```
C    PURPOSE: OBTAIN Fundamental modal frequency (hertz)
C
C    YOU MUST WRITE CODE THAT, USING
C    THE VARIABLES IN THE LABELLED
C    COMMON BLOCKS AS INPUT, ULTIMATELY
C    YIELDS THE RESPONSE VARIABLE FOR
C    THE ith LOAD CASE, ILOADX:
C
C      FREQ(ILOADX)
C
C    AS OUTPUT. THE ith CASE REFERS
C    TO ith ENVIRONMENT (e.g. load com-
C    bination).
C
C    DEFINITIONS OF INPUT DATA:
C     IMODX  = DESIGN CONTROL INTEGER:
C      IMODX = 0 MEANS BASELINE DESIGN
C      IMODX = 1 MEANS PERTURBED DESIGN
C     IFILE = FILE FOR OUTPUT LIST:
C     NPRINX= OUTPUT CONTROL INTEGER:
C      NPRINX=0 MEANS SMALLEST AMOUNT
C      NPRINX=1 MEANS MEDIUM AMOUNT
C      NPRINX=2 MEANS LOTS OF OUTPUT
C
C      ILOADX = ith LOADING COMBINATION
C      PHRASE = Fundamental modal frequency (hertz)
C
C    OUTPUT:
C
C      FREQ(ILOADX)
C
       CHARACTER*80 PHRASE
C   INSERT ADDITIONAL COMMON BLOCKS:(This is automatically done by GENOPT)
      COMMON/FV07/NX(20)
      REAL NX
      COMMON/FV11/STRESS(20),STRSSA(20),STRSSF(20)
      REAL STRESS,STRSSA,STRSSF
      COMMON/FV14/BSYM(20),BSYMA(20),BSYMF(20)
      REAL BSYM,BSYMA,BSYMF
      COMMON/FV17/BANTI(20),BANTIA(20),BANTIF(20)
      REAL BANTI,BANTIA,BANTIF
      COMMON/FV20/FREQ(20),FREQA(20),FREQF(20)
      REAL FREQ,FREQA,FREQF
      COMMON/IV01/IBOUND
      INTEGER IBOUND
      COMMON/FV01/LENGTH,RADIUS,THICK,ESTIFF,NU,DENS,WEIGHT
      REAL LENGTH,RADIUS,THICK,ESTIFF,NU,DENS,WEIGHT
      COMMON/FV08/PRESS(20)
      REAL PRESS
C
C
C   INSERT SUBROUTINE STATEMENTS HERE.   (The GENOPT user added the following)
C
      COMMON/INSTAB/INDIC
      COMMON/EIGB4M/EIGCOM(200),IWAVEB  (These are computed in B4MAIN)
      COMMON/WVEB4M/NWVCOM(200)         (This is computed in B4MAIN)
      COMMON/EIGBUK/EIGCRT              (This is computed in B4MAIN)
      COMMON/NWVBUK/NWVCRT              (This is computed in B4MAIN)
      COMMON/BUCKN/NOBX,NMINBX,NMAXBX,INCRBX  (These are used in B4MAIN)
      COMMON/PRMOUT/IFILE3,IFILE4,IFILE8,IFILE9,IFIL11
      COMMON/EIGALL/EIG2,EIG3,EIG4
      COMMON/WAVALL/NWAV2,NWAV3,NWAV4   (These must be saved for perturbation)
```

```
C
      INDIC = 2
      N0B = 2
      NMAXB = 10
      CALL BOSDEC(4,ILOADX,INDIC)
      CALL B4READ
      IF (IMODX.EQ.0) THEN         (IMODX = 0 means "current design")
         N0BX = N0B
         NMINBX = N0B
         NMAXBX = NMAXB
         INCRBX = 1
      ELSE                         (IMODX = 1 means "perturbed design")
         NOBX = NWAV4
         NMINBX = NWAV4
         NMAXBX = NWAV4
         INCRBX = 1
      ENDIF
      REWIND IFILE9
      CALL STOCM1(IFILE9)
      CALL STOCM2(IFILE9)
      CALL B4MAIN
      CALL GASP(DUM1,DUM2,-2,DUM3)   (GENOPT user has to reset GASP)
      IF (IMODX.EQ.0) THEN         (IMODX = 0 means "current design")
         EIG4 = EIGCRT
         NWAV4= NWVCRT
      ENDIF
      WRITE(IFILE,'(/,A)')
     1 ' NATURAL FREQUENCIES AND MODES (BEHX4)'
      DO 10 I = 1,IWAVEB
         WRITE(IFILE,'(A,1P,E12.4,A,I4,A)')
     1  '          ',EIGCOM(I),'(',NWVCOM(I),')'
   10 CONTINUE
      WRITE(IFILE,'(A,1P,E12.4)')
     1' Critical buckling load factor, FREQ=',EIGCRT
      WRITE(IFILE,'(A,I5)')
     1' Critical number of circumferential waves, NWVCRT=',NWVCRT
      FREQ(ILOADX) = EIGCRT
C                                    (End of the GENOPT user's statements)
C
      RETURN
      END
C
C   (lines omitted (USRCOM, USRLNK) to save space)
C
C=DECK      OBJECT
      SUBROUTINE OBJECT(IFILE,NPRINX,IMODX,OBJGEN,PHRASE)
C   PURPOSE:weight of half of cyl. shell
C
C   YOU MUST WRITE CODE THAT, USING
C   THE VARIABLES IN THE LABELLED
C   COMMON BLOCKS AS INPUT, ULTIMATELY
C   YIELDS THE OBJECTIVE FUNCTION
C         WEIGHT
C   AS OUTPUT. MAKE SURE TO INCLUDE AT
C   THE END OF THE SUBROUTINE, THE
C   STATEMENT: OBJGEN = WEIGHT
C
C
C   DEFINITIONS OF INPUT DATA:
C    IMODX  = DESIGN CONTROL INTEGER:
C     IMODX = 0 MEANS BASELINE DESIGN
C     IMODX = 1 MEANS PERTURBED DESIGN
```

```
C     IFILE = FILE FOR OUTPUT LIST:
C     NPRINX= OUTPUT CONTROL INTEGER:
C      NPRINX=0 MEANS SMALLEST AMOUNT
C      NPRINX=1 MEANS MEDIUM AMOUNT
C      NPRINX=2 MEANS LOTS OF OUTPUT
C
C    DEFINITION OF PHRASE:
C      PHRASE = weight of half of cyl. shell
C
       CHARACTER*80 PHRASE
C   INSERT ADDITIONAL COMMON BLOCKS:(This is automatically done by GENOPT)
      COMMON/FV07/NX(20)
      REAL NX
      COMMON/FV11/STRESS(20),STRSSA(20),STRSSF(20)
      REAL STRESS,STRSSA,STRSSF
      COMMON/FV14/BSYM(20),BSYMA(20),BSYMF(20)
      REAL BSYM,BSYMA,BSYMF
      COMMON/FV17/BANTI(20),BANTIA(20),BANTIF(20)
      REAL BANTI,BANTIA,BANTIF
      COMMON/FV20/FREQ(20),FREQA(20),FREQF(20)
      REAL FREQ,FREQA,FREQF
      COMMON/IV01/IBOUND
      INTEGER IBOUND
      COMMON/FV01/LENGTH,RADIUS,THICK,ESTIFF,NU,DENS,WEIGHT
      REAL LENGTH,RADIUS,THICK,ESTIFF,NU,DENS,WEIGHT
      COMMON/FV08/PRESS(20)
      REAL PRESS
C
C
C   INSERT SUBROUTINE STATEMENTS HERE. (The GENOPT user did not change this.)
C
C
      OBJGEN =WEIGHT
C
C
      RETURN
      END
============================================================================
```

Table A.7 An input file, *.ALL, for the BOSOR4 computer program. The GENOPT user should first use BOSOR4 to set up a typical input file to be used as a model that is very useful for later creating SUBROUTINE BOSDEC. The following input is for buckling of a monocoque cylindrical shell.

```
===========================================================================
BOSOR4 input for cyl. shell
        1          $ INDIC = analysis type indicator
        1          $ NPRT = output options (1=minimum, 2=medium, 3=maximum)
        0          $ ISTRES= output control (0=resultants, 1=sigma, 2=epsilon)
        1          $ NSEG  = number of shell segments (less than 95)
     H             $
     H             $ SEGMENT NUMBER    1    1    1    1    1    1    1    1
     H             $ NODAL POINT DISTRIBUTION FOLLOWS...
       97          $ NMESH = number of node points (5 = min.; 98 = max.)( 1)
        3          $ NTYPEH= control integer (1 or 3) for nodal point spacing
     H             $ REFERENCE SURFACE GEOMETRY FOLLOWS...
        1          $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
      100          $ R1      = radius at beginning of segment (see p. 66)
        0          $ Z1      = global axial coordinate at beginning of segment
      100          $ R2      = radius at end of segment
      200          $ Z2      = global axial coordinate at end of segment
     H             $ IMPERFECTION SHAPE FOLLOWS...
        0          $ IMP    = indicator for imperfection (0=none, 1=some)
     H             $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
        3          $ NTYPEZ= control (1 or 3) for reference surface location
  0.5000000        $ ZVAL  = distance from leftmost surf. to reference surf.
     N             $ Do you want to print out r(s), r'(s), etc. for this segment?
     H             $ DISCRETE RING INPUT FOLLOWS...
        1          $ NRINGS= number (max=20) of discrete rings in this segment
        2          $ NTYPE = control for identification of ring location (2=z,3=r)
        0          $ Z(I)  = axial coordinate of Ith ring, z( 1)
        0          $ NTYPER= type (0 or 1 or 2 or 4 or 5) of discrete ring no.(1)
        0          $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
     H             $ LINE LOAD INPUT FOLLOWS...
        1          $ LINTYP= indicator (0, 1, 2 or 3) for type of line loads
        1          $ NLOAD(1)=indicator for axial load or disp.(0=none,1=some)
        0          $ NLOAD(2)=indicator for shear load or disp.(0=none,1=some)
        0          $ NLOAD(3)=indicator for radial load or disp.(0 or 1)
        0          $ NLOAD(4)=indicator for line moment or rotation (0 or 1)
 0.0000000E+00     $ V(i)=fixed or initial axial load or displacement, V( 1)
        1          $ NLOAD(1)=indicator for axial load or disp. increment(0 or 1)
        0          $ NLOAD(2)= should be zero
        0          $ NLOAD(3)=indicator for radial load or disp. increment(0 or 1)
        0          $ NLOAD(4)=indicator for moment or rot. increment (0 or 1)
 -1.000000         $ DV(i)=axial load or displacement increment, DV( 1)
     H             $ DISTRIBUTED LOAD INPUT FOLLOWS...
        1          $ IDISAB= indicator (0, 1, 2 or 3) for load set A and B
     H             $ SURFACE LOAD INPUT FOR LOAD SET "A" FOLLOWS
        1          $ NLTYPE=control (0,1,2,3) for type of surface loading
        2          $ NPSTAT= number of meridional callouts for surface loading
        0          $ NLOAD(1)=indicator for meridional traction (0=none, 1=some)
        0          $ NLOAD(2)=indicator for circumferential traction
        1          $ NLOAD(3)=indicator for normal pressure     (0=none, 1=some)
 -1.000000         $ PN(i)    = normal pressure (p.74) at ith callout, PN( 1)
 -1.000000         $ PN(i)    = normal pressure (p.74) at ith callout, PN( 2)
        2          $ NTYPE = control for meaning of loading callout (2=z, 3=r)
 0.0000000E+00     $ Z(I)  = axial coordinate of Ith loading callout, z( 1)
  200.0000         $ Z(I)  = axial coordinate of Ith loading callout, z( 2)
     H             $ SHELL WALL CONSTRUCTION FOLLOWS...
        2          $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9) for wall construction
 0.1000000E+08     $ E      = Young's modulus for skin
 0.3000000         $ U      = Poisson's ratio for skin
```

```
 0.2500000E-03 $ SM =mass density of skin (e.g. alum.=.00025 lb-sec**2/in**4)
      0        $ ALPHA = coefficient of thermal expansion
      0        $ NRS  = control (0 or 1) for addition of smeared stiffeners
      0        $ NSUR   = control for thickness input (0 or 1 or -1)
   N           $ Do you want to print out ref. surf. location and thickness?
   N           $ Do you want to print out the C(i,j) at meridional stations?
   N           $ Do you want to print out distributed loads along meridian?
   H           $
   H           $ GLOBAL DATA BEGINS...
      0        $ NLAST = plot options  (-1=none, 0=geometry, 1=u,v,w)
   N           $ Are there any regions for which you want expanded plots?
      2        $ N0B   = starting number of circ. waves (buckling analysis)
      2        $ NMINB = minimum number of circ. waves  (buckling analysis)
     10        $ NMAXB = maximum number of circ. waves  (buckling analysis)
      1        $ INCRB = increment in number of circ. waves (buckling)
      1        $ NVEC  = number of eigenvalues for each wave number
 0.0000000E+00 $ P       = pressure or surface traction multiplier
  10.00000     $ DP      = pressure or surface traction multiplier increment
      0        $ TEMP    = temperature rise multiplier
      0        $ DTEMP   = temperature rise multiplier increment
      0        $ OMEGA   = angular vel. about axis of revolution (rad/sec)
      0        $ DOMEGA = angular velocity increment (rad/sec)
   H           $ CONSTRAINT CONDITIONS FOLLOW....
      1        $ How many segments in the structure?
   H           $
   H           $ CONSTRAINT CONDITIONS FOR SEGMENT NO.    1    1    1    1
   H           $ POLES INPUT FOLLOWS...
      0        $ Number of poles (places where r=0) in SEGMENT( 1)
   H           $ INPUT FOR CONSTRAINTS TO GROUND FOLLOWS...
      2        $ At how many stations is this segment constrained to ground?
      1        $ INODE = nodal point number of constraint to ground, INODE(1)
      0        $ IUSTAR=axial displacement constraint (0 or 1 or 2)
      1        $ IVSTAR=circumferential displacement(0=free,1=0,2=imposed)
      1        $ IWSTAR=radial displacement(0=free,1=constrained,2=imposed)
      0        $ ICHI=meridional rotation (0=free,1=constrained,2=imposed)
      0        $ D1    = radial component of offset of ground support
      0        $ D2    = axial component of offset of ground support
   N           $ Is this constraint the same for both prebuckling and bucklng?
      0        $ IUSTARB= axial displacement for buckling or vibration phase
      1        $ IVSTARB= circ. displacement for buckling or vibration phase
      1        $ IWSTARB= radial displacement for buckling or vibration
      0        $ ICHIB  = meridional rotation for buckling or vibration
     97        $ INODE = nodal point number of constraint to ground, INODE(2)
      1        $ IUSTAR=axial displacement constraint (0 or 1 or 2)
      0        $ IVSTAR=circumferential displacement(0=free,1=0,2=imposed)
      0        $ IWSTAR=radial displacement(0=free,1=constrained,2=imposed)
      1        $ ICHI=meridional rotation (0=free,1=constrained,2=imposed)
      0        $ D1    = radial component of offset of ground support
      0        $ D2    = axial component of offset of ground support
   N           $ Is this constraint the same for both prebuckling and bucklng?
      0        $ IUSTARB= axial displacement for buckling or vibration phase
      1        $ IVSTARB= circ. displacement for buckling or vibration phase
      1        $ IWSTARB= radial displacement for buckling or vibration
      0        $ ICHIB  = meridional rotation for buckling or vibration
   H           $ JUNCTION CONDITION INPUT FOLLOWS...
   N           $ Is this segment joined to any lower-numbered segments?
   H           $ RIGID BODY CONSTRAINT INPUT FOLLOWS...
   N           $ Given existing constraints, are rigid body modes possible?
   H           $ "GLOBAL3" QUESTIONS (AT END OF CASE)...
   Y           $ Do you want to list output for segment( 1)
   Y           $ Do you want to list forces in the discrete rings, if any?
===============================================================================
```

Table A.8 List of a file called GLOBAL2.QUE, generated to see what input data are needed for the case, INDIC = 0. (Nonlinear axisymmetric stress analysis. The list in the previous table is for INDIC = 1)

```
==============================================================================
     H          $ GLOBAL DATA BEGINS...
        0       $ NLAST = plot options  (-1=none, 0=geometry, 1=u,v,w)
     N          $ Are there any regions for which you want expanded plots?
  10.00000      $ P      = pressure or surface traction multiplier
  1.000000      $ DP     = pressure or surface traction multiplier increment
        0       $ TEMP   = temperature rise multiplier
        0       $ DTEMP  = temperature rise multiplier increment
        1       $ Number of load steps
        0       $ OMEGA  = angular vel. about axis of revolution (rad/sec)
        0       $ DOMEGA = angular velocity increment (rad/sec)
     H          $ CONSTRAINT CONDITIONS FOLLOW....
        1       $ How many segments in the structure?
==============================================================================
```

Table A.9 List of another file called GLOBAL2.QUE, generated to see what input data are needed for the case, INDIC = 2 (modal vibration of prestressed shell)

```
==============================================================================
     H          $ GLOBAL DATA BEGINS...
        0       $ NLAST = plot options  (-1=none, 0=geometry, 1=u,v,w)
     N          $ Are there any regions for which you want expanded plots?
        2       $ N0B   = starting number of circ. waves (buckling analysis)
        2       $ NMINB = minimum number of circ. waves  (buckling analysis)
       10       $ NMAXB = maximum number of circ. waves  (buckling analysis)
        1       $ INCRB = increment in number of circ. waves (buckling)
        1       $ NVEC  = number of eigenvalues for each wave number
  10.00000      $ P      = pressure or surface traction multiplier
        0       $ TEMP   = temperature rise multiplier
        0       $ OMEGA  = angular vel. about axis of revolution (rad/sec)
     H          $ CONSTRAINT CONDITIONS FOLLOW....
        1       $ How many segments in the structure?
==============================================================================
```

Table A.10 List of SUBROUTINE BOSDEC, which must be written by the GENOPT user. The purpose of BOSDEC is to produce an input file, *.ALL, legal for input to the BOSOR4 preprocessor, B4READ

```
===============================================================================
C=DECK      BOSDEC
C
C  PURPOSE IS TO SET UP BOSOR4 INPUT FILE FOR cyl.
C
      SUBROUTINE BOSDEC(INDX,ILOADX,INDIC)
C
C  INPUT: INDX = behavior number:
C                1 = nonlinear stress analysis (INDIC=0)
C                2 = buckling symmetric at midlength symmetry plane
C                3 = buckling antisymmetric at midlength sym. plane
C                4 = modal vibration frequency
C                5 = objective
C        ILOADX = load set number. (There is only one load set here)
C        INDIC  = BOSOR4 analysis type indicator:
C                 0 = nonlinear stress
C                 1 = "linear" bifurcation buckling
C                 2 = modal vibration of prestressed shell
C
C  Insert labelled common blocks: cylinder.COM (produced by GENOPT, but
      COMMON/FV07/NX(20)                          inserted here by GENOPT user)
      REAL NX
      COMMON/FV11/STRESS(20),STRSSA(20),STRSSF(20)
      REAL STRESS,STRSSA,STRSSF
      COMMON/FV14/BSYM(20),BSYMA(20),BSYMF(20)
      REAL BSYM,BSYMA,BSYMF
      COMMON/FV17/BANTI(20),BANTIA(20),BANTIF(20)
      REAL BANTI,BANTIA,BANTIF
      COMMON/FV20/FREQ(20),FREQA(20),FREQF(20)
      REAL FREQ,FREQA,FREQF
      COMMON/IV01/IBOUND
      INTEGER IBOUND
      COMMON/FV01/LENGTH,RADIUS,THICK,ESTIFF,NU,DENS,WEIGHT
      REAL LENGTH,RADIUS,THICK,ESTIFF,NU,DENS,WEIGHT
      COMMON/FV08/PRESS(20)
      REAL PRESS
C  end of cylinder.COM
      IFIL14 = 24                       (This becomes the *.ALL file)
      REWIND IFIL14
C
      WRITE(IFILE4,3)
    3 FORMAT(//'  ****************  BOSDEC  *******************'/
     1'  The purpose of BOSDEC is to set up an input file, NAME.ALL,'/
     1'  for a cylindrical shell. NAME is your name for'/
     1'  the case. The file NAME.ALL is a BOSOR4 input "deck" used'/
     1'  by SUBROUTINE B4READ.'/
     1'  *********************************************'/)
C
      IF (INDIC.EQ.0) WRITE(IFIL14,'(A)')
     1' Nonlinear axisymmetric stress analysis (INDIC=0)'
      IF (INDIC.EQ.1) WRITE(IFIL14,'(A)')
     1' Bifurcation buckling analysis (INDIC=1)'
      IF (INDIC.EQ.2) WRITE(IFIL14,'(A)')
     1' Modal vibration of prestressed shell'
      WRITE(IFIL14,'(I3,A)') INDIC,  ' $ INDIC'
      WRITE(IFIL14,'(A)')'  1      $ NPRT'
      ISTRES = 0
      IF (INDIC.EQ.0) ISTRES = 1
      WRITE(IFIL14,'(I3,A)') ISTRES,  ' $ ISTRES'
```

```
      WRITE(IFIL14,'(A)')'  1       $ NSEG'
      WRITE(IFIL14,'(A)')' 97       $ NMESH'  (This might have been a variable)
      WRITE(IFIL14,'(A)')'  3       $ NTYPEH'
      WRITE(IFIL14,'(A)')'  1       $ NSHAPE'
      WRITE(IFIL14,'(1P,E14.6,A)') RADIUS, ' $ R1'
      WRITE(IFIL14,'(A)')' 0.       $ Z1'
      WRITE(IFIL14,'(1P,E14.6,A)') RADIUS, ' $ R2'
      AXIAL = 0.5*LENGTH
      IF (INDIC.EQ.0.AND.INDX.EQ.1) THEN
         BLL = 2.73*SQRT(RADIUS*THICK)
         AXIAL = MIN(0.5*LENGTH,BLL)
      ENDIF
      WRITE(IFIL14,'(1P,E14.6,A)') AXIAL, ' $ Z2'
      WRITE(IFIL14,'(A)')'  0       $ IMP'
      WRITE(IFIL14,'(A)')'  3       $ NTYPEZ'
      WRITE(IFIL14,'(1P,E14.6,A)') 0.5*THICK, ' $ THICK'
      WRITE(IFIL14,'(A)')'  N       $ print r(s)...?'
      WRITE(IFIL14,'(A)')'  1       $ NRINGS'
      WRITE(IFIL14,'(A)')'  2       $ NTYPE'
      WRITE(IFIL14,'(A)')'  0       $ Z(I)'
      WRITE(IFIL14,'(A)')'  0       $ NTYPER'
      WRITE(IFIL14,'(A)')'  0       $ K'
      WRITE(IFIL14,'(A)')'  1       $ LINTYP'
      WRITE(IFIL14,'(A)')'  1       $ NLOAD(1)'
      WRITE(IFIL14,'(A)')'  0       $ NLOAD(2)'
      WRITE(IFIL14,'(A)')'  0       $ NLOAD(3)'
      WRITE(IFIL14,'(A)')'  0       $ NLOAD(4)'
      IF (INDIC.EQ.0.OR.INDIC.EQ.2)
     1WRITE(IFIL14,'(1P,E14.6,A)') NX(ILOADX),   ' $ V(1)'
      IF (INDIC.EQ.1) WRITE(IFIL14,'(A)')'  0.      $ V(1)'
      WRITE(IFIL14,'(A)')'  1       $ NLOAD(1)'
      WRITE(IFIL14,'(A)')'  0       $ NLOAD(2)'
      WRITE(IFIL14,'(A)')'  0       $ NLOAD(3)'
      WRITE(IFIL14,'(A)')'  0       $ NLOAD(4)'
      IF (INDIC.EQ.0)
     1WRITE(IFIL14,'(1P,E14.6,A)') NX(ILOADX),   ' $ DV(1)'
      IF (INDIC.EQ.2) WRITE(IFIL14,'(A)')'  0.   $ DV(1)'
      IF (INDIC.EQ.1)
     1WRITE(IFIL14,'(1P,E14.6,A)') NX(ILOADX)/1000.,  ' $ DV(1)'
      WRITE(IFIL14,'(A)')'  1       $ IDISAB'
      WRITE(IFIL14,'(A)')'  1       $ NLTYPE'
      WRITE(IFIL14,'(A)')'  2       $ NPSTAT'
      WRITE(IFIL14,'(A)')'  0       $ NLOAD(1)'
      WRITE(IFIL14,'(A)')'  0       $ NLOAD(2)'
      WRITE(IFIL14,'(A)')'  1       $ NLOAD(3)'
      WRITE(IFIL14,'(A)')'  1.      $ PN(1)'
      WRITE(IFIL14,'(A)')'  1.      $ PN(2)'
      WRITE(IFIL14,'(A)')'  2       $ NTYPE'
      WRITE(IFIL14,'(A)')'  0.      $ Z(1)'
      WRITE(IFIL14,'(1P,E14.6,A)')  AXIAL,   ' $ Z(2)'
      WRITE(IFIL14,'(A)')'  2       $ NWALL'
      WRITE(IFIL14,'(1P,E14.6,A)') ESTIFF,    ' $ E'
      WRITE(IFIL14,'(1P,E14.6,A)') NU,        ' $ U'
      WRITE(IFIL14,'(1P,E14.6,A)') DENS,      ' $ SM'
      WRITE(IFIL14,'(A)')'  0.      $ ALPHA'
      WRITE(IFIL14,'(A)')'  0       $ NRS'
      WRITE(IFIL14,'(A)')'  0       $ NSUR'
C
      WRITE(IFIL14,'(A)')'  N       $ print refsurf...?'
      WRITE(IFIL14,'(A)')'  N       $ print Cij?'
      WRITE(IFIL14,'(A)')'  N       $ print loads?'
      WRITE(IFIL14,'(A)')'  0       $ NLAST'
```

```
      WRITE(IFIL14,'(A)')'  N      $ expanded plots?'
      IF (INDIC.NE.0) THEN
         WRITE(IFIL14,'(A)')'  2       $ NOB'      (These might well have been
         WRITE(IFIL14,'(A)')'  2       $ NMINB'     variables rather than
         IF (INDX.NE.3)                             "hardwired" as they are
     1   WRITE(IFIL14,'(A)')' 10       $ NMAXB'     in this particular example.)
         IF (INDX.EQ.3)
     1   WRITE(IFIL14,'(A)')' 15       $ NMAXB'
         WRITE(IFIL14,'(A)')'  1       $ INCRB'
         WRITE(IFIL14,'(A)')'  1       $ NVEC'
      ENDIF
      IF (INDIC.EQ.0.OR.INDIC.EQ.2)
     1WRITE(IFIL14,'(1P,E14.6,A)') PRESS(ILOADX),   ' $ P'
      IF (INDIC.EQ.1) WRITE(IFIL14,'(A)')'  0.    $ P'
      IF (INDIC.EQ.0.OR.INDIC.EQ.1)
     1WRITE(IFIL14,'(1P,E14.6,A)') PRESS(ILOADX)/1000.,  ' $ DP'
      WRITE(IFIL14,'(A)')'  0.      $ TEMP'
      IF (INDIC.EQ.0.OR.INDIC.EQ.1)
     1WRITE(IFIL14,'(A)')'  0.      $ DTEMP'
      IF (INDIC.EQ.0) WRITE(IFIL14,'(A)')'  1      $ NSTEPS'
      WRITE(IFIL14,'(A)')'  0.      $ OMEGA'
      IF (INDIC.EQ.0.OR.INDIC.EQ.1)
     1WRITE(IFIL14,'(A)')'  0.      $ DOMEGA'
C
      WRITE(IFIL14,'(A)')'  1      $ how many segs?'
C
      WRITE(IFIL14,'(A)')'  0      $ number of poles'
      WRITE(IFIL14,'(A)')'  2      $ how many stations?'
      WRITE(IFIL14,'(A)')'  1      $ INODE'
      WRITE(IFIL14,'(A)')'  0      $ IUSTAR'
      WRITE(IFIL14,'(A)')'  1      $ IVSTAR'
      WRITE(IFIL14,'(A)')'  1      $ IWSTAR'
      ICHI = 0
      IF (IBOUND.EQ.2) ICHI = 1
      WRITE(IFIL14,'(I3,A)')  ICHI,   ' $ ICHI'
      WRITE(IFIL14,'(A)')'  0.     $ D1'
      WRITE(IFIL14,'(A)')'  0.     $ D2'
      WRITE(IFIL14,'(A)')'  N      $ bc same for pre,bif?'
      IUSTARB = 0
      IF (IBOUND.EQ.2) IUSTARB = 1
      WRITE(IFIL14,'(I3,A)') IUSTARB,   ' $ IUSTARB'
      WRITE(IFIL14,'(A)')'  1      $ IVSTARB'
      WRITE(IFIL14,'(A)')'  1      $ IWSTARB'
      ICHIB = 0
      IF (IBOUND.EQ.2) ICHIB = 1
      write(ifil14,'(I3,A)')  ICHIB,   ' $ ICHIB'
C
      WRITE(IFIL14,'(A)')' 97      $ INODE'
      WRITE(IFIL14,'(A)')'  1      $ IUSTAR'
      WRITE(IFIL14,'(A)')'  0      $ IVSTAR'
      WRITE(IFIL14,'(A)')'  0      $ IWSTAR'
      WRITE(IFIL14,'(A)')'  1      $ ICHI'
      WRITE(IFIL14,'(A)')'  0.     $ D1'
      WRITE(IFIL14,'(A)')'  0.     $ D2'
      IF (INDX.NE.3) THEN
         WRITE(IFIL14,'(A)')'  Y      $ bc same for pre,bif?'
      ELSE
         WRITE(IFIL14,'(A)')'  N      $ bc same for pre,bif?'
         WRITE(IFIL14,'(A)')'  0      $ IUSTARB'
         WRITE(IFIL14,'(A)')'  1      $ IVSTARB'
         WRITE(IFIL14,'(A)')'  1      $ IWSTARB'
         WRITE(IFIL14,'(A)')'  0      $ ICHIB'
```

```
      ENDIF
      WRITE(IFIL14,'(A)')'  N      $ joined to lower segs?'
      WRITE(IFIL14,'(A)')'  N      $ rigid body possible?'
      WRITE(IFIL14,'(A)')'  Y      $ output for seg. 1?'
      WRITE(IFIL14,'(A)')'  Y      $ output for rings?'
C
      RETURN
      END
==============================================================================
```

```
Table A.11 The "make" script by means of which the elements of the
user-friendly "CYLINDER" program system (BEGIN, DECIDE, MAINSETUP,
OPTIMIZE, CHANGE, AUTOCHANGE, CHOOSEPLOT are compiled and assembled.
The following script is called "usermake.sgi"
===================================================================
# usermake.sgi
# Makefile for GENOPTCASE on the Silicon Graphics IRIS workstation
# This makefile generates the executables called begin, decide, mainsetup,
# change, optimize, store, chooseplot.  The GENOPT user makes
# using this file when running genprograms.

SHELL = /bin/csh
FC = f77
MACHINE = sgi
CFLAGS = -g -Dsgi
FFLAGS = -static -g -Dsgi -O0 -Wb,-force_branch_fixup
OPTFFLAGS = -static -Dsgi -O
HOME = /usr6/bushnell
HOME2 = /usr5/bush
GENOPT = $(HOME)/genopt
BOSDEC = $(HOME2)/bosdec
UTIL = $(HOME)/util
LIB = libraries.sgi
BIN = $(HOME)/bin
OBJ = objects.sgi
GOBJ = $(GENOPT)/objects.sgi
BSRC = $(BOSDEC)/sources
BOBJ = $(BOSDEC)/objects.sgi
EXE = $(GENOPT)/execute

.PRECIOUS:  begin.sgi\
            change.sgi\
            chooseplot.sgi\
            decide.sgi\
            mainsetup.sgi\
            optimize.sgi\
            store.sgi\
            autochange.sgi

genoptcase: begin.sgi\
            change.sgi\
            chooseplot.sgi\
            decide.sgi\
            mainsetup.sgi\
            optimize.sgi\
            store.sgi\
            autochange.sgi

begin.sgi: $(LIB)/begin.a
        ar xv $(LIB)/begin.a BEGIN.o
        $(FC) $(FFLAGS) -o $@ BEGIN.o $(LIB)/begin.a $(UTIL)/sig_sgi.o
        /bin/rm -f BEGIN.o

change.sgi: $(LIB)/change.a
        ar xv $(LIB)/change.a CHANGE.o
        $(FC) $(FFLAGS) -o $@ CHANGE.o $(LIB)/change.a $(UTIL)/sig_sgi.o
        /bin/rm -f CHANGE.o

chooseplot.sgi: $(LIB)/chooseplot.a
        ar xv $(LIB)/chooseplot.a CHPLOT.o
        $(FC) $(FFLAGS) -o $@ CHPLOT.o $(LIB)/chooseplot.a $(UTIL)/sig_sgi.o
        /bin/rm -f CHPLOT.o
```

```
decide.sgi: $(LIB)/decide.a
        ar xv $(LIB)/decide.a DECIDE.o
        $(FC) $(FFLAGS) -o $@ DECIDE.o $(LIB)/decide.a $(UTIL)/sig_sgi.o
        /bin/rm -f DECIDE.o

mainsetup.sgi: $(LIB)/mainsetup.a
        ar xv $(LIB)/mainsetup.a MAINS.o
        $(FC) $(FFLAGS) -o $@ MAINS.o $(LIB)/mainsetup.a $(UTIL)/sig_sgi.o
        /bin/rm -f MAINS.o

optimize.sgi: $(LIB)/optimize.a $(UTIL)/ieeexx_sgi.o
        ar xv $(LIB)/optimize.a MAIN.o
        $(FC) $(FFLAGS) -o $@ MAIN.o $(LIB)/optimize.a $(UTIL)/ieeexx_sgi.o
        /bin/rm -f MAIN.o

store.sgi: $(LIB)/store.a
        ar xv $(LIB)/store.a STORE.o
        $(FC) $(FFLAGS) -o $@ STORE.o $(LIB)/store.a
        /bin/rm -f STORE.o

autochange.sgi: $(LIB)/autochange.a
        ar xv $(LIB)/autochange.a CHAUTO.o
        $(FC) $(FFLAGS) -o $@ CHAUTO.o $(LIB)/autochange.a
        /bin/rm -f CHAUTO.o

# Update libraries ...

$(LIB)/begin.a: $(OBJ)/begin.a $(OBJ)/stoget.a $(GOBJ)/util.a\
                $(GOBJ)/prompter.a
        csh $(BIN)/updatelib $@ $?

$(LIB)/change.a: $(OBJ)/begin.a     $(OBJ)/change.a $(GOBJ)/decide.a\
                 $(GOBJ)/prompter.a $(OBJ)/stoget.a $(GOBJ)/util.a\
                 $(GOBJ)/conman.a
        csh $(BIN)/updatelib $@ $?
        -ar dsl $@ begin.o
        -ar dsl $@ decide.o

$(LIB)/chooseplot.a: $(OBJ)/begin.a     $(GOBJ)/chplot.a\
                     $(GOBJ)/prompter.a $(OBJ)/stoget.a $(GOBJ)/util.a
        csh $(BIN)/updatelib $@ $?
        -ar dsl $@ begin.o

$(LIB)/decide.a: $(OBJ)/begin.a  $(GOBJ)/decide.a $(GOBJ)/prompter.a\
                 $(OBJ)/stoget.a $(GOBJ)/util.a   $(GOBJ)/conman.a
        csh $(BIN)/updatelib $@ $?
        -ar dsl $@ begin.o

$(LIB)/mainsetup.a: $(GOBJ)/mainsetup.a $(GOBJ)/prompter.a\
                    $(OBJ)/stoget.a     $(GOBJ)/util.a
        csh $(BIN)/updatelib $@ $?

$(LIB)/optimize.a: $(GOBJ)/prompter2.a $(GOBJ)/ads.a    $(OBJ)/begin.a\
                   $(GOBJ)/conman.a    $(GOBJ)/decide.a $(GOBJ)/main.a\
                   $(OBJ)/stoget.a    $(OBJ)/struct.a\
                   $(OBJ)/behavior.a\
                   $(BOBJ)/bosdec.a    $(BOBJ)/opngen.a $(BOBJ)/addbosor4.a\
                   $(BOBJ)/b4plot.a    $(BOBJ)/b4util.a\
                   $(BOBJ)/resetup.a   $(BOBJ)/gasp.a   $(BOBJ)/prompter.a\
                   $(GOBJ)/util.a
        csh $(BIN)/updatelib $@ $?
```

```
        -ar dsl $@ begin.o
        -ar dsl $@ decide.o

$(LIB)/store.a: $(GOBJ)/prompter.a $(OBJ)/stoget.a $(GOBJ)/store.a\
                $(GOBJ)/util.a     $(OBJ)/begin.a  $(GOBJ)/conman.a\
                $(OBJ)/behavior.a
        csh $(BIN)/updatelib $@ $?

$(LIB)/autochange.a: $(GOBJ)/chauto.a   $(OBJ)/begin.a   $(GOBJ)/decide.a\
                     $(GOBJ)/prompter.a $(OBJ)/stoget.a  $(GOBJ)/util.a\
                     $(GOBJ)/conman.a   $(OBJ)/behavior.a
        csh $(BIN)/updatelib $@ $?
        -ar dsl $@ begin.o
        -ar dsl $@ decide.o

# Update objects ...

$(OBJ)/begin.a: begin.new
        csh $(BIN)/updateobj $(FC) "$(FFLAGS)" begin.new $@

$(OBJ)/behavior.a: behavior.new
        csh $(BIN)/updateobj $(FC) "$(FFLAGS)" behavior.new $@

$(OBJ)/change.a: change.new
        csh $(BIN)/updateobj $(FC) "$(FFLAGS)" change.new $@

$(OBJ)/stoget.a: stoget.new
        csh $(BIN)/updateobj $(FC) "$(FFLAGS)" stoget.new $@

$(OBJ)/struct.a: struct.new
        csh $(BIN)/updateobj $(FC) "$(FFLAGS)" struct.new $@

$(BOBJ)/gasp.a: $(BSRC)/gasp.f $(BSRC)/bio_$(MACHINE).c
        cd $(BSRC) &&\
        $(FC) $(FFLAGS) -c $(BSRC)/gasp.f &&\
        $(CC) $(CFLAGS) -c $(BSRC)/bio_$(MACHINE).c &&\
        mv gasp.o gasp_$(MACHINE).o &&\
        ar rv $@ gasp_$(MACHINE).o bio_$(MACHINE).o

$(BOBJ)/prompter.a: $(BSRC)/prompter.src
        csh $(BIN)/updateobj $(FC) "$(FFLAGS)" $? $@

$(BOBJ)/bosdec.a: $(BSRC)/bosdec.src
        csh $(BIN)/updateobj $(FC) "$(FFLAGS)" $? $@

$(BOBJ)/opngen.a: $(BSRC)/opngen.src
        csh $(BIN)/updateobj $(FC) "$(FFLAGS)" $? $@

$(BOBJ)/resetup.a: $(BSRC)/resetup.src
        csh $(BIN)/updateobj $(FC) "$(FFLAGS)" $? $@

$(BOBJ)/addbosor4.a: $(BSRC)/addbosor4.src
        csh $(BIN)/updateobj $(FC) "$(FFLAGS)" $? $@

$(BOBJ)/b4plot.a: $(BSRC)/b4plot.src
        csh $(BIN)/updateobj $(FC) "$(FFLAGS)" $? $@

$(BOBJ)/b4util.a: $(BSRC)/b4util.src
        csh $(BIN)/updateobj $(FC) "$(FFLAGS)" $? $@

$(UTIL)/ieeexx_$(MACHINE).o: $(UTIL)/ieeexx.c
        cd $(UTIL) && \
```

```
        cc $(CFLAGS) -D$(MACHINE) -c ieeexx.c && \
        mv ieeexx.o ieeexx_$(MACHINE).o

$(UTIL)/sig_$(MACHINE).o: $(UTIL)/sig.f
        cd $(UTIL) && \
        $(FC) $(FFLAGS) -c sig.f && \
        mv sig.o sig_$(MACHINE).o
============================================================================
```

Table A.12 Input for the "BEGIN" processor of the "cylinder" system. The following input file is called cyl.BEG because the "cylinder" user named this specific case "cyl".

```
=============================================================================
      N            $ Do you want a tutorial session and tutorial output?
        200        $ Length of the cylindrical shell: LENGTH
        100        $ Radius of the cylindrical shell: RADIUS
   1.000000        $ Thickness of the cylindrical shell: THICK
  0.1000000E+08    $ Youngs modulus of the shell wall: ESTIFF
  0.3000000        $ Poisson ratio of the shell wall: NU
  0.2500000E-03    $ mass density (e.g. lb-sec^2/in^4): DENS
          2        $ IBOUND = 1 = simple support; 2 = clamped: IBOUND
          1        $ Number NCASES of load cases (environments): NCASES
   -1000.00        $ Axial resultant (e.g. lb/in): NX( 1)
   -20.0000        $ Pressure, positive for internal: PRESS( 1)
   30000.00        $ Maximum allowable stress: STRSSA( 1)
          1        $ Factor of safety for stress: STRSSF( 1)
   1000.000        $ Allowable for sym. buckling load factor: BSYMA( 1)
   1.250000        $ Factor of safety for sym. buckling load: BSYMF( 1)
   1000.000        $ Allowable for antisym. buckling load factor: BANTIA( 1)
   1.250000        $ Factor of safety for antisym. buckling load: BANTIF( 1)
   20.0000         $ Allowable for modal frequency: FREQA( 1)
   1.000000        $ Factor of safety for modal frequency: FREQF( 1)
=============================================================================
```

Table A.13 Input for the "DECIDE" processor of the "cylinder" system. The following input file is called cyl.DEC.

```
=============================================================================
      N            $ Do you want a tutorial session and tutorial output?
          1        $ Choose a decision variable (1,2,3,...)
  0.1000000E-01    $ Lower bound of variable no.( 1)
   3.000000        $ Upper bound of variable no.( 1)
      N            $ Any more decision variables (Y or N) ?
      N            $ Any linked variables (Y or N) ?
      N            $ Any inequality relations among variables? (type H)
      Y            $ Any escape variables (Y or N) ?
      Y            $ Want to have escape variables chosen by default?
=============================================================================
```

Table A.14 Input for the "MAINSETUP" and "OPTIMIZE" processors of the "cylinder" system. The following input file is called cyl.OPT.

```
=============================================================================
      N            $ Do you want a tutorial session and tutorial output?
          0        $ Choose an analysis you DON'T want (1, 2,..), IBEHAV
          0        $ NPRINT= output index (0=GOOD, 1=ok, 2=debug, 3=too much)
          1        $ Choose type of analysis (1=opt., 2=fixed, 3=sensit.) ITYPE
          5        $ How many design iterations in this run (3 to 25)?
          1        $ Choose (1="conservative"), (2="liberal") move limits, IMOVE
      Y            $ Do you want default (RATIO=10) for initial move limit jump?
      Y            $ Do you want the default perturbation (dx/x = 0.05)?
      N            $ Do you want to reset total iterations to zero (Type H)?
=============================================================================
```

Table A.15 Output file, cyl.OPP, after two "OPTIMIZEs"

```
==============================================================================
 *****************  OCTOBER 1999 VERSION OF GENOPT     **************
 ***************** THIS IS THE  cyl.OPP FILE *****************
 casename=cyl: ITER, ITRLST=    1    6

 *********** MARGINS FOR   8 ITERATIONS **********
 1-(STRESS(1 )/STRSSA(1 )) X STRSSF(1 ); F.S.=1. =
  8.7920E-01  8.6578E-01  8.5411E-01  8.4368E-01  8.3455E-01  8.2670E-01
  8.2670E-01  8.2262E-01
 (BSYM(1 )/BSYMA(1 )) / BSYMF(1 )-1; F.S.=1.25 =
  1.5947E+00  1.0045E+00  6.4474E-01  3.9561E-01  2.0251E-01  6.6472E-02
  6.6472E-02  4.6413E-03
 (BANTI(1 )/BANTIA(1 )) / BANTIF(1 )-1; F.S.=  1.25 =
  3.5453E+00  2.4777E+00  1.8298E+00  1.3953E+00  1.0718E+00  8.3744E-01
  8.3744E-01  7.3091E-01
 (FREQ(1 )/FREQA(1 )) / FREQF(1 )-1; F.S.=1. =
  1.1818E+00  9.8406E-01  7.7115E-01  5.4974E-01  3.5538E-01  1.8263E-01
  1.8263E-01  8.8667E-02

 ****** DESIGN VARIABLES FOR   8 ITERATIONS ******
 Thickness of the cylindrical shell: THICK =
  1.0000E+00  9.0000E-01  8.2800E-01  7.7270E-01  7.3003E-01  6.9694E-01
  6.9694E-01  6.8091E-01

 ********** OBJECTIVE FOR   8 ITERATIONS *********
 weight of half of cyl. shell: WEIGHT =
  6.0696E+03  5.4626E+03  5.0256E+03  4.6900E+03  4.4309E+03  4.2301E+03
  4.2301E+03  4.1328E+03

 ITERATION                                             NUMBER OF
  NUMBER      OBJECTIVE     THE DESIGN IS...   CRITICAL MARGINS
 -------------------------------------------------------------
 ------------------------------------------------------OPTIMIZE
    1          6.0696E+03         FEASIBLE              0
    2          5.4626E+03         FEASIBLE              0
    3          5.0256E+03         FEASIBLE              0
    4          4.6900E+03         FEASIBLE              0
    5          4.4309E+03         FEASIBLE              0
    6          4.2301E+03         FEASIBLE              0
 ------------------------------------------------------OPTIMIZE
    7          4.2301E+03         FEASIBLE              0
    8          4.1328E+03         FEASIBLE              2

  VALUES OF DESIGN VARIABLES CORRESPOND.TO MINIMUM-OBJECTIVE DESIG
 VAR.   CURRENT
 NO.     VALUE             DEFINITION
  1    6.809E-01  Thickness of the cylindrical shell: THICK

 ******************** DESIGN OBJECTIVE *******************
  CORRESPONDING VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE             DEFINITION
  1    4.133E+03  weight of half of cyl. shell: WEIGHT
 ******************** DESIGN OBJECTIVE *******************
 IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN, BE SURE TO
 RUN  "OPTIMIZE"  MANY TIMES DURING AN OPTIMIZATION.
 ***************** END OF THE  cyl.OPP FILE *****************
==============================================================================
```

