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Finite-Element-Analysis Model and Preliminary Ground Testing of Controls-Structures Interaction Evolutionary Model Reflector

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Abstract

Results of two different nonlinear finite-element analyses and preliminary static test results for the final design of the Controls-Structures Interaction Evolutionary Model reflector are presented. Load-deflection data bases are generated from analysis and testing of the 16-ft diameter, dish-shaped reflector, and natural frequencies and mode shapes are obtained from vibrational analysis. Experimental and analytical results show similar trends; however, future test hardware modifications and finite-element model refinement would be necessary to obtain better correlation. The two nonlinear analysis approaches are both adequate techniques for the analysis of prestressed structures with complex geometry.

Introduction

Future space structures, such as the proposed *Space Station Freedom*—which consists of a truss structure with many appendages such as antennas and motors—present new challenges to structure and control-system design. The structural design requirement of low mass results in very flexible structures. To be able to meet pointing-control requirements in space, engineers need complete knowledge of the static and dynamic characteristics of the structure.

New technology for ground testing and analysis to characterize controlled flexible space structures is being developed and tested as described in references 1 and 2. Correlation of experimental and analytical results leads to the refinement of the analytical models, which gives engineers more confidence in the analytical predictions. The final goal is to be able to characterize and design space structures by means of analysis only or by means of analysis and testing of individual components of the structure.

Langley Research Center recently conducted closed-loop-control ground tests on the Controls-Structures Interaction Evolutionary Model (CEM), an experimental model that is generically similar to a future space platform to be instrumented to monitor the Earth's climate. Figure 1 shows the main components of the CEM. Preliminary design, test, and analysis results are described in reference 2. As shown in the figure, the Evolutionary Model consists primarily of a flexible truss structure and an antenna-like appendage called a reflector. The reflector, shown in detail in figure 2, is an important dynamic component of the global line-of-sight (LOS) pointing path. To monitor the LOS pointing accuracy, a laser is mounted on the vertical truss tower of the CEM, such that the laser beam reflects upon the reflector mirror. The laser-beam reflection is measured by a photodiode array above the reflector. This laser-reflector-detector system allows the pointing accuracy of the CEM to be measured and controlled. Because of the complexity of the geometry of the reflector, and in an effort to update the finite-element analytical model of the whole structure, testing and analysis of that individual component have been conducted. Reference 3 presents preliminary design, test, and analysis results of the developmental model of the reflector. The present paper describes the results obtained from the finite-element analysis and static test for the final design of the reflector and some preliminary results from vibrational analysis. Nonlinear capabilities of MSC/NASTRAN (ref. 4) were used to account for large-displacements and pretensioning effects in the finite-element analysis of the reflector; results were compared with the nonlinear technique described in reference 3.

Evolutionary Model Reflector

The CEM reflector (figs. 2 and 3) is a dish-shaped structure 185.5 in. in diameter and 19.93 in. deep. The main components are the ribs, hub, and sensor plate. Each of the eight aluminum ribs is 0.25 in. thick and 96 in. long and is tapered in width over its length from 2 in. to 1 in. The ribs are oriented at angles of 45° around the hub—a 3/8-in.-thick aluminum plate, with a 4-in. inside diameter and an 8-in. outside diameter. One end of the ribs is attached to the hub, and the other end is connected to each adjacent rib by a 1/32-in.-diameter steel cable. Tensioning the cable by means of thumb screws on each rib deforms the ribs to obtain the desired shape of the reflector.

The sensor plate is a 1.5-in.-thick fiberglass-honeycomb composite panel with a mirrored surface. The top view of the reflector in figure 3 reveals the octagonal shape of the reflector plate and the circular mirror on its center. Each corner of the octagonal panel is attached to the ribs by swivel-head bolts to prevent transmission of moments from the ribs to the panel. A detailed view of that connection is shown in figure 3. Four aluminum rods stiffen the plate and connect it to the hub. The hub is the connecting linkage between the reflector and the supporting structure. A detailed view of the connections between the hub and sensor plate and between the hub and truss tower is shown in figure 4.

During this investigation, the reflector was statically tested in two positions—horizontally (fig. 5) and inclined 39.1° (fig. 6). The inclined position is the same as for the CEM. It was supported in the horizontal position by a single 10-in. cubical truss bay fixed at the bottom (fig. 5). The supporting structure for the inclined reflector test setup (fig. 6) was the upper section of the truss tower; this tower consisted of a tapered truss bay and one cubic bay that was also fixed at its bottom. The truss members of the cubical bays are aluminum tubes connected by node-ball joints. A typical truss member and node-ball joint are shown in figure 7. The vertical members of the tapered bay are aluminum tubes, and the diagonal and top members are aluminum structural angles. Dynamic analyses were performed only in the inclined position.

Finite-Element Models

The dish shape of the reflector is a result of the deflection of the ribs caused by tensioning the cables. Previous finite-element analysis of a preliminary reflector design (ref. 3) showed that small-deflection nonlinear analysis can be used if the post-tensioned geometry and compressive loads of a typical rib are known. A model of a prestressed reflector following this approach was created by using the MacNeal-Schwendler Corp. MSC/NASTRAN. A second nonlinear analysis, which included MSC/NASTRAN nonlinear analysis capabilities, was used to model the large deflections of the reflector, starting from its undeformed position, to obtain the correct geometry and stiffness of the prestressed structure. The only physical parameter needed for the analysis in this case, other than material properties and basic dimensions, is the tension in the cables for the final configuration. Results from both analyses were compared with test results.

In the finite-element models of the reflector, each rib consists of 12 beam elements dimensioned according to the tapered shape of the ribs. The cables are modeled by using 1/32-in.-diameter rod elements with material properties of steel wire. The hub is modeled with 24 3/8-in.-thick triangular plate elements. The steel bolts connecting the ribs to the hub are represented by 1/4-in.-diameter bar elements. Due to the short length and high stiffness of the bolts connecting the hub to the supporting structure, zero-length scalar spring elements (1.5×10^8 lb/in.) for all six degrees of freedom are used for each connector. All support brackets and truss elements of the supporting structure were modeled by using two-noded CBAR elements.

The sensor plate is modeled by using 24 triangular plate elements. Since the material properties of the honeycomb composite panel were unknown, an effective plate thickness of 0.408 in. was computed, and the known material properties of the fiberglass sheets were used as material properties for the equivalent plate. The following equation was used to compute the effective thickness t_{eff} of the composite panel:

$$I = \frac{t_{\text{eff}}^3}{12} \times b = \frac{b\left(h_o^3 - h_i^3\right)}{12}$$

Therefore,

$$t_{\text{eff}}^3 = \left(h_o^3 - h_i^3\right)$$

where I is the area moment of inertia for a rectangular cross-sectional element of the panel of length b and height h_o. (See fig. 8.) Honeycomb core thickness is denoted by h_i. The mirrored surface of the reflector plate was represented by a lumped mass at its center. The swivel-head bolts connecting the sensor plate to the ribs were modeled with CBAR elements, and the rotational degree of freedom about the axis passing through the eye of each bolt (see detail in fig. 3) was left free by using pin flags. Since CROD elements only have torsional and axial stiffness, they were also used to model the swivel-head bolts; results were compared with those obtained with CBAR elements.

The input geometry of the undeformed rib for the large-displacements nonlinear model should not be represented by a horizontal line. A bifurcation would exist and the ribs could deflect either up or down. To ensure that the ribs would move in the correct direction, the rib was represented by a straight line that made a 6° angle with a horizontal line (fig. 9).

Analysis

The MSC/NASTRAN solution 64 employs an iterative procedure with a modified Newton-Raphson approach to solve geometric nonlinear problems. The large-displacements nonlinear analysis for the reflector involved two steps, which are summarized in figure 10. In the first step, the structure was preloaded and shaped by applying a thermal load to the cables that was equivalent to the measured tension in the cables on the shaped structure. Gravity effects and target weights were also included. Fifteen iterations were required for force convergence, and the first iteration was the linear static solution. Differential stiffness calculations were skipped to avoid instability or mechanism errors. The second step was a restart from step 1 to apply external loads. Fifteen dummy subcases were required in the case control deck to restart from the last stress state in step 1. Three iterations were required for final convergence in step 2. Superimposing results from steps 1 and 2 gives the displacements that result from external loading. These results are compared with small-displacements nonlinear analysis and experimental results.

Analysis with a prestressed reflector model, similar to the analysis described in reference 3, was also performed by using solution 64; however, the geometry input for the ribs was that of a deflected and prestressed rib. Since there were no large deflections of the preshaped structure, the CBEAM elements were replaced by the easier to use CBAR elements. The analysis consisted of the three steps shown in figure 11. First, a thermal load equivalent to the compressive preload is applied to the ribs, which are completely restrained (ref. 3). A thermal preload is also applied to the cables. The constraint forces obtained in this step are the forces required to maintain equilibrium when all degrees of freedom are released in step 2. The second step is to release all degrees of freedom, apply the computed constraint forces, gravity load, and target weights to obtain the final prestress state, which is equivalent to step 1 for the large-displacements nonlinear model. Step 3 involves the application of external loads. Results from steps 2 and 3 are combined to obtain the final displacements. For this case, each step ran independently, no data base was required. Each step required three iterations for convergence—a linear static solution, a differential stiffness calculation, and one nonlinear iteration. Figure 9 shows the geometry of a preloaded rib that results from small-displacements nonlinear analysis and large-displacements nonlinear analyses. Listings of the NASTRAN data decks for both models are included in the appendix.

The analysis results seem very sensitive to different models of swivel-head bolts. Changing the swivel bolt element from CBAR with pin flags to CROD greatly reduces the stiffness of the ribs and smooths the stress distribution along the ribs. Figure 12 shows the deformation of one of the ribs under gravity and target weight for the small-displacements analysis with two different connector models. Significant changes occur in the axial-force distribution along the ribs for the large-displacements nonlinear model. (See table 1.)

Vibrational analysis was also performed by using the data bases generated for the final prestressed states for both the small-displacements and the large-displacements nonlinear analytical models of the reflector in its inclined position. Mode shapes and frequencies were computed for modes below 10 Hz.

Correlation of Static Tests With Analysis

Static tests of the reflector on its horizontal and inclined configurations were conducted to obtain load-deflection characteristics for comparison with analytical results. Four of the eight reflector ribs, numbered as shown in figure 3, were instrumented with target plates and proximity probes to measure rib-tip and plate-end displacements. Loads were applied at specific locations on the ribs and plate ends to provide the required symmetric or unsymmetric loading condition. Loads were applied and removed in step increments. Table 2 summarizes the loading cycles that were conducted to obtain the data base for this investigation; figure 13 shows the details of the target and weight configurations. Output data from the proximity probes were displayed on voltmeters and were recorded manually.

Load-deflection plots for each loading condition described in table 2 were generated from the test data for comparison with load-deflection plots generated from large-displacements nonlinear and small-displacements nonlinear analyses. Symmetric and asymmetric stiffness characteristics of the reflector ribs for test and analysis of the reflector on its inclined position are shown in figure 14. Both sets of data indicate that the load deflections are linear during load-application and load-relief cycles; there is good correlation between small-displacements and large-displacements nonlinear analysis results. As explained subsequently in this section, correlation between experimental and analytical results is acceptable, considering possible errors in experimental measurements. Similar plots were generated that described load-deflection characteristics of the reflector in its horizontal position when loads were applied at the sensor-plate ends. Experimental and analytical results obtained from symmetric and asymmetric loading of the plate ends are shown in figure 15. For this set of data, because of the symmetry of the structure, all the measured and generated displacement data obtained for each of the four locations on the sensor plate were combined and curve fitted. Experimental data show hysteresis losses during the loading and unloading cycles; however, load-deflection characteristics can be considered linear. Hysteresis loss is a common characteristic of composite material structures. Even though the present analytical tools do not have the capabilities to model hysteretic energy losses, load-deflection characteristics obtained from both analyses again agree with experimental results, and correlation between results from both analytical models was very good. The symmetry of the horizontal structure is very well described by the analytical models. Table 3 summarizes the percentage error between the slopes of the test and analysis curves for load cycles 1 to 4.

The discrepancies between experimental and analytical results in some tests increase with increasing load and deflection. These discrepancies may be caused by the way the target-plate assembly is attached to the ribs. Before any loads are applied to the ribs or plate ends, the target plates are perpendicular to the proximity probes. When the ribs are displaced by the applied load, the target plates, which are fixed to the ribs, follow the rib displacement; the rib displacement includes rotation. In its final position, the target plate is at an angle with the proximity probe. Therefore, the measured vertical displacement is not the vertical component of the displacement vector of the point of interest on the rib. The error is a function of the horizontal displacement of the target-plate center and the angle the target plate makes with the horizontal. Some of the discrepancies between experimental and analytical results could have been eliminated if swivel joints were used to attach the target assembly to the ribs.

Results of Vibrational Analysis

Vibrational analysis of the reflector has been conducted to correlate results from both analytical models and for future correlation with experimental data. The first 13 natural frequencies for the reflector in its inclined position, obtained from large-displacements nonlinear analysis and small-displacements nonlinear analysis, are listed in table 4. Corresponding mode shapes are shown in figure 16 for the large-displacements nonlinear model. The eigenvalues and mode shapes obtained from the two analytical models show close agreement.

The first global mode shape identified, mode 4, exhibits a rocking motion of the reflector about the hub. Mode 9, the second global mode, involves torsion of the reflector around the hub center. Modes 1 to 3 and 6 to 8 are different combinations of first bending modes of the individual ribs. Second rib bending modes are in mode 10. Many of the mode shapes are similar and have similar frequencies because of the symmetry of the structure.

Frequency-response functions for random excitation at rib 2 were also generated by using the NASTRAN models. The plot in figure 17 shows a typical frequency-response function (FRF) taken in the vertical plane for rib 2. The point of excitation was the connection between the rib and sensor plate, and the measurement was taken 2.5 ft along the rib from the connector. The two analytical models show similar results.

Concluding Remarks

Two different nonlinear finite-element models for the final design of the Controls-Structures Interaction Evolutionary Model (CEM) reflector were developed and load-deflection data bases were generated for comparison with experimental results. Static tests to obtain load-deflection characteristics of the Controls-Structures Interaction (CSI) Evolutionary Model reflector were conducted. Limited vibrational analysis was also conducted, and preliminary system modes were computed for future system identification.

Excellent agreement between small-displacements and large-displacements nonlinear models for the reflector has been demonstrated. The modeling techniques described could be used in future applications involving the analysis of prestressed structures with complex geometry. The small-displacements nonlinear analysis approach works well for the analysis of prestressed structures where both the shape and the preload are known. During the design stage, the large-displacements nonlinear analysis approach can be used to design shape and prestress simultaneously.

Analytical and experimental results follow similar trends, but there are some discrepancies. These discrepancies may be reduced by modifying the displacement measurement hardware and by incorporating composite material data for the sensor plate into the finite-element models. Further refinement of the swivel-head bolt model is also warranted.

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Appendix

Listing of Finite-Element Analyses

```
RUNSTREAM OF NONLINEAR MODEL,REFLECTOR IN HORIZONTAL POSITION, STEP 1
 NASTRAN FILES=(DB01)
ID STATIC NL ANALYSIS, REFLECTOR IN HORIZONTAL POSITION
APP DISPLACEMENT
SOL 64
TIME 120
CEND
$
$ CASE CONTROL DECK FOLLOWS
$
TITLE = REFLECTOR WITH TAPERED RIBS, NONLINEAR PRELOAD RUN, STEP 1
ECHO = SORT
SPC = 1
LOAD=100 $ GRAVITY AND TARGET WEIGHTS
TEMP(LOAD)=13 $ THERMAL LOAD ON CABLES
SUBCASE 1
 LABEL= LINEAR STATIC SOLUTION
 DISPLACEMENT = ALL
 ELFOR=ALL
SUBCASE 2
SUBCASE 3
SUBCASE 4
SUBCASE 5
SUBCASE 6
SUBCASE 7
SUBCASE 8
SUBCASE 9
SUBCASE 10
SUBCASE 11
SUBCASE 12
SUBCASE 13
SPCF=ALL
SUBCASE 14
SUBCASE 15
SPCF=ALL
DISP=ALL
ELFOR=ALL
$ FIFTEEN ITERATIONS REQUIRED FOR CONVERGENCE
OUTPUT(PLOT)
CSCALE=1.8
PLOTTER NAST
SET 30=ALL
AXES Y,X,Z
VIEW 0.0,0.0,0.0
PTITLE=NONLINEAR STATIC ANALYSIS OF HORIZONTAL REFLECTOR
FIND SCALE,ORIGIN 30,SET 30
PLOT STATIC DEFORMATION 0,15,SET 30,ORIGIN 30
$ BULK DATA DECK FOLLOWS
$
BEGIN BULK
$
GRAV         200        0     386.      0.0      0.0     -1.0
LOAD,100,1.,1.,60,1.,200
LOAD,101,1.,1.,60,1.,64,1.,200
$ TARGET WEIGHTS
FORCE,60,2201,0,.4,0.,0.,-1.
FORCE,60,2301,0,.4,0.,0.,-1.
FORCE,60,2401,0,.4,0.,0.,-1.
FORCE,60,2501,0,.4,0.,0.,-1.
FORCE,60,2601,0,.4,0.,0.,-1.
FORCE,60,2701,0,.4,0.,0.,-1.
FORCE,60,2801,0,.4,0.,0.,-1.
FORCE,60,2901,0,.4,0.,0.,-1.
$
FORCE,60,2206,0,.3,0.,0.,-1.
FORCE,60,2306,0,.3,0.,0.,-1.
FORCE,60,2406,0,.3,0.,0.,-1.
FORCE,60,2506,0,.3,0.,0.,-1.
FORCE,60,2606,0,.3,0.,0.,-1.
```

```
FORCE,60,2706,0,.3,0.,0.,-1.
FORCE,60,2806,0,.3,0.,0.,-1.
FORCE,60,2906,0,.3,0.,0.,-1.
$
PARAM,COUPMASS,1
PARAM,GRDPNT,0
PARAM,MAXRATIO,5.E+06
PARAM,K6ROT,10.
PARAM,TESTNEG,-2 $ SKIP DIFFERENTIAL STIFFNESS CALCULATIONS
CORD2C         4              0.0     0.0     0.0     0.0     0.0     5.0CORD
+ORD         5.0     0.0      5.0
$
$ GRID POINTS - RIBS GEOMETRY
GRID        2001       4    96.00    22.5  8.3705
GRID        2002       4    82.11    22.5  6.8685
GRID        2003       4    71.79    22.5  5.7535
GRID        2004       4    59.66    22.5  4.4415
GRID        2005       4    47.83    22.5  3.1635
GRID        2006       4    35.75    22.5  1.8572
GRID        2007       4    35.35    22.5  2.4375
GRID        2008       4     26.5    22.5   .8572
GRID        2009       4    17.25    22.5   .3572
GRID        2010       4      8.0    22.5   .3125
GRID        2011       4    4.625    22.5   .3125
GRID        2012       4      8.0    22.5  0.0
GRID        2013       4    4.625    22.5  0.0
$
GRID        2014       4    96.00    67.5  8.3705
GRID        2015       4    82.11    67.5  6.8685
GRID        2016       4    71.79    67.5  5.7535
GRID        2017       4    59.66    67.5  4.4415
GRID        2018       4    47.83    67.5  3.1635
GRID        2019       4    35.75    67.5  1.8572
GRID        2020       4    35.35    67.5  2.4375
GRID        2021       4     26.5    67.5   .8572
GRID        2022       4    17.25    67.5   .3572
GRID        2023       4      8.0    67.5   .3125
GRID        2024       4    4.625    67.5   .3125
GRID        2025       4      8.0    67.5  0.0
GRID        2026       4    4.625    67.5  0.0
$
GRID        2027       4    96.00   112.5  8.3705
GRID        2028       4    82.11   112.5  6.8685
GRID        2029       4    71.79   112.5  5.7535
GRID        2030       4    59.66   112.5  4.4415
GRID        2031       4    47.83   112.5  3.1635
GRID        2032       4    35.75   112.5  1.8572
GRID        2033       4    35.35   112.5  2.4375
GRID        2034       4     26.5   112.5   .8572
GRID        2035       4    17.25   112.5   .3572
GRID        2036       4      8.0   112.5   .3125
GRID        2037       4    4.625   112.5   .3125
GRID        2038       4      8.0   112.5  0.0
GRID        2039       4    4.625   112.5  0.0
$
GRID        2040       4    96.00   157.5  8.3705
GRID        2041       4    82.11   157.5  6.8685
GRID        2042       4    71.79   157.5  5.7535
GRID        2043       4    59.66   157.5  4.4415
GRID        2044       4    47.83   157.5  3.1635
GRID        2045       4    35.75   157.5  1.8572
GRID        2046       4    35.35   157.5  2.4375
GRID        2047       4     26.5   157.5   .8572
GRID        2048       4    17.25   157.5   .3572
GRID        2049       4      8.0   157.5   .3125
GRID        2050       4    4.625   157.5   .3125
GRID        2051       4      8.0   157.5  0.0
GRID        2052       4    4.625   157.5  0.0
$
GRID        2053       4    96.00   202.5  8.3705
GRID        2054       4    82.11   202.5  6.8685
GRID        2055       4    71.79   202.5  5.7535
GRID        2056       4    59.66   202.5  4.4415
GRID        2057       4    47.83   202.5  3.1635
```

