DAVID BUSHNEL

DECEMBER 1974 LMSC-D407166

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BOSOR5 – A COMPUTER PROGRAM FOR BUCKLING OF ELASTIC-PLASTIC COMPLEX SHELLS OF REVOLUTION INCLUDING LARGE DEFLECTIONS AND CREEP

VOL. 1: USER'S MANUAL, INPUT DATA

By
DAVID BUSHNELL

THIS RESEARCH WAS SPONSORED BY
THE DEPARTMENT OF STRUCTURAL MECHANICS
OF THE NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER
AND ADMINISTERED BY
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UNDER
CONTRACT N00014-73-C-0065

LOCKHEED MISSILES & SPACE COMPANY, INC.
A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION
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FOREWORD

This work was sponsored by the Structural Mechanics Laboratory of the Naval Ship Research and Development Center, Carderock, Maryland (NSRDC) under Contract N00014-73-C-0065. The work was administered under the direction of the Naval Ship Research and Development Center with Dr. Rembert Jones, Mr. Tom Kiernan, and Ms. Joan Roderick as technical monitors.

TABLE OF CONTENTS

SECTION

ABSTRACT

This volume contains the instructions to the user for constructing data decks for the BOSOR5 computer program. BOSOR5 runs on the UNIVAC 1108 and the CDC6600. It is divided into three separate programs, a pre-processor, a main-processor, and a post-processor. These programs may be run as one job in a runstream or separately. The program includes a restart capability. BOSOR5 can handle segmented and branched shells with discrete ring stiffeners, meridional discontinuities, and multi-material construction. The shell wall can be made up of as many as six layers, each of which is of a different nonlinear material. In the prebuckling analysis axisymmetric behavior is presumed. Bifurcation buckling loads are computed corresponding to axisymmetric or non-axisymmetric buckling modes. The strategy for solving the nonlinear prebuckling problem is such that the user obtains reasonably accurate answers even if he uses very large load or time steps. BOSOR5 has been checked by means of numerous runs in which the results have been compared to other analyses and to tests.

SECTION

SECTION 1

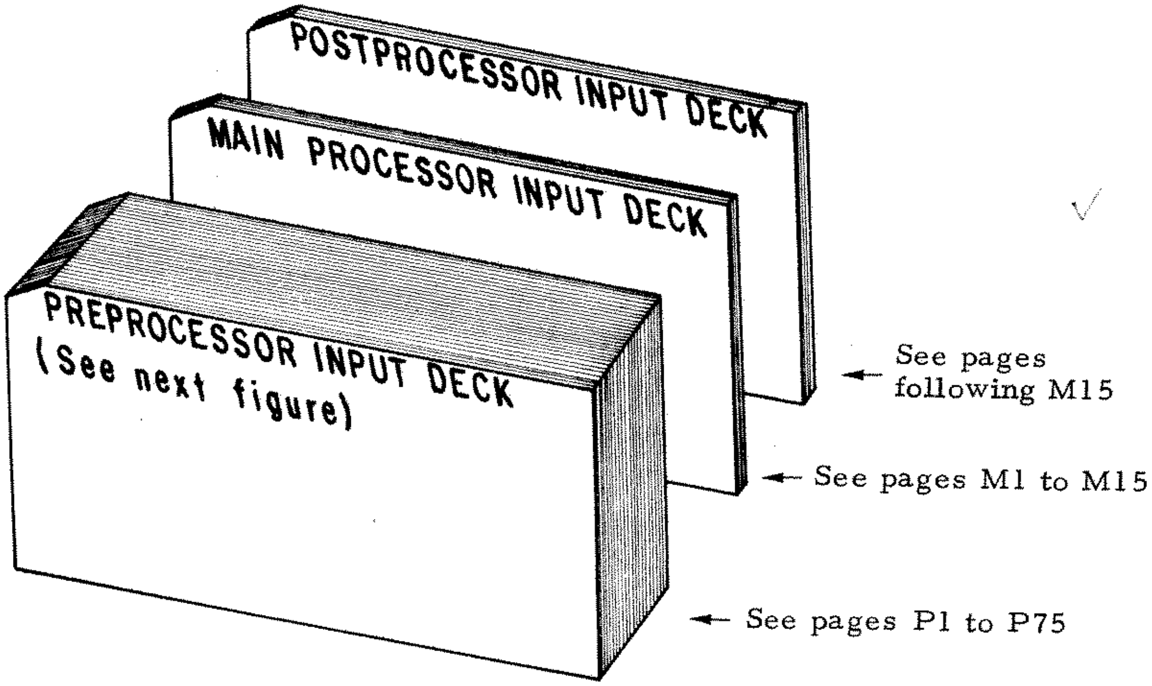
PROLOGUE

ACKNOWLEDGMENTS

The author is particularly indebted to Jessie Vosti, who drew the figures in this user's manual. Some of the subroutines used in BOSOR5 were written by others than myself: Frank Brogan wrote FACTR and SOLVE for solving linear equation systems and EBAND2 for extracting eigenvalues and eigenvectors; Chet Dyche wrote PLOTOP for plotting displacements, stresses, and stress resultants; Tom Petersen wrote GEOPLT and ARROW for plotting the undeformed and deformed structure and line loads; and Bill Loden wrote GASP for transferring data to and from core and auxiliary devices. The author also appreciates the many fruitful discussions with Bo Almroth, Phil Underwood, and Jorgen Skogh, colleagues at LMSC and John Hutchinson of Harvard University, all very knowledgeable in the fields of large deflections, plasticity, and creep. Joan Roderick of NSRDC was very helpful in providing suggestions as to how to make BOSOR5 easy to use.

1.1 GENERAL STRUCTURE OF THE BOSOR5 INPUT DATA DECK

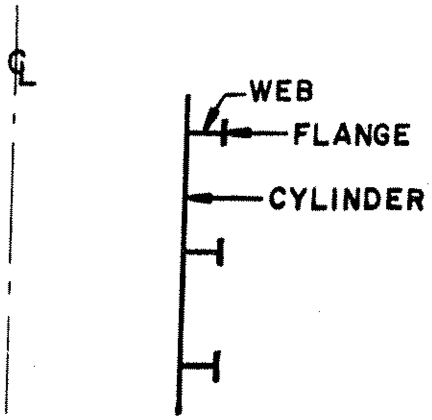
BOSOR5 is divided into three parts, a preprocessor, a main processor, and a postprocessor. Most of the input data is read by the preprocessor. The figure below shows the structure of a typical data deck. The three parts of BOSOR5 can be run separately. It is possible to restart a case.

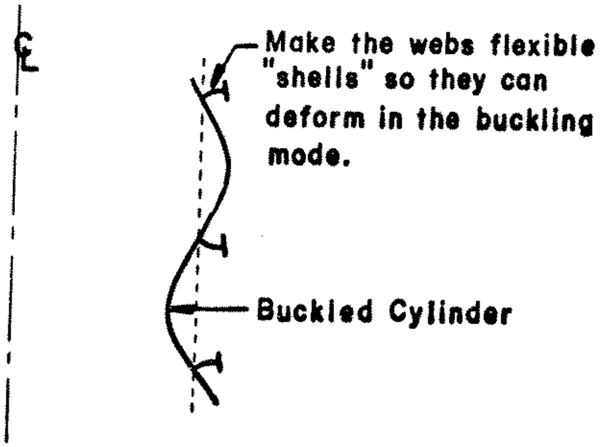


BØSØR5 INPUT DATA

1.2 MODELING DISCRETE RINGS WHEN LOCAL BUCKLING BETWEEN RINGS IS POSSIBLE

BOSOR4 users have found that sometimes the buckling loads predicted for ring-stiffened cylinders are higher than expected. The predicted buckling modes were always local in such cases. (Maximum deflection between rings with rings at nodes in the buckling pattern). Aside from the question of initial imperfections, there is another reason that too high buckling loads may be calculated: In the actual structure the webs of ring stiffeners probably deform considerably in the local buckling mode. This deformation can be accounted for if the webs of the rings are treated as shell branches. It is urged that you include in your parameter studies a branched model, at least for a section of ring-stiffened shell spanning at least two adjacent rings. Rarely is it necessary to include the outstanding flanges as shells. They can remain discrete rings. See the paper "Evaluation of Various Analytical Models" . . . by David Bushnell in the AIAA JOURNAL, Vol. 11, No. 9, Sept. 1973, pp. 1283-1291 for more details.

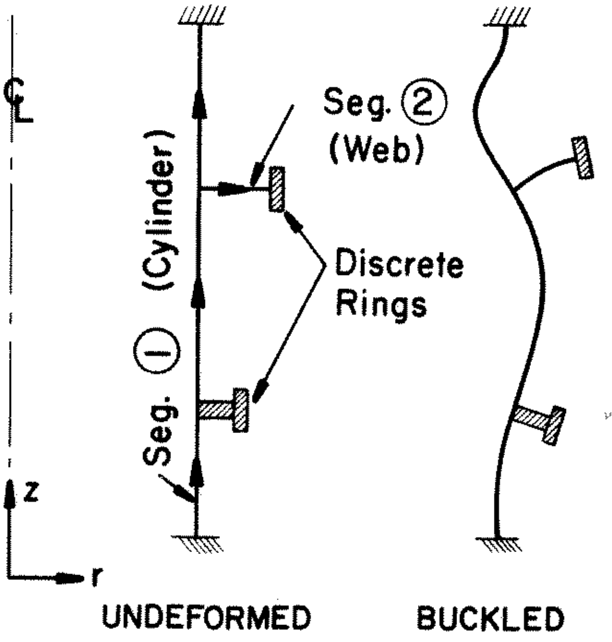




1.3 SOME USEFUL HINTS ON HOW TO SET UP A CASE

1. Decide how many segments the shell should be divided into. Should ring stiffeners be treated as shell segments or discrete rings? It is often advisable to handle ring webs as flexible shell segments rather than as discrete ring segments.

2. Decide how to number the segments. Think of the axis of revolution as being vertical and the shell meridian that you are working with as being to the right-hand-side of this axis. Try to "travel" along the structure in a generally "northeasterly" direction whenever possible.

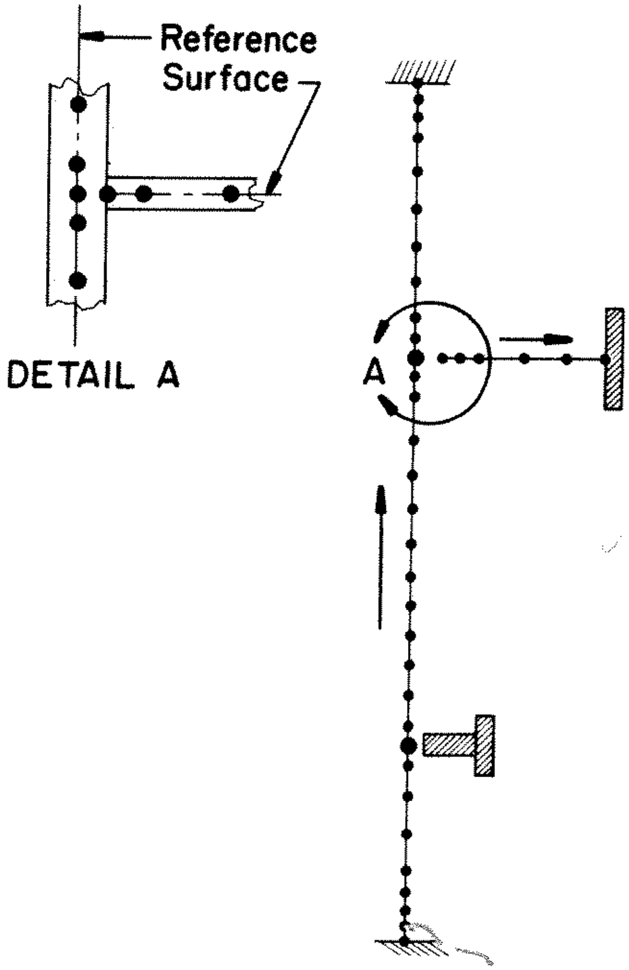


3. Lay out the entire structure on graph paper.

4. Use the middle surface as a reference surface whenever it is reasonably easy to do so. Convergence with increasing mesh point density is fastest that way.

5. Decide on mesh point distributions in each segment. Show the nodal points on the graph paper. Nodes should be located at discrete ring stations and at branch stations. Nodes should be equally spaced for at least one interval on either side of these rings and branch stations.

6. Plan to use at least 5 nodes per half-wavelength of the probable buckling modes. Concentrate nodes near stress concentrations.



CDC DECK FOR INITIAL RUN OF BOSOR5 PRE, MAIN, AND POST-PROCESSORS

```
REQUEST(TAPE2,*PF)
REQUEST(TAPE3,*PF)
ATTACH(BREAD,BREAD)
ATTACH(BMAIN,BMAIN)
ATTACH(BPOST,BPOST)
COPYBR(INPUT,DATA)
REWIND(DATA)
COPYSBF(DATA)
REWIND(DATA)
LDSET(PRESET=ZERO)
BREAD(DATA)
REWIND(DATA)
REWIND(TAPE2,TAPE3)
COPYBR(INPUT,DATA)
REWIND(DATA)
COPYSBF(DATA)
REWIND(DATA)
LDSET(PRESET=ZERO)
BMAIN(DATA)
REWIND(DATA)
REWIND(TAPE2,TAPE3)
COPYBR(INPUT,DATA)
REWIND(DATA)
COPYSBF(DATA)
REWIND DATA)
LDSET(PRESET=ZERO)
BPOST(DATA)
CATALOG(TAPE2,BSMALL)
CATALOG(TAPE3,BLARGE)
*
   DATA FOR BOSOR5 PREPROCESSOR GOES HERE

*
   DATA FOR BOSOR5 MAIN PROCESSOR GOES HERE.

*
   DATA FOR BOSOR5 POST PROCESSOR GOES HERE

*
**
```

ATTACH(BREAD,BREAD), ATTACH(BMAIN,BMAIN), ATTACH(BPOST,BPOST) } — absolute elements of BOSOR5 pre, main, post processors

Scope 3.4
BOSOR5
April 1977

CATALOG(TAPE2,BSMALL) ← sequential file

CATALOG(TAPE3,BLARGE) ← random access file.

CDC DECK FOR RESTART RUN OF BOSOR5 MAIN PROCESSOR

```
ATTACH(FILE2,BSMALL)
REQUEST(TAPE2,*PF)
COPYBF(FILE2,TAPE2)
ATTACH(FILE3,BLARGE)
REQUEST(TAPE3,*PF)
COPY(FILE3,TAPE3)
REWIND(TAPE2,TAPE3)
ATTACH(BMAIN,BMAIN)
COPYBR(INPUT,DATA)
REWIND(DATA)
COPYSBF(DATA)
REWIND(DATA)
LDSET(PRESET=ZERO)
BMAIN(DATA)
PURGE(FILE2)
PURGE(FILE3)
CATALOG(TAPE2,BSMALL)
CATALOG(TAPE3,BLARGE)
*
```

Scope 3.4

BOSOR5

~~(Except~~ April 1977

DATA FOR MAIN PROCESSOR GOES HERE

```
*
**
```

UNIVAC 1110 CONTROL CARDS
INITIAL RUN

THE FOLLOWING IS A RUNSTREAM IN WHICH YOU ARE STARTING FROM SCRATCH.

IN THIS EXAMPLE I SHOW ALL THREE BOSOR5 PROCESSORS BEING EXECUTED IN THE RUNSTREAM. USUALLY YOU WILL RUN ONLY THE PREPROCESSOR AND THE MAINPROCESSOR IN A SINGLE RUNSTREAM. YOU WILL THEN USE THE POSTPROCESSOR AFTER YOU HAVE OBTAINED THE RESULTS OF THE FIRST RUN. DATA FROM THIS RUN ARE STORED ON BSMALL (A SEQUENTIAL FILE ONLY 550 WORDS IN LENGTH) AND ON BLARGE (A LARGE RANDOM-ACCESS FILE).

```
[DELETE,C DB*BSMALL.
[ASG,UP DB*BSMALL.,F2
[USE 15,DB*BSMALL
[DELETE,C DB*BLARGE.
[ASG,UP DB*BLARGE.,F2
[USE 27,DB*BLARGE
[ASG,A DB*BOSORREAD.
[XQT DB*BOSORREAD.

      INSERT THE DATA CARDS FOR THE PREPROCESSOR HERE.

[ASG,A DB*BOSORMAIN.
[XQT DB*BOSORMAIN.

      INSERT THE DATA CARDS FOR THE MAINPROCESSOR HERE.

[PIC
[ASG,A DB*BOSORPOST.
[XQT DB*BOSORPOST.

      INSERT THE DATA CARDS FOR THE POSTPROCESSOR HERE.

[FIN
```

UNIVAC 1110 CONTROL CARDS
RESTART RUN

THE FOLLOWING IS A RUNSTREAM IN WHICH YOU ARE RESTARTING A CASE AFTER HAVING OBTAINED SOME DATA FROM A PREVIOUS RUN. DATA FROM A PREVIOUS RUN OR RUNS HAVE BEEN STORED ON THE PERMANENT FILES BSMALL AND BLARGE. THESE DATA WILL BE USED BY THIS RUN.

```
[ASG,A DB*BSMALL.
[USE 15,DB*BSMALL
[ASG,A DB*BLARGE.
[USE 27,DB*BLARGE
[ASG,A DB*BOSORMAIN.
[XQT DB*BOSORMAIN.
```

INSERT THE DATA CARDS FOR THE MAINPROCESSOR HERE.

```
[PIC
[ASG,A DB*BOSORPOST.
[XQT DB*BOSORPOST.
```

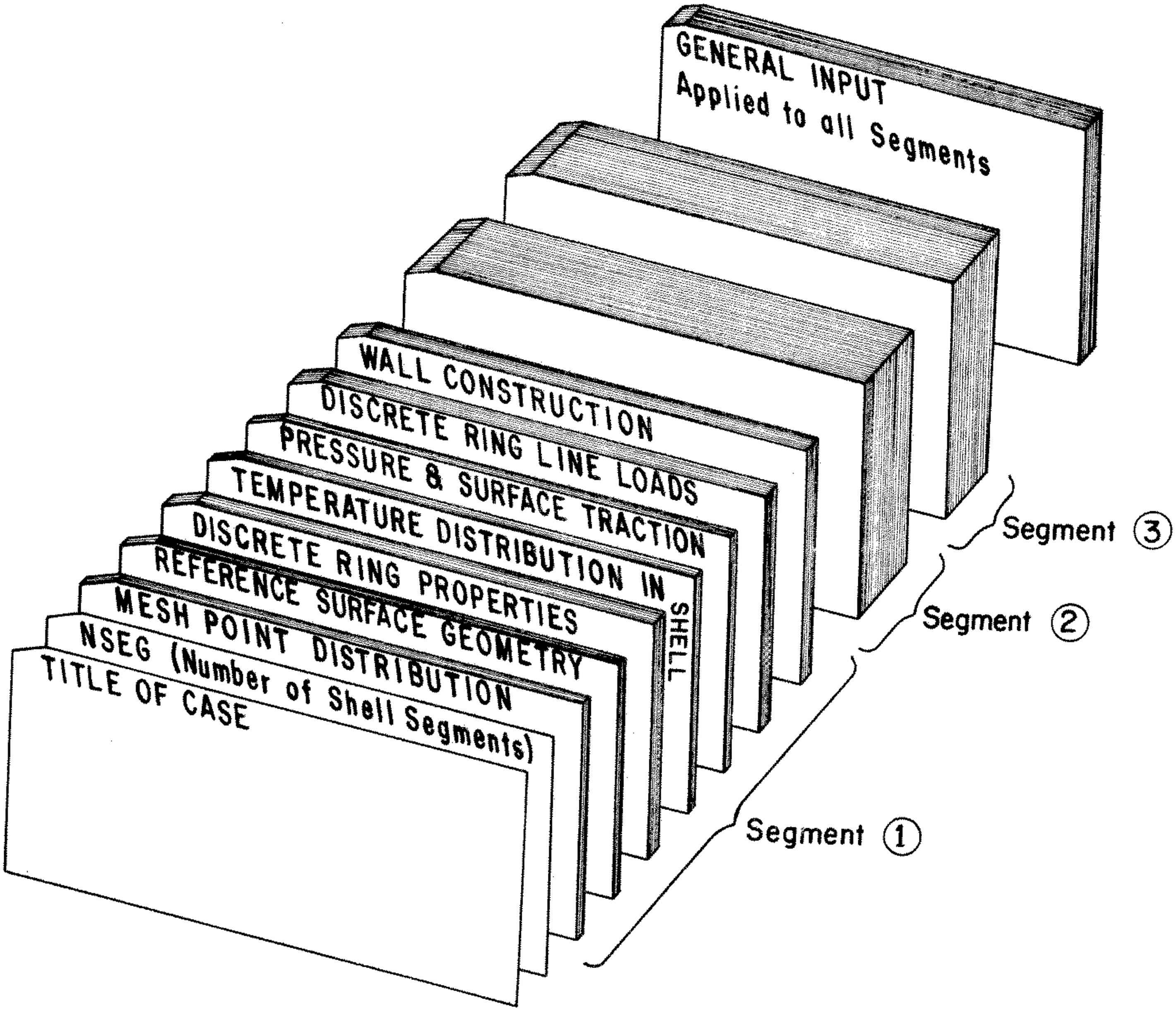
INSERT THE DATA CARDS FOR THE POSTPROCESSOR HERE.

```
[FIN
```

SECTION 2

USER INSTRUCTIONS FOR THE BOSOR5 PREPROCESSOR

SUBSECTION PAGE



PREPROCESSOR INPUT DECK

(Input data formats appear in these columns)

DATA 12A6 **TITLE(12)**

TITLE OF CASE. FIRST 41 CHARACTERS APPEAR ON PLOTS.

DATA I6 **NSEG**

NSEG= TOTAL NUMBER OF SHELL SEGMENTS. ALL OF THE FOLLOWING DATA THROUGH STATEMENT LABEL 1000 ARE READ IN FOR EACH AND EVERY SHELL SEGMENT. UP TO 24 SHELL SEGMENTS CAN BE HANDLED.

NOW BEGIN THE LOOP OVER ALL SHELL SEGMENTS....

5 CONTINUE

****** DO 1000 ISEG = 1 TO NSEG *********** (LOOP OVER ALL SEGMENTS)

DATA 5I6 ** NMESH, IFACT, INTVAL(ISEG) **

6

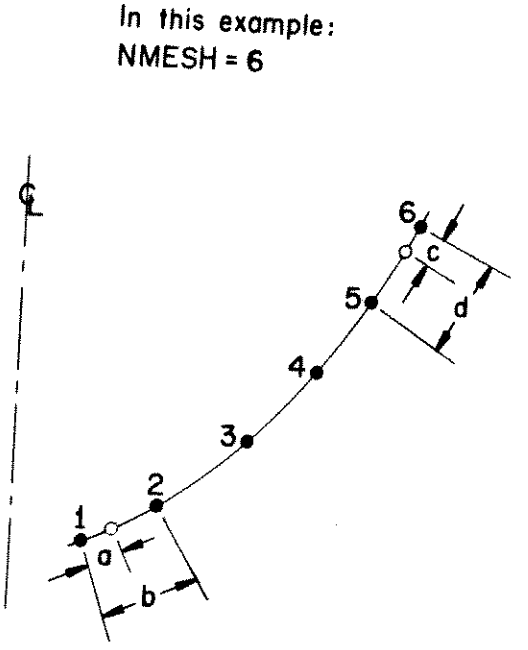
NMESH= NUMBER OF MESH POINTS IN SEGMENT ISEG. RANGE OF NMESH IS 3 TO 98 (DURING EXECUTION TWO ADDITIONAL MESH POINTS ARE ADDED, ONE ADJACENT TO EACH SEGMENT END. THIS IS TO MINIMIZE TRUNCATION ERRORS WHICH ARE BIGGER AT SEGMENT BOUNDARIES THAN ELSEWHERE. IN THE INPUT DATA, YOU ASSUME THESE EXTRA TWO MESH POINTS DO NOT EXIST. BOSOR5 WILL MAKE APPROPRIATE ADJUSTMENTS AUTOMATICALLY.) SEE THE FIGURE OPPOSITE

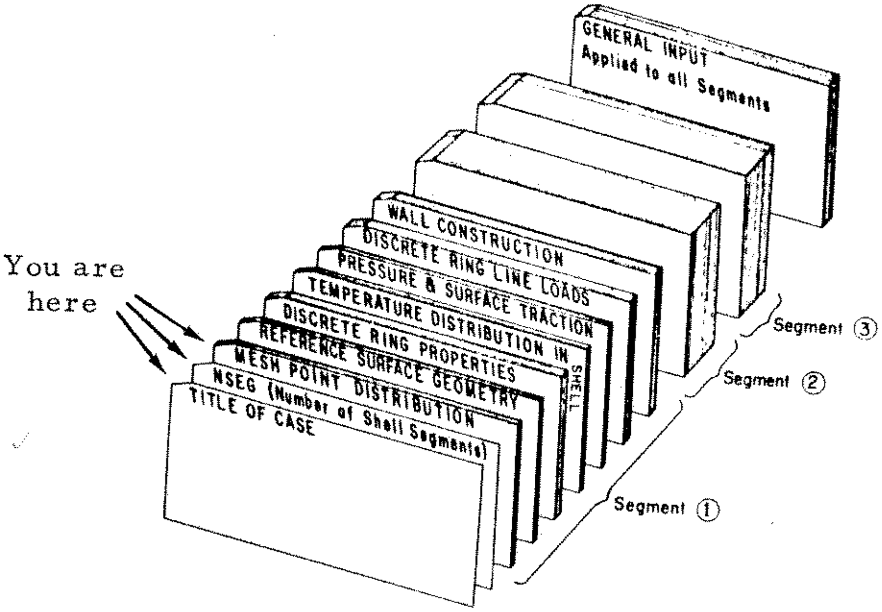
IFACT =CONTROL INTEGER FOR LOCATION OF 'EXTRA' 'W' MESH POINTS WHICH ARE INSERTED ADJACENT TO SEGMENT ENDS. FOR EXAMPLE, IFACT=3 WOULD MEAN THAT THE EXTRA POINTS ARE INSERTED ONE THIRD OF THE DISTANCE BETWEEN THE EDGE POINT AND THE POINT NEXT TO THE EDGE POINT. IF IFACT IS LESS THAN 2, THE EXTRA POINT WILL BE LOCATED 1/20TH OF THE DISTANCE BETWEEN THE EDGE POINT AND THE POINT ADJACENT TO THE EDGE POINT. USER SHOULD ORDINARILY USE IFACT=0. RANGE OF IFACT IS 0-20. SEE THE FIGURE.

INTVAL(ISEG)= PREBUCKLING STRESSES AND STRAINS WILL BE PRINTED OUT FOR EVERY INTVAL(ISEG)TH LOAD STEP. SINCE THESE PREBUCKLING QUANTITIES ARE CALCULATED BY THE BOSOR5 POSTPROCESSOR FOR ANY USER-SELECTED COLLECTION OF LOAD STEPS, A VALUE OF INTVAL(ISEG) BETWEEN 3 AND 20 IS PROBABLY MOST SUITABLE HERE.

NMESH . . .

Number of mesh points in a shell segment. NMESH is one of the most important variables in the analysis, since it governs, to a large extent, the accuracy of the solution. A feeling for proper value for NMESH comes with experience. Few points are needed for cases in which the solution is expected to vary slowly along the shell meridian. Points should be concentrated in areas where the solution is expected to vary rapidly. Note that buckling modal displacements may not necessarily vary rapidly in the same areas as prebuckling quantities. If the accuracy of some numerical results is in doubt one may run the case again with more or with fewer mesh points. A jagged solution for the buckling mode indicates the need for more mesh points. If one is planning to perform a parameter study based on shells of similar geometries one should choose a sample case and run with different numbers and distributions of mesh points.

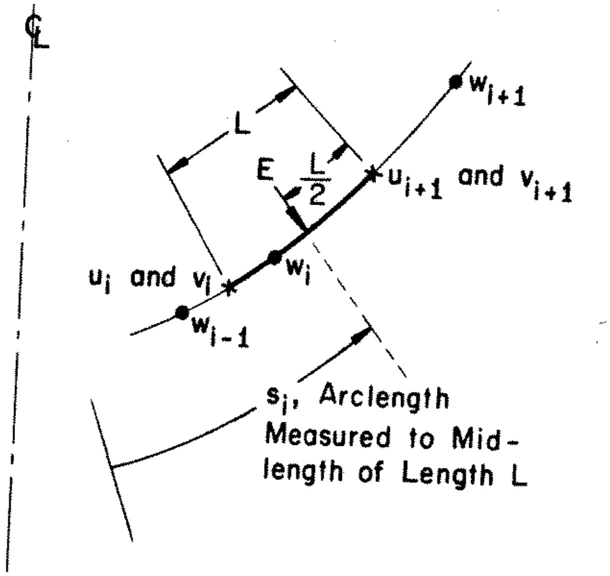




IFACT = b/a = d/c

● User-Specified "w" Nodal Points

○ Additional Nodal Points Automatically Added by BØSØR5 to Reduce Truncation Error at Boundaries of Shell Segments.



WHERE ALL THE MESH POINTS ARE:

L = elemental integration length

E = point where geometry, stresses, strains, displacements are evaluated, and discrete rings are attached.

u and v nodal points are located halfway between the w nodal points.

```
          NEXT. READ INPUT FOR MESH POINT DISTRIBUTION IN THIS
          SEGMENT...                              (MESH POINT DISTRIBUTION)

DATA    I6    **NTYPEH**

          NTYPEH= CONTROL INTEGER FOR VARIABLE OR CONSTANT
                  MESH POINT SPACING..

                  IF NTYPEH = 1 SPACING OF MESH POINTS WILL BE
                                SPECIFIED AT CERTAIN MESH POINTS.
                                THE SPACING EVERYWHERE WILL THEN
                                BE DETERMINED BY LINEAR INTER-
                                POLATION.  SEE FIG.   *** GO TO 10 ***

                  IF NTYPEH = 2 SPACES BETWEEN ALL MESH POINTS
                                WILL BE READ IN.       *** GO TO 20 ***

                  IF NTYPEH = 3 SPACING IS CONSTANT. *** GO TO 30 ***

 10     CONTINUE                                 (MESH POINT DISTRIBUTION)
          SEE THE FIGURE FOR THIS OPTION.

DATA    I6    **NHVALU**                                         (NTYPEH=1)

          NHVALU= NUMBER OF STATIONS IN THIS SEGMENT FOR         (NTYPEH=1)
                  WHICH MESH POINT SPACING IS CALLED OUT.        (NTYPEH=1)
                  RANGE IS 2 TO 50                               (NTYPEH=1)

DATA   10I6   **(IHVALU(J), J=1, NHVALU)**                       (NTYPEH=1)

          IHVALU(J)= MESH POINT NUMBER CORRESPONDING TO JTH      (NTYPEH=1)
                     CALLOUT. THIS IS THE 'W' POINT JUST         (NTYPEH=1)
                     BEFORE THE CORRESPONDING SPACING.           (NTYPEH=1)
                     FIRST MESH POINT AND SECOND-TO-LAST         (NTYPEH=1)
                     MESH POINT MUST BE INCLUDED.  ALL CALL-     (NTYPEH=1)
                     OUTS MUST BE SPECIFIED IN ASCENDING ORDER.

DATA  6E12.8  **( HVALU(J), J= 1,NHVALU)**                       (NTYPEH=1)

         HVALU(J)= ARC LENGTH FROM MESH POINT NO. IHVALU(J)      (NTYPEH=1)
                   TO MESH POINT NO. IHVALU(J) + 1               (NTYPEH=1)
         THE FIGURE ILLUSTRATES THE PROPER INPUT DATA .          (NTYPEH=1)

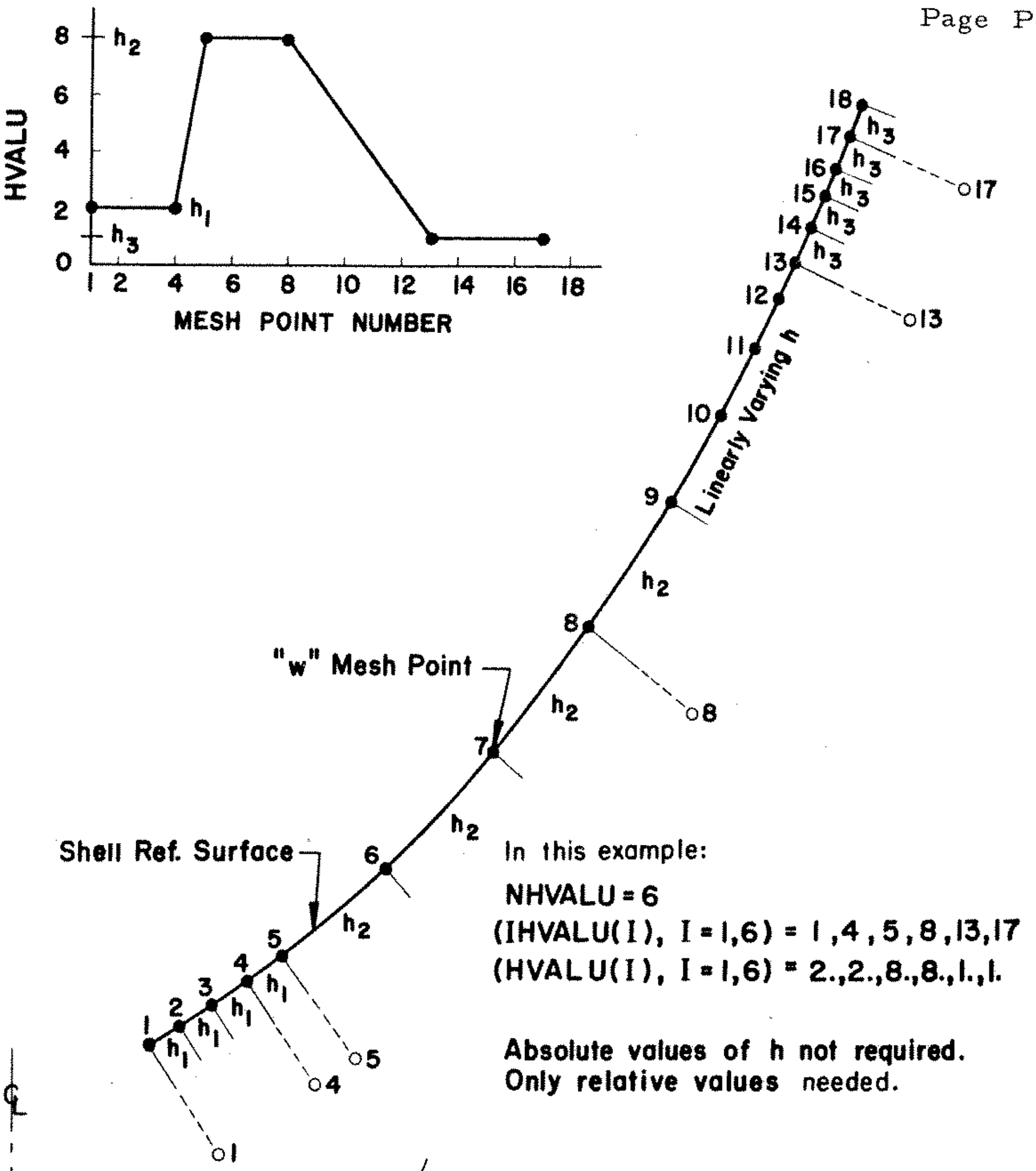
      ***GO TO 30***

20      CONTINUE

DATA  6E12.8  **( HVALU(J), J=1, NMESH-1)**                      (NTYPEH=2)

         HVALU(J)= ARC LENGTH FROM MESH POINT J TO MESH          (NTYPEH=2)
                   POINT J+1                                     (NTYPEH=2)
         NMESH = NUMBER OF MESH POINTS IN CURRENT SEGMENT.

      ***GO TO 30***
```



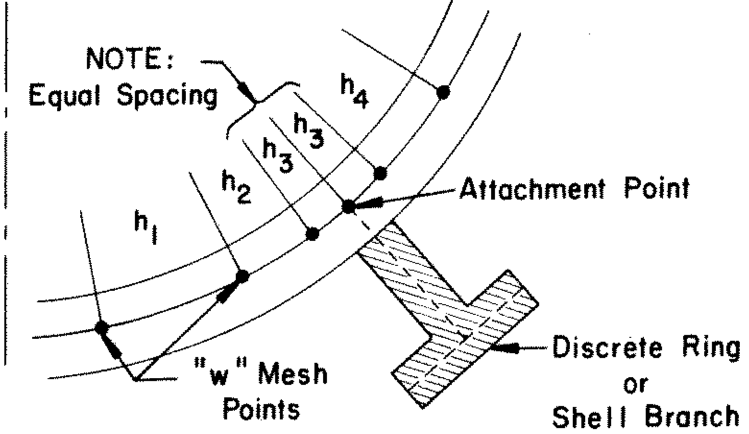
In this example:

NHVALU = 6

(IHVALU(I), I = 1,6) = 1, 4, 5, 8, 13, 17

(HVALU(I), I = 1,6) = 2., 2., 8., 8., 1., 1.

Absolute values of h not required. Only relative values needed.



NOTE: "w" Nodes should be equally spaced for at least one interval (h_3 in example immediately above) on either side of any discrete ring attachment point or shell branch point.

```
30     CONTINUE
             NEXT, READ GEOMETRY PARAMETERS FOR THIS SEGMENT....

DATA    I6    **NSHAPE**
                                                            (SHELL GEOMETRY)

             NSHAPE= CONTROL INTEGER FOR SHAPE OF  MERIDIAN OF
                     THIS SHELL SEGMENT...

                     NSHAPE=1 IS FOR FLAT PLATE, CONE, OR CYLINDER
                              *** GO TO 40 ***

                     NSHAPE=2 IS FOR OGIVAL, SPHERICAL, OR TOR-
                             OIDAL SEGMENT. *** GO TO 50 ***

                     NSHAPE=4 IS FOR GENERAL MERIDIONAL SHAPE
                              *** GO TO 60 ***

40     CONTINUE
                                                            (SHELL GEOMETRY)
            NEXT, READ DATA FOR CYLINDRICAL, CONICAL, OR FLAT PLATE
            SEGMENT.....

DATA   4E12.8 **R1, Z1, R2, Z2**
                                                                  (NSHAPE=1)

            R1= RADIUS FROM AXIS OF REVOLUTION TO BEGINNING OF (NSHAPE=1)
                REFERENCE SURFACE. SEE FIGURE                  (NSHAPE=1)
            Z1= AXIAL DISTANCE FROM SOME DATUM TO BEGINNING OF (NSHAPE=1)
                REFERENCE SURFACE.                             (NSHAPE=1)
            R2= RADIUS FROM AXIS OF REVOLUTION TO END OF REFER (NSHAPE=1)
                ENCE SURFACE.                                  (NSHAPE=1)
            Z2= AXIAL DISTANCE FROM DATUM TO END OF REF. SURF. (NSHAPE=1)

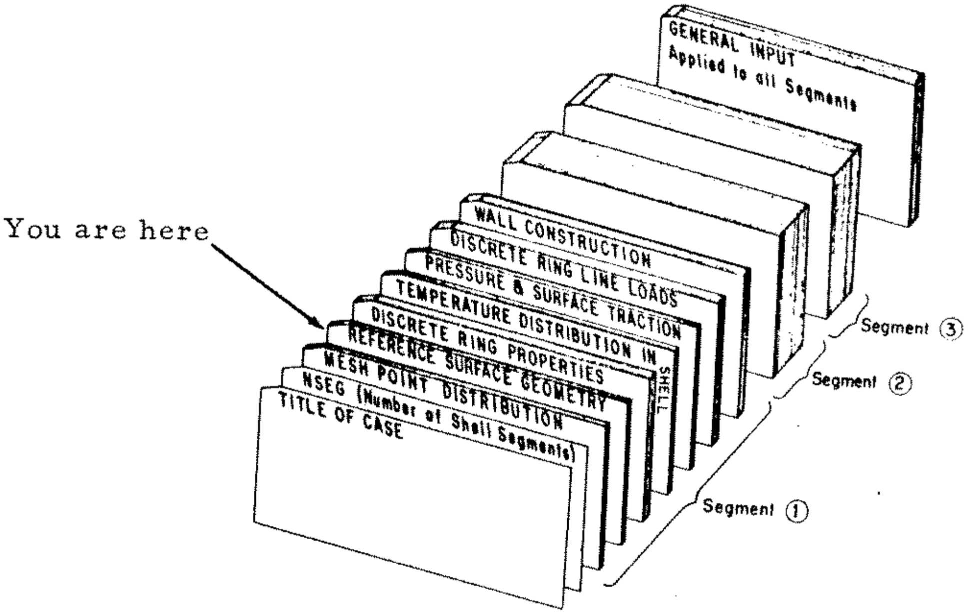
      ***GO TO 70***

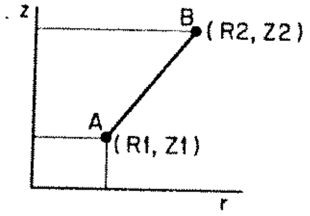
50     CONTINUE
                                                            (SHELL GEOMETRY)
            NEXT, READ DATA FOR OGIVAL, SPHERICAL, OR TOROIDAL
            SEGMENT.....

DATA   6E12.8 **R1, Z1, R2, Z2, RC, ZC**
DATA    E12.8 **SROT**                                            (NSHAPE=2)
                                                                  (NSHAPE=2)

            R1= RADIUS FROM AXIS OF REVOLUTION TO BEGINNING OF (NSHAPE=2)
                REFERENCE SURFACE. SEE FIGURE                  (NSHAPE=2)
            Z1= AXIAL DISTANCE FROM SOME DATUM TO BEGINNING OF (NSHAPE=2)
                REFERENCE SURFACE.                             (NSHAPE=2)
            R2= RADIUS FROM AXIS OF REVOLUTION TO END OF REFER (NSHAPE=2)
                ENCE SURFACE.                                  (NSHAPE=2)
                                                               (NSHAPE=2)
            Z2= AXIAL DISTANCE FROM DATUM TO END OF REF. SURF. (NSHAPE=2)
            RC= RADIUS FROM AXIS OF REVOLUTION TO CENTER OF    (NSHAPE=2)
                MERIDIONAL CURVATURE.                          (NSHAPE=2)
            ZC= AXIAL DISTANCE FROM DATUM TO CENTER OF         (NSHAPE=2)
                MERIDIONAL CURVATURE.                          (NSHAPE=2)
          SROT= +1.0 IF DIRECTION FROM (R1,Z1) TO (R2,Z2)      (NSHAPE=2)
                     REPRESENTS CLOCKWISE MOTION ABOUT (RC,ZC)NSHAPE=2)
                -1.0=COUNTERCLOCKWISE MOTION ABOUT (RC,ZC)     (NSHAPE=2)

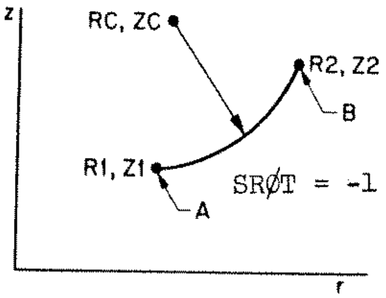
      ***GO TO 70***
```





NSHAPE = 1

(a)



NSHAPE = 2

```
 60     CONTINUE
                                                            (SHELL GEOMETRY)
              NEXT, READ PARAMETERS FOR GENERAL MERIDIONAL SHAPE,
              WITH SPECIAL SUB-BRANCHES FOR HYPERBOLOIDAL OR
              ELLIPSOIDAL SEGMENTS.......

DATA     I6   **NST**
              NST= CONTROL INTEGER FOR TYPE OF GENERAL SHELL..  (NSHAPE=4)
                   NST=1..GENERAL SHELL SHAPE FOR WHICH CAR-    (NSHAPE=4)
                          TESIAN COORDINATES OF REFERENCE SUR-  (NSHAPE=4)
                          FACE WILL BE GIVEN. *** GO TO 62 ***  (NSHAPE=4)
                                                                (NSHAPE=4)

                   NST=4..ELLIPSOIDAL SEGMENT OR TOROIDAL SEGMENT
                          WITH ELLIPTICAL CROSS-SECTION.        (NSHAPE=4)
                                              *** GO TO 64 ***

                   NST=6..HYPERBOLOIDAL SHELL. SEE SUBROUTINE
                          SHELL FOR THIS OPTION. THEN ***GO TO 70***

          IMPORTANT NOTE.. USER CAN PROVIDE OTHER OPTIONS BY APPROPRIATE
                           CHANGES TO SUBROUTINE SHELL.  USE THE
                           CODING ASSOCIATED WITH THE HYPERBOLOIDAL
                           SHELL AS A GUIDE.

 62     CONTINUE
                                                            (SHELL GEOMETRY)
              GENERAL MERIDIONAL SHAPE SPECIFIED BY (Z,R) COORDINATES...

DATA     I6   **NRZIN**
DATA  6E12.8  **(Z(I), R(I), I=1,NRZIN)**                 (NST=1,NSHAPE=4)
                                                          (NST=1,NSHAPE=4)

              NRZIN= NUMBER OF (R,Z) PAIRS TO BE READ IN  (NST=1,NSHAPE=4)
              Z(I)= AXIAL COORDINATES OF REFERENCE SURF.  (NST=1,NSHAPE=4)
                    CURVE.  SEE FIGURE                    (NST=1,NSHAPE=4)
              R(I)= RADIAL COORDINATES OF REFERENCE SURF. (NST=1,NSHAPE=4)
                    CURVE.                                (NST=1,NSHAPE=4)

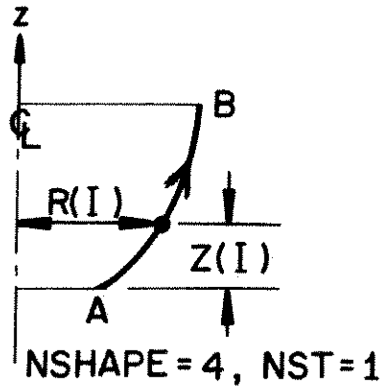
          NOTE... YOU CAN INTRODUCE AN ARBITRARY INITIAL AXISYMMETRIC
                  IMPERFECTION BY USING THIS OPTION.

       ***GO TO 70***

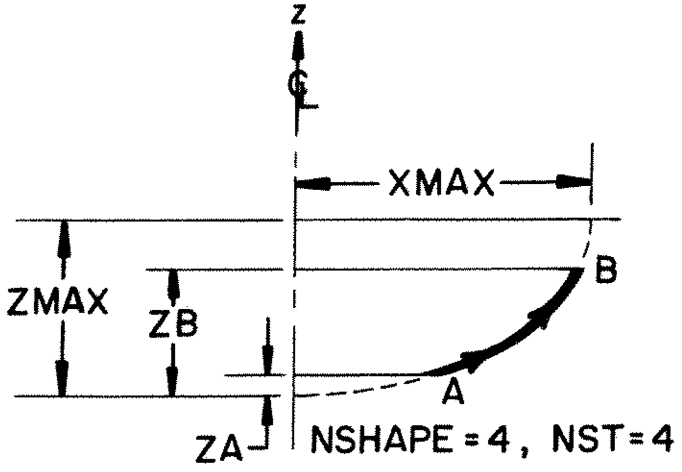
 64     CONTINUE
                                                            (SHELL GEOMETRY)
              ELLIPSOIDAL SEGMENT.....

DATA  6E12.8  **ZMAX, XMAX, ZA, ZB, ZNUMB, ALPHAT**       (NST=4,NSHAPE=4)

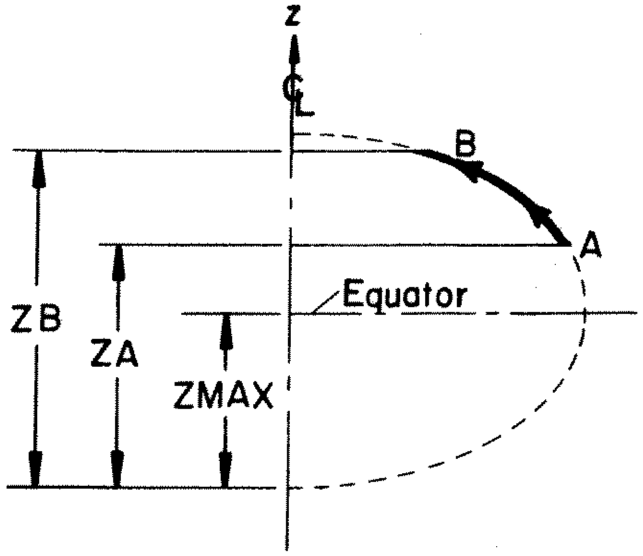
              ZMAX= AXIAL DIMENSION OF ELLIPSE. SEE FIG.  (NST=4,NSHAPE=4)
              XMAX= RADIAL DIMENSION OF ELLIPSE.          (NST=4,NSHAPE=4)
              ZA=   AXIAL COORDINATE OF BEGINNING OF SEG. (NST=4,NSHAPE=4)
              ZB=   AXIAL COORDINATE OF END OF SEGMENT.   (NST=4,NSHAPE=4)
              ZNUMB=NUMBER OF POINTS FOR CURVE FIT. PLEASE (NST=4,NSHAPE=4)
                    USE FEWER THAN 50-75.                 (NST=4,NSHAPE=4)
              ALPHAT=DISTANCE FROM AXIS OF REVOLUTION TO  (NST=4,NSHAPE=4)
                    POINT OF INTERSECTION OF MAJOR AND    (NST=4,NSHAPE=4)
                    MINOR AXES.                           (NST=4,NSHAPE=4)
       ***GO TO 70***
```



GENERAL SHAPE



ELLIPSOIDAL SEGMENT



CORRECT INPUT DATA FOR
ELLIPTICAL SEGMENT FALLING
ABOVE THE EQUATOR

```
70     CONTINUE
                                                                 (IMPERFECTION)
             NEXT, READ DATA FOR GEOMETRICAL IMPERFECTIONS IN THIS
             SEGMENT......

DATA      I6     **IMP**

             IMP= CONTROL INTEGER IDENTIFYING WHETHER THIS SEGMENT
                  IS PERFECT OR IMPERFECT.

                  IF IMP=0 SEGMENT IS PERFECT.

                  IF IMP=0 ***GO TO 90***

                  IF IMP=1 SEGMENT IS IMPERFECT.

                  IF IMP=1 ***GO TO 80***
80     CONTINUE
                                                                 (IMPERFECTION)
DATA      I6     **ITYPE**
                                                                      (IMP=1)
             ITYPE = CONTROL INTEGER FOR TYPE OF IMPERFECTION..       (IMP=1)

                  ITYPE=1 MEANS IMPERFECTIONS ARE SINUSOIDAL          (IMP=1)
                          WITH RANDOM AMPLITUDES AND WAVELENGTHS(IMP=1)
                          (MANY SUPERPOSED WAVES)

                  IF ITYPE=1 ***GO TO 82***                           (IMP=1)

                  ITYPE=2 MEANS SINUSOIDAL IMPERFECTIONS              (IMP=1)
                          (SINGLE KNOWN WAVELENGTH AND AMPLITUDE)

                  IF ITYPE=2 ***GO TO 84***                           (IMP=1)

                  ITYPE=3 MEANS THAT AN ARBITRARY IMPERFECTION        (IMP=1)
                          WILL BE SPECIFIED BY MEANS OF VECTOR        (IMP=1)
                          OF NORMAL DISPLACEMENTS FROM PERFECT        (IMP=1)
                          SHAPE.
                                                                      (IMP=1)
                  IF ITYPE=3 ***GO TO 86***                           (IMP=1)
82     CONTINUE
                                                                 (IMPERFECTION)
             IMPERFECTION IS A RANDOM SERIES OF TRIGONOMETRIC TERMS...

DATA   4E12.8 **FM, C, FLMIN, FLMAX**
                                                             (IMP=1,ITYPE=1)
             FM= NUMBER OF WAVELENGTHS TO BE INCLUDED IN     (IMP=1,ITYPE=1)
                 REPRESENTATION OF IMPERFECTION.             (IMP=1,ITYPE=1)
             C=  MAXIMUM AMPLITUDE OF IMPERFECTION.          (IMP=1,ITYPE=1)
             FLMIN= MINIMUM HALF-WAVELENGTH TO BE INCLUDED   (IMP=1,ITYPE=1)
                    IN REPRESENTATION OF IMPERFECTION.       (IMP=1,ITYPE=1)
             FLMAX= MAXIMUM HALF-WAVELENGTH TO BE INCLUDED   (IMP=1,ITYPE=1)
                    IN REPRESENTATION OF IMPERFECTION.       (IMP=1,ITYPE=1)

       ***GO TO 90***
```

84 CONTINUE

IMPERFECTION IS A SINGLE SINUSOIDAL WAVE.....