Table A.16 Output (cyl.OPM) from last OPTIMIZE command

```
==========================================================================
    N         $ Do you want a tutorial session and tutorial output?
      0       $ Choose an analysis you DON'T want (1, 2,..), IBEHAV
      0       $ NPRINT= output index (0=GOOD, 1=ok, 2=debug, 3=too much)
      1       $ Choose type of analysis (1=opt., 2=fixed, 3=sensit.) ITYPE
      5       $ How many design iterations in this run (3 to 25)?
      1       $ Choose (1="conservative"), (2="liberal") move limits, IMOVE
    Y         $ Do you want default (RATIO=10) for initial move limit jump?
    Y         $ Do you want the default perturbation (dx/x = 0.05)?
    N         $ Do you want to reset total iterations to zero (Type H)?

 ************ END OF THE  cyl.OPT  FILE ***********
 ************ OCTOBER, 1999 VERSION OF GENOPT ****************
 ******** BEGINNING OF THE  cyl.OPM  FILE *********

 *********************** MAIN PROCESSOR **********************
 The purpose of the mainprocessor, OPTIMIZE, is to perform,
 in a batch mode, the work specified by MAINSETUP for the case
 called cyl.  Results are stored in the file  cyl.OPM.
 Please inspect cyl.OPM before doing more design iterations.
 ***********************************************************

 STRUCTURAL ANALYSIS FOR DESIGN ITERATION NO.    0:
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
  Thickness of the cylindrical shell: THICK
   1   Y     Y     N      0    0.00E+00  1.00E-02 6.9694E-01  3.00E+00

 Maximum effective stress from BEHX1: STRESS=  5.1990E+03

 SYMMETRIC BUCKLING LOAD FACTORS AND MODES (BEHX2)
        2.9460E+04(   2)
        2.8784E+04(   3)
        9.0429E+03(   4)
        3.5436E+03(   5)
        1.8834E+03(   6)
        1.3932E+03(   7)
        1.3331E+03(   8)
        1.4613E+03(   9)
        1.6885E+03(  10)
  Critical buckling load factor, BSYM=  1.3331E+03
  Critical number of circumferential waves, NWVCRT=     8

 ANTISYMMETRIC BUCKLING LOAD FACTORS AND MODES (BEHX3)
        2.9485E+04(   2)
        2.8802E+04(   3)
        2.7805E+04(   4)
        1.2713E+04(   5)
        6.4176E+03(   6)
        3.8247E+03(   7)
        2.7465E+03(   8)
        2.3520E+03(   9)
        2.2968E+03(  10)
        2.4271E+03(  11)
        2.6698E+03(  12)
        2.9882E+03(  13)
        3.3629E+03(  14)
        3.7837E+03(  15)
  Critical buckling load factor, BANTI=  2.2968E+03
  Critical number of circumferential waves, NWVCRT=    10
```

```
NATURAL FREQUENCIES AND MODES (BEHX4)
       1.2526E+02(   2)
       8.5338E+01(   3)
       6.0026E+01(   4)
       4.2537E+01(   5)
       3.0265E+01(   6)
       2.3653E+01(   7)
       2.4880E+01(   8)
       3.2899E+01(   9)
       4.4642E+01(  10)
Critical buckling load factor, FREQ=  2.3653E+01
Critical number of circumferential waves, NWVCRT=    7

         SUMMARY OF INFORMATION FROM OPTIMIZATION ANALYSIS
VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER
 NO. VAR.  VAR.  VAR.     TO   CONSTANT  BOUND      VALUE     BOUND
 Thickness of the cylindrical shell: THICK
  1   Y     Y     N      0    0.00E+00  1.00E-02 6.9694E-01  3.00E+00

***** RESULTS FOR LOAD SET NO.  1  ******
THOSE MARGINS LESS THAN UNITY CORRESPONDING TO CURRENT DESIGN
MARGIN CURRENT
NO.     VALUE            DEFINITION
 1    6.647E-02  (BSYM(1 )/BSYMA(1 )) / BSYMF(1 )-1; F.S.=  1.25
 2    1.826E-01  (FREQ(1 )/FREQA(1 )) / FREQF(1 )-1; F.S.=  1.00

******************** DESIGN OBJECTIVE *******************
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:
VAR.  CURRENT
NO.     VALUE            DEFINITION
 1    4.230E+03  weight of half of cyl. shell: WEIGHT
******************** DESIGN OBJECTIVE *******************

STRUCTURAL ANALYSIS WITH DECISION VARIABLE NO. 1
PERTURBED BY X PER CENT.  DECISION VARIABLE NO.  1
CORRESPONDS TO DESIGN VARIABLE NO.  1. ITS UNPERTURBED
VALUE IS   6.9694E-01 AND ITS DEFINITION IS:
Thickness of the cylindrical shell: THICK

 STRUCTURAL ANALYSIS WITH PERTURBED DECISION VARIABLE
VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER
 NO. VAR.  VAR.  VAR.     TO   CONSTANT  BOUND      VALUE     BOUND
 Thickness of the cylindrical shell: THICK
  1   Y     Y     N      0    0.00E+00  1.00E-02 7.3622E-01  3.00E+00

Maximum effective stress from BEHX1: STRESS=  4.9218E+03

SYMMETRIC BUCKLING LOAD FACTORS AND MODES (BEHX2)
       1.5366E+03(   8)

ANTISYMMETRIC BUCKLING LOAD FACTORS AND MODES (BEHX3)
       2.6474E+03(  10)

NATURAL FREQUENCIES AND MODES (BEHX4)
       2.7706E+01(   7)

THOSE MARGINS LESS THAN UNITY CORRESPONDING TO PERTURBED DESIGN
MARGIN CURRENT
NO.     VALUE            DEFINITION
 1    2.293E-01  (BSYM(1 )/BSYMA(1 )) / BSYMF(1 )-1; F.S.=  1.25
 2    3.853E-01  (FREQ(1 )/FREQA(1 )) / FREQF(1 )-1; F.S.=  1.00
```

```
STRUCTURAL ANALYSIS FOR DESIGN ITERATION NO.    1:
 STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
VAR. DEC. ESCAPE LINK. LINKED  LINKING    LOWER     CURRENT     UPPER
 NO. VAR.  VAR.   VAR.    TO   CONSTANT   BOUND      VALUE      BOUND
 Thickness of the cylindrical shell: THICK
  1   Y     Y      N       0    0.00E+00  1.00E-02 6.8091E-01  3.00E+00

Maximum effective stress from BEHX1: STRESS=  5.3213E+03

SYMMETRIC BUCKLING LOAD FACTORS AND MODES (BEHX2)
       2.8138E+04(   2)
       2.7504E+04(   3)
       8.8176E+03(   4)
       3.4408E+03(   5)
       1.8121E+03(   6)
       1.3246E+03(   7)
       1.2558E+03(   8)
       1.3695E+03(   9)
       1.5784E+03(  10)
Critical buckling load factor, BSYM=  1.2558E+03
Critical number of circumferential waves, NWVCRT=    8

ANTISYMMETRIC BUCKLING LOAD FACTORS AND MODES (BEHX3)
       2.8155E+04(   2)
       2.7524E+04(   3)
       2.6597E+04(   4)
       1.2385E+04(   5)
       6.2299E+03(   6)
       3.6895E+03(   7)
       2.6268E+03(   8)
       2.2302E+03(   9)
       2.1636E+03(  10)
       2.2768E+03(  11)
       2.4983E+03(  12)
       2.7922E+03(  13)
       3.1399E+03(  14)
       3.5312E+03(  15)
Critical buckling load factor, BANTI=  2.1636E+03
Critical number of circumferential waves, NWVCRT=   10

NATURAL FREQUENCIES AND MODES (BEHX4)
       1.2524E+02(   2)
       8.5280E+01(   3)
       5.9876E+01(   4)
       4.2163E+01(   5)
       2.9371E+01(   6)
       2.1773E+01(   7)
       2.2088E+01(   8)
       2.9803E+01(   9)
       4.1403E+01(  10)
Critical buckling load factor, FREQ=  2.1773E+01
Critical number of circumferential waves, NWVCRT=    7

        SUMMARY OF INFORMATION FROM OPTIMIZATION ANALYSIS
VAR. DEC. ESCAPE LINK. LINKED  LINKING    LOWER     CURRENT     UPPER
 NO. VAR.  VAR.   VAR.    TO   CONSTANT   BOUND      VALUE      BOUND
 Thickness of the cylindrical shell: THICK
  1   Y     Y      N       0    0.00E+00  1.00E-02 6.8091E-01  3.00E+00

***** RESULTS FOR LOAD SET NO.  1  ******
THOSE MARGINS LESS THAN UNITY CORRESPONDING TO CURRENT DESIGN
```

```
MARGIN CURRENT
NO.     VALUE             DEFINITION
 1    4.641E-03  (BSYM(1 )/BSYMA(1 )) / BSYMF(1 )-1; F.S.=  1.25
 2    8.867E-02  (FREQ(1 )/FREQA(1 )) / FREQF(1 )-1; F.S.=  1.00

******************** DESIGN OBJECTIVE *******************
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:
VAR.  CURRENT
NO.     VALUE             DEFINITION
 1    4.133E+03  weight of half of cyl. shell: WEIGHT
******************** DESIGN OBJECTIVE *******************

    (lines omitted to save space)

***** RESULTS FOR LOAD SET NO.  1  ******
PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)
BEH.  CURRENT
NO.     VALUE             DEFINITION
 1    5.321E+03   Maximum effective stress in wall of shell: STRESS(1 )
 2    1.256E+03   Symmetric buckling load factor: BSYM(1 )
 3    1.256E+03   Antisymmetric buckling load factor: BANTI(1 )
 4    2.177E+01   Fundamental modal frequency (hertz): FREQ(1 )

***** RESULTS FOR LOAD SET NO.  1  ******
MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
MAR.  CURRENT
NO.     VALUE             DEFINITION
 1    8.226E-01  1-(STRESS(1 )/STRSSA(1 )) X STRSSF(1 ); F.S.=1.
 2    4.641E-03  (BSYM(1 )/BSYMA(1 )) / BSYMF(1 )-1; F.S.=1.25
 3    4.641E-03  (BANTI(1 )/BANTIA(1 )) / BANTIF(1 )-1; F.S.=1.25
 4    8.867E-02  (FREQ(1 )/FREQA(1 )) / FREQF(1 )-1; F.S.=1.
***********  ALL 1 LOAD CASES PROCESSED ***********
*****************************************************

PARAMETERS WHICH ARE ALWAYS FIXED.  NONE CAN BE DECISION VARIAB.
VAR.  CURRENT
NO.     VALUE             DEFINITION
 1    2.000E+02  Length of the cylindrical shell: LENGTH
 2    1.000E+02  Radius of the cylindrical shell: RADIUS
 3    1.000E+07  Youngs modulus of the shell wall: ESTIFF
 4    3.000E-01  Poisson ratio of the shell wall: NU
 5    2.500E-04  mass density (e.g. lb-sec^2/in^4): DENS

PARAMETERS WHICH ARE ENVIRONMENTAL FACTORS (e.g. loads, temps.)
VAR.  CURRENT
NO.     VALUE             DEFINITION
 1   -1.000E+03  Axial resultant (e.g. lb/in): NX(1 )
 2   -2.000E+01  Pressure, positive for internal: PRESS(1 )

PARAMETERS WHICH ARE CLASSIFIED AS ALLOWABLES (e.g. max. stress)
VAR.  CURRENT
NO.     VALUE             DEFINITION
 1    3.000E+04  Maximum allowable stress: STRSSA(1 )
 2    1.000E+03  Allowable for sym. buckling load factor: BSYMA(1 )
 3    1.000E+03  Allowable for antisym. buckling load factor: BANTIA(1 )
 4    2.000E+01  Allowable for modal frequency: FREQA(1 )

PARAMETERS WHICH ARE FACTORS OF SAFETY
VAR.  CURRENT
NO.     VALUE             DEFINITION
 1    1.000E+00  Factor of safety for stress: STRSSF(1 )
```

```
  2    1.250E+00  Factor of safety for sym. buckling load: BSYMF(1 )
  3    1.250E+00  Factor of safety for antisym. buckling load: BANTIF(1 )
  4    1.000E+00  Factor of safety for modal frequency: FREQF(1 )

   0 INEQUALITY CONSTRAINTS WHICH MUST BE SATISFIED

 DESCRIPTION OF FILES USED AND GENERATED IN THIS RUN:
 cyl.NAM = This file contains only the name of the case.
 cyl.OPM = Output data. Please list this file and inspect
             carefully before proceeding.
 cyl.OPP = Output file containing evolution of design and
             margins since the beginning of optimization cycles.
 cyl.CBL = Labelled common blocks for analysis.
             (This is an unformatted sequential file.)
 cyl.OPT = This file contains the input data for MAINSETUP
              as well as OPTIMIZE. The batch command OPTIMIZE
              can be given over and over again without having
              to return to MAINSETUP because cyl.OPT exists.

 Menu of commands: CHOOSEPLOT, OPTIMIZE, MAINSETUP, CHANGE,
                   DECIDE, SUPEROPT

 IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN, BE SURE TO
 RUN  "OPTIMIZE"  MANY TIMES DURING AN OPTIMIZATION AND/OR USE
 THE "GLOBAL" OPTIMIZING SCRIPT, "SUPEROPT".
 ******************** END OF cyl.OPM FILE *****************
=========================================================================
```

```
Table A.17 Input (cyl.OPT) and output (cyl.OPM) corresponding to
a single user-selected behavior (BSYM in this example). The purpose
is to obtain the cyl.DOC file listed in the following table) so that
a BOSOR4 run can be executed and BOSOR4 plots can therefore be obtained.
========================================================================
    N        $ Do you want a tutorial session and tutorial output?
      1      $ Choose an analysis you DON'T want (1, 2,..), IBEHAV
    Y        $ Any more analysis types NOT wanted (Y or N) ?
      3      $ Choose an analysis you DON'T want (1, 2,..), IBEHAV
    Y        $ Any more analysis types NOT wanted (Y or N) ?
      4      $ Choose an analysis you DON'T want (1, 2,..), IBEHAV
    N        $ Any more analysis types NOT wanted (Y or N) ?
      0      $ NPRINT= output index (0=GOOD, 1=ok, 2=debug, 3=too much)
      2      $ Choose type of analysis (1=opt., 2=fixed, 3=sensit.) ITYPE

 ************ END OF THE  cyl.OPT  FILE ***********
 ************ OCTOBER, 1999 VERSION OF GENOPT ****************
 ******** BEGINNING OF THE  cyl.OPM  FILE *********

 *********************** MAIN PROCESSOR *********************
 The purpose of the mainprocessor, OPTIMIZE, is to perform,
 in a batch mode, the work specified by MAINSETUP for the case
 called cyl.  Results are stored in the file  cyl.OPM.
 Please inspect cyl.OPM before doing more design iterations.
 ************************************************************

 STRUCTURAL ANALYSIS FOR DESIGN ITERATION NO.    0:
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER      CURRENT     UPPER
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND       VALUE      BOUND
  Thickness of the cylindrical shell: THICK
   1   Y     Y     N      0    0.00E+00  1.00E-02 6.8091E-01  3.00E+00

 SYMMETRIC BUCKLING LOAD FACTORS AND MODES (BEHX2)
         2.8138E+04(   2)
         2.7504E+04(   3)
         8.8176E+03(   4)
         3.4408E+03(   5)
         1.8121E+03(   6)
         1.3246E+03(   7)
         1.2558E+03(   8)
         1.3695E+03(   9)
         1.5784E+03(  10)
  Critical buckling load factor, BSYM=  1.2558E+03
  Critical number of circumferential waves, NWVCRT=    8

  ***** RESULTS FOR LOAD SET NO.  1   ******
  PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)
  BEH.   CURRENT
  NO.     VALUE            DEFINITION
   1    1.000E-10   Maximum effective stress in wall of shell: STRESS(1 )
   2    1.256E+03   Symmetric buckling load factor: BSYM(1 )
   3    1.000E+10   Antisymmetric buckling load factor: BANTI(1 )
   4    1.000E+10   Fundamental modal frequency (hertz): FREQ(1 )

  MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
  MARGIN CURRENT
  NO.     VALUE            DEFINITION
   1    1.000E+00  1-(STRESS(1 )/STRSSA(1 )) X STRSSF(1 ); F.S.=  1.00
   2    4.641E-03  (BSYM(1 )/BSYMA(1 )) / BSYMF(1 )-1; F.S.=  1.25
   3    8.000E+06  (BANTI(1 )/BANTIA(1 )) / BANTIF(1 )-1; F.S.=  1.25
```

```
 ******************** DESIGN OBJECTIVE *******************
    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.      VALUE            DEFINITION
  1     4.133E+03  weight of half of cyl. shell: WEIGHT
 ******************** DESIGN OBJECTIVE *******************
 ***********  ALL 1 LOAD CASES PROCESSED ***********

   (lines omitted to save space)
===========================================================================
```

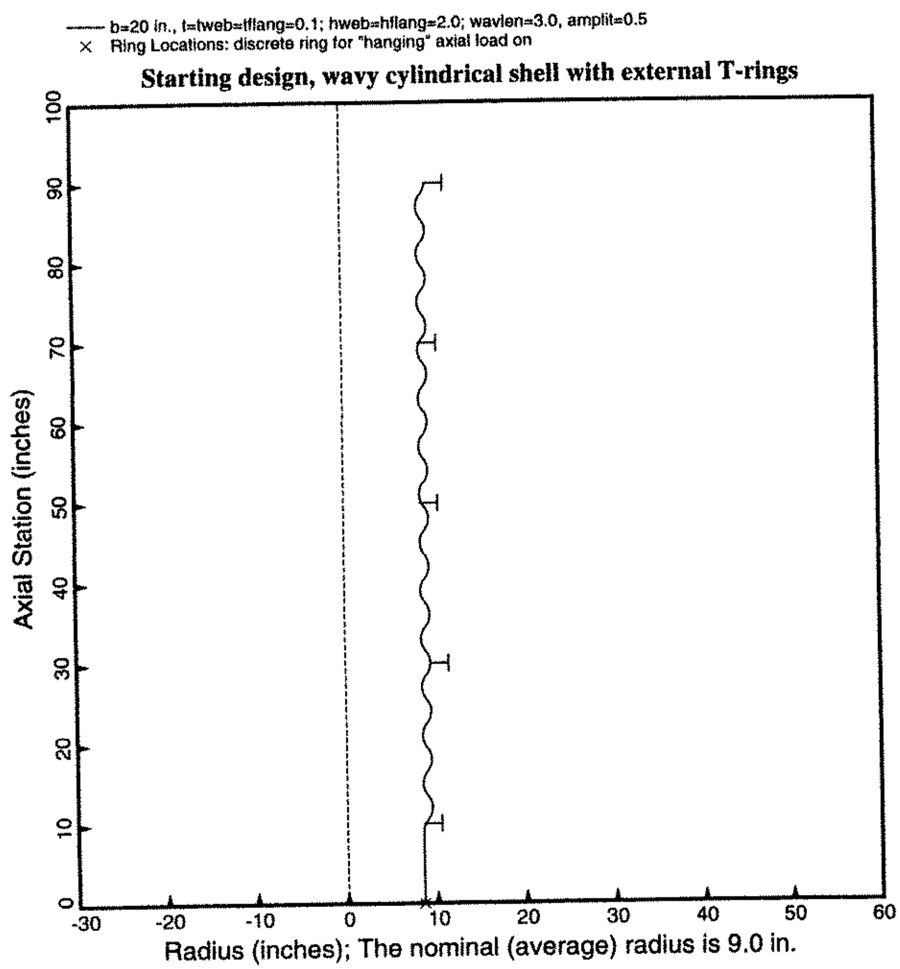
Table A.18 List of the file, cyl.DOC, produced by the "CYLINDER" system.
This file can be copied into cyl.ALL, which can then be used to run BOSOR4
and thereby obtain BOSOR4 plots for the user-selected behavior, BSYM
(buckling that is symmetric with respect to the midlength symmetry plane,
BEHX2, Fig. A.4).

```
==========================================================================
 Bifurcation buckling analysis (INDIC=1)
        1          $ INDIC = analysis type indicator
        1          $ NPRT = output options (1=minimum, 2=medium, 3=maximum)
        0          $ ISTRES= output control (0=resultants, 1=sigma, 2=epsilon)
        1          $ NSEG  = number of shell segments (less than 95)
     H             $
     H             $ SEGMENT NUMBER    1    1    1    1    1    1    1    1
     H             $ NODAL POINT DISTRIBUTION FOLLOWS...
       97          $ NMESH = number of node points (5 = min.; 98 = max.)(  1)
        3          $ NTYPEH= control integer (1 or 3) for nodal point spacing
     H             $ REFERENCE SURFACE GEOMETRY FOLLOWS...
        1          $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
  100.0000         $ R1     = radius at beginning of segment (see p. 66)
 0.0000000E+00     $ Z1     = global axial coordinate at beginning of segment
  100.0000         $ R2     = radius at end of segment
  100.0000         $ Z2     = global axial coordinate at end of segment
     H             $ IMPERFECTION SHAPE FOLLOWS...
        0          $ IMP   = indicator for imperfection (0=none, 1=some)
     H             $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
        3          $ NTYPEZ= control (1 or 3) for reference surface location
 0.3404534         $ ZVAL  = distance from leftmost surf. to reference surf.
     N             $ Do you want to print out r(s), r'(s), etc. for this segment?
     H             $ DISCRETE RING INPUT FOLLOWS...
        1          $ NRINGS= number (max=20) of discrete rings in this segment
        2          $ NTYPE = control for identification of ring location (2=z,3=r)
        0          $ Z(I)  = axial coordinate of Ith ring, z(  1)
        0          $ NTYPER= type (0 or 1 or 2 or 4 or 5) of discrete ring no.(1)
        0          $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
     H             $ LINE LOAD INPUT FOLLOWS...
        1          $ LINTYP= indicator (0, 1, 2 or 3) for type of line loads
        1          $ NLOAD(1)=indicator for axial load or disp.(0=none,1=some)
        0          $ NLOAD(2)=indicator for shear load or disp.(0=none,1=some)
        0          $ NLOAD(3)=indicator for radial load or disp.(0 or 1)
        0          $ NLOAD(4)=indicator for line moment or rotation (0 or 1)
 0.0000000E+00     $ V(i)=fixed or initial axial load or displacement, V(  1)
        1          $ NLOAD(1)=indicator for axial load or disp. increment(0 or 1)
        0          $ NLOAD(2)= should be zero
        0          $ NLOAD(3)=indicator for radial load or disp. increment(0 or 1)
        0          $ NLOAD(4)=indicator for moment or rot. increment (0 or 1)
 -1.000000         $ DV(i)=axial load or displacement increment, DV(  1)
     H             $ DISTRIBUTED LOAD INPUT FOLLOWS...
        1          $ IDISAB= indicator (0, 1, 2 or 3) for load set A and B
     H             $ SURFACE LOAD INPUT FOR LOAD SET "A" FOLLOWS
        1          $ NLTYPE=control (0,1,2,3) for type of surface loading
        2          $ NPSTAT= number of meridional callouts for surface loading
        0          $ NLOAD(1)=indicator for meridional traction (0=none, 1=some)
        0          $ NLOAD(2)=indicator for circumferential traction
        1          $ NLOAD(3)=indicator for normal pressure    (0=none, 1=some)
  1.000000         $ PN(i)   = normal pressure (p.74) at ith callout, PN(  1)
  1.000000         $ PN(i)   = normal pressure (p.74) at ith callout, PN(  2)
        2          $ NTYPE = control for meaning of loading callout (2=z, 3=r)
 0.0000000E+00     $ Z(I)  = axial coordinate of Ith loading callout, z(  1)
  100.0000         $ Z(I)  = axial coordinate of Ith loading callout, z(  2)
     H             $ SHELL WALL CONSTRUCTION FOLLOWS...
        2          $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9) for wall construction
 0.1000000E+08     $ E     = Young's modulus for skin
```

```
  0.3000000      $ U      = Poisson's ratio for skin
  0.2500000E-03 $ SM =mass density of skin (e.g. alum.=.00025 lb-sec**2/in**4)
  0.0000000E+00 $ ALPHA = coefficient of thermal expansion
      0         $ NRS  = control (0 or 1) for addition of smeared stiffeners
      0         $ NSUR   = control for thickness input (0 or 1 or -1)
    N           $ Do you want to print out ref. surf. location and thickness?
    N           $ Do you want to print out the C(i,j) at meridional stations?
    N           $ Do you want to print out distributed loads along meridian?
    H           $
    H           $ GLOBAL DATA BEGINS...
      0         $ NLAST = plot options  (-1=none, 0=geometry, 1=u,v,w)
    N           $ Are there any regions for which you want expanded plots?
      2         $ N0B   = starting number of circ. waves (buckling analysis)
      2         $ NMINB = minimum number of circ. waves  (buckling analysis)
     10         $ NMAXB = maximum number of circ. waves  (buckling analysis)
      1         $ INCRB = increment in number of circ. waves (buckling)
      1         $ NVEC  = number of eigenvalues for each wave number
  0.0000000E+00 $ P      = pressure or surface traction multiplier
 -0.2000000E-01 $ DP     = pressure or surface traction multiplier increment
  0.0000000E+00 $ TEMP   = temperature rise multiplier
  0.0000000E+00 $ DTEMP  = temperature rise multiplier increment
  0.0000000E+00 $ OMEGA  = angular vel. about axis of revolution (rad/sec)
  0.0000000E+00 $ DOMEGA = angular velocity increment (rad/sec)
    H           $ CONSTRAINT CONDITIONS FOLLOW....
      1         $ How many segments in the structure?
    H           $
    H           $ CONSTRAINT CONDITIONS FOR SEGMENT NO.    1    1    1    1
    H           $ POLES INPUT FOLLOWS...
      0         $ Number of poles (places where r=0) in SEGMENT(  1)
    H           $ INPUT FOR CONSTRAINTS TO GROUND FOLLOWS...
      2         $ At how many stations is this segment constrained to ground?
      1         $ INODE = nodal point number of constraint to ground, INODE(1)
      0         $ IUSTAR=axial displacement constraint (0 or 1 or 2)
      1         $ IVSTAR=circumferential displacement(0=free,1=0,2=imposed)
      1         $ IWSTAR=radial displacement(0=free,1=constrained,2=imposed)
      1         $ ICHI=meridional rotation (0=free,1=constrained,2=imposed)
  0.0000000E+00 $ D1     = radial component of offset of ground support
  0.0000000E+00 $ D2     = axial component of offset of ground support
    N           $ Is this constraint the same for both prebuckling and bucklng?
      1         $ IUSTARB= axial displacement for buckling or vibration phase
      1         $ IVSTARB= circ. displacement for buckling or vibration phase
      1         $ IWSTARB= radial displacement for buckling or vibration
      1         $ ICHIB  = meridional rotation for buckling or vibration
     97         $ INODE = nodal point number of constraint to ground, INODE(2)
      1         $ IUSTAR=axial displacement constraint (0 or 1 or 2)
      0         $ IVSTAR=circumferential displacement(0=free,1=0,2=imposed)
      0         $ IWSTAR=radial displacement(0=free,1=constrained,2=imposed)
      1         $ ICHI=meridional rotation (0=free,1=constrained,2=imposed)
  0.0000000E+00 $ D1     = radial component of offset of ground support
  0.0000000E+00 $ D2     = axial component of offset of ground support
    Y           $ Is this constraint the same for both prebuckling and bucklng?
    H           $ JUNCTION CONDITION INPUT FOLLOWS...
    N           $ Is this segment joined to any lower-numbered segments?
    H           $ RIGID BODY CONSTRAINT INPUT FOLLOWS...
    N           $ Given existing constraints, are rigid body modes possible?
    H           $ "GLOBAL3" QUESTIONS (AT END OF CASE)...
    Y           $ Do you want to list output for segment(  1)
    Y           $ Do you want to list forces in the discrete rings, if any?
===============================================================================
```

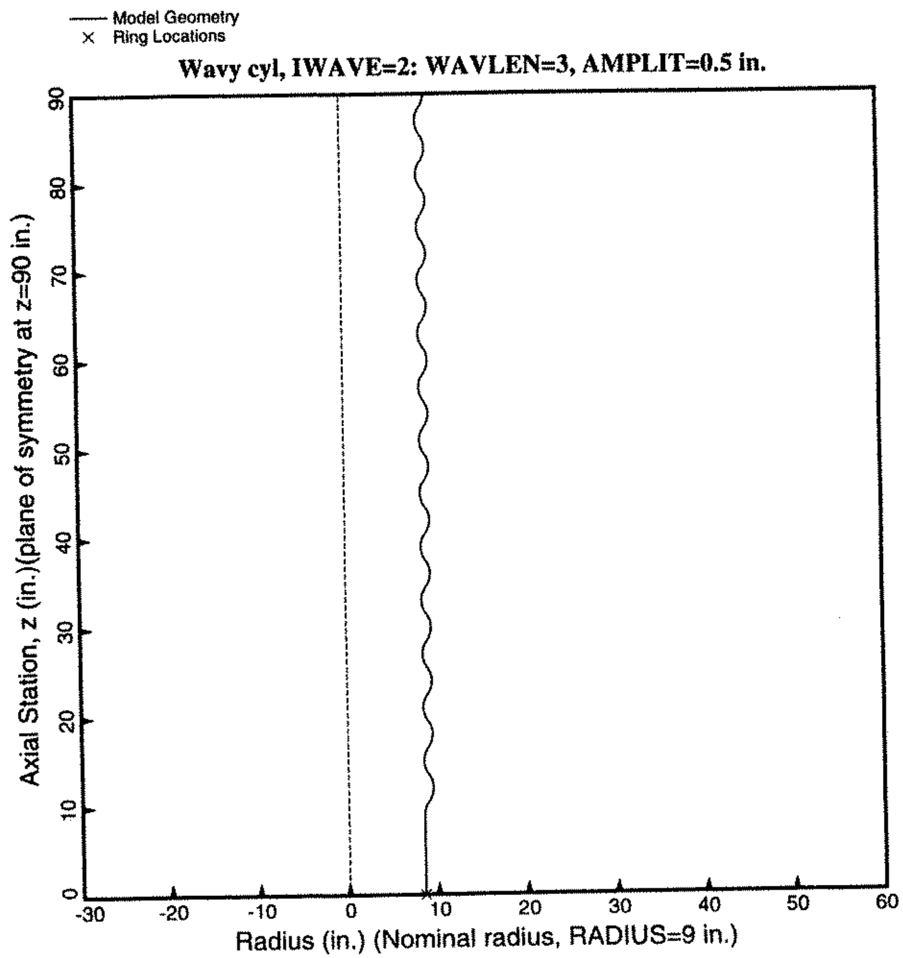
Table A.19 Input (cyl.OPT) for MAINSETUP/OPTIMIZE for design sensitivity run

```
==============================================================================
     N          $ Do you want a tutorial session and tutorial output?
        0       $ Choose an analysis you DON'T want (1, 2,..), IBEHAV
        0       $ NPRINT= output index (0=GOOD, 1=ok, 2=debug, 3=too much)
        3       $ Choose type of analysis (1=opt., 2=fixed, 3=sensit.) ITYPE
        1       $ Choose a design variable (1, 2, 3, ...), IBVAR
  0.4000000     $ Starting value of the design parameter, VARBEG
   1.000000     $ Ending value of the design parameter, VAREND
     y          $ Do you want to use the default for the number of steps?
==============================================================================
```



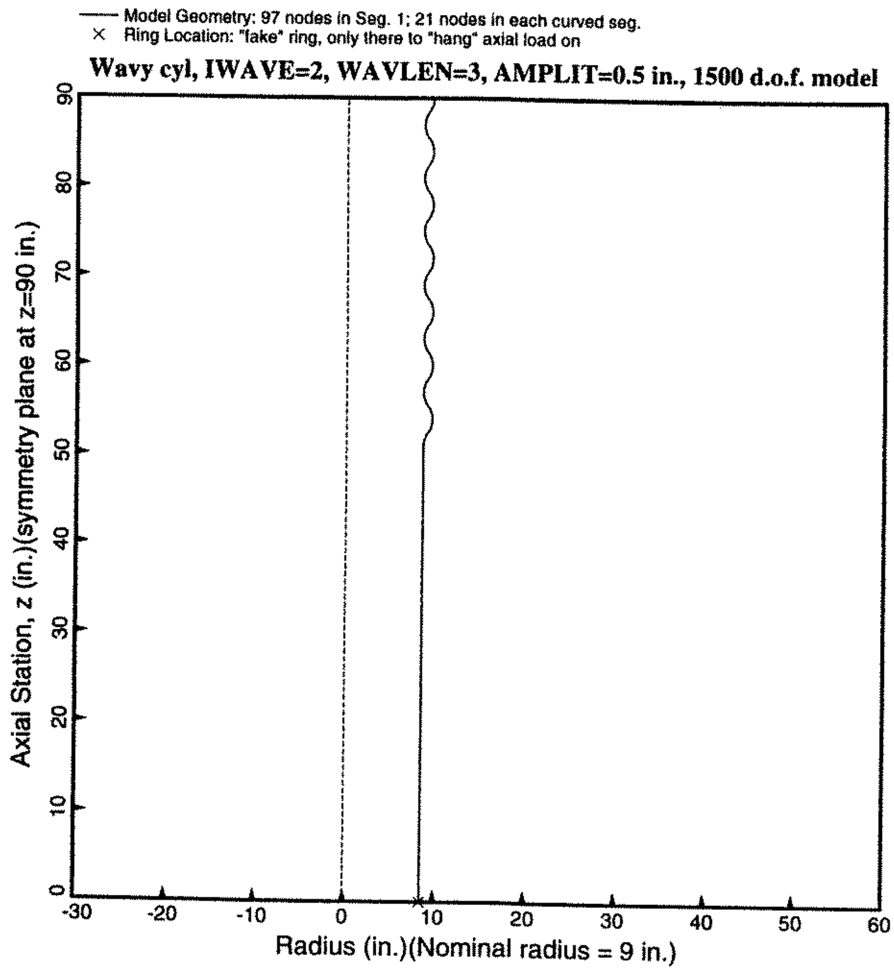
b=20 in., t=tweb=tflang=0.1; hweb=hflang=2.0; wavlen=3.0, amplit=0.5
Ring Locations: discrete ring for "hanging" axial load on
Starting design, wavy cylindrical shell with external T-rings
Axial Station (inches)
Radius (inches); The nominal (average) radius is 9.0 in.

FIG. 1



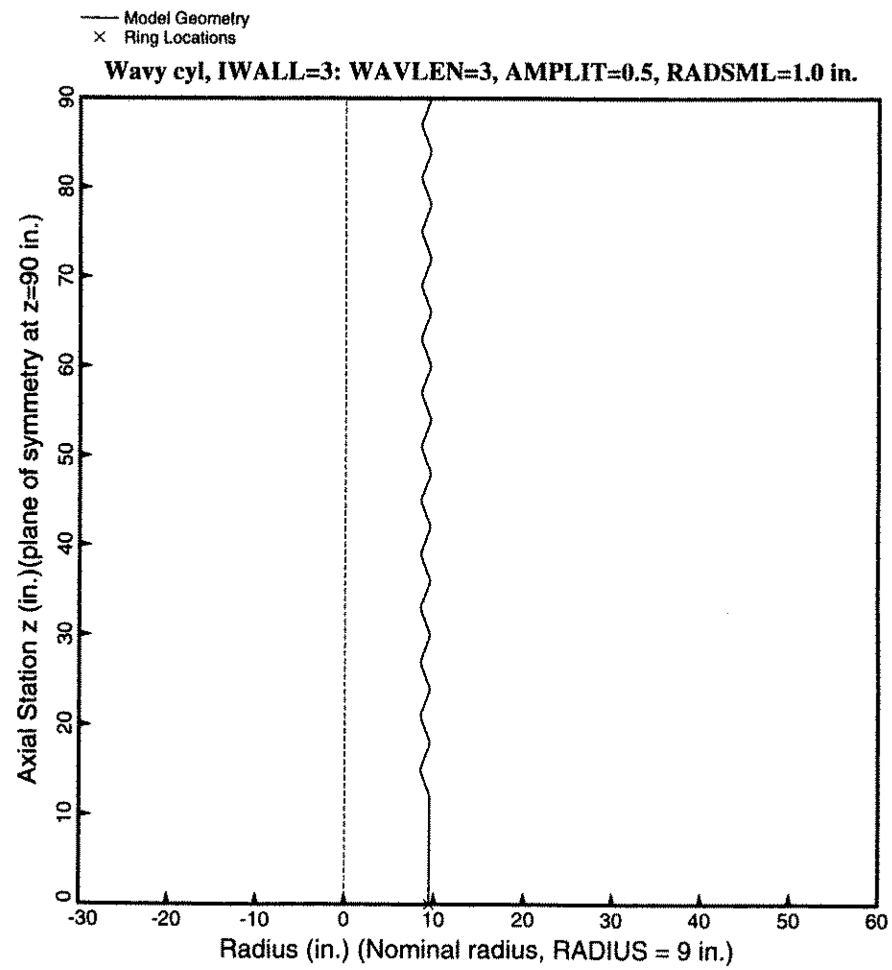
Model Geometry
Ring Locations
Wavy cyl, IWAVE=2: WAVLEN=3, AMPLIT=0.5 in.
Axial Station, z (in.)(plane of symmetry at z=90 in.)
Radius (in.) (Nominal radius, RADIUS=9 in.)

FIG. 2



Model Geometry: 97 nodes in Seg. 1; 21 nodes in each curved seg.
Ring Location: "fake" ring, only there to "hang" axial load on
Wavy cyl, IWAVE=2, WAVLEN=3, AMPLIT=0.5 in., 1500 d.o.f. model
Axial Station, z (in.)(symmetry plane at z=90 in.)
Radius (in.)(Nominal radius = 9 in.)
0
10
20
30
40
50
60
70
80
90
-30
-20
-10
0
10
20
30
40
50
60

FIG. 3



Model Geometry
Ring Locations
Wavy cyl, IWALL=3: WAVLEN=3, AMPLIT=0.5, RADSML=1.0 in.
Axial Station z (in.)(plane of symmetry at z=90 in.)
Radius (in.) (Nominal radius, RADIUS = 9 in.)
0
10
20
30
40
50
60
70
80
90
-30
-20
-10
0
10
20
30
40
50
60

FIG. 4

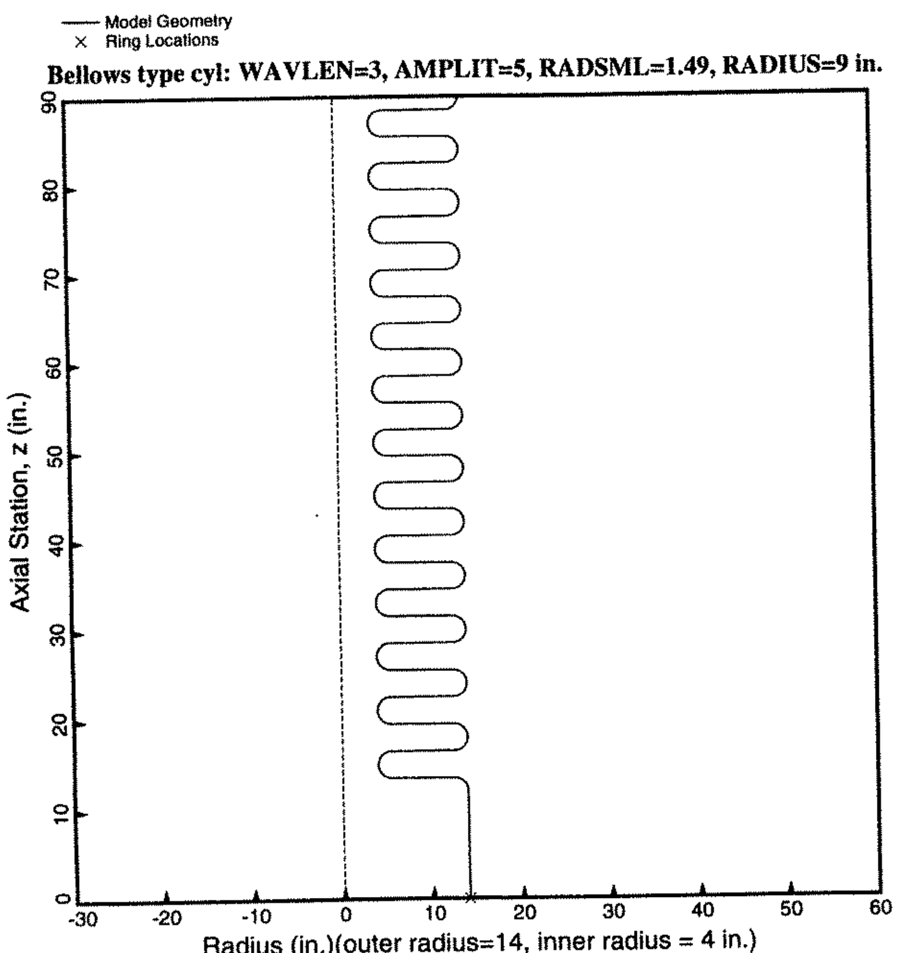

Model Geometry
Ring Locations
Bellows type cyl: WAVLEN=3, AMPLIT=5, RADSML=1.49, RADIUS=9 in.
Axial Station, z (in.)
Radius (in.)(outer radius=14, inner radius = 4 in.)

FIG. 5

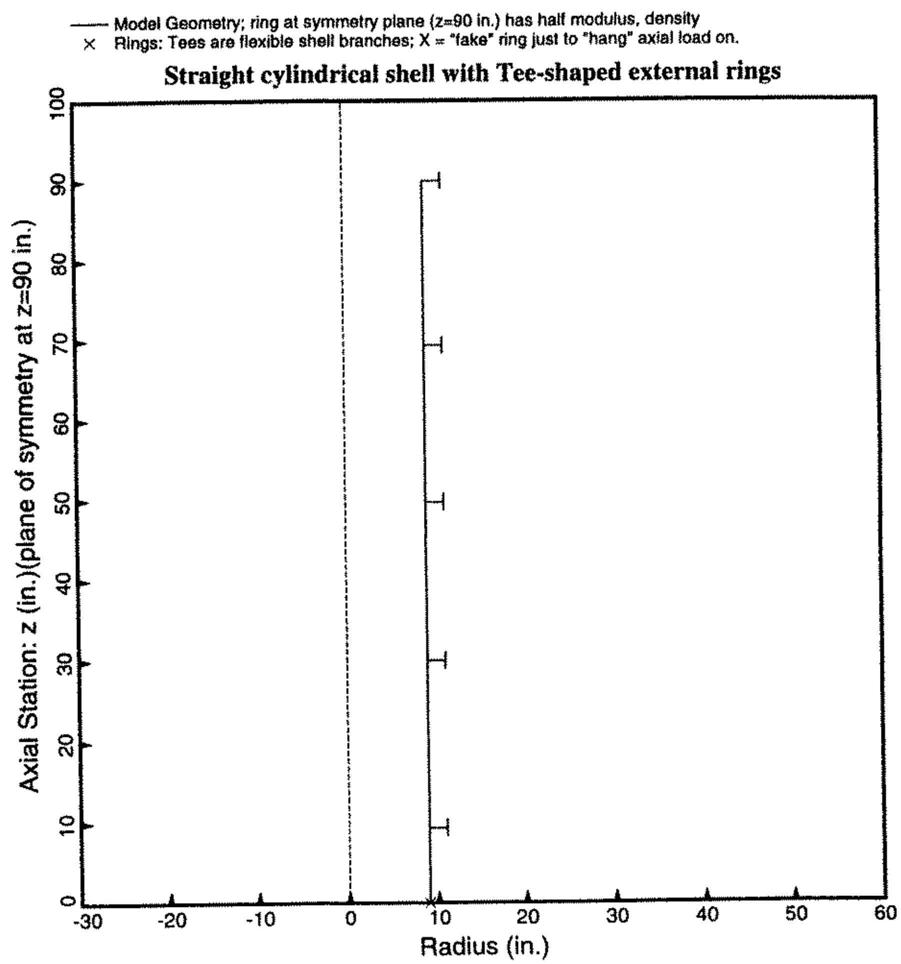
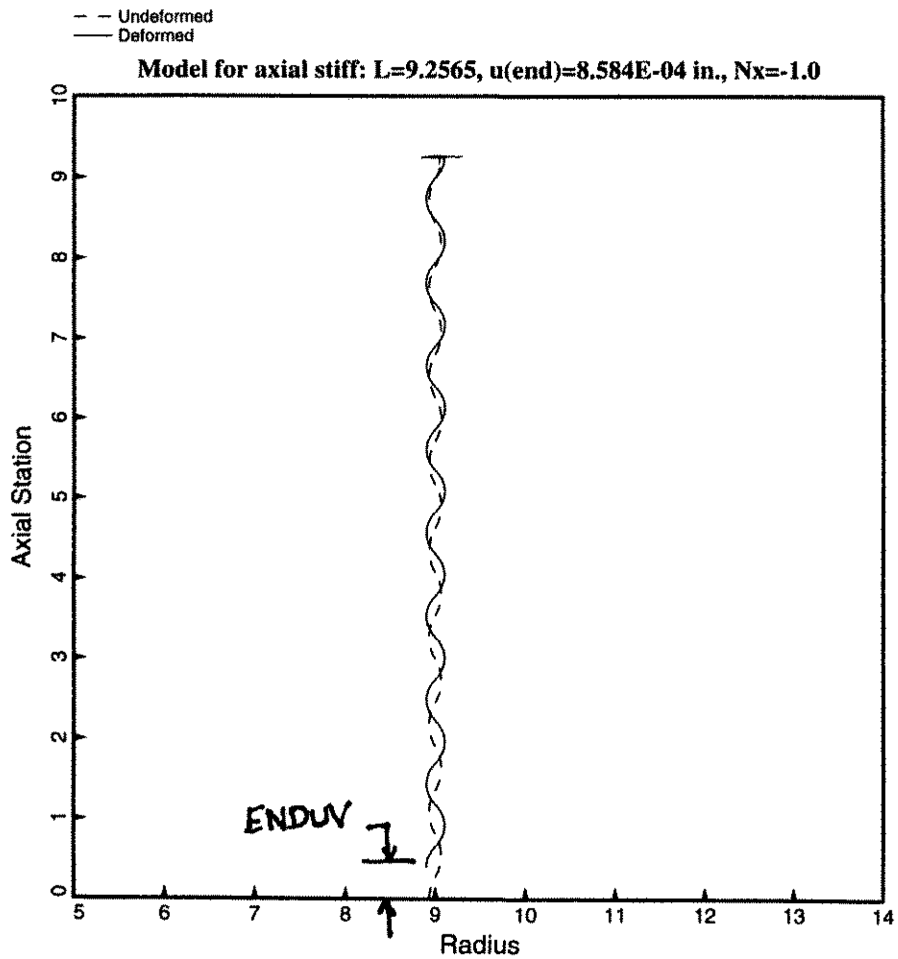
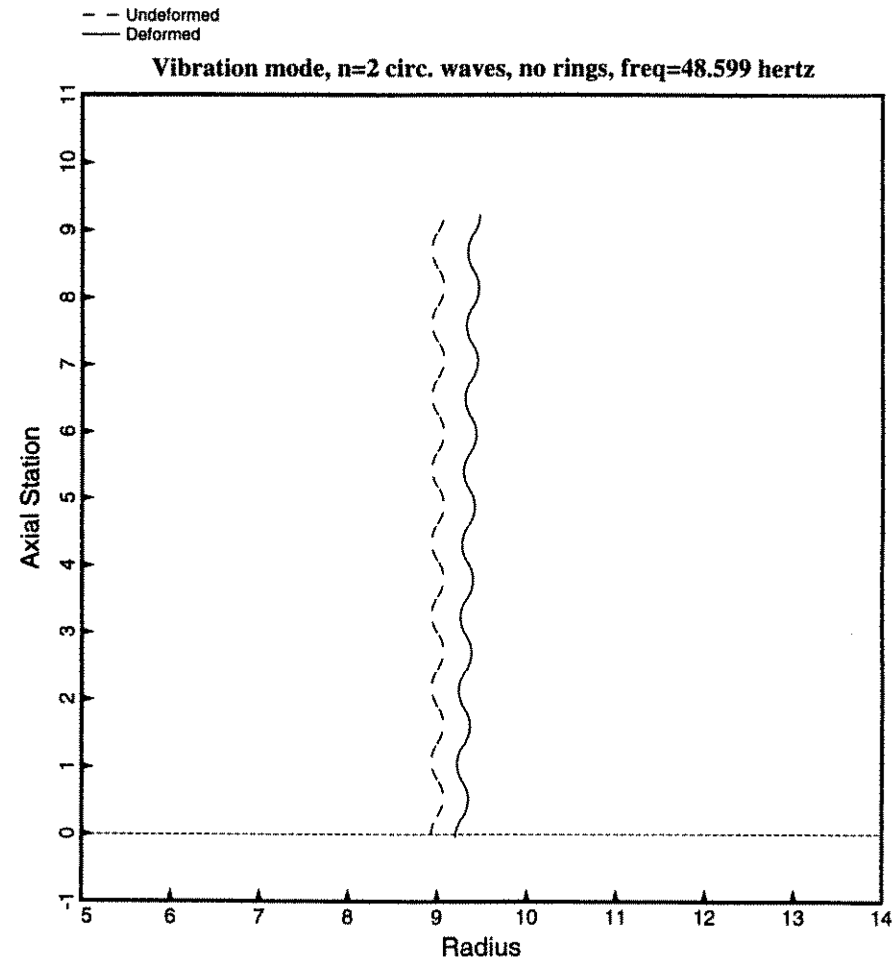

Model Geometry; ring at symmetry plane (z=90 in.) has half modulus, density
Rings: Tees are flexible shell branches; X = "fake" ring just to "hang" axial load on.
Straight cylindrical shell with Tee-shaped external rings
Axial Station: z (in.)(plane of symmetry at z=90 in.)
Radius (in.)

FIG. 6



Undeformed
Deformed
Model for axial stiff: L=9.2565, u(end)=8.584E-04 in., Nx=-1.0
Axial Station
Radius
ENDUV

FIG. 7



Undeformed
Deformed
Vibration mode, n=2 circ. waves, no rings, freq=48.599 hertz
Axial Station
Radius

FIG. 8

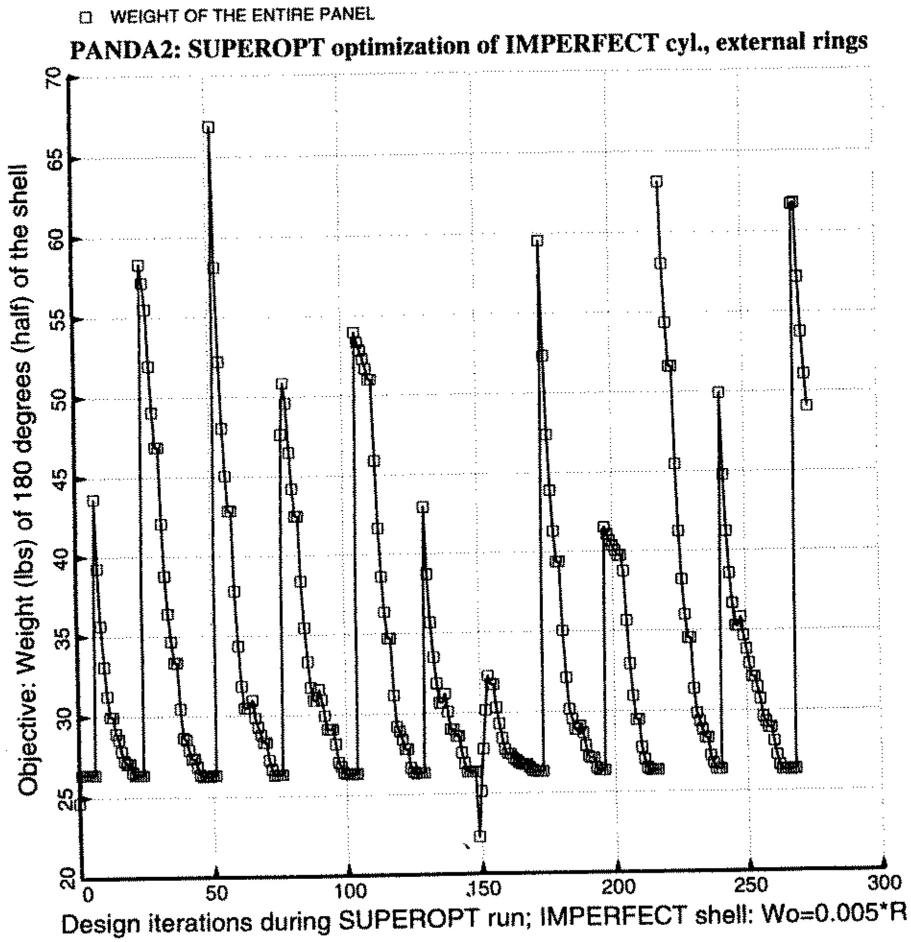

WEIGHT OF THE ENTIRE PANEL
PANDA2: SUPEROPT optimization of IMPERFECT cyl., external rings
Objective: Weight (lbs) of 180 degrees (half) of the shell
Design iterations during SUPEROPT run; IMPERFECT shell: Wo=0.005*R

FIG. 9

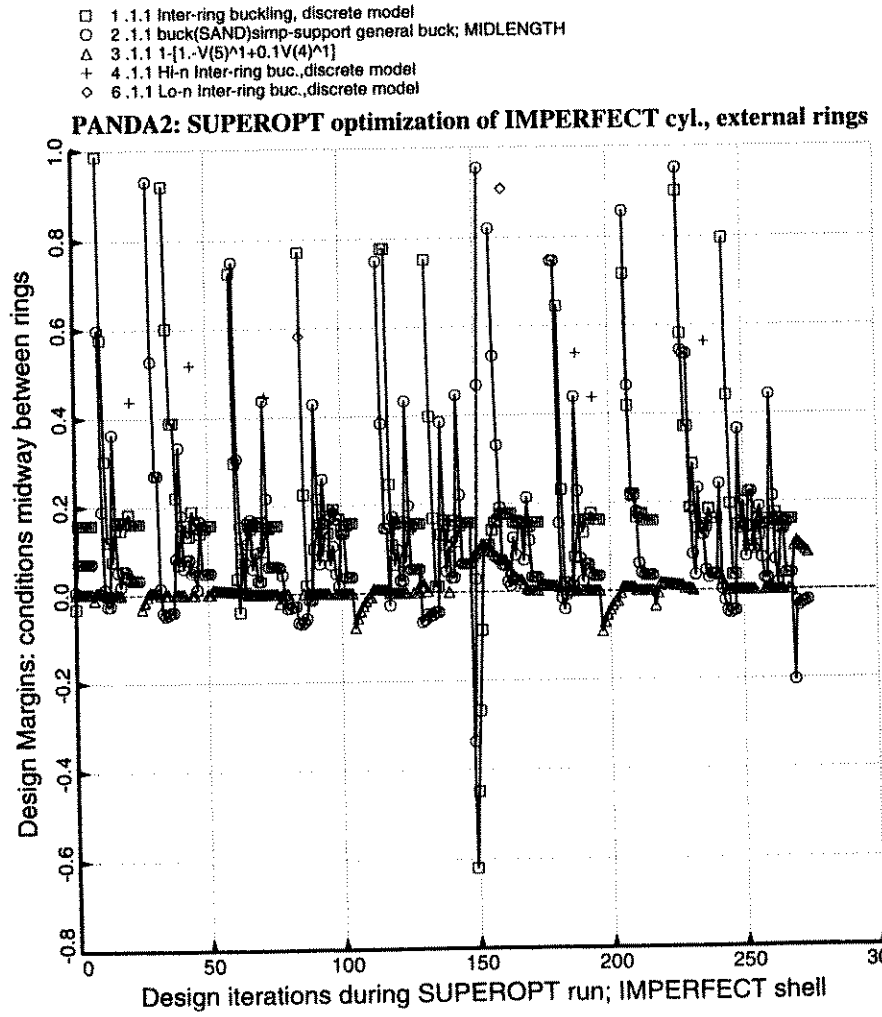

1 .1.1 Inter-ring buckling, discrete model
2 .1.1 buck(SAND)simp-support general buck; MIDLENGTH
3 .1.1 1-[1.-V(5)^1+0.1V(4)^1]
4 .1.1 Hi-n Inter-ring buc.,discrete model
6 .1.1 Lo-n Inter-ring buc.,discrete model
PANDA2: SUPEROPT optimization of IMPERFECT cyl., external rings
Design Margins: conditions midway between rings
Design iterations during SUPEROPT run; IMPERFECT shell

FIG. 10

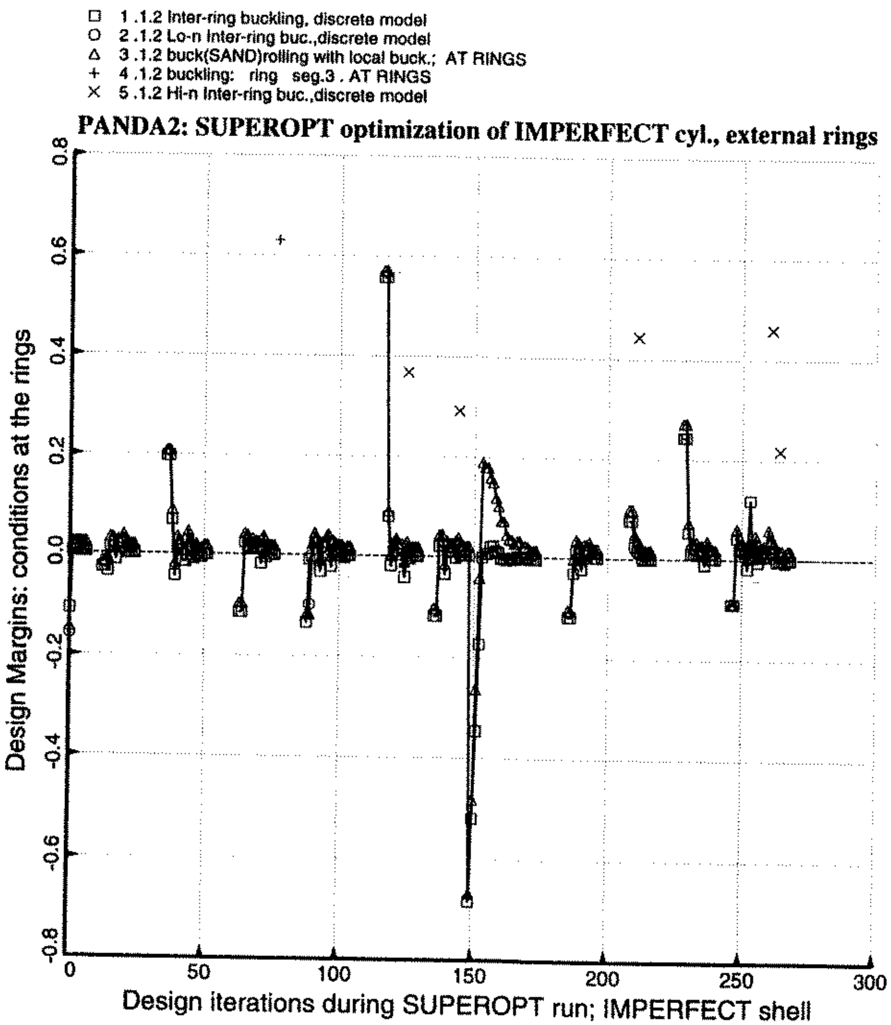

1 .1.2 Inter-ring buckling, discrete model
2 .1.2 Lo-n Inter-ring buc.,discrete model
3 .1.2 buck(SAND)rolling with local buck.; AT RINGS
4 .1.2 buckling: ring seg.3 . AT RINGS
5 .1.2 Hi-n Inter-ring buc.,discrete model
PANDA2: SUPEROPT optimization of IMPERFECT cyl., external rings
Design Margins: conditions at the rings
Design iterations during SUPEROPT run; IMPERFECT shell
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
0
50
100
150
200
250
300
11