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GRID         2058        4   35.75    202.5  1.8572
GRID         2059        4   35.35    202.5  2.4375
GRID         2060        4    26.5    202.5   .8572
GRID         2061        4   17.25    202.5   .3572
GRID         2062        4     8.0    202.5   .3125
GRID         2063        4   4.625    202.5   .3125
GRID         2064        4     8.0    202.5  0.0
GRID         2065        4   4.625    202.5  0.0
$
GRID         2066        4   96.00    247.5  8.3705
GRID         2067        4   82.11    247.5  6.8685
GRID         2068        4   71.79    247.5  5.7535
GRID         2069        4   59.66    247.5  4.4415
GRID         2070        4   47.83    247.5  3.1635
GRID         2071        4   35.75    247.5  1.8572
GRID         2072        4   35.35    247.5  2.4375
GRID         2073        4    26.5    247.5   .8572
GRID         2074        4   17.25    247.5   .3572
GRID         2075        4     8.0    247.5   .3125
GRID         2076        4   4.625    247.5   .3125
GRID         2077        4     8.0    247.5  0.0
GRID         2078        4   4.625    247.5  0.0
$
GRID         2079        4   96.00    292.5  8.3705
GRID         2080        4   82.11    292.5  6.8685
GRID         2081        4   71.79    292.5  5.7535
GRID         2082        4   59.66    292.5  4.4415
GRID         2083        4   47.83    292.5  3.1635
GRID         2084        4   35.75    292.5  1.8572
GRID         2085        4   35.35    292.5  2.4375
GRID         2086        4    26.5    292.5   .8572
GRID         2087        4   17.25    292.5   .3572
GRID         2088        4     8.0    292.5   .3125
GRID         2089        4   4.625    292.5   .3125
GRID         2090        4     8.0    292.5  0.0
GRID         2091        4   4.625    292.5  0.0
$
GRID         2092        4   96.00    337.5  8.3705
GRID         2093        4   82.11    337.5  6.8685
GRID         2094        4   71.79    337.5  5.7535
GRID         2095        4   59.66    337.5  4.4415
GRID         2096        4   47.83    337.5  3.1635
GRID         2097        4   35.75    337.5  1.8572
GRID         2098        4   35.35    337.5  2.4375
GRID         2099        4    26.5    337.5   .8572
GRID         2100        4   17.25    337.5   .3572
GRID         2101        4     8.0    337.5   .3125
GRID         2102        4   4.625    337.5   .3125
GRID         2103        4     8.0    337.5  0.0
GRID         2104        4   4.625    337.5  0.0
GRID         2106        4     0.0      0.0  2.4375
$ HUB
GRID         2110        4     8.5      0.0  0.0
GRID         2111        4    7.07     45.0  0.0
GRID         2112        4    8.50     90.0  0.0
GRID         2113        4    7.07    135.0  0.0
GRID         2114        4    8.50    180.0  0.0
GRID         2115        4    7.07    225.0  0.0
GRID         2116        4    8.50    270.0  0.0
GRID         2117        4    7.07    315.0  0.0
$ SENSOR PLATE
GRID         2119        4     8.5      0.0  2.4375
GRID         2120        4     8.5     90.0  2.4375
GRID         2121        4     8.5    180.0  2.4375
GRID         2122        4     8.5    270.0  2.4375
$ TRUSS BAY
GRID          315        4  7.0711     45.0  -.8125
GRID          316        4  7.0711    -45.0  -.8125
GRID          404        4  7.0711    135.0  -.8125
GRID          405        4  7.0711   -135.0  -.8125
GRID          313        4  7.0711     45.0 -10.812
GRID          314        4  7.0711    -45.0 -10.812
GRID          402        4  7.0711    135.0 -10.812
GRID          403        4  7.0711   -135.0 -10.812
```

```
$ TARGET LOCATIONS
GRID,2201,4,94.012,22.5,8.1555
GRID,2301,4,94.012,67.5,8.1555
GRID,2401,4,94.012,112.5,8.1555
GRID,2501,4,94.012,157.5,8.1555
GRID,2601,4,94.012,202.5,8.1555
GRID,2701,4,94.012,247.5,8.1555
GRID,2801,4,94.012,292.5,8.1555
GRID,2901,4,94.012,337.5,8.1555
GRID,2206,4,41.8397,22.5,2.5157
GRID,2306,4,41.8397,67.5,2.5157
GRID,2406,4,41.8397,112.5,2.5157
GRID,2506,4,41.8397,157.5,2.5157
GRID,2606,4,41.8397,202.5,2.5157
GRID,2706,4,41.8397,247.5,2.5157
GRID,2806,4,41.8397,292.5,2.5157
GRID,2906,4,41.8397,337.5,2.5157
$ CONSTRAINT POINTS, BAY BOTTOM
SPC1           1  123456     313
SPC1           1  123456     314
SPC1           1  123456     402
SPC1           1  123456     403
$ RIBS ELEMENTS
CBEAM          1       1    2001    2201     0.0     0.0     1.0
CBEAM          2       1    2014    2301     0.0     0.0     1.0
CBEAM          3       1    2027    2401     0.0     0.0     1.0
CBEAM          4       1    2040    2501     0.0     0.0     1.0
CBEAM          5       1    2053    2601     0.0     0.0     1.0
CBEAM          6       1    2066    2701     0.0     0.0     1.0
CBEAM          7       1    2079    2801     0.0     0.0     1.0
CBEAM          8       1    2092    2901     0.0     0.0     1.0
$
CBEAM          9       2    2002    2003     0.0     0.0     1.0
CBEAM         10       2    2015    2016     0.0     0.0     1.0
CBEAM         11       2    2028    2029     0.0     0.0     1.0
CBEAM         12       2    2041    2042     0.0     0.0     1.0
CBEAM         13       2    2054    2055     0.0     0.0     1.0
CBEAM         14       2    2067    2068     0.0     0.0     1.0
CBEAM         15       2    2080    2081     0.0     0.0     1.0
CBEAM         16       2    2093    2094     0.0     0.0     1.0
$
CBEAM         17       3    2003    2004     0.0     0.0     1.0
CBEAM         18       3    2016    2017     0.0     0.0     1.0
CBEAM         19       3    2029    2030     0.0     0.0     1.0
CBEAM         20       3    2042    2043     0.0     0.0     1.0
CBEAM         21       3    2055    2056     0.0     0.0     1.0
CBEAM         22       3    2068    2069     0.0     0.0     1.0
CBEAM         23       3    2081    2082     0.0     0.0     1.0
CBEAM         24       3    2094    2095     0.0     0.0     1.0
$
CBEAM         25       4    2004    2005     0.0     0.0     1.0
CBEAM         26       4    2017    2018     0.0     0.0     1.0
CBEAM         27       4    2030    2031     0.0     0.0     1.0
CBEAM         28       4    2043    2044     0.0     0.0     1.0
CBEAM         29       4    2056    2057     0.0     0.0     1.0
CBEAM         30       4    2069    2070     0.0     0.0     1.0
CBEAM         31       4    2082    2083     0.0     0.0     1.0
CBEAM         32       4    2095    2096     0.0     0.0     1.0
$
CBEAM         33       5    2005    2206     0.0     0.0     1.0
CBEAM         34       5    2018    2306     0.0     0.0     1.0
CBEAM         35       5    2031    2406     0.0     0.0     1.0
CBEAM         36       5    2044    2506     0.0     0.0     1.0
CBEAM         37       5    2057    2606     0.0     0.0     1.0
CBEAM         38       5    2070    2706     0.0     0.0     1.0
CBEAM         39       5    2083    2806     0.0     0.0     1.0
CBEAM         40       5    2096    2906     0.0     0.0     1.0
$
CBEAM         41       6    2006    2008     0.0     0.0    1.00
CBEAM         42       6    2019    2021     0.0     0.0    1.00
CBEAM         43       6    2032    2034     0.0     0.0    1.00
CBEAM         44       6    2045    2047     0.0     0.0    1.00
CBEAM         45       6    2058    2060     0.0     0.0    1.00
CBEAM         46       6    2071    2073     0.0     0.0    1.00
```

```
CBEAM        47      6     2084    2086     0.0     0.0     1.00
CBEAM        48      6     2097    2099     0.0     0.0     1.00
$
CBEAM        49      6     2008    2009     0.0     0.0     1.00
CBEAM        50      6     2021    2022     0.0     0.0     1.00
CBEAM        51      6     2034    2035     0.0     0.0     1.00
CBEAM        52      6     2047    2048     0.0     0.0     1.00
CBEAM        53      6     2060    2061     0.0     0.0     1.00
CBEAM        54      6     2073    2074     0.0     0.0     1.00
CBEAM        55      6     2086    2087     0.0     0.0     1.00
CBEAM        56      6     2099    2100     0.0     0.0     1.00
$
CBEAM        57      6     2009    2010     0.0     0.0     1.00
CBEAM        58      6     2022    2023     0.0     0.0     1.00
CBEAM        59      6     2035    2036     0.0     0.0     1.00
CBEAM        60      6     2048    2049     0.0     0.0     1.00
CBEAM        61      6     2061    2062     0.0     0.0     1.00
CBEAM        62      6     2074    2075     0.0     0.0     1.00
CBEAM        63      6     2087    2088     0.0     0.0     1.00
CBEAM        64      6     2100    2101     0.0     0.0     1.00
$
CBEAM        65      6     2010    2011     0.0     0.0     1.00
CBEAM        66      6     2023    2024     0.0     0.0     1.00
CBEAM        67      6     2036    2037     0.0     0.0     1.00
CBEAM        68      6     2049    2050     0.0     0.0     1.00
CBEAM        69      6     2062    2063     0.0     0.0     1.00
CBEAM        70      6     2075    2076     0.0     0.0     1.00
CBEAM        71      6     2088    2089     0.0     0.0     1.00
CBEAM        72      6     2101    2102     0.0     0.0     1.00
CBEAM,140,1,2201,2002,0.,0.,1.
CBEAM,141,1,2301,2015,0.,0.,1.
CBEAM,142,1,2401,2028,0.,0.,1.
CBEAM,143,1,2501,2041,0.,0.,1.
CBEAM,144,1,2601,2054,0.,0.,1.
CBEAM,145,1,2701,2067,0.,0.,1.
CBEAM,146,1,2801,2080,0.,0.,1.
CBEAM,147,1,2901,2093,0.,0.,1.
CBEAM,148,5,2206,2006,0.,0.,1.
CBEAM,149,5,2306,2019,0.,0.,1.
CBEAM,150,5,2406,2032,0.,0.,1.
CBEAM,151,5,2506,2045,0.,0.,1.
CBEAM,152,5,2606,2058,0.,0.,1.
CBEAM,153,5,2706,2071,0.,0.,1.
CBEAM,154,5,2806,2084,0.,0.,1.
CBEAM,155,5,2906,2097,0.,0.,1.
$ END TAPERED RIBS
$ START CONNECTOR BOLTS - RIBS TO HUB
CBAR         73      8     2010    2012    2062
CBAR         74      8     2023    2025    2075
CBAR         75      8     2036    2038    2088
CBAR         76      8     2049    2051    2101
CBAR         77      8     2062    2064    2010
CBAR         78      8     2075    2077    2023
CBAR         79      8     2088    2090    2036
CBAR         80      8     2101    2103    2049
CBAR         81      8     2011    2013    2063
CBAR         82      8     2024    2026    2076
CBAR         83      8     2037    2039    2089
CBAR         84      8     2050    2052    2102
CBAR         85      8     2063    2065    2011
CBAR         86      8     2076    2078    2024
CBAR         87      8     2089    2091    2037
CBAR         88      8     2102    2104    2050
$ START CONNECTORS BETWEEN RIBS AND SENSOR PLATE
CBAR,89,9,2006,2007,2005
,,6
CBAR,90,9,2019,2020,2018
,,6
CBAR,91,9,2032,2033,2031
,,6
CBAR,92,9,2045,2046,2044
,,6
CBAR,93,9,2058,2059,2057
,,6
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CBAR,94,9,2071,2072,2070
,,6
CBAR,95,9,2084,2085,2083
,,6
CBAR,96,9,2097,2098,2096
,,6
$ START COMPRESSION MEMBERS BETWEEN HUB AND SENSOR  PLATE, D=.375"
CBAR            97       14      2110      2119      1.0       1.0
CBAR            98       14      2112      2120      1.0       1.0
CBAR            99       14      2114      2121      1.0       1.0
CBAR           100       14      2116      2122      1.0       1.0
$ START TENSION CABLE AT TIP OF RIBS
CROD           101        7      2001      2014
CROD           102        7      2014      2027
CROD           103        7      2027      2040
CROD           104        7      2040      2053
CROD           105        7      2053      2066
CROD           106        7      2066      2079
CROD           107        7      2079      2092
CROD           108        7      2092      2001
$ TRUSS BAY
CBAR           105       12       404       405      1.0       1.0       1.0
CBAR           106       12       405       316      1.0       1.0       1.0
CBAR           107       12       315       316      1.0       1.0       1.0
CBAR           108       13       315       405      1.0       1.0       1.0
CBAR           109       12       315       404      1.0       1.0       1.0
CBAR           110       12       402       404      1.0       1.0       1.0
CBAR           111       12       403       405      1.0       1.0       1.0
CBAR           112       12       313       315      1.0       1.0       1.0
CBAR           113       12       314       316      1.0       1.0       1.0
CBAR           114       12       402       403      1.0       1.0       1.0
CBAR           115       12       403       314      1.0       1.0       1.0
CBAR           116       12       314       313      1.0       1.0       1.0
CBAR           117       12       313       402      1.0       1.0       1.0
CBAR           118       13       402       405      1.0       1.0       1.0
CBAR           119       13       313       404      1.0       1.0       1.0
CBAR           120       13       314       315      1.0       1.0       1.0
CBAR           121       13       403       316      1.0       1.0       1.0
CBAR           122       13       314       402      1.0       1.0       1.0
$ 1/4" DIAM BOLTS WHICH CONNECT RFL HUB TO SUPPORT STRUCTURE
CELAS2         123 1.5E+08    315         1     2111       1
CELAS2         124 1.5E+08    315         2     2111       2
CELAS2         125 1.5E+08    315         3     2111       3
CELAS2         126 1.5E+08    315         4     2111       4
CELAS2         127 1.5E+08    315         5     2111       5
CELAS2         128 1.5E+08    315         6     2111       6
CELAS2         129 1.5E+08    316         1     2117       1
CELAS2         130 1.5E+08    316         2     2117       2
CELAS2         131 1.5E+08    316         3     2117       3
CELAS2         132 1.5E+08    316         4     2117       4
CELAS2         133 1.5E+08    316         5     2117       5
CELAS2         134 1.5E+08    316         6     2117       6
CELAS2         135 1.5E+08    404         1     2113       1
CELAS2         136 1.5E+08    404         2     2113       2
CELAS2         137 1.5E+08    404         3     2113       3
CELAS2         138 1.5E+08    404         4     2113       4
CELAS2         139 1.5E+08    404         5     2113       5
CELAS2         140 1.5E+08    404         6     2113       6
CELAS2         141 1.5E+08    405         1     2115       1
CELAS2         142 1.5E+08    405         2     2115       2
CELAS2         143 1.5E+08    405         3     2115       3
CELAS2         144 1.5E+08    405         4     2115       4
CELAS2         145 1.5E+08    405         5     2115       5
CELAS2         146 1.5E+08    405         6     2115       6
$ LUMP MASS AT RIB TIPS
CONM2          205     2001          4 .000259
CONM2          206     2014          4 .000259
CONM2          207     2027          4 .000259
CONM2          208     2040          4 .000259
CONM2          209     2053          4 .000259
CONM2          210     2066          4 .000259
CONM2          211     2079          4 .000259
CONM2          212     2092          4 .000259
$ LUMP MASS-TRUSS JOINTS
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CONM2        213     402       4  .00142
CONM2        214     403       4  .00106
CONM2        215     404       4  .00124
CONM2        216     405       4  .00124
CONM2        217     313       4  .00124
CONM2        218     314       4  .00142
CONM2        219     315       4  .00124
CONM2        220     316       4  .00106
$ MIRROR LUMP MASS
CONM2        221    2106       4 .049223                                CON
+ON        6.795           6.795                  13.591
$ SENSOR PLATE AND HUB ELEMENTS
CTRIA3       229      11    2104    2013    2010
CTRIA3       230      11    2026    2039    2112
CTRIA3       231      11    2052    2065    2114
CTRIA3       232      11    2078    2091    2116
CQUAD4       261      10    2007    2020    2120    2119
CTRIA3       233      11    2012    2111    2013
CTRIA3       234      11    2111    2025    2026
CTRIA3       235      11    2038    2113    2039
CTRIA3       236      11    2113    2051    2052
CQUAD4       262      10    2033    2046    2121    2120
CTRIA3       237      11    2064    2115    2065
CTRIA3       238      11    2115    2077    2078
CTRIA3       239      11    2090    2117    2091
CTRIA3       240      11    2117    2103    2104
CQUAD4       263      10    2059    2072    2122    2121
CTRIA3       241      11    2013    2026    2111
CTRIA3       242      11    2039    2052    2113
CTRIA3       243      11    2065    2078    2115
CTRIA3       244      11    2091    2104    2117
CQUAD4       264      10    2085    2098    2119    2122
CTRIA3       245      11    2110    2012    2013
CTRIA3       246      11    2025    2112    2026
CTRIA3       247      11    2112    2038    2039
CTRIA3       248      11    2051    2114    2052
CTRIA3       249      11    2114    2064    2065
CTRIA3       250      11    2077    2116    2078
CTRIA3       251      11    2116    2090    2091
CTRIA3       252      11    2103    2110    2104
CTRIA3       253      10    2007    2119    2098
CTRIA3       254      10    2033    2120    2020
CTRIA3       255      10    2059    2121    2046
CTRIA3       256      10    2085    2122    2072
CTRIA3       257      10    2119    2106    2120
CTRIA3       258      10    2120    2106    2121
CTRIA3       259      10    2121    2106    2122
CTRIA3       260      10    2122    2106    2119
$
$ PROPERTIES
$ RIBS
PBEAM  *               1               1             .29    .00151041667 PB1
*PB1         .0325186667             0.0    .00522150000
PBEAM  *               2               1           .3375    .00175781250 PB5
*PB5         .0512578125             0.0       .00621100
PBEAM  *               3               1            .384            .002 PB9
*PB9         .0754974720             0.0        .0071797
PBEAM  *               4               1             .43    .00223958333 PB13
*PB13         .106009333             0.0         .008138
PBEAM  *               5               1           .4775    .00248697917 PB17
*PB17         .145163979             0.0        .0091276
PBEAM  *               6               1              .5    .00260416667 PB21
*PB21         .166666667             0.0        .0095964
$ HUB TO RIBS CONNECTORS
PBAR   *               8               3     .0490873859   .000191747598 PB25
*PB25      .000191747598   .000383495197             0.0                 PB26
$ SENSOR PLATE TO RIBS CONNECTORS
PBAR   *               9               3     .0283528741  .639711713E-04 PB29
*PB29     .639711713E-04   .000127942343             0.0                 PB30
$ TRUSS BAY
PBAR          12      11  .12316   .0042   .0042   .0084     0.0
PBAR          13      12   .1166   .0042   .0042   .0084     0.0
$ COMPRESSION MEMBERS BETWEEN HUB AND SENSOR PLATE
PBAR          14       3 .110446.0009707.0009707.0019414     0.0
```

```
$ CABLES
PROD           7       2 .000767     .00             .00
$ SENSOR PLATE
PSHELL        10       4 0.40807       4                            .000
$ HUB
PSHELL        11       5    .375       5                            .000
$ MATERIAL CARDS
$ RIBS
MAT1   *               1         1.0E+07  .375093773E+07                MAT1
*MAT1           .0002539             0.0
$ CABLES
MAT1   *               2         3.0E+07  .115384615E+08                MAT3
*MAT3           .0004585      -2.535E-06
$ RIB TO HUB CONNECTORS
MAT1   *               3         .30E+08  .115384615E+08                MAT5
*MAT5           .0007332
$ SENSOR PLATE
MAT1   *               4         .65E+07         .25E+07                MAT7
*MAT7           .0000512
$ HUB
MAT1   *               5         .10E+08  .375093773E+07                MAT9
*MAT9           .0002751
$ TRUSS BAY
MAT1          11  1.E+07            .3332.19E-04      0.      0.
MAT1          12  1.E+07            .3332.29E-04      0.      0.
TEMPD         13  15000.
$
ENDDATA
```

