated on an individual sector basis and then summed to provide the total mass addition between two adjacent increment dividing planes.

The macroscopic flow through the SRB-IIID model is shown in Figure 2-3. The program is broken down into two separate and distinct phases. The first phase is the initialization and input phase, and the second phase is the (time-step) internal ballistic solution.

The functions of the first phase are to read the input data, initialize reference plane/sector geometry and burn rate values, place the increment dividing planes in the manner mentioned above, check for input data errors and print the end section and cylindrical section (sector) initial geometry values.

After phase 1 is completed, the internal ballistic solution is initiated by determining the sector geometry values at each reference plane and the

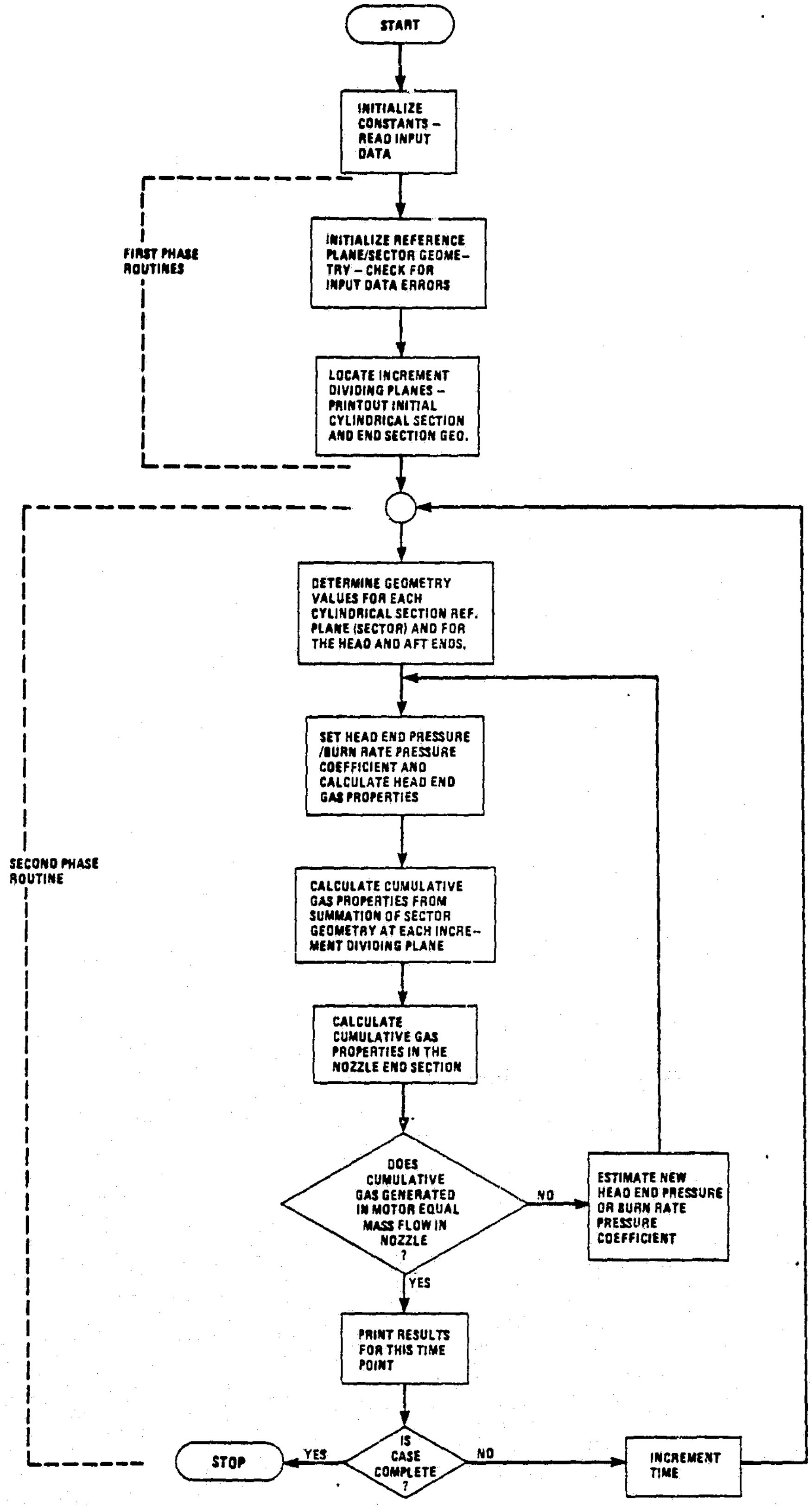


Figure 2-3. SRB-IIID INTERNAL BALLISTICS MACROSCOPIC FLOWCHART

geometry for both end sections using linear interpolation of the input geometry tables (burn area versus distance burned in the end sections and reference plane/sector port perimeter as a function of distance burned in the cylindrical section). The solution proceeds to the calculation of the start transient using input values of head-end pressure as a function of time. An initial estimate of the burn rate pressure coefficient is made, based on the motor configuration parameters and the appropriate (time) value of head-end pressure. This value of the burn rate pressure coefficient is then used in the burn rate law to determine the instantaneous values of mass addition and mass discharge from the head-end section. These values establish the initial thermodynamic conditions for the start of the solution in the cylindrical section.

The solution of the cylindrical section (which is where the IIID modeling concept has been installed) is begun by setting the geometry values in each sector of increment dividing plane 1 equal to the sector values at reference plane 1. Next, a sector burn rate is found as a function of the static pressure at increment dividing plane 1 for each sector being simulated. (The process by which increment dividing plane sector burn rates are established is described in more detail in subsection 2.5 of this manual.)

The values of sector geometry at increment dividing plane 2 are found using linear interpolation between the appropriate sectors of reference planes 1 and 2 (the upstream and downstream reference planes). The increment section mass addition rate is determined for each sector in the mass addition region as a function of sector values of port perimeter at the upstream and downstream increment dividing planes, the increment distance (ΔZ), and the sector burning rate at the upstream adjacent increment dividing plane. Once pertinent variables in each sector being simulated have been calculated in this manner, the resulting sector mass generation rates are summed to produce a total for that mass addition region. (This portion of the solution is done in a similar manner to SRB-II, the only difference is that the calculations are done on a sector basis rather than an entire mass addition region and the sector results are then summed to produce the total for the mass addition region. (Sections 4 and 5 of Reference 3 should be consulted for a more detailed description of the solution within a mass addition region.)

With the total mass generation calculated for the mass addition region, the solving then proceeds to determine the static pressure loss (due to mass generation) and other thermodynamic parameters which are the inlet conditions for the next mass addition region. The sector burn rates for increment dividing plane 2 are then determined, as a function of the static pressure just calculated.

This procedure is then initiated again by interpolating the sector geometry values at the next increment dividing plane and so on until the downstream reference plane is reached. At this point the downstream reference plane becomes the upstream plane and the next reference plane is picked up to continue the solution of the cylindrical section.

Once the solution in the cylindrical section is complete (the aft tangent plane is reached) the same general calculations are performed in the aft-end section, with the exception that a sector solution is not necessary.

Following the solution in the aft end, the flow rate of propellant discharged through the nozzle is computed on the basis of being isentropic (for choked flow) and is then compared with the total propellant discharged from the three sections of motor grain. If these two values do not agree within a specified tolerance, the burn rate pressure coefficient is adjusted and the program returns to the head-end section to solve the entire model over again. This process is repeated until convergence is achieved. Once equilibrium is reached, additional ballistic properties are computed and the motor performance data is printed for the current time point.

Following the motor performance printout the thickness burned during the previous time step in each sector of each increment dividing plane is calculated as a function of the sector burn rates and added to the previous values of sector distance burned. A check is made to detemine if a web burnout has occurred during the previous time in any of the sectors being simulated at each of the increment dividing planes. If a burnout has occurred in any sector, a comment is printed which notes the sector number and increment dividing plane location of the burnout.

The time is incremented by the computed time interval and the program returns to begin the next time point solution.

When the start transient has been completed (determined by the last time point in the input head pressure-time history tables), steady flow conditions are assumed and the burn rate pressure coefficient is held constant (with the exception of modification due to radial gradients, see subsection 2.5) while the head-end pressure is iterated upon to seek equilibrium during each time point solution.

This entire process is repeated for each time point solution until any one of the following criteria is met: the chamber pressure is less than or equal to the ambient pressure, the input value of maximum time is reached, or the propellant is totally expended.

2.4 SRB-II PROGRAM MODIFICATIONS

To facilitate the implementation of the SRB-IIID concept into SRB-II several of the broad capabilities contained in SRB-II were removed. The following list shows the general capabilities which were eliminated.

(1) All theoretical Isp and grain composition calculations
(2) Lewis thermochemical module
(3) Anisotropic burn capability
(4) Inert sliver options
(5) Reconstruction capability
(6) All CG and MOI calculations
(7) Dispersion module
(8) Thrust scaling module
(9) Capability to model totally uninhibited slot interfaces
(10) Capability to model cross sectional shapes other than a circular port in the cylindrical section of the motor.

Once these items and the associated program logic were removed from SRB-II, the next objective was to install the IIID concept in such a way as to leave the remaining program logic unchanged, particularly in the internal ballistics solution. An example of how this was accomplished was briefly described in the previous subsection pertaining to the SRB-IIID method of solution. This involved the solution of sectors of mass addition regions in the cylindrical section, then summing the sector contributions to determine the mass addition region total mass generation and resulting total port geometry prior to performing the gas dynamic solution of the discharge conditions.

2.5 SRB-IIID THEORETICAL EQUATION MODIFICATION

Two areas of calculation which were contained in the original SRB-II modeling logic were modified specifically for use in the SRB-IIID model. These areas pertained to the method of burn rate calculation and to the manner in which the port volume was calculated for use in the mass addition region gas dynamic solution.

The simplified form of the burn rate law which is used in SRB-II is shown in Equation (1) below. (References 2 and 3 should be consulted for a more detailed development of the burn rate law.)

$$r_b = aP^n \qquad (1)$$

where:

r_b is the burn rate

a is the burn rate pressure coefficient

P is the local static pressure

n is the burn rate pressure exponent.

For the purposes of modeling asymmetric radial thermal gradients or grain bulk temperatures which are different from the assumed reference bulk temperature the burn rate pressure coefficient is modified as shown in Equation (2).

$$a' = a*[e^{(\sigma_p(T_G - T_R))}] \qquad (2)$$

where:

a' is the modified burn rate pressure coefficient

a is the original burn rate pressure coefficient e is the exponential function

σ_p is the pressure coefficient temperature sensitivity factor

T_G is the grain temperature present at the burning face

T_R is the reference bulk temperature upon which σ_p is based.

When thermal gradients are being simulated, the sector burn rate is determined as a function of the temperature (T_G) existing in that sector in addition to the static pressure existing at the particular increment dividing plane. The grain temperature in each sector is determined during the burn simulation as a function of the local sector burn face distance from the case wall.