FIG. 11

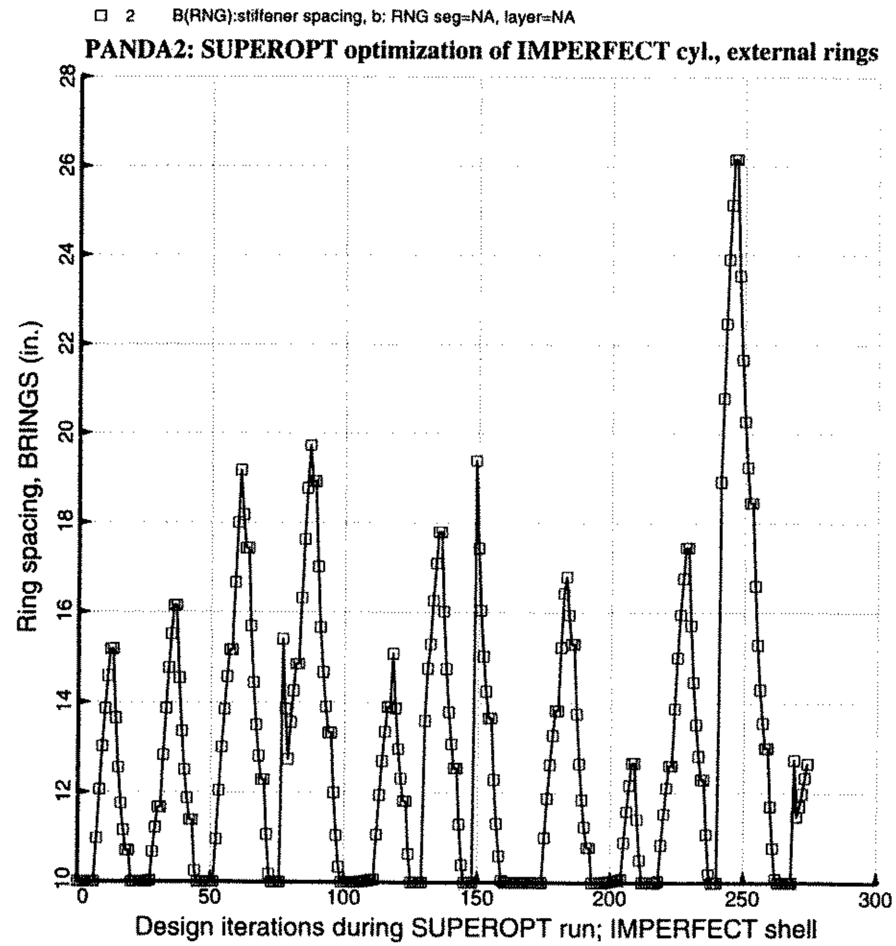
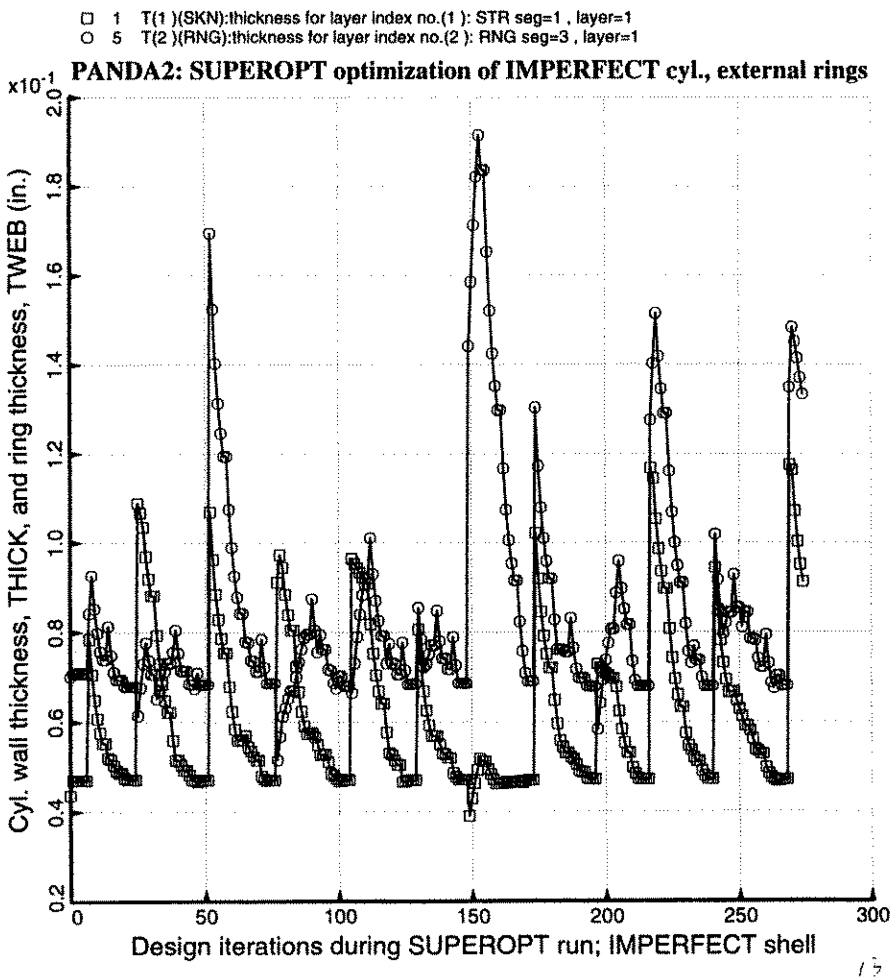
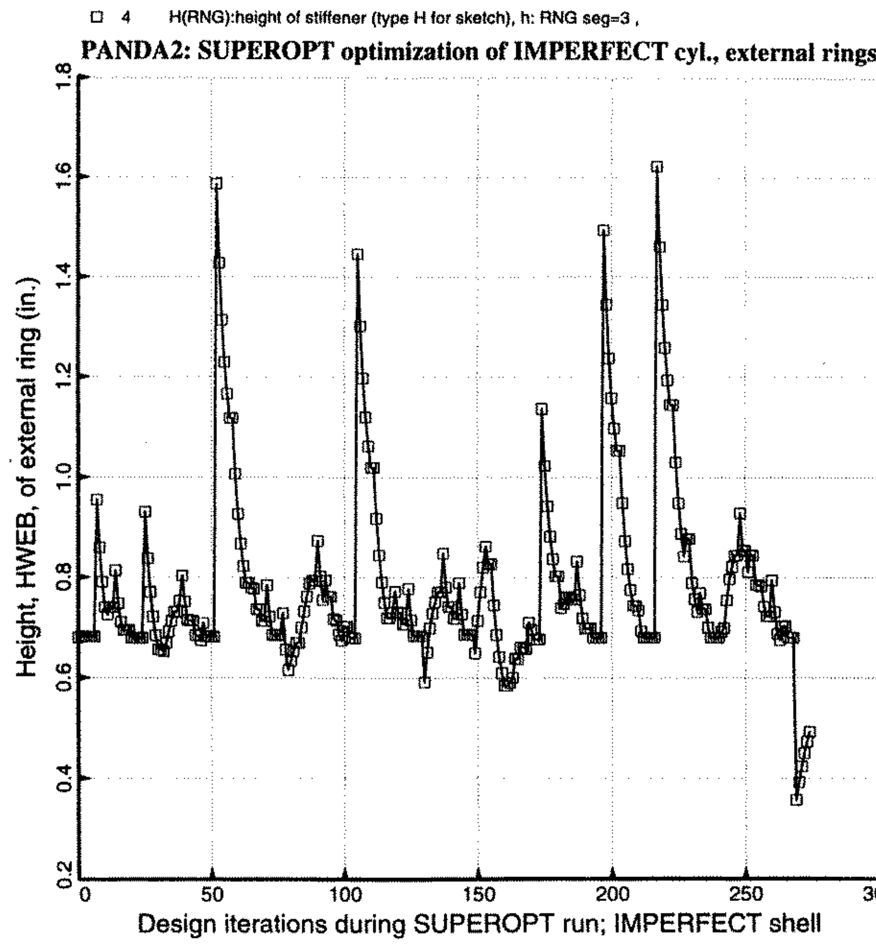

2 B(RNG):stiffener spacing, b: RNG seg=NA, layer=NA
PANDA2: SUPEROPT optimization of IMPERFECT cyl., external rings
Ring spacing, BRINGS (in.)
Design iterations during SUPEROPT run; IMPERFECT shell
28
26
24
22
20
18
16
14
12
10
0
50
100
150
200
250
300
12

FIG. 12



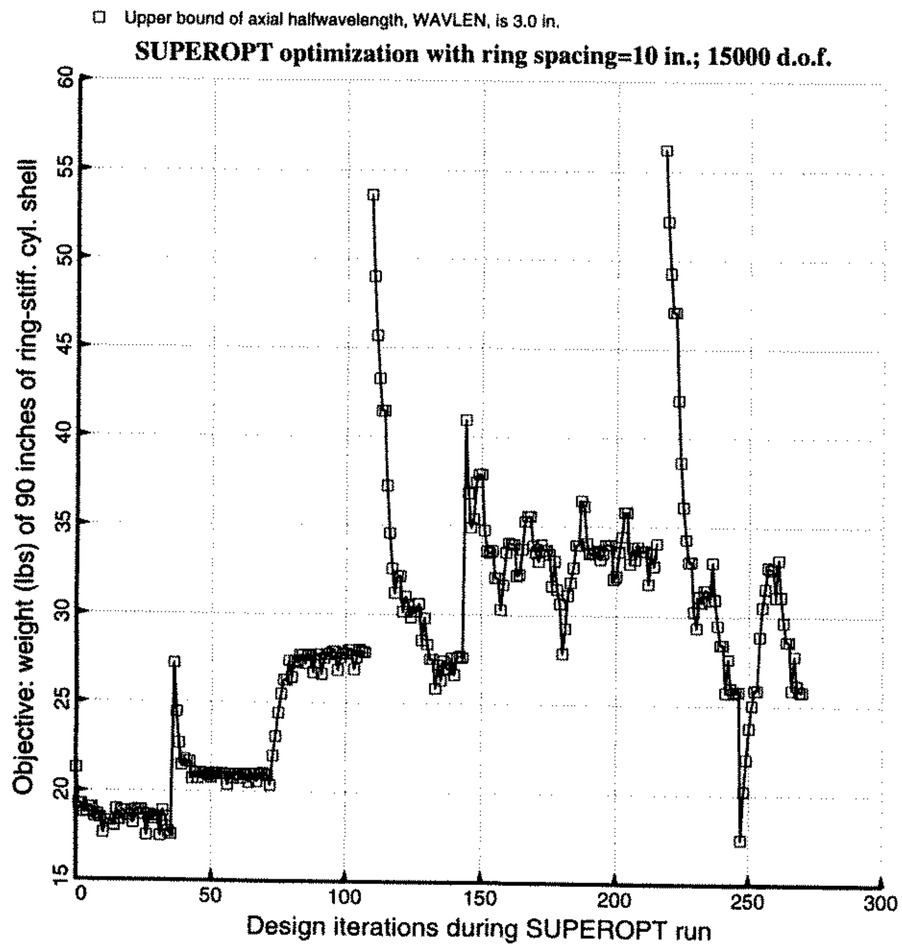
□ 1 T(1)(SKN):thickness for layer index no.(1): STR seg=1 , layer=1
○ 5 T(2)(RNG):thickness for layer index no.(2): RNG seg=3 , layer=1
PANDA2: SUPEROPT optimization of IMPERFECT cyl., external rings
x10⁻¹
Cyl. wall thickness, THICK, and ring thickness, TWEB (in.)
Design iterations during SUPEROPT run; IMPERFECT shell

FIG. 13



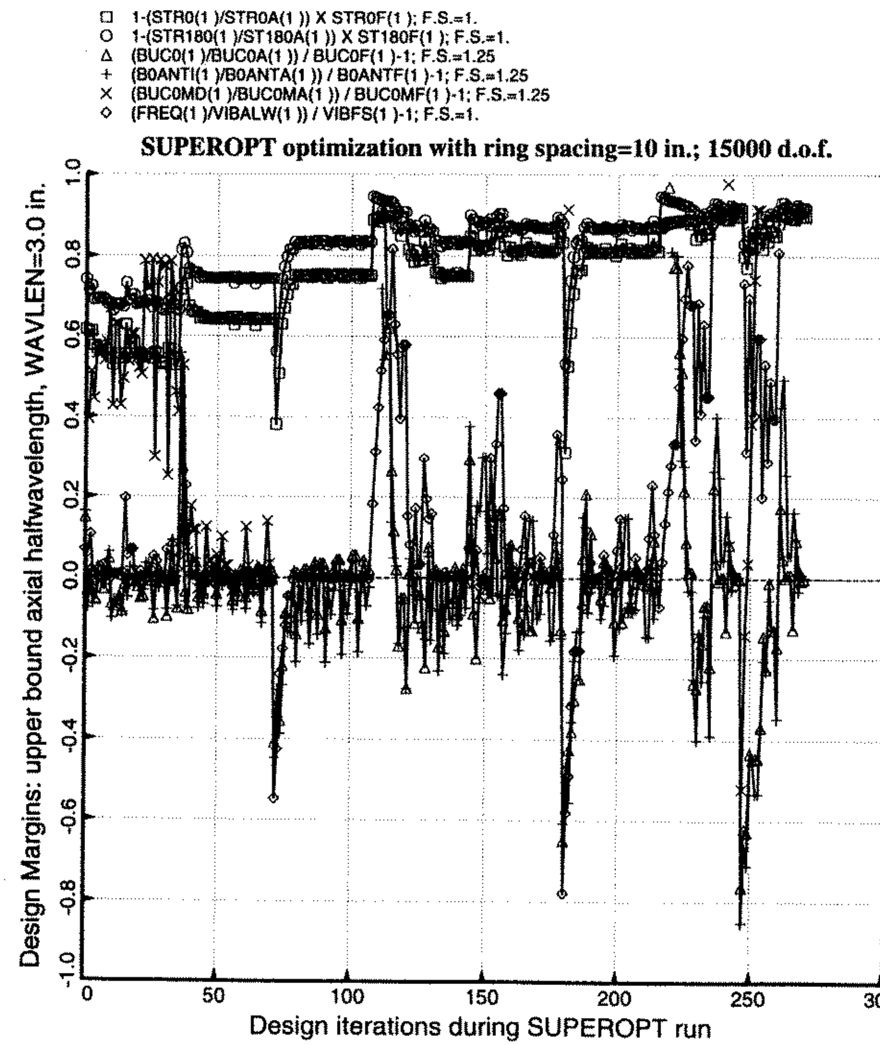
□ 4 H(RNG):height of stiffener (type H for sketch), h: RNG seg=3 ,
PANDA2: SUPEROPT optimization of IMPERFECT cyl., external rings
Height, HWEB, of external ring (in.)
Design iterations during SUPEROPT run; IMPERFECT shell

FIG. 14



Upper bound of axial halfwavelength, WAVLEN, is 3.0 in.
SUPEROPT optimization with ring spacing=10 in.; 15000 d.o.f.
Objective: weight (lbs) of 90 inches of ring-stiff. cyl. shell
Design iterations during SUPEROPT run

FIG. 15



1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.=1.
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.=1.
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.=1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.=1.25
(BUC0MD(1)/BUC0MA(1)) / BUC0MF(1)-1; F.S.=1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.=1.
SUPEROPT optimization with ring spacing=10 in.; 15000 d.o.f.
Design Margins: upper bound axial halfwavelength, WAVLEN=3.0 in.
Design iterations during SUPEROPT run

FIG. 16

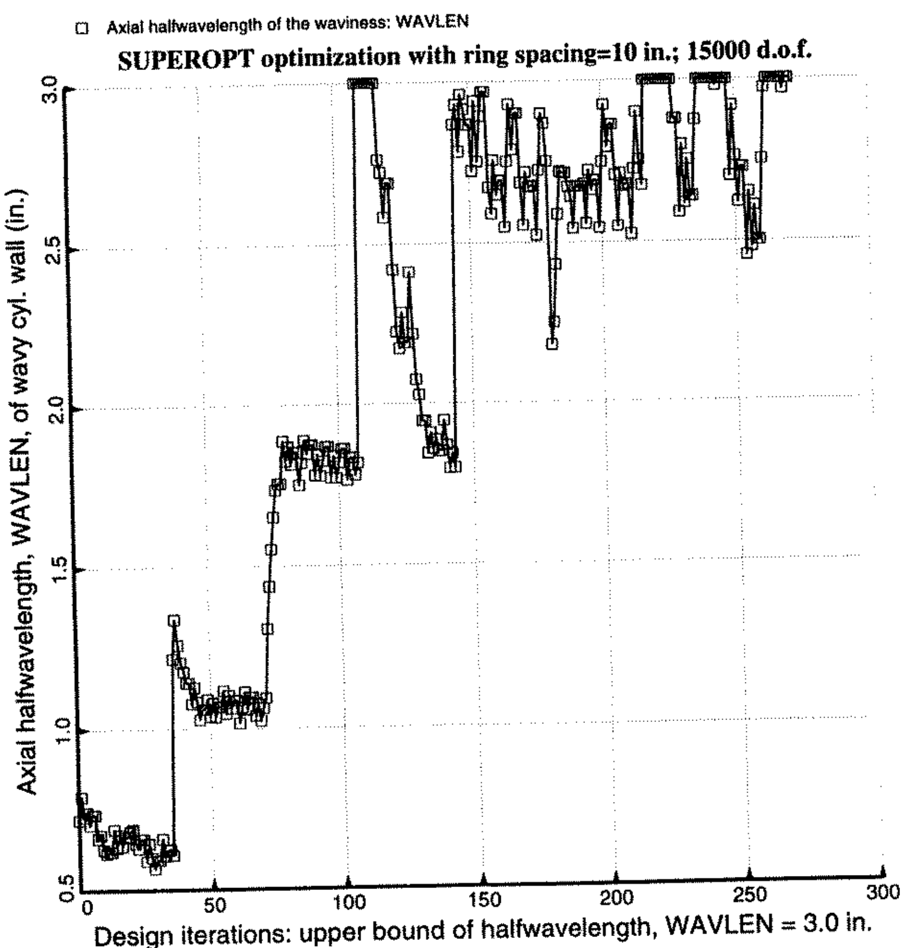

Axial halfwavelength of the waviness: WAVLEN
SUPEROPT optimization with ring spacing=10 in.; 15000 d.o.f.
Axial halfwavelength, WAVLEN, of wavy cyl. wall (in.)
0.5
1.0
1.5
2.0
2.5
3.0
0
50
100
150
200
250
300
Design iterations: upper bound of halfwavelength, WAVLEN = 3.0 in.

FIG. 17

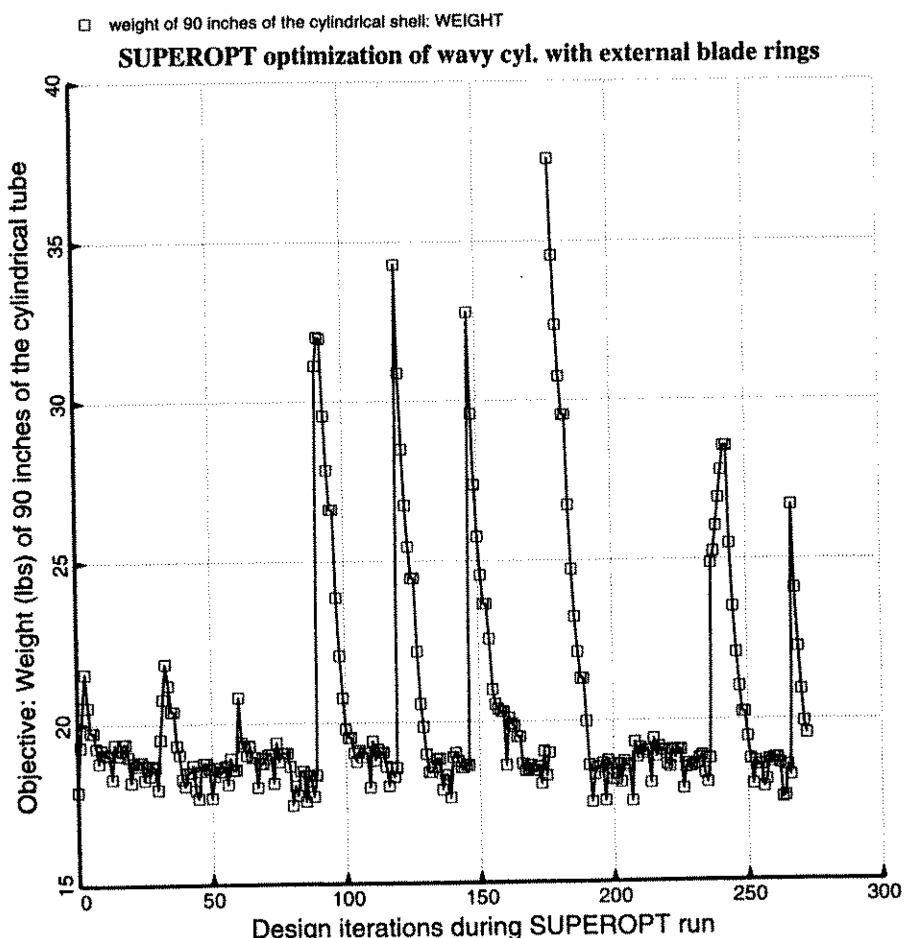

weight of 90 inches of the cylindrical shell: WEIGHT
SUPEROPT optimization of wavy cyl. with external blade rings
Objective: Weight (lbs) of 90 inches of the cylindrical tube
15
20
25
30
35
40
0
50
100
150
200
250
300
Design iterations during SUPEROPT run

FIG. 18

WAVLENUpper bnd = 0.8

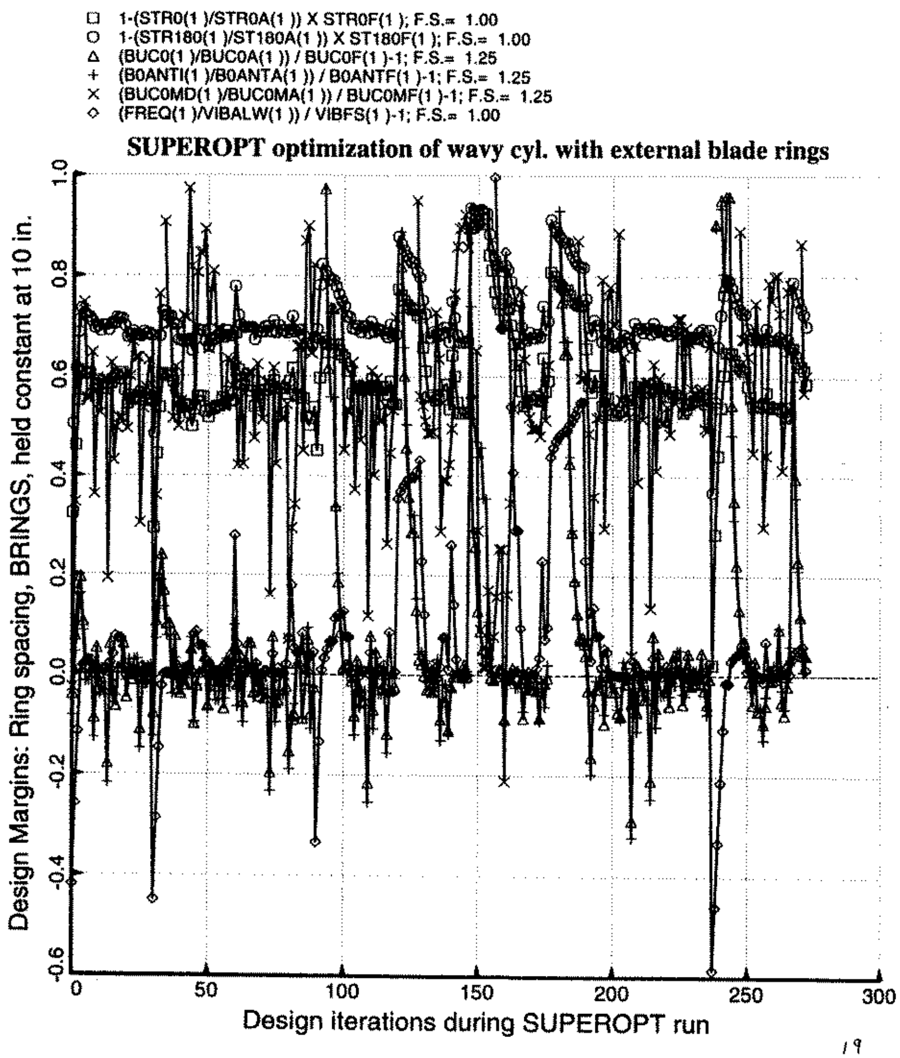


FIG. 19

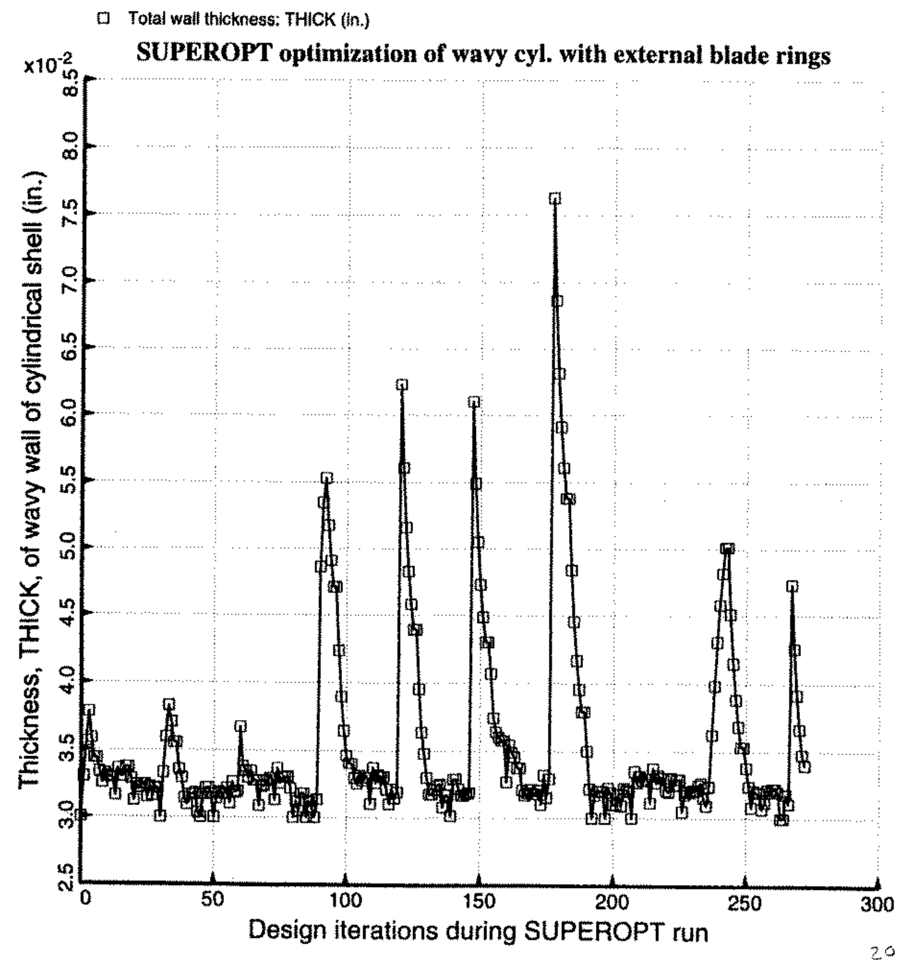
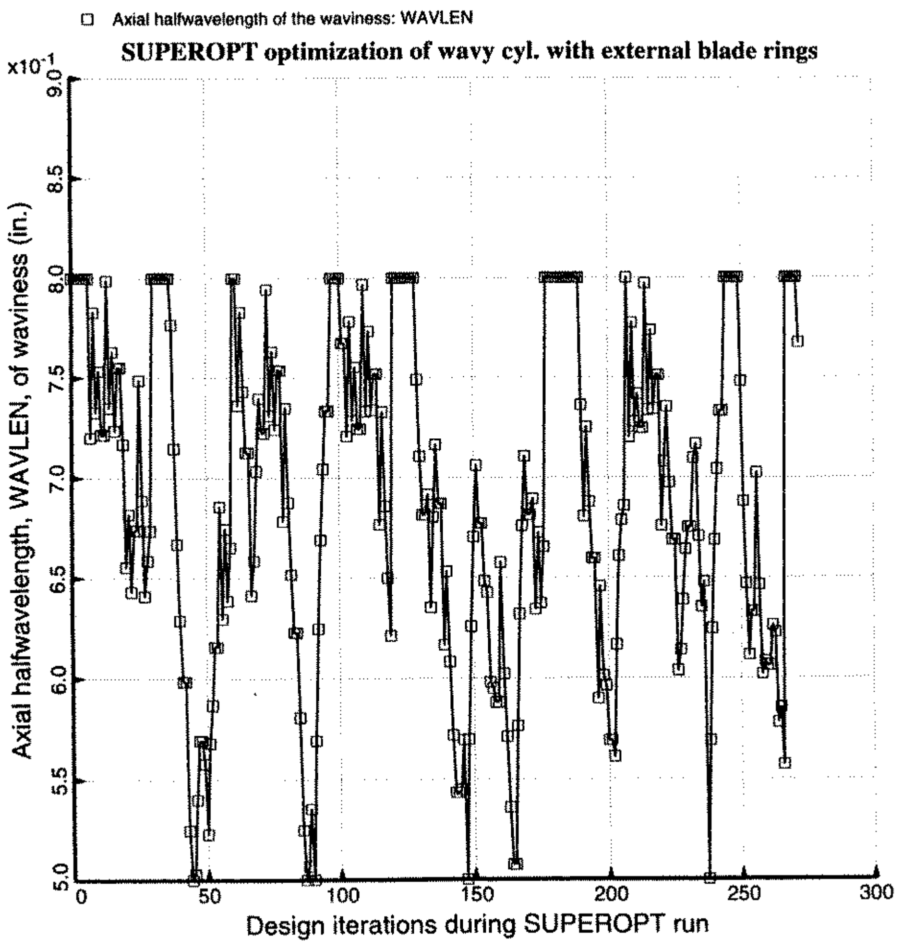
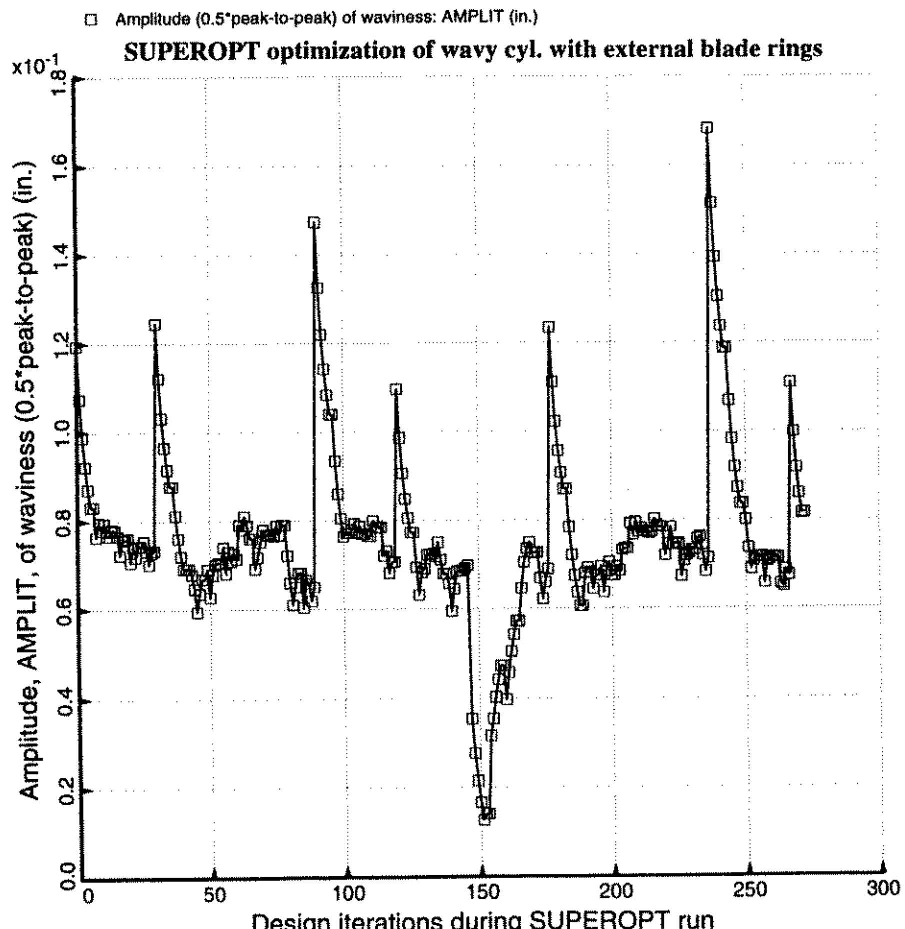


FIG. 20



Axial halfwavelength of the waviness: WAVLEN
SUPEROPT optimization of wavy cyl. with external blade rings
x10^-1
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Axial halfwavelength, WAVLEN, of waviness (in.)
0
50
100
150
200
250
300
Design iterations during SUPEROPT run

FIG. 21



Amplitude (0.5*peak-to-peak) of waviness: AMPLIT (in.)
SUPEROPT optimization of wavy cyl. with external blade rings
x10^-1
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Amplitude, AMPLIT, of waviness (0.5*peak-to-peak) (in.)
0
50
100
150
200
250
300
Design iterations during SUPEROPT run

FIG. 22

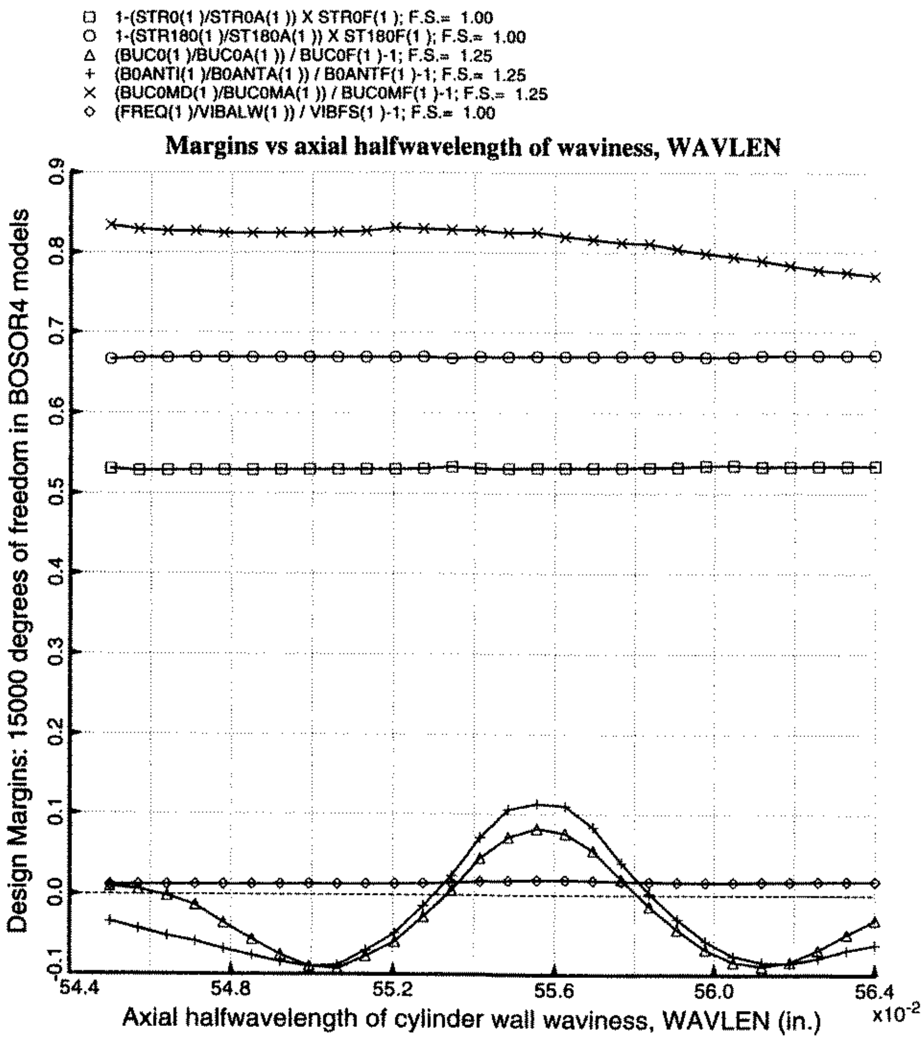

1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
(BUC0MD(1)/BUC0MA(1)) / BUC0MF(1)-1; F.S.= 1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
Margins vs axial halfwavelength of waviness, WAVLEN
Design Margins: 15000 degrees of freedom in BOSOR4 models
Axial halfwavelength of cylinder wall waviness, WAVLEN (in.)
x10-2

FIG. 23

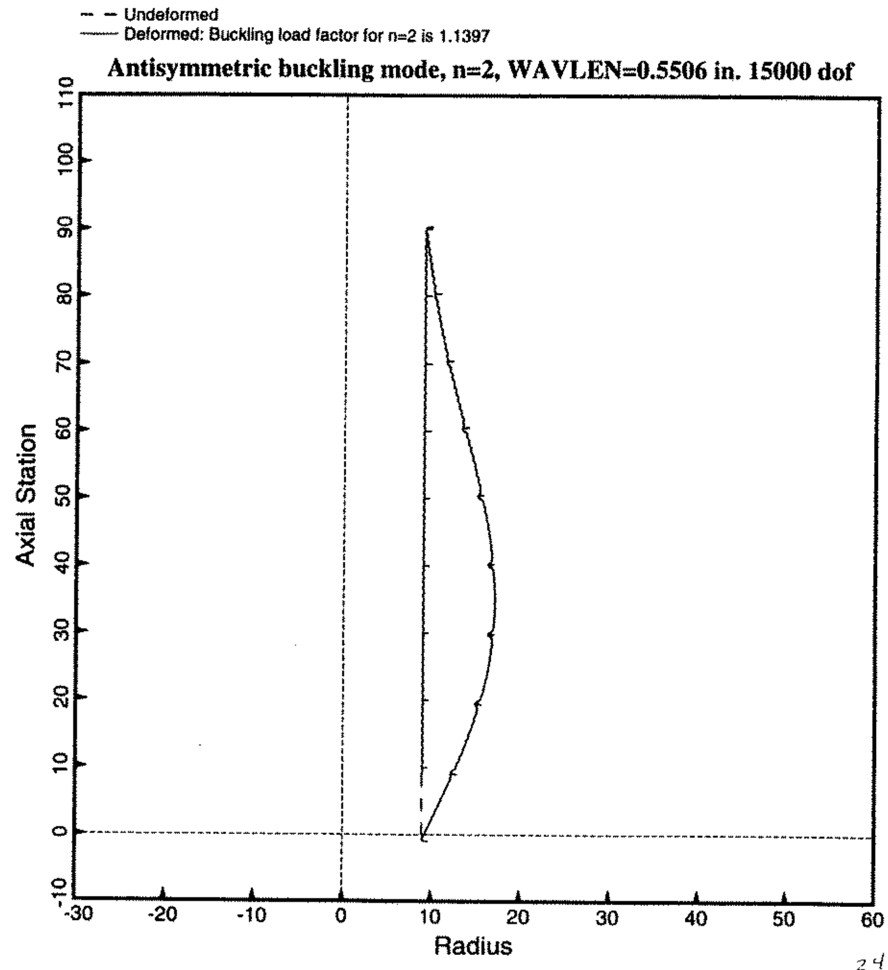

Undeformed
Deformed: Buckling load factor for n=2 is 1.1397
Antisymmetric buckling mode, n=2, WAVLEN=0.5506 in. 15000 dof
Axial Station
Radius
24