```
 NONLINEAR ANALYSIS STEP 2, RESTART FROM LAST ITERATION IN STEP 1
$ REFLECTOR ON ITS HORIZONTAL POSITION
NASTRAN FILES=(DB01)
ID STATIC NON-LINEAR ANALYSIS
SOL 64
TIME 120
CEND
$ CASE CONTROL DECK FOLLOWS
TITLE=REFLECTOR WITH TAPERED RIBS, HORIZONTAL POSITION
SPC=1  $ CONSTRAINTS
TEMP(LOAD)=13  $ CABLES THERMAL LOAD
ECHO=SORT
LINE=40
LOAD=100  $ APPLIED LOADS
$ FIFTEEN DUMMY SUBCASES INCLUDED TO START FROM LATEST STRESS STATE IN STEP 1
SUBCASE 1 $DUMMY
SUBCASE 2 $DUMMY
SUBCASE 3 $DUMMY
SUBCASE 4 $DUMMY
SUBCASE 5 $DUMMY
SUBCASE 6 $DUMMY
SUBCASE 7 $DUMMY
SUBCASE 8 $DUMMY
SUBCASE 9 $DUMMY
SUBCASE 10 $DUMMY
SUBCASE 11 $DUMMY
SUBCASE 12 $DUMMY
SUBCASE 13 $DUMMY
SUBCASE 14 $DUMMY
SUBCASE 15 $DUMMY
SUBCASE 16
SUBCASE 17
SUBCASE 18
DISP=ALL
SPCF=ALL
ELFOR=ALL
$ PLOTTING
OUTPUT(PLOT)
CSCALE=1.8
SCALE=0.1
PLOTTER NAST
SET 1 INCLUDE ALL
PTITLE=NL ANALYSIS - SEMI-PRESHAPED REFLECTOR
FIND ORIGIN 1,SET 1
VIEW 180.0,0.0,0.0
PLOT SET 1,ORIGIN 1,SHAPE
PLOT STATIC DEFORMATION,SET 1,ORIGIN 1,SHAPE
PLOT STATIC DEFORMATION 0,SET 1,ORIGIN 1,SYMBOLS 1
$ BULK DATA FOLLOWS
BEGIN BULK
$ LOAD APPLIED AT SENSOR PLATE ENDS
FORCE,60,2006,0,0.,0.,0.,-1.
FORCE,60,2019,0,0.,0.,0.,-1.
FORCE,60,2032,0,3.,0.,0.,-1.
FORCE,60,2045,0,0.,0.,0.,-1.
FORCE,60,2058,0,3.,0.,0.,-1.
FORCE,60,2071,0,0.,0.,0.,-1.
FORCE,60,2084,0,0.,0.,0.,-1.
FORCE,60,2097,0,0.,0.,0.,-1.
$ TARGET WEIGHTS
FORCE,62,2201,0,.4,0.,0.,-1.
FORCE,62,2301,0,.4,0.,0.,-1.
FORCE,62,2401,0,.4,0.,0.,-1.
FORCE,62,2501,0,.4,0.,0.,-1.
FORCE,62,2601,0,.4,0.,0.,-1.
FORCE,62,2701,0,.4,0.,0.,-1.
FORCE,62,2801,0,.4,0.,0.,-1.
FORCE,62,2901,0,.4,0.,0.,-1.
FORCE,62,2206,0,.3,0.,0.,-1.
FORCE,62,2306,0,.3,0.,0.,-1.
FORCE,62,2406,0,.3,0.,0.,-1.
FORCE,62,2506,0,.3,0.,0.,-1.
FORCE,62,2606,0,.3,0.,0.,-1.
FORCE,62,2706,0,.3,0.,0.,-1.
```

```
FORCE,62,2806,0,.3,0.,0.,-1.
FORCE,62,2906,0,.3,0.,0.,-1.
GRAV,200,0,386.,0.0,0.0,-1.
LOAD,100,1.,1.,200,1.,60,1.,62
PARAM,COUPMASS,1
PARAM,DLOAD,-1
PARAM,GRDPNT,0
PARAM,MAXRATIO,5.E+06
PARAM,SUBSKP,15
PARAM,TESTNEG,-2
PARAM,K6ROT,10.
TEMPD,13,15000.
ENDDATA
```

```
 RUNSTREAM OF PRESTRESS MODEL OF INCLINED REFLECTOR , STEP 2
$ APPLIED LOADS ARE CABLE THERMAL LOAD,GRAVITY,TARGET WEIGHTS AND PRESTRESS
  FORCES
NASTRAN FILES=(DB01)
ID INCLINED REFLECTOR
APP DISPLACEMENT
SOL 64
TIME 120
CEND
$ Start Case Control Deck
TITLE = INCLINED REFLECTOR,PRESTRESS MODEL,STEP 1
ECHO = SORT
LINE = 35
SET 20 = 2001 THRU 2072, 2101 THRU 2108, 2157 thru 2176
SPC = 100  $ Constraints
LOAD=262  $ Applied loads
TEMP(LOAD)=13 $ Thermal load on cables
SUBCASE 1
 LABEL= LINEAR STATIC SOLUTION
SUBCASE 2
 LABEL = K + DIFFERENTIAL K
SUBCASE 3
 LABEL=FIRST NON-LINEAR ITERATION
OUTPUT(PLOT)
 CSCALE=1.8
 PLOTTER NAST
 SET 30 = all
 AXES Y,X,Z
 VIEW=0.,0.,0.
 PTITLE=SIDE VIEW
 PLOT STATIC DEFORMATION,3,SET 30,ORIGIN 30
 PLOT STATIC DEFORMATION 0,3,SET 30,ORIGIN 30
BEGIN BULK
CORD2C          3       0  615.00 0.00000   56.110   590.22 0.00000   86.707+CS     3
+CS     3  645.60 0.00000  80.885
LOAD,262,1.,1.,62,1.,200,1.,60
PARAM   GRDPNT  0
PARAM   COUPMASS1
PARAM,K6ROT,10.
PARAM,MAXRATIO,1.5E+05
SPC1,100,123456,261
SPC1,100,123456,262
SPC1,100,123456,263
SPC1,100,123456,264
$
GRAV    200     0       386.    0.      0.      -1.
$ TARGET WEIGHTS
FORCE,60,2201,0,.4,0.,0.,-1.
FORCE,60,2206,0,.3,0.,0.,-1.
FORCE,60,2301,0,.4,0.,0.,-1.
FORCE,60,2306,0,.3,0.,0.,-1.
FORCE,60,2401,0,.4,0.,0.,-1.
FORCE,60,2406,0,.3,0.,0.,-1.
FORCE,60,2501,0,.4,0.,0.,-1.
FORCE,60,2506,0,.3,0.,0.,-1.
FORCE,60,2601,0,.4,0.,0.,-1.
FORCE,60,2606,0,.3,0.,0.,-1.
FORCE,60,2701,0,.4,0.,0.,-1.
FORCE,60,2706,0,.3,0.,0.,-1.
FORCE,60,2801,0,.4,0.,0.,-1.
FORCE,60,2806,0,.3,0.,0.,-1.
FORCE,60,2901,0,.4,0.,0.,-1.
FORCE,60,2906,0,.3,0.,0.,-1.
$ EXTERNAL APPLIED FORCE AT THE RIBS
FORCE,63,2002,0,.5,0.,0.,-1.
FORCE,63,2015,0,.5,0.,0.,-1.
FORCE,63,2028,0,.5,0.,0.,-1.
FORCE,63,2041,0,.5,0.,0.,-1.
FORCE,63,2054,0,.5,0.,0.,-1.
FORCE,63,2067,0,.5,0.,0.,-1.
FORCE,63,2080,0,.5,0.,0.,-1.
FORCE,63,2093,0,.5,0.,0.,-1.
TEMPD,13,235.8
$ PRESTRESS FORCES GENERATED FROM PRESTRESS CASE FOR TEMP=235.8 DEG F
```

```
FORCE  62,  2001,  3,  1.39078,1.,0.,0.
FORCE  62,  2001,  3, -0.00006,0.,1.,0.
FORCE  62,  2001,  3, -3.99135,0.,0.,1.
FORCE  62,  2002,  3, -1.65445,1.,0.,0.
FORCE  62,  2002,  3, -0.00001,0.,1.,0.
FORCE  62,  2002,  3, -0.26564,0.,0.,1.
FORCE  62,  2003,  3, -1.68624,1.,0.,0.
FORCE  62,  2003,  3,  0.00001,0.,1.,0.
FORCE  62,  2003,  3, -0.03636,0.,0.,1.
FORCE  62,  2004,  3, -0.35100,1.,0.,0.
FORCE  62,  2004,  3, -0.00002,0.,1.,0.
FORCE  62,  2004,  3,  1.20939,0.,0.,1.
FORCE  62,  2005,  3, -1.79837,1.,0.,0.
FORCE  62,  2005,  3,  0.00003,0.,1.,0.
FORCE  62,  2005,  3,  0.61360,0.,0.,1.
FORCE  62,  2006,  3, -0.93170,1.,0.,0.
FORCE  62,  2006,  3, -0.00001,0.,1.,0.
FORCE  62,  2006,  3,  1.04994,0.,0.,1.
FORCE  62,  2008,  3, -0.07452,1.,0.,0.
FORCE  62,  2008,  3, -0.00002,0.,1.,0.
FORCE  62,  2008,  3,  0.91970,0.,0.,1.
FORCE  62,  2009,  3, -0.02486,1.,0.,0.
FORCE  62,  2009,  3,  0.00004,0.,1.,0.
FORCE  62,  2009,  3,  0.84485,0.,0.,1.
FORCE  62,  2010,  3, -0.00020,1.,0.,0.
FORCE  62,  2010,  3, -0.00002,0.,1.,0.
FORCE  62,  2010,  3,  0.08302,0.,0.,1.
FORCE  62,  2011,  3, 17.18982,1.,0.,0.
FORCE  62,  2011,  3, -0.00001,0.,1.,0.
FORCE  62,  2011,  3,  0.00001,0.,0.,1.
FORCE  62,  2014,  3,  1.39077,1.,0.,0.
FORCE  62,  2014,  3, -0.00004,0.,1.,0.
FORCE  62,  2014,  3, -3.99131,0.,0.,1.
FORCE  62,  2015,  3, -1.65447,1.,0.,0.
FORCE  62,  2015,  3,  0.00003,0.,1.,0.
FORCE  62,  2015,  3, -0.26559,0.,0.,1.
FORCE  62,  2016,  3, -1.68624,1.,0.,0.
FORCE  62,  2016,  3,  0.00000,0.,1.,0.
FORCE  62,  2016,  3, -0.03636,0.,0.,1.
FORCE  62,  2017,  3, -0.35102,1.,0.,0.
FORCE  62,  2017,  3,  0.00000,0.,1.,0.
FORCE  62,  2017,  3,  1.20949,0.,0.,1.
FORCE  62,  2018,  3, -1.79836,1.,0.,0.
FORCE  62,  2018,  3,  0.00012,0.,1.,0.
FORCE  62,  2018,  3,  0.61359,0.,0.,1.
FORCE  62,  2019,  3, -0.93171,1.,0.,0.
FORCE  62,  2019,  3,  0.00007,0.,1.,0.
FORCE  62,  2019,  3,  1.05002,0.,0.,1.
FORCE  62,  2021,  3, -0.07452,1.,0.,0.
FORCE  62,  2021,  3,  0.00001,0.,1.,0.
FORCE  62,  2021,  3,  0.91979,0.,0.,1.
FORCE  62,  2022,  3, -0.02486,1.,0.,0.
FORCE  62,  2022,  3, -0.00007,0.,1.,0.
FORCE  62,  2022,  3,  0.84470,0.,0.,1.
FORCE  62,  2023,  3, -0.00020,1.,0.,0.
FORCE  62,  2023,  3,  0.00003,0.,1.,0.
FORCE  62,  2023,  3,  0.08309,0.,0.,1.
FORCE  62,  2024,  3, 17.18982,1.,0.,0.
FORCE  62,  2024,  3,  0.00009,0.,1.,0.
FORCE  62,  2024,  3,  0.00002,0.,0.,1.
FORCE  62,  2027,  3,  1.39080,1.,0.,0.
FORCE  62,  2027,  3, -0.00020,0.,1.,0.
FORCE  62,  2027,  3, -3.99135,0.,0.,1.
FORCE  62,  2028,  3, -1.65446,1.,0.,0.
FORCE  62,  2028,  3,  0.00000,0.,1.,0.
FORCE  62,  2028,  3, -0.26561,0.,0.,1.
FORCE  62,  2029,  3, -1.68623,1.,0.,0.
FORCE  62,  2029,  3, -0.00001,0.,1.,0.
FORCE  62,  2029,  3, -0.03638,0.,0.,1.
FORCE  62,  2030,  3, -0.35099,1.,0.,0.
FORCE  62,  2030,  3, -0.00010,0.,1.,0.
FORCE  62,  2030,  3,  1.20939,0.,0.,1.
FORCE  62,  2031,  3, -1.79834,1.,0.,0.
FORCE  62,  2031,  3, -0.00003,0.,1.,0.
```

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FORCE   62,   2031,   3,  0.61348,0.,0.,1.
FORCE   62,   2032,   3, -0.93170,1.,0.,0.
FORCE   62,   2032,   3, -0.00003,0.,1.,0.
FORCE   62,   2032,   3,  1.04993,0.,0.,1.
FORCE   62,   2034,   3, -0.07452,1.,0.,0.
FORCE   62,   2034,   3,  0.00002,0.,1.,0.
FORCE   62,   2034,   3,  0.91978,0.,0.,1.
FORCE   62,   2035,   3, -0.02486,1.,0.,0.
FORCE   62,   2035,   3, -0.00007,0.,1.,0.
FORCE   62,   2035,   3,  0.84470,0.,0.,1.
FORCE   62,   2036,   3, -0.00020,1.,0.,0.
FORCE   62,   2036,   3,  0.00006,0.,1.,0.
FORCE   62,   2036,   3,  0.08313,0.,0.,1.
FORCE   62,   2037,   3, 17.18982,1.,0.,0.
FORCE   62,   2037,   3,  0.00004,0.,1.,0.
FORCE   62,   2037,   3, -0.00002,0.,0.,1.
FORCE   62,   2040,   3,  1.39074,1.,0.,0.
FORCE   62,   2040,   3,  0.00004,0.,1.,0.
FORCE   62,   2040,   3, -3.99126,0.,0.,1.
FORCE   62,   2041,   3, -1.65445,1.,0.,0.
FORCE   62,   2041,   3,  0.00000,0.,1.,0.
FORCE   62,   2041,   3, -0.26565,0.,0.,1.
FORCE   62,   2042,   3, -1.68627,1.,0.,0.
FORCE   62,   2042,   3,  0.00000,0.,1.,0.
FORCE   62,   2042,   3, -0.03627,0.,0.,1.
FORCE   62,   2043,   3, -0.35103,1.,0.,0.
FORCE   62,   2043,   3,  0.00003,0.,1.,0.
FORCE   62,   2043,   3,  1.20951,0.,0.,1.
FORCE   62,   2044,   3, -1.79834,1.,0.,0.
FORCE   62,   2044,   3,  0.00000,0.,1.,0.
FORCE   62,   2044,   3,  0.61349,0.,0.,1.
FORCE   62,   2045,   3, -0.93171,1.,0.,0.
FORCE   62,   2045,   3,  0.00002,0.,1.,0.
FORCE   62,   2045,   3,  1.04999,0.,0.,1.
FORCE   62,   2047,   3, -0.07452,1.,0.,0.
FORCE   62,   2047,   3,  0.00001,0.,1.,0.
FORCE   62,   2047,   3,  0.91978,0.,0.,1.
FORCE   62,   2048,   3, -0.02486,1.,0.,0.
FORCE   62,   2048,   3,  0.00001,0.,1.,0.
FORCE   62,   2048,   3,  0.84476,0.,0.,1.
FORCE   62,   2049,   3, -0.00020,1.,0.,0.
FORCE   62,   2049,   3, -0.00001,0.,1.,0.
FORCE   62,   2049,   3,  0.08306,0.,0.,1.
FORCE   62,   2050,   3, 17.18982,1.,0.,0.
FORCE   62,   2050,   3, -0.00001,0.,1.,0.
FORCE   62,   2050,   3, -0.00001,0.,0.,1.
FORCE   62,   2053,   3,  1.39074,1.,0.,0.
FORCE   62,   2053,   3, -0.00004,0.,1.,0.
FORCE   62,   2053,   3, -3.99126,0.,0.,1.
FORCE   62,   2054,   3, -1.65445,1.,0.,0.
FORCE   62,   2054,   3, -0.00001,0.,1.,0.
FORCE   62,   2054,   3, -0.26565,0.,0.,1.
FORCE   62,   2055,   3, -1.68627,1.,0.,0.
FORCE   62,   2055,   3,  0.00000,0.,1.,0.
FORCE   62,   2055,   3, -0.03627,0.,0.,1.
FORCE   62,   2056,   3, -0.35103,1.,0.,0.
FORCE   62,   2056,   3, -0.00003,0.,1.,0.
FORCE   62,   2056,   3,  1.20951,0.,0.,1.
FORCE   62,   2057,   3, -1.79834,1.,0.,0.
FORCE   62,   2057,   3,  0.00000,0.,1.,0.
FORCE   62,   2057,   3,  0.61349,0.,0.,1.
FORCE   62,   2058,   3, -0.93171,1.,0.,0.
FORCE   62,   2058,   3, -0.00003,0.,1.,0.
FORCE   62,   2058,   3,  1.04999,0.,0.,1.
FORCE   62,   2060,   3, -0.07452,1.,0.,0.
FORCE   62,   2060,   3, -0.00001,0.,1.,0.
FORCE   62,   2060,   3,  0.91978,0.,0.,1.
FORCE   62,   2061,   3, -0.02486,1.,0.,0.
FORCE   62,   2061,   3, -0.00001,0.,1.,0.
FORCE   62,   2061,   3,  0.84476,0.,0.,1.
FORCE   62,   2062,   3, -0.00020,1.,0.,0.
FORCE   62,   2062,   3,  0.00001,0.,1.,0.
FORCE   62,   2062,   3,  0.08306,0.,0.,1.
FORCE   62,   2063,   3, 17.18982,1.,0.,0.
```