The calculation of port volume within a mass addition region was modified in SRB-IIID to account for asymmetric radial web burn outs. Prior to a web burn out in any sector of a mass addition region, the sector port volume is calculated as a function of port area at the up and downstream increment dividing planes and the increment length as shown in Equation (3) below:

$$V1 = \frac{(A_1 + A_2)}{2} * \Delta Z_1 \qquad (3)$$

where:

V1 is the sector port volume

A_I is the sector port area at the upstream increment dividing plane

A_2 is the sector port area at the downstream increment dividing plane

ΔZ_1 is the increment length

When a web burn out occurs within a sector of a mass addition region, part of the sector between the increment dividing planes which define the mass addition region contains fuel and part of the sector is void of fuel. The ΔZ_1 term in the above equation becomes the length of fuel remaining in the sector mass addition region and a new $\Delta Z'$ is calculated to account for the length within the sector mass addition region which is void of fuel. The new $\Delta Z'$ is the distance from either the upstream increment dividing plane or the downstream plane to the point where the remaining grain intersects the case wall (see Figure 2-4) depending on the direction from which the burn out occurs. The revised port volume calculation is then as shown in Equation (4) below:

$$V_T = \frac{(A_1 + A_2)}{2} * \Delta Z_1 + A_1 * \Delta Z' + A_2 * \Delta Z' \qquad (4)$$

In the above equation one of the last two terms would be zero depending on the direction from which the burn out occurs as shown in Figure 2-4.

2.6 SRB-IIID PROGRAM LIMITATIONS

The SRB-IIID program has the following further limitations in addition to those limitations in SRB-II noted in References 1 and 3.

(1) A maximum of 8 circumferential sectors is used to describe grain asymmetrics.

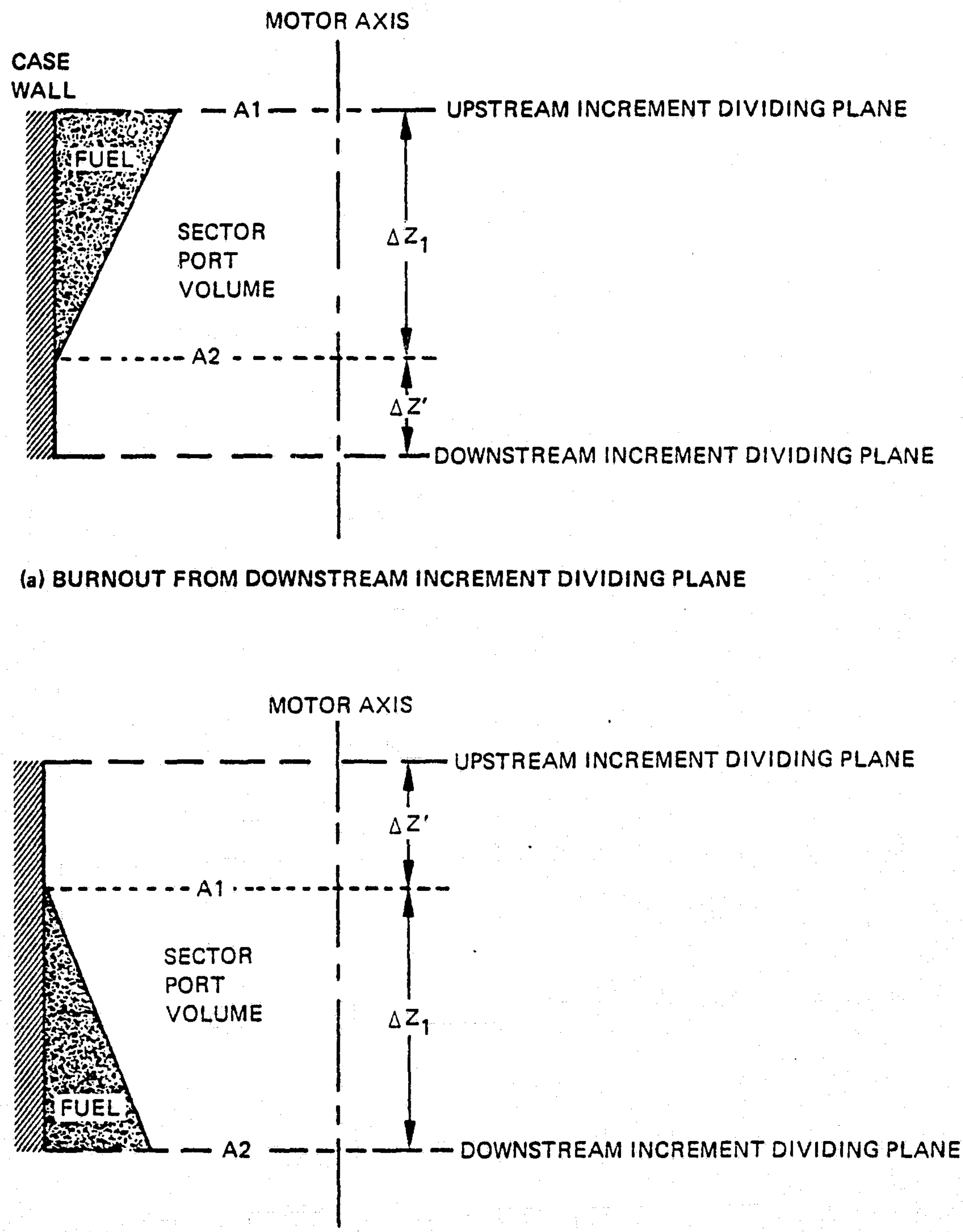
(2) Circular port (with minor deviations) is the only cross sectional configuration allowed in the cylindrical section.

(3) Sector radial gradient inputs are applied equally at all longitudinal locations (no longitudinal variations allowed).

(4) If more than one sector is being simulated, sector initial geometry must be defined for at least sector I of each input reference plane.

(5) Circumferential sector divisions do not apply in the head or aft end sections.

The next portion of this manual further describes the SRB-IIID program and provides information necessary to the user of this program.



(a) BURNOUT FROM DOWNSTREAM INCREMENT DIVIDING PLANE

(b) BURNOUT FROM UPSTREAM MOVEMENT DIVIDING PLANE

Figure 2-4. PARTIAL WEB BURNOUT WITHIN A SECTOR OF A MASS ADDITION REGION

Section III

PART II - SRB-IIID USERS INFORMATION

3.1 PROGRAM INPUT DATA

The input data for the SRB-IIID model consist of variables compiled as an integral part of the program (BLOCK DATA) and data input from punched cards. Punched card input is the prime avenue of input and entered under the two separate NAMELIST data packages described below. SRB-IIID requires no set-format input data cards as required by the Lewis thermochemical routines described in Reference 2 since these routines have been eliminated. The IDNOZL data package has also been eliminated from SRB-IIID. The remaining data packages are arranged on cards as shown in Figure 3-1.

3.1.1 Control Data Package

The control data package denoted by a "CONTROL DATA PACKAGE" control card is composed of NAMELIST data under the name INPUT1 and contains integer constants which control the optional outputs such as plot tapes, punched card outputs, and so forth, and a title header card. The variables included under the NAMELIST name INPUT1 are defined in Reference 2.

3.1.2 IBM Data Package

The data necessary to make an internal ballistics prediction are contained under the "IBM DATA PACKAGE" control card and are entered through the NAMELIST name IBDATA. The variables contained in this data package include motor case and propellant grain geometry factors; propellant properties and burning rate model parameters; non-steady flow, steady-state, and program time control parameters; nozzle parameters and geometry table parameters.

The revised inputs under the NAMELIST name IBDATA which were installed for SRB-IIID are shown in Table 3-1. In addition, several inputs which were formerly available for use in SRB-II and which have been eliminated from SRB-IIID are listed in Table 3-2. The definitions of these parameters can be found in the SRB-II Users Manual (Reference 2).

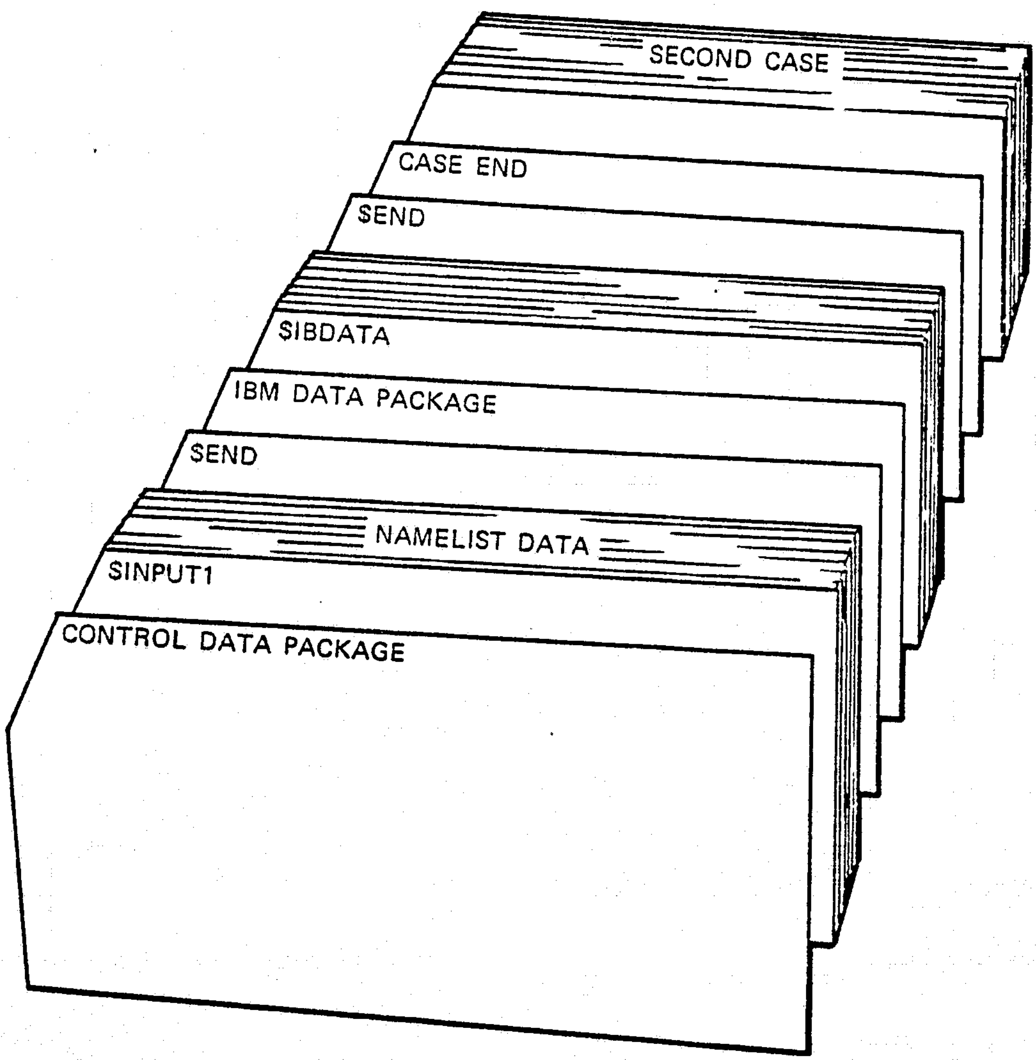


Figure 3-1. INPUT DATA PACKAGE CARD ARRANGEMENT

Table 3-1. SRB-IIID INPUT VARIABLE DEFINITIONS

VARIABLE NAME	DEFINITION
BLKTEM	Grain bulk temperature (°F). Input of this variable > 0 will override any other thermal gradients.
NAKAFT	Number of points in the aft end temperature gradient arrays. Maximum allowable = 25. See TEMAFT(I) and TAUAFT(I).
NAKHED	Number of points in the head-end temperature gradient arrays (TEMHED(I) and TAUHED(I). Maximum allowable = 25.
NSCTRS	Number of circumferential sectors being simulated in the cylindrical section. NSCTRS must always be input if greater than 1.
NTAB(IS)	Number of points in the cylindrical section/sector thermal gradient arrays TABI(N,IS) and TABD(N,IS). Dimensional size is (8) and the maximum allowable points per sector is 25.
REFTEM	Grain bulk reference temperature (°F) used in the burn rate law.
RF(IR,IS)	Array of reference plane/sector outer fuel radii (in.) (see Figure 2-2). Dimensional size is (18,8).
RI(IR,IS)	Array of reference plane/sector inner port radii (in.) (see Figure 2-2). Dimensional size is (18,8).
RPL(I,N)	Formerly TAUPL(I,N) in SRB-II. Distance burned in from the initial port interface (in.). The independent array for the reference plane dependent array ALPPL(I,N). Dimensional size is (50,18).
SIGMAP	Burn rate pressure coefficient temperature sensitivity factor ($°F^{-1}$). This factor is used to modify the value of the burn rate pressure coefficient whenever a grain temperature different than the reference temperature (REFTEM) is being simulated.
TABD(N,IS)	Sector dependent array of radial temperature gradient data (°F). Dimensional size is (25,8). See NTAB(I) and TABI(N,IS).

