FACILITY FORM 602

N67 25899	
(ACCESSION NUMBER)	(THRU)
116 180	1
(PAGES)	(CODE)
CR-83919	31
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

TECHNICAL REPORT
HREC/5485-1
LMSC/HREC A712573

LOCKHEED MISSILES & SPACE CO~~MPANY~~
HUNTSVILLE RESEARCH & ENGINEERING CENTER
HUNTSVILLE RESEARCH PARK
4800 BRADFORD DRIVE, HUNTSVILLE, ALABAMA

AUTOMATED NOSE FAIRING DESIGN -- HONEYCOMB SANDWICH CONSTRUCTION

Contract NAS8-15485

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for J. S. Farrior
Resident Manager
Huntsville R & E Center

9 November 1965

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 describes the computer program for honeycomb sandwich construction. Major contributors to the development of this computer program are B. O. Almroth of the Palo Alto Research Laboratories and E. S. Hendrix, I. M. Landis, and Z. Adams of Huntsville Research & Engineering Center. Appendix K of this report was written by B. O. Almroth, and the remainder was written by Z. Adams.

SUMMARY

The computer program described in this report synthesizes near-optimum designs for honeycomb sandwich 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. Either standard gauges or non-standard gauges can be used for faces and ribbons.

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 synthesizes near-optimum structural designs for ring stiffened, honeycomb sandwich nose fairings. When the external geometry, aerodynamic loading, ring spacing, and a practical set of design constraints are given, the computer program selects a combination of honeycomb panel face thickness, core height and ring cross-section that gives a minimum fairing weight. Provisions have been made to use either standard or non-standard gauges of material for faces and ribbons. The external geometry can consist of up to ten intersecting conical frustums capped with a spherical nose cap. Figure 1 illustrates the external geometry and type of contruction.

A condensed flow chart illustrating the major logical steps performed by 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, lateral pressure and/or internal pressure. The combination of face thickness, core height, ribbon thickness, cell size and ring cross-section which results in minimum weight-to-volume ratio for a bay is considered to be the optimum design for that bay.

The computer program consists of the main program and a number of subroutines. The logical steps needed to design the fairing are performed in the main program. Specialized and repetitive functions are performed in the subroutines. This particular arrangement, as well as the liberal use of comment cards, is intended to facilitate future modifications.

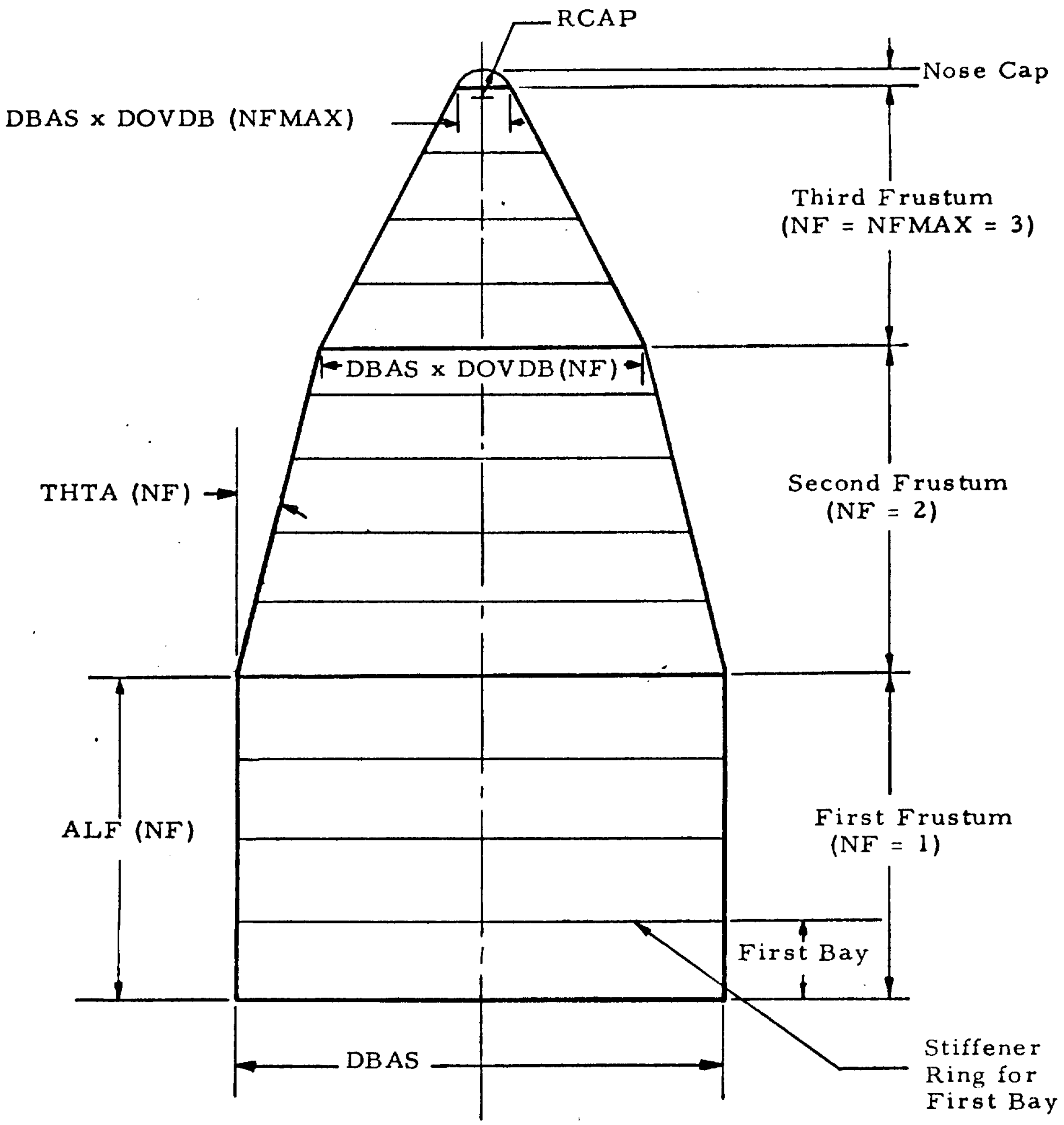
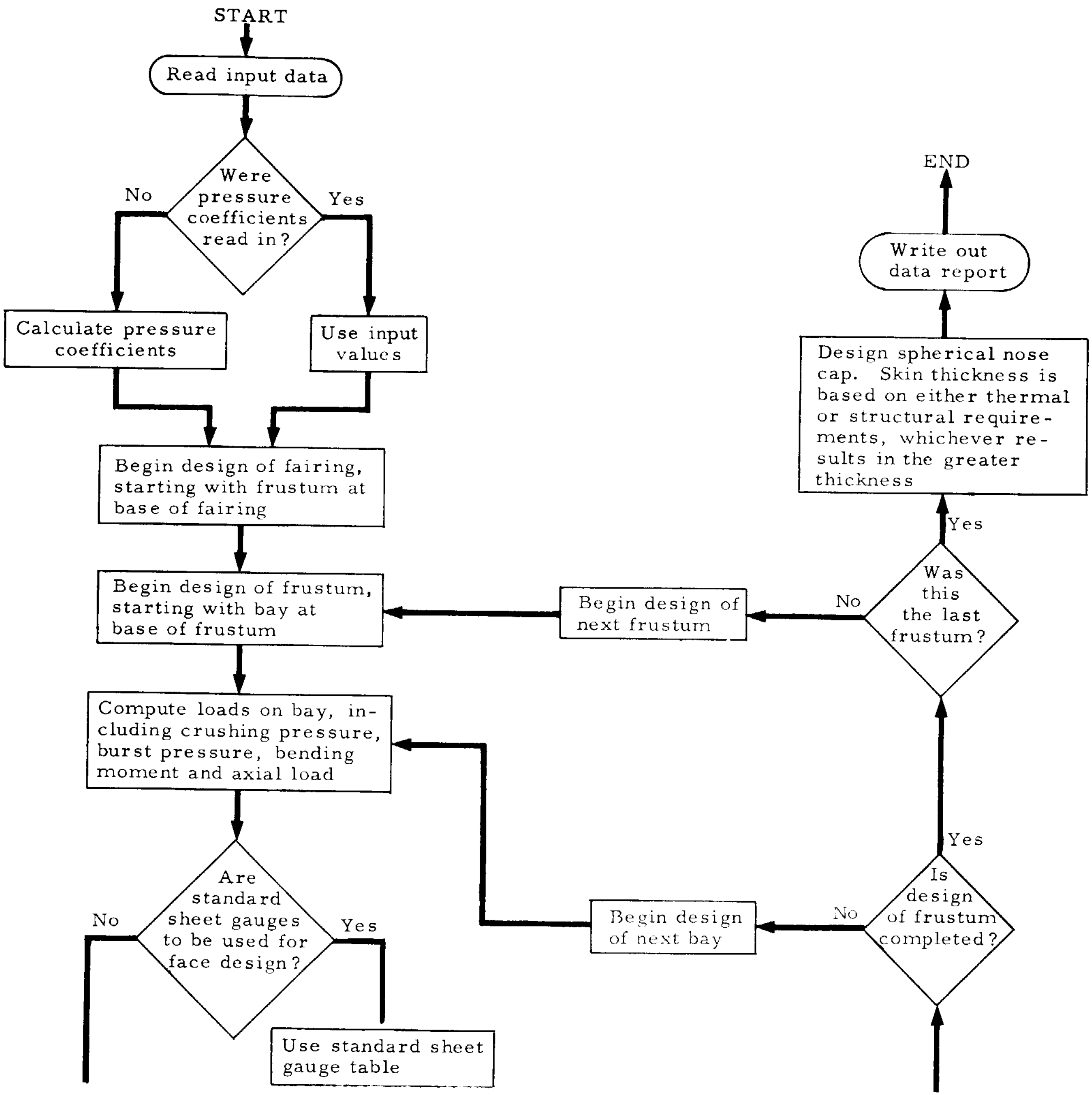


Figure 1 - Nose Fairing Geometry


START
Read input data
Were pressure coefficients read in?
No
Yes
Calculate pressure coefficients
Use input values
Begin design of fairing, starting with frustum at base of fairing
Begin design of frustum, starting with bay at base of frustum
Compute loads on bay, including crushing pressure, burst pressure, bending moment and axial load
Are standard sheet gauges to be used for face design?
No
Yes
Use standard sheet gauge table
END
Write out data report
Design spherical nose cap. Skin thickness is based on either thermal or structural requirements, whichever results in the greater thickness
Yes
Was this the last frustum?
No
Begin design of next frustum
Yes
Is design of frustum completed?
No
Begin design of next bay

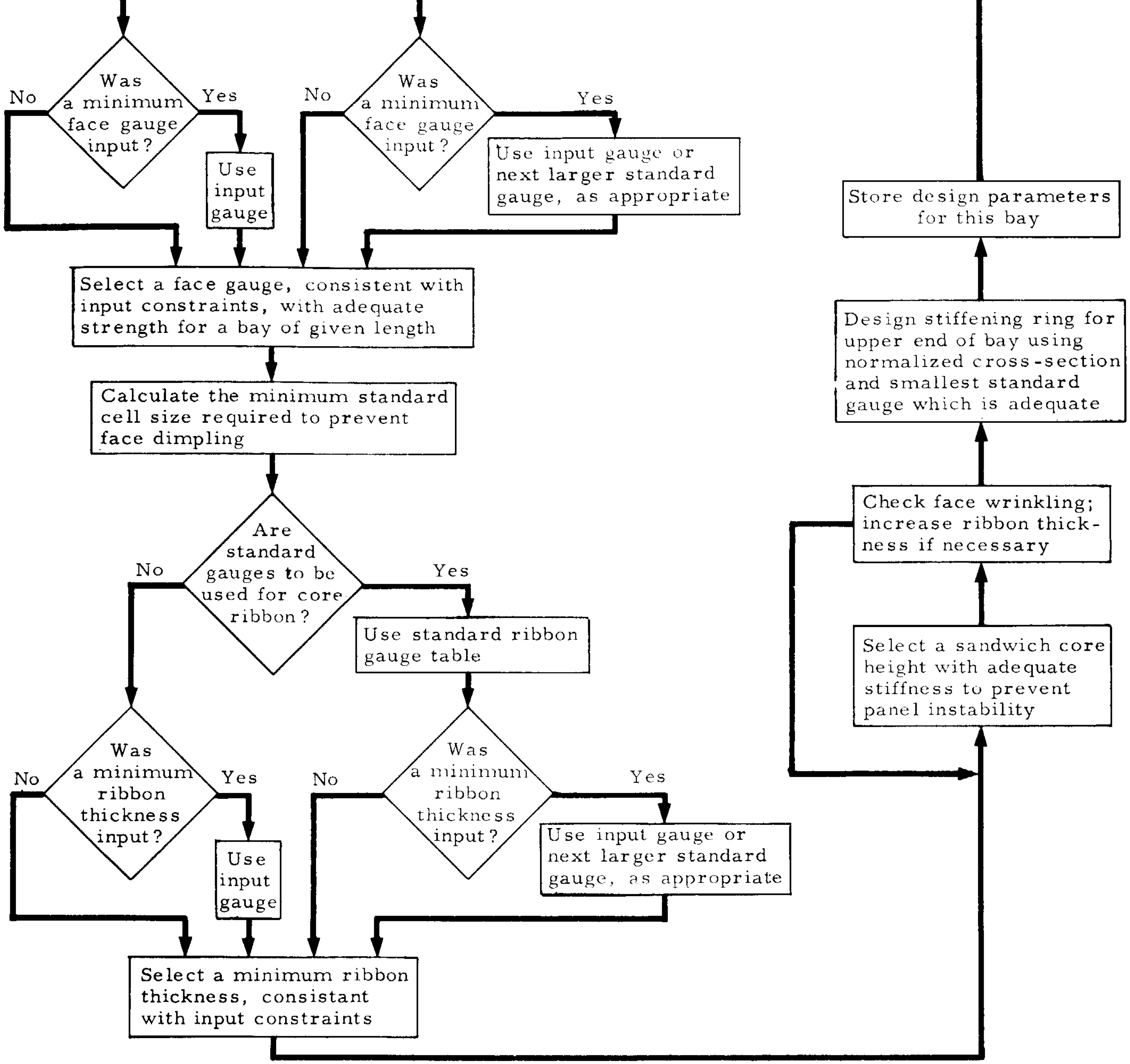


Figure 2 - Flow Chart Showing the Major Steps Performed in Optimizing the Design of a Multi-Frustum Nose Fairing -- Honeycomb Sandwich Construction

```
C          AXIS.  IF THE CELL HEIGHT TO WIDTH RATIO IS LESS THAN 5.0,    SWD0347
C          APPLY A WARPAGE CORRECTION FACTOR BASED ON FIGURE 6 OF THE    SWD0348
C          PENZIEN AND DIDRIKKON PAPER.                                  SWD0349
      PHI          = 0.5 * PI                                            SWD0350
      GC2          = (GCORE * TRIBN * SBETA * (R + CBETA))/(A * (((1. + R) SWD0351
     1 * SBETA**2 * (COS(PHI))**2) + (R + CBETA)**2 * (SIN(PHI))**2))    SWD0352
      PHI          = 0.0                                                 SWD0353
      GC1          = (GCORE * TRIBN * SBETA * (R + CBETA))/(A * (((1. + R) SWD0354
     1 * SBETA**2 * (COS(PHI))**2) + (R + CBETA)**2 * (SIN(PHI))**2))    SWD0355
      KY          =0                                                     SWD0356
C             MAKE FIRST ESTIMATE OF CORE HEIGHT.                        SWD0357
      H            = .25 + TF                                            SWD0358
      IF (I.GT.1) KY = 1                                                 SWD0359
      T1           = TF                                                  SWD0360
      T2           = TF                                                  SWD0361
  251 CONTINUE                                                           SWD0362
      IF ( H/W .GT. 5.0) GO TO 228                                       SWD0363
      Y            = (9.3 / (H/W)) - (2.1 / (H/W)**2)                    SWD0364
      IF ( H/W .LT. 0.5)  Y = 11.0                                       SWD0365
  228 CONTINUE                                                           SWD0366
      G1           = GC1 * (1.0 + .01 * Y)                               SWD0367
      G2           = GC2 * (1.0 + .01 * Y)                               SWD0368
      P            = PDESMX                                              SWD0369
C                  CHECK PANEL STABILITY ON WINDWARD SIDE. IF DESIGN IS  SWD0370
C         SATISFACTORY, PROCEED TO CHECK LEEWARD SIDE. IF DESIGN IS      SWD0371
C         UNSATISFACTORY, INCREASE CORE HEIGHT. IF A HEIGHT OF 4 INCHESSWD0372
C         IS REACHED AND THE DESIGN IS STILL UNSATISFACTORY, INCREASE    SWD0373
C         FACE THICKNESS.                                                SWD0374
      CALL INSTBL                                                        SWD0375
      IF (KG .EQ. 1) GO TO 98                                            SWD0376
      IF (CRG .GE. ANFIMN) GO TO 252                                     SWD0377
      IF ( H .GT. 2.0) GO TO 229                                         SWD0378
      H            = H + .125                                            SWD0379
      KY          =1                                                     SWD0380
      GO TO 251                                                          SWD0381
  229 CONTINUE                                                           SWD0382
      IF (KTFSTD .EQ. 1) GO TO 234                                       SWD0383
      TF           = 1.1 * TF                                            SWD0384
      GO TO 239                                                          SWD0385
```

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 larger end of the bay, frustum or fairing

bay - the conical frustum between two rings plus the ring at the upper end of this conical frustum

frustum - the conical frustum 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 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.

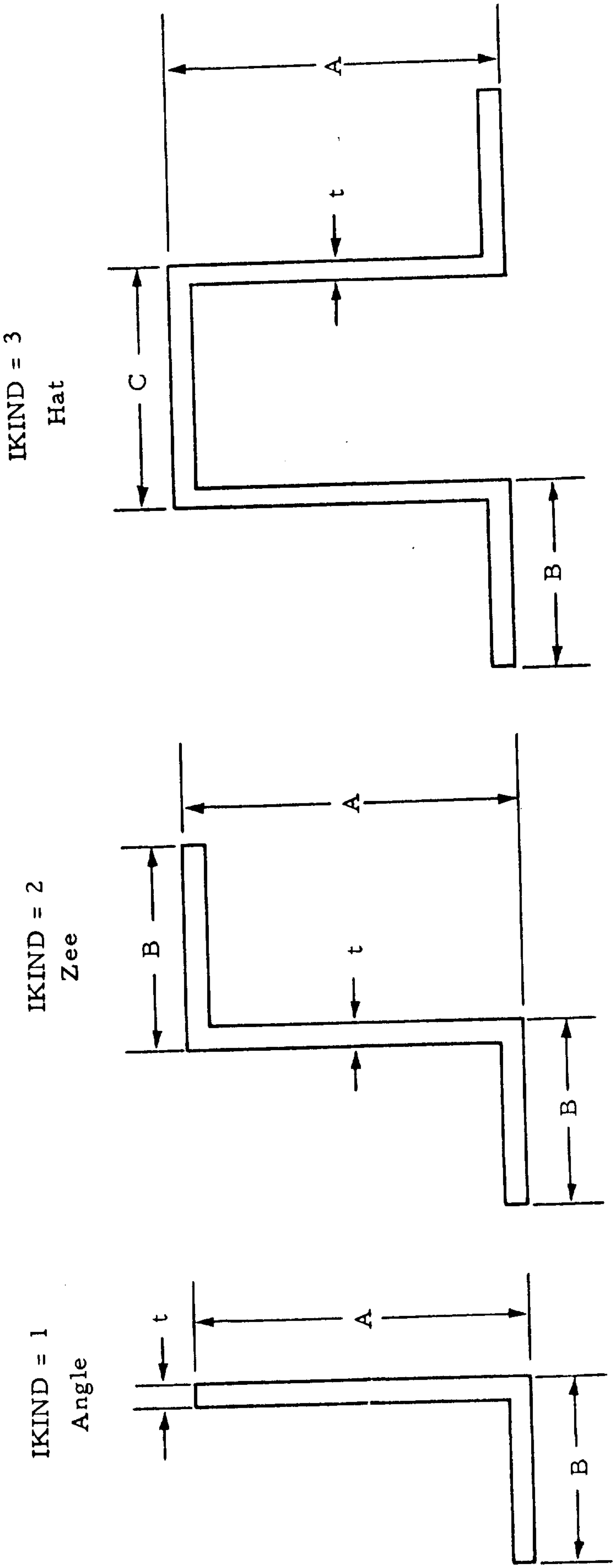


Figure 3 - Stiffener Cross-Section

1.3 Required Input Data

The following input data is required by the computer program:

1. External fairing geometry (Figure 1)
2. Design constraints
    a. Minimum distance between rings, in.
    b. Ring type (zee, hat, or angle), also flange and web thickness ratios - see Figure 3.
    c. Ring outstanding flange buckling stress level, psi.
3. Structural material
    a. Kind of material to be used. (Certain properties of five materials are stored in the program. See Section 1.5 of Technical Discussion.)
    b. Additional properties of sandwich face material
        (1) Tensile allowable stress, psi
        (2) Compressive allowable stress, psi
        (3) Shear allowable stress, psi
        (4) Young's modulus, psi
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 1.13.)
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. $\frac{\partial}{(x/D)} \left(\frac{\partial C_N}{\partial \alpha} \right)$

In Option 3

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

α = 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.

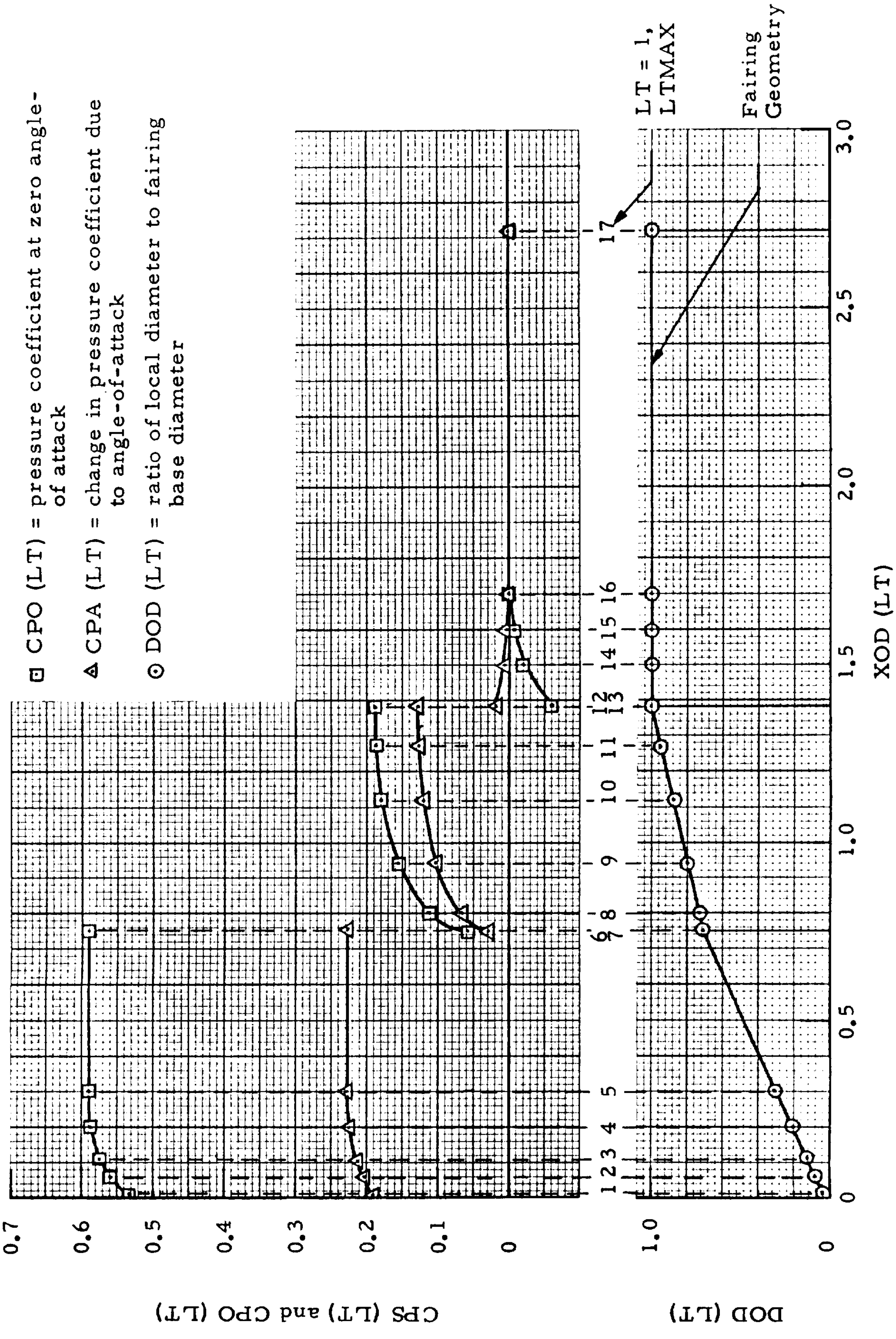


Figure 4 - Pressure Profile Used in Sample Problem

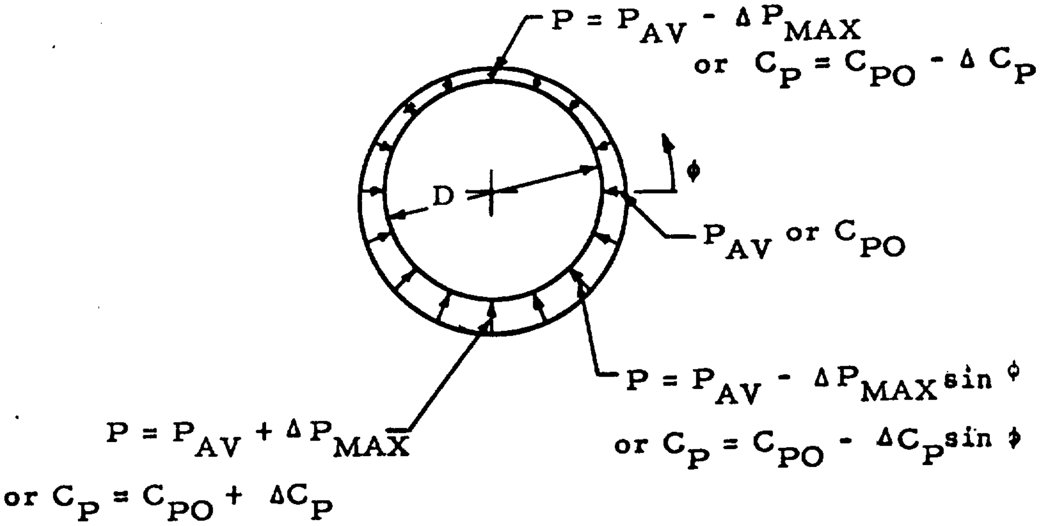


Figure 5 - Circumferential Pressure Distribution

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

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.

The quantities stored in the program are sufficient for most of the program's operations. However, additional data is required for the shell buckling analysis. Since the shell buckling analysis is based upon elastic behavior, it is necessary to input a face cut-off stress level which will ensure that plasticity effects do not become significant.

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 stiffening rings. Either standard or non-standard gauges may be used for the sandwich faces and ribbons.

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.

1.9 Last Bay in the Frustum

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.

Additional weight is added to the top ring of each frustum to provide for attachment to the next frustum or nose cap.

1.10 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.

1.11 Output Data

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

1. Design summary only (Figure 6A)

2. Design summary plus design details (Figures 6A, 6B and 6C)

3. Design summary plus design details plus loads details (Figures 6A, 6B, 6C, 6D and 6E).

Most of the headings appearing in the output are self-explanatory. However, there are two which require some comment.

