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# 3 AUTOMATED NOSE FAIRING DESIGN -- RING AND SKIN CONSTRUCTION 6 ii

25 Contract NAS8-15485 -29ACV

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# FOREWORD

This Technical Report describes one of three computer programs which were developed as tools for generating parametric weight and design data for nose fairings suitable for Saturn-class payloads. The work was performed by Lockheed Missiles & Space Company, Huntsville Research & Engineering Center, with support from the LMSC/Palo Alto Research Laboratories, for the National Aeronautics and Space Administration/ Marshall Space Flight Center under Contract NAS8-15485, from July through November 1965.

The three computer programs developed under this contract are described in the following three reports.

1. Automated Nose Fairing Design -- Ring and Skin Construction, LMSC Technical Report LMSC/HREC A712552, November 1965.
2. Automated Nose Fairing Design -- Ring, Skin and Stringer Construction, LMSC Technical Report LMSC/HREC A712572 November 1965.
3. Automated Nose Fairing Design -- Honeycomb Sandwich Construction, LMSC Technical Report LMSC/HREC A712573 November 1965.

Many of the subroutines and the methods of specifying external geometry and aerodynamics loads are common to all three programs.

This report (which describes the computer program for ring and skin construction) supersedes LMSC Technical Report LMSC/HREC A711099 which describes an earlier version of the same program. Major contributors to the development of this computer program were A. B. Burns [illegible] ETAL 9CV the Palo Alto Research Laboratories and E. S. Hendrix and I. M. Landis of Huntsville Research & Engineering Center. Appendix K of this report was written by A. B. Burns, and the remainder was written by I. M. Landis.

## SUMMARY

The computer program described in this report determines the optimum design for ring-stiffened sheet metal nose fairings with an external geometry consisting of up to ten intersecting conical frustums (or cylinders) capped with a spherical nose cap. The combined effects of bending moments, axial loading due to drag, and lateral pressure are considered in performing the design. Only standard gauge materials are used in the design of the shell and rings. Because of the difficulty of applying the more powerful mathematical techniques to optimizing such a design, the designer is limited to time-consuming "cut-and-try" procedures in his search for the minimum weight design. These procedures have been methodically arranged and mechanized in the Fortran IV computer program described in this report.

The main part of the report is devoted to description of the logic followed in designing a fairing, description of the computer program, and instructions on operation of the program. The program listing and details of the methods of analysis used in design of fairing appear in the Appendixes.

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# INTRODUCTION

The computer program described in this report determines the optimum structural design of ring stiffened, sheet metal nose fairings. When external geometry, aerodynamic loading, and a practical set of design constraints are given, the computer program selects the combination of sheet metal thickness, ring cross-section and ring spacing which results in the minimum fairing weight. (Sheet metal will be referred to as "skin" throughout the remainder of the report.) Only standard sheet metal gauges are considered for design of the skin and rings. The external geometry can consist of up to ten intersecting conical frustums (or cylinders) capped with a spherical nose cap. Figure 1 illustrates both the external geometry and the type of construction.

A condensed flow chart illustrating the major logical steps performed in the program is shown in Figure 2. Design begins at the base of the fairing and moves toward the nose cap. Each bay is designed to withstand loads imposed by the interaction of bending moments, axial loading and lateral pressure. The combination of skin thickness, bay length and ring cross-section which results in the minimum weight-to-volume ratio for the bay is considered to be the optimum design for the bay. An additional constraint placed on the design of the top frustum and nose cap is the maximum temperature to be reached by the skin due to aerodynamic heating. The computer program does this by computing the minimum skin thickness to be used in each of these areas.

The computer program consists of the main program and fourteen subroutines. The logical steps to be followed in designing the fairing and minor design calculations are performed in the main program. Specialized functions, such as computation of aerodynamic loads, are performed in the subroutines. This arrangement permits the methods of analysis used in designing the fairing to be easily modified.

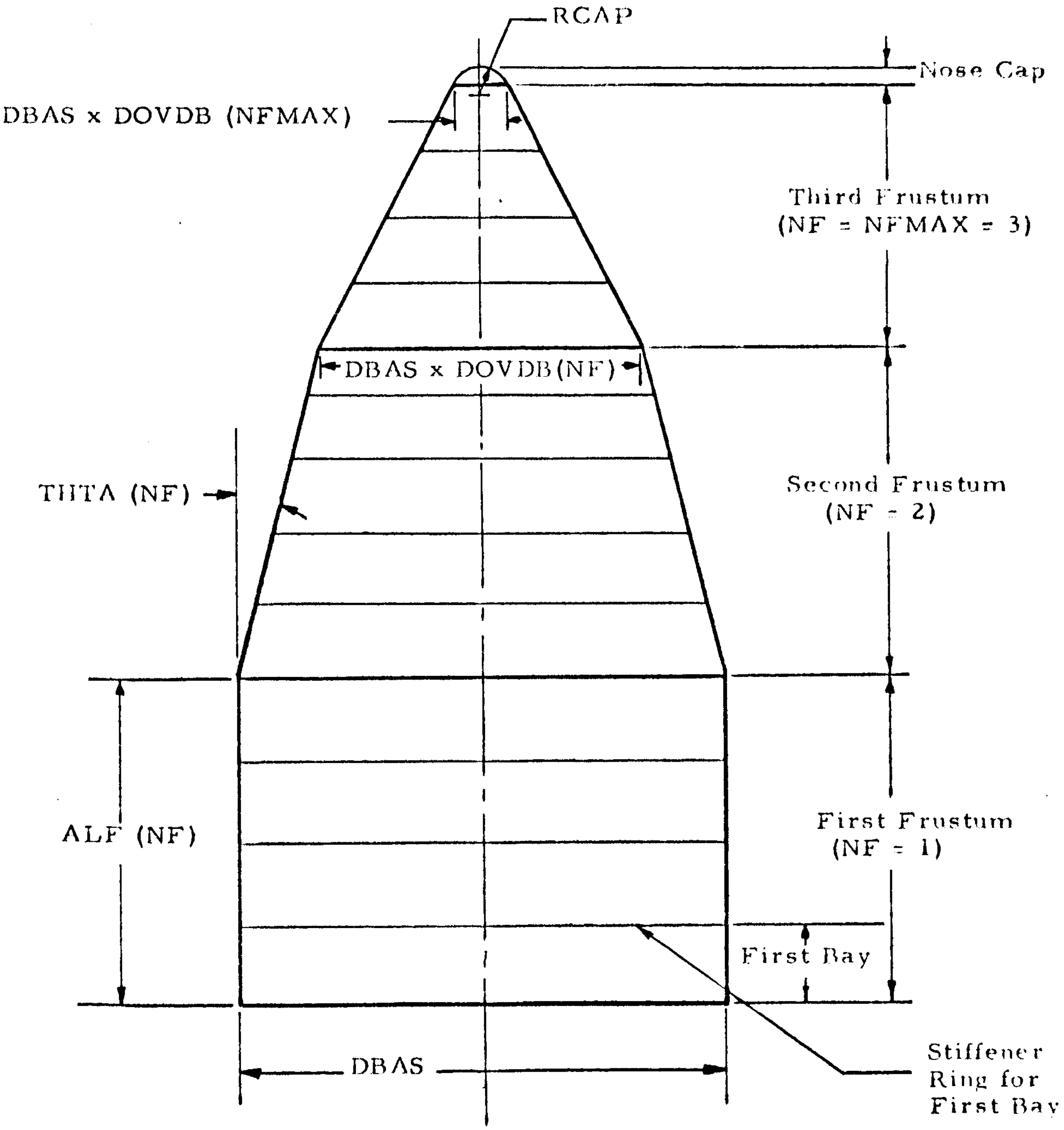
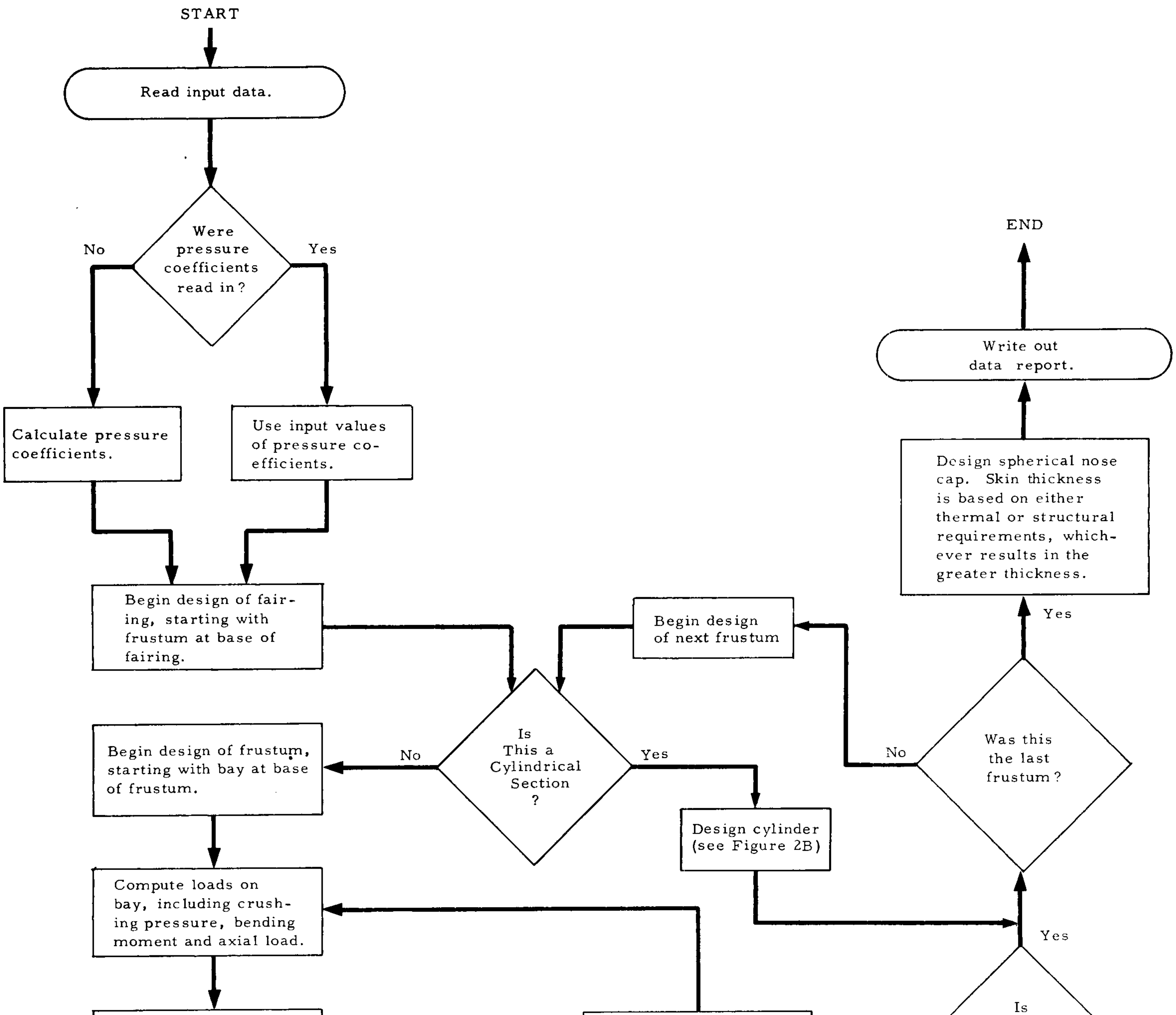


Figure 1 - Nose Fairing Geometry


START
Read input data.
Were pressure coefficients read in?
No
Yes
Calculate pressure coefficients.
Use input values of pressure coefficients.
Begin design of fairing, starting with frustum at base of fairing.
Is This a Cylindrical Section ?
No
Yes
Begin design of frustum, starting with bay at base of frustum.
Design cylinder (see Figure 2B)
Compute loads on bay, including crushing pressure, bending moment and axial load.
Begin design of next frustum
Was this the last frustum ?
No
Yes
Design spherical nose cap. Skin thickness is based on either thermal or structural requirements, whichever results in the greater thickness.
Write out data report.
END
Yes
Is

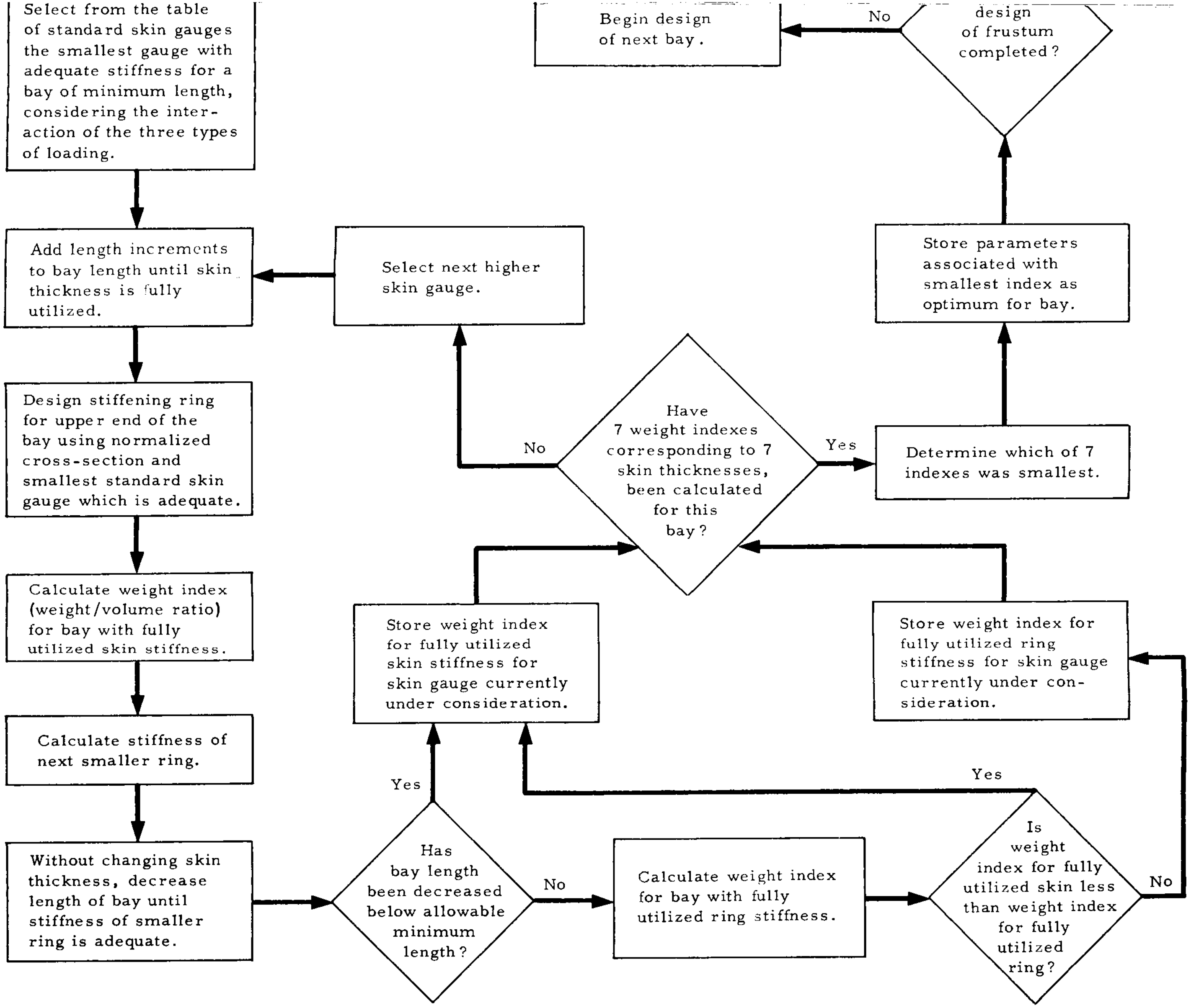


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Figure 2A. Flow Chart Showing the Major Steps Performed in Optimizing the Design of a Multi-Frustum Nose Fairing.

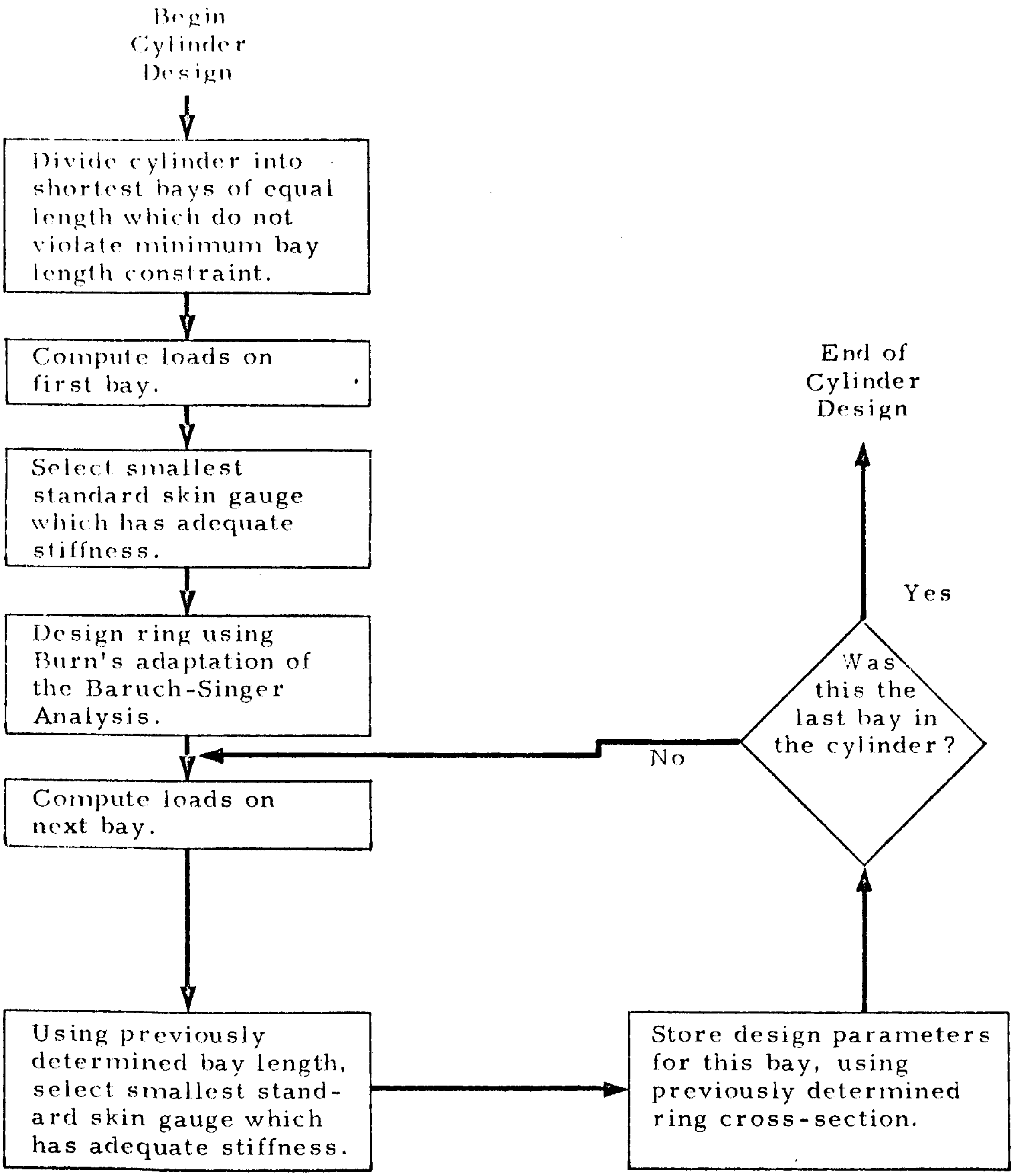


Figure 2B. Flow Chart Showing the Major Steps Performed in Designing a Cylindrical Section of the Fairing.

# TECHNICAL DISCUSSION

## 1.0 THE MAIN PROGRAM

### 1.1 Terminology and Geometric Parameters

Following are definitions of terms used in this technical discussion. The terms are also illustrated in Figure 1.

base - the bottom end of the bay, frustum or fairing

bay - the section of skin between two rings plus the ring at the upper end of this section

frustum - the section of fairing consisting of all bays having the same half angle

nose cap - the spherical segment which closes the top of the fairing.

The external geometry of the fairing is specified by the base diameter of the fairing (DBAS), by the half-angle of each frustum (THTA (NF)), and either the ratio of the top diameter of each frustum to the base diameter of the fairing (DOVDB (NF)), or (mandatory when the frustum is a cylinder) the length of the frustum (ALF (NF)). Frustums are numbered by index NF starting at the base of the fairing. Frustum geometry is completely described by the same parameters used to describe fairing geometry. Bay geometry is described by the base diameter of the bay (DSUBB), the half angle of the bay (THETA), and the length of the bay measured along the axis of symmetry (ALB). Bays within a frustum are numbered by index I starting at the base of the frustum. The outside diameter of a ring associated with a bay is equal to the top diameter of the bay. All dimensions of the ring cross-section are expressed in terms of the material thickness used to form the ring (see Figure 3). This thickness will be one of the standard gauges stored in the program.

### 1.2 Design Logic

The major logical steps followed in designing a nose fairing are shown in the condensed flow chart in Figure 2. In Appendix A, more detailed information is provided by a program listing which includes detailed comments describing in words the operations being performed. Definitions of the more

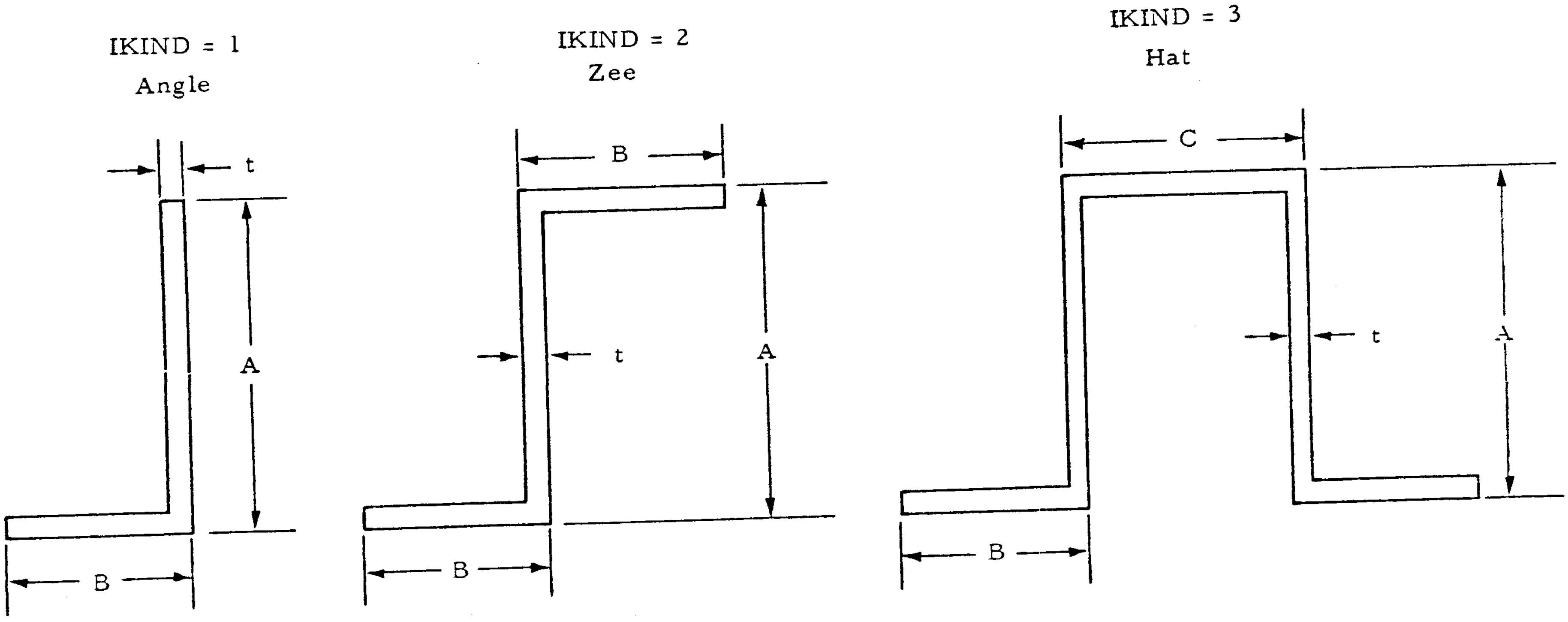


Figure 3 - Stiffener Cross-Section

commonly used variable names in this listing appear in Appendix B. The discussion which follows is supplemental to the information in the flow chart and program listing, and in general follows the sequence of the listing.

## 1.3 Required Input Data

The following input data is required by the computer program:

1. External fairing geometry (Figure 1)
2. Design specifications
   a. Type of ring cross-section
   b. Minimum distance between rings
   c. Minimum skin gauge to be used for each frustum and the nose cap
   d. Maximum skin temperature (if no value is input, the value stored in the program for the material specified will be used.)
3. Structural material (Properties for five materials are stored in the program. (See Section 1.5.)
4. Aerodynamic data at a design point in the trajectory
   a. Mach number
   b. Dynamic pressure
   c. Angle of attack
   d. Difference between internal pressure of fairing and free-stream pressure
5. Factor of safety (If no value is input a factor of 1.4 will be used.)
6. Program controls
   a. Is pressure profile data input? If so, the type of lift data is indicated.
   b. The desired type of output is indicated. (See Section 1.14)

c. The magnitude of the increment to be used in perturbing bay length.

7. Pressure profile data (optional). If a pressure profile is not input, it is computed in Subroutine AERO.

Detailed instructions on how to input this data are provided in Section 3.

## 1.4 The Pressure Profile

Whether input or computed, the system used to specify the pressure profile in the axial direction on the section of fairing composed of conical frustums is illustrated in Figure 4. LT is an index indicating station number, starting with the first station at the junction of the nose cap and top frustum. Uniform spacing between stations is not necessary. Two stations must be located at each intersection of the conical frustums. Where discontinuities in the pressure profile exist, two stations can be indicated for the same location.

The following three parameters are required by the computer program at each station.

1. CPO (LT) - The pressure coefficient at zero angle of attack.
2. CPA (LT) - The difference between the pressure coefficient on the windward side when flying at an angle of attack and CPO (LT).
3. XOD (LT) - The axial distance measured from the tip of the nose cap divided by the fairing base diameter.

When the pressure profile is input to the program, three options are available for inputing lift data.

1. CPA (LT) as described above
2. CPA (LT) per radian angle of attack
3. $\frac{\partial}{(x/D)} \left( \frac{\partial C_N}{\partial \alpha} \right)$

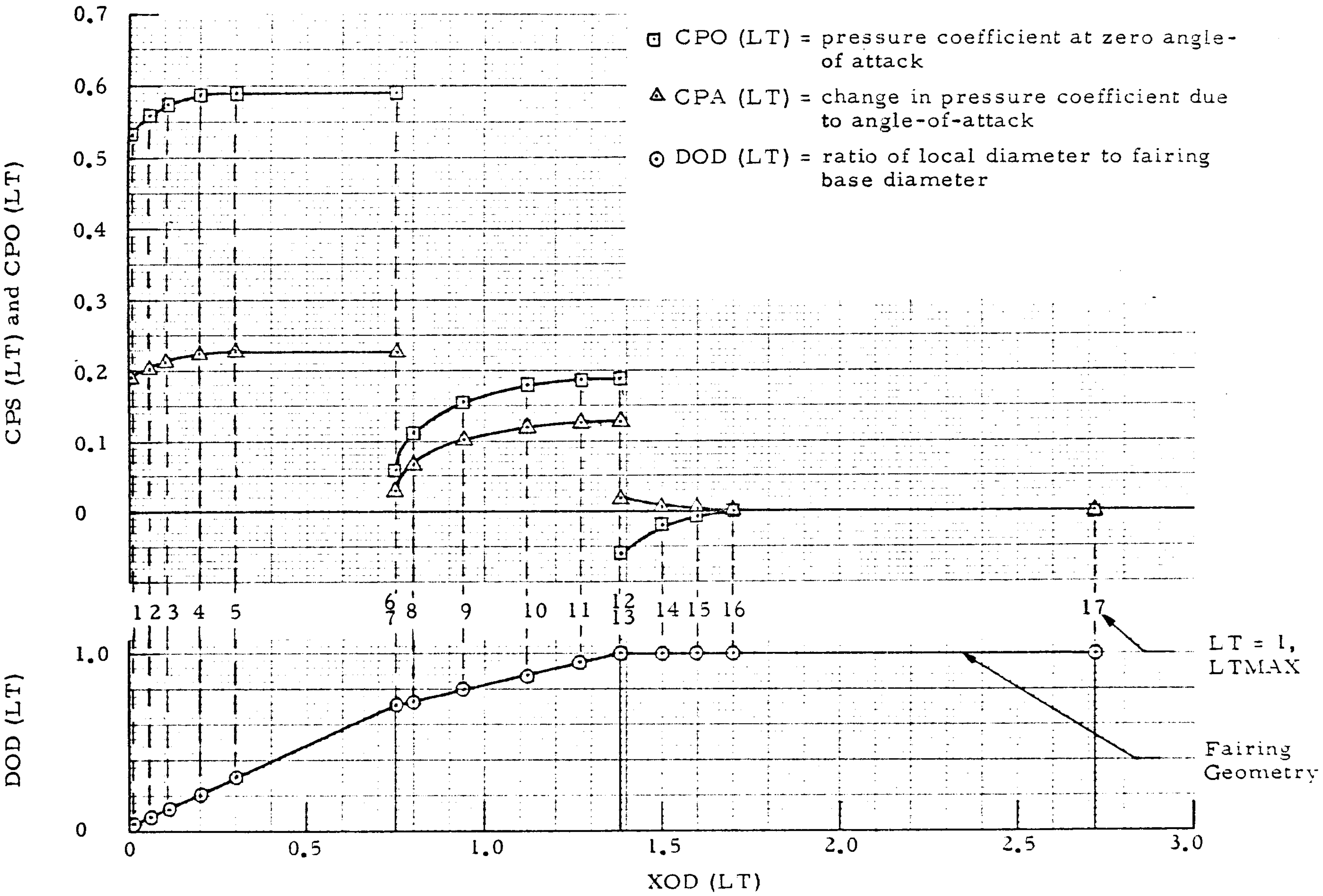


Figure 4 - Pressure Profile Used in Sample Problem

In option 3

$C_N$ = the normal force coefficient with the fairing base as a reference area

$\alpha$ = angle of attack in radians

$x/D$ = distance from the leading point in calibers

After they are read into the program, the lift data in Options 2 and 3 are converted to the form of Option 1. A sinusoidal pressure distribution (see Figure 5) in the circumferential direction is used in converting Option 3 to Option 1. Provisions can be made to read in other types of lift parameters, if the parameter can be converted to CPA (LT) after it is input.

The option is available to either compute or input axial force and lift data for the nose cap. In either case they are specified by the following three parameters:

1. Drag coefficient with the base area of the nose cap as the reference area
2. Normal force coefficient per radian angle of attack with the base area of the nose cap as a reference area
3. The location of the center of lifting pressure measured from the base of the nose cap.

## 1.5 Material Properties

Properties for the following five materials are now stored in the program in Subroutine PROPTY:

1. Aluminum
2. Magnesium
3. Titanium
4. Stainless steel
5. Lockalloy

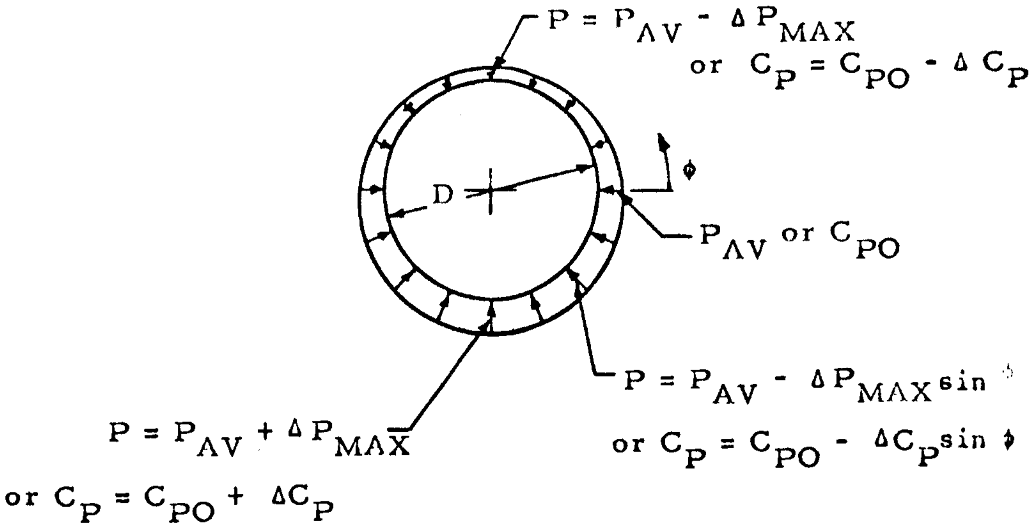


Figure 5 - Circumferential Pressure Distribution

Additional materials can be readily added to this list. Properties which are stored are as follows:

1. Modulus of elasticity
2. Poisson's ratio
3. Density
4. Maximum allowable temperature.

If a value is input for maximum allowable temperature the stored value is not used.

## 1.6 Thermal Considerations

The maximum temperature reached by the skin due to aerodynamic heating can be controlled by placing a lower limit on the skin thickness to be used in the nose cap and the top frustum. These minimum thicknesses are computed in Subroutine THERML. The minimum thickness computed for the nose cap is based on heating at the stagnation point, and the minimum thickness for the top frustum is based on heating at the point at which the nose cap is tangent to the top frustum. The equations in Subroutine THERML are based on a nominal trajectory of two-stage Saturn V vehicle ascending to a 100 nautical mile circular orbit.

## 1.7 Standard Skin Gauges

Only standard gauges are used in designing the shell portion of the bay and the stiffening ring. The stiffening ring cross-section has the shape shown in Figure 3. The standard gauges are listed in ascending order starting with 0.032 inch. (See BLOCK DATA subroutine in program listing in Appendix A.)

## 1.8 Design Loads

The individual bay is subjected to bending moments, axial forces and lateral pressure loads. Bending moments and axial forces at the base of the bay are computed in Subroutine LOAD, using the pressure profile data. These loads are then converted to line loads (force per unit of length on the circumference) on both the windward and leeward sides of the bay, and the factor of safety is applied.

The lateral pressure used in design of the bay is the difference between external and internal pressure multiplied by the factor of safety.

The maximum lateral pressures occurring along the length of the bay on both the windward and leeward sides are computed in Subroutine PRESUR, using pressure profile data and the input aerodynamic data.

## 1.9 The Weight Index (Does not apply to cylindrical sections.)

When designing a given bay; bay length, skin thickness and ring size can be varied within limits. A number of designs which will withstand the loading conditions are possible. In order to select a design as optimum it is necessary to have a measure of merit. In this program the measure of merit is the weight index -- the weight of the bay divided by its volume. The bay configuration having the smallest weight index is chosen as optimum.

The behavior of the weight index as the length of a typical bay is increased is shown in Figure 6. An abrupt change in the weight index occurs whenever an increase in skin gauge or ring gauge is necessary. The weight indexes computed by the program correspond to the low points on the curve. In general, the minimum weight index occurs at a relatively short bay length.

## 1.10 Estimation of Bay Lengths (Does not apply to cylindrical sections.)

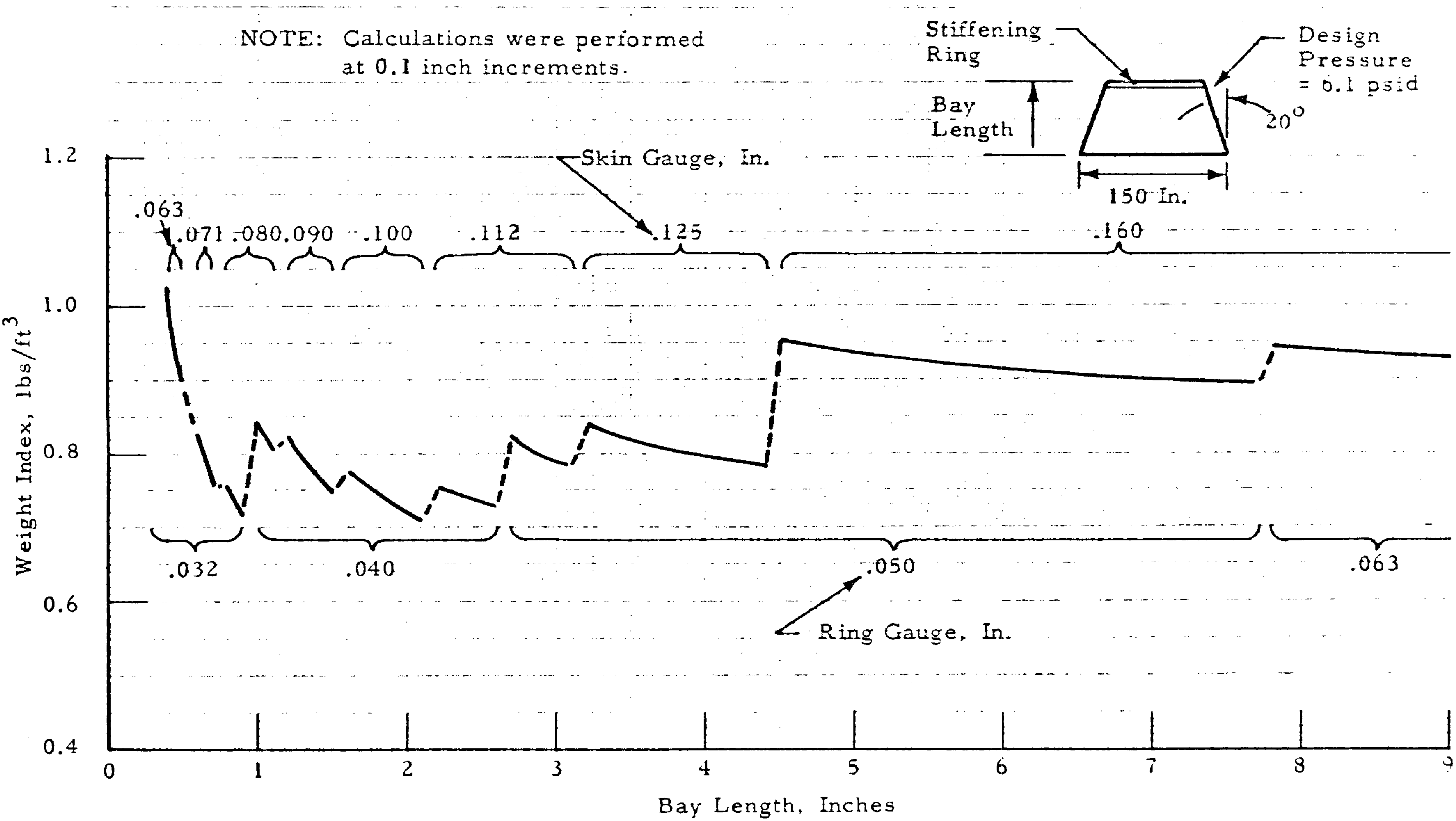
Up to seven different skin gauges for each bay are considered in the search for the best design. For each skin gauge there is a bay length at which the skin stiffness is fully utilized. Because of the complexity of the equations it is necessary to determine this length by iteration. Much computer time can be saved by estimating this length before the iteration procedure is started.

After the first of the seven skin gauges has been established for a bay, the bay length associated with the next skin gauge is estimated by equations developed in Appendix I. One of the parameters in the computer program used to compute this approximate length is AK (J), which is defined as follows:

$$AK(J) = \left( \frac{T(J)}{T(J-1)} \right)^{3.28}$$

in which T (J) is the Jth stored standard skin gauge. AK (J) has been computed for each skin gauge listed (except the first) and stored in the program.

After assigning an approximate length to the bay, the design is checked, and length increments are either added or subtracted until the correct length is found.



NOTE: Calculations were performed at 0.1 inch increments.

Figure 6 - Variation of Weight Index with Bay Length for a Typical Bay.

## 1.11 Last Bay in the Frustum (Does not apply to cylindrical sections.)

Before beginning the design of a bay, a check is made to determine if there is sufficient length remaining on the frustum for one more bay of minimum length. If there is not sufficient length for one more bay, the length of the last bay designed is added to the remaining undesigned length, and a routine is then begun to determine the minimum weight configuration of either one or two bays which completes the design of the frustum.

First, a check is made to determine if there is sufficient length remaining for two more bays of minimum length. If there is not sufficient space, one bay is designed, and the program goes on to the next frustum or the nose cap.

If there is enough space for two more bays, the program determines the weight of a number of two-bay configurations. While designing the last bay (the length of which was added to the undesigned length), the bay length and weight associated with each of the seven skin gauges were stored temporarily. These weights and lengths are now used for the first bays of the two-bay configurations. Weights of second bays, which fill out the frustum, are added to each of the first bay weights (within the constraint that second bays must be minimum length or longer). After exhausting these possibilities for two-bay configurations, the second bay length is set equal to minimum bay length, and the first and second bays are designed accordingly. Another possiblity is to make one long bay. The weights of all of the above configurations are compared and the configuration having the smallest weight is chosen to fill out the frustum.

Additional weight is added to the top ring of each frustum to provide for attachment to the next frustum or nose cap. The magnitude of this additional weight in pounds is 10% of outside diameter of the ring in inches.

## 1.12 Nose Cap Design

Both structural and thermal requirements are considered in the design of the nose cap. The thickness required to limit the temperature to the specified maximum is computed in Subroutine THERML. (For details of the thermal analysis see Appendix J.) The thickness required to withstand aerodynamic loads is computed in Subroutine TNOSST. (For details see Appendix H.) In both cases thickness is determined for conditions at the stagnation point. The greater of these two thicknesses is then used to design an unstiffened cap with uniform skin thickness. Nose cap skin thickness is not limited to standard gauges.

## 1.13 Design of Cylindrical Sections

On cylindrical sections of the fairing axial forces and bending moments are the predominant form of loading with lateral pressure playing a minor role. Whereas, on conical frustums, crushing pressure is likely to predominate. For this reason, the design procedure for the cylindrical sections differ from that of the conical frustums.

The design procedure for the cylindrical sections is based on A. B. Burn's adaptation of the Baruch-Singer General Instability Analysis (see Appendix K). This analysis assumes uniform skin thickness and equally spaced rings of uniform cross-section.

After determining the bay length which will give equally spaced rings without violating the minimum bay length constraint, the required skin thickness for the bottom bay of the cylindrical section is computed by the same methods used for the conical frustums (see Appendix F). The first value of the stored standard gauges is then assigned to the web thickness of the stiffeners ring. Assuming that this ring cross-section and the first bay loads and skin thickness prevail throughout the cylindrical section, the adequacy of the design is checked by Subroutine BARUCH. If the design fails, the ring web thickness is increased until the smallest standard gauge which provides a satisfactory design is found. This web thickness is then assigned to all rings in the cylindrical section.

Having determined the ring spacing and ring cross-section, skin thickness for each of the bays is computed by the same methods used for the conical frustums, using the loads acting on each of the bays.

## 1.14 Output Data

Three options are available on the amount of detail provided by the output data.

1. Design summary only (Figure 7A)
2. Design summary plus design details (Figure 7A, 7B and 7C)
3. Design summary plus design details plus loads details (Figures 7A, 7B, 7C and 7D).