Table 3-1. SRB-IIID INPUT VARIABLE DEFINITIONS (Concluded)

VARIABLE NAME	DEFINITION
TABI(N,IS)	Sector independent array of distance from the case wall (in.). See NTAB(I) and TABD(N,IS). Dimensional size is (25,8).
TAUAFT(I)	Distance burned (in) from the port interface in the aft-end. The independent array for the aft-end dependent array TEMAFT(I). See NAKAFT and TEMAFT(I). Dimensional size is (25).
TAUHED(I)	Distance burned (in) from the port interface in the head-end. The independent array for the head-end dependent array TEMHED(I). See NAKHED and TEMHED(I). Dimensional size is (25).
TEMAFT(I)	Dependent array of aft-end temperature gradient data (°F). See NAKAFT and TAUAFT(I). Dimensional size is (25).
TEMHED(I)	Dependent array of head-end temperature gradient data (°F). See NAKHED and TAUHED(I). Dimensional size is (25).

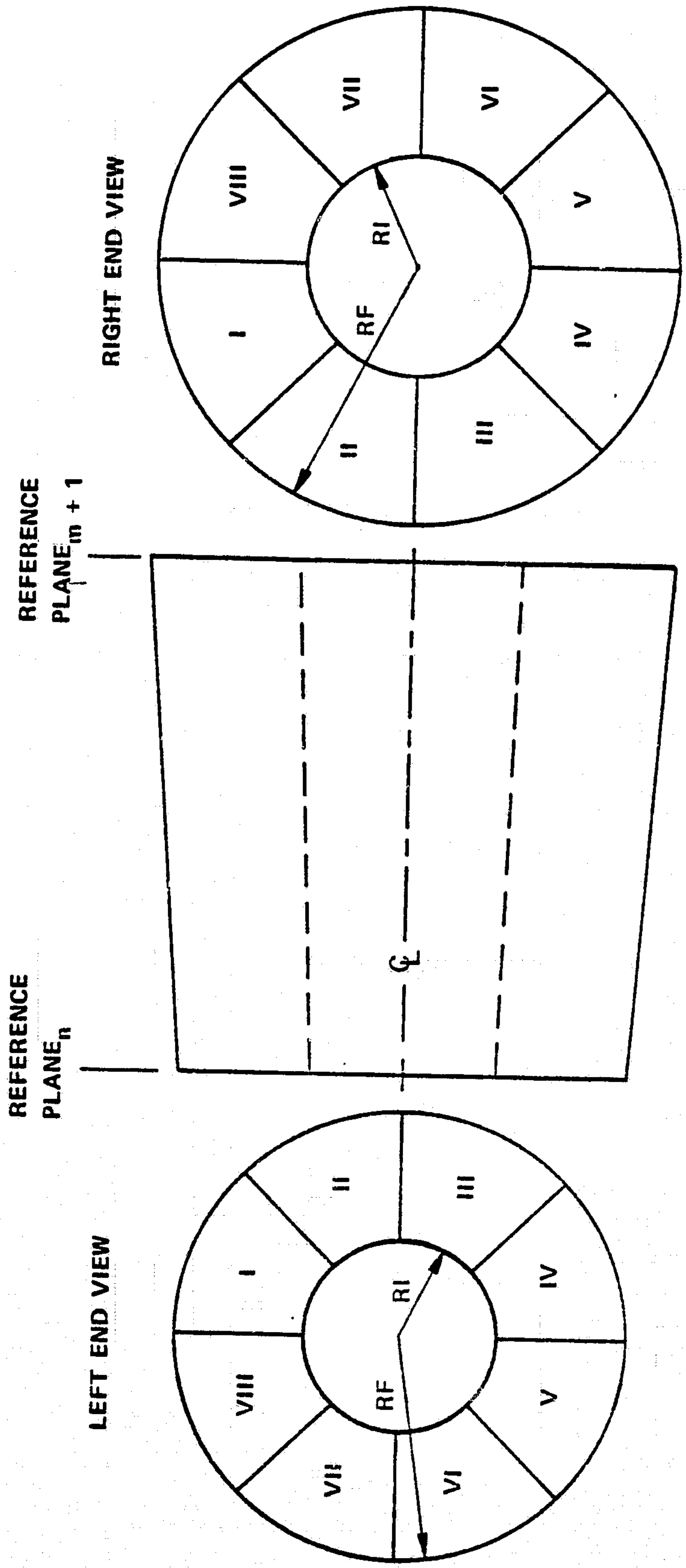


Figure 3-2. SECTOR GEOMETRY DEFINITION

Table 3-2. SRB-II INPUT VARIABLES WHICH HAVE BEEN ELIMINATED IN SRB-IIID

ALS1	ALB	NPUTAB
ALS2	ALE	PMOIHD
TAUW	THO	RMOIHD
A01	TSLVR	XCGHD
A02	DTAU	PMOIN
A03	DTAUW	RMOIN
A04	RIG	XCGN
A05	AK	AKGYP
R2	DRVRF	GEOCON
R3	AKK	PMOINA
R4	AINCPL	PMOINB
R5	RBFLAG	RMOINA
R6	NAKRST	RMOINB
R7	TAUAKR	XCGNA
R8	AKRTAU	XCGNB
ALA	NWRTAB	KMOICG
		GEORUN

3.1.3 SRB-IIID Data Requirements and Options

SRB-IIID has the capability to model from 1 to 8 circumferential sectors in the cylindrical section of the motor. The variable "NSCTRS" must be set to the appropriate value if more than one sector is being simulated. The program assumes that the angle subtended by each sector throughout the entire length of the cylindrical section to be 2π/NSCTRS. The placement of sector I within a given motor is arbitrary, however, care should be exercised by the user to insure that sector properties which are unique are defined in a consistent manner for each input reference plane.

The variable "RF" and "RI" are the only required sector geometry inputs. Values of these variables must be defined for sector I at all input reference planes, even if the grain configuration being simulated is initially symmetrical. To simplify the amount of required input, only the values of the inner radius (RI) and/or the outer radius (RF) of sectors which are different from the values defined for sector I need be input at the respective reference planes.

The only restriction upon the values of RF and RI is that they are assumed to be measured at the angular mid point of the appropriate sector.

The input variables in SRB-IIID which have been established for asymmetrical radial gradients have been specialized to thermal gradients. For the cylindrical section of a motor, these inputs include TABI, TABD, and NTAB (defined in Table 3-1). In the head-end, a single thermal gradient may be input using the arrays TAUHED and TEMHED. In the aft-end a single gradient may also be input using the independent array TAUAFT together with the dependent array TEMAFT. When thermal gradient cases are desired to be simulated, the variable NAKEND (defined in Reference 2) should be used to include either or both of the end-sections.

SRB-IIID also has the capability to model grain bulk temperatures (as opposed to radial thermal gradients) through the specification of the variable BLKTEM in the input. It should be noted, however, when it is desired to simulate radial gradients, BLKTEM should be set to 0.0, since it has a preset value of 60°F which will override any thermal gradient data input.

3.2 CURRENT GRAIN DESIGN INPUT DATA

The basic input data required to simulate the latest SRB grain design are stored in an element file on the SRB-IIID program tape number 07994. This method of storing the input data eliminates the need for a large and cumbersome data deck. The data element (CARDZ) contains the basic input data for the Thiokol TC-227A-75 grain design. The compiled listing of this element is shown in Figure 3-3 and should be referred to whenever it is desired to change, modify or add to this data for a particular simulation.

3.3 SRB-IIID SAMPLE PROGRAM RUN DECK

The following is a list of the card deck needed to execute the SRB-IIID program on the Univac 1108 at MSFC. In all cases the @ symbol (7/8 punch) is in card column 1 and blank spaces are denoted by the symbol ƀ.

```
Card 1 @RUNƀSRB3D,1HNTSV453013,URNAMEBINXXX,XX,XXX/XXX
                               A      B   C  D   E

Card 2 @HDG,P
Card 3 @ASG,TƀSRB3D1,T,07994
Card 4 @FREEƀTPF$.
Card 5 @ASG,TƀTPF$.,F//POS/50
Card 6 @REWINDƀSRB3D1.
Card 7 @COPINƀSRB3D1.,TPF$.
Card 8 @FREEƀSRB3D1.
Card 9 @ELT,ULƀCARDZ
           Data updates as required for specific run (see Figure 3-3
           and the description of card 9 below)
Card 10 @XQTƀPROG
Card 11 @ADD,PƀCARDZ
Card 12 @FIN
```

```
CARDZ

AINKLRBIN2IS.TPFS(0),CARDZ
       CONTROL DATA CARDS
        $INPUT1
        TITLE(1)=6HTC-227,6HA-75  ,6HREVISE,6HD HEAD,6HEND    ,6H4/1/76,6H SRB3D,
        NSCARD=1,
        MITOT=7358.,
        $END
       IBM DATA CARDS
        $IBDATA
        AINCIN(1)=0.0,116.761,116.771,143.919,403.048,427.351,427.061,463.204,726.191,
        746.336,746.346,794.831,854.781,1040.791,1084.171,
        HCO=1384.171,
        ANO(1)=15*0.0,
        RF(1,1)=
        72.384,72.384,72.384,72.314,72.214,72.214,72.214,72.314,72.214,72.214,72.214,
        RF(12,1)=
        72.180,72.130,71.344,71.139,
        RI(1,1)=
        28.727,29.110,29.110,28.980,30.750,31.185,31.185,28.950,30.750,31.185,31.185,
        RI(12,1)=
        30.910,31.567,40.320,41.680,
        SA(1)=116.761,427.051,746.336,
        SB(1)=116.771,427.061,746.346,
        DELZ=15.,
        HHR=201.14,
        SLTBRN(1)=3*3.0,
        KPLANE=15,
        BH=1.,
        AOHM=90.,
        BTAOE=0.0,
        BHI=42.0,
        BN=1.,
        BNI=90.,
        AOHM=90.,
        DLRF=0.01,
        AKU(1)=5000.,
        AKR(2)=0.03783,0.35,
        AKR(36)=0.03783,0.35,
        REFTEM=60.0,
        BLKTEM=0.0,
        SIGMAP=0.000975,
        AKSLOT(1)=0.03783,0.35,
        SLTBRN(1)=3*3.,
        DELF=0.06345,
        CM=0.9595,
        DELH=22.81,
        ERBAR=0.0078,
        EREXP=0.86,
        PONBAR=634.,
        PA=14.778,
        TAUMNA=29.46,
        TAUMNB=20.67,
        HSUBMG=27.854,
        *FCOR=-3335.,
```