DATA 2E12.8 **WO, WLNGTH** (IMP=1,ITYPE=2)

WO= AMPLITUDE OF SINUSOIDAL IMPERFECTION. (IMP=1,ITYPE=2)
WLNGTH= HALF-WAVELENGTH OF SINUSOIDAL IMPERF. (IMP=1,ITYPE=2)

GO TO 90

86 CONTINUE (IMPERFECTION)

IMPERFECTION IS OF ARBITRARY SHAPE.... (IMP=1,ITYPE=3)

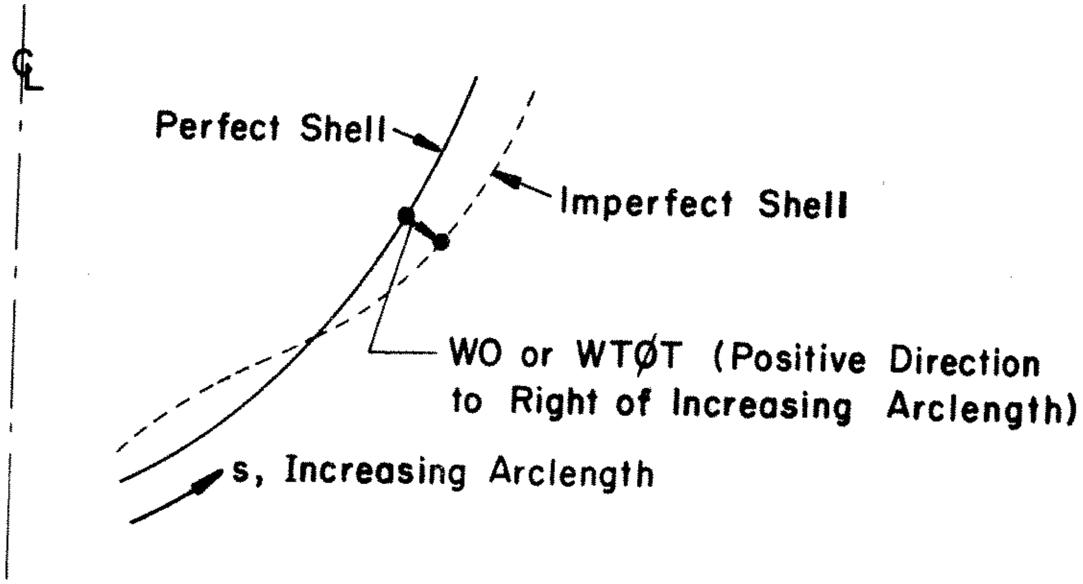
DATA 6E12.8 ** (WTOT(I), I=1,NMESH+2) ** (IMP=1,ITYPE=3)

WTOT( ) = NORMAL DISPLACEMENT FROM PERFECT TO IMPERFECT SHAPE, POSITIVE WTOT RIGHTWARD OF INCREASING ARC LENGTH. (SAME AS POSITIVE W) SEE THE FIGURE.

NMESH = NUMBER OF MESH POINTS IN CURRENT SEGMENT

NOTE.. IN THIS CASE YOU HAVE TO PROVIDE VALUES CORRESPONDING TO THE TWO 'EXTRA' MESH POINTS ADJACENT TO THE EDGES OF THE SEGMENT. THAT IS WHY THE UPPER LIMIT ON THE IMPLIED DO-LOOP IS NMESH+2 INSTEAD OF NMESH. THIS IS THE ONLY EXCEPTION TO THE RULE THAT YOU CAN IGNORE THESE EXTRA TWO POINTS IN MAKING UP AN INPUT DATA DECK. (IMP=1,ITYPE=3)

GO TO 90



```
 90     CONTINUE                                          (REFERENCE SURFACE)
                NEXT, READ DATA FOR SPECIFICATION OF REFERENCE SURFACE
                LOCATION RELATIVE TO SHELL WALL MATERIAL....

 DATA     I6    **NTYPEZ**

                NTYPEZ= CONTROL INTEGER FOR TYPE OF DATA NEEDED TO
                        SPECIFY THE LOCATION OF THE SEGMENT REFERENCE
                        SURFACE RELATIVE TO THE 'LEFTMOST' SURFACE OF
                        THE SHELL WALL AS WE FACE IN THE DIRECTION OF
                        INCREASING MERIDIONAL ARC LENGTH, S.
                        NOTE THAT WE ARE NOT REFERRING TO THE THICKNESS
                        HERE.  THE THICKNESS WILL BE SPECIFIED LATER.
                        SEE THE FIGURES GIVEN HERE FOR EXAMPLES OF
                        REFERENCE SURFACE LOCATION SPECIFICATION.

                        NTYPEZ=1 MEANS THAT A CERTAIN QUANTITY, NZVALU,
                                 OF CALLOUTS AND CERTAIN CALLOUTS,
                                  (ZVAL(J),J =1,NZVALU)   FOR THE
                                 REFERENCE SURFACE LOCATION WILL BE READ IN.
                                 THE REFERENCE SURFACE LOCATION EVERY-
                                 WHERE WILL THEN BE DETERMINED AUTOMATICAL-
                                 LY BY LINEAR INTERPOLATION BETWEEN THOSE
                                 STATIONS WHERE IT IS CALLED OUT.
                                 SEE THE FIGURE LABELED  (C)  FOR
                                 AN EXAMPLE.

                        IF NTYPEZ=1 ***GO TO 92***

                        NTYPEZ=2 MEANS THAT THE REF. SURF. LOCATION
                                 WILL BE SPECIFIED BY A FORMULA.

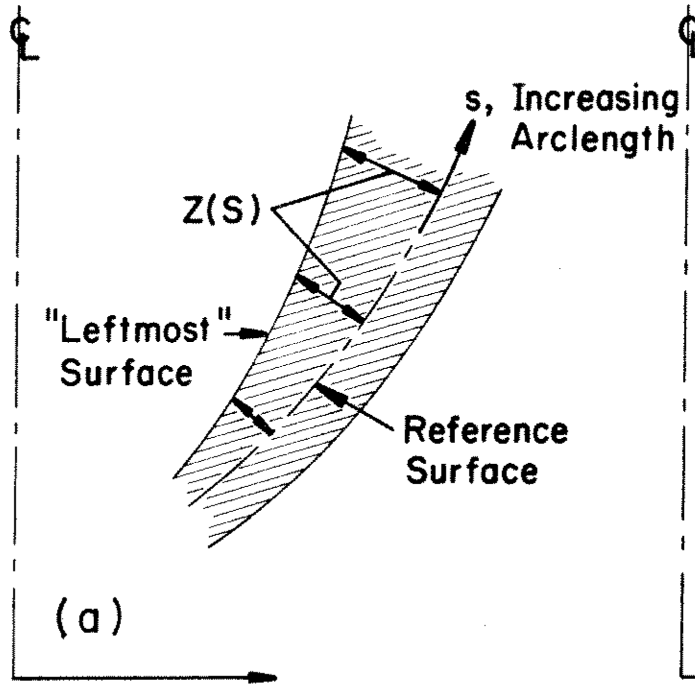
                        IF NTYPEZ=2 ***GO TO 94***

                        NTYPEZ=3 MEANS THAT THE REFERENCE SURFACE IS
                                 LOCATED A CONSTANT DISTANCE, ZVAL, FROM THE
                                 LEFTMOST SURFACE FOR THIS SHELL SEG.
                                 THIS IS THE BRANCH YOU WILL PROBABLY BE
                                 USING MOST OF THE TIME.  NOTE FROM THE
                                 FIGURE LABELED 'NTYPEZ=3' THAT EVEN IF
                                 THE THICKNESS VARIES, THE DISTANCE, ZVAL,
                                 FROM THE 'LEFTMOST' SURFACE TO THE
                                 REFERENCE SURFACE MAY BE CONSTANT.

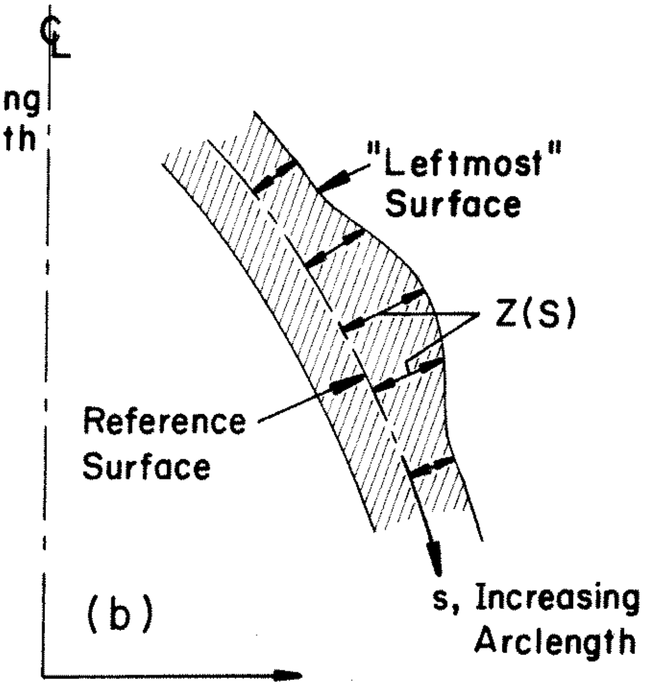
                        IF NTYPEZ=3 ***GO TO 96***

 92     CONTINUE                                          (REFERENCE SURFACE)

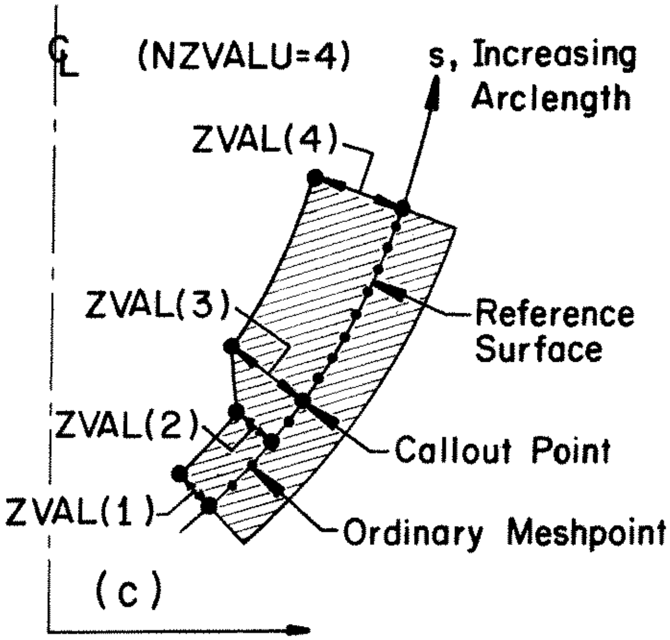
 DATA     I6    **NZVALU**                                      (NTYPEZ=1)
                NZVALU=NUMBER OF CALLOUTS FOR REFERENCE SURFACE  (NTYPEZ=1)
                       LOCATION RELATIVE TO LEFTMOST SURFACE.    (NTYPEZ=1)
                       THE USER MUST ALWAYS INCLUDE THE FIRST AND LAST
                       POINTS IN THE SEGMENT AS CALLOUT POINTS.
                       SEE THE FIGURE LABELED  (C)  FOR AN       (NTYPEZ=1)
                       ILLUSTRATION OF PROPER INPUT.             (NTYPEZ=1)
```



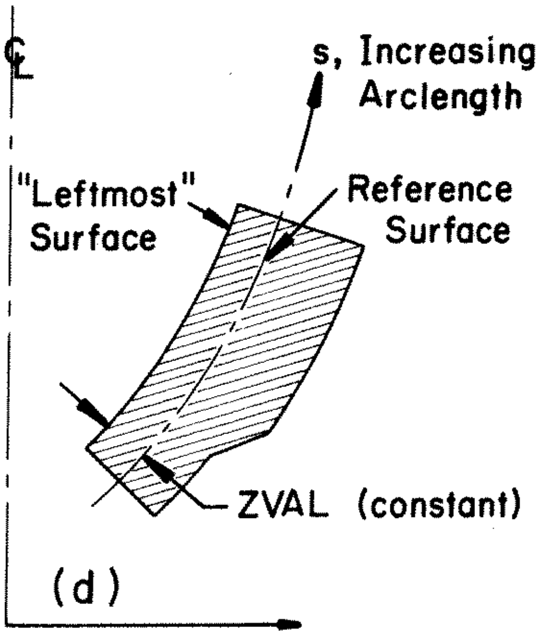
NTYPEZ = 1 or 2



NTYPEZ = 1



NTYPEZ = 1



NTYPEZ = 3

```
             NEXT, ESTABLISH LOCATIONS ALONG THE MERIDIAN WHERE
             THE REFERENCE SURFACE POSITION RELATIVE TO THE
             LEFTMOST SURFACE IS TO BE CALLED OUT...    (REFERENCE SURFACE)
*************NOTE... NUMBER OF CALLOUTS = NZVALU  ********        (NTYPEZ=1)

DATA     I6     **NTYPE**
             NTYPE= CONTROL INTEGER FOR CALLOUT SPECIFICATION....

                   NTYPE=1 MESH POINTS WILL BE CALLED OUT DIRECTLY.
                   IF NTYPE = 1  ***GO TO A***
                   NTYPE=2 AXIAL DISTANCES, Z, FROM DATUM CALLED OUT
                   IF NTYPE = 2  ***GO TO B***
                   NTYPE=3 DISTANCES, R, FROM AXIS OF REV. CALLED OUT
                   IF NTYPE = 3  ***GO TO C***
                   NTYPE=4 ARC LENGTHS, S, FROM SEG. START CALLED OUT
                   IF NTYPE = 4  ***GO TO D***
                   NTYPE=5 ANGLES, THETA, IN DEGREES FROM AXIS OF REV.
                   IF NTYPE = 5  ***GO TO E***

A       CONTINUE                                       (REFERENCE SURFACE)

DATA    10I6  **(IPOINT(J), J=1,NZVALU) **                       (NTYPE=1)

             IPOINT= MESH POINT NUMBERS OF CALLOUTS              (NTYPE=1)

              ***GO TO F***
B       CONTINUE
                                                       (REFERENCE SURFACE)
DATA   6E12.8 **(      Z(J), J=1,NZVALU) **                      (NTYPE=2)

             Z= AXIAL DISTANCES TO CALLOUTS, MEASURED FROM  THE  (NTYPE=2)
                SAME DATUM AS THAT USED FOR THE SPECIFICATION    (NTYPE=2)
                OF THE MERIDIONAL GEOMETRY. (SHELL GEOMETRY)     (NTYPE=2)

              ***GO TO F***
C       CONTINUE
                                                       (REFERENCE SURFACE)

DATA   6E12.8 **(      R(J), J=1,NZVALU) **                      (NTYPE=3)

             R= RADIAL DISTANCES FROM AXIS TO CALLOUTS           (NTYPE=3)

              ***GO TO F***
D       CONTINUE
                                                       (REFERENCE SURFACE)

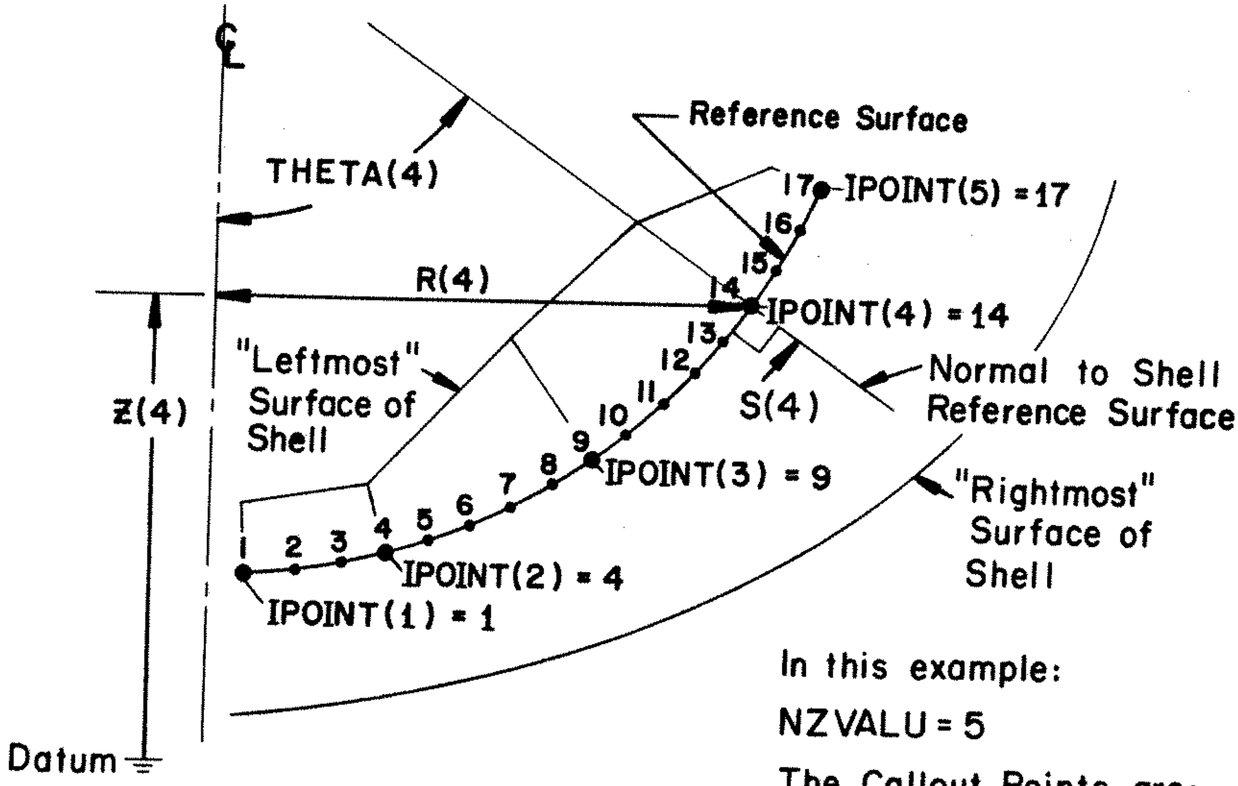
DATA   6E12.8 **(      S(J), J=1,NZVALU) **                      (NTYPE=4)

             S= ARC LENGTHS FROM SEG. START TO CALLOUTS          (NTYPE=4)

              ***GO TO F***
E       CONTINUE
                                                       (REFERENCE SURFACE)

DATA   6E12.8 **( THETA(J), J=1,NZVALU) **                       (NTYPE=5)

             THETA= ANGLES IN DEGREES FROM AXIS OF REVOLUTION    (NTYPE=5)
                   TO CALLOUTS. (NORMAL TO REF. SURF.)           (NTYPE=5)
F       CONTINUE
                                                       (REFERENCE SURFACE)
```



In this example:

NZVALU = 5

The Callout Points are:
1, 4, 9, 14, 17

Z(4) measured from same datum used to specify geometry of the current shell segment

```
DATA   6E12.8 **(ZVAL(K), K= 1,NZVALU) **               (REFERENCE SURFACE)
                                                                (NTYPEZ=1)

          ZVAL(K)= DISTANCE FROM LEFTMOST SHELL WALL SURFACE (NTYPEZ=1)
                   TO REFERENCE SURFACE AT KTH CALLOUT.      (NTYPEZ=1)
                   MEASURED AS SHOWN IN FIGURE         .     (NTYPEZ=1)
                   POSITIVE IF REF. SURF. LIES TO THE RIGHT  (NTYPEZ=1)
                   OF THIS EXTREME SURFACE OF THE SHELL WALL.(NTYPEZ=1)
                   'LEFT' AND 'RIGHT' HERE ASSUME THAT WE FACE
                   IN THE DIRECTION OF INCREASING MERIDIONAL ARC, S.

         NZVALU = NUMBER OF CALLOUTS FOR REFERENCE SURFACE
                  LOCATION.

        *** GO TO 100***
 94    CONTINUE
                                                        (REFERENCE SURFACE)
DATA   5E12.8 **Z1, Z2, Z3, Z4, Z5**
                                                                (NTYPEZ=2)

         Z1 THRU Z5 ARE COEFFICIENTS IN THE FUNCTION...         (NTYPEZ=2)

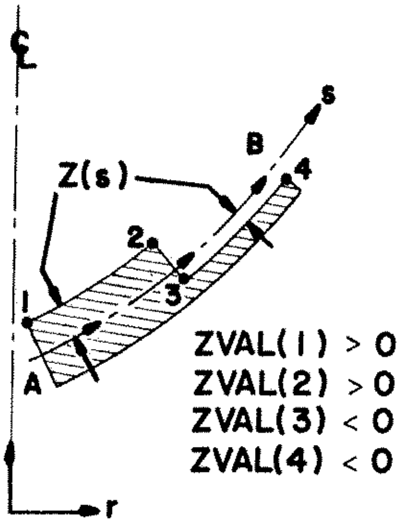
           ZVAL(S) = Z1 +Z2*S**Z3 +Z4*S**Z5                     (NTYPEZ=2)

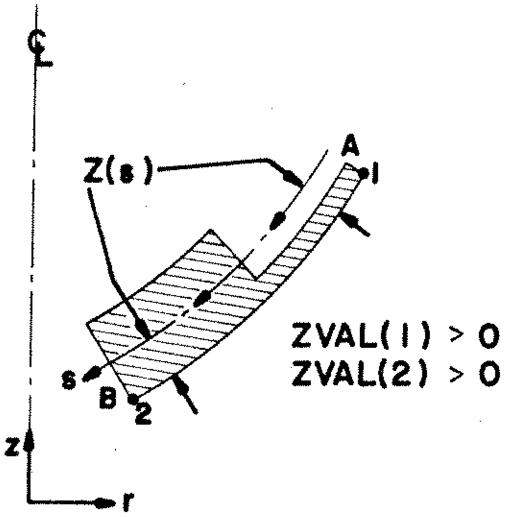
         ZVAL =  SEE ABOVE FOR DEFINITION.
            S = ARC LENGTH ALONG REFERENCE SURFACE, MEASURED
                FROM THE BEGINNING OF THE CURRENT SEGMENT.

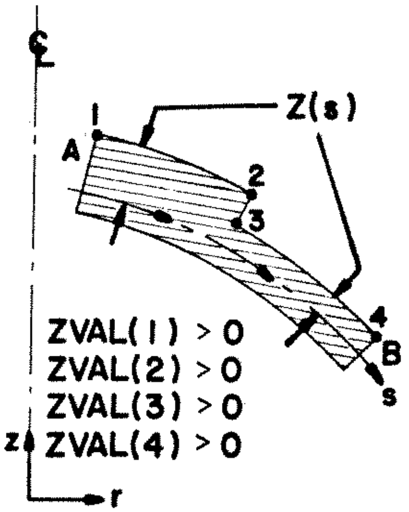
     *** GO TO 100***
 96    CONTINUE
                                                        (REFERENCE SURFACE)
DATA   E12.8 **ZVAL**
                                                                (NTYPEZ=3)

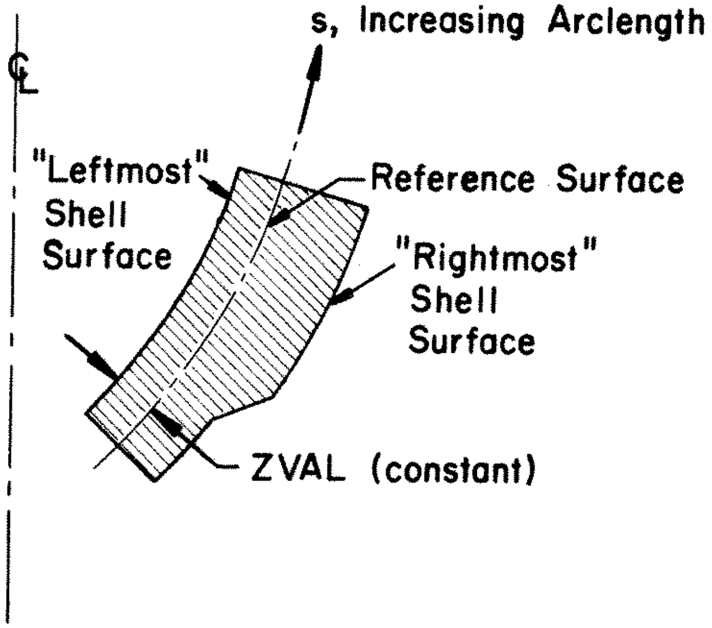
         ZVAL= DISTANCE FROM SHELL SEGMENT LEFTMOST SURFACE (NTYPEZ=3)
               TO THE REFERENCE SURFACE, EQUAL TO HALF OF   (NTYPEZ=3)
               THE THICKNESS IF THE MIDDLE SURFACE IS USED  (NTYPEZ=3)
               AS THE REFERENCE SURFACE.  POSITIVE IF THE   (NTYPEZ=3)
               REFERENCE SURFACE LIES TO THE RIGHT OF THE   (NTYPEZ=3)
               EXTREME LEFT SURFACE OF THE WALL IN THIS SEG.(NTYPEZ=3)
               'RIGHT' AND 'LEFT' HERE ARE BASED ON THE ASSUMPTION
               THAT WE ARE FACING IN THE DIRECTION OF INCREASING
               MERIDIONAL ARC LENGTH, S.  SEE THE FIGURE.

   *** GO TO 100***
```


℄
s
B
Z(s)
4
2
3
1
A
ZVAL(1) > 0
ZVAL(2) > 0
ZVAL(3) < 0
ZVAL(4) < 0
z
r


℄
A
Z(s)
1
s
B
2
ZVAL(1) > 0
ZVAL(2) > 0
z
r


℄
1
Z(s)
A
2
3
4
B
s
ZVAL(1) > 0
ZVAL(2) > 0
ZVAL(3) > 0
ZVAL(4) > 0
z
r


s, Increasing Arclength
℄
"Leftmost" Shell Surface
Reference Surface
"Rightmost" Shell Surface
ZVAL (constant)

```
100    CONTINUE
            NEXT, READ DATA PERTINENT TO THE DISCRETE RINGS IN
            THIS SEGMENT.......

DATA     I6    **NRINGS**

            NRINGS= NUMBER OF DISCRETE RINGS, INCLUDING 'FICTITIOUS'
                    RINGS, IN CURRENT SHELL SEGMENT.  FICTITIOUS
                    RINGS, OR IN OTHER WORDS RINGS WHICH HAVE NULL
                    PHYSICAL PROPERTIES, ARE REQUIRED FOR STATIONS
                    AT WHICH LINE LOADS ARE APPLIED BUT FOR WHICH
                    NO ACTUAL RINGS EXIST.              (DISCRETE RINGS)

                  IF NRINGS=0  ***GO TO 170***

            FIRST THE LOCATIONS OF THE DISCRETE RINGS ARE TO BE
            SPECIFIED. THE TYPE OF INPUT DATA TO BE USED IN THIS
            SPECIFICATION IS DETERMINED BY THE CONTROL INTEGER NTYPE.

DATA     I6    **NTYPE**

            NTYPE= CONTROL INTEGER FOR TYPE OF DATA TO BE USED
                   FOR LOCATION OF DISCRETE RING ATTACHMENT POINTS...
                   (RING ATTACHMENT POINTS ARE CONSIDERED TO BE
                    LOCATED ON THE SHELL REFERENCE SURFACE.)

                  NTYPE=1 MESH POINTS WILL BE CALLED OUT DIRECTLY.
                  IF NTYPE = 1  ***GO TO A***
                  NTYPE=2 AXIAL DISTANCES, Z, FROM DATUM CALLED OUT
                  IF NTYPE = 2  ***GO TO B***
                  NTYPE=3 DISTANCES, R, FROM AXIS OF REV. CALLED OUT
                  IF NTYPE = 3  ***GO TO C***
                  NTYPE=4 ARC LENGTHS, S, FROM SEG. START CALLED OUT
                  IF NTYPE = 4  ***GO TO D***
                  NTYPE=5 ANGLES, THETA, IN DEGREES FROM AXIS OF REV.
                  IF NTYPE = 5  ***GO TO E***

A      CONTINUE
                                                        (DISCRETE RINGS)
DATA   10I6  **(IPOINT(J), J=1,NRINGS) **                      (NTYPE=1)

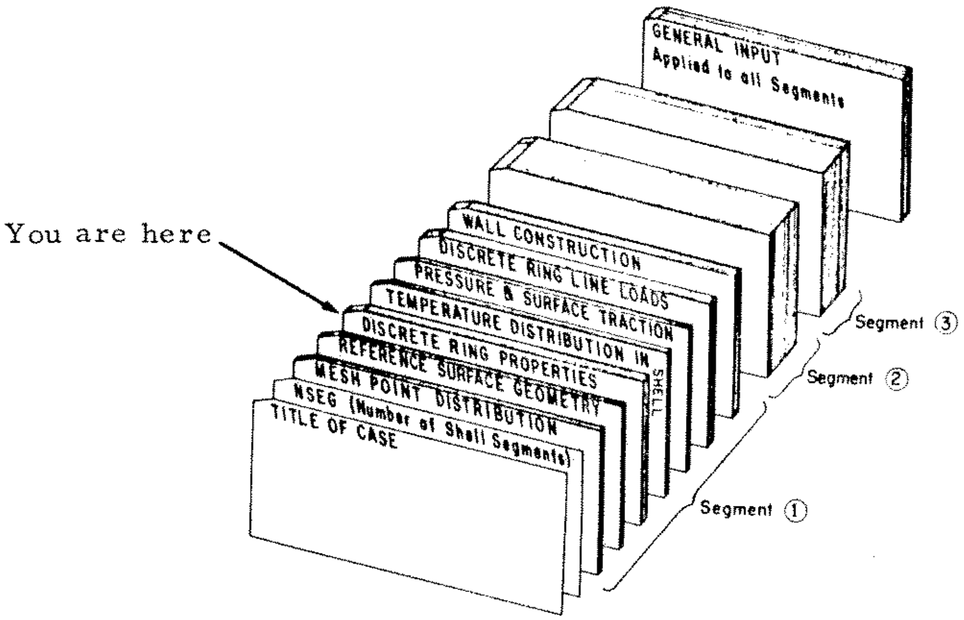
            IPOINT= MESH POINT NUMBERS OF RING ATTACH. PTS.    (NTYPE=1)

             ***GO TO F***

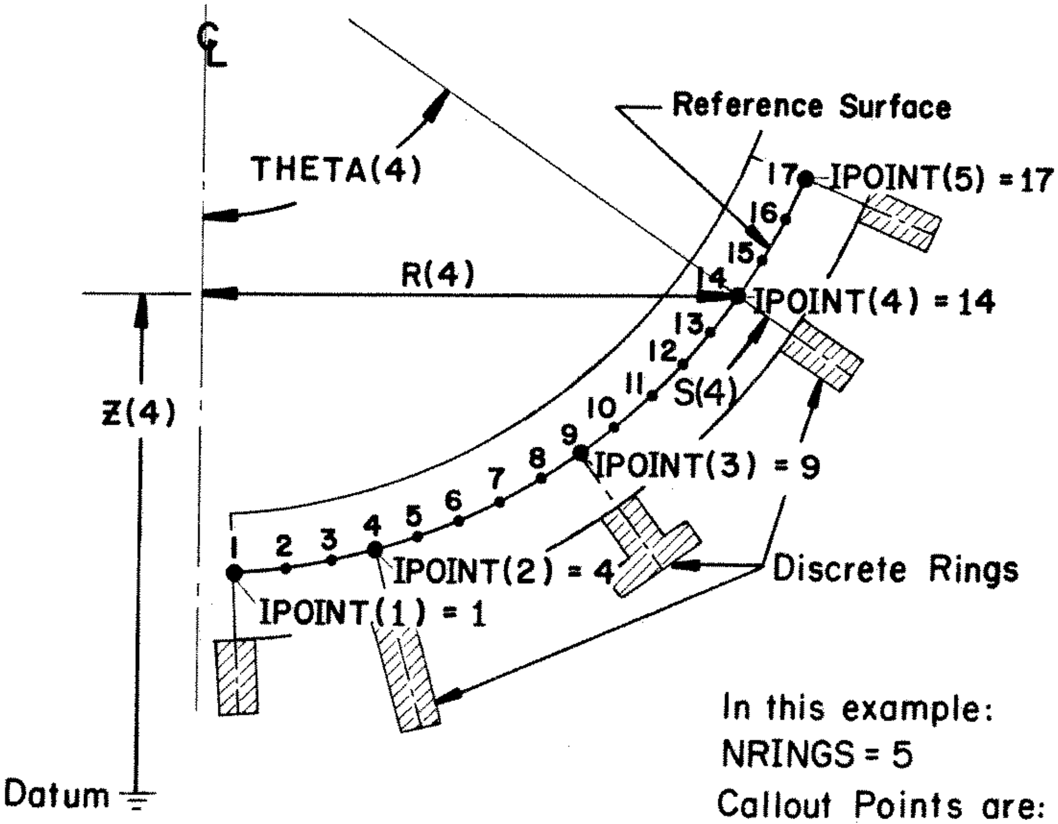
B      CONTINUE                                         (DISCRETE RINGS)
DATA   6E12.8 **(      Z(J), J=1,NRINGS) **                    (NTYPE=2)

           Z= AXIAL DISTANCES TO CALLOUTS, MEASURED FROM  THE  (NTYPE=2)
              SAME DATUM AS THAT USED FOR THE SPECIFICATION    (NTYPE=2)
              OF THE MERIDIONAL GEOMETRY. (SHELL GEOMETRY)     (NTYPE=2)

             ***GO TO F***
```



NRINGS . . . Number of discrete rings in a given segment. It is pointed out here that line loads can be applied only at mesh stations which correspond to discrete ring locations. Hence, the input parameter NRINGS must allow for any "fictitious" rings which correspond to points on the meridian at which line loads are applied, but at which no actual rings exist.



Z(4) measured from same datum used to specify geometry of the current shell segment.

In this example:
NRINGS = 5
Callout Points are:
1, 4, 9, 14, 17. Discrete rings are considered to be attached to the shell at the reference surface at the callout points.

```
C       CONTINUE
                                                                 (DISCRETE RINGS)
DATA   6E12.8 **(      R(J), J=1,NRINGS) **
                                                                        (NTYPE=3)
             R= RADIAL DISTANCES FROM AXIS TO RING ATTACH PTS.   (NTYPE=3)

              ***GO TO F***

D       CONTINUE
                                                                 (DISCRETE RINGS)
DATA   6E12.8 **(      S(J), J=1,NRINGS) **
                                                                        (NTYPE=4)
             S= ARC LENGTHS FROM SEG. START TO RING ATTACH. PTS.(NTYPE=4)

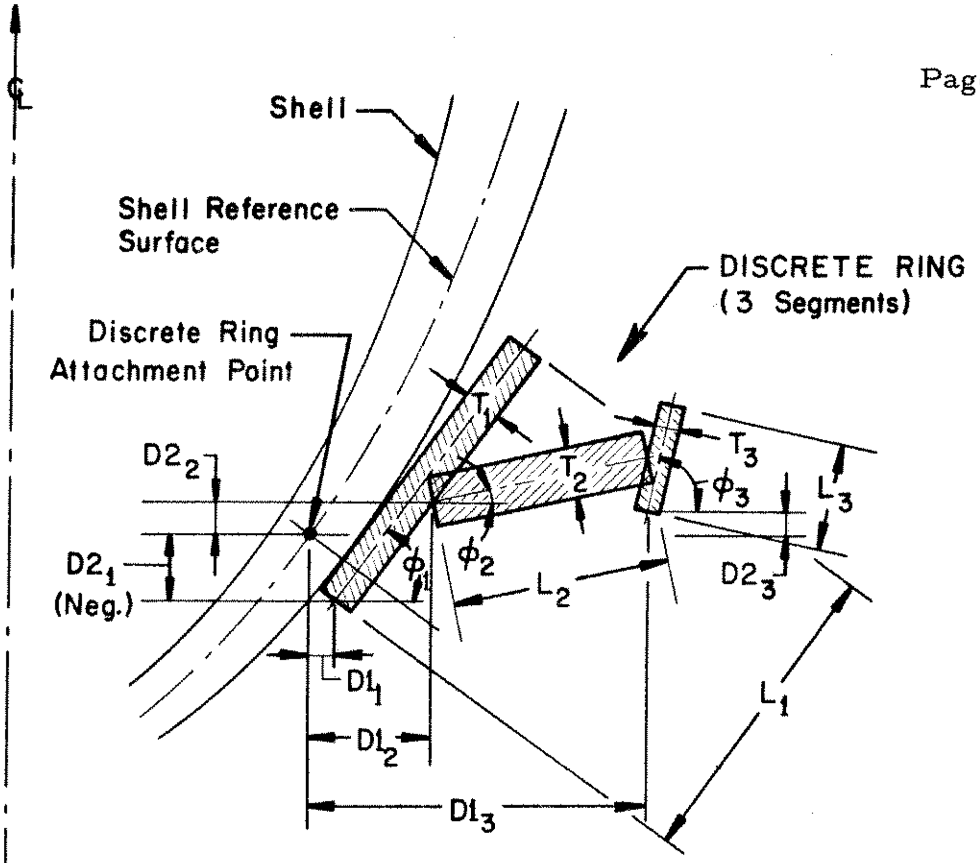
              ***GO TO F***

E       CONTINUE
                                                                 (DISCRETE RINGS)
DATA   6E12.8 **( THETA(J), J=1,NRINGS) **
                                                                        (NTYPE=5)
             THETA= ANGLES IN DEGREES FROM AXIS OF REVOLUTION    (NTYPE=5)
                    TO RING ATTACHMENT POINTS. (NORMAL TO REF.   (NTYPE=5)
                    SURFACE)                                     (NTYPE=5)
F       CONTINUE
                                                                 (DISCRETE RINGS)
          NEXT, CONTROL INTEGERS WILL BE READ IN FOR SPECIFICATION OF
            WHAT TYPES OF DISCRETE RINGS EXIST IN THIS SEGMENT..
DATA    10I6    **(NTYPER(K),K=1,NRINGS)**

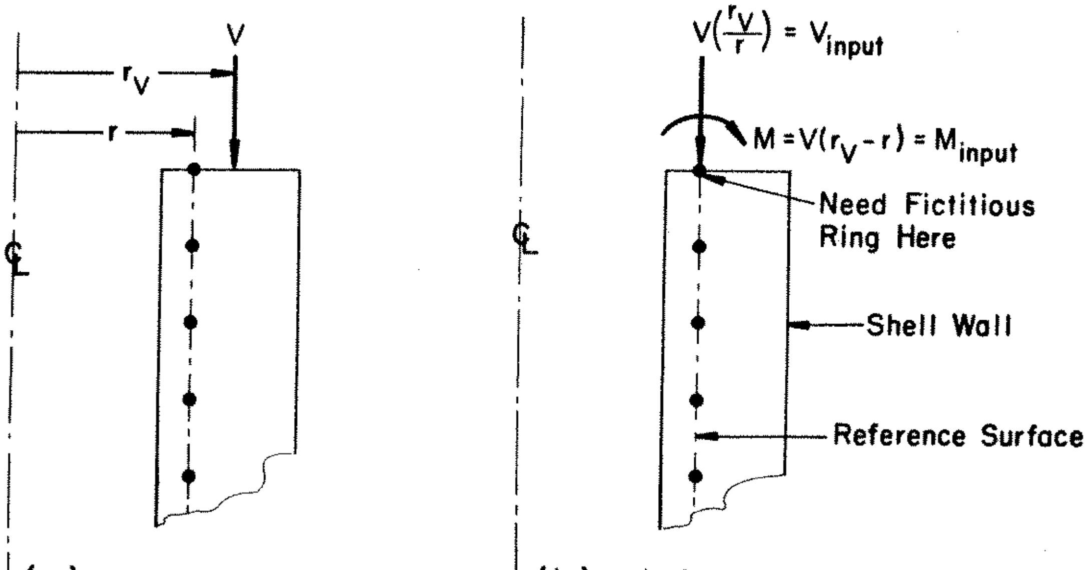
            NTYPER( )= CONTROL INTEGERS FOR TYPES OF DISCRETE
                       RINGS IN CURRENT SEGMENT. MAY BE 0 OR 1

              NTYPER(K)=0 MEANS FICTITIOUS RING.  THIS OPTION IS
                          USED IF LINE LOADS ARE APPLIED WHERE
                          THERE IS NO ACTUAL RING.  SEE THE FIGURE
                          OPPOSITE (WITH V AND M) FOR ADDITIONAL
                          WARNING.

              NTYPER(K)=1 INDICATES THE PRESENCE OF A REAL RING.
                          DATA FOR THE KTH DISCRETE
                          RING IN THE CURRENT SEGMENT WILL BE
                          READ IN.  THE DISCRETE RING IS CONSI-
                          DERED TO BE COMPOSED OF A NUMBER OF
                          STRAIGHT SEGMENTS OF UNIFORM
                          THICKNESS.  CONTROL INTEGERS ARE FIRST
                          READ IN TO DETERMINE WHETHER OR NOT A
                          SIMILAR RING SEGMENT HAS BEEN SPECIFIED
                          PREVIOUSLY, EITHER IN THIS CURRENT
                          SHELL SEGMENT OR IN A PREVIOUS SHELL
                          SEGMENT..
```



NOTE: Discrete ring attachment point is considered to be located on the shell reference surface.



(a) ACTUAL CASE

(b) BØSØR5 MODEL

Note: V_{input} and M_{input} will be read in later. If the fictitious ring option NTYPER(K) = 0 is used, the actual line loads must be transferred by the user to the shell reference surface.

```
******** DO 160  K = 1,NRINGS *******            (BEGIN LOOP OVER NO. OF RINGS

               IF NTYPER(K)=0  *** GO TO 160 ***      (FICTITIOUS RING)
DATA    I6    **NPARTS**
                                                       (DISCRETE RING)

          NPARTS= NUMBER OF SEGMENTS IN THIS DISCRETE RING.

****** DO 150  J = 1,NPARTS ******      (BEGIN LOOP OVER NO. OF RING SEGS)
DATA    5I6    **NGEOM(J), NTEMP(J), NMATL(J), INTEG(J), NCREEP(J) **

          THE PURPOSE OF NGEOM, NTEMP, AND NMATL IS TO TELL
          BOSOR5 WHETHER OR NOT CERTAIN PROPERTIES HAVE
          PREVIOUSLY BEEN SPECIFIED, EVEN IF THIS PREVIOUS
          SPECIFICATION IS ASSOCIATED WITH A PREVIOUS SHELL SEGMENT.
          IF THEY HAVE, THEY NEEDN'T BE SPECIFIED AGAIN.  THIS
          SPARES THE USER SOME EFFORT IF, FOR EXAMPLE, HE IS
          MODELING A SHELL WITH MANY DISCRETE RINGS WHICH ARE
          THE SAME.

          NGEOM(J)= INTEGER WHICH INDICATES GEOMETRY OF THIS
                    RING SEGMENT.  IF THE GEOMETRY , AS SPECIFIED
                    BY THE DIMENSIONS D1, D2, PHI, T, AND FL (SEE FIG.)
                    OF THIS RING SEGMENT IS DIFFERENT FROM ANY
                    PREVIOUSLY SPECIFIED DISCRETE RING SEGMENT,
                    SET NGEOM(J) EQUAL TO ONE PLUS THE HIGHEST
                    VALUE OF NGEOM PREVIOUSLY PROVIDED IN THIS
                    CASE.  NOTE....  NGEOM(1) MUST BE 1 .
                    IF THE GEOMETRY OF THIS DISCRETE
                    RING SEGMENT IS THE SAME AS THAT OF SOME
                    PREVIOUSLY SPECIFIED DISCRETE RING SEGMENT,
                    SET NGEOM(J) EQUAL TO THE VALUE OF NGEOM
                    WHICH WAS USED WHEN THAT EARLIER SEGMENT WAS
                    FIRST SPECIFIED.                      (RING SEGMENT)

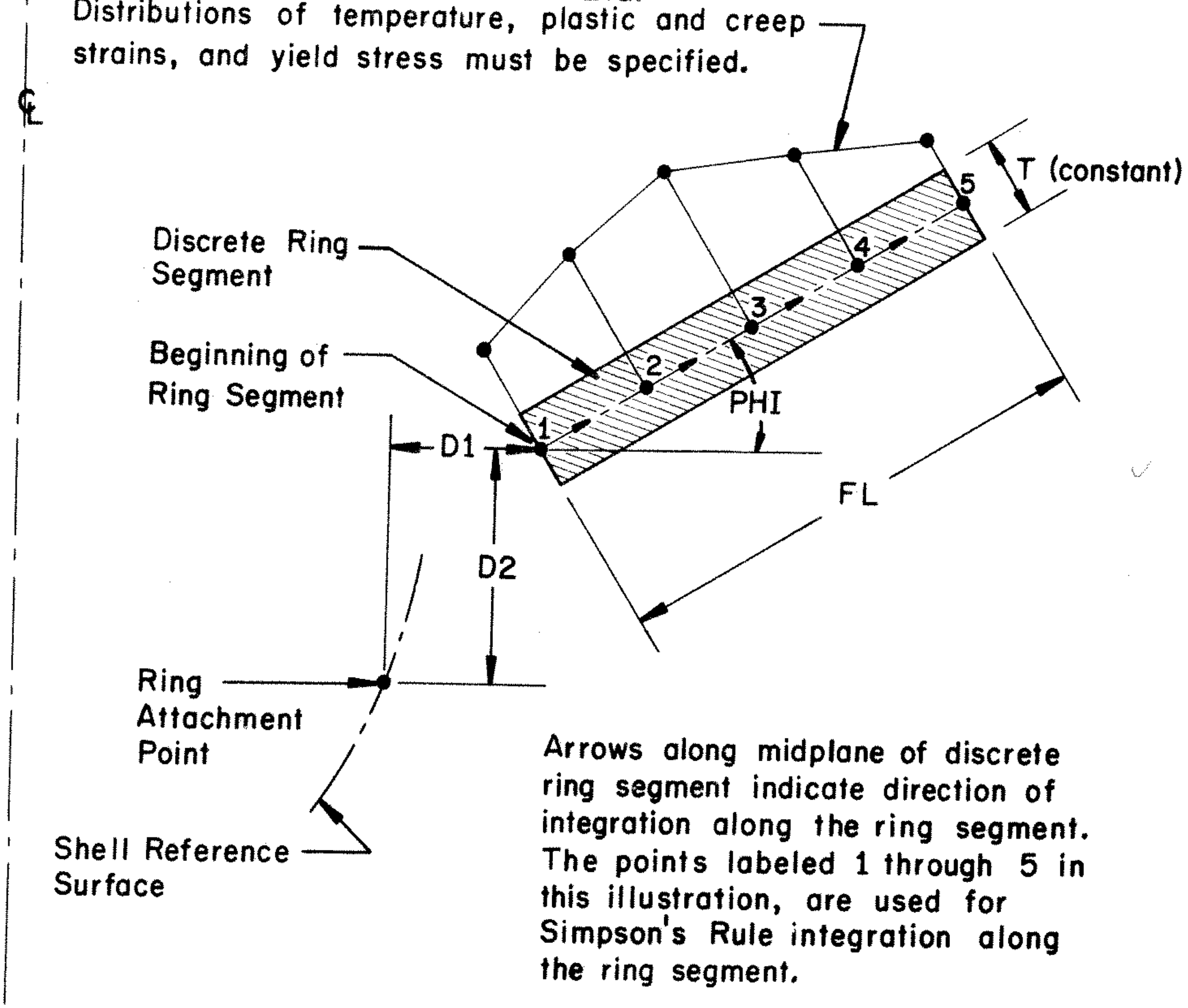
         NTEMP(J)= INTEGER WHICH INDICATES TEMPERATURE DISTRI-
                   BUTION ALONG THIS RING SEGMENT. (TEMP. AS-
                   SUMED UNIFORM THRU THICKNESS OF RING SEGMENT.)
                   THE WAY IN WHICH THIS CONTROL INTEGER IS USED
                   IS ANALOGOUS TO THAT DESCRIBED ABOVE FOR NGEOM.

         NMATL(J)= INTEGER (BETWEEN 1 AND 6,INCLUSIVE) WHICH
                   INDICATES THE MATERIAL TYPE OF THIS RING SEG-
                   MENT.  THE WAY IN WHICH THIS CONTROL INTEGER
                   IS USED IS ANALOGOUS TO THAT DESCRIBED ABOVE
                   FOR NGEOM.                             (RING SEGMENT)

         INTEG(J)= NUMBER OF INTEGRATION POINTS TO BE USED FOR
                   THIS RING SEGMENT. (INTEGRATION POINTS ARE
                   ALWAYS EQUALLY SPACED. SIMPSON'S RULE IS USED.)
                   USE INTEG(J) = 5 OR 7 OR 9
```

This is the beginning of a double do-loop. The outer loop (K-loop) is over the number of discrete rings in this shell segment. The inner loop (J-loop) is over the number of parts or segments in each discrete ring. For example, NPARTS = 3 for the three-segment discrete ring shown on the previous page.