FIG. 24

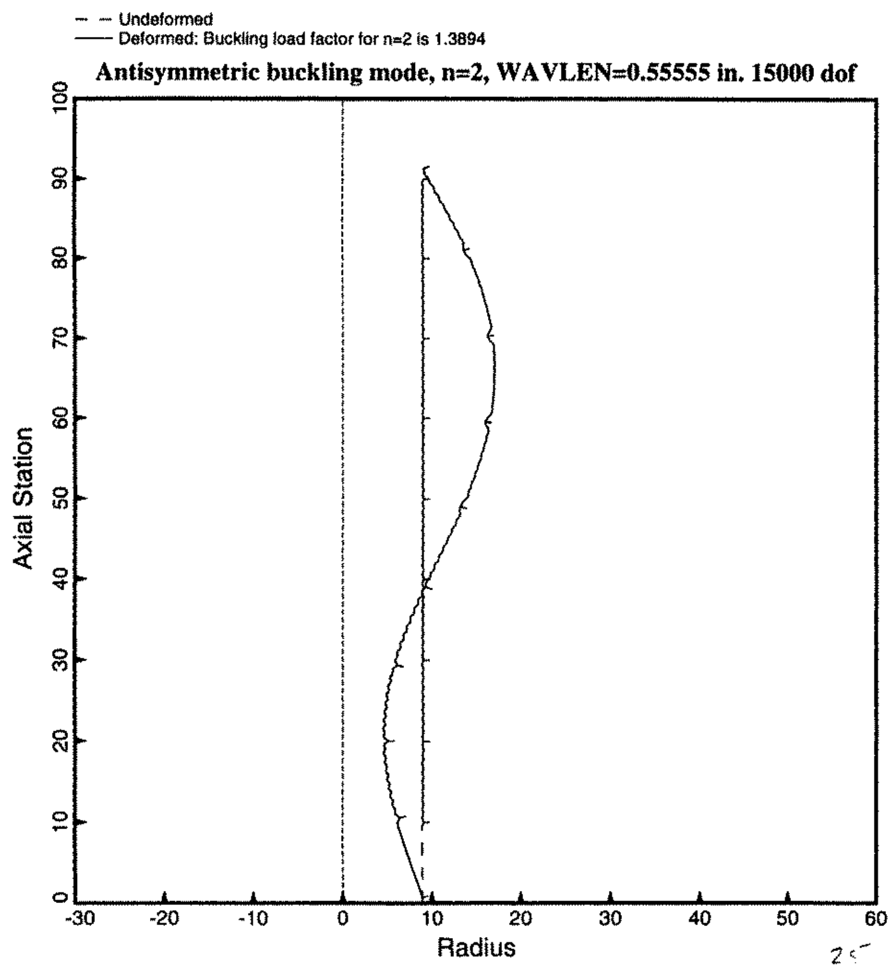


FIG. 25

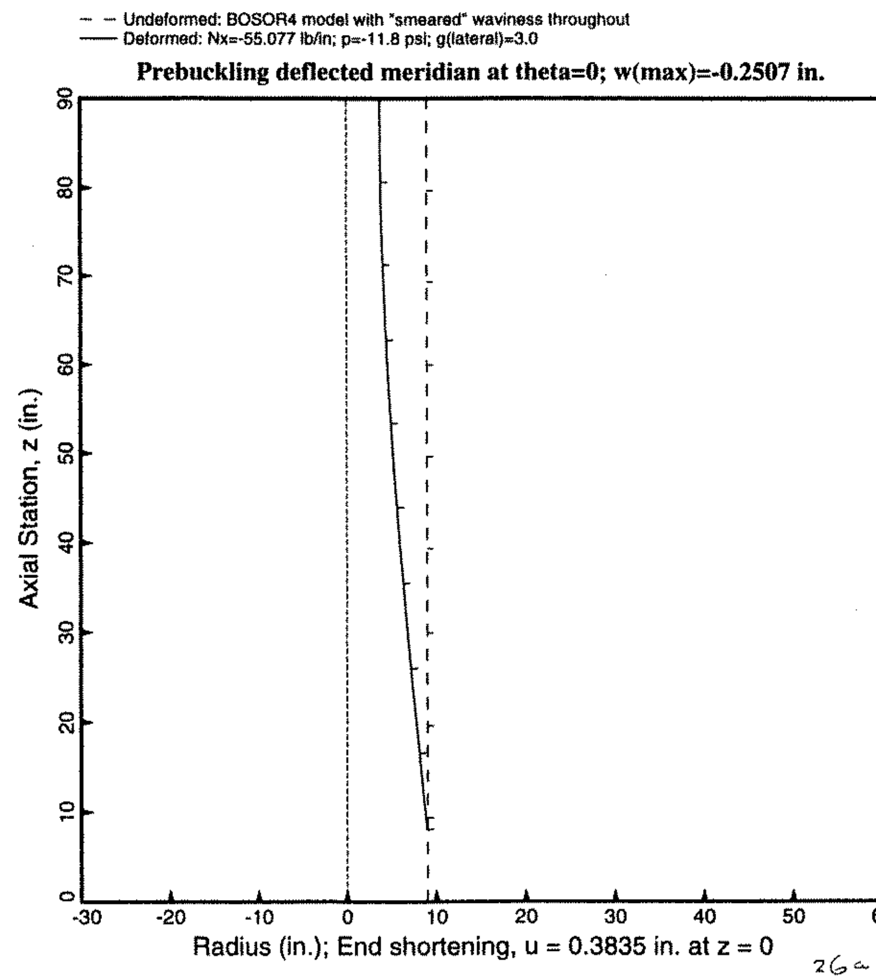


FIG. 26a

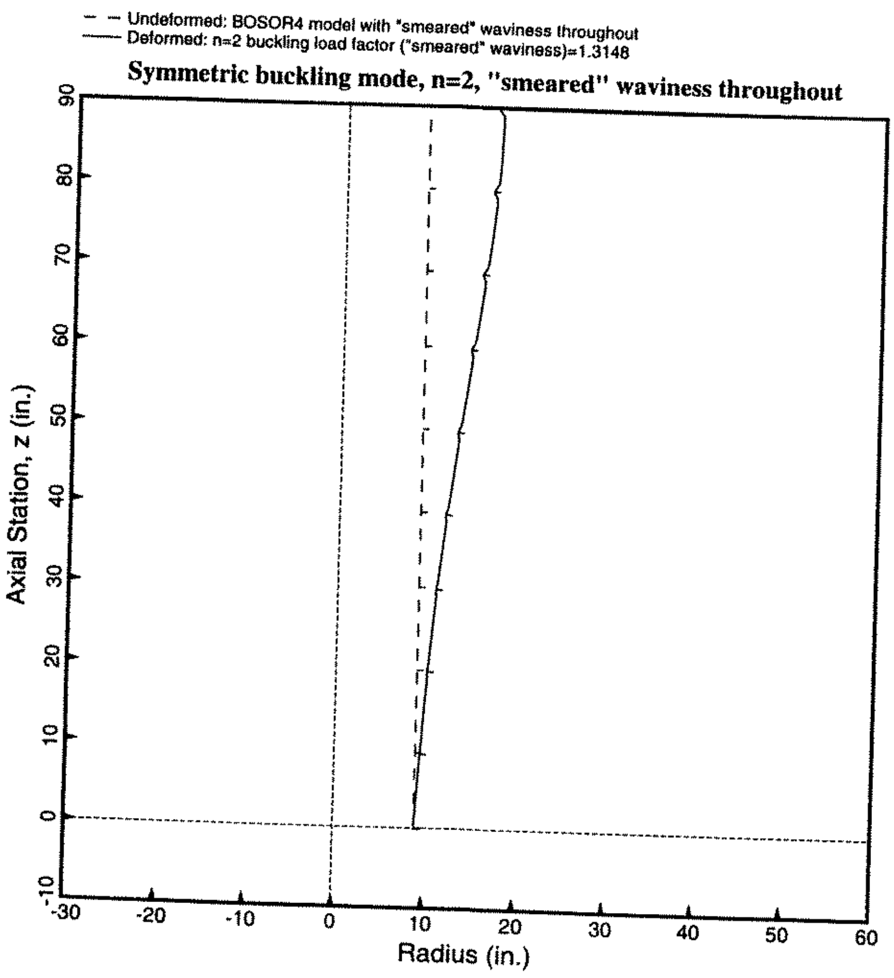


FIG. 26b

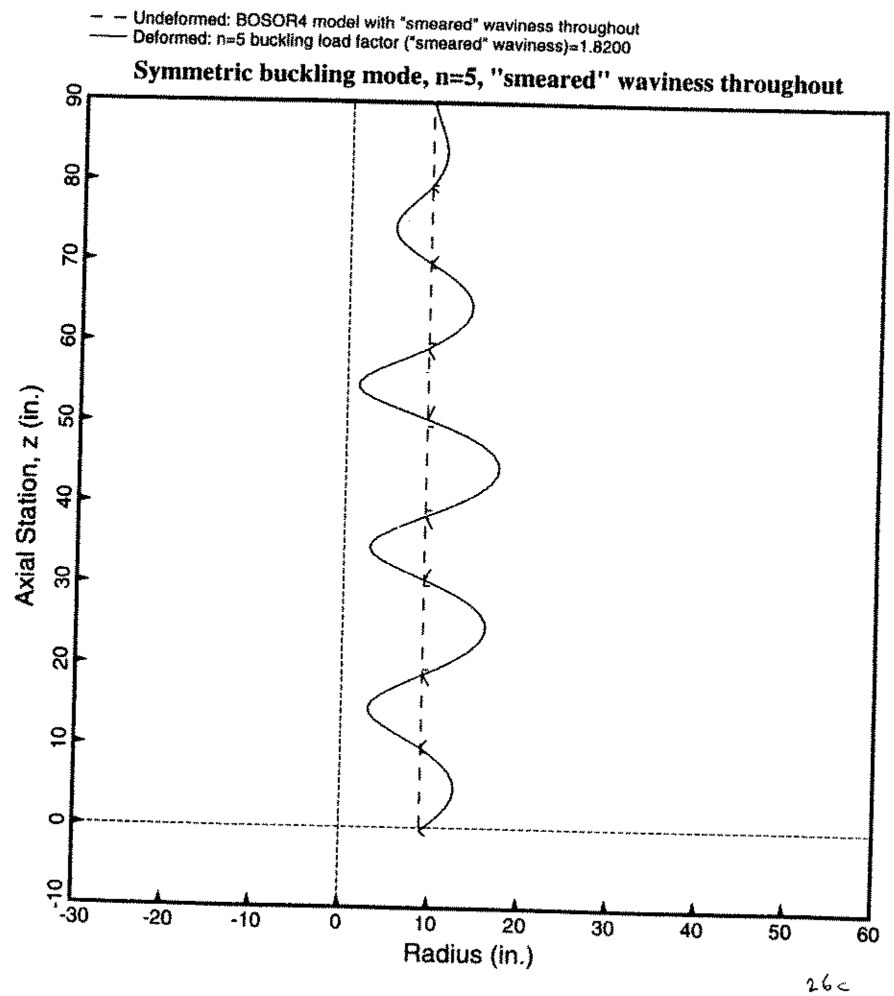


FIG. 26c

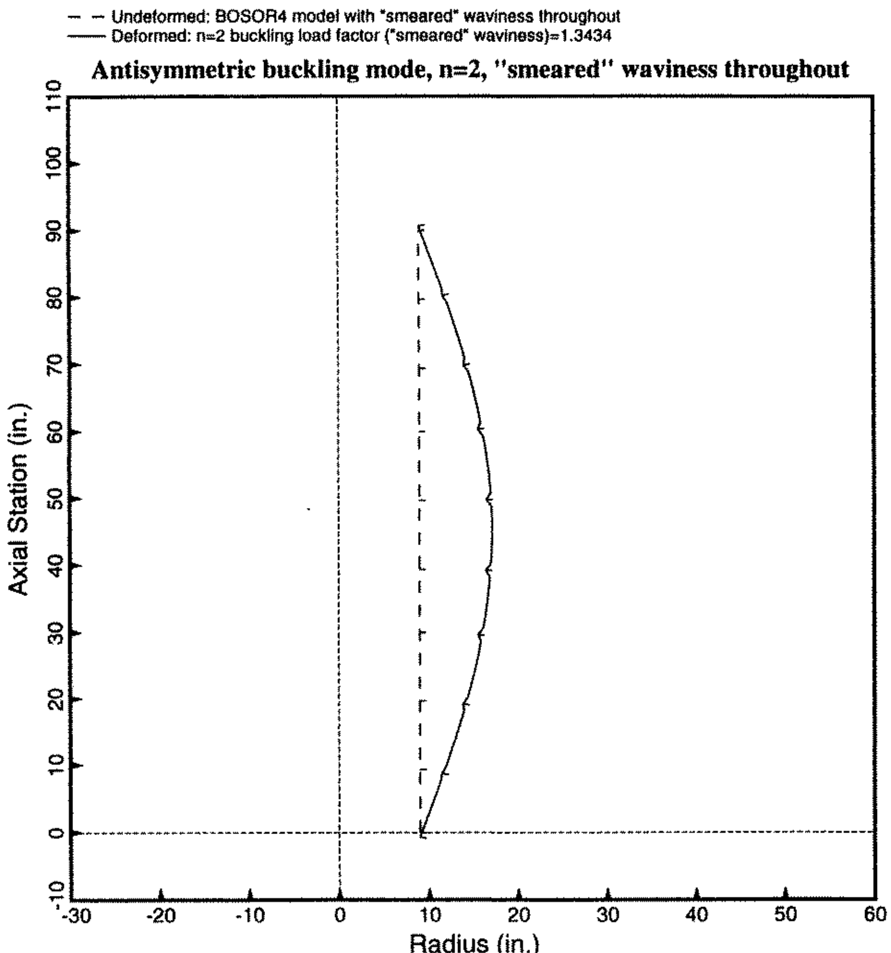


FIG. 26d

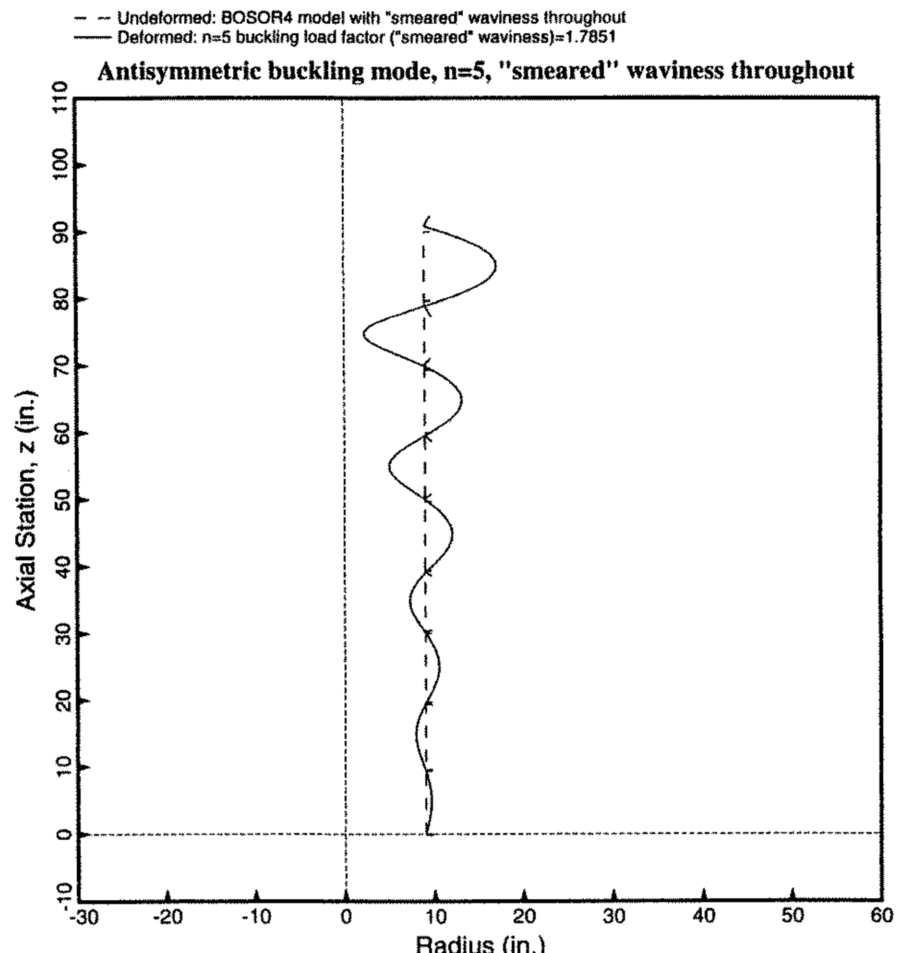


FIG. 26e

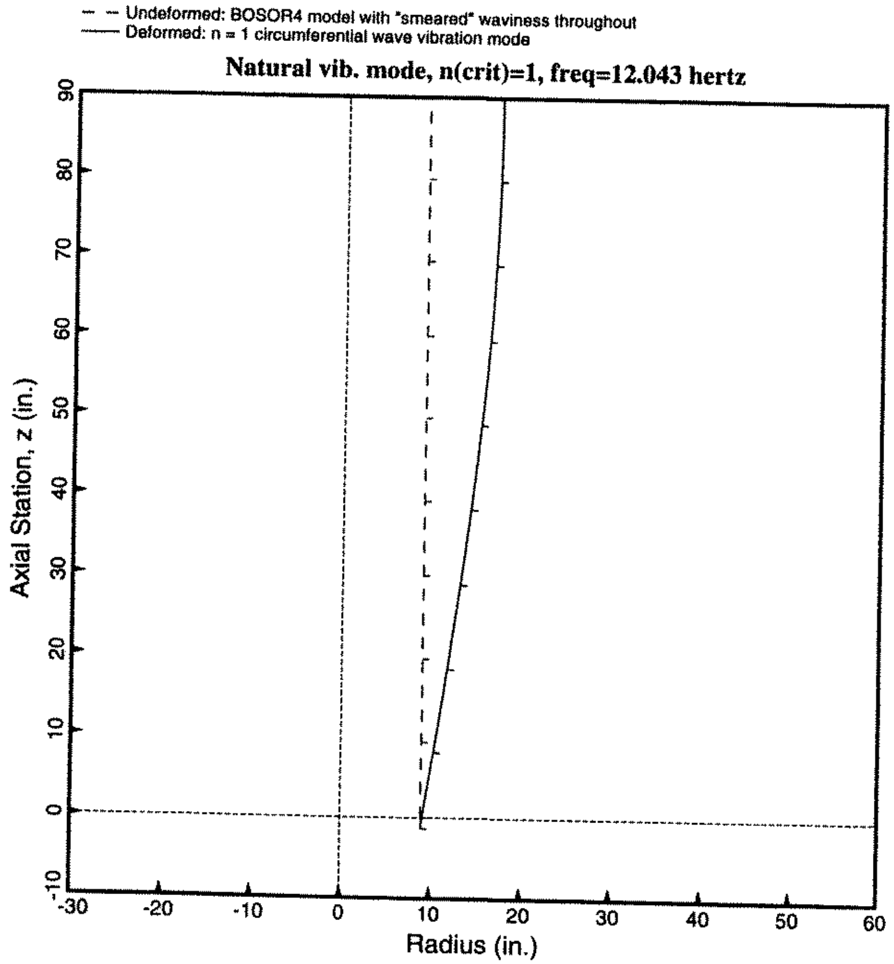


FIG. 26f

26f

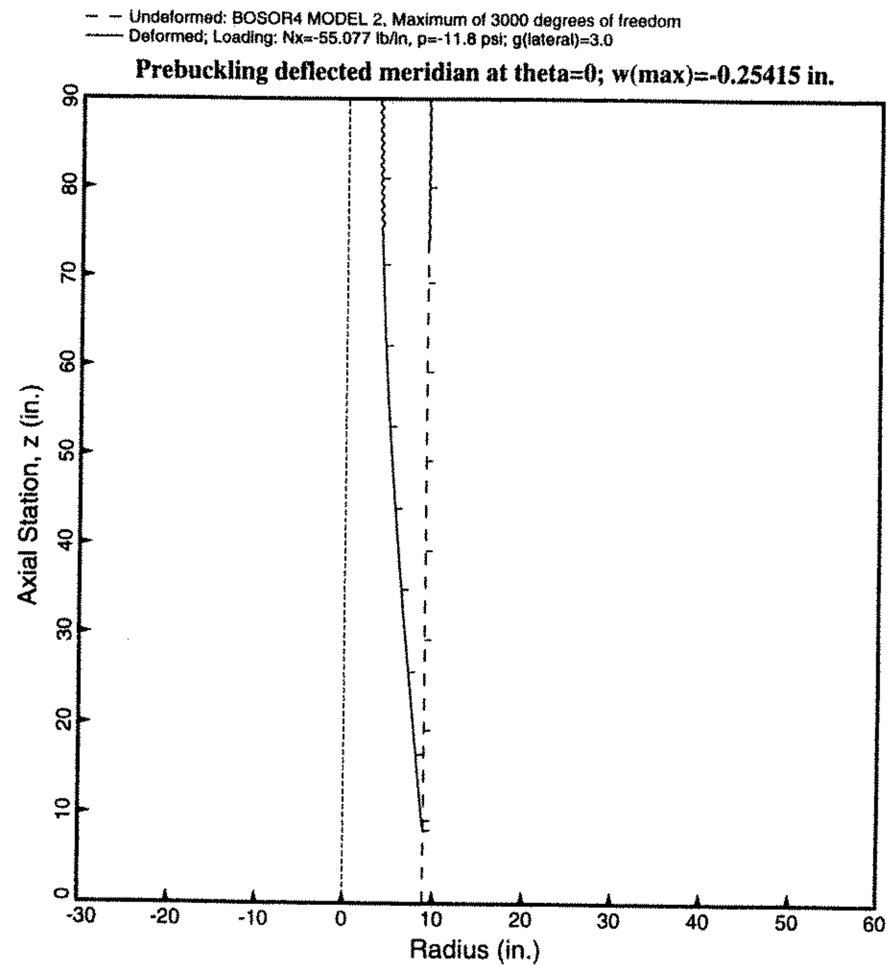
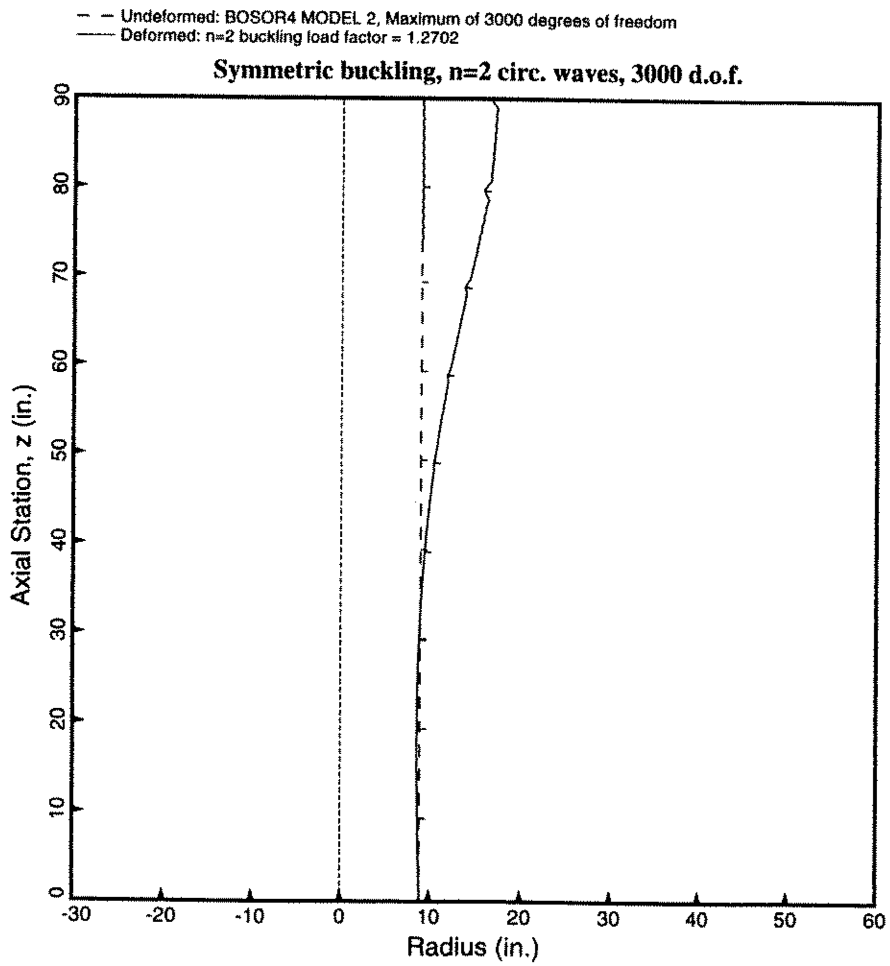


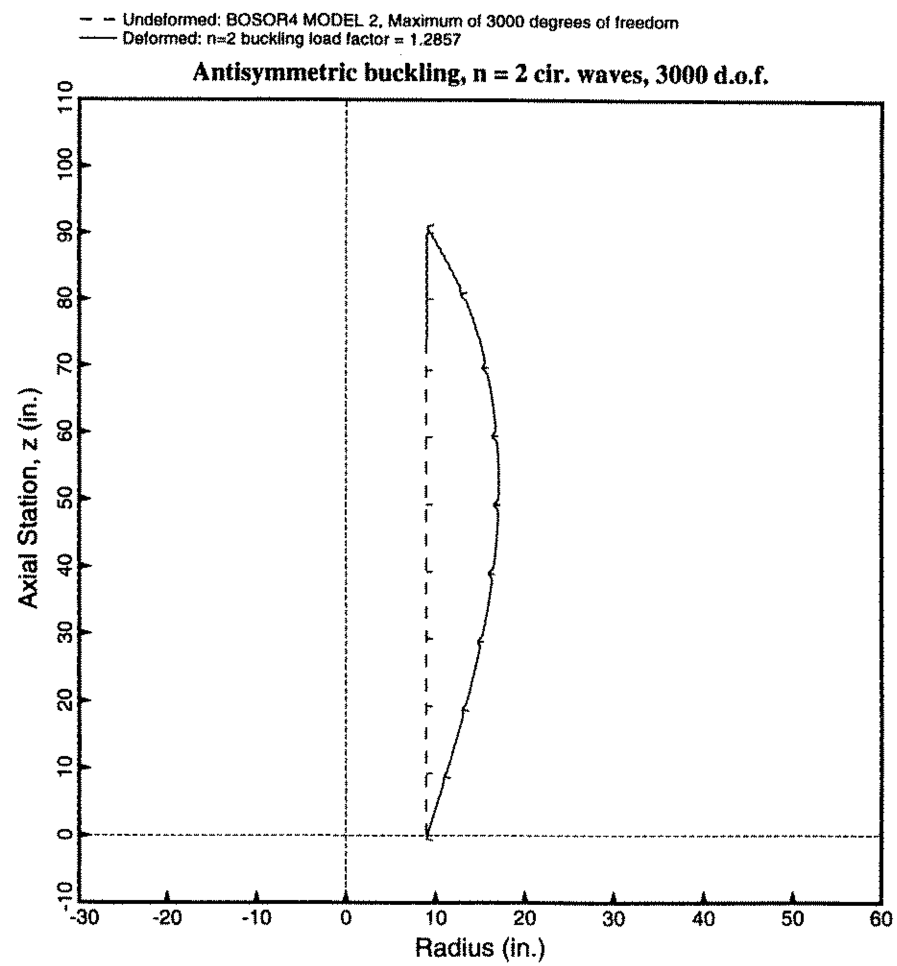
FIG. 27a

27a



27b

FIG. 27b



27c

FIG. 27c

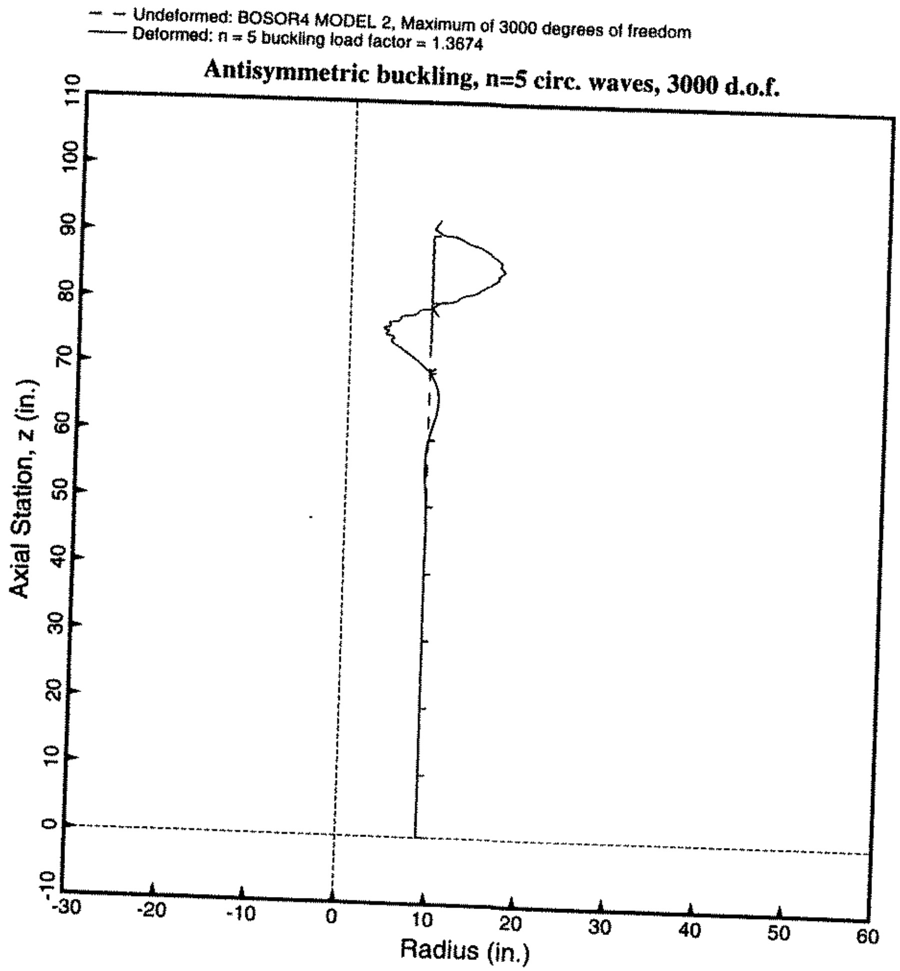


FIG. 27d

27d

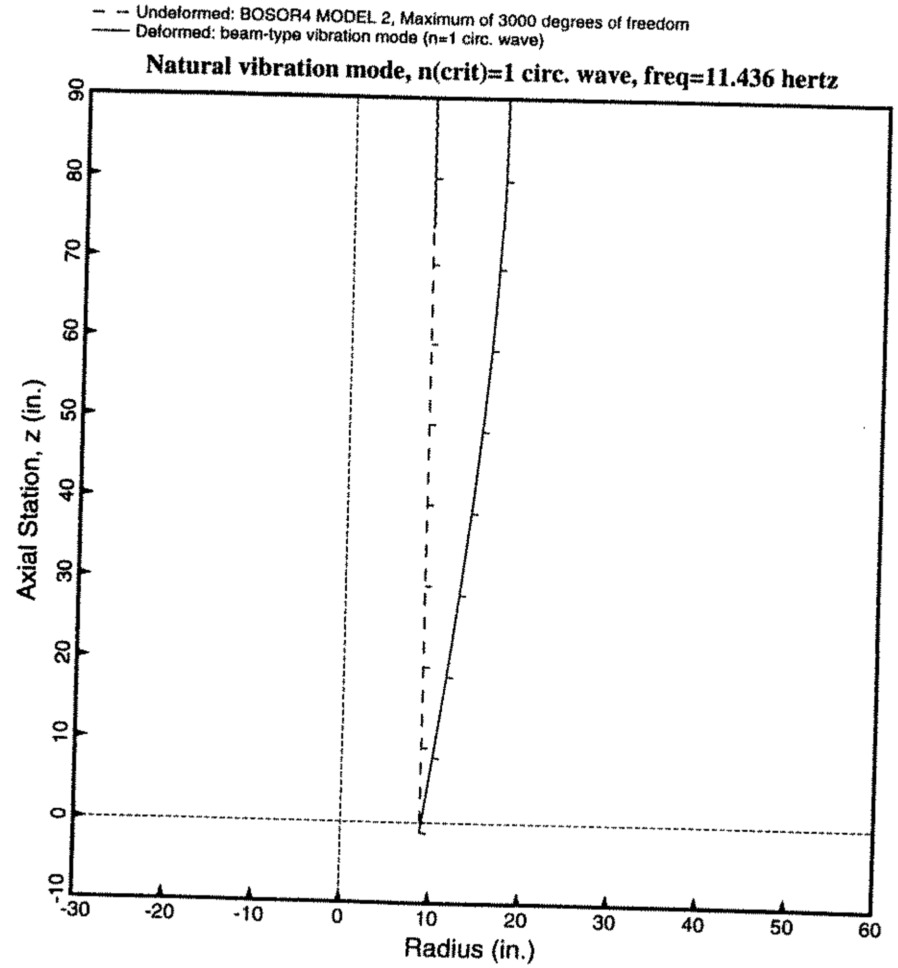


FIG. 27e

27e

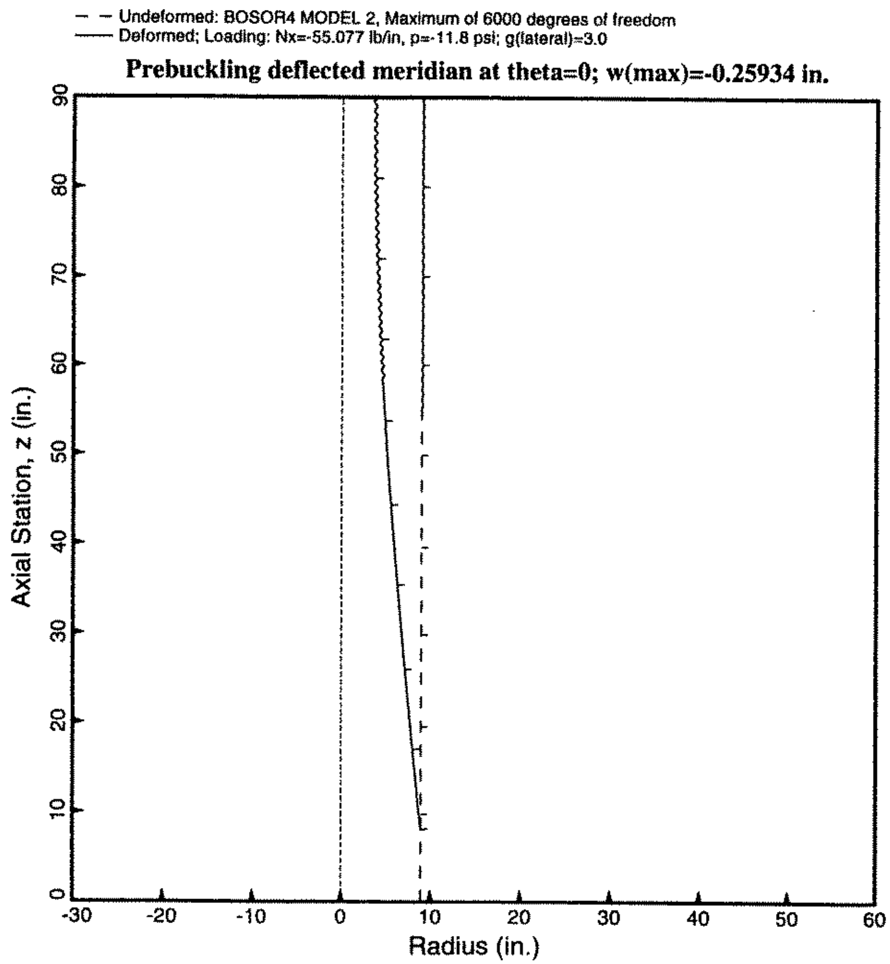


FIG. 28a

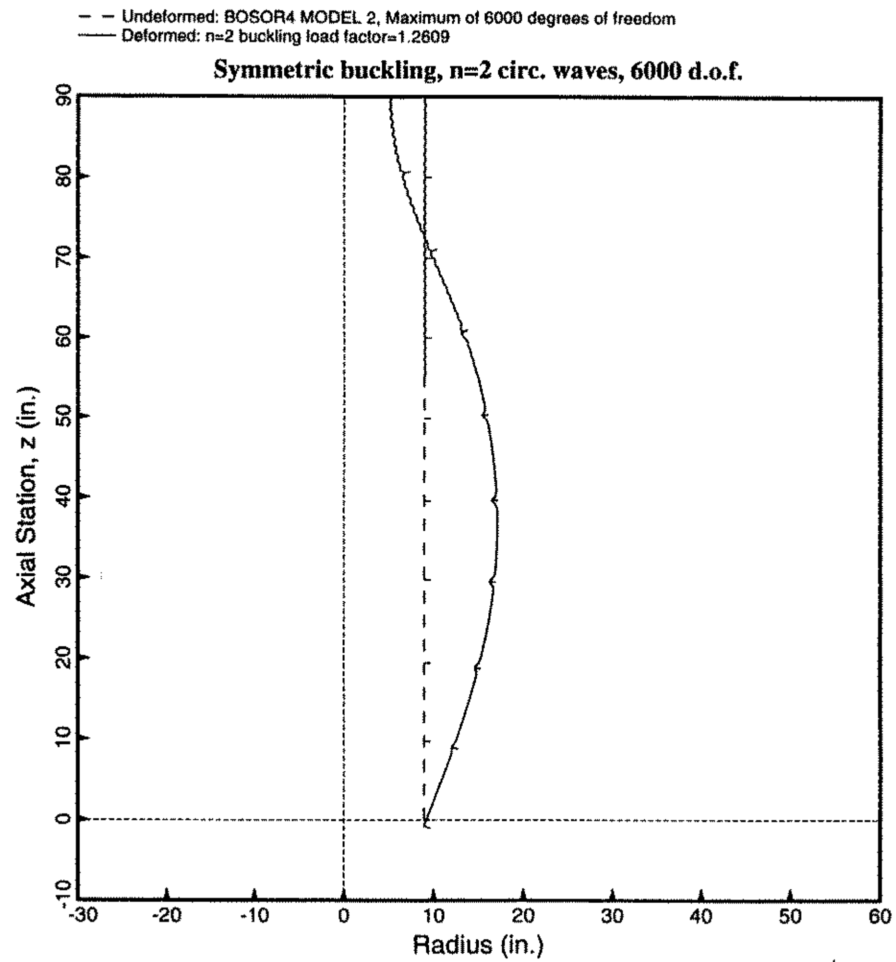


FIG. 28b

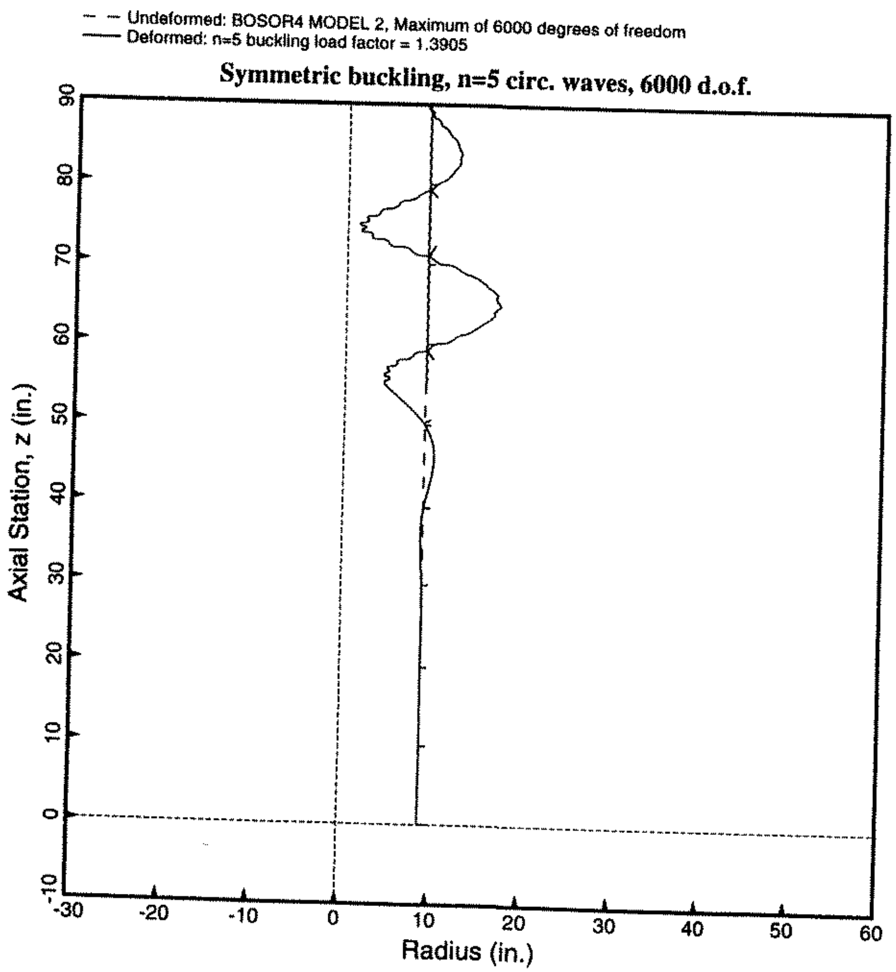


FIG. 28c

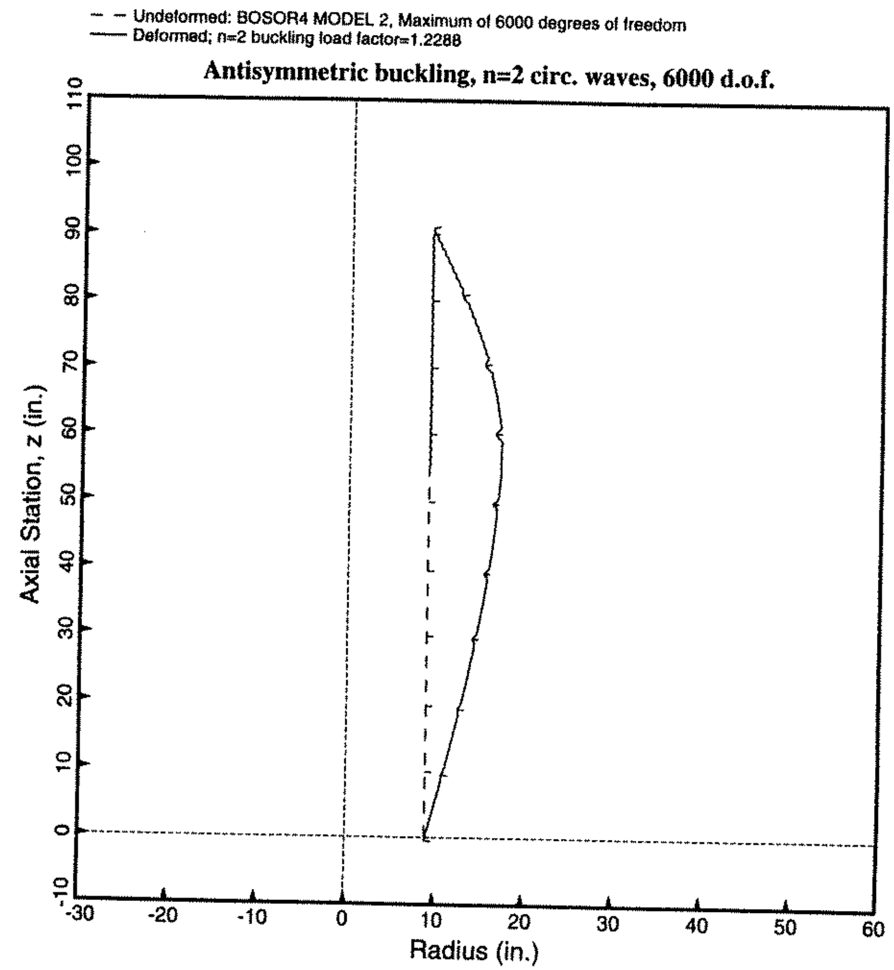


FIG. 28d

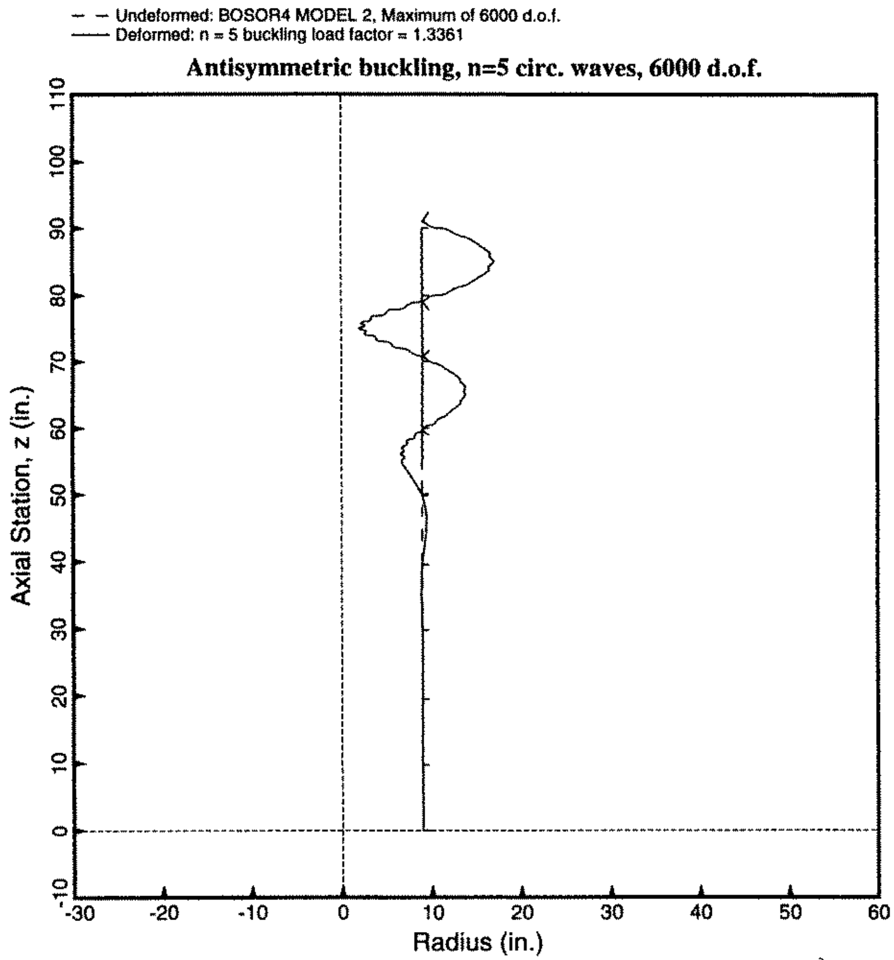


FIG. 28e

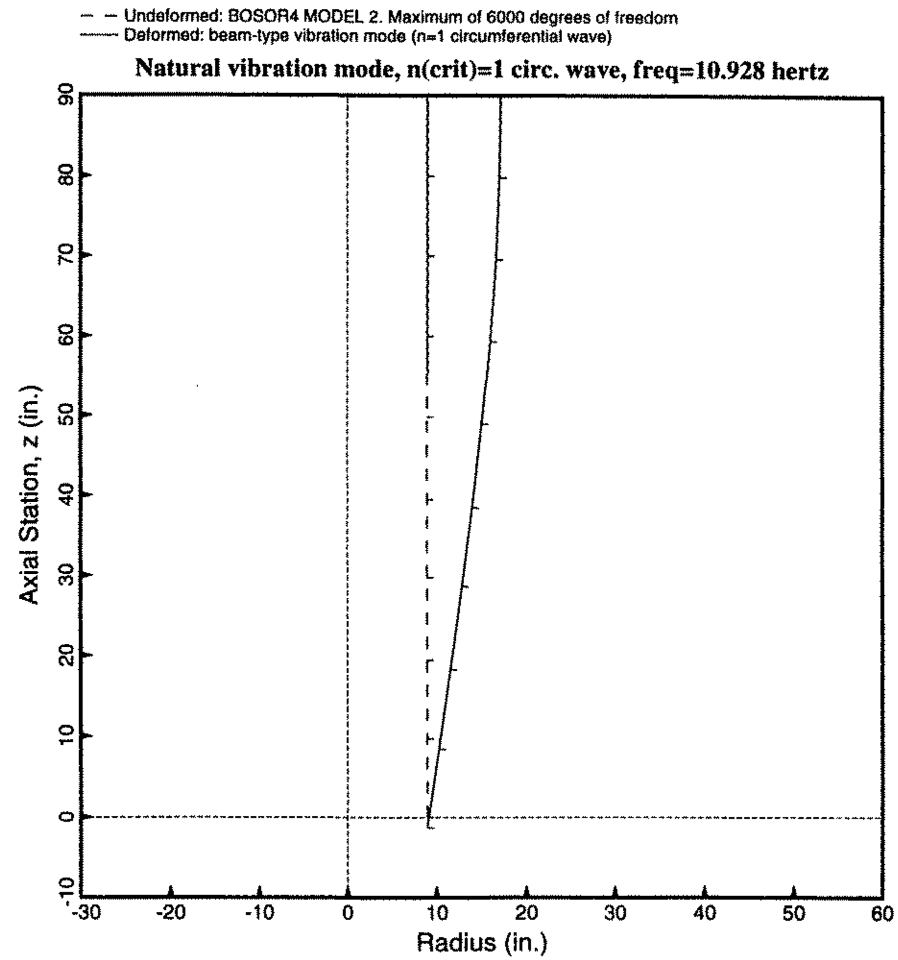
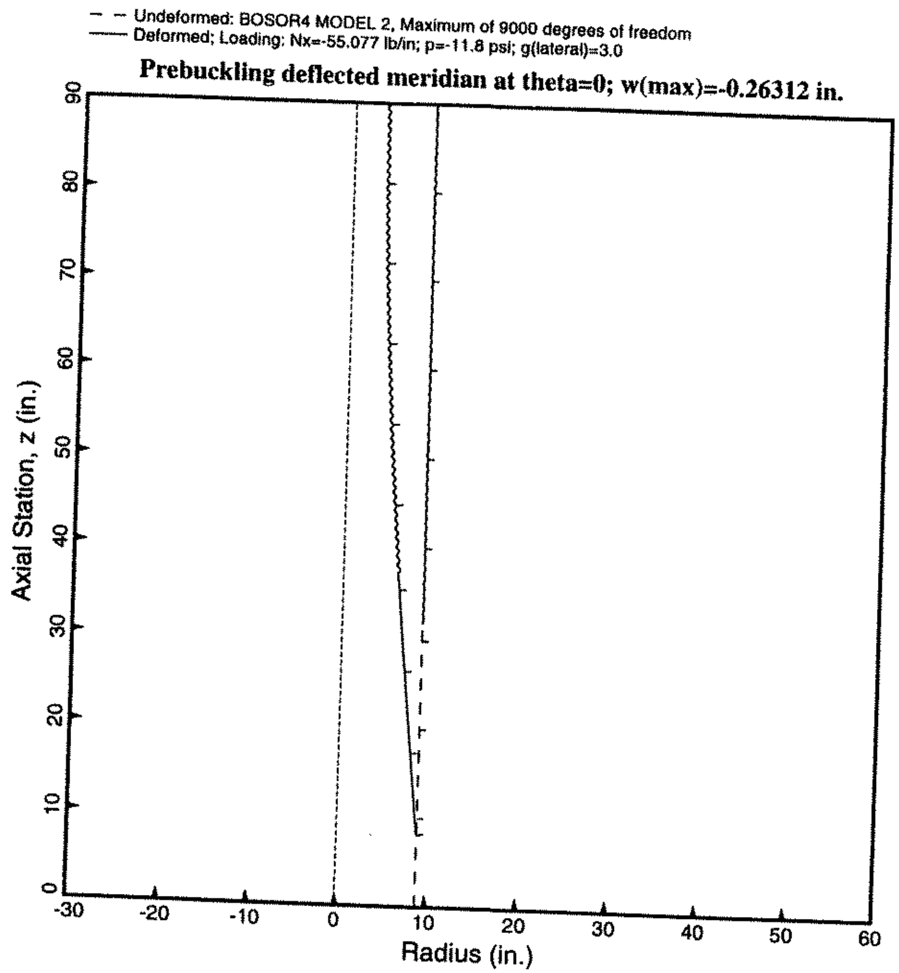