Figure 3-3. COMPILER LISTING OF INPUT DATA ELEMENT CARDZ

```
CARDZ

      NPH=5,
      PHST(1)=14.77,405.,810.,840.,860.,
      TIMEPH(1)=0.0,0.25,0.50,0.75,1.0,
      R=55.35,
      NCSTR=7,
      PRESS(1)=0.,200.,400.,600.,800.,1000.,2000.,
      TCOMB(1)=5907.,5984.,6054.,6116.,6163.,2*6191.,
      AMWG(1)=27.96,28.096,28.217,28.322,28.404,2*28.458,
      GAMAG(1)=1.15914,1.15933,1.15953,1.15972,1.15992,2*1.16011,
      CSTR(1)=5072.2,5089.9,5104.7,5116.6,5125.6,2*5131.6,
      STFLAG=1.,
      DELTST=0.25,
      DELTSS=2.0,
      PRTISS=2.0,
      DELTTO=0.50,
      PRTITO=0.5,
      TIMAX=127.,
      ISI=1.,
      ANITW=2.0,
      AN2=17.9,
      THETEX=11.2,
      DE=145.645,
      DT=54.43,
      NCONT=1,
      PRTFLG=1.,
      PHI=29.556,
      NSUBHG=1,
      TA1B(1)=2538.,3514.,4547.,5637.,6783.,7985.,9245.,2*10470.,
      TA2B(1)=853.,1787.,2826.,3884.,5034.,6240.,7417.,2*8666.,
      TAUNB(1)=0.,3.,6.,9.,12.,15.,18.,20.8,50.,
      TRSUB(1)=41.5,43.8,44.6,48.6,48.6,45.0,48.0,
      TXSUB(1)=0.0,1.0,3.0,22.0,40.0,40.5,44.72,
      NPSUB=7,
      NPA=33,
      TIMEPA(1)=0.0,4.,8.,12.,16.,20.,24.,28.,32.,36.,40.,44.,48.,52.,56.,60.,64.,
                68.,72.,76.,80.,84.,88.,92.,96.,100.,104.,108.,112.,116.,120.,124.,
                1000.,
      TBLPA(1)=14.778,14.708,14.493,14.132,13.625,12.972,12.194,11.306,10.326,
               9.306,8.271,7.243,6.264,5.34,4.5,3.736,3.049,2.451,1.944,1.521,1.174,
               0.903,0.681,0.507,0.375,0.278,0.201,0.146,0.104,0.076,0.056,2*0.035,
      NGEUHD=50,
      TAUHD(1)=
         .0000000  ,    .1000000+01,   .2000000+01,   .3000000+01,   .4000000+01,
         .5000000+01,   .6000000+01,   .7000000+01,   .8000000+01,   .8500000+01,
         .8800000+01,   .8810000+01,   .9000000+01,   .9500000+01,   .9810000+01,
         .1000000+02,   .1081000+02,   .1100000+02,   .1181000+02,   .1200000+02,
         .1281000+02,   .1300000+02,   .1400000+02,   .1481000+02,   .1500000+02,
         .1600000+02,   .1681000+02,   .1700000+02,   .1781000+02,   .1800000+02,
         .1881000+02,   .1900000+02,   .1960000+02,   .1963800+02,   .1964800+02,
         .2000000+02,   .2200000+02,   .2400000+02,   .2600000+02,   .2800000+02,
         .3000000+02,   .3200000+02,   .3400000+02,   .3600000+02,   .3800000+02,
         .4000000+02,   .4200000+02,   .4364700+02,   .4365700+02,   .5000000+02,
      ABHD(1)=
         .1963625+06,   .1992819+06,   .1996675+06,   .1997799+06,   .1962201+06,
```

Figure 3-3. COMPILER LISTING OF INPUT DATA ELEMENT CARDZ (Continued)

```
CARDZ
          .1925525+06,  .1892787+06,  .1850205+06,  .1807487+06,  .1766137+06,
          .1719924+06,  .1704647+06,  .1551024+06,  .1457076+06,  .1439015+06,
          .1405634+06,  .1268905+06,  .1238614+06,  .1122951+06,  .1096236+06,
          .9819881+05,  .9551628+05,  .8141196+05,  .7066291+05,  .6738955+05,
          .5368681+05,  .4348506+05,  .4127281+05,  .3281297+05,  .3104130+05,
          .2456551+05,  .2312928+05,  .1844226+05,  .1818823+05,  .1812474+05,
          .17928915+05, .17271091+05, .15551291+05, .14270041+05, .13251059+05,
          .11729036+05, .10348896+05, .90286500+04, .75671199+04, .60107009+04,
          .44499825+04, .28806650+04, .36115848+03, .76293945-05, .00000,
     NGEOMN=22,
     TAUN(1)=0.,2.,4.,6.,8.,10.,12.,14.,16.,17.,18.,19.,20.,20.670,21.,22.,23.,24.,
     26.,28.,29.46,50.,
     ABNA(1)=9279.,9608.,9979.,10351.,10656.,10988.,11397.,11729.,12088.,12239.,
     12389.,12559.,12729.,12450.,10500.,6649.,5500.,4646.,2892.,1148.,2*0.0,
     ABNB(1)=14209.,14696.,14768.,14487.,13964.,13263.,12289.,11300.,9726.,8650.,
     7390.,5500.,3050.,9*0.0,
     VCHINP=3362642.14,
     VCNINP=1040420.,
     VCNINA=441001.,
     VCNINB=599419.,
     VFNO=2831295.1,
     VFNO=505126.,
     VFNOA=264736.,
     VFNOB=240390.,
     NGEO(1)=32,
     NGEO( 2)=    24,
     NGEO(3)=24,
     NGEO(4)=24,
     NGEO( 5)=    23,
     NGEO( 6)=    23,
     NGEO( 7)=24,
     NGEO( 8)=24,
     NGEO( 9)=    23,
     NGEO(10)=    23,
     NGEO(11)=23,
     NGEO(12)=23,
     NGEO(13)=    23,
     NGEO(14)=    18,
     NGEO(15)=    19,
     APORT(1)=
                                        0.25926E 04,0.26622E 04,0.26622E 04,
     0.26384E 04,0.29706E 04,0.30552E 04,0.30552E 04,0.26330E 04,0.29706E 04,
     0.30552E 04,0.30552E 04,0.30316E 04,0.31305E 04,0.51073E 04,0.54576E 04,
     RPL   (1,1)=0.,1.,2.,3.,4.,5.,6.,7.,8.,8.8,9.,10.,11.,12.,14.,16.,18.,19.6,20.,
     22.,24.,26.,28.,30.,32.,34.,36.,38.,40.,42.,43.647,43.657,
     ALPPL(1,1)=180.5,186.8,193.1,199.4,205.6,211.9,218.2,224.5,230.8,235.8,237.1,
                243.3,249.6,255.9,268.5,281.0,293.6,299.9,306.2,318.7,331.3,343.9,
                356.4,369.0,381.6,394.1,406.7,419.3,431.8,444.4,454.7,0.0,
     RPL(1,2)=
     0.0          , 0.20000E 01, 0.40000E 01, 0.60000E 01, 0.80000E 01, 0.10000E 02,
     0.12000E 02, 0.14000E 02, 0.16000E 02, 0.18000E 02, 0.20000E 02, 0.22000E 02,
     0.24000E 02, 0.26000E 02, 0.28000E 02, 0.30000E 02, 0.32000E 02, 0.34000E 02,
     0.36000E 02, 0.38000E 02, 0.40000E 02, 0.42000E 02, 0.43264E 02, 0.43274E 02,
     ALPPL(1, 2)=
```

Figure 3-3. COMPILER LISTING OF INPUT DATA ELEMENT CARDZ (Continued)

```
CARDZ
      0.18290E 03, 0.19547E 03, 0.20804E 03, 0.22060E 03, 0.23317E 03, 0.24574E 03,
      0.25830E 03, 0.27087E 03, 0.28343E 03, 0.29600E 03, 0.30857E 03, 0.32113E 03,
      0.33370E 03, 0.34627E 03, 0.35883E 03, 0.37140E 03, 0.38397E 03, 0.39653E 03,
      0.40910E 03, 0.42166E 03, 0.43423E 03, 0.44680E 03, 0.45474E 03, 0.0          ,
      RPL  (1,3)=0.,2.,4.,6.,8.,10.,12.,14.,16.,18.,20.,22.,24.,26.,28.,30.,32.,34.,
      36.,38.,40.,42.,43.324,43.334,
      ALPPL(1,3)=248.5,235.2,232.2,234.6,240.6,251.2,262.6,272.6,283.3,291.4,296.7,
                 307.0,315.3,321.7,327.4,335.8,339.9,345.2,349.5,264.7,-118.2,-346.2,
                 -454.0,0.0.
      RPL  (1,4)=0.,2.,4.,6.,8.,10.,12.,14.,16.,18.,20.,22.,24.,26.,28.,30.,32.,34.,
      36.,38.,40.,42.,43.324,43.334,
      ALPPL(1,4)=182.1,194.7,207.2,219.8,232.4,244.9,257.5,270.1,282.6,295.2,307.8,
                 320.3,332.9,345.5,358.0,370.6,383.2,395.7,408.3,420.9,433.4,446.0,
                 454.0,0.0.
      RPL(1,5)=
      0.0          , 0.20000E 01, 0.40000E 01, 0.60000E 01, 0.80000E 01, 0.10000E 02,
      0.12000E 02, 0.14000E 02, 0.16000E 02, 0.18000E 02, 0.20000E 02, 0.22000E 02,
      0.24000E 02, 0.26000E 02, 0.28000E 02, 0.30000E 02, 0.32000E 02, 0.34000E 02,
      0.36000E 02, 0.38000E 02, 0.40000E 02, 0.41463E 02, 0.41464E 02,
      ALPPL(1, 5)=
      0.19887E 03, 0.21144E 03, 0.22400E 03, 0.23657E 03, 0.24913E 03, 0.26170E 03,
      0.27427E 03, 0.28683E 03, 0.29940E 03, 0.31197E 03, 0.32453E 03, 0.33710E 03,
      0.34967E 03, 0.36223E 03, 0.37480E 03, 0.38736E 03, 0.39993E 03, 0.41250E 03,
      0.42506E 03, 0.43763E 03, 0.45020E 03, 0.45367E 03, 0.0          ,
      RPL(1,6)=
      0.0          , 0.20000E 01, 0.40000E 01, 0.60000E 01, 0.80000E 01, 0.10000E 02,
      0.12000E 02, 0.14000E 02, 0.16000E 02, 0.18000E 02, 0.20000E 02, 0.22000E 02,
      0.24000E 02, 0.26000E 02, 0.28000E 02, 0.30000E 02, 0.32000E 02, 0.34000E 02,
      0.36000E 02, 0.38000E 02, 0.40000E 02, 0.41019E 02, 0.41029E 02,
      ALPPL(1, 6)=
      0.19594E 03, 0.20851E 03, 0.22107E 03, 0.23364E 03, 0.24621E 03, 0.25877E 03,
      0.27134E 03, 0.28391E 03, 0.29647E 03, 0.30904E 03, 0.32160E 03, 0.33417E 03,
      0.34674E 03, 0.35930E 03, 0.37187E 03, 0.38444E 03, 0.39700E 03, 0.40957E 03,
      0.42214E 03, 0.43470E 03, 0.44727E 03, 0.45367E 03, 0.0          ,
      RPL  (1, 7)=0.,2.,4.,6.,8.,10.,12.,14.,16.,18.,20.,22.,24.,26.,28.,30.,32.,34.,
      36.,38.,40.,42.,43.354,43.364,
      ALPPL(1, 7)=369.9,377.2,387.3,396.5,403.9,413.8,415.6,420.2,428.2,434.4,442.4,
                  450.2,457.1,463.8,355.4,155.8,52.5,-36.7,-129.4,-228.9,-320.1,
                  -413.4,-454.3,0.0.
      RPL  (1, 8)=0.,2.,4.,6.,8.,10.,12.,14.,16.,18.,20.,22.,24.,26.,28.,30.,32.,34.,
      36.,38.,40.,42.,43.354,43.364,
      ALPPL(1, 8)=181.9,194.5,207.0,219.6,232.2,244.7,257.3,269.9,282.4,295.0,307.6,
                  320.1,332.7,345.3,357.8,370.4,383.0,395.5,408.1,420.7,433.2,445.8,
                  454.3,0.0.
      RPL(1,9)=
      0.0          , 0.20000E 01, 0.40000E 01, 0.60000E 01, 0.80000E 01, 0.10000E 02,
      0.12000E 02, 0.14000E 02, 0.16000E 02, 0.18000E 02, 0.20000E 02, 0.22000E 02,
      0.24000E 02, 0.26000E 02, 0.28000E 02, 0.30000E 02, 0.32000E 02, 0.34000E 02,
      0.36000E 02, 0.38000E 02, 0.40000E 02, 0.41454E 02, 0.41464E 02,
      ALPPL(1, 9)=
      0.19321E 03, 0.20577E 03, 0.21834E 03, 0.23091E 03, 0.24347E 03, 0.25604E 03,
      0.26861E 03, 0.28117E 03, 0.29374E 03, 0.30631E 03, 0.31887E 03, 0.33144E 03,
      0.34400E 03, 0.35657E 03, 0.36914E 03, 0.38170E 03, 0.39427E 03, 0.40684E 03,
      0.41940E 03, 0.43197E 03, 0.44454E 03, 0.45367E 03, 0.0          ,
```