Most of the headings appearing in the output are self-explanatory. However, there are several in Figure 7C and 7D which require some comment. Listed below for Figure 7C are several of the column headings and their definitions.

| | |
|---|---|
| Weight Index | - Weight of the bay divided by the inclosed volume of the bay. |

| | |
|---|---|
| Line Load | - Force per running inch of circumference, parallel to the skin surface, normal to the circumferential direction. A factor of safety has been applied to this force. |
| Stress Ratio, Axial | - The ratio of applied line load to the line load at which the skin buckles. |
| Stress Ratio, Press. | - The ratio of design pressure to the pressure at which the skin buckles. |
| Load Index | - A parameter which indicates that the skin design is satisfactory when it has a value equal to or less than 1.0. (See CHKWND and CHKLEE in Appendix B). |

In Figure 7D, the design pressures listed represent the maximum value occurring along the length of the bay. These values include the factor of safety. The axial load, skin load and bending moment listed occur at the base of the bay. These quantities do not include a factor of safety.

```
                         DATA REPØRT FØR ØPTIMIZED NØSE FAIRING STRUCTURE

                                      MATERIAL = ALUMINUM

                                       AERØDYNAMIC LØADS

    DYNAMIC PRESSURE, LBS./SQ. FT.                                     QBAR   =    765.00
    MACH NUMBER AT DESIGN DYNAMIC PRESSURE                             AMACH  =     1.500
    ANGLE ØF ATTACK AT DESIGN DYNAMIC PRESSURE, DEGREES                ALPHA  =      6.50
    INTERNAL-TØ-AMBIENT PRESSURE DIFFERENCE AT DESIGN CØNDITIØNS,PSI   DELTAP =    -0.000
    AMBIENT PRESSURE AT DESIGN CØNDITIØNS, PSI                         PSTAT  =     3.373

                              CØNSTRAINTS ØN DESIGN ØF FRUSTUMS

    INCREMENTS BY WHICH BAY LENGTHS ARE INCREASED, IN.                 DELTAL =     0.100
    MAXIMUM ALLØWABLE TEMPERATURE ØF SKIN, DEG. F.                     TMPMAX =     500.0
    CØNICAL SECTIØN SKIN THICKNESS REQUIRED FØR THERMAL REASØNS, IN.   TCØNTH =    0.1165

                              DESIGN SUMMARY FØR FRUSTUM SECTIØN

  FRUS-    LARGE     SMALL      HALF    LENGTH   MIN. BAY    MIN.    NØ.     USEFUL      WEIGHT
   TUM      DIA.      DIA.     ANGLE              LENGTH    GAUGE    ØF      VØLUME
   NØ.      (IN)      (IN)     (DEG)     (IN)      (IN)     (IN)    BAYS    (CU FT)       (LB)

    1     260.00    260.00      0.00    349.0      16.0    0.0320    21    10070.11    5410.50
    2     260.00    187.20     12.50    164.2      16.0    0.0320     8     3385.02    2246.98
    3     187.20      7.80     25.00    192.4      16.0    0.0320     8      931.04    1249.51
                                        -----                        ---    --------    -------
                              TØTALS    708.0                         37    14387.18    8906.99

                                        NØSE CAP DESIGN

    DESIGN PRESSURE ØN NØSE CAP, PSI                                   PDSPH  =    11.396
    MINIMUM ALLØWABLE THICKNESS ØF NØSE CAP SKIN, IN.                  TMINN  =    0.0320
    MAXIMUM ALLØWABLE TEMPERATURE ØF SKIN, DEG. F.                     TMPMAX =     500.0
    NØSE CAP SKIN THICKNESS REQUIRED FØR STRUCTURAL INTEGRITY, IN.     TCAPST =     0.032
    NØSE CAP SKIN THICKNESS REQUIRED FØR THERMAL REASØNS, IN.          TCAPTH =     0.391
    NØSE CAP SKIN THICKNESS USED TØ CALCULATE WEIGHT, IN.              TCAP   =     0.391
    NØSE CAP RADIUS, IN.                                               RCAP   =     4.303
    LENGTH ØF NØSE CAP, IN.                                            ALCAP  =      1.48
    NØSE CAP SURFACE AREA, SQ. IN.                                     SCAP   =     57.18
    USEFUL VØLUME ØF NØSE CAP, CU. FT.                                 VCAP   =      0.01
    WEIGHT ØF NØSE CAP, LBS.                                           WCAP   =      2.63

                         TØTAL LENGTH, VØLUME AND WEIGHT ØF FAIRING

    TØTAL LENGTH ØF FAIRING, IN.                                       ALTØT  =    709.04
    USEFUL VØLUME ØF FAIRING, CU. FEET                                 VTØT   =  14387.19
    TØTAL VØLUME ØF FAIRING, CU. FEET                                  VGRØSS =  15555.77
    TØTAL WEIGHT ØF FAIRING, LBS.                                      WTØT   =   8909.61
```

Figure 7A - Computer Output for Sample Problem - Design Summary

```
                               DESIGN DETAILS ØF CØNICAL FRUSTUMS

                                 RING DATA, FRUSTUM NUMBER  1
TYPE                                                                  ZEE SECTIØN
BASE LEG B/T                                                          BØT       =   10.00
UPRIGHT LEG B/T                                                       AØT       =   20.00
ØUTSTANDING LEG B/T                                                   CØT       =    0.00
FLANGE BUCKLING STRESS, PSI                                           FCFB      =  30000.
                                 RING DATA, FRUSTUM NUMBER  2
TYPE                                                                  ZEE SECTIØN
BASE LEG B/T                                                          BØT       =   10.00
UPRIGHT LEG B/T                                                       AØT       =   20.00
ØUTSTANDING LEG B/T                                                   CØT       =    0.00
FLANGE BUCKLING STRESS, PSI                                           FCFB      =  30000.
                                 RING DATA, FRUSTUM NUMBER  3
TYPE                                                                  ZEE SECTIØN
BASE LEG B/T                                                          BØT       =   10.00
UPRIGHT LEG B/T                                                       AØT       =   20.00
ØUTSTANDING LEG B/T                                                   CØT       =    0.00
FLANGE BUCKLING STRESS, PSI                                           FCFB      =  30000.
```

Figure 7B - Computer Output for Sample Problem - Design Details

```
                                                                              WINDWARD                                   LEEWARD
                                                                  ------------------------------------   ------------------------------------
FRUSTUM  RING    BAY    SKIN   RING    SKIN   RING   WEIGHT        LINE   STRESS  STRESS  WNDWRD      LINE   STRESS  STRESS  LEEWRD
 -BAY    O.D.  LENGTH  GAUGE  GAUGE     WT.    WT.   INDEX         LOAD   RATIO,  RATIO,   LOAD       LOAD   RATIO,  RATIO,   LOAD
  NO.    (IN)   (IN)   (IN)   (IN)     (IN)   (LB) (LB/CU FT)   (LB/IN)   AXIAL   PRESS.   INDEX    (LB/IN)   AXIAL   PRESS.   INDEX

 1- 1   250.0   16.6   0.220  0.071   298.64  15.56  0.6153     750.09   -0.476  -0.000  -0.385  -1122.45   0.712  -0.000   0.594
 1- 2   250.0   16.6   0.190  0.071   257.92  15.56  0.5356     718.85   -0.651  -0.000  -0.514  -1091.21   0.988  -0.000   0.986
 1- 3   250.0   16.6   0.190  0.071   257.92  15.56  0.5356     687.61   -0.623  -0.000  -0.494  -1059.97   0.960  -0.000   0.954
 1- 4   250.0   16.6   0.190  0.071   257.92  15.56  0.5356     656.37   -0.594  -0.000  -0.473  -1028.73   0.931  -0.000   0.922
 1- 5   250.0   16.6   0.190  0.071   257.92  15.56  0.5356     625.14   -0.566  -0.000  -0.453   -997.50   0.903  -0.000   0.891
 1- 6   250.0   16.6   0.190  0.071   257.92  15.56  0.5356     593.90   -0.538  -0.000  -0.432   -966.26   0.875  -0.000   0.860
 1- 7   250.0   16.6   0.190  0.071   257.92  15.56  0.5356     562.66   -0.509  -0.000  -0.410   -935.02   0.847  -0.000   0.828
 1- 8   250.0   16.6   0.190  0.071   257.92  15.56  0.5356     531.42   -0.481  -0.000  -0.389   -903.78   0.818  -0.000   0.798
 1- 9   250.0   16.6   0.190  0.071   257.92  15.56  0.5356     500.19   -0.453  -0.000  -0.368   -872.55   0.790  -0.000   0.767
 1-10   250.0   16.6   0.190  0.071   257.92  15.56  0.5356     468.95   -0.425  -0.000  -0.346   -841.31   0.762  -0.000   0.736
 1-11   250.0   16.6   0.190  0.071   257.92  15.56  0.5356     437.71   -0.396  -0.000  -0.324   -810.07   0.733  -0.000   0.705
 1-12   250.0   16.6   0.190  0.071   257.92  15.56  0.5356     406.47   -0.368  -0.000  -0.302   -778.83   0.705  -0.000   0.675
 1-13   250.0   16.6   0.190  0.071   257.92  15.56  0.5356     375.24   -0.340  -0.000  -0.280   -747.60   0.577  -0.000   0.647
 1-14   250.0   16.6   0.160  0.071   217.19  15.56  0.4558     344.00   -0.473  -0.000  -0.383   -716.36   0.985  -0.000   0.983
 1-15   250.0   16.6   0.160  0.071   217.19  15.56  0.4558     312.76   -0.430  -0.000  -0.350   -685.12   0.942  -0.000   0.934
 1-16   250.0   16.6   0.160  0.071   217.19  15.56  0.4558     281.52   -0.387  -0.000  -0.317   -653.88   0.899  -0.000   0.885
 1-17   250.0   16.6   0.160  0.071   217.19  15.56  0.4558     250.29   -0.344  -0.000  -0.284   -622.65   0.856  -0.000   0.839
 1-18   250.0   16.6   0.160  0.071   217.19  15.56  0.4558     219.05   -0.301  -0.021  -0.271   -591.41   0.813  -0.026   0.796
 1-19   250.0   16.6   0.160  0.071   217.19  15.56  0.4558     187.83   -0.258  -0.040  -0.255   -560.19   0.770  -0.055   0.590
 1-20   250.0   16.6   0.160  0.071   217.19  15.56  0.4558     156.63   -0.215  -0.054  -0.235   -526.99   0.727  -0.089   0.511
 1-21   250.0   16.6   0.125  0.071   169.68  41.56  0.4137     125.53   -0.315  -0.178  -0.439   -497.89   1.249  -0.339   0.955
 2- 1   248.8   25.3   0.190  0.125   393.50  45.94  0.5904      96.90   -0.117   1.097   0.998   -476.30   0.575   0.206   0.747
 2- 2   236.7   27.3   0.190  0.125   405.14  43.68  0.6138      73.33   -0.069   1.074   0.998   -455.32   0.555   0.201   0.723
 2- 3   228.9   17.5   0.160  0.112   209.75  33.95  0.5653      47.07   -0.063   1.051   0.997   -430.84   0.574   0.204   0.745
 2- 4   220.3   19.4   0.160  0.112   224.35  32.66  0.5776      29.51   -0.041   1.033   0.998   -415.37   0.578   0.205   0.750
 2- 5   212.6   17.4   0.160  0.100   193.92  25.14  0.5911       9.12   -0.011   0.862   0.852   -398.36   0.500   0.167   0.632
 2- 6   203.7   20.0   0.160  0.100   214.35  24.08  0.6052     -10.20    0.014   0.859   0.871   -383.16   0.513   0.161   0.640
 2- 7   194.3   21.3   0.150  0.100   218.14  22.96  0.6290     -33.99    0.046   0.748   0.738   -365.68   0.493   0.142   0.600
 2- 8   187.2   15.0   0.125  0.090   122.76  36.65  0.6024     -62.19    0.122   0.848   0.956   -346.97   0.683   0.168   0.821
 3- 1   172.3   16.0   0.220  0.090   219.31  16.48  1.0031     -93.45    0.047   0.957   0.998   -358.57   0.179   0.420   0.579
 3- 2   153.4   20.2   0.220  0.090   250.88  14.66  1.0892     -86.31    0.046   0.959   1.000   -329.48   0.176   0.421   0.578
 3- 3   138.5   16.0   0.190  0.090   153.83  13.22  1.0770     -77.31    0.047   0.959   1.000   -292.72   0.177   0.421   0.579
 3- 4   118.5   21.4   0.190  0.080   181.17   8.94  1.1805     -70.19    0.046   0.959   0.999   -263.56   0.172   0.421   0.574
 3- 5   103.0   15.7   0.160  0.071   102.60   6.11  1.1653     -60.66    0.046   0.943   0.932   -224.50   0.169   0.414   0.564
 3- 6    76.2   26.5   0.160  0.071   133.63   4.62  1.3850     -53.20    0.044   0.961   1.000   -193.98   0.162   0.422   0.565
 3- 7    56.8   22.9   0.125  0.063    66.93   2.63  1.4557     -41.08    0.044   0.959   0.998   -145.37   0.157   0.421   0.560
 3- 8     7.8   52.6   0.125  0.032    73.59   0.87  2.5048     -30.35    0.021   0.519   0.537   -104.21   0.073   0.233   0.297
```

Figure 7C - Computer Output for Sample Problem - Design Details (Continued)

```
                                              DETAILED LOADS DATA

FRUSTUM   BAY BASE   BAY TOP     BAY     DISTANCE    DES. PRES.   DES. PRES.    AXIAL       SHEAR       BENDING
 -BAY       DIA.       DIA.     LENGTH   FROM BASE     WNDWRD       LEEWRD       LOAD        LOAD        MOMENT
  NO.       (IN)       (IN)      (IN)      (IN)        (PSI)        (PSI)       (LBS)       (LBS)      (IN-LBS)

1- 1       260.0      260.0     16.6        0.0        -0.00        -0.00     108624.7     71281.9   35506594.5
1- 2       260.0      260.0     16.6       16.6        -0.00        -0.00     108624.7     71281.9   34321955.5
1- 3       260.0      260.0     16.6       33.2        -0.00        -0.00     108624.7     71281.9   33107317.8
1- 4       260.0      260.0     16.6       49.9        -0.00        -0.00     108624.7     71281.9   [illegible]
1- 5       260.0      260.0     16.6       66.5        -0.00        -0.00     108624.7     71281.9   [illegible]
1- 6       260.0      260.0     16.6       83.1        -0.00        -0.00     108624.7     71281.9   [illegible]
1- 7       260.0      260.0     16.6       99.7        -0.00        -0.00     108624.7     71281.9   28398759.
1- 8       260.0      260.0     16.6      116.3        -0.00        -0.00     108624.7     71281.9   27214131.5
1- 9       260.0      260.0     16.6      133.0        -0.00        -0.00     108624.7     71281.9   26029434.5
1-10       260.0      260.0     16.6      149.6        -0.00        -0.00     108624.7     71281.9   24844955.5
1-11       260.0      260.0     16.6      166.2        -0.00        -0.00     108624.7     71281.9   23660219.0
1-12       260.0      260.0     16.6      182.8        -0.00        -0.00     108624.7     71281.9   22475541.0
1-13       260.0      260.0     16.6      199.4        -0.00        -0.00     108624.7     71281.9   21290944.0
1-14       260.0      260.0     16.6      216.0        -0.00        -0.00     108624.7     71281.9   20105306.3
1-15       260.0      260.0     16.6      232.7        -0.00        -0.00     108624.7     71281.9   18921669.0
1-16       260.0      260.0     16.6      249.3        -0.00        -0.00     108624.7     71281.9   17737031.0
1-17       260.0      260.0     16.6      265.9        -0.00        -0.00     108624.7     71281.9   16552394.0
1-18       260.0      260.0     16.6      282.5        -0.04        -0.05     108624.7     71270.6   15367818.9
1-19       260.0      260.0     16.6      299.1        -0.05        -0.11     108624.7     71229.9   14183655.8
1-20       260.0      260.0     16.6      315.8        -0.11        -0.18     108624.7     71103.5   13000744.0
1-21       260.0      260.0     16.6      332.4        -0.20        -0.36     108624.7     70320.7   11820943.5
2- 1       260.0      248.8     25.3      349.0         2.38         0.45     108624.7     70244.7   10643409.8
2- 2       248.8      236.7     27.3      374.3         2.38         0.45     104100.1     63206.7    8950191.1
2- 3       236.7      228.9     17.5      401.6         2.29         0.45      99496.2     56197.1    7331123.3
2- 4       228.9      220.3     19.4      419.1         2.22         0.44      96755.2     52056.2    6384409.4
2- 5       220.3      212.6     17.4      438.5         2.13         0.41      93936.1     47785.0    5416458.1
2- 6       212.6      203.7     20.0      455.9         2.05         0.38      91608.2     44217.0    4616394.9
2- 7       203.7      194.3     21.3      475.9         1.83         0.35      89196.3     40490.1    3770303.8
2- 8       194.3      187.2     16.0      497.2         1.53         0.30      87081.2     37206.2    2943906.3
3- 1       187.2      172.3     16.0      513.2         6.10         2.68      86045.1     35742.3    2301903.0
3- 2       172.3      153.4     20.2      529.2         6.10         2.69      72840.5     30222.4    1834793.1
3- 3       153.4      138.5     16.0      549.4         6.10         2.68      57734.7     23904.7    1289295.1
3- 4       138.5      118.6     21.4      565.4         6.10         2.68      47010.1     19425.8     943230.1
3- 5       118.6      103.0     16.7      586.8         6.10         2.68      34379.5     14146.3     585470.1
3- 6       103.0       73.2     26.6      603.5         6.10         2.68      25385.4     10595.8     379558.3
3- 7        73.2       56.8     22.9      630.1         6.10         2.69      14621.9      5971.3     162034.4
3- 8        56.8        7.8     52.6      653.0         5.97         2.68       7774.9      3056.6      60615.2
TANG. PT.    7.8                          705.6                                   224.2        56.7        158.2
```

Figure 7D - Computer Output for Sample Problem - Detailed Loads

## 2.0 DESCRIPTION OF SUBROUTINES

### 2.1 Subroutine THERML (Thermal Computations)

This subroutine computes the minimum thickness of skin required to limit the skin temperature to the specified maximum. Minimum thicknesses are computed for both the nose cap and top frustum. The analytical basis for the computations performed in Subroutine THERML is presented in Appendix J. The analysis is based on a nominal two-stage Saturn V ascent trajectory to a 100 nautical mile circular orbit.

The equations and stored coefficients in Subroutine THERML were developed by means of a multiple regression analysis of a large amount of analytical data generated for the trajectory mentioned above. Details of the multiple regression analysis are also presented in Appendix J.

The parameters required from the main program for computations in Subroutine THERML are RCAP, THETA, TMPMAX and MAT. Returned to the main program are TCONTH and TCAPTH.

### 2.2 Subroutine TNOSST (Nose Cap Structure)

Subroutine TNOSST calculates the nose cap skin thickness required to withstand the pressure differential, PDSPH, at the stagnation point. The method used to calculate PDSPH and the structural analysis of a spherical nose cap are described in Appendix H.

Parameters required by Subroutine TNOSST are PDSPH, E, RCAP and TMINN. Returned to the main program is TCAPST.

### 2.3 Subroutine AERO (Pressure Coefficients)

When a pressure profile is not input to the program the pressure coefficient data for the profile is computed in Subroutine AERO. The analytical basis for the computations performed in this subroutine is presented in Appendix C. Because of the assumptions made in computing this data, the pressure coefficient at zero angle of attack and the change in pressure coefficient due to angle of attack are uniform over the length of each frustum. The pressure profile is then constructed by assigning the pressure coefficient data for each frustum to the beginning and end points of each frustum. Double points occur at the intersection of two frustums.

Parameters required to make the computations in Subroutine AERO are NF, THTA (NF), AMACH and ALPHA. Returned to the main program are CPOO and CPAA.

A sinusoidal pressure distribution in the circumferential direction, such as that illustrated in Figure 6, is used in computing CPAA.

## 2.4 Subroutine LOAD (Bending Moment, Axial Force and Shear Force)

Using the pressure profile data, Subroutine LOAD computes the bending moment, axial force and shear force at the base of each bay. Bending moment and axial force are then converted to line loads (force per unit length of circumference) for both the windward and leeward sides of the bay, and the factor of safety is applied to these line loads.

When Subroutine LOAD is called upon for loads on the first bay, the bending moment, axial force and shear force are computed at the base of the fairing. As design of the fairing moves from the base to the nose cap, increments of the loads contributed by the pressure profile between the previous bay location and the new bay location are substracted from the previous totals. Derivation of the equations used in this subroutine appear in Appendix D.

Information required for the computations in Subroutine LOAD is

1. Pressure profile data:

   LTMAX

   CPO (LT) LT = 1, LTMAX

   CPA (LT) LT = 1, LTMAX

   XOD (LT) LT = 1, LTMAX

2. Fairing geometry:

   NFMAX

   DBAS

   ALF (NF) NF = 1, NFMAX

   THTA (NF) NF = 1, NFMAX

3. Aerodynamic data:

   AMACH

QBAR

DELTAP

ALPHA

4. Miscellaneous:

DSUBB

C2

FS

LFLG

LTRIG

Parameters computed by Subroutine LOAD are ANFIMX, ANFIMN, FSUBZ and LTUNCT (NF) for NF = 1 to NFMAX.

## 2.5 Subroutine PRESUR (Lateral Pressure)

Using pressure profile data, Subroutine PRESUR computes the pressure differential across the skin along the length of the bay. The maximum differential occurring along the bay length is determined for both the windward and leeward sides, multiplied by the factor of safety and returned to the main program. The equations used in this subroutine are developed in Appendix E.

Parameters required for computations performed in Subroutine PRESUR are

1. Pressure profile data

LTMAX

| | |
|---|---|
| CPO (LT) | LT = 1, LTMAX |
| CPA (LT) | LT = 1, LTMAX |
| XOD (LT) | LT = 1, LTMAX |

2. Other parameters: LPFL, C2, DBAS, DSUBB, ALB, QBAR, NFMAX, NF, DELTAP, FS and LTUNCT (NF) for NF = 1 to NFMAX.

Parameters computed in Subroutine PRESUR are PDESMN, PDESMX, ALN and ALX.

## 2.6 Subroutine CHKLOD (Checks Adequacy of Skin Design)

When given the line loads, lateral pressure, geometry of the bay and skin thickness, Subroutine CHKLOD determines whether the skin is thick enough. The criteria used to appraise the design are presented in Appendix F.

Parameters required to perform the computations in Subroutine CHKLOD are DSUBB, DELTAS, ALB, C1, C2, C3, C4, ANFIMN, ANFIMX, E, PDESMN and PDESMX.

Parameters computed in Subroutine CHKLOD are RPMIN, RPMAX, RAXMIN, RAXMAX, CHKWND, CHKLEE, and CHK.

## 2.7 Subroutine DIAM (Local Diameter)

When given the parameters describing the external geometry of the fairing and the distance from the tip of the nose cap in calibers this subroutine computes the local fairing diameter.

Parameters required by this subroutine are:

ALTOT

ALF (NF), NF = 1, NFMAX

THTA (NF), NF = 1, NFMAX

DMN (NF), NF = 1, NFMAX

XN

NFMAX

The local diameter, DLOC, is computed by this subroutine.

## 2.8 Subroutine DLOD (Incremental Loads)

When given the geometry and pressure coefficient data for an incremental length of the fairing this subroutine computes the contribution by this increment to the total bending moment, axial load and shear load.

Input parameters are XOD1, XOD2, D1, D2, CP01, CP02, CPA1, CPA2, A3, A4, and DP.

Parameters computed in Subroutine DLOD are FSBZ, BND, and AXLOD.

## 2.9 Subroutine RING (Ring Strength and Stiffness)

When given the cross-sectional shape of the ring and the skin gauge from which is to be fabricated this subroutine computes the moment of inertia of the ring with and without the effective skin, its cross-sectional area, eccentricity and torsion constant. This subroutine also calls Subroutine RSTRES which computes the local stress level in the ring.

Input parameters required by RING are E, IKIND, AOT, BOT, COT, WSEF, J, K, PI, and T(J) when J = 1, 30.

Output parameters are AIRING, AISTT, AST, A, Z, ECC and TCONST.

## 2.10 Subroutine RSTRES (Local Stress Level in Ring)

When designing a stiffener ring it is necessary to check for local instability in the ring flange or web (see Appendix G). Subroutine RSTRES computes the local stress level in the ring. This computed stress level is then compared to an input flange buckling stress level, and, if necessary, a greater web thickness is assigned to the ring.

Input parameters for Subroutine RSTRES are A, T(J), Z, PDESMX, DSUBB, CTH, AL(J), AST, and AISTT.

The output parameter is FRING.

## 2.11 Subroutine IREQ (Required Moment of Inertia)

This subroutine computes the stiffening ring moment of inertia requirements to prevent general instability of the structure. The methods used to compute this required moment of inertia are described in Appendix G.

Input parameters are THTA (NF), C6, AL(J), DSUBB, C2, PDESMX, T(J), PI, ANFIMX, E and ALCONE.

The output parameter is AIREQ.

## 2.12 Subroutine PROPTY (Material Properties)

Properties of several commonly used materials are stored in this subroutine.

The material for which properties are desired is indicated by the input parameter MAT.

Output parameters are the material properties E, AMU, RHO, and TMPMAX.

## 2.13 Subroutine BARUCH (Designs Rings for Cylindrical Sections)

When given a skin gauge, crushing pressure, ring spacing and ring cross-section, Subroutine BARUCH computes the line load at which general instability of the composite structure of a cylindrical section occurs. The procedure followed in designing a cylindrical section is discussed in Section 1.13, and Burn's adaption of the Baruch-Singer analysis (which is used in Subroutine BARUCH) is discussed in Appendix K.

Subroutine BARUCH requires a large amount of tabular information which, for reasons of convenience, is read into the program as regular input data. This data is physically located immediately after the program deck followed by a comment card stating, "END OF BARUCH-SINGER DATA CARDS - - BEGIN NOSE FAIRING DATA CARDS." Nose fairing data cards for a number of nose fairing designs can be stacked in the usual manner after this comment card.

The complete Baruch-Singer analysis as used in this program consists of five subroutines. However, all communication with the main program is channeled through Subroutine BARUCH. Input parameters required by Subroutine BARUCH are AST, ECC, AIST, DY, DELTAS, AMU, E, RCYL, ALF (NF), TCONST and either PDESMN when checking the design on the leeward side or PDESMX when checking the design on the windward side.

The output parameter from Subroutine BARUCH is ANFICR, the line load at which failure will occur.

## 3.0 INPUT FORMAT

In addition to the data cards required by Subroutine BARUCH (see Section 2.13), which should be considered a permanent part of the program, input data describing the fairing to be designed is required by the program. These nose fairing data cards should be physically located after the comment card stating "END OF BARUCH-SINGER DATA CARDS -- BEGIN NOSE FAIRING DATA CARDS." A number of nose fairing design cases can be stacked in the usual manner after this comment card.

When the pressure profile and nose cap lift and drag data are to be computed in the program, the following three types of input data cards are the only types required.

| | |
|---|---|
| Types 1 and 2. | Parameters which apply to the entire fairing. |
| Types 3 and 4. | Parameters which apply to individual frustum (one of each per frustum). |

When lift and drag data for the nose cap are to be input, or when a pressure profile is to be input, the following additional card type is required.

| | |
|---|---|
| Type 5. | Lift and drag data for the nose cap. |

When pressure profile data is to be input, two additional card types are required.

| | |
|---|---|
| Type 6. | Pressure profile data points (one card per data point). |
| Type 7. | Card indicating end of pressure profile data. |

The detailed format for these cards is as follows:

Type 1: Format (5 F 12.8, I 12)

Data:

DBAS - Base diameter of fairing, in.

DELTAL - Increment by which bay length is changed during design iteration (usually 0.1 inches), in.

QBAR - Dynamic pressure at design point in the trajectory, lbs/sq. ft.

AMACH - Mach number at design point in the trajectory.

ALPHA - Angle of attack at design point in the trajectory, degrees.

KEY - An integer indicating the type of output desired. The code is as follows:

(0) Design summary only. (See Figure 7A).

(1) Design summary plus design details (Figures 7A, 7B, and 7C.

(2) Design summary plus design details plus load details (Figures 7A, 7B, 7C and 7D).

Type 2: Format (2I6, 4F12.8, I12)

Data: MAT - An integer indicating the material to be used. The code is as follows:

(1) aluminum

(2) magnesium

(3) titanium

(4) stainless steel

(5) Lockalloy (a Be-Al alloy)

NFMAX - The number of conical frustums in the fairing.

TMP - The maximum allowable skin temperature for the nose cap and top frustum, °F. (If no value is input, the value stored with the material properties is used. If a value equal to or greater than 10,000 is input, no thermal constraint is imposed on the skin thickness.)

TMINN - The minimum skin gauge to be used in nose cap design, in.

DELTAP - Difference between internal and free-stream pressure, psi

FS - Factor of safety. (If no value is input, a factor of safety of 1.4 is used.)

LPRES - An integer indicating whether nose cap lift and drag data and/or pressure profile data will be input. If pressure profile data is input, LPRES also indicates the type of lift data to be input. The code is as follows:

(-1) Lift and drag data for the nose cap is input, but no pressure profile data is input.

(0) No nose cap or pressure profile data is input.

(1) Nose cap data and pressure profile data with CPA (LT) as defined in Figure 5 and Appendix B is input on Card type 5.

(2) Same as (1) except that CPA (LT) per radian angle of attack is input for CPA (LT) on Card type 5.

(3) Same as (1) except that

$$\frac{\partial}{\partial x}\left(\frac{\partial C_N}{\partial \alpha}\right)$$

(See Section 1.4) is input for CPA (LT) on Card type 5.

(One Type 3 and Type 4 card is required for each frustum .)

Type 3: Format (4F12.8)

Data: ALF (NF) - Ratio of top diameter of frustum to base diameter of fairing or length of the frustum in inches. If the number is equal to or greater than 1. it will be treated as frustum length. For conical sections, either the diameter ratio or length can be used. For cylindrical sections, only length can be input.

THTA (NF) - Frustum half angle, degrees.

ELMIN (NF) - Minimum bay length to be used in designing frustum, in.

TMNC (NF) - Minimum skin thickness to be used in designing frustum, in.

Type 4: Format (I5, 6E12.8)

Data: IKIND - Indicates shape of stiffener ring (see Figure 3 for code).

AOT - The ratio A/t (see Figure 3).

BOT - The ratio B/t (see Figure 3).

| | | |
|---|---|---|
| COT | - | The ratio C/t (see Figure 3). |
| FCFB | - | Ring outstanding flange buckling level, PSI. |

The next card type is required only when nose cap lift and drag data or a pressure profile is read in (LPRES =-1, 1, 2 or 3 in Card Type 2). If a blank card is inserted for Card Type 5 when LPRES = 1, 2 or 3, the program will compute CDCAP, CNCAP and XBCAP.

Type 5: Format (3F12.8)

| | | | |
|---|---|---|---|
| Data: | CDCAP | - | Spherical nose cap drag coefficient with nose cap base area as a reference area. |
| | CNCAP | - | Normal force coefficient per radian angle of attack for the nose. Reference area is nose cap base area. |
| | XBCAP | - | Distance from base of nose cap to center of pressure for the nose cap, in. |

The next two card types are required only when pressure profile data is input (LPRES = 1, 2 or 3). (See Section 1.4 and Figure 4.)

Type 6: Format (3F12.8)

| | | | |
|---|---|---|---|
| Data: | CPO (LT) | - | Zero angle of attack pressure coefficient at station LT. |
| | CPA (LT) | - | Lift parameter at station LT. See LPRES on Card Type 2 and Section 1.4 for options which are available. |
| | XOD (LT) | - | Axial distance from nose in calibers. |

(One card is required for each data point, starting with the first point at the junction of the nose cap and top frustum.)

Type 7: Format (71X, I1)

| | | | |
|---|---|---|---|
| Data: | LSTOP = 1 | - | This signals the computer that the last pressure profile data point has been read in. |

The set of data cards described above will design one fairing. A number of fairings can be designed with one computer run by placing several sets of data cards behind the program deck.

## 4.0 SAMPLE PROBLEM

The following sample problem illustrates the input format of the program. Input data is as follows:

Fairing geometry:

DBAS = 260.0 inches
NFMAX = 3
ALF (1) = 349.0 inches
ALF (2) = 0.72
ALF (3) = 0.03
THTA (1) = 0.00 degrees
THTA (2) = 12.5 degrees
THTA (3) = 25.0 degrees

Design specifications:

ELMIN(1) = 16.0 inches
ELMIN(2) = 16.0 inches
ELMIN(3) = 16.0 inches
TMNC(1) = 0.032 inches
TMNC(2) = 0.032 inches
TMNC(3) = 0.032 inches
TMINN = 0.032 inches
TMP = 600.0 °F

One ring shape is specified for all three frustums.

IKIND = 2
AOT = 20.0
BOT = 10.0
COT = 0.0
FCFB = 30000.0 psi

Material:

MAT = 1 (aluminum)

Aerodynamic data:

AMACH = 1.5
QBAR = 765.0 lbs/sq ft
ALPHA = 8.5 degrees
DELTAP = 0. psi

Factor of Safety:

FS = 1.4 (It is not necessary to input this value, since 1.4 is the value which the program uses when no value is indicated.)

Program Controls:

LPRES = 1
KEY = 2
DELTAL = 0.1 inches

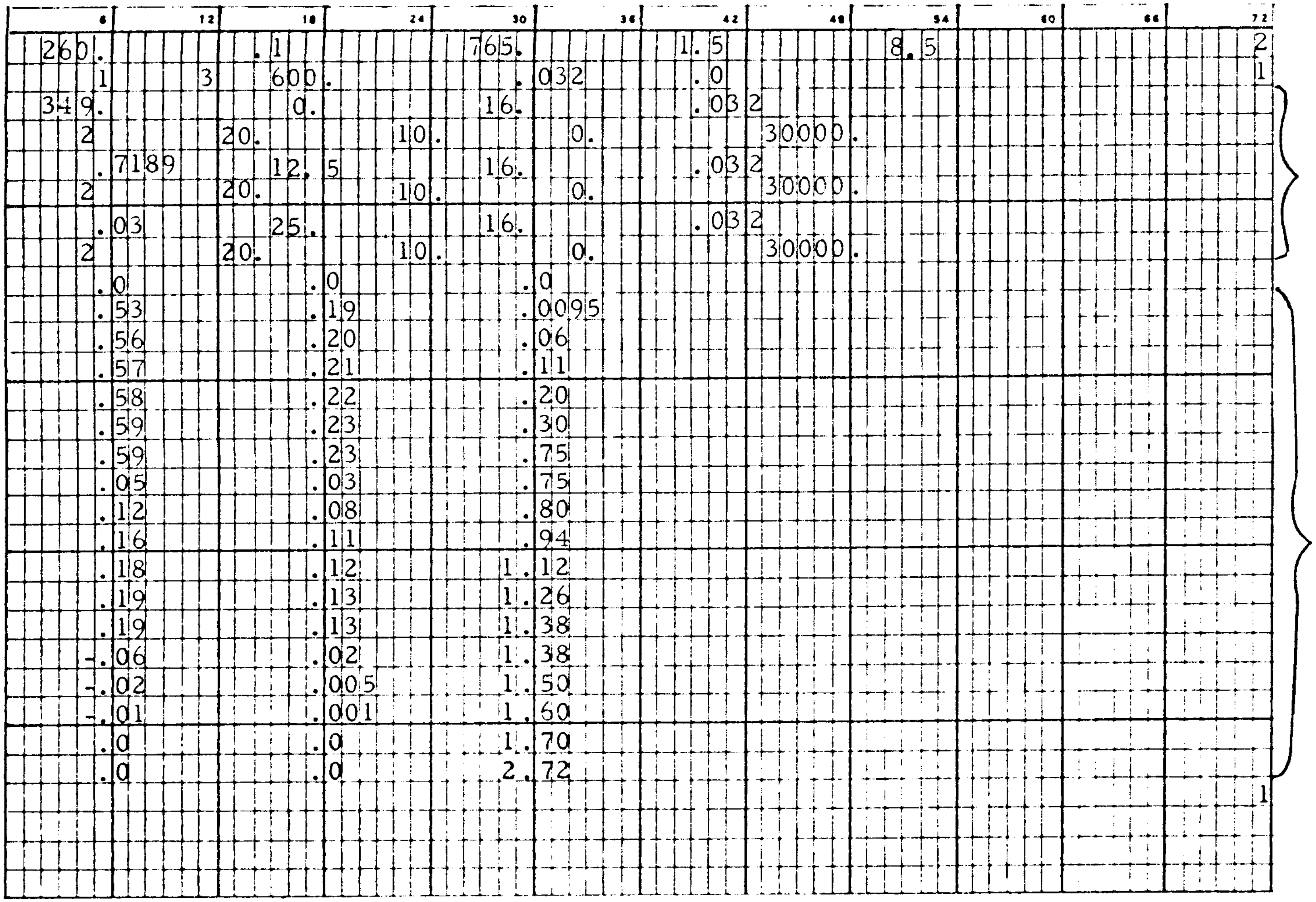
Nose cap lift and drag data:

A blank card is inserted in the deck in place of Card Type 5, causing the program to compute this data.

Pressure profile data:

Data for the pressure profile is taken from Figure 4 and listed in Figure 8 under Card Type 6.

This input data is arranged in key-punch format in Figure 8. The computer output for this problem is shown in Figures 7A, 7B, 7C and 7D.



```
     6    12    18    24    30    36    42    48    54    60    66    72
  260.        .1          765.        1.5         8.5                  2   Card Type 1
     1     3   600.          .032      .0                              1   Card Type 2
  349.          0.         16.         .032
    2       20.       10.       0.         30000.
     .7189     12.5        16.         .032                                Card Type 3
    2       20.       10.       0.         30000.                          Card Type 4
     .03       25.         16.         .032
    2       20.       10.       0.         30000.
     .0          .0          .0                                            Card Type 5
     .53         .19         .0095
     .56         .20         .06
     .57         .21         .11
     .58         .22         .20
     .59         .23         .30
     .59         .23         .75
     .05         .03         .75
     .12         .08         .80
     .16         .11         .94                                           Card Type 6
     .18         .12        1.12
     .19         .13        1.26
     .19         .13        1.38
    -.06         .02        1.38
    -.02         .005       1.50
    -.01         .001       1.60
     .0          .0         1.70
     .0          .0         2.72
                                                                       1   Card Type 7
```

Figure 8 - Sample Problem Input Data in Key-Punch Format

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14. Hendrix, E., Unpublished notes, dated August 28, 1964.