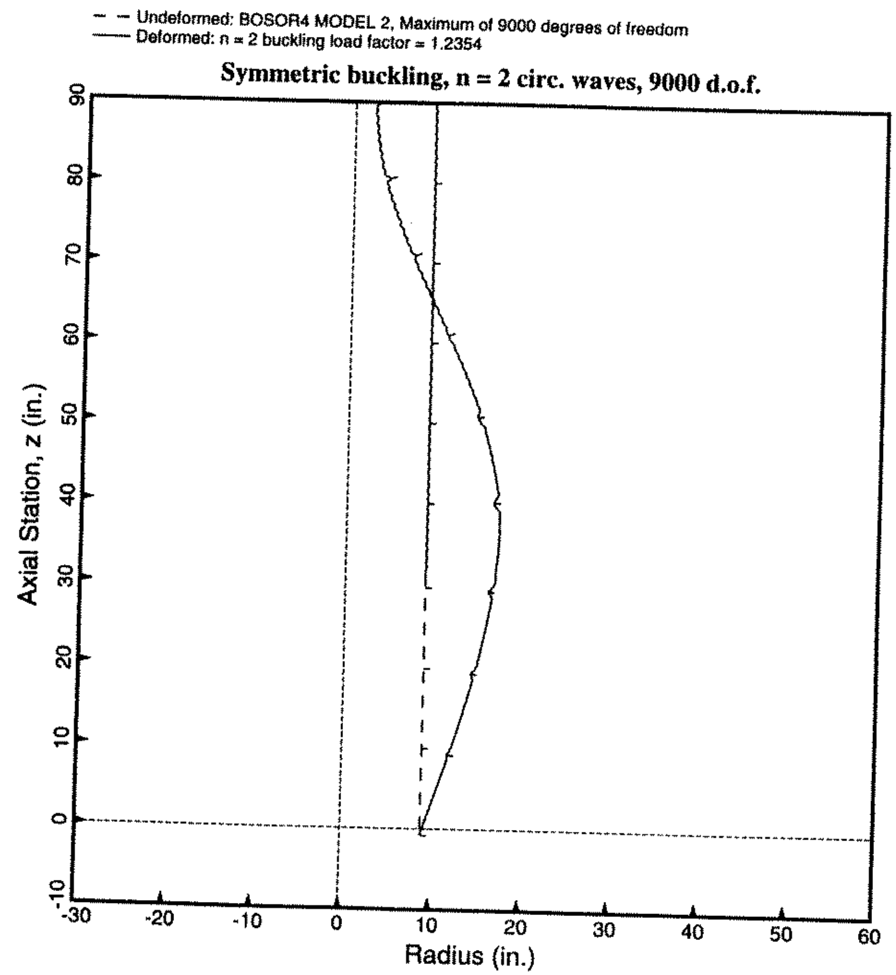
FIG. 28f

28f



29a

FIG. 29a



29b

FIG. 29b

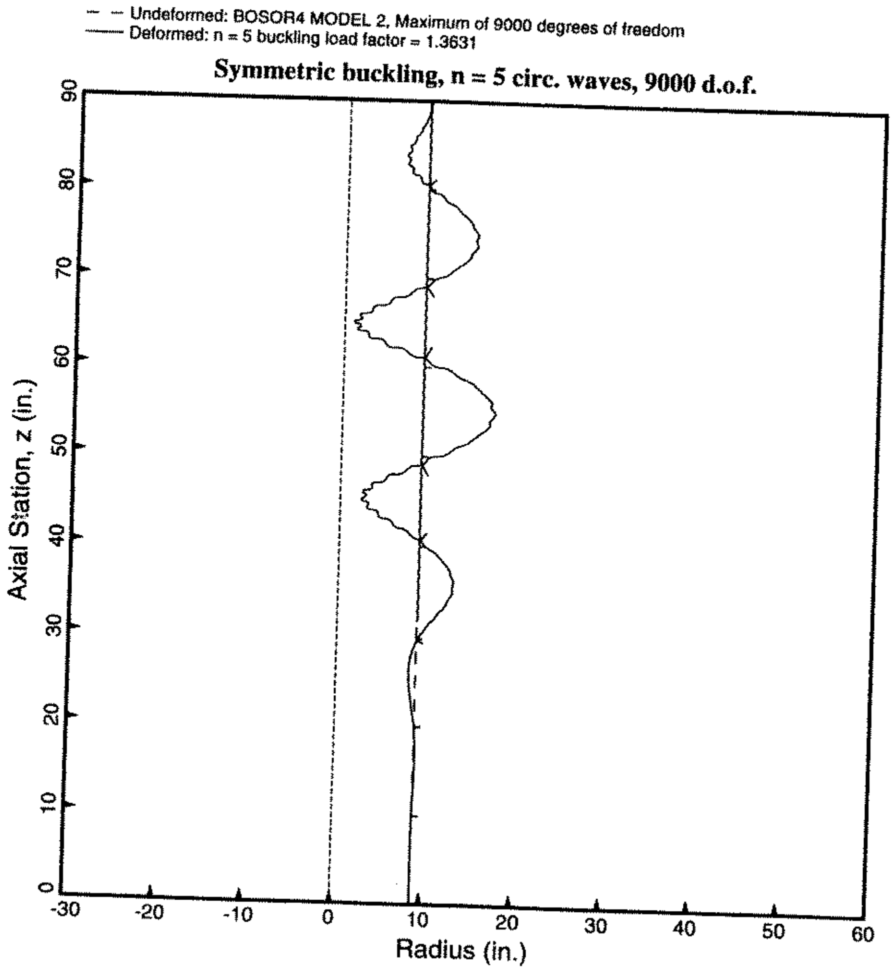


FIG. 29c

29c

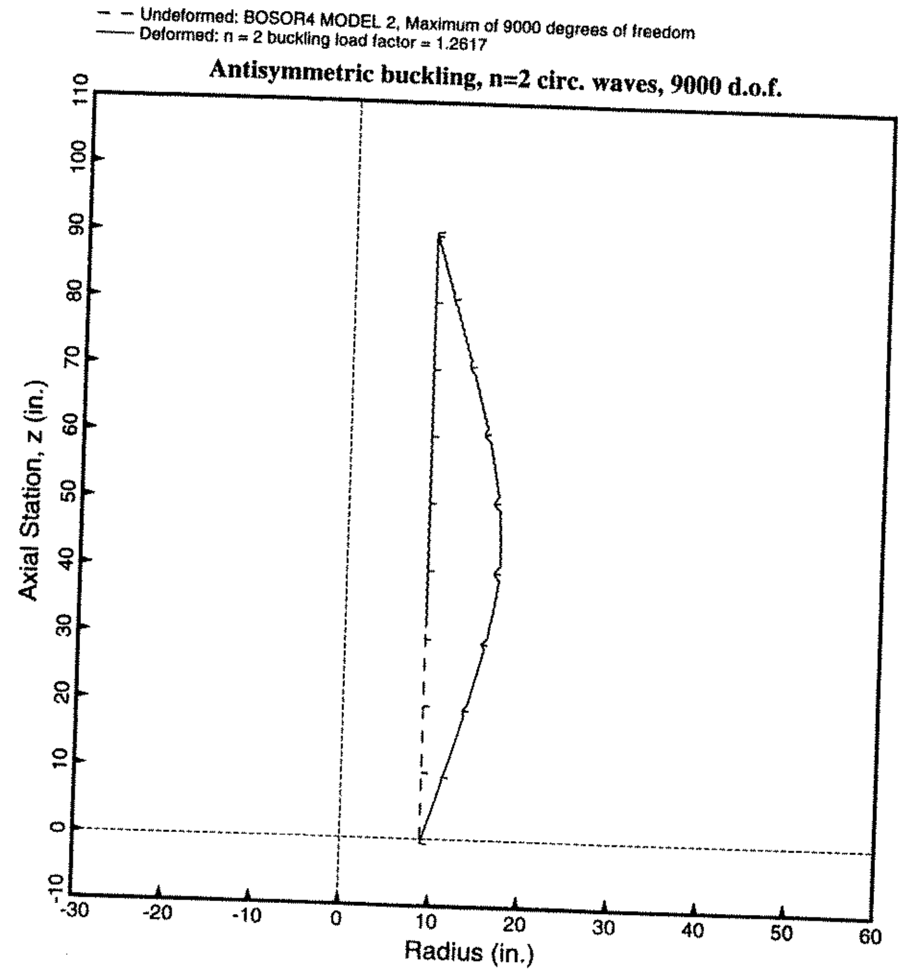


FIG. 29d

29d

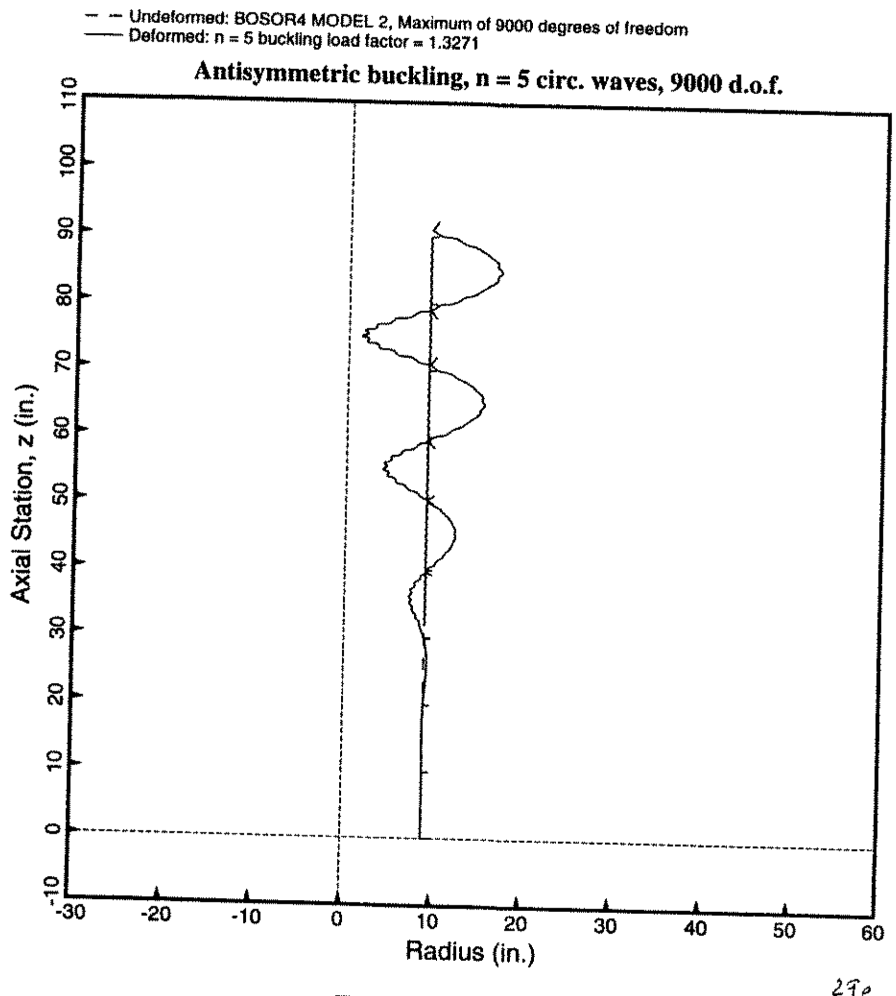


FIG. 29e

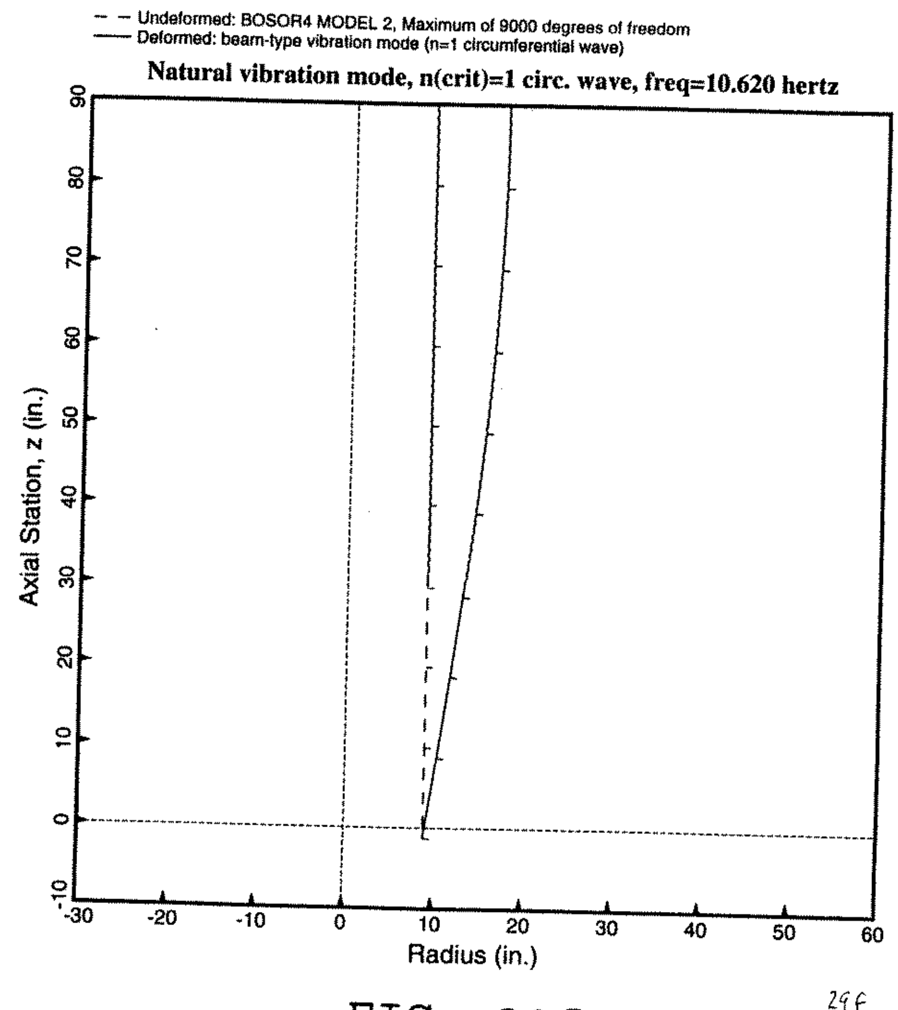


FIG. 29f

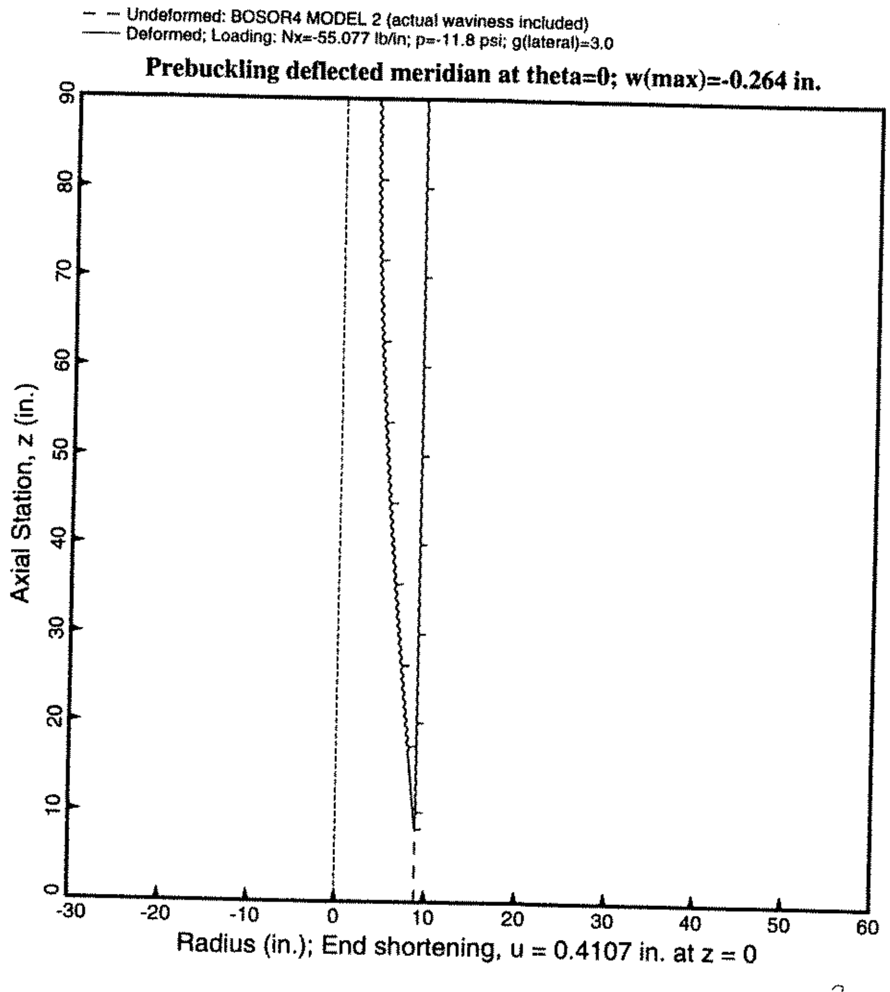


FIG. 30a

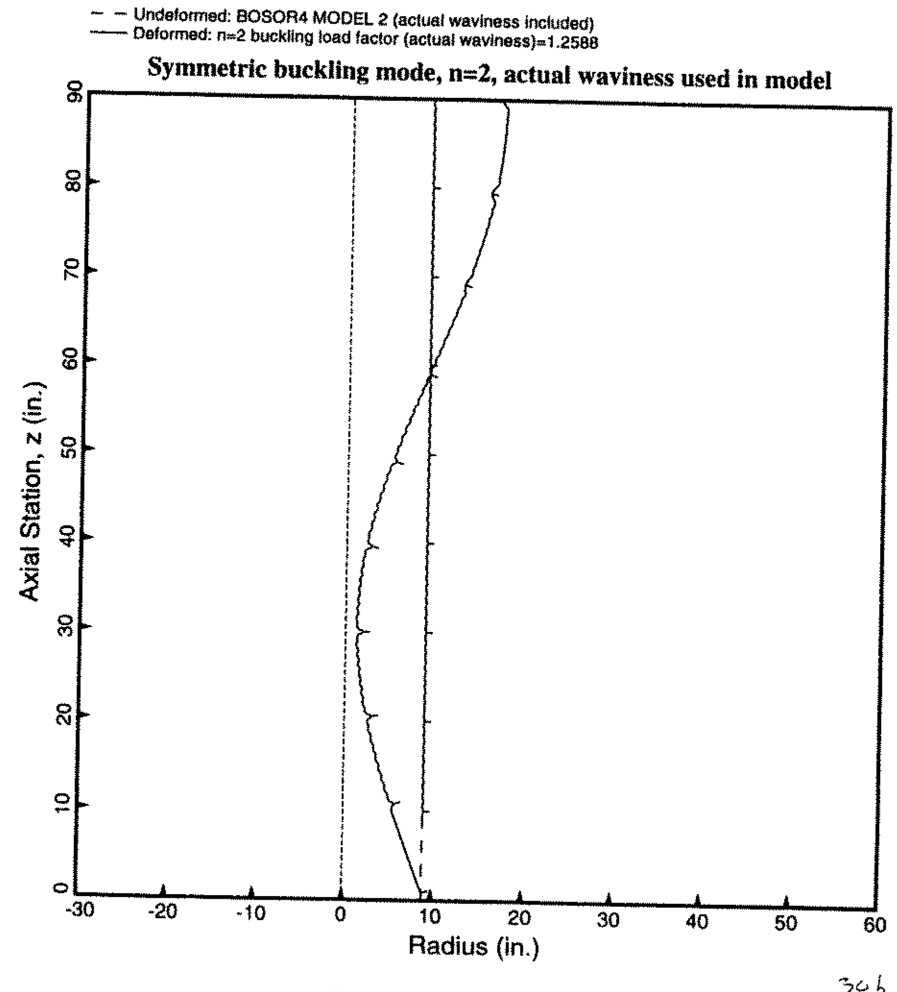
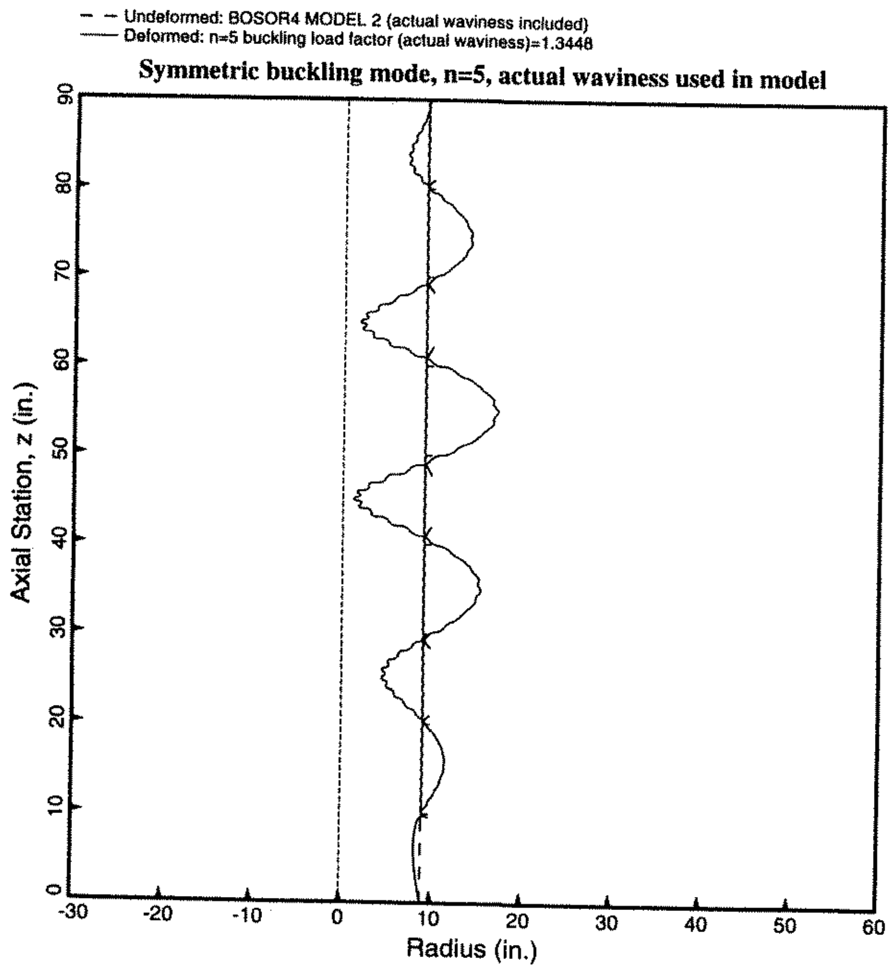
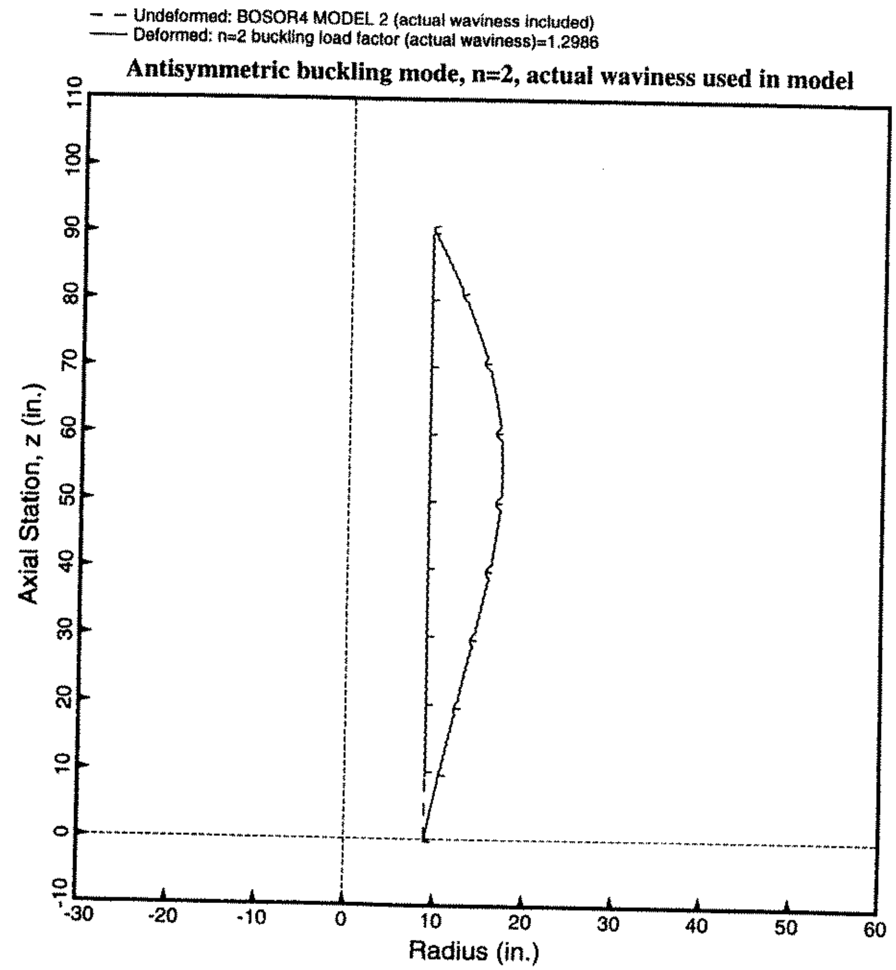


FIG. 30b



30c

FIG. 30c



30d

FIG. 30d

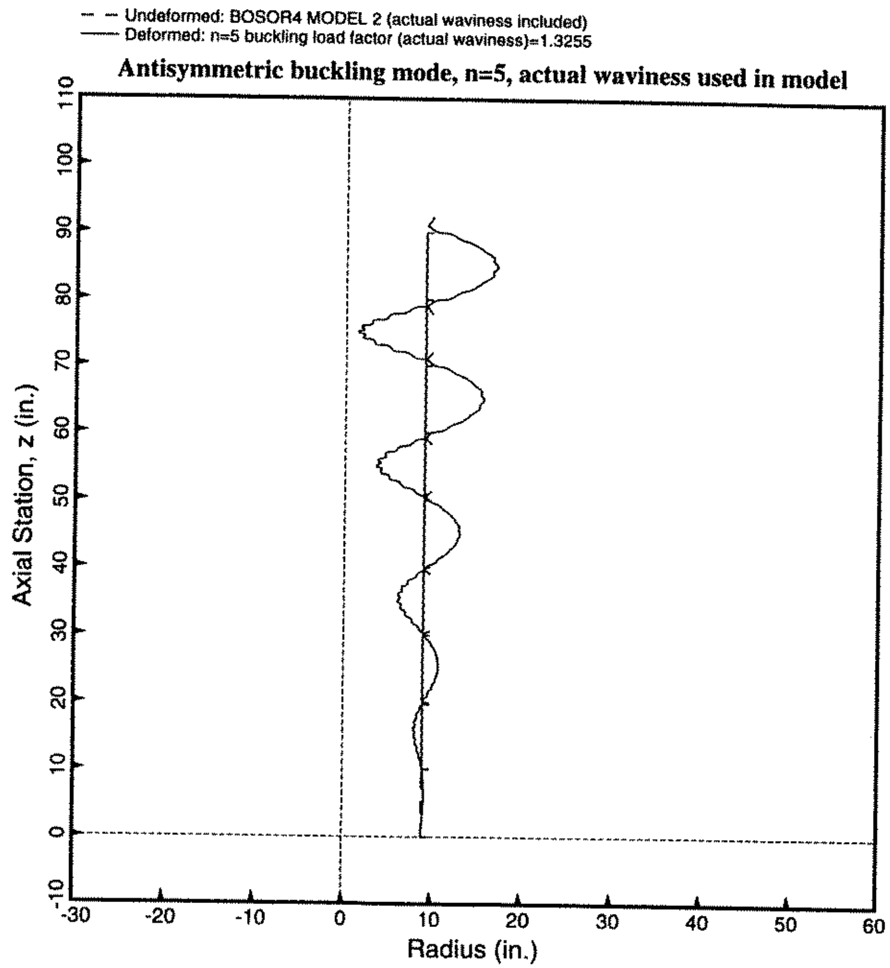


FIG. 30e

30e

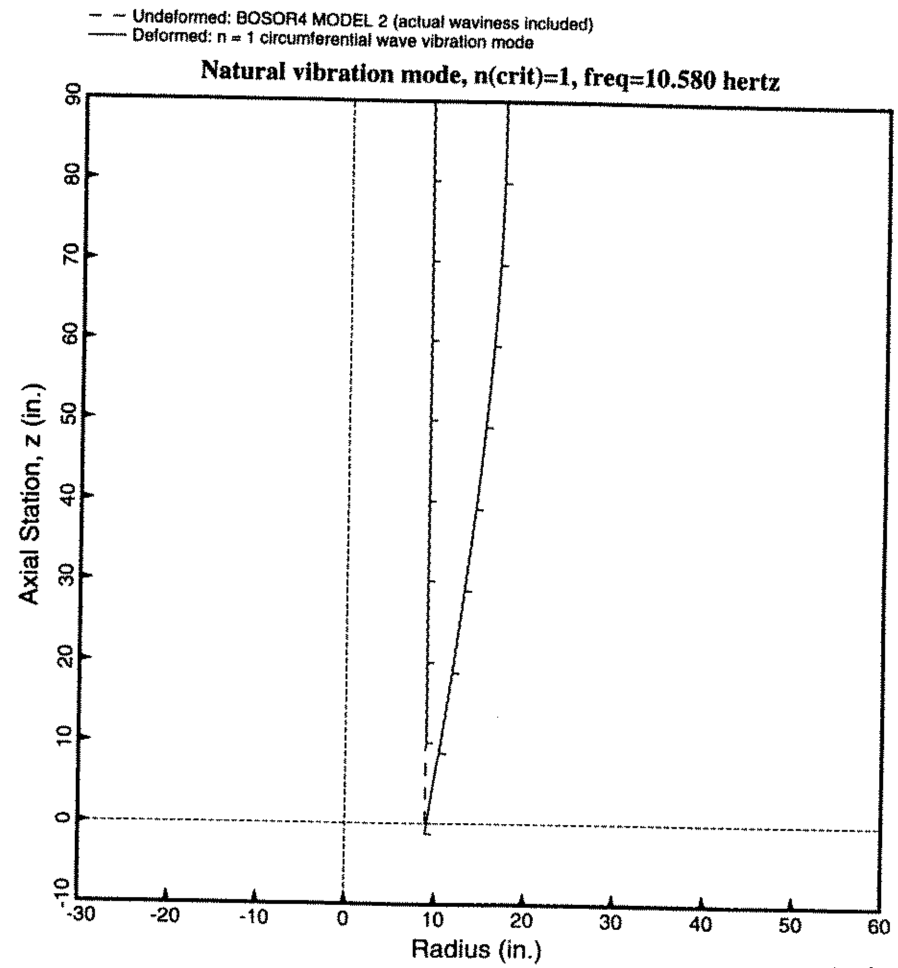


FIG. 30f

30f

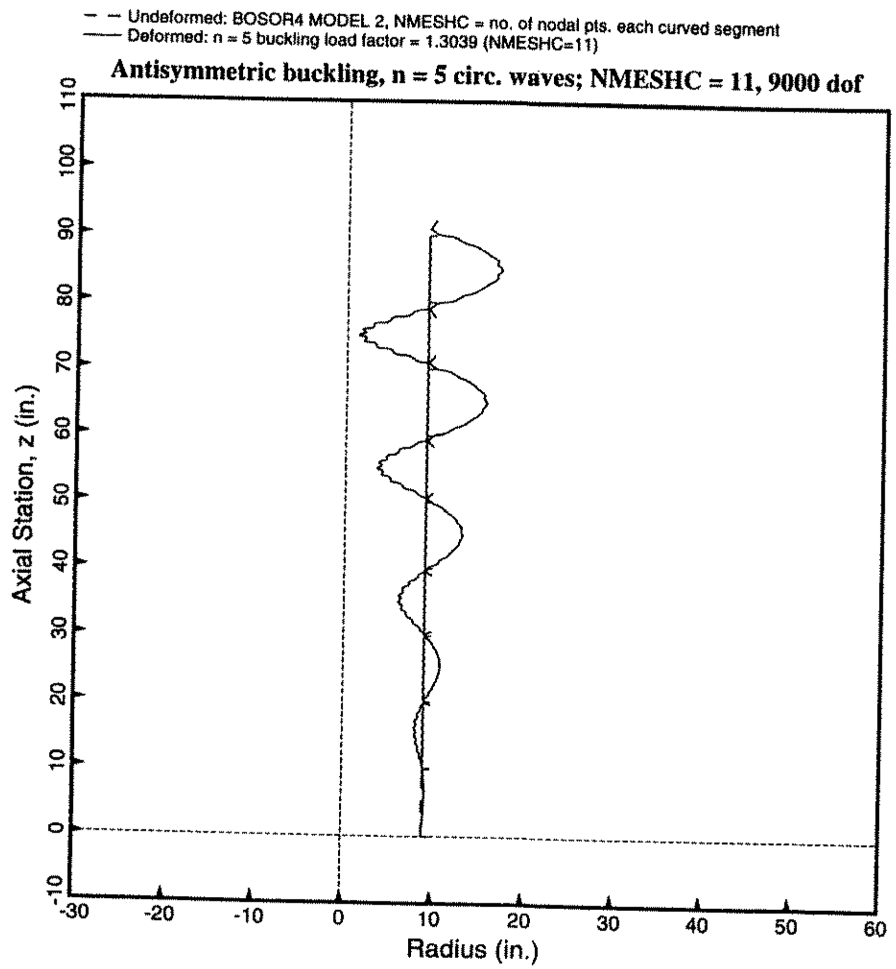


FIG. 31

31

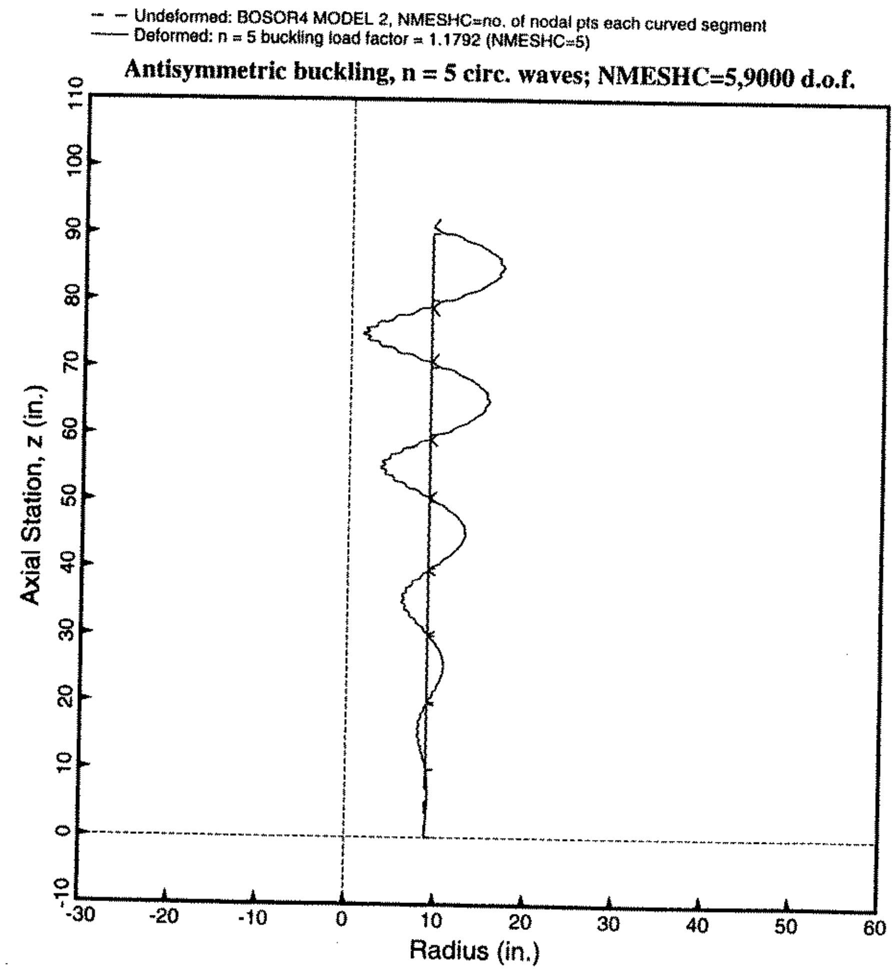


FIG. 32

32

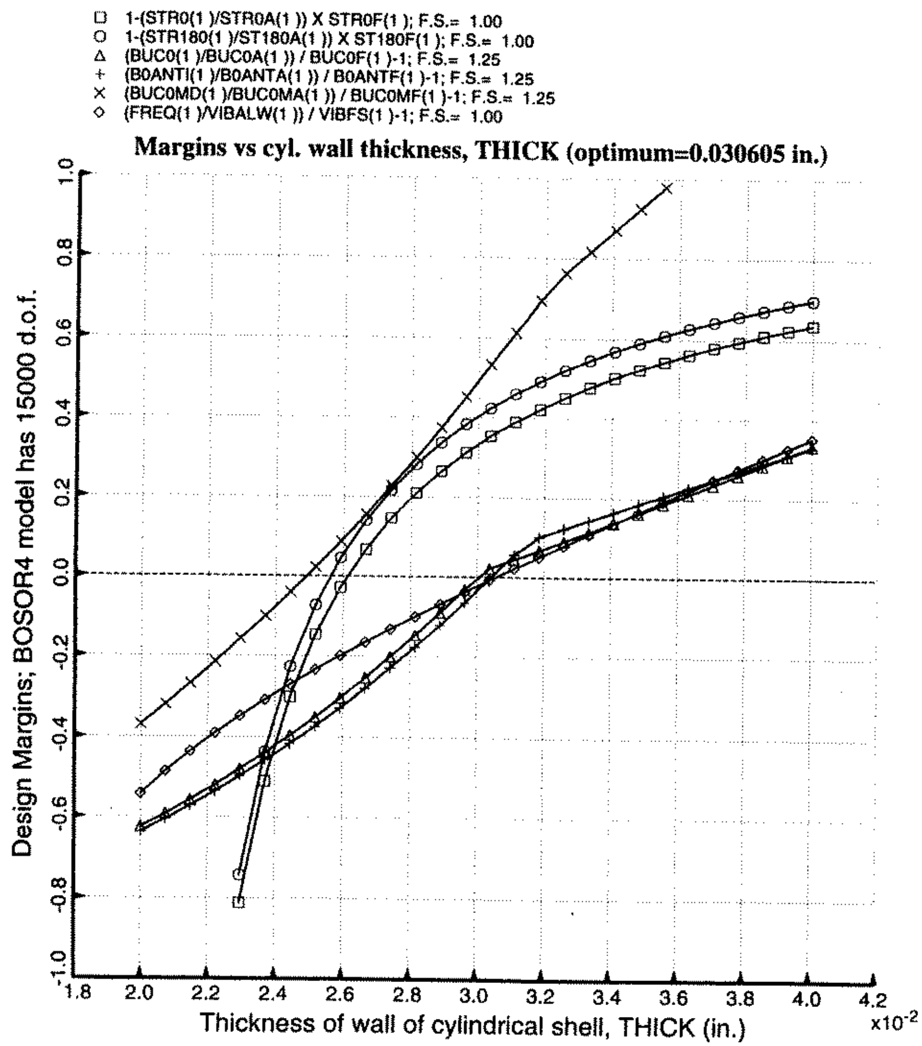

1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
(BUC0MD(1)/BUC0MA(1)) / BUC0MF(1)-1; F.S.= 1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
Margins vs cyl. wall thickness, THICK (optimum=0.030605 in.)
Design Margins; BOSOR4 model has 15000 d.o.f.
Thickness of wall of cylindrical shell, THICK (in.)
x10-2

FIG. 33

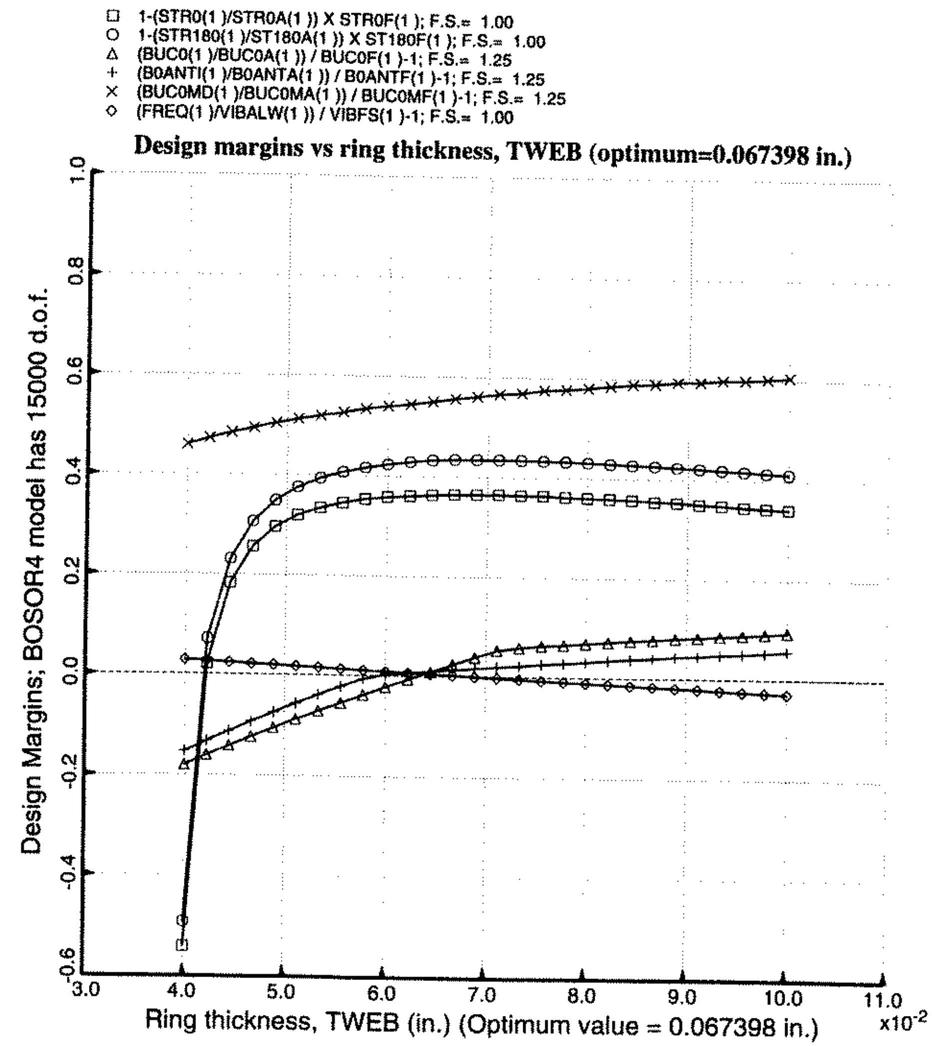
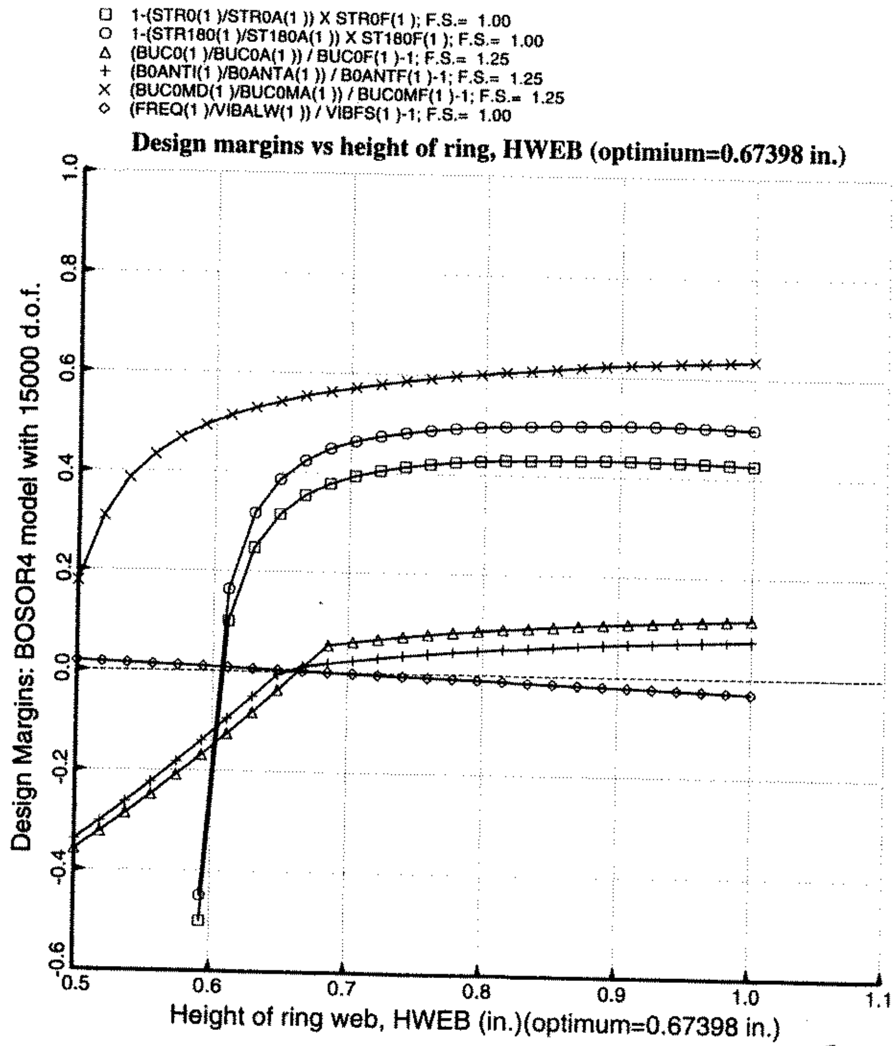
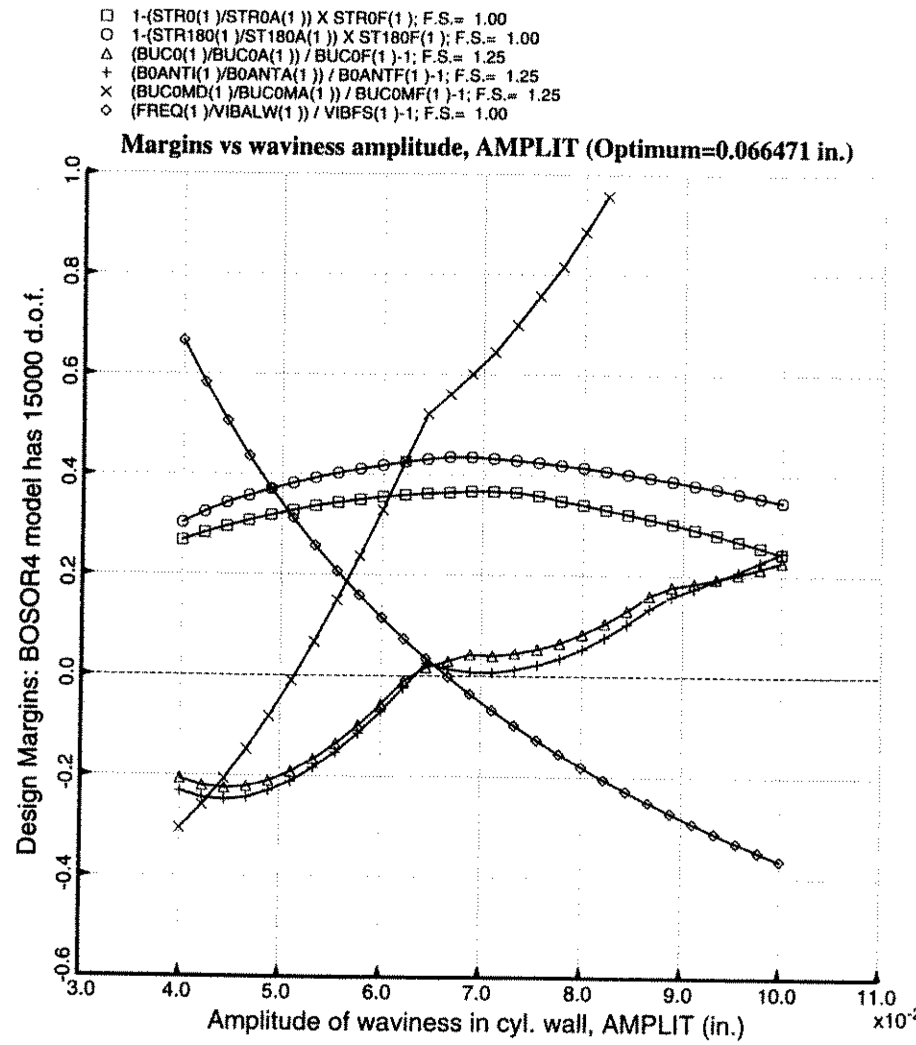

1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
(BUC0MD(1)/BUC0MA(1)) / BUC0MF(1)-1; F.S.= 1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
Design margins vs ring thickness, TWEB (optimum=0.067398 in.)
Design Margins; BOSOR4 model has 15000 d.o.f.
Ring thickness, TWEB (in.) (Optimum value = 0.067398 in.)
x10-2

FIG. 34



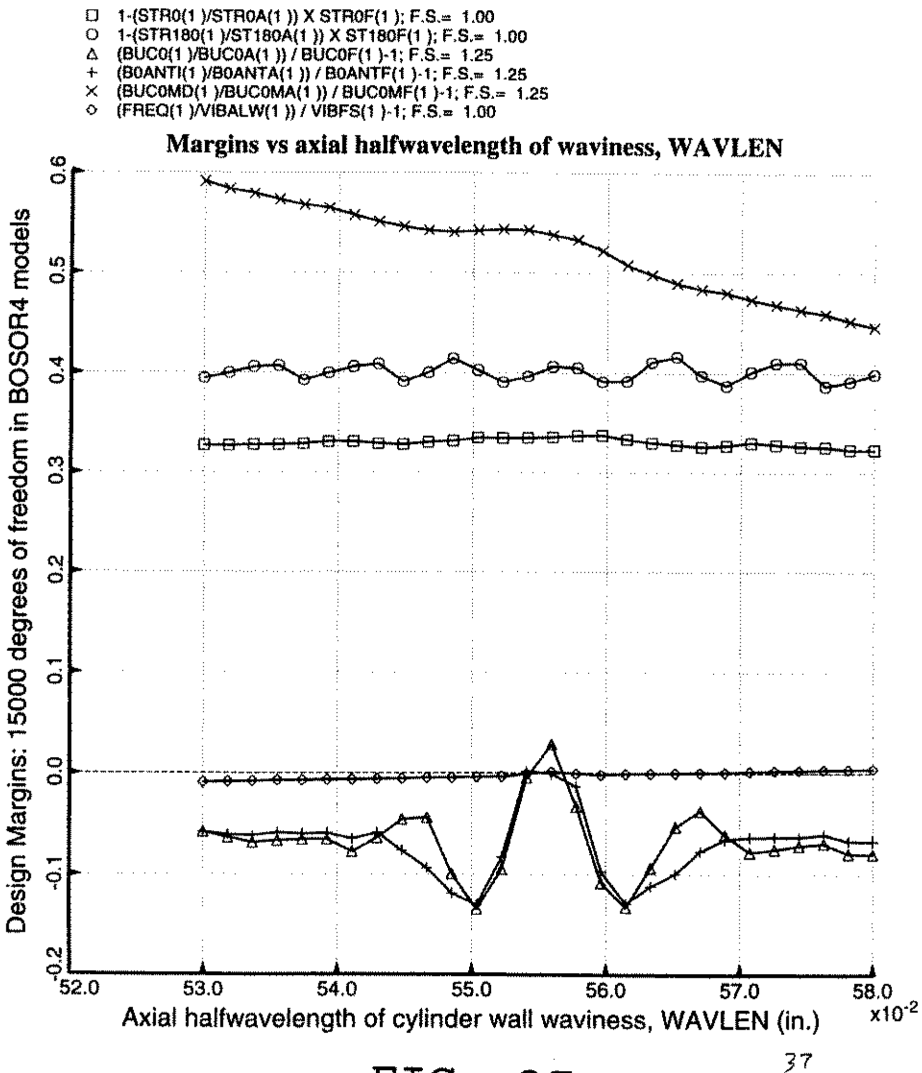
35

FIG. 35



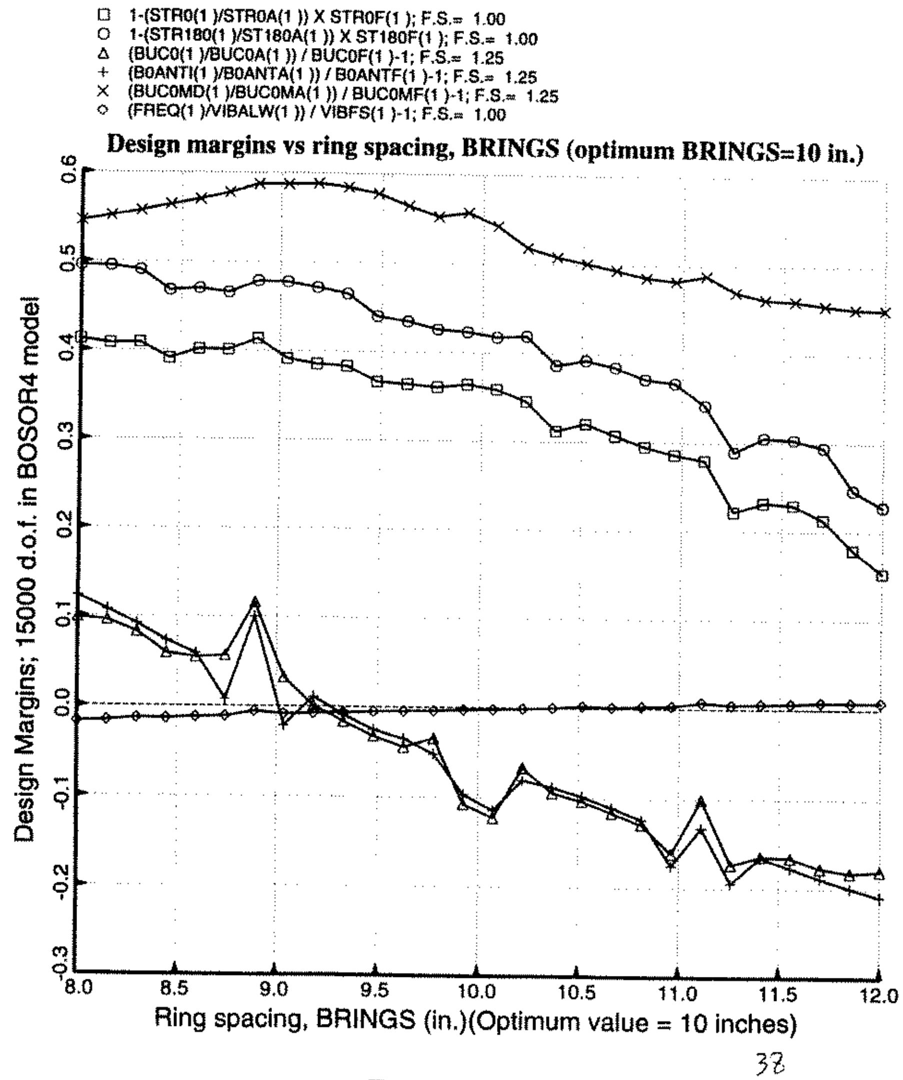
36

FIG. 36



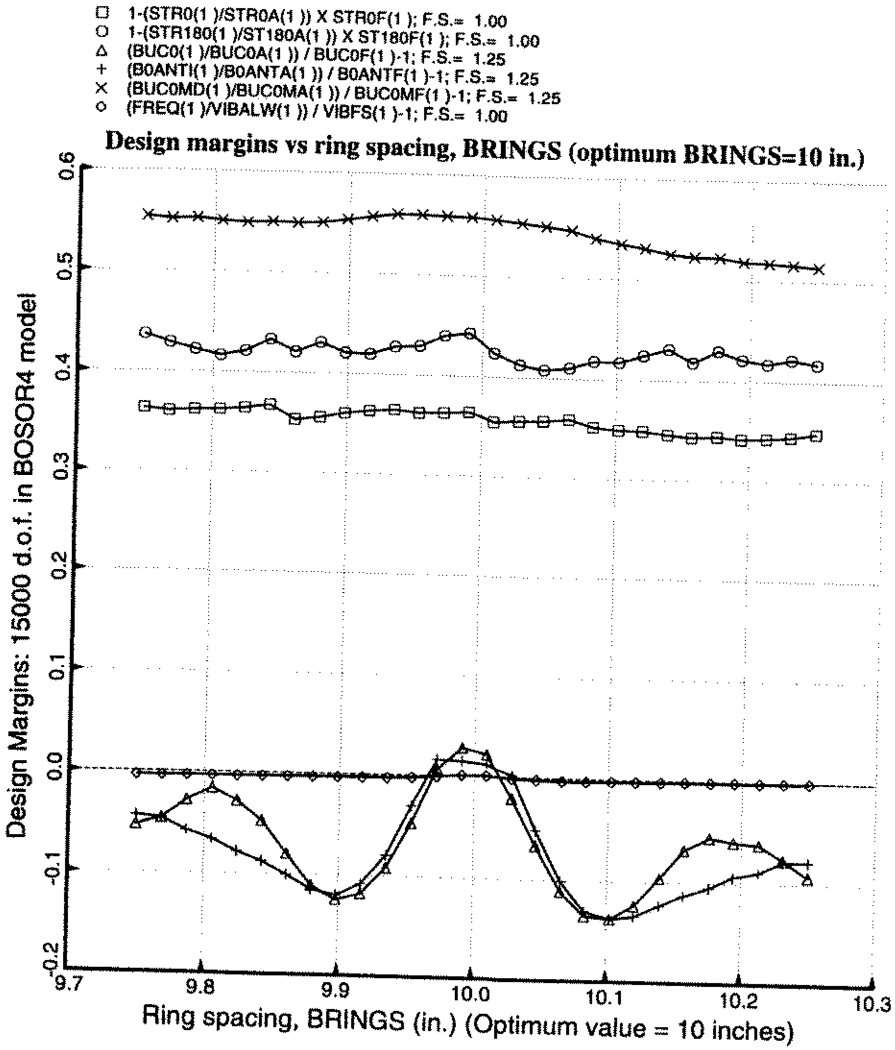
1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
(BUC0MD(1)/BUC0MA(1)) / BUC0MF(1)-1; F.S.= 1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
Margins vs axial halfwavelength of waviness, WAVLEN
Design Margins: 15000 degrees of freedom in BOSOR4 models
Axial halfwavelength of cylinder wall waviness, WAVLEN (in.)
x10-2
37

FIG. 37



1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
(BUC0MD(1)/BUC0MA(1)) / BUC0MF(1)-1; F.S.= 1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
Design margins vs ring spacing, BRINGS (optimum BRINGS=10 in.)
Design Margins; 15000 d.o.f. in BOSOR4 model
Ring spacing, BRINGS (in.)(Optimum value = 10 inches)
38

FIG. 38



37

FIG. 39

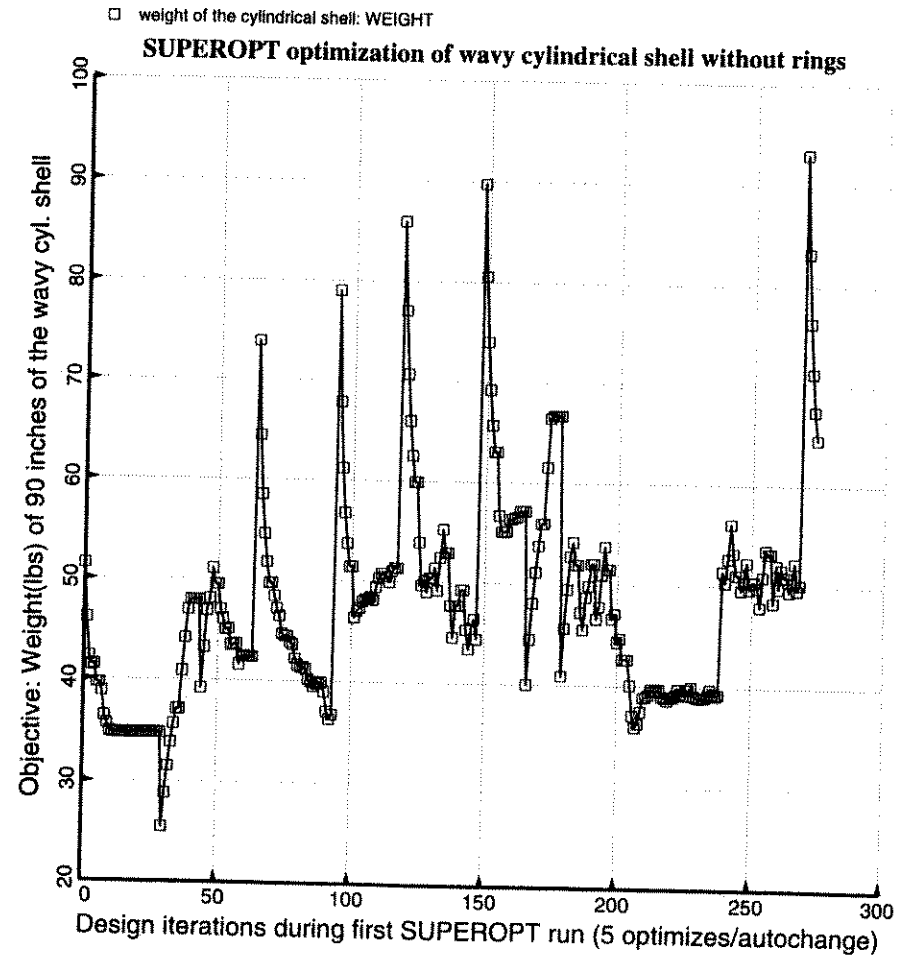


FIG. 40

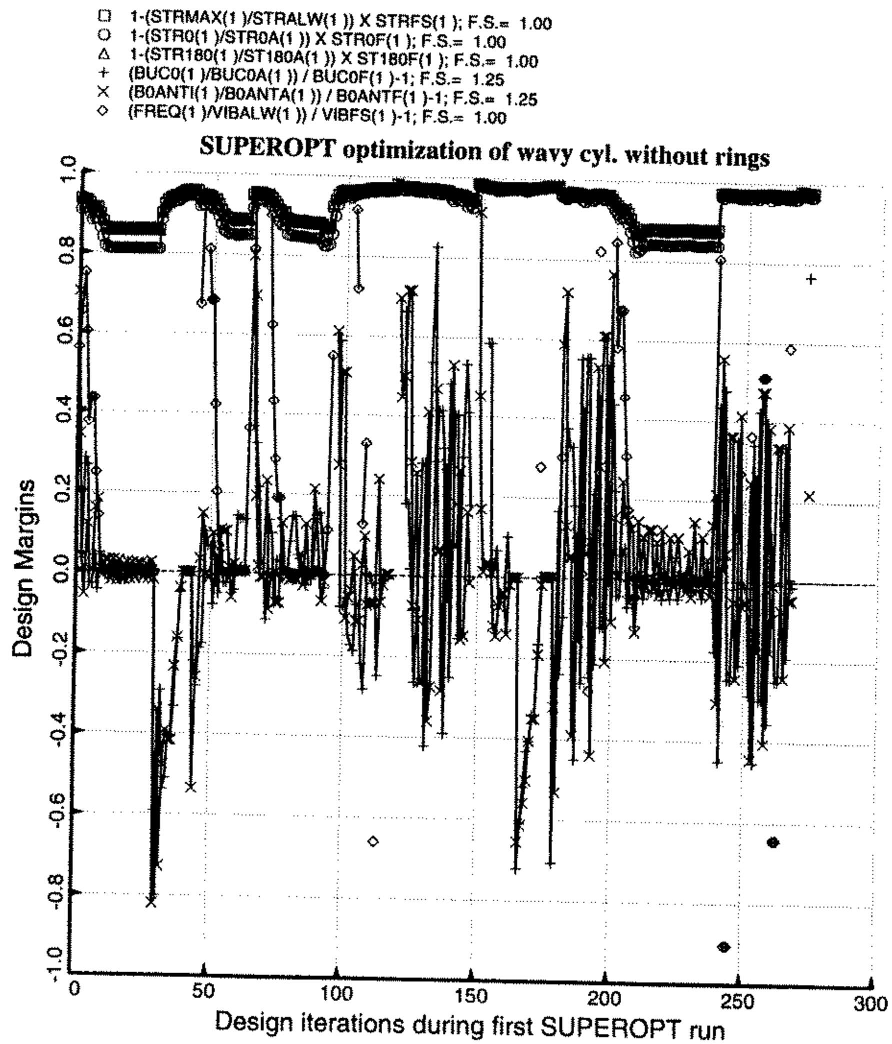

□ 1-(STRMAX(1)/STRALW(1)) X STRFS(1); F.S.= 1.00
○ 1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
△ 1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
+ (BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
× (B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
◇ (FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
SUPEROPT optimization of wavy cyl. without rings
Design Margins
Design iterations during first SUPEROPT run

FIG. 41

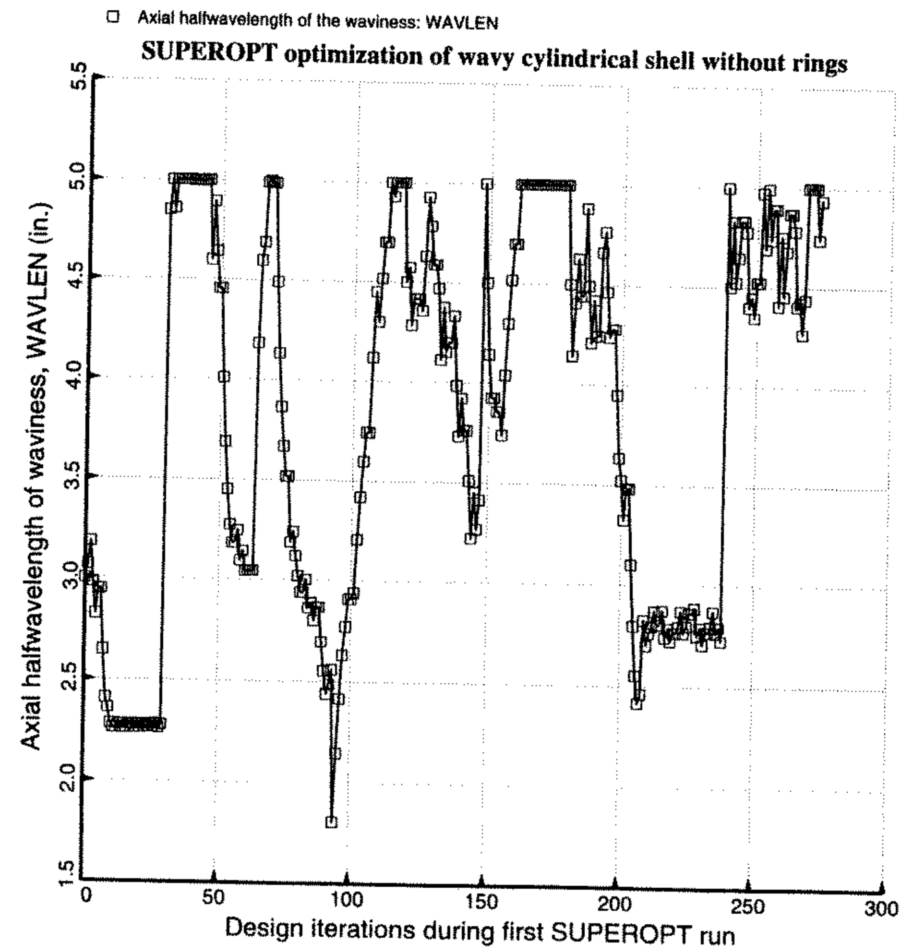

□ Axial halfwavelength of the waviness: WAVLEN
SUPEROPT optimization of wavy cylindrical shell without rings
Axial halfwavelength of waviness, WAVLEN (in.)
Design iterations during first SUPEROPT run

FIG. 42

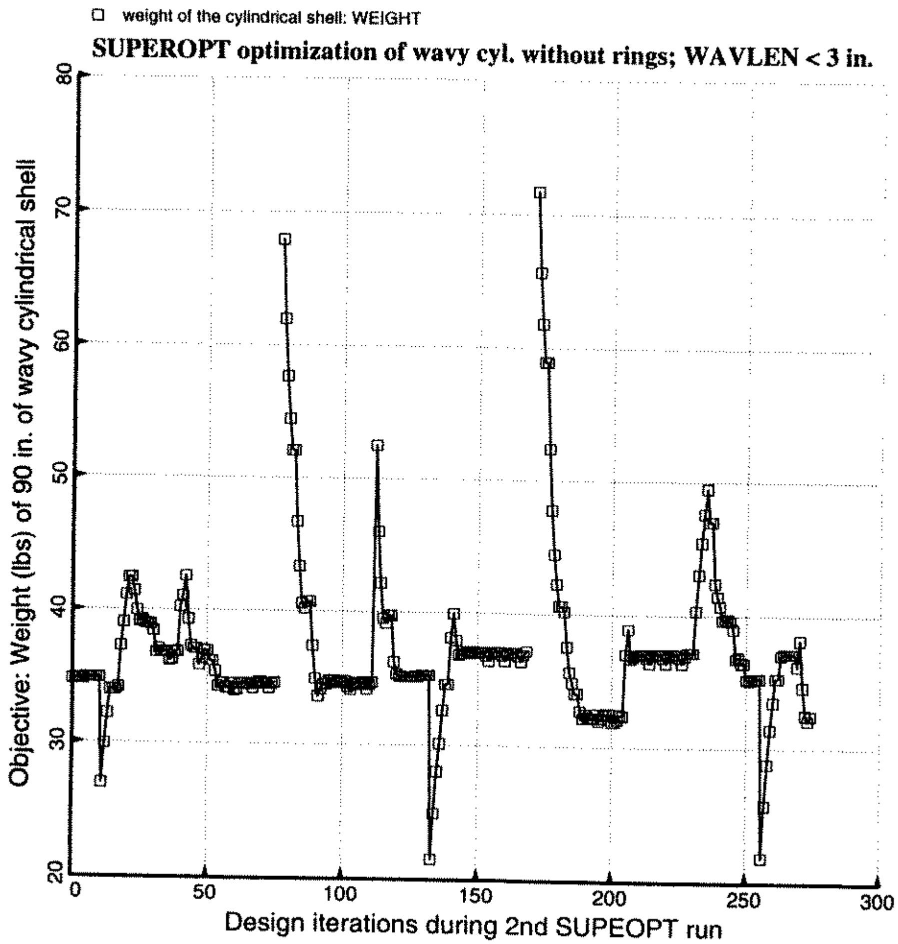

weight of the cylindrical shell: WEIGHT
SUPEROPT optimization of wavy cyl. without rings; WAVLEN < 3 in.
Objective: Weight (lbs) of 90 in. of wavy cylindrical shell
Design iterations during 2nd SUPEOPT run
0
50
100
150
200
250
300
20
30
40
50
60
70
80