STARTING HERE WE READ IN SOME DATA FOR EACH DISCRETE RING SEGMENT OF THE K TH DISCRETE RING.



Distributions of temperature, plastic and creep strains, and yield stress must be specified.

Arrows along midplane of discrete ring segment indicate direction of integration along the ring segment. The points labeled 1 through 5 in this illustration, are used for Simpson's Rule integration along the ring segment.

Also to be Specified:

- Ring Segment Geometry: D1, D2, PHI, T, FL
- Ring Segment Material Properties:
  Stress-Strain Curve
  Creep Law
  Elastic Modulus
  Coefficient of Thermal Expansion

IMPORTANT NOTE... USE OF DIFFERENT VALUES OF INTEG IN DIFFERENT RING SEGMENTS REQUIRES CORRESPONDING RE-SPECIFICATION OF TEMPERATURE DISTRIBUTION EVEN IF THIS DISTRIBUTION IS IDENTICAL IN THE DIFFERENT RING SEGMENTS. THIS IS BECAUSE THE NUMBER OF INPUT QUANTITIES INVOLVED DEPENDS ON INTEG. IT IS PROBABLY BEST TO CHOOSE A VALUE FOR INTEG AND STAY WITH IT THROUGHOUT THE CASE. (RING SEGMENT)

NCREEP(J) = INTEGER WHICH INDICATES WHETHER OR NOT THE RING MATERIAL CREEPS....

NCREEP(J)=0 RING MATERIAL DOES NOT CREEP.
NCREEP(J)=1 RING MATERIAL DOES CREEP.

NEXT, START READING DATA FOR THE CURRENT RING SEGMENT...

IF THE GEOMETRY OF THIS DISCRETE RING SEGMENT IS IDENTICAL TO THAT OF SOME PREVIOUSLY DEFINED DISCRETE RING SEGMENT, NO MATTER WHAT SHELL SEGMENT THAT PREVIOUS RING SEGMENT IS ASSOCIATED WITH, *** GO TO 110 *** IN OTHER WORDS, IF THE VALUE OF NGEOM(J) JUST READ IS THE SAME AS SOME PREVIOUSLY READ VALUE OF NGEOM, *** GO TO 110 ***

OTHERWISE, READ THE FOLLOWING... (RING SEGMENT GEOMETRY)

DATA 5E12.8 **D1(NGEOM), D2(NGEOM), PHI(NGEOM), T(NGEOM), FL(NGEOM) **

SEE THE FIGURE FOR DEFINITIONS OF D1,D2,PHI,T,FL

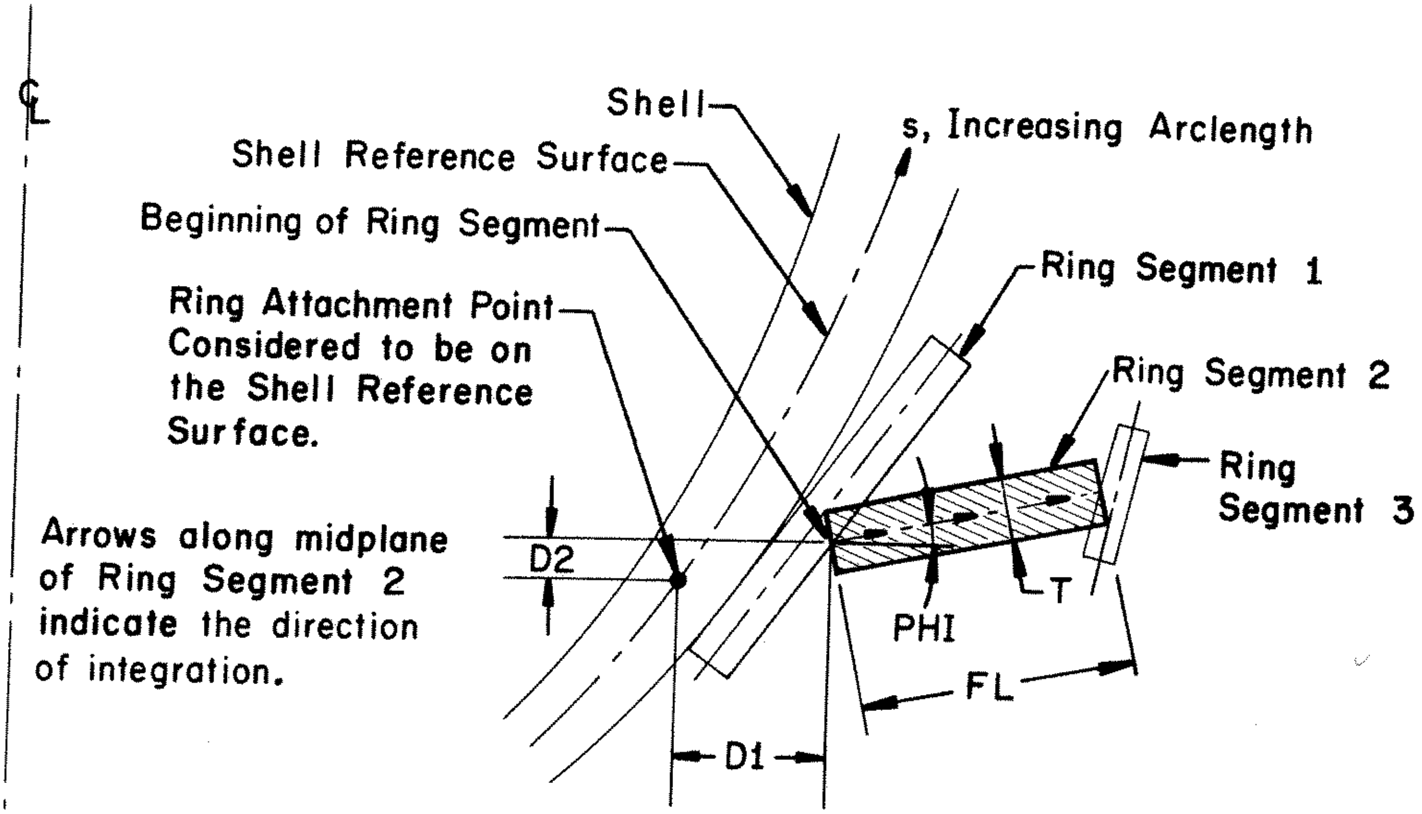
D1 = RADIAL DISTANCE FROM ATTACHMENT POINT TO BEGINNING OF DISCRETE RING SEGMENT, POSITIVE IF THE BEGINNING OF THE RING SEGMENT LIES AT A GREATER DISTANCE FROM THE AXIS OF REVOLUTION THAN THE ATTACHMENT POINT OF THE RING TO THE SHELL. THE ATTACHMENT POINT IS CONSIDERED TO BE ON THE REFERENCE SURFACE OF THE SHELL.

D2 = AXIAL DISTANCE FROM RING ATTACHMENT POINT TO BEGINNING OF DISCRETE RING SEGMENT. POSITIVE IF THE BEGINNING OF THE RING SEGMENT LIES ABOVE THE ATTACHMENT POINT OF THE RING TO THE SHELL.

PHI= ANGLE IN DEGREES FROM HORIZONTAL TO LINE WHICH INDICATES THE DIRECTION OF INTEGRATION ALONG THE RING SEGMENT. THIS DIRECTION IS INDICATED BY ARROWS IN THE FIGURES ASSOCIATED WITH THIS SECTION.

T = THICKNESS OF THE RING SEGMENT, ASSUMED UNIFORM. T IS ALWAYS THE DIMENSION NORMAL TO THE DIRECTION OF INTEGRATION ALONG THE RING SEGMENT.

FL = LENGTH OF RING SEGMENT



Arrows along midplane of Ring Segment 2 indicate the direction of integration.

NOTE: All quantities as shown above, are positive.
If the beginning of the ring segment were located <u>inside</u> the shell reference surface, then D1 would be negative. If the beginning of the ring segment should be located <u>below</u> the ring attachment point, then D2 would be negative.

110 CONTINUE (RING SEGMENT TEMPERATURE)

IF THE TEMPERATURE DISTRIBUTION IN THIS DISCRETE RING SEGMENT IS IDENTICAL TO THAT OF SOME PREVIOUSLY DEFINED RING SEGMENT, *** GO TO 120 ***
IN OTHER WORDS, IF THE VALUE OF NTEMP(J) JUST READ IS THE SAME AS SOME PREVIOUSLY READ VALUE OF NTEMP, ***GO TO 120***
OTHERWISE, READ THE FOLLOWING..

DATA 6E12.8 **(TEMP(L), L = 1,INTEG(J))**

TEMP = TEMPERATURE DIFFERENCE FROM ZERO STRESS STATE.
INTEG = NUMBER OF INTEGRATION POINTS IN RING SEGMENT

120 CONTINUE (RING SEGMENT MATERIAL PROPERTIES)

IF THE MATERIAL PROPERTIES OF THIS DISCRETE RING SEGMENT ARE IDENTICAL TO THOSE OF SOME PREVIOUSLY DEFINED DISCRETE RING SEGMENT, *** GO TO 130 ***
OTHERWISE, READ THE FOLLOWING...

DATA 2E12.8 **E(NMATL),ALPHA(NMATL) ** RHO(NMATL)

E = RING SEGMENT ELASTIC MODULUS
ALPHA= RING SEGMENT THERMAL EXPANSION COEFFICIENT
RHO = RING SEGMENT MASS Density (e.G. ALUMINUM = 0.0002535 (lb-sec^2)/in^4

DATA I6 **NPOINT(NMATL)**

NPOINT = NUMBER OF POINTS USED TO SPECIFY THE RING SEGMENT STRESS-STRAIN CURVE. DON'T FORGET TO INCLUDE THE (0,0) POINT IN THE INPUT DATA. FOR PURELY ELASTIC MATERIAL, YOU MUST STILL READ IN A STRESS-STRAIN 'CURVE'. HOWEVER, IN THIS CASE YOU CAN SIMPLY READ NPOINT = 2 AND THEN GIVE (FOR EXAMPLE) 0.0,1.0 FOR THE STRAIN COORDINATES AND 0.0, 10000000. FOR THE STRESS COORDINATES, IF THE MODULUS IS 10000000.

DATA 6E12.8 **(EPS(L), L =1,NPOINT(NMATL))**
DATA 6E12.8 **(SIGMA(L), L =1,NPOINT(NMATL))**

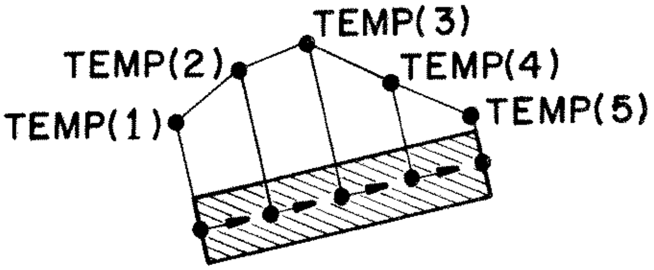
EPS = STRAIN COORDINATES FOR RING MAT'L STRESS-STRAIN CURVE
SIGMA = STRESS COORDINATES FOR RING MAT'L STRESS-STRAIN CURVE

NOTE.. IF THE RING MATERIAL IS THE SAME AS SOME PREVIOUSLY DEFINED SHELL MATERIAL, YOU MUST STILL PROVIDE INPUT DATA HERE IF THE SAME DISCRETE RING MATERIAL HAS NOT PREVIOUSLY BEEN SPECIFIED.

IF THE RING MATERIAL DOES NOT CREEP (NCREEP(J)=0) *** GO TO 130 ***
OTHERWISE, READ THE FOLLOWING .....

DATA 4E12.8 ** RN(MATL), RM(MATL), RA(MATL), RB(MATL) ** (RING CREEP)

RN, RM, RA, RB = COEFFICIENTS IN THE RING MATERIAL CREEP LAW WHICH IS GIVEN ON THE OPPOSITE PAGE. USER WILL ORDINARILY SET RB = 0.0



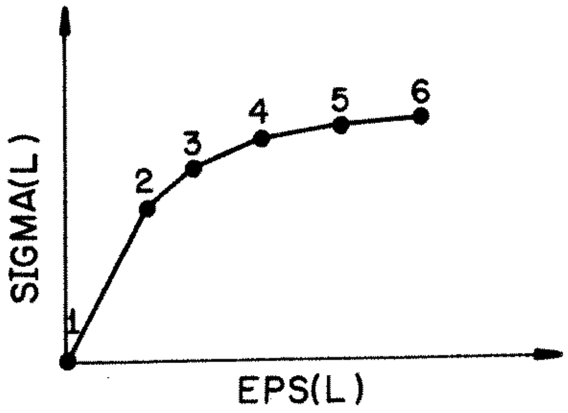
In this example:
J = 2
INTEG(J) = 5

RING MATERIAL CREEP LAW:

$$\bar{\varepsilon}^{c} = \left(\frac{\bar{\sigma}}{\sigma_y}\right)^{RM} (t + t_o)^{RN}$$

$\sigma_y \equiv$ RA

$t_o \equiv$ RB



In this example:
NPOINT(NMATL) = 6

If the ring is at a plane of symmetry, use $\frac{1}{2}$ the actual modulus and $\frac{1}{2}$ the actual values of SIGMA (L) for given EPS(L).

```
130    CONTINUE

150   CONTINUE       (END OF J-LOOP OVER SEGMENTS OF KTH DISCRETE RING)
           IF THERE ARE MORE SEGMENTS IN THIS KTH DISCRETE RING,
             GO BACK TO THE BEGINNING OF THE J-LOOP (WHERE IT
             SAYS, 'DO 150, J = 1,NPARTS')

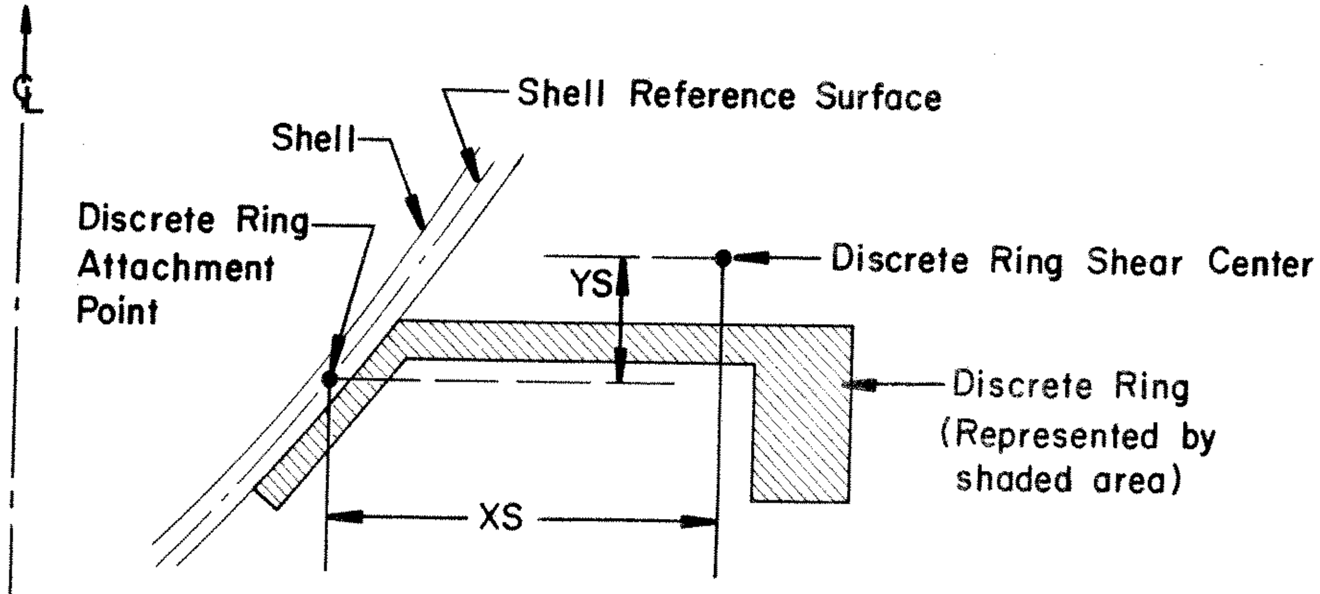
           NEXT, AFTER DATA FOR ALL SEGMENTS IN THIS KTH DISCRETE
           RING HAVE BEEN READ, SPECIFY THE LOCATION OF THE
           RING SHEAR CENTER....

DATA  2E12.8 ** XS, YS **                              (DISCRETE RING)

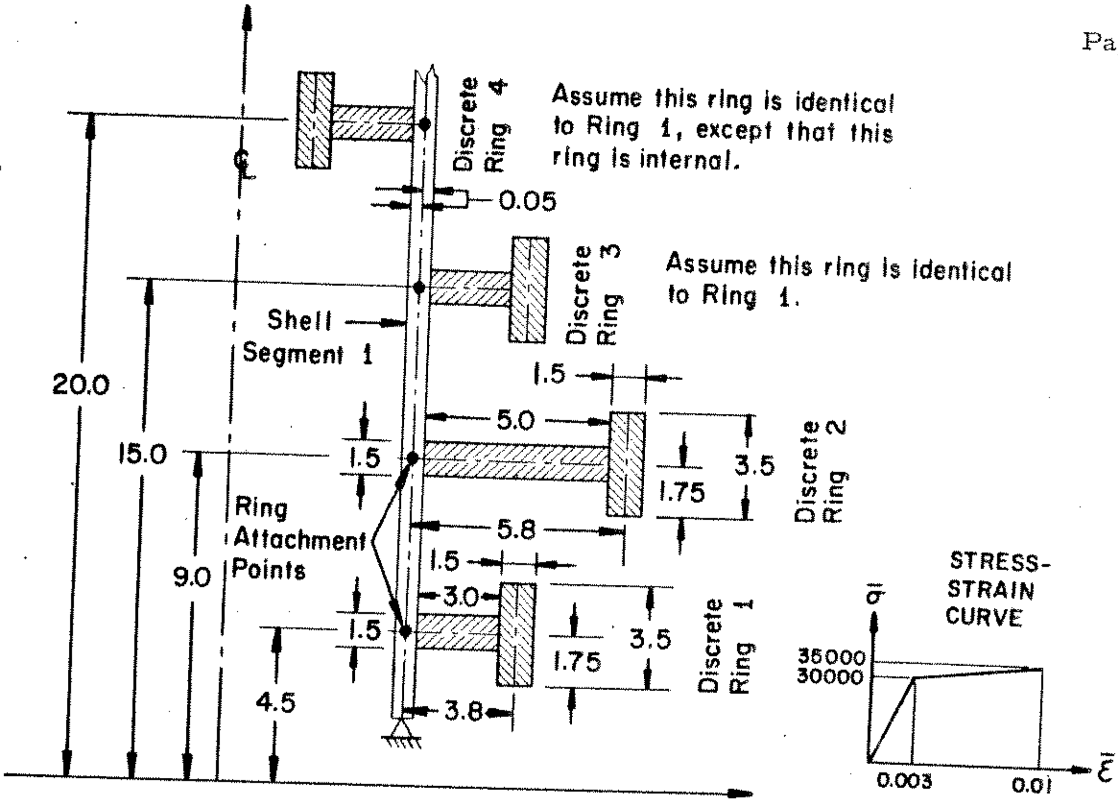
           COORDINATES OF DISCRETE RING SHEAR CENTER RELATIVE TO
           THE ATTACHMENT POINT ON SHELL REFERENCE SURFACE..

           XS = RADIAL DISTANCE (POSITIVE IF RADIUS TO SHEAR CENTER
                IS LARGER THAN RADIUS TO RING ATTACHMENT POINT)
           YS = AXIAL DISTANCE (POSITIVE IF SHEAR CENTER LIES ABOVE
                THE RING ATTACHMENT POINT.)                (DISCRETE RING)


160   CONTINUE    (END OF K-LOOP OVER DISCRETE RINGS IN THIS SHELL SEGMENT)
         IF THERE ARE MORE DISCRETE RINGS IN THIS SHELL SEGMENT,
         GO BACK TO THE BEGINNING OF THE K-LOOP (WHERE IT SAYS
         'DO 160, K = 1,NRINGS')
```



NOTE: The discrete ring attachment point is considered to be located on the shell reference surface.



SAMPLE INPUT DATA FOR A CASE WITH 4 DISCRETE RINGS IN A GIVEN SEGMENT

```
COL. 6     12    18    24    30    36          48          60          72

     4                                                                      NRINGS
     2                                                                       NTYPE
     4.5         9.0          15.0        20.0                  (Z(J), J=1,NRINGS)
     1     1     1     1                                   (NTYPER(K), K=1,NRINGS)
     2                                             NPARTS (DISCRETE RING NO. 1)
     1     1     1     5     1     NGEOM(1),NTEMP(1),NMATL(1),INTEG(1),NCREEP(1)
     0.05        0.0        0.0         1.5         3.0        D1, D2, PHI, T, FL
     0.0         0.0        0.0         0.0         0.0    (TEMP(L),L=1,INTEG(1))
10000000.0       0.0                                                     E, ALPHA
     3                                                                  NPOINT(1)
     0.0         0.003      0.01                           (EPS(L), L=1,NPOINT(1))
     0.0     30000.0     35000.0                         (SIGMA(L), L=1,NPOINT(1))
    0.24     6.4         76000.0    0.0           RCREEN, RCREEM, RCREEA, RCREEB
     2     1     1     5     1     NGEOM(2),NTEMP(2),NMATL(2),INTEG(2),NCREEP(2)
     3.8        -1.75       90.0        1.5         3.5        D1, D2, PHI, T, FL
     3.8         0.0                                                       XS, YS
     2                                             NPARTS (DISCRETE RING NO. 2)
     3     1     1     5     1     NGEOM(1),NTEMP(1),NMATL(1),INTEG(1),NCREEP(1)
     0.05        0.0        0.0         1.5         5.0        D1, D2, PHI, T, FL
     4     1     1     5     1     NGEOM(2),NTEMP(2),NMATL(2),INTEG(2),NCREEP(2)
     5.8        -1.75       90.0        1.5         3.5        D1, D2, PHI, T, FL
     5.8         0.0                                                       XS, YS
     2                                             NPARTS (DISCRETE RING NO. 3)
     1     1     1     5     1     NGEOM(1),NTEMP(1),NMATL(1),INTEG(1),NCREEP(1)
     2     1     1     5     1     NGEOM(2),NTEMP(2),NMATL(2),INTEG(2),NCREEP(2)
     3.8         0.0                                                       XS, YS
     2                                             NPARTS (DISCRETE RING NO. 4)
     5     1     1     5     1     NGEOM(1),NTEMP(1),NMATL(1),INTEG(1),NCREEP(1)
    -0.05        0.0       180.0        1.5         3.0        D1, D2, PHI, T, FL
     6     1     1     5     1     NGEOM(2),NTEMP(2),NMATL(2),INTEG(2),NCREEP(2)
    -3.8        -1.75       90.0        1.5         3.5        D1, D2, PHI, T, FL
    -3.8         0.0                                                       XS, YS
```

```
170    CONTINUE
            NEXT, THE LOADS ON THIS SHELL SEGMENT WILL BE
            SPECIFIED.  FIRST THE TEMPERATURE DISTRIBUTION THROUGH
            THE SHELL THICKNESS AT VARIOUS MERIDIONAL STATIONS
            WILL BE SPECIFIED.  THEN THE PRESSURE AND MERIDIONAL
            TRACTION DISTRIBUTIONS WILL BE SPECIFIED,  AND THEN
            THE LINE LOADS WILL BE SPECIFIED.    IN THIS SECTION,
            WHICH PERTAINS ONLY TO THE CURRENT SHELL SEGMENT. ONLY
            THE SPATIAL DISTRIBUTIONS OF THE LOADS WILL BE GIVEN.
            THE TIME VARIATIONS WILL BE INDICATED HERE BY POINTERS
            ONLY. AND THE ACTUAL TIME FUNCTIONS TO WHICH THESE
            POINTERS POINT WILL BE SPECIFIED AFTER DATA FOR ALL
            SHELL SEGMENTS HAVE BEEN READ IN.  JUST REMEMBER NOW
            THAT ALL LOADS ARE CONSIDERED TO BE PRODUCTS  SUCH AS

                          P(S,TIME) = PO(S)*F(TIME)

                                                              (LOADS)
```

The concept of time-varying loads is

- necessary for the solution of problems which involve creep.
- useful for the treatment of problems which involve several simultaneously applied nonproportionally "time" varying loads, even if creep is not present and if there are no "real-time" effects in the problem.

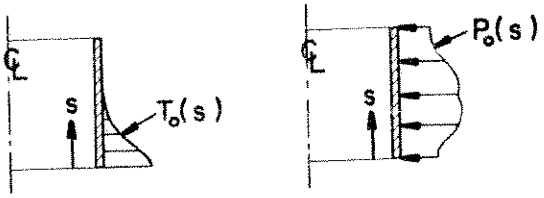
For example, one may wish to calculate the buckling pressure of a cylinder which is subjected to some known and fixed temperature distribution. The temperature is considered to be given by

$$T(s,t) = T_o(s)f_1(t)$$

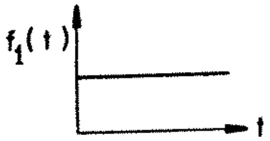
and the pressure by

$$p(s,t) = P_o(s)f_2(t)$$

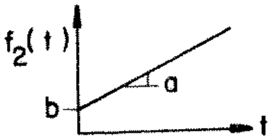
where in this example



$f_1(t)$ = constant, as shown below

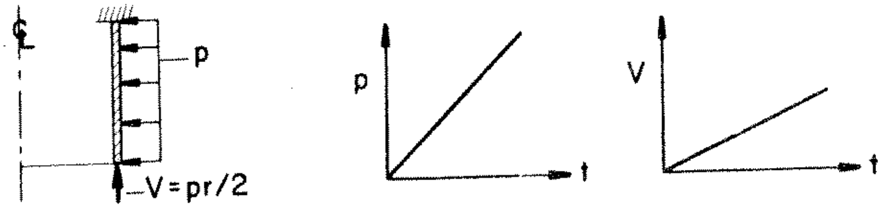


$f_2(t) = at + b$, as shown below

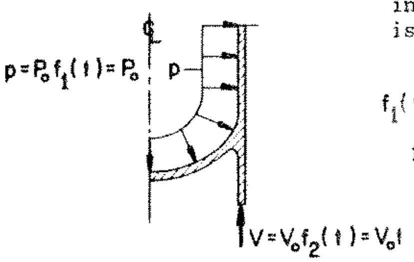


More generally, $f_1(t)$ and $f_2(t)$ may both vary in some arbitrary, user-specified manner. Line loads and moments may also vary with time in a manner different from that of pressure or temperature. The figures below illustrate various proportional and nonproportional loading systems.

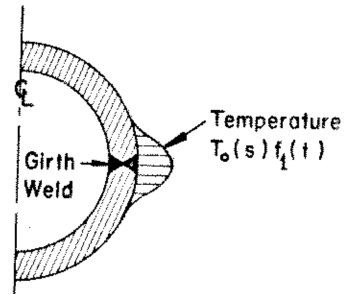
Example 1: Proportional loading. Hydrostatically compressed cylinder. $p = P_o t$

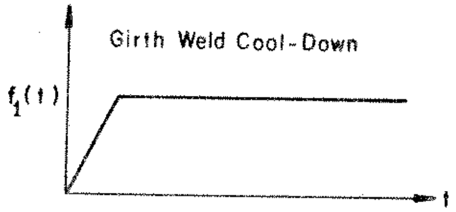


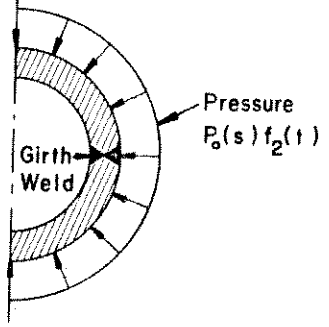
Example 2: Non-proportional loading. Rocket motor case with internal pressure which remains constant during the case and and axial compression which increases during the case. We may wish to know, "What is the axial buckling load?"

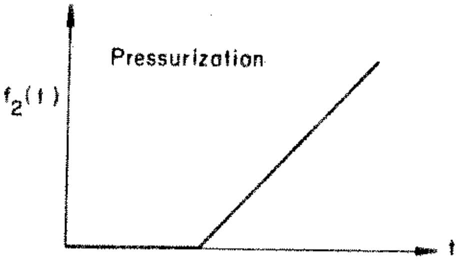


Example 3: Non-proportional loading. Effect of a manufacturing process (welding), with subsequent pressurization. We may wonder, "What is the effect of weld shrinkage and residual stress on the buckling pressure of a spherical shell?"



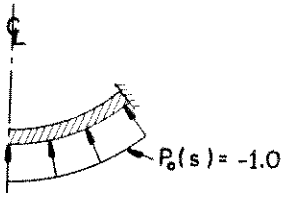


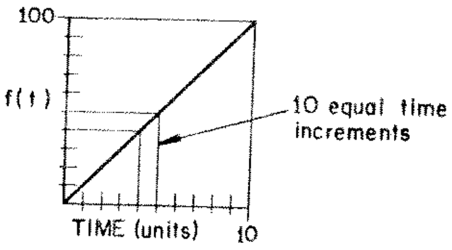




In the following sections the time-independent spatial distributions of temperature $T_o(s)$ and pressure $P_o(s)$ will be specified, after which the time-independent magnitudes of the line loads, such as $V_o = P_o r/2$ in Example 1, will be specified. Associated with each of these types of loads will be a "pointer"--an integer which will indicate which time function, $f_i(t)$ the spatial distribution is to be multiplied by. The various time functions, $f_i(t)$, will then be specified after data for all shell segments have been read in.

At this point the user must decide whether to associate the sign and amplitude of the loading with the spatial function or with the time function. Since the actual load is the product of the two functions, the user is free to choose at this point, a freedom which may cause him to feel unsure. Perhaps an example would help. Suppose that you wish to find the collapse pressure of a shallow spherical cap. You know that the critical pressure lies between 0 and 100 psi, and you decide that you would like to cover this range in ten equal pressure increments. How should you choose your spatial and temporal functions such that the product $p = P_o(s)f(t)$ satisfies these requirements? The figure below illustrates a proper specification of the loading. Alternatively, one could have chosen $P_o(s) = +1.0$ and the time function as varying between 0 and -100 over the time range of 10 units.





NEXT READ DATA FOR TEMPERATURE DISTRIBUTION IN THE CURRENT SHELL SEGMENT. TEMPERATURES THROUGH THE THICKNESS AT VARIOUS MERIDIONAL STATIONS MUST BE SPECIFIED. THE VALUES GIVEN ARE TEMPERATURE RISE (+) OR FALL(-) ABOVE OR BELOW THE ZERO-STRESS-STATE TEMPERATURE.

DATA I6 ** NTSTAT ** (TEMPERATURE)

NTSTAT = NUMBER OF POINTS ALONG MERIDIAN OF THIS SHELL SEGMENT FOR WHICH TEMPERATURES ARE TO BE CALLED OUT.

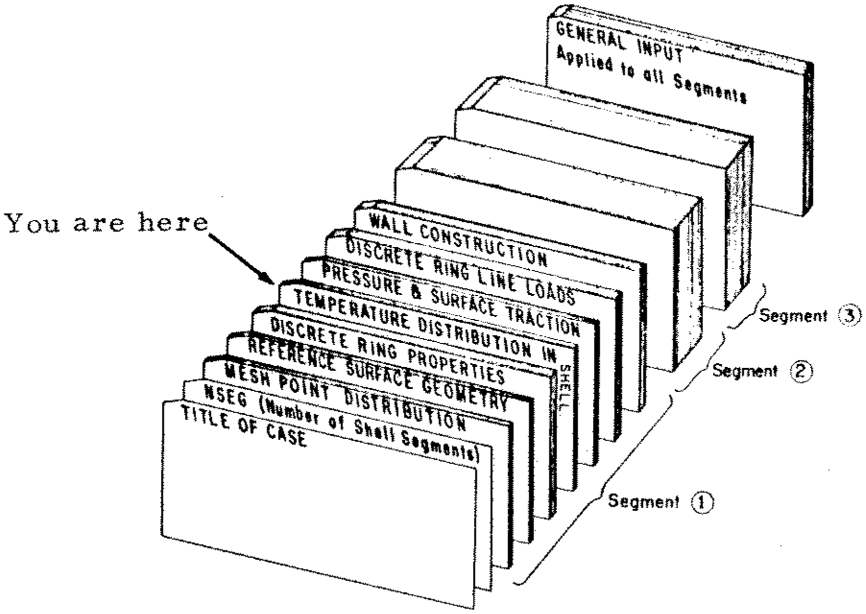
IF NTSTAT = 0. THERE IS NO TEMPERATURE DISTRIBUTION TO BE SPECIFIED IN THIS SHELL SEGMENT...
*** GO TO 210 ***

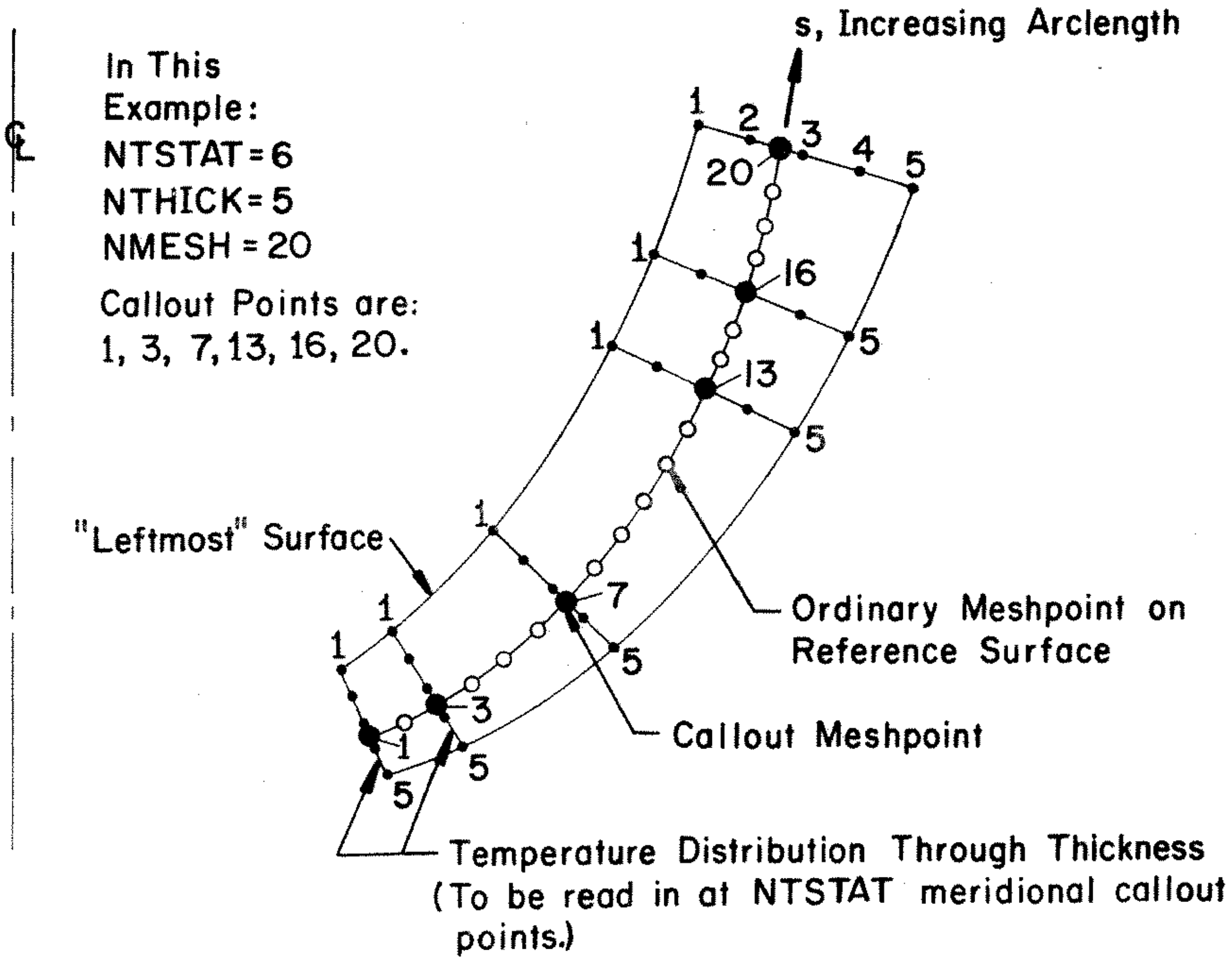
DATA I6 ** NTHICK ** (TEMPERATURE)

NTHICK = NUMBER OF STATIONS THROUGH THE THICKNESS OF THE SHELL WALL AT WHICH THE TEMPERATURE IS TO BE SPECIFIED. NTHICK MAY BE AS LOW AS 1 AND AS HIGH AS THE NUMBER OF INTEGRATION POINTS THROUGH THE SHELL WALL THICKNESS.

IF NTSTAT = 1. THE TEMPERATURE MAY VARY THRU THE THICKNESS OF THE SHELL WALL. BUT IT IS UNIFORM ALONG THE MERIDIAN IN THIS SEG.
*** GO TO 180 ***

IF NTSTAT IS GREATER THAN 1, THE TEMPERATURE DISTRIBUTION THROUGH THE THICKNESS WILL BE READ IN FOR CERTAIN CALLOUT POINTS ALONG THE MERIDIAN. VALUES AT ALL MERIDIONAL STATIONS WILL BE DETERMINED BY LINEAR INTERPOLATION BETWEEN CALLOUTS.
THE USER MUST INCLUDE THE FIRST AND LAST POINTS OF THE SEGMENT AS MERIDIONAL CALLOUTS.


GENERAL INPUT
Applied to all Segments
You are here
WALL CONSTRUCTION
DISCRETE RING LINE LOADS
PRESSURE & SURFACE TRACTION
TEMPERATURE DISTRIBUTION IN SHELL
DISCRETE RING PROPERTIES
REFERENCE SURFACE GEOMETRY
MESH POINT DISTRIBUTION
NSEG (Number of Shell Segments)
TITLE OF CASE
Segment ③
Segment ②
Segment ①


s, Increasing Arclength
℄
In This Example:
NTSTAT = 6
NTHICK = 5
NMESH = 20
Callout Points are:
1, 3, 7, 13, 16, 20.
1
2
3
4
5
20
16
13
7
"Leftmost" Surface
Ordinary Meshpoint on Reference Surface
Callout Meshpoint
Temperature Distribution Through Thickness (To be read in at NTSTAT meridional callout points.)

```
           NEXT, ESTABLISH LOCATIONS ALONG THE MERIDIAN WHERE   (TEMP.)
           TEMPERATURES ARE TO BE READ IN THRU THE THICKNESS.
*************NOTE... NUMBER OF CALLOUTS = NTSTAT  ***********

DATA    I6    **NTYPE**                                      (NTSTAT.GT.1)
           NTYPE= CONTROL INTEGER FOR CALLOUT SPECIFICATION....

                  NTYPE=1 MESH POINTS WILL BE CALLED OUT DIRECTLY.
                  IF NTYPE = 1  ***GO TO A***
                  NTYPE=2 AXIAL DISTANCES, Z, FROM DATUM CALLED OUT
                  IF NTYPE = 2  ***GO TO B***
                  NTYPE=3 DISTANCES, R, FROM AXIS OF REV. CALLED OUT
                  IF NTYPE = 3  ***GO TO C***
                  NTYPE=4 ARC LENGTHS, S, FROM SEG. START CALLED OUT
                  IF NTYPE = 4  ***GO TO D***
                  NTYPE=5 ANGLES, THETA, IN DEGREES FROM AXIS OF REV.
                  IF NTYPE = 5  ***GO TO E***

A     CONTINUE                                               (NTSTAT.GT.1)

DATA   10I6  **(IPOINT(J), J=1,NTSTAT) **                        (NTYPE=1)

           IPOINT= MESH POINT NUMBERS OF CALLOUTS               (NTYPE=1)

            ***GO TO F***
B     CONTINUE                                               (NTSTAT.GT.1)

DATA  6E12.8 **(     Z(J), J=1,NTSTAT) **                        (NTYPE=2)

           Z= AXIAL DISTANCES TO CALLOUTS, MEASURED FROM  THE  (NTYPE=2)
              SAME DATUM AS THAT USED FOR THE SPECIFICATION    (NTYPE=2)
              OF THE MERIDIONAL GEOMETRY. (SHELL GEOMETRY)     (NTYPE=2)

            ***GO TO F***
C     CONTINUE                                               (NTSTAT.GT.1)

DATA  6E12.8 **(     R(J), J=1,NTSTAT) **                        (NTYPE=3)

           R= RADIAL DISTANCES FROM AXIS TO CALLOUTS            (NTYPE=3)

            ***GO TO F***
D     CONTINUE                                               (NTSTAT.GT.1)

DATA  6E12.8 **(     S(J), J=1,NTSTAT) **                        (NTYPE=4)

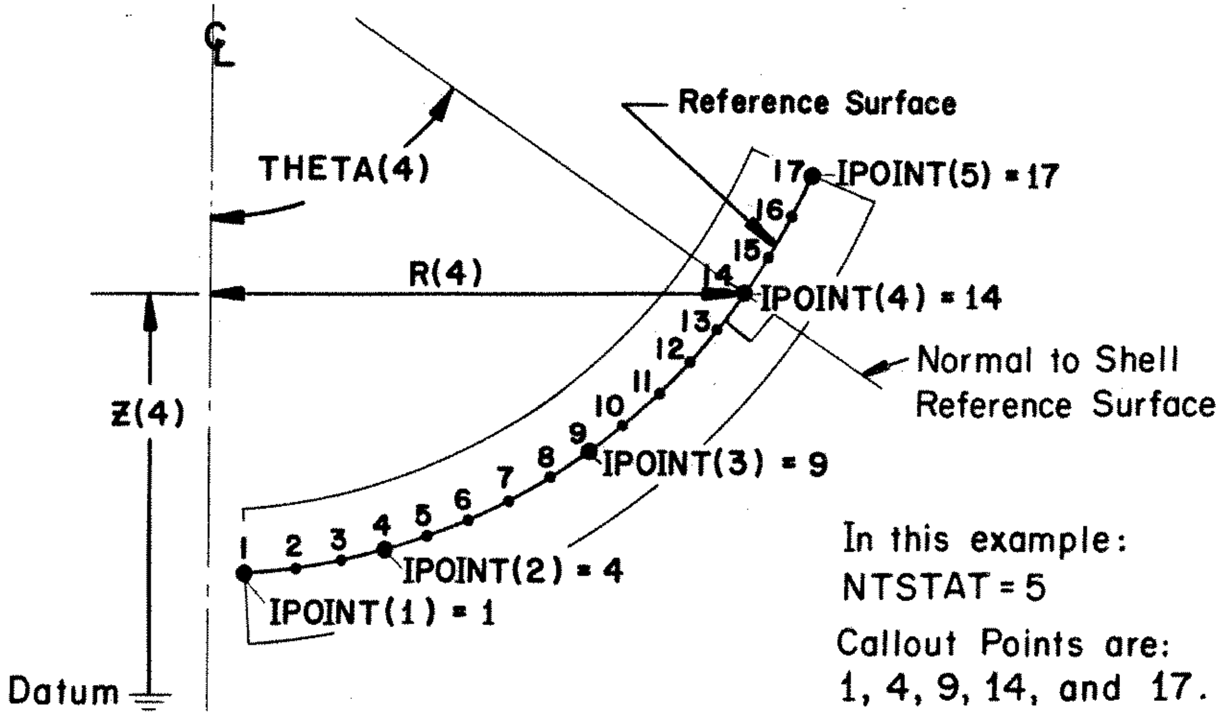
           S= ARC LENGTHS FROM SEG. START TO CALLOUTS           (NTYPE=4)

            ***GO TO F***
E     CONTINUE                                               (NTSTAT.GT.1)

DATA  6E12.8 **( THETA(J), J=1,NTSTAT) **                        (NTYPE=5)

           THETA= ANGLES IN DEGREES FROM AXIS OF REVOLUTION   (NTYPE=5)
                  TO CALLOUTS, (NORMAL TO REF. SURF.)          (NTYPE=5)

F     CONTINUE                                               (TEMPERATURE)
```



In this example:
NTSTAT = 5
Callout Points are:
1, 4, 9, 14, and 17.

Z(4) measured from same datum used to specify geometry of the current shell segment.

180 CONTINUE

NEXT, READ TEMPERATURE RISE THRU THICKNESS AT ALL MERIDIONAL CALLOUT STATIONS...

****** DO 190 L = 1,NTSTAT ****** (TEMPERATURE DISTRIBUTION)

DATA 6E12.8 ** (TEMP(L,J), J = 1,NTHICK) **

NTSTAT = NUMBER OF POINTS ALONG MERIDIAN OF THIS SHELL SEGMENT FOR WHICH TEMPERATURES ARE CALLED OUT.

NTHICK = NUMBER OF STATIONS THROUGH THE THICKNESS OF THE SHELL WALL AT WHICH THE TEMPERATURE IS SPECIFIED.

TEMP(L,J) = TEMPERATURE RISE OR FALL AT LTH MERIDIONAL CALLOUT STATION AND AT JTH POINT THRU THE THICKNESS. TEMP(L,J), J=1,NTHICK, MUST BE READ IN IN THE PROPER ORDER.. FROM LEFT TO RIGHT AS YOU FACE IN THE DIRECTION OF INCREASING MERIDIONAL ARC, S. INCREASING MERIDIONAL CALLOUT INDEX, L, MUST CORRESPOND TO MOVEMENT FROM THE BEGINNING TOWARD THE END OF THE SEGMENT.

(TEMPERATURE)

190 CONTINUE

NEXT, IF NTHICK IS GREATER THAN 2, READ THE COORDINATES THRU THE THICKNESS OF THE SHELL WALL WHICH CORRESPOND TO THE VALUES OF TEMP ALREADY READ IN. YOU DO NOT READ THE VALUES CORRESPONDING TO THE SURFACES, ONLY THOSE CORRESPONDING TO POINTS WITHIN THE WALL. FOR EXAMPLE, IF YOU READ THE TEMPERATURE AT 5 STATIONS THRU THE THICKNESS, YOU ONLY READ 3 VALUES FOR THE THICKNESS STATIONS. THESE MUST BE IN THE PROPER ORDER.. FROM LEFT TO RIGHT AS YOU FACE IN THE DIRECTION OF INCREASING MERIDIONAL COORDINATE, S. SEE FIG. OPPOSITE.

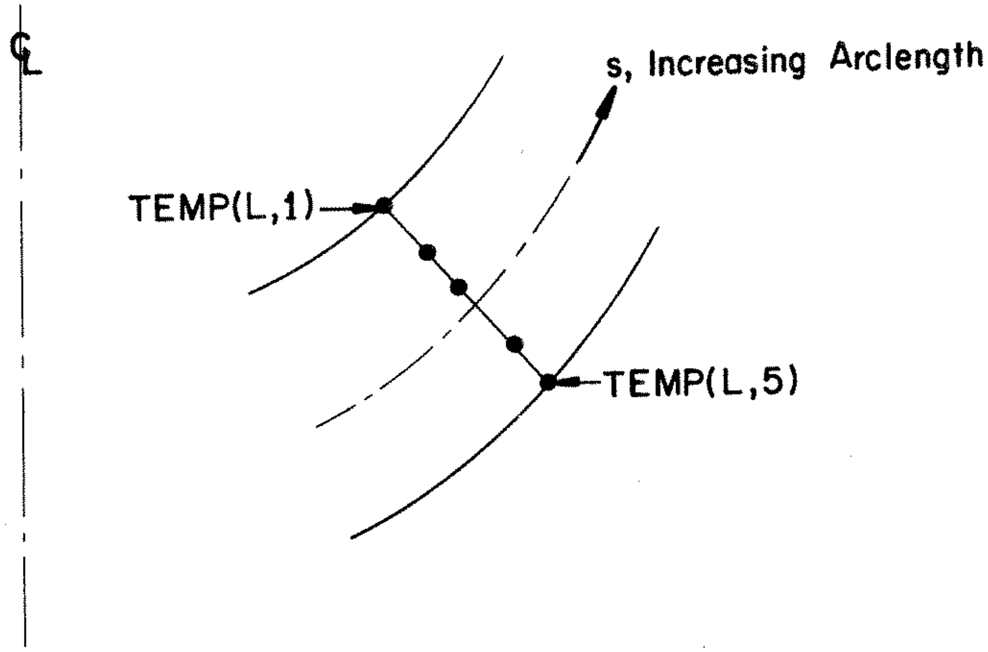
IF NTHICK IS LESS THAN OR EQUAL TO 2, *** GO TO 205 ***

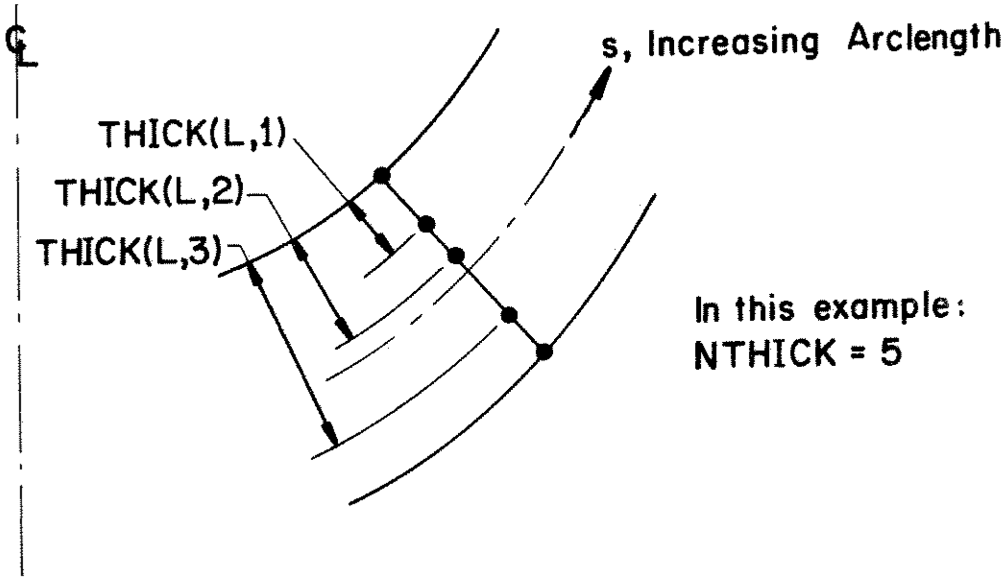
******* DO 200 L = 1,NTSTAT ******

DATA 6E12.8 ** (THICK(L,J), J=1,NTHICK-2) **

THICK = DISTANCES FROM LEFTMOST SHELL SURFACE TO POINTS WITHIN SHELL WALL FOR WHICH TEMPERATURE RISE HAS BEEN SPECIFIED BY PREVIOUS INPUT, TEMP.