# APPENDIX A

# PROGRAM LISTING

```
$IBFTC RS01     DECK                                                          RS200000
C        STRUCTURAL OPTIMIZATION AND DESIGN OF MULTI-FRUSTUM NOSE RS200010
C           FAIRINGS USING RING AND SKIN CONSTRUCTION, NOVEMBER 1965.     RS200020
C                                                                         RS200030
      DIMENSION          TR(30 ),WR(30 ),WS(30 ),WSEG(30 ),VSEG(30 ),     RS200040
     1AINDEX(30 ),        D(400),ALOPT(400),TSKIN(400),TRING(400),        RS200050
     2WRING(400),WSKIN(400),WTDEX(400),ENFIMX(400),ENFIMN(400),           RS200060
     3WT(29),AL1(28),      ELMIN(10),TMNC(10),IMX(10),RAXMN(400),FZ(400),RS200070
     4RPMN(400),CHKWD(400),RAXMX(400),RPMX(400),CHKLE(400),W1(28)         RS200080
      COMMON /RNG2/ ECC                                                   RS200090
     2  , TCONST                                                          RS200100
      COMMON RCAP,E,PDESMN,PDESMX,PSTAT,TMINN,PDSPH,TCAPST,ANFIMN,        RS200110
     1   ANFIMX,DSUBB,LPFL,ALX,ALN,CPOO,CPAA,CZALFA,CDCAP,CNCAP,XBCAP     RS200120
      COMMON /AERLOD/ CPMN,CPMX,CPO(121),CPA(121),XOD(121),THTA(10),      RS200130
     1   ALF(10),DELTAP,NFMAX,DBAS,LTMAX,AMACH,QBAR,ALPHA,FS,NF,FSUBZ,    RS200140
     2   AXLDCP,FSBZCP,BNDCAP,LFLG,LTRIG,ALTOT,ALCAP,SUMAL,DMN(10)        RS200150
      COMMON / RNG/ IKIND,AOT,BOT,COT,WSEF,T(30),J,K,AIREQ,CTH,FRING,     RS200160
     1    FCC,AL(30),AIRING ,AST,AISTT,C6,PI,A,TT,AK(30),Z,ALCONE         RS200170
      COMMON /CHKLD/ C1,C3,C4,ALB,DELTAS,CHK,RAXMIN,RAXMAX,RPMIN,RPMAX,   RS200180
     1   CHKWND,CHKLEE,C2                                                 RS200190
      COMMON /THRML/ TMPMAX,MAT,TCONTH,TCAPTH,THETA                       RS200200
      EQUIVALENCE (AIRING,AIST)                                           RS200210
  131 FORMAT (5F12.8,I12)                                                 RS200220
  132 FORMAT (2I6,4F12.8,I12)                                             RS200230
  365 FORMAT (3F12.8,35X,I1)                                              RS200240
  989 FORMAT(I5,6E12.8)                                                   RS200250
      PI        = 3.14159                                                 RS200260
C                                                                         RS200270
C              CALL BARUCH IN ORDER TO READ IN PERMANENT TABULAR DATA.    RS200280
C                                                                         RS200290
      CALL BARUCH (0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.)                   RS200300
C                                                                         RS200310
C              READ PARAMETERS WHICH APPLY TO ENTIRE FAIRING.             RS200320
C                                                                         RS200330
  134 READ (5,131) DBAS,DELTAL,QBAR,AMACH,ALPHA,KEY                       RS200340
      READ (5,132) MAT,NFMAX,TMP,TMINN,DELTAP,FS,LPRES                    RS200350
      IF (10-NFMAX) 98,174,174                                            RS200360
  174 CONTINUE                                                            RS200370
C                                                                         RS200380
```

```
C              READ PARAMETERS WHICH DESCRIBE INDIVIDUAL FRUSTUMS.        RS200390
C                                                                         RS200400
      ALTOT     = 0.                                                      RS200410
      DMX       = DBAS                                                    RS200420
      DO 173 NF = 1,NFMAX                                                 RS200430
      READ (5,131)    ALF(NF),THTA(NF),ELMIN(NF),TMNC(NF)                 RS200440
      READ (5,989) IKIND, AOT, BOT, COT, FCFB                             RS200450
      THETA     = 0.0174532925*THTA(NF)                                   RS200460
      IF (1.-ALF(NF)) 481,481,482                                         RS200470
  481 CONTINUE                                                            RS200480
      DMN(NF)   = DMX - 2.*ALF(NF)*SIN(THETA)/COS(THETA)                  RS200490
      GO TO 483                                                           RS200500
  482 CONTINUE                                                            RS200510
      DMN(NF)   = DBAS*ALF(NF)                                            RS200520
      ALF(NF)   = (DMX-DMN(NF))*COS(THETA)*.5/SIN(THETA)                  RS200530
  483 CONTINUE                                                            RS200540
      DMX       = DMN(NF)                                                 RS200550
      ALTOT     = ALTOT + ALF(NF)                                         RS200560
  173 CONTINUE                                                            RS200570
      DMX       = DBAS                                                    RS200580
C                                                                         RS200590
C              CHECK TO DETERMINE IF PRESSURE PROFILE DATA IS TO BE       RS200600
C          READ IN.                                                       RS200610
C                                                                         RS200620
      IF (LPRES) 368,367,368                                              RS200630
  368 CONTINUE                                                            RS200640
C                                                                         RS200650
C              READ NOSE CAP LIFT AND DRAG DATA.                          RS200660
C                                                                         RS200670
      READ (5,131) CDCAP,CNCAP,XBCAP                                      RS200680
      IF (LPRES) 448,448,449                                              RS200690
  449 CONTINUE                                                            RS200700
C                                                                         RS200710
C              READ PRESSURE PROFILE DATA.                                RS200720
C                                                                         RS200730
      DO 369 LT = 1,101                                                   RS200740
      READ (5,365) CPO(LT),CPA(LT),XOD(LT),LSTOP                          RS200750
      IF (LSTOP) 369,369,370                                              RS200760
```

```
  369 CONTINUE                                                          RS200770
  370 CONTINUE                                                          RS200780
      LTMAX      = LT - 1                                               RS200790
      GO TO 448                                                         RS200800
  367 CONTINUE                                                          RS200810
      CDCAP      = 0.                                                   RS200820
  448 CONTINUE                                                          RS200830
C                                                                       RS200840
C               WRITE OUT HEADINGS FOR DATA REPORT.                     RS200850
C                                                                       RS200860
      WRITE (6,30)                                                      RS200870
      WRITE (6,52)                                                      RS200880
C                                                                       RS200890
C               IF A FACTOR-OF-SAFETY WAS INPUT, THE INPUT VALUE IS     RS200900
C           USED. OTHERWISE THE FACTOR-OF-SAFETY IS 1.4.                RS200910
C                                                                       RS200920
      IF (FS)340,340,341                                                RS200930
  340 FS         = 1.4                                                  RS200940
  341 CONTINUE                                                          RS200950
C                                                                       RS200960
C               RADIUS OF SPHERICAL NOSE CAP IS COMPUTED.               RS200970
C                                                                       RS200980
      THETA      = 0.0174532925 * THTA(NFMAX)                           RS200990
      RCAP       = 0.5*DMN(NFMAX)/COS(THETA)                            RS201000
      ALCAP      = RCAP*(1.-SIN(THETA))                                 RS201010
      ALTOT      = ALTOT + ALCAP                                        RS201020
C                                                                       RS201030
C               IF NOSE CAP RADIUS IS ZERO, A NOTE IS WRITTEN OUT, AND  RS201040
C           MAXIMUM ALLOWABLE TEMPERATURE IS SET EQUAL TO 10000. THIS   RS201050
C           CAUSES THE PROGRAM TO BY-PASS THE THERMAL EQUATIONS, WHICH  RS201060
C           ARE NOT VALID FOR A NOSE CAP RADIUS OF ZERO.                RS201070
C                                                                       RS201080
      IF (RCAP) 176,176,177                                             RS201090
  176 CONTINUE                                                          RS201100
      WRITE (6,178)                                                     RS201110
  178 FORMAT (14X,107H RADIUS OF THE NOSE CAP IS ZERO. FOR THIS CASE THERS201120
     1 HEAT TRANSFER EQUATIONS ARE NOT VALID. THEREFORE, NO      )      RS201130
      WRITE (6,179)                                                     RS201140
  179 FORMAT (9X, 71H THERMAL CONSTRAINTS HAVE BEEN IMPOSED ON THE DESIGRS201150
```

```
     1IN OF THIS FAIRING.      ///)                                     RS201160
      TMP        = 10000.                                               RS201170
  177 CONTINUE                                                          RS201180
C                                                                       RS201190
C              THE PROGRAM PICKS UP THE MATERIAL PROPERTIES AND MAXIMUM RS201200
C         ALLOWABLE TEMPERATURE FOR THE MATERIAL INDICATED IN THE       RS201210
C         INPUT DATA.                                                   RS201220
C                                                                       RS201230
      CALL PROPTY (MAT, E, AMU, RHO, TMPMAX )                           RS201240
C                                                                       RS201250
C              IF MAXIMUM ALLOWABLE TEMPERATURE IS EQUAL TO OR GREATER  RS201260
C         THAN 10000., EITHER FROM INPUT DATA OR BECAUSE NOSE CAP       RS201270
C         RADIUS EQUALS ZERO, THE REQUIRED THERMAL THICKNESS OF BOTH    RS201280
C         THE NOSE CAP AND TOP FRUSTUM ARE SET EQUAL TO ZERO.           RS201290
C                                                                       RS201300
      IF (TMP - 10000.) 200,78,78                                       RS201310
   78 CONTINUE                                                          RS201320
      TMPMAX     = TMP                                                  RS201330
      TCONTH     = 0.0                                                  RS201340
      TCAPTH     = 0.0                                                  RS201350
      GO TO 77                                                          RS201360
C                                                                       RS201370
C              IF THE INPUT VALUE FOR MAXIMUM ALLOWABLE TEMPERATURE     RS201380
C         IS EQUAL TO 0., THE STORED VALUE IS USED. IF THE INPUT VALUE RS201390
C         IS GREATER THAN 0. BUT LESS THAN 10000., THE INPUT VALUE IS   RS201400
C         USED FOR MAXIMUM ALLOWABLE TEMPERATURE.                       RS201410
C                                                                       RS201420
  200 IF (TMP) 192,192,193                                              RS201430
  193 TMPMAX     = TMP                                                  RS201440
  192 CONTINUE                                                          RS201450
C                                                                       RS201460
C              THE SKIN THICKNESSES REQUIRED TO KEEP SKIN TEMPERATURE   RS201470
C         BELOW THE MAXIMUM SPECIFIED ARE COMPUTED FOR BOTH THE NOSE    RS201480
C         CAP (TCAPTH) AND THE TOP FRUSTUM (TCONTH) IN SUBROUTINE       RS201490
C         THERML.                                                       RS201500
C                                                                       RS201510
      CALL THERML                                                       RS201520
   77 CONTINUE                                                          RS201530
```

```
      C4        = (3.1416**2 * E) / (12. * SQRT(1.0 - AMU**2))             RS201540
C                                                                          RS201550
C             AMBIENT PRESSURE AT DESIGN CONDITIONS AND DESIGN PRESSURERS201560
C        ON THE NOSE CAP ARE COMPUTED.                                     RS201570
C                                                                          RS201580
      PSTAT     = QBAR / ( 100.8 * AMACH**2)                               RS201590
      PDSPH     = FS*(PSTAT*((166.92158*(AMACH)**7.)/((7.*(AMACH)**2)      RS201600
     1              -1.)**2.5)-PSTAT - DELTAP)                             RS201610
C                                                                          RS201620
C             AERODYNAMIC DATA ARE WRITTEN OUT.                            RS201630
C                                                                          RS201640
      WRITE (6,307)                                                        RS201650
      WRITE (6,72) QBAR                                                    RS201660
      WRITE (6,73) AMACH                                                   RS201670
      WRITE (6,74) ALPHA                                                   RS201680
      WRITE (6,163) DELTAP                                                 RS201690
      WRITE (6,162) PSTAT                                                  RS201700
C                                                                          RS201710
C             DESIGN CONSTRAINTS FOR FRUSTUM SECTION ARE WRITTEN OUT.      RS201720
C                                                                          RS201730
      WRITE (6,308)                                                        RS201740
      WRITE (6,65) DELTAL                                                  RS201750
      WRITE (6,96) TMPMAX                                                  RS201760
      WRITE (6,164) TCONTH                                                 RS201770
C                                                                          RS201780
C             HEADINGS FOR SUMMARY REPORT ARE WRITTEN OUT.                 RS201790
C                                                                          RS201800
      WRITE (6,309)                                                        RS201810
      WRITE (6,310)                                                        RS201820
      WRITE (6,311)                                                        RS201830
      WRITE (6,312)                                                        RS201840
      WRITE (6,607)                                                        RS201850
      ALPHA     = 0.0174532925 * ALPHA                                     RS201860
C                                                                          RS201870
C             CHECK TO DETERMINE IF PRESSURE PROFILE DATA HAS BEEN         RS201880
C        INPUT.                                                            RS201890
C                                                                          RS201900
      IF (LPRES) 397,397,398                                               RS201910
  397 CONTINUE                                                             RS201920
```

```
C                                                                       RS201930
C             SINCE PRESSURE DATA WAS NOT INPUT, PRESSURE PROFILE       RS201940
C         DATA IS COMPUTED IN SUBROUTINE AERO.                          RS201950
C                                                                       RS201960
      ALPR        = ALTOT                                               RS201970
      LTMAX       = 2*NFMAX                                             RS201980
      LT          = LTMAX + 1                                           RS201990
      DO 396 NF = 1,NFMAX                                               RS202000
      CALL AERO                                                         RS202010
      LT          = LT - 1                                              RS202020
      CPO(LT)     = CPOO                                                RS202030
      CPA(LT)     = CPAA                                                RS202040
      XOD(LT)     = ALPR/DBAS                                           RS202050
      ALPR        = ALPR - ALF(NF)                                      RS202060
      LT          = LT - 1                                              RS202070
      CPO(LT)     = CPOO                                                RS202080
      CPA(LT)     = CPAA                                                RS202090
      XOD(LT)     = ALPR/DBAS                                           RS202100
  396 CONTINUE                                                          RS202110
      GO TO 437                                                         RS202120
  398 CONTINUE                                                          RS202130
C                                                                       RS202140
C             PRESSURE PROFILE DATA WAS INPUT. THE TYPE OF DATA IS      RS202150
C         INDICATED BY LPRES.                                           RS202160
C                                                                       RS202170
      GO TO (437,438,440) ,LPRES                                        RS202180
  438 CONTINUE                                                          RS202190
C                                                                       RS202200
C             SLOPE OF THE NORMAL FORCE COEFFICIENT CURVE HAS BEEN      RS202210
C         INPUT. THESE VALUES ARE CONVERTED TO THE MAXIMUM CHANGE       RS202220
C         CAUSED IN THE LOCAL PRESSURE COEFFICIENT BY THE SPECIFIED     RS202230
C         ANGLE-OF-ATTACK.                                              RS202240
C                                                                       RS202250
      DO 439 LT = 1,LTMAX                                               RS202260
      XN          = XOD(LT)*DBAS                                        RS202270
      CALL DIAM (XN,DLOC)                                               RS202280
      DOD         = DLOC/DBAS                                           RS202290
  439 CPA(LT)     = 0.5*ALPHA*CPA(LT)/DOD                               RS202300
```

```
      GO TO 437                                                         RS202310
  440 CONTINUE                                                          RS202320
C                                                                       RS202330
C               THE CHANGE IN SURFACE PRESSURE COEFFICIENT PER RADIAN   RS202340
C          ANGLE-OF-ATTACK HAS BEEN INPUT. THESE VALUES ARE CONVERTED   RS202350
C          TO THE MAXIMUM CHANGE CAUSED IN THE LOCAL PRESSURE           RS202360
C          COEFFICIENT BY THE SPECIFIED ANGLE-OF-ATTACK.                RS202370
C                                                                       RS202380
      DO 441 LT = 1,LTMAX                                               RS202390
  441 CPA(LT)    = ALPHA*CPA(LT)                                        RS202400
  437 CONTINUE                                                          RS202410
C                                                                       RS202420
C               PARAMETERS USED IN DESIGN OF THE ENTIRE FAIRING ARE     RS202430
C          INITIALIZED.                                                 RS202440
C                                                                       RS202450
      SUMAL      = 0.                                                   RS202460
      VGROSS     = 0.0                                                  RS202470
      I          = 0                                                    RS202480
      WTOT       = 0.                                                   RS202490
      VTOT       = 0.                                                   RS202500
      DBASE      = DBAS                                                 RS202510
      LPFL       = 1                                                    RS202520
      LTRIG      = -1                                                   RS202530
C                                                                       RS202540
C               DO-LOOP WHICH DESIGNS THE FRUSTUMS IS INITIALIZED.      RS202550
C                                                                       RS202560
      DO 129  NF = 1,NFMAX                                              RS202570
      THETA      = 0.0174532925*THTA(NF)                                RS202580
      CTH        = COS(THETA)                                           RS202590
      STH        = SIN(THETA)                                           RS202600
      ALCONE     = ALF(NF)                                              RS202610
      DMIN       = DMN(NF)                                              RS202620
      C1         =  SQRT(1.0 - AMU**2)/(0.3*CTH)                        RS202630
      C2         = 2.*STH/CTH                                           RS202640
      C3         = 0.3/CTH                                              RS202650
      C5         = 3.1416/CTH                                           RS202660
      C6         = (0.25/CTH**2)*(DBASE/(5.51*E*C2))**1.33333           RS202670
      C7         = C2/2.                                                RS202680
      ALMIN      = ELMIN(NF)                                            RS202690
```

```
      TMINC      = TMNC(NF)                                             RS202700
      WCONE      = 0.                                                   RS202710
      SLOPT      = 0.                                                   RS202720
      VUSE       = 0.                                                   RS202730
      NBAY       = 1                                                    RS202740
      ALMX1      = ALMIN + 40.                                          RS202750
      DSUBB      = DBASE                                                RS202760
C                                                                       RS202770
C            IF THE TOP FRUSTUM IS BEING DESIGNED, REQUIRED THERMAL     RS202780
C        THICKNESS AND MINIMUM ALLOWABLE THICKNESS ARE COMPARED. THE    RS202790
C        GREATER OF THE TWO IS USED AS MINIMUM ALLOWABLE THICKNESS      RS202800
C        FOR THE TOP FRUSTUM.                                           RS202810
C                                                                       RS202820
      IF (NFMAX - NF) 338,338,127                                       RS202830
  338 CONTINUE                                                          RS202840
      IF (TCONTH - TMINC) 127,127,128                                   RS202850
  128 CONTINUE                                                          RS202860
      TMINC      = TCONTH                                               RS202870
  127 CONTINUE                                                          RS202880
C                                                                       RS202890
C            THE VALUE OF THE J-INDEX CORRESPONDING TO THE MINIMUM      RS202900
C        ALLOWABLE THICKNESS IS DETERMINED FOR THE FRUSTUM UNDER        RS202910
C        DESIGN.                                                        RS202920
C                                                                       RS202930
      J          = 1                                                    RS202940
   11 J          = J + 1                                                RS202950
      IF (29  - J) 98,98,124                                            RS202960
  124 CONTINUE                                                          RS202970
      IF (T(J)-TMINC) 11,12,12                                          RS202980
   12 JMIN       = J                                                    RS202990
C                                                                       RS203000
C            TEST IS MADE TO DETERMINE IF THIS IS A CYLINDRICAL         RS203010
C        SECTION OR A CONICAL FRUSTUM.                                  RS203020
C                                                                       RS203030
      IF (THTA(NF).GT..01) GO TO 17                                     RS203040
C                                                                       RS203050
C            SINCE IT IS A CYLINDRICAL SECTION, THE NUMBER OF EQUALLY RS203060
C        SPACED RINGS REQUIRED AND THE RING SPACING ARE COMPUTED.       RS203070
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C                                                                       RS203080
      NRNGS     =ALF(NF)/ALMIN                                          RS203090
      RNGS      =NRNGS                                                  RS203100
      DY        = ALF(NF)/RNGS                                          RS203110
C                                                                       RS203120
C              SKIN GAUGE FOR THE FIRST BAY IS COMPUTED.                RS203130
C                                                                       RS203140
      CALL LOAD                                                         RS203150
      ALB       = DY                                                    RS203160
      CALL PRESUR                                                       RS203170
      J         = JMIN - 1                                              RS203180
   16 J         = J + 1                                                 RS203190
      DELTAS    = T(J)                                                  RS203200
      CALL CHKLOD                                                       RS203210
      IF (CHK.LT..9) GO TO 16                                           RS203220
C                                                                       RS203230
C              USING THE BARUCH-SINGER GENERAL STABILITY ANALYSIS, THE  RS203240
C          RING GAUGE REQUIRED IS DETERMINED BY TRYING SUCESSIVELY      RS203250
C          INCREASING GAUGES UNTIL CYLINDER IS STABLE.                  RS203260
C              RING WEB THICKNESS IS DETERMINED FOR LOADING ON THE WIND-RS203270
C          WARD SIDE.                                                   RS203280
C                                                                       RS203290
      K         = 1                                                     RS203300
      LPFL      = 2                                                     RS203310
      ALB       = ALF(NF)                                               RS203320
      CALL PRESUR                                                       RS203330
      RCYL      = DSUBB/2.                                              RS203340
  561 K         = K + 1                                                 RS203350
      CALL RING                                                         RS203360
      CALL BARUCH (AST,ECC,AIST,DY,DELTAS,AMU,E,RCYL,ALF(NF),TCONST,    RS203370
     1   PDESMX,ANFICR)                                                 RS203380
      IF (ANFICR.LT.ANFIMN) GO TO 561                                   RS203390
      KF        = K                                                     RS203400
C                                                                       RS203410
C              RING WEB THICKNESS IS DETERMINED FOR LOADING ON THE LEE- RS203420
C          WARD SIDE.                                                   RS203430
C                                                                       RS203440
      K         = 1                                                     RS203450
  562 K         = K + 1                                                 RS203460
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      CALL RING                                                         RS203470
      CALL BARUCH (AST,ECC,AIST,DY,DELTAS,AMU,E,RCYL,ALF(NF),TCONST,    RS203480
     1   PDESMN,ANFICR)                                                 RS203490
      IF (ANFICR.LT.ANFIMX) GO TO 562                                   RS203500
      ALB        = DY                                                   RS203510
C                                                                       RS203520
C          THE GREATER OF THE TWO WEB THICKNESSES IS CHOSEN AND RINGRS203530
C       WEIGHT IS COMPUTED.                                             RS203540
C                                                                       RS203550
      IF (K.LT.KF) K = KF                                               RS203560
      CALL RING                                                         RS203570
      WRNG       = PI*(DSUBB-A)*AST*RHO                                 RS203580
      DUSE       = DSUBB - 2.*A - .02*DBASE                             RS203590
      VUSB       = .25*PI*DUSE **2*ALB/1728.                            RS203600
      VB         = .25*PI*DSUBB**2*ALB/1728.                            RS203610
      I1         = I + 1                                                RS203620
      I2         = I + NRNGS                                            RS203630
C                                                                       RS203640
C          SKIN GAUGE AND OTHER BAY PARAMETERS ARE COMPUTED FOR EACHRS203650
C       OF THE BAYS IN THE CYLINDRICAL SECTION USING THE RING SPACINGRS203660
C       AND RING WEB THICKNESS COMPUTED ABOVE.                          RS203670
C                                                                       RS203680
      DO 570  I = I1,I2                                                 RS203690
      CALL LOAD                                                         RS203700
      CALL PRESUR                                                       RS203710
      J          = JMIN - 1                                             RS203720
  563 J          = J + 1                                                RS203730
      DELTAS     = T(J)                                                 RS203740
      CALL CHKLOD                                                       RS203750
      IF (CHK.LT..9) GO TO 563                                          RS203760
      ALOPT(I)   = ALB                                                  RS203770
      D(I)       = DSUBB                                                RS203780
      TSKIN(I)   = T(J)                                                 RS203790
      TRING(I)   = T(K)                                                 RS203800
      WRING(I)   = WRNG                                                 RS203810
      WSKIN(I)   = PI*ALB*DSUBB*T(J)*RHO                                RS203820
      WTDEX(I)   = (WRNG+WSKIN(I))/VB                                   RS203830
      WCONE      = WCONE + WSKIN(I) + WRNG                              RS203840
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      VUSE        = VUSE + VUSB                                             RS203850
      SUMAL       = SUMAL + ALOPT(I)                                        RS203860
      RAXMN(I)    = RAXMIN                                                  RS203870
      RAXMX(I)    = RAXMAX                                                  RS203880
      RPMN(I)     = RPMIN                                                   RS203890
      RPMX(I)     = RPMAX                                                   RS203900
      CHKWD(I)    = CHKWND                                                  RS203910
      CHKLE(I)    = CHKLEE                                                  RS203920
      SLOPT       = SLOPT    +ALOPT(I)                                      RS203930
      DSUBB       = D(I)                                                    RS203940
      ENFIMN(I)   = ANFIMN                                                  RS203950
      ENFIMX(I)   = ANFIMX                                                  RS203960
      FZ(I)       = FSUBZ                                                   RS203970
  570 CONTINUE                                                              RS203980
      I           = I2                                                      RS203990
      NBAY        = NRNGS                                                   RS204000
      WRING(I)    = WRING(I) + .1*DSUBB                                     RS204010
      WTDEX(I)    = WTDEX(I) + .1*DSUBB/VB                                  RS204020
      GO TO 569                                                             RS204030
C                                                                           RS204040
C                 BAY DESIGN FOR THE CONICAL FRUSTUMS BEGINS HERE.          RS204050
C                                                                           RS204060
   17 J           = JMIN                                                    RS204070
      IF ( 400 - I) 98,98,99                                                RS204080
   99 I           = I + 1                                                   RS204090
C                                                                           RS204100
C                 THE REMAINING LENGTH OF THE FRUSTUM IS COMPUTED.          RS204110
C                                                                           RS204120
      ALMX2       = ALF(NF)-SLOPT-.0001                                     RS204130
C                                                                           RS204140
C                 A CONSTANT USED IN COMPUTING APPROXIMATE BAY LENGTHS IS   RS204150
C            CALCULATED.                                                    RS204160
C                                                                           RS204170
      CL          = 1.7 * DSUBB/C2                                          RS204180
C                                                                           RS204190
C                 SET INITIAL BAY LENGTH TO MINIMUM ALLOWABLE BAY LENGTH.   RS204200
C                                                                           RS204210
      AL(J)       = ALMIN                                                   RS204220
      ALMN        = ALMIN                                                   RS204230
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C                                                                       RS204240
C             LINE LOADS AND SHEAR LOADS AT THE BASE OF THE BAY ARE     RS204250
C        COMPUTED IN SUBROUTINE LOAD.                                   RS204260
C                                                                       RS204270
      CALL LOAD                                                         RS204280
      ENFIMN(I) = ANFIMN                                                RS204290
      ENFIMX(I) = ANFIMX                                                RS204300
      FZ(I)     = FSUBZ                                                 RS204310
C                                                                       RS204320
C             MAXIMUM DESIGN PRESSURES ALONG THE LENGTH OF THE BAY      RS204330
C        ARE COMPUTED ON BOTH THE WINDWARD AND LEEWARD SIDES.           RS204340
C                                                                       RS204350
      ALB       = AL(J)                                                 RS204360
      CALL PRESUR                                                       RS204370
C                                                                       RS204380
C             ADEQUACY OF THE DESIGN IS CHECKED FOR MINIMUM BAY LENGTH RS204390
C        AND SKIN THICKNESS. IF THE DESIGN IS INADEQUATE. SKIN GAUGE   RS204400
C        IS INCREASED TO THE NEXT STANDARD GAUGE. AND THE DESIGN IS    RS204410
C        RE-CHECKED. THIS PROCESS IS REPEATED UNTIL A STANDARD SKIN    RS204420
C        GAUGE WHICH IS ADEQUATE IS FOUND.                              RS204430
C                                                                       RS204440
   19 CONTINUE                                                          RS204450
      DELTAS    = T(J)                                                  RS204460
      CALL CHKLOD                                                       RS204470
      IF (CHK) 20.421.421                                               RS204480
   20 AL(J+1)   = AL(J)                                                 RS204490
      J         = J+1                                                   RS204500
      IF (29  - J) 98.98.125                                            RS204510
  125 CONTINUE                                                          RS204520
      GO TO 19                                                          RS204530
C                                                                       RS204540
C             PROCEDURE IS INITIATED TO CALCULATE WEIGHT INDEXES FOR    RS204550
C        SEVEN CONSECUTIVE SKIN GAUGES.                                 RS204560
C                                                                       RS204570
  421 J1        = J                                                     RS204580
      J2        = J + 1                                                 RS204590
      J3        = J + 2                                                 RS204600
      J7        = J + 6                                                 RS204610
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      J5         = J7                                                   RS204620
      JF         = J                                                    RS204630
      LAST       = 0                                                    RS204640
      DO 126  J = J1,J7                                                 RS204650
C                                                                       RS204660
C               THE MAXIMUM LENGTH OF THE BAYS FOR THE FIRST THREE SKIN RS204670
C           GAUGES IS THE REMAINING LENGTH OF THE FRUSTUM. FOR THE LAST RS204680
C           FOUR SKIN GAUGES AN ADDITIONAL CONSTRAINT OF ALMX1 (ALMIN +  RS204690
C           40 INCHES) IS PLACED ON BAY LENGTH.                         RS204700
C                                                                       RS204710
      IF (J3-J) 470,471,471                                             RS204720
  471 CONTINUE                                                          RS204730
      ALMAX      = ALMX2                                                RS204740
      GO TO 339                                                         RS204750
  470  CONTINUE                                                         RS204760
      ALMAX      = AMIN1 (ALMX1,ALMX2)                                  RS204770
  339 CONTINUE                                                          RS204780
C                                                                       RS204790
C               IF THIS IS THE FIRST OF SEVEN SKIN GAUGES TRIED, CONTROL RS204800
C           IS TRANSFERRED TO STATEMENT NO. 40, BELOW. OTHERWISE, AN     RS204810
C           APPROXIMATE BAY LENGTH IS CALCULATED.                       RS204820
C                                                                       RS204830
      IF (J-J1) 40,40,140                                               RS204840
  140 CONTINUE                                                          RS204850
      AL(J  )    = AL(29 ) * AK(J  )                                    RS204860
      ALMN       = AL(29 )                                              RS204870
      IF (ALMAX - AL(J  )) 113,401,401                                  RS204880
  401 CONTINUE                                                          RS204890
      IF (C2 - .0001) 149,457,457                                       RS204900
  457 CONTINUE                                                          RS204910
      AK2        = (AL(J  ))*((CL-AL(29 ))**2.28)                       RS204920
      AL(J  )    = AK2  /     ((CL-AL(J  ))**2.28)                      RS204930
      IF (ALMAX - AL(J  )) 113,149,149                                  RS204940
  149 CONTINUE                                                          RS204950
      ANL        = AL(J  )/DELTAL                                       RS204960
      ANL        = AINT(ANL)                                            RS204970
      AL(J  )    = ANL*DELTAL                                           RS204980
      GO TO 158                                                         RS204990
  113 AL(J)      = ALMAX                                                RS205000
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  158 CONTINUE                                                          RS205010
C                                                                       RS205020
C              THE DESIGN IS CHECKED TO DETERMINE WHETHER THE APPROXI-  RS205030
C          MATE LENGTH CALCULATED ABOVE IS TOO LONG OR TOO SHORT.       RS205040
C                                                                       RS205050
      ALB        = AL(J)                                                RS205060
      DELTAS     = T(J)                                                 RS205070
      LPFL       = 2                                                    RS205080
      CALL PRESUR                                                       RS205090
      CALL CHKLOD                                                       RS205100
      IF (CHK) 112,22,21                                                RS205110
  112 CONTINUE                                                          RS205120
C                                                                       RS205130
C              CONTROL HAS BEEN TRANSFERRED TO THIS POINT BECAUSE THE   RS205140
C          BAY IS TOO LONG.  INCREMENTS OF LENGTH ARE SUBTRACTED UNTIL  RS205150
C          THE SKIN STIFFNESS IS ADEQUATE.                              RS205160
C                                                                       RS205170
      AL(J)      = AL(J) - DELTAL                                       RS205180
      ALB        = AL(J)                                                RS205190
      DELTAS     = T(J)                                                 RS205200
      IF (AL(J) - ALX) 430,432,432                                      RS205210
  430 CONTINUE                                                          RS205220
      LPFL       = 4                                                    RS205230
      CALL PRESUR                                                       RS205240
  432 CONTINUE                                                          RS205250
      CALL CHKLOD                                                       RS205260
      IF (CHK) 112,22,22                                                RS205270
   21 IF(ALMAX - AL(J)) 42,42,40                                        RS205280
   40 CONTINUE                                                          RS205290
C                                                                       RS205300
C              CONTROL HAS BEEN TRANSFERRED TO THIS POINT BECAUSE THE   RS205310
C          BAY IS TOO SHORT. INCREMENTS OF LENGTH ARE ADDED TO THE BAY  RS205320
C          UNTIL THE SKIN STIFFNESS IS FULLY UTILIZED.                  RS205330
C                                                                       RS205340
      AL(J)      = AL(J) + DELTAL                                       RS205350
      ALB        = AL(J)                                                RS205360
      DELTAS     = T(J)                                                 RS205370
      LPFL       = 3                                                    RS205380
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      CALL PRESUR                                                       RS205390
      CALL CHKLOD                                                       RS205400
      IF (CHK) 33,22,21                                                 RS205410
   33 CONTINUE                                                          RS205420
      AL(J)      = AL(J) - DELTAL                                       RS205430
      IF (AL(J) - ALX) 730,732,732                                      RS205440
  730 CONTINUE                                                          RS205450
      LPFL       = 4                                                    RS205460
      CALL PRESUR                                                       RS205470
  732 CONTINUE                                                          RS205480
C                                                                       RS205490
C              REQUIRED MOMENT OF INERTIA OF STIFFENING RING IS CALCUL- RS205500
C          ATED BY THE METHOD DEVLOPED BY NEVINS AND HELTON IN NASA     RS205510
C          REPORT NO. MTP-P+VE-S-63-4. THIS IS A MODIFICATION OF THE    RS205520
C          CYLINDRICAL GENERAL STABILITY EQUATION DEVELOPED BY BECKER   RS205530
C          IN NACA TR 3786.                                             RS205540
C                                                                       RS205550
   22 IF(ALMAX - AL(J)) 42,42,940                                       RS205560
  940 CONTINUE                                                          RS205570
      CALL IREQ                                                         RS205580
C                                                                       RS205590
C              STIFFENING RING FOR THE BAY IS DESIGNED USING STANDARD   RS205600
C          SKIN GAUGES AND NORMALIZED RING CROSS-SECTION.               RS205610
C                                                                       RS205620
      K          = 1                                                    RS205630
   23 K          = K + 1                                                RS205640
      IF (29  - K) 98,98,123                                            RS205650
  123 CONTINUE                                                          RS205660
      CALL RING                                                         RS205670
      IF ( AIREQ. GT. AIRING)  GO TO 23                                 RS205680
C                                                                       RS205690
C          CHECK RING OUTSTANDING FLANGE STABILITY.                     RS205700
C                                                                       RS205710
      IF ( FRING. GT. FCFB ) GO TO 23                                   RS205720
C                                                                       RS205730
C              N-INDEX IS SET TO 29 TO INDICATE PARAMETERS ASSOCIATED   RS205740
C          WITH BAY IN WHICH THE SKIN STIFFNESS IS FULLY UTILIZED, BUT  RS205750
C          RING STIFFNESS IS NOT NECESSARILY FULLY UTILIZED.            RS205760
C                                                                       RS205770
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   24 N          = 29                                                   RS205780
      WR(N)      = (DSUBB - C2*AL(J) - A) * PI * AST * RHO              RS205790
      TR(N)      = T(K)                                                 RS205800
      WS(N)      =C5*(DSUBB   -C7*AL(J))*T(J)*AL(J)*RHO                 RS205810
      WSEG(N)    = WR(N) + WS(N)                                        RS205820
      VSEG(N)    =0.2618*AL(J)*((DSUBB   )**2+(DSUBB   -C2*AL(J))       RS205830
     1               *(2.0*DSUBB   -C2*AL(J)))                          RS205840
      AL(N)      = AL(J)                                                RS205850
C                                                                       RS205860
C               CALCULATE WEIGHT INDEX OF SEGMENT.                      RS205870
C                                                                       RS205880
      AINDEX(N) = WSEG(N)/VSEG(N)                                       RS205890
C                                                                       RS205900
C               N-INDEX IS SET TO 30 TO INDICATE PARAMETERS ASSOCIATED  RS205910
C          WITH BAY IN WHICH RING STIFFNESS IS FULLY UTILIZED, BUT SKIN RS205920
C          STIFFNESS IS NOT FULLY UTILIZED.                             RS205930
C                                                                       RS205940
      N          = 30                                                   RS205950
C                                                                       RS205960
C               MOMENT-OF-INERTIA OF THE NEXT SMALLER RING CROSS-SECTION RS205970
C          IS CALCULATED.                                               RS205980
C                                                                       RS205990
      K          = K - 1                                                RS206000
      CALL RING                                                         RS206010
  301 CONTINUE                                                          RS206020
C                                                                       RS206030
C               INCREMENTS OF LENGTH ARE SUBTRACTED FROM THE BAY UNTIL  RS206040
C          THE SMALLER RING CROSS-SECTION IS ADEQUATE.                  RS206050
C                                                                       RS206060
      IF (AL(J) - ALMN ) 303,303,306                                    RS206070
  306 CONTINUE                                                          RS206080
      AL(J)      = AL(J) - DELTAL                                       RS206090
      IF (AL(J) - ALX) 530,532,532                                      RS206100
  530 CONTINUE                                                          RS206110
      LPFL       = 4                                                    RS206120
      CALL PRESUR                                                       RS206130
  532 CONTINUE                                                          RS206140
      CALL RSTRES                                                       RS206150
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      CALL IREQ                                                         RS206160
      IF ( FRING. GT. FCFB ) GO TO 301                                  RS206170
      IF (AIRING - AIREQ) 301,302,302                                   RS206180
  302 CONTINUE                                                          RS206190
C                                                                       RS206200
C               PARAMETERS ASSOCIATED WITH THE SHORTER BAY ARE CALCUL-  RS206210
C                                                                       RS206220
      AL(N)       = AL(J)                                               RS206230
      WS(N)       =C5*(DSUBB    -C7*AL(J))*T(J)*AL(J)*RHO               RS206240
      WR(N)       = (DSUBB - C2*AL(J) - A) * PI * AST * RHO             RS206250
      WSEG(N)     = WR(N) + WS(N)                                       RS206260
      LAST        = LAST + 1                                            RS206270
      AL1(LAST) = AL(30)                                                RS206280
      W1(LAST) = WSEG(30)                                               RS206290
      LAST        = LAST + 1                                            RS206300
      AL1(LAST) = AL(29)                                                RS206310
      W1(LAST)    = WSEG(29)                                            RS206320
      TR(N)       = T(K)                                                RS206330
      VSEG(N)     =0.2618*AL(J)*((DSUBB    )**2+(DSUBB    -C2*AL(J))    RS206340
     1                  *(2.0*DSUBB    -C2*AL(J)))                      RS206350
      AINDEX(N) = WSEG(N)/VSEG(N)                                       RS206360
C                                                                       RS206370
C               WEIGHT INDEXES FOR THE ABOVE TWO CASES ARE COMPARED.    RS206380
C           PARAMETERS ASSOCIATED WITH THE SMALLER OF THE TWO WEIGHT    RS206390
C           INDEXES ARE STORED FOR THE SKIN THICKNESS BEING CONSIDERED. RS206400
C                                                                       RS206410
      IF (AINDEX(29 ) - AINDEX(30 )) 303,303,304                        RS206420
  304 CONTINUE                                                          RS206430
      N           = 30                                                  RS206440
      GO TO 305                                                         RS206450
  303 CONTINUE                                                          RS206460
      N           = 29                                                  RS206470
      LAST        = LAST + 1                                            RS206480
      AL1(LAST) = AL(29)                                                RS206490
      W1(LAST)    = WSEG(29)                                            RS206500
  305 CONTINUE                                                          RS206510
      AL(J)       = AL(N)                                               RS206520
      WR(J)       = WR(N)                                               RS206530
      TR(J)       = TR(N)                                               RS206540
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      WS(J)      = WS(N)                                                RS206550
      WSEG(J)    = WSEG(N)                                              RS206560
      VSEG(J)    = VSEG(N)                                              RS206570
      AINDEX(J) = AINDEX(N)                                             RS206580
      IF (28  - J) 98,98,126                                            RS206590
  126 CONTINUE                                                          RS206600
      GO TO 460                                                         RS206610
   42 CONTINUE                                                          RS206620
C                                                                       RS206630
C             CONTROL HAS BEEN TRANSFERRED TO THIS POINT BECAUSE        RS206640
C        THE LENGTH OF CONICAL SECTION HAS BEEN EXCEEDED. SEGMENT       RS206650
C        LENGTH IS SET EQUAL TO REMAINING LENGTH, AND THE WEIGHT INDEXRS206660
C        FOR THE SKIN THICKNESS IS CALCULATED.                          RS206670
C                                                                       RS206680
      AL(J)      = ALMAX                                                RS206690
      CALL IREQ                                                         RS206700
      K          = 1                                                    RS206710
  443 K          = K + 1                                                RS206720
      IF (29  - K) 98,98,523                                            RS206730
  523 CONTINUE                                                          RS206740
      CALL RING                                                         RS206750
      IF ( FRING. GT. FCFB ) GO TO 443                                  RS206760
      IF (AIREQ    - AIRING   ) 444,444,443                             RS206770
  444 WR(J)      = (DSUBB - C2*AL(J) - A) * PI * AST * RHO              RS206780
      TR(J)      = T(K)                                                 RS206790
      WS(J)      =C5*(DSUBB   -C7*AL(J))*T(J)*AL(J)*RHO                 RS206800
      WSEG(J)    = WR(J) + WS(J)                                        RS206810
      VSEG(J)    =0.2618*AL(J)*((DSUBB   )**2+(DSUBB   -C2*AL(J))       RS206820
     1                *(2.0*DSUBB   -C2*AL(J)))                         RS206830
      AINDEX(J) = WSEG(J)/VSEG(J)                                       RS206840
      LAST       = LAST + 1                                             RS206850
      W1(LAST)   = WSEG(J)                                              RS206860
      AL1(LAST) = ALMAX                                                 RS206870
      LL         = LAST                                                 RS206880
C                                                                       RS206890
C            THE REMAINDER OF THE SEVEN WEIGHT INDEXES ARE ASSIGNED A RS206900
C        HIGH NUMBER SO THAT THEY WILL NOT BE SELECTED AS OPTIMUM.      RS206910
C                                                                       RS206920
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      JEND          = J+ 1                                              RS206930
      DO 453   J =  JEND,J7                                             RS206940
  453 AINDEX(J)  =  10000.                                              RS206950
  460 CONTINUE                                                          RS206960
C                                                                       RS206970
C              J CORRESPONDING TO THE SMALLEST OF THE SEVEN WEIGHT      RS206980
C          INDEXES IS DETERMINED.                                       RS206990
C                                                                       RS207000
      DO 420   J =  J2,J7                                               RS207010
      IF(AINDEX(J) - AINDEX(JF)) 410,410,420                            RS207020
  410 JF            = J                                                 RS207030
  420 CONTINUE                                                          RS207040
C                                                                       RS207050
C              LENGTH IS CHECKED TO DETERMINE IF AT LEAST ONE MINIMUM   RS207060
C          BAY LENGTH REMAINS FOR NEXT BAY.                             RS207070
C                                                                       RS207080
      LPFL          = 2                                                 RS207090
   34 IF (ALCONE -SLOPT     -AL(JF ) - ALMIN) 35,36,36                  RS207100
C                                                                       RS207110
C              PARAMETERS ASSOCIATED WITH SMALLEST WEIGHT INDEX ARE     RS207120
C          STORED AS OPTIMUM FOR THE BAY UNDER CONSIDERATION.           RS207130
C                                                                       RS207140
   36 ALOPT(I)      = AL(JF )                                           RS207150
      D(I)          = DSUBB     -(C2)*(AL(JF ))                         RS207160
      TSKIN(I)      = T(JF )                                            RS207170
      TRING(I)      = TR(JF )                                           RS207180
      WRING(I)      = WR(JF )                                           RS207190
      WSKIN(I)      = WS(JF )                                           RS207200
      WTDEX(I)      = AINDEX(JF) * 1728.                                RS207210
      DELTAS        = TSKIN(I)                                          RS207220
      ALB           = ALOPT(I)                                          RS207230
      CALL CHKLOD                                                       RS207240
      RAXMN(I)      = RAXMIN                                            RS207250
      RAXMX(I)      = RAXMAX                                            RS207260
      RPMN(I)       = RPMIN                                             RS207270
      RPMX(I)       = RPMAX                                             RS207280
      CHKWD(I)      = CHKWND                                            RS207290
      CHKLE(I)      = CHKLEE                                            RS207300
      SLOPT         = SLOPT    +ALOPT(I)                                RS207310
```

```
      SUMAL      = SUMAL + ALOPT(I)
      WCONE      = WCONE + WSEG(JF)
C
C             BAY VOLUME WHICH IS USEFUL FOR PAYLOAD IS CALCULATED
C         NEXT. TWO RING HEIGHTS AND TWO PERCENT OF THE BASE DIAMETER
C         ARE SUBTRACTED FROM THE DIAMETERS OF THE CONICAL FRUSTUM IN
C         ORDER TO DETERMINE THIS USEFUL VOLUME.
C             USEFUL BAY VOLUME IS ADDED TO THE SUM OF PREVIOUS BAY
C         VOLUME FOR THIS FRUSTUM.
C
      DUSE1      = DSUBB    - 58.*TRING(I) -0.02 * DBASE
      DUSE2      = D(I) - 58.* TRING(I) - 0.02 * DBASE
      VUSE       = VUSE + .2617994 * ALOPT(I)*(DUSE1**2 + DUSE1*DUSE2
     1                               DUSE2**2)/1728.
      DSUBB      = D(I)
      NBAY       = NBAY + 1
C
C              THE PROGRAM GOES ON TO DESIGN THE NEXT BAY
C
      GO TO 17
   35 CONTINUE
C
C             CONTROL HAS BEEN TRANSFERRED TO THIS POINT BECAUSE LESS
C         THAN ONE MINIMUM BAY LENGTH REMAINS IN THE FRUSTUM.
C             A CHECK IS MADE TO DETERMINE IF TWO BAYS ARE POSSIBLE.
C         IF TWO BAYS ARE POSSIBLE THE WEIGHT OF A SINGLE BAY AND
C         THE WEIGHTS OF VARIOUS LENGTH COMBINATIONS OF A TWO-BAY
C         CONFIGURATION ARE COMPARED. THE CONFIGURATION WITH THE
C         SMALLEST WEIGHT IS CHOSEN TO FINISH OUT THE FRUSTUM.
C
      IF (0.5*ALMX2 - ALMIN) 342,343,343
  343 CONTINUE
      J          = JMIN
      ALB        = ALMX2 - ALMIN
      LFLAG      = 2
      GO TO 344
  356 CONTINUE
      LAST       = LAST + 1
```

```
      ALB          = ALMX2 - AL1(LAST)                                  RS207700
      IF (ALB-ALMIN) 353,354,354                                        RS207710
  353 CONTINUE                                                          RS207720
      ALB          = ALMIN                                              RS207730
      AL1(LAST)    = ALMX2 - ALB                                        RS207740
      LL           =  LAST                                              RS207750
      LFLAG        = 4                                                  RS207760
  354 CONTINUE                                                          RS207770
  360 CONTINUE                                                          RS207780
      J            = JMIN                                               RS207790
      DSUBB        = DMIN + C2*ALB                                      RS207800
      CALL LOAD                                                         RS207810
      GO TO 344                                                         RS207820
  342 CONTINUE                                                          RS207830
      LFLAG        = 1                                                  RS207840
      J            = JF                                                 RS207850
      ALB          = ALMX2                                              RS207860
  349 CONTINUE                                                          RS207870
      FSUBZ        = FZ(I)                                              RS207880
      ANFIMX       = ENFIMX(I)                                          RS207890
      ANFIMN       = ENFIMN(I)                                          RS207900
      IF (I-1) 451,451,452                                              RS207910
  451 DSUBB        = DBAS                                               RS207920
      GO TO 454                                                         RS207930