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

Line Load - Force per running inch of circumferences, parallel to the skin surface, normal to the circumferential direction. A factor of safety has been applied to this force.

```
                    DATA REPØRT FØR ØPTIMIZED NØSE FAIRING STRUCTURE
                                   CASE NUMBER    1

                                  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  =      8.50
      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

      MAXIMUM ALLØWABLE TEMPERATURE ØF SKIN, DEG. F.                      TMPMAX =  10000.0
      CØNICAL SECTIØN SKIN THICKNESS REQUIRED FØR THERMAL REASØNS, IN.    TCØNTH =    0.0000


                             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      16.6     0.0160    21     9712.96     4194.14
     2     260.00    186.91     12.50     164.8      16.4     0.0160    10     3446.23     1148.81
     3     186.91      7.80     25.00     192.1      16.6     0.0160    11      940.30      492.18
                                          -----                        ---    --------    --------
                               TØTALS     708.4                         42    14099.49     5835.12


                                     NØSE CAP DESIGN

      DESIGN PRESSURE ØN NØSE CAP, PSI                                    PDSPH  =    11.396
      MINIMUM ALLØWABLE THICKNESS ØF NØSE CAP SKIN, IN.                   TMINN  =   -0.0000
      MAXIMUM ALLØWABLE TEMPERATURE ØF SKIN, DEG. F.                      TMPMAX =   10000.0
      NØSE CAP SKIN THICKNESS REQUIRED FØR STRUCTURAL INTEGRITY, IN.      TCAPST =     0.009
      NØSE CAP SKIN THICKNESS REQUIRED FØR THERMAL REASØNS, IN.           TCAPTH =     0.000
      NØSE CAP SKIN THICKNESS USED TØ CALCULATE WEIGHT, IN.               TCAP   =     0.009
      NØSE CAP RADIUS, IN.                                                RCAP   =     4.303
      LENGTH ØF NØSE CAP, IN.                                             ALCAP  =      2.43
      NØSE CAP SURFACE AREA, SQ. IN.                                      SCAP   =     67.18
      USEFUL VØLUME ØF NØSE CAP, CU. FT.                                  VCAP   =      0.01
      WEIGHT ØF NØSE CAP, LBS.                                            WCAP   =      0.06


                         TØTAL LENGTH, VØLUME AND WEIGHT ØF FAIRING

      TØTAL LENGTH ØF FAIRING, IN.                                        ALTØT  =    708.37
      USEFUL VØLUME ØF FAIRING, CU. FEET                                  VTØT   =  14262.64
      TØTAL VØLUME ØF FAIRING, CU. FEET                                   VGRØSS =  15558.15
      TØTAL WEIGHT ØF FAIRING, LBS.                                       WTØT   =   5835.18
```

Figure 6A - Computer Output for Sample Problem - Design Summary

```
                         DESIGN DETAILS OF CONICAL FRUSTUMS

                                    RING DATA

TYPE                                                        ZEE SECTION
BASE LEG B/T                                                BOT      =   10.00
UPRIGHT LEG B/T                                             AOT      =   20.00
OUTSTANDING LEG B/T                                         COT      =    0.00
FLANGE BUCKLING STRESS, PSI                                 FCFB     =  30000.

                               SANDWICH FACE DATA

FACE MATERIAL                                         7075-T6 ALUMINUM
```

Figure 6B - Computer Output for Sample Problem - Design Details

```
FRUSTUM   SHELL     BAY     FACE     RIBBON    RING       TOTAL     TOTAL     RING      WEIGHT      SHELL       TOTAL     CELL
 -BAY     O.D.    LENGTH    GAUGE    GAUGE     GAUGE    FACE WT.  CORE WT.    WT.       INDEX     THICKNESS   BAY WT.   WIDTH
  NO.     (IN)     (IN)     (IN)     (IN)      (IN)       (LB)      (LB)      (LB)   (LB/CU FT)     (IN)       (LB)     (IN)

 1- 1     260.0    16.6    0.0320   0.00100   0.1900     86.49      3.14    109.65     0.4570     0.9070     234.1    1.0000
 1- 2     260.0    16.6    0.0200   0.00100   0.1900     54.00      4.03    109.44     0.3810     1.1450     194.3    0.5625
 1- 3     260.0    16.5    0.0200   0.00100   0.1900     54.00      4.03    109.44     0.3810     1.1450     194.3    0.5625
 1- 4     260.0    16.6    0.0250   0.00100   0.1900     67.57      3.14    109.55     0.4119     0.9000     210.1    0.8125
 1- 5     260.0    16.6    0.0200   0.00100   0.1900     53.99      4.48    109.34     0.3824     1.2700     195.0    0.5625
 1- 6     260.0    16.6    0.0200   0.00100   0.1900     53.92      5.36    109.12     0.3851     1.5200     196.4    0.5625
 1- 7     260.0    16.6    0.0200   0.00100   0.1900     53.95      4.92    109.23     0.3837     1.3950     195.7    0.5625
 1- 8     260.0    16.6    0.0200   0.00100   0.1900     54.00      4.03    109.44     0.3810     1.1450     194.3    0.5625
 1- 9     260.0    16.6    0.0200   0.00100   0.1900     54.05      3.59    109.55     0.3796     1.0200     193.6    0.6250
 1-10     260.0    16.6    0.0400   0.00100   0.1900    108.11      3.14    109.65     0.5129     0.9150     261.6    1.0000
 1-11     260.0    16.6    0.0250   0.00100   0.1900     67.44      4.92    109.23     0.4161     1.4000     213.2    0.8750
 1-12     260.0    16.6    0.0200   0.00100   0.1900     53.92      5.36    109.12     0.3851     1.5200     196.4    0.6250
 1-13     260.0    16.6    0.0250   0.00100   0.1900     67.53      3.59    109.55     0.4134     1.0250     210.9    0.9375
 1-14     260.0    16.6    0.0200   0.00100   0.1900     54.08      2.70    109.77     0.3769     0.7700     192.2    0.6875
 1-15     260.0    16.6    0.0200   0.00100   0.1900     53.98      4.48    109.34     0.3824     1.2700     195.0    0.6875
 1-16     260.0    16.6    0.0320   0.00100   0.1900     86.61      1.80    109.93     0.4535     0.5320     231.3    1.0000
 1-17     260.0    16.5    0.0200   0.00100   0.1900     54.11      2.25    109.87     0.3755     0.6450     191.5    0.7500
 1-18     260.0    16.6    0.0200   0.00100   0.1900     54.00      4.03    109.44     0.3810     1.1450     194.3    0.7500
 1-19     260.0    16.6    0.0320   0.00100   0.1900     86.36      4.48    109.34     0.4644     1.2820     236.9    1.0000
 1-20     260.0    16.6    0.0200   0.00100   0.1250     54.05      3.14     47.71     0.2568     0.8950     131.0    0.8125
 1-21     260.0    17.0    0.0200   0.00100   0.1250     55.38      2.76     95.50     0.2524     0.7700     131.9    0.8125
 2- 1     252.7    16.4    0.0250   0.00100   0.1250     67.24      5.35     46.09     0.3066     1.5250     150.2    1.0000
 2- 2     245.5    16.4    0.0200   0.00100   0.1250     52.26      5.19     44.73     0.2787     1.5200     128.9    0.8125
 2- 3     238.2    16.4    0.0200   0.00100   0.1250     50.94      1.69     43.75     0.2741     0.5200     119.5    0.8750
 2- 4     230.9    16.4    0.0200   0.00100   0.1250     49.11      6.09     41.88     0.3005     1.8950     123.2    0.8750
 2- 5     223.6    16.4    0.0250   0.00100   0.1250     59.77      2.38     40.95     0.3337     0.7750     129.5    1.0000
 2- 6     216.4    16.4    0.0200   0.00100   0.1250     46.31      1.92     39.64     0.3026     0.6450     109.2    0.8750
 2- 7     209.1    16.4    0.0200   0.00100   0.1250     44.35      1.12     38.38     0.3092     0.3950     104.3    0.9375
 2- 8     201.8    16.4    0.0200   0.00100   0.1250     43.24      1.80     36.93     0.3236     0.6450     101.8    0.9375
 2- 9     194.6    16.4    0.0200   0.00100   0.1000     41.70      1.73     22.83     0.2918     0.6450      95.4    0.9375
 2-10     186.9    17.2    0.0250   0.00100   0.1000     52.71      1.75     43.83     0.3428     0.6500      97.7    1.0000
 3- 1     171.4    16.6    0.0200   0.00100   0.1250     41.06      1.71     31.21     0.3788     0.6450      91.6    0.6875
 3- 2     156.0    16.5    0.0200   0.00100   0.1000     37.17      4.89     17.83     0.3882     2.0200      78.5    0.7500
 3- 3     140.5    16.6    0.0200   0.00100   0.1000     33.32      1.69     16.31     0.4025     0.7700      66.8    0.8125
 3- 4     125.0    16.6    0.0200   0.00100   0.0900     30.42      1.01     11.79     0.4217     0.5200      56.1    0.8125
 3- 5     109.5    16.5    0.0200   0.00100   0.0900     26.83      1.11     10.25     0.4783     0.6450      49.7    0.8750
 3- 6      94.0    16.5    0.0200   0.00100   0.0800     23.26      0.96      6.94     0.5246     0.6450      41.1    0.9375
 3- 7      78.5    16.5    0.0200   0.00100   0.0710     19.67      0.97      4.53     0.5964     0.7700      33.6    1.0000
 3- 8      63.1    16.6    0.0200   0.00100   0.0630     16.07      0.92      2.83     0.7035     0.8950      26.7    1.0000
 3- 9      47.6    16.6    0.0200   0.00100   0.0630     12.46      0.82      2.05     0.9899     1.0200      20.7    1.0000
 3-10      32.1    16.6    0.0200   0.00100   0.0500      9.11      0.15      0.91     1.1251     0.2700      13.6    1.0000
 3-11       7.8    25.1    0.0320   0.00100   0.0250     11.21      0.23      0.09     2.3595     0.5320      13.6    1.0000
```

Figure 6C - Computer Output for Sample Problem - Design Details (Cont.'d)

```
                                               MAX APPLIED FACE STRESS, PSI               ALLOWABLE STRESS, PSI

FRUSTUM   WINDWARD   LEEWARD                                                        FACE       FACE       FACE
-BAY      LINE LOAD  LINE LOAD      AXIAL      CIRC      SHEAR     BURST         WRINKLING    YIELD     DIMPLING
NO.       (LB/IN)    (LB/IN)

 1- 1      750.47    -1122.15       17534.      -0.      3726.     11602.         46858.     41500.     22113.
 1- 2      719.27    -1090.95       27274.      -0.      4362.     18564.         66048.     41500.     27300.
 1- 3      688.08    -1059.76       26494.      -0.      4362.     18564.         66048.     41500.     27300.
 1- 4      656.89    -1028.57       20571.      -0.      3490.     14851.         66048.     41500.     20445.
 1- 5      625.69     -997.37       24934.      -0.      4362.     18564.         66048.     41500.     27300.
 1- 6      594.50     -966.18       24155.      -0.      4362.     18564.         66048.     41500.     27300.
 1- 7      563.31     -934.99       23375.      -0.      4362.     18564.         66048.     41500.     27300.
 1- 8      532.12     -903.80       22595.      -0.      4362.     18564.         66048.     41500.     27300.
 1- 9      500.92     -872.60       21815.      -0.      4362.     18564.         66048.     41500.     22113.
 1-10      469.73     -841.41       10512.      -0.      2181.      9282.         52192.     41500.     34556.
 1-11      438.54     -810.22       16204.      -0.      3490.     14851.         66048.     41500.     17628.
 1-12      407.35     -779.02       19476.      -0.      4362.     18564.         66048.     41500.     22113.
 1-13      376.15     -747.83       14957.      -0.      3490.     14851.         66048.     41500.     15556.
 1-14      344.96     -716.64       17916.      -0.      4362.     18564.         66048.     41500.     18275.
 1-15      313.77     -685.45       17136.      -0.      4352.     18564.         66048.     41500.     18275.
 1-16      282.57     -654.25       10223.      -0.      2726.     11602.         61222.     41500.     22113.
 1-17      251.38     -623.06       15577.      -0.      4362.     18564.         66046.     41500.     15356.
 1-18      220.19     -591.87       14797.    -132.      4362.     18564.         66048.     41500.     15356.
 1-19      189.01     -560.69        8761.    -158.      2724.     11602.         66048.     41500.     22113.
 1-20      157.86     -529.54       13238.    -346.      4352.     18564.         66048.     41500.     13085.
 1-21      126.79     -498.47       12462.    -631.      4335.     18564.         66048.     41500.     13085.
 2- 1       97.47     -478.18        9564.    6338.      3439.     14962.         66048.     41500.     13497.
 2- 2       82.29     -463.27       11582.    7701.      4136.     18170.         66048.     41500.     13085.
 2- 3       66.85     -448.44       11211.    7466.      3971.     17638.         48955.     41500.     11282.
 2- 4       51.07     -433.76       10344.    7041.      3810.     17107.         66048.     41500.     11282.
 2- 5       34.80     -419.25        9345.    5302.      2927.     13260.         66048.     41500.     13497.
 2- 6       17.90     -404.85       10121.    6200.      3514.     16043.         66048.     41500.     11282.
 2- 7        0.18     -390.53        9763.    5782.      3377.     15511.         56170.     41500.      9828.
 2- 8      -18.46     -376.22        9405.    5378.      3247.     14979.         66046.     41500.      9825.
 2- 9      -38.46     -361.93        9048.    4590.      3134.     14448.         66048.     41500.      9828.
 2-10      -60.32     -347.52        6550.    3072.      2441.     11120.         48955.     41500.     13497.
 3- 1      -93.31     -358.01        8950.   13722.      3034.     14008.         66048.     41500.     18275.
 3- 2      -85.90     -327.83        8196.   14420.      2778.     12788.         66048.     41500.     15356.
 3- 3      -78.51     -297.62        7441.   13118.      2522.     11569.         66048.     41500.     13085.
 3- 4      -71.12     -267.38        6684.   11816.      2264.     10349.         48955.     41500.     13085.
 3- 5      -63.73     -237.09        5927.   10513.      2006.      9129.         66048.     41500.     11282.
 3- 6      -56.33     -206.77        5169.    9211.      1747.      7910.         66048.     41500.      9628.
 3- 7      -48.66     -175.41        4410.    7909.      1486.      6690.         66048.     41500.      9538.
 3- 8      -41.26     -146.09        3652.    6607.      1222.      5470.         66048.     41500.      9638.
 3- 9      -33.48     -116.12        2903.    5224.       960.      4251.         66048.     41500.      8638.
 3-10      -25.70      -86.81        2170.    3876.       707.      3031.         67939.     41500.      9538.
 3-11      -17.96      -58.34         512.    1605.       289.       877.         61222.     41500.     22113.
```

Figure 6D - Computer Output for Sample Problem - Loads and Stresses

```
                                         DETAILED LOADS DATA

FRUSTUM   BAY BASE   BAY TOP     BAY     DISTANCE   DES. PRES.  DES. PRES.   AXIAL       SHEAR       BENDING
 -BAY      DIA.       DIA.     LENGTH   FROM BASE    WINDWARD    LEEWARD     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    108426.4     71261.7    35508096.0
 1- 2      260.0      260.0     16.6      16.6        -0.00       -0.00    108426.4     71261.7    34325151.0
 1- 3      260.0      260.0     16.6      33.2        -0.00       -0.00    108426.4     71261.7    33142206.8
 1- 4      260.0      260.0     16.6      49.8        -0.00       -0.00    108426.4     71261.7    31959262.3
 1- 5      260.0      260.0     16.6      66.4        -0.00       -0.00    108426.4     71261.7    30776318.3
 1- 6      260.0      260.0     16.6      83.0        -0.00       -0.00    108426.4     71261.7    29593374.0
 1- 7      260.0      260.0     16.6      99.6        -0.00       -0.00    108426.4     71261.7    28410430.3
 1- 8      260.0      260.0     16.6     116.2        -0.00       -0.00    108426.4     71261.7    27227485.5
 1- 9      260.0      260.0     16.6     132.8        -0.00       -0.00    108426.4     71261.7    26044541.0
 1-10      260.0      260.0     16.6     149.4        -0.00       -0.00    108426.4     71261.7    24861597.0
 1-11      260.0      260.0     16.6     166.0        -0.00       -0.00    108426.4     71261.7    23678653.5
 1-12      260.0      260.0     16.6     182.6        -0.00       -0.00    108426.4     71261.7    22495708.0
 1-13      260.0      260.0     16.6     199.2        -0.00       -0.00    108426.4     71261.7    21312764.3
 1-14      260.0      260.0     16.6     215.8        -0.00       -0.00    108426.4     71261.7    20129820.5
 1-15      260.0      260.0     16.6     232.4        -0.00       -0.00    108426.4     71261.7    18946876.0
 1-16      260.0      260.0     16.6     249.0        -0.00       -0.00    108426.4     71261.7    17763931.8
 1-17      260.0      260.0     16.6     265.6        -0.00       -0.00    108426.4     71261.7    16580987.6
 1-18      260.0      260.0     16.6     282.2        -0.04       -0.05    108425.3     71251.3    15398096.5
 1-19      260.0      260.0     16.6     298.8        -0.03       -0.11    108426.3     71212.7    14215584.3
 1-20      260.0      260.0     16.6     315.4        -0.11       -0.17    108426.4     71095.1    13034303.1
 1-21      260.0      260.0     17.0     332.0        -0.19       -0.37    108426.4     70817.8    11856044.4
 2- 1      260.0      252.7     16.4     349.0         2.33        0.45    108426.4     70235.7    10656669.8
 2- 2      252.7      245.5     16.4     365.4         2.38        0.45    105470.7     65672.7     9542414.8
 2- 3      245.5      238.2     16.4     381.8         2.35        0.45    102596.9     61241.3     8501899.6
 2- 4      238.2      230.9     16.4     398.2         2.31        0.45     99847.9     57022.5     7532513.9
 2- 5      230.9      223.6     16.4     414.6         2.24        0.45     97243.8     53071.2     6630078.1
 2- 6      223.6      216.4     16.4     431.0         2.17        0.42     94794.7     49379.4     5790264.4
 2- 7      216.4      209.1     16.4     447.4         2.09        0.40     92517.1     45907.7     5009211.6
 2- 8      209.1      201.8     16.4     463.8         2.01        0.37     90405.2     42652.8     4283307.9
 2- 9      201.8      194.6     16.4     480.2         1.78        0.34     88519.7     39744.6     3608312.9
 2-10      194.6      186.9     17.2     496.6         1.54        0.31     86917.6     37305.9     2977122.8
 3- 1      186.9      171.4     16.6     513.8         6.10        2.68     85731.7     35532.2     2350960.1
 3- 2      171.4      156.0     16.6     530.4         6.10        2.68     72124.7     29925.7     1807528.5
 3- 3      156.0      140.5     16.6     547.0         6.10        2.68     59647.8     24709.1     1354765.4
 3- 4      140.5      125.0     16.6     563.6         6.10        2.68     48350.8     19985.5      964462.7
 3- 5      125.0      109.5     16.6     580.2         6.10        2.68     38233.9     15757.4      683492.7
 3- 6      109.5       94.0     16.6     596.8         6.10        2.69     29297.1     12021.4      459607.3
 3- 7       94.0       79.5     16.6     613.4         6.10        2.68     21540.2      8779.5      236638.7
 3- 8       79.5       63.1     16.6     630.0         6.10        2.66     14963.4      6030.4      164399.0
 3- 9       63.1       47.6     16.6     646.6         6.01        2.68      9593.6      3702.5       83546.4
 3-10       47.6       32.1     16.6     663.2         5.91        2.68      5443.6      2112.5       35106.2
 3-11       32.1        7.8     26.1     679.8         5.80        2.68      2490.5       932.9       10579.3
TANG. PT.    7.8                         705.9                                229.2        56.7         156.2
```

Figure 6E - 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 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 subtracted 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 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.

2.7 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 it 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 INSTBL (Panel Stability)

When given details of a tentative sandwich design for a bay, along with applied crushing or bursting pressure, INSTBL computes the line load at which the bay will fail due to overall instability. The analysis was prepared by B. O. Almroth of LMSC's Solid Mechanics Laboratory, and is described in Appendix K.

Subroutine INSTBL 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. Nose fairing data cards for a number of nose fairing designs can be stacked in the usual manner behind these cards.

Input parameters required by subroutine INSTBL are EFACE, G1, G2, AMU, T1, T2, APRC, H, KY, PXL, and KG. Output from the subroutine is CRG, the intial line load, which is compared to the applied line load at the position (windward or leeward) then under investigation.

3.0 INPUT FORMAT

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, 2, 3, and 4 Parameters which apply to the entire fairing.

Type 5 Parameters which apply to individual frustum (one card 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 6 Lift and drag data for the nose cap.

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

Type 7 Pressure profile data points (one card per data point.)

Type 8 Card indicating end of pressure profile data.

The detailed format for these cards is as follows:

Type 1: Format (5F12.8, 2I6)

Data: DBAS - Base diameter of fairing, 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 - A integer indicating the type of output desired. The code is as follows:

(0) Design summary only. (See Figure 6A).

(1) Design summary plus design details (Figures 6B and 6C.)

(2) Design summary plus design details plus load details (Figures 6C, 6D and 6E.)

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, $^{\circ}$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.

Type 3: Stringer Data (I5, 6E12.8)

Data: IKIND - Type of cross-section

1 = angle

2 = zee

3 = hat

AOT - Web height-to-thickness ratio (see Figure 3)

BOT - Flange width-to-thickness ratio (see Figure 3)

COT - Hat section flange width-to-thickness ratio (see Figure 3)

FCFB - Ring outstanding flange buckling level, psi

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

Data: MATF - Type of material

1 = 2024-T4 Alclad Aluminum

2 = 2024-T4 Aluminum

3 = 7075-T6 Aluminum

FTA - Face tensile allowable stress

FCA - Face compressive allowable stress

FSA - Face shear allowable stress

EFACE - Modulus of elasticity of face material

One Type 5 card is required for each frustum.

Type 5: (5F12.8, 2I6)

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, degress.

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

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

TRBMIN (NP) - Minimum ribbon thickness to be used in designing frustum, in.

KTRSTD - An integer indicating whether standard ribbon gauge material is to be used

0 - Use non-standard gauges

1 - Use standard gauges

KTFSTD - An integer indicating whether standard gauge material is to be used for sandwich faces.

0 - Use non-standard gauges

1 - Use standard gauges

The next card type is required only when nose cap lift and drag data or a pressure profile is read in (PRES = -1, 1, 2 or 3 in Card Type 2). If a blank card is inserted for Card Type 6 when LPRES = 1, 2 or 3, the program will compute CDCAP, CNCAP and XBCAP.

Type 6: 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 7: 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) - Local to base diameter ratio at station LT.

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

Type 8: 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) = 16.6 inches
ELMIN (2) = 16.4 inches
ELMIN (3) = 16.6 inches
TMNC (1) = 0.016 inches
TMNC (2) = 0.016 inches
TMNC (3) = 0.016 inches
KTFSTD = 1 (use standard gauges for faces)
TRBMIN (1) = 0.001 inches
TRBMIN (2) = 0.001 inches
TRBMIN (3) = 0.001 inches
KTRSTD = 1 (use standard gauges for ribbon)
TMINN = 0.0 inches
TMP = 10000.0°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)

Face Material:

MATF = 1 (7075-T6 Aluminum)
FTA = 58000. psi
FCA = 41500. psi
FSA = 27000. psi
EFACE = 10300000. psi

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 4, 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 7.

This input data is arranged in key-punch format in Figure 7. The computer output for this problem is shown in Figures 6A, 6B, 6C and 6D.