200 CONTINUE


℄
s, Increasing Arclength
TEMP(L,1)
TEMP(L,5)


℄
s, Increasing Arclength
THICK(L,1)
THICK(L,2)
THICK(L,3)
In this example:
NTHICK = 5

205 CONTINUE

DATA I6 ** IDTEMP(ISEG) ** (POINTER)

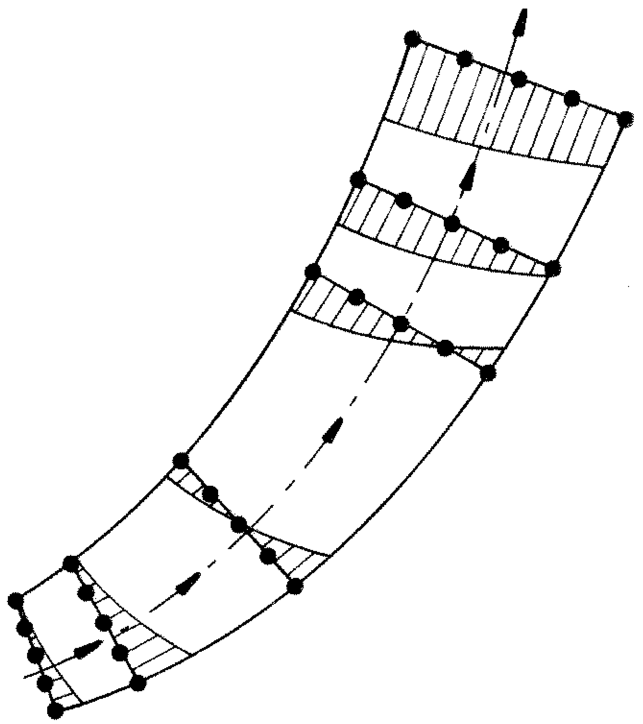
IDTEMP= CONTROL INTEGER FOR TIME FUNCTION TO BE ASSOCIATED WITH TEMPERATURE RISE IN SEGMENT, ISEG. NOTE THAT DIFFERENT TIME FUNCTIONS MAY BE ASSOCIATED WITH TEMP IN DIFFERENT SHELL SEGMENTS.

ISEG = CURRENT SHELL SEGMENT NUMBER.

NOTE... THE TIME FUNCTION INDICATOR, IDTEMP(ISEG) IS A POINTER WHICH WILL CAUSE THE APPROPRIATE FUNCTION OF TIME TO BE ASSOCIATED WITH THE TEMPERATURE DISTRIBUTION IN SEGMENT NO. ISEG. DIFFERENT TIME FUNCTIONS CAN BE ASSOCIATED WITH THE TEMPERATURE DISTRIBUTIONS IN DIFFERENT SHELL SEGMENTS. THE EXACT NATURE OF THESE TIME FUNCTIONS WILL BE SPECIFIED LATER. RIGHT NOW, ALL THE USER NEED DO IS SPECIFY 1, 2, 3, OR OTHER SIMPLE INTEGER. START WITH AN APPROPRIATE VALUE WHICH DEPENDS ON WHAT OTHER LOADS HAVE ALREADY BEEN SPECIFIED IN THIS CASE UP TO NOW. IDTEMP(ISEG) SHOULD BE UNITY IF THIS IS THE FIRST 'LOAD' EVER SPECIFIED IN THIS CASE.
EACH TIME A NEW TIME FUNCTION IS TO BE INTRODUCED, USE A HIGHER INTEGER (HIGHER BY 1) THAN HAS EVER BEEN USED BEFORE TO SPECIFY THE TIME VARIATION OF ANY LOAD, WHETHER IT BE FOR A PREVIOUSLY SPECIFIED LINE LOAD, DISTRIBUTED LOAD, OR TEMPERATURE DISTRIBUTION. THIS WORD 'PREVIOUS' INCLUDES LOADS SPECIFIED IN PREVIOUS SEGMENTS AS WELL AS THOSE SPECIFIED PREVIOUSLY IN THE CURRENT SEGMENT.

NOTE...'NEW TIME FUNCTION' MEANS A DIFFERENT FUNCTION OF TIME THAN HAS BEEN SPECIFIED PREVIOUSLY.

EXAMPLE OF TEMPERATURE INPUT



EXAMPLE OF TEMPERATURE INPUT CORRESPONDING TO ABOVE FIGURE AND TO THE FIGURE ON PAGE P33

```
                                                     48             60              72
COL. 6    12      18     24      30     36
-------------------------------------------------------------------------------------------
                                                                              NTSTAT
     6                                                                        NTHICK
     5                                                                        NTYPE
     1                                                               (IPOINT(J),J=1,NTSTAT)
     1     3       7     13      16     20                           (TEMP(1,J),J=1,NTHICK)
   0.0           10.0            30.0          80.0         160.0    (TEMP(2,J),J=1,NTHICK)
  50.0           85.0           150.0         250.0         575.0    (TEMP(3,J),J=1,NTHICK)
 -65.0          -20.0            10.0         100.0         350.0    (TEMP(4,J),J=1,NTHICK)
-275.0         -200.0          -150.0         -10.0         150.0    (TEMP(5,J),J=1,NTHICK
-350.0         -300.0          -250.0        -150.0         -35.0    (TEMP(6,J),J=1,NTHICK
-600.0         -575.0          -540.0        -450.0        -400.0   (THICK(1,J),J=1,NTHICK-2
   0.2            0.4            0.55                               (THICK(2,J),J=1,NTHICK-2
   0.25           0.50           0.70                               (THICK(3,J),J=1,NTHICK-2
   0.3            0.6            0.85                               (THICK(4,J),J=1,NTHICK-2
   0.33           0.64           0.92                               (THICK(5,J),J=1,NTHICK-2
   0.40           0.75           1.20                               (THICK(6,J),J=1,NTHICK-2
   0.42           0.84           1.35                                         IDTEMP(ISEG
     1
```

```
210   CONTINUE

            NEXT THE DISTRIBUTED LOADS, IF ANY, ARE READ IN  ...

DATA      I6   ** NPSTAT **

            NPSTAT = NUMBER OF POINTS ALONG MERIDIAN OF THIS
                     SHELL SEGMENT FOR WHICH NORMAL PRESSURE AND
                     MERIDIONAL SURFACE TRACTION ARE TO BE CALLED
                     OUT. THESE LOADS ARE ASSUMED TO ACT ON THE
                     REFERENCE SURFACE.

            IF NPSTAT = 0, THERE ARE NO DISTRIBUTED LOADS IN THIS
                           SHELL SEGMENT...   *** GO TO 240 ***

            IF NPSTAT = 1, THE DISTRIBUTED LOADS ARE UNIFORM IN
                           THIS SHELL SEGMENT. PN AND PT WILL BE READ.
                           *** GO TO 215 ***

            IF NPSTAT IS GREATER THAN 1, THE NORMAL PRESSURE AND
                           MERIDIONAL SURFACE TRACTION WILL BE
                           READ IN FOR CERTAIN CALLOUT POINTS.
                           VALUES AT ALL MERIDIONAL STATIONS WILL
                           BE DETERMINED BY LINEAR INTERPOLATION
                           BETWEEN CALLOUTS.  THE USER MUST INCLUDE
                           THE FIRST AND LAST POINTS OF THE SEGMENT
                           AS CALLOUTS.   *** GO TO 220 ***

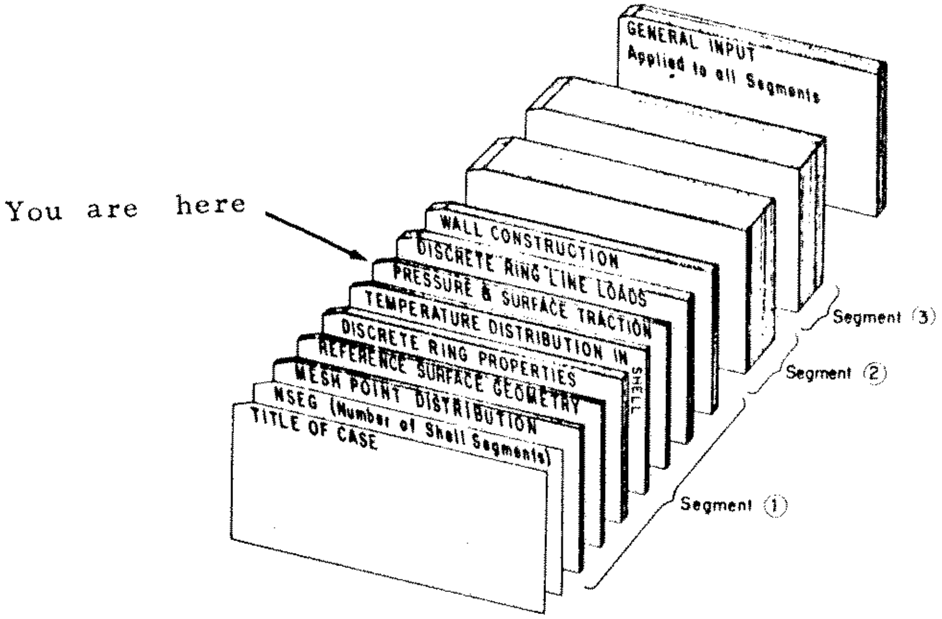
215   CONTINUE                                          (UNIFORM PN, PT)

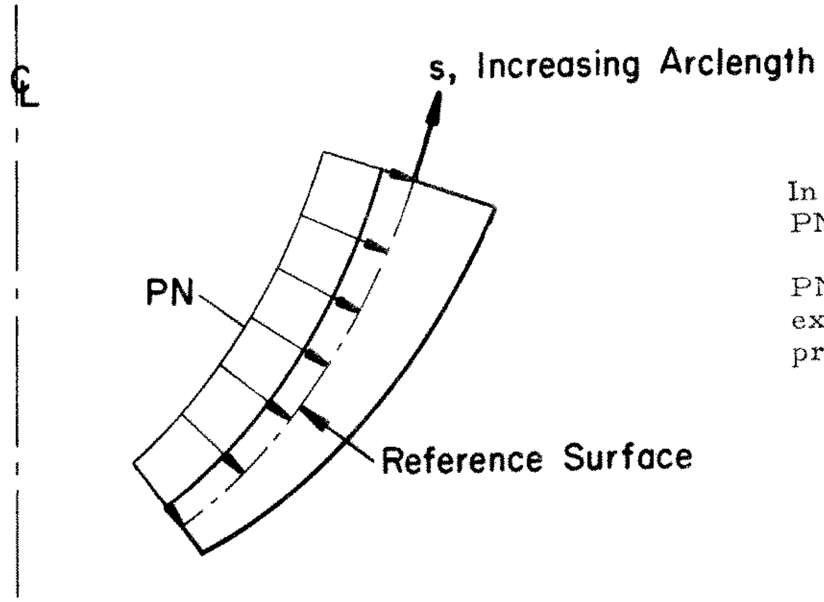
DATA  E12.8    ** PN **                                       (NPSTAT=1)
DATA  E12.8    ** PT **                                       (NPSTAT=1)

            PN = NORMAL PRESSURE, POSITIVE IF IT PUSHES YOU     (NPSTAT=1)
                 TO THE RIGHT AS YOU TRAVEL IN THE DIRECTION OF
                 INCREASING MERIDIONAL ARC, S.                  (PRESSURE)
                 ACTUAL PRESSURE IS REPRESENTED BY THE PRODUCT
                             P = PN*F(TIME)
                 IN WHICH THE FUNCTION OF TIME F(TIME) REMAINS
                 TO BE SPECIFIED.

            PT = MERIDIONAL SURFACE TRACTION (SAME UNITS AS PN)(NPSTAT=1)
                 POSITIVE IF IT PUSHES YOU IN DIRECTION OF
                 INCREASING MERIDIONAL COORDINATE, S.
                 PT  IS ASSOCIATED WITH THE SAME F(TIME) AS PN,
                 ALTHOUGH ITS AMPLITUDE MAY BE DIFFERENT FROM PN,
                 OF COURSE. FOR INSTANCE, PT CAN BE ZERO WHILE
                 PN IS NOT.

         *** GO TO 230 ***
```





In this example:
PN is Positive

PN = + 1.0, for example, if the pressure is uniform

Note: Pressure is considered to act on the reference surface.

Note: If the pressure is uniform, it is best to use ± 1.0 for PN and let the time function F(TIME) give the magnitude. Later on, the current pressure can then be read directly from the output of the BØSØR5 main processor, without the user having to refer back to the preprocessor for post-run calculation of PN x F(TIME). Input data for F(TIME) is to be read in below.

```
220    CONTINUE                                                 (NPSTAT.GT.1)
              NEXT, ESTABLISH LOCATIONS ALONG THE MERIDIAN WHERE
              PRESSURE AND MERIDIONAL TRACTION ARE CALLED OUT...
*************NOTE... NUMBER OF CALLOUTS = NPSTAT  ***********

DATA     I6   **NTYPE**                                         (NPSTAT.GT.1)
              NTYPE= CONTROL INTEGER FOR CALLOUT SPECIFICATION....

                    NTYPE=1 MESH POINTS WILL BE CALLED OUT DIRECTLY.
                    IF NTYPE = 1   ***GO TO A***
                    NTYPE=2 AXIAL DISTANCES, Z, FROM DATUM CALLED OUT
                    IF NTYPE = 2   ***GO TO B***
                    NTYPE=3 DISTANCES, R, FROM AXIS OF REV. CALLED OUT
                    IF NTYPE = 3   ***GO TO C***
                    NTYPE=4 ARC LENGTHS, S, FROM SEG. START CALLED OUT
                    IF NTYPE = 4   ***GO TO D***
                    NTYPE=5 ANGLES, THETA, IN DEGREES FROM AXIS OF REV.
                    IF NTYPE = 5   ***GO TO E***

A      CONTINUE                                                 (NPSTAT.GT.1)

DATA    10I6  **(IPOINT(J), J=1,NPSTAT) **                          (NTYPE=1)

              IPOINT= MESH POINT NUMBERS OF CALLOUTS               (NTYPE=1)

               ***GO TO F***
B      CONTINUE                                                 (NPSTAT.GT.1)

DATA   6E12.8 **(      Z(J), J=1,NPSTAT) **                         (NTYPE=2)

              Z= AXIAL DISTANCES TO CALLOUTS, MEASURED FROM  THE  (NTYPE=2)
                 SAME DATUM AS THAT USED FOR THE SPECIFICATION    (NTYPE=2)
                 OF THE MERIDIONAL GEOMETRY, (SHELL GEOMETRY)     (NTYPE=2)

               ***GO TO F***

C      CONTINUE                                                 (NPSTAT.GT.1)

DATA   6E12.8 **(      R(J), J=1,NPSTAT) **                         (NTYPE=3)

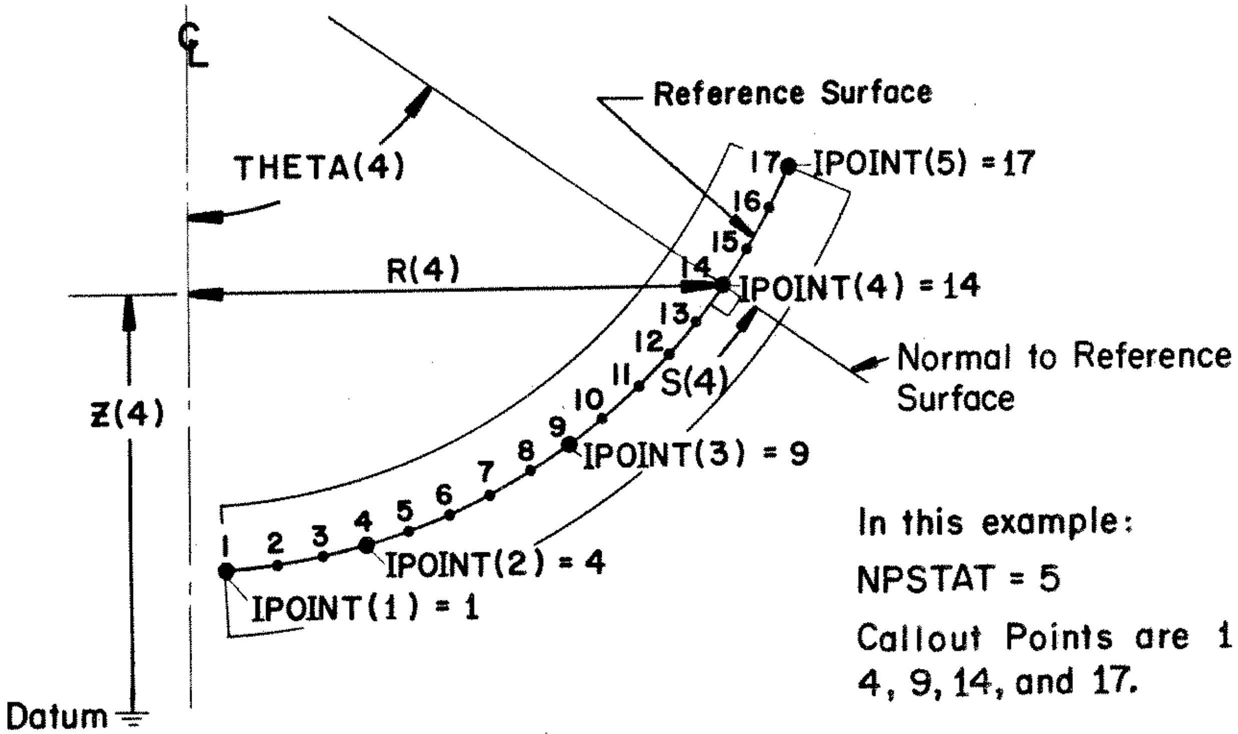
              R= RADIAL DISTANCES FROM AXIS TO CALLOUTS            (NTYPE=3)
               ***GO TO F***
D      CONTINUE                                                 (NPSTAT.GT.1)

DATA   6E12.8 **(      S(J), J=1,NPSTAT) **                         (NTYPE=4)

              S= ARC LENGTHS FROM SEG. START TO CALLOUTS           (NTYPE=4)
               ***GO TO F***
E      CONTINUE                                                 (NPSTAT.GT.1)

DATA   6E12.8 **( THETA(J), J=1,NPSTAT) **                          (NTYPE=5)

              THETA= ANGLES IN DEGREES FROM AXIS OF REVOLUTION    (NTYPE=5)
                    TO CALLOUTS, (NORMAL TO REF. SURF.)           (NTYPE=5)
F      CONTINUE                                                  (PRESSURE)
```



In this example:

NPSTAT = 5

Callout Points are 1, 4, 9, 14, and 17.

Z(4) measured from same datum used to specify geometry of current shell segment.

NOW READ THE NORMAL AND MERIDIONAL COMPONENTS...

DATA 6E12.8 ** (PN(J), J=1,NPSTAT) ** (PRESSURE)
DATA 6E12.8 ** (PT(J), J=1,NPSTAT) ** (MERIDIONAL TRACTION)

NPSTAT = NUMBER OF POINTS ALONG MERIDIAN OF THIS SHELL SEGMENT FOR WHICH NORMAL PRESSURE AND MERIDIONAL SURFACE TRACTION ARE CALLED OUT.

PN = NORMAL PRESSURE DISTRIBUTION AT CALLOUT POINTS. POSITIVE IF IT PUSHES YOU TO THE RIGHT AS YOU TRAVEL IN THE DIRECTION OF INCREASING MERIDIONAL ARC. ACTUAL DISTRIBUTION OBTAINED BY LINEAR INTERPOLATION. ACTUAL PRESSURE IS REPRESENTED BY THE PRODUCT

P = PN*F(TIME)

IN WHICH THE FUNCTION OF TIME F(TIME) REMAINS TO BE SPECIFIED.

PT = MERIDIONAL SURFACE TRACTION, POSITIVE IN SAME DIRECTION AS INCREASING MERIDIONAL ARC, S.

230 CONTINUE (PRESSURE)

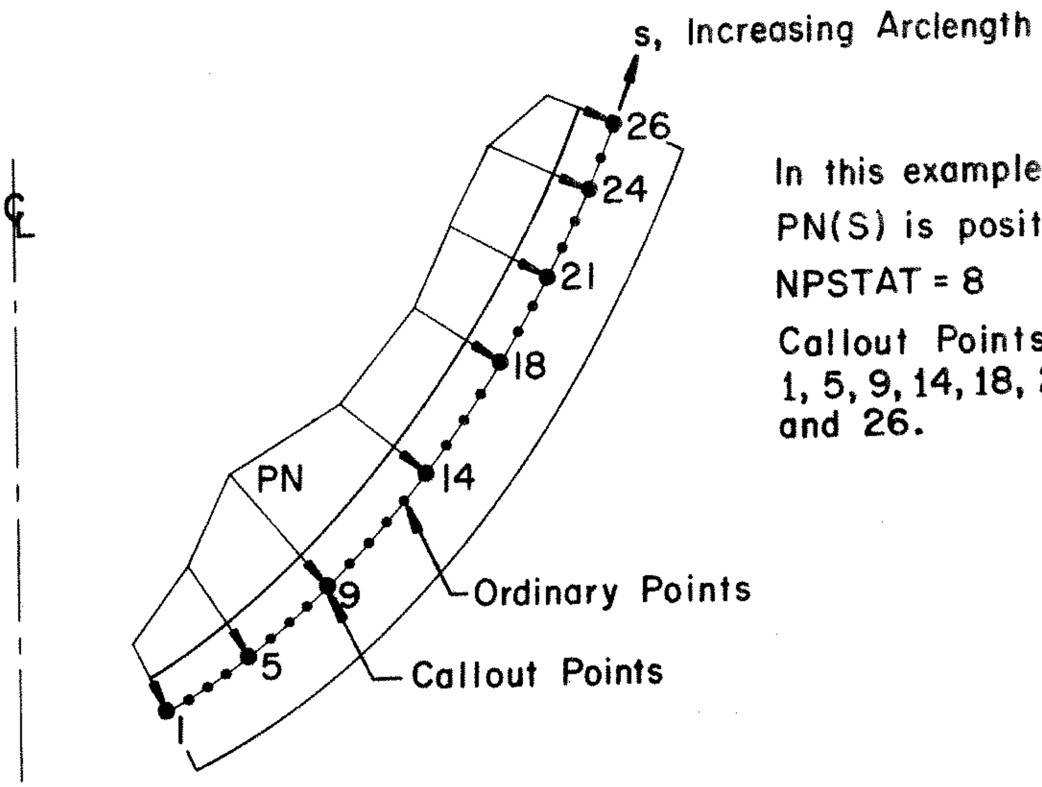
DATA I6 ** ISTEP(ISEG) ** (POINTER)

ISTEP= CONTROL INTEGER FOR TIME FUNCTION TO BE ASSOCIATED WITH NORMAL PRESSURE AND MERIDIONAL TRACTION. NOTE THAT THE SAME TIME FUNCTION IS TO BE ASSOCIATED WITH BOTH PN AND PT, BUT THAT DIFFERENT TIME FUNCTIONS MAY BE ASSOCIATED WITH PN AND PT IN DIFFERENT SHELL SEGMENTS.

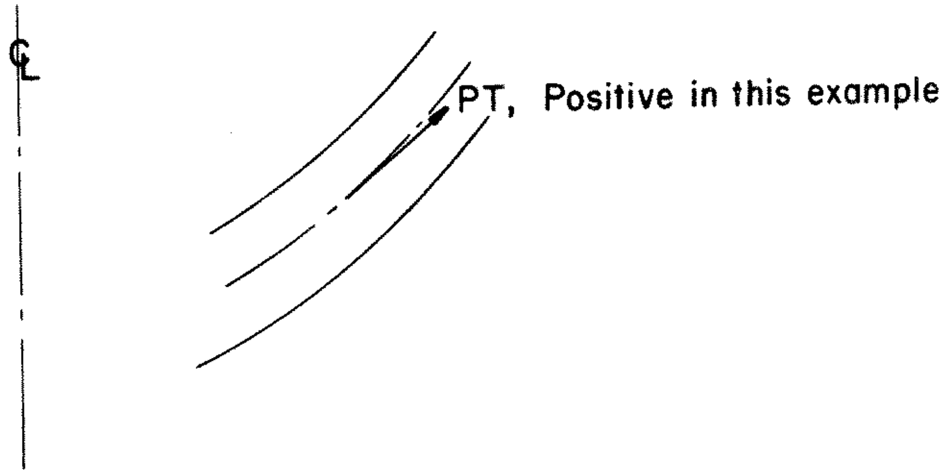
ISEG = THE CURRENT SHELL SEGMENT NUMBER.

NOTE... THE TIME FUNCTION INDICATOR, ISTEP(ISEG) IS A POINTER WHICH WILL CAUSE THE APPROPRIATE FUNCTION OF TIME TO BE ASSOCIATED WITH THE DISTRIBUTED LOADS IN SEGMENT NO. ISEG. DIFFERENT TIME FUNCTIONS CAN BE ASSOCIATED WITH THE DISTRIBUTED LOADS IN DIFFERENT SHELL SEGMENTS. THE EXACT NATURE OF THESE TIME FUNCTIONS WILL BE SPECIFIED LATER. RIGHT NOW, ALL THE USER NEED DO IS SPECIFY 1, 2, 3, OR OTHER SIMPLE INTEGER. START WITH AN APPROPRIATE VALUE, WHICH DEPENDS ON WHAT OTHER LOADS HAVE ALREADY BEEN SPECIFIED IN THIS CASE UP TO NOW. IF NO LOADS HAVE BEEN PREVIOUSLY SPECIFIED IN THIS CASE, SET ISTEP(ISEG) = 1 . EACH TIME A NEW TIME FUNCTION IS TO BE INTRODUCED, USE A HIGHER INTEGER (HIGHER BY 1) THAN HAS EVER BEEN USED BEFORE TO SPECIFY THE TIME VARIATION OF ANY LOAD, WHETHER IT BE FOR A PREVIOUSLY SPECIFIED LINE LOAD, DISTRIBUTED LOAD, OR TEMPERATURE DISTRIBUTION. THIS WORD 'PREVIOUS' INCLUDES LOADS SPECIFIED IN PREVIOUS SEGMENTS AS WELL AS THOSE SPECIFIED PREVIOUSLY IN THE CURRENT SEGMENT.

NOTE...'NEW TIME FUNCTION' MEANS A DIFFERENT FUNCTION OF TIME THAN HAS BEEN SPECIFIED PREVIOUSLY. (PRESSURE)



In this example:
PN(S) is positive
NPSTAT = 8
Callout Points are:
1, 5, 9, 14, 18, 21, 24 and 26.



```
EXAMPLE OF PRESSURE INPUT CORRESPONDING TO ABOVE FIGURE

COL    6    12    18    24    30    36    42    48    54    60    66    72
                                                                     NPSTAT
       8                                                             NTYPE
       1                                                (IPOINT(J),J=1,NPSTAT)
       1     5     9    14    18    21    24    26                 (PN(J),J=1,6)
  0.60        0.80        1.0         0.7         0.65        0.67 (PN(J),J=7,8)
  0.65        0.59                                                 (PT(J),J=1,6)
  0.0         0.0         0.0         0.0         0.0         0.0  (PT(J),J=7,8)
  0.0         0.0                                                  ISTEP(ISEG)
     1
```

```
240   CONTINUE
            NEXT, READ IN THE LINE LOADS FOR THIS SHELL SEGMENT...

DATA     I6  ** LINTYP **
```

LINTYP = 0 MEANS NO LINE LOADS
LINTYP = 1 MEANS THAT THERE ARE LINE LOADS

(REMEMBER THAT LINE LOADS MUST ALWAYS BE ASSOCIATED WITH A DISCRETE RING. IT MAY BE A FICTITIOUS DISCRETE RING. HYDROSTATIC PRESSURE MAY 'GENERATE' A LINE LOAD V=PR/2, THUS REQUIRING USER TO SET LINTYP = 1)

IF LINTYP = 0 *** GO TO 250 ***

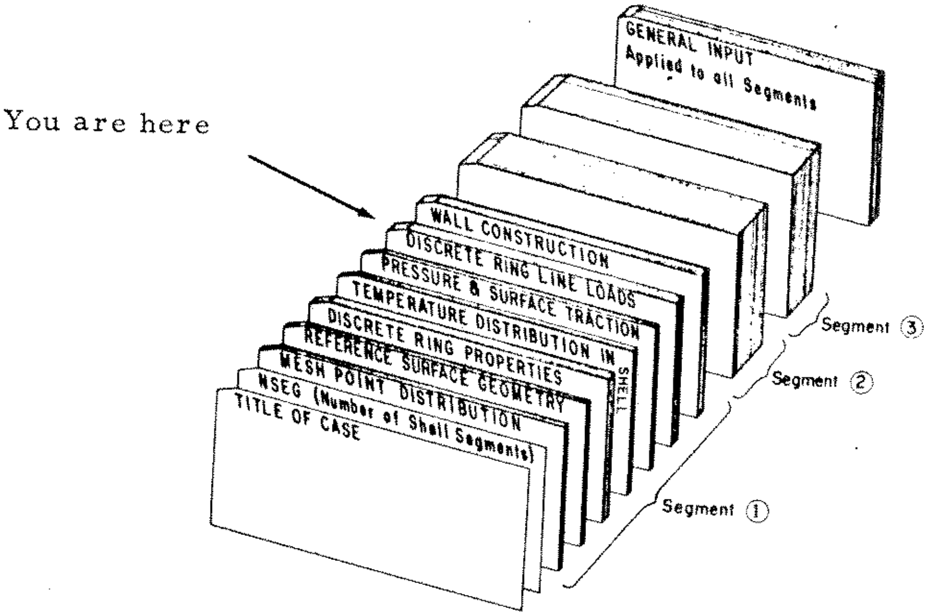
```
DATA  6E12.8 **(V(K),        K=1,NRINGS) **             (AXIAL LOAD/LENGTH)
DATA  6E12.8 **(HF(K),       K=1,NRINGS) **            (RADIAL LOAD/LENGTH)
DATA  6E12.8 **(FM(K),       K=1,NRINGS) **     (MERIDIONAL MOMENT/LENGTH)
DATA  10I6   **(ISTEP1(K), K=1,NRINGS) **                        (POINTER)
DATA  10I6   **(ISTEP2(K), K=1,NRINGS) **                        (POINTER)
DATA  10I6   **(ISTEP3(K), K=1,NRINGS) **                        (POINTER)
```

NRINGS = NUMBER OF DISCRETE RINGS IN CURRENT SHELL SEGMENT.
V = AXIAL LINE LOAD THRU RING CENTROID, POSITIVE AS SHOWN IN FIGURE.
HF = RADIAL LINE LOAD THRU RING CENTROID, POSITIVE AS SHOWN IN FIGURE
FM = LINE MOMENT ABOUT RING CENTROID, POSITIVE AS SHOWN IN FIGURE.

NOTE.. THE ACTUAL LINE LOADS ARE REPRESENTED BY PRODUCTS,
V*F1(TIME), HF*F2(TIME), FM*F3(TIME)
IN WHICH THE FUNCTIONS OF TIME F1,F2, AND F3 REMAIN TO BE SPECIFIED. (LINE LOADS)

ISTEP1 = CONTROL INTEGER FOR TIME FUNCTION OF V
ISTEP2 = CONTROL INTEGER FOR TIME FUNCTION OF HF
ISTEP3 = CONTROL INTEGER FOR TIME FUNCTION OF FM

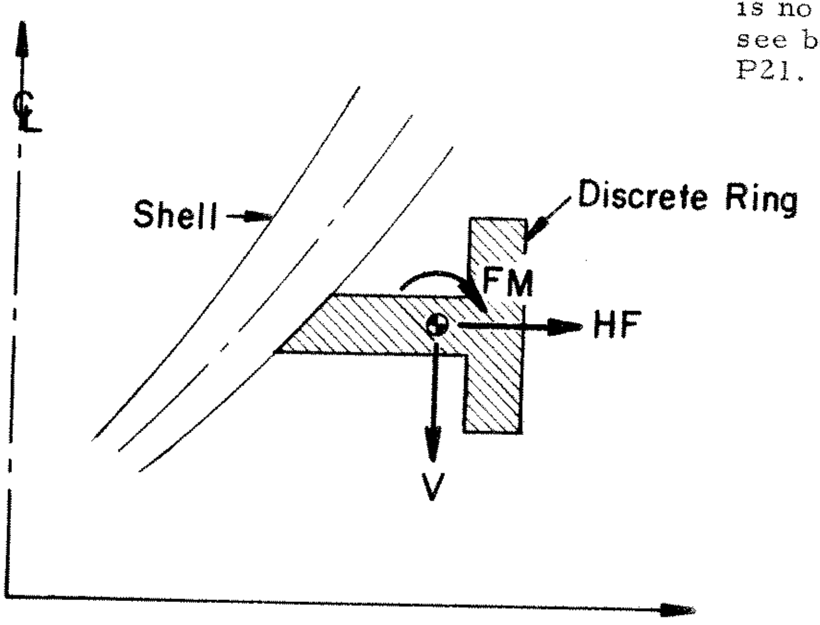
NOTE... THE TIME FUNCTION INDICATORS, ISTEP1,ISTEP2, AND ISTEP3,ARE POINTERS WHICH WILL CAUSE THE APPROPRIATE FUNCTIONS OF TIME TO BE ASSOCIATED WITH EACH OF THE LINE LOADS. DIFFERENT TIME FUNCTIONS CAN BE ASSOCIATED WITH EACH OF THE LINE LOADS. THE EXACT NATURE OF THESE TIME FUNCTIONS WILL BE SPECIFIED LATER. RIGHT NOW, ALL THE USER NEED DO IS SPECIFY 0, 1, 2, 3, OR OTHER SIMPLE INTEGER. START WITH AN APPROPRIATE VALUE, WHICH DEPENDS ON WHAT OTHER LOADS HAVE ALREADY BEEN SPECIFIED IN THIS CASE UP TO NOW. USE THE VALUE ZERO IF THERE IS NO LINE LOAD OF THAT PARTICULAR TYPE....
(E.G. ISTEP2(K) = 0 IF HF(K) = 0.0)
IF NO LOADS HAVE PREVIOUSLY BEEN SPECIFIED, SET THE FIRST 'MEANINGFUL' (NON-ZERO) ISTEP1(K) OR ISTEP2(K) OR ISTEP3(K) EQUAL TO UNITY.



Remember that for hydrostatic pressure

$$V = pr/2$$

at a boundary. The user must supply this V. Note, however, that the time function pointer, ISTEP1( ), corresponding to $V = pr/2$ will have the same value as the pointer, ISTEP (ISEG), corresponding to p. Don't forget the fictitious ring if there is no real ring! Also, see bottom half of Page P21.



NOTE:

(1) Line loads are shown in their positive directions in this figure;

(2) Line loads are assumed to act at the discrete ring centroid.

EACH TIME A NEW TIME FUNCTION IS TO BE INTRODUCED, USE A HIGHER INTEGER (HIGHER BY 1) THAN HAS EVER BEEN USED BEFORE TO SPECIFY THE TIME VARIATION OF ANY LOAD, WHETHER IT BE FOR A PREVIOUSLY SPECIFIED LINE LOAD, DISTRIBUTED LOAD, OR TEMPERATURE DISTRIBUTION, THIS WORD 'PREVIOUS' INCLUDES LOADS SPECIFIED IN PREVIOUS SEGMENTS AS WELL AS THOSE SPECIFIED PREVIOUSLY IN THE CURRENT SEGMENT.

NOTE...'NEW TIME FUNCTION' MEANS A DIFFERENT FUNCTION OF TIME THAN HAS BEEN SPECIFIED PREVIOUSLY.

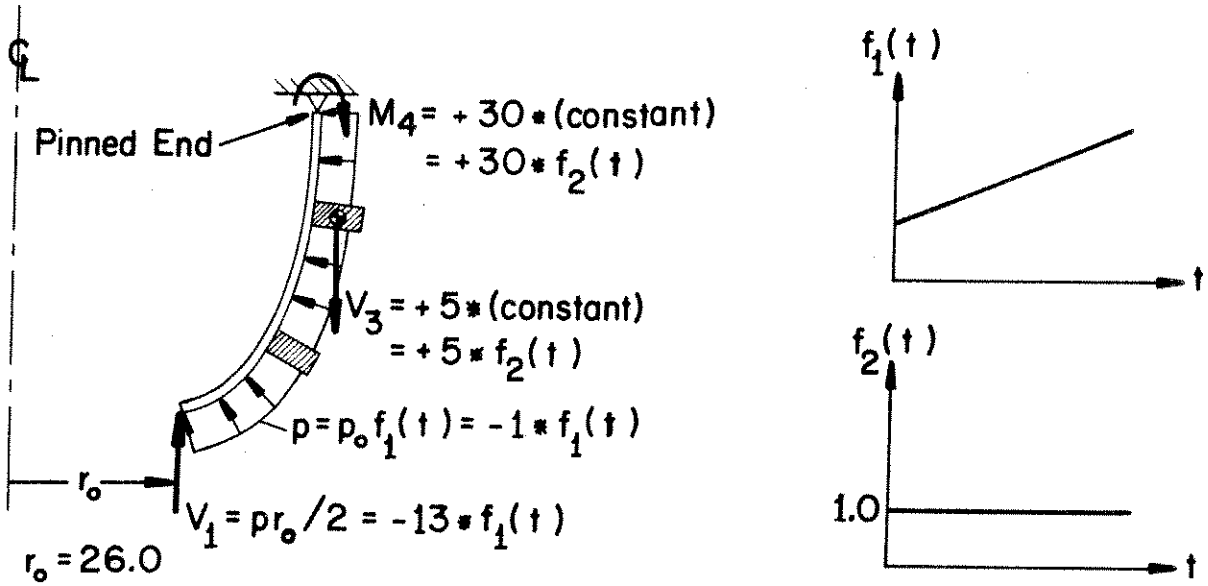
(LINE LOADS)

NOTE...IF THERE IS AN AXIAL LINE LOAD V(K) WHICH ARISES BECAUSE OF HYDROSTATIC PRESSURE, THAT IS, IF

V(K) = PN*R/2

THEN ISTEPI(K) SHOULD EQUAL ISTEP(ISEG), WHICH IS THE POINTER ASSOCIATED WITH THE PRESSURE TIME FUNCTION IN SHELL SEGMENT ISEG. ALSO, SEE THE EXAMPLE ON THE FACING PAGE.

EXAMPLE OF LINE LOAD INPUT



```
   INPUT CORRESPONDING TO ABOVE FIGURE  (NRINGS = 4, SINCE THERE ARE TWO
                                           FICTITIOUS AND TWO REAL RINGS.)

COL. 6     12     18     24     30     36     42     48     54     60
------------------------------------------------------------------------------
     1                                                              LINTYP
 -13.0        0.0           5.0         0.0                 (V(K),K=1,NRINGS)
   0.0        0.0           0.0         0.0                (HF(K),K=1,NRINGS'
   0.0        0.0           0.0        30.0                (FM(K),K=1,NRINGS'
     1      0      2      0                              (ISTEP1(K),K=1,NRINGS
     0      0      0      0                              (ISTEP2(K),K=1,NRINGS
     0      0      0      2                              (ISTEP3(K),K=1,NRINGS
```

```
250    CONTINUE

           NEXT. READ IN PROPERTIES OF THE SHELL WALL MATERIAL....

DATA    4I6    ** NALRED(ISEG), NPLAST(ISEG), NCREEP(ISEG), NMAT(ISEG) **

           ISEG = CURRENT SHELL SEGMENT NUMBER.

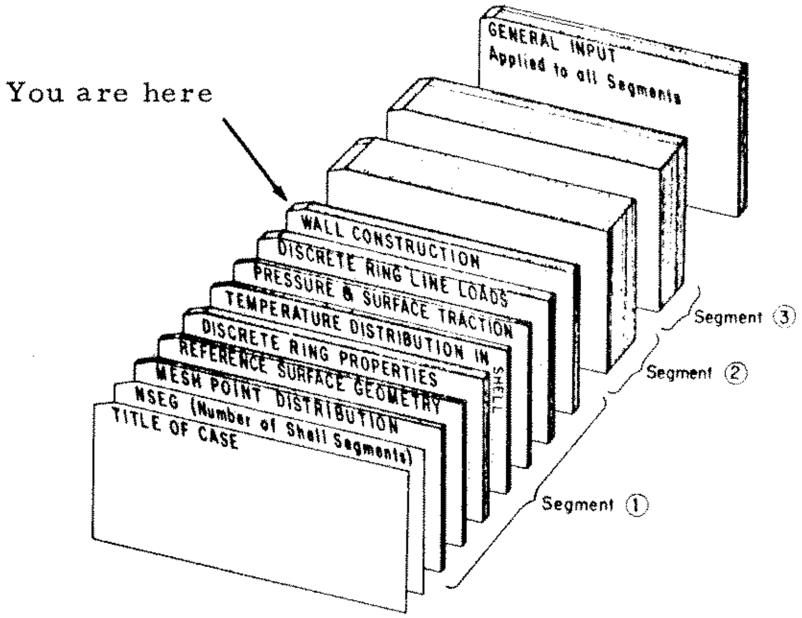
           NALRED= CONTROL INTEGER ....                          (SHELL WALL)
                   NALRED = 0 MEANS SHELL WALL MATERIAL PROPERTIES
                              HAVE NOT BEEN PREVIOUSLY SPECIFIED.
                   NALRED = 1 MEANS THAT SHELL WALL MATERIAL PROPERTIES
                              HAVE BEEN PREVIOUSLY SPECIFIED.

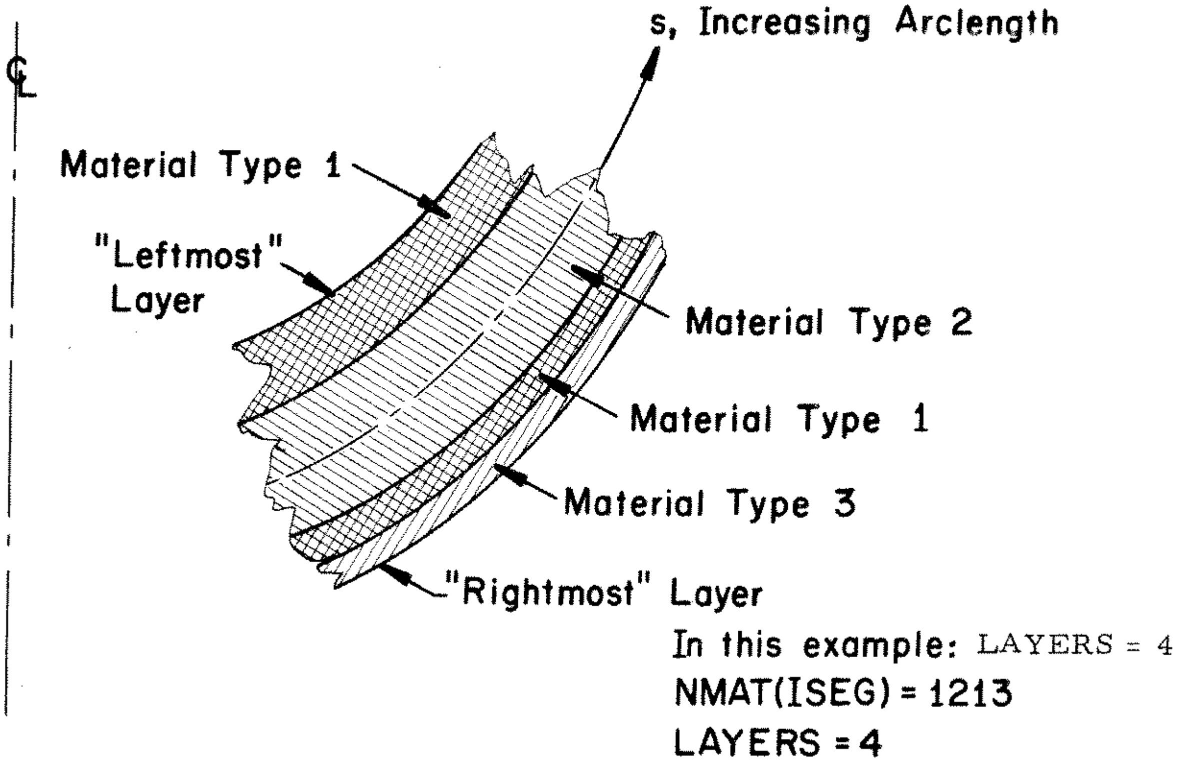
        IMPORTANT NOTE... EVEN IF THE SHELL WALL MATERIAL OF THIS
                          SEGMENT IS THE SAME AS PREVIOUSLY SPECI-
                          FIED DISCRETE RING MATERIAL, YOU STILL
                          HAVE TO SET NALRED(ISEG) = 0  IF THIS
                          MATERIAL HAS NOT BEEN SPECIFIED AS WALL
                          MATERIAL FOR A PREVIOUS SHELL SEGMENT.
                          IN BOSOR5, COMPLETELY SEPARATE ACCOUNTS
                          ARE MAINTAINED FOR SHELL WALL MATERIALS
                          AND FOR DISCRETE RING MATERIALS.

          NPLAST= CONTROL INTEGER FOR PLASTICITY.....         (SHELL WALL)
                  NPLAST = 0 MEANS THIS SEGMENT REMAINS ELASTIC
                  NPLAST = 1 MEANS THAT THIS SEGMENT MAY GO
                             PLASTIC.
          NCREEP= CONTROL INTEGER FOR CREEP.....              (SHELL WALL)
                  NCREEP = 0 MEANS THIS SEGMENT DOES NOT CREEP
                  NCREEP = 1 MEANS THAT THIS SEGMENT DOES CREEP

        IMPORTANT NOTE..  IF NCREEP= 1 THEN NPLAST MUST = 1 ALSO.

          NMAT =  CONTROL INTEGER FOR TYPE OF MATERIAL...  (SHELL WALL)
                  FOR A LAYERED SHELL, THE MATERIAL TYPES OF ALL
                  LAYERS ARE INDICATED IN THIS ONE WORD, NMAT.
                  UP TO 6 DIFFERENT MATERIALS CAN BE SPECIFIED.
                  THE SHELL MAY CONSIST OF UP TO 6 LAYERS.
                  FOR EXAMPLE, THE MATERIAL SPECIFICATION OF A
                  SHELL OF FOUR  LAYERS MAY BE  NMAT(ISEG) = 1213.
                  THIS MEANS THAT THE LEFTMOST LAYER IS OF MATERIAL
                  1, THE SECOND LAYER IS OF MATERIAL 2, THE
                  THIRD LAYER IS OF MATERIAL 1, AND THE RIGHTMOST
                  LAYER IS OF MATERIAL 3.  SEE THE FIGURE.
                  (HERE 'LEFTMOST' AND 'RIGHTMOST' ARE BASED ON
                   THE ASSUMPTION THAT WE ARE FACING IN THE
                   DIRECTION OF INCREASING MERIDIONAL ARC, S.)
```


You are here
GENERAL INPUT
Applied to all Segments
WALL CONSTRUCTION
DISCRETE RING LINE LOADS
PRESSURE & SURFACE TRACTION
TEMPERATURE DISTRIBUTION IN SHELL
DISCRETE RING PROPERTIES
REFERENCE SURFACE GEOMETRY
MESH POINT DISTRIBUTION
NSEG (Number of Shell Segments)
TITLE OF CASE
Segment ③
Segment ②
Segment ①


℄
s, Increasing Arclength
Material Type 1
"Leftmost" Layer
Material Type 2
Material Type 1
Material Type 3
"Rightmost" Layer
In this example: LAYERS = 4
NMAT(ISEG) = 1213
LAYERS = 4

```
DATA   316    ** LAYERS, NTYPET **

              LAYERS = NUMBER OF LAYERS IN THE WALL OF THIS SHELL
                       SEGMENT.  UP TO 6 LAYERS CAN BE HANDLED. IF
                       THE SEGMENT REMAINS ELASTIC, EACH LAYER CAN BE
                       ORTHOTROPIC.  IF THE SEGMENT GOES PLASTIC,
                       EACH LAYER CAN BE EITHER ISOTROPIC OR CAN
                       HAVE UNI-DIRECTIONAL PROPERTIES, SUCH AS
                       WOULD BE THE CASE IF 'SMEARED' RINGS OR
                       MERIDIONAL STIFFENERS WERE BEING MODELED AS
                       A SHELL LAYER OR LAYERS. ( IN FACT THIS IS
                       THE ONLY WAY THAT YOU CAN MODEL SMEARED RINGS
                       AND STRINGERS IN BOSOR5..SORRY ABOUT THAT...)

        IMPORTANT NOTE.. LAYER NUMBER 1 IS THE LEFTMOST LAYER,
                         AND LAYER NUMBER 'LAYER' IS THE RIGHTMOST
                         LAYER.  LEFT AND RIGHT ASSUME WE ARE FACING
                         IN THE DIRECTION OF INCREASING MERIDIONAL
                         ARC, S.                                  (SHELL WALL)

             NTYPET = CONTROL INTEGER FOR THICKNESS VARIATION ALONG
                      THE MERIDIAN OF THIS SEGMENT....
                      NTYPET = 0 MEANS THAT ALL LAYERS ARE OF
                                 CONSTANT THICKNESS.
                      NTYPET = 1 MEANS THAT AT LEAST ONE LAYER HAS
                                 THICKNESS WHICH VARIES IN THE
                                 MERIDIONAL DIRECTION.

             IF NTYPET = 1, *** GO TO 260 ***         (VARIABLE THICKNESS)

DATA  6E12.8 ** (T(I), I=1,LAYERS) **                 (CONSTANT THICKNESS)

             T(I) = THICKNESS OF ITH LAYER         (CONSTANT)  (NTYPET=0)

          NOTE.. LAYERS NUMBERED FROM LEFT TO RIGHT AS WE FACE
                 IN THE DIRECTION OF INCREASING MERIDIONAL ARC, S.

260    CONTINUE                           (SHELL WALL MATERIAL PROPERTIES)

DATA   6E12.8 ** (     G(I), I=1,LAYERS) **
DATA   6E12.8 ** (    EX(I), I=1,LAYERS) **
DATA   6E12.8 ** (    EY(I), I=1,LAYERS) **
DATA   6E12.8 ** (   UXY(I), I=1,LAYERS) **    NOTE...EY*UXY = EX*UYX
DATA   6E12.8 ** (ALPHA1(I), I=1,LAYERS) **
DATA   6E12.8 ** (ALPHA2(I), I=1,LAYERS) **
                  density
            G = SHEAR MODULUS ( E/(2(1+NU)))
           EX = MODULUS OF ELASTICITY IN MERIDIONAL DIRECTION
           EY = MODULUS OF ELASTICITY IN CIRCUMFERENTIAL DIRECTION
          UXY = POISSON'S RATIO
       ALPHA1 = THERMAL EXPANSION COEFFICIENT FOR MERIDIONAL EXPANSION
       ALPHA2 = THERMAL EXPANSION COEFFICIENT FOR CIRCUM, EXPANSION
```

```
        IF THE SHELL WALL MATERIAL STRESS-STRAIN CURVE(S)
        HAVE ALREADY BEEN READ IN AS SHELL MATERIAL, THAT IS,
        IF NALRED(ISEG) = 1,  *** GO TO 300 ***

             IF THE SHELL WALL MATERIAL DOES NOT GO PLASTIC AND
        DOES NOT CREEP, THAT IS, IF  NPLAST(ISEG) = 0 ,
                                               *** GO TO 300 ***

                                                         (STRESS-STRAIN)
THE MULTI-DIGIT WORD NMAT(ISEG) IS DISSECTED INTO ITS COMPONENT
SINGLE DIGITS, 1 THRU 6, AND EACH OF THESE SINGLE DIGITS IS
STORED AS A SEPARATE WORD IN THE ARRAY
        MPROP(I), I=1,LAYERS.                THESE DIGITS ARE
MONITORED SO THAT BOSOR5 ALWAYS KNOWS HOW MANY DIFFERENT SHELL
WALL MATERIALS HAVE BEEN SPECIFIED IN ALL PREVIOUS SEGMENTS.
(NOTE THAT DISCRETE RING MATERIALS ARE NOT INCLUDED IN THIS
 ACCOUNTING.  RING MATERIALS ARE HANDLED SEPARATELY, AS DES-
 SCRIBED ELSEWHERE.)

IN THE FOLLOWING DO-LOOP, THE STRESS-STRAIN CURVES AND/OR CREEP
PROPERTIES FOR ANY NEW MATERIALS ARE READ IN.  BOSOR5 KNOWS
THAT THE MATERIAL OF THE ITH LAYER IS NEW IF MPROP(I) IS LARGER
THAN ANY PREVIOUS VALUE OF MPROP.  THIS COMPARISON INCLUDES
VALUES FROM PREVIOUS LAYERS IN THIS SEGMENT AS WELL AS VALUES
FROM ALL PREVIOUS SEGMENTS.


          NEXT, READ IN STRESS-STRAIN CURVES FOR ALL SHELL WALL
          MATERIALS INTRODUCED FOR THE FIRST TIME IN THIS CASE....
```

EXAMPLE:

Suppose that NMAT(ISEG) = 1213 (LAYERS = 4)

Then,
MPROP(1) = 1
MPROP(2) = 2
MPROP(3) = 1
MPROP(4) = 3

If this is the first segment (ISEG = 1), stress-strain curves will be read in for the first, second, and fourth layers, but not for the third layer because the stress-strain curve for the third layer is the same as that for the first layer.