Figure 3-3. COMPILER LISTING OF INPUT DATA ELEMENT CARDZ (Continued)

```
CARDZ

      RPL(I,10)=
      0.0         , 0.20000E 01, 0.40000E 01, 0.60000E 01, 0.80000E 01, 0.10000E 02,
      0.12000E 02, 0.14000E 02, 0.16000E 02, 0.18000E 02, 0.20000E 02, 0.22000E 02,
      0.24000E 02, 0.26000E 02, 0.28000E 02, 0.30000E 02, 0.32000E 02, 0.34000E 02,
      0.36000E 02, 0.38000E 02, 0.40000E 02, 0.41019E 02, 0.41029E 02,
      ALPPL(I,10)=
      0.19594E 03, 0.20851E 03, 0.22107E 03, 0.23364E 03, 0.24621E 03, 0.25877E 03,
      0.27134E 03, 0.28391E 03, 0.29647E 03, 0.30904E 03, 0.32160E 03, 0.33417E 03,
      0.34674E 03, 0.35930E 03, 0.37187E 03, 0.38444E 03, 0.39700E 03, 0.40957E 03,
      0.42214E 03, 0.43470E 03, 0.44727E 03, 0.45367E 03, 0.0         ,
      RPL   (I,11)=0.,2.,4.,6.,8.,10.,12.,14.,16.,18.,20.,22.,24.,26.,28.,30.,32.,
      34.,36.,38.,40.,41.019,41.029,
      ALPPL(I,11)=349.4,349.5,354.6,362.5,371.6,380.8,385.7,393.5,403.2,412.3,420.7,
                  428.9,437.7,446.2,367.2,219.3,147.0,87.6,5.9,-130.2,-338.3,-453.5,
                  0.0,
      RPL   (I,12)=0.,2.,4.,6.,8.,10.,12.,14.,16.,18.,20.,22.,24.,26.,28.,30.,32.,
      34.,36.,38.,40.,41.26,41.27,
      ALPPL(I,12)=194.2,206.8,219.4,231.9,244.5,257.0,269.6,282.2,294.7,307.3,319.9,
                  332.4,345.0,357.6,370.1,382.7,395.3,407.8,420.4,433.0,445.5,453.5,
                  0.0,
      RPL(I,13)=
      0.0         , 0.20000E 01, 0.40000E 01, 0.60000E 01, 0.80000E 01, 0.10000E 02,
      0.12000E 02, 0.14000E 02, 0.16000E 02, 0.18000E 02, 0.20000E 02, 0.22000E 02,
      0.24000E 02, 0.26000E 02, 0.28000E 02, 0.30000E 02, 0.32000E 02, 0.34000E 02,
      0.36000E 02, 0.38000E 02, 0.40000E 02, 0.40553E 02, 0.40563E 02,
      ALPPL(I,13)=
      0.19834E 03, 0.21091E 03, 0.22347E 03, 0.23604E 03, 0.24861E 03, 0.26117E 03,
      0.27374E 03, 0.28631E 03, 0.29887E 03, 0.31144E 03, 0.32400E 03, 0.33657E 03,
      0.34914E 03, 0.36170E 03, 0.37427E 03, 0.38684E 03, 0.39940E 03, 0.41197E 03,
      0.42454E 03, 0.43710E 03, 0.44967E 03, 0.45314E 03, 0.0         ,
      RPL(I,14)=
      0.0         , 0.20000E 01, 0.40000E 01, 0.60000E 01, 0.80000E 01, 0.10000E 02,
      0.12000E 02, 0.14000E 02, 0.16000E 02, 0.18000E 02, 0.20000E 02, 0.22000E 02,
      0.24000E 02, 0.26000E 02, 0.28000E 02, 0.30000E 02, 0.31014E 02, 0.31024E 02,
      ALPPL(I,14)=
      0.25334E 03, 0.26590E 03, 0.27847E 03, 0.29104E 03, 0.30360E 03, 0.31617E 03,
      0.32874E 03, 0.34130E 03, 0.35387E 03, 0.36644E 03, 0.37900E 03, 0.39157E 03,
      0.40413E 03, 0.41670E 03, 0.42927E 03, 0.44183E 03, 0.44820E 03, 0.0         ,
      RPL(I,15)=
      0.0         , 0.20000E 01, 0.40000E 01, 0.60000E 01, 0.80000E 01, 0.10000E 02,
      0.12000E 02, 0.14000E 02, 0.16000E 02, 0.18000E 02, 0.20000E 02, 0.20790E 02,
      0.20800E 02, 0.22800E 02, 0.24800E 02, 0.26800E 02, 0.28800E 02, 0.29449E 02,
      0.29459E 02,
      ALPPL(I,15)=
      0.26188E 03, 0.27445E 03, 0.28702E 03, 0.29958E 03, 0.31215E 03, 0.32471E 03,
      0.33728E 03, 0.34985E 03, 0.36241E 03, 0.37498E 03, 0.38755E 03, 0.39251E 03,
      0.39257E 03, 0.40514E 03, 0.41771E 03, 0.43027E 03, 0.44284E 03, 0.44692E 03,
      0.0         ,
      ABN(I)=23488.,24304.,24747.,24838.,24620.,24251.,23686.,23029.,21814.,20889.,
             19779.,18059.,15779.,12450.,10500.,6649.,5530.,4646.,2892.,1148.,2*0.0,
      $END
     CASE END
```

Figure 3-3. COMPILER LISTING OF INPUT DATA ELEMENT CARDZ (Concluded)

The following is a brief description of each control card listed above.

Card 1

This is the run card of which two are required for each run on the MSFC/U1108 computer. The user should insert his name in space A , his bin number in space B , an estimate of the run time (recommended ≈ 10 minutes) in space C , estimated printer page output (≈ 500) in space D and an estimate of the punched cards output (if any is desired) in space E . In addition, it should be remembered that SRB-IIID requires 40K words of core storage which should be entered on run card number 2 (green card).

Card 2

This card is optional and causes the run date and page numbers to be printed at the start of each page of printed output.

Card 3

The third card defines the filename (SRB3D1) and tape number (07994) which contain the SRB-IIID program. Tape number 07994 should also be noted in the appropriate space on run card No. 2.

Card 4

Card 4 releases the temporary program file (TPF$) storage area.

Card 5

The fifth card redefines the TPF$ storage and expands it for the SRB-IIID program.

Card 6

This card causes the tape to be rewound to the beginning of the SRB3D1 program file.

Card 7

Card 7 reads the entire contents of SRB3D1 into TPF$.

Card 8

Card 8 causes the tape containing SRB3D1 to be rewound and releases the tape unit used for this file.

Card 9

This card signifies that the data element CARDZ is going to be updated, and that a listing of the entire element including updates, will be produced. To update this data element, the user is referred to Figure 3-3 which contains the element listing. Two examples of how this element could be updated are shown below.

(1) Change the value of an input variable card currently on the element file.

```
@ELT,UL CARDZ
-29,29
 KPLANE = 16,
```

(2) Add values not contained in CARDZ

```
@ELT,UL CARDZ
-23
 RI(10,6) = 31.385,
```

Card 10

The tenth card causes the absolute element of SRB-IIID to be executed.

Card 11

Card 11 causes the updated data element (CARDZ) to be added to the run-stream.

Card 12

This card signifies that the end of the program deck has been reached. Two of these cards are required on each deck.

3.4 PROGRAM PRINTED OUTPUT

The following paragraphs describe the SRB-IIID program output.

3.4.1 Input Data and Initial Values Printout

The input data and initial values printouts are standard forms of output for every SRB-IIID run. The input data printout duplicates the data element (including updates) and is done on a case by case basis. The initial values printout, as shown in Figure 3-4, lists values for constants, indicators and the inert mass schedule for the case to be executed. In addition to these items, the initial cylindrical section geometry is listed for each sector being simulated at each reference plane, as are geometry values input and calculated in the end regions.

3.4.2 Motor Performance Data Printout

Motor performance data are printed at the end of each computation time step. This printout, as shown in Figure 3-5, is identical to that provided for SRB-II with the exception that the total vacuum specific impulse (Isp) parameter has been added for SRB-IIID,

3.4.3 Increment Dividing Plane Data Printout

The increment dividing plane printout follows the motor performance data printout at each time step and is not optional. This print provides the user with detailed performance data of the mass addition regions in the cylindrical section as well as the head and aft ends (see Figure 3-6). The following list defines the parameters given for each increment dividing plane.