  452 DSUBB        = D(I-1)                                             RS207940
  454 CONTINUE                                                          RS207950
      LAST         = LAST + 1                                           RS207960
  344 CONTINUE                                                          RS207970
      AL(J)        = ALB                                                RS207980
   39 CONTINUE                                                          RS207990
      ALB          = AL(J)                                              RS208000
      DELTAS       = T(J)                                               RS208010
      CALL PRESUR                                                       RS208020
      CALL CHKLOD                                                       RS208030
      IF (CHK) 37,31,31                                                 RS208040
   37 J            = J + 1                                              RS208050
      IF (29  - J) 98,98,148                                            RS208060
  148 CONTINUE                                                          RS208070
      AL(J)        = AL(J-1)                                            RS208080
```

```
      GO TO 39                                                          RS208090
   31 CONTINUE                                                          RS208100
      CALL IREQ                                                         RS208110
      K           = 1                                                   RS208120
   43 K           = K + 1                                               RS208130
      IF (29  - K)98,98,122                                             RS208140
  122 CONTINUE                                                          RS208150
      CALL RING                                                         RS208160
      IF ( FRING. GT. FCFB ) GO TO 43                                   RS208170
      IF (AIREQ    - AIRING   ) 44,44,43                                RS208180
   44 WR(J)       = (DSUBB - C2*AL(J) - A) * PI * AST * RHO             RS208190
      TR(J)       = T(K)                                                RS208200
      WS(J)       =C5*(DSUBB   -C7*AL(J))*T(J)*AL(J)*RHO                RS208210
      WSEG(J)     = WR(J) + WS(J)                                       RS208220
      GO TO (26,355,345,357,346,26),LFLAG                               RS208230
  345 CONTINUE                                                          RS208240
      WT(LAST) = WSEG(J) + W1(LAST)                                     RS208250
      GO TO 356                                                         RS208260
  355 CONTINUE                                                          RS208270
      AL1L        = ALB                                                 RS208280
      W1L         = WSEG(J)                                             RS208290
      LFLAG       = 3                                                   RS208300
      LFLG        = 2                                                   RS208310
      LAST        = 0                                                   RS208320
      GO TO 356                                                         RS208330
  357 CONTINUE                                                          RS208340
      WT(LAST)    = WSEG(J) + W1L                                       RS208350
      ALB         = ALMX2                                               RS208360
      AL1(LAST+1) = ALMX2                                               RS208370
      LFLAG       = 5                                                   RS208380
      LFLG        = 3                                                   RS208390
      J           = JMIN                                                RS208400
      GO TO 349                                                         RS208410
  346 CONTINUE                                                          RS208420
      WT(LAST)    = WSEG(J)                                             RS208430
      LLL         = LAST                                                RS208440
      LF          = 1                                                   RS208450
      DO 347 LAST = 2,LLL                                               RS208460
```

```
      IF  (WT(LAST)-WT(LF)) 348•348•347                                 RS208470
  348 LF          = LAST                                                RS208480
  347 CONTINUE                                                          RS208490
      ALB         = AL1(LF)                                             RS208500
      J           = JMIN                                                RS208510
      LFLAG       = 6                                                   RS208520
      GO TO 349                                                         RS208530
   26 CONTINUE                                                          RS208540
C                                                                       RS208550
C               DATA ON THIS BAY ARE STORED•                            RS208560
C                                                                       RS208570
      VSEG(J)     =0•2618*AL(J)*((DSUBB    )**2+(DSUBB    -C2*AL(J))    RS208580
     1                  *(2•0*DSUBB    -C2*AL(J)))                      RS208590
      ALOPT(I)    = AL(J)                                               RS208600
      D(I)        = DSUBB    -C2*AL(J)                                  RS208610
      TSKIN(I)    = T(J)                                                RS208620
      TRING(I)    = TR(J)                                               RS208630
      WRING(I)    = WR(J)                                               RS208640
      WSKIN(I)    = WS(J)                                               RS208650
      WTDEX(I)    = 1728• * WSEG(J)/VSEG(J)                             RS208660
      WCONE       = WCONE + WSEG(J)                                     RS208670
      DUSE1       = DSUBB    - 58•*TRING(I) -0•02 * DBASE               RS208680
      DUSE2       = D(I) - 58•* TRING(I) - 0•02 * DBASE                 RS208690
      VUSE        = VUSE + •2617994 * ALOPT(I)*(DUSE1**2 + DUSE1*DUSE2  RS208700
     1                               DUSE2**2)/1728•                    RS208710
      DELTAS      = TSKIN(I)                                            RS208720
      ALB         = ALOPT(I)                                            RS208730
      CALL PRESUR                                                       RS208740
      CALL CHKLOD                                                       RS208750
      RAXMN(I)    = RAXMIN                                              RS208760
      RAXMX(I)    = RAXMAX                                              RS208770
      RPMN(I)     = RPMIN                                               RS208780
      RPMX(I)     = RPMAX                                               RS208790
      CHKWD(I)    = CHKWND                                              RS208800
      CHKLE(I)    = CHKLEE                                              RS208810
      SUMAL       = SUMAL + ALOPT(I)                                    RS208820
C                                                                       RS208830
C               A CHECK IS MADE TO DETERMINE IF THIS IS THE LAST BAY    RS208840
C          OF THE FRUSTUM•                                              RS208850
```

```
C                                                                        RS208860
      IF (ALMX2 - ALOPT(I)) 362,362,363                                  RS208870
  363 CONTINUE                                                           RS208880
C                                                                        RS208890
C               PARAMETERS ARE INITIALIZED FOR DESIGN OF THE LAST BAY    RS208900
C          OF THE FRUSTUM.                                               RS208910
C                                                                        RS208920
      ALB         = ALMX2 - ALOPT(I)                                     RS208930
      ALMX2       = ALMX2 - ALOPT(I)                                     RS208940
      I           = I + 1                                                RS208950
      NBAY        = NBAY + 1                                             RS208960
      GO TO 360                                                          RS208970
  362 CONTINUE                                                           RS208980
C                                                                        RS208990
C               THE LAST BAY OF THE FRUSTUM HAS BEEN DESIGNED. WEIGHT    RS209000
C          OF THE TOP RING OF THE FRUSTUM IS INCREASED TO ALLOW FOR      RS209010
C          ATTACHMENT PROVISIONS.                                        RS209020
C                                                                        RS209030
      WRING(I)    = WRING(I) + 0.1*D(I)                                  RS209040
      WSEG(J)     = WSKIN(I) + WRING(I)                                  RS209050
      WTDEX(I)    = 1728. * WSEG(J)/VSEG(J)                              RS209060
      WCONE       = WCONE + 0.1*D(I)                                     RS209070
      ENFIMN(I)   = ANFIMN                                               RS209080
      ENFIMX(I)   = ANFIMX                                               RS209090
      FZ(I)       = FSUBZ                                                RS209100
  569 CONTINUE                                                           RS209110
C                                                                        RS209120
C               DATA ON THIS FRUSTUM ARE WRITTEN OUT FOR THE SUMMARY     RS209130
C          REPORT.                                                       RS209140
C                                                                        RS209150
      WRITE (6,313) NF,DMX,DMIN,THTA(NF),                                RS209160
     1ALCONE,ELMIN(NF),TMNC(NF),NBAY,VUSE,WCONE                          RS209170
      DMX         = DMN(NF)                                              RS209180
      VGROS       = 0.2617994*ALCONE*(DBASE**2+DBASE*DMIN+DMIN**2)       RS209190
      VGROSS      = VGROSS + VGROS                                       RS209200
      VTOT        = VTOT + VUSE                                          RS209210
      WTOT        = WTOT + WCONE                                         RS209220
      DBASE       = DMIN                                                 RS209230
```

```
      IMX(NF)    = I                                                      RS209240
C                                                                         RS209250
C                     PROGRAM GOES ON TO NEXT FRUSTUM.                    RS209260
C                                                                         RS209270
  129 CONTINUE                                                            RS209280
      GO TO 326                                                           RS209290
C                                                                         RS209300
C                     CONTROL HAS BEEN TRANSFERRED TO THIS POINT BECAUSE THE   RS209310
C                INDEX OF ONE OF THE SUBSCRIPTED VARIABLES HAS EXCEEDED THE    RS209320
C                NUMBER PERMITTED BY THE DIMENSION STATEMENT.             RS209330
C                                                                         RS209340
   98 WRITE (6,30)                                                        RS209350
      WRITE (6,120)                                                       RS209360
      WRITE (6,121) I,J,K,NF                                              RS209370
      WRITE (6,30)                                                        RS209380
  326 CONTINUE                                                            RS209390
      IMAX = I                                                            RS209400
      WRITE(6,314)                                                        RS209410
      WRITE (6,315) ALTOT,IMAX,VTOT,WTOT                                  RS209420
      WRITE (6,606)                                                       RS209430
C                                                                         RS209440
C                     SURFACE AREA OF THE CAP IS                          RS209450
C                                                                         RS209460
      SCAP       = 6.2832 * RCAP * ALCAP                                  RS209470
C                                                                         RS209480
C                     NOSE CAP SKIN THICKNESS REQUIRED FOR STRUCTURAL INTEG-   RS209490
C                RITY IS DETERMINED AND COMPARED WITH THICKNESS PREVIOUSLY     RS209500
C                CALCULATED TO MEET THERMAL REQUIREMENTS. THE LARGER OF THE    RS209510
C                TWO THICKNESSES IS USED TO COMPUTE CAP WEIGHT.           RS209520
C                                                                         RS209530
      CALL TNOSST                                                         RS209540
      IF (TCAPST - TCAPTH) 60,61,61                                       RS209550
   60 TCAP       = TCAPTH                                                 RS209560
      GO TO 62                                                            RS209570
   61 TCAP       = TCAPST                                                 RS209580
C                                                                         RS209590
C                     NOSE CAP WEIGHT IS COMPUTED.                        RS209600
C                                                                         RS209610
   62 WCAP       = SCAP* RHO * TCAP                                       RS209620
```

```
C                                                                       RS209630
C           USEFUL VOLUME OF NOSE CAP IS CALCULATED.                    RS209640
C                                                                       RS209650
      RUSE      = RCAP - 29.* TRING(I) - 0.01*DBASE                     RS209660
      HUSE      = ALCAP - 29.* TRING(I) - .01* DBASE                    RS209670
      VCAP      = 1.0471976*HUSE*HUSE*(3.*RUSE - HUSE)/1728.            RS209680
C                                                                       RS209690
C           GROSS VOLUME OF CAP IS COMPUTED AND ADDED TO GROSS          RS209700
C         VOLUME OF THE FRUSTUMS.                                       RS209710
C                                                                       RS209720
      VGROS     = 1.0471976*ALCAP*ALCAP*(3.*RCAP - ALCAP)               RS209730
      VGROSS    = (VGROSS + VGROS)/ 1728.                               RS209740
      VTOT      = VTOT + VCAP                                           RS209750
      WTOT      = WTOT + WCAP                                           RS209760
C                                                                       RS209770
C           DATA REPORT IS WRITTEN OUT.                                 RS209780
C                                                                       RS209790
      WRITE (6,82)                                                      RS209800
      WRITE (6,70) PDSPH                                                RS209810
      WRITE (6,67) TMINN                                                RS209820
      WRITE (6,96) TMPMAX                                               RS209830
      WRITE (6,89) TCAPST                                               RS209840
      WRITE (6,90) TCAPTH                                               RS209850
      WRITE (6,91) TCAP                                                 RS209860
      WRITE (6,87) RCAP                                                 RS209870
      WRITE (6,84) ALCAP                                                RS209880
      WRITE (6,88) SCAP                                                 RS209890
      WRITE (6,316) VCAP                                                RS209900
      WRITE (6,94) WCAP                                                 RS209910
      WRITE (6,92)                                                      RS209920
      WRITE (6,85) ALTOT                                                RS209930
      WRITE (6,86) VTOT                                                 RS209940
      WRITE (6,329) VGROSS                                              RS209950
      WRITE (6,95) WTOT                                                 RS209960
C                                                                       RS209970
C           IF AN INTEGER WAS READ IN FOR KEY, DETAILED DESIGN          RS209980
C         INFORMATION IS WRITTEN OUT FOR THE FAIRING.                   RS209990
C                                                                       RS210000
```

```
      IF (KEY) 134,134,327                                              RS210010
C                                                                       RS210020
  327 CONTINUE                                                          RS210030
      WRITE (6,30)                                                      RS210040
      WRITE (6,606)                                                     RS210050
      WRITE (6,51)                                                      RS210060
      DO 2626  NF = 1, NFMAX                                            RS210070
      WRITE (6, 2610) NF                                                RS210080
 2610 FORMAT( 52X, 26HRING DATA, FRUSTUM NUMBER  , I2  //)              RS210090
      GO TO ( 1615, 1616, 1617 ), IKIND                                 RS210100
 1615 WRITE (6,2611)                                                    RS210110
      GO TO 2625                                                        RS210120
 1616 WRITE (6,2612)                                                    RS210130
      GO TO 2625                                                        RS210140
 1617 WRITE (6,2613)                                                    RS210150
      GO TO 2625                                                        RS210160
 2611 FORMAT( 23X,4HTYPE , 61X,  11HANGLE        )                      RS210170
 2612 FORMAT( 23X, 4HTYPE , 61X, 11HZEE SECTION  )                      RS210180
 2613 FORMAT(23X, 4HTYPE , 61X, 11HHAT SECTION  )                       RS210190
 2625 CONTINUE                                                          RS210200
      WRITE (6,1620) BOT , AOT, COT, FCFB                               RS210210
 2626 CONTINUE                                                          RS210220
 1620 FORMAT( 23X, 12HBASE LEG B/T , 53X, 11HBOT       = F7.2 /,        RS210230
     1 23X, 15HUPRIGHT LEG B/T  ,  50X,  11HAOT       = F7.2 /,         RS210240
     2 23X, 19HOUTSTANDING LEG B/T , 46X, 11HCOT      = F7.2 /,         RS210250
     3 23X, 27HFLANGE BUCKLING STRESS, PSI  , 38X, 11HFCFB     = F7.0//)RS210260
      WRITE (6,650)                                                     RS210270
      WRITE (6,165)                                                     RS210280
      WRITE (6,166)                                                     RS210290
      WRITE (6,167)                                                     RS210300
      WRITE (6,168)                                                     RS210310
      WRITE (6,169)                                                     RS210320
      WRITE (6,607)                                                     RS210330
      NF         = 1                                                    RS210340
      IW         = 1                                                    RS210350
      I1         = 1                                                    RS210360
      I2         = 46                                                   RS210370
  605 IF (IMAX - I2) 600,601,601                                        RS210380
  600 I2         = IMAX                                                 RS210390
```

```
601 DO 602  I = I1,I2                                                   RS210400
    ENFIMN(I) = - ENFIMN(I)                                             RS210410
    ENFIMX(I) = - ENFIMX(I)                                             RS210420
    WRITE (6,58) NF,IW,D(I),ALOPT(I),TSKIN(I),TRING(I),WSKIN(I),        RS210430
   1  WRING(I),WTDEX(I),ENFIMN(I),RAXMN(I),RPMX(I),CHKWD(I),ENFIMX(I) RS210440
   2  ,RAXMX(I),RPMN(I),CHKLE(I)                                        RS210450
    IW        = IW + 1                                                  RS210460
    IF (IMX(NF) - I) 215,215,602                                        RS210470
215 CONTINUE                                                            RS210480
    IW        = 1                                                       RS210490
    NF        = NF + 1                                                  RS210500
602 CONTINUE                                                            RS210510
    IF (IMAX - I2) 603,603,604                                          RS210520
604 I1        = I2 + 1                                                  RS210530
    I2        = I2 + 54                                                 RS210540
    WRITE (6,30)                                                        RS210550
    WRITE (6,606)                                                       RS210560
    GO TO 605                                                           RS210570
603 CONTINUE                                                            RS210580
C                                                                       RS210590
C            IF 2 WAS READ IN FOR KEY, DETAILED LOADS INFORMATION       RS210600
C         IS WRITTEN OUT.                                               RS210610
C                                                                       RS210620
    IF (2 - KEY) 442,442,134                                            RS210630
442 CONTINUE                                                            RS210640
    WRITE (6,30)                                                        RS210650
    WRITE (6,606)                                                       RS210660
    WRITE (6,612)                                                       RS210670
    WRITE (6,608)                                                       RS210680
    WRITE (6,609)                                                       RS210690
    WRITE (6,610)                                                       RS210700
    SUMAL     = 0.                                                      RS210710
    IW        = 1                                                       RS210720
    NF        = 1                                                       RS210730
    I1        = 1                                                       RS210740
    I2        = 46                                                      RS210750
    THETA     = 0.0174532925*THTA(NF)                                   RS210760
    CTH       = COS(THETA)                                              RS210770
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```
      STH          = SIN(THETA)                                       RS210780
      C2           = 2.*STH/CTH                                       RS210790
      C3           = 0.3/CTH                                          RS210800
      LPFL         = 1                                                RS210810
      DSUBB        = DBAS                                             RS210820
      ALB          = ALOPT(1)                                         RS210830
  705 IF (IMAX - I2) 700,701,701                                      RS210840
  700 I2           = IMAX                                             RS210850
  701 DO 702  I = I1,I2                                               RS210860
      CALL PRESUR                                                     RS210870
      LPFL         = 2                                                RS210880
      ANFIAX       = 0.5*(ENFIMN(I) + ENFIMX(I))/FS                   RS210890
      ANFIB        = ANFIAX - ENFIMN(I)/FS                            RS210900
      AXLOAD       =-ANFIAX*DSUBB*.94248/C3                           RS210910
      BEND         =-0.23562*ANFIB*DSUBB**2/C3                        RS210920
      WRITE (6,611) NF,IW,DSUBB,D(I),ALOPT(I),SUMAL,PDESMX,PDESMN,    RS210930
     1  AXLOAD,FZ(I),BEND                                             RS210940
      IW           = IW + 1                                           RS210950
      SUMAL        = SUMAL + ALOPT(I)                                 RS210960
      DSUBB        = D(I)                                             RS210970
      ALB          = ALOPT(I+1)                                       RS210980
      IF (IMX(NF) - I) 715,715,702                                    RS210990
  715 CONTINUE                                                        RS211000
      IW           = 1                                                RS211010
      NF           = NF + 1                                           RS211020
      THETA        = 0.0174532925*THTA(NF)                            RS211030
      CTH          = COS(THETA)                                       RS211040
      STH          = SIN(THETA)                                       RS211050
      C2           = 2.*STH/CTH                                       RS211060
      C3           = 0.3/CTH                                          RS211070
  702 CONTINUE                                                        RS211080
      IF (IMAX - I2) 703,703,704                                      RS211090
  704 I1           = I2 + 1                                           RS211100
      I2           = I2 + 54                                          RS211110
      WRITE (6,30)                                                    RS211120
      WRITE (6,606)                                                   RS211130
      GO TO 705                                                       RS211140
  703 CONTINUE                                                        RS211150
      WRITE (6,613) DSUBB,SUMAL,AXLDCP,FSBZCP,BNDCAP                  RS211160
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      GO TO 134                                                             RS211170
   30 FORMAT(1H1)                                                           RS211180
   48 FORMAT (23X,77H BASE DIAMTER OF FAIRING, IN.                          RS211190
     1                 DBASE   = ,F8.2)                                     RS211200
   49 FORMAT (23X,77H SEMI-VERTEX ANGLE OF CONE, DEGREES                    RS211210
     1                 THETA   = ,F8.2)                                     RS211220
   50 FORMAT (23X,77H BLUNTNESS RATIO OF FAIRING                            RS211230
     1                 BLUNT   = ,F8.4  ///)                                RS211240
   51 FORMAT (48X,36H DESIGN DETAILS OF CONICAL FRUSTUMS  ///)              RS211250
   52 FORMAT (41X,49H DATA REPORT FOR OPTIMIZED NOSE FAIRING STRUCTURE      RS211260
     1// )                                                                  RS211270
   54 FORMAT (54X,24H    FAIRING GEOMETRY      //)                          RS211280
   58 FORMAT (1X,I2,1H-,I2,F8.1,F7.1,2F8.3,F9.2,F8.2,F9.4,F10.2,F9.3,      RS211290
     1 2F8.3,F10.2,3F8.3)                                                   RS211300
   63 FORMAT (48X,33H   CONSTRAINTS ON FAIRING DESIGN      //)              RS211310
   64 FORMAT (23X,77H MINIMUM BAY LENGTH CONSIDERED,IN.                     RS211320
     1                 ALMIN   = ,F8.3)                                     RS211330
   65 FORMAT (23X,77H INCREMENTS BY WHICH BAY LENGTHS ARE INCREASED, IN.RS211340
     1                 DELTAL  = ,F8.3)                                     RS211350
   66 FORMAT (23X,77H MINIMUM ALLOWABLE THICKNESS OF CONE SKIN, IN.         RS211360
     1                 TMINC   = ,F8.4)                                     RS211370
   67 FORMAT (23X,77H MINIMUM ALLOWABLE THICKNESS OF NOSE CAP SKIN, IN. RS211380
     1                 TMINN   = ,F8.4    )                                 RS211390
   68 FORMAT (48X,36H     SPECIFIED DESIGN PRESSURES         //)            RS211400
   69 FORMAT (23X,77H DESIGN PRESSURE ON WNDWRD SIDE OF CONE, (SAFETY FARS211410
     1CTOR=1.4), PSI   PDESMX  = ,F8.3)                                     RS211420
   70 FORMAT (23X,77H DESIGN PRESSURE ON NOSE CAP, PSI                      RS211430
     1                 PDSPH   = ,F8.3     )                                RS211440
   71 FORMAT  (45X,42H AERODYNAMIC DATA USED IN COMPUTING LOADS  //)        RS211450
   72 FORMAT (23X,77H DYNAMIC PRESSURE, LBS./SQ. FT.                        RS211460
     1                 QBAR    = ,F8.2)                                     RS211470
   73 FORMAT (23X,77H MACH NUMBER AT DESIGN DYNAMIC PRESSURE                RS211480
     1                 AMACH   = ,F8.3)                                     RS211490
   74 FORMAT (23X,77H ANGLE OF ATTACK AT DESIGN DYNAMIC PRESSURE, DEGREERS211500
     1S                ALPHA   = ,F8.2 )                                    RS211510
   75 FORMAT (48X, 36H    COMPUTED AERODYNAMIC LOADS DATA     //)           RS211520
   76 FORMAT (23X,77H PRESSURE COEFFICIENT ON CONE AT ZERO ANGLE OF ATTARS211530
     1CK               CPO     = ,F8.4)                                     RS211540
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 82 FORMAT (57X,16H NOSE CAP DESIGN // )                                   RS211550
 83 FORMAT (23X,77H LENGTH OF CONICAL SECTION, IN.                          RS211560
   1                  ALCONE = ,F8.2)                                       RS211570
 84 FORMAT (23X,77H LENGTH OF NOSE CAP, IN.                                 RS211580
   1                  ALCAP  = ,F8.2)                                       RS211590
 85 FORMAT (23X,77H TOTAL LENGTH OF FAIRING, IN.                            RS211600
   1                  ALTOT  = ,F8.2    )                                   RS211610
 86 FORMAT (23X,76H USEFUL VOLUME OF FAIRING, CU. FEET                      RS211620
   1                  VTOT   =, F9.2          )                             RS211630
 87 FORMAT (23X,77H NOSE CAP RADIUS, IN.                                    RS211640
   1                  RCAP   = ,F8.3 )                                      RS211650
 88 FORMAT (23X,77H NOSE CAP SURFACE AREA, SQ. IN.                          RS211660
   1                  SCAP   = ,F8.2 )                                      RS211670
 89 FORMAT (23X,77H NOSE CAP SKIN THICKNESS REQUIRED FOR STRUCTURAL INRS211680
   1TEGRITY, IN.      TCAPST = ,F8.3 )                                      RS211690
 90 FORMAT (23X,77H NOSE CAP SKIN THICKNESS REQUIRED FOR THERMAL REASORS211700
   1NS, IN.           TCAPTH = ,F8.3 )                                      RS211710
 91 FORMAT (23X,77H NOSE CAP SKIN THICKNESS USED TO CALCULATE WEIGHT. RS211720
   1IN.               TCAP   = ,F8.3      )                                 RS211730
 92 FORMAT (44X,43H TOTAL LENGTH, VOLUME AND WEIGHT OF FAIRING // )   RS211740
 93 FORMAT (23X,77H WEIGHT OF CONICAL SECTION, LBS.                         RS211750
   1                  WCONE  = ,F8.2 )                                      RS211760
 94 FORMAT (23X,77H WEIGHT OF NOSE CAP, LBS.                                RS211770
   1                  WCAP   = ,F8.2 ///)                                   RS211780
 95 FORMAT (23X,77H TOTAL WEIGHT OF FAIRING, LBS.                           RS211790
   1                  WTOT   = ,F8.2 )                                      RS211800
 96 FORMAT (23X,77H MAXIMUM ALLOWABLE TEMPERATURE OF SKIN, DEG. F.    RS211810
   1                  TMPMAX = ,F8.1      )                                 RS211820
120 FORMAT (23X,82H DESIGN OF THE CONICAL SECTION OF THE FAIRING HAS NRS211830
   1OT BEEN COMPLETED. THE I, J, K )                                        RS211840
121 FORMAT (24X,80HOR NF INDEX HAS EXCEEDED THE MAXIMUM PERMITTED BY TRS211850
   1HE DIMENSION STATEMENT.          //                                     RS211860
   249X,3HI =,I3,6H, J =,I3,6H, K =,I3,7H, NF =,I3)                         RS211870
162 FORMAT (23X,77H AMBIENT PRESSURE AT DESIGN CONDITIONS, PSI              RS211880
   1                  PSTAT  = ,F8.3 ///)                                   RS211890
163 FORMAT (23X,77H INTERNAL-TO-AMBIENT PRESSURE DIFFERENCE AT DESIGN RS211900
   1CONDITIONS,PSI    DELTAP = ,F8.3      )                                 RS211910
164 FORMAT (23X,77H CONICAL SECTION SKIN THICKNESS REQUIRED FOR THERMARS211920
   1L REASONS, IN.    TCONTH = ,F8.4    ///)                                RS211930
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165 FORMAT (77X, 9H WINDWARD,27X,8H LEEWARD)                           RS211940
166 FORMAT (65X,67H  --------                            ------------- RS211950
   1------------   -    )                                              RS211960
167 FORMAT (132H FRUSTUM  RING    BAY    SKIN   RING    SKIN       RINGRS211970
   1   WEIGHT     LINE    STRESS  STRESS  WNDWRD    LINE   STRESS  STRS211980
   2RESS  LEEWRD)                                                      RS211990
168 FORMAT (132H  -BAY    O.D.  LENGTH  GAUGE  GAUGE     WT.        WT.RS212000
   1  INDEX       LOAD    RATIO,  RATIO,  LOAD      LOAD   RATIO,  RARS212010
   2TIO,   LOAD )                                                      RS212020
169 FORMAT (132H   NO.    (IN)   (IN)    (IN)    (IN)   (IN)       (LB)RS212030
   1 (LB/CU FT) (LB/IN)    AXIAL  PRESS.   INDEX   (LB/IN)  AXIAL    PRRS212040
   2ESS.   INDEX)                                                      RS212050
170 FORMAT (23X,77H DESIGN PRESSURE ON LEEWRD SIDE OF CONE, (SAFETY FARS212060
   1CTOR=1.4), PSI   PDESMN = ,F8.3)                                   RS212070
206 FORMAT (23X,77H CHANGE IN PRESSURE COEFFICIENT DUE TO ANGLE OF ATTRS212080
   1ACK              CPA     = ,F8.4)                                  RS212090
307 FORMAT (56X,18H AERODYNAMIC LOADS  // )                            RS212100
308 FORMAT (48X,34H CONSTRAINTS ON DESIGN OF FRUSTUMS //)              RS212110
309 FORMAT (48X,36H DESIGN SUMMARY FOR FRUSTUM SECTION   //)           RS212120
310 FORMAT (20X,                                    92H FRUS-     LARGRS212130
   1E    SMALL      HALF     LENGTH   MIN. BAY    MIN.     NO.     USEFURS212140
   2L     WEIGHT )                                                     RS212150
311 FORMAT (20X,                                    92H  TUM       DIARS212160
   1.     DIA.    ANGLE                  LENGTH    GAUGE    OF     VOLUMRS212170
   2E            )                                                     RS212180
312 FORMAT (20X,                                    92H  NO.       (INRS212190
   1)     (IN)    (DEG)     (IN)      (IN)     (IN)    BAYS     (CU FTRS212200
   2)     (LB)   )                                                     RS212210
313 FORMAT(21X,I4,            F10.2,F10.2,F9.2,F9.1,F10.1,             RS212220
   1  F10.4,I7,F11.2,F11.2)                                            RS212230
314 FORMAT (57X, 6H -----,24X,25H                       ----)          RS212240
315 FORMAT (46X,6HTOTALS,F11.1,23X,I4,2F11.2 )                         RS212250
316 FORMAT (23X,77H USEFUL VOLUME OF NOSE CAP, CU. FT.                 RS212260
   1                 VCAP    = ,F8.2 )                                 RS212270
329 FORMAT (23X,76H TOTAL VOLUME OF FAIRING, CU. FEET                  RS212280
   1                 VGROSS =, F9.2 )                                  RS212290
606 FORMAT (1X, //)                                                    RS212300
607 FORMAT (1X, /)                                                     RS212310
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  608 FORMAT (10X,112H FRUSTUM   BAY BASE   BAY TOP     BAY    DISTANCE RS212320
     1   DES. PRES.   DES. PRES.   AXIAL        SHEAR      BENDING     )RS212330
  609 FORMAT (10X,112H  -BAY       DIA.       DIA.    LENGTH   FROM BASERS212340
     1     WNDWRD       LEEWRD      LOAD         LOAD       MOMENT     )RS212350
  610 FORMAT (10X,112H   NO.      (IN)       (IN)     (IN)      (IN)   RS212360
     1     (PSI)        (PSI)      (LBS)        (LBS)     (IN-LBS)   //)RS212370
  611 FORMAT (10X,I2,1H-,I2,F12.1,F10.1,F9.1,F11.1,F12.2,F13.2,F13.1,   RS212380
     1 F12.1,F14.1)                                                     RS212390
  612 FORMAT (54X,24H  DETAILED LOADS DATA     ///)                     RS212400
  613 FORMAT (17H        TANG. PT.,F10.1,19X,F11.1,25X,F13.1,F12.1,     RS212410
     1   F14.1)                                                         RS212420
  650 FORMAT (1H1)                                                      RS212430
      END                                                               RS212440
$IBFTC RS02    DECK                                                     RS212450
      SUBROUTINE PROPTY (MAT, E, AMU, RHO, TMPMAX)                      RS212460
C                                                                       RS212470
C              MATERIAL PROPERTIES ARE STORED IN THIS SUBROUTINE.       RS212480
C                                                                       RS212490
      GO TO (1,2,3,4,5          ), MAT                                  RS212500
    1 CONTINUE                                                          RS212510
C                                                                       RS212520
C              ALUMINUM PROPERTIES (MAT = 1)                            RS212530
C                                                                       RS212540
      WRITE (6,141)                                                     RS212550
  141 FORMAT (54X,24H  MATERIAL = ALUMINUM     ///)                     RS212560
      E         = 10500000.0                                            RS212570
      AMU       = 0.3                                                   RS212580
      RHO       = 0.1                                                   RS212590
      TMPMAX    = 600.0                                                 RS212600
      RETURN                                                            RS212610
    2 CONTINUE                                                          RS212620
C                                                                       RS212630
C              MAGNESIUM PROPERTIES (MAT = 2)                           RS212640
C                                                                       RS212650
      WRITE (6,142)                                                     RS212660
  142 FORMAT (54X,24H  MATERIAL = MAGNESIUM    ///)                     RS212670
      E         = 6500000.0                                             RS212680
      AMU       = 0.34                                                  RS212690
      RHO       = 0.065                                                 RS212700
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      TMPMAX     = 700.0                                                RS212710
      RETURN                                                            RS212720
    3 CONTINUE                                                          RS212730
C                                                                       RS212740
C                TITANIUM PROPERTIES (MAT = 3)                          RS212750
C                                                                       RS212760
      WRITE (6,143)                                                     RS212770
  143 FORMAT (54X,24H  MATERIAL = TITANIUM      ///)                    RS212780
      E          = 16000000.0                                           RS212790
      AMU        = 0.3                                                  RS212800
      RHO        = 0.16                                                 RS212810
      TMPMAX     = 900.0                                                RS212820
      RETURN                                                            RS212830
    4 CONTINUE                                                          RS212840
C                                                                       RS212850
C                STAINLESS STEEL PROPERTIES (MAT = 4)                   RS212860
C                                                                       RS212870
      WRITE (6,144)                                                     RS212880
  144 FORMAT (54X,24H    MATERIAL = STEEL       ///)                    RS212890
      E          = 30000000.0                                           RS212900
      AMU        = 0.3                                                  RS212910
      RHO        = 0.283                                                RS212920
      TMPMAX     = 1100.0                                               RS212930
      RETURN                                                            RS212940
    5 CONTINUE                                                          RS212950
C                                                                       RS212960
C                LOCKALLOY PROPERTIES (MAT = 5)                         RS212970
C                                                                       RS212980
      WRITE (6,145)                                                     RS212990
  145 FORMAT (54X,24H  MATERIAL = LOCKALLOY     ///)                    RS213000
      E          = 27000000.0                                           RS213010
      AMU        = 0.3                                                  RS213020
      RHO        = 0.076                                                RS213030
      TMPMAX     = 700.0                                                RS213040
      RETURN                                                            RS213050
      END                                                               RS213060
$IBFTC RS03    DECK                                                     RS213070
C                                                                       RS213080
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C                THE FOLLOWING SUBROUTINE CALCULATES NOSE CAP SKIN THICK-RS213090
C          NESS REQUIRED FOR STRUCTURAL INTEGRITY. THE FAILURE CRITERIONRS213100
C          USED IS THAT PRESENTED FOR NON-SHALLOW SPHERICAL CAPS IN THE RS213110
C          LMSC STRUCTURAL METHODS HANDBOOK, SECTION 6.32.1, DATED      RS213120
C          30 SEPTEMBER 1962.                                           RS213130
C                                                                       RS213140
      SUBROUTINE TNOSST                                                 RS213150
      COMMON RCAP,E,PDESMN,PDESMX,PSTAT,TMINN,PDSPH,TCAPST,ANFIMN,      RS213160
     1   ANFIMX,DSUBB,LPFL,ALX,ALN,CPOO,CPAA,CZALFA,CDCAP,CNCAP,XBCAP   RS213170
   46 A          =0.606*E/(RCAP**2)                                     RS213180
      TCAPST     = TMINN -0.001                                         RS213190
   90 TCAPST     = TCAPST + 0.001                                       RS213200
      B          = 0.04*SQRT (RCAP/TCAPST)                              RS213210
      PCOLL      = A * (TCAPST ** 2)/EXP(B)                             RS213220
      IF (PCOLL - PDSPH) 90,91,91                                       RS213230
   91 CONTINUE                                                          RS213240
      RETURN                                                            RS213250
      END                                                               RS213260
$IBFTC RS04     DECK                                                    RS213270
C                                                                       RS213280
C                THIS SUBROUTINE CHECKS THE ADEQUACY OF THE BAY DESIGN  RS213290
C          USING SEIDE'S INTERACTION RELATIONSHIP AS REPORTED ON PAGES  RS213300
C          951 TO 955, JOURNAL OF AEROSPACE SCIENCES,AUGUST 1962.       RS213310
C                                                                       RS213320
      SUBROUTINE CHKLOD                                                 RS213330
      COMMON /CHKLD/ C1,C3,C4,ALB,DELTAS,CHK,RAXMIN,RAXMAX,RPMIN,RPMAX, RS213340
     1   CHKWND,CHKLEE,C2                                               RS213350
      COMMON RCAP,E,PDESMN,PDESMX,PSTAT,TMINN,PDSPH,TCAPST,ANFIMN,      RS213360
     1   ANFIMX,DSUBB,LPFL,ALX,ALN,CPOO,CPAA,CZALFA,CDCAP,CNCAP,XBCAP   RS213370
C                                                                       RS213380
C                CALCULATE THE MAXIMUM PERMISSIBLE AXIAL LOAD PER INCH  RS213390
C          IN THE SHELL, WITH NO LATERAL PRESSURE ACTING.               RS213400
C          USE THE METHOD RECOMMENDED  IN LOCKHEED'S STRUCTURAL         RS213410
C          METHODS HANDBOOK, SECTION 6.11.2.                            RS213420
C                                                                       RS213430
      ROR        = 1. - C2*ALB/DSUBB                                    RS213440
      ETA        = 0.6*(0.7 + ROR)                                      RS213450
      RHO        = C3*DSUBB/0.6                                         RS213460
      AR         = ETA*RHO                                              RS213470
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      ROT       = AR/DELTAS                                                  RS213480
      ALOR      = ALB/AR                                                     RS213490
      ALGROT    = ALOG10(ROT)                                                RS213500
      AM        = -0.0378 * (  ALGROT)   **2+ C.30 * ALGROT     +0.792 RS213510
      AN        = 2.0 * (AM    - 1.0)                                        RS213520
      C         = 0.871 / ((ROT   **(AM-1.0)) * (ALOR  **AN   ))            RS213530
      FCCR      =  C *  E / ROT                                              RS213540
      ANFIAL    = FCCR * DELTAS                                              RS213550
C                                                                            RS213560
C             CALCULATE THE MAXIMUM PERMISSIBLE LATERAL PRESSURE            RS213570
C        FOR THE SEGMENT WITH NO AXIAL LOAD ACTING. THE EQUATIONS ARE RS213580
C        BASED UPON THE EQUIVALENT CYLINDER METHOD OF ANALYSIS GIVEN  RS213590
C        IN THE LMSC STRUCTURAL METHODS HANDBOOK, SEC. 6.23.  FOR     RS213600
C        COMPUTATIONAL CONVENIENCE, THE NORMA_ FORMS OF THE EQUATIONS RS213610
C        HAVE BEEN ALTERED.                                                  RS213620
C                                                                            RS213630
      Z         = (C1*ALB**2)/(DELTAS*(1.7*DSUB3 - C2*ALB))                  RS213640
      CSUBP     = (0.875*Z + 1.122*SQRT(Z)) / (4.385 + SQRT(Z))              RS213650
      OMEGA     = C3*(1.7*DSUBB - C2*ALB)/DELTAS                             RS213660
      PCRT      = (C4 * CSUBP)/(Z * OMEGA**2)                                RS213670
      RPMAX     = PDESMX / PCRT                                              RS213680
      RAXMIN    = ANFIMN    / ANFIAL                                         RS213690
      RPMIN     = PDESMN/PCRT                                                RS213700
      RAXMAX    = ANFIMX/ANFIAL                                              RS213710
      AWND      = RAXMIN / 1.732051                                          RS213720
      ALEE      = RAXMAX / 1.732051                                          RS213730
      BWND      = SQRT(1. + AWND **2)                                        RS213740
      BLEE      = SQRT(1. + ALEE **2)                                        RS213750
      IF ((1.+AWND/BWND).LT..01) AWND=BWND                                   RS213760
      IF ((1.+ALEE/BLEE).LT..01) ALEE=BLEE                                   RS213770
      CHKWND     = RPMAX + 1. -(BWND -2.*AWND )*SQRT(BWND  +AWND )           RS213780
      CHKLEE     = RPMIN + 1. -(BLEE -2.*ALEE )*SQRT(BLEE  +ALEE )           RS213790
      IF (CHKWND - 1.0) 211,211,210                                          RS213800
  211 CONTINUE                                                               RS213810
      IF (CHKLEE - 1.) 214,214,210                                           RS213820
  214 IF (CHKWND - 1.0) 215,222,210                                          RS213830
  215 IF (CHKLEE - 1.) 221,222,210                                           RS213840
  221 CHK       = 1.0                                                        RS213850
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      GO TO 220                                                         RS213860
  222 CHK        = 0.                                                   RS213870
      GO TO 220                                                         RS213880
  210 CHK        = -1.0                                                 RS213890
  220 CONTINUE                                                          RS213900
      RETURN                                                            RS213910
      END                                                               RS213920
$IBFTC RS05    DECK                                                     RS213930
      SUBROUTINE THERML                                                 RS213940
C                                                                       RS213950
C                THIS SUBROUTINE COMPUTES SKIN THICKNESSES REQUIRED TO  RS213960
C           KEEP NOSE CAP AND TOP FRUSTUM SKIN TEMPERATURES UNDER TMPMAX.RS213970
C                THE EQUATIONS AND STORED COEFFICIENTS IN THIS SUBROUTINE RS213980
C           WERE OBTAINED BY MEANS OF A MULTIPLE REGRESSION ANALYSIS OF RS213990
C           DATA RESULTING FROM A THERMAL ANALYSIS OF SPHERES FLYING A  RS214000
C           NOMINAL LLSV TRAJECTORY. THE HOTTEST POINT ON THE NOSE CAP  RS214010
C           IS AT THE STAGNATION POINT OF THE SPHERE, AND THE HOTTEST   RS214020
C           POINT ON THE TOP FRUSTUM IS AT THE TANGENCY POINT OF THE    RS214030
C           SPHERICAL NOSE CAP AND TOP FRUSTUM. THE METHOD USED TO OBTAINRS214040
C           THE ORIGINAL THERMAL DATA IS DESCRIBED IN LMSC DOCUMENT NO. RS214050
C           TM 54-20-7.                                                 RS214060
C                                                                       RS214070
      DIMENSION AT(50),AS(20)                                           RS214080
      COMMON RCAP,E,PDESMN,PDESMX,PSTAT,TMINN,PDSPH,TCAPST,ANFIMN,      RS214090
     1   ANFIMX,DSUBB,LPFL,ALX,ALN,CPOO,CPAA,CZALFA,CDCAP,CNCAP,XBCAP   RS214100
      COMMON /THRML/ TMPMAX,MAT,TCONTH,TCAPTH,THETA                     RS214110
C                                                                       RS214120
C                TANGENCY POINT COEFFICIENTS FOR ALUMINUM.              RS214130
      DATA AT/     .027903,  -.010162,   .691498, -.013716,  2.108521,  RS214140
     1              .25293,    .52256,  -.560318,  .896866,  -.512848,  RS214150
C                                                                       RS214160
C                TANGENCY POINT COEFFICIENTS FOR MAGNESIUM              RS214170
     2            -.176254, -1.175537,  1.972534, -.051082,  2.988892,  RS214180
     3            -.392456,  1.529938, -1.154861,   .88208,  -.055298,  RS214190
C                                                                       RS214200
C                TANGENCY POINT COEFFICIENTS FOR  TITANIUM.             RS214210
     4             .056461,   .062469,   .579819, -.018108,  2.341248,  RS214220
     5             .206238,   .399368,  -.336502,  .835144,  -.355804,  RS214230
C                                                                       RS214240
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C              TANGENCY POINT COEFFICIENTS FOR  STAINLESS STEEL.          RS214250
     6           .194916, 1.457764, -1.19155, -.064727, 1.619629,        RS214260
     7          -.032959, -.851807,  .946594, 1.026367, -.943359,        RS214270
C                                                                         RS214280
C              TANGENCY POINT COEFFICIENTS FOR  LOCKALLOY.                RS214290
     8           .352531, 1.183907,  .312973,  .001026, 1.551514,        RS214300
     9           .084351, -.735126, -.335369,  .614578, -.366287/        RS214310
C                                                                         RS214320
C              STAGNATION POINT COEFFICIENTS FOR ALUMINUM.                RS214330
      DATA AS/-.014267,5.291153,-1.559019,-.010812,                       RS214340
C                                                                         RS214350
C              STAGNATION POINT COEFFICIENTS FOR MAGNESIUM.               RS214360
     1         -.029125,6.776562,-1.966431,-.033269,                      RS214370
C                                                                         RS214380
C              STAGNATION POINT COEFFICIENTS FOR TITANIUM.                RS214390
     2         -.001164,5.252344,-0.926601,-.012582,                      RS214400
C                                                                         RS214410
C              STAGNATION POINT COEFFICIENTS FOR STAINLESS STEEL.         RS214420
     3         0.009530,3.505341,-1.058136,-.017291,                      RS214430
C                                                                         RS214440
C              STAGNATION POINT COEFFICIENTS FOR LOCKALLOY.               RS214450
     4         -.008722,3.676389,-1.086252,-.000541/                      RS214460
C                                                                         RS214470
      S2       = (SIN(THETA))**2                                          RS214480
      X2       = 1.0/SQRT(RCAP)                                           RS214490
      X3       = 0.001*TMPMAX*X2                                          RS214500
      X4       = (0.001 * TMPMAX+ 0.46) ** 4                              RS214510
      X5       = X2*S2                                                    RS214520
      X6       = X5*(0.001*TMPMAX)                                        RS214530
      X7       = 1.0/(RCAP**.2)                                           RS214540
      X8       = .001*TMPMAX*X7                                           RS214550
      X9       = X7*S2                                                    RS214560
      X10      = 0.001*TMPMAX*X9                                          RS214570
      L        = 1 + 4*(MAT - 1)                                          RS214580
      M        = 1 + 10*(MAT - 1)                                         RS214590
      YTAN     = AT(M)+X2*AT(M+1)+X3*AT(M+2)+X4*AT(M+3)+X5*AT(M+4)        RS214600
     1    +X6*AT(M+5)+X7*AT(M+6)+X8*AT(M+7)+X9*AT(M+8)+X10*AT(M+9)        RS214610
      YSTG     = AS(L)+X2*AS(L+1)+X3*AS(L+2)+X4*AS(L+3)                   RS214620
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      TCAPTH     = 100.*YSTG/(TMPMAX-70.)                               RS214630
      TCONTH     = 100.*YTAN/(TMPMAX-70.)                               RS214640
      RETURN                                                            RS214650
      END                                                               RS214660
$IBFTC RS06     DECK                                                    RS214670
      SUBROUTINE AERO                                                   RS214680
C                                                                       RS214690
C              THIS SUBROUTINE COMPUTES PRESSURE COEFFICIENTS AT ZERO   RS214700
C         ANGLE-OF-ATTACK AND THE CHANGE IN PRESSURE COEFFICIENT DUE    RS214710
C         TO ANGLE-OF-ATTACK. FOR THE PURPOSE OF COMPUTING THESE        RS214720
C         COEFFICIENTS, EACH FRUSTUM IS TREATED AS A COMPLETE CONE.     RS214730
C              FIRST, THE PRESSURE COEFFICIENT AT ZERO ANGLE OF ATTACK  RS214740
C         IS CALCULATED BY THE METHOD OF SIMON AND WALTER, AIAA JOUNAL,RS214750
C         JULY 1963, PP 1696-97. THE METHOD APPROXIMATES EXACT          RS214760
C         SOLUTIONS WITH A MODIFIED QUADRATIC IN SINE SQUARE OF DELTA   RS214770
C         WITH COEFFICIENTS BEING FUNCTIONS OF GAMMA AND MACH NUMBER.   RS214780
C                                                                       RS214790
      COMMON /AERLOD/ CPMN,CPMX,CPO(121),CPA(121),XOD(121),THTA(10),    RS214800
     1   ALF(10),DELTAP,NFMAX,DBAS,LTMAX,AMACH,QBAR,ALPHA,FS,NF,FSUBZ,  RS214810
     2   AXLDCP,FSBZCP,BNDCAP,LFLG,LTRIG,ALTOT,ALCAP,SUMAL,DMN(10)      RS214820
      COMMON RCAP,E,PDESMN,PDESMX,PSTAT,TMINN,FDSPH,TCAPST,ANFIMN,      RS214830
     1   ANFIMX,DSUBB,LPFL,ALX,ALN,CPOO,CPAA,CZALFA,CDCAP,CNCAP,XBCAP   RS214840
      IF (THTA(NF)) 30,30,31                                            RS214850
   30 CPOO       = 0.                                                   RS214860
      CPAA       = 0.                                                   RS214870
      GO TO 300                                                         RS214880
   31 CONTINUE                                                          RS214890
      DELTA      = 0.0174532925*THTA(NF)                                RS214900
C     G=GAMMA=1.4, GAM1=(G+7)/(G+1), GAM2=(G+7)/4, GAM3=((G-1)/4)**2    RS214910
C     GAM4=G/2, GAM5=GAM4*GAM1, GAM6=GAM1/2                             RS214920
      GAM1=3.5                                                          RS214930
      GAM2=2.1                                                          RS214940
      GAM3=.01                                                          RS214950
      GAM4=.7                                                           RS214960
      GAM5=2.45                                                         RS214970
      GAM6=1.75                                                         RS214980
      EM         = AMACH                                                RS214990
      IF(EM-1.05)100,1,1                                                RS215000
    1 FINK=DELTA*57.2958                                                RS215010
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      IF(FINK-50.)3,3,4                                                 RS215020
    4 WRITE (6,5) FINK, EMO, EX                                         RS215030
    5 FORMAT(84HOSUBR RAP-AT ANGLES BEYOND 50 DEG THE CP OBTAINED IS LIKRS215040
     1ELY TO BE ERRONEOUS.  DELTA=F6.2,6H, EMO=F6.2,7H,    X=F8.2)      RS215050
      EM=0.                                                             RS215060
      RETURN                                                            RS215070
    3 SDELT=SIN (DELTA)                                                 RS215080
      SSDEL=SDELT*SDELT                                                 RS215090
      GSSDE=1.4*SSDEL                                                   RS215100
      EMSTR=SQRT ((1.+GSSDE)/(1.-GSSDE))                                RS215110
   22 IF(EM-EMSTR)110,2,2                                               RS215120
    2 EMS=EM*EM                                                         RS215130
      EM4=EMS*EMS                                                       RS215140
      EM6=EM4*EMS                                                       RS215150
      F1=((EMS-1.)/(EM4*SDELT))+(6./EM6)+GAM2-GAM3                      RS215160
      Q=1.+(1./EM6)                                                     RS215170
      Q1=1./EMS                                                         RS215180
      F1SSD=F1*SSDEL                                                    RS215190
      F2=GAM6*(1.-Q1)*Q                                                 RS215200
      F3=GAM5*(1.+Q1)*Q                                                 RS215210
      SQUID=(F2-F1SSD)**2-((F3-F1)*SSDEL)**2                            RS215220
      CPOO      = 0.5*((F2+F1SSD)-SQRT(SQUID))                          RS215230
C                                                                       RS215240
C              NEXT. THE INCREASE IN PRESSURE COEFFICIENT (ON THE HIGH  RS215250
C          PRESSURE SIDE OF THE CONE) DUE TO ANGLE OF ATTACK IS         RS215260
C          COMPUTED. THIS  CALCULATION  IS  BASED ON DATA FROM CHART 8  RS215270
C          OF NACA REPORT 1135 AT MACH 1.5,AND A CIRCUMFERENTIAL        RS215280
C          PRESSURE DISTRIBUTION WHICH IS SINUSOIDAL. THE EQUATION      RS215290
C          FOR CPAA IS VALID FOR MACH NUMBERS BETWEEN 1.4 AND 1.6.      RS215300
C              CHECK IF MACH NUMBER LIES BETWEEN 1.4 AND 1.6.           RS215310
C                                                                       RS215320
      IF (AMACH - 1.4) 201,202,203                                      RS215330
  203 IF (AMACH - 1.6) 202,202,201                                      RS215340
  201 WRITE (6,205)                                                     RS215350
      WRITE (6,204)                                                     RS215360
      WRITE (6,205)                                                     RS215370
  205 FORMAT (1H1)                                                      RS215380
  204 FORMAT (16X,100HMACH NUMBER LIES OUTSIDE THE INTERVAL FROM 1.4 TO RS215390
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     11.6, VALUES CALCULATED FOR CPA MAY BE INACCURATE.  )             RS215400
  202 CPAA      = (2.03 - 1.20*DELTA)*ALPHA*2.*SIN(DELTA)/COS(DELTA)   RS215410
  300 CONTINUE                                                          RS215420
      RETURN                                                            RS215430
  100 WRITE (6,101) EM, EMO, EM1, EX                                    RS215440
  101 FORMAT(32H0       SUBROUTINE RAP--MACH NO.(F6.2,26H) IS LESS THAN 1RS215450
     1.05   EMO=F6.2,7H,  EM1=F6.2,5H,  X=F8.2)                         RS215460
      EM=0.                                                             RS215470
      RETURN                                                            RS215480
  110 WRITE (6,111) FINK, EM, EMO, EM1, EX                              RS215490
  111 FORMAT(27H0     SUBROUTINE RAP--DELTA(F6.2,42H) EXCEEDS MAX ANGLE FRS215500
     1OR THE MACH NO. USED(F6.2,8H).  EMO=F6.2,7H,  EM1=F6.2,4H. X=F8.2)RS215510
      EM=0.                                                             RS215520
      RETURN                                                            RS215530
      END                                                               RS215540
$IBFTC RS07    DECK                                                     RS215550
      SUBROUTINE DIAM (XN,DLOC)                                         RS215560
C                                                                       RS215570
C              THIS SUBROUTINE COMPUTES THE LOCAL DIAMETER OF THE       RS215580
C          FAIRING WHEN GIVEN THE AXIAL DISTANCE FROM THE NOSE.         RS215590
C                                                                       RS215600
      COMMON /AERLOD/ CPMN,CPMX,CPO(121),CPA(121),XOD(121),THTA(10),    RS215610
     1   ALF(10),DELTAP,NFMAX,DBAS,LTMAX,AMACH,QBAR,ALPHA,FS,NF,FSUBZ,  RS215620
     2   AXLDCP,FSBZCP,BNDCAP,LFLG,LTRIG,ALTOT,ALCAP,SUMAL,DMN(10)      RS215630
      XTOT      = ALTOT                                                 RS215640
      DO 10 N1 = 1,NFMAX                                                RS215650
      XTOT      = XTOT - ALF(N1)                                        RS215660