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APPENDIX A

MAIN PROGRAM LISTING

```
$JOB           LMSC-C53/ADAMS SAB ,460040,00,12,140CEP                     SWD0001
$*           NOSE FAIRING OPTIMIZATION PROGRAM                               SWD0002
$EXECUTE       IBJOB                                                         SWD0003
$IBJOB LMSC    MAP                                                           SWD0004
$IBFTC C53S    DECK                                                          SWD0005
C              STRUCTURAL OPTIMIZATION AND DESIGN OF MULTI-FRUSTUM NOSE SWD0006
C           FAIRINGS USING RING AND SANDWICH CONSTRUCTION.                   SWD0007
      DIMENSION WSEG(400), VSEG(400), T(30), D(400), ALOPT(400) ,            SWD0008
     1TRING(400), WRING(400), WTDEX(400), ENFIMX(400), ENFIMN(400),          SWD0009
     2FFWR(400),FFDMP(400),ELMIN(400),TMNC(400),IMX(400),CELSIZ(400),        SWD0010
     3FZ(400),TRBN (400),WFACE(400),WTOTFC(400),TRBMIN(400),TRBSTD( 8),      SWD0011
     4  WTCORE(400),TFACE(400),FFAX(400),FFC(400),FFS(400),FFB(400),         SWD0012
     5          WSPLCE(400), TCORE(400)                                      SWD0013
      INTEGER CASE                                                           SWD0014
      COMMON ANFIMN,ANFIMX,DSUBB,PDESMN,PDESMX,E                             SWD0015
      COMMON /THRML/ TMPMAX,MAT,TCONTH,TCAPTH,THETA                          SWD0016
      COMMON/AERPRS/CPAA,CPOO,LPFL                                           SWD0017
      COMMON/INSTB/EFACE, G1, G2,AMU, T1, T2, APRC, H , CRG, KY, P, KG       SWD0018
      COMMON/LOADS/CDCAP,CNCAP,XBCAP,FSUBZ,AXLDCP,FSBZCP,BNDCAP,LTRIG,       SWD0019
     1 ALCAP                                                                 SWD0020
      COMMON/KLSS/XL                                                         SWD0021
      COMMON/PRESR/CPA(121),CPO(121),XOD(121),DELTAP, FS,LTMAX,SUMAL,        SWD0022
     1 QBAR,ALTOT                                                            SWD0023
      COMMON /CHKLD/ C1,C3,C4,ALB,DELTAS,CHK,RAXMIN,RAXMAX,RPMIN,RPMAX,      SWD0024
     1   CHKWND,CHKLEE,C2                                                    SWD0025
      COMMON/SFCTN/ GBAR, F                                                  SWD0026
      COMMON/CONFG/THTA(10),ALF(10),NFMAX,DBAS,DMN(10),ICONFG                SWD0027
      COMMON/AERLOD/ALPHA,AMACH,NF                                           SWD0028
      COMMON/IRQ/ TTM, PI, ALCONE, C6, AIREQ                                 SWD0029
      COMMON/RNG/ IKIND, AOT, BOT, COT, TSTD(30), K, AIRING, DD              SWD0030
      COMMON /RSTRSS/ AA, TF, Z, CTH, AST, AISTT, FRING                      SWD0031
      COMMON/TNOS/TMINN,PDSPH,TCAPST,RCAP                                    SWD0032
C                                                                            SWD0033
      CASE      = 0                                                          SWD0034
      PI        = 3.1415927                                                  SWD0035
C              READ PARAMETERS WHICH APPLY TO ENTIRE FAIRING.                SWD0036
   10 CONTINUE                                                               SWD0037
      READ (5,131) DBAS,DELTAL,QBAR,AMACH,ALPHA,KEY                          SWD0038
      READ (5,132) MAT,NFMAX,TMP,TMINN,DELTAP,FS,LPRES                       SWD0039
```

```
      READ(5,989) IKIND ,AOT,BOT,COT,FCFB                               SWD0040
      IF (NFMAX .GT. 10) GO TO 98                                       SWD0041
C              READ SANDWICH FACE MATERIAL DATA.  DO NOT USE ALLOWABLE  SWD0042
C         STRESSES IN EXCESS OF PROPORTIONAL LIMIT, SINCE BUCKLING      SWD0043
C         ANALYSES ASSUME ELASTIC BEHAVIOR.                             SWD0044
      READ (5,990) MATF, FTA, FCA, FSA, EFACE                           SWD0045
      ALTOT      = 0.                                                   SWD0046
      DMX        = DBAS                                                 SWD0047
      DO  30 NF = 1,NFMAX                                               SWD0048
C              READ PARAMETERS WHICH DESCRIBE INDIVIDUAL FRUSTUMS.      SWD0049
      READ(5,131) ALF(NF),THTA(NF),ELMIN(NF),TMNC(NF),TRBMIN(NF),KTRSTD,SWD0050
     1KTFSTD                                                            SWD0051
      THETA      = 0.0174532925*THTA(NF)                                SWD0052
      IF (ALF(NF) .LT. 1.) GO TO 20                                     SWD0053
      DMN(NF)    = DMX - 2.*ALF(NF)*SIN(THETA)/COS(THETA)               SWD0054
      GO TO 25                                                          SWD0055
   20 CONTINUE                                                          SWD0056
      DMN(NF)    = DBAS*ALF(NF)                                         SWD0057
      ALF(NF)    = (DMX-DMN(NF))*COS(THETA)*.5/SIN(THETA)               SWD0058
   25 CONTINUE                                                          SWD0059
      DMX        = DMN(NF)                                              SWD0060
      ALTOT      = ALTOT + ALF(NF)                                      SWD0061
   30 CONTINUE                                                          SWD0062
      DMX        = DBAS                                                 SWD0063
C              CHECK TO DETERMINE IF PRESSURE PROFILE DATA IS TO BE     SWD0064
C         READ IN.                                                      SWD0065
      IF (LPRES .EQ. 0) GO TO 45                                        SWD0066
C              READ NOSE CAP LIFT AND DRAG DATA IF INPUT INSTEAD OF     SWD0067
C         COMPUTED.                                                     SWD0068
      READ (5,131) CDCAP,CNCAP,XBCAP                                    SWD0069
      IF (LPRES .LT. 0) GO TO 50                                        SWD0070
C                                                                       SWD0071
C              READ PRESSURE PROFILE DATA.                              SWD0072
C                                                                       SWD0073
      DO 35  LT = 1,101                                                 SWD0074
      READ (5,365) CPO(LT),CPA(LT),XOD(LT),LSTOP                        SWD0075
      IF (LSTOP .GT. 0) GO TO 40                                        SWD0076
   35 CONTINUE                                                          SWD0077
```

```
   40 CONTINUE                                                           SWD0078
      LTMAX      = LT - 1                                                SWD0079
      GO TO 50                                                           SWD0080
   45 CONTINUE                                                           SWD0081
      CDCAP      = 0.                                                    SWD0082
   50 CONTINUE                                                           SWD0083
      CASE       = CASE + 1                                              SWD0084
C              WRITE OUT HEADINGS FOR DATA REPORT.                       SWD0085
      WRITE (6, 501)                                                     SWD0086
      WRITE (6,550)                                                      SWD0087
      WRITE (6,555) CASE                                                 SWD0088
C              IF A FACTOR-OF-SAFETY WAS INPUT, THE INPUT VALUE IS       SWD0089
C          USED. OTHERWISE THE FACTOR-OF-SAFETY IS 1.4.                  SWD0090
      IF (FS .LT. 1.)  FS = 1.4                                          SWD0091
C              RADIUS OF SPHERICAL NOSE CAP IS COMPUTED.                 SWD0092
      THETA      = 0.0174532925 * THTA(NFMAX)                            SWD0093
      RCAP       = 0.5*DMN(NFMAX)/COS(THETA)                             SWD0094
      ALCAP      = RCAP*(1.-SIN(THETA))                                  SWD0095
      ALTOT      = ALTOT + ALCAP                                         SWD0096
C              IF NOSE CAP RADIUS IS ZERO, A NOTE IS WRITTEN OUT, AND    SWD0097
C          MAXIMUM ALLOWABLE TEMPERATURE IS SET EQUAL TO 10000. THIS     SWD0098
C          CAUSES THE PROGRAM TO BY-PASS THE THERMAL EQUATIONS, WHICH    SWD0099
C          ARE NOT VALID FOR A NOSE CAP RADIUS OF ZERO.                  SWD0100
      IF (RCAP .GT. 0.) GO TO 55                                         SWD0101
      WRITE (6,178)                                                      SWD0102
      TMP        = 10000.                                                SWD0103
   55 CONTINUE                                                           SWD0104
C              PROPERTIES ARE LOOKED UP FOR THE INPUT MATERIAL.  IF      SWD0105
C          NO MAXIMUM TEMPERATURE WAS SPECIFIED, A NOMINAL VALUE WILL    SWD0106
C          BE CHOSEN AND USED.                                           SWD0107
      CALL PROPTY (MAT, E, AMU, RHO, TMPMAX )                            SWD0108
      C8         = SQRT (1. - AMU**2)                                    SWD0109
      C4         = (PI**2 *E) / (12. * C8)                               SWD0110
C              IF MAXIMUM ALLOWABLE TEMPERATURE IS EQUAL TO OR GREATER   SWD0111
C          THAN 10000., EITHER FROM INPUT DATA OR BECAUSE NOSE CAP       SWD0112
C          RADIUS EQUALS ZERO, THE REQUIRED THERMAL THICKNESS OF BOTH    SWD0113
C          THE NOSE CAP AND TOP FRUSTUM ARE SET EQUAL TO ZERO.           SWD0114
      IF (TMP .LT. 10000.) GO TO 60                                      SWD0115
      TMPMAX     = TMP                                                   SWD0116
```

```
      TCONTH     = 0.0                                                  SWD0117
      TCAPTH     = 0.0                                                  SWD0118
      GO TO 65                                                          SWD0119
C              IF THE INPUT VALUE FOR MAXIMUM ALLOWABLE TEMPERATURE     SWD0120
C          IF EQUAL TO 0., THE STORED VALUE IS USED. IF THE INPUT VALUE SWD0121
C          IF GREATER THAN 0. BUT LESS THAN 10000., THE INPUT VALUE IS  SWD0122
C          USED FOR MAXIMUM ALLOWABLE TEMPERATURE.                      SWD0123
   60 IF (TMP .GT. 0.) TMPMAX = TMP                                     SWD0124
C              THE SKIN THICKNESSES REQUIRED TO KEEP SKIN TEMPERATURE   SWD0125
C          BELOW THE MAXIMUM SPECIFIED ARE COMPUTED FOR BOTH THE NOSE   SWD0126
C          CAP (TCAPTH) AND THE TOP FRUSTUM (TCONTH) IN SUBROUTINE      SWD0127
C          THERML.                                                      SWD0128
      CALL THERML                                                       SWD0129
   65 CONTINUE                                                          SWD0130
      DATA T/ 0.001, 0.020, 0.040, 0.060, 0.080, 0.100, 0.120, 0.140,  SWD0131
     1 0.160, 0.180, 0.200, 0.220, 0.240, 0.260, 0.280, 0.300, 0.320,  SWD0132
     2 0.340, 0.360, 0.380, 0.400, 0.500, 0.600, 0.700, 0.800, 0.900,  SWD0133
     31.000, 1.250, 1.500, 2.000   /                                    SWD0134
C              STANDARD RIBBON THICKNESSES                              SWD0135
      DATA TRBSTD/ .0007, .001, .0015, .002, .0025, .003, .004, .005 /  SWD0136
C              AMBIENT PRESSURE AT DESIGN CONDITIONS AND DESIGN PRESSURESWD0137
C          ON THE NOSE CAP ARE COMPUTED.                                SWD0138
      PSTAT      = QBAR / ( 100.8 * AMACH**2)                           SWD0139
      PDSPH      = FS*(PSTAT*((166.92158*(AMACH)**7.)/((7.*(AMACH)**2)  SWD0140
     1                -1.)**2.5)-PSTAT - DELTAP)                        SWD0141
C              AERODYNAMIC DATA ARE WRITTEN OUT.                        SWD0142
      WRITE (6,307)                                                     SWD0143
      WRITE (6,72) QBAR                                                 SWD0144
      WRITE (6,73) AMACH                                                SWD0145
      WRITE (6,74) ALPHA                                                SWD0146
      WRITE (6,163) DELTAP                                              SWD0147
      WRITE (6,162) PSTAT                                               SWD0148
C                                                                       SWD0149
C              DESIGN CONSTRAINTS FOR FRUSTUM SECTION ARE WRITTEN OUT.  SWD0150
      WRITE (6,308)                                                     SWD0151
      WRITE (6,96) TMPMAX                                               SWD0152
      WRITE (6,164) TCONTH                                              SWD0153
C                                                                       SWD0154
```

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C              HEADINGS FOR SUMMARY REPORT ARE WRITTEN OUT.                     SWD0155
      WRITE (6,309)                                                             SWD0156
      WRITE (6,310)                                                             SWD0157
      WRITE (6,311)                                                             SWD0158
      WRITE (6,312)                                                             SWD0159
      WRITE (6,607)                                                             SWD0160
C              CONVERT ANGLE OF ATTACK FROM DEGREES TO RADIANS.                 SWD0161
      ALPHA     = 0.0174532925 * ALPHA                                          SWD0162
C              CHECK TO DETERMINE IF PRESSURE PROFILE DATA HAS BEEN             SWD0163
C          INPUT.                                                               SWD0164
      IF (LPRES .GT. 0) GO TO 398                                               SWD0165
C              SINCE PRESSURE DATA WAS NOT INPUT, PRESSURE PROFILE              SWD0166
C          DATA IS COMPUTED IN SUBROUTINE AERO.                                 SWD0167
      ALPR      = ALTOT                                                         SWD0168
      LTMAX     = 2*NFMAX                                                       SWD0169
      LT        = LTMAX + 1                                                     SWD0170
      DO 70 NF = 1, NFMAX                                                       SWD0171
      CALL AERO                                                                 SWD0172
      LT        = LT - 1                                                        SWD0173
      CPO(LT)   = CPOO                                                          SWD0174
      CPA(LT)   = CPAA                                                          SWD0175
      XOD(LT)   = ALPR/DBAS                                                     SWD0176
      ALPR      = ALPR - ALF(NF)                                                SWD0177
      LT        = LT - 1                                                        SWD0178
      CPO(LT)   = CPOO                                                          SWD0179
      CPA(LT)   = CPAA                                                          SWD0180
      XOD(LT)   = ALPR/DBAS                                                     SWD0181
   70 CONTINUE                                                                  SWD0182
      GO TO 437                                                                 SWD0183
  398 CONTINUE                                                                  SWD0184
C              PRESSURE PROFILE DATA WAS INPUT. THE TYPE OF DATA IS             SWD0185
C          INDICATED BY LPRES.                                                  SWD0186
      GO TO (437,438,440) ,LPRES                                                SWD0187
  438 CONTINUE                                                                  SWD0188
C              SLOPE OF THE NORMAL FORCE COEFFICIENT CURVE HAS BEEN             SWD0189
C          INPUT. THESE VALUES ARE CONVERTED TO THE MAXIMUM CHANGE              SWD0190
C          CAUSED IN THE LOCAL PRESSURE COEFFICIENT BY THE SPECIFIED            SWD0191
C          ANGLE-OF-ATTACK.                                                     SWD0192
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      DO 439 LT = 1.LTMAX                                                SWD0193
      XN         = XOD(LT)*DBAS                                          SWD0194
      CALL DIAM (XN.DLOC)                                                SWD0195
      DOD        = DLOC/DBAS                                             SWD0196
  439 CPA(LT)    = 0.5*ALPHA*CPA(LT)/DOD                                 SWD0197
      GO TO 437                                                          SWD0198
  440 CONTINUE                                                           SWD0199
C              THE CHANGE IN SURFACE PRESSURE COEFFICIENT PER RADIAN     SWD0200
C         ANGLE-OF-ATTACK HAS BEEN INPUT. THESE VALUES ARE CONVERTED     SWD0201
C         TO THE MAXIMUM CHANGE CAUSED IN THE LOCAL PRESSURE             SWD0202
C         COEFFICIENT BY THE SPECIFIED ANGLE-OF-ATTACK.                  SWD0203
      DO 441 LT = 1.LTMAX                                                SWD0204
  441 CPA(LT)    = ALPHA*CPA(LT)                                         SWD0205
  437 CONTINUE                                                           SWD0206
C              AT THIS POINT THE PRESSURE PROFILE DATA AT SPECIFIED      SWD0207
C         DIAMETER RATIOS IS IN THE FORM OF SURFACE PRESSURE             SWD0208
C         COEFFICIENT AT ZERO ANGLE-OF-ATTACK AND THE MAXIMUM CHANGE     SWD0209
C         IN PRESSURE COEFFICIENT DUE TO ANGLE-OF-ATTACK.                SWD0210
C                                                                        SWD0211
C              PARAMETERS USED IN DESIGN OF THE ENTIRE FAIRING ARE       SWD0212
C         INITIALIZED.                                                   SWD0213
      SUMAL      = 0.                                                    SWD0214
      VGROSS     = 0.0                                                   SWD0215
      I          = 0                                                     SWD0216
      WTOT       = 0.                                                    SWD0217
      VTOT       = 0.                                                    SWD0218
      DBASE      = DBAS                                                  SWD0219
      LPFL       = 1                                                     SWD0220
      LTRIG      = -1                                                    SWD0221
C              DO-LOOP WHICH DESIGNS THE FRUSTUMS IS INITIALIZED.        SWD0222
C                                                                        SWD0223
      DO 129  NF = 1.NFMAX                                               SWD0224
C              CONSTANTS ARE EVALUATED AND PARAMETERS ARE INITIALIZED    SWD0225
C         FOR THE FRUSTUM BEING DESIGNED.                                SWD0226
      THETA      = 0.0174532925*THTA(NF)                                 SWD0227
      CTH        = COS(THETA)                                            SWD0228
      STH        = SIN(THETA)                                            SWD0229
      C1         = C8 / (0.3 * CTH)                                      SWD0230
      C2         = 2.*STH/CTH                                            SWD0231
```