MASS ADDITION REGIONS	The longitudinal location of the downstream increment dividing plane
PO	Total pressure
P	Static pressure
T	Static temperature
U	Gas velocity
M	Mach number
LP	Port perimeter - (Sum of each sector's contribution)
AP	Port area - (Sum of each sector's contribution)
WDOT	Discharge mass flow rate (sum of each sector's contribution)
DWDOT	Generated mass flow rate - (Sum of each sector's contribution)
DW/DT	Mass buildup in region - (Sum of each sector's contribution)
RB	Sector/IDP average burn rate
TAU	Sector/IDP average burn distance.

```
                    THESE ARE THE INITIAL VALUES FOR CASE    1

                               PROGRAM CONSTANTS

    CURVE FIT CONSTANTS
    CSCOEF(1)=    4735.2300
    CSCOEF(2)=    .95469550-01
    CSCOEF(3)=   -.35990200-04

    INERT MASS CURVE FIT COEFFICIENTS
    COEINT(1)=    .00000000
    COEINT(2)=    1.7724571
    COEINT(3)=   -2.1492405
    COEINT(4)=    1.1124630
    COEINT(5)=    .26027876

    GENERAL PROGRAM INDICATORS
    LISTI=          T
    NCARD =         0
    NCASES=         1
    NF    =         1
    NLEWIS=         7
    NPLOT =         0
    NSI   =         4
    NTAPE =         0
    NSTAPE=         0
    NSCARD=         1

    INERT MASS ISP(SII)=    195.00000

    TOTAL INERT MASS(MITOT)=    7358.3000
```

Figure 3-4. SAMPLE SRB-IIID INITIAL VALUES PRINTOUT

CYLINDRICAL SECTION INITIAL GEOMETRY

SECTOR FUEL RADIUS (RF)

SECTOR / RP	1	2	3	4	5	6	7	8
1	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840
2	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840
3	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840
4	72.3140	72.3140	72.3140	72.3140	72.3140	72.3140	72.3140	72.3140
5	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140
6	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140
7	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140
8	72.3140	72.3140	72.3140	72.3140	72.3140	72.3140	72.3140	72.3140
9	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140
10	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140
11	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140
12	72.1800	72.1800	72.1800	72.1800	72.1800	72.1800	72.1800	72.1800
13	72.1300	72.1300	72.1300	72.1300	72.1300	72.1300	72.1300	72.1300
14	71.3440	71.3440	71.3440	71.3440	71.3440	71.3440	71.3440	71.3440
15	71.1390	71.1390	71.1390	71.1390	71.1390	71.1390	71.1390	71.1390

CYLINDRICAL SECTION INITIAL GEOMETRY

SECTOR PORT RADIUS (RI)

SECTOR / RP	1	2	3	4	5	6	7	8
1	28.7270	28.7270	28.7270	28.7270	28.7270	28.7270	28.7270	28.7270
2	29.1100	29.1100	29.1100	29.1100	29.1100	29.1100	29.1100	29.1100
3	29.1100	29.1100	29.1100	29.1100	29.1100	29.1100	29.1100	29.1100
4	28.9800	28.9800	28.9800	28.9800	28.9800	28.9800	28.9800	28.9800
5	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500
6	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850
7	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850
8	28.9500	28.9500	28.9500	28.9500	28.9500	28.9500	28.9500	28.9500
9	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500
10	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850
11	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850
12	30.9100	30.9100	30.7100	30.9100	30.9100	30.9100	30.9100	30.9100
13	31.5670	31.5670	31.5670	31.5670	31.5670	31.5670	31.5670	31.5670
14	40.3200	40.3200	40.3200	40.3200	40.3200	40.3200	40.3200	40.3200
15	41.6800	41.6800	41.6800	41.6800	41.6800	41.6800	41.6800	41.6800

Figure 3-4. SAMPLE SRB-IIID INITIAL VALUES PRINTOUT (Continued)

CYLINDRICAL SECTION INITIAL GEOMETRY

SECTOR PORT AREA (APRTSC)

RP \ SECTOR	1	2	3	4	5	6	7	8
1	324.0750	324.0750	324.0750	324.0750	324.0750	324.0750	324.0750	324.0750
2	332.7750	332.7750	332.7750	332.7750	332.7750	332.7750	332.7750	332.7750
3	332.7750	332.7750	332.7750	332.7750	332.7750	332.7750	332.7750	332.7750
4	329.8000	329.8000	329.8000	329.8000	329.8000	329.8000	329.8000	329.8000
5	371.3250	371.3250	371.3250	371.3250	371.3250	371.3250	371.3250	371.3250
6	381.9000	381.9000	381.9000	381.9000	381.9000	381.9000	381.9000	381.9000
7	381.9000	381.9000	381.9000	381.9000	381.9000	381.9000	381.9000	381.9000
8	329.1250	329.1250	329.1250	329.1250	329.1250	329.1250	329.1250	329.1250
9	371.3250	371.3250	371.3250	371.3250	371.3250	371.3250	371.3250	371.3250
10	381.9000	381.9000	381.9000	381.9000	381.9000	381.9000	381.9000	381.9000
11	381.9000	381.9000	381.9000	381.9000	381.9000	381.9000	381.9000	381.9000
12	375.2000	375.2000	375.2000	375.2000	375.2000	375.2000	375.2000	375.2000
13	391.3125	391.3125	391.3125	391.3125	391.3125	391.3125	391.3125	391.3125
14	638.4125	638.4125	638.4125	638.4125	638.4125	638.4125	638.4125	638.4125
15	682.2000	682.2000	682.2000	682.2000	682.2000	682.2000	682.2000	682.2000

CYLINDRICAL SECTION INITIAL GEOMETRY

SECTOR PORT PERIMETER (ALPSEC)

RP \ SECTOR	1	2	3	4	5	6	7	8
1	22.5625	22.5625	22.5625	22.5625	22.5625	22.5625	22.5625	22.5625
2	22.8625	22.8625	22.8625	22.8625	22.8625	22.8625	22.8625	22.8625
3	31.0625	31.0625	31.0625	31.0625	31.0625	31.0625	31.0625	31.0625
4	22.7625	22.7625	22.7625	22.7625	22.7625	22.7625	22.7625	22.7625
5	24.8588	24.8588	24.8588	24.8588	24.8588	24.8588	24.8588	24.8588
6	24.4925	24.4925	24.4925	24.4925	24.4925	24.4925	24.4925	24.4925
7	46.2375	46.2375	46.2375	46.2375	46.2375	46.2375	46.2375	46.2375
8	22.7375	22.7375	22.7375	22.7375	22.7375	22.7375	22.7375	22.7375
9	24.1512	24.1512	24.1512	24.1512	24.1512	24.1512	24.1512	24.1612
10	24.4925	24.4925	24.4925	24.4925	24.4925	24.4925	24.4925	24.4925
11	43.6750	43.6750	43.6750	43.6750	43.6750	43.6750	43.6750	43.6750
12	24.2750	24.2750	24.2750	24.2750	24.2750	24.2750	24.2750	24.2750
13	24.7925	24.7925	24.7925	24.7925	24.7925	24.7925	24.7925	24.7925
14	31.6675	31.6675	31.6675	31.6675	31.6675	31.6675	31.6675	31.6675
15	32.7350	32.7350	32.7350	32.7350	32.7350	32.7350	32.7350	32.7350