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FORCE   62,   2063,   3,   0.00001,0.,1.,0.
FORCE   62,   2063,   3,  -0.00001,0.,0.,1.
FORCE   62,   2066,   3,   1.39075,1.,0.,0.
FORCE   62,   2066,   3,  -0.00003,0.,1.,0.
FORCE   62,   2066,   3,  -3.99124,0.,0.,1.
FORCE   62,   2067,   3,  -1.65446,1.,0.,0.
FORCE   62,   2067,   3,  -0.00004,0.,1.,0.
FORCE   62,   2067,   3,  -0.26560,0.,0.,1.
FORCE   62,   2068,   3,  -1.68623,1.,0.,0.
FORCE   62,   2068,   3,   0.00001,0.,1.,0.
FORCE   62,   2068,   3,  -0.03637,0.,0.,1.
FORCE   62,   2069,   3,  -0.35099,1.,0.,0.
FORCE   62,   2069,   3,   0.00011,0.,1.,0.
FORCE   62,   2069,   3,   1.20940,0.,0.,1.
FORCE   62,   2070,   3,  -1.79834,1.,0.,0.
FORCE   62,   2070,   3,   0.00002,0.,1.,0.
FORCE   62,   2070,   3,   0.61348,0.,0.,1.
FORCE   62,   2071,   3,  -0.93170,1.,0.,0.
FORCE   62,   2071,   3,   0.00003,0.,1.,0.
FORCE   62,   2071,   3,   1.04993,0.,0.,1.
FORCE   62,   2073,   3,  -0.07452,1.,0.,0.
FORCE   62,   2073,   3,  -0.00002,0.,1.,0.
FORCE   62,   2073,   3,   0.91978,0.,0.,1.
FORCE   62,   2074,   3,  -0.02486,1.,0.,0.
FORCE   62,   2074,   3,   0.00007,0.,1.,0.
FORCE   62,   2074,   3,   0.84470,0.,0.,1.
FORCE   62,   2075,   3,  -0.00020,1.,0.,0.
FORCE   62,   2075,   3,  -0.00008,0.,1.,0.
FORCE   62,   2075,   3,   0.08311,0.,0.,1.
FORCE   62,   2076,   3,  17.18982,1.,0.,0.
FORCE   62,   2076,   3,  -0.00002,0.,1.,0.
FORCE   62,   2076,   3,   0.00000,0.,0.,1.
FORCE   62,   2079,   3,   1.39068,1.,0.,0.
FORCE   62,   2079,   3,  -0.00016,0.,1.,0.
FORCE   62,   2079,   3,  -3.99112,0.,0.,1.
FORCE   62,   2080,   3,  -1.65447,1.,0.,0.
FORCE   62,   2080,   3,  -0.00003,0.,1.,0.
FORCE   62,   2080,   3,  -0.26559,0.,0.,1.
FORCE   62,   2081,   3,  -1.68624,1.,0.,0.
FORCE   62,   2081,   3,   0.00001,0.,1.,0.
FORCE   62,   2081,   3,  -0.03636,0.,0.,1.
FORCE   62,   2082,   3,  -0.35102,1.,0.,0.
FORCE   62,   2082,   3,  -0.00001,0.,1.,0.
FORCE   62,   2082,   3,   1.20948,0.,0.,1.
FORCE   62,   2083,   3,  -1.79834,1.,0.,0.
FORCE   62,   2083,   3,   0.00003,0.,1.,0.
FORCE   62,   2083,   3,   0.61348,0.,0.,1.
FORCE   62,   2084,   3,  -0.93169,1.,0.,0.
FORCE   62,   2084,   3,   0.00005,0.,1.,0.
FORCE   62,   2084,   3,   1.04991,0.,0.,1.
FORCE   62,   2086,   3,  -0.07452,1.,0.,0.
FORCE   62,   2086,   3,  -0.00002,0.,1.,0.
FORCE   62,   2086,   3,   0.91978,0.,0.,1.
FORCE   62,   2087,   3,  -0.02486,1.,0.,0.
FORCE   62,   2087,   3,   0.00007,0.,1.,0.
FORCE   62,   2087,   3,   0.84470,0.,0.,1.
FORCE   62,   2088,   3,  -0.00020,1.,0.,0.
FORCE   62,   2088,   3,  -0.00003,0.,1.,0.
FORCE   62,   2088,   3,   0.08309,0.,0.,1.
FORCE   62,   2089,   3,  17.18982,1.,0.,0.
FORCE   62,   2089,   3,  -0.00009,0.,1.,0.
FORCE   62,   2089,   3,   0.00002,0.,0.,1.
FORCE   62,   2092,   3,   1.39079,1.,0.,0.
FORCE   62,   2092,   3,   0.00003,0.,1.,0.
FORCE   62,   2092,   3,  -3.99136,0.,0.,1.
FORCE   62,   2093,   3,  -1.65445,1.,0.,0.
FORCE   62,   2093,   3,   0.00001,0.,1.,0.
FORCE   62,   2093,   3,  -0.26564,0.,0.,1.
FORCE   62,   2094,   3,  -1.68624,1.,0.,0.
FORCE   62,   2094,   3,  -0.00001,0.,1.,0.
FORCE   62,   2094,   3,  -0.03636,0.,0.,1.
FORCE   62,   2095,   3,  -0.35100,1.,0.,0.
FORCE   62,   2095,   3,   0.00002,0.,1.,0.
FORCE   62,   2095,   3,   1.20940,0.,0.,1.
```

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FORCE  62,  2096,  3, -1.79836,1.,0.,0.
FORCE  62,  2096,  3, -0.00003,0.,1.,0.
FORCE  62,  2096,  3,  0.61358,0.,0.,1.
FORCE  62,  2097,  3, -0.93170,1.,0.,0.
FORCE  62,  2097,  3,  0.00001,0.,1.,0.
FORCE  62,  2097,  3,  1.04994,0.,0.,1.
FORCE  62,  2099,  3, -0.07452,1.,0.,0.
FORCE  62,  2099,  3,  0.00002,0.,1.,0.
FORCE  62,  2099,  3,  0.91970,0.,0.,1.
FORCE  62,  2100,  3, -0.02486,1.,0.,0.
FORCE  62,  2100,  3, -0.00004,0.,1.,0.
FORCE  62,  2100,  3,  0.84485,0.,0.,1.
FORCE  62,  2101,  3, -0.00020,1.,0.,0.
FORCE  62,  2101,  3,  0.00002,0.,1.,0.
FORCE  62,  2101,  3,  0.08302,0.,0.,1.
FORCE  62,  2102,  3, 17.18982,1.,0.,0.
FORCE  62,  2102,  3,  0.00001,0.,1.,0.
FORCE  62,  2102,  3,  0.00001,0.,0.,1.
FORCE  62,  2123,  3, -1.49813,1.,0.,0.
FORCE  62,  2123,  3,  0.00000,0.,1.,0.
FORCE  62,  2123,  3, -0.50658,0.,0.,1.
FORCE  62,  2124,  3, -1.49811,1.,0.,0.
FORCE  62,  2124,  3, -0.00002,0.,1.,0.
FORCE  62,  2124,  3, -0.50664,0.,0.,1.
FORCE  62,  2125,  3, -1.49814,1.,0.,0.
FORCE  62,  2125,  3,  0.00009,0.,1.,0.
FORCE  62,  2125,  3, -0.50655,0.,0.,1.
FORCE  62,  2126,  3, -1.49809,1.,0.,0.
FORCE  62,  2126,  3, -0.00003,0.,1.,0.
FORCE  62,  2126,  3, -0.50670,0.,0.,1.
FORCE  62,  2127,  3, -1.49809,1.,0.,0.
FORCE  62,  2127,  3,  0.00003,0.,1.,0.
FORCE  62,  2127,  3, -0.50670,0.,0.,1.
FORCE  62,  2128,  3, -1.49814,1.,0.,0.
FORCE  62,  2128,  3, -0.00009,0.,1.,0.
FORCE  62,  2128,  3, -0.50655,0.,0.,1.
FORCE  62,  2129,  3, -1.49811,1.,0.,0.
FORCE  62,  2129,  3,  0.00001,0.,1.,0.
FORCE  62,  2129,  3, -0.50665,0.,0.,1.
FORCE  62,  2130,  3, -1.49813,1.,0.,0.
FORCE  62,  2130,  3,  0.00000,0.,1.,0.
FORCE  62,  2130,  3, -0.50658,0.,0.,1.
FORCE  62,  2201,  3, -0.03391,1.,0.,0.
FORCE  62,  2201,  3,  0.00007,0.,1.,0.
FORCE  62,  2201,  3,  0.07853,0.,0.,1.
FORCE  62,  2206,  3, -0.00016,1.,0.,0.
FORCE  62,  2206,  3,  0.00000,0.,1.,0.
FORCE  62,  2206,  3,  0.00089,0.,0.,1.
FORCE  62,  2301,  3, -0.03388,1.,0.,0.
FORCE  62,  2301,  3,  0.00002,0.,1.,0.
FORCE  62,  2301,  3,  0.07846,0.,0.,1.
FORCE  62,  2306,  3, -0.00014,1.,0.,0.
FORCE  62,  2306,  3, -0.00017,0.,1.,0.
FORCE  62,  2306,  3,  0.00076,0.,0.,1.
FORCE  62,  2401,  3, -0.03390,1.,0.,0.
FORCE  62,  2401,  3,  0.00021,0.,1.,0.
FORCE  62,  2401,  3,  0.07852,0.,0.,1.
FORCE  62,  2406,  3, -0.00018,1.,0.,0.
FORCE  62,  2406,  3,  0.00008,0.,1.,0.
FORCE  62,  2406,  3,  0.00098,0.,0.,1.
FORCE  62,  2501,  3, -0.03386,1.,0.,0.
FORCE  62,  2501,  3, -0.00004,0.,1.,0.
FORCE  62,  2501,  3,  0.07842,0.,0.,1.
FORCE  62,  2506,  3, -0.00016,1.,0.,0.
FORCE  62,  2506,  3, -0.00003,0.,1.,0.
FORCE  62,  2506,  3,  0.00087,0.,0.,1.
FORCE  62,  2601,  3, -0.03386,1.,0.,0.
FORCE  62,  2601,  3,  0.00004,0.,1.,0.
FORCE  62,  2601,  3,  0.07842,0.,0.,1.
FORCE  62,  2606,  3, -0.00016,1.,0.,0.
FORCE  62,  2606,  3,  0.00003,0.,1.,0.
FORCE  62,  2606,  3,  0.00087,0.,0.,1.
FORCE  62,  2701,  3, -0.03385,1.,0.,0.
FORCE  62,  2701,  3,  0.00006,0.,1.,0.