```
      C3          = 0.3/CTH                                             SWD0232
      C5          = PI / CTH                                            SWD0233
      C6          = (0.25/CTH**2)*(DBASE/(5.51*E*C2))**1.33333          SWD0234
      C7          = STH/CTH                                             SWD0235
      DMIN        = DMN(NF)                                             SWD0236
      NBAY        = 0                                                   SWD0237
      ALCONE      = ALF(NF)                                             SWD0238
      ALB         = ELMIN(NF)                                           SWD0239
      TMINC       = TMNC(NF)                                            SWD0240
      WCONE       = 0.                                                  SWD0241
      SLOPT       = 0.                                                  SWD0242
      VUSE        = 0.                                                  SWD0243
C           IDENTIFY CONE BASE DIAMETER AS BASE DIAMETER OF BOTTOM      SWD0244
C       SEGMENT.                                                        SWD0245
      DSUBB       = DBASE                                               SWD0246
C           IF THE TOP FRUSTUM IS BEING DESIGNED. REQUIRED THERMAL      SWD0247
C       THICKNESS AND MINIMUM ALLOWABLE THICKNESS ARE COMPARED. THE     SWD0248
C       GREATER OF THE TWO IS USED AS MINIMUM ALLOWABLE THICKNESS       SWD0249
C       FOR THE TOP FRUSTUM.                                            SWD0250
      IF (NFMAX .GT. NF) GO TO 101                                      SWD0251
      IF (TCONTH .GT. TMINC) TMINC = TCONTH                             SWD0252
C           DESIGN OF THE INDIVIDUAL BAY BEGINS AT THIS POINT.          SWD0253
  101 CONTINUE                                                          SWD0254
      J           = 2                                                   SWD0255
      I           = I + 1                                               SWD0256
      IF (I .GT. 400) GO TO 98                                          SWD0257
C           THE REMAINING LENGTH OF THE FRUSTUM IS COMPUTED.            SWD0258
      ALMX2       = ALF(NF)-SLOPT                                       SWD0259
      IF(( 2.*ALB) . GT . ALMX2)  ALB = ALMX2                           SWD0260
C           LINE LOADS AND SHEAR LOADS AT THE BASE OF THE BAY ARE       SWD0261
C       COMPUTED IN SUBROUTINE LOAD. THEN REINDETIFIED AND STORED       SWD0262
C       FOR OUTPUT PURPOSES.                                            SWD0263
      CALL LOAD                                                         SWD0264
      ENFIMN(I) = ANFIMN                                                SWD0265
      ENFIMX(I) = ANFIMX                                                SWD0266
      FZ(I)       = FSUBZ                                               SWD0267
C           MAXIMUM DESIGN PRESSURES ALONG THE LENGTH OF THE BAY        SWD0268
C       ARE COMPUTED ON BOTH THE WINDWARD AND LEEWARD SIDES.            SWD0269
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      CALL PRESUR                                                       SWD0270
      LPFL       = 2                                                    SWD0271
C                                                                       SWD0272
C              MINIMUM MECHANICAL PROPERTIES OF HONEYCOMB MATERIALS ARE SWD0273
C          LISTED.                                                      SWD0274
      G          = E /(2.0 *(1.0 +AMU))                                 SWD0275
      GFACE      = EFACE / (2.*(1.+AMU))                                SWD0276
C                 CORE MATERIAL IS 2024-T4 ALUMINUM                     SWD0277
      CTA        = 40000.                                               SWD0278
      CCA        = 40000.                                               SWD0279
      CSA        = 23000.                                               SWD0280
      ECORE      = E                                                    SWD0281
      GCORE      = ECORE / (2.*(1.+AMU))                                SWD0282
C              CALCULATE SKIN THICKNESS REQUIRED TO CARRY THE           SWD0283
C          MERIDIANAL COMPRESSIVE LOAD PER INCH                         SWD0284
      TKMCL      = ANFIMX / FCA                                         SWD0285
C              CALCULATE SKIN THICKNESS REQUIRED FOR THE                SWD0286
C         CIRCUMFERENTIAL LOAD PER INCH                                 SWD0287
      TKCIL      = PDESMX * DSUBB / (2.0 * FCA * CTH)                   SWD0288
C              CALCULATE SKIN THICKNESS REQUIRED FOR SHEAR STRESS       SWD0289
C           DUE TO AERODYNAMIC LIFT                                     SWD0290
      TKSAL      = 2.0 * FZ(I)/ (PI * DSUBB * FSA)                      SWD0291
C              CALCULATE SKIN THICKNESS REQUIRED FOR HOOP STRESS. IT    SWD0292
C          IS ASSUMED THE PRESSURE DIFFERENTIAL WILL NOT EXCEED 4 PSI   SWD0293
      PDIFF      = 4.0                                                  SWD0294
C              CALCULATE EQUIVALENT PANEL RADIUS OF CURVATURE.          SWD0295
      ENSUBR     = 0.6 * (1.7 - 2.0 * ALB   * C7 / DSUBB)               SWD0296
      APRC       = 0.5 * DSUBB * ENSUBR / CTH                           SWD0297
      TKHOOP     = FS * PDIFF * APRC / FTA                              SWD0298
C              SELECT LARGEST VALUE OF SKIN THICKNESS. USE HALF THIS    SWD0299
C          VALUE AS FACE THICKNESS.                                     SWD0300
      TF         = 0.5 * AMAX1(TKMCL, TKCIL, TKSAL, TKHOOP)             SWD0301
C              NOW COMPARE THE THEORETICAL FACE THICKNESS WITH THE      SWD0302
C          MINIMUM ALLOWABLE FACE THICKNESS.                            SWD0303
C                 THE FACE THICKNESS MUST BE INCREASED TO MINIMUM ALLOWASWD0304
C         FACE THICKNESS.                                               SWD0305
      IF (TF .LT. TMINC)  TF = TMINC                                    SWD0306
C               NEXT, STANDARD GAUGES ARE TO BE USED IF KTFSTD IS 1.    SWD0307
      IF (KTFSTD .NE. 1) GO TO 239                                      SWD0308
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      JF        = 1                                                     SWD0309
  237 IF (TSTD(JF) .GT. TF)  GO TO 238                                  SWD0310
      IF (JF .GT. 30) GO TO 98                                          SWD0311
  234 JF        = JF + 1                                                SWD0312
      GO TO 237                                                         SWD0313
  238 TF        = TSTD(JF)                                              SWD0314
  239 CONTINUE                                                          SWD0315
      FFAX(I)   = ANFIMX /(2. * TF)                                     SWD0316
      FFC(I)    = (PDESMX * DSUBB)/(4. * TF * CTH)                      SWD0317
C                                                                       SWD0318
C               CALCULATE CELL SIZE.                                    SWD0319
      CELLWD    = SQRT((2. * TF**2*E)/(C8*AMAX1(FFAX(I),FFC(I))))       SWD0320
      NCELL     = CELLWD * 16.                                          SWD0321
      CELSIZ(I) = FLOAT(NCELL) * .0625                                  SWD0322
      IF (CELSIZ(I) .GT. 1.)  CELSIZ(I) = 1.                            SWD0323
C              THE CORE USED IN THIS ANALYSIS IS ASSUMED TO HAVE A HEXAGSWD0324
C           ONAL SHAPE. INITIALIZE DIMENSIONAL DATA.                    SWD0325
      BETADG    = 60.0                                                  SWD0326
      BETA      = 0.017453 * BETADG                                     SWD0327
      SBETA     = SIN(BETA)                                             SWD0328
      W         = 0.5 * (A + B)                                         SWD0333
      R         = B/A                                                   SWD0332
      B         = A                                                     SWD0331
      A         = CELSIZ /(2.0 * SBETA)                                 SWD0330
      CBETA     = COS(BETA)                                             SWD0329
C               SET FIRST TRIAL RIBBON THICKNESS                        SWD0334
      TRIBN     = AMAX1(TRBMIN(NF), .0005)                              SWD0335
C               IF KTRSTD IS 1, STANDARD RIBBON GAUGES ARE TO BE USED.  SWD0336
      IF (KTRSTD .NE. 1) GO TO 224                                      SWD0337
      JG        = 1                                                     SWD0338
  222 IF (TRBSTD(JG) .GE. TRIBN) GO TO 223                              SWD0339
      JG        = JG + 1                                                SWD0340
      IF (JG .GT. 8) GO TO 98                                           SWD0341
      GO TO 222                                                         SWD0342
  223 TRIBN     = TRBSTD(JG)                                            SWD0343
  224 CONTINUE                                                          SWD0344
      XL=ALB                                                            SWD0345
C         ASSUME THE RIBBON DIRECTION I PARALLEL TO THE VEHICLE         SWD0346
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  252 CONTINUE                                                          SWD0386
  253 CONTINUE                                                          SWD0387
      IF ( H/W .GT. 5.0) GO TO 227                                      SWD0388
      Y           = (9.3 / (H/W)) - (2.1 / (H/W)**2)                    SWD0389
      IF ( H/W .LT. 0.5)  Y = 11.0                                      SWD0390
  227 CONTINUE                                                          SWD0391
      G1          = GC1 * (1.0 + .01 * Y)                               SWD0392
      G2          = GC2 * (1.0 + .01 * Y)                               SWD0393
      P           = PDESMN                                              SWD0394
C                THIS BAY HAS PASSED A PANEL STABILITY TEST ON THE      SWD0395
C          WINDWARD SIDE.  NEXT, CHECK LEEWARD SIDE.                    SWD0396
      CALL INSTBL                                                       SWD0397
      IF (KG .EQ. 1) GO TO 98                                           SWD0398
      IF (CRG .GE. ANFIMX) GO TO 254                                    SWD0399
      IF ( H .GT. 2.0) GO TO 232                                        SWD0400
      H           = H + .125                                            SWD0401
      GO TO 253                                                         SWD0402
  232 CONTINUE                                                          SWD0403
      IF (KTFSTD .EQ. 1) GO TO 234                                      SWD0404
      TF          = 1.1 * TF                                            SWD0405
      GO TO 239                                                         SWD0406
  254 CONTINUE                                                          SWD0407
C                THE DESIGN HAS PASSED THE PANEL STABILITY TEST. THE    SWD0408
C          PANEL IS NOW CHECKED FOR WRINKLING, USING THE ANALYSIS BY    SWD0409
C          BURNS IN LOCKHEED TEHNICAL REPORT 6-62-64-17, DEC. 1964,     SWD0410
C          PAGES 3-3 AND 3-4.                                           SWD0411
  241 AFACT       = (2.496 * TF /H ) * ((EFACE * AMIN1(A,B)) /          SWD0412
     1(GCORE * TRIBN))**0.33333                                         SWD0413
      IF (AFACT .LT. 1.) GO TO 243                                      SWD0414
C                THIN CORE                                              SWD0415
      AFWRIN      = 0.93 * EFACE * ((GCORE * TRIBN * TF) /              SWD0416
     1     (EFACE * AMIN1(A,B) * H ))**0.5                              SWD0417
      GO TO 244                                                         SWD0418
C                THICK CORE                                             SWD0419
  243 AFWRIN    = 0.83* EFACE * ((GCORE * TRIBN)/(EFACE * AMIN1(A,B)))  SWD0420
     1**0.66667                                                         SWD0421
  244 CONTINUE                                                          SWD0422
C                COMPARE WRINKLING ALLOWABLE AND APPLIED STRESSES.  IF  SWD0423
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C          WRINKLING IS PREDICTED, INCREASE RIBBON THICKNESS.              SWD0424
      IF (AFWRIN - AMAX1(FFAX(I),FFC(I)))246, 247, 247                      SWD0425
  246 CONTINUE                                                             SWD0426
C                DESIGN IS INADEQUATE. INCREASE RIBBON THICKNESS. RETEST.  SWD0427
      IF (KTRSTD .NE. 1) GO TO 271                                         SWD0428
      IF (JG .GT. 8) GO TO 98                                              SWD0429
      JG          = JG + 1                                                 SWD0430
      TRIBN       = TRBSTD(JG)                                             SWD0431
      GO TO 241                                                            SWD0432
  271 TRIBN       = TRIBN + .00001                                         SWD0433
      GO TO 241                                                            SWD0434
  247 CONTINUE                                                             SWD0435
C                PANEL DESIGN FOR THIS BAY IS NOW STRUCTURALLY ADEQUATE.   SWD0436
                                                                           SWD0437
C                COMPUTE BAY DIMENSIONS NEEDED IN WEIGHT CALCULATIONS.     SWD0438
C            DSUBB IS OUTSIDE BASE DIAMETER, D(I) IS THE UPPER OUTSIDE     SWD0439
C            DIAMETER, DBNSD IS INSIDE BASE DIAMETER AND DINSD IS UPPER    SWD0440
C            INSIDE DIAMTER.                                               SWD0441
      D(I)        = DSUBB    -(C2)*(ALB)                                   SWD0442
      DINSD       = D(I) - 2. * ((H - TF) / CTH)                           SWD0443
      DBNSD       = DSUBB - 2. * ((H - TF) / CTH)                          SWD0444
C                                                                          SWD0445
C                CALCULATE WEIGHT OF INNER FACE.                           SWD0446
      WTINFC      = (ALB * C5) * ( DBNSD + DINSD ) * TF *                  SWD0447
     1 ( RHO / 2. )                                                        SWD0448
C                 CALCULATE WEIGHT OF OUTER FACE                           SWD0449
      WTOTFC      = ( ALB * C5 ) * ( DSUBB + D(I) ) * TF *                 SWD0450
     1 ( RHO / 2. )                                                        SWD0451
      WFACE(I) = WTINFC + WTOTFC                                           SWD0452
C                                                                          SWD0453
C                CALCULATE CORE WEIGHT                                     SWD0454
      VCORE       = ( PI/2. ) * ( DBNSD + DINSD ) * ( ALB   / CTH )  *     SWD0455
     1  (H - TF)                                                           SWD0456
      ROCORE      = (TRIBN * RHO * (1. +R))/(A * SBETA * (R + CBETA))      SWD0457
      WTCORE(I) = VCORE * ROCORE                                           SWD0458
C                                                                          SWD0459
C                MAKE AN ALLOWANCE FOR THE WEIGHT OF BONDING MATERIAL      SWD0460
C           ASSUME ONE OUNCE PER SQ. FT. PER FACE                          SWD0461
      WBOND       = ( PI/2. ) * ( DBNSD + DINSD ) * (ALB   / CTH )         SWD0462
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     1  * 0.125 / 144.0                                                 SWD0463
C             MAKE AN ALLOWANCE FOR CIRCUMFERENTIAL SPLICE WEIGHT.      SWD0464
      WSPLCE(I) = PI * (D(I) + DINSD) * (TF * (3.5 + H + TF)) * RHO     SWD0465
C             THE REQUIRED MOMENT OF INERTIA OF A STIFFENING RING IS    SWD0466
C           CALCULATED.                                                 SWD0467
      CALL IREQ                                                         SWD0468
C             STIFFENING RING FOR THE BAY IS DESIGNED USING STANDARD    SWD0469
C          SKIN GAUGES AND INPUT NORMALIZED RING CROSS-SECTION.         SWD0470
      K         = 0                                                     SWD0471
  256 K         = K + 1                                                 SWD0472
      IF (K .GT. 29) GO TO 98                                           SWD0473
      CALL RING                                                         SWD0474
C          CHECK RING TO SEE IF MOMENT OF INERTIA IS ADEQUATE. AND      SWD0475
C          IF OUTSTANDING FLANGE WILL BUCKLE.                           SWD0476
      CALL RSTRES                                                       SWD0477
      IF (FCFB .LT. FRING) GO TO 256                                    SWD0478
      IF (AIRING .GT. AIREQ) GO TO 257                                  SWD0479
      GO TO 256                                                         SWD0480
  257 CONTINUE                                                          SWD0481
      WRING(I)  = AST * (DINSD - 2. * DD / CTH) * PI * RHO              SWD0482
      WSEG(I)   = WFACE(I) + WTCORE(I) + WBOND + WRING(I) + WSPLCE(I)   SWD0483
      VSEG(I)   = (PI*ALB/12.)*(DSUBB**2 +DSUBB*D(I) + D(I)**2)         SWD0484
      WTDEX(I)  = WSEG(I) * 1728. / VSEG(I)                             SWD0485
      ALOPT(I)  = ALB                                                   SWD0486
      TFACE(I)  = TF                                                    SWD0487
      TRING(I)  = TSTD(K)                                               SWD0488
      TCORE(I)  = H                                                     SWD0489
      SLOPT     = SLOPT   + ALB                                         SWD0490
      SUMAL     = SUMAL + ALOPT(I)                                      SWD0491
      TRBN(I)   = TRIBN                                                 SWD0492
      FFS(I)    = FZ(I) / (PI * DSUBB * TF)                             SWD0493
      FFB(I)    = FS * PDIFF * APRC / (2. * TF)                         SWD0494
      FFWR(I)   = AFWRIN                                                SWD0495
      FFDMP(I)  = (2. * TF**2 * EFACE) / (C8 * CELSIZ(I)**2)            SWD0496
C                                                                       SWD0497
C            BAY WEIGHT IS ADDED TO PREVIOUS BAY WEIGHTS FOR THIS       SWD0498
C         FRUSTUM.                                                      SWD0499
      WCONE     = WCONE + WSEG(I)                                       SWD0500
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C             BAY VOLUME WHICH IS USEFUL FOR PAYLOAD IS CALCULATED     SWD0501
C        NEXT. TWO RING HEIGHTS AND TWO PERCENT OF THE BASE DIAMETER   SWD0502
C        ARE SUBTRACTED FROM THE DIAMETERS OF THE CONICAL FRUSTUM IN   SWD0503
C        ORDER TO DETERMINE THIS USEFUL VOLUME.                        SWD0504
C             USEFUL BAY VOLUME IS ADDED TO THE SUM OF PREVIOUS BAY    SWD0505
C        VOLUME FOR THIS FRUSTUM.                                      SWD0506
      DUSE1      = DSUBB - 2. * AOT * TRING(I) - .02 * DBASE           SWD0507
      DUSE2      = D(I)  - 2. * AOT * TRING(I) - .02 * DBASE           SWD0508
      VUSE       = VUSE + .2617994 * ALOPT(I)*(DUSE1**2 + DUSE1*DUSE2  SWD0509
     1                            DUSE2**2)/1728.                      SWD0510
C                                                                      SWD0511
C             BASE DIAMETER OF THE NEXT BAY IS SET EQUAL TO THE TOP    SWD0512
C        DIAMETER OF THE CURRENT BAY.                                  SWD0513
C                                                                      SWD0514
      DSUBB      = D(I)                                                SWD0515
C                                                                      SWD0516
C             THE NUMBER OF BAYS IN THIS FRUSTUM ARE COUNTED.          SWD0517
C                                                                      SWD0518
      NBAY       = NBAY + 1                                            SWD0519
C             A CHECK IS MADE TO DETERMINE IF THIS IS THE LAST BAY     SWD0520
C        OF THE FRUSTUM.                                               SWD0521
C                                                                      SWD0522
      IF( ALB. GE. ALMX2) GO TO 362                                    SWD0523
C              THE PROGRAM GOES ON TO DESIGN THE NEXT BAY.             SWD0524
      GO TO 101                                                        SWD0525
  362 CONTINUE                                                         SWD0526
C             THE LAST BAY OF THE FRUSTUM HAS BEEN DESIGNED. WEIGHT    SWD0527
C        OF THE TOP RING OF THE FRUSTUM IS INCREASED TO ALLOW FOR      SWD0528
C        ATTACHMENT PROVISIONS.                                        SWD0529
      WRING(I)   = 2. * WRING(I)                                       SWD0530
C             DATA ON THIS FRUSTUM ARE WRITTEN OUT FOR THE SUMMARY     SWD0531
C        REPORT.                                                       SWD0532
      WRITE (6,313) NF,DMX,DMIN,THTA(NF),                              SWD0533
     1ALCONE,ELMIN(NF),TMNC(NF),NBAY,VUSE,WCONE                        SWD0534
      DMX        = DMN(NF)                                             SWD0535
C             GROSS VOLUME OF THE FRUSTUM IS CALCULATED AND ADDED TO   SWD0536
C        THE GROSS VOLUME OF PREVIOUS FRUSTUMS.                        SWD0537
      VGROS      = 0.2617994*ALCONE*(DBASE**2+DBASE*DMIN+DMIN**2)      SWD0538
      VGROSS     = VGROSS + VGROS                                      SWD0539
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C                                                                       SWD0540
C             USEFUL VOLUME OF THIS FRUSTUM IS ADDED TO USEFUL VOLUME   SWD0541
C         OF PREVIOUS FRUSTUMS.                                         SWD0542
      VTOT        = VTOT + VUSE                                         SWD0543
C             WEIGHT OF THIS FRUSTUM IS ADDED TO WEIGHT OF PREVIOUS     SWD0544
C         FRUSTUMS.                                                     SWD0545
      WTOT        = WTOT + WCONE                                        SWD0546
C             BASE DIAMETER OF NEXT FRUSTUM IS SET EQUAL TO TOP         SWD0547
C         DIAMETER OF THIS FRUSTUM.                                     SWD0548
      DBASE       = DMIN                                                SWD0549
C             TOTAL NUMBER OF BAYS DESIGNED UP TO THIS POINT IS STORED.SWD0550
      IMX(NF)     = I                                                   SWD0551
C             PROGRAM GOES ON TO NEXT FRUSTUM.                          SWD0552
  129 CONTINUE                                                          SWD0553
      GO TO 326                                                         SWD0554
   98 CONTINUE                                                          SWD0555
C             CONTROL HAS BEEN TRANSFERRED TO THIS POINT BECAUSE THE    SWD0556
C         INDEX OF ONE OF THE SUBSCRIPTED VARIABLES HAS EXCEEDED THE    SWD0557
C         NUMBER PERMITTED BY THE DIMENSION STATEMENT.                  SWD0558
      WRITE (6,120)                                                     SWD0559
      WRITE (6,121)                                                     SWD0560
      WRITE (6,614) I,J,JF,JG,K                                         SWD0561
      IF(KG .EQ. 1) WRITE(6,201)GBAR                                    SWD0562
      WRITE (6, 501)                                                    SWD0563
  326 CONTINUE                                                          SWD0564
      IMAX = I                                                          SWD0565
      WRITE(6,314)                                                      SWD0566
      WRITE (6,315) ALTOT,IMAX,VTOT,WTOT                                SWD0567
      WRITE (6,606)                                                     SWD0568
C             SURFACE AREA OF THE NOSE CAP IS COMPUTED                  SWD0569
      SCAP        = 2. * PI * RCAP * ALCAP                              SWD0570
C             NOSE CAP SKIN THICKNESS REQUIRED FOR STRUCTURAL INTEG-    SWD0571
C         RITY IS DETERMINED AND COMPARED WITH THICKNESS PREVIOUSLY     SWD0572
C         CALCULATED TO MEET THERMAL REQUIREMENTS. THE LARGER OF THE    SWD0573
C         TWO THICKNESSES IS USED TO COMPUTE CAP WEIGHT.                SWD0574
      CALL TNOSST                                                       SWD0575
      TCAP          = AMAX1(TCAPST, TCAPTH)                             SWD0576
C             NOSE CAP WEIGHT IS COMPUTED.                              SWD0577
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      WCAP       = SCAP* RHO * TCAP                                     SWD0578
C             USEFUL VOLUME OF NOSE CAP IS CALCULATED.                  SWD0579
      RUSE       = RCAP - 2. * AOT * TRING(I) - .01 * DBASE             SWD0580
      HUSE       = ALCAP - 2. * AOT * TRING(I) - .01 * DBASE            SWD0581
      VCAP       = 1.0471976*HUSE*HUSE*(3.*RUSE - HUSE)/1728.           SWD0582
C             GROSS VOLUME OF CAP IS COMPUTED AND ADDED TO GROSS        SWD0583
C         VOLUME OF THE FRUSTUMS.                                       SWD0584
      VGROS      = 1.0471976*ALCAP*ALCAP*(3.*RCAP - ALCAP)              SWD0585
      VGROSS     = (VGROSS + VGROS)/ 1728.                              SWD0586
C             USEFUL VOLUME OF CAP IS ADDED TO USEFUL VOLUME OF CONE    SWD0587
C         TO OBTAIN TOTAL USEFUL VOLUME OF FAIRING.                     SWD0588
      VTOT       = VTOT + VCAP                                          SWD0589
C             TOTAL LENGTH OF FAIRING IS OBTAINED BY SUMMING CONE AND   SWD0590
C         CAP LENGTHS.                                                  SWD0591
C             TOTAL FAIRING WEIGHT IS THE SUM OF CAP WEIGHT AND CONE    SWD0592
C         WEIGHT.                                                       SWD0593
      WTOT       = WTOT + WCAP                                          SWD0594
C             DATA REPORT IS WRITTEN OUT.                               SWD0595
      WRITE (6,82)                                                      SWD0596
      WRITE (6,511) PDSPH                                               SWD0597
      WRITE (6,67) TMINN                                                SWD0598
      WRITE (6,96) TMPMAX                                               SWD0599
      WRITE (6,89) TCAPST                                               SWD0600
      WRITE (6,90) TCAPTH                                               SWD0601
      WRITE (6,91) TCAP                                                 SWD0602
      WRITE (6,87) RCAP                                                 SWD0603
      WRITE (6,84) ALCAP                                                SWD0604
      WRITE (6,88) SCAP                                                 SWD0605
      WRITE (6,316) VCAP                                                SWD0606
      WRITE (6,94) WCAP                                                 SWD0607
      WRITE (6,92)                                                      SWD0608
      WRITE (6,85) ALTOT                                                SWD0609
      WRITE (6,86) VTOT                                                 SWD0610
      WRITE (6,329) VGROSS                                              SWD0611
      WRITE (6,95) WTOT                                                 SWD0612
C                                                                       SWD0613
C             IF AN INTEGER WAS READ IN FOR KEY, DETAILED DESIGN        SWD0614
C         INFORMATION IS WRITTEN OUT FOR THE FAIRING.                   SWD0615
      IF (KEY .LT. 1) GO TO 10                                          SWD0616
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  327 CONTINUE                                                          SWD0617
      WRITE (6, 501)                                                    SWD0618
      WRITE (6,606)                                                     SWD0619
      WRITE (6,51)                                                      SWD0620
      WRITE (6, 14)                                                     SWD0621
   14 FORMAT (59X, 10HRING DATA ///)                                    SWD0622
      GO TO ( 1615, 1616, 1617 ), IKIND                                 SWD0623
 1615 WRITE (6,2611)                                                    SWD0624
 2611 FORMAT( 23X,4HTYPE , 61X,  11HANGLE         )                     SWD0625
      GO TO 2625                                                        SWD0626
 1616 WRITE (6,2612)                                                    SWD0627
 2612 FORMAT( 23X, 4HTYPE , 61X, 11HZEE SECTION  )                      SWD0628
      GO TO 2625                                                        SWD0629
 1617 WRITE (6,2613)                                                    SWD0630
 2613 FORMAT(23X, 4HTYPE , 61X, 11HHAT SECTION  )                       SWD0631
 2625 CONTINUE                                                          SWD0632
      WRITE (6,1620) BOT , AOT, COT, FCFB                               SWD0633
 1620 FORMAT( 23X, 12HBASE LEG B/T , 53X, 11HBOT      = F7.2 /,         SWD0634
     1 23X, 15HUPRIGHT LEG B/T  ,  50X,  11HAOT      = F7.2 /,          SWD0635
     2 23X, 19HOUTSTANDING LEG B/T , 46X, 11HCOT      = F7.2 /,         SWD0636
     3 23X, 27HFLANGE BUCKLING STRESS, PSI  , 38X, 11HFCFB     = F7.0//)SWD0637
      WRITE (6, 22)                                                     SWD0638
   22 FORMAT (55X, 18HSANDWICH FACE DATA //)                            SWD0639
      GO TO (671,672,673), MATF                                         SWD0640
  671 WRITE (6,676)                                                     SWD0641
  676 FORMAT (23X, 13HFACE MATERIAL ,36X,24H2024-T4 ALCLAD ALUMINUM )   SWD0642
      GO TO 679                                                         SWD0643
  672 WRITE (6,677)                                                     SWD0644
  677 FORMAT (23X,13HFACE MATERIAL ,42X, 17H2024-T4 ALUMINUM )          SWD0645
      GO TO 679                                                         SWD0646
  673 WRITE (6,678)                                                     SWD0647
  678 FORMAT (23X,13HFACE MATERIAL ,42X, 17H7075-T6 ALUMINUM )          SWD0648
  679 CONTINUE                                                          SWD0649
      WRITE (6,501)                                                     SWD0650
      WRITE (6,167)                                                     SWD0651
      WRITE (6,168)                                                     SWD0652
      WRITE (6,169)                                                     SWD0653
      WRITE (6,607)                                                     SWD0654
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      NF          = 1                                                   SWD0655
      IW          = 1                                                   SWD0656
      I1          = 1                                                   SWD0657
      I2          = 46                                                  SWD0658