Figure 3-4. SAMPLE SRB-IIID INITIAL VALUES PRINTOUT (Continued)

```
HEAD END
 DEI            RE             ADEH           NEND            DELH
   4.2000000+01   1.0000000+00   9.0000000+01       1            2.2810000+01
 REI            ALFEM          ALFE           RE2            HEI             HE2             HEO             HEM
   2.1000000+01   1.5737963+00   1.2764448+00   2.1000000+01   0.0000000      6.9270798+01    6.9270798+01    6.9270798+01
 VFEO           VCE            TAUEO          TAUEI          CAE             CBE             CCCE            CCVE
   0.0000000      7.9213087+05   8.6249240+01   0.0000000      0.0000000      0.0000000       2.0957773+04    0.0000000
 CDCE           CDVE           CECE           CEVE
   8.8022648+05   8.4000000+01   9.2423789+06   2.0957773+04

NOZZLE END
 DEI            RE             ADEH           NEND            DELH
   9.0000000+01   1.0000000+00   9.0000000+01       2            2.2810000+01
 REI            ALFEM          ALFE           RE2            HEI             HE2             HEO             HEM
   4.5000000+01   1.5737963+00   8.8593657-01   4.5000000+01   0.0000000      5.5097706+01    5.5097706+01    7.7907706+01
 VFEO           VCE            TAUEO          TAUEI          CAE             CBE             CCCE            CCVE
   2.8312951+06   1.0634843+06   6.0983642+01   0.0000000      0.0000000      0.0000000       2.0243029+04    0.0000000
 CDCE           CDVE           CECE           CEVE
   1.8218776+06   1.8000000+02   4.0992133+07   2.0243029+04
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Figure 3-4. SAMPLE SRB-IIID INITIAL VALUES PRINTOUT (Concluded)

IGNITION TIME, TIME (S) 91.500000

PARAMETER DESCRIPTION (UNITS)	PROGRAM NOMENCLATURE	INTERNATIONAL	ENGLISH
MOTOR PARAMETERS:			
TOTAL DELIVERED THRUST (N,LBF)	FTDEL	10725797.	2456216.8
TOTAL VACUUM THRUST (N,LBF)	FTVAC	11005269.	2474082.8
THRUST CONTRIBUTION OF INERTS (N,LBF)	FI	50062.804	11254.566
DELIVERED TOTAL IMPULSE (N*S,LBF*S)	SRMDTI	.92230696+09	.20736084+09
TOTAL VACUUM SPECIFIC IMPULSE (S,S)	TISP	256.86414	256.86414
VACUUM TOTAL IMPULSE (N*S,LBF*S)	SRMVTI	.97139043+09	.21837726+09
THRUST COEFFICIENT	CF	1.6248756	1.6248756
GRAIN DISCHARGE MASS FLOWRATE (KG/S,LBM/S)	WDOT	4342.0758	9572.6385
FLOWRATE INTEGRAL (KG,LBM)	SWDOTN	382227.54	842667.48
INERT MASS FLOWRATE (KG/S,LBM/S)	MIF	26.868344	59.234558
INERT MASS REMAINING (KG,LBM)	MIR	1075.3748	2370.7756
TOTAL BURN AREA (M**2,IN**2)	ABTOT	263.94333	409112.99
TOTAL PROPELLANT VOLUME (M**3,IN**3)	VF	70.802714	4320646.7
PROPELLANT MASS REMAINING (KG,LBM)	WF	123299.57	271829.03
TOTAL GAS MASS (KG,LBM)	WGTOT	1258.3258	2774.1335
RATIO OF SPECIFIC HEATS	GAMA	1.1597544	1.1597544
MOLECULAR WEIGHT OF GAS (KG/MOLE,LBM/MOLE)	AMW	12.853033	28.336088
CHARACTERISTIC EXHAUST VELOCITY (M/S,FT/S)	CSTAR	1559.8547	5117.6334
MAXIMUM CHAMBER MACH NUMBER	AMPN	.94623807-01	.94623807-01
HEAD END PARAMETERS:			
TOTAL PRESSURE (N/M**2,LBF/IN**2)	PH	.43737724+09	634.36207
PRESSURE INTEGRAL (N*S/M**2,LBF*S/IN**2)	SPHDT	.40999182+11	59464.287
BURN AREA (M**2,IN**2)	AHH	6.9763955	10813.435
BURN RATE (M/S,IN/S)	RBZ(1)	.93789346-02	.36924940
DISTANCE BURNED (M,IN)	TAUZ(1)	.79606555	31.341164
PROPELLANT VOLUME (M**3,IN**3)	VFH	1.4795631	90288.482
GAS VOLUME (M**3,IN**3)	VPH	53.624269	3272353.7
GAS STATIC TEMPERATURE (DEG K,DEG R)	PRNT(1,3)	3402.2608	6124.0694
CYLINDRICAL SECTION PARAMETERS:			
RADIAL BURN AREA (M**2,IN**2)	ABCYL	256.96694	398279.55
SEGMENT FACE BURN AREA (M**2,IN**2)	ABSLOT	.00000000	.00000000
PROPELLANT VOLUME (M**3,IN**3)	VFCYL	69.321250	4230242.2
GAS VOLUME (M**3,IN**3)	VP	218.67090	13344117.
AFT END PARAMETERS:			
TOTAL PRESSURE NOZ ENT (N/M**2,LBF/IN**2)	PON	.42951891+09	622.96452
PRESSURE INTEGRAL (N*S/M**2,LBF*S/IN**2)	SPONDT	.38787616+11	56256.681
BURN AREA (M**2,IN**2)	AAN	.00000000	.00000000
BURN RATE, REGION A (M/S,IN/SEC)	RBZ(NI+1,1)	.93651086-02	.36870506
BURN RATE, REGION B (M/S,IN/SEC)	RBZ(NI+2,1)	.93570785-02	.36838892
DISTANCE BURNED, REGION A (M,IN)	TAUZ(NI+1,1)	.74828400	29.460000
DISTANCE BURNED, REGION B (M,IN)	TAUZ(NI+2,1)	.52501800	20.670000
PROPELLANT VOLUME (M**3,IN**3)	VFN	.19023254-02	116.08702
GAS VOLUME (M**3,IN**3)	VPN	17.047527	1040303.9
GAS STATIC TEMP, NOZ ENT (DEG K,DEG R)	PRNT(NI+2,3)	3400.7742	6121.3936
PORT AREA, NOZ ENT (M**2,IN**2)	A2A	10.208839	15823.733
NOZZLE PARAMETERS:			
THROAT AREA (M**2,IN**2)	AT	1.5768785	2444.1664
EXPANSION RATIO	EPR	6.8163242	6.8163242
PRESSURE RATIO	PEPO	.23055702-01	.23055702-01
MISCELLANEOUS PARAMETERS:			
ANISOTROPIC BURN RATE COEFFICIENT	AKRST	.37810250-01	.37810250-01
NUMBER OF PRESSURE ITERATIONS	ANLOPS	3.0000000	3.0000000

Figure 3-5. SAMPLE MOTOR PERFORMANCE DATA PRINTOUT

INCREMENT DIVIDING PLANE DATA;

MASS ADDITION REGIONS	PO PSIA	P PSIA	T DEG. R	U FT/SEC	M	LP INCHES	AP SQ. IN.	WDOT LB/SEC	DWDOT LB/SEC	DW/DT LB/SEC	RB IN/SEC	TAU IN.	RBTO IN/SEC	TAUTO IN.
FORE	634.36	634.35	6124.07	12.03	.003	377.36	11326.98	258.67	253.20	-5.48	.3690	31.341	.0000	.000
15.000	634.35	634.34	6124.06	18.17	.005	377.62	11343.41	391.24	132.58	.01	.3690	31.306	.0000	.000
30.000	634.35	634.33	6124.05	24.29	.007	377.88	11359.83	523.91	132.67	.01	.3690	31.302	.0000	.000
45.000	634.34	634.31	6124.04	30.40	.009	378.14	11376.22	656.66	132.77	.01	.3690	31.297	.0000	.000
60.000	634.33	634.29	6124.02	36.50	.010	378.41	11392.58	789.50	132.86	.01	.3690	31.292	.0000	.000
75.000	634.32	634.27	6124.00	42.59	.012	378.67	11408.93	922.44	132.95	.01	.3690	31.287	.0000	.000
90.000	634.30	634.23	6123.98	48.66	.014	378.93	11425.24	1055.46	133.04	.01	.3690	31.282	.0000	.000
105.003	634.29	634.20	6123.96	54.72	.015	379.19	11441.54	1188.57	133.12	.01	.3690	31.277	.0000	.000
116.761	634.27	634.17	6123.94	59.47	.017	379.40	11454.30	1293.01	104.44	.01	.3690	31.272	.0000	.000
116.771	634.27	634.17	6123.94	59.65	.017	338.41	11419.51	1293.01	.00	-.00	.3690	31.273	.0000	.000
131.771	634.25	634.13	6123.91	65.37	.019	360.60	11410.40	1415.76	122.74	-.01	.3690	31.273	.0000	.000
143.919	634.24	634.09	6123.88	70.27	.020	370.57	11402.05	1520.87	105.11	.00	.3690	31.266	.0000	.000
158.919	634.21	634.04	6123.85	76.10	.022	379.50	11451.52	1653.97	133.11	.01	.3690	31.260	.0000	.000
173.919	634.18	633.98	6123.81	81.90	.023	380.43	11499.81	1787.38	133.43	.01	.3690	31.254	.0000	.000
188.919	634.15	633.92	6123.77	87.67	.025	381.35	11547.90	1921.12	133.75	.01	.3689	31.248	.0000	.000
203.919	634.12	633.86	6123.73	93.41	.026	382.28	11595.80	2055.18	134.07	.01	.3689	31.242	.0000	.000
218.919	634.08	633.79	6123.69	99.12	.028	383.21	11643.50	2189.56	134.39	.01	.3689	31.236	.0000	.000
233.919	634.05	633.72	6123.64	104.80	.030	384.13	11691.01	2325.26	134.71	.01	.3689	31.230	.0000	.000
248.919	634.01	633.65	6123.60	110.46	.031	385.06	11738.33	2459.27	135.03	.01	.3689	31.224	.0000	.000
263.919	633.97	633.57	6123.55	116.08	.033	385.99	11785.46	2594.61	135.35	.01	.3689	31.218	.0000	.000
278.919	633.92	633.49	6123.49	121.68	.034	386.91	11832.39	2730.27	135.66	.01	.3688	31.211	.0000	.000
293.919	633.88	633.40	6123.44	127.26	.036	387.84	11879.13	2866.25	135.98	.01	.3688	31.205	.0000	.000
308.919	633.83	633.31	6123.38	132.80	.038	388.77	11925.68	3002.54	136.30	.01	.3688	31.198	.0000	.000
323.919	633.78	633.21	6123.32	138.33	.039	389.69	11972.03	3139.15	136.62	.01	.3688	31.191	.0000	.000
338.919	633.72	633.11	6123.26	143.83	.041	390.62	12018.19	3276.08	136.94	.01	.3688	31.184	.0000	.000
353.919	633.67	633.01	6123.20	149.31	.042	391.55	12064.16	3413.33	137.25	.00	.3687	31.178	.0000	.000
368.919	633.61	632.91	6123.14	154.76	.044	392.47	12109.94	3550.89	137.57	.00	.3687	31.171	.0000	.000
383.919	633.55	632.80	6123.07	160.19	.045	393.40	12155.52	3688.78	137.89	.00	.3687	31.164	.0000	.000
398.919	633.49	632.68	6123.00	165.60	.047	394.33	12200.91	3826.97	138.20	.00	.3687	31.156	.0000	.000
403.048	633.47	632.65	6122.98	167.09	.047	394.58	12213.37	3865.07	38.19	.00	.3686	31.149	.0000	.000
418.048	633.42	632.53	6122.90	173.18	.049	392.72	12207.39	4003.18	138.11	.00	.3686	31.147	.0000	.000
427.051	633.38	632.46	6122.85	176.82	.050	391.60	12203.53	4085.75	82.58	.00	.3686	31.141	.0000	.000
427.061	633.34	632.76	6123.31	139.89	.040	95.58	15418.66	4085.76	.02	-.00	.3686	31.166	.0000	.000
442.061	633.47	632.73	6123.09	158.68	.045	212.50	13774.29	4140.08	54.05	-.27	.3687	31.167	.0000	.000
457.061	633.68	632.67	6122.72	185.50	.053	329.43	12054.23	4235.28	95.08	-.13	.3687	31.139	.0000	.000
463.204	633.79	632.62	6122.51	199.77	.057	377.32	11327.96	4286.07	50.78	-.01	.3687	31.098	.0000	.000
478.204	633.71	632.47	6122.42	205.33	.058	377.89	11364.14	4418.56	132.50	.01	.3687	31.077	.0000	.000
493.204	633.63	632.32	6122.33	210.88	.060	378.47	11400.19	4551.24	132.69	.01	.3686	31.068	.0000	.000
508.204	633.55	632.17	6122.24	216.40	.061	379.04	11436.11	4684.11	132.88	.01	.3686	31.059	.0000	.000
523.204	633.46	632.01	6122.14	221.90	.063	379.62	11471.90	4817.17	133.07	.01	.3686	31.049	.0000	.000
538.204	633.37	631.85	6122.05	227.39	.064	380.19	11507.56	4950.42	133.26	.01	.3685	31.039	.0000	.000
553.204	633.28	631.68	6121.95	232.86	.066	380.77	11543.10	5083.86	133.45	.01	.3685	31.030	.0000	.000
568.204	633.19	631.52	6121.85	238.31	.068	381.35	11578.50	5217.49	133.64	.01	.3685	31.020	.0000	.000
583.204	633.09	631.34	6121.74	243.74	.069	381.92	11613.77	5351.31	133.83	.01	.3684	31.010	.0000	.000
598.204	632.99	631.17	6121.64	249.16	.071	382.50	11648.91	5485.32	134.02	.01	.3684	31.000	.0000	.000
613.204	632.89	630.99	6121.53	254.55	.072	383.07	11683.92	5619.51	134.20	.01	.3684	30.990	.0000	.000

Figure 3-6. SAMPLE INCREMENT DIVIDING PLANE PRINTOUT

628.204	632.79	630.81	6121.42	259.94	.074	383.65	11718.80	5753.90	134.39	.01	.3683	30.980	.0000	.000
643.204	632.69	630.62	6121.31	265.30	.075	384.22	11753.54	5888.47	134.58	.01	.3683	30.970	.0000	.000
658.204	632.58	630.43	6121.20	270.65	.077	384.80	11788.16	6023.23	134.77	.01	.3682	30.960	.0000	.000
673.204	632.47	630.24	6121.09	275.99	.078	385.37	11822.65	6158.18	134.95	.01	.3682	30.949	.0000	.000
688.204	632.36	630.04	6120.97	281.31	.080	385.95	11857.01	6293.31	135.14	.00	.3682	30.939	.0000	.000
703.204	632.25	629.84	6120.85	286.62	.081	386.52	11891.24	6428.63	135.32	.00	.3681	30.929	.0000	.000
718.204	632.13	629.63	6120.73	291.91	.083	387.10	11925.34	6564.14	135.51	.00	.3681	30.918	.0000	.000
726.191	632.07	629.52	6120.67	294.73	.083	387.41	11943.44	6636.37	72.23	.00	.3680	30.908	.0000	.000
741.191	631.91	629.31	6120.60	297.80	.084	389.39	12066.30	6772.40	136.04	.00	.3680	30.902	.0000	.000
746.336	631.86	629.24	6120.57	298.86	.085	390.67	12108.13	6819.21	46.82	.00	.3679	30.897	.0000	.000
746.346	631.77	630.03	6121.75	243.58	.069	186.08	14840.05	6819.22	.00	-.00	.3681	30.945	.0000	.000
761.346	631.96	629.95	6121.38	261.85	.074	248.58	13960.34	6895.56	76.14	-.21	.3681	30.946	.0000	.000
776.346	632.19	629.83	6120.92	283.54	.080	311.07	13077.46	6993.73	98.03	-.13	.3681	30.921	.0000	.000
791.346	632.48	629.67	6120.32	309.41	.088	373.57	12191.42	7113.70	119.92	-.06	.3681	30.892	.0000	.000
794.831	632.56	629.62	6120.15	316.12	.090	388.09	11985.11	7144.69	30.99	-.00	.3680	30.856	.0000	.000
809.831	632.41	629.40	6120.04	320.61	.091	389.07	12046.52	7280.80	136.13	.00	.3680	30.850	.0000	.000
824.831	632.27	629.17	6119.93	325.09	.092	390.05	12107.51	7417.23	136.44	.00	.3680	30.841	.0000	.000
839.831	632.13	628.94	6119.81	329.55	.093	391.02	12168.09	7553.99	136.76	-.00	.3679	30.831	.0000	.000
854.781	631.98	628.71	6119.70	333.98	.095	392.00	12228.05	7690.62	136.62	-.00	.3679	30.821	.0000	.000
869.781	631.67	628.47	6119.80	330.23	.094	396.43	12593.74	7828.63	138.01	-.00	.3678	30.812	.0000	.000
884.781	631.38	628.24	6119.88	327.06	.093	400.87	12947.23	7968.17	139.53	-.01	.3677	30.817	.0000	.000
899.781	631.10	628.02	6119.95	324.42	.092	405.30	13288.51	8109.23	141.05	-.01	.3676	30.822	.0000	.000
914.781	630.84	627.80	6120.00	322.26	.091	409.74	13617.58	8251.81	142.57	-.01	.3675	30.824	.0000	.000
929.781	630.59	627.58	6120.04	320.55	.091	414.17	13934.45	8395.90	144.08	-.02	.3674	30.826	.0000	.000
944.781	630.36	627.37	6120.08	319.24	.090	418.61	14239.12	8541.52	145.60	-.02	.3674	30.826	.0000	.000
959.781	630.13	627.17	6120.10	318.31	.090	423.04	14531.58	8688.67	147.12	-.03	.3673	30.826	.0000	.000
974.781	629.92	626.96	6120.11	317.73	.090	427.48	14811.84	8837.37	148.67	-.03	.3673	30.826	.0000	.000
989.781	629.71	626.76	6120.12	317.50	.090	431.91	15079.89	8987.67	150.26	-.04	.3675	30.825	.0000	.000
1004.781	629.51	626.56	6120.12	317.58	.090	436.35	15335.74	9139.64	151.92	-.04	.3679	30.823	.0000	.000
1019.781	629.32	626.36	6120.11	317.97	.090	440.78	15579.38	9293.34	153.66	-.05	.3684	30.823	.0000	.000
1034.781	629.13	626.16	6120.09	318.66	.090	445.22	15810.82	9448.87	155.48	-.05	.3691	30.823	.0000	.000
1040.791	629.05	626.08	6120.08	319.02	.090	446.99	15900.13	9511.73	62.83	-.02	.3695	30.822	.0000	.000
1055.791	629.02	626.01	6120.03	320.96	.091	448.03	15903.59	9570.74	58.90	-.12	.3698	30.483	.0000	.000
1070.791	629.01	626.01	6120.04	320.71	.091	.00	15916.41	9570.98	.00	-.24	.3698	29.942	.0000	.000
1084.171	629.01	626.01	6120.04	320.61	.091	.00	15921.92	9571.32	.00	-.34	.3698	29.459	.0000	.000
AFT(A)	622.97	595.30	6083.92	986.59	.280	.....	15823.73	9572.64	.00	-.80	.3687	29.460	....	.....
AFT(B)	622.95	622.95	6121.39	-.03	.000	.....	10413.12	.52	.00	-.52	.3684	20.670	....	.....

Figure 3-6. SAMPLE INCREMENT DIVIDING PLANE PRINTOUT (Concluded)

If the motor being simulated is segmented, data for the variables listed above will also be included for each slot in the IDP printout. These data are printed for the slot forward and aft interface locations as shown in Figure 3-7.

3.4.4 Diagnostic Data Dumps

The diagnostic data dumps contained in SRB-IIID are the same as those in SRB-II. Users who desire to use those dumps should first consult the SRB-II Users Manual (Reference 2).

3.4.5 Web Burnout Data Printout

When a web burnout occurs in any sector of an increment dividing plane, a statement is printed as shown in Figure 3-8. The contents of this message are described below.

VARIABLE STATEMENT	DEFINITION
WEB BURNOUT INCREMENT LOCATION = XXX.XXX	This is the longitudinal location of the increment dividing plane.
SECTOR NO. = X	This is the sector number where the burnout has occurred.
TAU = XX.XXX	This is the increment dividing plane/sector value of distance burned.
TAUWDP = XX.XXX	This is the increment dividing plane/sector value of the web thickness.
TIME = XX.XX	This is the calculation time point at which the burnout was detected.

In addition to the web burnout statement mentioned above, subroutine PARTBN prints out a message (see Figure 3-8) for sectors of mass addition regions which are partially burned out. The contents of this message are shown below.

TIME = XXX.XX	Time at which PARTBN called
IS = X	Sector number
ZCALC(XXX) = XXX.XX	Downstream increment dividing plane longitudinal location

	SLOT INTERFACE LOCATION IN.	PO PSIA	P PSIA	T DEG. R	U FT/SEC	AP SQ. IN.	DWDOT LB/SEC	AB SQ. IN.	RB IN/SEC	DELTA TAU IN.	WSLOT LB/SEC
FOREWARD	1.1676+02	6.3427+02	6.3417+02	6.1239+03	4.1383+01	1.6460+04	0.0000	0.0000	0.0000	0.0000	1.2930+03
AFT	1.1677+02	6.3427+02	6.3417+02	6.1239+03	4.1383+01	1.6460+04	0.0000	0.0000	0.0000	0.0000	1.2930+03
GAS BUILDUP IN SLOT, DW/DT = -3.0802-04											
FOREWARD	4.2705+02	6.3330+02	6.3246+02	6.1228+03	1.3171+02	1.6383+04	0.0000	0.0000	0.0000	0.0000	4.0858+03
AFT	4.2706+02	6.3360+02	6.3276+02	6.1233+03	1.3166+02	1.6383+04	0.0000	0.0000	0.0000	0.0000	4.0858+03
GAS BUILDUP IN SLOT, DW/DT = -3.0609-04											
FOREWARD	7.4634+02	6.3186+02	6.2924+02	6.1206+03	2.2088+02	1.6383+04	0.0000	0.0000	0.0000	0.0000	6.8192+03
AFT	7.4635+02	6.3265+02	6.3003+02	6.1217+03	2.2064+02	1.6383+04	0.0000	0.0000	0.0000	0.0000	6.8192+03
GAS BUILDUP IN SLOT, DW/DT = -3.0545-04											

Figure 3-7. SAMPLE SLOT PARAMETERS PRINTOUT