      DELTA     = XN- XTOT                                              RS215670
      IF (DELTA) 10,20,20                                               RS215680
   10 CONTINUE                                                          RS215690
   20 CONTINUE                                                          RS215700
      ANGLE     = 0.0174532925*THTA(N1)                                 RS215710
      DLOC      = DMN(N1) + 2.*DELTA*SIN(ANGLE)/COS(ANGLE)              RS215720
      RETURN                                                            RS215730
      END                                                               RS215740
$IBFTC RS08    DECK                                                     RS215750
      SUBROUTINE DLOD                                                   RS215760
C                                                                       RS215770
C              THIS SUBROUTINE COMPUTES THE CONTRIBUTION OF AN          RS215780
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C          INCREMENTAL LENGTH OF FAIRING TO THE BENDING MOMENT, AXIAL    RS215790
C          LOAD AND SHEAR LOAD ON THE FAIRING.                           RS215800
C                                                                        RS215810
      COMMON /DLOAD/D1,D2,XOD1,XOD2,CPO1,CPO2,CPA1,CPA2,A3,A4,QB,DP,     RS215820
     1    FSBZ,BND,AXLOD                                                 RS215830
      DX1        = XOD1 - XOD2                                           RS215840
      IF (DX1.LE..002)GO TO 10                                           RS215850
      DX2        = XOD1**2 -XOD2**2                                      RS215860
      DX3        = XOD1**3 - XOD2**3                                     RS215870
      DX4        = XOD1**4 -XOD2**4                                      RS215880
      B2         = (CPO1 - CPO2)/DX1                                     RS215890
      B1         = CPO1 - B2*XOD1                                        RS215900
      B4         = (CPO1 - CPO2)/(D1 - D2)                               RS215910
      B3         = CPO1- B4*D1                                           RS215920
      A2         = (CPA1 -CPA2)/DX1                                      RS215930
      A1         = CPA1 - A2*XOD1                                        RS215940
      AD2        = (D1-D2)/DX1                                           RS215950
      AD1        = D1 - AD2*XOD1                                         RS215960
      BTA1       = A1*AD1                                                RS215970
      BTA2       = 0.5*(A1*AD2 + A2*AD1)                                 RS215980
      BTA3       = A2*AD2/3.                                             RS215990
      FSBZ       = A3*(BTA1*DX1 + BTA2*DX2 + BTA3*DX3)                   RS216000
      BND        = A4*(BTA1*DX2/2. - BTA1*XOD2*DX1 + BTA2*DX3/3.         RS216010
     1             -BTA2*DX1*XOD2**2 + BTA3*DX4/4. - BTA3*DX1*XOD2**3)   RS216020
      DD2        = (D1**2 - D2**2)/2.                                    RS216030
      DD3        = (D1**3 - D2**3)/3.                                    RS216040
      AXLOD      = 1.5707963*(DD2*(QB*B3-DP) + DD3*B4*QB)                RS216050
      GO TO 20                                                           RS216060
   10 DAV        = 0.5*(D1 + D2)                                         RS216070
      CPOAV      = 0.5*(CPO1 + CPO2)                                     RS216080
      CPAAV      = 0.5*(CPA1 + CPA2)                                     RS216090
      FSBZ       = A3*CPAAV*DX1*DAV                                      RS216100
      BND        = A3*DX1*DX1*DAV*(CPA1/2.+2.*(CPA2-CPA1)/3.)            RS216110
      AXLOD      = 1.5707963*(D1-D2)*DAV*(CPOAV* QB-DP)                  RS216120
   20 CONTINUE                                                           RS216130
      RETURN                                                             RS216140
      END                                                                RS216150
$IBFTC RS09    DECK                                                      RS216160
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      SUBROUTINE LOAD                                                   RS216170
C                                                                       RS216180
C             THIS SUBROUTINE COMPUTES AXIAL LOADS, SHEAR LOADS,        RS216190
C        BENDING MOMENTS AND THE RESULTING LINE LOADS USING EITHER      RS216200
C        THE INPUT PRESSURE DATA OR THAT COMPUTED IN SUBROUTINE AERO.   RS216210
C                                                                       RS216220
      COMMON /AERLOD/ CPMN,CPMX,CPO(121),CPA(121),XOD(121),THTA(10),    RS216230
     1   ALF(10),DELTAP,NFMAX,DBAS,LTMAX,AMACH,QBAR,ALPHA,FS,NF,FSUBZ,  RS216240
     2   AXLDCP,FSBZCP,BNDCAP,LFLG,LTRIG,ALTOT,ALCAP,SUMAL,DMN(10)      RS216250
      COMMON /DLOAD/D1,D2,XOD1,XOD2,CPO1,CPO2,CPA1,CPA2,A3,A4,QB,DP,    RS216260
     1    FSBZ,BND,AXLOD                                                RS216270
      COMMON /CHKLD/ C1,C3,C4,ALB,DELTAS,CHK,RAXMIN,RAXMAX,RPMIN,RPMAX, RS216280
     1   CHKWND,CHKLEE,C2                                               RS216290
      COMMON RCAP,E,PDESMN,PDESMX,PSTAT,TMINN,PDSPH,TCAPST,ANFIMN,      RS216300
     1   ANFIMX,DSUBB,LPFL,ALX,ALN,CPOO,CPAA,CZALFA,CDCAP,CNCAP,XBCAP   RS216310
      COMMON/PRSLOD/ LTJNCT(10)                                         RS216320
C                                                                       RS216330
C             DETERMINE IF THIS IS THE FIRST BAY.                       RS216340
C                                                                       RS216350
      IF (LTRIG) 399,399,393                                            RS216360
  399 CONTINUE                                                          RS216370
C                                                                       RS216380
C             SINCE THIS IS THE FIRST BAY THE SUBROUTINE IS             RS216390
C        INITIALIZED. PRESSURE PROFILE POINTS AT EACH FRUSTUM JUNCTIONRS216400
C        ARE IDENTIFIED AND PLACED EXACTLY ON THE JUNCTION.             RS216410
C                                                                       RS216420
      NX          = NFMAX                                               RS216430
      LTJNCT(NX)= 1                                                     RS216440
      XOD(1)      = ALCAP/DBAS                                          RS216450
      XODSTP      = (ALCAP + ALF(NFMAX))/DBAS                           RS216460
      DO 458 LTX= 2,LTMAX                                               RS216470
      IF ((XOD(LTX) - XOD(LTX-1)).GT..000001) GO TO 458                 RS216480
      NX          = NX - 1                                              RS216490
      LTJNCT(NX)= LTX                                                   RS216500
      XOD(LTX)    = XODSTP                                              RS216510
      XOD(LTX-1)= XODSTP                                                RS216520
      XODSTP      = XODSTP + ALF(NX)/DBAS                               RS216530
  458 CONTINUE                                                          RS216540
      XOD(LTMAX)= ALTOT/DBAS                                            RS216550
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      QB         = QBAR/144.                                              RS216560
      A3         = 1.5707963*QB*DBAS                                      RS216570
      A4         = A3*DBAS                                                RS216580
      DP         = DELTAP                                                 RS216590
C                                                                         RS216600
C           SINCE THIS IS THE FIRST BAY. THE BENDING MOMENT. AXIAL        RS216610
C       LOAD AND SHEAR LOAD AT THE BASE OF THE FAIRING ARE COMPUTED       RS216620
C       USING THE PRESSURE DATA FOR THE ENTIRE FAIRING.                   RS216630
C           THE LOADS CONTIBUTED BY THE CONICAL FRUSTUMS ARE              RS216640
C       COMPUTED FIRST.                                                   RS216650
C                                                                         RS216660
      LTRIG      = 1                                                      RS216670
      X          = 0.                                                     RS216680
      AXLOAD     = 0.                                                     RS216690
      BEND       = 0.                                                     RS216700
      FSUBZ      = 0.                                                     RS216710
      EL         = 0.                                                     RS216720
      N1         = 1                                                      RS216730
      LTMX1      = LTMAX + 1                                              RS216740
      LTR1       = 1                                                      RS216750
      DO 463 N1  = 1.NFMAX                                                RS216760
      LTR2       = LTMAX - LTJNCT(N1)                                     RS216770
      THETA      = 0.0174532925*THTA(N1)                                  RS216780
      C2         = 2.*SIN(THETA)/COS(THETA)                               RS216790
      DO 371 LTR= LTR1.LTR2                                               RS216800
      LT         = LTMX1 - LTR                                            RS216810
      XN         = XOD(LT)*DBAS                                           RS216820
      CALL DIAM (XN.D1)                                                   RS216830
      XN         = XOD(LT-1)*DBAS                                         RS216840
      CALL DIAM (XN.D2)                                                   RS216850
      XOD1       = XOD(LT)                                                RS216860
      XOD2       = XOD(LT-1)                                              RS216870
      CPO1       = CPO(LT)                                                RS216880
      CPO2       = CPO(LT-1)                                              RS216890
      CPA1       = CPA(LT)                                                RS216900
      CPA2       = CPA(LT-1)                                              RS216910
      CALL DLOD                                                           RS216920
      EL         = EL+X                                                   RS216930
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      X            =(XOD1-XOD2)*DBAS                                    RS216940
      AXLOAD       = AXLOD + AXLOAD                                     RS216950
      FSUBZ        = FSUBZ + FSBZ                                       RS216960
      BEND         = BEND + EL*FSBZ + BND                               RS216970
  371 CONTINUE                                                          RS216980
      LTR1         = LTR2 + 1                                           RS216990
  463 CONTINUE                                                          RS217000
C                                                                       RS217010
C              THE LOADS CONTRIBUTED BY THE SPHERICAL NOSE CAP ARE      RS217020
C          ADDED TO THE FRUSTUM LOADS.                                  RS217030
C                                                                       RS217040
      AC           = .7853982*DMN(NFMAX)**2                             RS217050
      EL           = EL + X                                             RS217060
      IF (CDCAP) 435,435,436                                            RS217070
  435 CONTINUE                                                          RS217080
      X            = DMN(NFMAX)/C2                                      RS217090
      XBCAP        = X/3.                                               RS217100
      CZALFA       = 2.03 - 1.2*THETA                                   RS217110
      CNCAP        = CZALFA                                             RS217120
      CPSTG        = (166.92158*AMACH**7./(7.*AMACH**2-1.)**2.5-1.)/    RS217130
     1                    (0.7*AMACH**2)                                RS217140
      STHTA        = SIN(THETA)                                         RS217150
      CDCAP        = CPSTG*(1.+STHTA**2)/2.                             RS217160
  436 CONTINUE                                                          RS217170
      XBAR         = XBCAP                                              RS217180
      AXLOD        = AC*(CDCAP*QB - DELTAP)                             RS217190
      FSBZ         = AC*CNCAP*ALPHA*QB                                  RS217200
      AXLDCP       = AXLOD                                              RS217210
      FSBZCP       = FSBZ                                               RS217220
      BNDCAP       = FSBZ*XBAR                                          RS217230
      AXLOAD       = AXLOD + AXLOAD                                     RS217240
      BEND         = BEND + (EL + XBAR)*FSBZ                            RS217250
      FSUBZ        = FSUBZ + FSBZ                                       RS217260
C                                                                       RS217270
C              PARAMETERS ARE INITIALIZED FOR USE IN COMPUTING UPPER    RS217280
C          BAY LOADS.                                                   RS217290
C                                                                       RS217300
      LFLG         = 1                                                  RS217310
      THETA        = 0.0174532925*THTA(NF)                              RS217320
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      C3          = 0.3 / COS(THETA)                                    RS217330
      C2          = 2.*SIN(THETA)/COS(THETA)                            RS217340
      C21         = C2                                                  RS217350
      CPO2        = CPO(LTMAX)                                          RS217360
      CPA2        = CPA(LTMAX)                                          RS217370
      XOD2        = XOD(LTMAX)                                          RS217380
      D2          = DBAS                                                RS217390
      LT          = LTMAX - 1                                           RS217400
      GO TO 386                                                         RS217410
  393 CONTINUE                                                          RS217420
      XODB        = (ALTOT - SUMAL)/DBAS                                RS217430
      GO TO (445,446,447),LFLG                                          RS217440
  446 CONTINUE                                                          RS217450
C                                                                       RS217460
C               LOAD PARAMETERS ARE STORED TEMPORARILY FOR USE LATER.   RS217470
C                                                                       RS217480
      LFLG        = 1                                                   RS217490
      BNDLB       = BEND                                                RS217500
      XODLB       = XOD2                                                RS217510
      CPOLB       = CPO2                                                RS217520
      CPALB       = CPA2                                                RS217530
      D2LB        = D2                                                  RS217540
      LTLB        = LT                                                  RS217550
      FZLB        = FSUBZ                                               RS217560
      AXLLB       = AXLOAD                                              RS217570
      GO TO 445                                                         RS217580
  447 CONTINUE                                                          RS217590
C                                                                       RS217600
C               STORED LOAD PARAMETERS ARE PICKED UP.                   RS217610
C                                                                       RS217620
      BEND        = BNDLB                                               RS217630
      FSUBZ       = FZLB                                                RS217640
      AXLOAD      = AXLLB                                               RS217650
      LFLG        = 1                                                   RS217660
      XOD2        = XODLB                                               RS217670
      CPO2        = CPOLB                                               RS217680
      CPA2        = CPALB                                               RS217690
      D2          = D2LB                                                RS217700
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      LT        = LTLB                                                  RS217710
  445 CONTINUE                                                          RS217720
C                                                                       RS217730
C              SINCE THIS IS AN UPPER BAY, THE LOADS AT THE BASE OF     RS217740
C         THIS BAY ARE DETERMINED BY FIRST COMPUTING THE LOADS PRODUCEDRS217750
C         BY THE PRESSURE PROFILE BETWEEN THIS BAY AND THE PREVIOUS     RS217760
C         BAY, AND THEN SUBTRACTING THESE COMPUTED LOADS FROM THE       RS217770
C         LOADS OF THE PREVIOUS BAY.                                    RS217780
C                                                                       RS217790
      XOD1      = XOD2                                                  RS217800
      CPO1      = CPO2                                                  RS217810
      CPA1      = CPA2                                                  RS217820
      D1        = D2                                                    RS217830
      IF (XOD(LT) - XODB) 387,388,388                                   RS217840
  387 CONTINUE                                                          RS217850
      XOD2      = XODB                                                  RS217860
      CPO2      = CPO(LT) + (CPO(LT+1) - CPO(LT))*(XODB - XOD(LT))      RS217870
     1                           /(XOD(LT+1) - XOD(LT))                 RS217880
      CPA2      = CPA(LT) + (CPA(LT+1) - CPA(LT))*(XODB - XOD(LT))      RS217890
     1                           /(XOD(LT+1) - XOD(LT))                 RS217900
      GO TO 389                                                         RS217910
  388 CONTINUE                                                          RS217920
      XOD2      = XOD(LT)                                               RS217930
      CPO2      = CPO(LT)                                               RS217940
      CPA2      = CPA(LT)                                               RS217950
      LT        = LT - 1                                                RS217960
  389 CONTINUE                                                          RS217970
      XN1       = XOD1*DBAS                                             RS217980
      XN2       = XOD2*DBAS                                             RS217990
      X         = XN1-XN2                                               RS218000
      CALL DIAM (XN1,D1)                                                RS218010
      CALL DIAM (XN2,D2)                                                RS218020
      CALL DLOD                                                         RS218030
      FSUBZ     = FSUBZ - FSBZ                                          RS218040
      AXLOAD    = AXLOAD - AXLOD                                        RS218050
      BEND      = BEND - BND - X*FSUBZ                                  RS218060
      IF (XOD2 - XODB) 386,386,445                                      RS218070
  386 CONTINUE                                                          RS218080
C                                                                       RS218090
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C                USING THE LOADS COMPUTED ABOVE, LINE LOADS WITH THE          RS218100
C           FACTOR OF SAFETY APPLIED ARE COMPUTED FOR BOTH THE WINDWARD       RS218110
C           AND LEEWARD SIDES OF THE BAY.                                     RS218120
C                                                                             RS218130
      ANFIAX     = C3*AXLOAD/(0.94248*DSUBB)                                  RS218140
      ANFIB      = BEND*C3 / (0.23562* DSUBB    **2)                          RS218150
      ANFIMN     = FS*(ANFIAX - ANFIB)                                        RS218160
      ANFIMX     = FS*(ANFIAX + ANFIB)                                        RS218170
      RETURN                                                                  RS218180
      END                                                                     RS218190
$IBFTC RS10    DECK                                                           RS218200
      SUBROUTINE PRESUR                                                       RS218210
C                                                                             RS218220
C                THIS SUBROUTINE COMPUTES THE MAXIMUM DESIGN PRESSURE         RS218230
C           OCCURRING ANYWHERE ALONG THE LENGTH OF THE BAY ON BOTH THE        RS218240
C           WINDWARD AND LEEWARD SIDES OF THE BAY, USING EITHER THE           RS218250
C           INPUT PRESSURE DATA OR THAT COMPUTED IN SUBROUTINE AERO.          RS218260
C                                                                             RS218270
      COMMON /PRSLOD/ LTJNCT(10)                                              RS218280
      COMMON RCAP,E,PDESMN,PDESMX,PSTAT,TMINN,PDSPH,TCAPST,ANFIMN,            RS218290
     1   ANFIMX,DSUBB,LPFL,ALX,ALN,CPOO,CPAA,CZALFA,CDCAP,CNCAP,XBCAP         RS218300
      COMMON /AERLOD/ CPMN,CPMX,CPO(121),CPA(121),XOD(121),THTA(10),          RS218310
     1   ALF(10),DELTAP,NFMAX,DBAS,LTMAX,AMACH,QBAR,ALPHA,FS,NF,FSUBZ,        RS218320
     2   AXLDCP,FSBZCP,BNDCAP,LFLG,LTRIG,ALTOT,ALCAP,SUMAL,DMN(10)            RS218330
      COMMON /CHKLD/ C1,C3,C4,ALB,DELTAS,CHK,RAXMIN,RAXMAX,RPMIN,RPMAX,       RS218340
     1   CHKWND,CHKLEE,C2                                                     RS218350
      GO TO (399,400,417,415),LPFL                                            RS218360
  399 CONTINUE                                                                RS218370
      XODB       = ALTOT/DBAS                                                 RS218380
      XOD1       = XODB                                                       RS218390
      QB         = QBAR/144.                                                  RS218400
      LT1        = LTMAX + 1                                                  RS218410
      CPMX1      = CPO(LTMAX) + CPA(LTMAX)                                    RS218420
      CPMN1      = CPO(LTMAX) - CPA(LTMAX)                                    RS218430
      GO TO 415                                                               RS218440
  400 CONTINUE                                                                RS218450
      L2         = LTMAX                                                      RS218460
      IF (NF.GT.1) L2 = LTJNCT(NF-1) - 1                                      RS218470
```

```
      L1          = LTJNCT(NF)                                                  RS218480
      XODB        = (ALTOT - SUMAL)/DBAS                                        RS218490
      XOD1        = XODB                                                        RS218500
      IF (XOD1.GE.XOD(L2)) XOD1 = XOD(L2) - .00001                              RS218510
      DO 412 LT1 = L1,L2                                                        RS218520
      IF (XOD1.LT.XOD(LT1)) GO TO 414                                           RS218530
  412 CONTINUE                                                                  RS218540
  414 LT          = LT1                                                         RS218550
      CPOO        = CPO(LT-1) + (CPO(LT) - CPO(LT-1))*(XOD1 - XOD(LT-1))        RS218560
     1                        /(XOD(LT) - XOD(LT-1))                            RS218570
      CPAA        = CPA(LT-1) + (CPA(LT) - CPA(LT-1))*(XOD1 -XOD(LT-1))         RS218580
     1                        /(XOD(LT) - XOD(LT-1))                            RS218590
      CPMX1       = CPOO + CPAA                                                 RS218600
      CPMN1       = CPOO - CPAA                                                 RS218610
  415 CONTINUE                                                                  RS218620
      LT          = LT1                                                         RS218630
      CPMX        = CPMX1                                                       RS218640
      CPMN        = CPMN1                                                       RS218650
      ALN         = 0.                                                          RS218660
      ALX         = 0.                                                          RS218670
  417 CONTINUE                                                                  RS218680
      XOD2        = (ALTOT - SUMAL - ALB)/DBAS                                  RS218690
      IF (XOD2.LE.XOD(L1)) XOD2 = XOD(L1)  + .00001                             RS218700
  433 LT          = LT - 1                                                      RS218710
      IF (LT.LE.L1) GO TO 419                                                   RS218720
      IF (XOD(LT) - XOD2) 419,422,422                                           RS218730
  419 CONTINUE                                                                  RS218740
      LT          = LT + 1                                                      RS218750
      CPAA        = CPA(LT-1) + (CPA(LT) - CPA(LT-1))*(XOD2 -XOD(LT-1))         RS218760
     1                        /(XOD(LT) - XOD(LT-1))                            RS218770
      CPOO        = CPO(LT-1) + (CPO(LT) - CPO(LT-1))*(XOD2 - XOD(LT-1))        RS218780
     1                        /(XOD(LT) - XOD(LT-1))                            RS218790
      CPX         = CPOO + CPAA                                                 RS218800
      CPN         = CPOO - CPAA                                                 RS218810
      JFIN        = 0                                                           RS218820
      GO TO 428                                                                 RS218830
  422 CONTINUE                                                                  RS218840
      CPN         = CPO(LT) - CPA(LT)                                           RS218850
      CPX         = CPO(LT) + CPA(LT)                                           RS218860
```

```
      JFIN        = 1                                                   RS218870
  428 IF (CPMX - CPX) 424,425,425                                       RS218880
  424 CONTINUE                                                          RS218890
      CPMX        = CPX                                                 RS218900
      ALX         = (XODB - XOD(LT))*DBAS                               RS218910
      IF (JFIN.EQ.0) ALX=ALB                                            RS218920
  425 CONTINUE                                                          RS218930
      IF (CPMN - CPN) 426,427,427                                       RS218940
  426 CONTINUE                                                          RS218950
      CPMN        = CPN                                                 RS218960
      ALN         = (XODB - XOD(LT))*DBAS                               RS218970
      IF (JFIN.EQ.0) ALN=ALB                                            RS218980
  427 CONTINUE                                                          RS218990
      IF (JFIN) 429,429,433                                             RS219000
  429 CONTINUE                                                          RS219010
      PDESMX      = FS*(CPMX*QB - DELTAP)                               RS219020
      PDESMN      = FS*(CPMN*QB - DELTAP)                               RS219030
      RETURN                                                            RS219040
      END                                                               RS219050
$IBFTC RS11    DECK                                                     RS219060
      SUBROUTINE RING                                                   RS219070
C                                                                       RS219080
C              THIS SUBROUTINE COMPUTES THE MOMENT OF INERTIA, TORSION  RS219090
C         CONSTANT, CROSS-SECTIONAL AREA AND ECCENTRICITY OF THE        RS219100
C         STIFFENER RING WHEN GIVEN THE DIMENSIONS OF ITS CROSS-        RS219110
C         SECTION.                                                      RS219120
C                                                                       RS219130
      COMMON /RNG2/ ECC                                                 RS219140
     2  , TCONST                                                        RS219150
      COMMON / RNG/ IKIND,AOT,BOT,COT,WSEF,T(30),J,K,AIREQ,CTH,FRING,   RS219160
     1    FCC,AL(30),AIRING ,AST,AISTT,C6,PI,A,TT,AK(30),Z,ALCONE       RS219170
      COMMON RCAP,E,PDESMN,PDESMX,PSTAT,TMINN,PDSPH,TCAPST,ANFIMN,      RS219180
     1   ANFIMX,DSUBB,LPFL,ALX,ALN,CPOO,CPAA,CZALFA,CDCAP,CNCAP,XBCAP   RS219190
C                                                                       RS219200
C     IKIND-IS THE SHAPE OF THE RING                                    RS219210
C     1=ELL--L                                                          RS219220
C     2=ZEE--Z                                                          RS219230
C     3=HAT                                                             RS219240
```

```
C                                                                         RS219250
      TT         = T(K)                                                   RS219260
      A          = AOT * TT                                               RS219270
      B          = BOT * TT                                               RS219280
      C          = COT * TT                                               RS219290
C                                                                         RS219300
      GO TO (1020,1030,1040), IKIND                                       RS219310
 1020 AST        = B*TT + (A-TT) * TT                                     RS219320
      DD         = ( A*A*TT/2. +(B-TT)*(TT/2.)**2)/AST                    RS219330
      AIB        = ((B-TT) * TT**3)/12.                                   RS219340
      AIF        = (A**3)*TT/12.                                          RS219350
      AB         = (B-TT)*TT                                              RS219360
      AF         = A*TT                                                   RS219370
      DB       = DD - TT/2.                                               RS219380
      DF         = A/2. -DD                                               RS219390
      AIST=AIB+AIF+AB*DB*DB+AF*DF*DF                                      RS219400
C                                                                         RS219410
C              DETERMINE TORSION CONSTANT OF RING CROSS-SECTION.  THE     RS219420
C          METHOD USED IS FROM PEERYS AIRCRAFT STRUCTURES, P.331.         RS219430
C                                                                         RS219440
      TCONST     = 0.333 * ( A*TT**3 + (B-TT)*TT**3     )                 RS219450
      GO TO 105                                                           RS219460
 1030 AST        = A*TT + 2.*(B-TT)*TT                                    RS219470
      DD   = A/2.                                                         RS219480
      AIB        = (B-TT) * (TT**3)/12.                                   RS219490
      AIW        = TT*(A**3)/12.                                          RS219500
      DB         = (A-TT)/2.                                              RS219510
      AB         = (B-TT)*TT                                              RS219520
      AIST=AIB*2.+AIW+AB*DB*DB*2.                                         RS219530
      TCONST     = 0.333 * ( A*TT**3 + 2.*(B-TT)*TT**3 )                  RS219540
      GO TO 105                                                           RS219550
 1040 AST=2.*B*TT +C*TT + 2.*(A-2.*TT)*TT                                 RS219560
      DD         = ((B-TT)*TT*TT + A*A*TT + (C-2.*TT)*(A-TT/2.)*TT)/AST   RS219570
      AB         = 2. * (B-TT)*TT                                         RS219580
      AW         = 2.0 * A * TT                                           RS219590
      AT         = (C -2.*TT)*TT                                          RS219600
      AIB        = (B-TT)*(TT**3)/12.                                     RS219610
      AIW        = TT*(A**3)/12.                                          RS219620
      AIT      = (C-2.*TT)*(TT**3)/12.                                    RS219630
```

```
      DB          =DD-TT/2.                                             RS219640
      DT          = (A-TT/2. -DD)                                       RS219650
      DW    = DD - A/2.                                                 RS219660
      AIST=AIB*2.+AIW*2.+AIT+AB*2.*DB*DB                                RS219670
     1+AW*DW*DW*2.+AT*DT*DT                                             RS219680
      TCONST      = 0.333 * ( 2.*A*TT**3 + (C-2.*TT)*TT**3 + 2.*(B-TT)  RS219690
     1  *TT**3 )                                                        RS219700
 1050 ECC         =DD + T(J)/2.                                         RS219710
      Z           = (AST * ECC) / (AST + WSEF * T(J))                   RS219720
C                                                                       RS219730
C               CALCULATE MOMENT OF INERTIA OF RING, INCLUDING EFFECTIVE RS219740
C          WIDTH OF SKIN.                                               RS219750
C                                                                       RS219760
      AISTT       = AIST +  (WSEF*T(J)**3/12.)  + AST * (ECC - Z)**2+   RS219770
     1 WSEF * T(J) * Z**2                                               RS219780
      AIRING      = AIST                                                RS219790
      CALL RSTRES                                                       RS219800
      RETURN                                                            RS219810
      END                                                               RS219820
$IBFTC RS12    DECK                                                     RS219830
      SUBROUTINE RSTRES                                                 RS219840
C                                                                       RS219850
C               THIS SUBROUTINE COMPUTES STRESS ON THE RING INNER       RS219860
C          FLANGE.                                                      RS219870
C                                                                       RS219880
      COMMON RCAP,E,PDESMN,PDESMX,PSTAT,TMINN,PDSPH,TCAPST,ANFIMN,      RS219890
     1   ANFIMX,DSUBB,LPFL,ALX,ALN,CPOO,CPAA,CZALFA,CDCAP,CNCAP,XBCAP   RS219900
      COMMON / RNG/ IKIND,AOT,BOT,COT,WSEF,T(30),J,K,AIREQ,CTH,FRING,   RS219910
     1    FCC,AL(30),AIRING ,AST,AISTT,C6,PI,A,TT,AK(30),Z,ALCONE       RS219920
C                                                                       RS219930
C               CHECK LOCAL  INSTABILITY.  FIRST DETERMINE LOAD IN THE  RS219940
C          BAY DUE TO UNIFORM LATERAL PRESSURE.  ASSUME STRAINS IN      RS219950
C          SHEET AND RING ARE EQUAL.                                    RS219960
C               CALCULATE STRESS IN RING DUE TO UNIFORM PRESSURE        RS219970
C                                                                       RS219980
      ZFLG        = A + T(J)/2. - Z                                     RS219990
      ANTHTA      = PDESMX *(DSUBB / (2.*CTH))                          RS220000
      ANRING      = ANTHTA * AL(J) * ( AST /(AST + AL(J)*T(J)))         RS220010
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C                                                                       RS220020
C             ESTIMATE COMPRESSIVE STRESS IN RING DUE TO OUT-OF-ROUND-  RS220030
C          NESS AND ASSYMMETRY OF LOADING. ( F= PR)                     RS220040
C                                                                       RS220050
      FBEND  =  ANRING * ZFLG / AISTT                                   RS220060
      FRING     = ANRING / AST   + FBEND                                RS220070
      RETURN                                                            RS220080
      END                                                               RS220090
$IBFTC RS13    DECK                                                     RS220100
      SUBROUTINE IREQ                                                   RS220110
C                                                                       RS220120
C             THIS SUBROUTINE COMPUTES THE MOMENT OF INERTIA REQUIRED   RS220130
C          OF THE STIFFENER RING.                                       RS220140
C                                                                       RS220150
      COMMON /AERLOD/ CPMN,CPMX,CPO(121),CPA(121),XOD(121),THTA(10),    RS220160
     1   ALF(10),DELTAP,NFMAX,DBAS,LTMAX,AMACH,QBAR,ALPHA,FS,NF,FSUBZ,  RS220170
     2   AXLDCP,FSBZCP,BNDCAP,LFLG,LTRIG,ALTOT,ALCAP,SUMAL,DMN(10)      RS220180
      COMMON /CHKLD/ C1,C3,C4,ALB,DELTAS,CHK,RAXMIN,RAXMAX,RPMIN,RPMAX, RS220190
     1   CHKWND,CHKLEE,C2                                               RS220200
      COMMON RCAP,E,PDESMN,PDESMX,PSTAT,TMINN,PDSPH,TCAPST,ANFIMN,      RS220210
     1   ANFIMX,DSUBB,LPFL,ALX,ALN,CPOO,CPAA,CZALFA,CDCAP,CNCAP,XBCAP   RS220220
      COMMON / RNG/ IKIND,AOT,BOT,COT,WSEF,T(30),J,K,AIREQ,CTH,FRING,   RS220230
     1    FCC,AL(30),AIRING ,AST,AISTT,C6,PI,A,TT,AK(30),Z,ALCONE       RS220240
      PI        = 3.14159                                               RS220250
      AIREQ     = C6*AL(J)*((DSUBB - C2*AL(J))**2)*(PDESMX**1.33333)    RS220260
     1                    /T(J)**.33333                                 RS220270
      RETURN                                                            RS220280
      END                                                               RS220290
$IBFTC RS14    DECK                                                     RS220300
      BLOCK DATA                                                        RS220310
      COMMON / RNG/ IKIND,AOT,BOT,COT,WSEF,T(30),J,K,AIREQ,CTH,FRING,   RS220320
     1    FCC,AL(30),AIRING ,AST,AISTT,C6,PI,A,TT,AK(30),Z,ALCONE       RS220330
C                                                                       RS220340
C             FOLLOWING ARE STORED STANDARD MATERIAL THICKNESSES (T)    RS220350
C          AND THE CORRESPONDING COEFFICIENTS (AK) USED IN MAKING       RS220360
C          INITIAL ESTIMATES OF BAY LENGTH.                             RS220370
C                                                                       RS220380
      DATA T/.00001,.032,.04,.05,.063,.071,.080,.090,.1,.112,.125,.16,  RS220390
     1   .19,.22,.25,.30,.35,.4,.5,.6,.7,.8,.9,1.,2.,3.,4.,5.,6.,7./,   RS220400
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    2   AK / 1.,1.,2.08,2.08,2.13,1.52,1.52,1.52,1.41,1.45,1.43,2.25,   RS220410
    3   1.76,1.62,1.52,1.82,1.65,1.54,2.08,1.82,1.65,1.54,1.52,1.41,    RS220420
    4   9.71,3.78,2.56,2.08,1.82,1.65/                                  RS220430
      END                                                               RS220440
$IBFTC RS15    DECK                                                     RS220450
      SUBROUTINE BARUCH (X1,X2,X3,X4,X5,X6,X7,X8,X9,X10,X11,X12)        RS220460
C                                                                       RS220470
C     PROGRAM FOR GEN INST ANALYSIS OF RING-STIFFENED CYLINDERS         RS220480
C     THIS PROGRAM HANDLES AXIAL COMPRESSION PLUS LATERAL PRESSURE      RS220490
C     THE CYLINDER WALL IS ASSUMED TO BE NON-BUCKLING TO ULTIMATE LOAD  RS220500
C     THE RINGS ARE EQUALLY SPACED, AND OF IDENTICAL CROSS SECTION      RS220510
C     THE RINGS ARE INSIDE                                              RS220520
C     THIS IS AN ELASTIC ANALYSIS                                       RS220530
C     THIS PROGRAM BASED ON BARUCH-SINGER EQUATIONS WITH KNOCKDOWN      RS220540
C         FACTOR BASED ON (R/T)EFF APPLIED TO CLASSICAL                 RS220550
C                BUCKLING LOAD SO OBTAINED                              RS220560
C                                                                       RS220570
C     SUBROUTINES CRIT, TERP4, TERP5 AND TERP7, WHICH FOLLOW THIS       RS220580
C     SUBROUTINE, ARE PART OF THE BARUCH-SINGER ANALYSIS.               RS220590
C                                                                       RS220600
      DIMENSION DYT(1),XK(11,7),FIG4(10,5,5),FIG5(8,5,5),ETAS1(13,8,5),ERS220610
     1TAS2(13,8,5),ETAS3(13,8,5)                                        RS220620
      COMMON/BRUCH/ T, AST, AIST, D, TK, P, XL, E, DY, RT, XLR1, PISQ,  RS220630
     1 PI, ALF1, GAM, ETAP, ETAS, XNBAR, XMU, XN1, XN2, XNXCR, FIG4,    RS220640
     2 FIG5, ETAS1, ETAS2, ETAS3, ISTECC, IRECC, A11A, A22A, A33A,      RS220650
     3 A12A, D12D, D33D, DXD, E1R, E2R, XMU1, XMU2, AM, KOUNT, ENCL, Y, RS220660
     4 R, CL, CR                                                        RS220670
  101 FORMAT(6E12.8)                                                    RS220680
  203 FORMAT(1H0,6HXNXCR=E15.8,5X2HN=F5.1,5X2HM=F7.3)                   RS220690
      IF (DUMMY. GT. 1. ) GO TO 7                                       RS220700
      READ (5,101)((XK(I,J),J=1,7),I=1,11)                              RS220710
      READ (5,101)(((FIG4(I,J,K),K=1,5),J=1,5),I=1,10)                  RS220720
      READ (5,101)(((FIG5(I,J,K),K=1,5),J=1,5),I=1,8)                   RS220730
      READ (5,101)(((ETAS1(I,J,K),K=1,5),J=1,8),I=1,13)                 RS220740
      READ (5,101)(((ETAS2(I,J,K),K=1,5),J=1,8),I=1,13)                 RS220750
      READ (5,101)(((ETAS3(I,J,K),K=1,5),J=1,8),I=1,13)                 RS220760
      READ (5,100)                                                      RS220770
  100 FORMAT(72X)                                                       RS220780
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      DUMMY      = 2.0                                                  RS220790
      RETURN                                                            RS220800
C                                                                       RS220810
C     FOR COLLAPSE PRESSURE P IS POSITIVE. FOR BURST P IS NEGATIVE      RS220820
C                                                                       RS220830
    7 I=1                                                               RS220840
      AST   = X1                                                        RS220850
      D     = X2                                                        RS220860
      AIST  = X3                                                        RS220870
      DY    = X4                                                        RS220880
      T     = X5                                                        RS220890
      XMU   = X6                                                        RS220900
      E     = X7                                                        RS220910
      R     = X8                                                        RS220920
      XL    = X9                                                        RS220930
      TK    = X1                                                        RS220940
      P     = X11                                                       RS220950
      PI=3.14159265                                                     RS220960
      PISQ=PI*PI                                                        RS220970
      DYT(I)=DY/T                                                       RS220980
      XLR1=XL/R                                                         RS220990
      RT=R/T                                                            RS221000
      DXD=1.0                                                           RS221010
      XMU1=0.0                                                          RS221020
      XMU2=(1.0-XMU**2)*AST/(DY*T)                                      RS221030
      XJYT=TK/(DY*T**3)                                                 RS221040
      D33D=3.0*(1.0-XMU)*(2.0/3.0+XJYT)                                 RS221050
      D12D=XMU                                                          RS221060
      A11A=1.0                                                          RS221070
      A22A=1./(1.+AST/(DY*T))                                           RS221080
      A12A=-XMU*A22A                                                    RS221090
      A33A=2.0*(1.0+XMU)                                                RS221100
      E1R=0.0                                                           RS221110
      E2R=(D+0.5*T)/R                                                   RS221120
      ISTECC=0                                                          RS221130
      IRECC=1                                                           RS221140
      NTI=2                                                             RS221150
      KOUNT=0                                                           RS221160
      CALL CRIT                                                         RS221170
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```
      CL=XNCL*R*E                                                       RS221180
      CR=XNXCR*R*E                                                      RS221190
      CODE = 1.                                                         RS221200
      X12  = CR                                                         RS221210
      RETURN                                                            RS221220
      END                                                               RS221230
$IBFTC RS16     DECK                                                    RS221240
C     DECK FOR 99 PERCENT PROBABILITY                                   RS221250
      SUBROUTINE CRIT                                                   RS221260
      DIMENSION PBL(7),PXLAM(11)                                        RS221270
      DIMENSION  DYT(1),XM(20),ZM(20),XK(11,7),FIG4(10,5,5),FIG5(8,5,5),RS221280
     1ETAS1(13,8,5),ETAS2(13,8,5),ETAS3(13,8,5)                         RS221290
      REAL LINE                                                         RS221300
      COMMON/BRUCH/ T, AST, AIST, D, TK, P, XL, E, DY, RT, XLR1, PISQ,  RS221310
     1 PI, ALF1, GAM, ETAP, ETAS, XNBAR, XMU, XN1, XN2, XNXCR, FIG4,    RS221320
     2 FIG5, ETAS1, ETAS2, ETAS3, ISTECC, IRECC, A11A, A22A, A33A,      RS221330
     3 A12A, D12D, D33D, DXD, E1R, E2R, XMU1, XMU2, AM, KOUNT, ENCL, Y, RS221340
     4 R, CL, CR                                                        RS221350
      LINE(Q000FL,Q001FL,Q002FL,Q003FL,Q004FL)=Q002FL+(Q004FL-Q002FL)*(QRS221360
     1000FL-Q001FL)/(Q003FL-Q001FL)                                     RS221370
      PBL(1)=0.                                                         RS221380
      PBL(2)=0.2                                                        RS221390
      PBL(3)=0.4                                                        RS221400
      PBL(4)=0.6                                                        RS221410
      PBL(5)=0.8                                                        RS221420
      PBL(6)=1.                                                         RS221430
      PBL(7)=1.E+06                                                     RS221440
      PXLAM(1)=0.0                                                      RS221450
      DO 24 J=2,11                                                      RS221460
   24 PXLAM(J)=PXLAM(J-1)+0.25                                          RS221470
      BETA=PI/XLR1                                                      RS221480
      IBETA=0                                                           RS221490
      IF(KOUNT)1,1,92                                                   RS221500
    1 XN=0.0                                                            RS221510
      XN0=0.0                                                           RS221520
   92 IT=0                                                              RS221530
      SN=0.1                                                            RS221540
      IFLIP=0                                                           RS221550
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```
  712 IF(NTI-1)2,2,3                                               RS221560
    2 Y=1.0                                                        RS221570
      GO TO 50                                                     RS221580
    3 BL=1.3161*DYT(I)/SQRT(RT)                                    RS221590
      XLAM=XN/SQRT(RT)                                             RS221600
      IF(BL-1.0)31,31,32                                           RS221610
   31 MOUNT=1                                                      RS221620
      A=BL                                                         RS221630
   36 IF(A)33,34,35                                                RS221640
   35 A=A-0.2                                                      RS221650
      MOUNT=MOUNT+1                                                RS221660
      GO TO 36                                                     RS221670
   33 J1=MOUNT-1                                                   RS221680
      J2=J1+1                                                      RS221690
      GO TO 37                                                     RS221700
   34 J1=MOUNT                                                     RS221710
      J2=J1                                                        RS221720
      GO TO 37                                                     RS221730
   32 J1=6                                                         RS221740
      J2=7                                                         RS221750
   37 IF(XLAM-2.5)38,38,39                                         RS221760
   38 A=XLAM                                                       RS221770
      MOUNT=1                                                      RS221780
   45 IF(A)41,42,43                                                RS221790
   43 A=A-0.25                                                     RS221800
      MOUNT=MOUNT+1                                                RS221810
      GO TO 45                                                     RS221820
   41 I1=MOUNT-1                                                   RS221830
      I2=I1+1                                                      RS221840
      GO TO 49                                                     RS221850
   42 I1=MOUNT                                                     RS221860
      I2=I1                                                        RS221870
      GO TO 49                                                     RS221880
   39 I1=10                                                        RS221890
      I2=11                                                        RS221900
   49 Y1=LINE(XLAM,PXLAM(I1),XK(I1,J1),PXLAM(I2),XK(I2,J1))        RS221910
      Y2=LINE(XLAM,PXLAM(I1),XK(I1,J2),PXLAM(I2),XK(I2,J2))        RS221920
      GRAFK=LINE(BL,PBL(J1),Y1,PBL(J2),Y2)                         RS221930
      Y=GRAFK*SQRT(RT)/DYT(I)                                      RS221940
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      IF(Y-1.0)50,50,51                                                 RS221950
   51 Y=1.0                                                             RS221960
   50 S1=XMU1*E1R                                                       RS221970
      S2=XMU2*E2R                                                       RS221980
      IF(KOUNT)901,901,903                                              RS221990
  901 IF(NTI-1)903,904,903                                              RS222000
  904 DYD=1.0                                                           RS222010
      GO TO 906                                                         RS222020
  903 E2=E2R*R                                                          RS222030
      AR=AST                                                            RS222040
      XIO = AIST                                                        RS222050
      ZY=AR*E2/(AR+Y*DY*T)                                              RS222060
      XIYT=1.0/(12.0*(1.0-XMU**2))+XIO/(DY*T**3)+Y*(ZY/T)**2+AR*(E2-ZY)*RS222070
     1*2/(DY*T**3)                                                      RS222080
      DYD=XIYT*12.0*(1.0-XMU**2)                                        RS222090
  906 IF(ISTECC)101,102,103                                             RS222100
  101 S1=-S1                                                            RS222110
      GO TO 103                                                         RS222120
  102 S1=0.0                                                            RS222130
  103 IF(IRECC)104,105,106                                              RS222140
  104 S2=-S2                                                            RS222150
      GO TO 106                                                         RS222160
  105 S2=0.0                                                            RS222170
  106 Z1=12.0*S1*(RT*RT)                                                RS222180
      Z2=12.0*S2*(RT*RT)                                                RS222190
      DON=0.5*(1.0-XMU)*(1.0+XMU2)*XN**4+((1.0+XMU1)*(1.0+XMU2)-XMU)*(BERS222200
     1TA*XN)**2+(1.0+XMU1)*(1.0-XMU)*0.5*BETA**4                        RS222210
      D1N=-(1.0+XMU)*0.5*S2*BETA*XN**4+(1.0+XMU2)*(S1*BETA**3+(1.0-XMU)*RS222220
     10.5*BETA)*XN**2+S1*(1.0-XMU)*0.5*BETA**5-XMU*(1.0-XMU)*0.5*BETA**3RS222230
      D2N=(1.0-XMU)*0.5*S2*XN**5+((1.0+XMU1)*S2*BETA**2-(1.0-XMU)*0.5*(1RS222240
     1.0+XMU2))*XN**3+XN*(((1.0+XMU)*0.5*XMU-(1.0+XMU1)*(1.0+XMU2))*BETARS222250
     2**2-(1.0+XMU)*0.5*S1*BETA**4)                                     RS222260
      AN=D1N/DON                                                        RS222270
      BN=D2N/DON                                                        RS222280
      F=Z1*(-BETA**3*AN)+Z2*(-2.0*XN**2-BN*XN**3)+DYD*XN**4+DXD*BETA**4+RS222290
     1(2.0*XMU+D33D-1.0)*2.0*(BETA*XN)**2+12.0*RT**2*((1.0+XMU2)*(1.0+BNRS222300
     2   *XN)+XM                                                        RS222310
     2U*BETA*AN+(S2*XN*XN)**2/((1.-XMU**2)*Y+XMU2)+(S1*BETA**2)**2/(1.-XRS222320
```

```
    3MU**2+XMU1))-12.*RT*(1.-XMU**2)*P/E*(XN*RT)**2                     RS222330
      XNCL=2.0*F/(BETA**2*RT**3*24.0*(1.0-XMU**2))                      RS222340
      IF(XN)25,25,26                                                    RS222350
   25 X1=XNCL                                                           RS222360
      XN=2.0                                                            RS222370
      IT=1                                                              RS222380
      GO TO 712                                                         RS222390
   26 IF(IT)27,27,28                                                    RS222400
   27 X1=XNCL                                                           RS222410
      XN=XN+SN                                                          RS222420
      IFLIP=1                                                           RS222430
   62 IT=1                                                              RS222440
      GO TO 712                                                         RS222450
   28 DIF=X1-XNCL                                                       RS222460
      IF(DIF)29,29,27                                                   RS222470
   29 IF(XN-XN0)229,230,229                                             RS222480
  230 IFLIP=0                                                           RS222490
  229 IF(IFLIP)611,611,72                                               RS222500
  611 IF(XN-2.0)612,612,61                                              RS222510
  612 XN=0.0                                                            RS222520
      GO TO 613                                                         RS222530
   61 SN=-SN                                                            RS222540
      XN=XN+2.0*SN                                                      RS222550
  613 IFLIP=1                                                           RS222560
      IT=0                                                              RS222570
      IF(XN)72,72,772                                                   RS222580
  772 IT=1                                                              RS222590
      GO TO 712                                                         RS222600
   72 IF(IBETA)73,73,74                                                 RS222610
   73 XN1=0.5*X1*RT*RT*SQRT(A11A*12.0*(1.0-XMU**2)/DYD)                 RS222620
      Q1=X1                                                             RS222630
      BETA=1.055*PI/XLR1                                                RS222640
      IBETA=1                                                           RS222650
      IF(XN)92,92,775                                                   RS222660
  775 XN0=XN+0.1                                                        RS222670
      GO TO 92                                                          RS222680
   74 IF(BETA-1.055*PI/XLR1)93,94,93                                    RS222690
   94 XN2=0.5*X1*RT*RT*SQRT(A11A*12.0*(1.0-XMU**2)/DYD)                 RS222700
   93 IF(Q1-X1)75,75,76                                                 RS222710
```

```
   75 XNCL=Q1                                                                   RS222720
      IF(XN)776,776,777                                                         RS222730
  777 XN=XN-SN                                                                  RS222740
  776 CON=BETA*XLR1/PI                                                          RS222750
      IF(CON-1.055)778,778,779                                                  RS222760
  778 BETA=PI/XLR1                                                              RS222770
      AM=1.0                                                                    RS222780
      GO TO 82                                                                  RS222790
  779 IF(KOUNT)781,782,781                                                      RS222800
  782 IF(NTI-1)781,781,783                                                      RS222810
  783 BETA=BETA-PI/XLR1                                                         RS222820
      AM=CON-1.                                                                 RS222830
      GO TO 784                                                                 RS222840
  781 BETA=BETA-0.1*PI/XLR1                                                     RS222850
      AM=CON-0.1                                                                RS222860
  784 XNO=XN+0.1                                                                RS222870
      GO TO 82                                                                  RS222880
   76 IF(KOUNT)763,761,763                                                      RS222890
  761 IF(NTI-1)763,763,762                                                      RS222900
  762 BETA=BETA+PI/XLR1                                                         RS222910
      GO TO 764                                                                 RS222920
  763 BETA=BETA+0.1*PI/XLR1                                                     RS222930
  764 Q1=X1                                                                     RS222940
      IF(XN)92,92,785                                                           RS222950
  785 XNO=XN+0.1                                                                RS222960
      GO TO 92                                                                  RS222970
   82 RTE=RT/SQRT(0.5*(DXD+DYD)*A11A)                                           RS222980
      IF(RTE-33.0)14,14,15                                                      RS222990
   14 PHIM=1.0                                                                  RS223000
      GO TO 16                                                                  RS223010
   15 PHIM=6.48/(RTE**0.54)                                                     RS223020
   16 ALF1=XLR1**2*RT*SQRT(A11A*12.0*(1.0-XMU**2)/DYD)/(2.0*PISQ*A22A)          RS223030
      ETAS=(A12A+0.5*A33A)/SQRT(A11A*A22A)                                      RS223040
      ETAP=(D12D+D33D)/SQRT(DXD*DYD)                                            RS223050
      GAM=DXD*A11A/(DYD*A22A)                                                   RS223060
   60 CALL TERP7(SI)                                                            RS223070
      SI1=SI                                                                    RS223080
      SIBAR1=SI1*XN1                                                            RS223090
```

```
      ALF1=ALF1*0.9                                                     RS223100
      CALL TERP7(SI)                                                    RS223110
      SI2=SI                                                            RS223120
      SIBAR2=SI2*XN2                                                    RS223130
      IF(SIBAR1-SIBAR2)18,17,17                                         RS223140
   18 SI=SI1                                                            RS223150
      GO TO 500                                                         RS223160
   17 IF(GAM-1.0)19,19,21                                               RS223170
   19 CALL TERP4(SI)                                                    RS223180
      GO TO 500                                                         RS223190
   21 CALL TERP5(SI)                                                    RS223200
  500 IF(SI-1.0)22,22,198                                               RS223210
  198 SI=1.0                                                            RS223220
   22 XNXCR=XNCL*(SI+(PHIM-0.12)/0.88*(1.0-SI))                         RS223230
   90 RETURN                                                            RS223240
      END                                                               RS223250
$IBFTC RS17    DECK                                                     RS223260
      SUBROUTINE TERP4(SI)                                              RS223270
      DIMENSION QETAS(5),QETAP(5),QGAM(10)                              RS223280
      DIMENSION  DYT(1),XM(20),ZM(20),XK(11,7),FIG4(10,5,5),FIG5(8,5,5),RS223290
     1ETAS1(13,8,5),ETAS2(13,8,5),ETAS3(13,8,5)                         RS223300
      REAL LOGLOG                                                       RS223310
      COMMON/BRUCH/ T, AST, AIST, D, TK, P, XL, E, DY, RT, XLR1, PISQ,  RS223320
     1 PI, ALF1, GAM, ETAP, ETAS, XNBAR, XMU, XN1, XN2, XNXCR, FIG4,    RS223330
     2 FIG5, ETAS1, ETAS2, ETAS3, ISTECC, IRECC, A11A, A22A, A33A,      RS223340