  451 CONTINUE                                                          SWD0659
      IF (I2 .GT. IMAX)  I2 = IMAX                                      SWD0660
      DO 453  I = I1, I2                                                SWD0661
      ENFIMN(I) = - ENFIMN(I)                                           SWD0662
      ENFIMX(I) = - ENFIMX(I)                                           SWD0663
      WRITE (6,58) NF, IW, D(I), ALOPT(I), TFACE(I), TRBN(I),  TRING(I),SWD0664
     1 WFACE(I), WTCORE(I), WRING(I), WTDEX(I),TCORE(I), WSEG(I),       SWD0665
     2CELSIZ(I)                                                         SWD0666
      IW          = IW + 1                                              SWD0667
      IF (IMX(NF) .GT. I) GO TO 453                                     SWD0668
      IW          = 1                                                   SWD0669
      NF          = NF + 1                                              SWD0670
  453 CONTINUE                                                          SWD0671
      IF (I2 .GE. IMAX) GO TO 457                                       SWD0672
      I1          = I2 + 1                                              SWD0673
      I2          = I2 + 54                                             SWD0674
      WRITE (6, 501)                                                    SWD0675
      WRITE (6,606)                                                     SWD0676
      GO TO 451                                                         SWD0677
  457 CONTINUE                                                          SWD0678
      WRITE (6, 501)                                                    SWD0679
      WRITE (6,806)                                                     SWD0680
      WRITE (6,807)                                                     SWD0681
      WRITE (6,808)                                                     SWD0682
      WRITE (6,809)                                                     SWD0683
      NF          = 1                                                   SWD0684
      IW          = 1                                                   SWD0685
      I1          = 1                                                   SWD0686
      I2          = 46                                                  SWD0687
  461 CONTINUE                                                          SWD0688
      IF (I2 .GT. IMAX) I2 = IMAX                                       SWD0689
      DO 463  I = I1, I2                                                SWD0690
      WRITE (6,508) NF, IW, ENFIMN(I), ENFIMX(I), FFAX(I), FFC(I),      SWD0691
     1 FFS(I), FFB(I), FFWR(I), FCA, FFDMP(I)                           SWD0692
      IW          = IW + 1                                              SWD0693
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      IF (IMX(NF) .GT. I) GO TO 463                                     SWD0694
      IW          = 1                                                   SWD0695
      NF          = NF + 1                                              SWD0696
  463 CONTINUE                                                          SWD0697
      IF (I2 .GE. IMAX) GO TO 467                                       SWD0698
      I1          = I2 + 1                                              SWD0699
      I2          = I2 + 54                                             SWD0700
      WRITE (6, 501)                                                    SWD0701
      WRITE (6, 606)                                                    SWD0702
      GO TO 461                                                         SWD0703
  467 CONTINUE                                                          SWD0704
C               IF 2 WAS READ IN FOR KEY. DETAILED LOADS INFORMATION    SWD0705
C          IS WRITTEN OUT.                                              SWD0706
      IF (KEY .NE. 2) GO TO 10                                          SWD0707
      WRITE (6, 501)                                                    SWD0708
      WRITE (6,606)                                                     SWD0709
      WRITE (6,612)                                                     SWD0710
      WRITE (6,608)                                                     SWD0711
      WRITE (6,609)                                                     SWD0712
      WRITE (6,610)                                                     SWD0713
      SUMAL       = 0.                                                  SWD0714
      IW          = 1                                                   SWD0715
      NF          = 1                                                   SWD0716
      I1          = 1                                                   SWD0717
      I2          = 46                                                  SWD0718
      THETA       = 0.0174532925*THTA(NF)                               SWD0719
      CTH         = COS(THETA)                                          SWD0720
      STH         = SIN(THETA)                                          SWD0721
      C2          = 2.*STH/CTH                                          SWD0722
      C3          = 0.3/CTH                                             SWD0723
      DSUBB       = DBAS                                                SWD0724
      ALB         = ALOPT(1)                                            SWD0725
      LPFL        = 1                                                   SWD0726
  471 IF (IMAX .LT. I2)  I2 = IMAX                                      SWD0727
      DO 473  I = I1, I2                                                SWD0728
      CALL PRESUR                                                       SWD0729
      LPFL        = 2                                                   SWD0730
      ANFIAX      = 0.5*(ENFIMN(I) + ENFIMX(I))/FS                      SWD0731
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      ANFIB       = ANFIAX - ENFIMN(I)/FS                                 SWD0732
      AXLOAD      =-ANFIAX*DSUBB*.94248/C3                                SWD0733
      BEND        =-0.23562*ANFIB*DSUBB**2/C3                             SWD0734
      WRITE (6,611) NF,IW,DSUBB,D(I),ALOPT(I),SUMAL,PDESMX,PDESMN,        SWD0735
     1  AXLOAD,FZ(I),BEND                                                 SWD0736
      IW          = IW + 1                                                SWD0737
      SUMAL       = SUMAL + ALOPT(I)                                      SWD0738
      DSUBB       = D(I)                                                  SWD0739
      ALB         = ALOPT(I+1)                                            SWD0740
      IF (IMX(NF) .GT. I) GO TO 473                                       SWD0741
      IW          = 1                                                     SWD0742
      NF          = NF + 1                                                SWD0743
      THETA       = 0.0174532925*THTA(NF)                                 SWD0744
      CTH         = COS(THETA)                                            SWD0745
      STH         = SIN(THETA)                                            SWD0746
      C2          = 2.*STH/CTH                                            SWD0747
      C3          = 0.3/CTH                                               SWD0748
  473 CONTINUE                                                            SWD0749
      IF (IMAX .LE. I2) GO TO 477                                         SWD0750
      I1          = I2 + 1                                                SWD0751
      I2          = I2 + 54                                               SWD0752
      WRITE (6, 501)                                                      SWD0753
      WRITE (6,606)                                                       SWD0754
      GO TO 471                                                           SWD0755
  477 CONTINUE                                                            SWD0756
      WRITE (6,613) DSUBB,SUMAL,AXLDCP,FSBZCP,BNDCAP                      SWD0757
      GO TO 10                                                            SWD0758
   51 FORMAT (48X,36H DESIGN DETAILS OF CONICAL FRUSTUMS   ///)           SWD0759
   54 FORMAT (54X,24H    FAIRING GEOMETRY     //)                         SWD0760
   58 FORMAT(1X,I2,1H-,I2,4X,F6.1,F8.1,F10.4,F9.5,F9.4,F11.2,             SWD0761
     1 F11.2, F9.2, F11.4, F11.4, F11.1, F10.4)                           SWD0762
   63 FORMAT (48X,33H   CONSTRAINTS ON FAIRING DESIGN     //)             SWD0763
   64 FORMAT (23X,77H MINIMUM BAY LENGTH CONSIDERED,IN.                   SWD0764
     1             ALMIN  = ,F8.3)                                        SWD0765
   66 FORMAT (23X,77H MINIMUM ALLOWABLE THICKNESS OF CONE SKIN, IN.       SWD0766
     1             TMINC  = ,F8.4)                                        SWD0767
   67 FORMAT (23X,77H MINIMUM ALLOWABLE THICKNESS OF NOSE CAP SKIN, IN.   SWD0768
     1             TMINN  = ,F8.4    )                                    SWD0769
   68 FORMAT (48X,36H     SPECIFIED DESIGN PRESSURES       //)            SWD0770
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   69 FORMAT (23X,77H DESIGN PRESSURE ON WNDWRD SIDE OF CONE, (SAFETY FASWD0771
     1CTOR=1.4), PSI    PDESMX = ,F8.3)                                 SWD0772
   71 FORMAT  (45X,42H AERODYNAMIC DATA USED IN COMPUTING LOADS  //)    SWD0773
   72 FORMAT (23X,77H DYNAMIC PRESSURE, LBS./SQ. FT.                    SWD0774
     1                  QBAR   = ,F8.2)                                 SWD0775
   73 FORMAT (23X,77H MACH NUMBER AT DESIGN DYNAMIC PRESSURE            SWD0776
     1                  AMACH  = ,F8.3)                                 SWD0777
   74 FORMAT (23X,77H ANGLE OF ATTACK AT DESIGN DYNAMIC PRESSURE, DEGREESWD0778
     1S                 ALPHA  = ,F8.2 )                                SWD0779
   75 FORMAT (48X, 36H   COMPUTED AERODYNAMIC LOADS DATA     //)        SWD0780
   76 FORMAT (23X,77H PRESSURE COEFFICIENT ON CONE AT ZERO ANGLE OF ATTASWD0781
     1CK                CPO    = ,F8.4)                                 SWD0782
   82 FORMAT (57X,16H NOSE CAP DESIGN // )                              SWD0783
   83 FORMAT (23X,77H LENGTH OF CONICAL SECTION, IN.                    SWD0784
     1                  ALCONE = ,F8.2)                                 SWD0785
   84 FORMAT (23X,77H LENGTH OF NOSE CAP, IN.                           SWD0786
     1                  ALCAP  = ,F8.2)                                 SWD0787
   85 FORMAT (23X,77H TOTAL LENGTH OF FAIRING, IN.                      SWD0788
     1                  ALTOT  = ,F8.2    )                             SWD0789
   86 FORMAT (23X,77H USEFUL VOLUME OF FAIRING, CU. FEET                SWD0790
     1                  VTOT   = ,F8.2         )                        SWD0791
   87 FORMAT (23X,77H NOSE CAP RADIUS, IN.                              SWD0792
     1                  RCAP   = ,F8.3 )                                SWD0793
   88 FORMAT (23X,77H NOSE CAP SURFACE AREA, SQ. IN.                    SWD0794
     1                  SCAP   = ,F8.2 )                                SWD0795
   89 FORMAT (23X,77H NOSE CAP SKIN THICKNESS REQUIRED FOR STRUCTURAL INSWD0796
     1TEGRITY, IN.      TCAPST = ,F8.3 )                                SWD0797
   90 FORMAT (23X,77H NOSE CAP SKIN THICKNESS REQUIRED FOR THERMAL REASOSWD0798
     1NS, IN.           TCAPTH = ,F8.3 )                                SWD0799
   91 FORMAT (23X,77H NOSE CAP SKIN THICKNESS USED TO CALCULATE WEIGHT, SWD0800
     1IN.               TCAP   = ,F8.3       )                          SWD0801
   92 FORMAT (44X,43H TOTAL LENGTH, VOLUME AND WEIGHT OF FAIRING // )   SWD0802
   93 FORMAT (23X,77H WEIGHT OF CONICAL SECTION, LBS.                   SWD0803
     1                  WCONE  = ,F8.2 )                                SWD0804
   94 FORMAT (23X,77H WEIGHT OF NOSE CAP, LBS.                          SWD0805
     1                  WCAP   = ,F8.2 ///)                             SWD0806
   95 FORMAT (23X,77H TOTAL WEIGHT OF FAIRING, LBS.                     SWD0807
     1                  WTOT   = ,F8.2 )                                SWD0808
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 96 FORMAT (23X,77H MAXIMUM ALLOWABLE TEMPERATURE OF SKIN, DEG. F.     SWD0809
   1                   TMPMAX = ,F8.1     )                            SWD0810
120 FORMAT (23X,80H DESIGN OF THE CONICAL SECTION OF THE FAIRING HAS NSWD0811
   1OT BEEN COMPLETED. THE I, J,    )                                  SWD0812
121 FORMAT (23X,80H OR K INDEX HAS EXCEEDED THE MAXIMUM PERMITTED BY TSWD0813
   1HE DIMENSION STATEMENT.         )                                  SWD0814
131 FORMAT (5F12.8, 2I6)                                               SWD0815
132 FORMAT (2I6,4F12.8,I12)                                            SWD0816
162 FORMAT (23X,77H AMBIENT PRESSURE AT DESIGN CONDITIONS, PSI         SWD0817
   1                   PSTAT  = ,F8.3 ///)                             SWD0818
163 FORMAT (23X,77H INTERNAL-TO-AMBIENT PRESSURE DIFFERENCE AT DESIGN SWD0819
   1CONDITIONS,PSI     DELTAP = ,F8.3     )                            SWD0820
164 FORMAT (23X,77H CONICAL SECTION SKIN THICKNESS REQUIRED FOR THERMASWD0821
   1L REASONS, IN.     TCONTH = ,F8.4    ///)                          SWD0822
165 FORMAT (77X, 9H WINDWARD,27X,8H LEEWARD)                           SWD0823
167 FORMAT (128H FRUSTUM    SHELL      BAY      FACE     RIBBON    RING  SWD0824
   1  TOTAL       TOTAL     RING      WEIGHT        SHELL         TOTAL  SWD0825
   2  CELL   )                                                         SWD0826
168 FORMAT (128H  -BAY        O.D.    LENGTH   GAUGE    GAUGE     GAUGE  SWD0827
   1  FACE WT.  CORE WT.     WT.       INDEX       THICKNESS    BAY WT.  SWD0828
   2 WIDTH   )                                                         SWD0829
169 FORMAT (128H   NO.        (IN)     (IN)     (IN)      (IN)      (IN)  SWD0830
   1   (LB)       (LB)      (LB)    (LB/CU FT)      (IN)         (LB)  SWD0831
   2  (IN)   )                                                         SWD0832
170 FORMAT (23X,77H DESIGN PRESSURE ON LEEWRD SIDE OF CONE, (SAFETY FASWD0833
   1CTOR=1.4), PSI    PDESMN = ,F8.3)                                  SWD0834
178 FORMAT (14X,103H RADIUS OF THE NOSE CAP IS ZERO. FOR THIS CASE THESWD0835
   1 HEAT TRANSFER EQUATIONS ARE NOT VALID. THEREFORE, NO/ 9X,70H THERSWD0836
   2MAL CONSTRAINTS HAVE BEEN IMPOSED ON THE DESIGN OF THIS FAIRING.  SWD0837
   3 ///)                                                              SWD0838
201 FORMAT (20X,52HCASE TERMINATED SINCE GBAR IS OUTSIDE RANGE. GBAR =SWD0839
   1 E11.4 )                                                           SWD0840
206 FORMAT (23X,77H CHANGE IN PRESSURE COEFFICIENT DUE TO ANGLE OF ATTSWD0841
   1ACK                CPA    = ,F8.4)                                 SWD0842
307 FORMAT (56X,18H AERODYNAMIC LOADS  // )                            SWD0843
308 FORMAT (48X,34H CONSTRAINTS ON DESIGN OF FRUSTUMS //)              SWD0844
309 FORMAT (48X,36H DESIGN SUMMARY FOR FRUSTUM SECTION   //)           SWD0845
310 FORMAT (20X,                                       92H FRUS-    LARGSWD0846
   1E     SMALL      HALF     LENGTH    MIN. BAY    MIN.    NO.     USEFUSWD0847
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    2L      WEIGHT )                                                                      SWD0848
 311 FORMAT (20X,                                                    92H   TUM       DIASWD0849
    1.       DIA.     ANGLE                   LENGTH     GAUGE      OF          VOLUMSWD0850
    2E               )                                                                    SWD0851
 312 FORMAT (20X,                                                    92H   NO.       (INSWD0852
    1)       (IN)     (DEG)      (IN)       (IN)       (IN)       BAYS        (CU FTSWD0853
    2)       (LB)    )                                                                    SWD0854
 313 FORMAT(21X,I4,                          F10.2,F10.2,F9.2,F9.1,F10.1,                 SWD0855
    1  F10.4,I7,F11.2,F11.2)                                                              SWD0856
 314 FORMAT (57X, 6H -----,24X,25H                                 ---)                   SWD0857
 315 FORMAT (46X,6HTOTALS,F11.1,23X,I4,2F11.2 )                                           SWD0858
 316 FORMAT (23X,77H USEFUL VOLUME OF NOSE CAP, CU. FT.                                   SWD0859
    1                 VCAP    = ,F8.2 )                                                   SWD0860
 329 FORMAT (23X,77H TOTAL VOLUME OF FAIRING, CU. FEET                                    SWD0861
    1                 VGROSS  = ,F8.2 )                                                   SWD0862
 365 FORMAT (3F12.8,35X,I1)                                                               SWD0863
 501 FORMAT (1H1)                                                                         SWD0864
 508 FORMAT (1X,I2,1H-,I2,4X,F8.2,4X,F8.2,5X,F7.0,F9.0,2F10.0,5X,F9.0,                    SWD0865
    1  4X,F7.0,5X,F7.0)                                                                   SWD0866
 511 FORMAT (23X,77H DESIGN PRESSURE ON NOSE CAP, PSI                                     SWD0867
    1                 PDSPH   = ,F8.3      )                                              SWD0868
 550 FORMAT (42X,48HDATA REPORT FOR OPTIMIZED NOSE FAIRING STRUCTURE /)SWD0869
 555 FORMAT (59X,12HCASE NUMBER ,I3 //)                                                   SWD0870
 606 FORMAT (1X, //)                                                                      SWD0871
 607 FORMAT (1X, /)                                                                       SWD0872
 608 FORMAT (10X,112H FRUSTUM    BAY BASE    BAY TOP      BAY     DISTANCE SWD0873
    1    DES. PRES.    DES. PRES.    AXIAL          SHEAR       BENDING      )SWD0874
 609 FORMAT (10X,112H   -BAY        DIA.        DIA.     LENGTH    FROM BASESWD0875
    1      WNDWRD        LEEWRD       LOAD           LOAD        MOMENT      )SWD0876
 610 FORMAT (10X,112H   NO.         (IN)        (IN)      (IN)       (IN)    SWD0877
    1      (PSI)         (PSI)       (LBS)          (LBS)      (IN-LBS)   //)SWD0878
 611 FORMAT (10X,I2,1H-,I2,F12.1,F10.1,F9.1,F11.1,F12.2,F13.2,F13.1,                      SWD0879
    1 F12.1,F14.1)                                                                        SWD0880
 612 FORMAT (54X,24H  DETAILED LOADS DATA      ///)                                       SWD0881
 613 FORMAT (17H          TANG. PT.,F10.1,19X,F11.1,25X,F13.1,F12.1,                      SWD0882
    1    F14.1)                                                                           SWD0883
 614 FORMAT (22X,93H DESIGN OF THE FAIRING HAS NOT BEEN COMPLETED. ONE SWD0884
    1OF THE SUBSCRIPTED VARIABLES HAS EXCEEDED /35X,20H THE MAXIMUM VALSWD0885
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      2UE, /11X,13H I(MAX) = 400 ,6X,12H J(MAX) = 29 ,7X,13H JF(MAX) = 29SWD0886
      3 ,6X,13H JG(MAX) = 8 ,7X,13H K(MAX) = 29 ,7X,12H M(MAX) = 7 /     SWD0887
      4 16X,3HI = ,I4, 11X,3HJ = ,I3,12X,4HJF = ,I3,11X,4HJG = ,I2, 12X, SWD0888
      5 3HK = ,I3,12X,3HM = ,I2 / )                                      SWD0889
  650 FORMAT (1H1)                                                       SWD0890
  806 FORMAT( 39X, 28HMAX APPLIED FACE STRESS, PSI   , 15X,              SWD0891
     1 21HALLOWABLE STRESS, PSI   // )                                   SWD0892
  807 FORMAT (1X,7HFRUSTUM, 3X, 8HWINDWARD, 4X, 7HLEEWARD, 49X, 4HFACE,  SWD0893
     1 8X, 4HFACE , 7X, 4HFACE )                                         SWD0894
  808 FORMAT ( 5H -BAY , 5X, 99HLINE LOAD   LINE LOAD     AXIAL     CIRCSWD0895
     1     SHEAR     BURST      WRINKLING     YIELD     DIMPLING     )   SWD0896
  809 FORMAT (4H NO. , 7X, 20H(LB/IN)      (LB/IN)         // )          SWD0897
  989 FORMAT(I5,6E12.8)                                                  SWD0898
  990 FORMAT (I6, 5F12.4, I6)                                            SWD0899
      END                                                                SWD0900
$IBFTC C53S2   DECK                                                      PTY 001
      SUBROUTINE PROPTY (MAT, E, AMU, RHO, TMPMAX)                       PTY 002
      GO TO (1,2,3,4,5           ), MAT                                  PTY 003
    1 CONTINUE                                                           PTY 004
C              ALUMINUM PROPERTIES (MAT = 1)                             PTY 005
      WRITE (6,141)                                                      PTY 006
  141 FORMAT (54X,24H  MATERIAL = ALUMINUM      ///)                     PTY 007
      E          = 10500000.0                                            PTY 008
      AMU        = 0.3                                                   PTY 009
      RHO        = 0.1                                                   PTY 010
      TMPMAX     = 600.0                                                 PTY 011
      RETURN                                                             PTY 012
    2 CONTINUE                                                           PTY 013
C              MAGNESIUM PROPERTIES (MAT = 2)                            PTY 014
      WRITE (6,142)                                                      PTY 015
  142 FORMAT (54X,24H  MATERIAL = MAGNESIUM     ///)                     PTY 016
      E          = 6500000.0                                             PTY 017
      AMU        = 0.34                                                  PTY 018
      RHO        = 0.065                                                 PTY 019
      TMPMAX     = 700.0                                                 PTY 020
      RETURN                                                             PTY 021
    3 CONTINUE                                                           PTY 022
C              TITANIUM PROPERTIES (MAT = 3)                             PTY 023
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      WRITE (6,143)                                                     PTY 024
  143 FORMAT (54X,24H  MATERIAL = TITANIUM     ///)                     PTY 025
      E           = 16000000.0                                          PTY 026
      AMU         = 0.3                                                 PTY 027
      RHO         = 0.16                                                PTY 028
      TMPMAX      = 900.0                                               PTY 029
      RETURN                                                            PTY 030
    4 CONTINUE                                                          PTY 031
C                STAINLESS STEEL PROPERTIES (MAT = 4)                   PTY 032
      WRITE (6,144)                                                     PTY 033
  144 FORMAT (54X,24H    MATERIAL = STEEL      ///)                     PTY 034
      E           = 30000000.0                                          PTY 035
      AMU         = 0.3                                                 PTY 036
      RHO         = 0.283                                               PTY 037
      TMPMAX      = 1100.0                                              PTY 038
      RETURN                                                            PTY 039
    5 CONTINUE                                                          PTY 040
C                LOCKALLOY PROPERTIES (MAT = 5)                         PTY 041
      WRITE (6,145)                                                     PTY 042
  145 FORMAT (54X,24H  MATERIAL = LOCKALLOY    ///)                     PTY 043
      E           = 27000000.0                                          PTY 044
      AMU         = 0.3                                                 PTY 045
      RHO         = 0.076                                               PTY 046
      TMPMAX      = 700.0                                               PTY 047
      RETURN                                                            PTY 048
      END                                                               PTY 049
$IBFTC C53S3   DECK                                                     TML 001
      SUBROUTINE THERML                                                 TML 002
C                THIS SUBROUTINE COMPUTES SKIN THICKNESSES REQUIRED TO  TML 003
C           KEEP NOSE CAP AND TOP FRUSTUM SKIN TEMPERATURES UNDER TMPMAX.TML 004
      DIMENSION AT(50),AS(20)                                           TML 005
      COMMON/TNOS/TMINN,PDSPH,TCAPST,RCAP                               TML 006
      COMMON /THRML/ TMPMAX,MAT,TCONTH,TCAPTH,THETA                     TML 007
C                THE EQUATIONS AND STORED COEFFICIENTS IN THIS SUBROUTINE TML 008
C           WERE OBTAINED BY MEANS OF A MULTIPLE REGRESSION ANALYSIS OF TML 009
C           DATA RESULTING FROM A THERMAL ANALYSIS OF SPHERES FLYING A  TML 010
C           NOMINAL LLSV TRAJECTORY. THE HOTTEST POINT ON THE NOSE CAP  TML 011
C           IS AT THE STAGNATION POINT OF THE SPHERE, AND THE HOTTEST   TML 012
C           POINT ON THE TOP FRUSTUM IS AT THE TANGENCY POINT OF THE    TML 013
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C         SPHERICAL NOSE CAP AND TOP FRUSTUM. THE METHOD USED TO OBTAINTML 014
C         THE ORIGINAL THERMAL DATA IS DESCRIBED IN LMSC DOCUMENT NO.  TML 015
C         TM 54-20-7.                                                  TML 016
C             TANGENCY POINT COEFFICIENTS FOR ALUMINUM.                TML 017
      DATA AT/    .027903,  -.010162,   .691498, -.013716,  2.108521,  TML 018
     1             .25293,    .52256,  -.560318,  .896866,  -.512848,  TML 019
C             TANGENCY POINT COEFFICIENTS FOR  MAGNESIUM.              TML 020
     2          -.176254, -1.175537,  1.972534, -.051082,  2.988892,   TML 021
     3          -.392456,  1.529938, -1.154861,   .88208,  -.055298,   TML 022
C             TANGENCY POINT COEFFICIENTS FOR  TITANIUM.               TML 023
     4           .056461,   .062469,   .579819, -.018108,  2.341248,   TML 024
     5           .206238,   .399368,  -.336502,  .835144,  -.355804,   TML 025
C             TANGENCY POINT COEFFICIENTS FOR  STAINLESS STEEL.        TML 026
     6           .194916,  1.457764,  -1.19165, -.064727,  1.619629,   TML 027
     7          -.032959,  -.851807,   .946594, 1.026367,  -.943359,   TML 028
C             TANGENCY POINT COEFFICIENTS FOR  LOCKALLOY.              TML 029
     8           .352531,  1.183907,   .312973,  .001026,  1.551514,   TML 030
     9           .084351,  -.735126,  -.335369,  .614578,  -.366287/   TML 031
C             STAGNATION POINT COEFFICIENTS FOR ALUMINUM.              TML 032
      DATA AS/-.014267,5.291153,-1.559019,-.010812,                    TML 033
C             STAGNATION POINT COEFFICIENTS FOR MAGNESIUM.             TML 034
     1     -.029125,6.776562,-1.966431,-.033269,                       TML 035
C             STAGNATION POINT COEFFICIENTS FOR TITANIUM.              TML 036
     2     -.001164,5.252344,-0.926601,-.012582,                       TML 037
C             STAGNATION POINT COEFFICIENTS FOR STAINLESS STEEL.       TML 038
     3     0.009530,3.505341,-1.058136,-.017291,                       TML 039
C             STAGNATION POINT COEFFICIENTS FOR LOCKALLOY.             TML 040
     4     -.008722,3.676389,-1.086252,-.000541/                       TML 041
      S2      = (SIN(THETA))**2                                        TML 042
      X2      = 1.0/SQRT(RCAP)                                         TML 043
      X3      = 0.001*TMPMAX*X2                                        TML 044
      X4      = (0.001 * TMPMAX+ 0.46) ** 4                            TML 045
      X5      = X2*S2                                                  TML 046
      X6      = X5*(0.001*TMPMAX)                                      TML 047
      X7      = 1.0/(RCAP**.2)                                         TML 048
      X8      = .001*TMPMAX*X7                                         TML 049
      X9      = X7*S2                                                  TML 050
      X10     = 0.001*TMPMAX*X9                                        TML 051
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      L          = 1 + 4*(MAT - 1)                                          TML 052
      M          = 1 + 10*(MAT - 1)                                         TML 053
      YTAN       = AT(M)+X2*AT(M+1)+X3*AT(M+2)+X4*AT(M+3)+X5*AT(M+4)        TML 054
     1     +X6*AT(M+5)+X7*AT(M+6)+X8*AT(M+7)+X9*AT(M+8)+X10*AT(M+9)         TML 055
      YSTG       = AS(L)+X2*AS(L+1)+X3*AS(L+2)+X4*AS(L+3)                   TML 056
      TCAPTH     = 100.*YSTG/(TMPMAX-70.)                                   TML 057
      TCONTH     = 100.*YTAN/(TMPMAX-70.)                                   TML 058
      RETURN                                                                TML 059
      END                                                                   TML 060
$IBFTC C53S4   DECK                                                         AER 001
      SUBROUTINE AERO                                                       AER 002
C              THIS SUBROUTINE COMPUTES PRESSURE COEFFICIENTS AT ZERO       AER 003
C          ANGLE-OF-ATTACK AND THE CHANGE IN PRESSURE COEFFICIENT DUE       AER 004
C          TO ANGLE-OF-ATTACK. FOR THE PURPOSE OF COMPUTING THESE           AER 005
C          COEFFICIENTS, EACH FRUSTUM IS TREATED AS A COMPLETE CONE.        AER 006
C              FIRST, THE PRESSURE COEFFICIENT AT ZERO ANGLE OF ATTACK      AER 007
C          IS CALCULATED BY THE METHOD OF SIMON AND WALTER, AIAA JOUNAL,AER 008
C          JULY 1963, PP 1696-97. THE METHOD APPROXIMATES EXACT             AER 009
C          SOLUTIONS WITH A MODIFIED QUADRATIC IN SINE SQUARE OF DELTA      AER 010
C          WITH COEFFICIENTS BEING FUNCTIONS OF GAMMA AND MACH NUMBER.      AER 011
      COMMON/AERPRS/CPAA,CPOO,LPFL                                          AER 012
      COMMON/CONFG/THTA(10),ALF(10),NFMAX,DBAS,DMN(10),ICONFG               AER 013
      COMMON/AERLOD/ALPHA,AMACH,NF                                          AER 014
      IF (THTA(NF)) 30,30,31                                                AER 015
   30 CPOO       = 0.                                                       AER 016
      CPAA       = 0.                                                       AER 017
      GO TO 300                                                             AER 018
   31 CONTINUE                                                              AER 019
      DELTA      = 0.0174532925*THTA(NF)                                    AER 020
C     G=GAMMA=1.4, GAM1=(G+7)/(G+1), GAM2=(G+7)/4, GAM3=((G-1)/4)**2        AER 021
C     GAM4=G/2, GAM5=GAM4*GAM1, GAM6=GAM1/2                                 AER 022
      GAM1=3.5                                                              AER 023
      GAM2=2.1                                                              AER 024
      GAM3=.01                                                              AER 025
      GAM4=.7                                                               AER 026
      GAM5=2.45                                                             AER 027
      GAM6=1.75                                                             AER 028
      EM         = AMACH                                                    AER 029
      IF(EM-1.05)100,1,1                                                    AER 030
```