FIG. 43

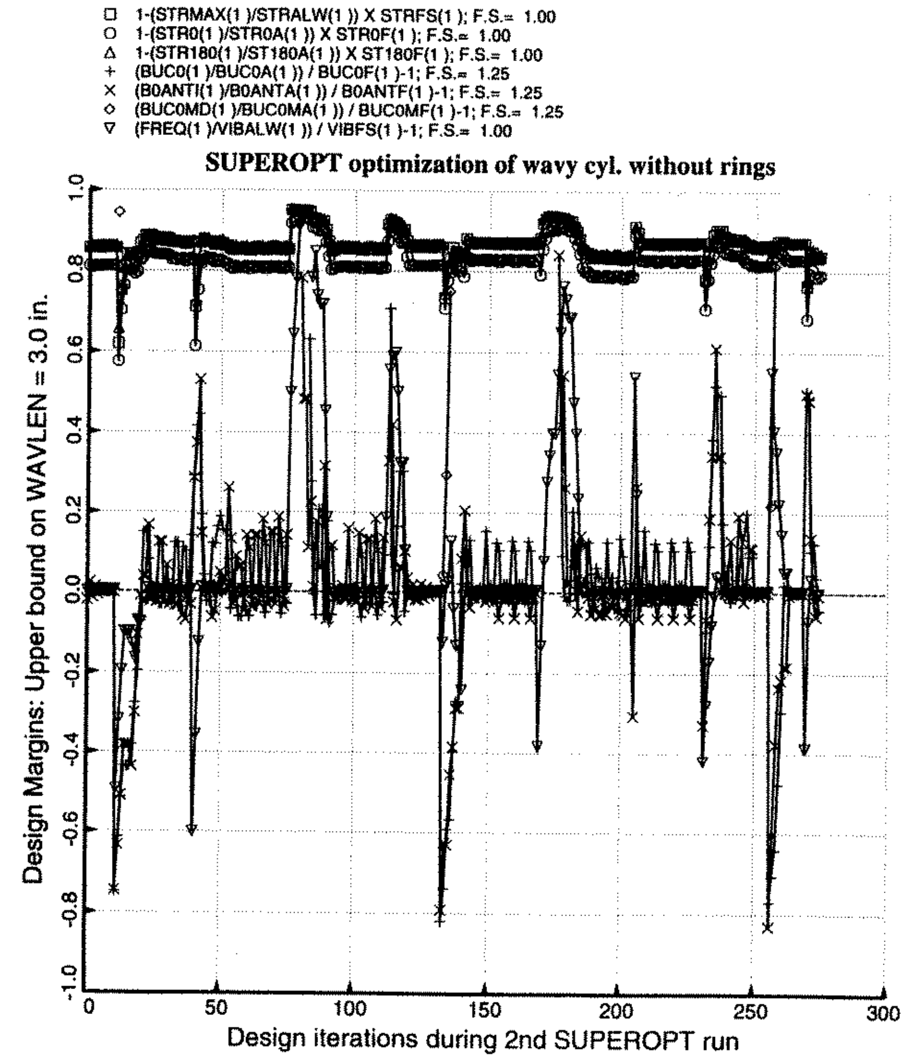

1-(STRMAX(1)/STRALW(1)) X STRFS(1); F.S.= 1.00
1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
(BUC0MD(1)/BUC0MA(1)) / BUC0MF(1)-1; F.S.= 1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
SUPEROPT optimization of wavy cyl. without rings
Design Margins: Upper bound on WAVLEN = 3.0 in.
Design iterations during 2nd SUPEROPT run
0
50
100
150
200
250
300
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0

FIG. 44

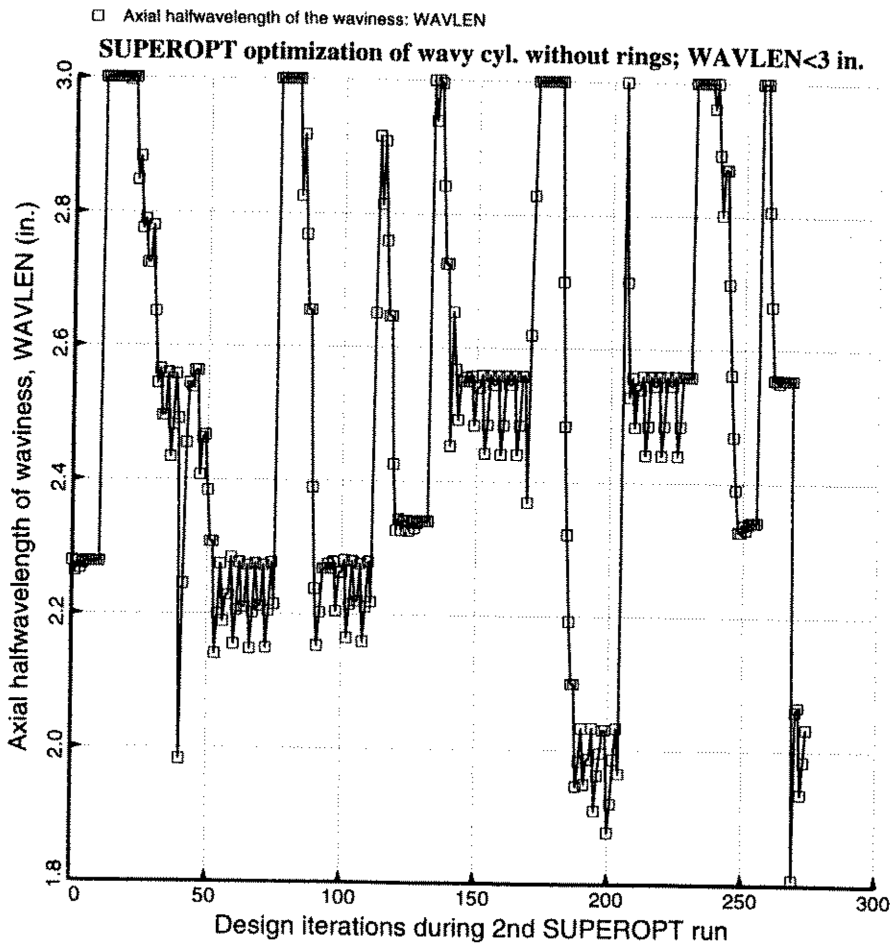

Axial halfwavelength of the waviness: WAVLEN
SUPEROPT optimization of wavy cyl. without rings; WAVLEN<3 in.
Axial halfwavelength of waviness, WAVLEN (in.)
3.0
2.8
2.6
2.4
2.2
2.0
1.8
0
50
100
150
200
250
300
Design iterations during 2nd SUPEROPT run

FIG. 45

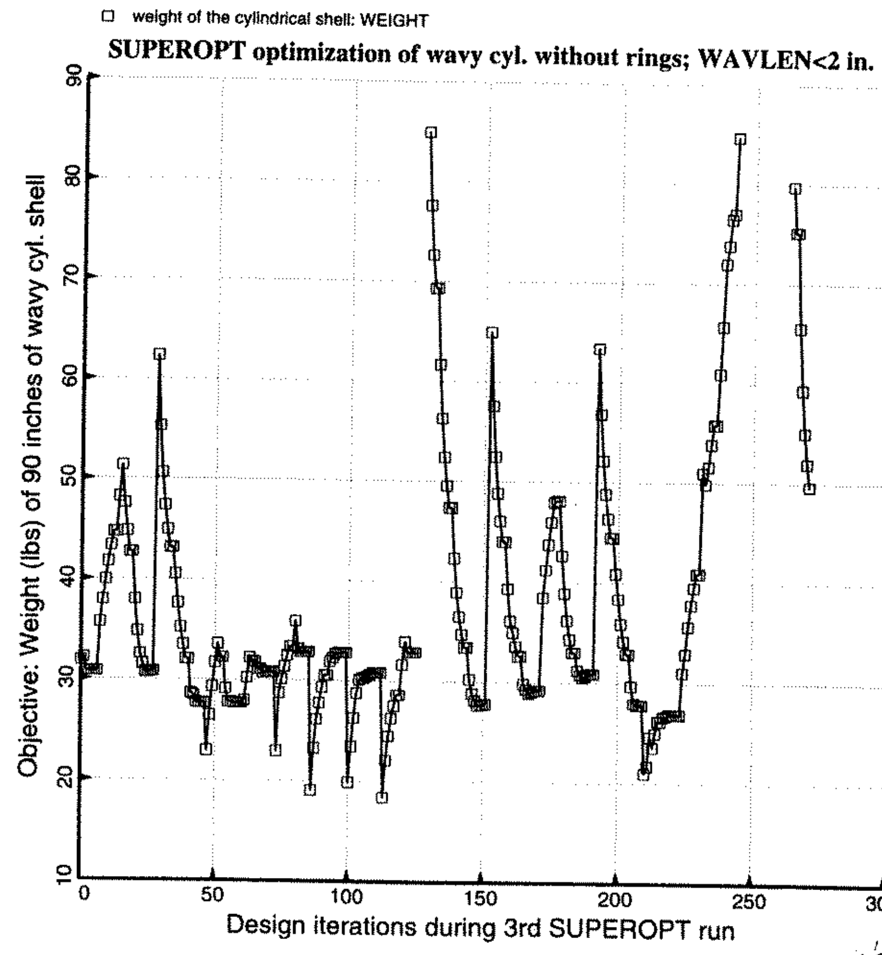

weight of the cylindrical shell: WEIGHT
SUPEROPT optimization of wavy cyl. without rings; WAVLEN<2 in.
Objective: Weight (lbs) of 90 inches of wavy cyl. shell
90
80
70
60
50
40
30
20
10
0
50
100
150
200
250
300
Design iterations during 3rd SUPEROPT run

FIG. 46

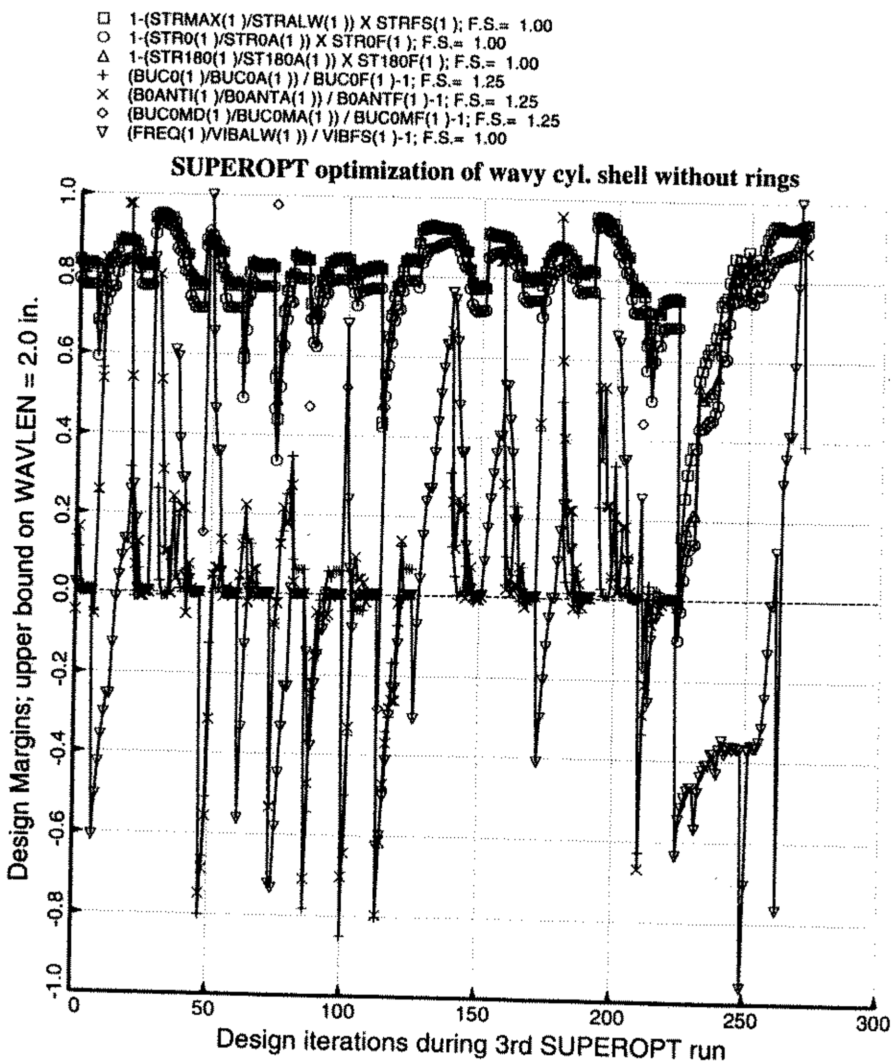

1-(STRMAX(1)/STRALW(1)) X STRFS(1); F.S.= 1.00
1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
(BUC0MD(1)/BUC0MA(1)) / BUC0MF(1)-1; F.S.= 1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
SUPEROPT optimization of wavy cyl. shell without rings
Design Margins; upper bound on WAVLEN = 2.0 in.
Design iterations during 3rd SUPEROPT run

FIG. 47

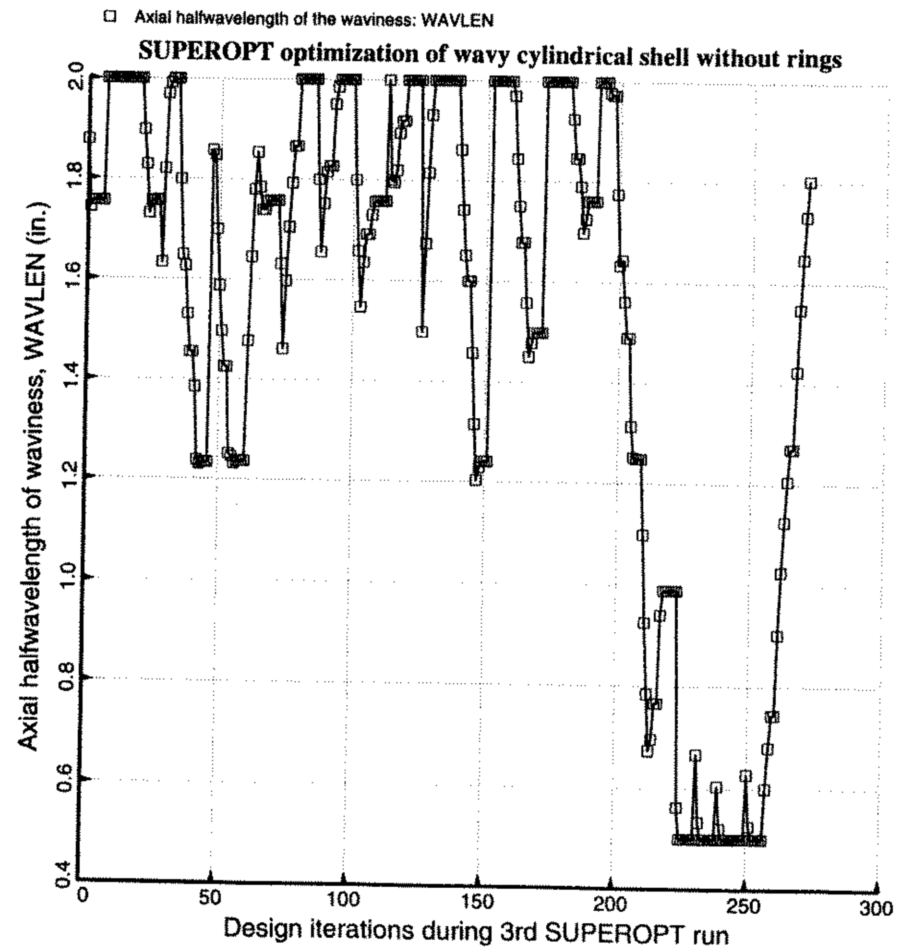

Axial halfwavelength of the waviness: WAVLEN
SUPEROPT optimization of wavy cylindrical shell without rings
Axial halfwavelength of waviness, WAVLEN (in.)
Design iterations during 3rd SUPEROPT run

FIG. 48

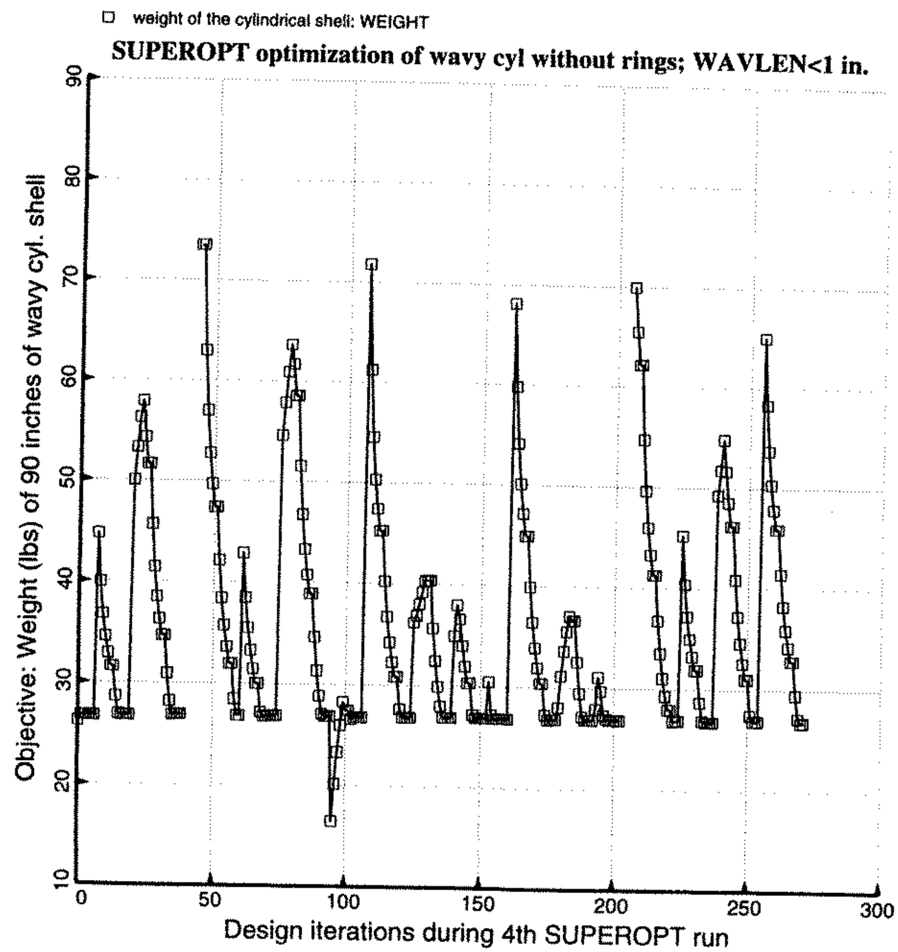

weight of the cylindrical shell: WEIGHT
SUPEROPT optimization of wavy cyl without rings; WAVLEN<1 in.
Objective: Weight (lbs) of 90 inches of wavy cyl. shell
Design iterations during 4th SUPEROPT run

FIG. 49

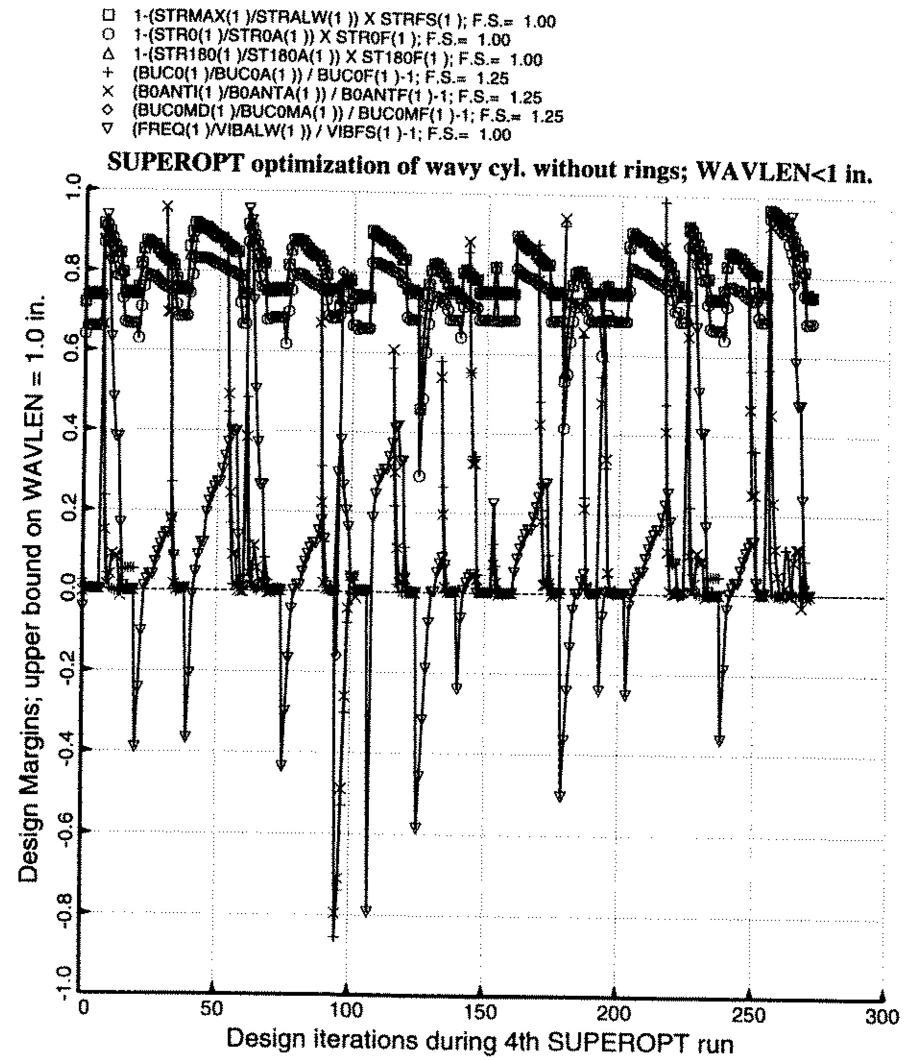
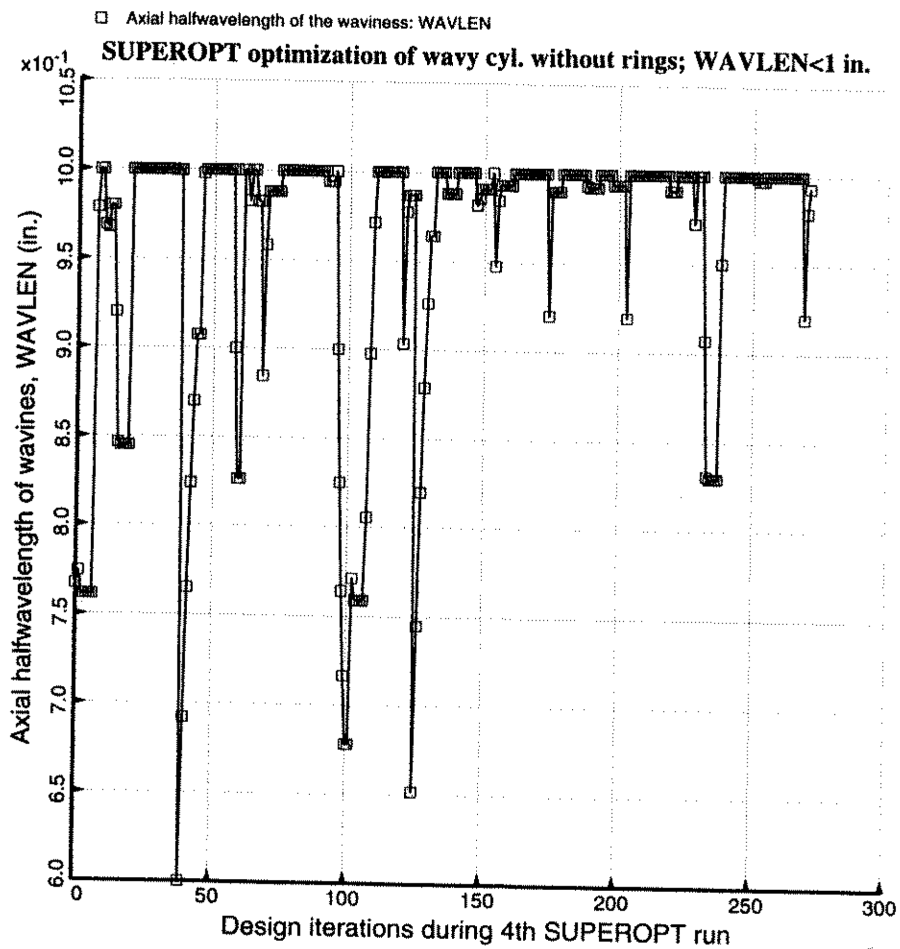
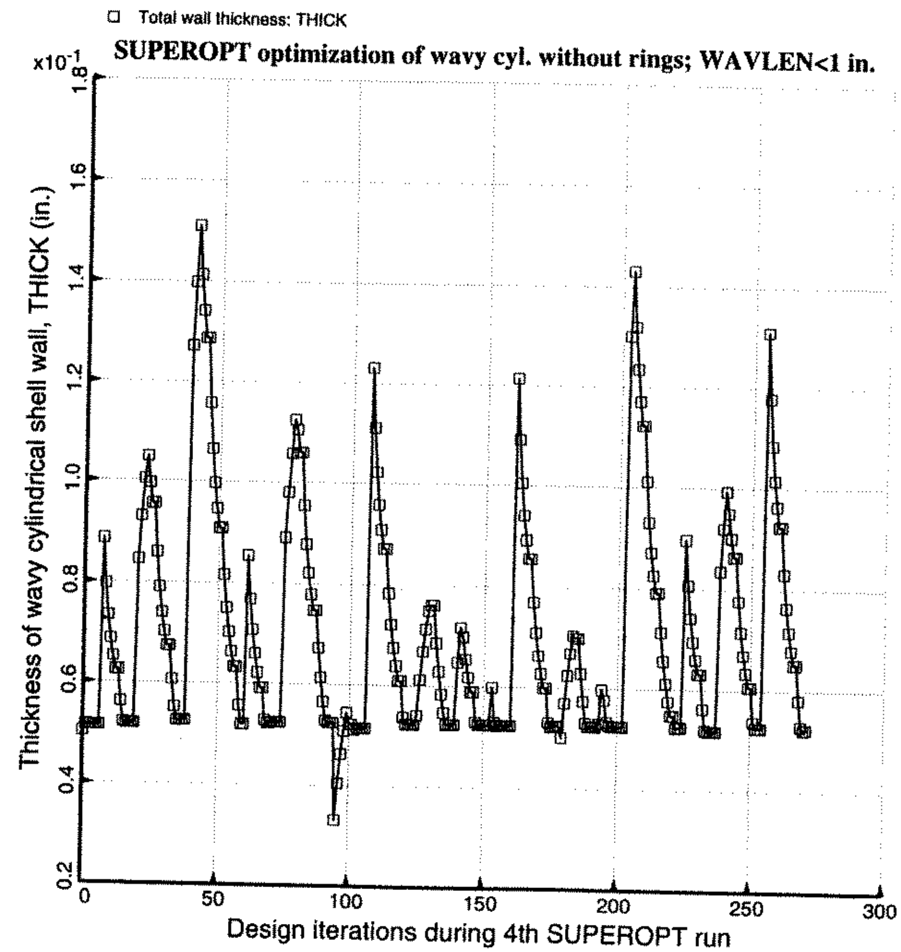

1-(STRMAX(1)/STRALW(1)) X STRFS(1); F.S.= 1.00
1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
(BUC0MD(1)/BUC0MA(1)) / BUC0MF(1)-1; F.S.= 1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
SUPEROPT optimization of wavy cyl. without rings; WAVLEN<1 in.
Design Margins; upper bound on WAVLEN = 1.0 in.
Design iterations during 4th SUPEROPT run

FIG. 50



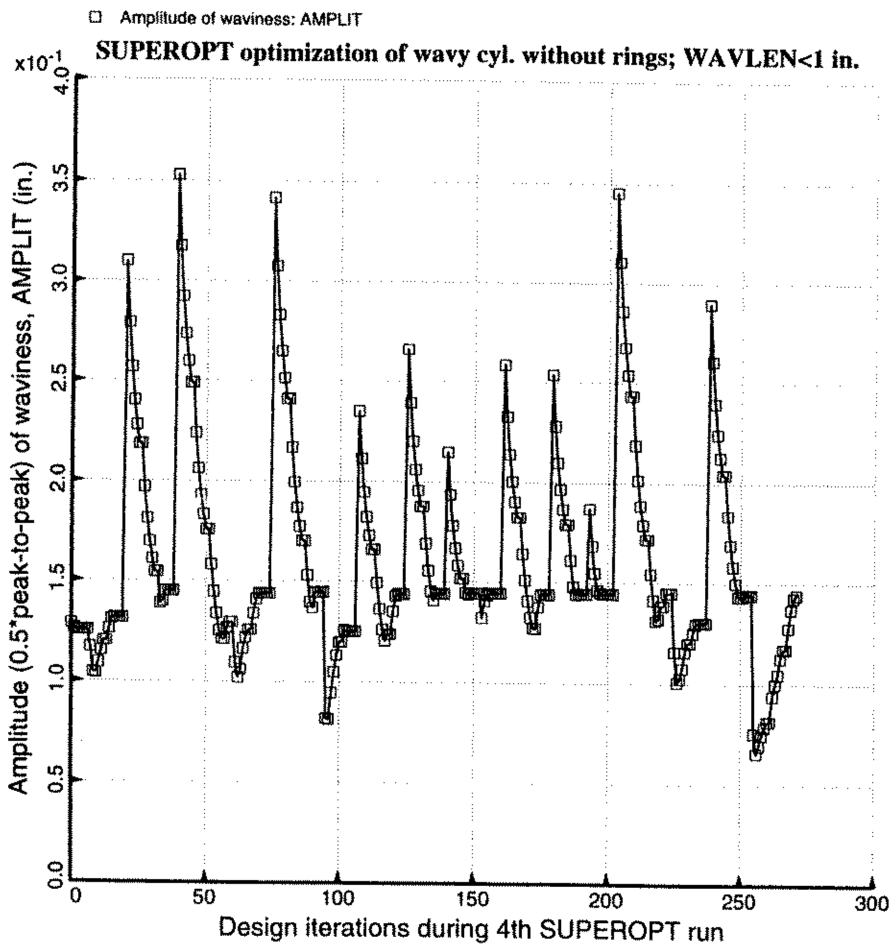
Axial halfwavelength of the waviness: WAVLEN
SUPEROPT optimization of wavy cyl. without rings; WAVLEN<1 in.
x10^-1
Axial halfwavelength of wavines, WAVLEN (in.)
Design iterations during 4th SUPEROPT run

FIG. 51



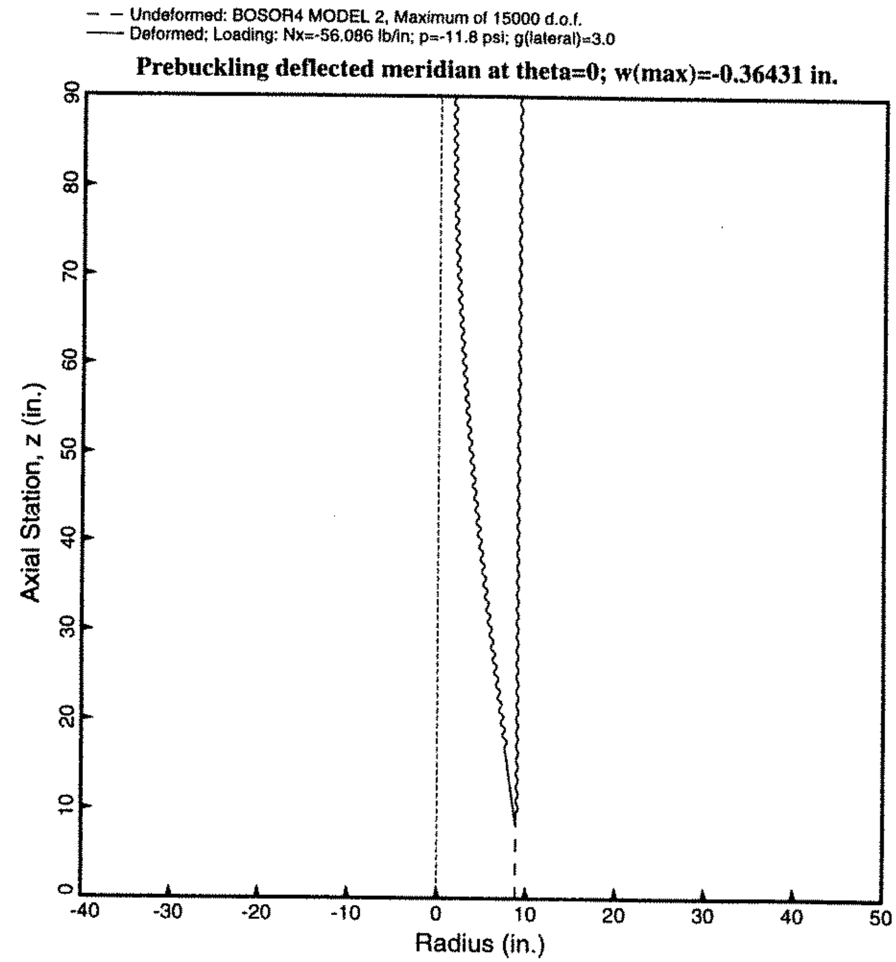
Total wall thickness: THICK
SUPEROPT optimization of wavy cyl. without rings; WAVLEN<1 in.
x10^-1
Thickness of wavy cylindrical shell wall, THICK (in.)
Design iterations during 4th SUPEROPT run

FIG. 52



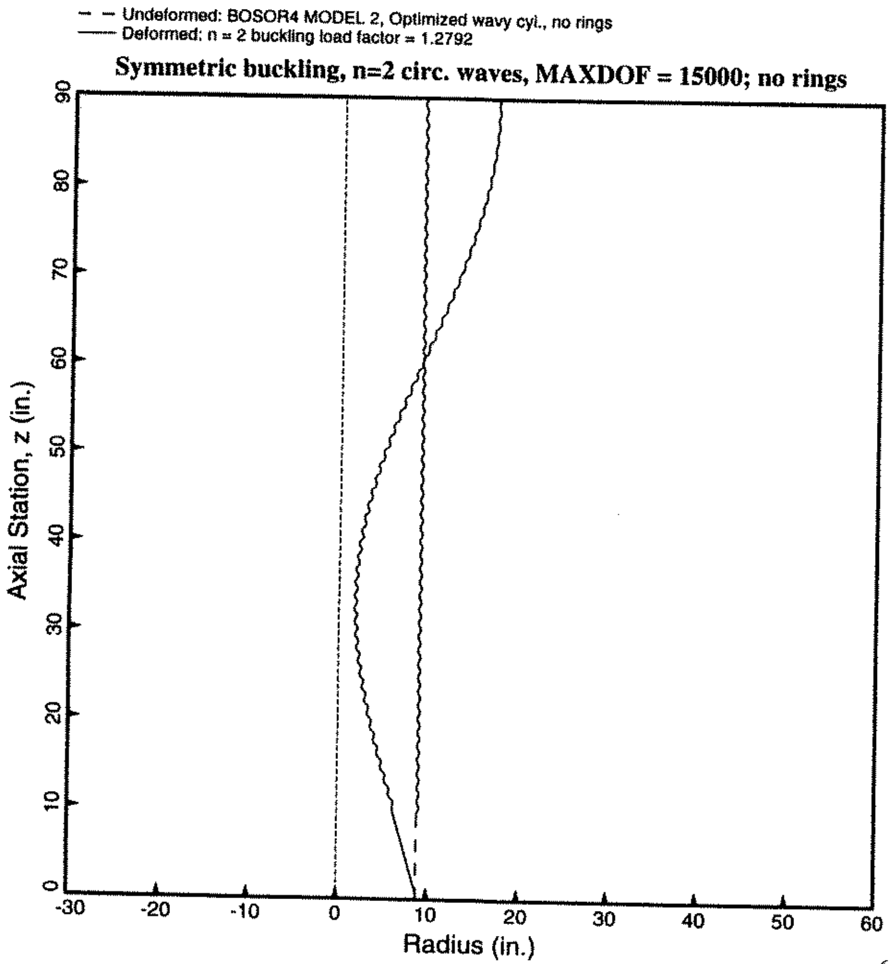
Amplitude of waviness: AMPLIT
SUPEROPT optimization of wavy cyl. without rings; WAVLEN<1 in.
Amplitude (0.5*peak-to-peak) of waviness, AMPLIT (in.)
x10-1
Design iterations during 4th SUPEROPT run

FIG. 53



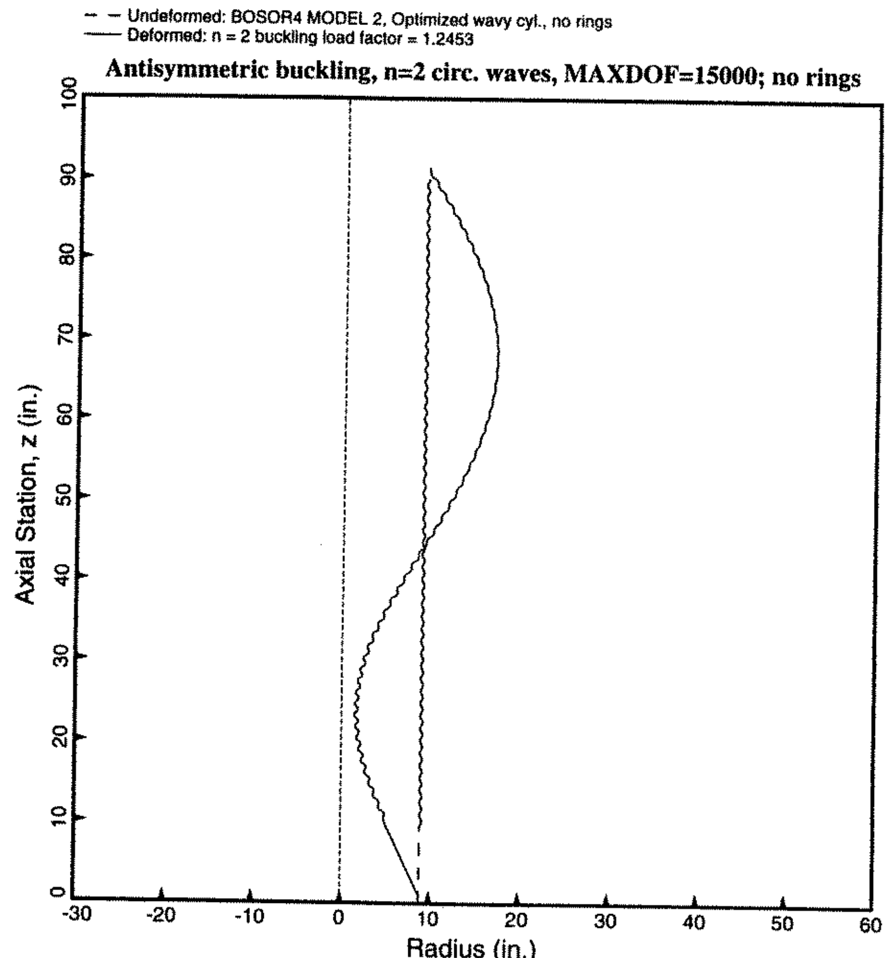
Undeformed: BOSOR4 MODEL 2, Maximum of 15000 d.o.f.
Deformed; Loading: Nx=-56.086 lb/in; p=-11.8 psi; g(lateral)=3.0
Prebuckling deflected meridian at theta=0; w(max)=-0.36431 in.
Axial Station, z (in.)
Radius (in.)

FIG. 54



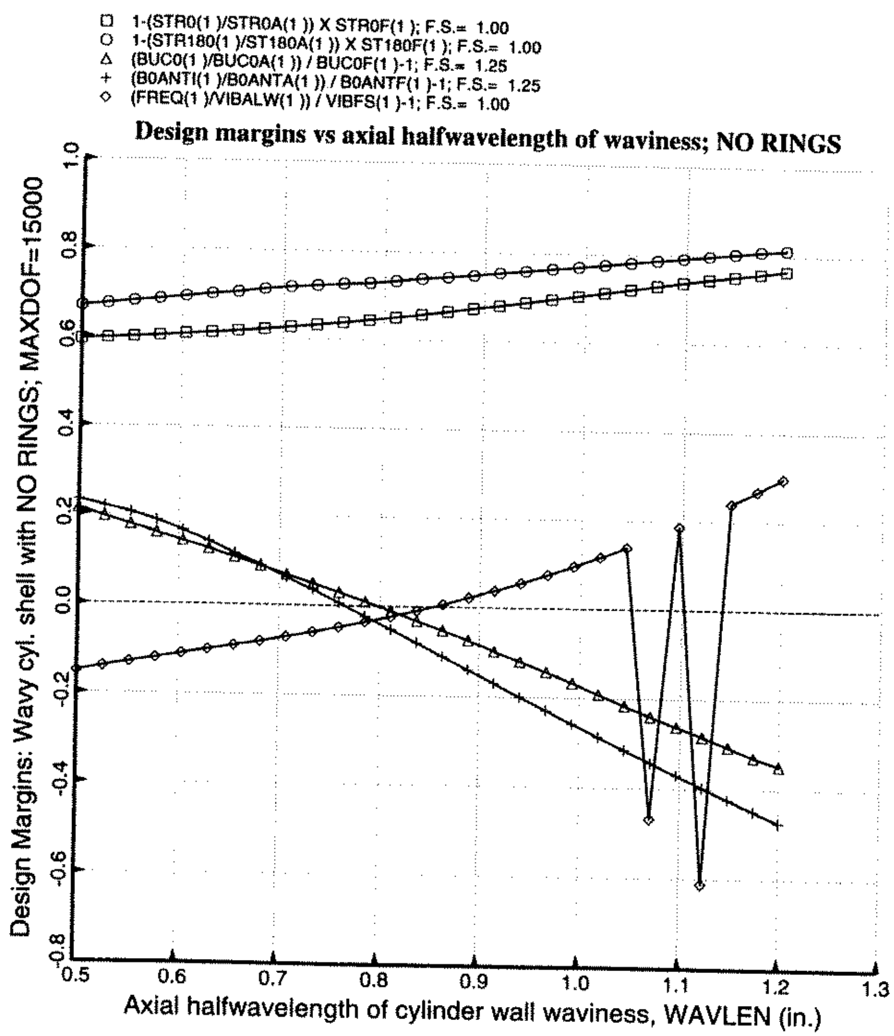
– – Undeformed: BOSOR4 MODEL 2, Optimized wavy cyl., no rings
—— Deformed: n = 2 buckling load factor = 1.2792
Symmetric buckling, n=2 circ. waves, MAXDOF = 15000; no rings
Axial Station, z (in.)
Radius (in.)
-30
-20
-10
0
10
20
30
40
50
60
70
80
90

FIG. 55



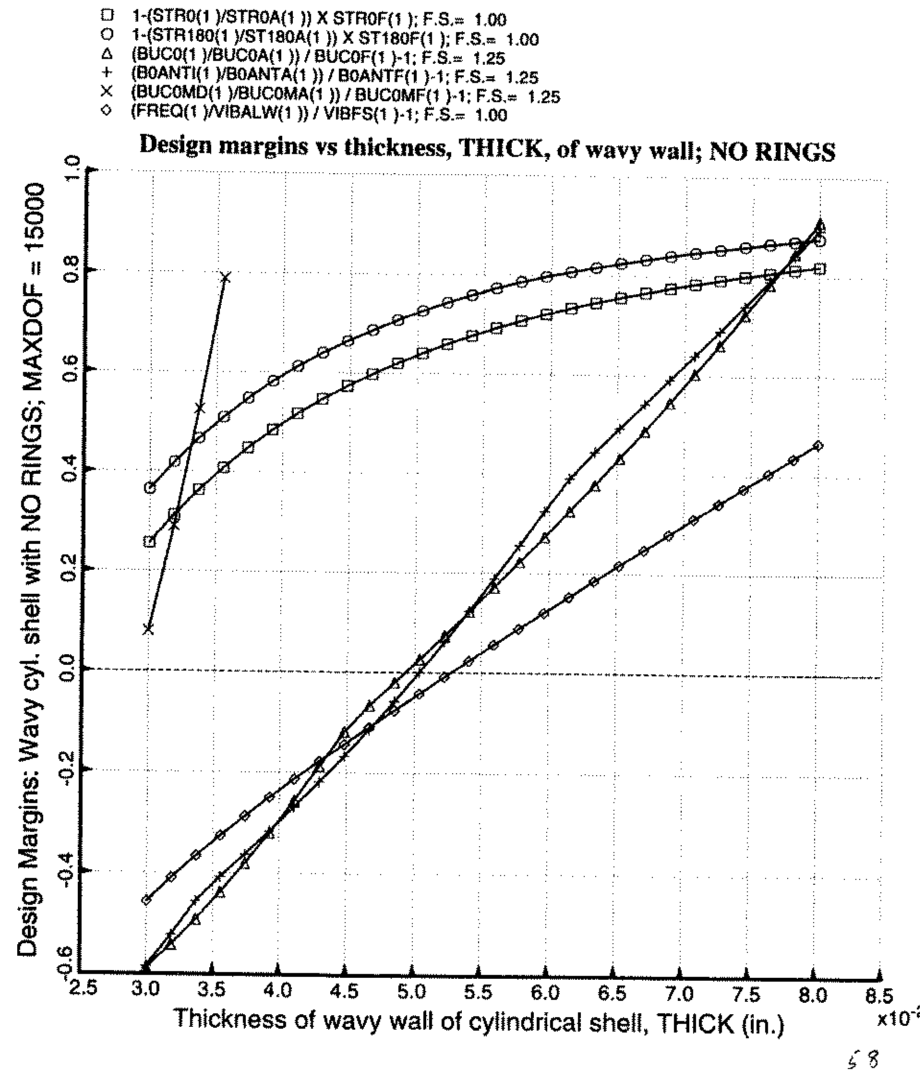
– – Undeformed: BOSOR4 MODEL 2, Optimized wavy cyl., no rings
—— Deformed: n = 2 buckling load factor = 1.2453
Antisymmetric buckling, n=2 circ. waves, MAXDOF=15000; no rings
Axial Station, z (in.)
Radius (in.)
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100

FIG. 56



□ 1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
○ 1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
△ (BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
+ (B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
◇ (FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
Design margins vs axial halfwavelength of waviness; NO RINGS
Design Margins: Wavy cyl. shell with NO RINGS; MAXDOF=15000
Axial halfwavelength of cylinder wall waviness, WAVLEN (in.)
57

FIG. 57



□ 1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
○ 1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
△ (BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
+ (B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
× (BUC0MD(1)/BUC0MA(1)) / BUC0MF(1)-1; F.S.= 1.25
◇ (FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
Design margins vs thickness, THICK, of wavy wall; NO RINGS
Design Margins: Wavy cyl. shell with NO RINGS; MAXDOF = 15000
Thickness of wavy wall of cylindrical shell, THICK (in.)
x10-2
58

FIG. 58

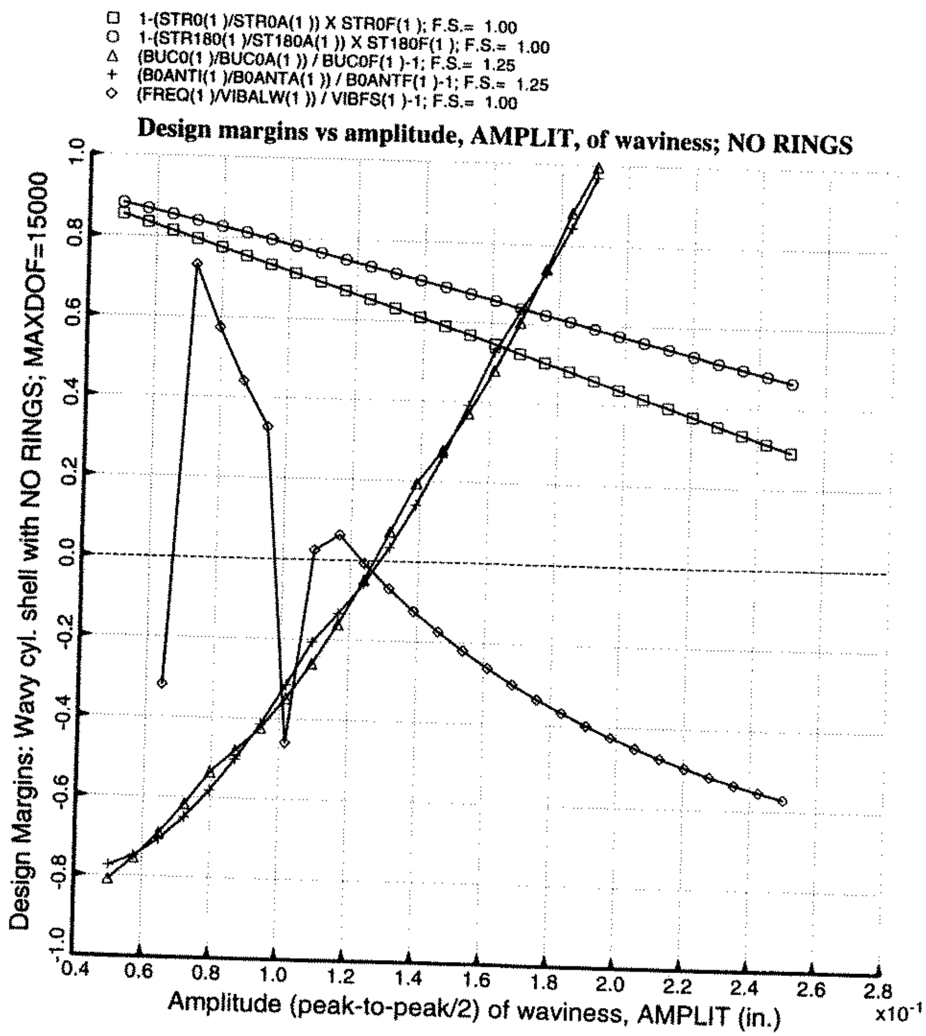

1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
Design margins vs amplitude, AMPLIT, of waviness; NO RINGS
Design Margins: Wavy cyl. shell with NO RINGS; MAXDOF=15000
Amplitude (peak-to-peak/2) of waviness, AMPLIT (in.)
x10-1