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FORCE  62,  2701,  3,  0.07839,0.,0.,1.
FORCE  62,  2706,  3, -0.00018,1.,0.,0.
FORCE  62,  2706,  3, -0.00008,0.,1.,0.
FORCE  62,  2706,  3,  0.00098,0.,0.,1.
FORCE  62,  2801,  3, -0.03379,1.,0.,0.
FORCE  62,  2801,  3,  0.00018,0.,1.,0.
FORCE  62,  2801,  3,  0.07825,0.,0.,1.
FORCE  62,  2806,  3, -0.00018,1.,0.,0.
FORCE  62,  2806,  3, -0.00008,0.,1.,0.
FORCE  62,  2806,  3,  0.00099,0.,0.,1.
FORCE  62,  2901,  3, -0.03392,1.,0.,0.
FORCE  62,  2901,  3, -0.00004,0.,1.,0.
FORCE  62,  2901,  3,  0.07855,0.,0.,1.
FORCE  62,  2906,  3, -0.00016,1.,0.,0.
FORCE  62,  2906,  3,  0.00000,0.,1.,0.
FORCE  62,  2906,  3,  0.00090,0.,0.,1.
$ REFLECTOR SUPPORT STRUCTURE
GRID, 261, 0,610.0000,  5.0000, 35.0000
GRID, 262, 0,610.0000, -5.0000, 35.0000
GRID, 263, 0,620.0000, -5.0000, 35.0000
GRID, 264, 0,620.0000,  5.0000, 35.0000
GRID, 265, 0,610.0000,  5.0000, 45.0000
GRID, 266, 0,610.0000, -5.0000, 45.0000
GRID, 267, 0,620.0000, -5.0000, 45.0000
GRID, 268, 0,620.0000,  5.0000, 45.0000
GRID, 485, 0,610.0000,  5.0000, 52.0600
GRID, 486, 0,610.0000, -5.0000, 52.0600
GRID, 487, 0,620.0000, -5.0000, 60.1600
GRID, 488, 0,620.0000,  5.0000, 60.1600
$ RIBS
GRID,2001, 3, 92.6563, 22.5000, 19.7947,3
GRID,2002, 3, 79.8800, 22.5000, 14.3245,3
GRID,2003, 3, 70.2500, 22.5000, 10.6072,3
GRID,2004, 3, 58.7500, 22.5000,  6.7322,3
GRID,2005, 3, 47.2500, 22.5000,  3.9197,3
GRID,2006, 3, 35.7500, 22.5000,  1.8572,3
GRID,2007, 3, 35.3500, 22.5000,  2.4375,3
GRID,2008, 3, 26.5000, 22.5000,  0.8572,3
GRID,2009, 3, 17.2500, 22.5000,  0.3572,3
GRID,2010, 3,  8.0000, 22.5000,  0.3125,3
GRID,2011, 3,  4.6000, 22.5000,  0.3125,3
GRID,2012, 3,  8.0000, 22.5000,  0.0000,3
GRID,2013, 3,  4.6000, 22.5000,  0.0000,3
GRID,2014, 3, 92.6563, 67.5000, 19.7947,3
GRID,2015, 3, 79.8800, 67.5000, 14.3245,3
GRID,2016, 3, 70.2500, 67.5000, 10.6072,3
GRID,2017, 3, 58.7500, 67.5000,  6.7322,3
GRID,2018, 3, 47.2500, 67.5000,  3.9197,3
GRID,2019, 3, 35.7500, 67.5000,  1.8572,3
GRID,2020, 3, 35.3500, 67.5000,  2.4375,3
GRID,2021, 3, 26.5000, 67.5000,  0.8572,3
GRID,2022, 3, 17.2500, 67.5000,  0.3572,3
GRID,2023, 3,  8.0000, 67.5000,  0.3125,3
GRID,2024, 3,  4.6000, 67.5000,  0.3125,3
GRID,2025, 3,  8.0000, 67.5000,  0.0000,3
GRID,2026, 3,  4.6000, 67.5000,  0.0000,3
GRID,2027, 3, 92.6563,112.5000, 19.7947,3
GRID,2028, 3, 79.8800,112.5000, 14.3245,3
GRID,2029, 3, 70.2500,112.5000, 10.6072,3
GRID,2030, 3, 58.7500,112.5000,  6.7322,3
GRID,2031, 3, 47.2500,112.5000,  3.9197,3
GRID,2032, 3, 35.7500,112.5000,  1.8572,3
GRID,2033, 3, 35.3500,112.5000,  2.4375,3
GRID,2034, 3, 26.5000,112.5000,  0.8572,3
GRID,2035, 3, 17.2500,112.5000,  0.3572,3
GRID,2036, 3,  8.0000,112.5000,  0.3125,3
GRID,2037, 3,  4.6000,112.5000,  0.3125,3
GRID,2038, 3,  8.0000,112.5000,  0.0000,3
GRID,2039, 3,  4.6000,112.5000,  0.0000,3
GRID,2040, 3, 92.6563,157.5000, 19.7947,3
GRID,2041, 3, 79.8800,157.5000, 14.3245,3
GRID,2042, 3, 70.2501,157.5000, 10.6072,3
GRID,2043, 3, 58.7500,157.5000,  6.7322,3
GRID,2044, 3, 47.2500,157.5000,  3.9197,3
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GRID,2045, 3, 35.7500,157.5000,  1.8572,3
GRID,2046, 3, 35.3500,157.5000,  2.4375,3
GRID,2047, 3, 26.5000,157.5000,  0.8572,3
GRID,2048, 3, 17.2500,157.5000,  0.3572,3
GRID,2049, 3,  8.0000,157.5000,  0.3125,3
GRID,2050, 3,  4.6000,157.5000,  0.3125,3
GRID,2051, 3,  8.0000,157.5000,  0.0000,3
GRID,2052, 3,  4.6000,157.5000,  0.0000,3
GRID,2053, 3, 92.6563,202.5000, 19.7947,3
GRID,2054, 3, 79.8800,202.5000, 14.3245,3
GRID,2055, 3, 70.2501,202.5000, 10.6072,3
GRID,2056, 3, 58.7500,202.5000,  6.7322,3
GRID,2057, 3, 47.2500,202.5000,  3.9197,3
GRID,2058, 3, 35.7500,202.5000,  1.8572,3
GRID,2059, 3, 35.3500,202.5000,  2.4375,3
GRID,2060, 3, 26.5000,202.5000,  0.8572,3
GRID,2061, 3, 17.2500,202.5000,  0.3572,3
GRID,2062, 3,  8.0000,202.5000,  0.3125,3
GRID,2063, 3,  4.6000,202.5000,  0.3125,3
GRID,2064, 3,  8.0000,202.5000,  0.0000,3
GRID,2065, 3,  4.6000,202.5000,  0.0000,3
GRID,2066, 3, 92.6563,247.5000, 19.7947,3
GRID,2067, 3, 79.8800,247.5000, 14.3245,3
GRID,2068, 3, 70.2500,247.5000, 10.6072,3
GRID,2069, 3, 58.7500,247.5000,  6.7322,3
GRID,2070, 3, 47.2500,247.5000,  3.9197,3
GRID,2071, 3, 35.7500,247.5000,  1.8572,3
GRID,2072, 3, 35.3500,247.5000,  2.4375,3
GRID,2073, 3, 26.5000,247.5000,  0.8572,3
GRID,2074, 3, 17.2500,247.5000,  0.3572,3
GRID,2075, 3,  8.0000,247.5000,  0.3125,3
GRID,2076, 3,  4.6000,247.5000,  0.3125,3
GRID,2077, 3,  8.0000,247.5000,  0.0000,3
GRID,2078, 3,  4.6000,247.5000,  0.0000,3
GRID,2079, 3, 92.6563,292.5000, 19.7947,3
GRID,2080, 3, 79.8800,292.5000, 14.3245,3
GRID,2081, 3, 70.2500,292.5000, 10.6072,3
GRID,2082, 3, 58.7500,292.5000,  6.7322,3
GRID,2083, 3, 47.2500,292.5000,  3.9197,3
GRID,2084, 3, 35.7500,292.5000,  1.8572,3
GRID,2085, 3, 35.3500,292.5000,  2.4375,3
GRID,2086, 3, 26.5000,292.5000,  0.8572,3
GRID,2087, 3, 17.2500,292.5000,  0.3572,3
GRID,2088, 3,  8.0000,292.5000,  0.3125,3
GRID,2089, 3,  4.6000,292.5000,  0.3125,3
GRID,2090, 3,  8.0000,292.5000,  0.0000,3
GRID,2091, 3,  4.6000,292.5000,  0.0000,3
GRID,2092, 3, 92.6563,337.5000, 19.7947,3
GRID,2093, 3, 79.8800,337.5000, 14.3245,3
GRID,2094, 3, 70.2500,337.5000, 10.6072,3
GRID,2095, 3, 58.7500,337.5000,  6.7322,3
GRID,2096, 3, 47.2500,337.5000,  3.9197,3
GRID,2097, 3, 35.7500,337.5000,  1.8572,3
GRID,2098, 3, 35.3500,337.5000,  2.4375,3
GRID,2099, 3, 26.5000,337.5000,  0.8572,3
GRID,2100, 3, 17.2500,337.5000,  0.3572,3
GRID,2101, 3,  8.0000,337.5000,  0.3125,3
GRID,2102, 3,  4.6000,337.5000,  0.3125,3
GRID,2103, 3,  8.0000,337.5000,  0.0000,3
GRID,2104, 3,  4.6000,337.5000,  0.0000,3
GRID,2106, 3,  0.0000,  0.0000,  2.4375,3
GRID,2107, 3,  7.3910,  0.0000,  0.0000,3
GRID,2108, 3,  8.1500, 37.8500,  0.0000,3
GRID,2109, 3,  7.3910, 90.0000,  0.0000,3
GRID,2110, 3,  8.1500,142.1500,  0.0000,3
GRID,2111, 3,  7.3910,180.0000,  0.0000,3
GRID,2112, 3,  8.1500,217.8500,  0.0000,3
GRID,2113, 3,  7.3910,270.0000,  0.0000,3
GRID,2114, 3,  8.1500,322.1500,  0.0000,3
GRID,2115, 3,  7.3910,  0.0000,  2.4375,3
GRID,2116, 3,  8.1500, 37.8500,  2.4375,3
GRID,2117, 3,  7.3910, 90.0000,  2.4375,3
GRID,2118, 3,  8.1500,142.1500,  2.4375,3
GRID,2119, 3,  7.3910,180.0000,  2.4375,3
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GRID,2120, 3,  8.1500,217.8500,  2.4375,3