```
    1 FINK=DELTA*57.2958                                                AER 031
      IF(FINK-50.)3,3,4                                                 AER 032
    4 WRITE (6,5) FINK                                                  AER 033
    5 FORMAT(84HOSUBR RAP-AT ANGLES BEYOND 50 DEG THE CP OBTAINED IS LIKAER 034
     1ELY TO BE ERRONEOUS.  DELTA=F6.2,6H, EMO=F6.2,7H,    X=F8.2)      AER 035
      EM=0.                                                             AER 036
      RETURN                                                            AER 037
    3 SDELT=SIN (DELTA)                                                 AER 038
      SSDEL=SDELT*SDELT                                                 AER 039
      GSSDE=1.4*SSDEL                                                   AER 040
      EMSTR=SQRT ((1.+GSSDE)/(1.-GSSDE))                                AER 041
   22 IF(EM-EMSTR)110,2,2                                               AER 042
    2 EMS=EM*EM                                                         AER 043
      EM4=EMS*EMS                                                       AER 044
      EM6=EM4*EMS                                                       AER 045
      F1=((EMS-1.)/(EM4*SDELT))+(6./EM6)+GAM2-GAM3                      AER 046
      Q=1.+(1./EM6)                                                     AER 047
      Q1=1./EMS                                                         AER 048
      F1SSD=F1*SSDEL                                                    AER 049
      F2=GAM6*(1.-Q1)*Q                                                 AER 050
      F3=GAM5*(1.+Q1)*Q                                                 AER 051
      SQUID=(F2-F1SSD)**2-((F3-F1)*SSDEL)**2                            AER 052
      CPOO       = 0.5*((F2+F1SSD)-SQRT(SQUID))                         AER 053
C                                                                       AER 054
C            NEXT. THE INCREASE IN PRESSURE COEFFICIENT (ON THE HIGH    AER 055
C        PRESSURE SIDE OF THE CONE) DUE TO ANGLE OF ATTACK IS           AER 056
C        COMPUTED. THIS  CALCULATION  IS  BASED ON DATA FROM CHART 8    AER 057
C        OF NACA REPORT 1135 AT MACH 1.5,AND A CIRCUMFERENTIAL          AER 058
C        PRESSURE DISTRIBUTION WHICH IS SINUSOIDAL. THE EQUATION        AER 059
C        FOR CPAA IS VALID FOR MACH NUMBERS BETWEEN 1.4 AND 1.6.        AER 060
C            CHECK IF MACH NUMBER LIES BETWEEN 1.4 AND 1.6.             AER 061
C                                                                       AER 062
      IF (AMACH - 1.4) 201,202,203                                      AER 063
  203 IF (AMACH - 1.6) 202,202,201                                      AER 064
  201 WRITE (6,205)                                                     AER 065
      WRITE (6,204)                                                     AER 066
      WRITE (6,205)                                                     AER 067
  205 FORMAT (1H1)                                                      AER 068
```

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  204 FORMAT (16X,100HMACH NUMBER LIES OUTSIDE THE INTERVAL FROM 1.4 TO AER 069
     11.6. VALUES CALCULATED FOR CPA MAY BE INACCURATE.   )             AER 070
C                                                                       AER 071
C              CALCULATE INCREASE IN THE PRESSURE COEFFICIENT.          AER 072
C                                                                       AER 073
  202 CPAA        = (2.03 - 1.20*DELTA)*ALPHA*2.*SIN(DELTA)/COS(DELTA)   AER 074
  300 CONTINUE                                                          AER 075
      RETURN                                                            AER 076
  100 WRITE (6,101) EM                                                  AER 077
  101 FORMAT(32H0      SUBROUTINE RAP--MACH NO.(F6.2,26H) IS LESS THAN 1AER 078
     1.05   EM0=F6.2,7H,  EM1=F6.2,5H,  X=F8.2)                         AER 079
      EM=0.                                                             AER 080
      RETURN                                                            AER 081
  110 WRITE (6,111) FINK, EM                                            AER 082
  111 FORMAT(27H0    SUBROUTINE RAP--DELTA(F6.2,42H) EXCEEDS MAX ANGLE FAER 083
     1OR THE MACH NO. USED(F6.2,8H).  EM0=F6.2,7H,  EM1=F6.2,4H, X=F8.2)AER 084
      EM=0.                                                             AER 085
      RETURN                                                            AER 086
      END                                                               AER 087
$IBFTC C53S5   DECK                                                     DIA 001
      SUBROUTINE DIAM (XN,DLOC)                                         DIA 002
C          INPUT PARAMETERS--XN,DMN(NF) FOR NF = 1 TO NFMAX,THTA(NF)     DIA 003
C          FOR NF = 1 TO NFMAX,NFMAX,ALTOT                              DIA 004
C          OUTPUT VARIABLES--DLOC                                       DIA 005
      COMMON/CONFG/THTA(10),ALF(10),NFMAX,DBAS,DMN(10),ICONFG           DIA 006
      COMMON/PRESR/CPA(121),CPO(121),XOD(121),DELTAP, FS,LTMAX,SUMAL,   DIA 007
     1 QBAR,ALTOT                                                       DIA 008
      XTOT        = ALTOT                                               DIA 009
      DO 10 N1 = 1,NFMAX                                                DIA 010
      XTOT        = XTOT - ALF(N1)                                      DIA 011
      DELTA       = XN- XTOT                                            DIA 012
      IF (DELTA) 10,20,20                                               DIA 013
   10 CONTINUE                                                          DIA 014
   20 CONTINUE                                                          DIA 015
      ANGLE       = 0.0174532925*THTA(N1)                               DIA 016
      DLOC        = DMN(N1) + 2.*DELTA*SIN(ANGLE)/COS(ANGLE)            DIA 017
      RETURN                                                            DIA 018
      END                                                               DIA 019
$IBFTC C53S6   DECK                                                     LDS 001
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      SUBROUTINE LOAD                                                   LDS 002
C               THIS SUBROUTINE COMPUTES AXIAL LOADS, SHEAR LOADS,      LDS 003
C          BENDING MOMENTS AND THE RESULTING LINE LOADS USING EITHER    LDS 004
C          THE INPUT PRESSURE DATA OR THAT COMPUTED IN SUBROUTINE AERO. LDS 005
C                                                                       LDS 006
      COMMON /DLOAD/D1,D2,XOD1,XOD2,CPO1,CPO2,CPA1,CPA2,A3,A4,QB,DP,    LDS 007
     1     FSBZ,BND,AXLOD                                               LDS 008
      COMMON ANFIMN,ANFIMX,DSUBB,PDESMN,PDESMX,E                        LDS 009
      COMMON/LOADS/CDCAP,CNCAP,XBCAP,FSUBZ,AXLDCP,FSBZCP,BNDCAP,LTRIG,  LDS 010
     1 ALCAP                                                            LDS 011
      COMMON/PRESR/CPA(121),CPO(121),XOD(121),DELTAP, FS,LTMAX,SUMAL,   LDS 012
     1 QBAR,ALTOT                                                       LDS 013
      COMMON/CONFG/THTA(10),ALF(10),NFMAX,DBAS,DMN(10),ICONFG           LDS 014
      COMMON/AERLOD/ALPHA,AMACH,NF                                      LDS 015
      COMMON /CHKLD/ C1,C3,C4,ALB,DELTAS,CHK,RAXMIN,RAXMAX,RPMIN,RPMAX, LDS 016
     1   CHKWND,CHKLEE,C2                                               LDS 017
      COMMON/PRSLOD/ LTJNCT(10)                                         LDS 018
C                                                                       LDS 019
C              DETERMINE IF THIS IS THE FIRST BAY.                      LDS 020
C                                                                       LDS 021
      IF (LTRIG) 399,399,393                                            LDS 022
  399 CONTINUE                                                          LDS 023
      NX          = NFMAX                                               LDS 024
      LTJNCT(NX)= 1                                                     LDS 025
      XOD(1)      = ALCAP/DBAS                                          LDS 026
      XODSTP      = (ALCAP + ALF(NFMAX))/DBAS                           LDS 027
      DO 458 LTX= 2,LTMAX                                               LDS 028
      IF ((XOD(LTX) - XOD(LTX-1)).GT..000001) GO TO 458                 LDS 029
      NX          = NX - 1                                              LDS 030
      LTJNCT(NX)= LTX                                                   LDS 031
      XOD(LTX)    = XODSTP                                              LDS 032
      XOD(LTX-1)= XODSTP                                                LDS 033
      XODSTP      = XODSTP + ALF(NX)/DBAS                               LDS 034
  458 CONTINUE                                                          LDS 035
      XOD(LTMAX)= ALTOT/DBAS                                            LDS 036
      QB          = QBAR/144.                                           LDS 037
      A3          = 1.5707963*QB*DBAS                                   LDS 038
      A4          = A3*DBAS                                             LDS 039
```

```
      DP          = DELTAP                                                LDS 040
C                                                                         LDS 041
C             SINCE THIS IS THE FIRST BAY, THE BENDING MOMENT, AXIAL      LDS 042
C         LOAD AND SHEAR LOAD AT THE BASE OF THE FAIRING ARE COMPUTED     LDS 043
C         USING THE PRESSURE DATA FOR THE ENTIRE FAIRING.                 LDS 044
C             THE LOADS CONTIBUTED BY THE CONICAL FRUSTUMS ARE            LDS 045
C         COMPUTED FIRST.                                                 LDS 046
C                                                                         LDS 047
      LTRIG       = 1                                                     LDS 048
      X           = 0.                                                    LDS 049
      AXLOAD      = 0.                                                    LDS 050
      BEND        = 0.                                                    LDS 051
      FSUBZ       = 0.                                                    LDS 052
      EL          = 0.                                                    LDS 053
      N1          = 1                                                     LDS 054
      LTMX1       = LTMAX + 1                                             LDS 055
      LTR1        = 1                                                     LDS 056
      DO 463 N1   = 1,NFMAX                                               LDS 057
      LTR2        = LTMAX - LTJNCT(N1)                                    LDS 058
      THETA       = 0.0174532925*THTA(N1)                                 LDS 059
      C2          = 2.*SIN(THETA)/COS(THETA)                              LDS 060
      DO 371 LTR= LTR1,LTR2                                               LDS 061
      LT          = LTMX1 - LTR                                           LDS 062
      XN          = XOD(LT)*DBAS                                          LDS 063
      CALL DIAM (XN,D1)                                                   LDS 064
      XN          = XOD(LT-1)*DBAS                                        LDS 065
      CALL DIAM (XN,D2)                                                   LDS 066
      XOD1        = XOD(LT)                                               LDS 067
      XOD2        = XOD(LT-1)                                             LDS 068
      CPO1        = CPO(LT)                                               LDS 069
      CPO2        = CPO(LT-1)                                             LDS 070
      CPA1        = CPA(LT)                                               LDS 071
      CPA2        = CPA(LT-1)                                             LDS 072
      CALL DLOD                                                           LDS 073
      EL          = EL+X                                                  LDS 074
      X           =(XOD1-XOD2)*DBAS                                       LDS 075
      AXLOAD      = AXLOD + AXLOAD                                        LDS 076
      FSUBZ       = FSUBZ + FSBZ                                          LDS 077
      BEND        = BEND + EL*FSBZ + BND                                  LDS 078
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```
  371 CONTINUE
      LTR1           = LTR2 + 1
  463 CONTINUE
C
C               THE LOADS CONTRIBUTED BY THE SPHERICAL NOSE CAP ARE
C           ADDED TO THE FRUSTUM LOADS.
C
      AC             = .7853982*DMN(NFMAX)**2
      EL             = EL + X
      IF (CDCAP) 435,435,436
  435 CONTINUE
      X              = DMN(NFMAX)/C2
      XBCAP          = X/3.
      CZALFA         = 2.03 - 1.2*THETA
      CNCAP          = CZALFA
      CPSTG          = (166.92158*AMACH**7./(7.*AMACH**2-1.)**2.5-1.)/
     1                      (0.7*AMACH**2)
      STHTA          = SIN(THETA)
      CDCAP          = CPSTG*(1.+STHTA**2)/2.
  436 CONTINUE
      XBAR           = XBCAP
      AXLOD          = AC*(CDCAP*QB - DELTAP)
      FSBZ           = AC*CNCAP*ALPHA*QB
      AXLDCP         = AXLOD
      FSBZCP         = FSBZ
      BNDCAP         = FSBZ*XBAR
      AXLOAD         = AXLOD + AXLOAD
      BEND           = BEND + (EL + XBAR)*FSBZ
      FSUBZ          = FSUBZ + FSBZ
C
C               PARAMETERS ARE INITIALIZED FOR USE IN COMPUTING UPPER
C           BAY LOADS.
C
      LFLG           = 1
      THETA          = 0.0174532925*THTA(NF)
      C3             = 0.3 / COS(THETA)
      C2             = 2.*SIN(THETA)/COS(THETA)
      C21            = C2
```

```
      CPO2        = CPO(LTMAX)
      CPA2        = CPA(LTMAX)
      XOD2        = XOD(LTMAX)
      D2          = DBAS
      LT          = LTMAX - 1
      GO TO 386
  393 CONTINUE
      XODB        = (ALTOT - SUMAL)/DBAS
      GO TO (445,446,447),LFLG
  446 CONTINUE
      LFLG        = 1
      BNDLB       = BEND
      XODLB       = XOD2
      CPOLB       = CPO2
      CPALB       = CPA2
      D2LB        = D2
      LTLB        = LT
      FZLB        = FSUBZ
      AXLLB       = AXLOAD
      GO TO 445
  447 CONTINUE
      BEND        = BNDLB
      FSUBZ       = FZLB
      AXLOAD      = AXLLB
      LFLG        = 1
      XOD2        = XODLB
      CPO2        = CPOLB
      CPA2        = CPALB
      D2          = D2LB
      LT          = LTLB
  445 CONTINUE
C
C           SINCE THIS IS AN UPPER BAY, THE LOADS AT THE BASE OF
C        THIS BAY ARE DETERMINED BY FIRST COMPUTING THE LOADS PRODUCED
C        BY THE PRESSURE PROFILE BETWEEN THIS BAY AND THE PREVIOUS
C        BAY, AND THEN SUBTRACTING THESE COMPUTED LOADS FROM THE
C        LOADS OF THE PREVIOUS BAY.
C
      XOD1        = XOD2
```

```
      CPO1        = CPO2                                                 LDS 156
      CPA1        = CPA2                                                 LDS 157
      D1          = D2                                                   LDS 158
      IF (XOD(LT) - XODB) 387,388,388                                    LDS 159
  387 CONTINUE                                                           LDS 160
      XOD2        = XODB                                                 LDS 161
      CPO2        = CPO(LT) + (CPO(LT+1) - CPO(LT))*(XODB - XOD(LT))     LDS 162
     1                        /(XOD(LT+1) - XOD(LT))                     LDS 163
      CPA2        = CPA(LT) + (CPA(LT+1) - CPA(LT))*(XODB - XOD(LT))     LDS 164
     1                        /(XOD(LT+1) - XOD(LT))                     LDS 165
      GO TO 389                                                          LDS 166
  388 CONTINUE                                                           LDS 167
      XOD2        = XOD(LT)                                              LDS 168
      CPO2        = CPO(LT)                                              LDS 169
      CPA2        = CPA(LT)                                              LDS 170
      LT          = LT - 1                                               LDS 171
  389 CONTINUE                                                           LDS 172
      XN1         = XOD1*DBAS                                            LDS 173
      XN2         = XOD2*DBAS                                            LDS 174
      X           = XN1-XN2                                              LDS 175
      CALL DIAM (XN1,D1)                                                 LDS 176
      CALL DIAM (XN2,D2)                                                 LDS 177
      CALL DLOD                                                          LDS 178
      FSUBZ       = FSUBZ - FSBZ                                         LDS 179
      AXLOAD      = AXLOAD - AXLOD                                       LDS 180
      BEND        = BEND - BND - X*FSUBZ                                 LDS 181
      IF (XOD2 - XODB) 386,386,445                                       LDS 182
  386 CONTINUE                                                           LDS 183
C                                                                        LDS 184
C             USING THE LOADS COMPUTED ABOVE, LINE LOADS WITH THE        LDS 185
C        FACTOR OF SAFETY APPLIED ARE COMPUTED FOR BOTH THE WINDWARD     LDS 186
C        AND LEEWARD SIDES OF THE BAY.                                   LDS 187
C                                                                        LDS 188
      ANFIAX      = C3*AXLOAD/(0.94248*DSUBB)                            LDS 189
      ANFIB       = BEND*C3 / (0.23562* DSUBB    **2)                    LDS 190
      ANFIMN      = FS*(ANFIAX - ANFIB)                                  LDS 191
      ANFIMX      = FS*(ANFIAX + ANFIB)                                  LDS 192
      RETURN                                                             LDS 193
```

```
      END                                                               LDS 194
$IBFTC C53S7   DECK                                                     DLD 001
      SUBROUTINE DLOD                                                   DLD 002
C            INPUT VARIABLES--D1,D2,XOD1,XOD2,CPO1,CPO2,CPA1,CPA2,A3,A4,DLD 003
C                  QB,DP                                                DLD 004
C            OUTPUT VARIABLES-- FSBZ,BND,AXLOD                          DLD 005
      COMMON /DLOAD/D1,D2,XOD1,XOD2,CPO1,CPO2,CPA1,CPA2,A3,A4,QB,DP,    DLD 006
     1      FSBZ,BND,AXLOD                                              DLD 007
      DX1         = XOD1 - XOD2                                         DLD 008
      IF (DX1.LE..002)GO TO 10                                          DLD 009
      DX2         = XOD1**2 -XOD2**2                                    DLD 010
      DX3         = XOD1**3 - XOD2**3                                   DLD 011
      DX4         = XOD1**4 -XOD2**4                                    DLD 012
      B2          = (CPO1 - CPO2)/DX1                                   DLD 013
      B1          = CPO1 - B2*XOD1                                      DLD 014
      B4          = (CPO1 - CPO2)/(D1 - D2)                             DLD 015
      B3          = CPO1- B4*D1                                         DLD 016
      A2          = (CPA1 -CPA2)/DX1                                    DLD 017
      A1          = CPA1 - A2*XOD1                                      DLD 018
      AD2         = (D1-D2)/DX1                                         DLD 019
      AD1         = D1 - AD2*XOD1                                       DLD 020
      BTA1        = A1*AD1                                              DLD 021
      BTA2        = 0.5*(A1*AD2 + A2*AD1)                               DLD 022
      BTA3        = A2*AD2/3.                                           DLD 023
      FSBZ        = A3*(BTA1*DX1 + BTA2*DX2 + BTA3*DX3)                 DLD 024
      BND         = A4*(BTA1*DX2/2. - BTA1*XOD2*DX1 + BTA2*DX3/3.       DLD 025
     1              -BTA2*DX1*XOD2**2 + BTA3*DX4/4. - BTA3*DX1*XOD2**3) DLD 026
      DD2         = (D1**2 - D2**2)/2.                                  DLD 027
      DD3         = (D1**3 - D2**3)/3.                                  DLD 028
      AXLOD       = 1.5707963*(DD2*(QB*B3-DP) + DD3*B4*QB)              DLD 029
      GO TO 20                                                          DLD 030
   10 DAV         = 0.5*(D1 + D2)                                       DLD 031
      CPOAV       = 0.5*(CPO1 + CPO2)                                   DLD 032
      FSBZ        = A3*CPAAV*DX1*DAV                                    DLD 034
      CPAAV       = 0.5*(CPA1 + CPA2)                                   DLD 033
      BND         = A3*DX1*DX1*DAV*(CPA1/2.+2.*(CPA2-CPA1)/3.)          DLD 035
      AXLOD       = 1.5707963*(D1-D2)*DAV*(CPOAV* QB-DP)                DLD 036
   20 CONTINUE                                                          DLD 037
      RETURN                                                            DLD 038
```

```
      END                                                               DLD 039
$IBFTC C53S8    DECK                                                    PRS 001
      SUBROUTINE PRESUR                                                 PRS 002
C              THIS SUBROUTINE COMPUTES THE MAXIMUM DESIGN PRESSURE     PRS 003
C         OCCURRING ANYWHERE ALONG THE LENGTH OF THE BAY ON BOTH THE    PRS 004
C         WINDWARD AND LEEWARD SIDES OF THE BAY, USING EITHER THE       PRS 005
C         INPUT PRESSURE DATA OR THAT COMPUTED IN SUBROUTINE AERO.      PRS 006
      COMMON/AERLOD/ALPHA, AMACH, NF                                    PRS 007
      COMMON /PRSLOD/ LTJNCT(10)                                        PRS 008
      COMMON ANFIMN,ANFIMX,DSUBB,PDESMN,PDESMX,E                        PRS 009
      COMMON/AERPRS/CPAA,CPOO,LPFL                                      PRS 010
      COMMON/PRESR/CPA(121),CPO(121),XOD(121),DELTAP, FS,LTMAX,SUMAL,   PRS 011
     1 QBAR,ALTOT                                                       PRS 012
      COMMON/CONFG/THTA(10),ALF(10),NFMAX,DBAS,DMN(10),ICONFG           PRS 013
      COMMON /CHKLD/ C1,C3,C4,ALB,DELTAS,CHK,RAXMIN,RAXMAX,RPMIN,RPMAX, PRS 014
     1   CHKWND,CHKLEE,C2                                               PRS 015
      GO TO (399,400,417,415),LPFL                                      PRS 016
  399 CONTINUE                                                          PRS 017
      XODB         = ALTOT/DBAS                                         PRS 018
      XOD1         = XODB                                               PRS 019
      QB           = QBAR/144.                                          PRS 020
      LT1          = LTMAX + 1                                          PRS 021
      CPMX1        = CPO(LTMAX) + CPA(LTMAX)                            PRS 022
      CPMN1        = CPO(LTMAX) - CPA(LTMAX)                            PRS 023
      GO TO 415                                                         PRS 024
  400 CONTINUE                                                          PRS 025
      L2           = LTMAX                                              PRS 026
      IF (NF.GT.1) L2 = LTJNCT(NF-1) - 1                                PRS 027
      L1           = LTJNCT(NF)                                         PRS 028
      XODB         = (ALTOT - SUMAL)/DBAS                               PRS 029
      XOD1         = XODB                                               PRS 030
      IF (XOD1.GE.XOD(L2)) XOD1 = XOD(L2) - .00001                      PRS 031
      DO 412 LT1 = L1,L2                                                PRS 032
      IF (XOD1.LT.XOD(LT1)) GO TO 414                                   PRS 033
  412 CONTINUE                                                          PRS 034
  414 LT           = LT1                                                PRS 035
      CPOO         = CPO(LT-1) + (CPO(LT) - CPO(LT-1))*(XOD1 - XOD(LT-1)) PRS 036
     1                         /(XOD(LT) - XOD(LT-1))                   PRS 037
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      CPAA       = CPA(LT-1) + (CPA(LT) - CPA(LT-1))*(XOD1 -XOD(LT-1))    PRS 038
     1                       /(XOD(LT) - XOD(LT-1))                         PRS 039
      CPMX1      = CPOO + CPAA                                              PRS 040
      CPMN1      = CPOO - CPAA                                              PRS 041
  415 CONTINUE                                                              PRS 042
      LT         = LT1                                                      PRS 043
      CPMX       = CPMX1                                                    PRS 044
      CPMN       = CPMN1                                                    PRS 045
      ALN        = 0.                                                       PRS 046
      ALX        = 0.                                                       PRS 047
  417 CONTINUE                                                              PRS 048
      XOD2       = (ALTOT - SUMAL - ALB)/DBAS                               PRS 049
      IF (XOD2.LE.XOD(L1)) XOD2 = XOD(L1)  + .00001                         PRS 050
  433 LT         = LT - 1                                                   PRS 051
      IF (LT.LE.L1) GO TO 419                                               PRS 052
      IF (XOD(LT) - XOD2) 419,422,422                                       PRS 053
  419 CONTINUE                                                              PRS 054
      LT         = LT + 1                                                   PRS 055
      CPAA       = CPA(LT-1) + (CPA(LT) - CPA(LT-1))*(XOD2 -XOD(LT-1))    PRS 056
     1                       /(XOD(LT) - XOD(LT-1))                         PRS 057
      CPOO       = CPO(LT-1) + (CPO(LT) - CPO(LT-1))*(XOD2 - XOD(LT-1))   PRS 058
     1                       /(XOD(LT) - XOD(LT-1))                         PRS 059
      CPX        = CPOO + CPAA                                              PRS 060
      CPN        = CPOO - CPAA                                              PRS 061
      JFIN       = 0                                                        PRS 062
      GO TO 428                                                             PRS 063
  422 CONTINUE                                                              PRS 064
      CPN        = CPO(LT) - CPA(LT)                                        PRS 065
      CPX        = CPO(LT) + CPA(LT)                                        PRS 066
      JFIN       = 1                                                        PRS 067
  428 IF (CPMX - CPX) 424,425,425                                           PRS 068
  424 CONTINUE                                                              PRS 069
      CPMX       = CPX                                                      PRS 070
      ALX        = (XODB - XOD(LT))*DBAS                                    PRS 071
      IF (JFIN.EQ.0) ALX=ALB                                                PRS 072
  425 CONTINUE                                                              PRS 073
      IF (CPMN - CPN) 426,427,427                                           PRS 074
  426 CONTINUE                                                              PRS 075
      CPMN       = CPN                                                      PRS 076
```

```
      ALN         = (XODB - XOD(LT))*DBAS                                PRS 077
      IF (JFIN.EQ.0) ALN=ALB                                             PRS 078
  427 CONTINUE                                                           PRS 079
      IF (JFIN) 429,429,433                                              PRS 080
  429 CONTINUE                                                           PRS 081
      PDESMX      = FS*(CPMX*QB - DELTAP)                                PRS 082
      PDESMN      = FS*(CPMN*QB - DELTAP)                                PRS 083
      RETURN                                                             PRS 084
      END                                                                PRS 085
$IBFTC C53S9   DECK                                                      STB 001
      SUBROUTINE INSTBL                                                  STB 002
C              THIS SUBROUTINE PERFORMS A GENERAL INSTABILITY ANALYSIS  STB 003
C         FOR SANDWICH CYLINDERS.  THE METHOD, DEVELOPED BY BO ALMROTH STB 004
C         OF LMSC SOLID MECHANICS LABORATORY, HANDLES AXIAL COMPRESSIONSTB 005
C         PLUS LATERAL PRESSURE.  THE ANALYSIS IS ELASTIC, AND INCLUDESSTB 006
C         TRANSVERSE SHEAR EFFECTS.  A KNOCKDOWN FACTOR BASED ON (R/T) STB 007
C         EFFECTIVE IS APPLIED TO THE CLASSICAL LOAD.  LATERAL PRESSURESTB 008
C         MAY BE EITHER BURSTING OR CRUSHING.                            STB 009
      DIMENSION X(44),A2(2,44),Z(4)                                      STB 010
      COMMON/KLSS/XL                                                     STB 011
      COMMON/INSTB/  E   , G1, G2, XNU, T1, T2,  RD, HT, CRG, K,P,KG     STB 012
      COMMON/KLASS/ CRW, XNCL, PBAR, XN, XN1, XN2, XN11, XN12, XN22      STB 013
      COMMON/INTRP/ X, A2, Z, XNMIN                                      STB 014
      COMMON/SFCTN/ GBAR, F                                              STB 015
  101 FORMAT(6E12.8)                                                     STB 016
  201 FORMAT(1H0,49HCASE SKIPPED SINCE GBAR WAS OUTSIDE RANGE - GBAR=E11STB 017
     1.4)                                                                STB 018
  202 FORMAT(1H0,43HCASE SKIPPED SINCE F WAS OUTSIDE RANGE - F=E11.4)    STB 019
  210 FORMAT(1H0,5HXNXR=E15.8)                                           STB 020
      KG          = 0                                                    STB 021
      Z(1) = 1.E-02                                                      STB 022
      Z(2)=1.E-03                                                        STB 023
      Z(3)=1.E-04                                                        STB 024
      Z(4)=1.E-05                                                        STB 025
      E1=E                                                               STB 026
      E2=E                                                               STB 027
      TR=T1/T2                                                           STB 028
      R=RD/HT                                                            STB 029
```

```
      H=HT/T2                                                           STB 030
   89 F=(TR**3+E2/E1)*(TR+1.0)**2/(H*H*TR*(1.0+E2/E1*TR))/12.0          STB 031
      GBAR=0.5*E1/G1*SQRT(E2/E1*TR/(1.0-XNU**2))/(R*H)*(1.0-(TR+1.0)/(2.STB 032
     10*H))                                                             STB 033
      IF(GBAR-X(1))52,10,10                                             STB 034
   52 XNMIN=0.123                                                       STB 035
      GO TO 531                                                         STB 036
   10 IF(GBAR-X(44))11,11,9                                             STB 037
    9 CONTINUE                                                          STB 038
      KG          = 1                                                   STB 039
      GO TO 500                                                         STB 040
   11 IF(F-Z(4))12,13,13                                                STB 041
   12 F = Z(4)                                                          STB 042
   13 IF (F - Z(1)) 51, 51, 122                                         STB 043
  122 F = Z(1)                                                          STB 044
   51 CALL INTERP                                                       STB 045
  531 CALL CLASS                                                        STB 046
      K=1                                                               STB 047
   53 XNR=2.0*XNCL*E1*SQRT(E2/E1*TR/(1.0-XNU**2))/(H*R*R)               STB 048
      XNN=XNMIN/XNCL                                                    STB 049
C                  XMIN IS BASED ON G1 = G2 (SQUARECELL CORE). XMIN ALSO STB 050
C          NEGLECTS PRESSURE EFFECTS. HOWEVER, THE KNOCKDOWN FACTOR IS  STB 051
C          APPROXIMATE, SO XMIN WILL BE ADEQUATE FOR OLTHER G1/G2       STB 052
C          VALUES AND FOR LOW PRESSURES.                                STB 053
      IF(XNN-1.0)15,15,14                                               STB 054
   14 XNN=1.0                                                           STB 055
   15 RTE=R*H*SQRT(TR+E2/E1)/SQRT(TR**3+E2/E1+12.0*H*H*TR*(1.0+E2/E1*TR)STB 056
     1/((TR+1.0)**2))                                                   STB 057
      IF (RTE .GT. 33.0) GO TO 17                                       STB 058
   16 PHI=1.0                                                           STB 059
      GO TO 18                                                          STB 060
   17 PHI=6.48/(RTE**0.54)                                              STB 061
   18 C=(PHI-0.12)/0.88                                                 STB 062
      XNXR=XNR*(XNN+C*(1.0-XNN))                                        STB 063
      CRG=XNXR*RD                                                       STB 064
   49 CONTINUE                                                          STB 065
  500 CONTINUE                                                          STB 066
      RETURN                                                            STB 067
      END                                                               STB 068
```

```
$IBFTC C53S10  DECK                                                     TRP 001
      SUBROUTINE INTERP                                                 TRP 002
C              THIS SUBROUTINE IS UTILIZED BY INSTBL                    TRP 003
      DIMENSION X(44),A2(2,44),Z(4)                                     TRP 004
      COMMON/INTRP/ X, A2, Z, XNMIN                                     TRP 005
      COMMON/SFCTN/ GBAR, F                                             TRP 006
      DIVDI(Q000FL,Q001FL,Q002FL,Q003FL,Q004FL,Q005FL,Q006FL)=Q001FL+(Q0TRP 007
     106FL-Q000FL)/(Q002FL-Q000FL)*(Q003FL-Q001FL)+(Q006FL-Q000FL)*(Q006TRP 008
     2FL-Q002FL)/(Q004FL-Q000FL)*((Q005FL-Q003FL)/(Q004FL-Q002FL)-(Q003FTRP 009
     3L-Q001FL)/(Q002FL-Q000FL))                                        TRP 010
      ABSLOG(Q007FL,Q008FL,Q009FL,Q010FL,Q011FL)=Q008FL+(ALOG(Q011FL)-ALTRP 011
     1OG(Q007FL))/(ALOG(Q009FL)-ALOG(Q007FL))*(Q010FL-Q008FL)           TRP 012
      M=0                                                               TRP 013
      N=0                                                               TRP 014
      IT=-1                                                             TRP 015
      DO 9 I=1,44                                                       TRP 016
      IF(GBAR-X(I))8,10,9                                               TRP 017
    9 CONTINUE                                                          TRP 018
   10 M=I                                                               TRP 019
    8 DO 11 J=1,4                                                       TRP 020
      IF(F-Z(J))11,13,12                                                TRP 021
   11 CONTINUE                                                          TRP 022
   13 N=J                                                               TRP 023
   12 IF(GBAR-0.2)14,14,15                                              TRP 024
   14 IF(F-Z(2))16,16,17                                                TRP 025
   16 K=2                                                               TRP 026
      GO TO 25                                                          TRP 027
   17 K=1                                                               TRP 028
   25 IF(M)18,18,19                                                     TRP 029
   19 XNMIN=A2(K,M)                                                     TRP 030
      GO TO 24                                                          TRP 031
   18 IF(I-2)20,20,21                                                   TRP 032
   20 I=I+1                                                             TRP 033
   21 X0=X(I-2)                                                         TRP 034
      X1=X(I-1)                                                         TRP 035
      X2=X(I)                                                           TRP 036
      XC=GBAR                                                           TRP 037
   27 IF(K-2)26,26,28                                                   TRP 038
```

```
 28 K=2                                                              TRP 039
 26 Y0=A2(K,I-2)                                                     TRP 040
    Y1=A2(K,I-1)                                                     TRP 041
    Y2=A2(K,I)                                                       TRP 042
    XNMIN=DIVDI(X0,Y0,X1,Y1,X2,Y2,XC)                                TRP 043
    IF(IT)24,29,30                                                   TRP 044
 24 IF(K-1)22,22,99                                                  TRP 045
 22 IF(N)23,23,99                                                    TRP 046
 23 IF(I-2)4,4,5                                                     TRP 047
  4 I=I+1                                                            TRP 048
  5 X0=X(I-2)                                                        TRP 049
    X1=X(I-1)                                                        TRP 050
    X2=X(I)                                                          TRP 051
    XC=GBAR                                                          TRP 052
    U0=Z(1)                                                          TRP 053
    U1=Z(2)                                                          TRP 054
    U=F                                                              TRP 055
    Y0=A2(2,I-2)                                                     TRP 056
    Y1=A2(2,I-1)                                                     TRP 057
    Y2=A2(2,I)                                                       TRP 058
    V1=DIVDI(X0,Y0,X1,Y1,X2,Y2,XC)                                   TRP 059
    V0=XNMIN                                                         TRP 060
    XNMIN=ABSLOG(U0,V0,U1,V1,U)                                      TRP 061
    GO TO 99                                                         TRP 062
 15 IF(N)33,33,34                                                    TRP 063
 34 K=N                                                              TRP 064
    GO TO 18                                                         TRP 065
 33 K=J-1                                                            TRP 066
    IT=0                                                             TRP 067
    GO TO 18                                                         TRP 068
 29 D0=XNMIN                                                         TRP 069
    K=J                                                              TRP 070
    IT=1                                                             TRP 071
    GO TO 18                                                         TRP 072