     3 A12A, D12D, D33D, DXD, E1R, E2R, XMU1, XMU2, AM, KOUNT, ENCL, Y, RS223350
     4 R, CL, CR                                                        RS223360
      TERM(Q000FL,Q001FL,Q002FL)=(ALOG(Q000FL)-ALOG(Q001FL))/(ALOG(Q002FRS223370
     1L)-ALOG(Q001FL))                                                  RS223380
      LOGLOG(Q003FL,Q004FL,Q005FL,Q006FL,Q007FL)=EXP(ALOG(Q005FL)+(ALOG(RS223390
     1Q007FL)-ALOG(Q005FL))*TERM(Q003FL,Q004FL,Q006FL))                 RS223400
      ORDLOG(Q008FL,Q009FL,Q010FL,Q011FL,Q012FL)=EXP(ALOG(Q010FL)+(Q008FRS223410
     1L-Q009FL)*(ALOG(Q012FL)-ALOG(Q010FL))/(Q011FL-Q009FL))            RS223420
   94 QETAS(1)=0.5                                                      RS223430
      QETAS(2)=1.0                                                      RS223440
      QETAS(3)=2.0                                                      RS223450
      QETAS(4)=4.0                                                      RS223460
      QETAS(5)=8.0                                                      RS223470
      QETAP(1)=0.0                                                      RS223480
```

```
      QETAP(2)=0.2                                                      RS223490
      QETAP(3)=0.5                                                      RS223500
      QETAP(4)=1.0                                                      RS223510
      QETAP(5)=2.0                                                      RS223520
      QGAM(1)=0.001                                                     RS223530
      QGAM(2)=0.002                                                     RS223540
      QGAM(3)=0.005                                                     RS223550
      QGAM(4)=0.010                                                     RS223560
      QGAM(5)=0.020                                                     RS223570
      QGAM(6)=0.050                                                     RS223580
      QGAM(7)=0.100                                                     RS223590
      QGAM(8)=0.200                                                     RS223600
      QGAM(9)=0.500                                                     RS223610
      QGAM(10)=1.0                                                      RS223620
      KOUNT=1                                                           RS223630
      IF(ETAS-8.0)2,3,3                                                 RS223640
    3 ETAS=8.0                                                          RS223650
      GO TO 28                                                          RS223660
    2 A=ETAS                                                            RS223670
   25 IF(A-0.5)22,23,24                                                 RS223680
   24 A=A/2.0                                                           RS223690
      KOUNT=KOUNT+1                                                     RS223700
      GO TO 25                                                          RS223710
   23 I1=KOUNT                                                          RS223720
      I2=I1+1                                                           RS223730
      GO TO 35                                                          RS223740
   22 I1=KOUNT-1                                                        RS223750
      I2=I1+1                                                           RS223760
      IF(I1)26,26,27                                                    RS223770
   26 I1=1                                                              RS223780
      I2=2                                                              RS223790
      GO TO 35                                                          RS223800
   27 IF(I1-5)35,28,28                                                  RS223810
   28 I1=4                                                              RS223820
      I2=5                                                              RS223830
   35 IF(ETAP-2.0)4,5,5                                                 RS223840
    5 ETAP=2.0                                                          RS223850
      GO TO 47                                                          RS223860
```

```
  4 IF(ETAP-0.5)34,40,37                                        RS223870
 34 IF(ETAP-0.2)39,39,40                                        RS223880
 39 J1=1                                                        RS223890
    J2=2                                                        RS223900
    GO TO 55                                                    RS223910
 40 J1=2                                                        RS223920
    J2=3                                                        RS223930
    GO TO 55                                                    RS223940
 37 KOUNT=3                                                     RS223950
    A=ETAP                                                      RS223960
 46 IF(A-0.5)43,44,45                                           RS223970
 45 A=A/2.0                                                     RS223980
    KOUNT=KOUNT+1                                               RS223990
    GO TO 46                                                    RS224000
 44 J1=KOUNT                                                    RS224010
    J2=J1+1                                                     RS224020
    GO TO 55                                                    RS224030
 43 J1=KOUNT-1                                                  RS224040
    J2=J1+1                                                     RS224050
    IF(J1-5)55,47,47                                            RS224060
 47 J1=4                                                        RS224070
    J2=5                                                        RS224080
 55 IF(GAM-1.0)7,6,6                                            RS224090
  6 GAM=1.0                                                     RS224100
    GO TO 79                                                    RS224110
  7 IF(GAM-0.001)56,56,58                                       RS224120
 56 K1=1                                                        RS224130
    K2=2                                                        RS224140
    GO TO 100                                                   RS224150
 58 IF(GAM-0.002)56,56,60                                       RS224160
 60 IF(GAM-0.02)61,61,66                                        RS224170
 61 KOUNT=3                                                     RS224180
    A=GAM                                                       RS224190
 65 IF(A-0.005)62,63,64                                         RS224200
 64 A=A/2.0                                                     RS224210
    KOUNT=KOUNT+1                                               RS224220
    GO TO 65                                                    RS224230
 63 K1=KOUNT                                                    RS224240
    K2=K1+1                                                     RS224250
```

```
      GO TO 100                                                         RS224260
   62 K1=KOUNT-1                                                        RS224270
      K2=K1+1                                                           RS224280
      GO TO 100                                                         RS224290
   66 IF(GAM-0.2)67,67,70                                               RS224300
   67 KOUNT=6                                                           RS224310
      A=GAM                                                             RS224320
   69 IF(A-0.05)62,63,68                                                RS224330
   68 A=A/2.0                                                           RS224340
      KOUNT=KOUNT+1                                                     RS224350
      GO TO 69                                                          RS224360
   70 IF(GAM-1.0)71,71,79                                               RS224370
   71 KOUNT=9                                                           RS224380
      A=GAM                                                             RS224390
   75 IF(A-0.5)62,63,74                                                 RS224400
   74 A=A/2.0                                                           RS224410
      KOUNT=KOUNT+1                                                     RS224420
      GO TO 75                                                          RS224430
   79 K1=9                                                              RS224440
      K2=10                                                             RS224450
  100 Y1=LOGLOG(ETAS,QETAS(I1),FIG4(K1,J1,I1),QETAS(I2),FIG4(K1,J1,I2)) RS224460
      Y2=LOGLOG(ETAS,QETAS(I1),FIG4(K1,J2,I1),QETAS(I2),FIG4(K1,J2,I2)) RS224470
      Y3=ORDLOG(ETAP,QETAP(J1),Y1,QETAP(J2),Y2)                         RS224480
      Y4=LOGLOG(ETAS,QETAS(I1),FIG4(K2,J1,I1),QETAS(I2),FIG4(K2,J1,I2)) RS224490
      Y5=LOGLOG(ETAS,QETAS(I1),FIG4(K2,J2,I1),QETAS(I2),FIG4(K2,J2,I2)) RS224500
      Y6=ORDLOG(ETAP,QETAP(J1),Y4,QETAP(J2),Y5)                         RS224510
  600 SI=LOGLOG(GAM,QGAM(K1),Y3,QGAM(K2),Y6)                            RS224520
      RETURN                                                            RS224530
      END                                                               RS224540
$IBFTC RS18     DECK                                                    RS224550
      SUBROUTINE TERP5(SI)                                              RS224560
      DIMENSION QETAS(5),QETAP(5),QGAM(10)                              RS224570
      DIMENSION  DYT(1),XM(20),ZM(20),XK(11,7),FIG4(10,5,5),FIG5(8,5,5),RS224580
     1ETAS1(13,8,5),ETAS2(13,8,5),ETAS3(13,8,5)                         RS224590
      REAL LOGLOG                                                       RS224600
      COMMON/BRUCH/ T, AST, AIST, D, TK, P, XL, E, DY, RT, XLR1, PISQ,  RS224610
     1 PI, ALF1, GAM, ETAP, ETAS, XNBAR, XMU, XN1, XN2, XNXCR, FIG4,    RS224620
     2 FIG5, ETAS1, ETAS2, ETAS3, ISTECC, IRECC, A11A, A22A, A33A,      RS224630
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```
    3 A12A, D12D, D33D, DXD, E1R, E2R, XMU1, XMU2, AM, KOUNT, ENCL, Y, RS224640
    4 R, CL, CR                                                          RS224650
     TERM(Q000FL,Q001FL,Q002FL)=(ALOG(Q000FL)-ALOG(Q001FL))/(ALOG(Q002FRS224660
    1L)-ALOG(Q001FL))                                                    RS224670
     LOGLOG(Q003FL,Q004FL,Q005FL,Q006FL,Q007FL)=EXP(ALOG(Q005FL)+(ALOG(RS224680
    1Q007FL)-ALOG(Q005FL))*TERM(Q003FL,Q004FL,Q006FL))                   RS224690
     ORDLOG(Q008FL,Q009FL,Q010FL,Q011FL,Q012FL)=EXP(ALOG(Q010FL)+(Q008FRS224700
    1L-Q009FL)*(ALOG(Q012FL)-ALOG(Q010FL))/(Q011FL-Q009FL))              RS224710
   95 QETAS(1)=0.5                                                       RS224720
      QETAS(2)=1.0                                                       RS224730
      QETAS(3)=2.0                                                       RS224740
      QETAS(4)=4.0                                                       RS224750
      QETAS(5)=8.0                                                       RS224760
      QETAP(1)=0.0                                                       RS224770
      QETAP(2)=0.2                                                       RS224780
      QETAP(3)=0.5                                                       RS224790
      QETAP(4)=1.0                                                       RS224800
      QETAP(5)=2.0                                                       RS224810
      QGAM(1)=1.0                                                        RS224820
      QGAM(2)=2.0                                                        RS224830
      QGAM(3)=5.0                                                        RS224840
      QGAM(4)=10.0                                                       RS224850
      QGAM(5)=20.0                                                       RS224860
      QGAM(6)=50.0                                                       RS224870
      QGAM(7)=100.0                                                      RS224880
      QGAM(8)=200.0                                                      RS224890
      IF(ETAS-8.0)2,3,3                                                  RS224900
    3 ETAS=8.0                                                           RS224910
      GO TO 107                                                          RS224920
    2 KOUNT=1                                                            RS224930
      A=ETAS                                                             RS224940
  104 IF(A-0.5)101,102,103                                               RS224950
  103 A=A/2.0                                                            RS224960
      KOUNT=KOUNT+1                                                      RS224970
      GO TO 104                                                          RS224980
  102 I1=KOUNT                                                           RS224990
      I2=I1+1                                                            RS225000
      GO TO 115                                                          RS225010
  101 I1=KOUNT-1                                                         RS225020
```

```
      I2=I1+1                                                           RS225030
      IF(I1)105,105,106                                                 RS225040
  105 I1=1                                                              RS225050
      I2=2                                                              RS225060
      GO TO 115                                                         RS225070
  106 IF(I1-5)115,107,107                                               RS225080
  107 I1=4                                                              RS225090
      I2=5                                                              RS225100
  115 IF(ETAP-2.0)6,7,7                                                 RS225110
    7 ETAP=2.0                                                          RS225120
      GO TO 127                                                         RS225130
    6 IF(ETAP-0.5)116,120,120                                           RS225140
  116 IF(ETAP-0.2)117,118,119                                           RS225150
  117 IF(ETAP)121,122,121                                               RS225160
  118 J1=1                                                              RS225170
      J2=2                                                              RS225180
      GO TO 130                                                         RS225190
  119 J1=2                                                              RS225200
      J2=3                                                              RS225210
      GO TO 130                                                         RS225220
  121 J1=1                                                              RS225230
      J2=2                                                              RS225240
      GO TO 130                                                         RS225250
  122 J1=1                                                              RS225260
      J2=2                                                              RS225270
      GO TO 130                                                         RS225280
  120 KOUNT=3                                                           RS225290
      A=ETAP                                                            RS225300
  126 IF(A-0.5)123,124,125                                              RS225310
  125 A=A/2.0                                                           RS225320
      KOUNT=KOUNT+1                                                     RS225330
      GO TO 126                                                         RS225340
  124 J1=KOUNT                                                          RS225350
      J2=J1+1                                                           RS225360
      GO TO 130                                                         RS225370
  123 J1=KOUNT-1                                                        RS225380
      J2=J1+1                                                           RS225390
      IF(J1-5)130,127,127                                               RS225400
```

```
  127 J1=4                                                                  RS225410
      J2=5                                                                  RS225420
  130 IF(GAM-200.0)8,9,9                                                    RS225430
    9 GAM=200.0                                                             RS225440
      GO TO 148                                                             RS225450
    8 IF(GAM-2.0)131,131,137                                                RS225460
  131 KOUNT=1                                                               RS225470
      A=GAM                                                                 RS225480
  135 IF(A-1.0)132,133,134                                                  RS225490
  134 A=A/2.0                                                               RS225500
      KOUNT=KOUNT+1                                                         RS225510
      GO TO 135                                                             RS225520
  133 K1=KOUNT                                                              RS225530
      K2=K1+1                                                               RS225540
      GO TO 160                                                             RS225550
  132 K1=KOUNT-1                                                            RS225560
      K2=K1+1                                                               RS225570
      IF(K1)136,136,160                                                     RS225580
  136 K1=1                                                                  RS225590
      K2=K1+1                                                               RS225600
      GO TO 160                                                             RS225610
  137 IF(GAM-20.0)138,138,145                                               RS225620
  138 KOUNT=3                                                               RS225630
      A=GAM                                                                 RS225640
  142 IF(A-5.0)132,133,139                                                  RS225650
  139 A=A/2.0                                                               RS225660
      KOUNT=KOUNT+1                                                         RS225670
      GO TO 142                                                             RS225680
  145 IF(GAM-200.0)140,140,148                                              RS225690
  140 KOUNT=6                                                               RS225700
      A=GAM                                                                 RS225710
  143 IF(A-50.0)132,133,141                                                 RS225720
  141 A=A/2.0                                                               RS225730
      KOUNT=KOUNT+1                                                         RS225740
      GO TO 143                                                             RS225750
  148 K1=7                                                                  RS225760
      K2=8                                                                  RS225770
  160 Y1=LOGLOG(ETAS,QETAS(I1),FIG5(K1,J1,I1),QETAS(I2),FIG5(K1,J1,I2)) RS225780
      Y2=LOGLOG(ETAS,QETAS(I1),FIG5(K1,J2,I1),QETAS(I2),FIG5(K1,J2,I2)) RS225790
```

```
      Y3=ORDLOG(ETAP,QETAP(J1),Y1,QETAP(J2),Y2)                         RS225800
      Y4=LOGLOG(ETAS,QETAS(I1),FIG5(K2,J1,I1),QETAS(I2),FIG5(K2,J1,I2)) RS225810
      Y5=LOGLOG(ETAS,QETAS(I1),FIG5(K2,J2,I1),QETAS(I2),FIG5(K2,J2,I2)) RS225820
      Y6=ORDLOG(ETAP,QETAP(J1),Y4,QETAP(J2),Y5)                         RS225830
  600 SI=LOGLOG(GAM,QGAM(K1),Y3,QGAM(K2),Y6)                            RS225840
      RETURN                                                            RS225850
      END                                                               RS225860
$IBFTC RS19    DECK                                                     RS225870
      SUBROUTINE TERP7(SI)                                              RS225880
      DIMENSION QETAS(5),QETAP(5),QGAM(10),QAL(13)                      RS225890
      DIMENSION  DYT(1),XM(20),ZM(20),XK(11,7),FIG4(10,5,5),FIG5(8,5,5),RS225900
     1ETAS1(13,8,5),ETAS2(13,8,5),ETAS3(13,8,5)                         RS225910
      REAL LOGLOG                                                       RS225920
      COMMON/BRUCH/ T, AST, AIST, D, TK, P, XL, E, DY, RT, XLR1, PISQ,  RS225930
     1 PI, ALF1, GAM, ETAP, ETAS, XNBAR, XMU, XN1, XN2, XNXCR, FIG4,    RS225940
     2 FIG5, ETAS1, ETAS2, ETAS3, ISTECC, IRECC, A11A, A22A, A33A,      RS225950
     3 A12A, D12D, D33D, DXD, E1R, E2R, XMU1, XMU2, AM, KOUNT, ENCL, Y, RS225960
     4 R, CL, CR                                                        RS225970
      TERM(Q000FL,Q001FL,Q002FL)=(ALOG(Q000FL)-ALOG(Q001FL))/(ALOG(Q002FRS225980
     1L)-ALOG(Q001FL))                                                  RS225990
      LOGLOG(Q003FL,Q004FL,Q005FL,Q006FL,Q007FL)=EXP(ALOG(Q005FL)+(ALOG(RS226000
     1Q007FL)-ALOG(Q005FL))*TERM(Q003FL,Q004FL,Q006FL))                 RS226010
      ORDLOG(Q008FL,Q009FL,Q010FL,Q011FL,Q012FL)=EXP(ALOG(Q010FL)+(Q008FRS226020
     1L-Q009FL)*(ALOG(Q012FL)-ALOG(Q010FL))/(Q011FL-Q009FL))            RS226030
   97 QETAS(1)=1.0                                                      RS226040
      QETAS(2)=2.0                                                      RS226050
      QETAS(3)=4.0                                                      RS226060
      QETAP(1)=0.0                                                      RS226070
      QETAP(2)=0.2                                                      RS226080
      QETAP(3)=0.5                                                      RS226090
      QETAP(4)=1.0                                                      RS226100
      QETAP(5)=2.0                                                      RS226110
      QGAM(1)=1.0                                                       RS226120
      QGAM(2)=2.0                                                       RS226130
      QGAM(3)=5.0                                                       RS226140
      QGAM(4)=10.0                                                      RS226150
      QGAM(5)=20.0                                                      RS226160
      QGAM(6)=50.0                                                      RS226170
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      QGAM(7)=100.0                                                     RS226180
      QGAM(8)=200.0                                                     RS226190
      QAL(1)=1.                                                         RS226200
      QAL(2)=2.                                                         RS226210
      QAL(3)=5.                                                         RS226220
      QAL(4)=10.0                                                       RS226230
      QAL(5)=20.0                                                       RS226240
      QAL(6)=50.0                                                       RS226250
      QAL(7)=100.0                                                      RS226260
      QAL(8)=200.0                                                      RS226270
      QAL(9)=500.0                                                      RS226280
      QAL(10)=1000.0                                                    RS226290
      QAL(11)=2000.0                                                    RS226300
      QAL(12)=5000.0                                                    RS226310
      QAL(13)=10000.0                                                   RS226320
      IF(ETAP-2.0)13,14,14                                              RS226330
   14 ETAP=2.0                                                          RS226340
      GO TO 20                                                          RS226350
   13 IF(ETAP-0.5)2,3,3                                                 RS226360
    2 IF(ETAP-0.2)5,9,7                                                 RS226370
    5 IF(ETAP)8,9,8                                                     RS226380
    8 I1=1                                                              RS226390
      I2=2                                                              RS226400
      GO TO 25                                                          RS226410
    9 I1=1                                                              RS226420
      I2=2                                                              RS226430
      GO TO 25                                                          RS226440
    7 I1=2                                                              RS226450
      I2=3                                                              RS226460
      GO TO 25                                                          RS226470
    3 KOUNT=3                                                           RS226480
      A=ETAP                                                            RS226490
   15 IF(A-0.5)10,11,12                                                 RS226500
   12 A=A/2.0                                                           RS226510
      KOUNT=KOUNT+1                                                     RS226520
      GO TO 15                                                          RS226530
   11 I1=KOUNT                                                          RS226540
      I2=I1                                                             RS226550
      GO TO 25                                                          RS226560
```

```
10  I1=KOUNT-1                                                      RS226570
    I2=I1+1                                                         RS226580
    IF(I1-5)25,20,20                                                RS226590
20  I1=4                                                            RS226600
    I2=5                                                            RS226610
25  IF(GAM-200.0)17,16,16                                           RS226620
16  GAM=200.0                                                       RS226630
    GO TO 38                                                        RS226640
17  IF(GAM-2.0)26,26,27                                             RS226650
26  KOUNT=1                                                         RS226660
    A=GAM                                                           RS226670
31  IF(A-1.0)28,29,30                                               RS226680
30  A=A/2.0                                                         RS226690
    KOUNT=KOUNT+1                                                   RS226700
    GO TO 31                                                        RS226710
29  J1=KOUNT                                                        RS226720
    J2=J1                                                           RS226730
    GO TO 60                                                        RS226740
28  J1=KOUNT-1                                                      RS226750
    J2=KOUNT                                                        RS226760
    IF(J1)32,32,60                                                  RS226770
32  J1=1                                                            RS226780
    J2=2                                                            RS226790
    GO TO 60                                                        RS226800
27  IF(GAM-20.0)33,33,34                                            RS226810
33  KOUNT=3                                                         RS226820
    A=GAM                                                           RS226830
36  IF(A-5.0)28,29,35                                               RS226840
35  A=A/2.0                                                         RS226850
    KOUNT=KOUNT+1                                                   RS226860
    GO TO 36                                                        RS226870
34  IF(GAM-200.0)37,37,38                                           RS226880
37  KOUNT=6                                                         RS226890
    A=GAM                                                           RS226900
40  IF(A-50.0)28,29,39                                              RS226910
39  A=A/2.0                                                         RS226920
    KOUNT=KOUNT+1                                                   RS226930
    GO TO 40                                                        RS226940
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38 J1=7                                                          RS226950
   J2=8                                                          RS226960
60 IF(ALF1-10000.0)51,52,52                                      RS226970
52 ALF1=10000.0                                                  RS226980
   GO TO 271                                                     RS226990
51 IF(ALF1-2.0)61,61,62                                          RS227000
61 KOUNT=1                                                       RS227010
   A=ALF1                                                        RS227020
66 IF(A-1.0)63,64,65                                             RS227030
65 A=A/2.0                                                       RS227040
   KOUNT=KOUNT+1                                                 RS227050
   GO TO 66                                                      RS227060
64 K1=KOUNT                                                      RS227070
   K2=K1                                                         RS227080
   GO TO 270                                                     RS227090
63 K1=KOUNT-1                                                    RS227100
   K2=K1+1                                                       RS227110
   IF(K1)67,67,270                                               RS227120
67 K1=1                                                          RS227130
   K2=2                                                          RS227140
   GO TO 270                                                     RS227150
62 IF(ALF1-20.0)68,68,75                                         RS227160
68 KOUNT=3                                                       RS227170
   A=ALF1                                                        RS227180
70 IF(A-5.0)63,64,69                                             RS227190
69 A=A/2.0                                                       RS227200
   KOUNT=KOUNT+1                                                 RS227210
   GO TO 70                                                      RS227220
75 IF(ALF1-200.0)71,71,72                                        RS227230
71 KOUNT=6                                                       RS227240
   A=ALF1                                                        RS227250
73 IF(A-50.0)63,64,74                                            RS227260
74 A=A/2.0                                                       RS227270
   KOUNT=KOUNT+1                                                 RS227280
   GO TO 73                                                      RS227290
72 IF(ALF1-2000.0)85,85,76                                       RS227300
85 KOUNT=9                                                       RS227310
   A=ALF1                                                        RS227320
77 IF(A-500.0)63,64,78                                           RS227330
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   78 A=A/2.0                                                           RS227340
      KOUNT=KOUNT+1                                                     RS227350
      GO TO 77                                                          RS227360
   76 IF(ALF1-1.E+04)79,79,271                                          RS227370
   79 KOUNT=12                                                          RS227380
      A=ALF1                                                            RS227390
   81 IF(A-5000.0)63,64,82                                              RS227400
   82 A=A/2.0                                                           RS227410
      KOUNT=KOUNT+1                                                     RS227420
      GO TO 81                                                          RS227430
  270 IF(K1-13)275,271,271                                              RS227440
  271 K1=12                                                             RS227450
      K2=13                                                             RS227460
  275 IF(ETAS-1.0)241,241,243                                           RS227470
  241 L1=1                                                              RS227480
      L2=2                                                              RS227490
      GO TO 300                                                         RS227500
  243 IF(ETAS-2.0)241,244,244                                           RS227510
  244 L1=2                                                              RS227520
      L2=3                                                              RS227530
      GO TO 350                                                         RS227540
  300 Y1=ORDLOG(ETAP,QETAP(I1),ETAS1(K1,J1,I1),QETAP(I2),ETAS1(K1,J1,I2)RS227550
     1)                                                                 RS227560
      Y2=ORDLOG(ETAP,QETAP(I1),ETAS1(K1,J2,I1),QETAP(I2),ETAS1(K1,J2,I2)RS227570
     1)                                                                 RS227580
      Y3=LOGLOG(GAM,QGAM(J1),Y1,QGAM(J2),Y2)                            RS227590
      Y4=ORDLOG(ETAP,QETAP(I1),ETAS1(K2,J1,I1),QETAP(I2),ETAS1(K2,J1,I2)RS227600
     1)                                                                 RS227610
      Y5=ORDLOG(ETAP,QETAP(I1),ETAS1(K2,J2,I1),QETAP(I2),ETAS1(K2,J2,I2)RS227620
     1)                                                                 RS227630
      Y6=LOGLOG(GAM,QGAM(J1),Y4,QGAM(J2),Y5)                            RS227640
      Y7=LOGLOG(ALF1,QAL(K1),Y3,QAL(K2),Y6)                             RS227650
  350 Z1=ORDLOG(ETAP,QETAP(I1),ETAS2(K1,J1,I1),QETAP(I2),ETAS2(K1,J1,I2)RS227660
     1)                                                                 RS227670
      Z2=ORDLOG(ETAP,QETAP(I1),ETAS2(K1,J2,I1),QETAP(I2),ETAS2(K1,J2,I2)RS227680
     1)                                                                 RS227690
      Z3=LOGLOG(GAM,QGAM(J1),Z1,QGAM(J2),Z2)                            RS227700
      Z4=ORDLOG(ETAP,QETAP(I1),ETAS2(K2,J1,I1),QETAP(I2),ETAS2(K2,J1,I2)RS227710
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     1)                                                                 RS227720
      Z5=ORDLOG(ETAP,QETAP(I1),ETAS2(K2,J2,I1),QETAP(I2),ETAS2(K2,J2,I2)RS227730
     1)                                                                 RS227740
      Z6=LOGLOG(GAM,QGAM(J1),Z4,QGAM(J2),Z5)                            RS227750
      Z7=LOGLOG(ALF1,QAL(K1),Z3,QAL(K2),Z6)                             RS227760
      IF(L1-1)280,280,400                                               RS227770
  400 W1=ORDLOG(ETAP,QETAP(I1),ETAS3(K1,J1,I1),QETAP(I2),ETAS3(K1,J1,I2)RS227780
     1)                                                                 RS227790
      W2=ORDLOG(ETAP,QETAP(I1),ETAS3(K1,J2,I1),QETAP(I2),ETAS3(K1,J2,I2)RS227800
     1)                                                                 RS227810
      W3=LOGLOG(GAM,QGAM(J1),W1,QGAM(J2),W2)                            RS227820
      W4=ORDLOG(ETAP,QETAP(I1),ETAS3(K2,J1,I1),QETAP(I2),ETAS3(K2,J1,I2)RS227830
     1)                                                                 RS227840
      W5=ORDLOG(ETAP,QETAP(I1),ETAS3(K2,J2,I1),QETAP(I2),ETAS3(K2,J2,I2)RS227850
     1)                                                                 RS227860
      W6=LOGLOG(GAM,QGAM(J1),W4,QGAM(J2),W5)                            RS227870
      W7=LOGLOG(ALF1,QAL(K1),W3,QAL(K2),W6)                             RS227880
  401 Y7=Z7                                                             RS227890
      Z7=W7                                                             RS227900
  280 SI=LOGLOG(ETAS,QETAS(L1),Y7,QETAS(L2),Z7)                         RS227910
  500 RETURN                                                            RS227920
      END                                                               RS227930
$DATA                                                                   RS227940
 38      +00 57    +00 805   +00 106   +01 1272  +01 1395  +01RS227950
 153     +01 38    +00 57    +00 802   +00 1047  +01 124   +01RS227960
 1363    +01 15    +01 377   +00 565   +00 787   +00 1018  +01RS227970
 1183    +01 1297  +01 1417  +01 375   +00 553   +00 757   +00RS227980
 956     +00 1103  +01 1193  +01 1278  +01 355   +00 53    +00RS227990
 72      +00 882   +00 1005  +01 107   +01 1137  +01 337   +00RS228000
 5       +00 675   +00 82    +00 9     +00 95    +00 997   +00RS228010
 303     +00 47    +00 63    +00 74    +00 806   +00 825   +00RS228020
 855     +00 27    +00 43    +00 583   +00 625   +00 722   +00RS228030
 733     +00 76    +00 243   +00 4     +00 537   +00 613   +00RS228040
 648     +00 657   +00 670   +00 22    +00 375   +00 5     +00RS228050
 57      +00 585   +00 593   +00 6     +00 2     +00 355   +00RS228060
 47      +00 52    +00 535   +00 54    +00 545   +00          RS228070
 645     +00 640   +00 635   +00 630   +00 650   +00 670   +00RS228080
 665     +00 660   +00 655   +00 655   +00 690   +00 690   +00RS228090
 680     +00 680   +00 680   +00 725   +00 730   +00 725   +00RS228100
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720    +00 720    +00 775    +00 770    +00 770    +00 770    +00RS228110
770    +00 605    +00 600    +00 590    +00 590    +00 605    +00RS228120
630    +00 620    +00 615    +00 605    +00 610    +00 655    +00RS228130
655    +00 645    +00 635    +00 630    +00 690    +00 690    +00RS228140
685    +00 675    +00 675    +00 745    +00 740    +00 735    +00RS228150
730    +00 725    +00 550    +00 540    +00 530    +00 530    +00RS228160
565    +00 570    +00 570    +00 550    +00 540    +00 555    +00RS228170
600    +00 600    +00 585    +00 570    +00 560    +00 640    +00RS228180
640    +00 630    +00 615    +00 610    +00 695    +00 690    +00RS228190
685    +00 675    +00 670    +00 505    +00 500    +00 480    +00RS228200
490    +00 530    +00 530    +00 515    +00 495    +00 495    +00RS228210
520    +00 560    +00 550    +00 530    +00 520    +00 520    +00RS228220
600    +00 595    +00 580    +00 560    +00 550    +00 655    +00RS228230
650    +00 640    +00 630    +00 610    +00 455    +00 440    +00RS228240
435    +00 445    +00 500    +00 475    +00 460    +00 435    +00RS228250
440    +00 485    +00 510    +00 495    +00 475    +00 450    +00RS228260
470    +00 555    +00 540    +00 520    +00 495    +00 475    +00RS228270
615    +00 600    +00 590    +00 570    +00 535    +00 370    +00RS228280
360    +00 360    +00 385    +00 435    +00 390    +00 370    +00RS228290
360    +00 375    +00 415    +00 415    +00 400    +00 370    +00RS228300
365    +00 400    +00 420    +00 420    +00 410    +00 375    +00RS228310
385    +00 505    +00 495    +00 480    +00 440    +00 410    +00RS228320
295    +00 290    +00 300    +00 335    +00 380    +00 300    +00RS228330
290    +00 295    +00 315    +00 370    +00 320    +00 315    +00RS228340
290    +00 310    +00 350    +00 355    +00 350    +00 330    +00RS228350
310    +00 350    +00 370    +00 365    +00 355    +00 335    +00RS228360
330    +00 225    +00 230    +00 250    +00 285    +00 340    +00RS228370
230    +00 230    +00 240    +00 275    +00 325    +00 250    +00RS228380
235    +00 240    +00 265    +00 315    +00 260    +00 255    +00RS228390
250    +00 260    +00 310    +00 275    +00 270    +00 260    +00RS228400
250    +00 280    +00 160    +00 175    +00 205    +00 240    +00RS228410
290    +00 155    +00 170    +00 195    +00 240    +00 290    +00RS228420
160    +00 165    +00 185    +00 225    +00 270    +00 175    +00RS228430
170    +00 180    +00 205    +00 265    +00 180    +00 185    +00RS228440
175    +00 185    +00 230    +00 135    +00 145    +00 175    +00RS228450
215    +00 260    +00 125    +00 140    +00 170    +00 210    +00RS228460
255    +00 120    +00 130    +00 160    +00 200    +00 245    +00RS228470
130    +00 130    +00 145    +00 185    +00 230    +00 145    +00RS228480
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135   +00 130   +00 160   +00 205   +00                       RS228490
130   +   150   +   177   +   213   +   268   +   125   +   RS228500
141   +   171   +   211   +   260   +   118   +   133   +   RS228510
158   +   195   +   248   +   109   +   123   +   144   +   RS228520
178   +   228   +   094   +   138   +   132   +   163   +   RS228530
205   +   121   +   134   +   157   +   191   +   240   +   RS228540
122   +   130   +   149   +   182   +   232   +   123   +   RS228550
123   +   142   +   175   +   220   +   124   +   129   +   RS228560
133   +   159   +   200   +   128   +   148   +   141   +   RS228570
149   +   185   +   122   +   125   +   140   +   167   +   RS228580
210   +   126   +   128   +   138   +   160   +   202   +   RS228590
132   +   129   +   131   +   152   +   191   +   143   +   RS228600
140   +   134   +   145   +   173   +   166   +   163   +   RS228610
155   +   146   +   162   +   126   +   126   +   133   +   RS228620
153   +   192   +   132   +   130   +   138   +   150   +   RS228630
184   +   141   +   135   +   133   +   144   +   173   +   RS228640
157   +   151   +   143   +   140   +   160   +   196   +   RS228650
176   +   168   +   155   +   150   +   132   +   150   +   RS228660
133   +   146   +   176   +   140   +   135   +   141   +   RS228670
147   +   170   +   152   +   146   +   142   +   140   +   RS228680
161   +   174   +   164   +   153   +   146   +   151   +   RS228690
229   +   190   +   180   +   169   +   155   +   146   +   RS228700
139   +   137   +   142   +   164   +   155   +   147   +   RS228710
150   +   145   +   158   +   169   +   162   +   157   +   RS228720
147   +   150   +   195   +   181   +   172   +   161   +   RS228730
152   +   260   +   200   +   198   +   188   +   170   +   RS228740
158   +   149   +   143   +   143   +   150   +   167   +   RS228750
155   +   160   +   148   +   150   +   181   +   175   +   RS228760
169   +   158   +   150   +   207   +   192   +   185   +   RS228770
173   +   160   +   270   +   200   +   200   +   198   +   RS228780
182   +   167   +   159   +   153   +   150   +   148   +   RS228790
178   +   166   +   171   +   159   +   152   +   195   +   RS228800
190   +   181   +   170   +   158   +   226   +   199   +   RS228810
195   +   188   +   175   +   308   +   200   +   200   +   RS228820
200   +   197   +         +                 +         +   RS228830
882   +00 867   +00 752   +00 750   +00 646   +00 1     +01RS228840
1     +01 1     +01 98    +00 875   +00 1     +01 1     +01RS228850
1     +01 1     +01 1     +01 1     +01 1     +01 1     +01RS228860
1     +01 1     +01 1     +01 1     +01 1     +01 1     +01RS228870
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1      +01  1     +01  1     +01  1     +01  1     +01  1     +01RS228880
1      +01  1     +01  1     +01  1     +01  1     +01  1     +01RS228890
1      +01  1     +01  1     +01  1     +01  522   +00  513   +00RS228900
500    +00  473   +00  440   +00  747   +00  740   +00  706   +00RS228910
663    +00  582   +00  1     +01  1     +01  935   +00  925   +00RS228920
835    +00  1     +01  1     +01  1     +01  1     +01  1     +01RS228930
1      +01  1     +01  1     +01  1     +01  1     +01  1     +01RS228940
1      +01  1     +01  1     +01  1     +01  1     +01  1     +01RS228950
1      +01  1     +01  1     +01  1     +01  1     +01  1     +01RS228960
1      +01  1     +01  271   +00  278   +00  284   +00  289   +00RS228970
289    +00  397   +00  395   +00  393   +00  384   +00  367   +00RS228980
660    +00  640   +00  605   +00  570   +00  520   +00  900   +00RS228990
865    +00  815   +00  755   +00  690   +00  1     +01  980   +00RS229000
1      +01  940   +00  870   +00  1     +01  1     +01  1     +01RS229010
1      +01  1     +01  1     +01  1     +01  1     +01  1     +01RS229020
1      +01  1     +01  1     +01  1     +01  1     +01  1     +01RS229030
187    +00  194   +00  206   +00  219   +00  234   +00  258   +00RS229040
262    +00  268   +00  274   +00  285   +00  415   +00  410   +00RS229050
410    +00  400   +00  380   +00  615   +00  595   +00  570   +00RS229060
530    +00  490   +00  870   +00  770   +00  830   +00  710   +00RS229070
635    +00  1     +01  1     +01  1     +01  950   +00  855   +00RS229080
1      +01  1     +01  1     +01  1     +01  1     +01  1     +01RS229090
1      +01  1     +01  1     +01  1     +01  145   +00  153   +00RS229100
162    +00  177   +00  193   +00  182   +00  192   +00  200   +00RS229110
214    +00  232   +00  270   +00  275   +00  285   +00  285   +00RS229120
295    +00  395   +00  390   +00  385   +00  375   +00  367   +00RS229130
582    +00  540   +00  565   +00  510   +00  460   +00  925   +00RS229140
870    +00  800   +00  735   +00  645   +00  1     +01  1     +01RS229150
990    +00  920   +00  815   +00  1     +01  1     +01  1     +01RS229160
1      +01  970   +00  120   +00  125   +00  133   +00  142   +00RS229170
160    +00  138   +00  145   +00  150   +00  164   +00  184   +00RS229180
175    +00  180   +00  195   +00  205   +00  225   +00  230   +00RS229190
240    +00  250   +00  255   +00  270   +00  327   +00  335   +00RS229200
335    +00  330   +00  330   +00  560   +00  550   +00  520   +00RS229210
480    +00  445   +00  820   +00  770   +00  710   +00  650   +00RS229220
570    +00  1     +01  1     +01  930   +00  835   +00  725   +00RS229230
112    +00  119   +00  120   +00  127   +00  143   +00  122   +00RS229240
127    +00  133   +00  144   +00  162   +00  140   +00  150   +00RS229250
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160   +00 170   +00 195   +00 175   +00 180   +00 195   +00RS229260
203   +00 223   +00 230   +00 245   +00 235   +00 255   +00RS229270
265   +00 370   +00 370   +00 570   +00 357   +00 350   +00RS229280
555   +00 535   +00 510   +00 480   +00 435   +00 810   +00RS229290
760   +00 710   +00 640   +00 560   +00 110   +00 113   +00RS229300
114   +00 122   +00 133   +00 114   +00 120   +00 122   +00RS229310
132   +00 146   +00 125   +00 130   +00 140   +00 150   +00RS229320
165   +00 140   +00 145   +00 160   +00 170   +00 190   +00RS229330
170   +00 190   +00 177   +00 200   +00 220   +00 250   +00RS229340
255   +00 260   +00 275   +00 280   +00 370   +00 370   +00RS229350
360   +00 360   +00 345   +00 550   +00 535   +00 515   +00RS229360
480   +00 435   +00 110   +00 113   +00 113   +00 120   +00RS229370
129   +00 114   +00 118   +00 120   +00 125   +00 135   +00RS229380
115   +00 120   +00 125   +00 135   +00 150   +00 125   +00RS229390
130   +00 140   +00 145   +00 165   +00 135   +00 155   +00RS229400
140   +00 160   +00 180   +00 170   +00 180   +00 190   +00RS229410
205   +00 220   +00 225   +00 230   +00 240   +00 255   +00RS229420
265   +00 320   +00 330   +00 330   +00 330   +00 325   +00RS229430
110   +00 113   +00 113   +00 120   +00 128   +00 114   +00RS229440
118   +00 120   +00 125   +00 133   +00 115   +00 120   +00RS229450
125   +00 130   +00 140   +00 120   +00 125   +00 130   +00RS229460
140   +00 152   +00 127   +00 140   +00 130   +00 150   +00RS229470
170   +00 145   +00 153   +00 165   +00 175   +00 195   +00RS229480
155   +00 182   +00 195   +00 207   +00 225   +00 230   +00RS229490
235   +00 245   +00 255   +00 267   +00 110   +00 113   +00RS229500
113   +00 120   +00 128   +00 114   +00 118   +00 120   +00RS229510
125   +00 133   +00 115   +00 120   +00 125   +00 135   +00RS229520
140   +00 120   +00 125   +00 135   +00 140   +00 150   +00RS229530
127   +00 135   +00 130   +00 147   +00 160   +00 135   +00RS229540
140   +00 150   +00 160   +00 180   +00 153   +00 160   +00RS229550
170   +00 180   +00 200   +00 180   +00 190   +00 200   +00RS229560
210   +00 230   +00 110   +00 113   +00 113   +00 120   +00RS229570
128   +00 114   +00 118   +00 120   +00 125   +00 133   +00RS229580
115   +00 120   +00 125   +00 137   +00 140   +00 120   +00RS229590
125   +00 135   +00 140   +00 150   +00 127   +00 135   +00RS229600
130   +00 147   +00 157   +00 135   +00 140   +00 150   +00RS229610
153   +00 170   +00 145   +00 150   +00 155   +00 167   +00RS229620
180   +00 155   +00 160   +00 170   +00 183   +00 203   +00RS229630
110   +00 113   +00 113   +00 120   +00 128   +00 114   +00RS229640
```

```
118    +00 120    +00 125    +00 133    +00 115    +00 120    +00RS229650
125    +00 130    +00 140    +00 120    +00 125    +00 130    +00RS229660
140    +00 150    +00 127    +00 135    +00 130    +00 147    +00RS229670
157    +00 135    +00 140    +00 150    +00 153    +00 170    +00RS229680
145    +00 150    +00 155    +00 167    +00 178    +00 153    +00RS229690
160    +00 162    +00 180    +00 193    +00                      RS229700
1      +01 1      +01 930    +00 860    +00 820    +00 1      +01RS229710
1      +01 1      +01 1      +01 1      +01 1      +01 1      +01RS229720
1      +01 1      +01 1      +01 1      +01 1      +01 1      +01RS229730
1      +01 1      +01 1      +01 1      +01 1      +01 1      +01RS229740
1      +01 1      +01 1      +01 1      +01 1      +01 1      +01RS229750
1      +01 1      +01 1      +01 1      +01 1      +01 1      +01RS229760
1      +01 1      +01 1      +01 1      +01 642    +00 618    +00RS229770
611    +00 567    +00 517    +00 911    +00 877    +00 843    +00RS229780
780    +00 690    +00 1      +01 1      +01 1      +01 1      +01RS229790
925    +00 1      +01 1      +01 1      +01 1      +01 1      +01RS229800
1      +01 1      +01 1      +01 1      +01 1      +01 1      +01RS229810
1      +01 1      +01 1      +01 1      +01 1      +01 1      +01RS229820
1      +01 1      +01 1      +01 1      +01 1      +01 1      +01RS229830
1      +01 1      +01 326    +00 333    +00 338    +00 341    +00RS229840
337    +00 470    +00 473    +00 465    +00 460    +00 427    +00RS229850
765    +00 745    +00 710    +00 670    +00 610    +00 980    +00RS229860
955    +00 915    +00 870    +00 790    +00 1      +01 1      +01RS229870
1      +01 1      +01 1      +01 1      +01 1      +01 1      +01RS229880
1      +01 1      +01 1      +01 1      +01 1      +01 1      +01RS229890
1      +01 1      +01 1      +01 1      +01 1      +01 1      +01RS229900
213    +00 223    +00 234    +00 246    +00 259    +00 292    +00RS229910
304    +00 306    +00 317    +00 322    +00 475    +00 475    +00RS229920
465    +00 460    +00 435    +00 705    +00 680    +00 645    +00RS229930
610    +00 560    +00 925    +00 845    +00 905    +00 790    +00RS229940
720    +00 1      +01 1      +01 1      +01 1      +01 950    +00RS229950
1      +01 1      +01 1      +01 1      +01 1      +01 1      +01RS229960
1      +01 1      +01 1      +01 1      +01 157    +00 167    +00RS229970
177    +00 192    +00 208    +00 200    +00 208    +00 219    +00RS229980
234    +00 253    +00 300    +00 310    +00 315    +00 320    +00RS229990
330    +00 435    +00 435    +00 430    +00 420    +00 405    +00RS230000
650    +00 595    +00 625    +00 560    +00 515    +00 970    +00RS230010
930    +00 870    +00 790    +00 715    +00 1      +01 1      +01RS230020
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 1       +01 960    +00 880    +00 1      +01 1      +01 1      +01RS230030
 1       +01 1      +01 122    +00 131    +00 140    +00 149    +00RS230040
 167     +00 142    +00 151    +00 159    +00 172    +00 191    +00RS230050
 185     +00 195    +00 205    +00 220    +00 245    +00 250    +00RS230060
 255     +00 265    +00 275    +00 290    +00 360    +00 360    +00RS230070
 360     +00 355    +00 350    +00 605    +00 580    +00 555    +00RS230080
 520     +00 480    +00 860    +00 810    +00 755    +00 685    +00RS230090
 610     +00 1      +01 1      +01 1      +01 880    +00 770    +00RS230100
 114     +00 119    +00 126    +00 134    +00 148    +00 123    +00RS230110
 133     +00 138    +00 147    +00 162    +00 145    +00 155    +00RS230120
 165     +00 180    +00 195    +00 175    +00 190    +00 200    +00RS230130
 215     +00 230    +00 235    +00 255    +00 250    +00 265    +00RS230140
 280     +00 390    +00 390    +00 385    +00 375    +00 365    +00RS230150
 580     +00 560    +00 530    +00 500    +00 460    +00 830    +00RS230160
 795     +00 735    +00 660    +00 585    +00 114    +00 114    +00RS230170
 119     +00 124    +00 137    +00 116    +00 120    +00 125    +00RS230180
 134     +00 146    +00 125    +00 135    +00 145    +00 155    +00RS230190
 170     +00 140    +00 150    +00 160    +00 175    +00 193    +00RS230200
 175     +00 195    +00 185    +00 210    +00 225    +00 260    +00RS230210
 270     +00 275    +00 280    +00 290    +00 380    +00 380    +00RS230220
 370     +00 370    +00 360    +00 570    +00 550    +00 520    +00RS230230
 490     +00 450    +00 114    +00 114    +00 114    +00 120    +00RS230240
 127     +00 114    +00 116    +00 120    +00 124    +00 134    +00RS230250
 115     +00 120    +00 130    +00 135    +00 150    +00 125    +00RS230260
 130     +00 135    +00 150    +00 162    +00 135    +00 155    +00RS230270
 145     +00 167    +00 185    +00 170    +00 180    +00 195    +00RS230280
 207     +00 220    +00 230    +00 235    +00 250    +00 257    +00RS230290
 270     +00 330    +00 330    +00 335    +00 335    +00 330    +00RS230300
 114     +00 114    +00 114    +00 120    +00 125    +00 114    +00RS230310
 116     +00 120    +00 124    +00 130    +00 115    +00 120    +00RS230320
 125     +00 130    +00 140    +00 120    +00 125    +00 130    +00RS230330
 140     +00 150    +00 127    +00 140    +00 130    +00 150    +00RS230340
 165     +00 145    +00 155    +00 163    +00 175    +00 193    +00RS230350
 175     +00 180    +00 195    +00 290    +00 225    +00 230    +00RS230360
 237     +00 250    +00 255    +00 270    +00 114    +00 114    +00RS230370
 114     +00 120    +00 125    +00 114    +00 116    +00 120    +00RS230380
 124     +00 130    +00 115    +00 120    +00 125    +00 130    +00RS230390
 140     +00 120    +00 125    +00 130    +00 137    +00 147    +00RS230400
 127     +00 135    +00 130    +00 145    +00 155    +00 133    +00RS230410
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140     +00 150     +00 160     +00 175     +00 150     +00 155     +00RS230420
167     +00 180     +00 200     +00 177     +00 190     +00 200     +00RS230430
210     +00 225     +00 114     +00 114     +00 114     +00 120     +00RS230440
125     +00 114     +00 116     +00 120     +00 124     +00 130     +00RS230450
115     +00 120     +00 125     +00 130     +00 140     +00 120     +00RS230460
125     +00 130     +00 137     +00 143     +00 127     +00 135     +00RS230470
130     +00 140     +00 150     +00 133     +00 140     +00 143     +00RS230480
153     +00 165     +00 140     +00 147     +00 152     +00 165     +00RS230490
180     +00 150     +00 160     +00 170     +00 180     +00 195     +00RS230500
114     +00 114     +00 114     +00 120     +00 125     +00 114     +00RS230510
116     +00 120     +00 124     +00 130     +00 115     +00 120     +00RS230520
125     +00 130     +00 140     +00 120     +00 125     +00 130     +00RS230530
137     +00 143     +00 127     +00 135     +00 130     +00 140     +00RS230540
150     +00 133     +00 140     +00 143     +00 153     +00 165     +00RS230550
140     +00 147     +00 152     +00 164     +00 174     +00 150     +00RS230560
155     +00 160     +00 170     +00 187     +00                       RS230570
1       +01 1       +01 1       +01 1       +01 964     +00 1       +01RS230580
1       +01 1       +01 1       +01 1       +01 1       +01 1       +01RS230590
1       +01 1       +01 1       +01 1       +01 1       +01 1       +01RS230600
1       +01 1       +01 1       +01 1       +01 1       +01 1       +01RS230610
1       +01 1       +01 1       +01 1       +01 1       +01 1       +01RS230620
1       +01 1       +01 1       +01 1       +01 1       +01 1       +01RS230630
1       +01 1       +01 1       +01 1       +01 820     +00 790     +00RS230640
755     +00 704     +00 634     +00 1       +01 1       +01 1       +01RS230650
928     +00 840     +00 1       +01 1       +01 1       +01 1       +01RS230660
1       +01 1       +01 1       +01 1       +01 1       +01 1       +01RS230670
1       +01 1       +01 1       +01 1       +01 1       +01 1       +01RS230680
1       +01 1       +01 1       +01 1       +01 1       +01 1       +01RS230690
1       +01 1       +01 1       +01 1       +01 1       +01 1       +01RS230700
1       +01 1       +01 417     +00 420     +00 426     +00 426     +00RS230710
413     +00 600     +00 596     +00 582     +00 558     +00 522     +00RS230720
960     +00 915     +00 870     +00 820     +00 725     +00 1       +01RS230730
1       +01 1       +01 1       +01 950     +00 1       +01 1       +01RS230740
1       +01 1       +01 1       +01 1       +01 1       +01 1       +01RS230750
1       +01 1       +01 1       +01 1       +01 1       +01 1       +01RS230760
1       +01 1       +01 1       +01 1       +01 1       +01 1       +01RS230770
263     +00 272     +00 283     +00 299     +00 312     +00 368     +00RS230780
377     +00 381     +00 384     +00 382     +00 590     +00 585     +00RS230790
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575    +00 555    +00 525    +00 840    +00 800    +00 780    +00RS230800
735    +00 670    +00 1      +01 980    +00 1      +01 910    +00RS230810
865    +00 1      +01 1      +01 1      +01 1      +01 1      +01RS230820
1      +01 1      +01 1      +01 1      +01 1      +01 1      +01RS230830
1      +01 1      +01 1      +01 1      +01 183    +00 194    +00RS230840
204    +00 220    +00 241    +00 239    +00 247    +00 258    +00RS230850
273    +00 288    +00 365    +00 370    +00 380    +00 380    +00RS230860
380    +00 525    +00 520    +00 515    +00 505    +00 480    +00RS230870
755    +00 700    +00 730    +00 665    +00 610    +00 1      +01RS230880
1      +01 970    +00 905    +00 830    +00 1      +01 1      +01RS230890
1      +01 1      +01 1      +01 1      +01 1      +01 1      +01RS230900
1      +01 1      +01 139    +00 143    +00 150    +00 165    +00RS230910
182    +00 157    +00 167    +00 176    +00 191    +00 213    +00RS230920
215    +00 220    +00 230    +00 245    +00 265    +00 285    +00RS230930
295    +00 305    +00 315    +00 322    +00 410    +00 410    +00RS230940
410    +00 410    +00 400    +00 680    +00 650    +00 620    +00RS230950
590    +00 545    +00 920    +00 882    +00 830    +00 770    +00RS230960
690    +00 1      +01 1      +01 1      +01 935    +00 870    +00RS230970
121    +00 129    +00 131    +00 144    +00 159    +00 133    +00RS230980
140    +00 145    +00 159    +00 178    +00 160    +00 165    +00RS230990
175    +00 195    +00 215    +00 195    +00 205    +00 215    +00RS231000
235    +00 250    +00 265    +00 280    +00 275    +00 290    +00RS231010
302    +00 430    +00 430    +00 420    +00 415    +00 400    +00RS231020
635    +00 610    +00 580    +00 550    +00 505    +00 890    +00RS231030
850    +00 790    +00 720    +00 645    +00 121    +00 126    +00RS231040
121    +00 131    +00 142    +00 122    +00 124    +00 129    +00RS231050
140    +00 155    +00 135    +00 140    +00 150    +00 160    +00RS231060
180    +00 150    +00 160    +00 170    +00 185    +00 205    +00RS231070
185    +00 210    +00 197    +00 220    +00 240    +00 280    +00RS231080
285    +00 290    +00 300    +00 310    +00 410    +00 410    +00RS231090
405    +00 395    +00 380    +00 600    +00 580    +00 560    +00RS231100
525    +00 480    +00 121    +00 120    +00 120    +00 124    +00RS231110
129    +00 120    +00 120    +00 123    +00 127    +00 139    +00RS231120
120    +00 125    +00 130    +00 140    +00 155    +00 125    +00RS231130
130    +00 140    +00 150    +00 170    +00 140    +00 157    +00RS231140
150    +00 170    +00 187    +00 180    +00 190    +00 200    +00RS231150
213    +00 230    +00 237    +00 250    +00 260    +00 265    +00RS231160
275    +00 345    +00 340    +00 350    +00 345    +00 340    +00RS231170
121    +00 120    +00 120    +00 120    +00 127    +00 120    +00RS231180
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120     +00 121    +00 124    +00 133    +00 120    +00 120    +00RS231190
125     +00 125    +00 140    +00 120    +00 125    +00 130    +00RS231200
140     +00 150    +00 130    +00 140    +00 130    +00 153    +00RS231210
167     +00 145    +00 155    +00 165    +00 180    +00 195    +00RS231220
177     +00 187    +00 195    +00 210    +00 230    +00 235    +00RS231230
240     +00 250    +00 260    +00 273    +00 121    +00 120    +00RS231240
120     +00 120    +00 127    +00 120    +00 120    +00 121    +00RS231250
124     +00 133    +00 120    +00 120    +00 125    +00 125    +00RS231260
140     +00 120    +00 125    +00 130    +00 130    +00 145    +00RS231270
125     +00 133    +00 127    +00 140    +00 155    +00 130    +00RS231280
137     +00 145    +00 160    +00 175    +00 150    +00 155    +00RS231290
165     +00 180    +00 195    +00 180    +00 187    +00 195    +00RS231300
210     +00 230    +00 121    +00 120    +00 120    +00 120    +00RS231310
127     +00 120    +00 120    +00 121    +00 124    +00 133    +00RS231320
120     +00 120    +00 125    +00 125    +00 140    +00 120    +00RS231330
125     +00 130    +00 130    +00 140    +00 125    +00 133    +00RS231340
127     +00 140    +00 150    +00 127    +00 130    +00 140    +00RS231350
150     +00 160    +00 135    +00 140    +00 150    +00 160    +00RS231360
175     +00 150    +00 155    +00 165    +00 175    +00 195    +00RS231370
121     +00 120    +00 120    +00 120    +00 127    +00 120    +00RS231380
120     +00 121    +00 124    +00 133    +00 120    +00 120    +00RS231390
125     +00 125    +00 140    +00 120    +00 125    +00 130    +00RS231400
130     +00 140    +00 125    +00 133    +00 127    +00 140    +00RS231410
150     +00 127    +00 130    +00 140    +00 145    +00 160    +00RS231420
135     +00 140    +00 150    +00 153    +00 170    +00 145    +00RS231430
150     +00 157    +00 165    +00 182    +00                      RS231440
  END OF BARUCK-SINGER DATA CARDS--BEGIN NOSE FAIRING DATA CARDS.      RS231450
 260.          .1          765.        1.5        8.5              2
   1      3   600.            .032      .0                         1
 349.          0.          16.          .032
   2      20.        10.         0.          30000.
   .72       12.5          16.          .032
   2      20.        10.         0.          30000.
   .03       25.           16.          .032
   2      20.        10.         0.          30000.
   .0          .0            .0
   .53         .19           .0095
   .56         .20           .06
```