If this is the second segment (ISEG = 2), and the first segment consists of a single layer of material type 1, that is NMAT(1) = 1, NMAT(2) = 1213; then stress-strain curves will be read in only for materials of type 2 and type 3, because only these materials are appearing for the first time as shell wall materials.

```
 ****** DO 280  I = 1,LAYERS ***********     (LOOP FOR STRESS-STRAIN)

 IF THE STRESS-STRAIN CURVE FOR THIS SHELL WALL MATERIAL HAS BEEN
 PREVIOUSLY READ IN,  THAT IS....
 IF  MPROP(I) = SOME PREVIOUSLY SPECIFIED MPROP, *** GO TO 280 ***

DATA   3I6   ** NPOINT, NITEG, ISSFUN **                    (STRESS-STRAIN)

             NPOINT = NUMBER OF POINTS USED FOR SPECIFICATION OF
                      THE STRESS-STRAIN CURVE. DON'T FORGET TO
                      INCLUDE THE (0.0) POINT.
             NITEG = NUMBER OF INTEGRATION POINTS TO BE USED FOR
                     INTEGRATION THRU THIS LAYER. USE 5 OR 7 OR 9
             ISSFUN = CONTROL INTEGER FOR SPECIFICATION OF EFFECTIVE
                      STRAIN AS A FUNCTION OF EFFECTIVE STRESS....
                      ISSFUN = 0 MEANS THAT EFFECTIVE STRAIN WILL
                                 BE READ IN POINT BY POINT.
                      ISSFUN = 1 MEANS THAT EFFECTIVE STRAIN WILL
                                 BE CALCULATED FROM A CERTAIN
                                 FORMULA WHICH CONTAINS THE EFFECTIVE
                                 STRESS TO A POWER  'POWER'  AND
                                 THE YIELD STRESS OF THE MATERIAL, SYP

             IF ISSFUN = 0,  *** GO TO 270 ***

DATA  2E12.8 ** SYP, POWER **                               (STRESS-STRAIN)

             SYP = YIELD STRESS OF THE MATERIAL (0.2 PER CENT)
           POWER = POWER  IN THE POWER LAW FOR EFFECTIVE STRAIN
                   AS A FUNCTION OF EFFECTIVE STRESS.  SEE SUBROUTINE
                   CEBS FOR THE ACTUAL FORMULA USED (CARD CEBS1530)
                   THE USER CAN CHANGE THIS FORMULA TO SUIT HIMSELF.

         *** GO TO 275 ***
270   CONTINUE                                              (STRESS-STRAIN)

DATA  6E12.8 ** (EPEFF(L), L=1,NPOINT) **

             EPEFF = STRAIN COORDINATES OF STRESS-STRAIN CURVE

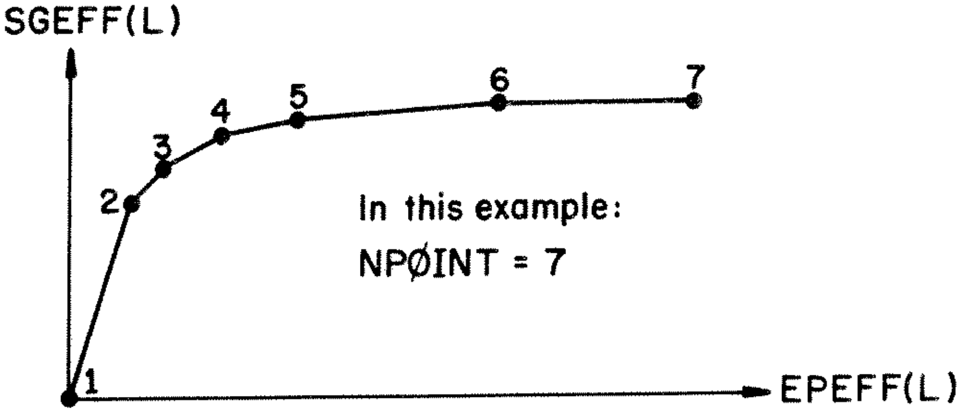
275   CONTINUE

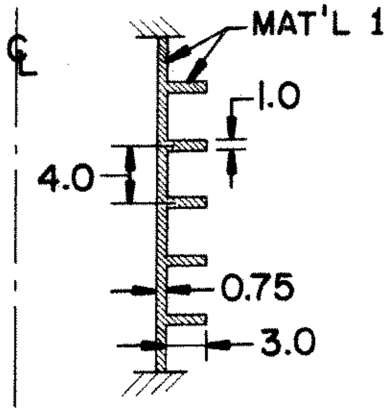
DATA  6E12.8 ** (SGEFF(L), L=1,NPOINT) **

             SGEFF = STRESS COORDINATES OF STRESS-STRAIN CURVE

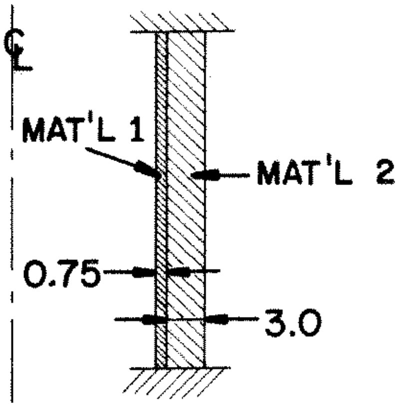
280   CONTINUE                        (END OF DO-LOOP FOR STRESS-STRAIN)


            IF THIS SHELL SEGMENT DOES NOT CREEP,  THAT IS....
            IF NCREEP(ISEG) = 0, *** GO TO 300 ***                (NO CREEP)
```

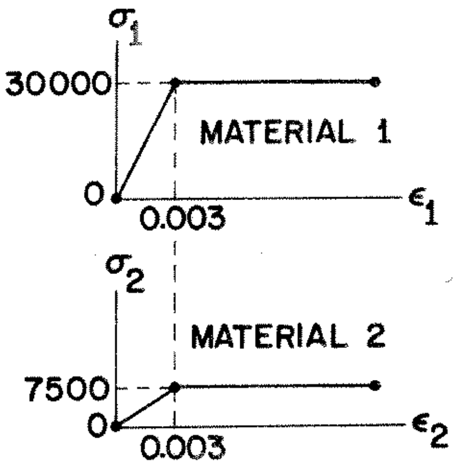




(a) ACTUAL
Aluminum shell with aluminum rings to be treated as smeared.



(b) BØSØR5 MODEL
2-Layered shell. Outer layer has hoop stiffness only.



Material 1 is aluminum. Material 2 has stiffness only in hoop direction.

```
  INPUT DATA CORRESPONDING TO ABOVE FIGURE, ASSUMING NEITHER MATERIAL HAS
       BEEN PREVIOUSLY SPECIFIED AS SHELL WALL MATERIAL

COL. 6     12     18     24     30     36     42     48     54     60     66

     0     1      0      12    NALRED(ISEG), NPLAST(ISEG), NCREEP(ISEG), NMAT(ISEG)
                                                                   LAYERS, NTYPET
     2     0
   0.75       3.0                                                (T(I),I=1,LAYERS)
  4000000.0       0.0                                            (G(I),I=1,LAYERS)
 10000000.0       0.0                                           (EX(I),I=1,LAYERS)
 10000000.0   2500000.0                                         (EY(I),I=1,LAYERS)
   0.32           0.0                                          (UXY(I),I=1,LAYERS)
 0.000005     0.0                                           (ALPHA1(I),I=1,LAYERS)
 0.000005     0.000005                                      (ALPHA2(I),I=1,LAYERS)
    3      5      0                                  NPOINT, NITEG, ISSFUN (MATL 1
   0.0        0.003        0.100                     (EPEFF(L),L=1,NPOINT) (MATL 1
   0.0        30000.0      30000.0                   (SPEFF(L),L=1,NPOINT) (MATL 1
    3      5      0                                  NPOINT, NITEG, ISSFUN (MATL 2
   0.0        0.003        0.100                     (EPEFF(L),L=1,NPOINT) (MATL 2
   0.0         7500.0       7500.0                   (SPEFF(L),L=1,NPOINT) (MATL 2
```

```
            NEXT, READ IN CREEP PROPERTIES FOR ALL SHELL MATERIALS
            INTRODUCED FOR THE FIRST TIME IN THIS CASE.....         (CREEP)

 ******* DO 290  I = 1,LAYERS ******              (DO-LOOP FOR CREEP PROPS)

  IF THE STRESS-STRAIN CURVE FOR THIS SHELL WALL MATERIAL HAS BEEN
  PREVIOUSLY READ IN,  THAT IS...
  IF  MPROP(I) = SOME PREVIOUSLY SPECIFIED MPROP, *** GO TO 290 ***

 DATA  5E12.8 ** DUMMY, CREEPN, CREEPM, CREEPA, CREEPB **           (CREEP)

            DUMMY = NOT USED, READ IN ZERO
            CREEPN, CREEPM, CREEPA, CREEPB.. SEE THE SHELL WALL
                    MATERIAL CREEP LAW GIVEN ON THE OPPOSITE PAGE.
                    USER WILL ORDINARILY SET CREEPB = 0.0
 290   CONTINUE                      (END OF DO-LOOP FOR CREEP PROPERTIES)

 300   CONTINUE                                            (SHELL WALL)
            IF ALL SHELL WALL LAYERS ARE OF CONSTANT THICKNESS IN
            THIS SEGMENT, THAT IS, IF  NTYPET = 0, *** GO TO 320 ***

            NEXT, READ DATA FOR VARIABLE THICKNESS....

 DATA     I6    **NTIN**                             (VARIABLE THICKNESS)

            NTIN = NUMBER OF MERIDIONAL STATIONS FOR WHICH THICK-
                   NESSES OF ALL LAYERS WILL BE READ IN.  THICKNESSES
                   WILL THEN BE DETERMINED AT ALL MESH POINTS IN THIS
                   SEGMENT BY LINEAR INTERPOLATION BETWEEN POINTS
                   WHERE THESE THICKNESSES ARE SPECIFIED.
                   REMEMBER TO INCLUDE THE FIRST AND LAST POINTS
                   IN THE SEGMENT AS CALLOUT POINTS.

            NEXT, DETERMINE LOCATIONS ALONG MERIDIAN WHERE THICKNESSES
            OF ALL LAYERS WILL BE SPECIFIED....
*************NOTE... NUMBER OF CALLOUTS = NTIN  *************

 DATA     I6    **NTYPE**                            (VARIABLE THICKNESS)
          NTYPE= CONTROL INTEGER FOR CALLOUT SPECIFICATION....

                 NTYPE=1 MESH POINTS WILL BE CALLED OUT DIRECTLY.
                 IF NTYPE = 1  ***GO TO A***
                 NTYPE=2 AXIAL DISTANCES, Z, FROM DATUM CALLED OUT
                 IF NTYPE = 2  ***GO TO B***
                 NTYPE=3 DISTANCES, R, FROM AXIS OF REV. CALLED OUT
                 IF NTYPE = 3  ***GO TO C***
                 NTYPE=4 ARC LENGTHS, S, FROM SEG. START CALLED OUT
                 IF NTYPE = 4  ***GO TO D***
                 NTYPE=5 ANGLES, THETA, IN DEGREES FROM AXIS OF REV.
                 IF NTYPE = 5  ***GO TO E***
 A     CONTINUE                                      (VARIABLE THICKNESS)

 DATA   10I6  **(IPOINT(J), J=1,NTIN) **                      (NTYPE=1)

          IPOINT= MESH POINT NUMBERS OF CALLOUTS              (NTYPE=1)
           ***GO TO F***
```

SHELL WALL MATERIAL CREEP LAW:

$$\bar{\varepsilon}^{c} = \left(\frac{\bar{\sigma}}{\sigma_y}\right)^{M} (t + t_o)^{N}$$

CREEPM = M (Floating Point)

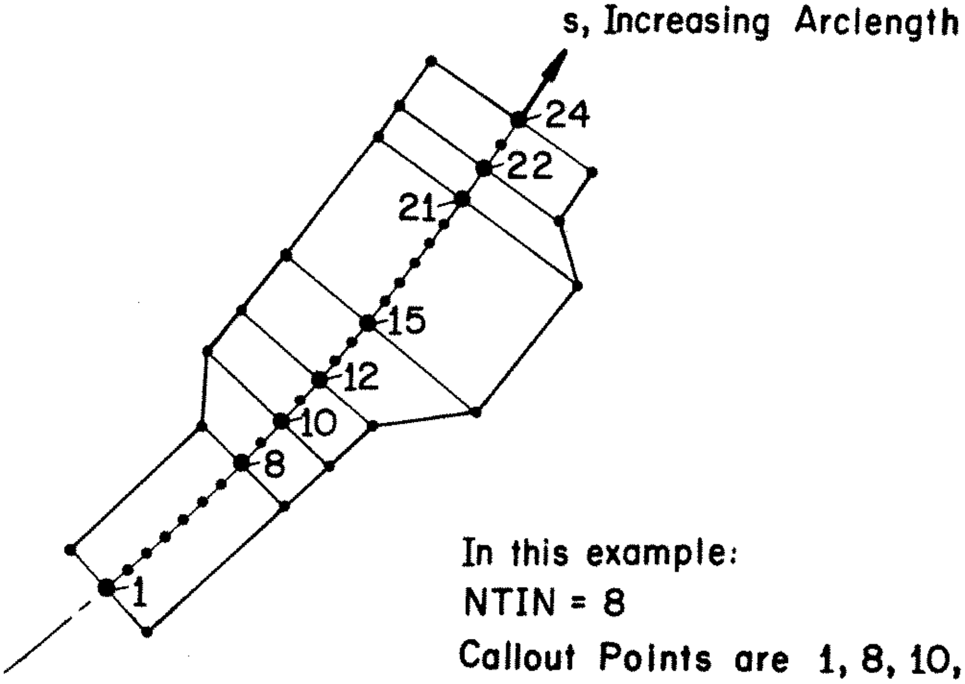
CREEPN = N (Floating Point)

CREEPA = σ_y (~0.2 % Yield Stress)

CREEPB = t_o

$$\bar{\varepsilon}^{c} = \left(\frac{\sigma}{630}\right)^{9.51} t^{.5412}$$

or value to fit test data



In this example:

NTIN = 8

Callout Points are 1, 8, 10, 12, 15, 21, 22 and 24

```
B      CONTINUE                                          (VARIABLE THICKNESS)

DATA   6E12.8 **(      Z(J), J=1,NTIN) **                          (NTYPE=2)

            Z= AXIAL DISTANCES TO CALLOUTS, MEASURED FROM  THE  (NTYPE=2)
               SAME DATUM AS THAT USED FOR THE SPECIFICATION    (NTYPE=2)
               OF THE MERIDIONAL GEOMETRY. (SHELL GEOMETRY)     (NTYPE=2)

             ***GO TO F***

C      CONTINUE                                          (VARIABLE THICKNESS)

DATA   6E12.8 **(      R(J), J=1,NTIN) **                          (NTYPE=3)

            R= RADIAL DISTANCES FROM AXIS TO CALLOUTS           (NTYPE=3)
             ***GO TO F***

D      CONTINUE                                          (VARIABLE THICKNESS)

DATA   6E12.8 **(      S(J), J=1,NTIN) **                          (NTYPE=4)

            S= ARC LENGTHS FROM SEG. START TO CALLOUTS          (NTYPE=4)
             ***GO TO F***

E      CONTINUE                                          (VARIABLE THICKNESS)

DATA   6E12.8 **( THETA(J), J=1,NTIN) **                           (NTYPE=5)

            THETA= ANGLES IN DEGREES FROM AXIS OF REVOLUTION    (NTYPE=5)
                   TO CALLOUTS. (NORMAL TO REF. SURF.)          (NTYPE=5)
F      CONTINUE                                                 (SHELL WALL)

            NEXT, READ IN THICKNESSES AT SPECIFIED MERIDIONAL
            LOCATIONS.....

******* DO 310  I = 1,LAYERS *******

DATA   6E12.8 ** (T(I,J), J=1,NTIN) **                   (VARIABLE THICKNESS)

            NTIN = NUMBER OF MERIDIONAL STATIONS FOR WHICH THICK-
                   NESSES OF ALL LAYERS WILL BE READ IN.

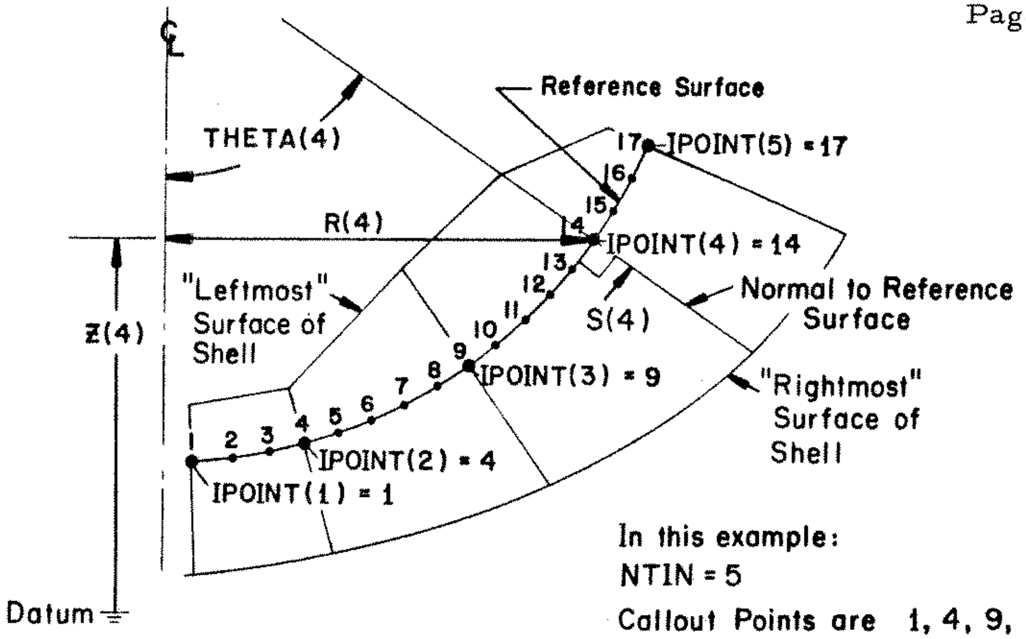
            T(I,J) = THICKNESS OF ITH LAYER AT JTH MERIDIONAL
                     CALLOUT.  MAKE SURE TO INCLUDE FIRST AND
                     LAST POINTS IN THE SEGMENT IN THIS INPUT.

310    CONTINUE                                          (VARIABLE THICKNESS)

320    CONTINUE          (END OF MATERIAL PROPERTIES FOR THIS SEGMENT)

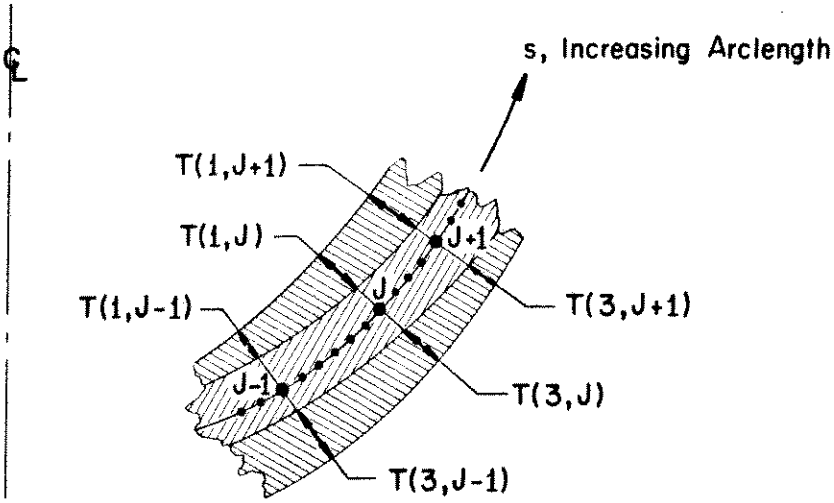
1000   CONTINUE                (END OF DO-LOOP OVER ALL SHELL SEGMENTS)

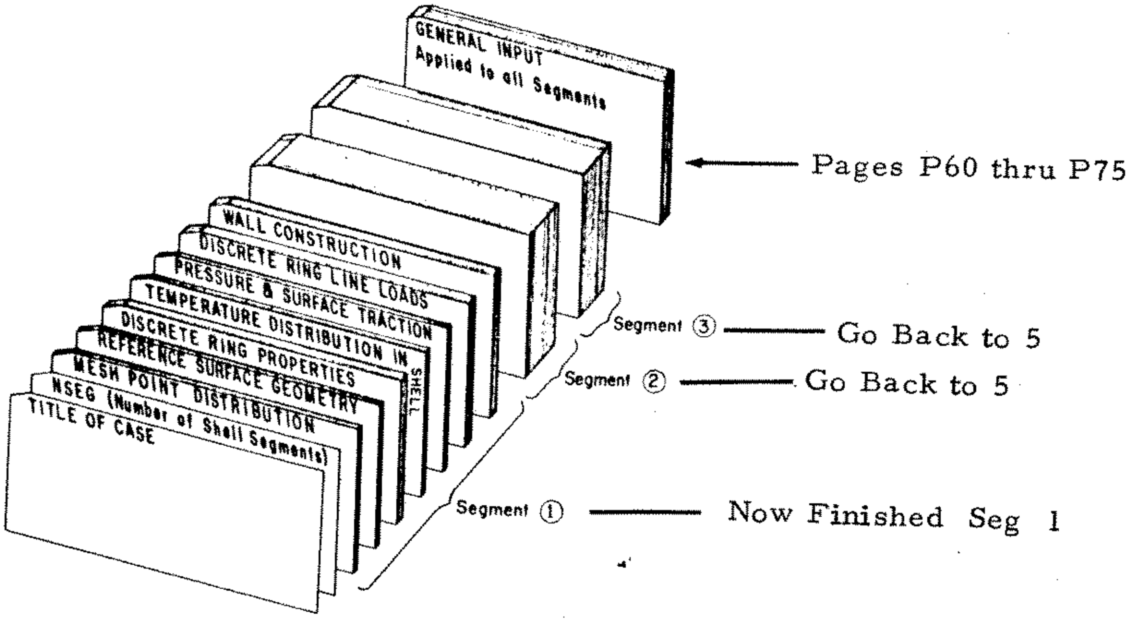
            IF THERE ARE MORE SHELL SEGMENTS,  *** GO BACK TO 5 ***
*****************************************************************
```



Z(4) measured from same datum used to specify geometry of the current shell segment.

In this example:
NTIN = 5
Callout Points are 1, 4, 9, 14 and 17.





(LOADING TIME FUNCTIONS)

NEXT, READ IN DATA THROUGH WHICH VARIOUS TIME FUNCTIONS CORRESPONDING TO VARIOUS LOADS AND TEMPERATURE ARE SPECIFIED.

DATA I6 ** IUTIME **

CONTROL INTEGER...

IUTIME = 1 MEANS THAT THE TIME INCREMENT DOES NOT VARY IN THIS CASE.

IUTIME = 0 MEANS THAT THE TIME INCREMENT VARIES IN THIS CASE.

IF IUTIME = 0, *** GO TO 1003 ***

DATA 2E12.8 ** DTIME, TMAX **

DTIME = TIME INCREMENT
TMAX = MAXIMUM TIME IN THIS CASE

*** GO TO 1005 ***

1003 CONTINUE

(VARIABLE TIME INCREMENT)

FIRST, DETERMINE THE TIME INCREMENTS TO BE USED THROUGHOUT THE TIME HISTORY OF THE CASE.......

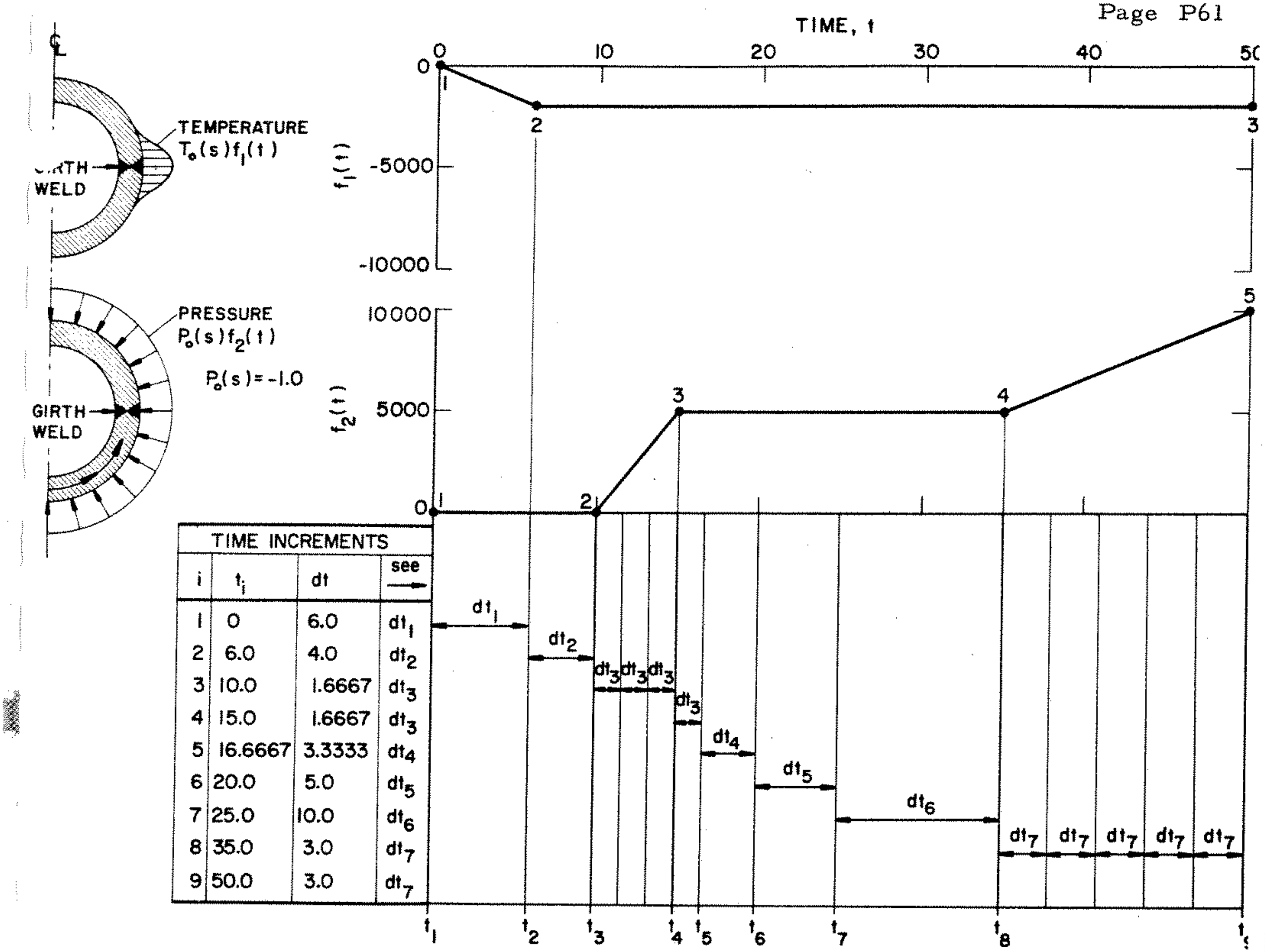
DATA I6 ** NTIME ** (TIME STEPS)

NTIME = NUMBER OF POINTS IN TIME FOR WHICH THE TIME INCREMENT IS TO BE SPECIFIED. THE TIME INCREMENT AT EVERY POINT IN TIME IS THEN AUTOMATICALLY DETERMINED BY LINEAR INTERPOLATION BETWEEN TIMES FOR WHICH THE TIME INCREMENT IS SPECIFIED. SEE THE FIGURE FOR AN EXAMPLE. NTIME MUST BE GREATER THAN OR EQUAL TO 2 AND LESS THAN 50.

DATA 6E12.8 ** (DTIME(I), I=1,NTIME) ** (TIME INCREMENTS)
DATA 6E12.8 ** (TIME(I), I=1,NTIME) ** (TIME CALLOUTS)

DTIME(I) = TIME INCREMENT DIRECTLY FOLLOWING TIME(I).

TIME(I) = POINT IN TIME FOR WHICH DTIME(I) IS SPECIFIED. SEE THE FIGURE FOR AN EXAMPLE. TIME INCREMENTS VARY LINEARLY FOR TIME STEPS WHICH OCCUR BETWEEN TIME(I) AND TIME(I+1).



TIME INCREMENTS

i	t_i	dt	see →
1	0	6.0	dt_1
2	6.0	4.0	dt_2
3	10.0	1.6667	dt_3
4	15.0	1.6667	dt_3
5	16.6667	3.3333	dt_4
6	20.0	5.0	dt_5
7	25.0	10.0	dt_6
8	35.0	3.0	dt_7
9	50.0	3.0	dt_7

EXAMPLF OF LOADING TIME FUNCTIONS CORRFSPONDING TO THE FIGURE ABOVE

```
COL. 6     12     18     24     30     36          48          60          72

     0                                                                  IUTIME
     9                                                                  NTIME
   6.0     4.0          1.6667      1.6667        3.3333       5.0(DTIME(I),I=1,6)
  10.0     3.0          3.0                                       (DTIME(I),I=7,9)
   0.0     6.0         10.0        15.0          16.6667      20.0 (TIME(I),I=1,6)
  25.0    35.0         50.0                                        (TIME(I),I=7,9)
   2                                                                 NFTIME
   3     5                                                  (NPOINT(I),I=1,NFTIME)
   0.0      -2000.0      -2000.0                            (F(1,J),J=1,NPOINT(1))
   0.0          6.0         50.0                            (T(1,J),J=1,NPOINT(1))
   0.0          0.0       5000.0      5000.0      10000.0   (F(2,J),J=1,NPOINT(2))
   0.0         10.0         15.0        35.0         50.0   (T(2,J),J=1,NPOINT(2))
```

```
1005  CONTINUE

         NEXT, SPECIFY THE VARIOUS TIME FUNCTIONS.......

DATA   I6    ** NFTIME **                                    (TIME FUNCTIONS)

          NFTIME = NUMBER OF DIFFERENT FUNCTIONS OF TIME.  FOR
                   EXAMPLE, YOU MAY HAVE A CASE INVOLVING A
                   TEMPERATURE DISTRIBUTION WHICH IS CONSTANT WITH
                   TIME AND A PRESSURE DISTRIBUTION WHICH VARIES
                   WITH TIME.  IN SUCH A CASE, NFTIME = 2, SINCE
                   THERE ARE TWO FUNCTIONS OF TIME--ONE FUNCTION
                   A CONSTANT AND THE OTHER A VARYING QUANTITY.
                   NFTIME MUST BE EQUAL TO THE HIGHEST VALUE OF ANY
                   OF THE (POINTERS) IDTEMP(ISEG), ISTEP(ISEG),
                   ISTEP1(K), ISTEP2(K), ISTEP3(K), WHICH WERE
                   SPECIFIED IN THE SECTIONS ON LOAD AND
                   TEMPERATURE INPUT. (IDTEMP(ISEG) ON PAGE P38,
                    ISTEP(ISEG) ON PAGE P44, AND ISTEP1(K),
                    ISTEP2(K), ISTEP3(K) ON PAGE P46)
              IF NFTIME = 0, GO TO 1110
DATA   1016  ** (NPOINT(I), I=1,NFTIME) **

          NPOINT(I) = NUMBER OF POINTS IN TIME AT WHICH THE ITH
                      TIME FUNCTION IS SPECIFIED.  THIS FUNCTION
                      IS ASSUMED TO VARY LINEARLY FOR TIMES BE-
                      TWEEN THOSE WHERE IT IS CALLED OUT.  SEE
                      THE FIGURE FOR AN EXAMPLE. NPOINT MUST BE
                      GREATER THAN OR EQUAL TO 2  AND LESS THAN
                      OR EQUAL TO 50.

******* DO 1100  I = 1,NFTIME *******                        (TIME FUNCTIONS)

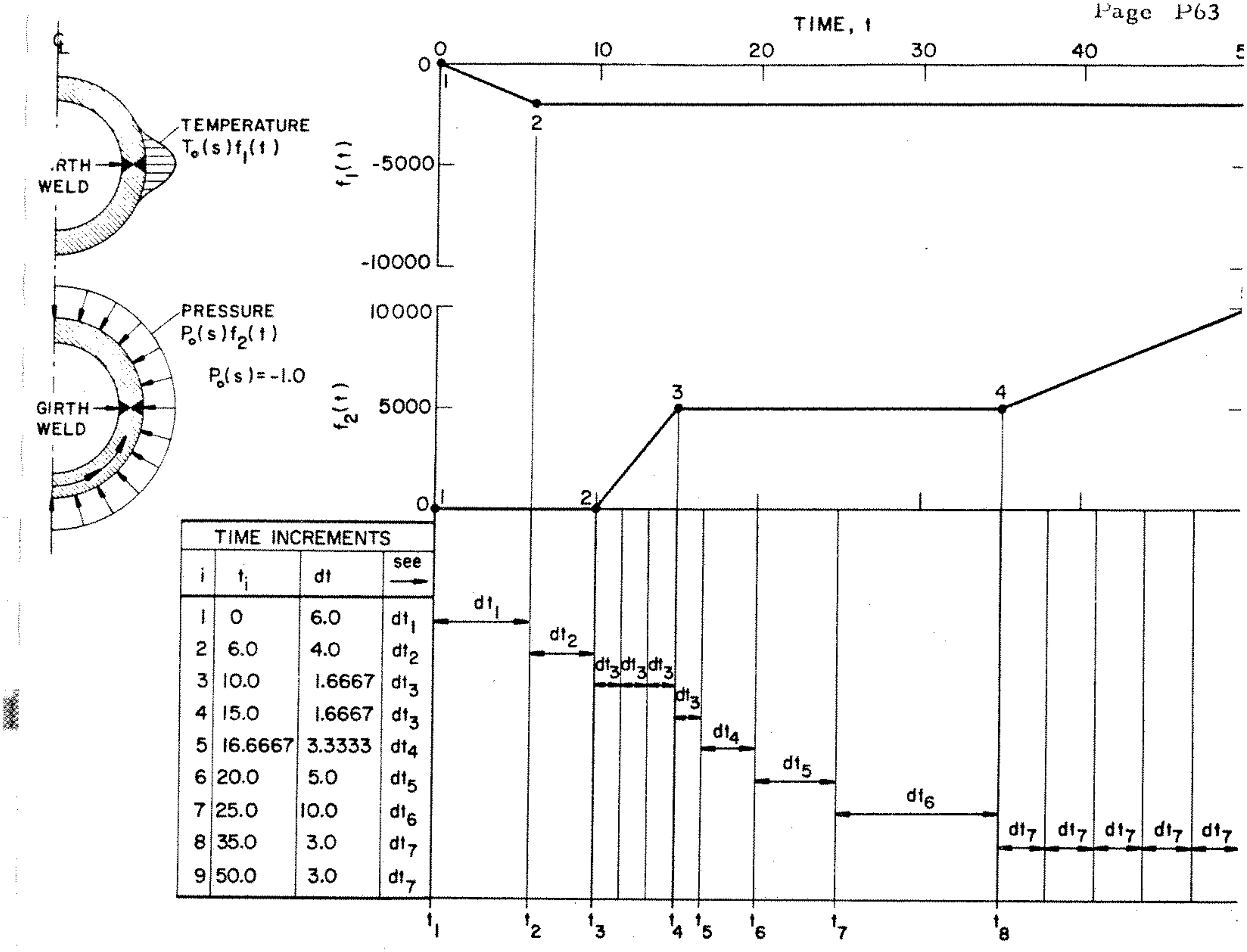
         NFTIME = NUMBER OF DIFFERENT TIME FUNCTIONS

DATA 6E12.8  ** (F(I,J), J= 1,NPOINT(I)) **                   ( F(TIME))
DATA 6E12.8  ** (T(I,J), J= 1,NPOINT(I)) **                   (  TIME  )

         F(I,J) = VALUE OF ITH TIME FUNCTION AT TIME T(I,J).
                  THIS FUNCTION VARIES LINEARLY BETWEEN
                  T(I,J) AND T(I,J+1)


         T(I,J) = POINT IN TIME TO WHICH F(I,J) CORRESPONDS.

1100  CONTINUE                                               (TIME FUNCTIONS)
```



TIME INCREMENTS			
i	t_i	dt	see →
1	0	6.0	dt_1
2	6.0	4.0	dt_2
3	10.0	1.6667	dt_3
4	15.0	1.6667	dt_3
5	16.6667	3.3333	dt_4
6	20.0	5.0	dt_5
7	25.0	10.0	dt_6
8	35.0	3.0	dt_7
9	50.0	3.0	dt_7

```
          EXAMPLF OF LOADING TIME FUNCTIONS CORRFSPONDING TO THE FIGURF ABOVE

COL. 6     12     18     24     30     36          48          60          72

     0                                                              IUTIME
     9                                                              NTIME
   6.0     4.0         1.6667      1.6667      3.3333       5.0(DTIME(I),I=1,6)
  10.0     3.0         3.0                                    (DTIME(I),I=7,9)
   0.0     6.0        10.0        15.0        16.6667      20.0 (TIME(I),I=1,6)
  25.0    35.0        50.0                                     (TIME(I),I=7,9)
     2                                                              NFTIME
     3     5                                              (NPOINT(I),I=1,NFTIME)
   0.0       -2000.0       -2000.0                        (F(1,J),J=1,NPOINT(1))
   0.0           6.0          50.0                        (T(1,J),J=1,NPOINT(1))
   0.0           0.0        5000.0      5000.0    10000.0 (F(2,J),J=1,NPOINT(2))
   0.0          10.0          15.0        35.0       50.0 (T(2,J),J=1,NPOINT(2))
```

1110 continue

NEXT, READ IN DATA WHICH GOVERN HOW THE VARIOUS SHELL SEGMENTS ARE CONNECTED TOGETHER, AND WHICH GOVERN WHAT BOUNDARY AND OTHER CONSTRAINT CONDITIONS EXIST. THESE CONDITIONS APPLY TO THE PREBUCKLING STRESS ANALYSIS ONLY.......

DATA I6 ** NCOND ** (PREBUCKLING CONSTRAINT CONDITIONS)

NCOND = NUMBER OF STATIONS IN STRUCTURE INVOLVED IN JUNCTURE OR CONSTRAINT OR BOUNDARY CONDITIONS. HERE WE ARE TALKING ABOUT THE PREBUCKLING ANALYSIS ONLY. THE MINIMUM VALUE OF NCOND IS (NSEG-1) . (NSEG = TOTAL NUMBER OF SHELL SEGMENTS.) THE MAX. VALUE OF NCOND IS 50. YOU MUST INCLUDE A CONSTRAINT STATION FOR EACH STATION AT WHICH THE SHELL INTERSECTS THE AXIS OF REVOLUTION.

********* DO 1200 I = 1,NCOND ******** (LOOP OVER PREBUCKLING CONDITION

DATA 6I6,2E12.8 ** (IFIX(I,J), J=1,6), D1(I), D2(I) **

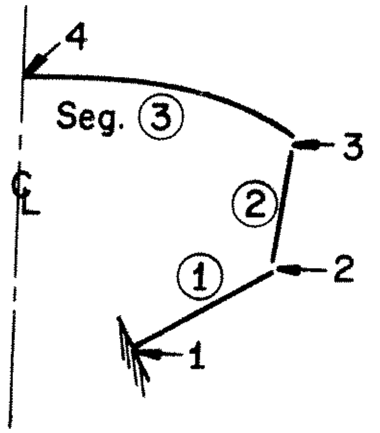
1200 CONTINUE (END OF DO-LOOP OVER PREBUCKLING CONSTRAINT COND.)

IFIX(I,1)= SHELL SEGMENT NUMBER AND MESH POINT NUMBER IN THAT SHELL SEGMENT INVOLVED IN A JUNCTURE OR CONSTRAINT OR BOUNDARY CONDITION. EXAMPLE.. IFIX(I,1) = 005033 MEANS SEGMENT NUMBER 5, MESH POINT NUMBER 33.

IFIX(I,2)= ANOTHER SHELL SEGMENT NUMBER AND MESH POINT NUMBER. (MAY BE THE SAME OR DIFFERENT FROM IFIX(I,1))
EXAMPLE.. IFIX(I,2) = 007005 (SEG. 7, POINT 5)

THE COMBINATION IFIX(I,1)=005033, IFIX(I,2)=007005 SIGNIFIES THAT SEG. 5, POINT 33 IS CONNECTED IN SOME WAY TO SEG. 7, POINT 5. THE EXACT NATURE OF THIS CONNECTION REMAINS TO BE SPECIFIED.

IMPORTANT NOTE... IF IFIX(I,1) = IFIX(I,2) THAT POINT IN THE SHELL IS CONNECTED TO GROUND IN SOME WAY WHICH REMAINS TO BE SPECIFIED.

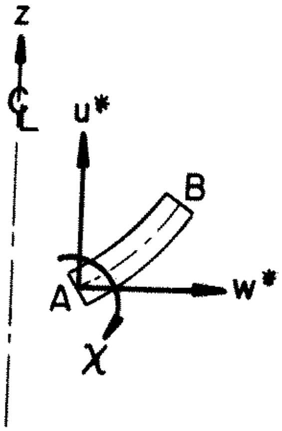


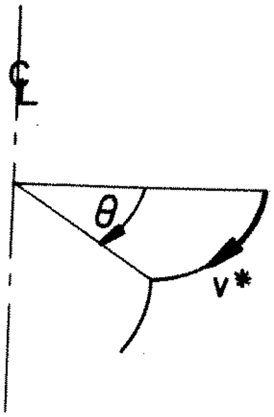
3-SEGMENT SHELL IN WHICH NCØND=4

Examples of constraint condition cards follow:

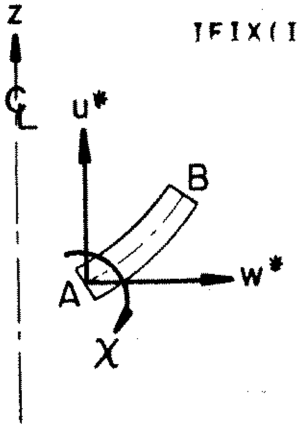
Input Card Column No.	1	6		12	18	24	30	36	48	60	Comments
(IFIX(1, J), J=1, 6), D1(1), D2(1)	001	001	001	001	0	1	1	0	+175 + 1	+25 + 1	bound. cond. card
(IFIX(2, J), J=1, 6), D1(2), D2(2)	001	095	002	001	1	1	1	1	+0 + 0	+0 + 0	junct. compat. card
(IFIX(3, J), J=1, 6), D1(3), D2(3)	001	095	003	001	1	1	1	1	+0 + 0	+0 + 0	branch compat. card
Definitions	Seg	Pt	Seg	Pt	u*	v*	w*	χ	D1	D2	
Identifications	location				variables constrained				radial disc.	axial disc.	

Translation of constraint #3: Seg. 1, point 95 is connected to Seg. 3, point 1. All variables are compatible.





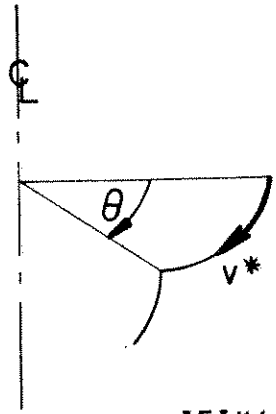
WHAT IS THE NATURE OF THE CONNECTION OR CONSTRAINT....



IFIX(I,3)= CONTROL INTEGER FOR INTER-SEGMENT AXIAL DISPLACEMENT (USTAR) COMPATIBILITY OR FOR SETTING USTAR = 0 AT THE POINT SPECIFIED BY IFIX(I,1) AND IFIX(I,2).

IFIX(I,3)=0 MEANS NO INTER-SEGMENT AXIAL DISPLACEMENT COMPATIBILITY OR USTAR IS FREE AT PT. IFIX(I,1)

IFIX(I,3)=1 MEANS THAT INTER-SEGMENT AXIAL DISPLACEMENT COMPATIBILITY IS IMPOSED OR THAT USTAR IS CONSTRAINED TO BE ZERO AT PT. IFIX(I,1)



IFIX(I,4)= CONTROL INTEGER FOR INTER-SEGMENT CIRCUMFERENTIAL DISPLACEMENT (VSTAR) COMPATIBILITY OR FOR SETTING VSTAR = 0 AT THE POINT SPECIFIED BY IFIX(I,1) AND IFIX(I,2).