 30 D1=XNMIN                                                         TRP 073
    B0=Z(J-1)                                                        TRP 074
    B1=Z(J)                                                          TRP 075
    IF(D0-D1)32,99,32                                                TRP 076
 32 XNMIN=ABSLOG(B0,D0,B1,D1,F)                                      TRP 077
```

```
   99 RETURN                                                            TRP 078
      END                                                               TRP 079
$IBFTC C53S11  DECK                                                     CLS 001
      SUBROUTINE CLASS                                                  CLS 002
C     NON-SYMMETRIC BUCKLING PROGRAM.   F. BROGAN. B. ALMROTH, B. BURNS CLS 003
C     WHEN K=0,  SUBROUTINE CLASS PICKS INITIAL ESTIMATES FOR THE       CLS 004
C     INDEPENDENT VARIABLES.                                            CLS 005
C     IF K GREATER THAN 0,  PREVIOUS SOLUTIONS ARE USED FOR STARTING    CLS 006
C     ESTIMATES FOR THE NEXT CASE.                                      CLS 007
C     IF IOUT=0,   NO INTERMEDIATE OUTPUT WILL BE PRINTED.              CLS 008
C     SET IOUT=1 IN SUBROUTINE CLASS IF INTERMEDIATE OUTPUT IS DESIRED. CLS 009
      COMMON/KLSS/XL                                                    CLS 010
      COMMON/KLASS/ CRW, XNCL, PBAR, XN, XN1, XN2, XN11, XN12, XN22     CLS 011
      COMMON/INSTB/   EX, G1, G2, ZNU, T1, T2,   RD,  HT, CRG, K ,P     CLS 012
      COMMON/SFCTN/ GBAR, F                                             CLS 013
  901 FORMAT ( 48H0 THE VALUES OF N, N1, N2, Z1, Z2, B, AND E ARE    /  CLS 014
     1 7E16.8 )                                                         CLS 015
  902 FORMAT ( 59H0 THE NON-SYMMETRIC BUCKLING PROGRAM HAS NOT CONVERGEDCLS 016
     1 IN   I4, 12H ITERATIONS.   / 3H B=  E16.8, 2HE= E16.8 )           CLS 017
  903 FORMAT ( 48H0  THE NON-SYMMETRIC BUCKLING HAS CONVERGED IN  I4,   CLS 018
     1 11H ITERATIONS /  33H THE VALUES OF N, B, AND E ARE    / 3E16.8) CLS 019
      PI2=3.1415927**2                                                  CLS 020
      ZN1=SQRT (1.-ZNU**2)                                              CLS 021
      AP=PI2*ZN1*RD*HT/XL**2                                            CLS 022
      KBR=AMAX1(KBR,1)                                                  CLS 023
      IBR=KBR                                                           CLS 024
      CFT=.75                                                           CLS 025
      IOUT=0                                                            CLS 026
      DEL=.1                                                            CLS 027
      DLTA=.0001                                                        CLS 028
      EH=EX*HT                                                          CLS 029
      ZMU=G1/G2                                                         CLS 030
      DELX=DEL                                                          CLS 031
      G=GBAR                                                            CLS 032
      M1=75                                                             CLS 033
      M2=75                                                             CLS 034
      M4=40                                                             CLS 035
      PBAR=P/EH*RD**2*SQRT ((1.-ZNU**2)/(T1*T2))                        CLS 036
```

```
      PS=PBAR                                                           CLS 037
      KM=K                                                              CLS 038
      ITER=0                                                            CLS 039
      IF (K) 101, 101, 104                                              CLS 040
  101 IF (G-.5) 102, 103, 103                                           CLS 041
  102 ZI=1./(2.-4.*G)                                                   CLS 042
      GO TO 104                                                         CLS 043
  103 ZI=1./(2.*SQRT (F))                                               CLS 044
  104 CONTINUE                                                          CLS 045
      DX=.001*ZI                                                        CLS 046
      DX2=2.*DX                                                         CLS 047
      DXX=DX*DX                                                         CLS 048
  105 CONTINUE                                                          CLS 049
      F1=SFUN(ZI-DX)                                                    CLS 050
      F2=SFUN(ZI)                                                       CLS 051
      F3=SFUN(ZI+DX)                                                    CLS 052
      DZ=(F3-F1)/DX2*DXX/(F3-2.*F2+F1)                                  CLS 053
      ZI=ZI-DZ                                                          CLS 054
      IF (ABS (DZ/ZI)-DLTA) 120, 120, 110                               CLS 055
  110 ITER=ITER+1                                                       CLS 056
      IF (ITER-M1) 105, 105, 130                                        CLS 057
  120 AN=F2                                                             CLS 058
      IF (IOUT) 150, 150, 121                                           CLS 059
  121 WRITE (6,908)ITER, F2, ZI                                         CLS 060
      GO TO 150                                                         CLS 061
  130 WRITE (6,906)ITER                                                 CLS 062
      AN=1.                                                             CLS 063
  906 FORMAT (40H0  THE SYMMETRIC BUCKLING HAS FAILED IN    I4,         CLS 064
     1 12H ITERATIONS   )                                               CLS 065
  908 FORMAT (10H0 ITER=    I4, 5H  AN=  E16.7,   4H Z=  E16.8)         CLS 066
  150 CONTINUE                                                          CLS 067
      ITER=0                                                            CLS 068
      IT2=0                                                             CLS 069
      B=BS                                                              CLS 070
      E=ES                                                              CLS 071
      IF (K) 3, 3, 4                                                    CLS 072
    3 B=1.                                                              CLS 073
      E=1.                                                              CLS 074
      KBR=1                                                             CLS 075
```

```
      IBR=1                                                              CLS 076
      Z2=0.                                                              CLS 077
      PBAR=0.                                                            CLS 078
      BS=B                                                               CLS 079
      ES=E                                                               CLS 080
      IF (AP-1.) 4, 4, 7                                                 CLS 081
    7 E=2.*AP                                                            CLS 082
      ES=E                                                               CLS 083
    4 CONTINUE                                                           CLS 084
      Y=1.-ZNU                                                           CLS 085
      Y1=Y+1.                                                            CLS 086
      Y2= (1.+F)/4.                                                      CLS 087
      Y3=.25*G                                                           CLS 088
      Y4=2.*Y*ZMU                                                        CLS 089
      Y5=2.*ZMU*ZNU                                                      CLS 090
      A=1./(G*E)                                                         CLS 091
      A1=A+Y                                                             CLS 092
      BB=B*B                                                             CLS 093
      V=1.+BB                                                            CLS 094
      W=2.*B                                                             CLS 095
      V1=Y*ZMU*BB                                                        CLS 096
      V2=A+V1                                                            CLS 097
      W2=Y*ZMU*W                                                         CLS 098
      V3=A+Y+BB                                                          CLS 099
      W3=W                                                               CLS 100
      V4=V2+ZMU                                                          CLS 101
      W4=W2                                                              CLS 102
      V5=V3*V4-ZMU*BB                                                    CLS 103
      W5=W3*V4+V3*W4-ZMU*W                                               CLS 104
      V11=1./BB                                                          CLS 105
      W11=-W*V11**2                                                      CLS 106
      V14=1./V5                                                          CLS 107
      W14=-W5*V14**2                                                     CLS 108
      V6=V/V5                                                            CLS 109
      W6=V*W14+W*V14                                                     CLS 110
      V7=V2*V6                                                           CLS 111
      W7=W2*V6+V2*W6                                                     CLS 112
      V9=V*V/BB                                                          CLS 113
```

```
      W9=W+W11                                                          CLS 114
      V15=1./V9                                                         CLS 115
      W15=-W9*V15**2                                                    CLS 116
      B2=-B*V7                                                          CLS 117
      B2B=-V7-B*W7                                                      CLS 118
      C2=-A1*V6                                                         CLS 119
      C2B=-A1*W6                                                        CLS 120
      V12=Y3*(B2**2+ZMU*C2**2)                                          CLS 121
      W12=2.*Y3*(B2*B2B+ZMU*C2*C2B)                                     CLS 122
      V20=A+4.*BB                                                       CLS 123
      W20=8.*B                                                          CLS 124
      V21=1./V2                                                         CLS 125
      V23=V21**2                                                        CLS 126
      W21=-W20*V23                                                      CLS 127
      V22=8.*B*BB                                                       CLS 128
      W22=24.*BB                                                        CLS 129
      B1=-V21*V22                                                       CLS 130
      B12=-V22*W21-W22/V20                                              CLS 131
      V24=ZMU*C2                                                        CLS 132
      W24=ZMU*C2B                                                       CLS 133
      B1B=B1**2                                                         CLS 134
      V25=BB*B1B                                                        CLS 135
      V26=B1*B12                                                        CLS 136
      W25=2.*(B*B1B+BB*V26)                                             CLS 137
      V30=B2+B*V24                                                      CLS 138
      W30=B2B+V24+B*W24                                                 CLS 139
      V31=B*(Y1+BB)                                                     CLS 140
      W31=Y1+3.*BB                                                      CLS 141
      V32=B2*V31                                                        CLS 142
      W32=B2*W31+B2B*V31                                                CLS 143
      V33=ZMU*(1.+Y1*BB)                                                CLS 144
      W33=Y1*ZMU*W                                                      CLS 145
      V34=C2*V33                                                        CLS 146
      W34=C2*W33+C2B*V33                                                CLS 147
      V35=2.*Y*V30**2                                                   CLS 148
      W35=4.*Y*W30*V30                                                  CLS 149
      V36=B2*C2                                                         CLS 150
      W36=B2*C2B+B2B*C2                                                 CLS 151
      V37=Y5*B*V36                                                      CLS 152
```

```
      W37=Y5*(V36+B*W36)                                                CLS 153
      S2=2.*(V25+V24**2+V37+V35)+4.*(V32+V34)                           CLS 154
      S2B=2.*(W25+2.*V24*W24+W37+W35)+4.*(W32+W34)                      CLS 155
      V16=V12+E*S2/8.-PBAR                                              CLS 156
      W16=W12+E*S2B/8.                                                  CLS 157
      AE=-G*A*A                                                         CLS 158
      U2=AE                                                             CLS 159
      U5=AE*(V3+V4)                                                     CLS 160
      U14=-U5*V14**2                                                    CLS 161
      U6=V*U14                                                          CLS 162
      U7=U2*V6+V2*U6                                                    CLS 163
      B2E=-B*U7                                                         CLS 164
      U21=-AE*V23                                                       CLS 165
      B1E=-V22*U21                                                      CLS 166
      C2E=-A1*U6-AE*V6                                                  CLS 167
      U24= ZMU*C2E                                                      CLS 168
      U12=2.*Y3*(B2*B2E+V24*C2E)                                        CLS 169
      U25=2.*BB*B1*B1E                                                  CLS 170
      U30=B2E+B*U24                                                     CLS 171
      U32=B2E*V31                                                       CLS 172
      U34=C2E*V33                                                       CLS 173
      U35=4.*Y*V30*U30                                                  CLS 174
      U36= B2*C2E+B2E*C2                                                CLS 175
      U37=Y5*B*U36                                                      CLS 176
      S2E=2.*(U25+2.*V24*U24+U37+U35)+4.*(U32+U34)                      CLS 177
      U16=U12+S2/8.+E*S2E/8.                                            CLS 178
      XN=Y2*E*V9+V15/E+V11*V16                                          CLS 179
      EB=AP*W11                                                         CLS 180
      XN1=Y2*E*W9+W15/E+V11*W16+W11*V16                                 CLS 181
      XN2=Y2*V9+G*V15*AE+V11*U16                                        CLS 182
      FN1=XN1+XN2*EB                                                    CLS 183
      IF (KM) 34, 34, 48                                                CLS 184
   34 IF (ITER) 40, 40, 35                                              CLS 185
   35 IF (XN-XNA) 40, 45, 45                                            CLS 186
   40 CONTINUE                                                          CLS 187
      XNAB=SQRT (XN1**2+XN2**2)/DELX                                    CLS 188
      XNA=XN                                                            CLS 189
      IT2=IT2+1                                                         CLS 190
```

```
      GO TO (36, 37), IBR                                               CLS 191
   36 CONTINUE                                                          CLS 192
      Z1=XN1/XNAB                                                       CLS 193
      Z2=XN2/XNAB                                                       CLS 194
      GO TO 39                                                          CLS 195
   37 CONTINUE                                                          CLS 196
      Z1=DELX*FN1/ABS (FN1)                                             CLS 197
      Z2=0.                                                             CLS 198
   39 CONTINUE                                                          CLS 199
      IF (IT2-M4) 47, 47, 44                                            CLS 200
   44 Z1=CFT*Z1                                                         CLS 201
      Z2=CFT*Z2                                                         CLS 202
      DELX=CFT*DELX                                                     CLS 203
      M4=15                                                             CLS 204
      IT2=0                                                             CLS 205
      GO TO 47                                                          CLS 206
   45 IF (DELX-.1*DLTA) 60, 60, 46                                      CLS 207
   46 DELX=DELX/3.                                                      CLS 208
      B=B+.66667*Z1                                                     CLS 209
      E=E+.66667*Z2                                                     CLS 210
      Z1=Z1/3.                                                          CLS 211
      Z2=Z2/3.                                                          CLS 212
      M4=10                                                             CLS 213
      IT2=0                                                             CLS 214
      GO TO 49                                                          CLS 215
   48 CONTINUE                                                          CLS 216
      WB2=Y4                                                            CLS 217
      WB5=2.*(W3*W4+V4+Y*ZMU*V3-ZMU)                                    CLS 218
      WB11=6.*V11**2                                                    CLS 219
      WB14=-2.*W5*V14*W14-WB5*V14**2                                    CLS 220
      WB6=2.*(W*W14+V14)+V*WB14                                         CLS 221
      WB7=2.*W2*W6+WB2*V6+V2*WB6                                        CLS 222
      WB9=2.+WB11                                                       CLS 223
      WB15=-WB9*V15**2+2.*W9**2*V15**3                                  CLS 224
      B2BB=-2.*W7-B*WB7                                                 CLS 225
      C2BB=-A1*WB6                                                      CLS 226
      WB12=2.*Y3*(B2*B2BB+B2B**2+ZMU*(C2*C2BB+C2B**2))                  CLS 227
      WB21=-2.*W20*V21*W21-8.*V23                                       CLS 228
      B12B=-2.*(W22*W21)-V22*WB21-48.*B/V20                             CLS 229
```

```
      WB24=ZMU*C2BB                                                     CLS 230
      WB25=2.*(B1B+4.*V26*B+BB*(B12**2+B1*B12B))                        CLS 231
      WB30=B2BB+2.*W24+ZMU*B*C2BB                                       CLS 232
      WB31=6.*B                                                         CLS 233
      WB32=2.*B2B*W31+B2*WB31+B2BB*V31                                  CLS 234
      WB34=2.*C2B*W33+C2*2.*Y1*ZMU+C2BB*V33                             CLS 235
      WB35=4.*Y*(W30**2+WB30*V30)                                       CLS 236
      WB36=2.*B2B*C2B+B2*C2BB+B2BB*C2                                   CLS 237
      WB37=Y5*(2.*W36+B*WB36)                                           CLS 238
      S2BB=2.*(WB25+2.*W24**2+2.*V24*WB24+WB37+WB35)+4.*(WB32+WB34)     CLS 239
      WB16=WB12+E*S2BB/8.                                               CLS 240
      AEE=-2.*G*AE*A                                                    CLS 241
      U5E=2.*AE**2+AEE*(V3+V4)                                          CLS 242
      U5B=AE*(W3+W4)                                                    CLS 243
      U14E=-2.*U5*V14*U14-U5E*V14**2                                    CLS 244
      W14E=-U5B*V14**2-2.*U5*V14*W14                                    CLS 245
      U6E=V*U14E                                                        CLS 246
      U6B=V*W14E+W*U14                                                  CLS 247
      U7E=2.*U2*U6+AEE*V6+V2*U6E                                        CLS 248
      U7B=U2*W6+W2*U6+V2*U6B                                            CLS 249
      B2EE=-B*U7E                                                       CLS 250
      B2EB=-U7-B*U7B                                                    CLS 251
      U21E=-2.*AE*V21*U21-AEE*V23                                       CLS 252
      U21B=-2.*AE*V21*W21                                               CLS 253
      B1EE=-V22*U21E                                                    CLS 254
      B1EB=-W22*U21-V22*U21B                                            CLS 255
      C2EE=-A1*U6E-AEE*V6-2.*AE*U6                                      CLS 256
      C2EB=-A1*U6B-AE*W6                                                CLS 257
      U24E=ZMU*C2EE                                                     CLS 258
      U24B=ZMU*C2EB                                                     CLS 259
      U12E=2.*Y3*(B2E**2+B2*B2EE+U24*C2E+V24*C2EE)                      CLS 260
      U12B=2.*Y3*(B2*B2EB+B2B*B2E+W24*C2E+V24*C2EB)                     CLS 261
      U25E=2.*BB*(B1E**2+B1*B1EE)                                       CLS 262
      U25B=4.*B*B1*B1E+2.*BB*(B12*B1E+B1*B1EB)                          CLS 263
      U30E=B2EE+B*U24E                                                  CLS 264
      U30B=B2EB+U24+B*U24B                                              CLS 265
      U32E=B2EE*V31                                                     CLS 266
      U32B=B2EB*V31+B2E*W31                                             CLS 267
```

```
      U34E=C2EE*V33                                                     CLS 268
      U34B=C2E*W33+C2EB*V33                                             CLS 269
      U35E=4.*Y*(U30**2+V30*U30E)                                       CLS 270
      U35B=4.*Y*(V30*U30B+W30*U30)                                      CLS 271
      U36E=2.*B2E*C2E+B2*C2EE+B2EE*C2                                   CLS 272
      U36B=B2B*C2E+B2*C2EB+B2EB*C2+B2E*C2B                              CLS 273
      U37E=Y5*B*U36E                                                    CLS 274
      U37B=Y5*U36+Y5*B*U36B                                             CLS 275
      S2EE=2.*(U25E+2.*(U24**2+V24*U24E)+U37E+U35E)+4.*(U32E+U34E)      CLS 276
      S2EB=2.*(U25B+2.*(W24*U24+V24*U24B)+U37B+U35B)+4.*(U32B+U34B)     CLS 277
      U16E=U12E+S2E/4.+E*S2EE/8.                                        CLS 278
      U16B=U12B+S2B/8.+E*S2EB/8.                                        CLS 279
      EBB=AP*WB11                                                       CLS 280
      EB2=EB**2                                                         CLS 281
      XN11=Y2*E*WB9+WB15/E+2.*W11*W16+V11*WB16+WB11*V16                 CLS 282
      XN12=Y2*W9+G*W15*AE+V11*U16B+W11*U16                              CLS 283
      XN22=G*V15*AEE+ V11*U16E                                          CLS 284
      GO TO (41, 42), IBR                                               CLS 285
   41 CONTINUE                                                          CLS 286
      XK=XN12/XN11                                                      CLS 287
      Z2=(XN2-XK*XN1)/(XN22-XK*XN12)                                    CLS 288
      Z1=(XN1-XN12*Z2)/XN11                                             CLS 289
      GO TO 47                                                          CLS 290
   42 CONTINUE                                                          CLS 291
      FN11=XN11+2.*XN12*EB+XN22*EB2+XN2*EBB                             CLS 292
      Z1=FN1/FN11                                                       CLS 293
      Z2=0.                                                             CLS 294
   47 CONTINUE                                                          CLS 295
      B=B-Z1                                                            CLS 296
      E=E-Z2                                                            CLS 297
   49 GO TO (55, 57), IBR                                               CLS 298
   55 IF (E-AP/B**2) 56, 56, 58                                         CLS 299
   56 IBR=2                                                             CLS 300
      KBR=2                                                             CLS 301
   57 E=AP/B**2                                                         CLS 302
   58 CONTINUE                                                          CLS 303
      D1=ABS (Z1/B)                                                     CLS 304
      D2=ABS (Z2/E)                                                     CLS 305
      IF (IOUT) 53, 53, 51                                              CLS 306
```

```
   51 CONTINUE                                                           CLS 307
      WRITE (6,901) XN, XN1, XN2, Z1, Z2, B, E                          CLS 308
   53 CONTINUE                                                           CLS 309
      IF (D1-DLTA) 50, 50, 52                                            CLS 310
   50 IF ( D2-DLTA) 60, 60, 52                                           CLS 311
   52 ITER=ITER+1                                                        CLS 312
      IF (ITER-M2) 4, 4, 96                                              CLS 313
   96 IF (KM) 97, 97, 98                                                 CLS 314
   97 KM=1                                                               CLS 315
      PBAR=PS                                                            CLS 316
      ITER=0                                                             CLS 317
      GO TO 4                                                            CLS 318
   60 WRITE (6,903) ITER, XN, B, E                                       CLS 319
      IF (KM) 97, 97, 68                                                 CLS 320
   68 GO TO (61, 62), IBR                                                CLS 321
   61 IBR=2                                                              CLS 322
      ES=E                                                               CLS 323
      BS=B                                                               CLS 324
      XNS=XN                                                             CLS 325
      B=1.                                                               CLS 326
      ITER=0                                                             CLS 327
      GO TO 7                                                            CLS 328
   62 GO TO (63, 65), KBR                                                CLS 329
   63 IF (XN-XNS) 66, 64, 64                                             CLS 330
   64 XN=XNS                                                             CLS 331
      GO TO 66                                                           CLS 332
   65 CONTINUE                                                           CLS 333
      BS=B                                                               CLS 334
      ES=E                                                               CLS 335
   66 CONTINUE                                                           CLS 336
      XNCL=AMIN1(AN,XN)                                                  CLS 337
      XNCL=MIN1 (AN,XN)                                                  CLS 338
      IF (KM) 97, 97, 99                                                 CLS 339
   98 WRITE (6, 902) ITER, B, E                                          CLS 340
      XNCL=AN                                                            CLS 341
   99 RETURN                                                             CLS 342
      END                                                                CLS 343
$IBFTC C53S12  DECK                                                      SFN 001
```

```
      FUNCTION SFUN (Z)                                                 SFN 002
      DIMENSION X(44),A2(2,44),Z(4)                                     SFN 003
      COMMON/SFCTN/ GBAR, F                                             SFN 004
      ZX=4.*Z                                                           SFN 005
      SFUN=(1.+F)*Z+1./ZX-ZX*Z/(1./GBAR+ZX)                             SFN 006
      RETURN                                                            SFN 007
      END                                                               SFN 008
$IBFTC C53S13  DECK                                                     IRQ 001
      SUBROUTINE IREQ                                                   IRQ 002
      COMMON/CONFG/THTA(10),ALF(10),NFMAX,DBAS,DMN(10),ICONFG           IRQ 003
      COMMON/AERLOD/ALPHA,AMACH,NF                                      IRQ 004
      COMMON /CHKLD/ C1,C3,C4,ALB,DELTAS,CHK,RAXMIN,RAXMAX,RPMIN,RPMAX, IRQ 005
     1   CHKWND,CHKLEE,C2                                               IRQ 006
      COMMON ANFIMN,ANFIMX,DSUBB,PDESMN,PDESMX,E                        IRQ 007
      COMMON/IRQ/ TTM, PI, ALCONE, C6, AIREQ                            IRQ 008
      IF (THTA(NF).LT. 0.01) GO TO 990                                  IRQ 009
      AIREQ     = C6*ALB   *((DSUBB - C2*ALB   )**2)*(PDESMX**1.33333)  IRQ 010
     1  /TTM**.33333                                                    IRQ 011
       GO TO 994                                                        IRQ 012
C             DETERMINE RING MOMENT OF INERTIA REQUIREMENTS TO PREVENT  IRQ 013
C        GENERAL INSTABILITY BY THE METHOD OF SHANLEY.  SEE BECKER'S    IRQ 014
C        HANDBOOK OF STRUCTURAL STABILITY, VOL. 6, P24. (NACA TN 3786)IRQ 015
  990  AIREQ = (ALB   * (2.5E - 04) * PI * ANFIMX * (DSUBB / 2.) ** 4)/ IRQ 016
     1 (E * ALCONE)                                                     IRQ 017
  994 CONTINUE                                                          IRQ 018
      RETURN                                                            IRQ 019
      END                                                               IRQ 020
$IBFTC C53S14  DECK                                                     RNG 001
      SUBROUTINE RING                                                   RNG 002
      COMMON/RNG/ IKIND, AOT, BOT, COT, TSTD(30), K, AIRING, DD         RNG 003
      COMMON /RSTRSS/ AA, TF, Z, CTH, AST, AISTT, FRING                 RNG 004
C             RINGS ARE ASSUMED TO BE FORMED SHEET METAL OF STANDARD    RNG 004
C        GAUGE. IKIND INDICATES THE TYPE OF RING...1 = ANGLE, 2 = ZEE,RNG 006
C        3 = HAT. BASE FLANGE WIDTH IS GIVEN BY B, RING DEPTH IS A,     RNG 007
C        AND OUTSTANDING OR UPPER FLANGE WIDTH IS GIVEN BY C. SHEET     RNG 008
C        THICKNESS IS INDICATED BY TT.                                  RNG 009
      TT        = TSTD(K)                                               RNG 010
      A         = AOT * TT                                              RNG 011
      B         = BOT * TT                                              RNG 012
```

```
      C          = COT * TT                                                  RNG 013
      GO TO (1020,1030,1040), IKIND                                          RNG 014
 1020 AST        = B*TT + (A-TT) * TT                                        RNG 015
      DD         = ( A*A*TT/2. +(B-TT)*(TT/2.)**2)/AST                       RNG 016
      AIB        = ((B-TT) * TT**3)/12.                                      RNG 017
      AIF        = (A**3)*TT/12.                                             RNG 018
      AB         = (B-TT)*TT                                                 RNG 019
      AF         = A*TT                                                      RNG 020
      DB       = DD - TT/2.                                                  RNG 021
      DF         = A/2. -DD                                                  RNG 022
      AIST=AIB+AIF+AB*DB*DB+AF*DF*DF                                         RNG 023
      GO TO 105                                                              RNG 024
 1030 AST        = A*TT + 2.*(B-TT)*TT                                       RNG 025
      DD  = A/2.                                                             RNG 026
      AIB        = (B-TT) * (TT**3)/12.                                      RNG 027
      AIW        = TT*(A**3)/12.                                             RNG 028
      DB         = (A-TT)/2.                                                 RNG 029
      AB         = (B-TT)*TT                                                 RNG 030
      AIST=AIB*2.+AIW+AB*DB*DB*2.                                            RNG 031
      GO TO 105                                                              RNG 032
 1040 AST=2.*B*TT +C*TT + 2.*(A-2.*TT)*TT                                    RNG 033
      DD         = ((B-TT)*TT*TT + A*A*TT + (C-2.*TT)*(A-TT/2.)*TT)/AST      RNG 034
      AB         = 2. * (B-TT)*TT                                            RNG 035
      AW         = 2.0 * A * TT                                              RNG 036
      AT         = (C -2.*TT)*TT                                             RNG 037
      AIB        = (B-TT)*(TT**3)/12.                                        RNG 038
      AIW        = TT*(A**3)/12.                                             RNG 039
      AIT      = (C-2.*TT)*(TT**3)/12.                                       RNG 040
      DB         =DD-TT/2.                                                   RNG 041
      DT         = (A-TT/2. -DD)                                             RNG 042
      DW    = DD - A/2.                                                      RNG 043
      AIST=AIB*2.+AIW*2.+AIT+AB*2.*DB*DB                                     RNG 044
     1+AW*DW*DW*2.+AT*DT*DT                                                  RNG 045
 1050 CONTINUE                                                               RNG 046
      ECC        = DD + .5 *TF                                               RNG 047
      Z          = (AST * ECC) / (AST + B * TF)                              RNG 048
C                CALCULATE MOMENT OF INERTIA OF RING,INCLUDING ONE FACE.     RNG 049
      AISTT      = AIST + (B * TF**3 / 12.) + AST * (ECC - Z)**2 +           RNG 050
```

```
      1   B * TF * Z**2                                                      RNG 051
       AA          = A                                                       RNG 052
       AIRING      = AIST                                                    RNG 053
       RETURN                                                                RNG 054
       END                                                                   RNG 055
$IBFTC C53S15  DECK                                                          BLK 001
       BLOCK DATA                                                            BLK 002
       DIMENSION X(44),A2(2,44),Z(4)                                         BLK 003
       COMMON/RNG/ IKIND, AOT, BOT, COT, TSTD(30), K, AIRING, AST, DD        BLK 004
       COMMON/INTRP/ X, A2, Z, XNMIN                                         BLK 005
       DATA TSTD/ .008, .012, .016, .020, .025, .032, .040, .050, .063,      BLK 006
      1 .071, .080, .090, .100, .125, .190, .250, .312, .375, .438, .500,BLK 007
      2 .562, .625, .688, .750, .812, .875, .938,1.000, 1.125, 1.250  /      BLK 008
       DATA X/.003,.004,.005,.006,.007,.008,.009,.01,.02,.03,.04,.05,.06,BLK 009
      1.07,.08,.09,.1,.2,.3,.4,.5,.6,.7,.8,.9,1.,2.,3.,4.,5.,6.,7.,8.,       BLK 010
      2 9.,10.,20.,30.,40.,50.,60.,70.,80.,90.,100.     /                    BLK 011
       END                                                                   BLK 012
$IBFTC C53S16  DECK                                                          RSS 001
       SUBROUTINE RSTRES                                                     RSS 002
       COMMON ANFIMN,ANFIMX,DSUBB,PDESMN,PDESMX,E                            RSS 003
       COMMON /CHKLD/ C1,C3,C4,ALB,DELTAS,CHK,RAXMIN,RAXMAX,RPMIN,RPMAX,     RSS 004
      1    CHKWND,CHKLEE,C2                                                  RSS 005
       COMMON /RSTRSS/ AA, TF, Z, CTH, AST, AISTT, FRING                     RSS 006
       ZFLG        = AA + .5 * TF - Z                                        RSS 007
       ANTHTA      = PDESMX * DSUBB / (2. * CTH)                             RSS 008
       ANRING      = ANTHTA * ALB * (AST /(AST + 2. * ALB * TF))             RSS 009
C              ESTIMATE COMPRESSIVE RING STRESS DUE TO OUT-OF-ROUNDNESS      RSS 010
C          AND ASSYMMETRY OF LOADING.   (F = PR)                             RSS 011
       FBEND       = ANRING * ZFLG / AISTT                                   RSS 012
       FRING       = ANRING / AST + FBEND                                    RSS 013
       RETURN                                                                RSS 014
       END                                                                   RSS 015
$IBFTC C53S17  DECK                                                          TNS 001
       SUBROUTINE TNOSST                                                     TNS 002
C              THE FOLLOWING SUBROUTINE CALCULATES NOSE CAP SKIN THICK-TNS 003
C         NESS REQUIRED FOR STRUCTURAL INTEGRITY. THE FAILURE CRITERIONTNS 004
C         USED IS THAT PRESENTED FOR NON-SHALLOW SPHERICAL CAPS IN THE TNS 005
C         LMSC STRUCTURAL METHODS HANDBOOK, SECTION 6.32.1, DATED      TNS 006
C         30 SEPTEMBER 1962.                                                 TNS 007
```

```
      COMMON/TNOS/TMINN,PDSPH,TCAPST,RCAP                               TNS 008
      COMMON ANFIMN,ANFIMX,DSUBB,PDESMN,PDESMX,E                        TNS 009
C               CONSTANT  USED IN CALCULATING THE COLLAPSE PRESSURE FOR TNS 010
C          THE NOSE CAP IS                                              TNS 011
   46 A             =0.606*E/(RCAP**2)                                  TNS 012
C               SHELL THICKNESS IS SET EQUAL TO TMINN, AND COLLAPSE     TNS 013
C          PRESSURE OF THE NOSE CAP IS CALCULATED. IF COLLAPSE PRESSURE TNS 014
C          IS LESS THAN THE DESIGN PRESSURE, SKIN THICKNESS IS INCREASEDTNS 015
C          BY INCREMENTS OF 0.001 INCH UNTIL COLLAPSE PRESSURE IS EQUAL TNS 016
C          TO OR GREATER THAN THE DESIGN PRESSURE.                      TNS 017
      TCAPST     = TMINN -0.001                                         TNS 018
   90 TCAPST    = TCAPST + 0.001                                        TNS 019
      B          = 0.04*SQRT (RCAP/TCAPST)                              TNS 020
      PCOLL      = A * (TCAPST ** 2)/EXP(B)                             TNS 021
      IF (PCOLL - PDSPH) 90,91,91                                       TNS 022
   91 CONTINUE                                                          TNS 023
      RETURN                                                            TNS 024
      END                                                               TNS 025
```