GRID,2121, 3,  7.3910,270.0000,  2.4375,3
GRID,2122, 3,  8.1500,322.1500,  2.4375,3
GRID,2123, 3, 64.2000, 22.5000,  8.5690,3
GRID,2124, 3, 64.2000, 67.5000,  8.5690,3
GRID,2125, 3, 64.2000,112.5000,  8.5690,3
GRID,2126, 3, 64.2000,157.5000,  8.5690,3
GRID,2127, 3, 64.2000,202.5000,  8.5690,3
GRID,2128, 3, 64.2000,247.5000,  8.5690,3
GRID,2129, 3, 64.2000,292.5000,  8.5690,3
GRID,2130, 3, 64.2000,337.5000,  8.5690,3
$ GRIDS FOR TARGET LOCATION
GRID,2201,3,90.82,22.5,18.9925,3
GRID,2206,3,41.78,22.5,2.9385,3
GRID,2301,3,90.82,67.5,18.9925,3
GRID,2306,3,41.78,67.5,2.9385,3
GRID,2401,3,90.82,112.5,18.9925,3
GRID,2406,3,41.78,112.5,2.9385,3
GRID,2501,3,90.82,157.5,18.9925,3
GRID,2506,3,41.78,157.5,2.9385,3
GRID,2601,3,90.82,202.5,18.9925,3
GRID,2606,3,41.78,202.5,2.9385,3
GRID,2701,3,90.82,247.5,18.9925,3
GRID,2706,3,41.78,247.5,2.9385,3
GRID,2801,3,90.82,292.5,18.9925,3
GRID,2806,3,41.78,292.5,2.9385,3
GRID,2901,3,90.82,337.5,18.9925,3
GRID,2906,3,41.78,337.5,2.9385,3
$ SUPPORT STRUCTURE
CBAR,  967,12, 261, 265,1.,1.,0.
CBAR,  968,12, 262, 266,1.,1.,0.
CBAR,  969,12, 263, 267,1.,1.,0.
CBAR,  970,12, 264, 268,1.,1.,0.
$ RFL TRUSS BATTENS
CBAR,  979, 2, 261, 262,1.,0.,1.
CBAR,  980, 2, 262, 263,1.,0.,1.
CBAR,  981, 2, 263, 264,1.,0.,1.
CBAR,  982, 2, 264, 261,1.,0.,1.
CBAR,  983, 2, 265, 266,1.,0.,1.
CBAR,  984, 2, 266, 267,1.,0.,1.
CBAR,  985, 2, 267, 268,1.,0.,1.
CBAR,  986, 2, 268, 265,1.,0.,1.
$ RFL TRUSS BATTEN DIAGONALS
CBAR,  989, 3, 261, 263,1.,0.,1.
CBAR,  990, 3, 266, 268,1.,0.,1.
$ rfl truss diagonals
CBAR,991,3,263,266,0.,1.,1.
CBAR,992,3,261,268,0.,1.,1.
CBAR,993,3,262,265,1.,0.,1.
CBAR,994,3,264,267,1.,0.,1.
$ START REFLECTOR EID'S
CBAR, 2001,16,2001,2201,0.,0.,1.
CBAR, 2002,16,2014,2301,0.,0.,1.
CBAR, 2003,16,2027,2401,0.,0.,1.
CBAR, 2004,16,2040,2501,0.,0.,1.
CBAR, 2005,16,2053,2601,0.,0.,1.
CBAR, 2006,16,2066,2701,0.,0.,1.
CBAR, 2007,16,2079,2801,0.,0.,1.
CBAR, 2008,16,2092,2901,0.,0.,1.
CBAR, 2009,17,2002,2003,0.,0.,1.
CBAR, 2010,17,2015,2016,0.,0.,1.
CBAR, 2011,17,2028,2029,0.,0.,1.
CBAR, 2012,17,2041,2042,0.,0.,1.
CBAR, 2013,17,2054,2055,0.,0.,1.
CBAR, 2014,17,2067,2068,0.,0.,1.
CBAR, 2015,17,2080,2081,0.,0.,1.
CBAR, 2016,17,2093,2094,0.,0.,1.
CBAR, 2017,18,2003,2123,0.,0.,1.
CBAR, 2018,18,2016,2124,0.,0.,1.
CBAR, 2019,18,2029,2125,0.,0.,1.
CBAR, 2020,18,2042,2126,0.,0.,1.
CBAR, 2021,18,2055,2127,0.,0.,1.
CBAR, 2022,18,2068,2128,0.,0.,1.
CBAR, 2023,18,2081,2129,0.,0.,1.
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CBAR, 2024,18,2094,2130,0.,0.,1.
$ RIBS WITH NEW GRID PT.
CBAR, 2025,19,2123,2004,0.,0.,1.
CBAR, 2026,19,2124,2017,0.,0.,1.
CBAR, 2027,19,2125,2030,0.,0.,1.
CBAR, 2028,19,2126,2043,0.,0.,1.
CBAR, 2029,19,2127,2056,0.,0.,1.
CBAR, 2030,19,2128,2069,0.,0.,1.
CBAR, 2031,19,2129,2082,0.,0.,1.
CBAR, 2032,19,2130,2095,0.,0.,1.
CBAR, 2033,20,2005,2206,0.,0.,1.
CBAR, 2034,20,2018,2306,0.,0.,1.
CBAR, 2035,20,2031,2406,0.,0.,1.
CBAR, 2036,20,2044,2506,0.,0.,1.
CBAR, 2037,20,2057,2606,0.,0.,1.
CBAR, 2038,20,2070,2706,0.,0.,1.
CBAR, 2039,20,2083,2806,0.,0.,1.
CBAR, 2040,20,2096,2906,0.,0.,1.
CBAR, 2041,21,2006,2008,0.,0.,1.
CBAR, 2042,21,2019,2021,0.,0.,1.
CBAR, 2043,21,2032,2034,0.,0.,1.
CBAR, 2044,21,2045,2047,0.,0.,1.
CBAR, 2045,21,2058,2060,0.,0.,1.
CBAR, 2046,21,2071,2073,0.,0.,1.
CBAR, 2047,21,2084,2086,0.,0.,1.
CBAR, 2048,21,2097,2099,0.,0.,1.
CBAR, 2049,21,2008,2009,0.,0.,1.
CBAR, 2050,21,2021,2022,0.,0.,1.
CBAR, 2051,21,2034,2035,0.,0.,1.
CBAR, 2052,21,2047,2048,0.,0.,1.
CBAR, 2053,21,2060,2061,0.,0.,1.
CBAR, 2054,21,2073,2074,0.,0.,1.
CBAR, 2055,21,2086,2087,0.,0.,1.
CBAR, 2056,21,2099,2100,0.,0.,1.
CBAR, 2057,21,2009,2010,0.,0.,1.
CBAR, 2058,21,2022,2023,0.,0.,1.
CBAR, 2059,21,2035,2036,0.,0.,1.
CBAR, 2060,21,2048,2049,0.,0.,1.
CBAR, 2061,21,2061,2062,0.,0.,1.
CBAR, 2062,21,2074,2075,0.,0.,1.
CBAR, 2063,21,2087,2088,0.,0.,1.
CBAR, 2064,21,2100,2101,0.,0.,1.
CBAR, 2065,21,2010,2011,0.,0.,1.
CBAR, 2066,21,2023,2024,0.,0.,1.
CBAR, 2067,21,2036,2037,0.,0.,1.
CBAR, 2068,21,2049,2050,0.,0.,1.
CBAR, 2069,21,2062,2063,0.,0.,1.
CBAR, 2070,21,2075,2076,0.,0.,1.
CBAR, 2071,21,2088,2089,0.,0.,1.
CBAR, 2072,21,2101,2102,0.,0.,1.
CBAR, 2169,19,2004,2005,0.,0.,1.
CBAR, 2170,19,2017,2018,0.,0.,1.
CBAR, 2171,19,2030,2031,0.,0.,1.
CBAR, 2172,19,2043,2044,0.,0.,1.
CBAR, 2173,19,2056,2057,0.,0.,1.
CBAR, 2174,19,2069,2070,0.,0.,1.
CBAR, 2175,19,2082,2083,0.,0.,1.
CBAR, 2176,19,2095,2096,0.,0.,1.
CBAR,2177,16,2201,2002,0.,0.,1.
CBAR,2178,16,2301,2015,0.,0.,1.
CBAR,2179,16,2401,2028,0.,0.,1.
CBAR,2180,16,2501,2041,0.,0.,1.
CBAR,2181,16,2601,2054,0.,0.,1.
CBAR,2182,16,2701,2067,0.,0.,1.
CBAR,2183,16,2801,2080,0.,0.,1.
CBAR,2184,16,2901,2093,0.,0.,1.
CBAR,2185,20,2206,2006,0.,0.,1.
CBAR,2186,20,2306,2019,0.,0.,1.
CBAR,2187,20,2406,2032,0.,0.,1.
CBAR,2188,20,2506,2045,0.,0.,1.
CBAR,2189,20,2606,2058,0.,0.,1.
CBAR,2190,20,2706,2071,0.,0.,1.
CBAR,2191,20,2806,2084,0.,0.,1.
CBAR,2192,20,2906,2097,0.,0.,1.
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$ END RIBS
$ CONNECTOR BOLTS-RIBS TO HUB
CBAR, 2073,23,2010,2012,2062
CBAR, 2074,23,2023,2025,2075
CBAR, 2075,23,2036,2038,2088
CBAR, 2076,23,2049,2051,2101
CBAR, 2077,23,2062,2064,2010
CBAR, 2078,23,2075,2077,2023
CBAR, 2079,23,2088,2090,2036
CBAR, 2080,23,2101,2103,2049
CBAR, 2081,23,2011,2013,2063
CBAR, 2082,23,2024,2026,2076
CBAR, 2083,23,2037,2039,2089
CBAR, 2084,23,2050,2052,2102
CBAR, 2085,23,2063,2065,2011
CBAR, 2086,23,2076,2078,2024
CBAR, 2087,23,2089,2091,2037
CBAR, 2088,23,2102,2104,2050
$ START CONNECTORS BETWEEN RIBS AND SENSOR PLATE
CBAR, 2089,24,2006,2007,2005
,,6
CBAR, 2090,24,2019,2020,2018
,,6
CBAR, 2091,24,2032,2033,2031
,,6
CBAR, 2092,24,2045,2046,2044
,,6
CBAR, 2093,24,2058,2059,2057
,,6
CBAR, 2094,24,2071,2072,2070
,,6
CBAR, 2095,24,2084,2085,2083
,,6
CBAR, 2096,24,2097,2098,2096
,,6
$ START COMPRESSION MEMBERS BETWEEN REFLECTOR PLATE AND HUB, D=.375"
CBAR, 2097,30,2107,2115,1.,1.,0.
CBAR, 2098,30,2109,2117,1.,1.,0.
CBAR, 2099,30,2111,2119,1.,1.,0.
CBAR, 2100,30,2113,2121,1.,1.,0.
$ CABLES
CROD, 2101, 22, 2001, 2014
CROD, 2102, 22, 2014, 2027
CROD, 2103, 22, 2027, 2040
CROD, 2104, 22, 2040, 2053
CROD, 2105, 22, 2053, 2066
CROD, 2106, 22, 2066, 2079
CROD, 2107, 22, 2079, 2092
CROD, 2108, 22, 2092, 2001
$ REFLECTOR PLATE AND HUB
CTRIA3      2109      26     2107     2012     2013       0.