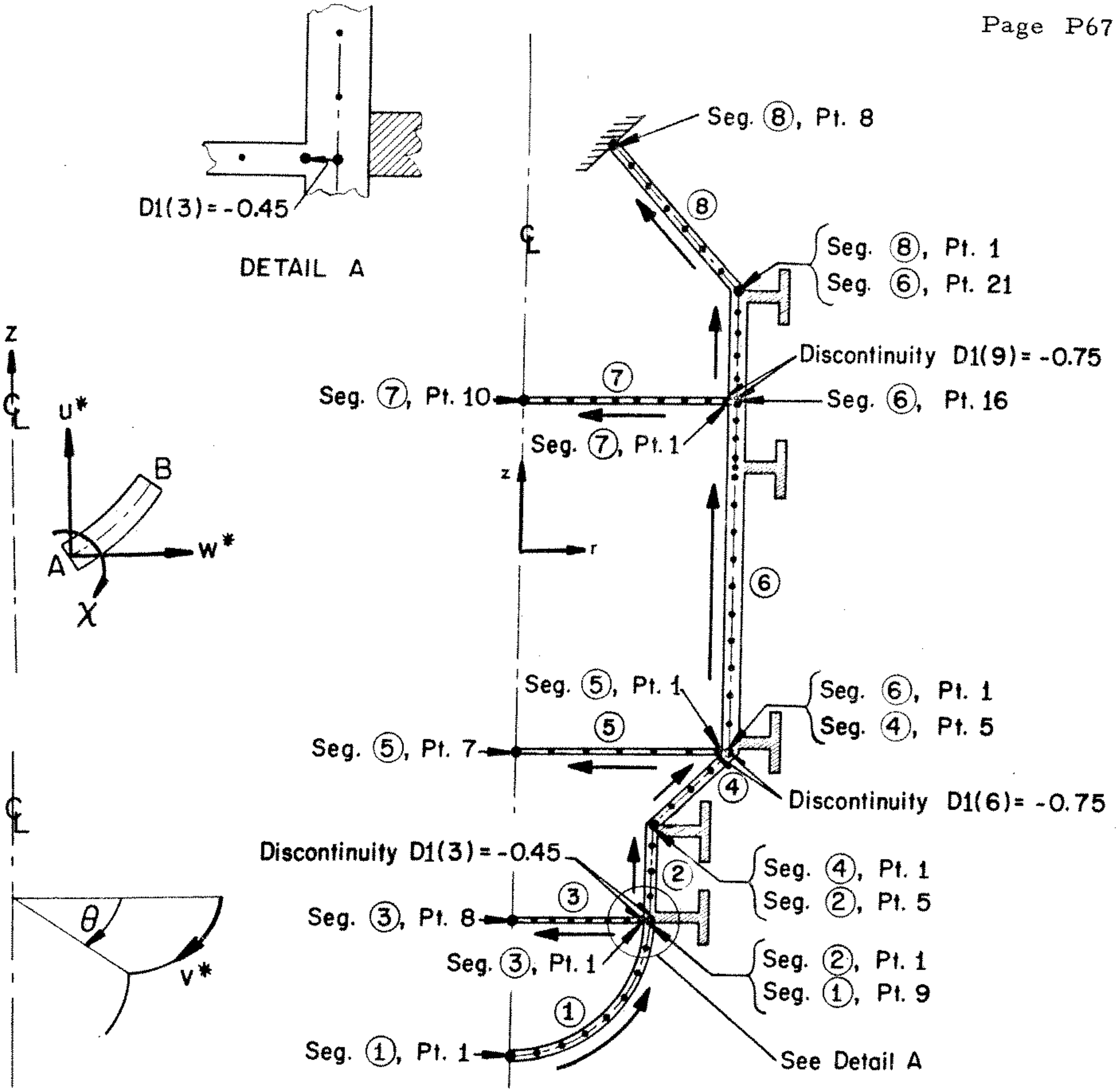
IFIX(I,4)=0 MEANS NO INTER-SEGMENT CIRCUMFERENTIAL DISPLACEMENT COMPATIBILITY OR VSTAR IS FREE AT PT. IFIX(I,1)

IFIX(I,4)=1 MEANS THAT INTER-SEGMENT CIRCUMF. DISPLACEMENT COMPATIBILITY IS IMPOSED OR THAT VSTAR IS CONSTRAINED TO BE ZERO AT PT. IFIX(I,1)

IFIX(I,5)= CONTROL INTEGER FOR INTER-SEGMENT RADIAL DISPLACEMENT (WSTAR) COMPATIBILITY OR FOR SETTING WSTAR = 0 AT THE POINT SPECIFIED BY IFIX(I,1) AND IFIX(I,2).

IFIX(I,5)=0 MEANS NO INTER-SEGMENT RADIAL DISPLACEMENT COMPATIBILITY OR WSTAR IS FREE AT PT. IFIX(I,1)

IFIX(I,5)=1 MEANS THAT INTER-SEGMENT RADIAL DISPLACEMENT COMPATIBILITY IS IMPOSED OR THAT WSTAR IS CONSTRAINED TO BE ZERO AT PT. IFIX(I,1)



EXAMPLE OF CONSTRAINT CONDITIONS CORRESPONDING TO THE FIGURE ABOVE

```
COL. 6    12    18    24    30    36          48          60            72

   12                                                                NCOND
001001001001                                   (IFIX(1,J),J=1,6),D1(1),D2(1)
001009002001   1     1     1     1     0.0         0.0      IFIX(2,J),D1(2),D2(2)
001009003001   1     1     1     1    -0.45        0.0      IFIX(3,J),D1(3),D2(3)
003008003008                                                IFIX(4,J),D1(4),D2(4)
002005004001   1     1     1     1     0.0         0.0      IFIX(5,J),D1(5),D2(5)
004005005001   1     1     1     1    -0.75        0.0      IFIX(6,J),D1(6),D2(6)
004005006001   1     1     1     1     0.0         0.0      IFIX(7,J),D1(7),D2(7)
 5007005007                                                 IFIX(8,J),D1(8),D2(8)
006016007001   1     1     1     1    -0.75        0.0      IFIX(9,J),D1(9),D2(9)
007010007010                                              IFIX(10,J),D1(10),D2(10)
006021008001   1     1     1     1     0.0         0.0    IFIX(11,J),D1(11),D2(11)
008008008008   1     1     1     1     0.0         0.0    IFIX(12,J),D1(12),D2(12)
```

```
     IFIX(I,6)= CONTROL INTEGER FOR INTER-SEGMENT MERIDIONAL
                ROTATION     (BETA ) COMPATIBILITY OR FOR
                SETTING BETA  = 0 AT THE POINT SPECIFIED BY
                IFIX(I,1) AND IFIX(I,2).

                IFIX(I,6)=0 MEANS NO INTER-SEGMENT MERIDIONAL
                            ROTATION COMPATIBILITY OR
                             BETA IS FREE AT PT. IFIX(I,1)

                IFIX(I,6)=1 MEANS THAT INTER-SEGMENT MERIDIONAL
                            ROTATION COMPATIBILITY IS
                            IMPOSED OR THAT BETA  IS CON-
                            STRAINED TO BE ZERO AT PT. IFIX(I,1)

  IMPORTANT NOTE... USTAR AND WSTAR ARE THE AXIAL AND RADIAL
                    DISPLACEMENT COMPONENTS, RESPECTIVELY.
                    NOT THE MERIDIONAL AND NORMAL SHELL WALL
                    DISPLACEMENTS U AND W.    THUS, BOUNDARY
                    CONDITIONS ARE IMPOSED ON USTAR AND WSTAR,
                    NOT ON U AND W.  THIS IS AN IMPORTANT NOTE...

        D1(I) = RADIAL COMPONENT OF MERIDIONAL DISCONTINUITY OR
                SUPPORT OFFSET FROM REFERENCE SURFACE OF SHELL.
                SEE FIGURE FOR SIGN CONVENTION.

        D2(I) = AXIAL COMPONENT OF MERIDIONAL DISCONTINUITY
                OR SUPPORT OFFSET FROM REF. SURF. (SEE FIG.)

                                    (END OF PREBUCKLING CONSTRAINT CONDITIONS)
```

The figure opposite shows a meridional discontinuity (a) and boundary support points at the beginning of a segment and at the end of a segment (b).

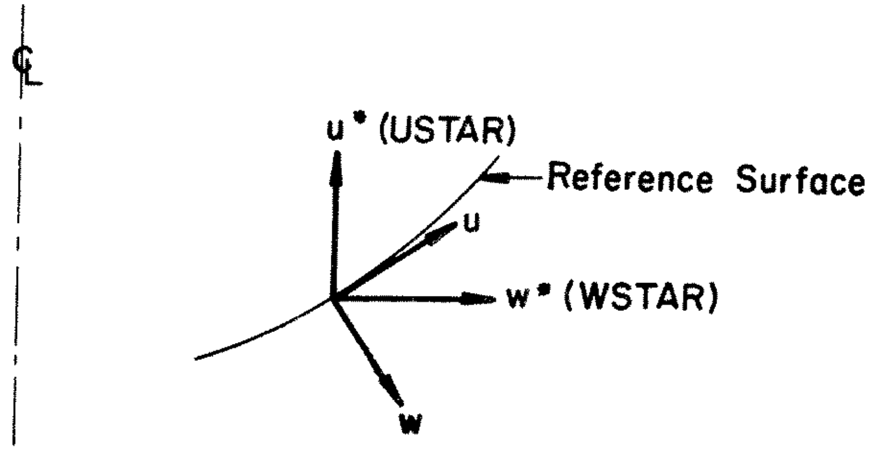
In Fig. (a) :

1) D1 and D2 are positive as shown if $J > 0$

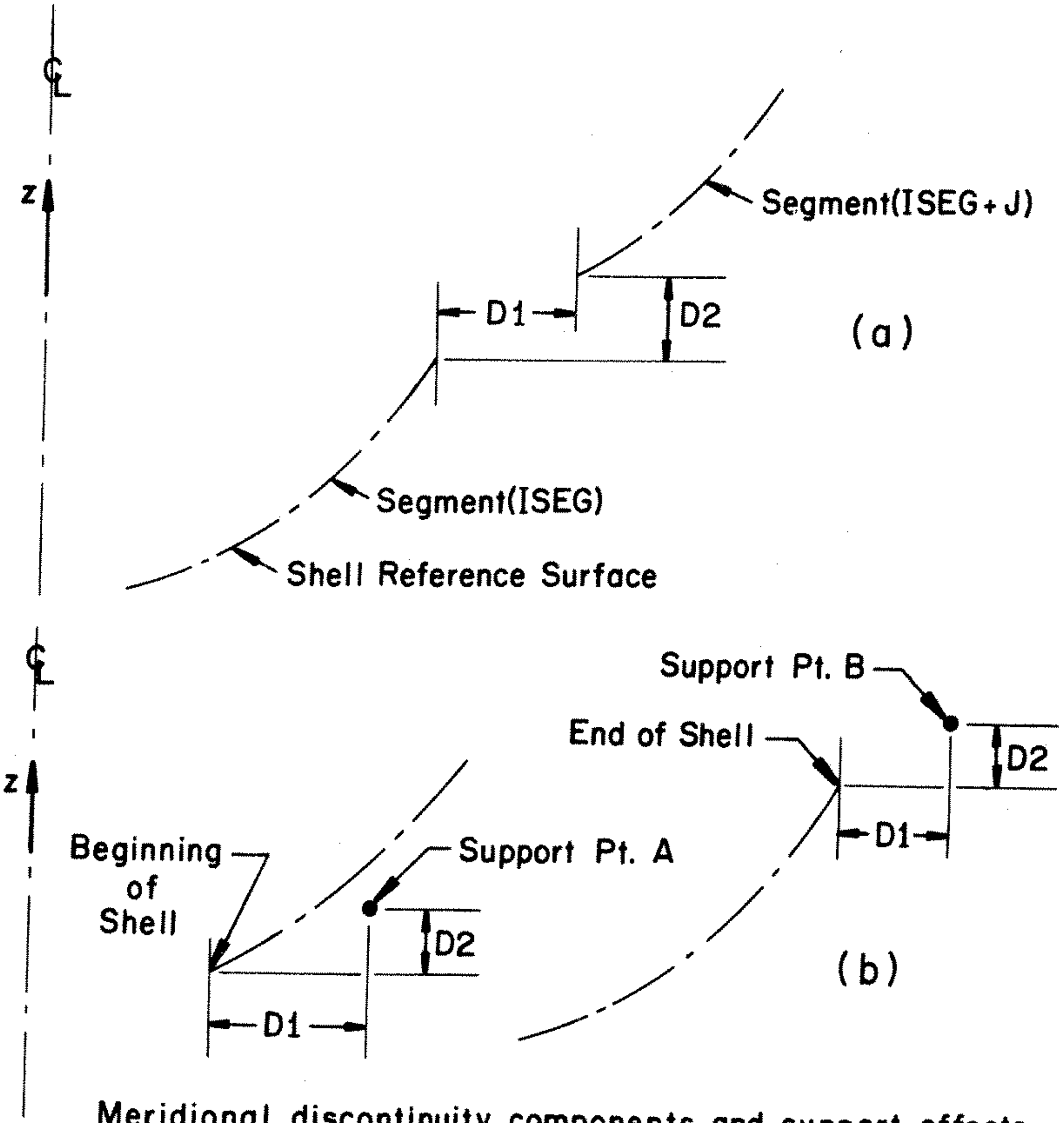
2) D1 and D2 are negative as shown if $J < 0$

This sign convention thus depends only on the relative numbering of the segments involved in the junction. It does not depend on the direction of increasing arc length s. Nor does it depend on whether the user specifies "Segment ISEG is connected to segment ISEG + J" or "Segment ISEG + J is connected to ISEG."

In Fig. (b) the "discontinuities" D1 and D2 are positive as shown independent of the direction of increasing arc length s.



NOTE: Boundary and other constraint conditions are written in terms of axial (USTAR) and radial (WSTAR) displacements, <u>not in terms</u> of meridional (u) and normal (w) displacements.



Meridional discontinuity components and support offsets are positive in the above illustrations.

NEXT, SPECIFY THE JUNCTURE AND BOUNDARY CONDITIONS FOR BIFURCATION BUCKLING. NOTE THAT THESE MAY DIFFER FROM THE PREBUCKLING JUNCTURE AND CONSTRAINT CONDITIONS.......

DATA 4I6 ** ISEGA, ISEGB, NCONDB, IRIGID ** (BUCKLING CONSTRAINTS)

ISEGA = FIRST SEGMENT (LOWEST NO.) INVOLVED IN STABILITY ANALYSIS.
ISEGB = LAST SEGMENT (HIGHEST NO.) INVOLVED IN STABILITY ANALYSIS.

NOTE.. ALL SHELL SEGMENTS WILL ALWAYS BE INCLUDED IN THE PREBUCKLING ANALYSIS. HOWEVER, THE USER CAN IDENTIFY A CERTAIN SUBREGION IN THE SHELL STRUCTURE FOR WHICH HE WANTS A BIFURCATION BUCKLING ANALYSIS. THIS SUBREGION IS DELIMITED BY ISEGA AND ISEGB, AND INCLUDES THE SEGMENTS ISEGA AND ISEGB. THE SUBREGION THUS IDENTIFIED BY THE USER MUST BE CONTIGUOUS. GENERALLY THE USER WILL SET ISEGA=1 AND ISEGB=NSEG. (NSEG = TOTAL NUMBER OF SHELL SEGMENTS) HOWEVER, IF THE STABILITY ANALYSIS INVOLVES A WIDE RANGE OF CIRCUMFERENTIAL WAVENUMBERS, IT MAY BE ECONOMICAL TO CHOOSE ISEGA AND ISEGB SUCH THAT LOCAL BUCKLING PHENOMENA IN A LARGE STRUCTURE WITH MANY DEGREES OF FREEDOM CAN BE INVESTIGATED WITHOUT CARRYING ALONG MANY DEGREES OF FREEDOM WHICH DO NOT PARTICIPATE IN THE BUCKLING MODE. THE USER MUST THEN CHOOSE ISEGA AND ISEGB CAREFULLY AND MUST ALSO SEE TO IT THAT APPROPRIATE BOUNDARY CONDITIONS AT THE BEGINNING OF SEG. ISEGA AND AT THE END OF SEG. ISEGB ARE SPECIFIED FOR THIS 'PARTIAL' STABILITY ANALYSIS. REMEMBER THAT THESE CONDITIONS WILL PROBABLY BE DIFFERENT FROM THE PREBUCKLING CONDITIONS, WHICH ARE PROBABLY JUNCTURE CONDITIONS RELATING THE DISPLACEMENTS OF THE BEGINNING OF SEGMENT ISEGA TO THOSE AT THE END OF SEGMENT (ISEGA - 1) AND JUNCTURE CONDITIONS RELATING THE DISPLACEMENTS AT THE END OF SEGMENT ISEGB TO THOSE AT THE BEGINNING OF SEGMENT (ISEGB + 1).

NCONDB = NUMBER OF STATIONS IN THE ISEGA THRU ISEGB PORTION OF THE STRUCTURE INVOLVED IN JUNCTURE OR CONSTRAINT OR BOUNDARY CONDITIONS. HERE WE ARE REFERRING TO THE STABILITY ANALYSIS ONLY. THE MINIMUM VALUE OF NCONDB IS (ISEGB-ISEGA). THE MAX. VALUE IS 50. YOU MUST INCLUDE A CONSTRAINT STATION FOR EACH STATION AT WHICH THE SHELL INTERSECTS THE AXIS OF REVOLUTION. (BUCKLING CONSTRAINTS)

IFIX (I, J):

Displacement restraint coefficients. Although most practical shell structures are supported by discrete rings or other structures which can be modeled as discrete rings, it is often desirable to be able to specify one or more of the displacement components u^*, v^*, w^*, and the meridional rotation χ equal to zero at the boundaries of or at certain points within a shell. These restraints may be applied even though there is a ring present at the same point. The displacements can be specified equal to zero at a support point which does not necessarily correspond to the edge of the reference surface. In Fig. (b) on Page P69 is shown a shell which has a support at a point "A" which is removed a certain distance specified by (D1, D2) from the end of the reference surface.

Certain displacement restraint conditions apply for planes of symmetry in shell structures. In buckling problems if use is made of symmetry conditions one must test for buckling loads corresponding to modes both symmetric and antisymmetric at that end of the shell which corresponds to its plane of symmetry.

D1(I), D2(I):

Axial, radial discontinuities in meridian between adjacent segments or distances from support points to meridian. The specification of these parameters sometimes depends upon how the user decides to construct the model of the actual composite shell structure. A shell with discrete rings, for example, might be modeled as a single segment with the discrete rings considered to be attached at certain points along the meridian. In this case the analysis "permits" the shell wall to bend under the portion of the ring which is attached to it, since the attachment point is assumed to have zero length. However, the analyst can also treat the same problem as a shell of many segments in which the portions of shell wall in contact with the discrete rings are considered to be parts of the rings. In this case discontinuities exist between the reference surfaces of adjacent segments. In especially important cases the user is urged to model the structure in various ways and to compare the results. It is particularly advantageous to construct the models in such ways as to obtain upper and lower bounds on stresses and buckling loads.

In general, it is recommended that users construct models such that there are no axial discontinuities ($D2 = 0$) between segments. Axial discontinuities tend to lead to gross overestimates of the stiffness of a structure, and hence to overestimates of buckling loads. See the article "Evaluation of various analytical models for buckling and vibration of stiffened shells" by David Bushnell, AIAA JOURNAL, Vol. N o. 9, pp. 1283-1291, September, 1973, for examples.

IRIGID = CONTROL INTEGER FOR RIGID BODY BEHAVIOR...

IRIGID = 0 MEANS THAT IT IS NOT NECESSARY TO IMPOSE AN ADDITIONAL CONSTRAINT IN ORDER TO PREVENT RIGID BODY BUCKLING MODAL DISPLACEMENTS.

IRIGID = 1 MEANS THAT IT IS NECESSARY TO IMPOSE AN ADDITIONAL CONSTRAINT IN ORDER TO PREVENT RIGID BODY BUCKLING DISPLACEMENTS. YOU ONLY NEED TO SET IRIGID = 1 IF BIFURCATION BUCKLING LOADS ARE BEING SOUGHT FOR N = 0 AND N = 1 CIRCUMFERENTIAL WAVES, AND THEN ONLY IF THE STABILITY CONSTRAINT CONDITIONS TO BE IMPOSED WILL BE INADEQUATE TO PREVENT RIGID BODY BUCKLING MODES. SEE THE DISCUSSION ON THE FACING PAGE.

```
********** DO 1300  I = 1, NCONDB *********  (LOOP OVER STABILITY CONSTRAINTS)

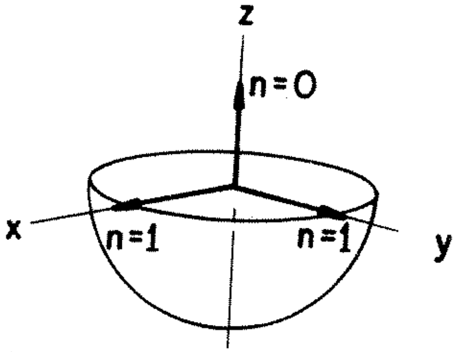
DATA  6I6, 2E12.8  ** (IFIXB(I,J), J=1,6),   D1B(I), D2B(I) **

1300  CONTINUE      (END OF DO-LOOP OVER STABILITY CONSTRAINT CONDITIONS)
```

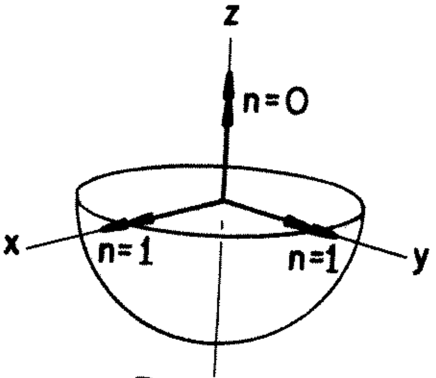
IFIXB(I,J) = SEE THE DESCRIPTION ABOVE FOR THE PREBUCKLING CONSTRAINT CONDITIONS, IFIX(I,J). REMEMBER, IF YOU WISH, THE CONDITIONS IFIXB CAN BE DIFFERENT FROM THOSE SPECIFIED FOR THE PREBUCKLING ANALYSIS. FOR EXAMPLE, SYMMETRY CONDITIONS CAN BE IMPOSED AT A SYMMETRY PLANE IN THE PREBUCKLING ANALYSIS, WHEREAS ANTISYMMETRY CONDITIONS CAN BE IMPOSED THERE IN THE STABILITY ANALYSIS.

D1B(I) = SEE DESCRIPTION ON PAGE P68 FOR D1(I)
D2B(I) = SEE DESCRIPTION ON PAGE P68 FOR D2(I)

Rigid body modes are prevented by the user through introduction of input as described below. These additional input data are required only in cases involving n = 0 and n = 1 circumferential waves. For n = 0 and n = 1 rigid body motion is possible if the shell is not sufficiently constrained by the boundary conditions. There are six rigid body modes, three translational and three rotational. These modes are shown below

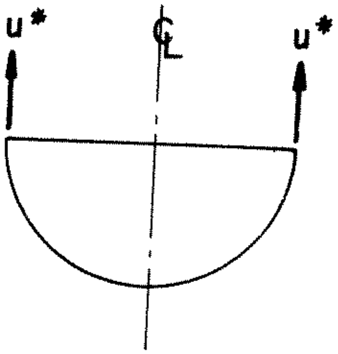


Translation



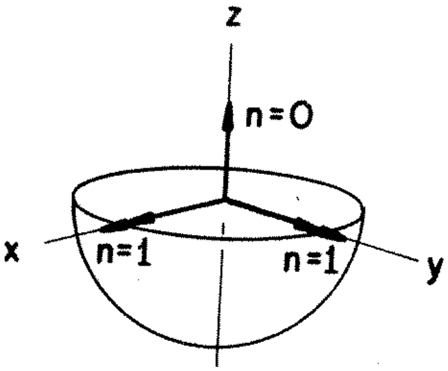
Rotation

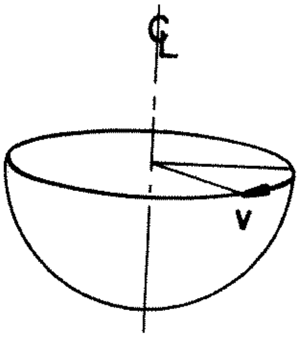
All of these rigid body motions can be prevented by choosing a meridional station at which to restrain the axial displacement u^* and the circumferential displacement v^* or v. The figures below show why:



The constraint $u^* = 0$ prevents:

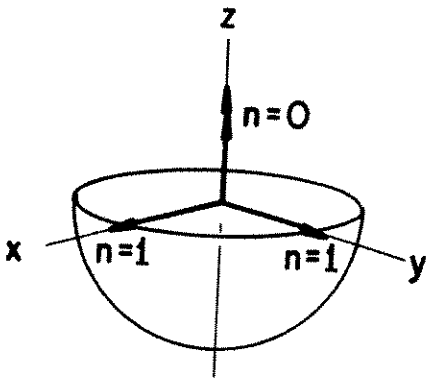
(1) Translation along z-axis (n=0)
(2) Rotation about x-axis (n=1)
(3) Rotation about y-axis (n=1)





The constraint v=0 prevents:

(1) Rotation about z-axis (n=0)
(2) Translation along x-axis (n=1)
(3) Translation along y-axis (n=1)



```
IF  IRIGID = 0  *** GO TO 1500 *** (NO RIGID-BODY CONSTRAINT REQD)
```

IRIGID = CONTROL INTEGER TO PREVENT RIGID BODY MODES

```
DATA    6I6    ** (ISTOPO(J), J=1,6) **                    (RIGID BODY)
DATA    6I6    ** (ISTOP1(J), J=1,6) **                    (RIGID BODY)
```

ISTOPO(J) = CONSTRAINT CONDITION FOR PREVENTING AXISYMMETRIC (N=0) RIGID BODY BUCKLING DISPLACEMENTS. IN BOSOR5 THIS CONDITION WILL BE IMPOSED ONLY IF N=0. IT WILL NOT BE IMPOSED FOR ANY OTHER VALUE OF CIRC. WAVE NUMBER, N.

ISTOP1(J) = CONSTRAINT CONDITION FOR PREVENTING RIGID BODY MOTION WHICH CORRESPONDS TO N=1. (1 CIRC. WAVE, SUCH AS WOULD BE THE CASE IF THE STRUCTURE TRANSLATED NORMAL TO ITS AXIS OF REVOLUTION, OR IF THE STRUCTURE ROTATED ABOUT ONE OF ITS ENDS.)

ISTOPO AND ISTOP1 HAVE THE SAME FORMAT AS IFIX(I,J), WHICH ARE DESCRIBED ABOVE. SEE THE EXAMPLE OPPOSITE.

IMPORTANT NOTES....   (RIGID BODY CONSTRAINTS)

1. ISTOPO(1) MUST EQUAL ISTOPO(2)
2. ISTOP1(1) MUST EQUAL ISTOP1(2)
3. ISTOPO(1) CAN EQUAL ISTOP1(1), AND ORDINARILY THE USER WOULD DO THIS.
4. ISTOPO(1) AND ISTOP1(1) MUST BE EQUAL TO ONE OF THE BOUNDARY STATIONS SPECIFIED BY IFIXB(I,1). THIS IFIXB(I,1) MUST CORRESPOND TO A BOUNDARY CONDITION, NOT TO A JUNCTURE CONDITION.
5. IT MAY BE NECESSARY TO INTRODUCE AN EXTRA IFIXB(I,J) SOLELY IN ORDER TO SUPPLY A STATION FOR THE RIGID BODY MODE CONSTRAINT CONDITION. A COMPLETELY CLOSED SHELL, SUCH AS A COMPLETE SPHERE IS AN EXAMPLE. ANOTHER EXAMPLE IS SHOWN ON THE OPPOSITE PAGE, WHERE THE CONDITION 2001 2001 IS INTRODUCED FOR THIS PURPOSE.

(END OF BIFURCATION BUCKLING CONSTRAINT CONDITIONS)

```
1500  CONTINUE        (END OF INPUT FOR BOSOR5 PREPROCESSOR. ADDITIONAL
                DATA WILL BE READ IN BY THE BOSOR5 MAIN PROCESSOR......)
```

Example:

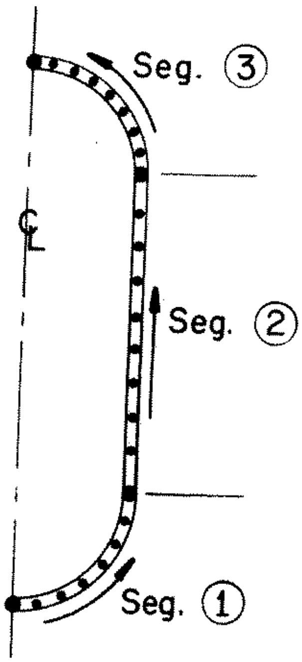


Table below gives possible input data for the example shown above.

```
       EXAMPLE OF CONSTRAINT CONDITIONS CORRESPONDING TO THE ABOVE FIGURE,
                    WITH RIGID BODY BUCKLING MODAL DISPLACEMENT CONSTRAINTS

 COL. 6     12     18     24     30     36              48              60              72

      1      3      5      1
 001001001001                                                ISEGA, ISEGB, NCONDB, IRIGID
 001008002001      1      1      1      1     0.0        (IFIXB(1,J),J=1,6),D1B(1),D2B(1)
→002001002001                                         0.0   IFIXB(2,J),D1B(2),D2B(2)
 002010003001      1      1      1      1                   IFIXB(3,J),D1B(3),D2B(3)
 003009003009                                 0.0     0.0   IFIXB(4,J),D1B(4),D2B(4)
 002001002001      1      1      0      0                   IFIXB(5,J),D1B(5),D2B(5)
 002001002001      1      1      0      0                          (ISTOP0(J),J=1,6)
                                                                   (ISTOP1(J),J=1,6)
```

Note that an extra constraint point is provided in order to have a station at which to apply the rigid body mode constraints for n = 0 and n = 1 circumferential waves.

SECTION 3

USER INSTRUCTIONS FOR THE BØSØR5 MAIN-PROCESSOR

```
*******BOSOR5 MAIN PROCESSOR INPUT DATA *******

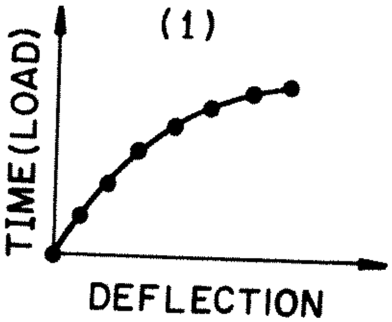
DATA   216    ** INDIC,IDEFORM **   —, NPRINT, ICPRE

             INDIC = INDICATOR FOR TYPE OF ANALYSIS...
                     AVAILABLE OPTIONS ARE INDIC = 0, -2, AND -3...

                     INDIC = 0 MEANS NONLINEAR STRESS ANALYSIS
                               WILL BE PERFORMED FOR A SEQUENCE OF
                               TIME STEPS SPECIFIED BY THE USER EITHER
                               IN THE BOSOR5 PREPROCESSOR OR IN THE
                               FOLLOWING INPUT DECK.  THE RESULTS
                               OF THIS ANALYSIS FOR EVERY TIME STEP
                               ARE STORED ON MASS STORAGE. A CASE
                               CAN BE RESTARTED AT ANY TIME STEP.

                     INDIC = -2 MEANS THAT A NONLINEAR STRESS ANALYSIS
                               WILL BE PERFORMED AND THAT THE STABILITY
                               DETERMINANT WILL BE CALCULATED FOR
                               A CERTAIN FIXED NUMBER, NOB, OF CIR-
                               CUMFERENTIAL WAVES AND A USER-SPECIFIED
                               TIME RANGE.  IF THE STABILITY DETERMIN-
                               ANT FOR NOB WAVES CHANGES SIGN IN THIS
                               TIME RANGE, THEN BIFURCATION BUCKLING
                               LOADS ARE CALCULATED FOR A RANGE OF
                               CIRCUMFERENTIAL WAVE NUMBERS, NMINB
                               THROUGH NMAXB.  NMINB AND NMAXB ARE
                               TO BE PROVIDED BY THE USER.   IF THE
                               STABILITY DETERMINANT DOES NOT CHANGE SIGN
                               IN THE USER-SPECIFIED TIME RANGE, THEN
                               THE BIFURCATION BUCKLING LOADS CORRES-
                               PONDING TO OTHER THAN NOB CIRCUMFERENTIAL
                               WAVES WILL NOT BE CALCULATED IN THIS RUN.
                               IN GENERAL THE USER WILL THEN HAVE TO
                               RESORT TO A SERIES OF  INDIC = -3 RUNS
                               WITH OTHER VALUES OF NOB,  AND/OR HE WILL
                               HAVE TO PERSUE THE STABILITY DETERMINANT
                               WITH N = NOB FOR HIGHER LOADS.
                               IN THIS ANALYSIS BRANCH THE RESULTS OF THE
                               PREBUCKLING ANALYSIS AND THE EIGEN-
                               VALUES AND EIGENVECTORS (BUCKLING MODES)
                               ARE STORED ON MASS STORAGE. A CASE CAN
                               BE RESTARTED AT ANY TIME STEP.
```

INDIC = 0



(1) Nonlinear Stress Analysis Only

INDIC = -2

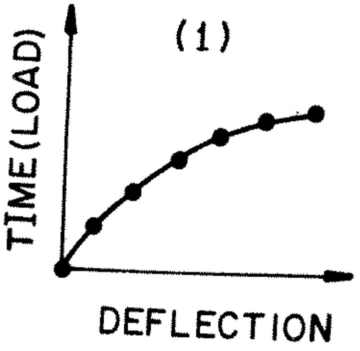
(1) Nonlinear Stress Analysis

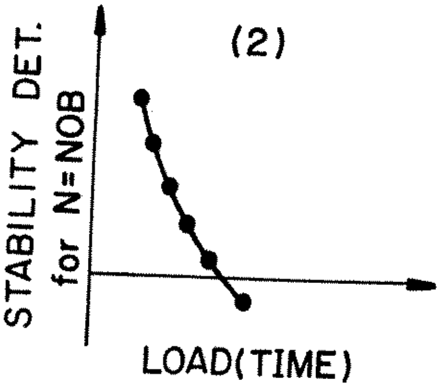
AND

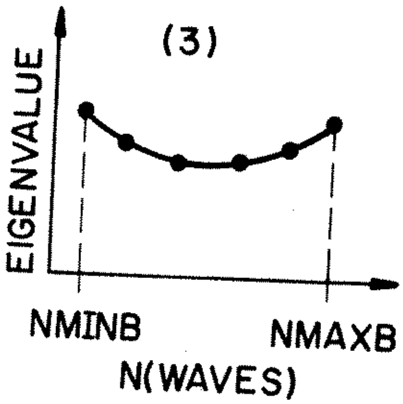
(2) Stability Determinant Calculation

AND

(3) Eigenvalue vs N Calculation







```
                    INDIC = -3 MEANS THAT THE STABILITY DETERMINANT
                            FOR A GIVEN NUMBER NOB OF CIRCUM. WAVES
                            WILL BE CALCULATED FOR A SEQUENCE OF
                            TIME STEPS FOR WHICH A PREBUCKLING
                            ANALYSIS HAS BEEN MADE IN A PREVIOUS
                            RUN WITH INDIC = 0 OR INDIC = -2.
                            IF THE STABILITY DETERMINANT FOR N= NOB
                            CHANGES SIGN IN THIS TIME RANGE , THEN
                            BIFURCATION BUCKLING LOADS
                            ARE CALCULATED FOR A RANGE OF CIRCUMFER
                            ENTIAL WAVE NUMBERS  NMINB THRU NMAXB
                            TO BE PROVIDED BY THE USER.
                            IF THE STABILITY DETERMINANT DOES NOT
                            CHANGE SIGN IN THE USER-SPECIFIED TIME
                            RANGE, THE BUCKLING LOADS CORRESPONDING
                            TO OTHER THAN NOB CIRCUM. WAVES WILL NOT
                            BE CALCULATED IN THIS RUN.

              IMPORTANT NOTE... BEFORE THE INDIC = -3 OPTION CAN
                                BE USED. A PREVIOUS INDIC = 0 OR
                                INDIC = -2 RUN OR RUNS MUST HAVE BEEN
                                MADE.  THIS IS BECAUSE THE INDIC = -3
                                OPTION DOES NOT DO ANY PREBUCKLING
                                ANALYSIS, BUT REQUIRES THE RESULTS
                                OF SUCH AN ANALYSIS TO BE AVAILABLE
                                ON MASS STORAGE.

            IDEFORM = INDICATOR FOR TYPE OF PLASTICITY THEORY ...

                    IDEFORM=0 MEANS THAT FLOW THEORY WILL BE USED
                              TO CALCULATE THE CONSTITUTIVE LAW FOR
                              BOTH THE PREBUCKLING AND BIFURCATION
                              ANALYSES.

                    IDEFORM=1 MEANS THAT FLOW THEORY WILL BE USED
                              IN THE PREBUCKLING ANALYSIS AND
                              DEFORMATION THEORY IN THE BIFURCATION
                              BUCKLING ANALYSIS.

                   NOTE.. FLOW THEORY IS ALWAYS USED FOR THE
                          PREBUCKLING ANALYSIS.

                   NOTE.. IN ORDER TO RUN INDIC = -3 WITH DEFORMATION
                          THEORY, YOU MUST HAVE PREVIOUSLY RUN
                          INDIC = -2 WITH IDEFORM = 1.

IF INDIC = 0   *** GO TO 1550 ***                (NONLINEAR STRESS ANALYSIS)

IF INDIC =-2   *** GO TO 2050 *** (NONLIN. STRESS ANAL. WITH STAB. DET.)

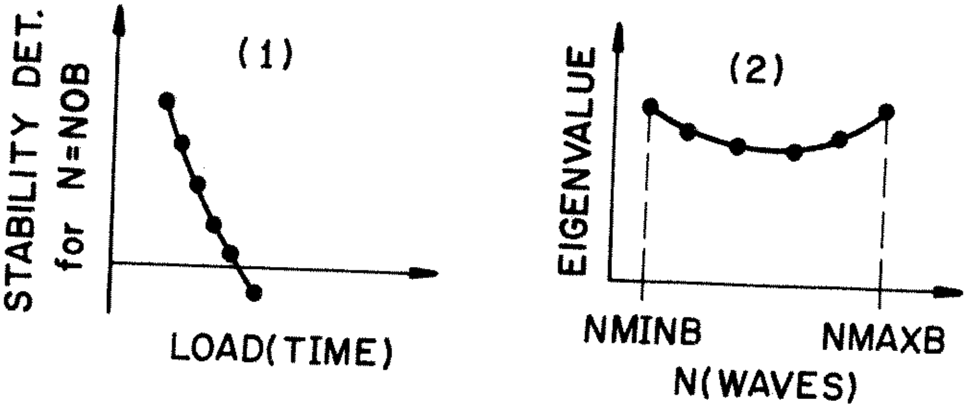
IF INDIC =-3   *** GO TO 3050 *** (CALCULATION OF STABILITY DETERMINANT)
```

NPRINT: USE 0.

ICPRE: Generally, use 1. However, read the paper by Lagae and Bushnell on buckling of toriispherical heads for more details.

(1) Stability Determinant Calculation
AND
(2) Eigenvalue vs N Calculation

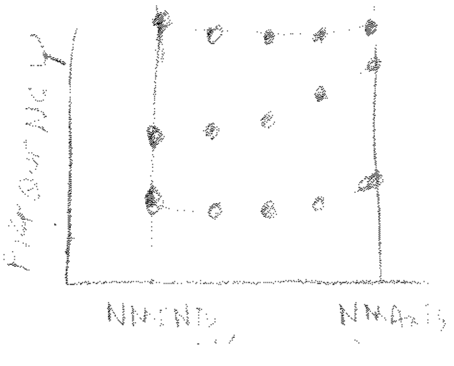
INDIC = -3



INDIC = 2 means that a modal vibration analysis of an axisymmetrically loaded structure will be performed. NVEC frequencies and modes will be found for circumferential wave numbers in the range NMIN to NMAX in increments of INCR

Note: The absolute element called 'BUKVIB' must be used if INDIC = 2.

INDIC = 2



([illegible] 1))

(INDIC = 0)

1550 CONTINUE

**** INPUT DATA FOR THE INDIC=0 OPTION. (NONLINEAR STRESS ANALYSIS ONLY)

DATA ~~5~~7I6 ** KSTEP,KMAX,MAXTRL,ITMAX,ITIME, ISTRAT, IPRINT ** (INDIC = 0)

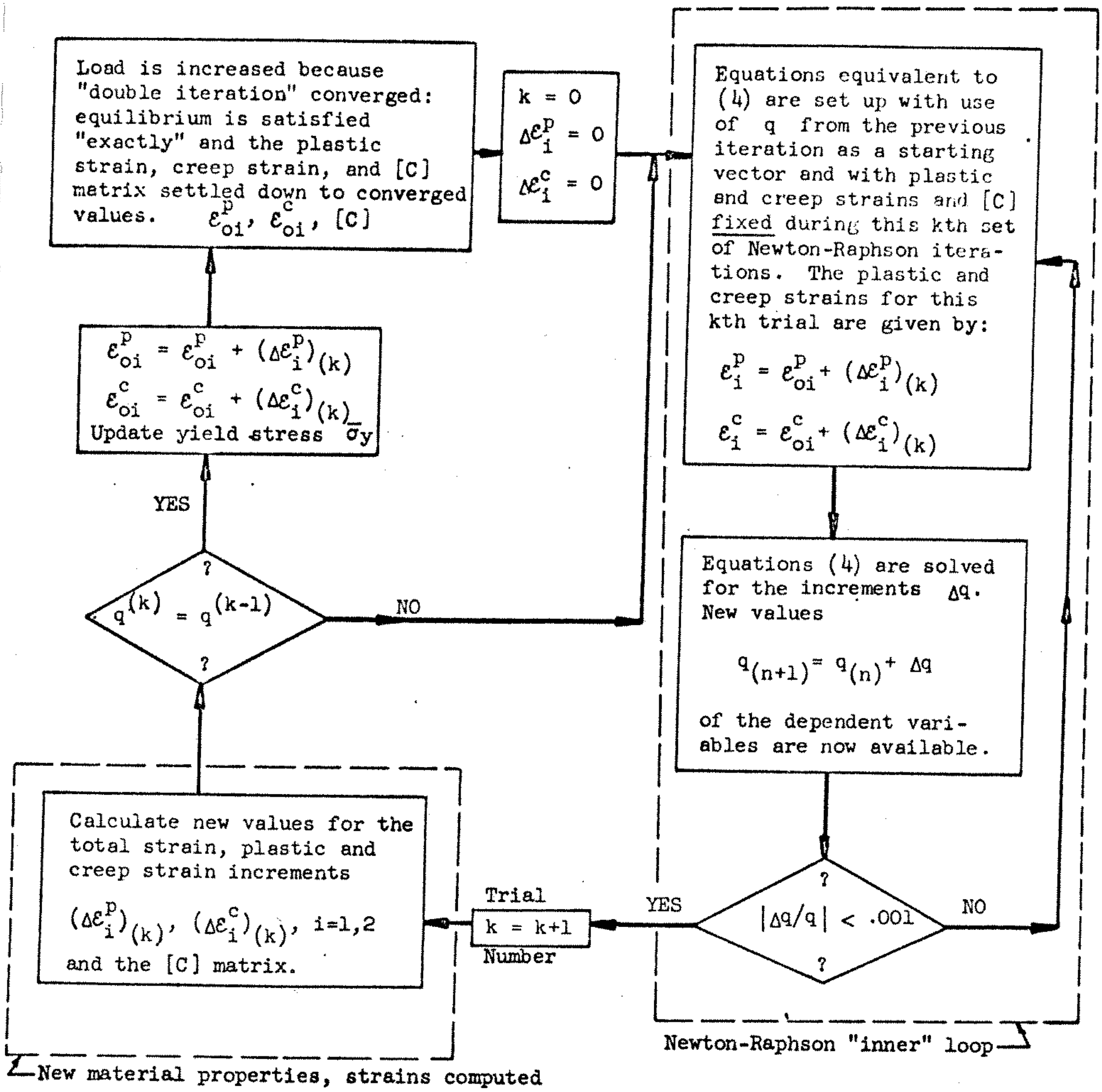
KSTEP = STARTING TIME STEP NUMBER. IF THIS IS THE FIRST RUN WITH THIS CASE, THEN KSTEP MUST BE 0. IF YOU ARE RESTARTING, SET KSTEP = A VALUE FOR WHICH PREBUCKLING RESULTS HAVE ALREADY BEEN OBTAINED BY A PREVIOUS RUN. (INDIC = 0)

KMAX = MAXIMUM TIME STEP NUMBER. KMAX CANNOT BE LARGER THAN 99.

MAXTRL = MAXIMUM NUMBER OF TRIALS TO BE PERMITTED BEFORE PROCEEDING TO THE NEXT TIME STEP. ~~A 'TRIAL' IS DEFINED IN ASME PUBLICATION.... AMD VOL. 6, NOV. 1973, EDITOR R.F. HARTUNG, 'NUMERICAL SOLUTION OF NONLINEAR STRUCTURAL PROBLEMS' PAGE 106, TOP. (ARTICLE ON SHELLS OF REVOLUTION BY DAVID BUSHNELL.)~~ SEVERAL TRIALS FOR A CONVERGED SOLUTION ARE ATTEMPTED AT EACH TIME STEP. FOR EACH TRIAL THE MATERIAL PROPERTIES ARE UPDATED AND THE NONLINEAR ALGEBRAIC EQUATIONS FOR THE PREBUCKLING ANALYSIS WITH FIXED MATERIAL PROPERTIES ARE SOLVED BY THE NEWTON-RAPHSON METHOD. WHEN THE MATERIAL PROPERTIES STOP CHANGING WITH EACH TRIAL, OR WHEN THE NUMBER OF TRIALS = MAXTRL, THE RUN PROCEEDS TO THE NEXT TIME STEP. THIS WILL USUALLY HAPPEN AFTER ABOUT 2 TO 6 TRIALS. GENERALLY THE USER SHOULD SET MAXTRL EQUAL TO SOME VALUE BETWEEN 5 AND 10. HOWEVER, IF HE WISHES TO GET AN ECONOMICAL ESTIMATE OF THE BEHAVIOR OF THE STRUCTURE, HE CAN SET MAXTRL EQUAL TO SOME SMALLER NUMBER, EVEN 1, PERHAPS. (MAXTRL=1 IS THE MOST SUITABLE CHOICE IF THIS IS AN ELASTIC ANALYSIS WITH NO CREEP.) IT SHOULD BE NOTED, HOWEVER, THAT THE SOLUTIONS OBTAINED WITH VERY SMALL MAXTRL MAY NOT HAVE CONVERGED TO A SUFFICIENT DEGREE OF ACCURACY IF PLASTICITY OR CREEP ARE PRESENT. THE FLOW CHART ON THE FACING PAGE SHOWS THE STRATEGY USED FOR SOLVING PROBLEMS IN WHICH BOTH LARGE DEFLECTIONS AND NONLINEAR MATERIAL PROPERTIES ARE PRESENT.

(INDIC = 0)

ITMAX = MAXIMUM NUMBER OF NEWTON-RAPHSON ITERATIONS TO BE PERMITTED FOR EACH TRIAL. GENERALLY THE USER SHOULD SET ITMAX = 10 OR MORE. COMPUTER TIME IS SAVED MORE BY LIMITING MAXTRL THAN BY LIMITING ITMAX.



$$\sum_{j=1}^{N} \frac{\partial \psi_i}{\partial q_j} \Delta q_j = - \psi_i \qquad i = 1,2 \ldots N \qquad (4)$$

(INDIC = 0)

ITIME = CONTROL INTEGER FOR TIME STEPS AND LOADING
FUNCTIONS OF TIME. ITIME CAN BE 0 OR 1 OR 2

(INDIC = 0)

ITIME = 0 MEANS THAT THE TIME STEPS AND
LOADING FUNCTIONS OF TIME SPECIFIED
BY THE USER IN THE BOSOR5 PREPROCESSOR
WILL BE HONORED IN THIS RUN. 6

ITIME = 1 MEANS THAT THE LOADING FUNCTIONS OF
TIME SPECIFIED BY THE USER IN THE
6 BOSOR5 PREPROCESSOR WILL BE HONORED, BUT
THAT THE TIME STEPS WILL NOT. A NEW
TIME STEP, DTIME, WILL BE READ IN AND
USED IN THIS RUN.

Insert 2)

ITIME = 2 MEANS THAT NEW TIME FUNCTIONS AND TIME
STEPS WILL BE SPECIFIED BY THE USER IN
THIS RUN. ~~THE INPUT DATA WILL FOLLOW
EXACTLY THE SAME FORMAT AS THE DATA IN
THE BOSOR5 PREPROCESSOR HAVING TO DO
WITH 'TIME FUNCTIONS'.~~ (INDIC = 0)

15

NEXT, READ IN THE INITIAL TIME.... (INDIC = 0)

DATA E12.8 **TIME ** (STARTING TIME)

TIME = TIME AT THE BEGINNING OF THIS RUN.

IF THIS IS THE FIRST RUN (THAT IS, IF KSTEP = 0),
THEN TIME MUST EQUAL ZERO.
IF THIS IS A RESTART, THEN TIME MUST BE THAT
TIME WHICH CORRESPONDS TO KSTEP, THE STARTING TIME
STEP NUMBER FOR THIS RUN. (INDIC = 0)

IF ITIME = 0 *** GO TO 2000 *** (USE ORIGINAL TIME INCREMENTS
AND TIME FUNCTIONS)

IF ITIME = 1 *** GO TO 1600 *** (USE NEW TIME INCREMENT,
ORIGINAL TIME FUNCTIONS)

IF ITIME = 2 *** GO TO 1700 *** (USE NEW TIME INCREMENT
AND NEW TIME FUNCTIONS)

1600 CONTINUE (ITIME = 1)

WITH ITIME = 1 WE HAVE TO READ THE NEW TIME INCREMENT,
WHICH WILL BE CONSTANT THROUGHOUT THIS RUN REGARDLESS OF
WHAT WAS ORIGINALLY SPECIFIED IN THE BOSOR5 PREPROCESSOR.
6

DATA E12.8 ** DTIME ** (ITIME = 1)

DTIME = NEW TIME INCREMENT, HELD CONSTANT DURING THIS RUN.

*** GO TO 2000 ***

1700 CONTINUE

(NEW TIME FUNCTIONS AND INCREMENTS)
(ITIME = 2)

NEXT, READ IN DATA THROUGH WHICH VARIOUS TIME FUNCTIONS CORRESPONDING TO VARIOUS LOADS AND TEMPERATURE ARE SPECIFIED.

FIRST, DETERMINE THE TIME INCREMENTS TO BE USED THROUGHOUT THE TIME HISTORY OF THE RUN ....

DATA I6 ** NTIME **

(TIME STEPS)

NTIME = NUMBER OF POINTS IN TIME FOR WHICH THE TIME INCREMENT IS TO BE SPECIFIED. THE TIME INCREMENT AT EVERY POINT IN TIME IS THEN AUTOMATICALLY DETERMINED BY LINEAR INTERPOLATION BETWEEN TIMES FOR WHICH THE TIME INCREMENT IS SPECIFIED. SEE THE FIGURE ON PAGE ~~P61~~. NTIME MUST BE GREATER THAN OR EQUAL TO 2 AND LESS THAN 50.

DATA 6E12.8 ** (DTIME(I), I=1,NTIME) **

DATA 6E12.8 ** (TIME(I), I=1,NTIME) **

(TIME INCREMENTS)
(TIME CALLOUTS)

DTIME(I) = TIME INCREMENT DIRECTLY FOLLOWING TIME(I).