APPENDIX B

DEFINITIONS OF VARIABLE NAMES

A	-	The length of the free side of a honeycomb cell, in.
AA	-	The height of the stiffening ring, in.
AFACT	-	Used to determine which equations to use in determining wrinkling stress.
AGWRIN	-	Allowable face wrinkling stress, psi.
AIREQ	-	Moment of inertia required of the stiffening ring cross-section, $in.^4$
AIRING	-	Moment of inertia of the stiffening ring, $in.^4$
AISTT	-	Moment of inertia of ring and effective skin, $in.^4$
ALB	-	Bay length, in.
ALCAP	-	Axial length of nose cap, in.
ALCONE	-	Frustum length, in.
ALF (NF)	-	Length of frustum number NF, in.
ALMX2	-	Axial distance from base of bay to top of frustum, in.
ALPHA	-	Angle of attack, degrees when read in and radians when used in computations.
ALTOT	-	Total length of fairing, in.
AMACH	-	Mach number.
AMU	-	Poisson's ratio.
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).

APRC	-	An equivalent radius of curvature of the particular bay under consideration.
AST	-	Cross-sectional area of ring, sq. in.
AXLDCP	-	Axial load contributed by nose cap, lbs.
AXLOAD	-	Axial load at some specified location on fairing, lbs.
B	-	The length of the bonded side of a honeycomb cell, in.
BEND	-	Bending moment at some specified location on fairing, lb-in.
BETA	-	The acute angle formed by the sides of a honeycomb cell, radians.
BETADG	-	The acute angle formed by the sides of a honeycomb cell, degrees.
BNDCAP	-	Bending moment of the nose cap about its base, lbs/in.
BOT	-	The ratio of width of attaching ring flange to ring thickness (see Figure 3).
CASE	-	The number of a particular set of data in a sequence of runs.
CBETA	-	Cosine of the angle BETA.
CCA	-	Honeycomb core allowable compressive stress, psi.
CDCAP	-	Drag coefficient for the spherical nose cap with the base area of the nose cap as a reference area.
CELLWD	-	Calculated honeycomb cell size, in.
CELSIZ	-	Honeycomb cell size reduced to a standard size, in.
CNCAP	-	Normal force coefficient per radian angle of attack for the spherical nose cap using nose cap base area as a reference area, /radian.
COT	-	The ratio of the width of the cap of stiffener to ring thickness (see Figure 3).
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 as CPA(LT).

CPO(LT) - Pressure coefficient at zero angle of attack at station LT.

CPOO - Same as CPO(LT).

CRG - Critical line load for general panel instability, lbs/in.

CSA - Sandwich core allowable shear stress, psi.

CTA - Sandwich core allowable tensile stress, psi.

D (I) - Small diameter of the Ith bay, in.

DBAS - Base diameter of fairing, in.

DBASE - Base diameter of a frustum, in.

DBNSD - Inside base diameter of bay, in.

DD - Distance from the centroid of the stiffening ring to the inside bay wall, in.

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

DELTAS - Bay skin thickness, in.

DINSD - Inside upper diameter of bay, in.

DMIN - Small diameter of frustum, in.

DMN - Same as DMIN.

DOD(LT) - Ratio of local diameter to fairing base diameter at station LT.

DOVDB(NF) - Ratio of small diameter of frustum NF to base diameter of fairing.

DSUBB - Base diameter of bay, in.

DUSE1 - Diameter of area useful for payload at the base of the bay. (See Line SWD 0507 of program listing in Appendix A.)

DUSE2 - Diameter of area useful for payload at top of bay. (See Line SWD 0508 of program listing in Appendix A.)

E - Modulus of elasticity of structural material, in.

ECORE - Modulus of elasticity of core material, psi.

EFACE - Modulus of elasticity of face material, psi.

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.
ENSUBR	-	Radius conversion factor for conical frustums.
FCA	-	Sandwich face allowable compressive stress, psi.
FCFB	-	Ring outstanding flange allowable buckling stress, psi.
FFAX (I)	-	Face axial stress at base of Ith bay, psi.
FFB (I)	-	Face bursting stress in Ith bay, psi.
FFC (I)	-	Face compressive stress in Ith bay, psi.
FFDMP	-	Face dimpling stress, psi.
FFS (I)	-	Face shear stress due to aerodynamic lift, psi.
FFWR (I)	-	Face wrinkling stress, psi.
FRING	-	Maximum compressive stress in ring flange, psi.
FS	-	Factor of safety.
FSA	-	Sandwich face allowable shear stress, psi.
FSBZCP	-	Shear force contributed by nose cap, lbs.
FSUBZ	-	Shear force at a specified location on the fairing, lbs.
FTA	-	Sandwich face allowable tensile stress, psi.
FZ (I)	-	Shear force at the base of the Ith bay, lbs.
G	-	Modulus of shear, psi.
GCORE	-	Modulus of shear of core material, psi.
GC1	-	Effective shear modulus of the honeycomb cellular material in the ribbon direction, psi.
GC2	-	Effective shear modulus of the core in the direction perpendicular to the ribbons, psi.
GFACE	-	Modulus of shear of face material, psi.
G1	-	Effective shear modulus of the core material corrected for height to cell size ratio, in the ribbon direction, psi.

G2 - Effective shear modulus corrected for height to cell size ratio, perpendicular to the ribbon direction, psi.

H - Distance between midplanes of facing sheets, in.

HUSE - Useful axial length of nose cap, in.

I - Index indicating bay. Numbering begins at base of fairing.

IKIND - Type of ring. 1 = angle, 2 = Zee, 3 = hat.

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.

I1 - Lower index used for writing output data.

I2 - Upper index used for writing output data.

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

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

JG - Index used for determining minimum adequate ribbon thickness.

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

KG - Parameter generated by Subroutine INSTBL, indicating that GBAR has exceeded the range in which it is valid.

KTFSTD - An input parameter which tells if standard gauges are to be used for sandwich faces.

RTRSTD - An input parameter which tells if standard gauges are to be used for core ribbons.

KY - An optional control used to obtain faster convergence in Subroutine INSTBL.

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.
LT	-	Index that identifies a particular point on the fairing.
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.)
MATF	-	An integer indicating the type of material to be used for sandwich faces.
NBAY	-	Number of bays in a frustum.
NF	-	Index indicating frustum number.
NFMAX	-	Total number of frustums in the fairing.
P	-	Pressure differential, equal to either PDESMN or PDESMX, as appropriate, psi.
PDESMN	-	Maximum pressure differential across the sandwich, multiplied by the factor of safety, on the leeward side of the bay, psi.
PDESMX	-	Maximum pressure differential across the sandwich, multiplied by the factor of safety, on the windward side of the fairing, psi.
PDIFF	-	Maximum burst pressure differential, psi.
PDSPH	-	Maximum pressure differential across the nose cap skin, multiplied by a factor of safety, psi.
PHI	-	Angle between the applied load and the direction of the honeycomb ribbon.

PSTAT	-	Free-stream pressure, psi.
QBAR	-	Dynamic pressure, lbs/sq. ft.
RCAP	-	Radius of spherical nose cap, in.
RHO	-	Material density, lbs./cu. in.
ROCORE	-	Core material density, lbs/cu. in.
RUSE	-	Radius of nose cap volume which is useful for payload, in.
SCAP	-	Surface area of spherical nose cap, sq. in.
SLOPT	-	Sum of bay lengths within a frustum, in.
SUMAL	-	Distance from the base of the fairing to the base of the bay, 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.
TCONTH	-	Thickness of skin required on the top frustum to limit its temperature to the maximum specified, in.
TCORE(I)	-	Honeycomb core height in the Ith bay, in.
TF	-	Sandwich face thickness, in.
TFACE(I)	-	Face thickness in the Ith bay, in.
THETA	-	Frustum half angle, radians
THTA(NF)	-	Half angle of frustum NF, degrees.
TKCIL	-	Skin thickness required to carry the circumferential load, in.
TKHOOP	-	Skin thickness required for hoop stress due to internal pressure, in.

TKMCL	-	Skin thickness required to carry the meridianal compressive load, in.
TKSAL	-	Skin thickness required for shear stress due to aerodynamic lift, in.
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.
TRBMIN	-	Input value of minimum ribbon thickness, in.
TRBN(I)	-	Ribbon thickness for the Ith bay, in.
TRBSTD(JG)	-	Block data values to be used for ribbon thickness if KTRSTD is equal to 1.
TRIBN	-	Ribbon thickness, in.
TRING (I)	-	Thickness of ring material for optimized design of the Ith bay, in.
TSTD	-	Block data of standard sheet metal gauges, in.
T1	-	Thickness of outer face of sandwich, in.
T2	-	Thickness of inner face of sandwich, in.
VCAP	-	Volume of nose cap which is useful for payload. (See HUSE and RUSE), cu. ft.
VCORE	-	Volume enclosed between the two sandwich faces, cu. in.
VGROS	-	Gross volume of nose cap, cu. in.
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.
W	-	Average length of a core cell wall, equal to 1/2 (ATB), in.
WBOND (I)	-	Weight of adhesive bond material used to attach faces to core, lbs.
WCAP	-	Weight of nose cap, lbs.
WCONE	-	Frustum weight, lbs.
WFACE (I)	-	Weight of both sandwich faces of the Ith bay, lbs.
WRING (I)	-	Weight of ring for the Ith bay, lbs.
WSEG (I)	-	Weight of the Ith bay, lbs.
WSPLCE (I)	-	Weight of panel splices in the Ith bay, lbs.
WTCORE (I)	-	Weight of core material in the Ith bay, lbs.
WTDEX (I)	-	Weight of bay divided by volume of bay, lbs/cu. in.
WTINFC	-	Weight of inner sandwich face material in the Ith bay, lbs.
WTOT	-	Total fairing weight, lbs.
WTOTFC	-	Weight of outer face material in the Ith bay, lbs.
XBCAP	-	Distance from base of nose cap to center of lift pressure on the nose cap, in.
XL	-	Length of bay, in.
Y	-	Warpage correction factor for thick cores.

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, ΔF_N, produced on an incremental length, ΔX, 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, ΔF_N, produced by a short length, ΔX, of this cone is

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

in which ΔA 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, ΔD, for a change in length, ΔX, is

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

in which θ is the half angle of the cone. Substituting Equations C8 and C9 into C7 yields the following expression for ΔF_N:

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

When the two expressions for ΔF_N (Equations C5 and C10) are equated and solved for ΔC_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_α} is plotted as a function of cone half angle θ and Mach number. C_{N_α} is defined as

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

in which α 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 θ 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 α and θ 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 = ΔC_P).

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

In Equation C15, ΔC_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 ΔC_P as a function of X/D between locations $(X/D)_1$ and $(X/D)_2$ is as follows:

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

At a specified location ΔC_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:

ΔC_{P1} = CPA (LT+1)

ΔC_{P2} = CPA (LT)

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

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

Let

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

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

Then, combining Equations D1, D2 and D3

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

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

ΔC_P - Change in pressure coefficient due to angle of attack (identical to CPAA in program listing).

D - Local diameter of fairing

θ - Half angle of frustum

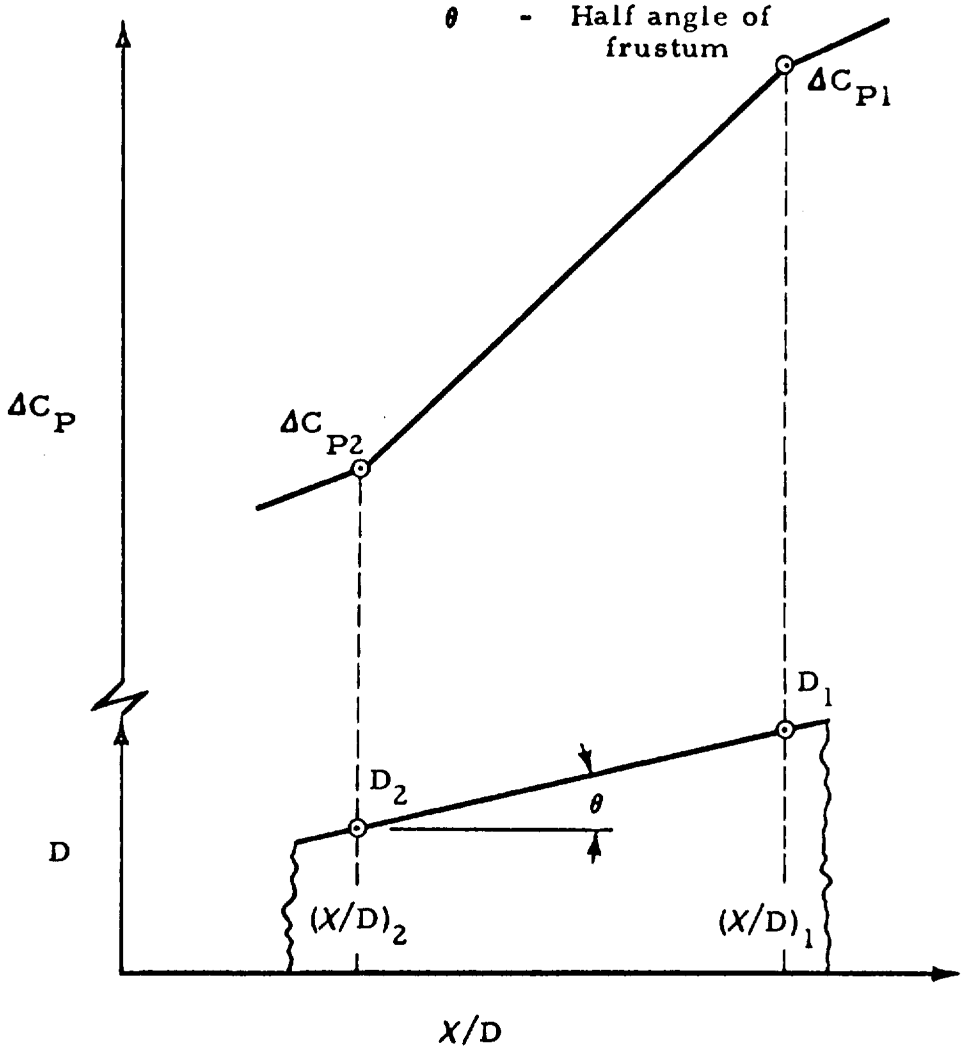

Figure D1 - Nomenclature Used in Derivation of Bending Moment Equation

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, ΔF_N, for an increment of length, ΔX, 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.

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

$$\left. + \beta_3 \left[(X/D)^3 - (X/D)_2^3 \right] \right\} \qquad \text{(D9)}$$

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.

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

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

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 ΔC_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 ΔP 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

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

in which

F_{ax} = Axial force at the base of the bay
D = Diameter at the base of the bay
θ = 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:

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

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

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

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

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_α}, and $\bar{X}$, 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_α} 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:

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

in which ϕ 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_∞, is expressed by the following equation taken from Reference 11.

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

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

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

An expression for P_∞ derived from basic definitions is as follows:

$$P_\infty = \frac{q}{\frac{1}{2}\gamma M^2} \qquad \text{(D28)}$$

For air, Equation D28 reduces to

$$P_\infty = \frac{q}{0.7\ M^2} \qquad \text{(D29)}$$

Using the definition for pressure coefficient

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

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

Combining Equations D27, D29 and D30 yields the following equation

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

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.

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

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:

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

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_α} can then be computed by Equation C14 which is derived in Appendix C.

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

Shear force contribution of the nose cap is

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

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.

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

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

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.

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

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

In which

P_S = surface pressure

P_∞ = free-stream pressure

q = dynamic pressure

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

$$\Delta P = P_{int} - P_\infty \tag{E5}$$

In which

ΔP = 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.

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

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

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

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

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

APPENDIX F

FACE WRINKLING AND DIMPLING

Face wrinkling involves the buckling of one face only. Normally, an analysis is made in a manner similar to a beam on an elastic foundation. The analysis used here (Reference 12) depends upon whether the core is "thin" or "thick". If the core is thin, it is assumed to behave like a group of independent springs with no shearing forces between them. If the core is thick, shear forces between these springs are considered. If $\frac{h}{R} > \frac{2W}{R}$ as determined by the following equation, the core is considered thick.

$$\frac{2W}{R} = \frac{2.496\, t_f}{R} \left(\frac{E/G_c}{t_{c/a}} \right)$$

where:

R = cylinder mean radius
t_f = face thickness
E = elastic modulus of face
G_c = shear modulus of core
t_c = core ribbon thickness
a = free honeycomb-core wall dimension between nodes

For thick cores, wrinkling stress is predicted by

$$\sigma_\omega = 1.66\, (E)^{1/3}\, (G_c)^{2/3}\, (t_c/a)^{2/3}$$

For thin cores, wrinkling stress is predicted by

$$\sigma_\omega = 1.86\, (E)^{1/2}\, (G_c)^{1/2}\, (t_c/a)^{1/2}\, (t_f/h)^{1/2}$$

where:

h = distance between midplanes of face sheets

The above equations predict wrinkling stress levels if there are no imperfections in the face sheets. To approximately account for the deleterious effect of reasonable imperfections, half of the predicted wrinkling stress level has been used as an allowable stress. Normally, designs having practical ribbon and face thicknesses will not be critical for wrinkling.

Face dimpling considerations limit the maximum size of the core hexagon. From Reference 12, the following equation is used to predict dimpling:

$$\sigma_d = \frac{2t_f^2 \; E}{a^2(1-\nu^2)}$$

where:

ν = Poisson's ratio of face sheets.

a = Minimum distance between nodes.

One half of the predicted dimpling stress value as determined by the above equation was used as an allowable stress level.

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.

θ = 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

ΔP = internal to free-stream pressure difference

APPENDIX I

EFFECTIVE SHEAR MODULUS OF HONEYCOMB CELLULAR STRUCTURE

The general instability analysis developed for this program accounts for the effect of transverse shear deformation, hence buckling loads are a function of cone shear stiffness. Core shear stiffness is calculated for aluminum hexagon honeycomb using the analysis of Penzien and Didriksson (Reference 13). The effective shear modulus is

$$G_c = \frac{G \sin\beta\,(R + \cos\beta)}{\frac{A}{t_r}\left[(1 + R)\sin^2\beta\cos^2\phi + (R + \cos\beta)^2\sin^2\phi\right]}$$

where:

G = shear modulus of core material
R = B/A (See Figure 1 below)
t_r = thickness of core material
ϕ = angle between direction of the shear force and ribbon direction

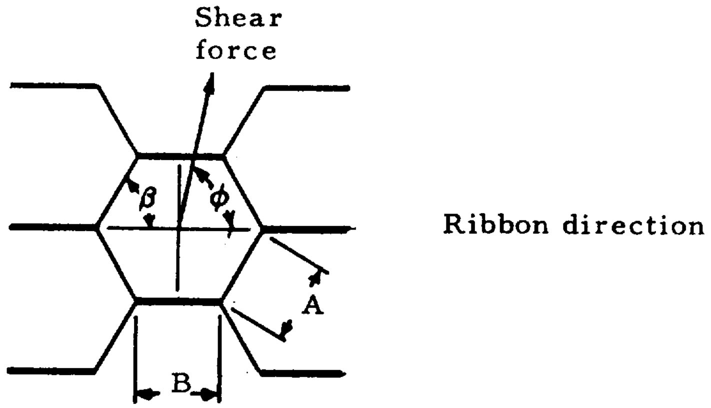

Figure 1 - Geometry of honeycomb cells

A correction factor based on Figure 6 of Reference 13 is also applied to the above equation when the ratio of core height (H) to average cell wall length ($\frac{1}{2}$A + $\frac{1}{2}$B) is 5 or less.

When the ratio of core height to the quantity $W = 0.5\ (A + B)$ is five or less, prevention of warpage increases the effective shear modulus (See Figure 6 of Reference 13). For values of H/W less than five, the effective shear modulus is calculated from the equation

$$G_{ceff} = G_c\ (1 + 0.01Y)$$

where:

$$Y = (9.3/(H/W)) - (2.1/(H/W)^2)$$

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
θ = 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, ^oF

t = thickness of the skin

When applying this data to nose fairing design, θ 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 ¢ in Reference 6 is the complement of θ.)

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.

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

in which

ρ = density of skin

C_p = specific heat of skin

ϵ = 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

$K_4 \epsilon (T_{max} + 460)^4$ = 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.

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

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, θ , 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

GENERAL INSTABILITY ANALYSIS OF HONEYCOMB SANDWICH CYLINDERS

by

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GENERAL INSTABILITY ANALYSIS OF HONEYCOMB SANDWICH CYLINDERS

Summary

In the establishment of the general instability load for a sandwich shell, the practical method of analysis which was recommended in Ref. 1 is used. This method uses the classical buckling load as an upper bound and the minimum postbuckling load as a lower bound to the critical load of the shell. An empirical reduction factor is applied to the upper bound in such a manner that the critical load will not fall below the lower bound. For the case of pure axial compression upper as well as lower bound analyses are available in Ref. 2. The classical buckling load analysis is modified here to include the effects of lateral pressure but the reduction factor has been chosen in a more expedient manner.

Classical Buckling Load

For sandwich cylinders under pure axial compression it was found in Ref. 3 that buckling can occur either in an axisymmetrical or in a nonsymmetrical mode, the former being critical for cylinders with weaker cores. It may be shown that the critical axial load corresponding to symmetrical buckling is independent of the lateral pressure. On the other hand the nonsymmetrical buckling load is reduced in the presence of an external pressure. According to Ref. 2, for the symmetrical pattern:

$$\bar{N} = (1 + F)z + 1/(4z) - 4z^2/[4z + (1/\bar{G})]$$

Here $\bar{N}$ is to be minimized with respect to the wavelength parameter z .

After addition of the influence of external pressure, we have for the nonsymmetrical buckling mode:

$$\begin{aligned}\bar{N} = {} & (1 + F)(1 + \beta^2)^2/(4\beta^2/\eta) + (\beta^2/\eta)/(1 + \beta^2)^2 \\ & + (b_2^2 + \mu c_2^2)/(4\beta^2/\bar{G}) + s_2/(8\beta^2/\eta) - \bar{p}/\beta^2\end{aligned}$$

where

$$\begin{aligned}s_2 = {} & 2[\beta^2 b_1^2 + \mu^2 c_2^2 + 2\nu\mu\beta b_2 c_2 + 2(1 - \nu)(b_2 + \mu\beta c_2)^2 \\ & + 4[b_2\beta(2 - \nu + \beta^2) + c_2\mu\{1 + (2 - \nu)\beta^2\}]]\end{aligned}$$

$$b_1 = -8\beta^3/[1/(\bar{G}\eta) + 4\beta^2] \tag{1}$$

$$\begin{aligned}b_2 = {} & -\beta(1 + \beta^2)\{1/(\bar{G}\eta) + (1 - \nu)\mu\beta^2\}/[\{1/(\bar{G}\eta) + (1 - \nu)\mu\beta^2 + \mu\} \\ & \{1/(\bar{G}\eta) + 1 - \nu + \beta^2\} - \mu\beta^2]\end{aligned}$$

$$\begin{aligned}c_2 = {} & -(1 + \beta^2)\{1/(\bar{G}\eta) + 1 - \nu\}/[\{1/(\bar{G}\eta) + (1 - \nu)\mu\beta^2 + \mu\} \\ & \{1/(\bar{G}\eta) + 1 - \nu + \beta^2\} - \mu\beta^2]\end{aligned}$$

The nonsymmetrical buckling load is found through minimization of $\bar{N}$ with respect to the wavelength parameters η and β. These parameters can only take on the specific values which correspond to an integer value for the number of waves in the circumferential and the number of halfwaves in the axial direction. However, we will only apply here the restriction that the axial halfwave length cannot be larger than the shell length. That is

$$\eta \le \alpha/\beta^2$$

where, for equal face sheets

$$\alpha = \pi^2\sqrt{1 - \nu^2}\,Rh/L^2$$

In the computer program the symmetrical buckling load is first determined. The equation $\partial\bar{N}/\partial z = 0$ is solved by use of the Newton-Raphson method. As initial estimates for z are used

$$z = \begin{cases} 1/(2 - 4\bar{G}) & \text{if } \bar{G} < .5 \\ 1/\sqrt{4F} & \text{if } \bar{G} \geq .5 \end{cases}$$

It appears that the Newton-Raphson method would be most efficient whenever reasonably close estimates are available. In the procedure of optimization close estimates are generally available in the form of previous solutions. In such cases the Newton-Raphson method is used directly. However, when a new case is started close initial estimates are not available and the procedure is modified as follows. The initial estimates are

$$\beta = 1$$

$$\eta = \begin{cases} 2\alpha & \text{if } \alpha \geq 1 \\ 1 & \text{if } \alpha < 1 \end{cases}$$

These estimates are improved by use of the steepest descent method before they are used in the Newton-Raphson method. If during iteration η becomes less than α/β^2 this indicates that buckling will be with one halfwave in the axial direction. Consequently we set $\eta = \alpha/\beta^2$ and minimize with respect to β only. After minimization the proper value of $\bar{N}$ is computed and the classical buckling load is chosen as the lowest of the symmetrical and non-symmetrical buckling loads.

Reduction Factor

Inclusion of lateral pressure in the lower bound analysis would be a major undertaking and was not considered necessary for the purpose of this study. For monocoque cylinders it was shown in Ref. 3 that the ratio between lower and upper bound increases when an internal pressure is added. It seems reasonable to assume that this is the case also for sandwich cylinders. It is well known also that for cylinders under external pressure the agreement between theory and test is much better than it is for cylinders under axial compression. Consequently it seems safe to assume that a conservative estimate of the reduction factor will be obtained if the effect of lateral pressure is neglected. It is expected that the shells in this investigation will be primarily subjected to axial compression and thus the conservatism involved will be moderate.

When the effects of lateral pressure are neglected, the ratio $N_{min}/N_{c\ell}$ may be obtained from Ref. 2. A number of values of $N_{min}/N_{c\ell}$ are read from the curves of that analysis and stored in the computer. These values correspond to different shell parameter combinations in such a manner that intermediate results can be obtained easily through interpolation.

According to Ref. 1:

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

where

$$c = \frac{\varphi - 0.12}{0.88}$$

$$\varphi = \begin{cases} 1.0 & \text{for } (R/t)_e \le 33 \\ 6.48/[(R/t)_e] & \text{for } (R/t)_e > 33 \end{cases} \qquad (2)$$

For equal face sheets

$$(R/t)_e = R/\sqrt{t^2 + 3h^2}$$

Nomenclature

R	mean radius of cylinder
E	Young's modulus of face sheets
ν	Poisson's ratio of face sheets
t	thickness of face sheets
h	distance between midplanes of face sheets
G_1	shear modulus of core in axial direction
G_2	shear modulus of core in circumferential direction
ℓ_x, ℓ_y	axial and circumferential half-wave lengths
p	external pressure
N	axial compressive load per unit width
$\bar{N}$	$RN(1 - \nu^2)^{1/2}/(2Eht)$
$\bar{p}$	$R^2p(1 - \nu^2)^{1/2}/(Eht)$
F	$(t/h)^2/3$
$\bar{G}$	$1/2(E/G_1)(t/R)(1 - t/h)(1 - \nu^2)^{-1/2}$
μ	G_1/G_2
α	$\pi^2(1 - \nu^2)^{1/2}(Rh/L^2)$
z	β^2/η
β	ℓ_y/ℓ_x
η	$\pi^2(1 - \nu^2)^{1/2}(Rh/\ell_y^2)$
$N_{min}/N_{c\ell}$	ratio between lower and upper bounds for critical load
c	see Eq. 2
φ	see Eq. 2
b_1, b_2, c_2, s_2	see Eq. 1
$(R/t)_e$	$R/\sqrt{t^2 + 3h^2}$

Subroutine Symbols

CRG1	critical buckling line load (pounds/in)
E	Young's modulus of facing sheets
G1	Effective shear modulus of core in axial direction
G2	Effective shear modulus of core in circumferential direction
HT	distance between midplanes of sandwich facing sheets
K	optional control; used to speed up calculations for classical buckling load if desired
P	collapse pressure (psi); burst pressure is entered as negative quantity
RD	cylinder mean radius
T1, T2	thicknesses of face sheets
XL	cylinder length
XNU	Poisson's ratio of facings material

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