CTRIA3      2110      26     2012     2108     2013       0.
CTRIA3      2111      26     2108     2025     2026       0.
CTRIA3      2112      26     2025     2109     2026       0.
CTRIA3      2113      26     2109     2038     2039       0.
CTRIA3      2114      26     2038     2110     2039       0.
CTRIA3      2115      26     2110     2051     2052       0.
CTRIA3      2116      26     2051     2111     2052       0.
CTRIA3      2117      26     2111     2064     2065       0.
CTRIA3      2118      26     2064     2112     2065       0.
CTRIA3      2119      26     2112     2077     2078       0.
CTRIA3      2120      26     2077     2113     2078       0.
CTRIA3      2121      26     2113     2090     2091       0.
CTRIA3      2122      26     2090     2114     2091       0.
CTRIA3      2123      26     2114     2103     2104       0.
CTRIA3      2124      26     2103     2107     2104       0.
CTRIA3      2125      26     2104     2013     2107       0.
CTRIA3      2126      26     2013     2026     2108       0.
CTRIA3      2127      26     2026     2039     2109       0.
CTRIA3      2128      26     2039     2052     2110       0.
CTRIA3      2129      26     2052     2065     2111       0.
CTRIA3      2130      26     2065     2078     2112       0.
CTRIA3      2131      26     2078     2091     2113       0.
CTRIA3      2132      26     2091     2104     2114       0.
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CTRIA3    2133    25   2098   2007   2115    0.
CTRIA3    2134    25   2007   2020   2116    0.
CTRIA3    2135    25   2020   2033   2117    0.
CTRIA3    2136    25   2033   2046   2118    0.
CTRIA3    2137    25   2046   2059   2119    0.
CTRIA3    2138    25   2059   2072   2120    0.
CTRIA3    2139    25   2072   2085   2121    0.
CTRIA3    2140    25   2085   2098   2122    0.
CTRIA3    2141    25   2115   2116   2007    0.
CTRIA3    2142    25   2116   2117   2020    0.
CTRIA3    2143    25   2117   2118   2033    0.
CTRIA3    2144    25   2118   2119   2046    0.
CTRIA3    2145    25   2119   2120   2059    0.
CTRIA3    2146    25   2120   2121   2072    0.
CTRIA3    2147    25   2121   2122   2085    0.
CTRIA3    2148    25   2122   2115   2098    0.
CTRIA3    2149    25   2115   2116   2106    0.
CTRIA3    2150    25   2116   2117   2106    0.
CTRIA3    2151    25   2117   2118   2106    0.
CTRIA3    2152    25   2118   2119   2106    0.
CTRIA3    2153    25   2119   2120   2106    0.
CTRIA3    2154    25   2120   2121   2106    0.
CTRIA3    2155    25   2121   2122   2106    0.
CTRIA3    2156    25   2122   2115   2106    0.
$ START RFL SUPPORT BRACKETS
CBAR, 2157,27, 265, 485,266
CBAR, 2158,27, 266, 486,267
CBAR, 2159,27, 267, 487,268
CBAR, 2160,27, 268, 488,265
CBAR, 2161,28, 267, 488,485
CBAR, 2162,28, 268, 487,486
CBAR, 2163,28, 265, 486,487
CBAR, 2164,28, 266, 485,488
CBAR, 2165,28, 265, 488,487
CBAR, 2166,28, 266, 487,488
CBAR, 2167,29, 485, 488,487
CBAR, 2168,29, 486, 487,488
$ 1/4" DIAM BOLTS WHICH CONNECT RFL; BASE PLATE TO SUPPORT STRUCTURE
CELAS2, 2211, 1.5E+08, 488, 1, 2108, 1
CELAS2, 2212, 1.5E+08, 488, 2, 2108, 2
CELAS2, 2213, 1.5E+08, 488, 3, 2108, 3
CELAS2, 2214, 1.5E+08, 488, 4, 2108, 4
CELAS2, 2215, 1.5E+08, 488, 5, 2108, 5
CELAS2, 2216, 1.5E+08, 488, 6, 2108, 6
CELAS2, 2217, 1.5E+08, 485, 1, 2110, 1
CELAS2, 2218, 1.5E+08, 485, 2, 2110, 2
CELAS2, 2219, 1.5E+08, 485, 3, 2110, 3
CELAS2, 2220, 1.5E+08, 485, 4, 2110, 4
CELAS2, 2221, 1.5E+08, 485, 5, 2110, 5
CELAS2, 2222, 1.5E+08, 485, 6, 2110, 6
CELAS2, 2223, 1.5E+08, 486, 1, 2112, 1
CELAS2, 2224, 1.5E+08, 486, 2, 2112, 2
CELAS2, 2225, 1.5E+08, 486, 3, 2112, 3
CELAS2, 2226, 1.5E+08, 486, 4, 2112, 4
CELAS2, 2227, 1.5E+08, 486, 5, 2112, 5
CELAS2, 2228, 1.5E+08, 486, 6, 2112, 6
CELAS2, 2229, 1.5E+08, 487, 1, 2114, 1
CELAS2, 2230, 1.5E+08, 487, 2, 2114, 2
CELAS2, 2231, 1.5E+08, 487, 3, 2114, 3
CELAS2, 2232, 1.5E+08, 487, 4, 2114, 4
CELAS2, 2233, 1.5E+08, 487, 5, 2114, 5
CELAS2, 2234, 1.5E+08, 487, 6, 2114, 6
$ START JOINT LUMPED MASSES
CONM2      3289     262       0  .00142      0.       0.       0.       +EA 2011
+EA 2011     0.      0.      0.      0.      0.       0.
CONM2      3290     264       0  .00142      0.       0.       0.       +EA 2012
+EA 2012     0.      0.      0.      0.      0.       0.
CONM2      3291     265       0  .00123      0.       0.       0.       +EA 2013
+EA 2013     0.      0.      0.      0.      0.       0.
CONM2      3292     267       0  .00142      0.       0.       0.       +EA 2014
+EA 2014     0.      0.      0.      0.      0.       0.
CONM2      3293     261       0  .00160      0.       0.       0.       +EA 2015
+EA 2015     0.      0.      0.      0.      0.       0.
CONM2      3294     263       0  .00160      0.       0.       0.       +EA 2016
```

```
+EA 2016      0.      0.      0.      0.      0.      0.
CONM2       3295     266       0  .00142      0.      0.      0.        +EA 2017
+EA 2017      0.      0.      0.      0.      0.      0.
CONM2       3296     268       0  .00160      0.      0.      0.        +EA 2018
+EA 2018      0.      0.      0.      0.      0.      0.
$ LUMP MASS AT RIB TIP
CONM2, 3501, 2001, 3, 2.59E-04
CONM2, 3502, 2014, 3, 2.59E-04
CONM2, 3503, 2027, 3, 2.59E-04
CONM2, 3504, 2040, 3, 2.59E-04
CONM2, 3505, 2053, 3, 2.59E-04
CONM2, 3506, 2066, 3, 2.59E-04
CONM2, 3507, 2079, 3, 2.59E-04
CONM2, 3508, 2092, 3, 2.59E-04
$ MIRROR LUMP MASS
CONM2, 3510, 2106, 3, .049223, 0., 0., 0.
, 6.795, , 6.795, ,  , 13.591
$ TRUSS MAT1 CARDS
MAT1, 1, 1.E+07, ,.333, 2.19E-04, 0.
MAT1, 2, 1.E+07, ,.333, 2.23E-04, 0.
MAT1, 4, 1.E+07, ,.333, 0.
$
$ REFLECTOR MAT1 CARDS
MAT1,11, 1.0E+07,.375E+07, ,.0002539,0.0
MAT1,12, 3.0E+07,.11538+8, ,.0004585,-2.535-6
MAT1,13, .30E+08,.11538+8, ,.0007332
MAT1,14, .65E+07,.25000+7, ,.0000512
MAT1,15, .10E+08,.37509+7, ,.0003375
MAT1,16, .10E+08,.37509+7, ,.0002539
$
$ TRUSS PID CARDS
PBAR, 1, 1, .12316, 4.20E-03, 4.20E-03, 8.40E-03, 0.
PBAR, 2, 1, .12316, 4.20E-03, 4.20E-03, 8.40E-03, 0.
PBAR, 3, 2, .11660, 4.20E-03, 4.20E-03, 8.40E-03, 0.
$
PBAR,12, 1, .12316, 4.20E-03, 4.20E-03, 8.40E-03, 0.
PBAR,13, 2, .11660, 4.20E-03, 4.20E-03, 8.40E-03, 0.
$
$ REFLECTOR PID CARDS
PBAR,16,11, .2900000, .0015104, .0325188, .0052215, 0.0
PBAR,17,11, .3375000, .0017578, .0512578, .0062110, 0.0
PBAR,18,11, .3840000, .0020000, .0754975, .0071797, 0.0