| | | |
|---|---|---|
| .57 | .21 | .11 |
| .58 | .22 | .20 |
| .59 | .23 | .30 |
| .59 | .23 | .75 |
| .05 | .03 | .75 |
| .12 | .08 | .80 |
| .16 | .11 | .94 |
| .18 | .12 | 1.12 |
| .19 | .13 | 1.26 |
| .19 | .13 | 1.38 |
| -.06 | .02 | 1.38 |
| -.02 | .005 | 1.50 |
| -.01 | .001 | 1.60 |
| .0 | .0 | 1.70 |
| .0 | .0 | 2.72 |

1

# APPENDIX B

# DEFINITIONS OF VARIABLE NAMES

A - Ring cross-sectional dimension (see Figure 3), in.

AC - Area of the base of the spherical nose cap, sq. in.

AIST - Moment of inertia of ring, in.$^4$

AISTT - Moment of inertia of ring and effective skin, in.$^4$

AINDEX(J) - Weight index (weight of bay divided by volume of bay), lbs/cu in.

AIREQ - Moment of inertia required of the stiffening ring cross-section, in.$^4$

AIRING - Moment of inertia of the stiffening ring, in.$^4$

AK(J) - A factor used in making a first estimate of bay length when increasing skin thickness from T (J-1) to T (J).

AL(J) - Bay length, in.

ALI(J) - Length of next to last bay in frustum, in.

ALB - Bay length, in.

ALCAP - Axial length of nose cap, in.

ALCONE - Frustum length, in.

ALF (NF) - Length of frustum number NF, in.

ALMAX - Maximum bay length. (For the first three skin gauges tried, ALMAX is equal to ALMX 2, and for the last four skin gauges ALMAX is equal to either ALMXI or ALMX2, whichever is less.) in.

ALMIN - Minimum length specified for bay, in.

ALMN - Either ALMIN or the bay length computed for next smaller skin gauge, whichever is greater, in.

ALMXI - ALMIN plus 40 inches, in.

ALMX2 - Axial distance from base of bay to top of frustum, in.

ALN - Axial distance from base of bay to point at which lateral pressure on the leeward side of the bay is greatest, in.

ALPHA - Angle of attack, degrees when read in and radians when used in computations.

ALOPT(I) - Optimum length for Ith bay, in.

ALTOT - Total length of fairing, in.

ALX - Axial distance from base to bay to point at which the lateral pressure on the windward side is a maximum, in.

AMACH - Mach number.

AMU - Poisson's ratio.

ANFIAL - Maximum allowable line load for a given bay configuration, lbs/in.

ANFIAX - Line load contributed by axial loading on bay, lbs/in.

ANFIB - Line load contributed by bending moments on bay, lbs/in.

ANFICR - Critical line load, lbs/in.

ANFIMN - Total line load on windward side of fairing multiplied by factor of safety, lbs/in.

ANFIMX - Total line load on leeward side of fairing multiplied by factor of safety, lbs/in.

AOT - The ratio A/t (see Figure 3)

AS - A coefficient determined by "least squares" techniques for the linear equation representing heat input to the nose cap skin at the stagnation point.

AST - Cross-sectional area of ring, sq in.

AT - A coefficient determined by "least squares" techniques for the linear equation representing heat input to top frustum skin at its junction with the nose cap.

AXLDCP - Axial load contributed by nose cap, lbs.

AXLOAD - Axial load at some specified location on fairing, lbs.

AXLOD - Axial load contribution of a segment of the pressure profile, lbs.

BEND - Bending moment at some specified location on fairing, lbs/in.

BND - Bending moment of a segment of the pressure profile computed about the point on the segment nearest the fairing base, lbs-in.

BNDCAP - Bending moment of the nose cap about its base, lbs-in.

BOT - The ratio B/t (see Figure 3)

C1 - A constant defined by Line No. RS202630 of the program listing in Appendix A.

C2 - A constant defined by Line No. RS202640 of the program listing in Appendix A.

C3 - A constant defined by Line No. RS202650 of the program listing in Appendix A.

C4 - A constant defined by Line No. RS201540 of the program listing in Appendix A.

C5 - A constant defined by Line No. RS202660 of the program listing in Appendix A.

C6 - A constant defined by Line No. RS202670 of the program listing in Appendix A.

C7 - A constant defined by Line No. RS202680 of the program listing in Appendix A.

CDCAP - Drag coefficient for the spherical nose cap with the base area of the nose cap as a reference area.

CHK - A parameter computed in Subroutine CHKLOD which indicates the adequacy of the design. The code is as follows:

1.0 More than adequate
0.0 Adequate
-1.0 Less than adequate

CHKLE(I) - A parameter computed in Subroutine CHKLOD which indicates the adequacy of the design on the leeward side of fairing. The design is adequate when CHKLE(I) is equal to or less than 1.0.

CHKLEE - Same as CHKLE(I).

CHKWD(I) - A parameter computed in Subroutine CHKLOD which indicates the adequacy of the design on the windward side of the fairing. The design is adequate when CHKWD(I) is equal to or less than 1.0.

CHKWND - Same as CHKWD(I).

| | | |
|---|---|---|
| CL | - | A constant defined by Line No. RS204180 of the program listing in Appendix A. |
| CNCAP | - | Normal force coefficient per radian angle of attack for the spherical nose cap using nose cap base area as a reference area, /radian. |
| CPA(LT) | - | The change in pressure coefficient on either the windward or leeward side of the fairing due to angle of attack at station LT. (See Figures 4 and 5.) |
| CPAA | - | Same a CPA(LT). |
| CPMN | - | Pressure coefficient on the leeward side of the fairing. |
| CPMX | - | Pressure coefficient on the windward side of the fairing. |
| CPO(LT) | - | Pressure coefficient at zero angle of attack at station LT. |
| CPOO | - | Same as CPO(LT). |
| CPSTG | - | Pressure coefficient at stagnation point of the nose cap. |
| CSUBP | - | Coefficient of critical buckling pressure (See Equation F5 in Appendix F.) |
| CTH | - | Cosine of THETA. |
| CZALFA | - | Normal force coefficient per radian angle of attack. |
| D (I) | - | Small diameter of the Ith bay, in. |
| DBAS | - | Base diameter of fairing, in. |
| DBASE | - | Base diameter of a frustum, in. |
| DELTA | - | Same as THETA. |
| DELTAL | - | Increment by which bay length is perturbated while designing a bay, in. |
| DELTAP | - | Difference between internal and free-stream pressure, psi. |
| DELTAS | - | Bay skin thickness, in. |

DMIN - Small diameter of frustum, in.

DMN(NF) - Small diameter of frustum number NF, in.

DUSE1 - Diameter of area useful for payload at the base of the bay. (See Line RS207420of program listing in Appendix A.)

DUSE2 - Diameter of area useful for payload at top of bay. (See Line RS207430of program listing in Appendix A.)

DSUBB - Base diameter of bay, in.

DY - Bay length, in.

E - Modulus of elasticity of structural material, in.

ECC - Distance from ring centroid to skin centerline, in.

ELMIN(NF) - Minimum bay length for frustum NF, in.

ENFIMN (I) - ANFIMN for Ith bay, lbs/in.

ENFIMX (I) - ANFIMX for Ith bay, lbs/in.

FCFB - Maximum allowable local stress in ring, psi.

FCCR - Compressive stress at which skin buckles in the absence of other loading, psi.

FRING - Local stress in ring, psi.

FS - Factor of safety.

FSBZ - Shear force contributed by an increment of pressure profile, lbs.

FSBZCP - Shear force contributed by nose cap, lbs.

FSUBZ - Shear force at a specified location on the fairing, lbs.

FZ (I) - Shear force at the base of the Ith bay, lbs.

HUSE - Useful axial length of nose cap (see Line No. RS209670 in Appendix A), in.

IKIND - Code number for ring cross-sectional shape. (See Figure 3.)

IMAX - Total number of bays in fairing.

IMX(NF) - Number of bays from bottom of fairing to top of frustum NF.

IW - Index indicating bay number within a frustum.

J - Index indicating parameter associated with skin thickness T (J).

JF - Index of skin thickness which is optimum for a bay.

JMIN - Index of the smallest skin thickness which is equal to or greater than the minimum thickness specified.

K - Index indicating ring parameters associated with a ring using thickness T (K).

KEY - Input parameter indicating type of output desired. (See Section 3.0 of the TECHNICAL DISCUSSION.)

LAST - An index used to identify a particular two-bay configuration designed to complete a frustum.

LFLAG - An integer used to control manipulation of candidate configurations for completing the design of a frustum.

LFLG - An integer used to control computation of loads during completion of frustum design.

LPFL - An integer used to control computation of lateral pressures.

LPRES - An integer indicating type of pressure profile to be read in. (See Section 3.0 of TECHNICAL DISCUSSION.)

LSTOP - An integer indicating that the last pressure profile data card has been read.

LTMAX - Total number of pressure profile data points.

MAT - An integer indicating the material to be used. (See Section 3.0 of the TECHNICAL DISCUSSION.)

NBAY - Number of bays in a frustum.

NF - Index indicating frustum number.

NFMAX - Total number of frustums in the fairing.

OMEGA - Defined in Line No. RS213660in the program listing in Appendix A.

PCOLL - Pressure at which nose cap structure will collapse, psi.

PCRT - Lateral pressure at which skin buckles in the absence of other loading, psi.

PDESMN - Maximum pressure differential across the skin, multiplied by the factor of safety, on the leeward side of the bay, psi.

PDESMX - Maximum pressure differential across the skin, multiplied by the factor of safety, on the windward side of the fairing, psi.

PDSPH - Maximum pressure differential across the nose cap skin, multiplied by a factor of safety, psi.

PSTAT - Free-stream pressure, psi.

QB - Dynamic pressure, psi.

QBAR - Dynamic pressure, lbs/sq. ft.

RAXMAX - ANFIMX/ANFIAL

RAXMIN - ANFMN/ANFIAL

RAXMN(I) - RAXMIN for the Ith bay.

RAXMX(I) - RAXMAX for the Ith bay.

RCAP - Radius of spherical nose cap, in.

RCYL - Radius of cylindrical section, in.

RHO - Material density, lbs /cu. in.

RPMAX - PDESMX/PCRT

RPMIN - PDESMN/PCRT

RPMN (I) - RPMIN for the Ith bay.

RPMX (I) - RPMAX for the Ith bay.

RUSE - Radius of nose cap volume which is useful for payload. (See Line No. RS209660 of the program listing in Appendix A.), in.

SCAP - Surface area of spherical nose cap, sq. in.

SLOPT - Sum of bay lengths within a frustum, in.

STH - Sine of THETA.

SUMAL - Distance from the base of the fairing to the base of the bay, in.

T (J) - A standard skin gauge stored in the program, in.

TCAP - Thickness of nose cap skin, in.

TCAPST - Thickness of nose cap skin required to withstand pressure loads, in.

TCAPTH - Thickness of nose cap skin required to limit its temperature to the maximum specified, in.

TCONST - Torsion constant of ring, in.$^4$

TCONTH - Thickness of skin required on the top frustum to limit its temperature to the maximum specified, in.

THETA - Frustum half angle, radians

THTA(NF) - Half angle of frustum NF, degrees.

TMINC - Minimum skin thickness to be used in designing a frustum, in.

TMINN - Minimum skin thickness to be used in designing the nose cap, in.

TMNC(NF) - TMINC for frustum NF, in.

TMP - Maximum allowable temperature for both the top frustum and nose cap, $^{o}$F.

TMPMAX - Same as TMP.

TR (J) - Thickness of ring material required with a bay design using a skin thickness of T (J), in.

TRING (I) - Thickness of ring material for optimized design of the Ith bay, in.

TSKIN (I) - Thickness of skin for optimized design of the Ith bay, in.

TT - Ring web thickness, in.

VCAP - Volume of nose cap which is useful for payload (see HUSE and RUSE), cu. ft.

VGROSS - Gross volume of fairing, cu. ft.

VSEG (J) - Volume of bay designed for a skin gauge of T (J), cu. in.

VTOT - Useful volume of fairing (see DUSE1, DUSE2, HUSE and RUSE), cu. ft.

VUSE - Useful volume of frustum (see DUSE1 and DUSE2), cu. ft.

WCAP - Weight of nose cap, lbs.

WCONE - Frustum weight, lbs.

WR (J) - Weight of ring when the skin gauge for the bay is T (J), lbs.

WRING (I) - Weight of ring for the Ith bay, lbs.

WS (J) - Weight of skin for bay design using skin gauge T (J), lbs.

WSEF - Width of skin which contributes to ring stiffness, in.

WSEG (J) - Weight of bay when bay is designed using a skin gauge of T (J), lbs.

WSKIN (I) - Weight of skin for optimized design of the Ith bay, lbs.

WT (LAST) - Weight of two-bay configuration required to complete the design of a frustum, lbs.

WTDEX (I) - Weight index, weight to volume ratio for the optimized design for the Ith bay, lbs/cu. ft.

WTOT - Total fairing weight, lbs.

X - Length of pressure profile increment, in.

XBCAP - Distance from base of nose cap to center of lift pressure on the nose cap, in.

XOD(LT) - Axial location measured from the forward-most point on the nose divided by base diameter.

# APPENDIX C

# AERODYNAMIC PRESSURE COEFFICIENTS

When data for the fairing pressure profile is not input, the pressure coefficient at zero angle of attack, CPOO, and the maximum change in pressure coefficient due to angle of attack, CPAA, are computed for each conical frustum in Subroutine AERO. For the purpose of computing these parameters, each frustum is treated as a complete cone with an attached shock. Both CPOO and CPAA will then be uniform in the axial direction for each frustum. In order to construct the pressure profile as described in Section 1.4 and Figure 4, the values computed for CPOO and CPAA for the frustum are assigned to the stations at the ends of the frustum. That is

CPO (LT) = CPOO
CPO (LT+1) = CPOO
CPA (LT) = CPAA
CPA (LT+1) = CPAA

In which LT is the station at the small diameter of the frustum, and (LT+1) is the station at the large diameter of the frustum.

Using the ground rules indicated above, CPOO can be readily determined through the use of equations developed by Simon and Walter in Reference 2, which agree within a few percent with data presented in Chart 6 of Reference 3 (NACA Report 1135). These equations have been programmed in Subroutine AERO and are used in computing CPOO for each frustum.

When flying at an angle of attack the pressure distribution in the circumferential direction varies with circumferential position. This circumferential pressure distribution is assumed to be sinusoidal (see Figure 5). Since each frustum is treated as a complete cone, the distribution in the axial direction is uniform. The pressure distribution over the entire frustum can now be described by equations specifying the circumferential pressure distribution. These equations, as illustrated in Figure 5, are

$$C_P = C_{PO} - \Delta C_P \sin\phi \qquad \text{(C1)}$$

$$P = P_{AV} - \Delta P_{MAX} \sin\phi \qquad \text{(C2)}$$

In which

$$C_{PO} = \text{CPOO}$$

$$\Delta C_P = \text{CPAA}$$

The normal force, $\Delta F_N$, produced on an incremental length, $\Delta X$, by this pressure distribution can be computed as follows:

$$\Delta F_N = \Delta X \int_0^{2\pi} (-P\sin\phi)\left(\frac{D}{2}\right) d\phi \qquad \text{(C3)}$$

in which D is the diameter of the increment. When the expression for P (Equation C2) is substituted in Equation C3, and the integration performed

$$\Delta F_N = \frac{\pi}{2} D\,(\Delta X)\,(\Delta P_{MAX}) \qquad \text{(C4)}$$

In which

$$\Delta P_{MAX} = (\Delta C_P)\,q$$

and

$$\Delta F_N = \frac{\pi}{2} D\,(\Delta X)\,(\Delta C_P)\,q \qquad \text{(C5)}$$

The normal force on the same increment of cone can also be computed by using the normal force coefficient, $C_N$. For a complete cone the normal force, $F_N$, is expressed by

$$F_N = C_N\,q\,A \qquad \text{(C6)}$$

in which A is the base area of the cone. The incremental normal force, $\Delta F_N$, produced by a short length, $\Delta X$, of this cone is

$$\Delta F_N = C_N\,q\,(\Delta A) \qquad \text{(C7)}$$

in which $\Delta A$ is the surface area of the increment projected on the cone base, expressed by

$$\Delta A = \frac{\Delta D}{2}\,(\pi D) \qquad \text{(C8)}$$

The change in diameter, $\Delta D$, for a change in length, $\Delta X$, is

$$\Delta D = 2\,(\Delta X)\,\tan\theta \qquad \text{(C9)}$$

in which $\theta$ is the half angle of the cone. Substituting Equations C8 and C9 into C7 yields the following expression for $\Delta F_N$:

$$\Delta F_N = C_N\,q\,(\pi D)\,(\Delta X)\,\tan\theta \qquad \text{(C10)}$$

When the two expressions for $\Delta F_N$ (Equations C5 and C10) are equated and solved for $\Delta C_P$, the following expression is obtained.

$$\Delta C_P = 2\,C_N\,\tan\theta \qquad \text{(C11)}$$

In Chart 8 of Reference 3 $C_{N_\alpha}$ is plotted as a function of cone half angle $\theta$ and Mach number. $C_{N\alpha}$ is defined as

$$C_{N\alpha} = \left(\frac{\partial C_N}{\partial \alpha}\right)_{\alpha = 0} \tag{C12}$$

in which $\alpha$ is the angle of attack. For small angles of attack the following relationship is valid:

$$C_N = (C_{N\alpha})\alpha \tag{C13}$$

For the study for which this computer program was developed maximum loads occur in the neighborhood of Mach 1.5. In this region $C_{N\alpha}$ is not a strong function of Mach number. Therefore, a plot was made of $C_{N\alpha}$ versus $\theta$ at Mach 1.5. The points fell on a straight line expressed by the following equation.

$$C_{N\alpha} = 2.03 - 1.2\,\theta \tag{C14}$$

In Equation C14 both $\alpha$ and $\theta$ are expressed in radians. Substituting Equations C13 and C14 into C11 yields the following equation which is used to compute CPAA in Subroutine AERO (CPAA = $\Delta C_P$).

$$\Delta C_P = (2\tan\theta)\ (2.03 - 1.2\theta)\alpha \tag{C15}$$

In Equation C15, $\Delta C_P$ is the difference between the pressure coefficient on the windward side of the fairing and the pressure coefficient at the neutral position on the fairing.

# APPENDIX D

# BENDING MOMENTS, AXIAL LOADS AND SHEAR LOADS

In order to design a bay within the nose fairing structure, it is necessary to know the magnitude of the loads to which the bay is subjected. In addition to lateral pressure there are bending moments and axial loads which are used in computing line loads (force per running inch on the circumference) for the bay being analyzed. These computations are performed in Subroutine LOAD using the pressure profile data which was either computed in Subroutine AERO or input to the program.

The pressure profile data consists of a number of points connected by straight line segments as illustrated in Figure 4. In order to compute axial loads, shear loads and bending moments, it is necessary to compute the contribution of each of these pressure profile increments to the total load. In computing these incremental loads the point on the increment nearest the base of the fairing is used as a reference point.

First, an equation is derived to represent the shear force contributed by a pressure profile increment at its reference point. Nomenclature for this derivation is illustrated in Figure D1. The expression for $\Delta C_P$ as a function of $X/D$ between locations $(X/D)_1$ and $(X/D)_2$ is as follows:

$$\Delta C_P = \Delta C_{P1} - \frac{\Delta C_{P1} - \Delta CP_2}{(X/D)_1 - (X/D)_2} \left[(X/D)_1 - (X/D)\right] \qquad \text{(D1)}$$

At a specified location $\Delta C_P$ is the difference between the pressure coefficient on the windward side of the fairing and the pressure coefficient at the neutral position on the fairing (see Figure 5). The relationship between the variables in Equation D1 and Figure 4 are as follows:

$\Delta C_{P1}$ = CPA (LT+1)

$\Delta C_{P2}$ = CPA (LT)

$(X/D)_1$= XOD (LT+1)

$(X/D)_2$= XOD (LT)

Let

$$A_2 = \frac{\Delta C_{P1} - \Delta C_{P2}}{(X/D)_1 - (X/D)_2} \qquad \text{(D2)}$$

$$A_1 = \Delta C_{P1} - A_2 (X/D)_1 \qquad \text{(D3)}$$

Then, combining Equations D1, D2 and D3

$$\Delta C_P = A_1 + A_2 (X/D) \qquad \text{(D4)}$$

$X/D$ - Axial location measured from the nose in calibers.

$\Delta C_P$ - Change in pressure coefficient due to angle of attack (identical to CPAA in program listing).

D - Local diameter of fairing

$\theta$ - Half angle of frustum

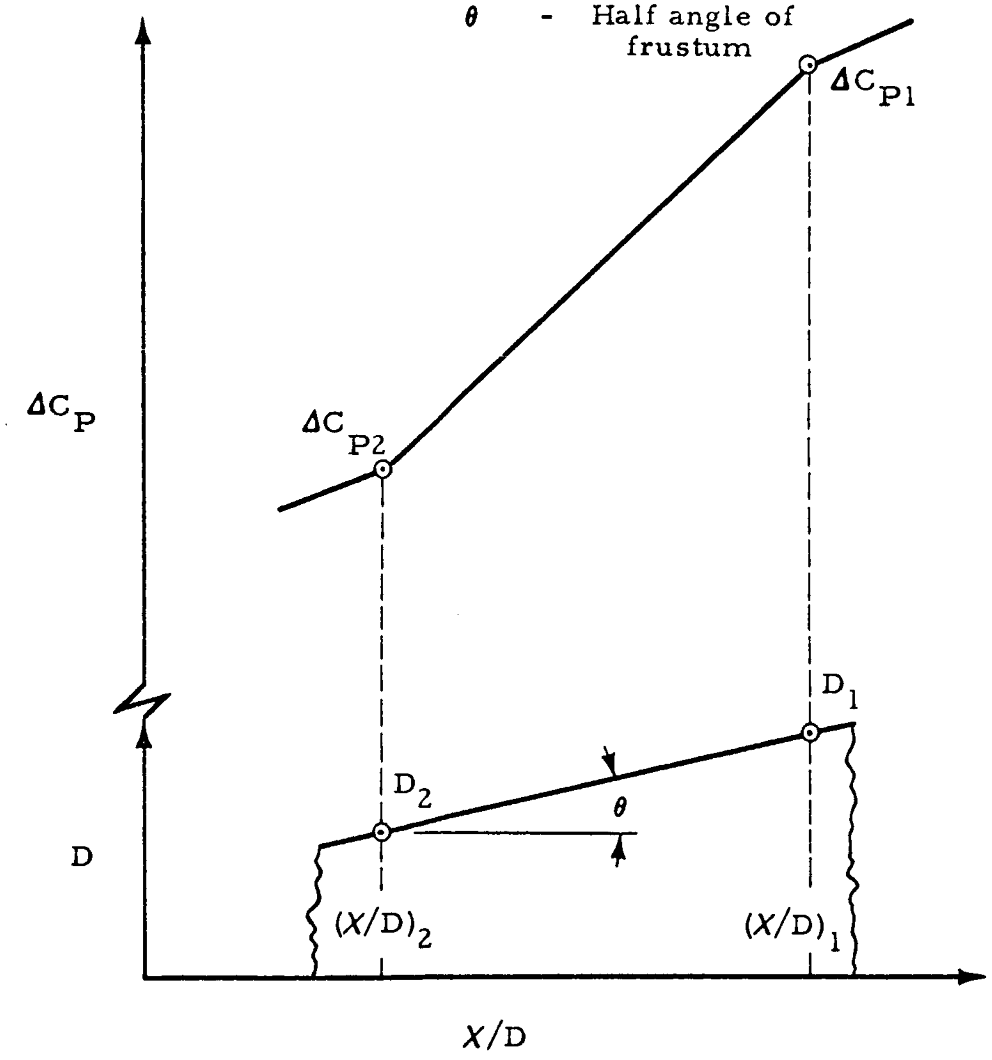

Figure D1 - Nomenclature Used in Derivation of Bending Moment Equation

In a similar manner the following expression can be obtained for the local diameter D.

$$D = A_{D1} + A_{D2}(X/D) \tag{D5}$$

In which

$$A_{D2} = \frac{D_1 - D_2}{(X/D)_1 - (X/D)_2}$$

$$A_{D1} = D_1 - A_{D2}(X/D)_1$$

In Appendix C an equation for the normal force, $\Delta F_N$, for an increment of length, $\Delta X$, was derived for a sinusoidal pressure distribution in the circumferential direction. This equation (Equation C5) is as follows:

$$\Delta F_N = \frac{\Pi}{2} D (\Delta X) (\Delta C_p) q$$

in which q is dynamic pressure. Using Equation C5 the running load in the axial direction, w, is expressed as follows:

$$w = \frac{\Delta F_N}{\Delta X}$$

$$= \frac{\Pi}{2} D (\Delta C_p) q \tag{D6}$$

By combining Equations D4, D5 and D6, the following expression is obtained for w.

$$w = \frac{\Pi}{2} q \left[A_1 A_{D1} + A_1 A_{D2}(X/D) + A_2 A_{D1}(X/D) + A_2 A_{D2}(X/D)^2\right] \tag{D7}$$

The shear force, v, at any point on the increment is

$$v = \int_{X_1}^{X} - w \, dX$$

$$= - D_{base} \int_{(X/D)_1}^{X/D} w \, d(X/D) \tag{D8}$$

In which $D_{base}$ is the base diameter of the fairing. When the integration is performed, the following expression is the result.

$$v = \frac{\Pi}{2} q D_{base} \left\{ \beta_1 \left[ X/D - (X/D)_2 \right] + \beta_2 \left[ (X/D)^2 - (X/D)_2^2 \right] + \beta_3 \left[ (X/D)^3 - (X/D)_2^3 \right] \right\} \qquad \text{(D9)}$$

In which

$$\beta_1 = A_1 A_{D1}$$

$$\beta_2 = \frac{A_1 A_{D2} + A_2 A_{D1}}{2}$$

$$\beta_3 = \frac{A_2 A_{D2}}{3}$$

The incremental shear force, $v_i$, at the reference point of the ith increment (the point nearest the fairing base), due to aerodynamic pressure acting on the ith increment, is obtained by substituting $(X/D)_1$ for X/D in Equation D9.