TIME(I) = POINT IN TIME FOR WHICH DTIME(I) IS SPECIFIED. SEE THE FIGURE ON PAGE ~~P61~~. TIME INCREMENTS VARY LINEARLY FOR TIME STEPS WHICH OCCUR BETWEEN TIME(I) AND TIME(I+1). (TIME STEPS)

NEXT, SPECIFY THE VARIOUS TIME FUNCTIONS.......(TIME FUNCTIONS)

DATA I6 ** NFTIME **

(TIME FUNCTIONS)

NFTIME = NUMBER OF DIFFERENT FUNCTIONS OF TIME. FOR EXAMPLE, YOU MAY HAVE A CASE INVOLVING A TEMPERATURE DISTRIBUTION WHICH IS CONSTANT WITH TIME AND A PRESSURE DISTRIBUTION WHICH VARIES WITH TIME. IN SUCH A CASE, NFTIME = 2, SINCE THERE ARE TWO FUNCTIONS OF TIME--ONE FUNCTION A CONSTANT AND THE OTHER A VARYING QUANTITY.

DATA 10I6 ** (NPOINT(I), I=1,NFTIME) **

NPOINT(I) = NUMBER OF POINTS IN TIME AT WHICH THE ITH TIME FUNCTION IS SPECIFIED. THIS FUNCTION IS ASSUMED TO VARY LINEARLY FOR TIMES BETWEEN THOSE WHERE IT IS CALLED OUT. SEE THE FIGURE ON PAGE P61, FOR EXAMPLE.

```
******* DO 1800  I = 1,NFTIME *******                     (TIME FUNCTIONS)

          NFTIME = NUMBER OF DIFFERENT TIME FUNCTIONS

DATA 6E12.8  ** (F(I,J), J= 1,NPOINT(I)) **                    ( F(TIME))
DATA 6E12.8  ** (T(I,J), J= 1,NPOINT(I)) **                    (  TIME  )

          F(I,J) = VALUE OF ITH TIME FUNCTION AT TIME T(I,J).
                   THIS FUNCTION VARIES LINEARLY BETWEEN
                   T(I,J) AND T(I,J+1)

          T(I,J) = POINT IN TIME TO WHICH F(I,J) CORRESPONDS.

1800 .CONTINUE                                            (TIME FUNCTIONS)

2000  CONTINUE                 (END OF INPUT DATA FOR INDIC = 0 ANALYSIS)

   *** GO TO 4000 ***
```

2050 CONTINUE

****** INPUT DATA FOR THE INDIC = -2 OPTION ****** (INDIC = -2)

(NONLINEAR STRESS ANALYSIS WITH CALCULATION OF STABILITY DETERMINANT)

DATA 5I6 ** KSTEP, KMAX, MAXTRL, ITMAX, ITIME ** ISTRAT (INDIC = -2)

SEE THE INDIC = 0 BRANCH FOR FULLER EXPLANATION OF VARIABLES THAN THAT GIVEN BELOW....

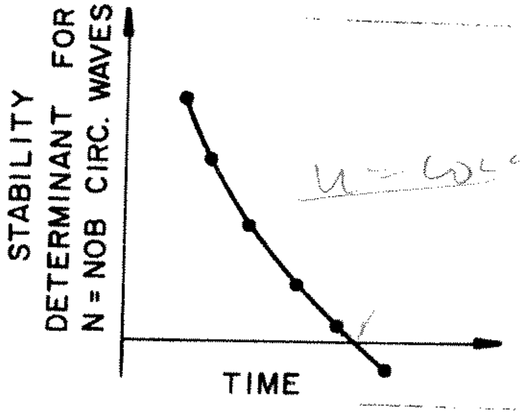
KSTEP = STARTING TIME STEP NUMBER (0 IF FIRST RUN)
KMAX = MAXIMUM TIME STEP NUMBER (LESS THAN OR EQUAL TO 99)
MAXTRL= MAXIMUM NUMBER OF TRIALS PERMITTED BEFORE GOING TO NEXT TIME STEP. (INDIC = -2)
ITMAX = MAXIMUM NUMBER OF NEWTON-RAPHSON ITERATIONS/TRIAL
ITIME ....
  0 = KEEP ORIGINAL TIME INCREMENTS AND FUNCTIONS
  1 = KEEP ORIGINAL TIME FUNCTIONS, USE NEW INCREMENT
  2 = GENERATE NEW TIME INCREMENTS AND TIME FUNCTIONS.

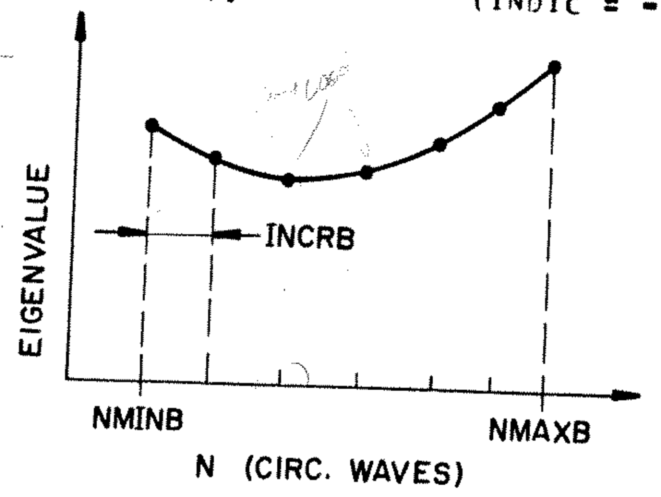
NEXT, READ IN THE INITIAL CIRCUMFERENTIAL WAVE NUMBER AND THE RANGE OF CIRCUMFERENTIAL WAVE NUMBERS TO BE USED IN THE STABILITY ANALYSIS......

DATA 5I6 ** NOB, NMINB, NMAXB, INCRB, NVEC ** (INDIC = -2)

NOB = INITIAL CIRCUMFERENTIAL WAVE NUMBER. STABILITY DETERMINANT WILL BE CALCULATED FOR A SEQUENCE OF TIME STEPS WITH N = NOB HELD CONSTANT. IF THE STABILITY DETERMINANT CHANGES SIGN, A SEQUENCE OF EIGENVALUES WILL BE CALCULATED CORRESPONDING TO THE RANGE OF CIRCUMFERENTIAL WAVENUMBERS NMINB THROUGH NMAXB IN INCREMENTS OF INCRB. SEE NEXT PAGE FOR RULES TO USE FOR CHOOSING APPROPRIATE VALUE FOR NOB.

NMINB = MINIMUM NUMBER OF CIRCUMFERENTIAL WAVES IN BUCKLING MODE.
NMAXB = MAXIMUM NUMBER OF CIRCUMFERENTIAL WAVES IN BUCKLING MODE.
INCRB = INCREMENT IN THE CIRCUMFERENTIAL WAVENUMBER TO BE USED IN EXPLORING THE RANGE NMINB TO NMAXB.
NVEC = NUMBER OF EIGENVALUES PER WAVENUMBER TO BE SOUGHT. THE USER SHOULD SET NVEC = 1. (INDIC = -2)





NOB, NMINB, NMAXB:

Initial buckling circumferential wave number, minimum wave number, maximum wave number. The minimum buckling load with circumferential wave number is being searched for. Experimental evidence is of course very useful in determining a good choice of NOB, NMINB, and NMAXB. If none is available the user is advised to try the following formulas:

(1) "Square" buckles for short shells or panel buckling

$N = \pi r/L$, where L is the shell meridional arc length between nodes of the buckling mode.

(2) For monocoque deep shells, axial compression:

$N = [\text{(Nominal circumferential rad. of curve)}/t]^{1/2} (1 - \nu^2)$

(3) For shallow spherical caps supported rigidly at their edges; external pressure

$N = 1.8 * \alpha_2 * (R/t)^{1/2} - 5$

(4) For axially compressed conical shells and frustrums

Use formula 2 where the circumferential radius of curvature, R, is the average of the radii at the ends.

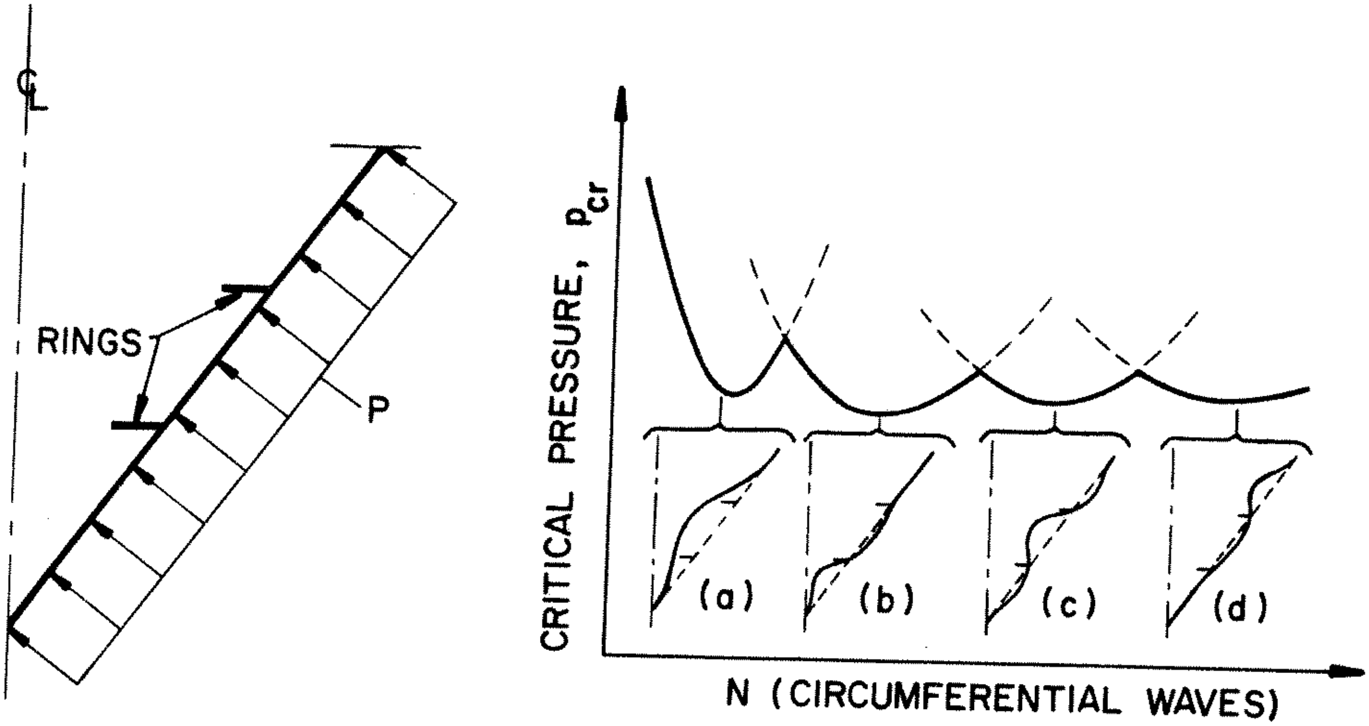
(5) Spherical segments of any depth under axial tension

$N = 1.8 * (R/t)^{1/2} \sin [\alpha_1 + 4.2 (t/R)^{1/2}]$
where α_1 and α_2 are the meridional angles at the segment beginning and end, respectively.

The above list of formulas is by no means complete. However, notice that $(R/t)^{1/2}$ is a significant parameter. If N is known for a shell of a given geometry loaded in a certain way, a new value can be predicted for a new R/t through the knowledge that N often seems to vary as $(R/t)^{1/2}$. (R is the circumferential radius of curvature.) Experience in the use of the program will lead to further competence in the selection of appropriate values for NOB, the initial guess at N. The user must be sure that the input range $\text{NMINB} \le N \le \text{NMAXB}$ includes the minimum minimum buckling load (see next page).

INCRB:

Value for the increment by which N, the number of circumferential waves in the buckling mode, is increased in buckling problems. In the search for the minimum buckling load, for example, one may only be certain that the N corresponding to the minimum buckling load N (critical lies in the range $2 \le N \le 100$. One might, therefore, choose INCRB = 10 and "zero in" on a more accurate value in a additional run. The user should ordinarily set $\text{INCRB} \approx 0.05 * (\text{NMINB}+\text{NMAXB})$.



Several buckling moles for ring-stiffened conical shell

(a) General instability
(b) 1st bay buckling
(c) 2nd bay buckling
(d) 3rd bay buckling

Finding the Minimum Minimum Buckling Load

The theory on which BØSØR5 is based does not exclude the possibility that several values of circumferential wave number N may be associated with minimum buckling loads. One must always find the minimum minimum. This problem frequently arises in the calculation of buckling loads for complex shells or ring stiffened shells. A ring-stiffened conical shell under external pressure is such a case (Figure above). Here there could be a minimum buckling load corresponding to general instability and additional minima (at higher values of N) corresponding to the local failure of each conical frustrum (the bays between the rings). Physical intuition is invaluable as a guide for finding the absolute minimum load in this respect. One may idealize each bay of a ring-stiffened shell by assuming that the bay is simply-supported, calculate corresponding "panel" buckling loads with certain appropriate ranges of N, and then use the critical loads and values of N as starting points in an investigation of the assembled structure.

```
        NEXT, READ IN THE INITIAL TIME....                          (INDIC = -2)

DATA   E12.8 **TIME **                                         (STARTING TIME)

        TIME = TIME AT THE BEGINNING OF THIS RUN.
               SEE INDIC = 0 OPTION FOR MORE DETAILS.             (INDIC = -2)

     IF  ITIME = 0    *** GO TO 3000 *** (USE ORIGINAL TIME INCREMENTS
                                           AND TIME FUNCTIONS)

     IF  ITIME = 1    *** GO TO 2600 *** (USE NEW TIME INCREMENT,
                                           ORIGINAL TIME FUNCTIONS)

     IF  ITIME = 2    *** GO TO 2700 *** (USE NEW TIME INCREMENT
                                           AND NEW TIME FUNCTIONS)
                                                                  (INDIC = -2)
2600  CONTINUE                                                    (ITIME = 1)

        WITH ITIME = 1 WE HAVE TO READ THE NEW TIME INCREMENT,
        WHICH WILL BE CONSTANT THROUGHOUT THIS RUN REGARDLESS OF
        WHAT WAS ORIGINALLY SPECIFIED IN THE BOSOR5 PREPROCESSOR.

DATA   E12.8 ** DTIME **                                          (ITIME = 1)

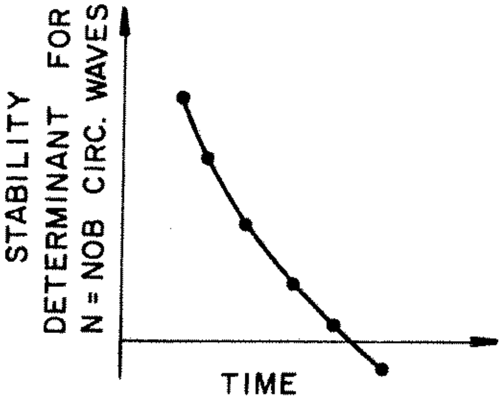
        DTIME = NEW TIME INCREMENT, HELD CONSTANT DURING THIS RUN.

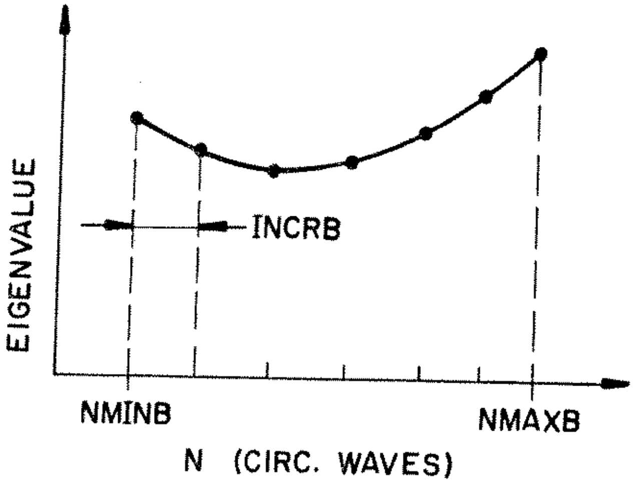
    ***  GO TO 3000 ***

2700 CONTINUE                          (NEW TIME FUNCTIONS AND INCREMENTS)
                                                                  (ITIME = 2)
        SEE THE INDIC = 0 OPTION FOR DETAILS.....(LABEL 1700)

3000  CONTINUE                  (END OF INPUT DATA FOR INDIC= -2 ANALYSIS)

  *** GO TO 4000 ***
```





3050 CONTINUE (INDIC = -3)

****** INPUT DATA FOR THE INDIC = -3 OPTION ****** (INDIC = -3)

(CALCULATION OF STABILITY DETERMINANT WITH PREBUCKLING ANALYSIS HAVING BEEN DONE IN A PREVIOUS RUN)

DATA I6 ** NSTEPS ** (INDIC = -3)

NSTEPS = QUANTITY OF TIME STEPS FOR WHICH STABILITY DETERMINANT WILL BE CALCULATED.

DATA 10I6 ** (LSTEPS(I), I=1,NSTEPS) ** (INDIC = -3)

LSTEPS(I) = TIME STEP NUMBERS FOR WHICH STABILITY DETERMINANT WILL BE CALCULATED.

DATA 6E12.8 ** (TIMES(I), I=1,NSTEPS) ** (INDIC = -3)

TIMES(I) = TIMES CORRESPONDING TO THE TIME STEP NUMBERS, LSTEPS(I) . (INDIC = -3)

NEXT, READ IN THE INITIAL CIRCUMFERENTIAL WAVE NUMBER AND THE RANGE OF CIRCUMFERENTIAL WAVE NUMBERS TO BE USED IN THE STABILITY ANALYSIS......

DATA 5I6 ** NOB, NMINB, NMAXB, INCRB, NVEC ** (INDIC = -3)

NOB = INITIAL CIRCUMFERENTIAL WAVE NUMBER. STABILITY DETERMINANT WILL BE CALCULATED FOR A SEQUENCE OF TIME STEPS WITH N = NOB HELD CONSTANT. IF THE STABILITY DETERMINANT CHANGES SIGN, A SEQUENCE OF EIGENVALUES WILL BE CALCULATED CORRESPONDING TO THE RANGE OF CIRCUMFERENTIAL WAVENUMBERS NMINB THROUGH NMAXB IN INCREMENTS OF INCRB.

NMINB = MINIMUM NUMBER OF CIRCUMFERENTIAL WAVES IN BUCKLING MODE.

NMAXB = MAXIMUM NUMBER OF CIRCUMFERENTIAL WAVES IN BUCKLING MODE.

INCRB = INCREMENT IN THE CIRCUMFERENTIAL WAVENUMBER TO BE USED IN EXPLORING THE RANGE NMINB TO NMAXB.

NVEC = NUMBER OF EIGENVALUES PER WAVENUMBER TO BE SOUGHT. THE USER SHOULD SET NVEC = 1. (INDIC = -3)

****** END OF INPUT DATA FOR THE INDIC = -3 OPTION ******* (INDIC = -3)

4000 CONTINUE (END OF INPUT DATA FOR THE BOSOR5 MAINPROCESSOR)

SECTION 4

USER INSTRUCTIONS
FOR THE
BOSOR5 POST-PROCESSOR

```
****** INPUT DATA FOR THE BOSOR5 POST-PROCESSOR *******

DATA   2I6    ** IPRINT, IPLOT **

              IPRINT = CONTROL INTEGER FOR LIST OUTPUT....

                        IPRINT = 0  DO NOT USE
                        IPRINT = 1 PREBUCKLING STATES PRINTED FOR
                                   SELECTED TIME STEPS.
                        IPRINT = 2 BUCKLING MODES PRINTED FOR
                                   SELECTED CIRCUMFERENTIAL WAVE NUMBERS
                        IPRINT = 3 PREBUCKLING STATES AND BUCKLING
                                   MODES PRINTED.

             IPLOT = CONTROL INTEGER FOR PLOTTING

                        IPLOT = 0  NO PLOTS AT ALL
                        IPLOT = 1  PREBUCKLING STATES PLOTTED FOR
                                   SELECTED TIME STEPS.
                        IPLOT = 2  BUCKLING MODES PLOTTED FOR
                                   SELECTED CIRCUMFERENTIAL WAVE NUMBERS.
                        IPLOT = 3  PREBUCKLING STATES AND BUCKLING
                                   MODES PLOTTED

       IF (IPRINT = 1)  *** GO TO 10 ***
       IF (IPRINT = 3)  *** GO TO 10 ***

        OTHERWISE,  *** GO TO 40 ***
```

```
10     CONTINUE                                        (PREBUCKLING OUTPUT)

                NEXT, IDENTIFY FOR WHICH TIME STEPS YOU WANT OUTPUT
      LISTED AND POSSIBLY PLOTTED ......

DATA   2I6    ** NSTEPS, IFLAG **

              NSTEPS = QUANTITY OF TIME STEPS FOR WHICH OUTPUT IS DESIRED
              IFLAG = CONTROL INTEGER FOR HOW MUCH OUTPUT IS DESIRED
                   AT EACH TIME STEP...
                   IFLAG = 0  JUST PRINT OUT THE MERIDIONAL
                              DISTRIBUTIONS OF DISPLACEMENTS AND
                              STRESS RESULTANTS FOR NSTEPS TIME STEPS.

                   IFLAG = 1  PRINT OUT MERIDIONAL DISTRIBUTIONS OF
                              DISPLACEMENTS AND STRESS RESULTANTS
                              AND STRESSES AND STRAINS THROUGH THE
                              THICKNESS AT EACH MERIDIONAL STATION
                              FOR  NSTEPS  TIME STEPS.

DATA  10I6    ** (LSTEPS(I), I=1,NSTEPS) **
DATA 6E12.8   ** (TIMES(I),  I=1,NSTEPS) **
DATA  E12.8   ** EMAX **

              LSTEPS(I) = TIME STEP NUMBERS FOR WHICH OUTPUT IS DESIRED.
               TIMES(I) = TIMES CORRESPONDING TO LSTEPS(I)

                 EMAX = FACTOR BY WHICH DISPLACEMENT FIELD IS NORMALIZED
                        WHEN PLOTS OF DEFORMED STRUCTURE ARE TO BE GIVEN...
                        THE USER SHOULD GENERALLY SET  EMAX = TO ABOUT
                        ONE  HALF  TIMES THE ABSOLUTE VALUE OF THE
                        MAXIMUM DISPLACEMENT ENCOUNTERED IN THE SHELL
                        DURING THE CASE.

     IF (IPRINT = 1)  *** GO TO 100 ***          (NO BUCKLING MODES )
```

```
 40     CONTINUE
                                                    (BUCKLING MODE OUTPUT)

              NEXT, PRINT AND PLOT THE BUCKLING MODES FOR CERTAIN
              USER-SELECTED CIRCUMFERENTIAL WAVE NUMBERS....

 DATA     I6    ** NMODES **
 DATA   10I6    ** (NTHMOD(I), I=1,NMODES) **
 DATA   10I6    ** (NWAVES(I), I=1,NMODES) **

               NMODES = QUANILITY OF BUCKLING MODES TO BE PRINTED
                        AND PLOTTED.

               NTHMOD()= WHICH MODES ARE TO BE PRINTED OR PLOTTED..
                         USE THE ORDER IN WHICH THE MODES WERE CAL-
                         CULATED AS A GUIDE.. FOR EXAMPLE, IF MODES
                         WERE CALCULATED FOR N = 0, 5, 10, 15, 20,
                         IN THAT ORDER,
                         AND YOU WANT THE N = 5 AND THE N = 15 MODES
                         PRINTED AND PLOTTED, SET NTHMOD(1) = 2 (SECOND
                         MODE CALCULATED)  AND  NTHMOD(2) = 4 (FOURTH
                         MODE CALCULATED).

               NWAVES()= NUMHERS OF CIRCUMFERENTIAL WAVES IN THE
                         BUCKLING MODES TO BE PRINTED AND PLOTTED.
                         IN THE ABOVE EXAMPLE, NWAVES(1) = 5 ,
                         NWAVES(2) = 15.

 100    CONTINUE

 ******  END OF INPUT DATA FOR BOSORS POST-PROCESSOR ******

 EXAMPLE OF POSTPROCESSOR INPUT DATA

 COL. 6     12     18     24     30     36     42     48     54     60     66     72

      3     3
      2     1                                                         IPRINT, IPLOT
      2    14                                                         NSTEPS, IFLAG
    1.0          13.0                                            (LSTEPS(I), I=1,NSTEPS)
  0.005                                                          ( TIMES(I), I=1,NSTEPS)
      2                                                                    FMAX
      2     4                                                              NMODES
      5    15                                                    (NTHMOD(I), I=1,NMODES)
                                                                 (NWAVES(I), I=1,NMODES)
```

SECTION 5

SOME POSSIBLE PITFALLS

5.5 Missing refs !

5.1 "ILLEGAL" BRANCHING AND OTHER "ILLEGAL" CONSTRAINT CONDITIONS

BOSOR5 will handle arbitrary branched shells of revolution. However, the user will at times encounter the diagnostic "illegal branching condition, constraint points too dense in Segment ________." Another diagnostic that may mystify the user reads, "Maximum block size exceeded ....

The purpose of this addendum to the user's manual is to explain the meaning of these diagnostics and to provide the user with guidelines for changing his model in order to avoid them.

(1) "Illegal" Branching Conditions

Figure 1(a) represents a schematic of a stiffness matrix of a shell consisting of four segments. It is always true that as the segment number i is increased the banded global stiffness matrix fills up from the top to the

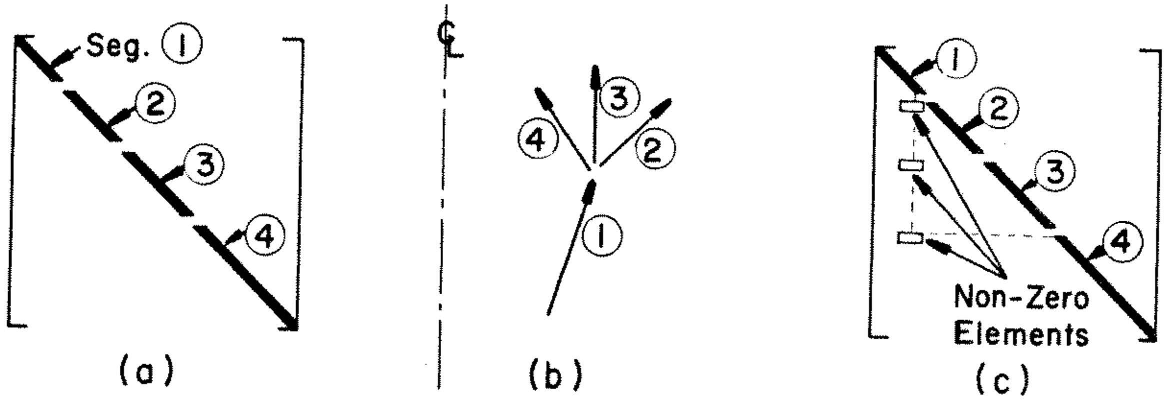


Figure 1 Stiffness Matrix Configuration

bottom. In other words, the equations corresponding to a segment i + 1 always come after those corresponding to segment i . The constraint conditions (branch conditions) are not shown in Fig. 1(a). Now suppose that we have modeled a branched shell as shown in Fig. 1(b). The configuration of the lower triangular part of the (symmetric) stiffness matrix, including the branch conditions is given in Fig. 1(c), if we consider the beginning of segments 2 , 3 , and 4 to be "slaved" or connected to the end of segment 1 .

The connection scheme shown in Fig. 1(b) is legal, and will give the user no trouble provided the block sizes, to be described below, are not too large (The block size may get too large if the bandwidths associated with one or more of the branch conditions are too large. This problem will be described in more detail below).

Notice in Fig. 1(c) that more than one rectangle of non-zero elements falls on the same vertical line. There are three such rectangles shown in Fig. 1(c), corresponding to the end of segment 1 being connected to each of segments 2 , 3 , and 4 . This is a permissible configuration.

However, an illegal branching condition results if the segment numbers are shuffled such that more than one of the three rectangles shown in Fig. 1(c) occur on the same horizontal line. This would happen if the segments were numbered as shown in Fig. 2(a) or Fig. 2(b). Figures 2(c) and 2(d) show the "illegal" stiffness matrix configurations that would result from the

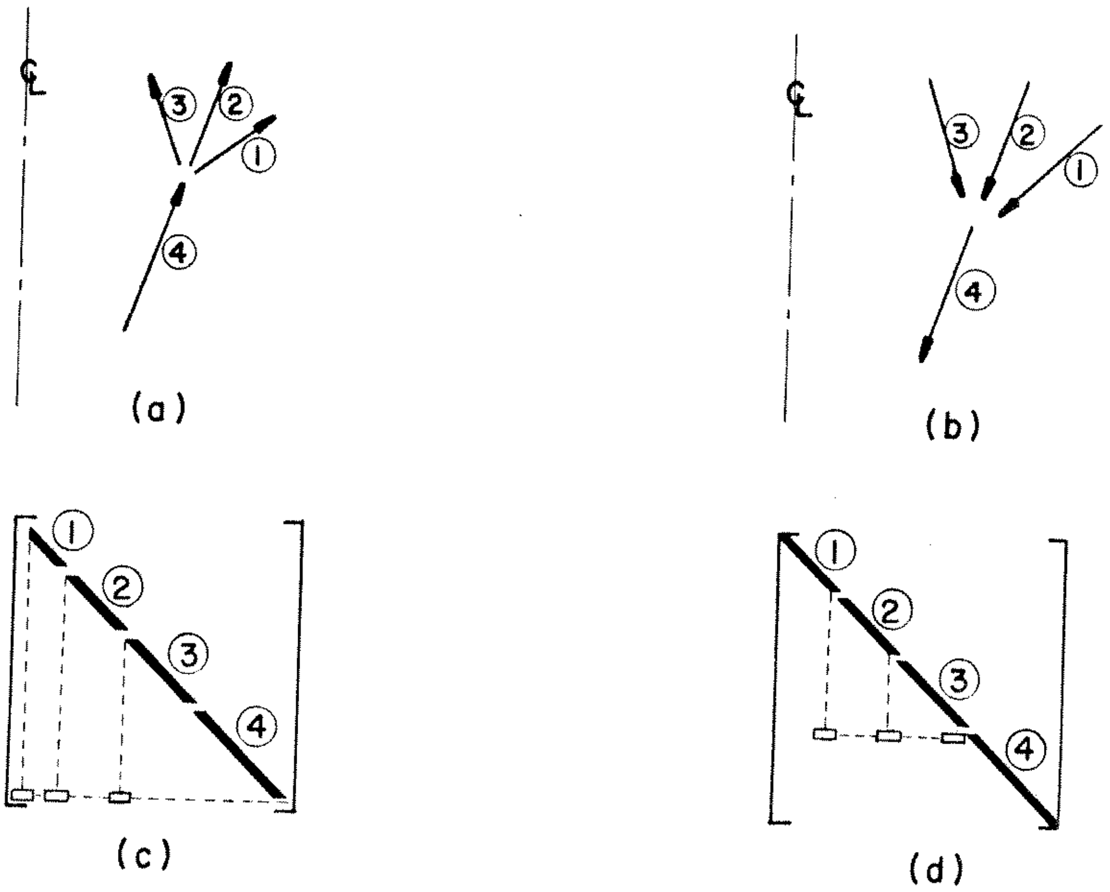


Figure 2 Examples of Illegal Branching

segment arrangements given in Figs. 2(a) and 2(b), respectively. These two configurations are illegal because more than one condition contributes terms to the same horizontal line or same equation. In complex cases the BOSOR5 user should set up a diagram or diagrams such as shown in Figs. (1) and (2) in order to check whether or not such an illegal condition or conditions exists. Figure 3 is an example of how the user might set up a schematic diagram of a stiffness matrix in a complicated case. This example represents an actual engineering problem.

(2) Other "Illegal" Constraint Conditions

The other type of illegal constraint condition has to do with the "density" of constraint conditions in a given segment. Figures similar to 1 and 2 can be used to illustrate the situation.

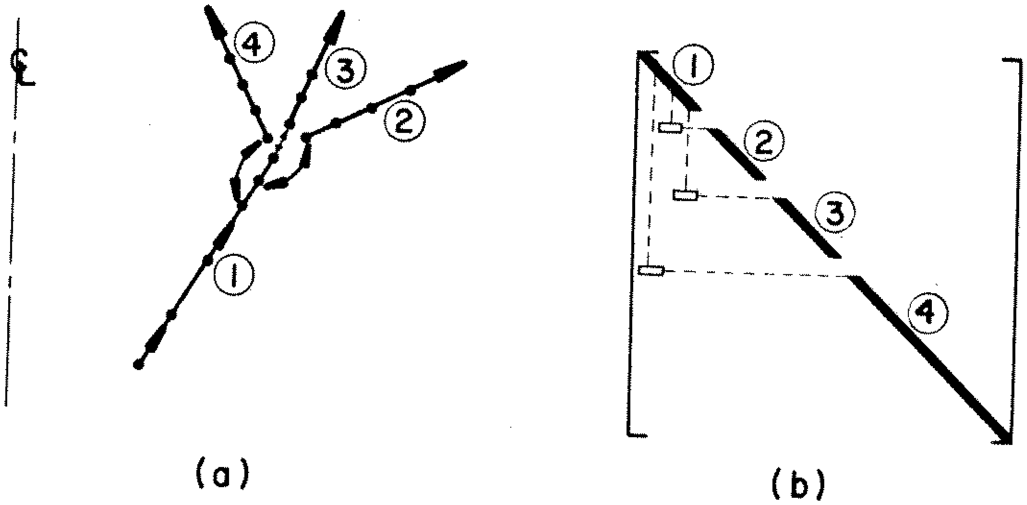


Figure 4 Example of Legal Closely Spaced Juncture Condition

Figure 4(a) represents a similar structure to that shown in Fig. 1(b). The difference is that instead of the same end point of segment 1 being connected to the beginnings of segments 2, 3, and 4, different adjacent points in Segment 1 are connected to the beginnings of segments 2, 3, and 4, as indicated by arrows. Because the rectangles (Fig. 4(b)) are arranged in a basically vertical fashion, however, this arrangement is perfectly legal.

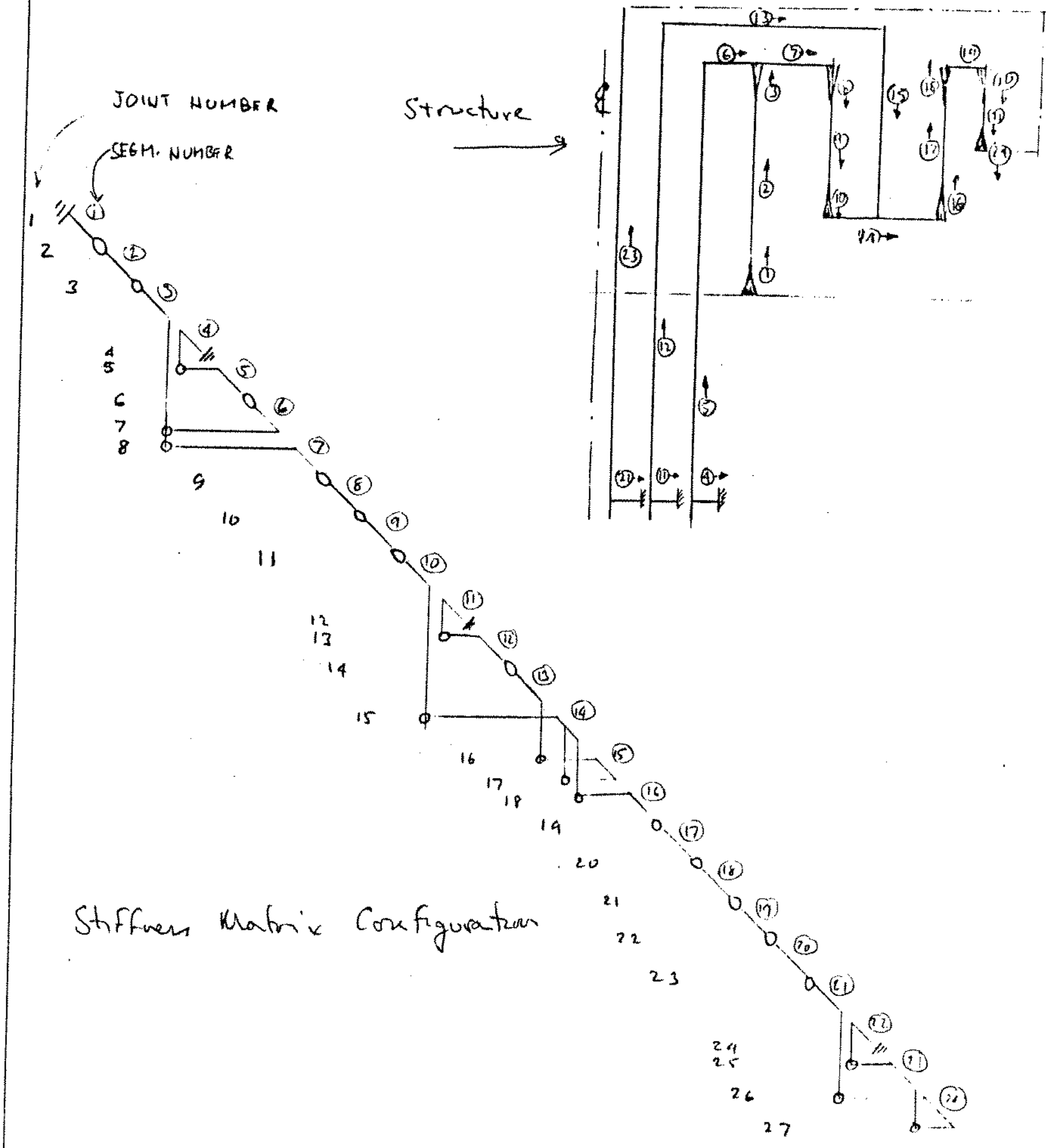


Fig. 3 Stiffness Matrix Configuration for Complicated Branched Shell of Revolution

Figure 5 represents a situation analogous to Figs. 2(a) and 2(c) in which the segment numbers have been shuffled. The condition is illegal because the rectangles line up almost horizontally. An example of a legal condition in which the rectangles almost line up horizontally is shown in Fig. 6. The test for legality is whether in the highest numbered segment involved in the constraint or juncture condition, there are at least two unconstrained mesh points between those involved in the condition. Please note the qualification "highest numbered segment involved in the constraint or juncture condition." For example, we saw from Fig. 4 that adjacent points in segment 1 could be "slaved" to those of segments with higher numbers.

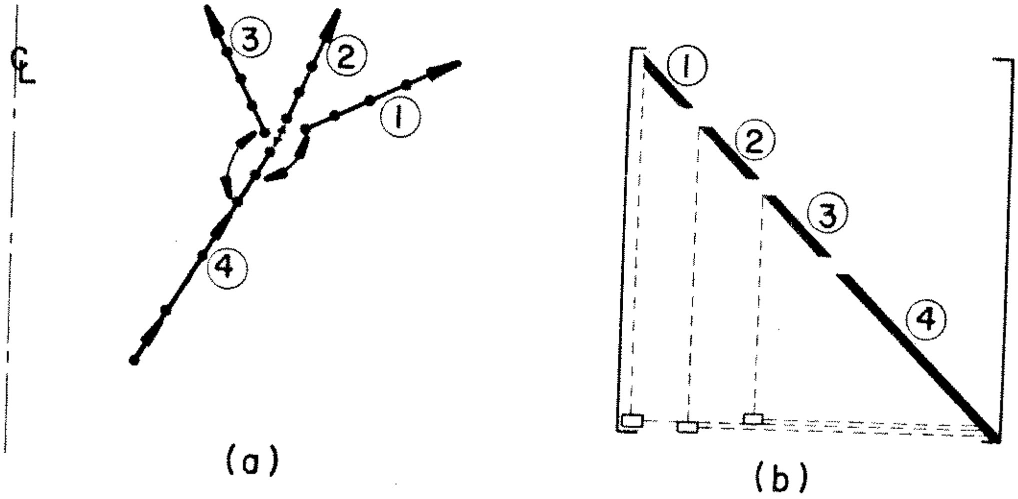


Figure 5 Example of Illegal Closely Spaced Juncture Conditions

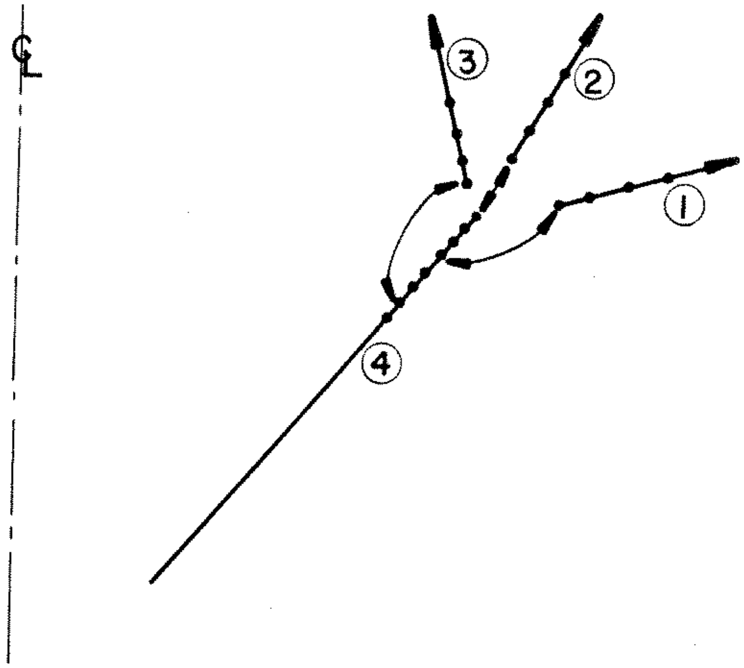


Figure 6 Example of <u>Legal</u> Closely Spaced Juncture Condition

It is illegal to constrain adjacent or every other mesh point to ground. Figure 7 shows two illegal and one legal scheme.

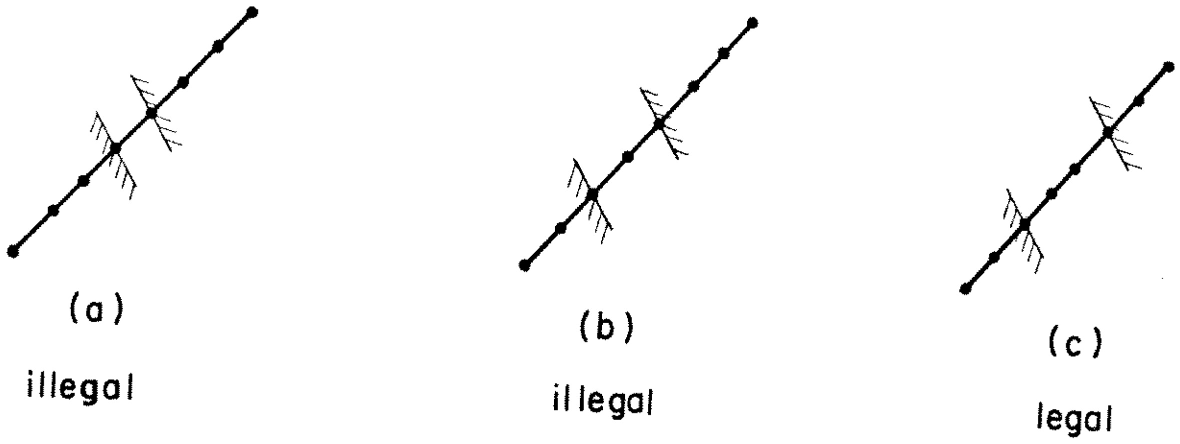


Figure 7 Constraints to Ground

5.2 BLOCK SIZES TOO LARGE

On occasion the user will encounter the diagnostic "Block size of Segment No. ___ exceeds maximum allowable ___. Run abort. Reduce degrees of freedom or renumber segments."

What is a block? In BOSOR5 the stiffness, mass, and load-geometric matrices are stored on disk or drum in blocks. The logic in the program is set up such that a given block must contain the information relevant to collection of complete shell segments. The lowest possible number of segments per block is one, of course. Figure 14 of the BOSOR4 User's Manual, reproduced here for convenience, shows a stiffness matrix configuration. Only the elements inside the "skyline" - the heavy line enclosing all non-zero elements below and including the main diagonal--are stored . The block size is equal to the number of little squares. The maximum block size depends on the size of the problem. The program checks at the end of each segment to see if the elements corresponding to the next segment will cause the block to overflow. If they do, a new block is started.

It occasionally happens that the number of elements within the "skyline" corresponding to a single segment exceeds the allowable limits of max. block size. For example, referring to Figure 14, you can imagine that if the horizontal "Skyscrapers" corresponding to the juncture conditions in segment 2 were very long, or if there were very many of them, the number of little squares within the skyline from Equation 30 to Equation 64 (Segment 2) might exceed the allowable limits. It is this situation that causes the message "Block size . . . exceeds maximum allowable . . ."

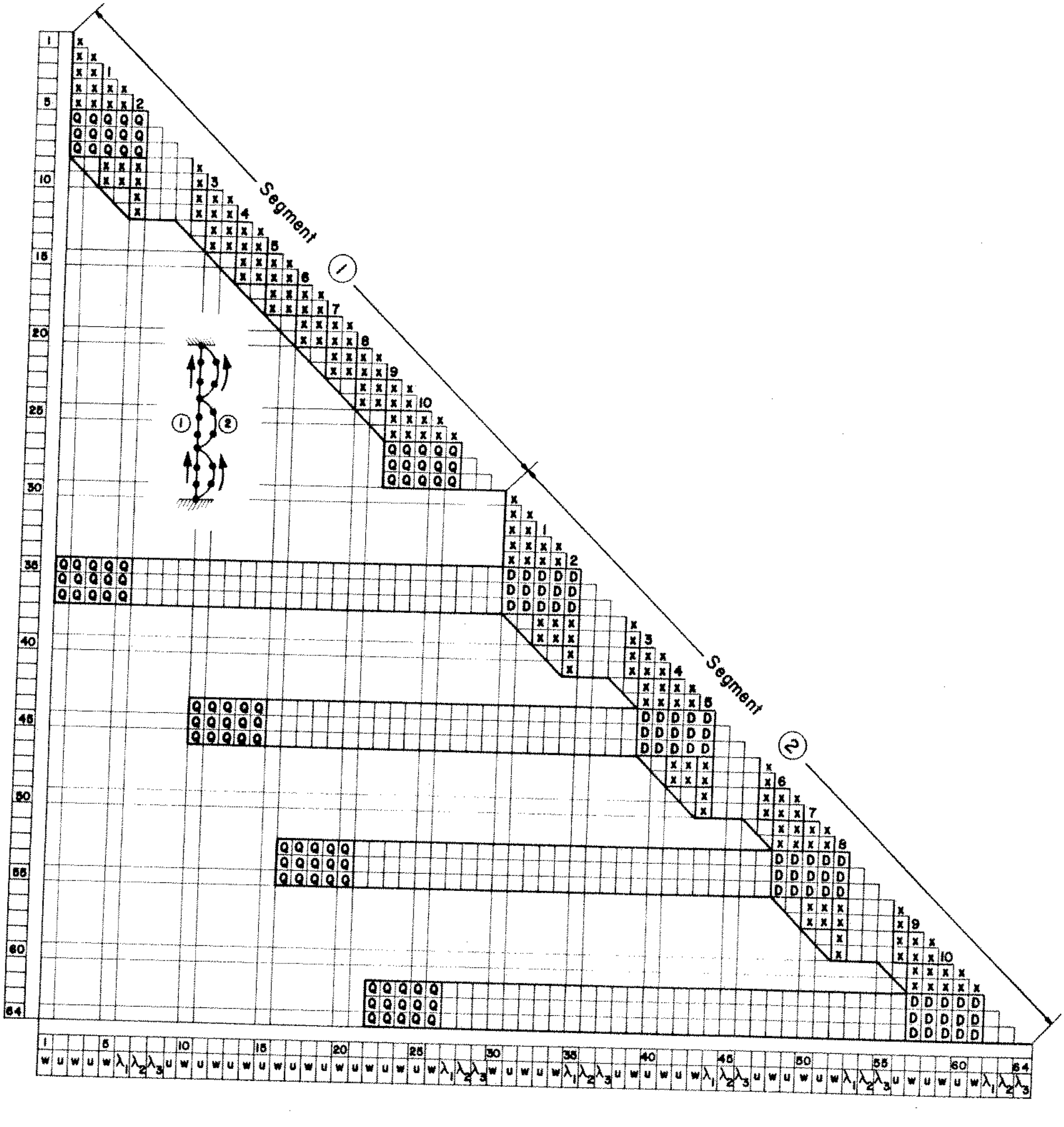


Fig. 14 Stiffness Matrix Configuration for Double-Walled Structure Fastened Intermittently

to be printed and the run to be aborted. The user can almost always find a way around this problem by reordering the segments or dividing up the segment with many branch conditions into more than one segment.