FIG. 59

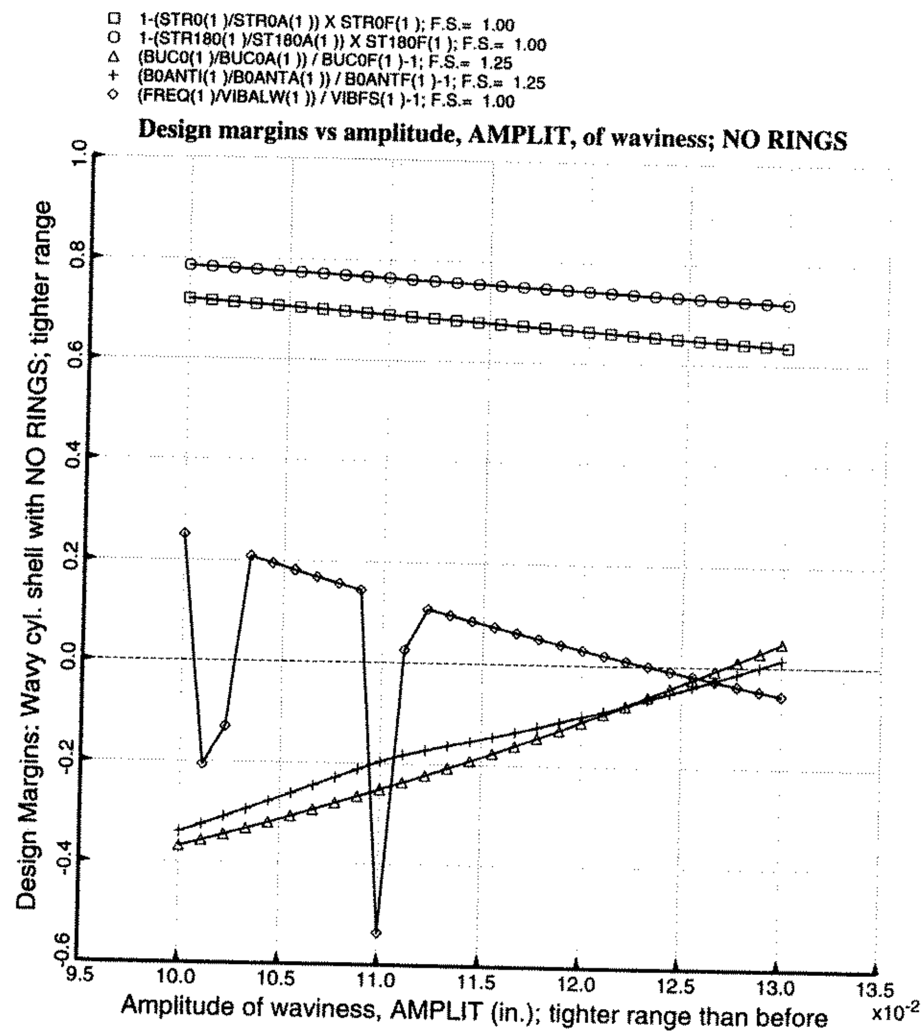
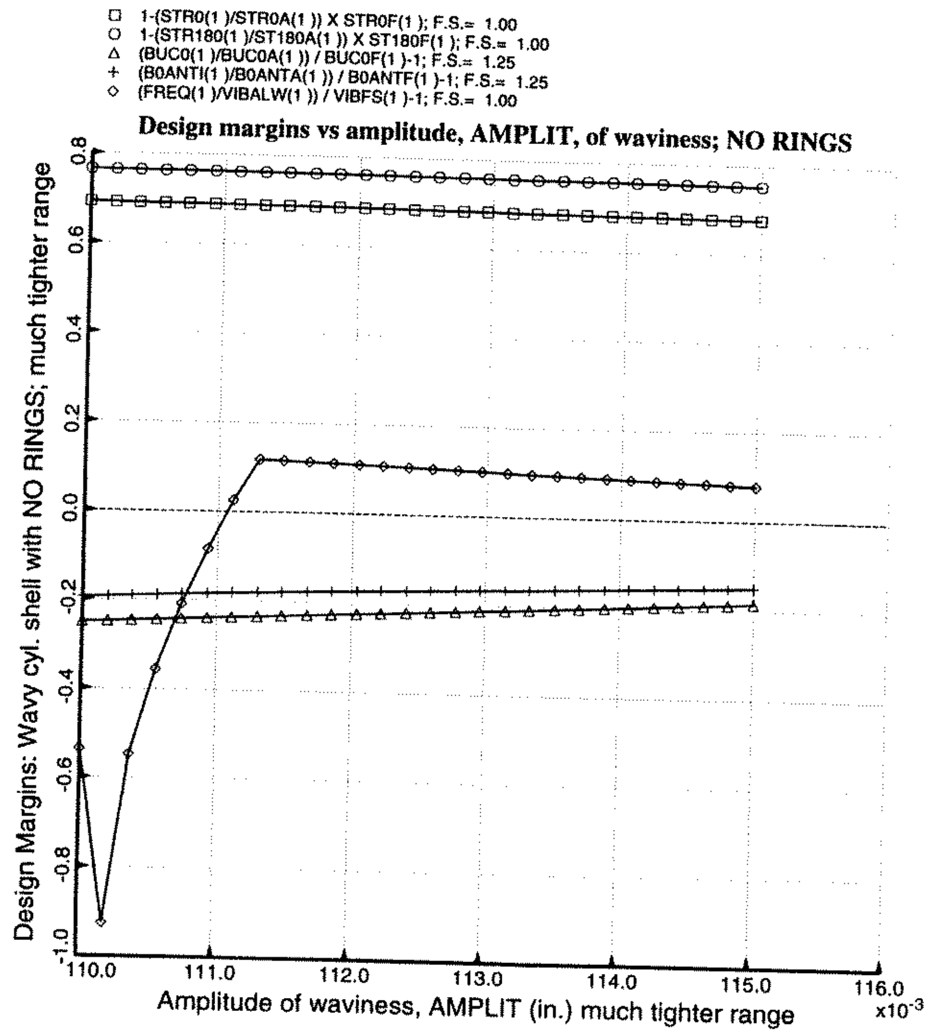
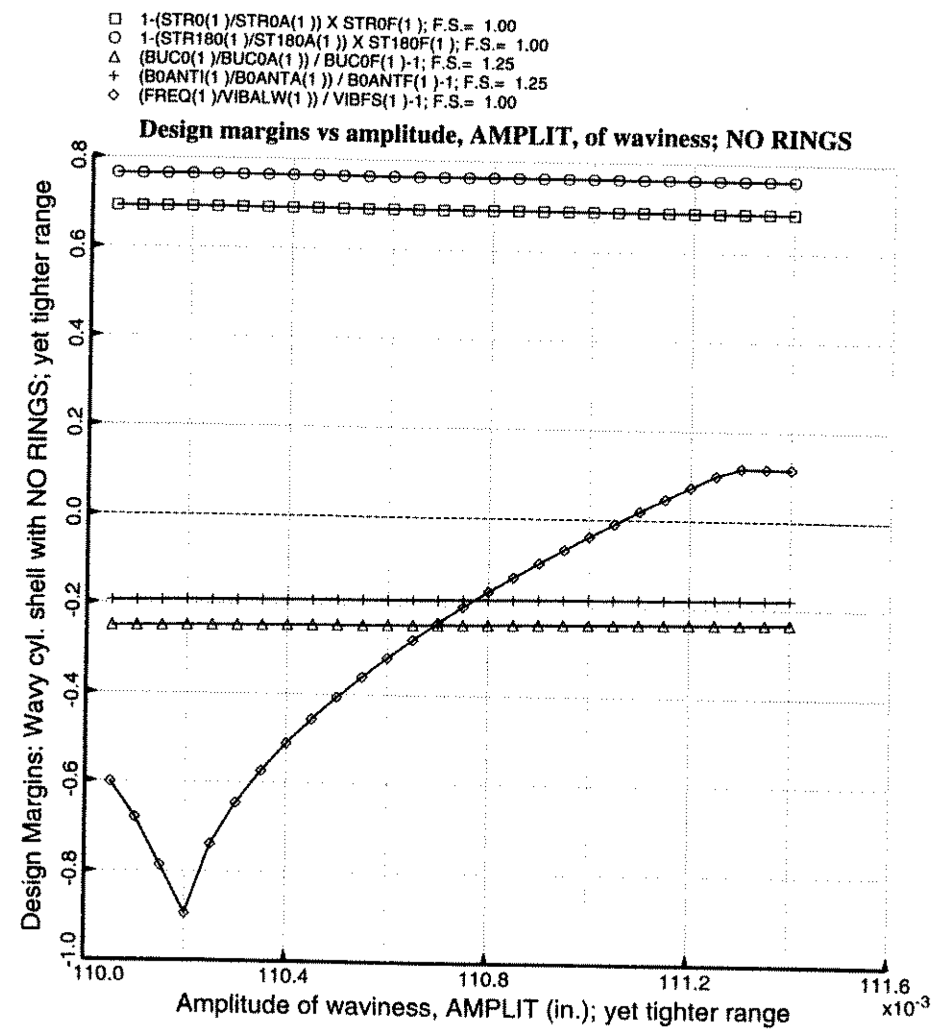

1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
Design margins vs amplitude, AMPLIT, of waviness; NO RINGS
Design Margins: Wavy cyl. shell with NO RINGS; tighter range
Amplitude of waviness, AMPLIT (in.); tighter range than before
x10-2

FIG. 60



□ 1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
○ 1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
△ (BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
+ (B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
◇ (FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
Design margins vs amplitude, AMPLIT, of waviness; NO RINGS
Design Margins: Wavy cyl. shell with NO RINGS; much tighter range
Amplitude of waviness, AMPLIT (in.) much tighter range
x10-3

FIG. 61



□ 1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
○ 1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
△ (BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
+ (B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
◇ (FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
Design margins vs amplitude, AMPLIT, of waviness; NO RINGS
Design Margins: Wavy cyl. shell with NO RINGS; yet tighter range
Amplitude of waviness, AMPLIT (in.); yet tighter range
x10-3

FIG. 62

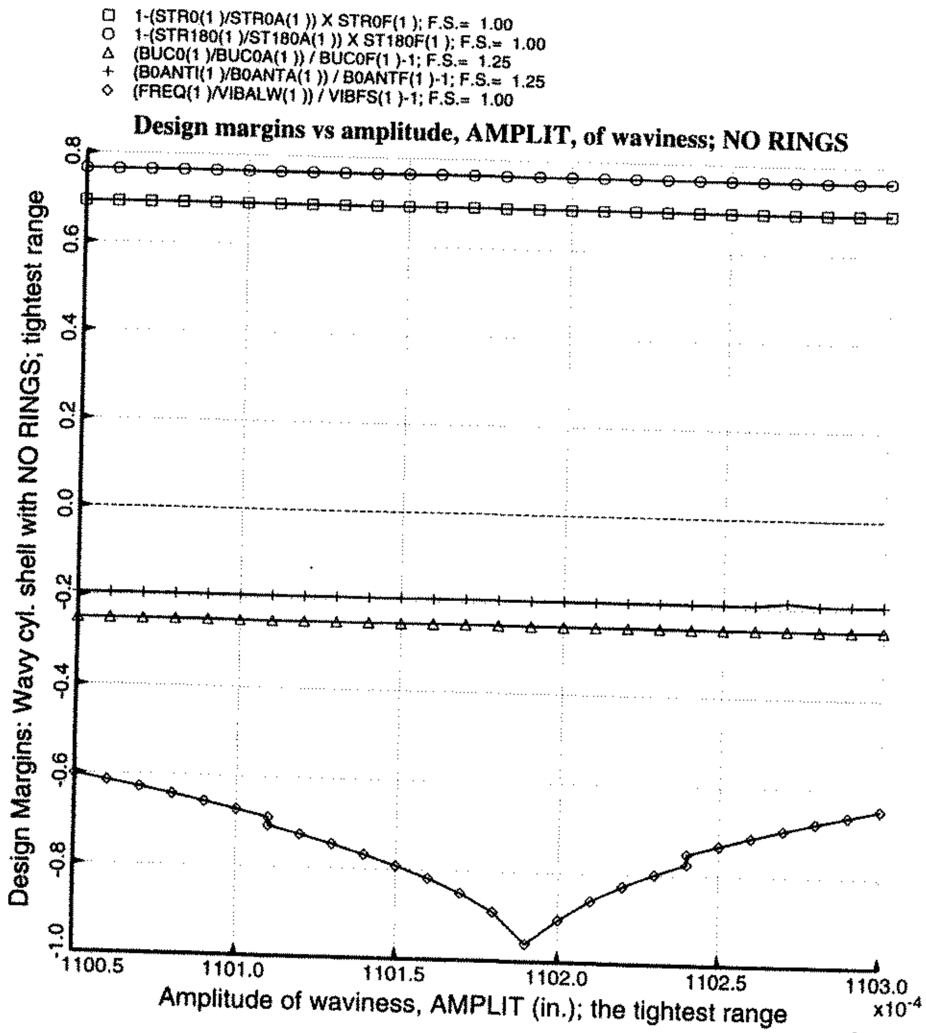

1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.= 1.00
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.= 1.00
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.= 1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.= 1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.= 1.00
Design margins vs amplitude, AMPLIT, of waviness; NO RINGS
Design Margins: Wavy cyl. shell with NO RINGS; tightest range
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
1100.5
1101.0
1101.5
1102.0
1102.5
1103.0
x10-4
Amplitude of waviness, AMPLIT (in.); the tightest range

FIG. 63

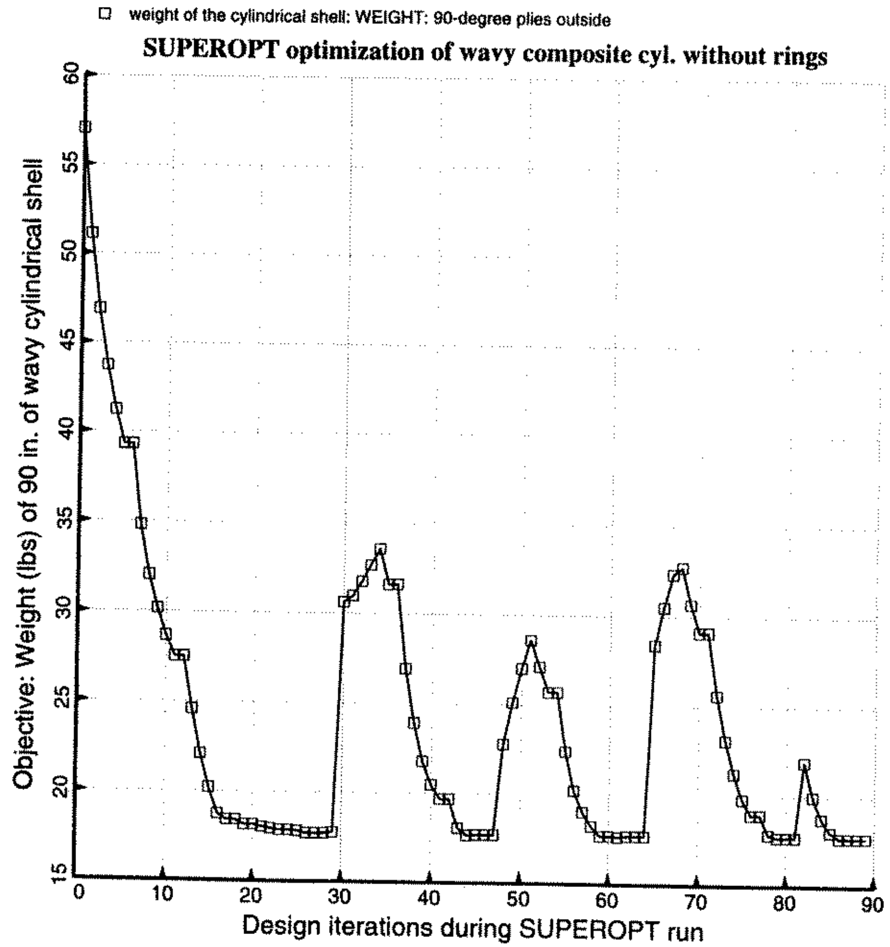
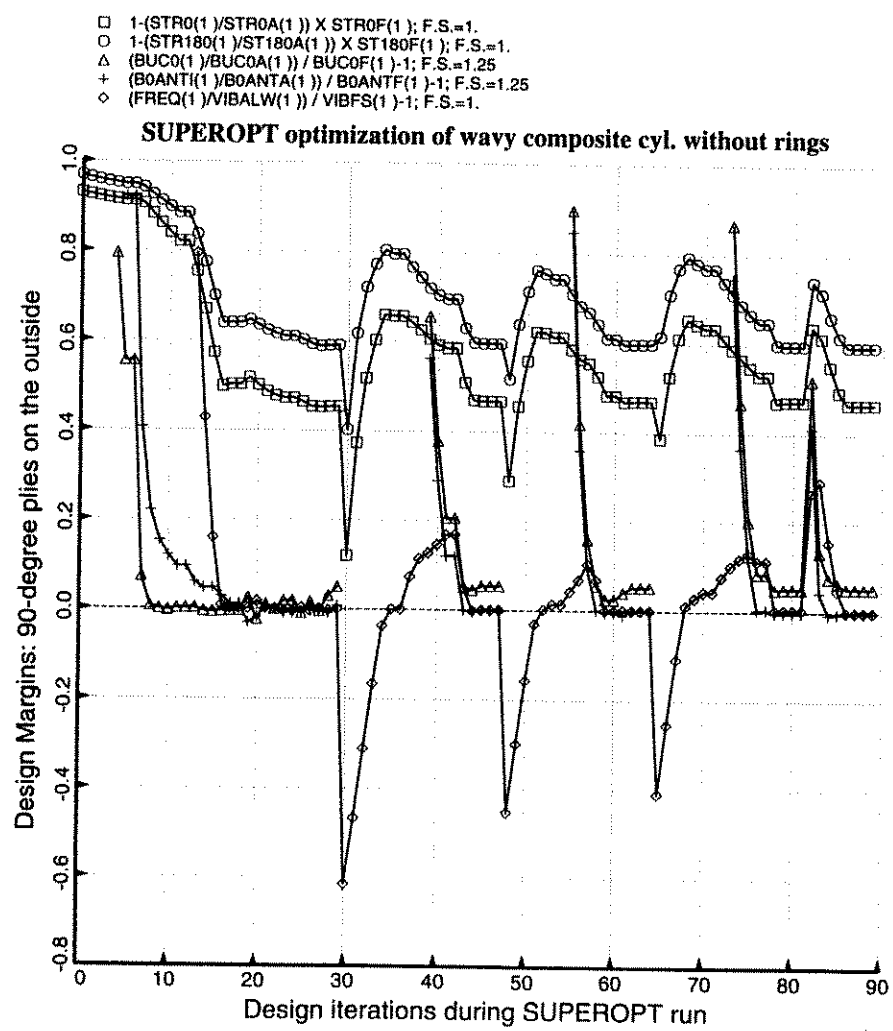
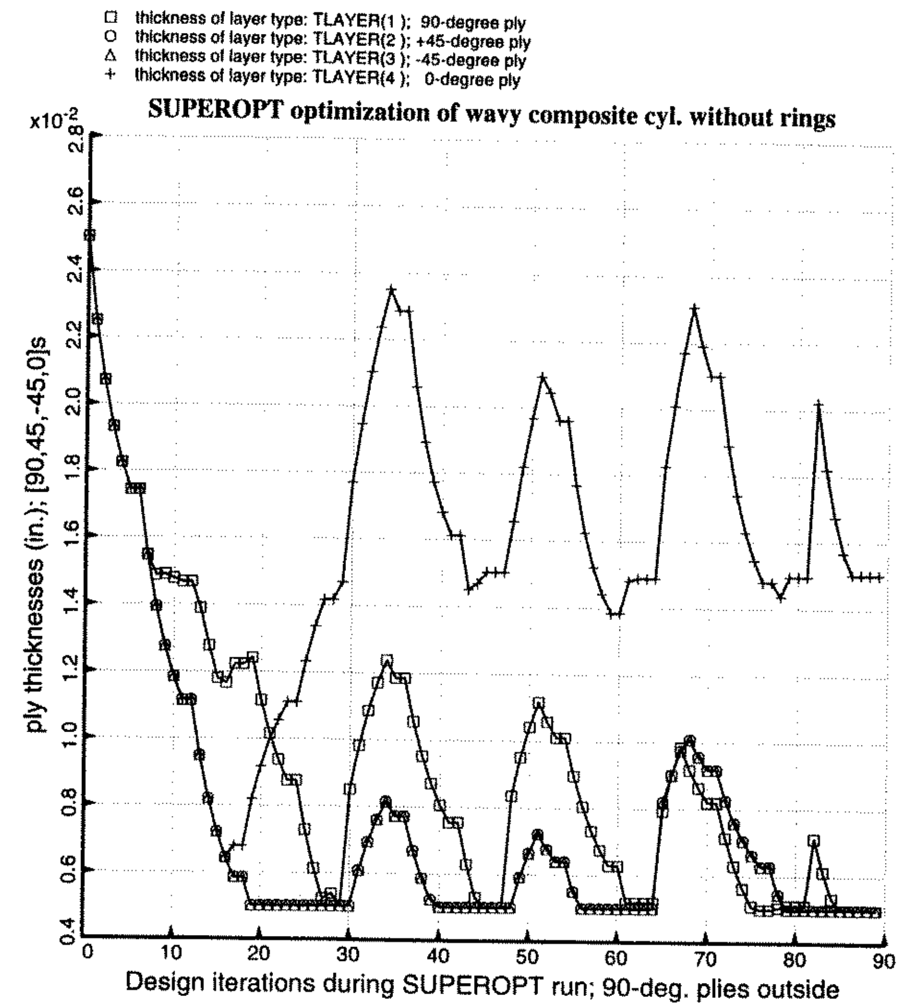

weight of the cylindrical shell: WEIGHT: 90-degree plies outside
SUPEROPT optimization of wavy composite cyl. without rings
Objective: Weight (lbs) of 90 in. of wavy cylindrical shell
60
55
50
45
40
35
30
25
20
15
0
10
20
30
40
50
60
70
80
90
Design iterations during SUPEROPT run

FIG. 64



□ 1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.=1.
○ 1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.=1.
△ (BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.=1.25
+ (B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.=1.25
◇ (FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.=1.
SUPEROPT optimization of wavy composite cyl. without rings
Design Margins: 90-degree plies on the outside
Design iterations during SUPEROPT run

FIG. 65



□ thickness of layer type: TLAYER(1); 90-degree ply
○ thickness of layer type: TLAYER(2); +45-degree ply
△ thickness of layer type: TLAYER(3); -45-degree ply
+ thickness of layer type: TLAYER(4); 0-degree ply
SUPEROPT optimization of wavy composite cyl. without rings
x10-2
ply thicknesses (in.); [90,45,-45,0]s
Design iterations during SUPEROPT run; 90-deg. plies outside

FIG. 66

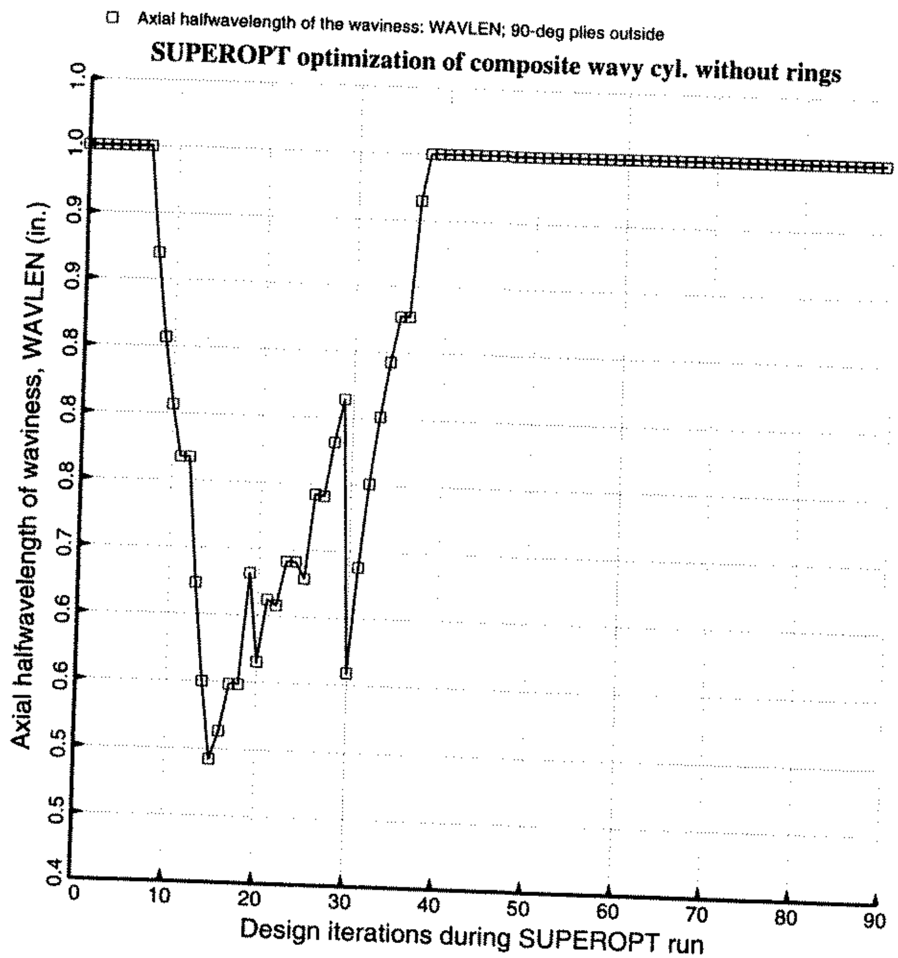

Axial halfwavelength of the waviness: WAVLEN; 90-deg plies outside
SUPEROPT optimization of composite wavy cyl. without rings
Axial halfwavelength of waviness, WAVLEN (in.)
Design iterations during SUPEROPT run

FIG. 67

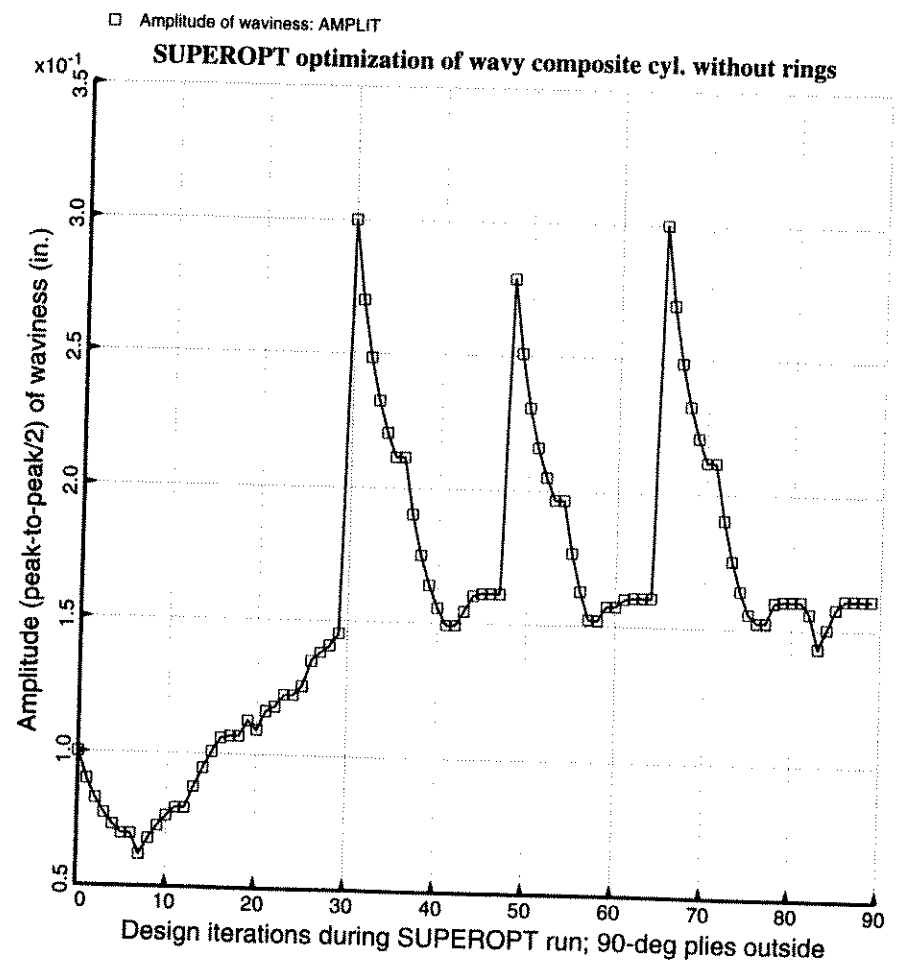
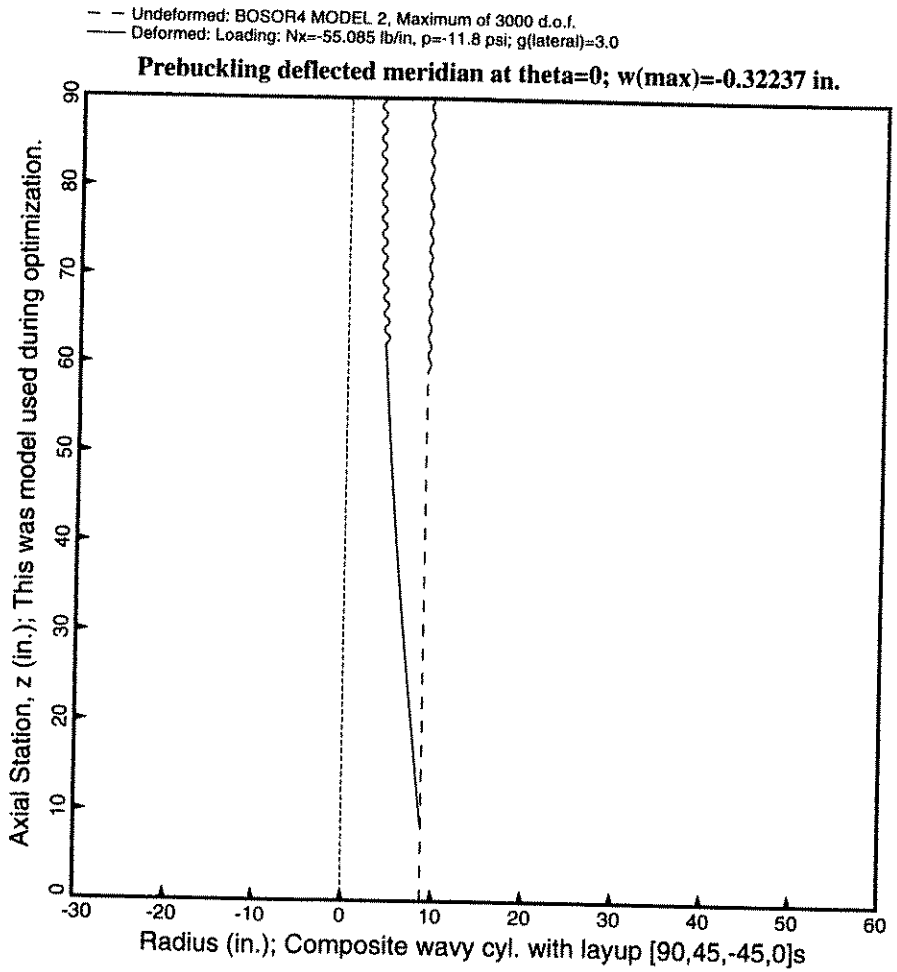
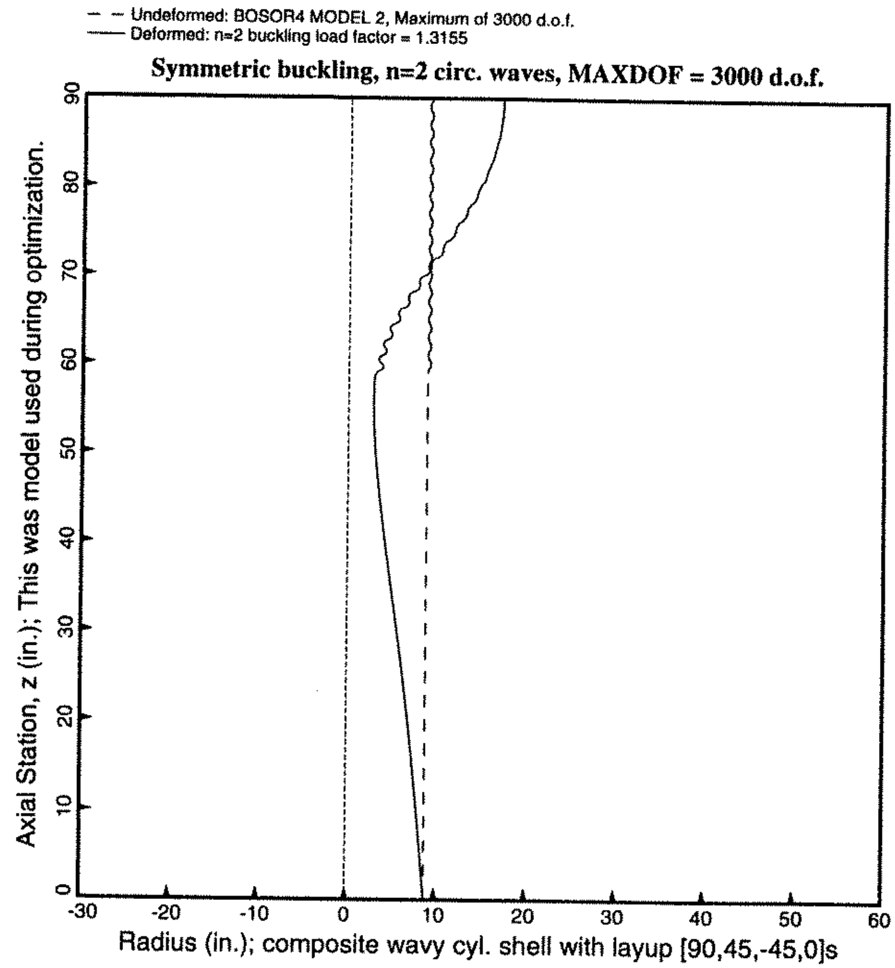

Amplitude of waviness: AMPLIT
SUPEROPT optimization of wavy composite cyl. without rings
Amplitude (peak-to-peak/2) of waviness (in.)
x10^-1
Design iterations during SUPEROPT run; 90-deg plies outside

FIG. 68



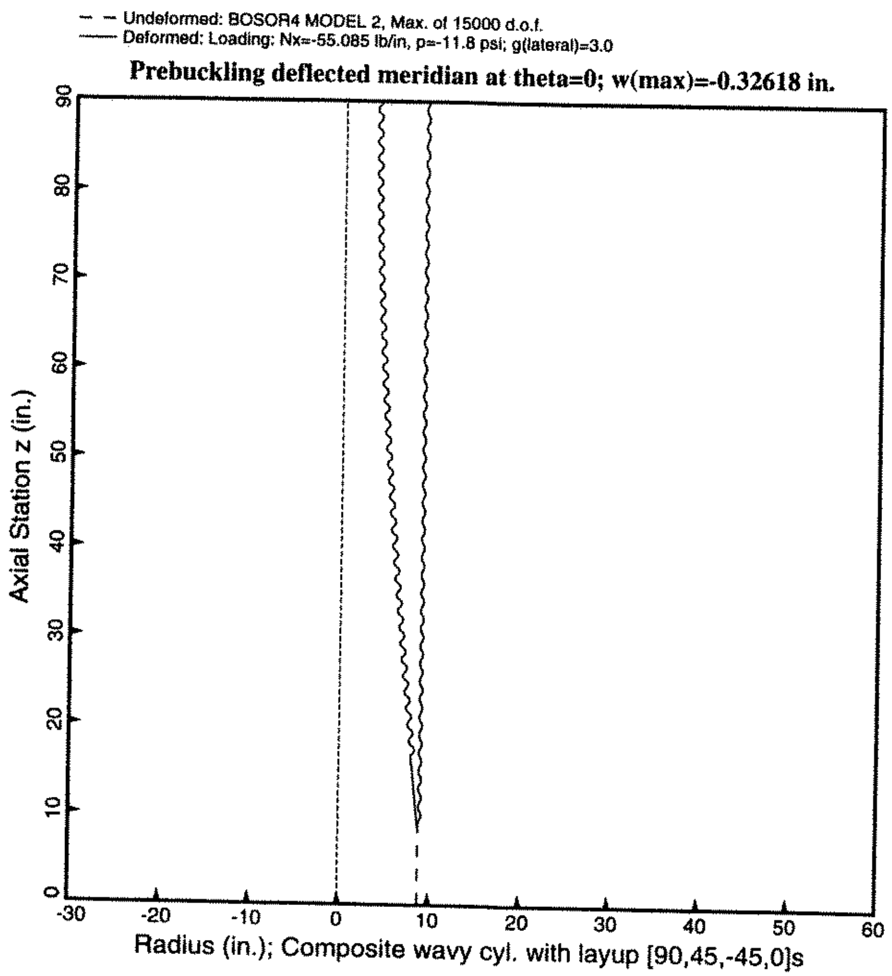
Undeformed: BOSOR4 MODEL 2, Maximum of 3000 d.o.f.
Deformed: Loading: Nx=-55.085 lb/in, p=-11.8 psi; g(lateral)=3.0
Prebuckling deflected meridian at theta=0; w(max)=-0.32237 in.
Axial Station, z (in.); This was model used during optimization.
Radius (in.); Composite wavy cyl. with layup [90,45,-45,0]s
-30
-20
-10
0
10
20
30
40
50
60
70
80
90

FIG. 69



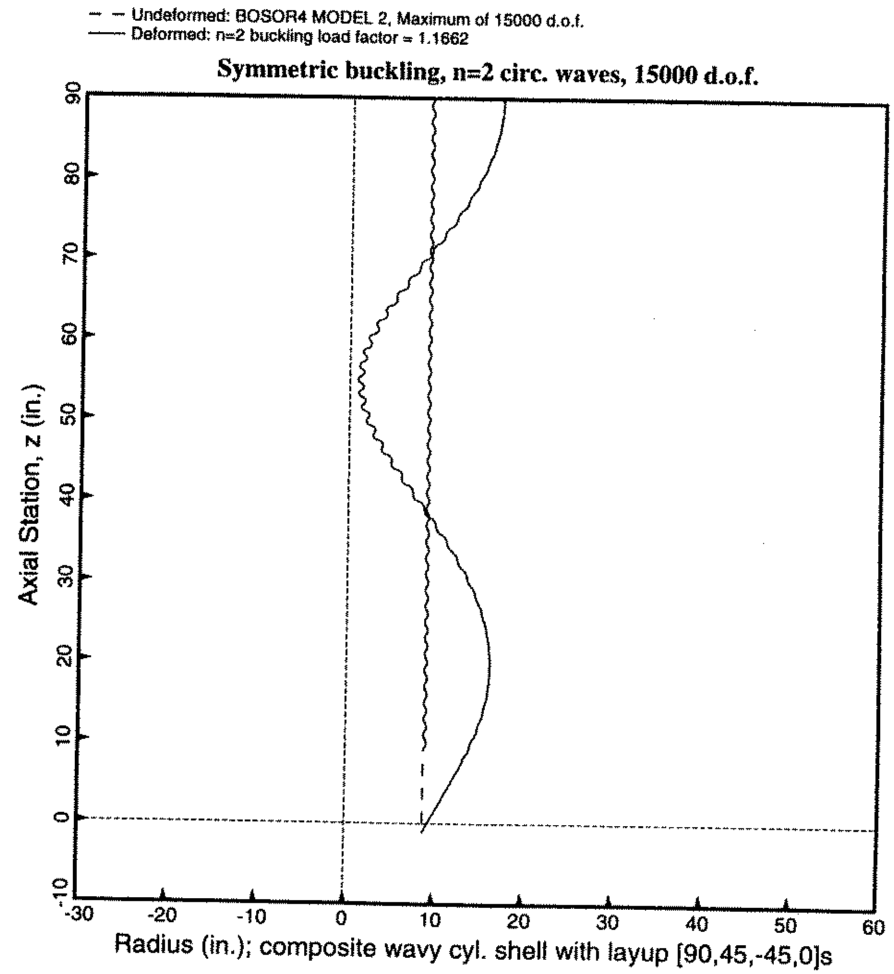
Undeformed: BOSOR4 MODEL 2, Maximum of 3000 d.o.f.
Deformed: n=2 buckling load factor = 1.3155
Symmetric buckling, n=2 circ. waves, MAXDOF = 3000 d.o.f.
Axial Station, z (in.); This was model used during optimization.
Radius (in.); composite wavy cyl. shell with layup [90,45,-45,0]s
-30
-20
-10
0
10
20
30
40
50
60
70
80
90

FIG. 70



– – Undeformed: BOSOR4 MODEL 2, Max. of 15000 d.o.f.
—— Deformed: Loading: Nx=-55.085 lb/in, p=-11.8 psi; g(lateral)=3.0
Prebuckling deflected meridian at theta=0; w(max)=-0.32618 in.
Axial Station z (in.)
Radius (in.); Composite wavy cyl. with layup [90,45,-45,0]s

FIG. 71



– – Undeformed: BOSOR4 MODEL 2, Maximum of 15000 d.o.f.
—— Deformed: n=2 buckling load factor = 1.1662
Symmetric buckling, n=2 circ. waves, 15000 d.o.f.
Axial Station, z (in.)
Radius (in.); composite wavy cyl. shell with layup [90,45,-45,0]s

FIG. 72

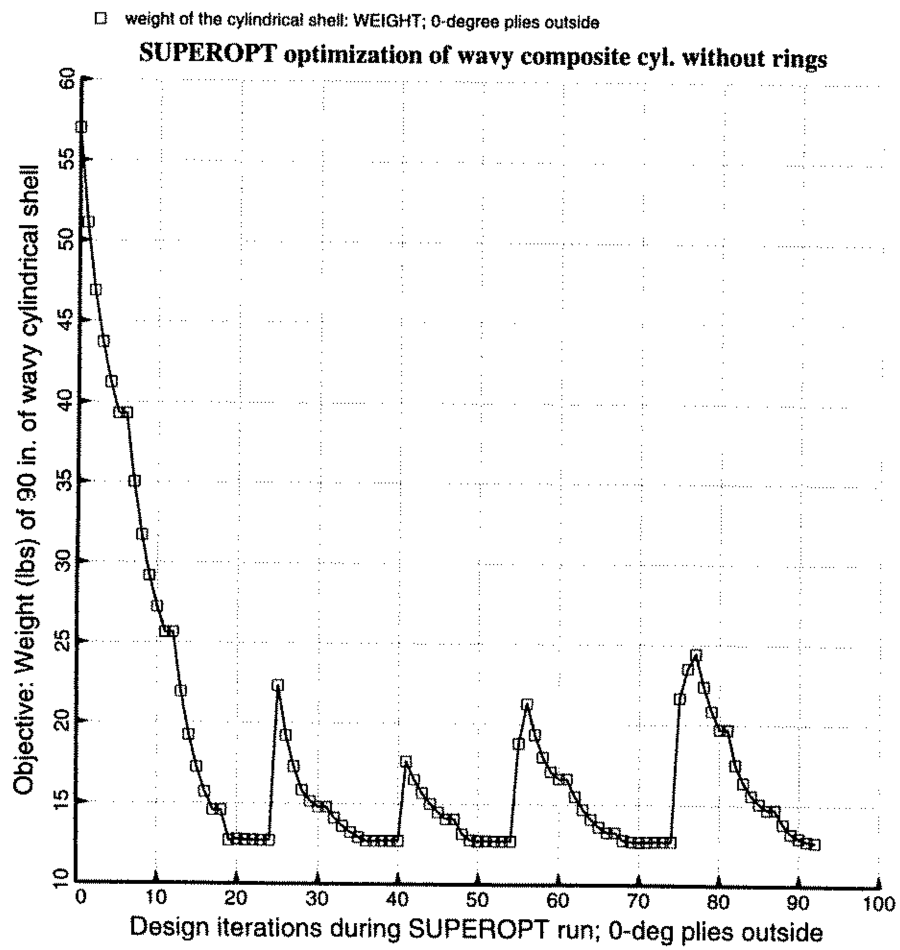


FIG. 73

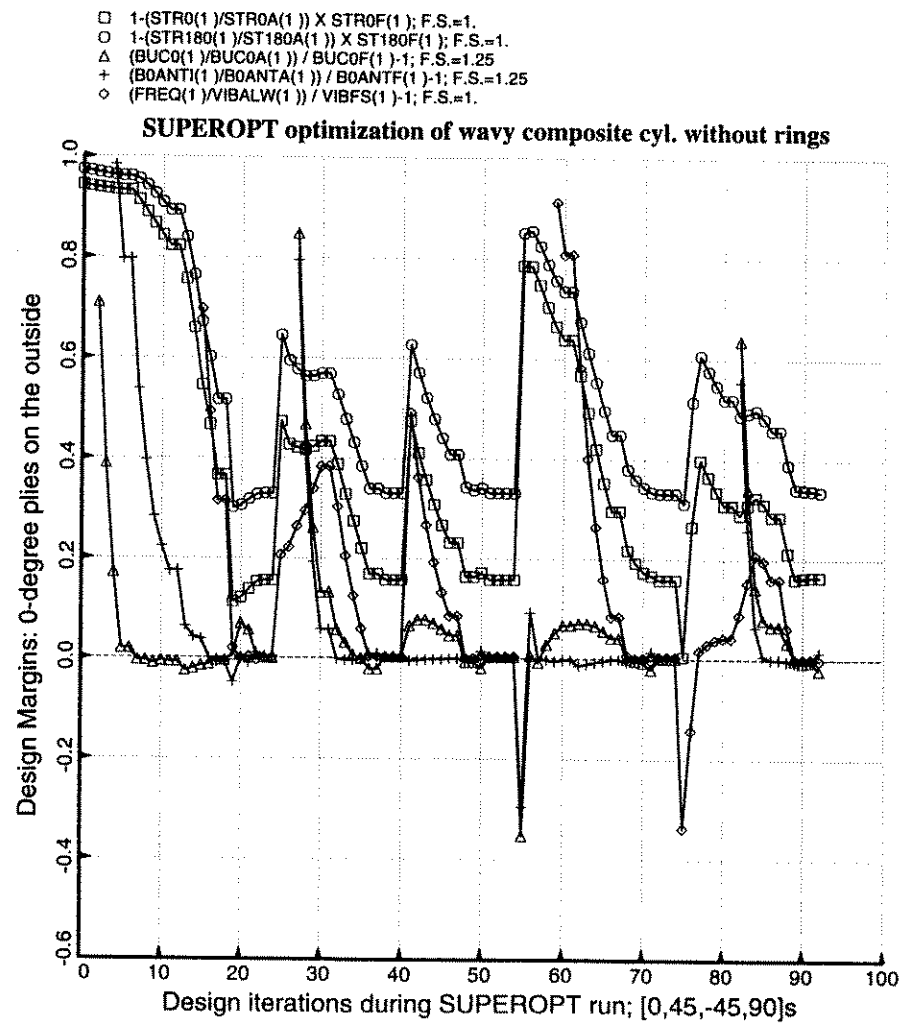
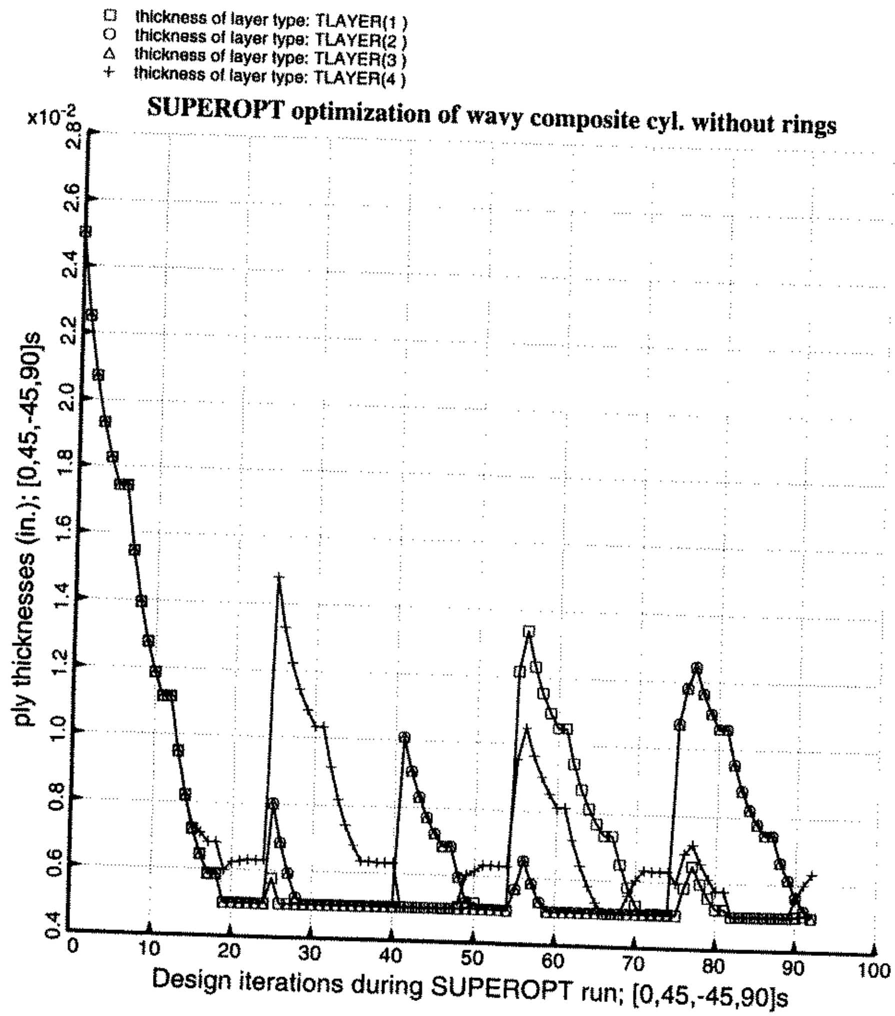


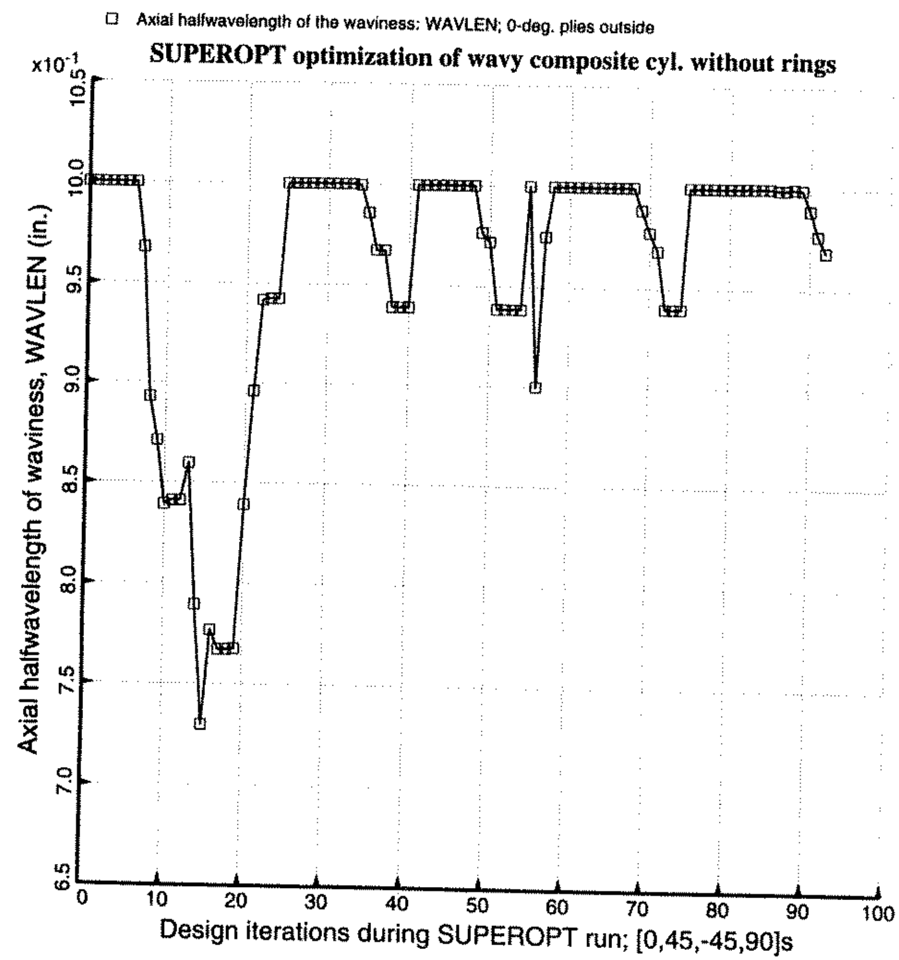
FIG. 74

74



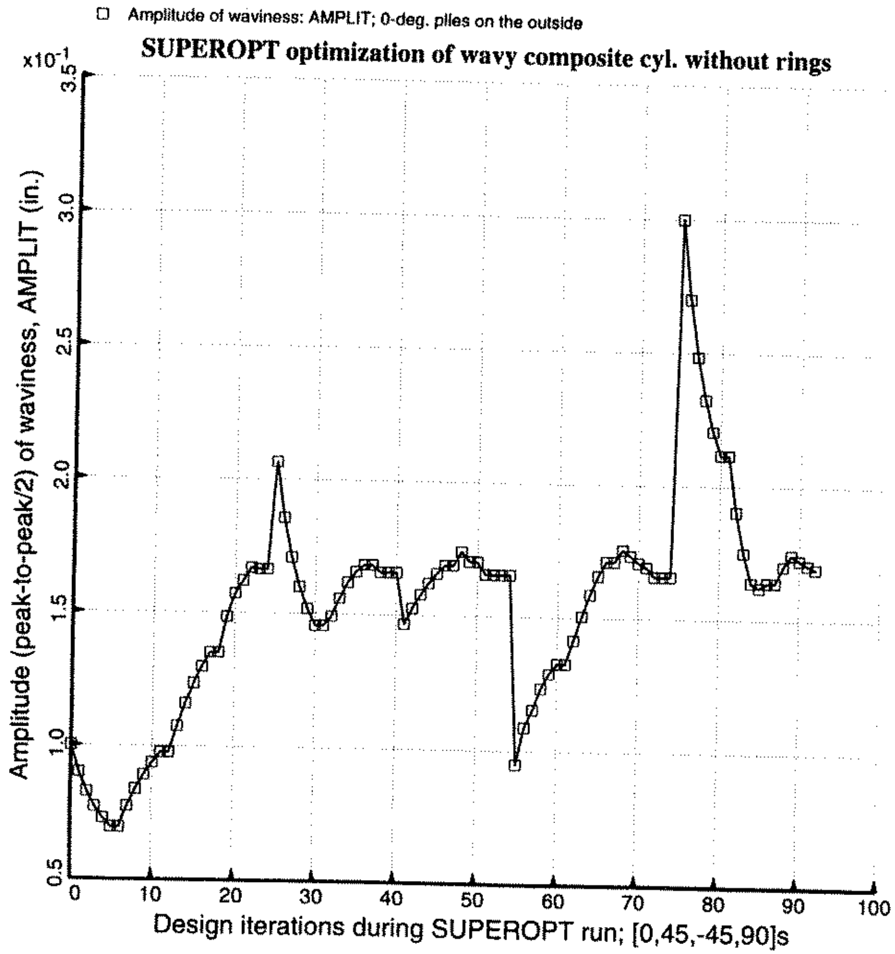
□ thickness of layer type: TLAYER(1)
○ thickness of layer type: TLAYER(2)
△ thickness of layer type: TLAYER(3)
+ thickness of layer type: TLAYER(4)
SUPEROPT optimization of wavy composite cyl. without rings
x10-2
ply thicknesses (in.); [0,45,-45,90]s
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
0
10
20
30
40
50
60
70
80
90
100
Design iterations during SUPEROPT run; [0,45,-45,90]s