The incremental bending moment, $M_i$, about the reference point of the ith increment is expressed as follows:

$$M_i = \int_{X_2}^{X_1} v \, dx$$

$$= D_{base} \int_{(X/D)_2}^{(X/D)_1} v \, d(X/D) \qquad \text{(D10)}$$

By substituting Equation D9 into Equation D10 and performing the integration, the following expression is obtained.

$$M_i = \frac{\Pi}{2} \, q \, D_{base}^2 \left\{ \frac{\beta_1}{2} \left[(X/D)_1^2 - (X/D)_2^2\right] - \beta_1 (X/D)_2 \left[(X/D)_1 - (X/D)_2\right] + \frac{\beta_2}{3} \left[(X/D)_1^3 - (X/D)_2^3\right] - \beta_2 (X/D)_2^2 \left[(X/D)_1 - (X/D)_2\right] + \frac{\beta_3}{4} \left[(X/D)_1^4 - (X/D)_2^4\right] - \beta_3 (X/D)_2^3 \left[(X/D)_1 - (X/D)_2\right] \right\} \quad \text{(D11)}$$

These incremental shear loads and bending moments are now used to compute the shear load, $V_{base}$, and bending moment, $M_{base}$, at the base of the fairing.

$$V_{base} = \sum_{i=1}^{I} v_i + \begin{array}{l}\text{Contribution}\\ \text{of nose cap}\end{array} \quad \text{(D12)}$$

$$M_{base} = \sum_{i=1}^{I} (v_i L_i + m_i) + \begin{array}{l}\text{Contribution}\\ \text{of nose cap}\end{array} \quad \text{(D13)}$$

in which I is the total number of increments and $L_i$ is the distance from the base of the fairing to the reference point of the ith increment. The shear moment contribution of the nose cap are discussed below.

As design of the fairing moves from the base toward the nose cap, shear and moment contributed by each of the increments of pressure profile are subtracted from the total shear and bending moment. In moving from the reference point of the (i-1)th increment to the reference point of the ith increment the shear and bending moments at the ith reference point are computed as follows:

$$V_i = V_{i-1} - v_{i-1} \tag{D14}$$

$$M_i = M_{i-1} - m_{i-1} - V_i x_{i-1} \tag{D15}$$

in which x is the length of the increment.

Usually the location of the base of a bay will not coincide with the beginning or end of a pressure profile increment. In this case the pressure profile increment is divided at the base of the bay and each part is treated as a complete increment.

Computation of axial loads is handled in much the same manner as computation of shear force. Using nomenclature similar to that used previously for the $\Delta C_P$ calculations (see Figure D1) the equation for the pressure coefficient within a pressure profile increment is

$$C_P = B_1 + B_2 D \tag{D16}$$

in which

$$B_1 = C_{P1} - \frac{C_{P1} - C_{P2}}{D_1 - D_2} D_1 \tag{D17}$$

$$B_2 = \frac{C_{P1} - C_{P2}}{D_1 - D_2} \tag{D18}$$

The incremental axial load is

$$\Delta F_{ax} = \int_{D_1}^{D_2} (q\,C_P - \Delta P)\,(\pi D)\,\frac{dD}{2} \tag{D19}$$

in which $\Delta P$ is the difference between fairing internal pressure and ambient pressure. When the expression for $C_P$ is substituted into this equation and the integration is performed, the following equation is obtained.

$$\Delta F_{ax} = \frac{\pi}{2}\left[\frac{1}{2}(q\,B_1 - \Delta P)(D_1^2 - D_2^2) + \frac{1}{3}\,q\,B_2\,(D_1^3 - D_2^3)\right] \tag{D20}$$

Total axial load at the base of the fairing is computed by summing up the incremental loads plus the drag contributed by the nose cap. As design of the fairing progresses from the base towards the nose cap, increments of axial load are subtracted in a manner similar to that employed in computing shear loads.

When the bending moment and axial load are known at the base of a bay, the circumferential line load can be computed. This is the load per unit length of circumference parallel to the surface of the skin. The axial load places a uniform compressive load on the circumference. The bending moment places a compressive load on the leeward side and a tensile load on the windward side. The line load due to the axial force is

$$(N\phi)_{AX} = \frac{F_{ax}}{\pi D \cos\theta} \tag{D21}$$

in which

$F_{ax}$ = Axial force at the base of the bay
$D$ = Diameter at the base of the bay
$\theta$ = Semi-vertex angle of the bay

Using the assumption that the strain in the skin due to bending is proportional to the distance from the neutral plane, the maximum contribution of bending moment to the line load is computed by the following equation:

$$(N\phi)_{BEND} = \frac{M}{\frac{\pi}{4} D^2} \qquad \frac{1}{\cos\theta} \tag{D22}$$

When line load due to bending is superimposed on line load due to axial force the total becomes

$$(N\phi)_{WND} = (N\phi)_{AX} - (N\phi)_{BEND} \tag{D23}$$

$$(N\phi)_{LEE} = (N\phi)_{AX} + (N\phi)_{BEND} \tag{D24}$$

The subscript WND indicates windward side, and the subscript LEE indicates the leeward side.

The contribution of the nose cap to axial load, shear force and bending moment are computed by means of the nose cap drag coefficient, $C_D$, normal force coefficient per radian angle of attack, $C_{N_\alpha}$, and $\overline{X}$, the distance from the base of the nose cap to center of pressure on the normal plane. The reference area for $C_D$ and $C_{N_\alpha}$ is the base area of the nose cap. These parameters can be read into the computer or computed in Subroutine LOAD.

The computations for the nose cap $C_D$ in Subroutine LOAD are based on a computed pressure coefficient at the stagnation point, $(C_P)_{stg}$, and a pressure distribution over the nose cap described by the following equation:

$$C_P = (C_P)_{stg} \sin^2 \phi \tag{D25}$$

in which $\phi$ is the angle between a plane tangent to the nose cap surface and the line of flight.

In order to compute $(C_P)_{stg}$, the pressure at the stagnation point is assumed to be equal to the stagnation pressure downstream from a normal shock with upstream Mach number equal to that of the vehicle. For one-dimensional flow of a perfect gas with constant specific heat and molecular weight the ratio of downstream stagnation pressure, $P_o$, to upstream static pressure, $P_\infty$, is expressed by the following equation taken from Reference 11.

$$\frac{Po}{P_\infty} = \left[\frac{\gamma+1}{2} M^2\right]^{\frac{\gamma}{\gamma-1}} \left[\frac{2\gamma}{\gamma+1} M^2 - \frac{\gamma-1}{\gamma+1}\right]^{\frac{1}{1-\gamma}} \tag{D26}$$

in which $\gamma$ is the specific heat ratio of air and M is the Mach number of the vehicle. When $\gamma = 1.4$, Equation D26 reduces to

$$\frac{Po}{P_\infty} = \frac{166.92 \; M^7}{(7M^2 - 1)^{2.5}} \tag{D27}$$

An expression for $P_\infty$ derived from basic definitions is as follows:

$$P_\infty = \frac{q}{\frac{1}{2} \gamma M^2} \tag{D28}$$

For air, Equation D28 reduces to

$$P_\infty = \frac{q}{0.7 \, M^2} \tag{D29}$$

Using the definition for pressure coefficient

$$(C_P)_{stg} = \frac{Po - P_\infty}{q}$$

$$= \left(\frac{Po}{P_\infty} - 1\right) \frac{P_\infty}{q} \qquad \text{(D30)}$$

Combining Equations D27, D29 and D30 yields the following equation

$$(C_P)_{stg} = \frac{1}{0.7\ M^2} \left[\frac{166.92\ M^7}{(7M^2 - 1)^{2.5}} - 1\right] \qquad \text{(D31)}$$

The pressure coefficient, $C_P$, at all points on the nose cap is now defined by Equations D25 and D 31. By integrating $C_P$ over the nose cap surface the following expression is obtained for $C_D$.

$$C_P = \frac{1}{2} (C_P)_{stg} (1 + \sin^2\theta) \qquad \text{(D32)}$$

in which θ is the half angle of the top frustum. The axial force contributed by the nose cap is now expressed by the following equation:

$$(\Delta F_{ax})_{CAP} = C_D\ q\ A \qquad \text{(D33)}$$

in which A is the base area of the cap.

For small bluntness ratio (less than 0.2) the bending moment contribution of the nose cap can be approximated by assuming that the nose cap is replaced by a cone having the same half angle as the top frustum. $C_{N_\alpha}$ can then be computed by Equation C14 which is derived in Appendix C.

$$C_{N_\alpha} = 2.03 - 1.2\ \theta \qquad \text{(D34)}$$

Shear force contribution of the nose cap is

$$V_{CAP} = \alpha\ C_{N_\alpha} q\ A \qquad \text{(D35)}$$

For a complete cone the normal force (shear force) acts a point one-third of the distance from the base of the cone to its apex.

$$\bar{X} = \frac{1}{3} \frac{d}{2 \tan \theta} \tag{D36}$$

In which d is the diameter of the nose cap base. The bending moment at the base of the nose cap is expressed as follows:

$$m_{CAP} = \bar{X} \; v_{CAP} \tag{D37}$$

# APPENDIX E

# LATERAL PRESSURE

The lateral pressure used to design the fairing is the difference between internal and external surface pressure multiplied by a factor of safety. This pressure is computed on both the windward and leeward sides of the bay, using the pressure profile data and input aerodynamic data.

Pressure coefficients on the windward and leeward sides of the bay are expressed by the following equations.

$$(C_P)_{WND} = C_{PO} + \Delta C_P \qquad \text{(E1)}$$

$$(C_P)_{LEE} = C_{PO} - \Delta C_P \qquad \text{(E2)}$$

In which

$(C_P)_{WND}$ = pressure coefficient on windward side

$(C_P)_{LEE}$ = pressure coefficient on leeward side

$C_{PO}$ = pressure coefficient at zero angle of attack

$C_P$ = change in pressure coefficient due to angle of attack

The difference between surface pressure and free-stream pressure is expressed by the following equations.

$$(P_S)_{WND} - P_\infty = (C_P)_{WND}\, q \qquad \text{(E3)}$$

$$(P_S)_{LEE} - P_\infty = (C_P)_{LEE}\, q \qquad \text{(E4)}$$

In which

$P_S$ = surface pressure

$P_\infty$ = free-stream pressure

$q$ = dynamic pressure

Recall that the difference between internal pressure and free-stream pressure is an input parameter.

$$\Delta P = P_{int} - P_\infty \qquad \text{(E5)}$$

In which

$\Delta P$ = the input value of pressure difference

$P_{int}$ = absolute pressure inside the fairing

Combining Equation E3 with E5 and E4 with E5 the following equations for pressure difference are obtained.

$$(P_S)_{WND} - P_{int} = (C_P)_{WND}\, q - \Delta P \qquad \text{(E6)}$$

$$(P_S)_{LEE} - P_{int} = (C_P)_{LEE}\, q - \Delta P \qquad \text{(E7)}$$

Design pressures are obtained by multiplying these pressure differences by the factor of safety, FS.

$$(P_{des})_{WND} = FS \left[ (C_P)_{WND}\, q - \Delta P \right] \qquad \text{(E8)}$$

$$(P_{des})_{LEE} = FS \left[ (C_P)_{LEE}\, q - \Delta P \right] \qquad \text{(E9)}$$

# APPENDIX F

# SHELL DESIGN

When bay geometry, bay loading and shell thickness are specified the adequacy of the shell design is determined in Subroutine CHKLOD. In analyzing a bay design both line load (from Subroutine LOAD) and design pressure (from Subroutine PRESUR) are considered on both the windward and leeward sides of the fairing. An interaction relationship is used to account for the combined effect of these two types of loading.

The following interaction equation, which is used in Subroutine CHKLOD, was developed by Paul Seide (Reference 12).

$$(R_p)_{al} = \left[ \sqrt{1+\left(\frac{R_{AX}}{\sqrt{3}}\right)^2} - 2\left(\frac{R_{AX}}{\sqrt{3}}\right) \right] \times \sqrt{\sqrt{1+\left(\frac{R_{AX}}{\sqrt{3}}\right)^2} + \left(\frac{R_{AX}}{\sqrt{3}}\right)} \qquad \text{(F1)}$$

In which

$$R_p = \frac{P}{P_{crt}} \qquad \text{(F2)}$$

$(R_p)_{al}$ = maximum allowable value for $R_p$

$$R_{AX} = \frac{N\phi}{(N\phi)_{crt}} \qquad \text{(F3)}$$

$P$ = design pressure

$P_{crt}$ = the external to internal pressure difference at which the shell would fail in the absence of other forms of loading (critical pressure)

$N_\phi$ = circumferential line load

$(N_\phi)_{crt}$ = the compressive circumferential line load at which the shell will buckle in the absence of other loading (critical line load)

Critical pressure for the shell is computed by the method presented in Section 6.23.2, Reference 4. This is the "equivalent cylinder" technique of Reference 13 applied to the elastic design of truncated cones with a taper ratio $( 1 - R_1/R_2) \leq 0.95$ and a semivertex angle $\theta \lesssim 75$ deg:

$$P_{cr} = \frac{C_P \pi^2 E}{12 Z \sqrt{1 - \mu^2}} \left(\frac{t}{\rho}\right)^2 \tag{F4}$$

where

$$C_P = \frac{0.875 Z + 1.122 \sqrt{Z}}{4.385 + \sqrt{Z}} \tag{F5}$$

$$Z = \frac{\sqrt{1 - \mu^2}}{\eta_r} \left(\frac{L}{R_2}\right)^2 \left(\frac{R_2}{t}\right) \frac{1}{\cos\theta} \tag{F6}$$

$$\eta_r \approx 0.60 (0.70 + R_1/R_2) \tag{F7}$$

$$\left(\frac{\rho}{t}\right) = \frac{\eta_r}{\cos\theta} \left(\frac{R_2}{t}\right) \tag{F8}$$

and

$E$ = modulus of elasticity

$\mu$ = Poisson's ratio

$L$ = length of shell

$t$ = thickness of shell

$\theta$ = semivertex angle of frustum

$\rho$ = an equivalent radius

$R_1$ = small diameter of frustum

$R_2$ = large diameter of frustum

(For computational convenience the form of the above equations has been altered in the design program.)

The critical line load is computed by equations for short monocoque cylinders (Section 6.11.2 of Reference 4) modified by E. Hendrix, Reference 14, for use in the analysis of conical frustums. The basic equation is

$$F_{crt} = C \frac{\eta E}{(\rho/t)} \tag{F9}$$

In which

$F_{crt}$ = the critical compressive stress

$C$ = the buckling coefficient

$E$ = modulus of elasticity

$\eta$ = plasticity reduction factor

The ratio, $\rho/t$, is computed by Equations F7 and F8 above.

The buckling coefficient, C, is expressed by the following equation:

$$C = \frac{0.871}{(\frac{\rho}{t})^{m-1} (\frac{L}{\rho})^{n}} \tag{F10}$$

In which

$n = 2(m-1)$

Values for m are presented graphically in Figure 6.11-2 of Reference 4 for three different levels of probability -- average, 90% and 99%. A curve-fit of the 99% probability curve yielded the following equation which is used in the design program.

$$m = -0.378 \left[\ln (\frac{\rho}{t})\right]^2 + 0.3 \left[\ln (\frac{\rho}{t})\right] + 0.792 \tag{F11}$$

The parameter $\eta$ in Equation F9 is a plasticity reduction factor which is equal to one for the low loading intensities typical of nose fairings.

Since loads are expressed in terms of line load it is necessary to convert the critical compressive stress to the critical compressive line load. This is done by the following equation

$$(N_\phi)_{crt} = (F_{crt})(t) \tag{F12}$$

The ratios indicated in Equations F2 and F3 can now be calculated, and a value for $(R_P)_{al}$ can be computed by Equation F1. If $R_P$ is equal to or less than $(R_P)_{al}$ the design is satisfactory.

For use in the program it is desirable to define a new parameter, $C_K$, which is equal to or less than 1 for a satisfactory design. Algebraically, $C_K$, $R_P$ and $(R_P)_{al}$ are related as follows:

$$C_K = 1 + R_P - (R_P)_{al} \tag{F13}$$

$C_K$ is computed for both the windward and leeward sides of the fairing, corresponding to the variable names CHKWND and CHKLEE in the computer program. When both CHKWND and CHKLEE are equal to or less than one the design is adequate. In the computer output under "Design Details of Conical Frustums" some of the ratios and parameters developed in this appendix are listed for both the windward and leeward sides of the bay under the following headings:

$N_\phi$ - Line Load

$R_{ax}$ - Stress Ratio, Axial

$R_P$ - Stress Ratio, Press.

$C_K$ - Load Index

# APPENDIX G

# STIFFENING RING DESIGN

After the shell portion of a bay has been designed, it is necessary to provide a ring of adequate stiffness to prevent general instability of the composite structure, i.e., to prevent the entire side of the fairing from caving in. This ring is placed at the upper end of the bay. For tapered conical sections, lateral crushing pressure is normally the dominant factor in ring size determination. For these sections, the required moment of inertia of such a ring is expressed by the following equation which was used by Nevins and Helton in a similar study reported in Reference 1.

$$I_{req} = L_{bay} \left(\frac{D}{2 \cos \theta}\right)^2 \left(\frac{1}{t}\right)^{1/3} \left[\frac{(P_{des})_{WND}\ D_b}{11.02\ E \tan \theta}\right]^{4/3} \qquad \text{(G1)}$$

in which

$L_{bay}$ = length of bay, in.

$D$ = small diameter of bay, in.

$\theta$ = semivertex angle of bay

$t$ = skin thickness, in.

$(P_{des})_{WND}$ = the crushing pressure on the windward side of the fairing, psi.

$D_b$ = the base diameter of the fairing, in.

$E$ = modulus of elasticity of the material, psi.

This equation is a modification of the general stability equation developed by Becker in Reference 5.

For cylindrical sections, axial loads are higher and lateral collapse pressure much lower than in conical sections, hence rings are sized on a different basis. As stated in Section 1.13, the cylindrical section is divided into bays of equal length using stiffening rings of identical cross-section. Skin gauge for the first bay is determined by the same methods used elsewhere in the fairing. Then assuming that the skin gauge and loading determined for the first bay prevail throughout the cylindrical section, the minimum ring cross-section required to prevent general instability is computed by the method of Baruch-Singer adapted for use in this program by A. B. Burns (see Appendix K).

After computing the moment of inertia required of the ring, the ring cross-section which will provide this moment of inertia is selected. The three types of cross-sectional shapes which may be specified are shown in Figure 3. Also to be specified are B/t ratios of the web(s) and flanges. When designing the ring, the computer program selects the smallest standard skin gauge which provides a ring cross-section with moment of inertia equal to or greater than that required, providing that the selected ring has no buckled flanges.

It is necessary to check for flange (or web) buckling because large B/t values may be input, and these large B/t values present a definite possibility of local instability occurring. In making this check, a small (one percent) ovality tolerance was assumed, and bending stress due to this ovality effect are added to the hoop compression stress. The total flange stress thus obtained, is compared to an input flange buckling stress level (FCFB), and if excessive, the ring web thickness is increased as required.

# APPENDIX H

# STRUCTURAL DESIGN OF SPHERICAL NOSE CAP

The nose cap design is analyzed structually as an unstiffened, non-shallow spherical cap with uniform shell thickness. The method of analysis used is presented in Section 6.23.1 of Reference 4. From experiments it is observed that non-shallow (the ratio of height to radius is greater than 1/6) spherical caps buckle in the form of a small dimple in some area of the surface of the cap. Therefore, the critical buckling pressure for non-shallow caps is independent of the height to radius ratio, depending only on the radius to thickness ratio and the modulus of elasticity of the shell material.

The equation recommended in Reference 4 is

$$P_{crt} = \frac{0.606\ E}{\left(\frac{R}{t}\right)^2 e^{0.04\sqrt{R/t}}} \qquad \text{(H1)}$$

In which

$P_{crt}$ = critical buckling pressure

$R$ = nose cap radius

$E$ = modulus of elasticity

$t$ = shell thickness

A trial and error procedure is used in determining the minimum shell thickness required for the nose cap. When R, E and design pressure are known the shell thickness is increased by 0.001 inch increments until $P_{crt}$ is equal to or greater than the design pressure computed for the nose cap.

Maximum design pressure for the nose cap occurs at the stagnation point. Assuming that the pressure on this point is the same as the stagnation pressure downstream from a normal shock, the pressure coefficient, $(C_P)_{stg}$, is expressed by Equation D30, and the design pressure is expressed by the following equation:

$$(P_d)_{CAP} = (FS) \left[ q\ (C_P)_{stg} - \Delta P \right] \qquad \text{(H2)}$$

in which

FS = factor of safety

$q$ = dynamic pressure

$\Delta P$ = internal to free-stream pressure difference

# APPENDIX I

# DERIVATION OF APPROXIMATE BAY LENGTH EQUATIONS

Because of the complexity of the equations relating bay geometry and acceptable loading level it is necessary to determine bay length by an iterative procedure. Computer time can be saved by making a good first guess for this bay length. After establishing the bay length for the first of seven skin gauges to be used in the search for the optimum configuration, the lengths corresponding to each of the remaining six skin gauges can be scaled by using the ratio of the skin gauges and the previous bay length, both of which are known. Because lateral pressure is the dominant type of loading the derivation of the scaling equation which follows is based on the equation in Appendix F relating critical buckling pressure and bay geometry.

These equations are as follows:

$$P_{CR} = \frac{C_P \pi^2 E}{12 Z \sqrt{1-\mu^2}} \quad \frac{1}{(\rho/t)^2} \qquad \text{(I1)}$$

$$C_P = \frac{0.875Z + 1.122\sqrt{Z}}{4.385 + \sqrt{Z}} \qquad \text{(I2)}$$

$$Z = \frac{\sqrt{1-\mu^2}}{\eta_R \cos\theta} \left(\frac{2L}{D_B}\right)^2 \left(\frac{D_B}{2t}\right) \qquad \text{(I3)}$$

$$\eta_R \approx 0.6 \left(0.7 + \frac{D}{D_B}\right) \qquad \text{(I4)}$$

$$\frac{\rho}{t} = \frac{\eta_R}{\cos\theta} \left(\frac{D_B}{2t}\right) \qquad \text{(I5)}$$

In which

$P_{cr}$ = lateral pressure at which the skin buckles
$E$ = modulus of elasticity
$\mu$ = Poisson's ratio
$\theta$ = half angle of bay
$L$ = bay length
$D$ = small diameter of bay
$D_B$ = large diameter of bay
$t$ = skin thickness
$\rho$ = an effective bay radius

In equation I1 the only parameters influenced by bay length and skin gauge are $C_P$, Z and $\rho/t$. Therefore, the following relationship can be written, using subscript 1 to indicate the parameters associated with the bay which has been designed and subscript 2 to indicate parameters associated with the bay whose length is being estimated.

$$\frac{(C_P)_2}{(C_P)_1} \; \frac{Z_1}{Z_2} \left[\frac{(\rho/t)_1}{(\rho/t)_2}\right]^2 = 1 \qquad \text{(I6)}$$

A log - log plot of $C_P$ versus Z using Equation I2 reveals that Equation I2 can be replaced by the following approximate relationship.

$$C_P = 0.37Z^{0.64} \qquad \text{(I7)}$$

From which

$$\frac{(C_P)_2}{(C_P)_1} = \left(\frac{Z_2}{Z_1}\right)^{0.64} \qquad \text{(I8)}$$

Substituting into Equation I6

$$\left(\frac{Z_1}{Z_2}\right)^{0.36} \left[\frac{(\rho/t)_1}{(\rho/t)_2}\right]^2 = 1 \qquad \text{(I9)}$$

Again dropping terms not influenced by L and t, the following ratio is obtained from Equation I3.

$$\frac{Z_1}{Z_2} = \left(\frac{\eta_{R2}}{\eta_{R1}}\right) \left(\frac{L_1}{L_2}\right)^2 \frac{t_2}{t_1} \qquad \text{(I10)}$$

And from Equation I4

$$\frac{\eta_{R1}}{\eta_{R2}} = \frac{0.7 + D_1/D_B}{0.7 + D_2/D_B} \qquad \text{(I11)}$$

Which can be written as follows using the trignometric relationship between D, $D_B$, and $\theta$ .

$$\frac{\eta_{R1}}{\eta_{R2}} = \frac{1.7 - 2\frac{L_1}{D_B}\tan\theta}{1.7 - 2\frac{L_2}{D_B}\tan\theta} \qquad \text{(I12)}$$

From Equation I5

$$\frac{(\rho/t)_1}{(\rho/t)_2} = \left(\frac{\eta_{R1}}{\eta_{R2}}\right)\left(\frac{t_2}{t_1}\right) \qquad \text{(I13)}$$

By substituting Equation I10 and I13 into Equation I9 the following relationship is obtained.

$$\frac{L_2}{L_1} = \left(\frac{\eta_{R1}}{\eta_{R2}}\right)^{2.28}\left(\frac{t_2}{t_1}\right)^{3.28} \qquad \text{(I14)}$$

However, it is necessary to have a value for $L_2$ before computing the ratio $\eta_{R1}/\eta_{R2}$ using Equation I12. A close approximation to $L_2$ can be obtained by letting $\eta_{R1}/\eta_{R2}$ be equal to 1 in Equation I14. The ratio $\eta_{R1}/\eta_{R2}$ can then be computed using Equation I12, and the ratio $L_2/L_1$, can be obtained from Equation I14.

# APPENDIX J

# THERMAL ANALYSIS

The maximum temperature reached by the skin due to aerodynamic heating can be controlled by placing a lower limit on the thickness of skin to be used in critical locations. Provisions have been made in the program to place such constraints on both the nose cap and top frustum of the fairing, either by specifying the minimum skin thickness to be used or by specifying the maximum temperature to be reached by the skin.

Design curves for determining the minimum thicknesses have been prepared by LMSC/HREC. These curves and the methods used in generating the data for these curves are presented in Reference 6. The trajectory used in this analysis was a nominal two-stage Saturn V ascent trajectory to a 100 nautical mile circular orbit.

Both laminar and turbulent heating occur during the flight. Laminar flow was assumed to exist when the Reynolds number based on momentum thickness of the local boundary layer was equal to or less than 500. Turbulent flow was assumed to exist at Reynolds numbers above 500. When the flow was laminar, the method of Fay and Riddell (Reference 7) was used together with the laminar heating rate distribution of Lees (Reference 8). When the flow was turbulent, heating rates were calculated by using a method from Reference 9 (Bromberg, Fox and Ackermann). Radiation from the outer surface was also taken into account.

Other assumptions were that the heat flow is one-dimensional, that at any time or location on the fairing the skin temperature is uniform throughout the thickness of the skin, and that the inner surface of the skin is perfectly insulated. These latter assumptions were found to have only a minor effect on the final results.

Maximum temperature constraints are applied to the nose cap and the top frustum. The thickness of material required to limit the maximum temperature of the nose cap is based on heating at the stagnation point of the nose cap, and the thickness required for the top frustum is based on heating on the nose cap at its junction with the top frustum. Thus, the heating data required to establish these constraints can be obtained from a spherical shell.

Several hundred data points were generated for each of the following five materials: aluminum, magnesium, titanium, stainless steel and Lockalloy. Each data point for a specified material is completely described by the following four parameters:

$R$ = radius of spherical nose cap
$\theta$ = the angle between the line of flight and a plane tangent to the nose cap at the point of interest

$T_{max}$ = the maximum temperature reached by the skin, $^{o}F$

t = thickness of the skin

When applying this data to nose fairing design, $\theta$ is equal to $90^{o}$ at the stagnation point and to the half angle of the top frustum at the junction of the nose cap and top frustum. (Note that $\phi$ in Reference 6 is the complement of $\theta$.)

In order to avoid the necessity of storing all of these data points in the fairing design program, a set of linear algebraic equations which fit the data within a few percent was developed by a technique commonly referred to as multiple regression analysis. A detailed description of multiple regression analysis can be found in many statistical text books such as Reference 10, Chapters 4 and 5.

Two major steps are involved in such an analysis. First, it is necessary to establish the form of the equation relating the variables which describe the data points. This step can be based on intuition and/or a knowledge of the physical laws relating the variables. This equation must be reduced to linear form, which is then referred to as a linear model. The linear model has the general form

$$y = c_1 x_1 + c_2 x_2 + \ldots + c_n x_n \qquad (J1)$$

The variables y and $x_1$, $x_2$, ---, $x_n$ may be grouped parameters such as $(T_{max}-70)$ and $T_{max} / \sqrt{R}$. However, these variables must be such that numerical values can be obtained for each variable for each data point.

Having developed a linear model the next step is to determine the set of coefficients ($c_1$, $c_2$, ---, $c_n$) which give the best fit to the data. This is done by means of the "least squares" curve fit technique. Usually several different linear models are tried in an attempt to curve-fit a given set of data.

For this application two models were developed, one for the stagnation point and the other for the point of tangency between the spherical nose cap and the top frustum. A set of coefficients was computed for each of the two models for each of the five materials, making a total of ten sets of coefficients. The equations and coefficients appear in Subroutine THERML.

The linear model representing heating at the stagnation point is based on laminar and radiative heating theory. It is postulated that the following relationship is approximately true.

$$\rho C_p t\,(T_{max} - 70) = K_1 + \frac{K_2}{\sqrt{R}}(K_3 - T_{max}) - K_4\,\varepsilon\,(T_{max} + 460)^4 \tag{J2}$$

in which

$\rho$ = density of skin

$C_p$ = specific heat of skin

$\varepsilon$ = emissivity of skin

The terms in Equation J2 represent the following physical quantities:

$C_p t\,(T_{max}-70)$ = the maximum quantity of heat stored in a unit area of skin during the flight

$K_1$ = a constant

$\frac{K_2}{\sqrt{R}}(K_3 - T_{max})$ = convective heat input (laminar flow) to the unit area

$K_4\varepsilon\,(T_{max} + 460)^4$ = radiative heat loss from the unit area

When material properties are dropped (coefficients are determined for each material) and when the multiplications are performed Equation J2 reduces to the following linear form.

$$t\,(T_{max}-70) = a_1 + a_2\frac{1}{\sqrt{R}} + a_3\frac{T_{max}}{\sqrt{R}} + a_4\,(T_{max} + 460)^4 \tag{J 3}$$

Comparing this to Equation J1

$y = t\,(T_{max}-70)$

$X_1 = 1$

$$X_2 = \frac{1}{\sqrt{R}}$$

$$X_3 = \frac{T_{max}}{\sqrt{R}}$$

$$X_4 = (T_{max} + 460)^4$$

Using the data generated in Reference 6 the coefficients $a_1$, $a_2$, $a_3$ and $a_4$ can be determined by the least-squares technique.

A more complex model is required to represent heating at the point at which the nose cap is tangent to the top frustum. Turbulent flow occurs during part of the flight, and laminar flow occurs during the remainder. It is also necessary to specify the angular location, $\theta$ , on the sphere. The following model was postulated:

$$\rho C_P t\,(T_{max}-70) = K_1 + \frac{K_2}{\sqrt{R}}(K_4 + \sin^2\theta)(K_5 - T_{max})$$

$$+ \frac{K_3}{R^{0.2}}(K_4 + \sin^2\theta)(K_5 - T_{max}) - K_6\,\epsilon(T_{max} + 460)^4$$

The additional terms in this equation have the following physical significance:

$\frac{K_2}{\sqrt{R}}(K_4 + \sin^2\theta)(K_5 - T_{max})$ = convective heat input during laminar flow

$\frac{K_3}{R^{0.2}}(K_4 + \sin^2\theta)(K_5 - T_{max})$ = convective heat input during turbulent flow

in which $(K_4 + \sin^2\theta)$ accounts for pressure variation with angular position on the nose cap. When material properties are dropped and the multiplications are performed the quantities corresponding to the variables in the linear model are as follows:

$$y = t\,(T_{max}-70)$$

$$X_1 = 1$$

$$X_2 = \frac{1}{\sqrt{R}}$$

$$x_3 = \frac{T_{max}}{\sqrt{R}}$$

$$x_4 = (T_{max} + 460)^4$$

$$x_5 = \frac{\sin^2 \theta}{\sqrt{R}}$$

$$x_6 = \frac{T_{max} \sin^2 \theta}{\sqrt{R}}$$

$$x_7 = \frac{1}{R^{0.2}}$$

$$x_8 = \frac{T_{max}}{R^{0.2}}$$

$$x_9 = \frac{\sin^2 \theta}{R^{0.2}}$$

$$x_{10} = \frac{T_{max} \sin^2 \theta}{R^{0.2}}$$

Note that y and $x_1$, $x_2$, $x_3$, and $x_4$ are identical for both the stagnation point and tangency point models.

Coefficients were determined for each of the five materials at both the stagnation point and the tangency point. A summary of pertinent information about the curve fit is presented in Table J1.

The coefficients stored in Subroutine THERML were determined for a nominal two-stage Saturn V ascent trajectory to a 100 nautical mile orbit. If the subroutine is to be used for trajectories which differ greatly from this trajectory it would be adviseable to determine a new set of coefficients based on thermal data for the new trajectory. The linear models used in Subroutine THERML will probably be valid for a wide range of trajectories.

## TABLE JI

## THERMAL CURVE-FIT INFORMATION

| Location | Material | Range of Data | | | | No. of Data Points | Range of Errors in Skin Thickness, Percent | |
|---|---|---|---|---|---|---|---|---|
| | | Temperature, °F | | Skin Thickness, in | | | | |
| | | Low | High | Low | High | | Negative | Positive |
| Stagnation Point | Aluminum | 366 | 987 | 0.050 | 0.400 | 28 | -0.66 | 0.50 |
| | Magnesium | 388 | 1000 | 0.060 | 0.500 | 28 | -0.93 | 0.42 |
| | Titanium | 579 | 1234 | 0.040 | 0.250 | 21 | -0.39 | 0.30 |
| | Stainless Steel | 746 | 1361 | 0.025 | 0.080 | 23 | -0.91 | 1.26 |
| | Lockalloy | 369 | 1175 | 0.035 | 0.300 | 30 | -1.50 | 0.78 |
| Tangency Point | Aluminum | 404 | 1091 | 0.025 | 0.200 | 124 | -3.44 | 3.84 |
| | Magnesium | 396 | 1132 | 0.020 | 0.300 | 149 | -7.00 | 4.81 |
| | Titanium | 475 | 1365 | 0.015 | 0.200 | 125 | -3.49 | 3.79 |
| | Stainless Steel | 647 | 1147 | 0.0125 | 0.060 | 72 | -4.55 | 7.84 |
| | Lockalloy | 395 | 1234 | 0.025 | 0.150 | 105 | -6.03 | 7.20 |

NOTES:

Nose cap radius ranges from 13 to 52 inches for both locations and all materials.

Angular location of the tangency point (half angle of the top frustum) ranges from 0 to 45 degrees for all materials for the tangency point data.

# APPENDIX K

# THE BARUCH-SINGER GENERAL INSTABILITY ANALYSIS

by

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# THE BARUCH-SINGER GENERAL INSTABILITY ANALYSIS

## Analytical Basis

The equations presented by Baruch and Singer (Ref. 1) may be easily modified to predict the classical buckling load for the general mode of instability in stiffened cylinders subjected to a combination of axial compression and either internal or external lateral pressure. In the present analysis, modified Baruch-Singer equations have been written in a form which yields the classical axial load-carrying ability of the cylinder given a particular ring geometry and spacing, and a specified lateral pressure. These equations have two significant features: (1) they include the effects of ring eccentricity, and (2) they assume that local instability does not precede the onset of general instability in any of the elements of the composite cross-section. In addition, they apply to cylinders stiffened with equally spaced rings of identical cross section.

Of course, the classical buckling load is usually much too optimistic for cylinders carrying predominantly axial loads, and a practical method for adjusting the classical buckling downward is required. The method utilized here is that recommended in Ref. 2. Briefly, the critical buckling load is equal to the minimum postbuckling load (the lower bound), plus a percentage of the difference between the classical buckling load (the upper bound) and the minimum postbuckling load, depending upon the geometry of the cylinder. Thus:

$$\left(\frac{N_x}{RE}\right)_{cr} = \frac{N_{c\ell}}{RE}\left[\frac{N_{min}}{N_{c\ell}} + c\left(1 - \frac{N_{min}}{N_{c\ell}}\right)\right]$$

When $N_{min} = N_{c\ell}$, i.e., when the upper and lower bounds to the critical buckling load are equal, the critical buckling load is set equal to the classical buckling load and the term containing the factor c is zero. When $N_{min} < N_{c\ell}$, the factor c has the form:

$$c = (\varphi - 0.12)/0.88$$

where $\varphi$, an empirical reduction factor, is defined as follows:

$$\varphi = 1.0 \quad \text{when} \quad (R/t)_e \leq 33 \ .$$

$$\varphi = 6.48(R/t)_e^{-0.54} \quad \text{when} \quad (R/t)_e > 33 \ .$$

where:

$$(R/t)_e = R/t \ (t_x/t)^{0.5} \ [5.46(I_x/t^3 + I_y/t^3)]^{-0.5}$$

Note that the formulation for $(R/t)_e$ reduces to $R/t$ for monocoque cylinders. Thus, the reduction factor is tailored to apply to stiffened cylinders ranging from those with minimal stiffening to those with extensive stiffening.

Although the classical buckling load calculated here is dependent upon the applied lateral pressure, the minimum postbuckling load is calculated assuming zero pressure. This procedure has been adopted in the interest of expediency because a major effort beyond the intent of this study would be required to obtain minimum postbuckling loads which represent the combination of axial compression and lateral pressure loads on the cylinder. Likewise, the correction factor c is also calculated assuming zero pressure since it is expected that axial compression will be the predominant loading on cylinders analyzed with this subroutine. Under these circumstances, these limitations are expected to result in minor conservatism.

Computer Solution

The subroutine which has been written to solve the above noted equations accepts data relative to the rings in a general form; ring area, ring moment of inertia, ring centroidal distance, ring spacing and ring torsional stiffness are required. Therefore, any ring cross-section may be subjected to analysis in this subroutine for which the above noted properties have been written in a common form and are made available elsewhere in the program.

The classical buckling load is obtained by setting $m = 1$ and systematically investigating increasing values of $n$ until a minimum $N_{c\ell}$ is obtained. The value of $m$ is then increased and $n$ is again varied. If $N_{c\ell_{m=1}} \leq N_{c\ell_{m>1}}$, the cylinder is short; that is, the natural axial half wave length is greater than the length of the cylinder, and $N_{c\ell_{m=1}}$ is accepted as the classical buckling load. If $N_{c\ell_{m=1}} > N_{c\ell_{m>1}}$, the cylinder is long, and the value of $m$ is increased in increments (and for each increment, the value of $n$ is varied) until the lowest value of $N_{c\ell}$ is found. As part of these calculations, an effective width factor $Y$ is applied to the skin between rings, as required, to account for shear lag effects which reduce the bending stiffness of the composite section in the circumferential direction. Note that the skin is still assumed to be non-buckling. The minimum postbuckling load is subsequently calculated. Information pertinent to this quantity is stored as constant data in the program. This information has been taken from the work of Almroth (Ref. 3) wherein Almroth's graphical results have been converted here into tabular form. Additional subroutines are used to interpolate between adjacent points in the constant data. Initial calculations for the minimum postbuckling load establish whether the cylinder is long or short, and are carried out in a manner similar to that described above relative to the classical buckling load. If the cylinder is long, either subroutine TERP 4 of TERP 5 is called for interpolation purposes, depending upon the value of the geometric parameter $\gamma$ . If the cylinder is short, subroutine TERP 7 is called.

Having calculated the classical buckling load and the minimum postbuckling load, the correction factor $c$ is calculated as outlined above and these quantities are then used to calculate the critical buckling load.

The pressure applied to the cylinder may be positive (collapse pressure) or negative (burst pressure). For positive pressures, the subroutine may yield negative critical buckling loads in the early stages of sizing the rings, which indicate that the shell geometry is critical under the applied pressure, and tensile axial loads are required to maintain stability. Positive critical buckling loads (compression) will be obtained as the rings are increased in size.

The subroutine computes an elastic critical buckling load. Corrections for plasticity (or maximum permissible stress) are made elsewhere. Although the present subroutine has been written for internally stiffened cylinders, cylinders stiffened externally with rings may also be analyzed, if desired, by setting the control IRECC appearing at the beginning of the subroutine equal to -1 .

Notation

| | |
|---|---|
| $c$ | correction factor |
| $E$ | Young's Modulus |
| $I_x$ | moment of inertia per unit of circumferential width of cylinder wall cross section, taken about the centroid of the cross section. |
| $I_y$ | moment of inertia per unit of length of cylinder wall cross section, taken about the centroid of the cross section |
| $m$ | number of axial half-waves |
| $n$ | number of circumferential full waves |
| $N_{c\ell}$ | classical buckling load per unit of circumference for the general instability mode |
| $N_{min}$ | minimum postbuckling load per unit of circumference for the general instability mode |
| $N_x$ | applied axial load per unit of circumference |
| $p$ | applied pressure per unit of surface area |
| $R$ | cylinder radius |
| $t$ | cylinder wall thickness |
| $t_x$ | equivalent thickness in the axial direction (see Ref. 2) |
| $t_y$ | equivalent thickness in the circumferential direction (see Ref. 2) |
| $Y$ | effective width correction factor (see Ref. 2) |
| $\gamma$ | $I_x t_y / I_y t_x$ |
| $\varphi$ | empirical correction factor |

Subroutine Symbols

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|---|---|
| AIST | ring moment of inertia |
| AST | ring area |
| CR | critical buckling line load (pounds/in) |
| D | ring centroidal distance |
| DY | ring spacing |
| E | Young's Modulus |
| P | collapse pressure (psi); burst pressure if entered as negative quantity. |
| R | cylinder radius |
| T | cylinder wall gage |
| TK | ring torsion constant |
| XL | cylinder length |
| XMU | Poisson's ratio |

References

(1) M. Baruch and J. Singer, "Effect of Eccentricity of Stiffeners on the General Instability of Stiffened Cylindrical Shells under Hydrostatic Pressure," Journal of Mechanical Engineering Science, Vol. 5, No. 1, 1963, pp 23-27

(2) A. B. Burns and B. O. Almroth, "Structural Optimization of Axially Compressed, Ring-Stringer Stiffened Cylinders," Journal of Spacecraft and Rockets, Vol. 2, No. 6, 1965

(3) B. O. Almroth, "Postbuckling Behavior of Orthotropic Cylinders under Axial Compression," AIAA Journal Vol. 2, No. 10, 1964, pp 1795-1799