```
WEB BURNOUT INCREMENT LOCATION = 1040.7910     SECTOR NO.  2   TAU = 31.0240   TAUWDP = 31.0240   TIME =  81.50
WEB BURNOUT INCREMENT LOCATION = 1040.7910     SECTOR NO.  3   TAU = 31.0240   TAUWDP = 31.0240   TIME =  81.50
*PARTBN* TIME= 82.00 IS=1 ZCALC( 78)=1040.79 ZCALC( 77)=1034.78 AINCW=1040.74 AINCHI=1034.78 DELZ= 5.957 ALP=448.20 ALPHI=446.50
*PARTBN* TIME= 82.00 IS=2 ZCALC( 78)=1040.79 ZCALC( 77)=1034.78 AINCW=1040.23 AINCHI=1034.78 DELZ= 5.446 ALP=448.21 ALPHI=446.66
*PARTBN* TIME= 82.00 IS=3 ZCALC( 78)=1040.79 ZCALC( 77)=1034.78 AINCW=1040.27 AINCHI=1034.78 DELZ= 5.494 ALP=448.21 ALPHI=446.65
*PARTBN* TIME= 82.00 IS=4 ZCALC( 78)=1040.79 ZCALC( 77)=1034.78 AINCW=1040.94 AINCHI=1034.78 DELZ= 6.158 ALP=448.20 ALPHI=446.42
*PARTBN* TIME= 82.00 IS=5 ZCALC( 79)=1055.79 ZCALC( 78)=1040.79 AINCW=1042.06 AINCHI=1040.79 DELZ= 1.266 ALP=448.16 ALPHI=447.98
*PARTBN* TIME= 82.00 IS=6 ZCALC( 79)=1055.79 ZCALC( 78)=1040.79 AINCW=1042.29 AINCHI=1040.79 DELZ= 1.496 ALP=448.16 ALPHI=447.93
*PARTBN* TIME= 82.00 IS=7 ZCALC( 79)=1055.79 ZCALC( 78)=1040.79 AINCW=1042.21 AINCHI=1040.79 DELZ= 1.416 ALP=448.16 ALPHI=447.94
*PARTBN* TIME= 82.00 IS=8 ZCALC( 79)=1055.79 ZCALC( 78)=1040.79 AINCW=1041.92 AINCHI=1040.79 DELZ= 1.125 ALP=448.17 ALPHI=448.01
```

Figure 3-8. SAMPLE WEB BURNOUT PRINT

ZCALC(XXX) = XXX.XX	Upstream increment dividing plane longitudinal location.
AINCW = XXX.XX	New location of downstream limit of sector mass addition region
AINCHI = XXX.XX	New location of upstream limit of sector mass addition region
DELZ = XX.XXX	Distance between AINCW and AINCHI.
ALP = XXX.XX	Total circular perimeter existing at AINCW
ALPHI = XXX.XX	Total circular perimeter existing at AINCHI.

It should be noted that while this message is printed for each sector of the mass addition region which is partially burned out, the values of perimeter (ALP and ALPHI) are not sector values but total perimeters. These values should be divided by the number of sectors being simulated to determine the sector values.

3.5 MAGNETIC TAPE OUTPUT

The SRB-IIID program has three optional magnetic tape outputs. The first two are the internal ballistics data tape written on unit 12, and the internal ballistics plot tape written on unit 13, both of which are discussed in the SRB-II Users Manual. The third tape is one which is set up to generate data specifically for the Shuttle vehicle program and contains the following data written at each computation time step.

(1) Time from ignition (sec)

(2) Total vacuum thrust (lbf)

(3) Total vacuum Isp (sec)

(4) Thrust coefficient

(5) Throat area (in.^{2})

(6) Nozzle exit area (in.^{2})

(7) Nozzle entrance total pressure (psia)

(8) Inert mass flow rate (lbm/sec)

The writing of this tape is controlled by specifying variable NSTAPE = 1, in the Control Data Package of the input.

3.6 PUNCHED CARD OUTPUT

SRB-IIID will punch performance parameters on cards at the conclusion of each time step by setting the variable NSCARD = 1, in the control data package of the input data. The parameters which are punched on each card are shown below.

(1) Time from ignition (sec)

(2) Total vacuum thrust (lbf)

(3) Total vacuum Isp (sec)

(4) Head-end total pressure (psia)

When this optional output is selected, the user is reminded to specify card output on his run card and estimate the number of cards to be punched. A nominal value of 200 should be adequate for most cases.

The sample case contained in Volume II will provide the user with a better understanding of the input data and prediction outputs.

Section IV

REFERENCES

1. Solid Rocket Booster Performance Evaluation Model, Volume I - Engineering Description. Boeing Document DCN-1-2-50-23786, September 7, 1974.

2. Solid Rocket Booster Performance Evaluation Model, Volume II - Users Manual. Boeing Document DCN-1-2-50-23786, September 7, 1974.

3. Solid Propellant Rocket Motor Internal Ballistics Computer Program - Program Manual. Boeing Document D2-125286-1, February 28, 1967.