5.4 MOMENT RESULTANTS AND REFERENCE SURFACE LOCATION

More than one BOSOR4 user has indicated concern about the values obtained for the moment resultants M10, M20 or M1, M2. In this paragraph I wish to emphasize that these moment resultants are the values with respect to the reference surface, which may not necessarily be the middle surface. The magnitude of the moment resultants depends, therefore, on the location of the reference surface relative to the shell wall material. For example, in a uniformly loaded monocoque cylinder, if the inner or outer surface is used as the reference surface, the moments M1, M2 will approach the values

$$|M1| = |N1|\,t/2 \quad ; \quad M2 = |N2|\,t/2$$

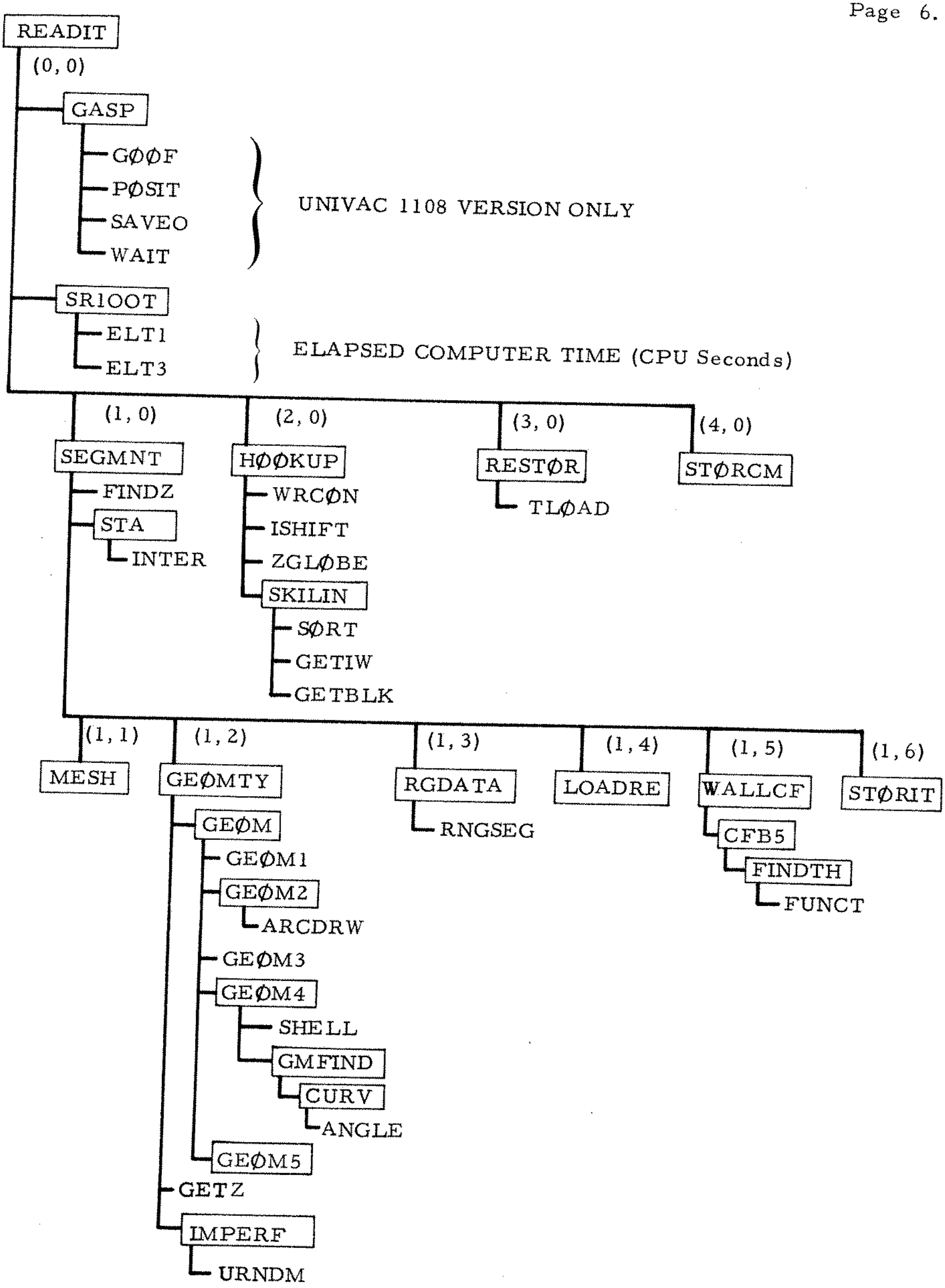
far away from the edges (t=thickness; N1, N2=stress resultants). Note, however, that the extreme fiber stresses are of course not dependent on the location of the reference surface. In this connection please recall that the commonly used formula for extreme fiber stress

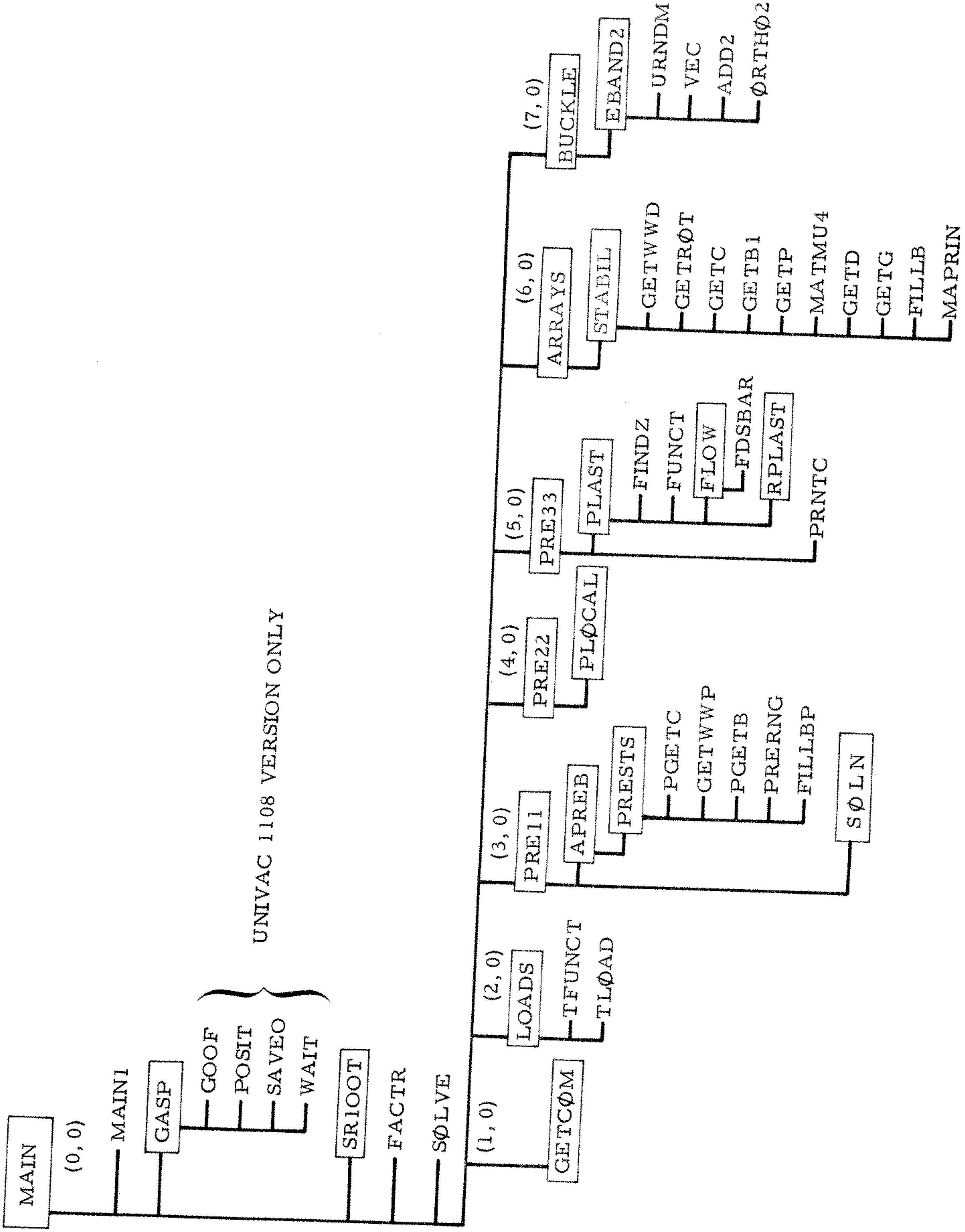
$$\sigma = \frac{N}{t} \pm \frac{6M}{t^2}$$

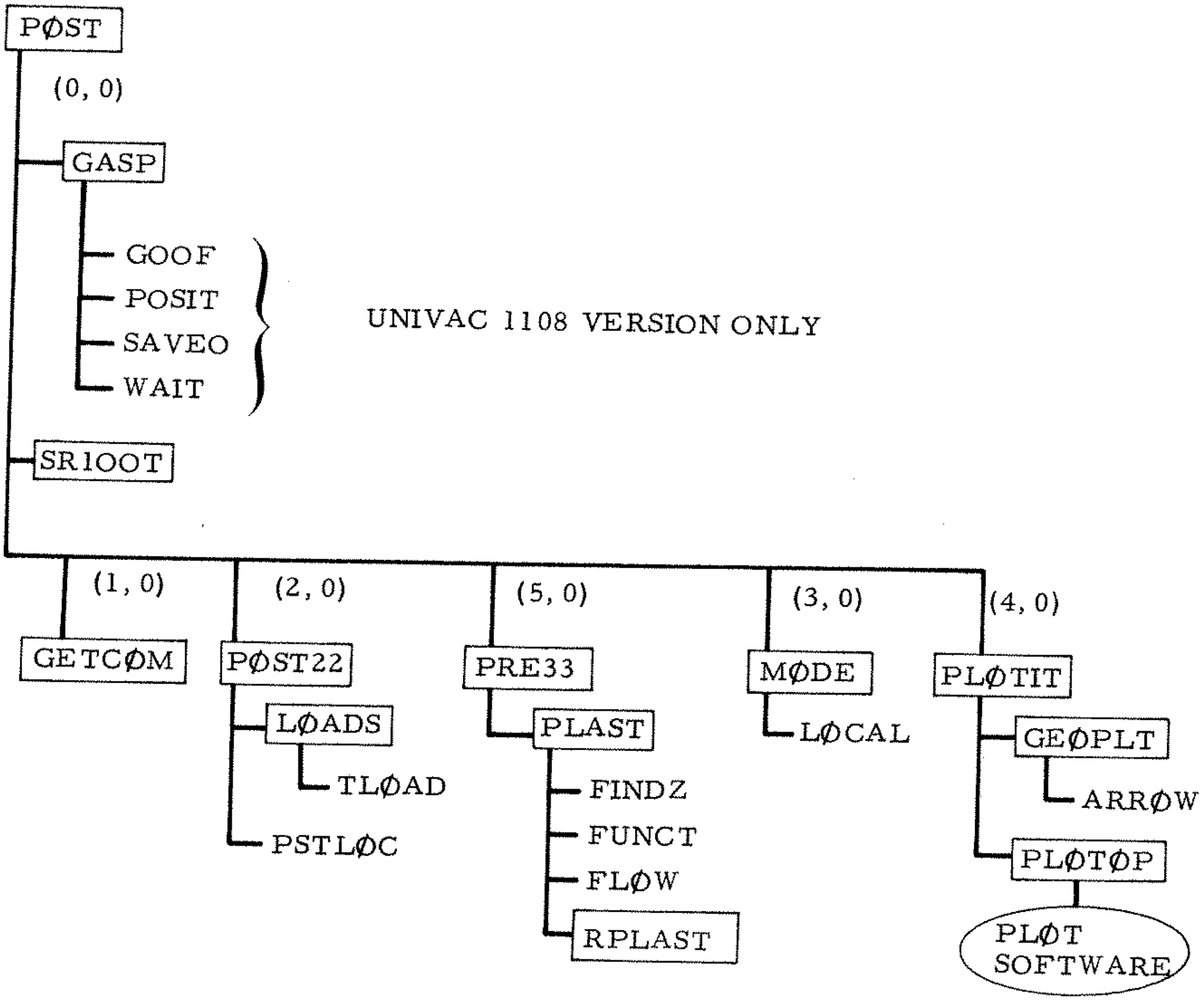
only applies if the shell is monocoque, if the middle surface is used as the reference surface, and if the material behavior is elastic.

SECTION 6

BOSOR5 PROGRAM ORGANIZATION


READIT
(0, 0)
GASP
GØØF
PØSIT
SAVEO
WAIT
UNIVAC 1108 VERSION ONLY
SR1OOT
ELT1
ELT3
ELAPSED COMPUTER TIME (CPU Seconds)
(1, 0)
SEGMNT
FINDZ
STA
INTER
(2, 0)
HØØKUP
WRCØN
ISHIFT
ZGLØBE
SKILIN
SØRT
GETIW
GETBLK
(3, 0)
RESTØR
TLØAD
(4, 0)
STØRCM
(1, 1)
MESH
(1, 2)
GEØMTY
GEØM
GEØM1
GEØM2
ARCDRW
GEØM3
GEØM4
SHELL
GMFIND
CURV
ANGLE
GEØM5
GETZ
IMPERF
URNDM
(1, 3)
RGDATA
RNGSEG
(1, 4)
LOADRE
(1, 5)
WALLCF
CFB5
FINDTH
FUNCT
(1, 6)
STØRIT


MAIN
(0, 0)
MAIN1
GASP
GOOF
POSIT
SAVEO
WAIT
UNIVAC 1108 VERSION ONLY
SR100T
FACTR
S0LVE
(1, 0)
GETC0M
(2, 0)
LOADS
TFUNCT
TL0AD
(3, 0)
PRE11
APREB
PRESTS
PGETC
GETWWP
PGETB
PRERNG
FILLBP
S0LN
(4, 0)
PRE22
PL0CAL
(5, 0)
PRE33
PLAST
FINDZ
FUNCT
FLOW
FDSBAR
RPLAST
PRNTC
(6, 0)
ARRAYS
STABIL
GETWWD
GETR0T
GETC
GETB1
GETP
MATMU4
GETD
GETG
FILLB
MAPRIN
(7, 0)
BUCKLE
EBAND2
URNDM
VEC
ADD2
0RTH02


PØST
(0, 0)
GASP
GOOF
POSIT
SAVEO
WAIT
UNIVAC 1108 VERSION ONLY
SR1OOT
(1, 0)
(2, 0)
(5, 0)
(3, 0)
(4, 0)
GETCØM
PØST22
LØADS
TLØAD
PSTLØC
PRE33
PLAST
FINDZ
FUNCT
FLØW
RPLAST
MØDE
LØCAL
PLØTIT
GEØPLT
ARRØW
PLØTØP
PLØT SOFTWARE

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 3   GASP      REL          335    0273   10/31/74 F40UA4J   18.09.03. SCOPE
 4   SR100T    REL           17    2730   10/31/74 F40UA4J   18.09.03. SCOPE
 5   OVERLAY   TEXT           2    5067                OVERLAY(1,0)
 6   SEGMNT    REL          300    6233   10/31/74 F40UA4J   18.09.03. SCOPE
 7   FINDZ     REL          167    6512   10/31/74 F40UA4J   18.09.03. SCOPE
 8   STA       REL          650    3705   10/31/74 F40UA4J   18.09.03. SCOPE
 9   INTER     REL          274    2537   10/31/74 F40UA4J   18.09.03. SCOPE
10   OVERLAY   TEXT           2    4267                OVERLAY(1,1)
11   MESH      REL          475    3112   10/31/74 F40UA4J   18.09.03. SCOPE
12   OVERLAY   TEXT           2    4467                OVERLAY(1,2)
13   GEOMTY    REL          550    6207   10/31/74 F40UA4J   18.09.03. SCOPE
14   GEOM      REL          415    0445   10/31/74 F40UA4J   18.09.03. SCOPE
15   GEOM1     REL          401    5707   10/31/74 F40UA4J   18.09.03. SCOPE
16   GEOM2     REL          572    5561   10/31/74 F40UA4J   18.09.03. SCOPE
17   ARCORW    REL          202    4643   10/31/74 F40UA4J   18.09.03. SCOPE
18   GEOM3     REL          435    0777   10/31/74 F40UA4J   18.09.03. SCOPE
19   GEOM4     REL          360    0741   10/31/74 F40UA4J   18.09.03. SCOPE
20   SHELL     REL          662    4033   10/31/74 F40UA4J   18.09.03. SCOPE
21   GMFIND    REL         1150    4110   10/31/74 F40UA4J   18.09.03. SCOPE
22   CURV      REL          216    7735   10/31/74 F40UA4J   18.09.03. SCOPE
23   ANGLE     REL           42    2324   10/31/74 F40UA4J   18.09.03. SCOPE
24   GEOM5     REL          367    3652   10/31/74 F40UA4J   18.09.03. SCOPE
25   GETZ      REL          526    0312   10/31/74 F40UA4J   18.09.03. SCOPE
26   IMPERF    REL         1043    2375   10/31/74 F40UA4J   18.09.03. SCOPE
27   URNOM     REL          120    0756   10/31/74 F40UA4J   18.09.03. SCOPE
28   OVERLAY   TEXT           2    3667                OVERLAY(1,3)
 9   RGDATA    REL          276    5267   10/31/74 F40UA4J   18.09.03. SCOPE
 0   RNGSEG    REL         2555    0721   10/31/74 F40UA4J   18.09.03. SCOPE
 1   OVERLAY   TEXT           2    4067                OVERLAY(1,4)
 2   LOADRE    REL         2015    4612   10/31/74 F40UA4J   18.09.03. SCOPE
 3   OVERLAY   TEXT           2    3270                OVERLAY(1,5)
 4   WALLCF    REL         1137    1146   10/31/74 F40UA4J   18.09.03. SCOPE
 5   CFB5      REL         3000    7444   10/31/74 F40UA4J   18.09.03. SCOPE
 6   FINDTH    REL          132    6310   10/31/74 F40UA4J   18.09.03. SCOPE
 7   FUNCT     REL          100    6621   10/31/74 F40UA4J   18.09.03. SCOPE
 8   OVERLAY   TEXT           2    3470                OVERLAY(1,6)
 9   STORIT    REL          433    0726   10/31/74 F40UA4J   18.09.03. SCOPE
 0   OVERLAY   TEXT           2    5467                OVERLAY(2,0)
     HOOKUP    REL         2415    5752   10/31/74 F40UA4J   18.09.03. SCOPE
     WRCON     REL          175    1321   10/31/74 F40UA4J   18.09.03. SCOPE
     ISHIFT    REL          101    0776   10/31/74 F40UA4J   18.09.03. SCOPE
     ZGLOBE    REL          333    3772   10/31/74 F40UA4J   18.09.03. SCOPE
     SKILIN    REL         2270    6774   10/31/74 F40UA4J   18.09.03. SCOPE
     SORT      REL          145    3713   10/31/74 F40UA4J   18.09.03. SCOPE
     GETIW     REL          211    7440   10/31/74 F40UA4J   18.09.03. SCOPE
     GETBLK    REL          401    0662   10/31/74 F40UA4J   18.09.03. SCOPE
     OVERLAY   TEXT           2    6067                OVERLAY(3,0)
     RESTOR    REL         2556    7323   10/31/74 F40UA4J   18.09.03. SCOPE
     TLOAD     REL          110    7452   10/31/74 F40UA4J   18.09.03. SCOPE
     OVERLAY   TEXT           2    6467                OVERLAY(4,0)
     STORCM    REL         1063    1777   10/31/74 F40UA4J   18.09.03. SCOPE

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BOSOR5 CDC 6600 PREPROCESSOR

ABSOLUTE ELEMENT

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  3   MESH      OVL 01,01     1336     4102    10/31/74
  4   GEOMTY    OVL 01,02    12272     6323    10/31/74
  5   RGDATA    OVL 01,03     6074     0652    10/31/74
  6   LOADRE    OVL 01,04     2026     5215    10/31/74
  7   WALLCF    OVL 01,05    12051     2601    10/31/74
  8   STORIT    OVL 01,06      257     2202    10/31/74
  9   HOOKUP    OVL 02,00    42134     0767    10/31/74
 10   RESTOR    OVL 03,00    61346     0335    10/31/74
 11   STORCM    OVL 04,00    10606     4367    10/31/74

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  3   MAIN1     REL               51      4126    10/31/74 F40XA4P    20.04.29. SCOPE
  4   GASP      REL              335      0273    10/31/74 F40XA4P    20.04.29. SCOPE
  5   SR100T    REL               17      2730    10/31/74 F40XA4P    20.04.29. SCOPE
  6   FACTR     REL              565      5612    10/31/74 F40XA4P    20.04.29. SCOPE
  7   SOLVE     REL              371      5414    10/31/74 F40XA4P    20.04.29. SCOPE
  8   OVERLAY   TEXT               2      5067                  OVERLAY(1,0)
  9   GETCOM    REL             1056      5346    10/31/74 F40XA4P    20.04.29. SCOPE
 10   OVERLAY   TEXT               2      5467                  OVERLAY(2,0)
 11   LOADS     REL              545      6747    10/31/74 F40XA4P    20.04.29. SCOPE
 12   TFUNCT    REL              445      3542    10/31/74 F40XA4P    20.04.29. SCOPE
 13   TLOAD     REL              110      7452    10/31/74 F40XA4P    20.04.29. SCOPE
 14   OVERLAY   TEXT               2      6067                  OVERLAY(3,0)
 15   PRE11     REL              215      5754    10/31/74 F40XA4P    20.04.29. SCOPE
 16   APREB     REL              642      7547    10/31/74 F40XA4P    20.04.29. SCOPE
 17   PRESTS    REL             2312      5042    10/31/74 F40XA4P    20.04.29. SCOPE
 18   PGETC     REL              166      2666    10/31/74 F40XA4P    20.04.29. SCOPE
 19   GETWWP    REL              112      5247    10/31/74 F40XA4P    20.04.29. SCOPE
 20   PGETB     REL              223      2527    10/31/74 F40XA4P    20.04.29. SCOPE
 21   PRERNG    REL              515      2110    10/31/74 F40XA4P    20.04.29. SCOPE
 22   FILLBP    REL              161      2341    10/31/74 F40XA4P    20.04.29. SCOPE
 23   SOLN      REL              143      1065    10/31/74 F40XA4P    20.04.29. SCOPE
 24   OVERLAY   TEXT               2      6467                  OVERLAY(4,0)
 25   PRE22     REL              732      4106    10/31/74 F40XA4P    20.04.29. SCOPE
 26   PLOCAL    REL             1113      0547    10/31/74 F40XA4P    20.04.29. SCOPE
 27   OVERLAY   TEXT               2      7070                  OVERLAY(5,0)
 28   PRE33     REL             1161      4477    10/31/74 F40XA4P    20.04.29. SCOPE
 29   PLAST     REL             2707      3331    10/31/74 F40XA4P    20.04.29. SCOPE
 30   FINDZ     REL              167      6512    10/31/74 F40XA4P    20.04.29. SCOPE
 31   FUNCT     REL              100      6621    10/31/74 F40XA4P    20.04.29. SCOPE
 32   FLOW      REL             2337      6730    10/31/74 F40XA4P    20.04.29. SCOPE
 33   FDSBAR    REL               63      6742    10/31/74 F40XA4P    20.04.29. SCOPE
 34   RPLAST    REL             1213      2241    10/31/74 F40XA4P    20.04.29. SCOPE
 35   PRNTC     REL              306      5123    10/31/74 F40XA4P    20.04.29. SCOPE
 36   OVERLAY   TEXT               2      7470                  OVERLAY(6,0)
 37   ARRAYS    REL             1133      5336    10/31/74 F40XA4P    20.04.29. SCOPE
 38   STABIL    REL             2562      7416    10/31/74 F40XA4P    20.04.29. SCOPE
 39   GETWWD    REL              112      5213    10/31/74 F40XA4P    20.04.29. SCOPE
  0   GETROT    REL              221      3207    10/31/74 F40XA4P    20.04.29. SCOPE
  1   GETC      REL              226      3312    10/31/74 F40XA4P    20.04.29. SCOPE
  2   GETB1     REL              463      1264    10/31/74 F40XA4P    20.04.29. SCOPE
  3   GETP      REL              171      7730    10/31/74 F40XA4P    20.04.29. SCOPE
  4   MATMU4    REL              214      5167    10/31/74 F40XA4P    20.04.29. SCOPE
  5   GETD      REL              107      2773    10/31/74 F40XA4P    20.04.29. SCOPE
  6   GETG      REL              604      7132    10/31/74 F40XA4P    20.04.29. SCOPE
  7   FILLB     REL              177      1107    10/31/74 F40XA4P    20.04.29. SCOPE
  8   MAPRIN    REL              276      6132    10/31/74 F40XA4P    20.04.29. SCOPE
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  1   EBAND2    REL             3406      7477    10/31/74 F40XA4P    20.04.29. SCOPE
  2   URNOM     REL              120      0756    10/31/74 F40XA4P    20.04.29. SCOPE
  3   VEC       REL              210      3574    10/31/74 F40XA4P    20.04.29. SCO
  4   ACD2      REL              170      1055    10/31/74 F40XA4P    20.04.29. SCOPE
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BOSOR5 CDC 6600 MAINPROCESSOR

ABSOLUTE ELEMENT

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  2   GETCOM    OVL 01,00      10603      0452   10/31/74
  3   LOADS     OVL 02,00       1011      7752   10/31/74
  4   PRE11     OVL 03,00       5175      6257   10/31/74
  5   PRE22     OVL 04,00       1577      3614   10/31/74
  6   PRE33     OVL 05,00      16544      5200   10/31/74
  7   ARRAYS    OVL 06,00       7222      7722   10/31/74
  8   BUCKLE    OVL 07,00       5147      0302   10/31/74

  9   * EOF *        SUM =    107443      1155
```

```
EC   NAME      TYPE        LENGTH     CKSUM    DATE       COMMENTS

 1   OVERLAY   TEXT             2     0234              OVERLAY(BPOST,0,0)
 2   POST      REL            575     7152     10/31/74 F40ZA40    21.46.48. SCOPE
 3   GASP      REL            335     0273     10/31/74 F40ZA40    21.46.48. SCOPE
 4   SR100T    REL             17     2730     10/31/74 F40ZA40    21.46.48. SCOPE
 5   OVERLAY   TEXT             2     5067              OVERLAY(1,0)
 6   GETCOM    REL           1056     5346     10/31/74 F40ZA40    21.46.48. SCOPE
 7   OVERLAY   TEXT             2     5467              OVERLAY(2,0)
 8   POST22    REL            370     4652     10/31/74 F40ZA40    21.46.48. SCOPE
 9   LOADS     REL            337     4653     10/31/74 F40ZA40    21.46.48. SCOPE
10   TLOAD     REL            110     7452     10/31/74 F40ZA40    21.46.48. SCOPE
11   PSTLOC    REL           1015     4624     10/31/74 F40ZA40    21.46.48. SCOPE
12   OVERLAY   TEXT             2     7070              OVERLAY(5,0)
13   PRE33     REL            541     4260     10/31/74 F40ZA40    21.46.48. SCOPE
14   PLAST     REL           2354     5436     10/31/74 F40ZA40    21.46.48. SCOPE
15   FINDZ     REL            167     6512     10/31/74 F40ZA40    21.46.48. SCOPE
16   FUNCT     REL            100     6621     10/31/74 F40ZA40    21.46.48. SCOPE
17   FLOW      REL            605     2063     10/31/74 F40ZA40    21.46.48. SCOPE
18   RPLAST    REL            625     2125     10/31/74 F40ZA40    21.46.48. SCOPE
19   PRNTC     REL            205     0334     10/31/74 F40ZA40    21.46.48. SCOPE
20   OVERLAY   TEXT             2     6067              OVERLAY(3,0)
21   MODE      REL            345     7135     10/31/74 F40ZA40    21.46.48. SCOPE
22   LOCAL     REL            367     3776     10/31/74 F40ZA40    21.46.48. SCOPE
23   OVERLAY   TEXT             2     6467              OVERLAY(4,0)
24   PLCTIT    REL           1102     6555     10/31/74 F40ZA40    21.46.48. SCOP
25   GEOPLT    REL           2675     1335     10/31/74 F40ZA40    21.46.48. SCOPE
26   ARROW     REL           1030     3034     10/31/74 F40ZA40    21.46.48. SCOPE
27   PLCTOP    REL           1277     3776     10/31/74 F40ZA40    21.46.48. SCOPE

28   * EOF *      SUM =     21044     3233
```

BOSOR5 CDC 6600 POSTPROCESSOR

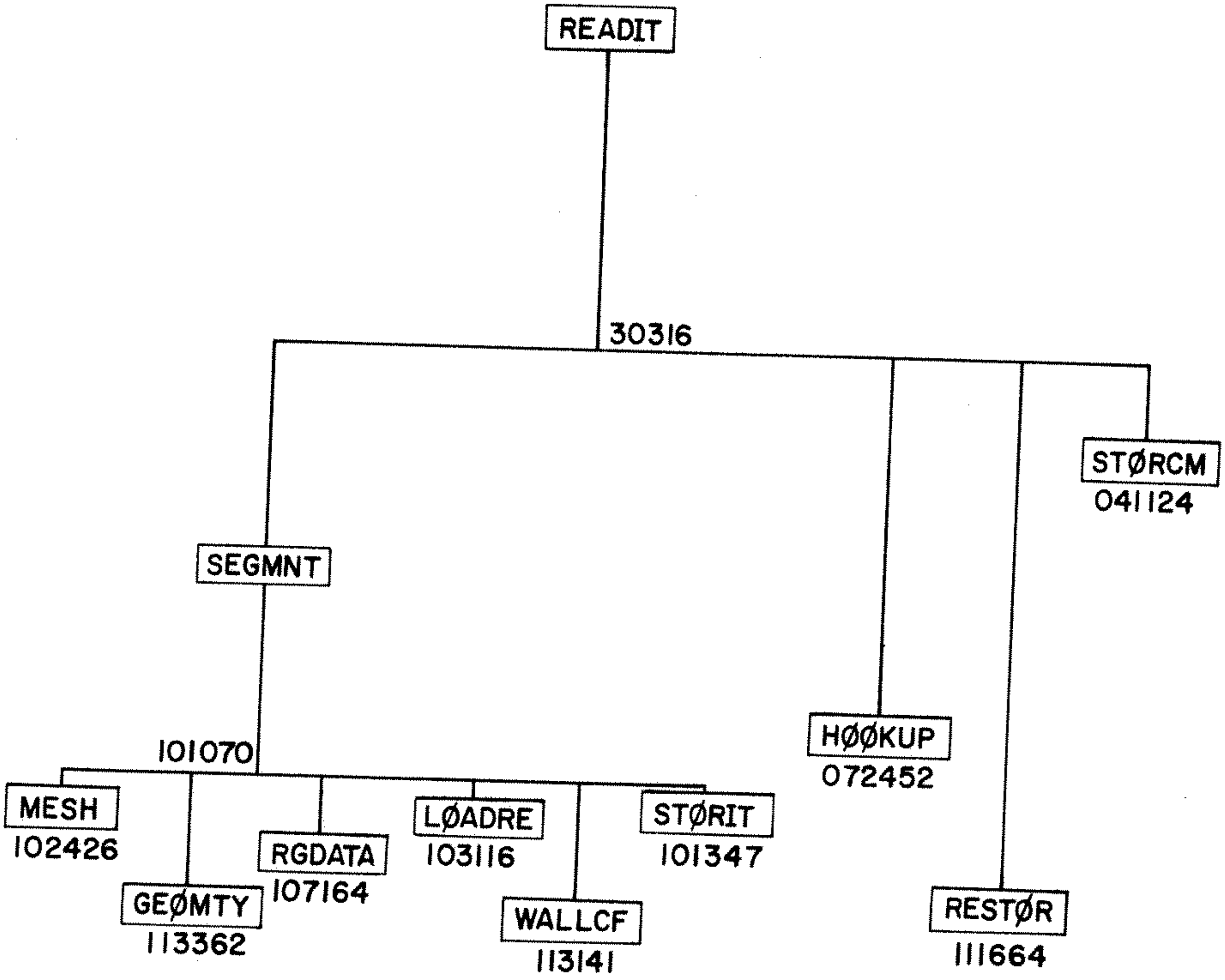
ABSOLUTE ELEMENT

```
REC   NAME       TYPE          LENGTH     CKSUM     DATE       COMMENTS

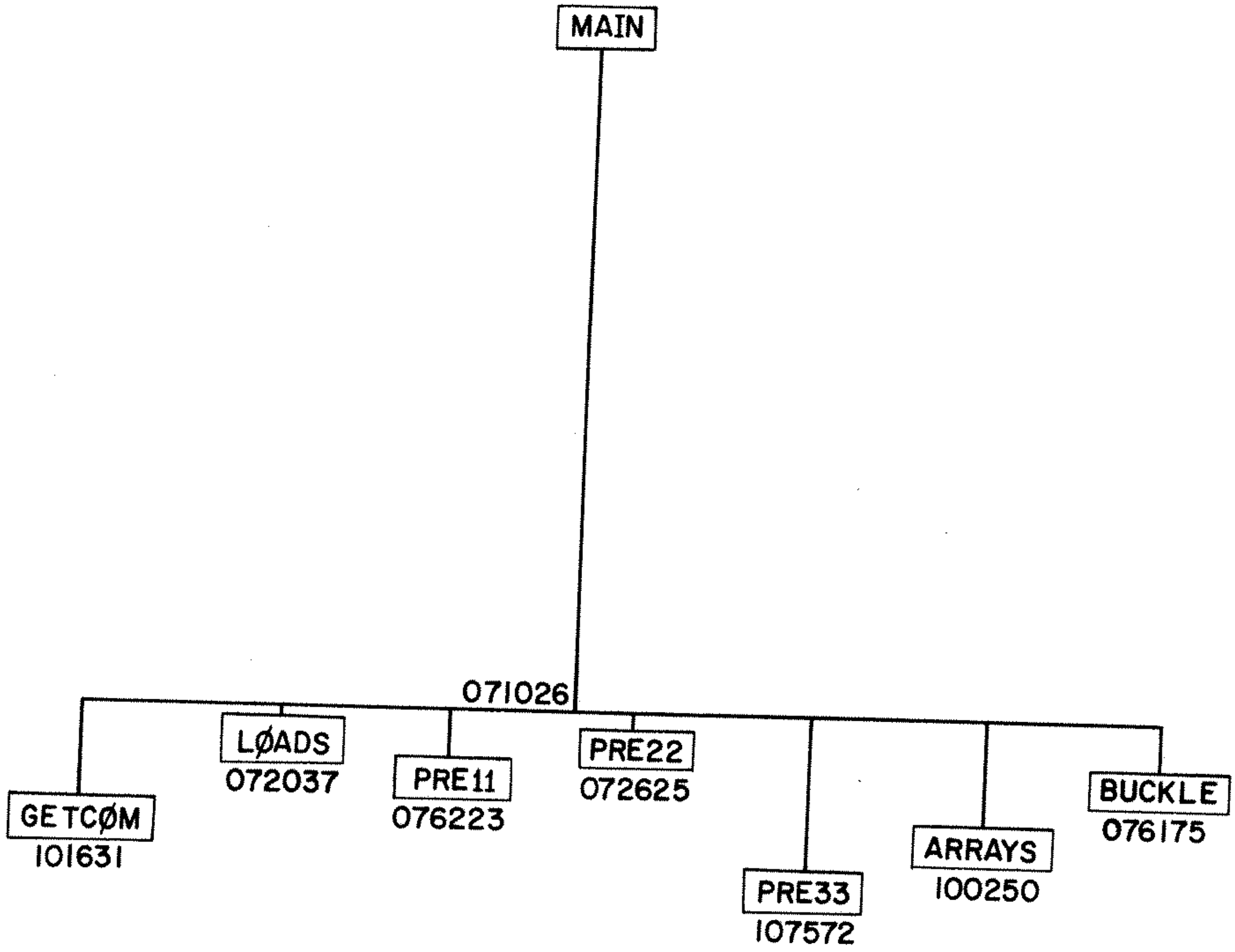
  1   POST       OVL  00,00     32751      2400   10/31/74
  2   GETCOM     OVL  01,00     11405      0273   10/31/74
  3   POST22     OVL  02,00      1572      6454   10/31/74
  4   PRE33      OVL  05,00     11416      6744   10/31/74
  5   MODE       OVL  03,00       571      0612   10/31/74
  6   PLOTIT     OVL  04,00     46453      6305   10/31/74

  7   * EOF *       SUM =      127032      7443
```

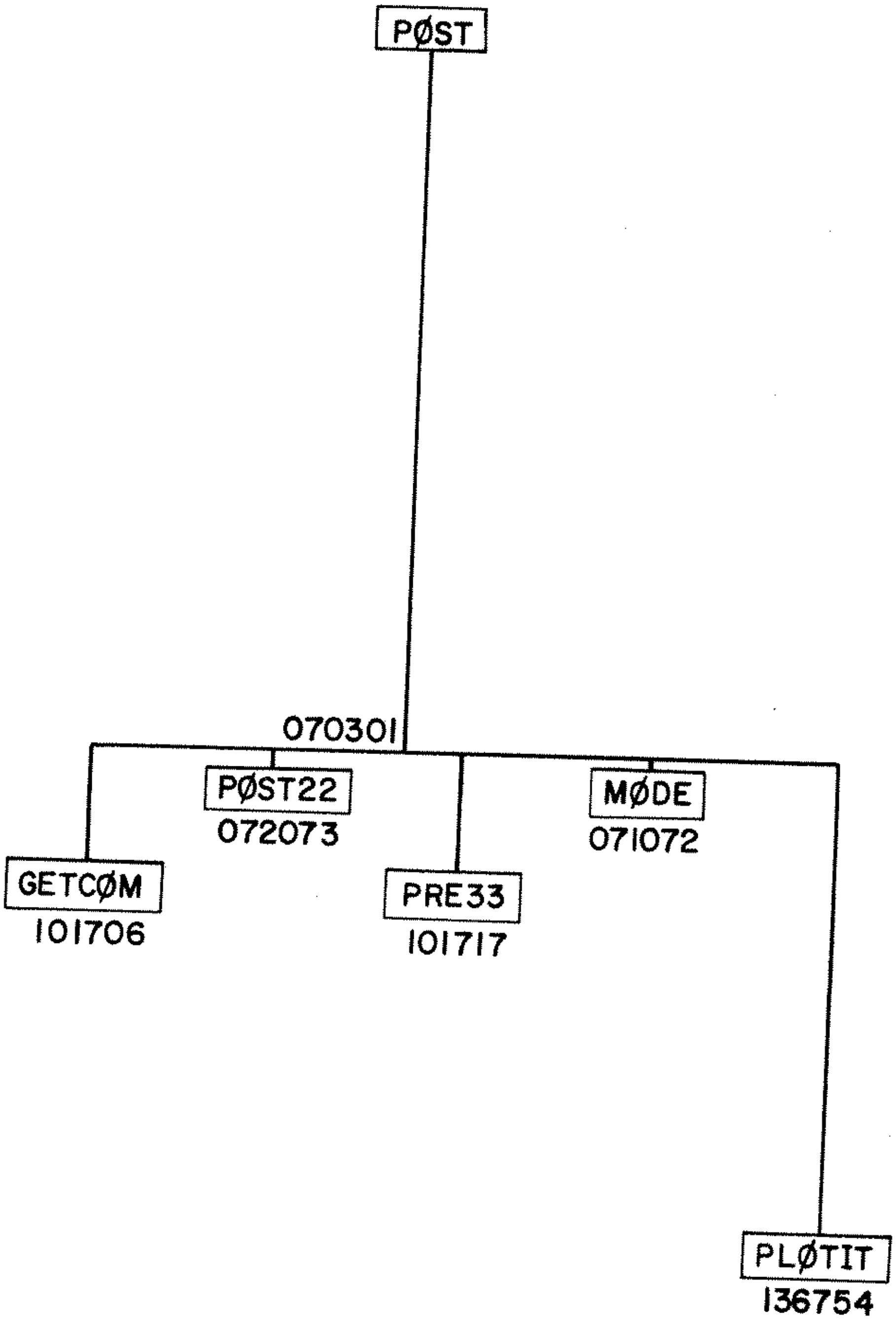
BOSOR5 PREPROCESSOR OVERLAY CHART
WITH OCTAL LENGTHS OF VARIOUS OVERLAYS (CDC 6600)



BOSOR5 MAINPROCESSOR OVERLAY CHART WITH OCTAL LENGTHS OF VARIOUS OVERLAYS (CDC 6600)



BOSOR5 POSTPROCESSOR OVERLAY CHART WITH OCTAL LENGTHS OF VARIOUS OVERLAYS (CDC 6600)



```
BANK SEGMENTS DRAWN TO SCALE:  200 WORDS DECIMAL PER DASH

READIT (5452)
---------------------------
                           LINK1* (1002)
                           -----
                                SUB1* (293)
                                --
                                SUB2* (4942)
                                -------------------------
                                SUB3* (1114)
                                ------
                                SUB4* (805)
                                ----
                                SUB5* (2034)
                                ----------
                                SUB6* (152)
                                -
                           LINK2* (3116)
                           ----------------
                           LINK3* (1078)
                           ------
                           LINK4* (524)
                           ---
```

```
DBANK SEGMENTS DRAWN TO SCALE:  500 WORDS DECIMAL PER DASH

READIT (6694)
--------------
              LINK1* (20415)
              -----------------------------------------
                                                       SUB1* (597)
                                                       -
                                                       SUB2* (2969)
                                                       ------
                                                       SUB3* (2452)
                                                       ----
                                                       SUB4* (651)
                                                       -
                                                       SUB5* (3779)
                                                       -------
                                                       SUB6* (24)
                                                       -
              LINK2* (15787)
              -------------------------------
              LINK3* (24756)
              -------------------------------------------------
              LINK4* (4042)
              --------
```

BOSOR5 1110 MAIN-PROCESSOR OVERLAYS

```
IBANK SEGMENTS DRAWN TO SCALE:   200 WORDS DECIMAL PER DASH

MAIN (6800)
----------------------------------
                                  LINK1* (563)
                                  ---
                                  LINK2* (564)
                                  ---
                                  LINK3* (3297)
                                  ----------------
                                  LINK4* (1253)
                                  ------
                                  LINK5* (5042)
                                  -------------------------
                                  LINK6* (4187)
                                  ---------------------
                                  LINK7* (2388)
                                  ------------




DBANK SEGMENTS DRAWN TO SCALE:   700 WORDS DECIMAL PER DASH

MAIN (40713)
-----------------------------------------------------------
                                                           LINK1* (4136)
                                                           ------
                                                           LINK2* (272)
                                                           -
                                                           LINK3* (1399)
                                                           --
                                                           LINK4* (319)
                                                           -
                                                           LINK5* (4896)
                                                           -------
                                                           LINK6* (1894)
                                                           ---
                                                           LINK7* (1544)
                                                           ---
```

BOSOR5 1110 POST-PROCESSOR OVERLAYS

```
IBANK SEGMENTS DRAWN TO SCALE:   200 WORDS DECIMAL PER DASH

POST (7343)
-------------------------------------
                                     LINK1* (563)
                                     ---
                                     LINK2* (1237)
                                     ------
                                     LINK3* (2603)
                                     -------------
                                     LINK4* (565)
                                     ---
                                     LINK5* (5898)
                                     ------------------------------


DBANK SEGMENTS DRAWN TO SCALE:   500 WORDS DECIMAL PER DASH

POST (24011)
-------------------------------------------------
                                                 LINK1* (4522)
                                                 ---------
                                                 LINK2* (371)
                                                 -
                                                 LINK3* (3382)
                                                 -------
                                                 LINK4* (152)
                                                 -
                                                 LINK5* (10742)
                                                 ----------------------
```

PURPOSES OF THE SUBROUTINES OF THE BOSOR5 PREPROCESSOR

READIT				The main program of the preprocessor. Calls the other subroutines.
GASP				Transfers data to and from mass storage devices. There are two files involved: a large random-access file (called BLARGE on the control cards) and a small sequential-access file (called BSMALL and consisting of 550 words, most of these integers which identify where on BLARGE the random-access data blocks are stored).
SR1OOT				Causes the elapsed CPU time from the beginning of the case to be printed.
SEGMNT				Causes all input data for one shell segment to be read in and prepared for execution by the main processor.
	FINDZ			Linear interpolator.
	STA			Finds callout mesh point given various kinds of input data, such as axial stations, arc lengths to callouts, radii to callouts, etc.
	MESH			Reads in data for mesh point distribution and calculates lengths over which energy is "integrated" (lumped).
	GEOMTY			Reads in data for meridional geometry of a shell segment; imperfection; reference surface location relative to shell wall material.
		GEOM		Meridional geometry of reference surface....
			GEOM1	Flat plate, cylinder, cone
			GEOM2	Spherical, ogival, toroidal.
			GEOM3	Not used.
			GEOM4	General meridional shape; ellipsoid; hyperboloid.
			GEOM5	Not used.
		GETZ		Finds location of reference surface relative to shell wall "leftmost" surface.
		IMPERF		Reads in data for imperfection distribution along meridian.
	RGDATA			Reads in data pertinent to discrete ring stiffeners.
	LOADRE			Reads in data for temperature distribution, pressure and surface traction distribution, and line loads.
	WALLCF			Reads in data for wall construction and calculates elastic integrated constitutive law coefficients, C_{ij}.
	STORIT			Stores data for a given shell segment temporarily on mass storage device.

HOOKUP	Reads in data for time variation of loads, for juncture and other constraint conditions; calculates global axial coordinates for plotting purposes; and derives templates for the prebuckling and stability coefficient matrices....	
	WRCON	writes out the constraint conditions.
	ISHIFT	modifies constraint conditions to account for "extra" mesh points added at segment ends.
	ZGLOBE	calculates global axial coordinates of assembled structure.
	SKILIN	calculates the "skylines" of prebuckling matrices and stability matrices.
RESTOR	Retrieves the data for each segment from mass storage and restores same data in bigger blocks to avoid too much I/O computer time in main processor runs.	
STORCM	Stores labeled common blocks for retrieval by main processor and post processor.	

PURPOSES OF THE SUBROUTINES OF THE BOSOR5 MAIN PROCESSOR

MAIN	The main program, calls the other subroutines.			
MAIN1	A kind of "dummy" program for storing additional labeled common.			
GASP	For reading data to and from auxiliary storage devices. (See preprocessor)			
SR1OOT	Calculates and prints elapsed CPU time from start of case.			
FACTR	Decomposes a coefficient matrix into its lower triangular form.			Equation Solver
SOLVE	Performs back substitution for solution of equation system.			
GETCOM	Retrieves labeled common data stored on mass storage by STORCM. (See preprocessor)			
LOADS	Finds loads on the shell corresponding to the next time step.			
PRE11	Sets up and solves the nonlinear (large deflection) prebuckling equations, given material properties.			
	APREB	Sets up the equations for the next Newton iteration.		
	SOLN	Factors and solves the system of linear equations derived by APREB		
	(loop over APREB and SOLN until Newton iterations converge.)			
PRE22	Derives strains and stress resultants, given the solution obtained by PRE11.			
PRE33	Finds updated material properties, given new values of total strains by PRE22.			
	PLAST	retrieves temperature distribution and calculates new plastic and creep strain components in shell wall and in discrete rings....		
		FLOW	uses flow or deformation theory to find plastic and creep strain components for a given point along the meridian and within the thickness of the shell wall (or within discrete ring).	
		RPLAST	finds plastic and creep strains at several stations within each discrete ring.	
		PRNTC	prints the integrated shell wall constitutive coefficients, C_{ij}.	
ARRAYS	Derives the stability equations for given circumferential wavenumber, n, and calculates the stability determinant for a given time step.			
	STABIL	calculates the stiffness matrix and the load-geometric matrix.		
		GETWWD	finite-difference expressions for variable mesh.	
		GETROT	derives 3 x 7 matrix relating rotations of shell wall to nodal point displacements.	
		CETC	stores 6 x 6 matrix for local C_{ij} (constitutive law).	
		GETB1	derives 6 x 7 matrix relating strains and curvature changes to nodal point displacements (kinematic law).	
		GETP	derives pressure-rotation terms.	
		MATMU4	utility routine for finding $A = B^T C B$.	

	GETD	derives 4 x 7 matrix relating shell wall displacements and meridional rotation to nodal point displacements.
	GETG	derives stiffness matrix for discrete ring; load-geometric matrix for discrete ring.
	FILLB	assembles local 7 x 7 matrices into global matrix.
	MAPRIN	not called by program in its present form. Prints out local matrices. A tool for debugging.
BUCKLE	Eigenvalue solver for given circumferential wavenumber, n.	
	EBAND2	Uses inverse power iteration method to extract eigenvalues for stability problem.

PURPOSES OF THE SUBROUTINES OF THE BOSOR5 POST PROCESSOR

POST		The main program of the post processor, calls the other subroutines.
GASP		Causes data to be transferred to and from auxiliary devices. (See preprocessor)
SR1OOT		Not used.
GETCOM		Retrieves labeled common data stored on mass storage by STORCM. (See preprocessor)
POST22		Calculates prebuckling displacements and stress resultants from solution vector corresponding to a given load or time step.
PRE33		Calculates plastic and creep strain components and prints these out for all meridional stations and integration points through the shell wall thickness. PLAST FLOW RPLAST } see the definitions given in the section on the main processor.
MODE		Calculates the buckling modal displacements from the eigenvector obtained by EBAND2 (see main processor).
PLOTIT		Plots various information (presently only SC4020 plot software is available).
	GEOPLT	Undeformed and deformed prebuckling and buckling modal structures are plotted.
	ARROW	Affixes arrows showing direction of line loads and moments.
	PLOTOP	Plots displacements and stress resultants and modal displacements in x, y frames. Information for all shell segments plotted in series.

Research Laboratory

BOSOR5 A Computer Program for Buckling of Elastic-Plastic Complex Shells of Revolution Including Large Deflections and Creep
Vol. 1: User's Manual, Input Data

Final Report on Contract N00014-73-C-0065, Palo Alto, California, December, 1974

125 pages

1. Shells
2. Nonlinear
3. Elastic-Plastic
4. Large Deflection
5. Stiffened
6. Stability
7. Temperature
8. Stress
9. Computer

I. N00014-73-C-0065
II. LMSC-D407166

Lockheed Palo Alto Research Laboratory

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13. ABSTRACT

This volume contains the instructions to the user for constructing data decks for the BOSOR5 computer program. BOSOR5 runs on the UNIVAC 1108 and on the CDC 6600. It is divided into three separate programs, a preprocessor, a main-processor, and a post-processor. These programs may be run as one job in a runstream or separately. The program includes a restart capability. BOSOR5 can handle segmented and branched shells with discrete ring stiffeners, meridional discontinuities, and multi-material construction. The shell wall can be made up of as many as six layers, each of which is of a different nonlinear material. In the prebuckling analysis axisymmetric behavior is presumed. Bifurcation buckling loads are computed corresponding to axisymmetric or nonaxisymmetric buckling modes. The strategy for solving the nonlinear prebuckling problem is such that the user obtains reasonably accurate answers even if he uses very large load or time steps. BOSOR5 has been checked by means of numerous runs in which the results have been compared to other analyses and to tests.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Shells						
Shell						
Stress						
Stability						
Nonlinear						
Large Displacement						
Elastic						
Elastic-Plastic						
Creep						
Thermal						
Stiffened						
Rings						
Branched						
Segmented						
Buckling						
Collapse						
Computer Program						
Shell of Revolution						
Pressure Vessel						
Pressure						
Temperature						
Primary Creep						
Secondary Creep						
Plastic						
Structure						
Finite Element						
Finite Difference						
Energy						
Displacement						
Numerical						