FIG. 75



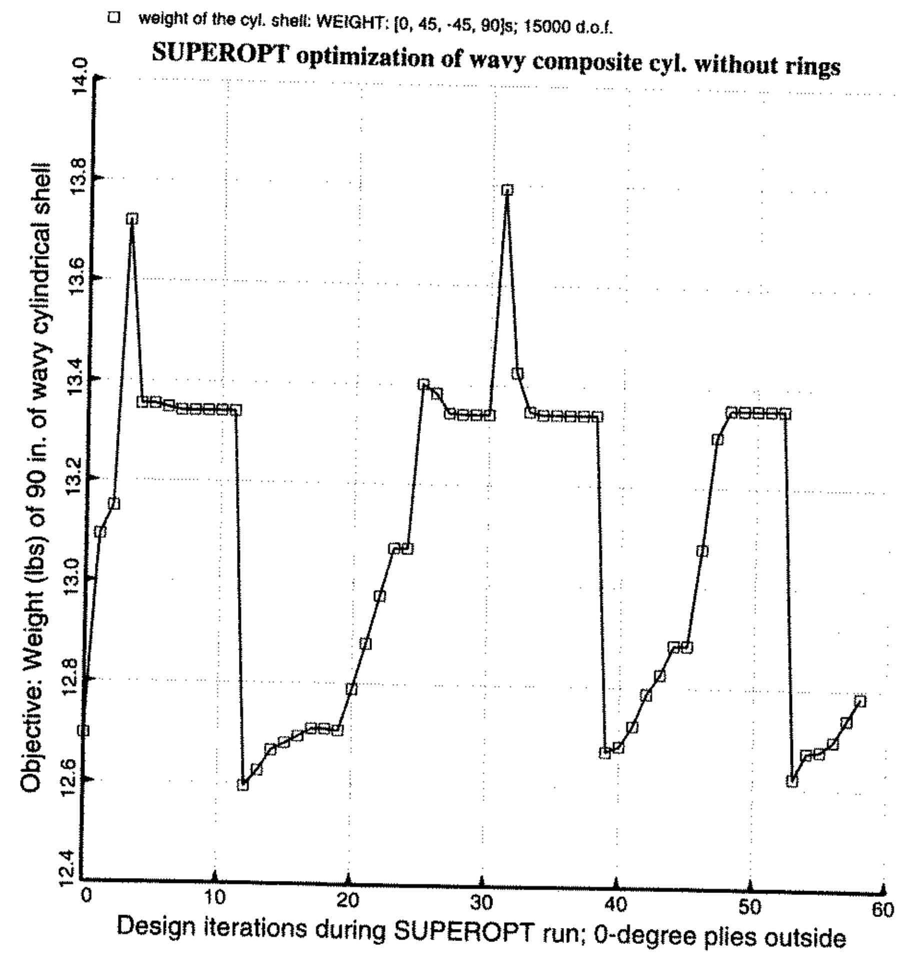
□ Axial halfwavelength of the waviness: WAVLEN; 0-deg. plies outside
SUPEROPT optimization of wavy composite cyl. without rings
x10-1
Axial halfwavelength of waviness, WAVLEN (in.)
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
0
10
20
30
40
50
60
70
80
90
100
Design iterations during SUPEROPT run; [0,45,-45,90]s

FIG. 76



Amplitude of waviness: AMPLIT; 0-deg. plies on the outside
SUPEROPT optimization of wavy composite cyl. without rings
Amplitude (peak-to-peak/2) of waviness, AMPLIT (in.)
x10-1
Design iterations during SUPEROPT run; [0,45,-45,90]s

FIG. 77



weight of the cyl. shell: WEIGHT: [0, 45, -45, 90]s; 15000 d.o.f.
SUPEROPT optimization of wavy composite cyl. without rings
Objective: Weight (lbs) of 90 in. of wavy cylindrical shell
Design iterations during SUPEROPT run; 0-degree plies outside

FIG. 78

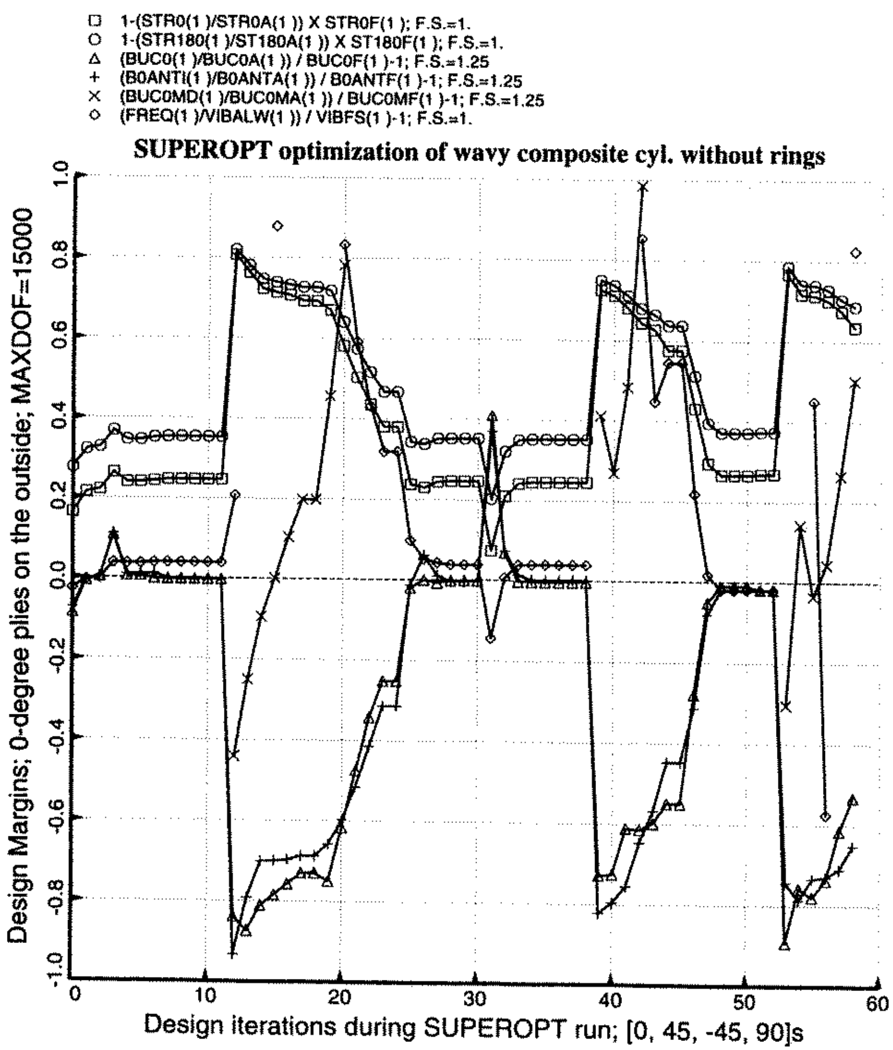

1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.=1.
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.=1.
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.=1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.=1.25
(BUC0MD(1)/BUC0MA(1)) / BUC0MF(1)-1; F.S.=1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.=1.
SUPEROPT optimization of wavy composite cyl. without rings
Design Margins; 0-degree plies on the outside; MAXDOF=15000
Design iterations during SUPEROPT run; [0, 45, -45, 90]s

FIG. 79

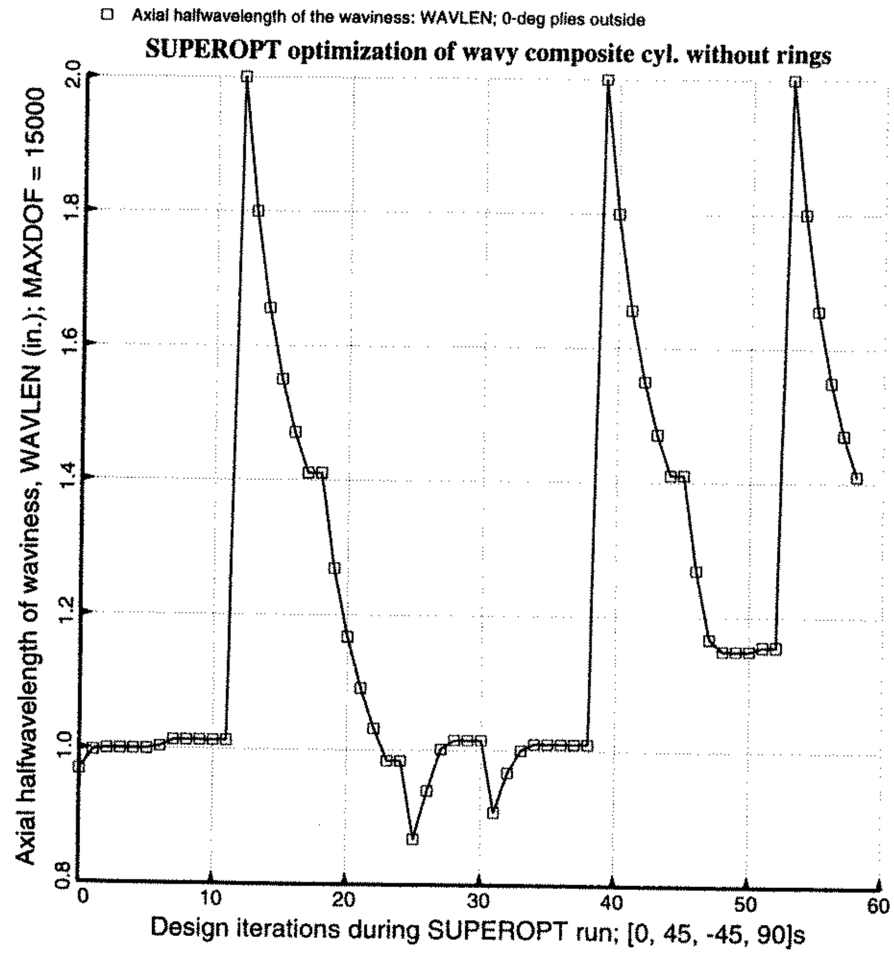
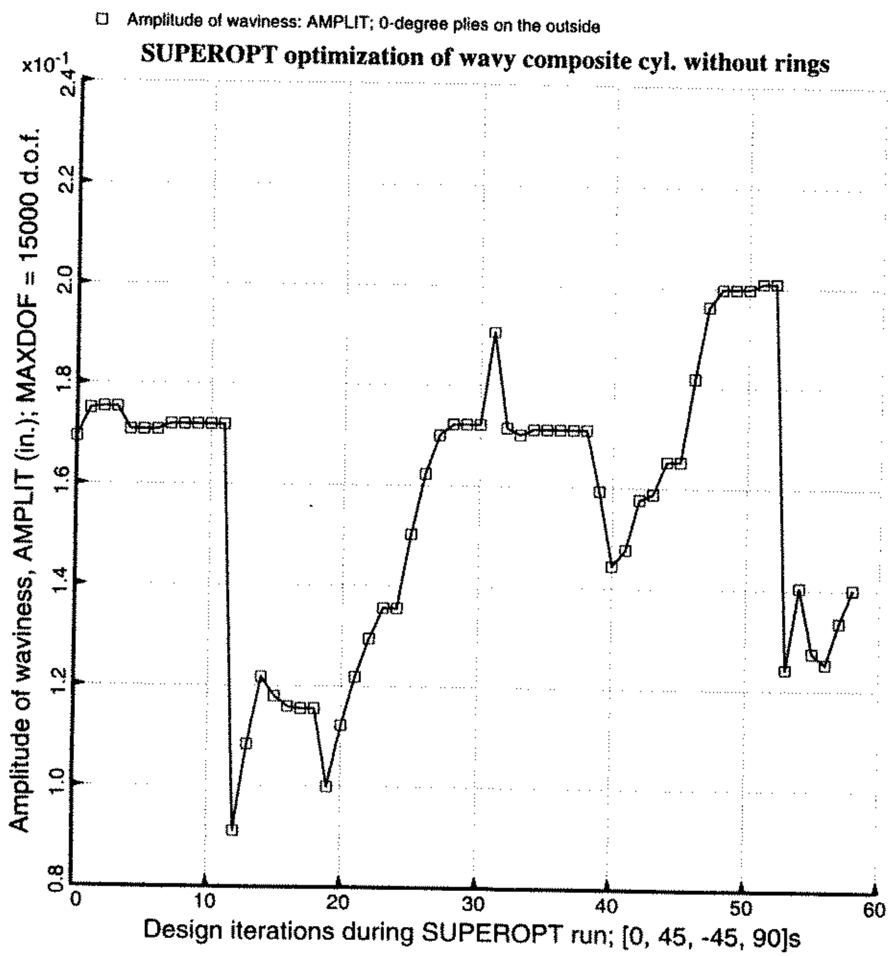
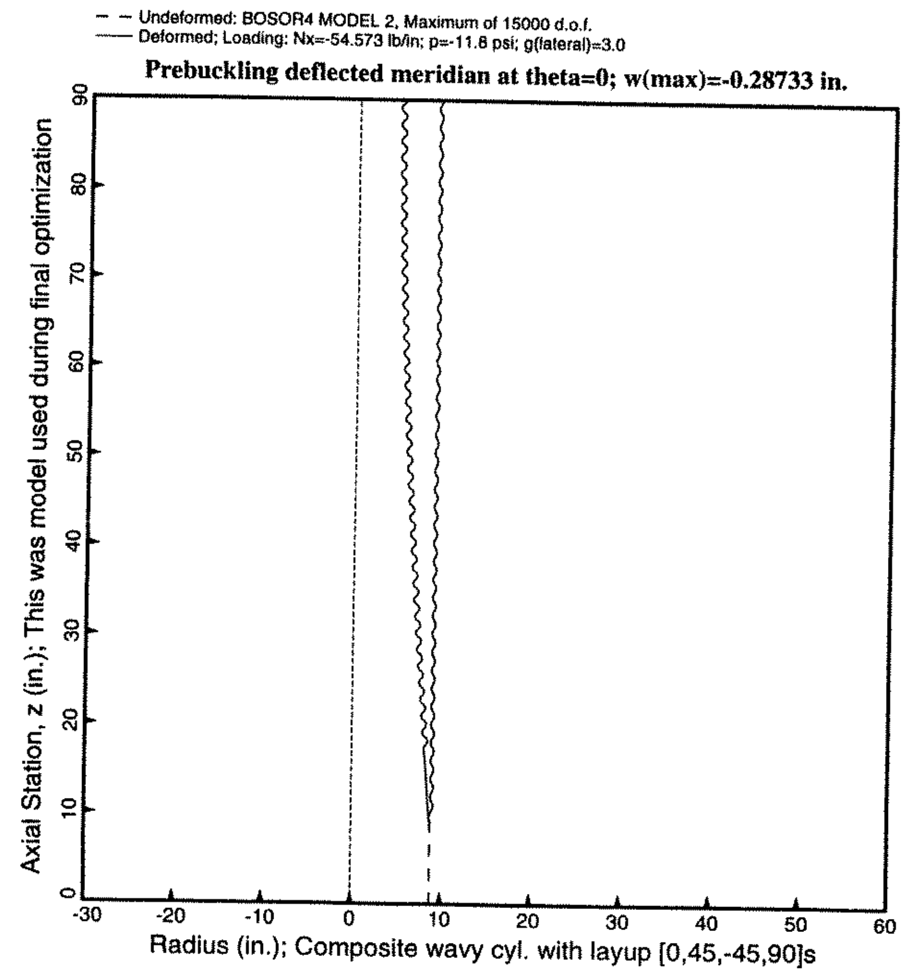

Axial halfwavelength of the waviness: WAVLEN; 0-deg plies outside
SUPEROPT optimization of wavy composite cyl. without rings
Axial halfwavelength of waviness, WAVLEN (in.); MAXDOF = 15000
Design iterations during SUPEROPT run; [0, 45, -45, 90]s

FIG. 80



Amplitude of waviness: AMPLIT; 0-degree plies on the outside
SUPEROPT optimization of wavy composite cyl. without rings
x10-1
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
Amplitude of waviness, AMPLIT (in.); MAXDOF = 15000 d.o.f.
0
10
20
30
40
50
60
Design iterations during SUPEROPT run; [0, 45, -45, 90]s

FIG. 81



Undeformed: BOSOR4 MODEL 2, Maximum of 15000 d.o.f.
Deformed; Loading: Nx=-54.573 lb/in; p=-11.8 psi; g(lateral)=3.0
Prebuckling deflected meridian at theta=0; w(max)=-0.28733 in.
90
80
70
60
50
40
30
20
10
0
Axial Station, z (in.); This was model used during final optimization
-30
-20
-10
0
10
20
30
40
50
60
Radius (in.); Composite wavy cyl. with layup [0,45,-45,90]s

FIG. 82

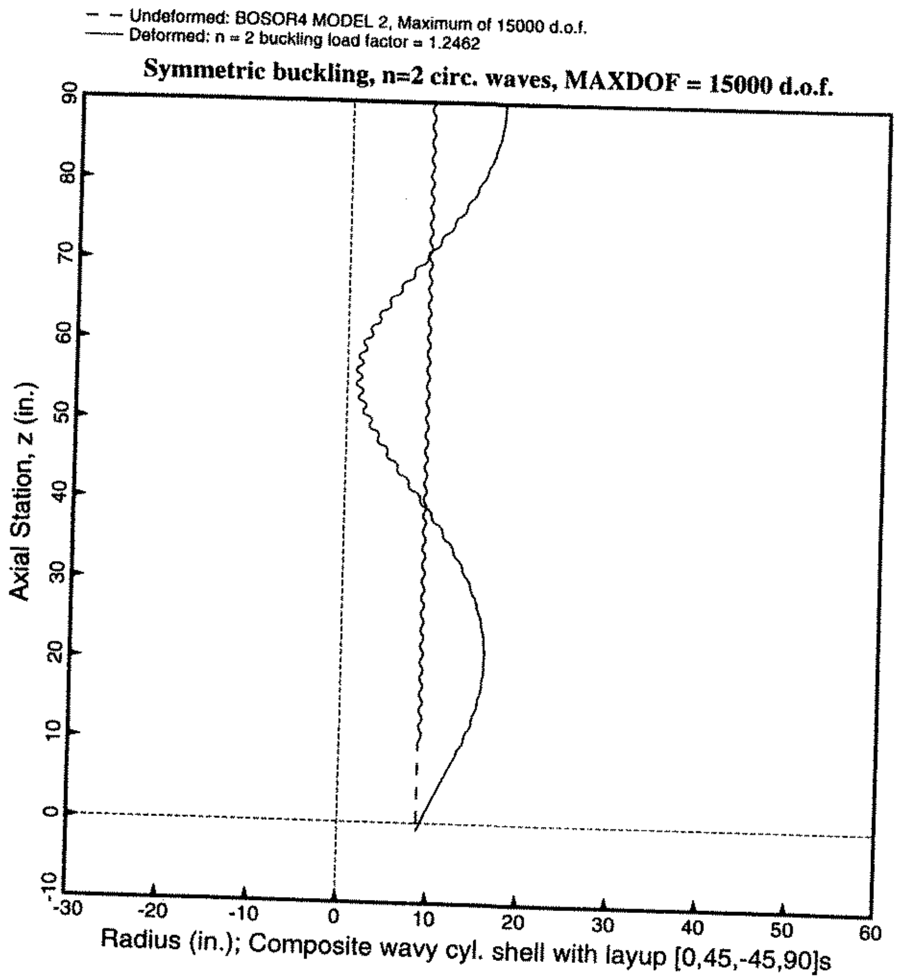

Undeformed: BOSOR4 MODEL 2, Maximum of 15000 d.o.f.
Deformed: n = 2 buckling load factor = 1.2462
Symmetric buckling, n=2 circ. waves, MAXDOF = 15000 d.o.f.
Axial Station, z (in.)
Radius (in.); Composite wavy cyl. shell with layup [0,45,-45,90]s

FIG. 83

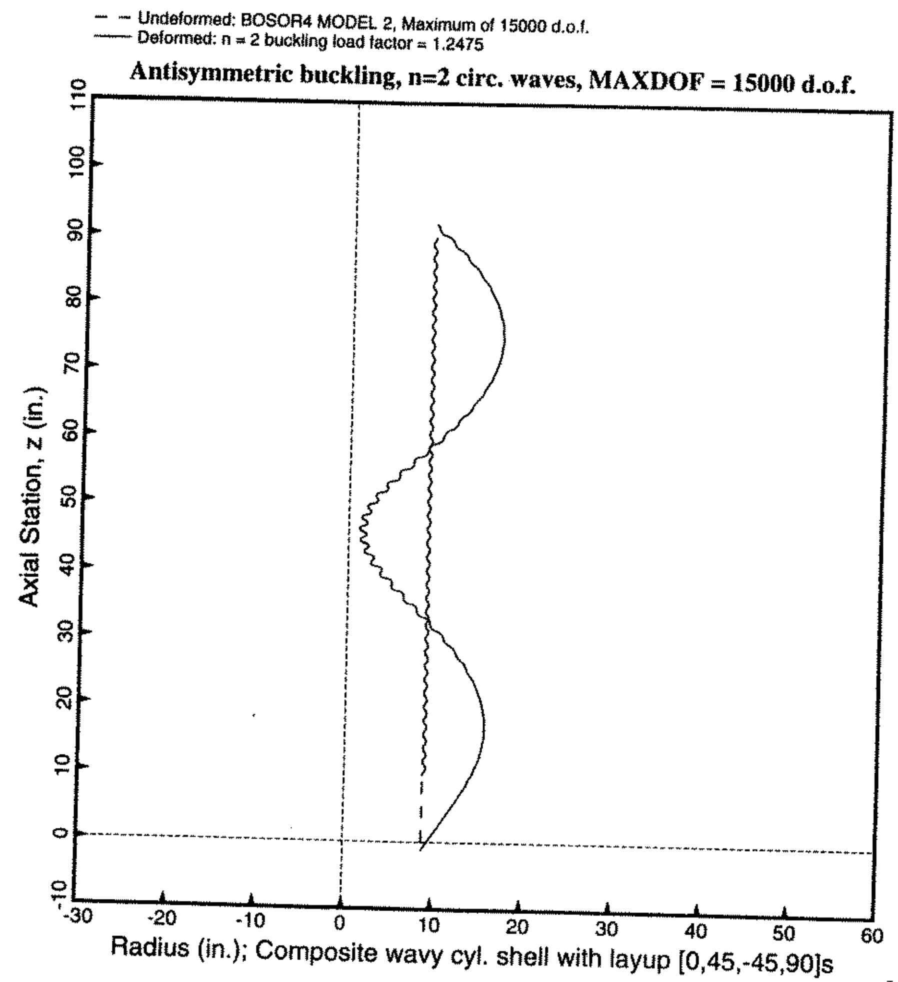
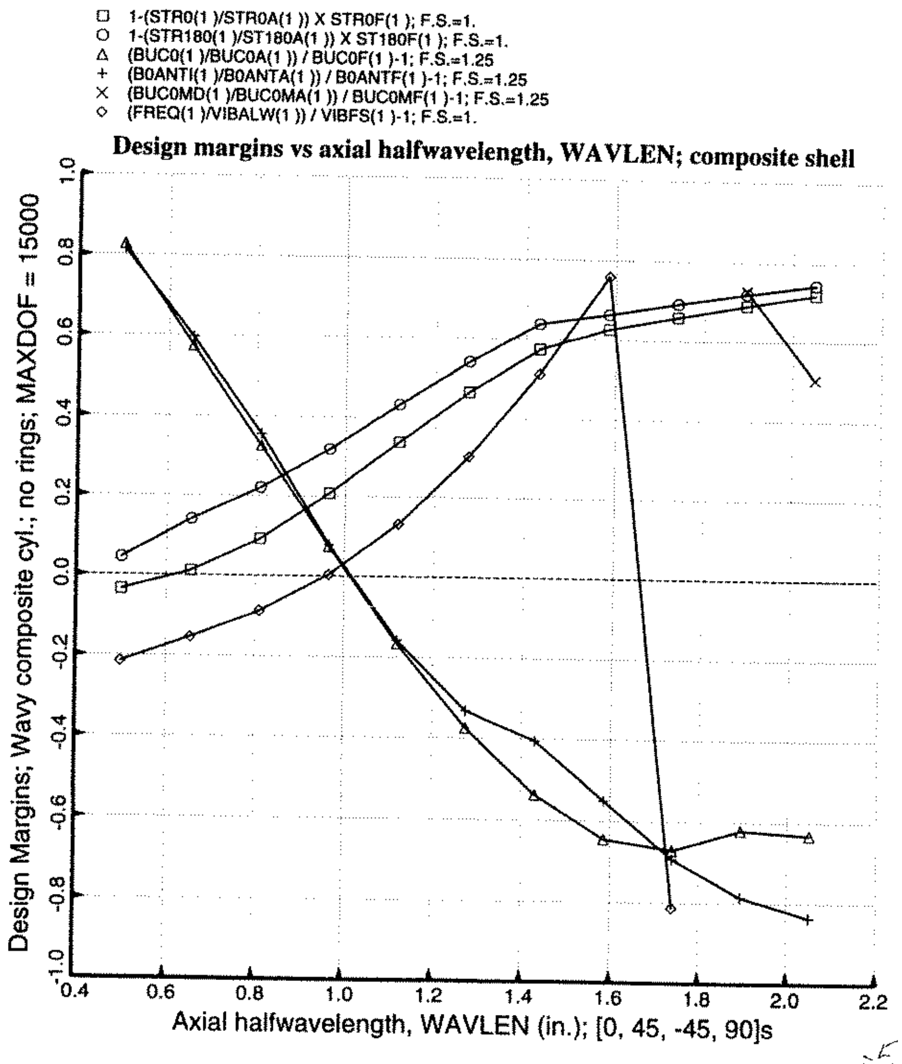
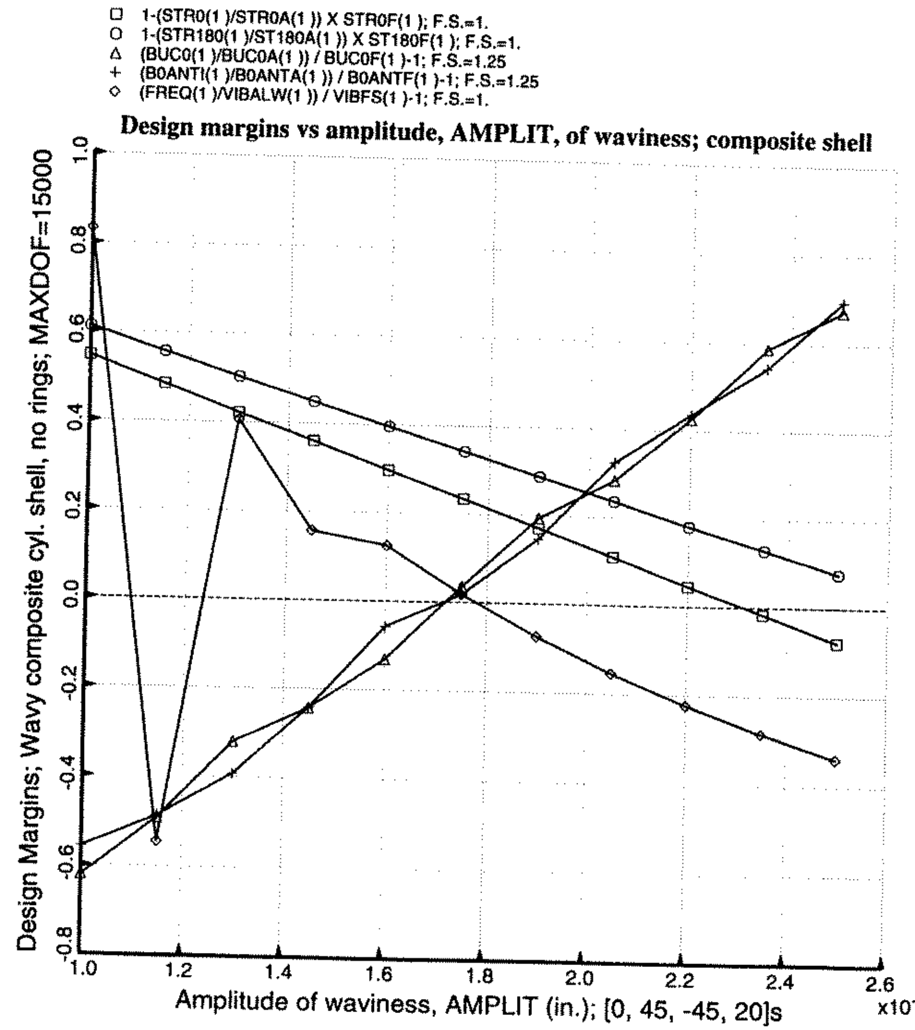

Undeformed: BOSOR4 MODEL 2, Maximum of 15000 d.o.f.
Deformed: n = 2 buckling load factor = 1.2475
Antisymmetric buckling, n=2 circ. waves, MAXDOF = 15000 d.o.f.
Axial Station, z (in.)
Radius (in.); Composite wavy cyl. shell with layup [0,45,-45,90]s

FIG. 84



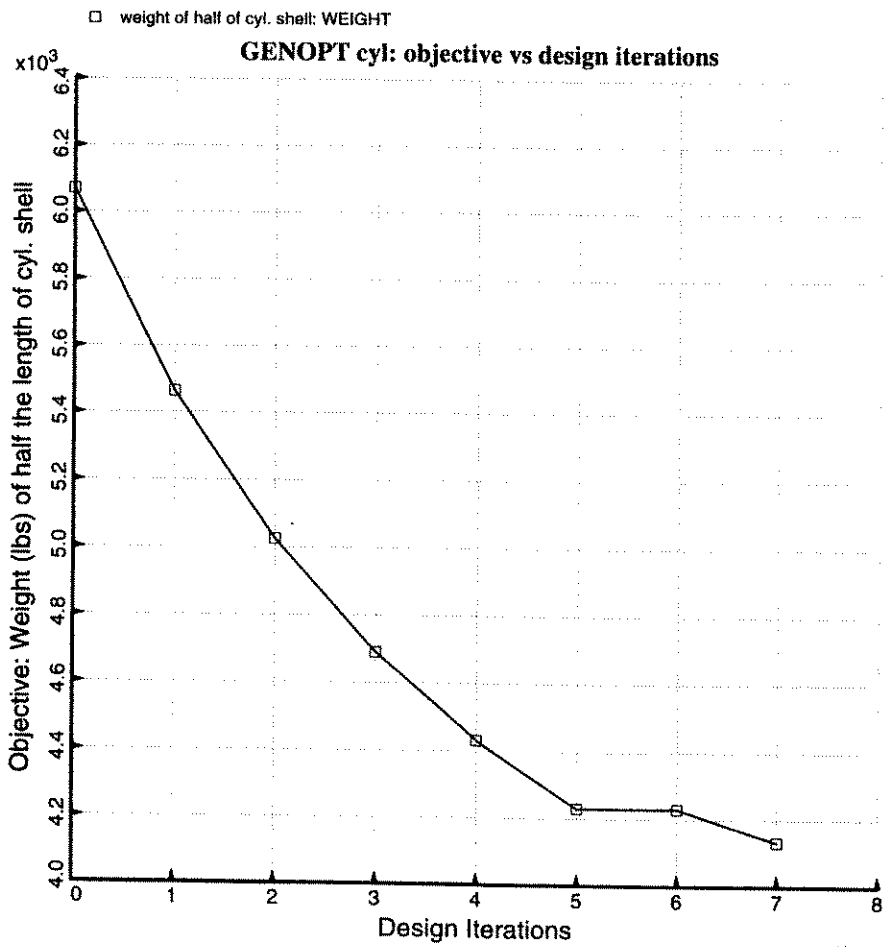
1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.=1.
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.=1.
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.=1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.=1.25
(BUC0MD(1)/BUC0MA(1)) / BUC0MF(1)-1; F.S.=1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.=1.
Design margins vs axial halfwavelength, WAVLEN; composite shell
Design Margins; Wavy composite cyl.; no rings; MAXDOF = 15000
Axial halfwavelength, WAVLEN (in.); [0, 45, -45, 90]s

FIG. 85



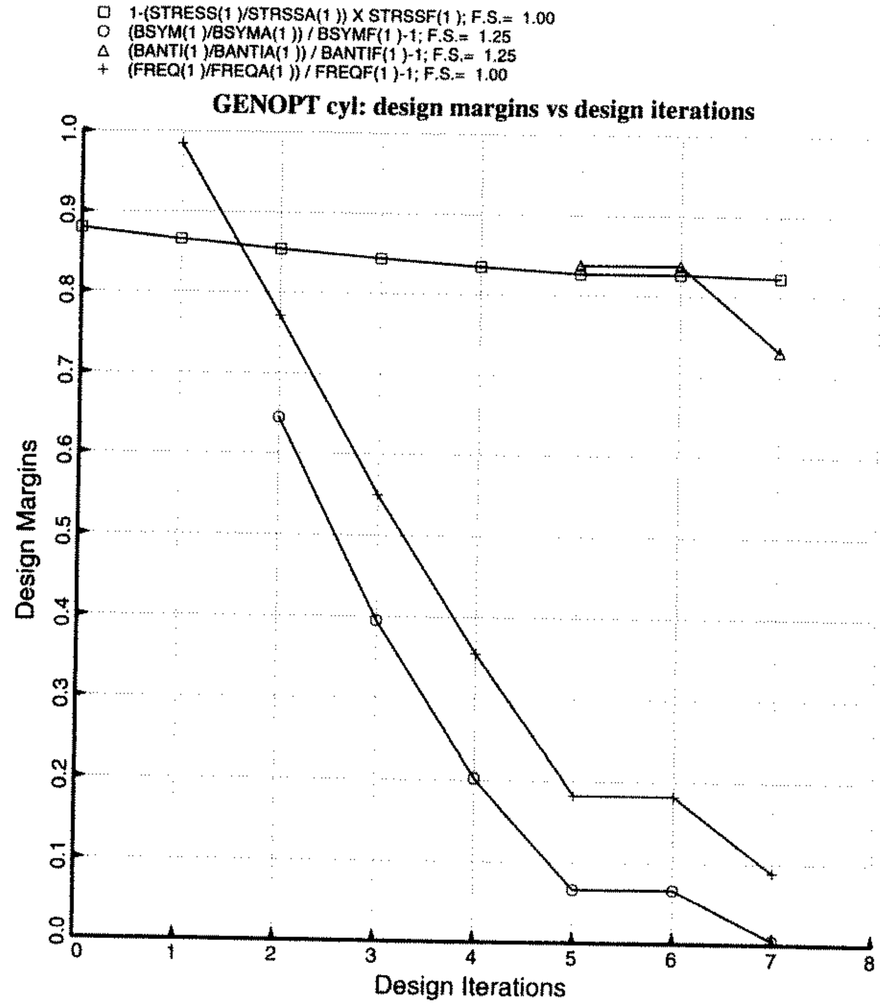
1-(STR0(1)/STR0A(1)) X STR0F(1); F.S.=1.
1-(STR180(1)/ST180A(1)) X ST180F(1); F.S.=1.
(BUC0(1)/BUC0A(1)) / BUC0F(1)-1; F.S.=1.25
(B0ANTI(1)/B0ANTA(1)) / B0ANTF(1)-1; F.S.=1.25
(FREQ(1)/VIBALW(1)) / VIBFS(1)-1; F.S.=1.
Design margins vs amplitude, AMPLIT, of waviness; composite shell
Design Margins; Wavy composite cyl. shell, no rings; MAXDOF=15000
Amplitude of waviness, AMPLIT (in.); [0, 45, -45, 20]s
x10-1

FIG. 86



weight of half of cyl. shell: WEIGHT
GENOPT cyl: objective vs design iterations
Objective: Weight (lbs) of half the length of cyl. shell
x10^3
Design Iterations

FIG. A1



1-(STRESS(1)/STRSSA(1)) X STRSSF(1); F.S.= 1.00
(BSYM(1)/BSYMA(1)) / BSYMF(1)-1; F.S.= 1.25
(BANTI(1)/BANTIA(1)) / BANTIF(1)-1; F.S.= 1.25
(FREQ(1)/FREQA(1)) / FREQF(1)-1; F.S.= 1.00
GENOPT cyl: design margins vs design iterations
Design Margins
Design Iterations

FIG. A2

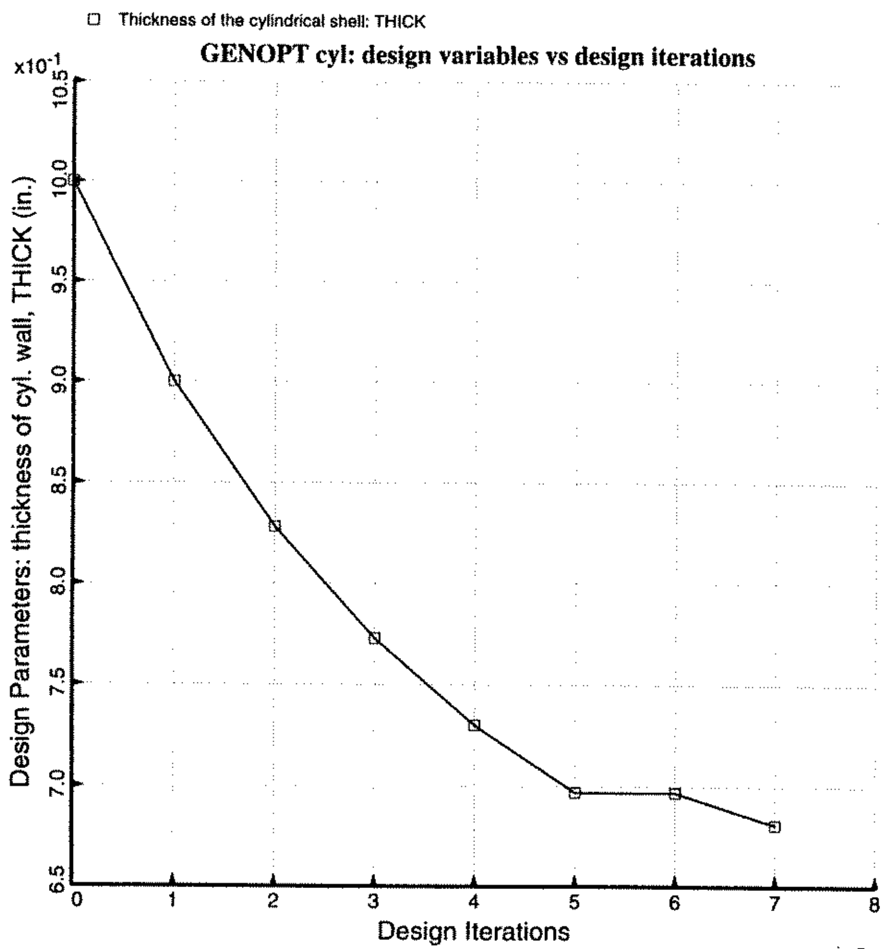

□ Thickness of the cylindrical shell: THICK
GENOPT cyl: design variables vs design iterations
x10-1
Design Parameters: thickness of cyl. wall, THICK (in.)
Design Iterations

FIG. A3

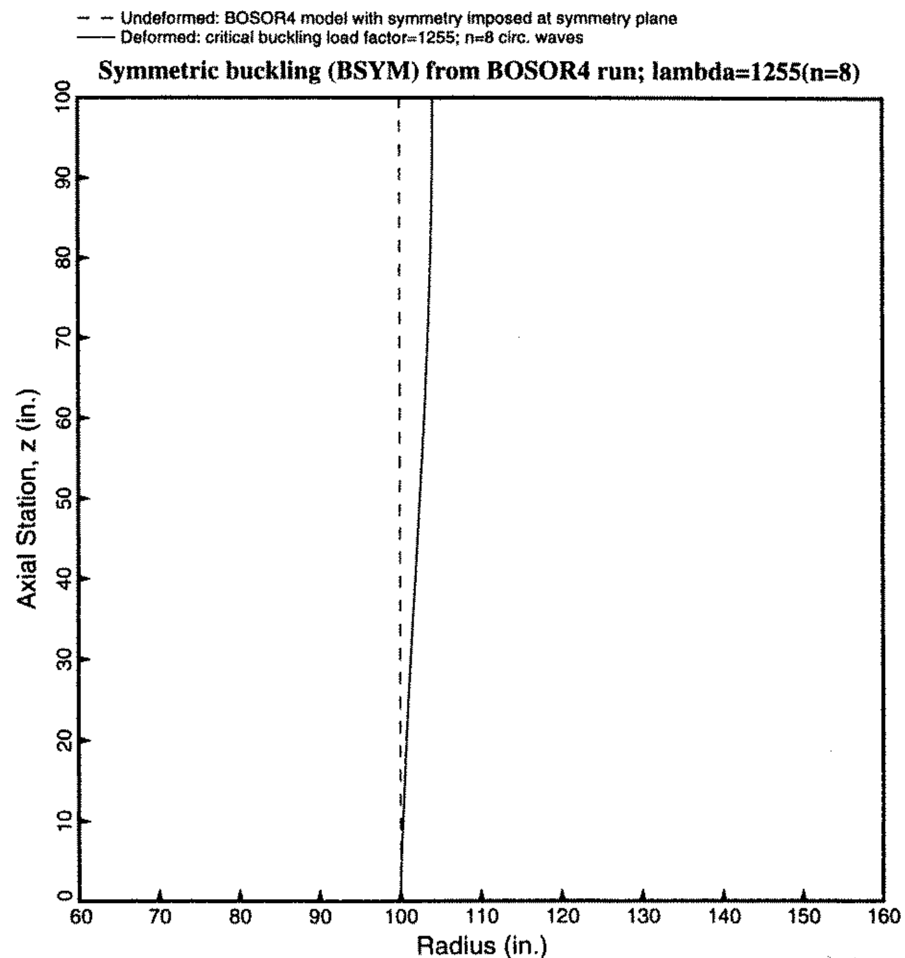

Undeformed: BOSOR4 model with symmetry imposed at symmetry plane
Deformed: critical buckling load factor=1255; n=8 circ. waves
Symmetric buckling (BSYM) from BOSOR4 run; lambda=1255(n=8)
Axial Station, z (in.)
Radius (in.)

FIG. A4

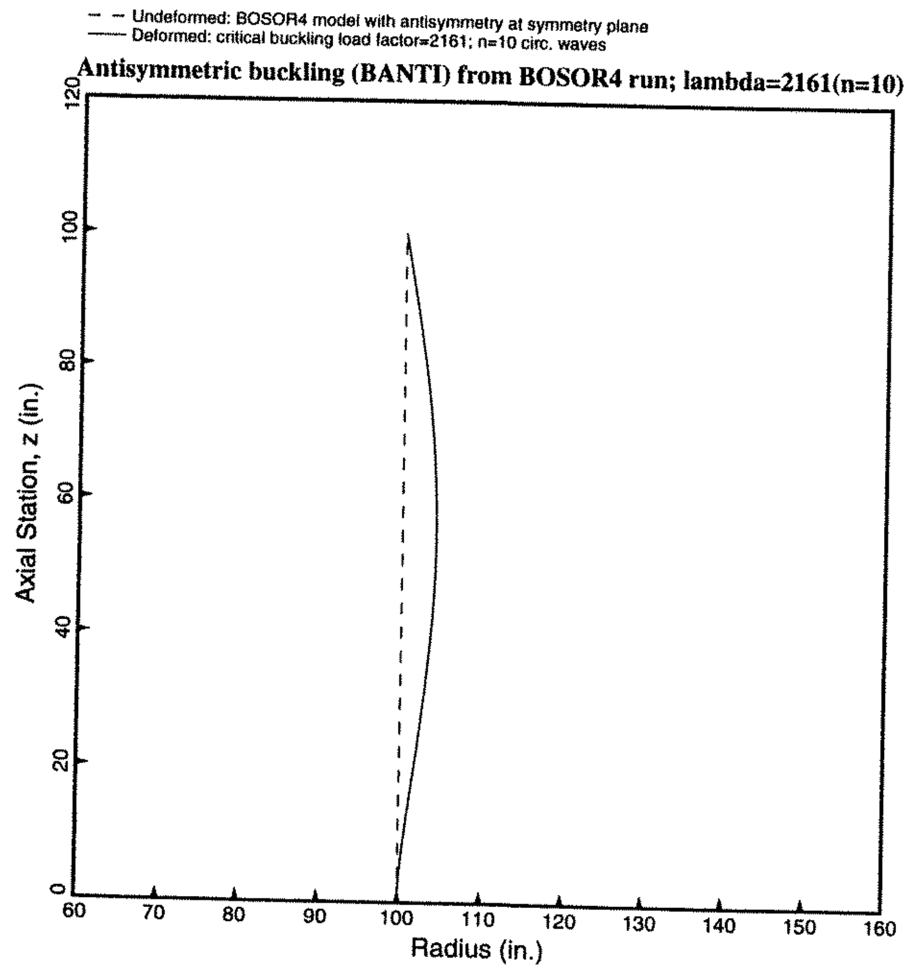

- - Undeformed: BOSOR4 model with antisymmetry at symmetry plane
—— Deformed: critical buckling load factor=2161; n=10 circ. waves
Antisymmetric buckling (BANTI) from BOSOR4 run; lambda=2161(n=10)
Axial Station, z (in.)
0
20
40
60
80
100
120
Radius (in.)
60
70
80
90
100
110
120
130
140
150
160

FIG. A5

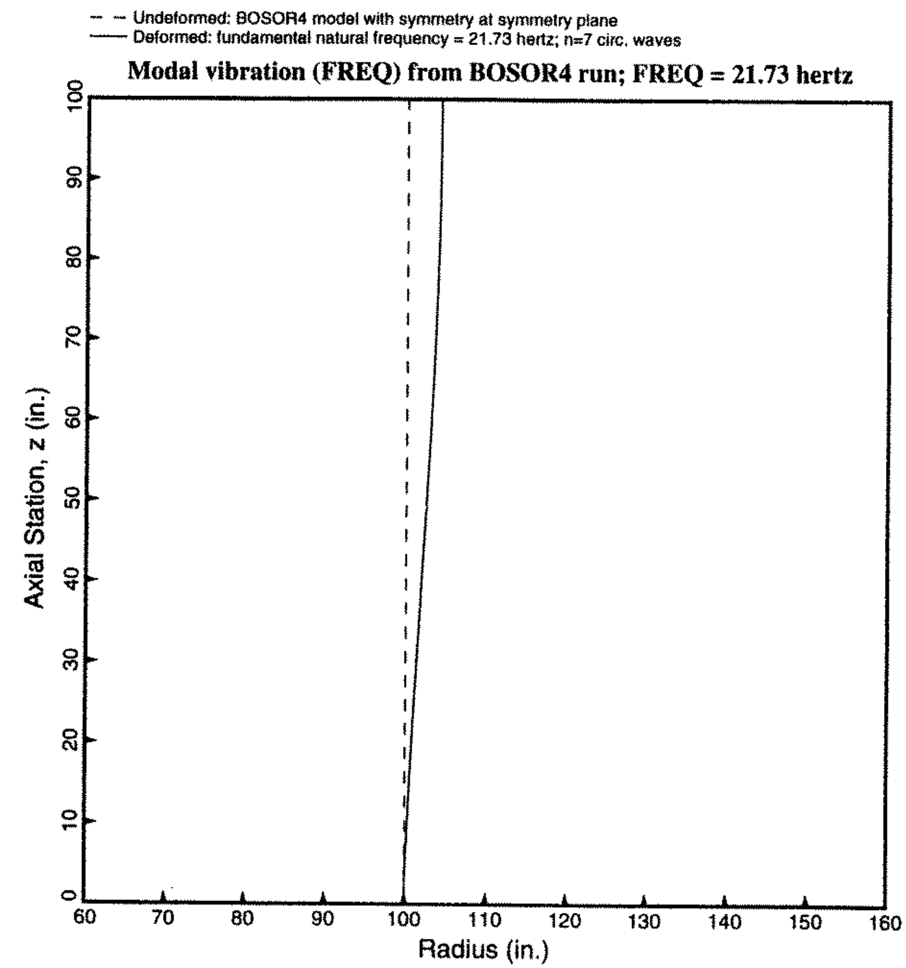
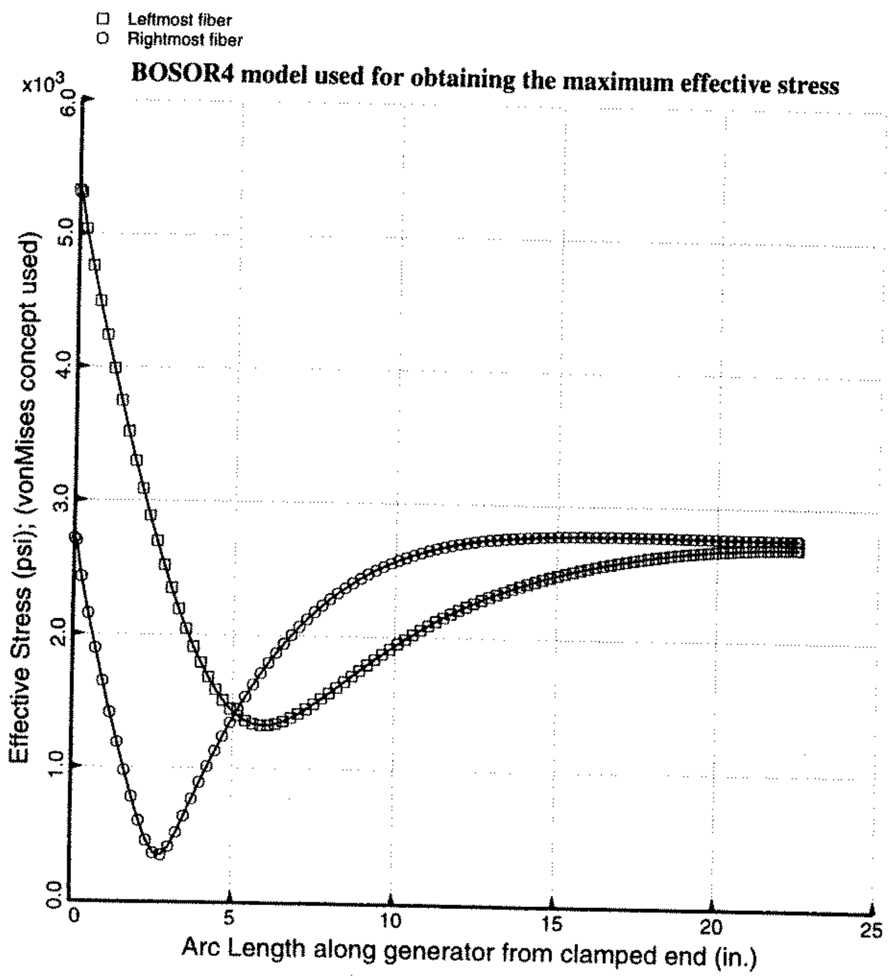
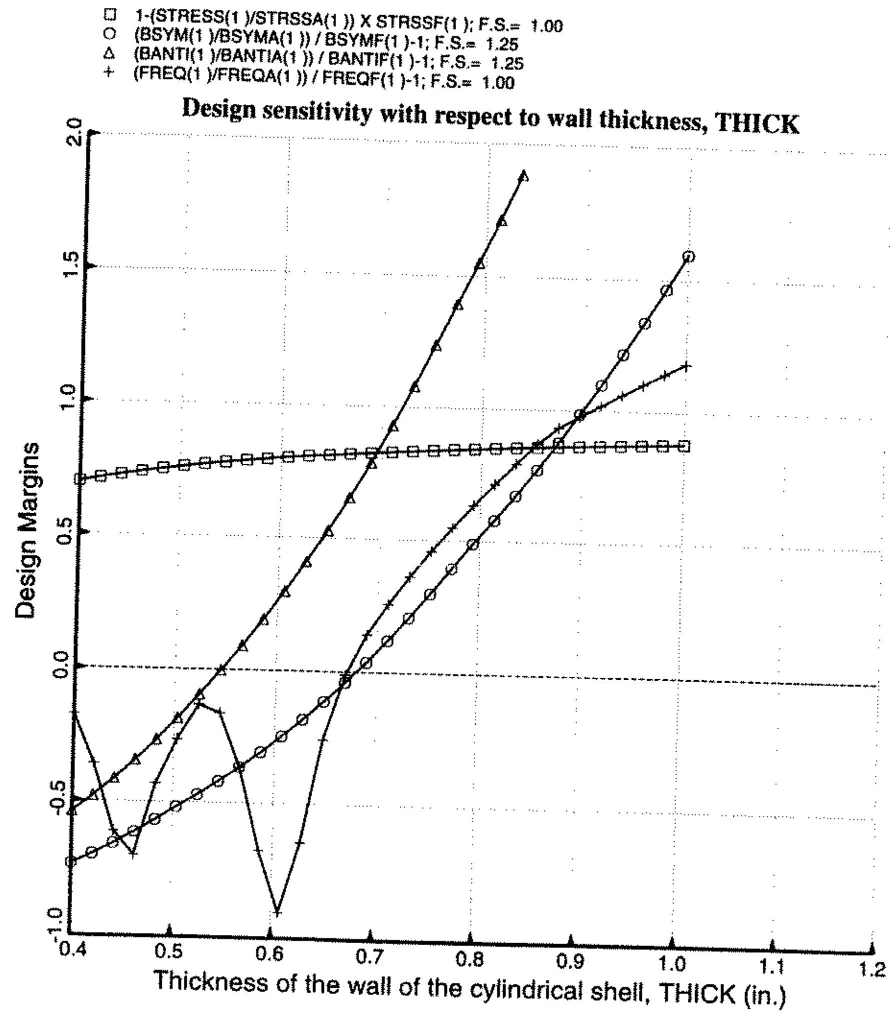

- - Undeformed: BOSOR4 model with symmetry at symmetry plane
—— Deformed: fundamental natural frequency = 21.73 hertz; n=7 circ. waves
Modal vibration (FREQ) from BOSOR4 run; FREQ = 21.73 hertz
Axial Station, z (in.)
0
10
20
30
40
50
60
70
80
90
100
Radius (in.)
60
70
80
90
100
110
120
130
140
150
160

FIG. A6



Leftmost fiber
Rightmost fiber
BOSOR4 model used for obtaining the maximum effective stress
x10^3
Effective Stress (psi); (vonMises concept used)
Arc Length along generator from clamped end (in.)

FIG. A7



1-(STRESS(1)/STRSSA(1)) X STRSSF(1); F.S.= 1.00
(BSYM(1)/BSYMA(1)) / BSYMF(1)-1; F.S.= 1.25
(BANTI(1)/BANTIA(1)) / BANTIF(1)-1; F.S.= 1.25
(FREQ(1)/FREQA(1)) / FREQF(1)-1; F.S.= 1.00
Design sensitivity with respect to wall thickness, THICK
Design Margins
Thickness of the wall of the cylindrical shell, THICK (in.)

FIG. A8