PBAR,19,11, .4300000, .0022396, .1060093, .0081380, 0.0
PBAR,20,11, .4775000, .0024870, .1451640, .0091276, 0.0
PBAR,21,11, .5000000, .0026042, .1666667, .0095964, 0.0
PBAR,23,13, .0490873, .0001918, .0001918, .0003835, 0.0
PBAR,24,13, .0283529, .0000640, .0000640, .0001280, 0.0
PROD,22,12, .0007670, .0000000, .0000000
$
$ SENSOR PLATE
PSHELL,25,14, .40807,14
$
$ HUB
PSHELL,26,15, .37500,15
$
$ VERTICAL MEMBER OF SUPPORT STRUCTURE
PBAR,27,16, .4418  ,1.55E-02  ,1.55E-02 , 3.1E-02 , 0.
$
$ 1X1X5/16" AL ANGLE CROSS MEMBERS
PBAR,28,16, 0.339, 3.E-02  ,3.E-02   , .00439, 0.
$
$ 1X11/4X1/4" AL ANGLE THAT SUPPORTS BASE PLATE
PBAR,29,16,  .5    ,3.97E-02  ,7.10E-02 , .1107   , 0.
$
$ COMPRESSION MEMBERS BETWEEN HUB AND SENSOR PLATE
PBAR,30,13, .110447, .000971, .000971, .001942, 0.0
$
ENDDATA
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References

1. Sparks, Dean W., Jr.; Horner, Garnett C.; Juang, Jer-Nan; and Klose, Gerhard: A Survey of Experiments and Experimental Facilities for Active Control of Flexible Structures. *NASA/DOD Controls-Structures Interaction Technology 1989,* Jerry R. Newsom, compiler, NASA CP-3041, 1989, pp. 285–315.

2. Belvin, W. Keith; Elliott, Kenny E.; Bruner, Anne; Sulla, Jeff; and Bailey, Jim: the LaRC CSI Phase-O Evolutionary Model Testbed: Design and Experimental Results. *Proceedings of the Fourth NASA/DOD Control/Structures Interaction Technology Conference,* Andrew D. Swanson, compiler, WL-TR-91-3013, U.S. Air Force, Jan. 1991, pp. 594–613.

3. Birchenough, Shawn A.: *Analysis and Test of a 16-Foot Radial Rib Reflector Developmental Model.* NASA TM-101648, 1989.

4. *MSC/NASTRAN User's Manual—MSC/NASTRAN Version 65.* MSR-39, MacNeal-Schwendler Corp., Nov. 1985.

Table 1. Axial-Force Distribution on Rib 7 Under Gravity and Target Weight for Large-Displacements Nonlinear Analysis

Rib beam element	Axial force on rib elements, lb, for CBAR connector	Axial force on rib elements, lb, for CROD connector
1	−11.87	−10.83
9	−12.66	−11.52
17	−13.12	−11.90
25	−13.50	−12.23
33	−13.65	−12.38
41	115.0	−9.77
49	115.0	−9.11

Table 2. Static Test Matrix for Inclined and Horizontal Positions of Reflector

Load cycle	Load location	Load range, lb	Increment, lb
1	All rib tips	0 to 2	0.5
2	Rib tips 5 and 7	0 to 1.5	0.5
3	All plate ends	0 to 24	3.0
4	Plate ends 1 and 3	0 to 24	3.0

Table 3. Test and Analysis Curve-Fitting Errors

Load cycle; measurement location	Small-displacements analysis versus large-displacements analysis, percent error	Test versus small-displacements analysis, percent error	Test versus large-displacements analysis, percent error
Inclined position			
1; Rib 1	8	10	16
1; Rib 3	6	33	25
1; Rib 5	29	11	14
1; Rib 7	2	18	16
2; Rib 1	13	36	17
2; Rib 3	13	22	7
2; Rib 5	5	12	6
2; Rib 7	3	20	16
Horizontal position			
3; Plate ends 1, 3, 5, and 7	2	14	12
4; Plate ends 1 and 3	2	8	9
4; Plate ends 5 and 7	2	19	17

Table 4. Analytical Natural Frequencies for Reflector

Mode	Frequencies, Hz, for small-displacements analysis	Frequencies, Hz, for large-displacements analysis
1	2.524	2.524
2	2.994	3.063
3	2.995	3.064
4	3.172	3.253
5	3.219	3.301
6	3.517	3.563
7	3.529	3.567
8	3.757	3.792
9	5.613	5.447
10	6.583	6.350
11	10.178	9.826
12	10.357	9.995
13	10.895	10.601

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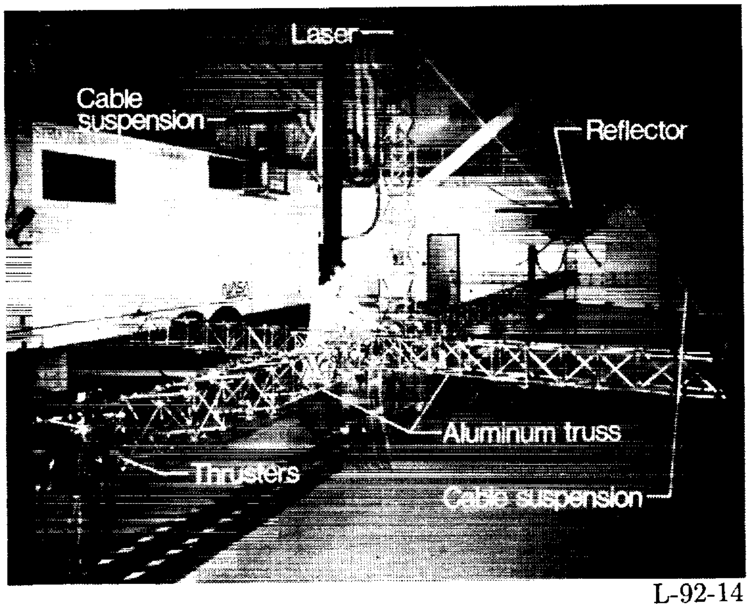

L-92-14

Figure 1. Controls-Structures Interaction Evolutionary Model (CEM).

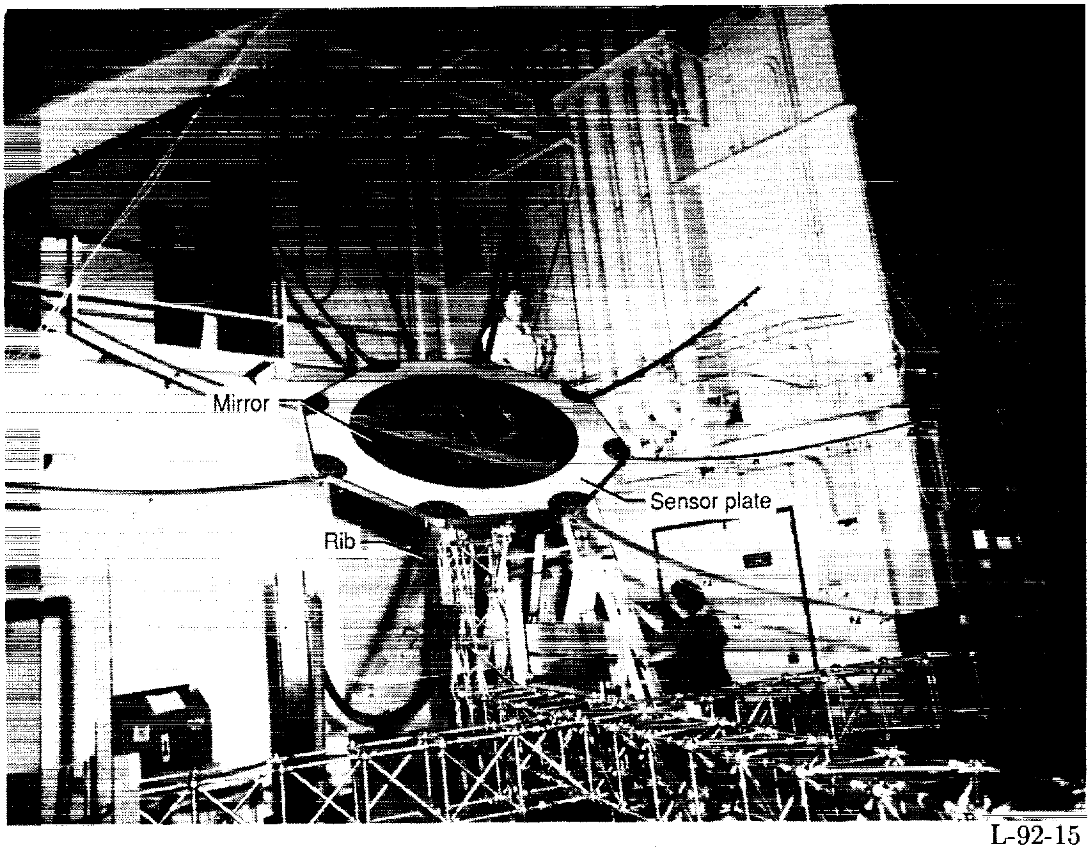

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Figure 2. Controls-Structures Interaction Evolutionary Model reflector.

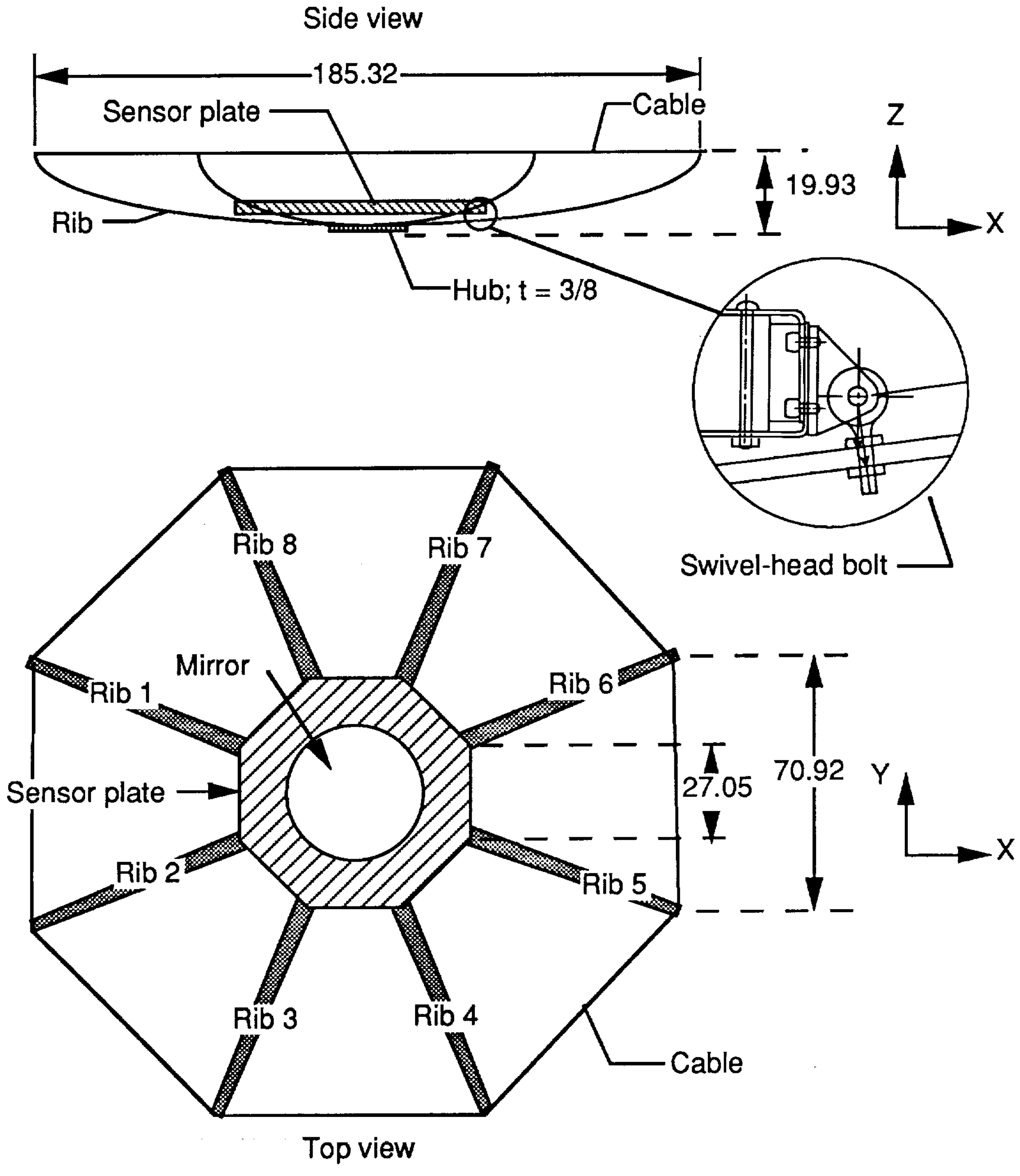

Figure 3. Side and top views of reflector. All linear dimensions are in inches.

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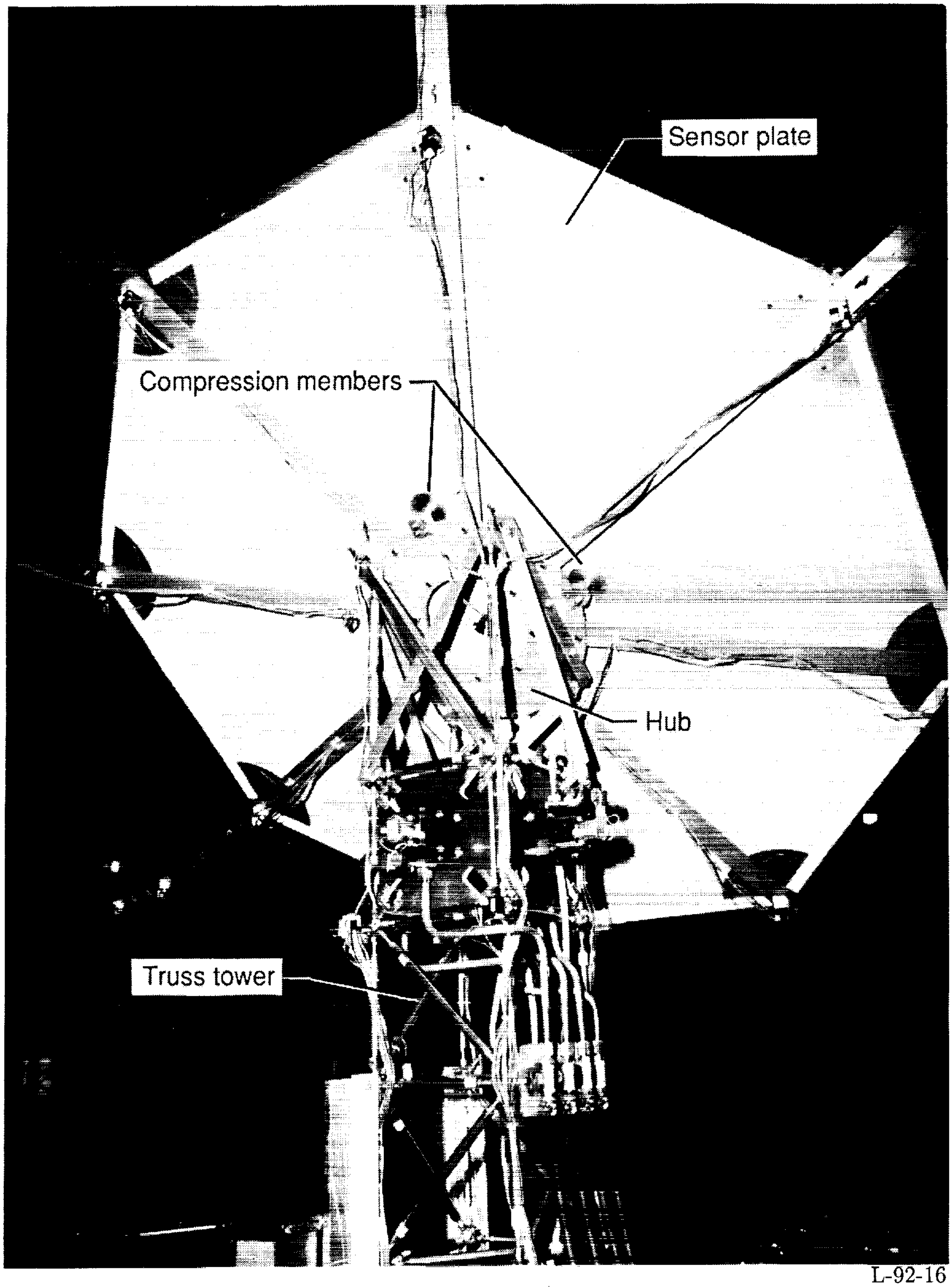


L-92-16

Figure 4. Detailed view of connections.

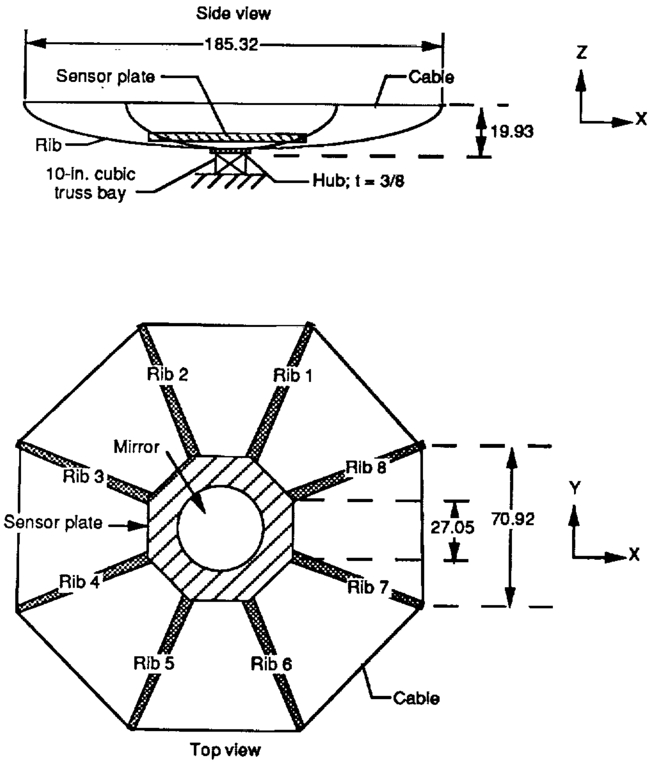


Figure 5. Side and top views of reflector in horizontal position. All linear dimensions are in inches.

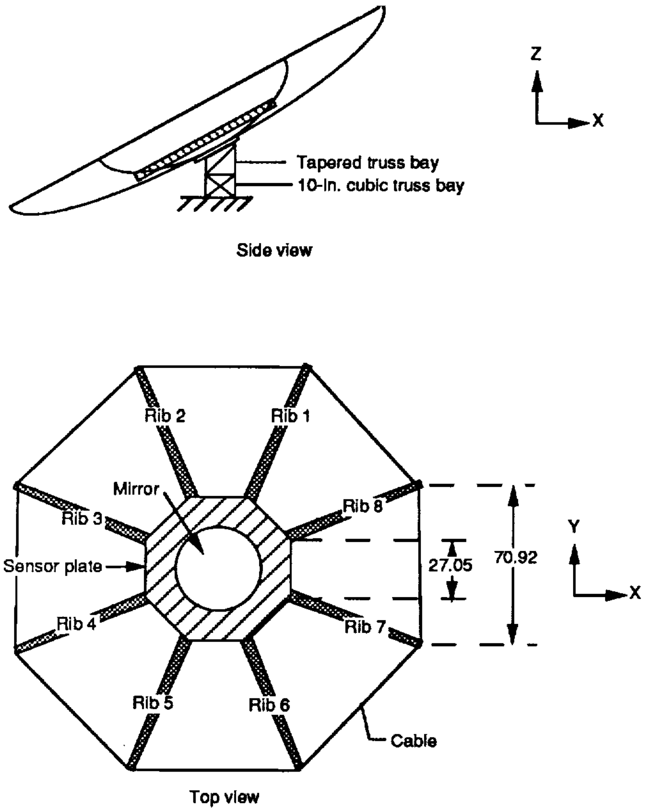


Figure 6. Side and top views of reflector in inclined position. All linear dimensions are in inches.

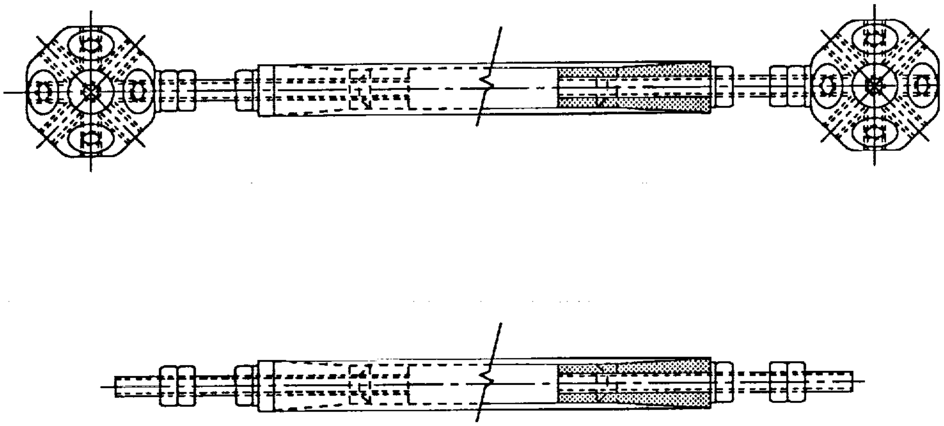


Figure 7. Typical truss strut and node-ball joint.

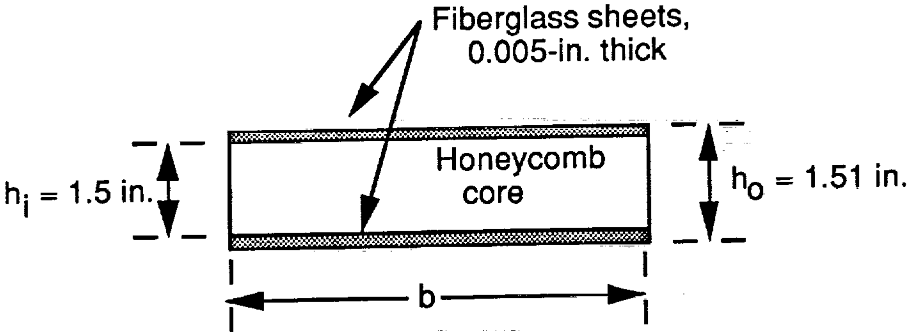


Figure 8. Composite panel cross-sectional element.

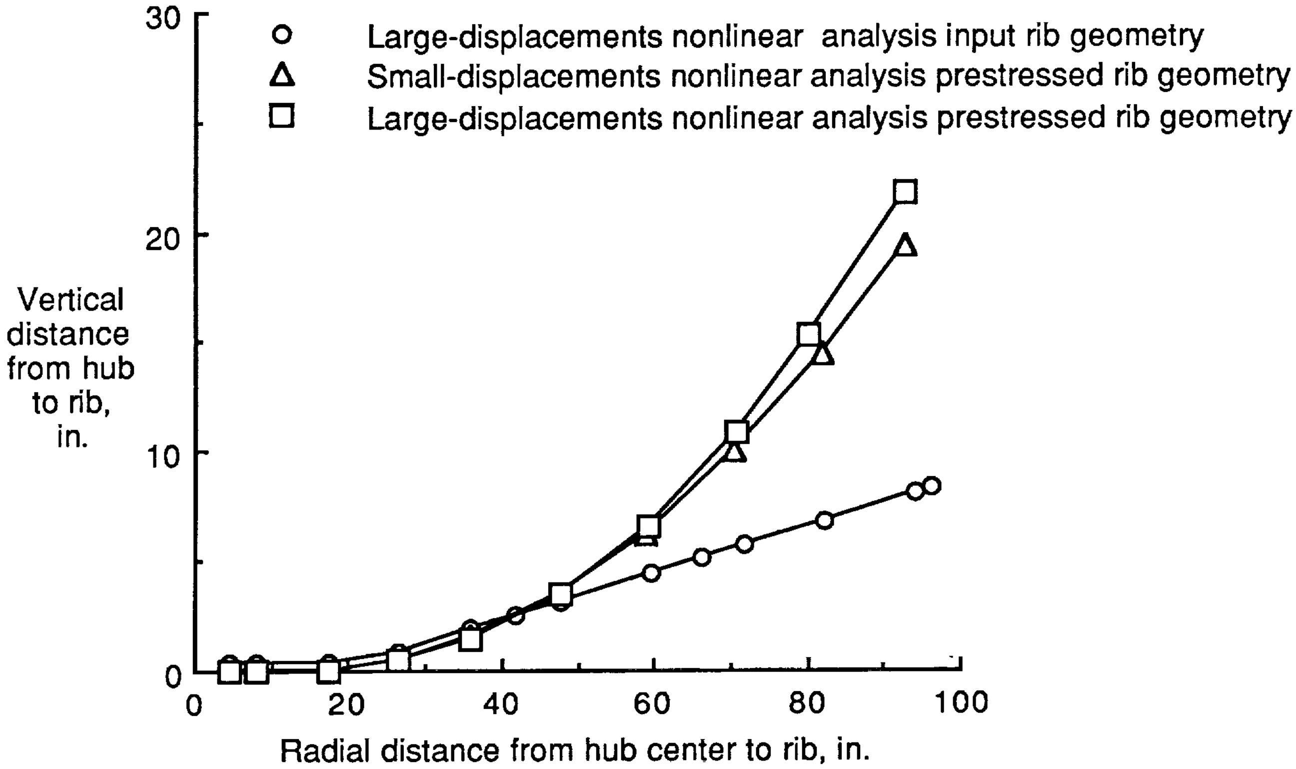


Figure 9. Rib analytical geometry for initial and prestressed states.

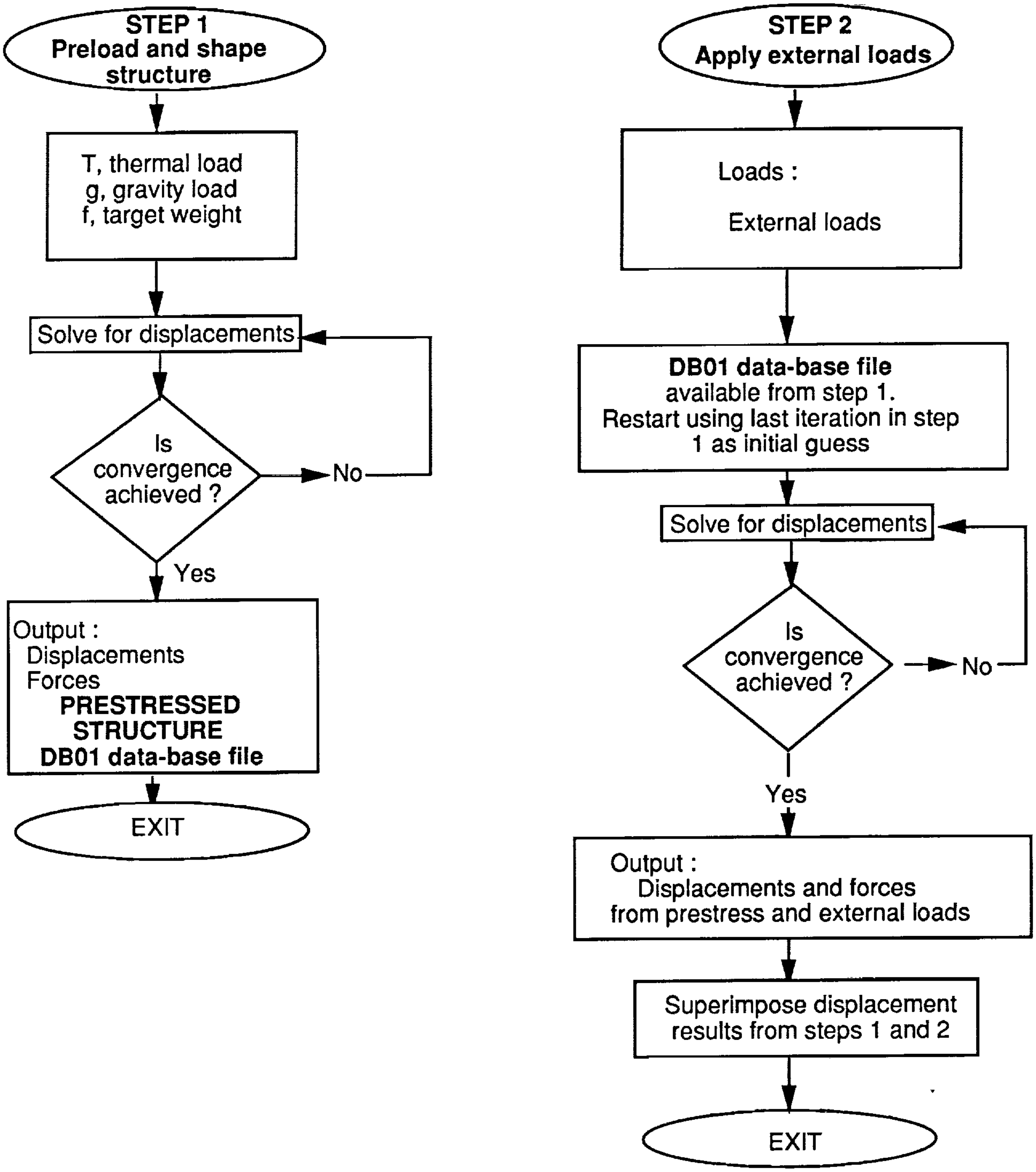


Figure 10. Large-displacements nonlinear analysis data-base dependent steps.

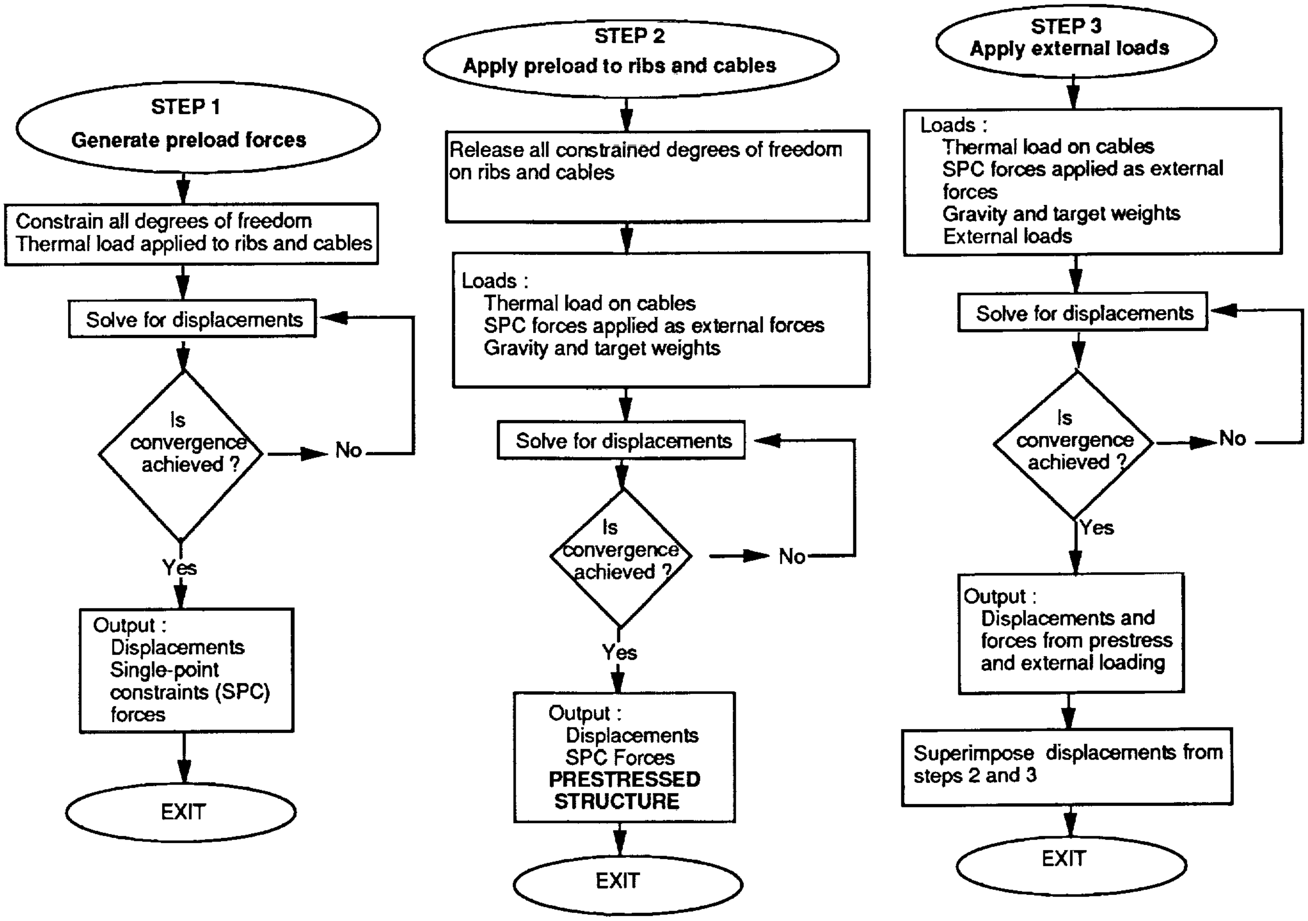


Figure 11. Small-displacements nonlinear analysis data-base independent steps.

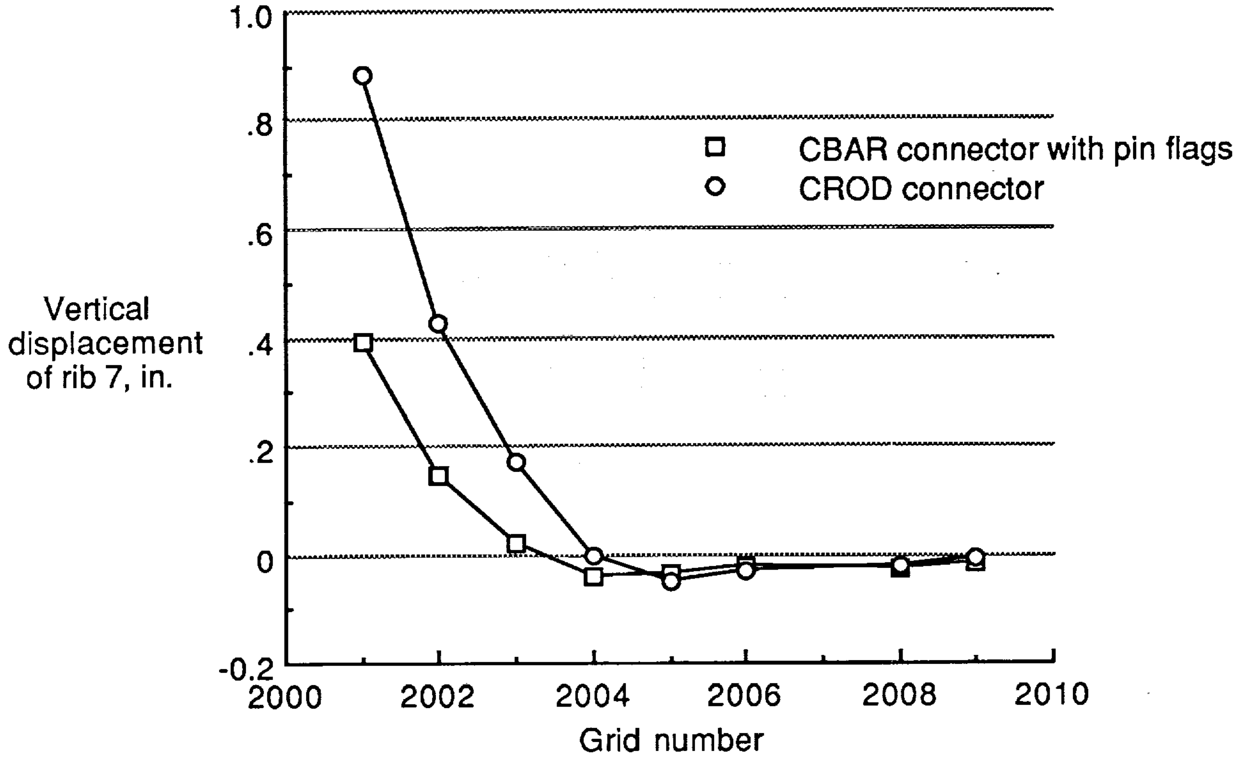


Figure 12. Sensitivity of rib displacement under gravity and target weight loads to changes in swivel-head bolt model.

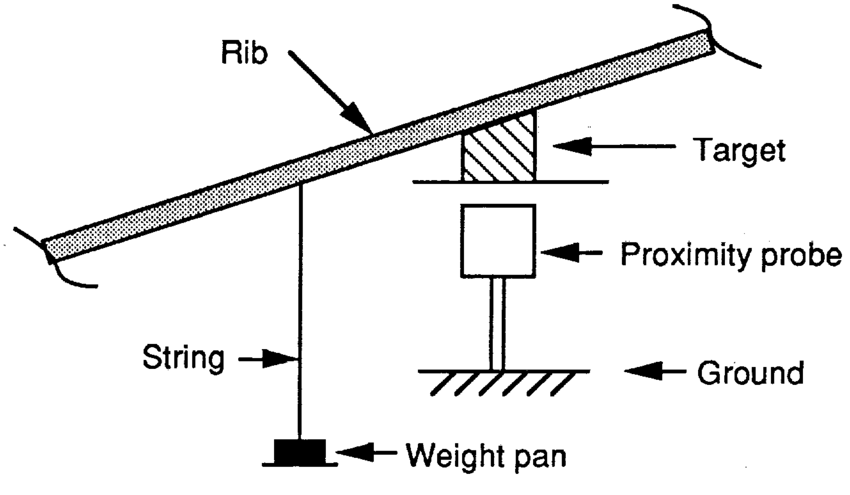
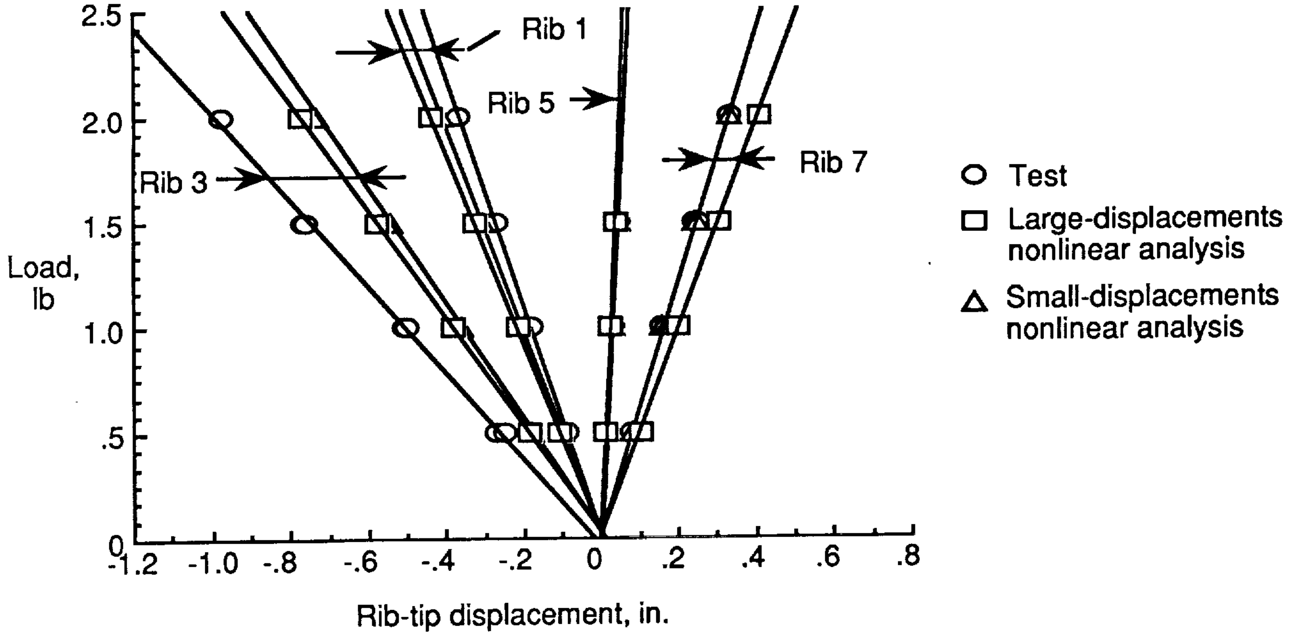
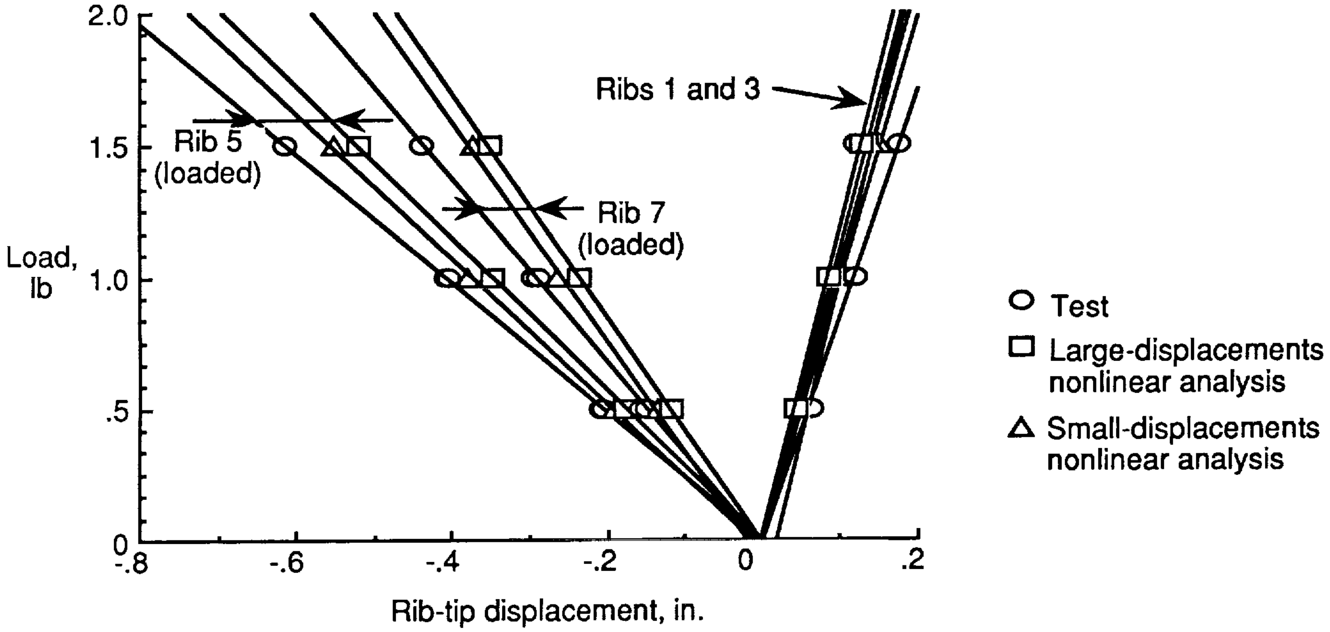


Figure 13. Load application and displacement measurement setup.

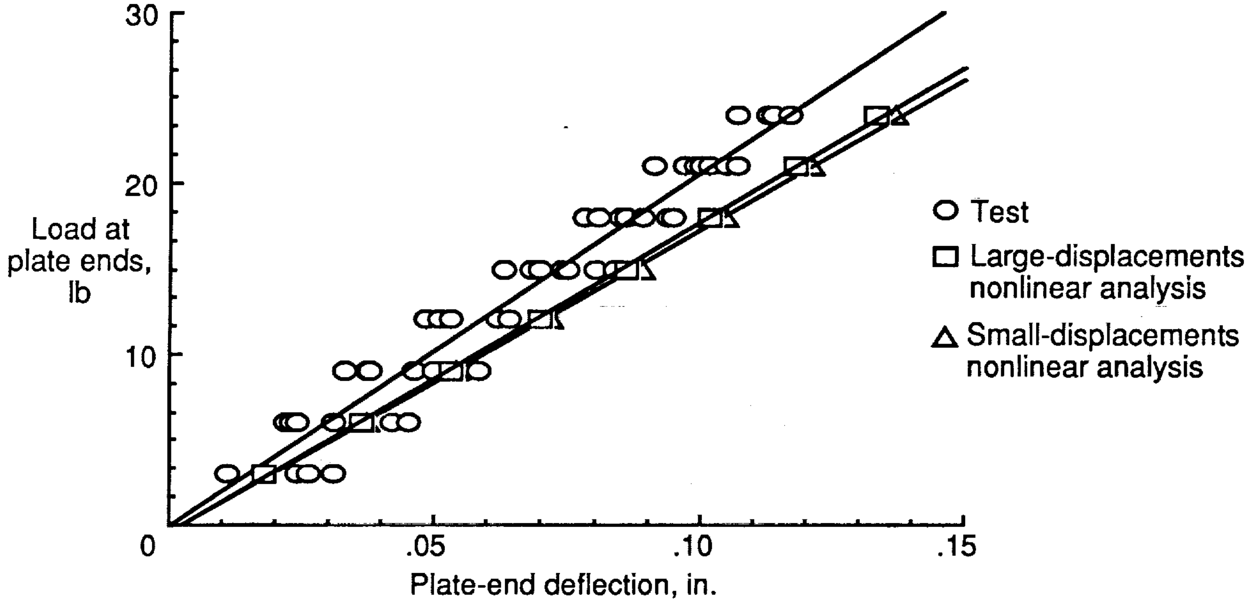


(a) Load cycle 1: symmetric loading of ribs.

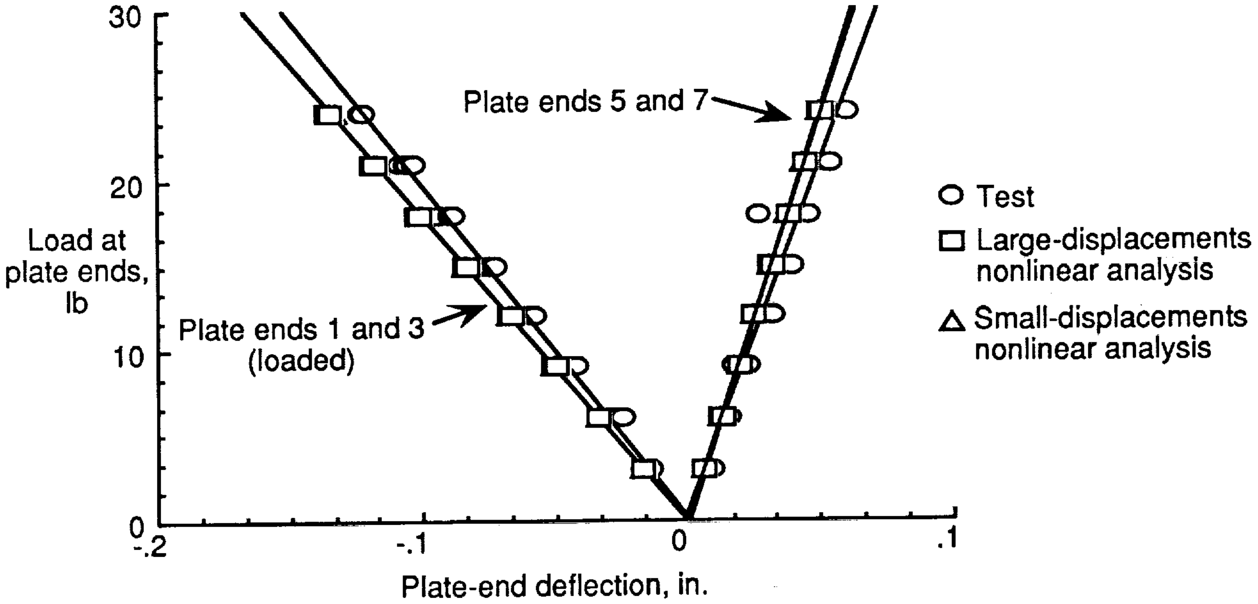


(b) Load cycle 2: asymmetric loading of ribs.

Figure 14. Symmetric and asymmetric load-deflection characteristics of ribs. Inclined position.

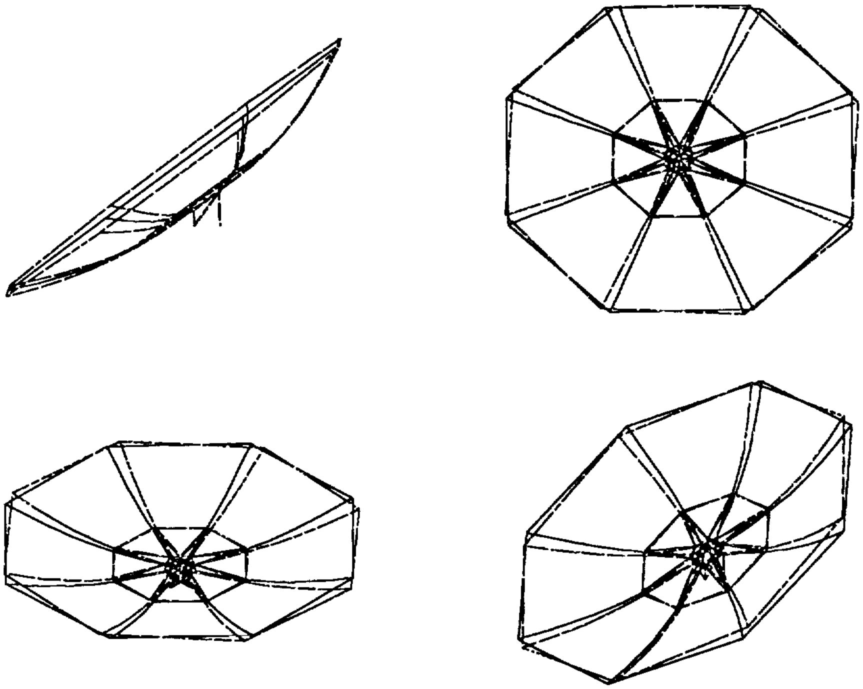


(a) Load cycle 3: symmetric loading of plate ends.

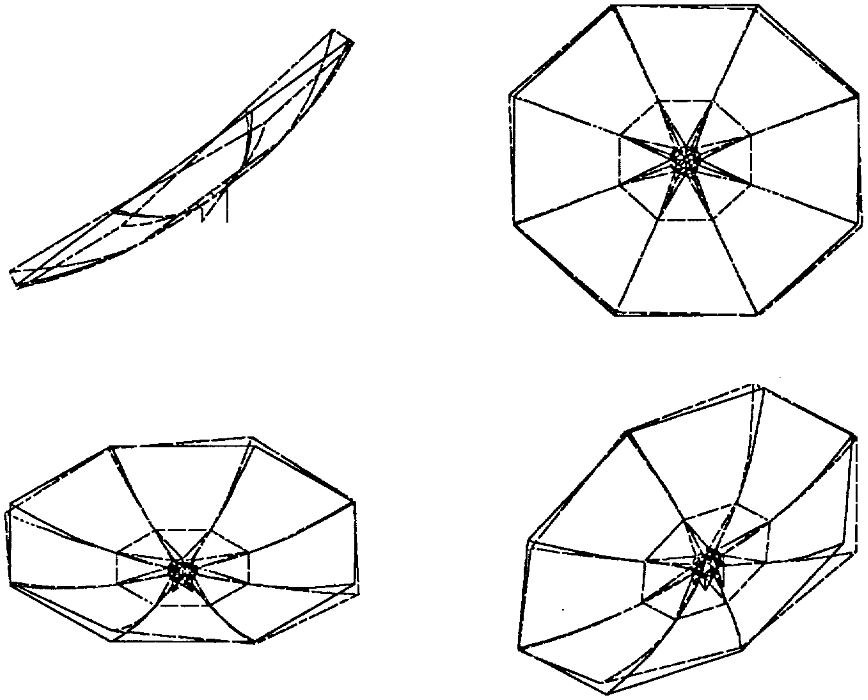


(b) Load cycle 4: asymmetric loading of plate ends.

Figure 15. Symmetric and asymmetric loading of plate ends. Horizontal position.

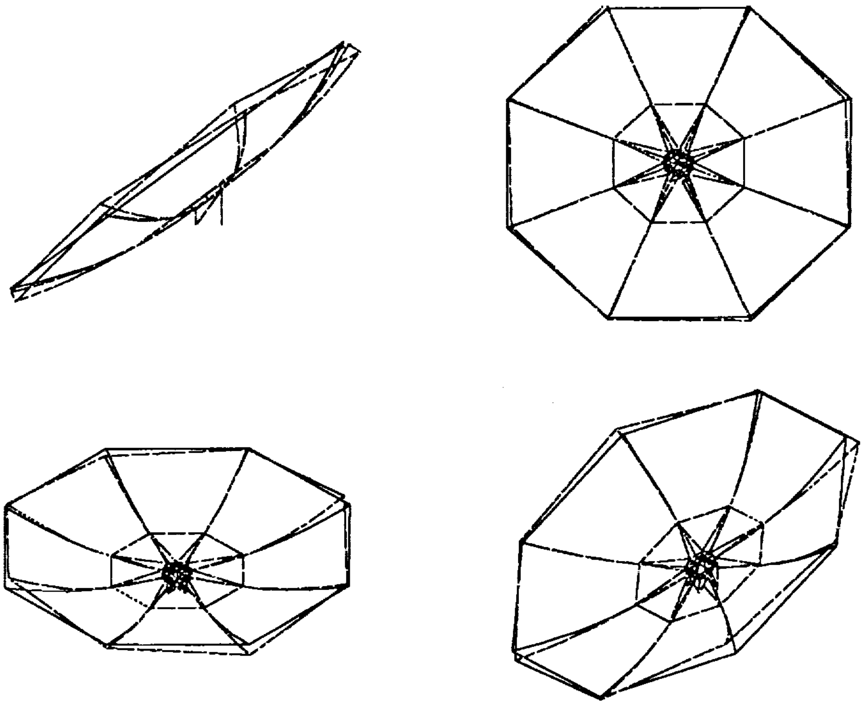


(a) Mode 1; 2.54 Hz.

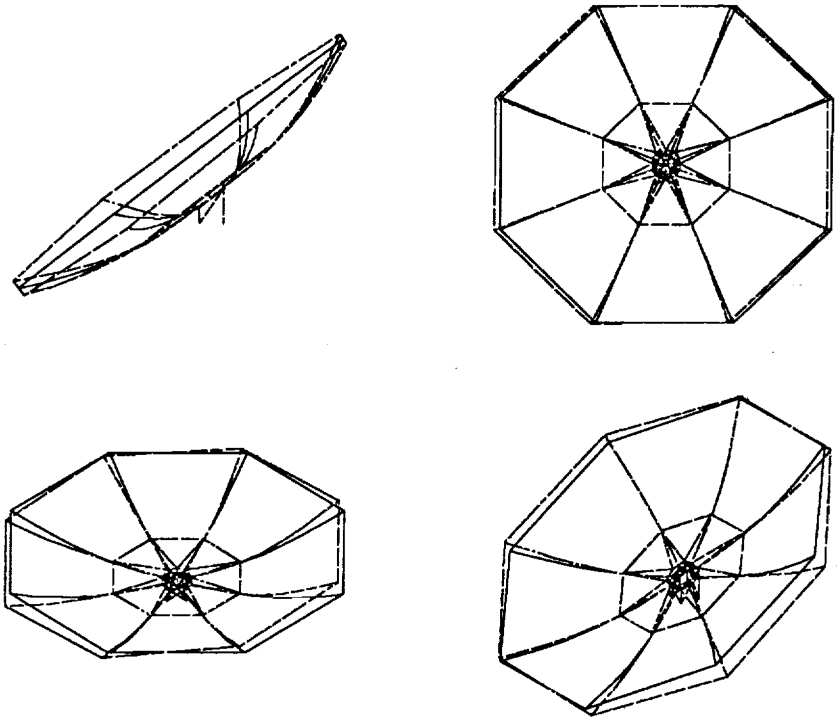


(b) Mode 2; 3.063 Hz.

Figure 16. Large-displacements analysis.

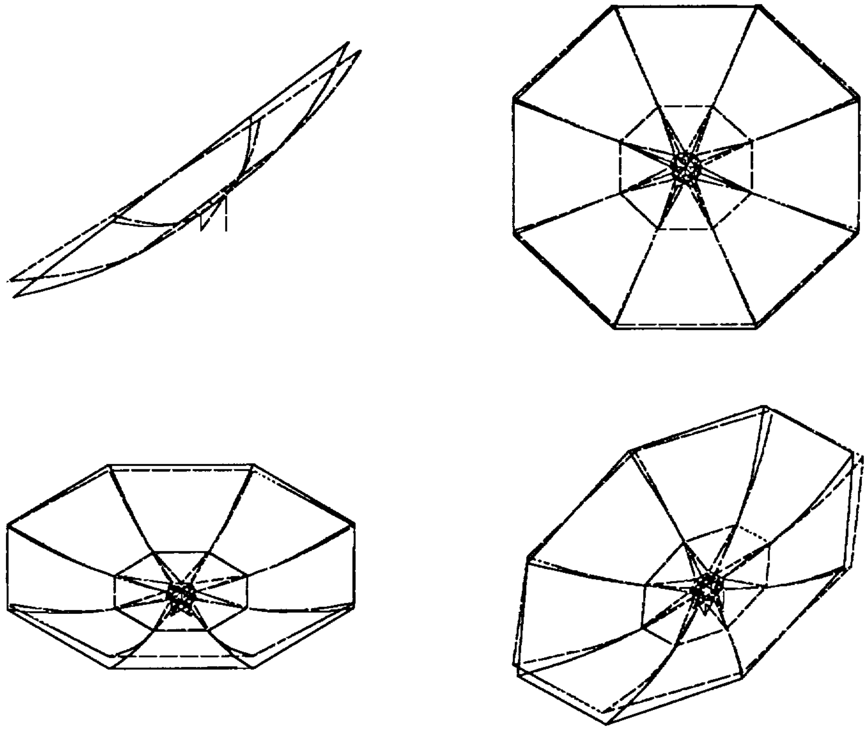


(c) Mode 3; 3.064 Hz.

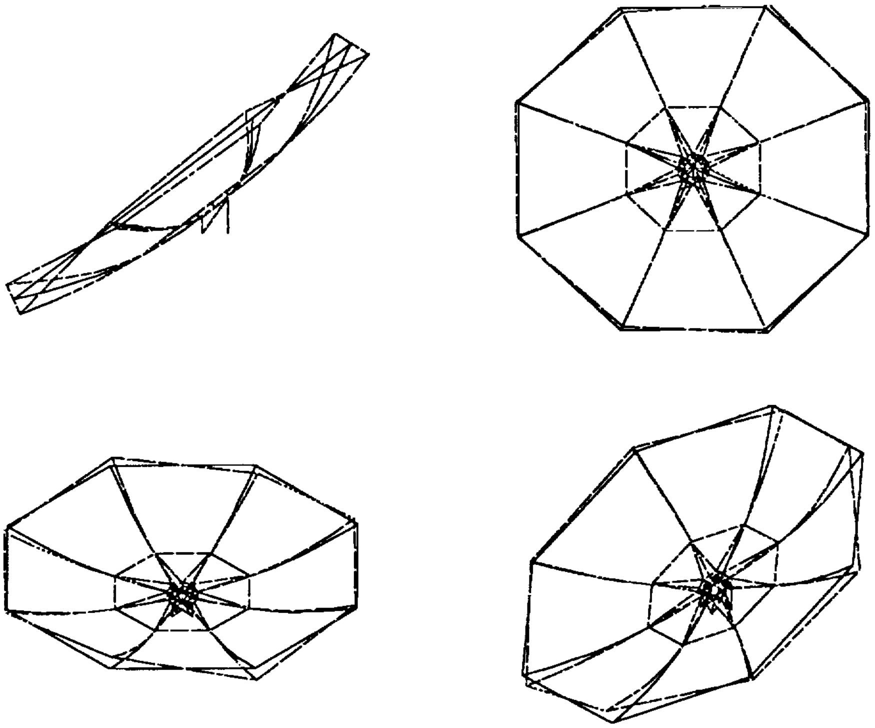


(d) Mode 4; 3.253 Hz.

Figure 16. Continued.

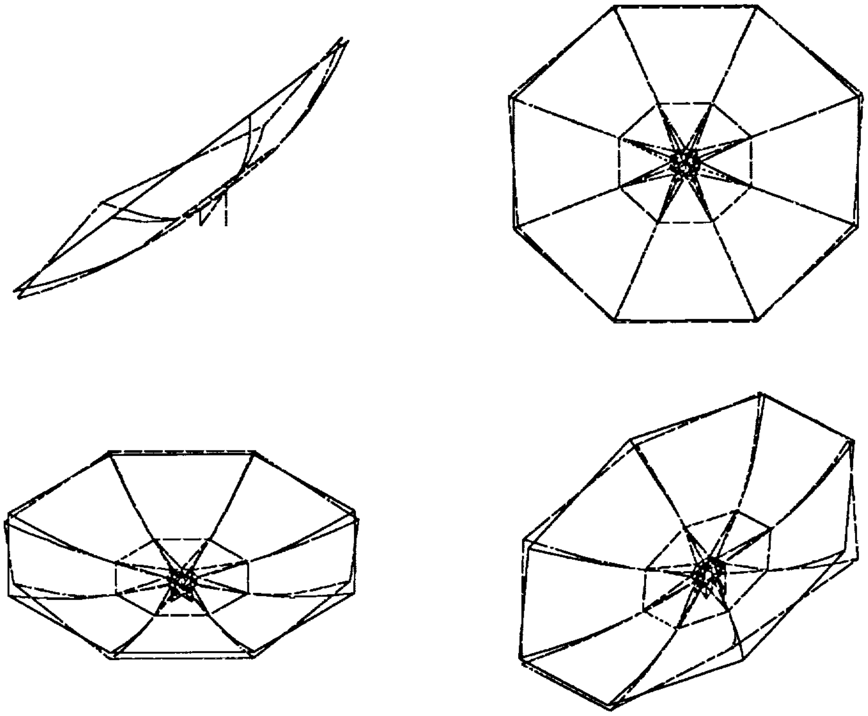


(e) Mode 5; 3.301 Hz.

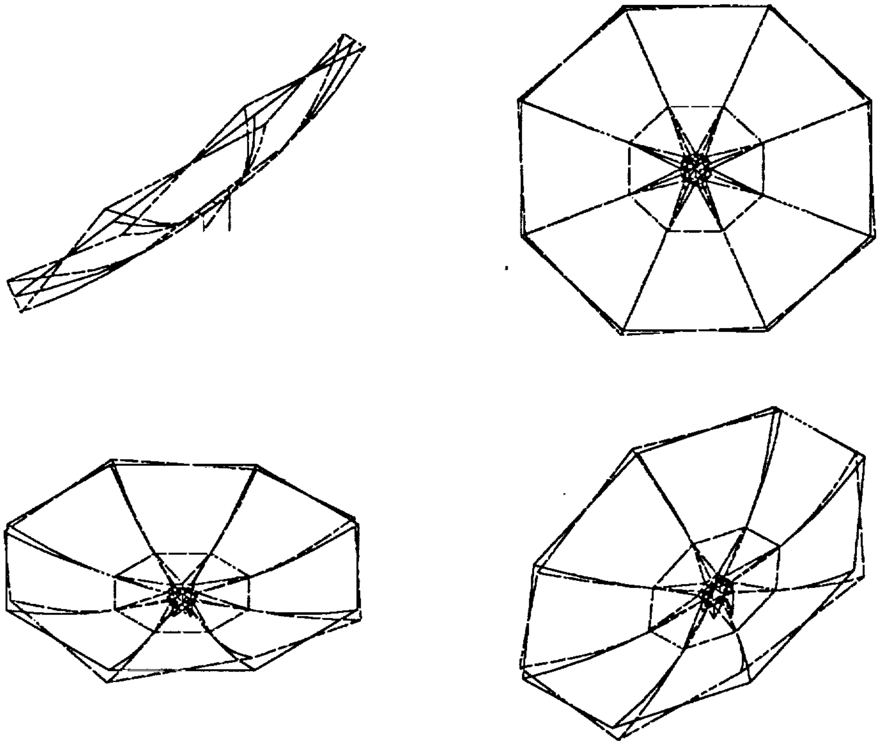


(f) Mode 6; 3.563 Hz.

Figure 16. Continued.

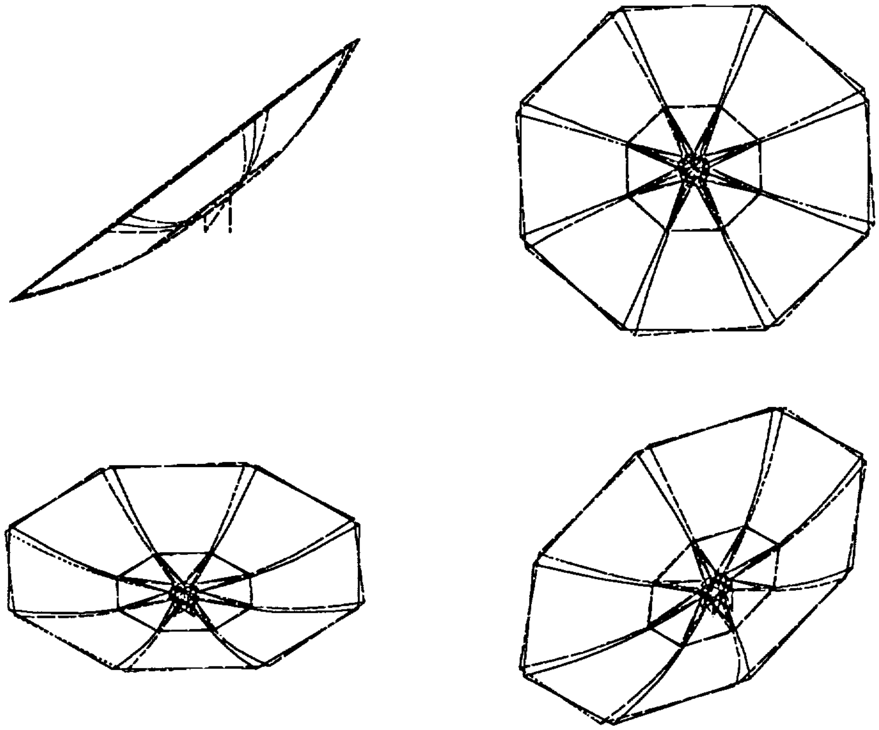


(g) Mode 7; 3.567 Hz.

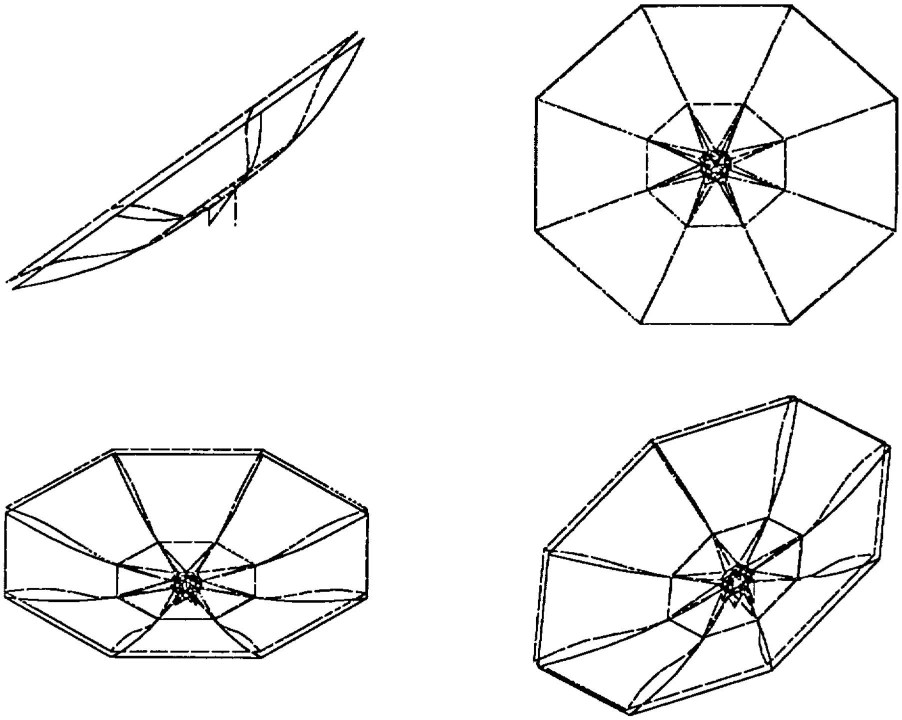


(h) Mode 8; 3.792 Hz.

Figure 16. Continued.

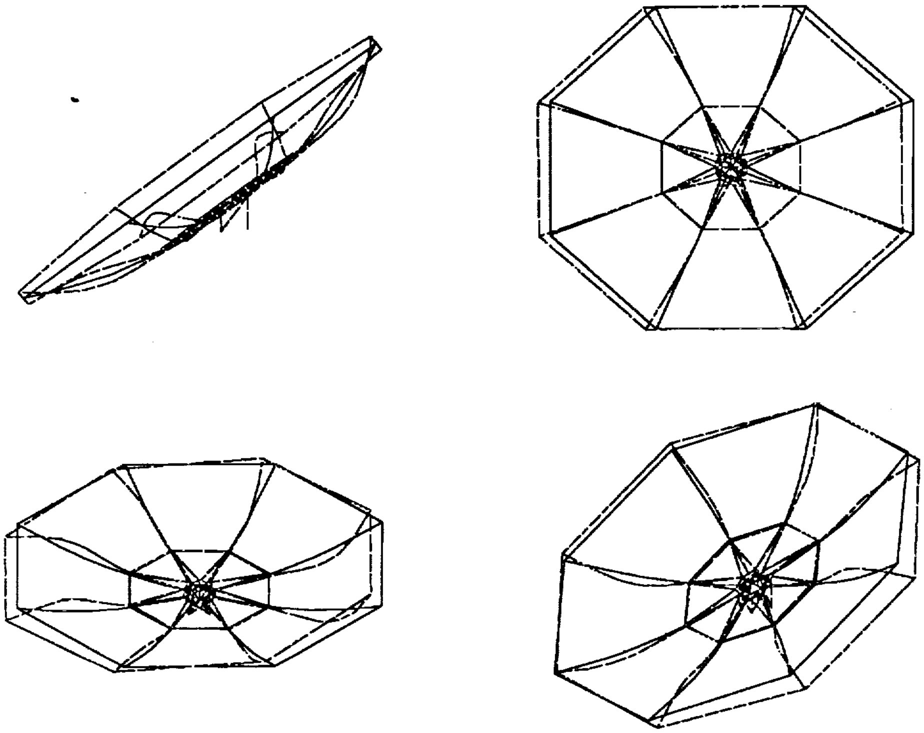


(i) Mode 9; 5.447 Hz.

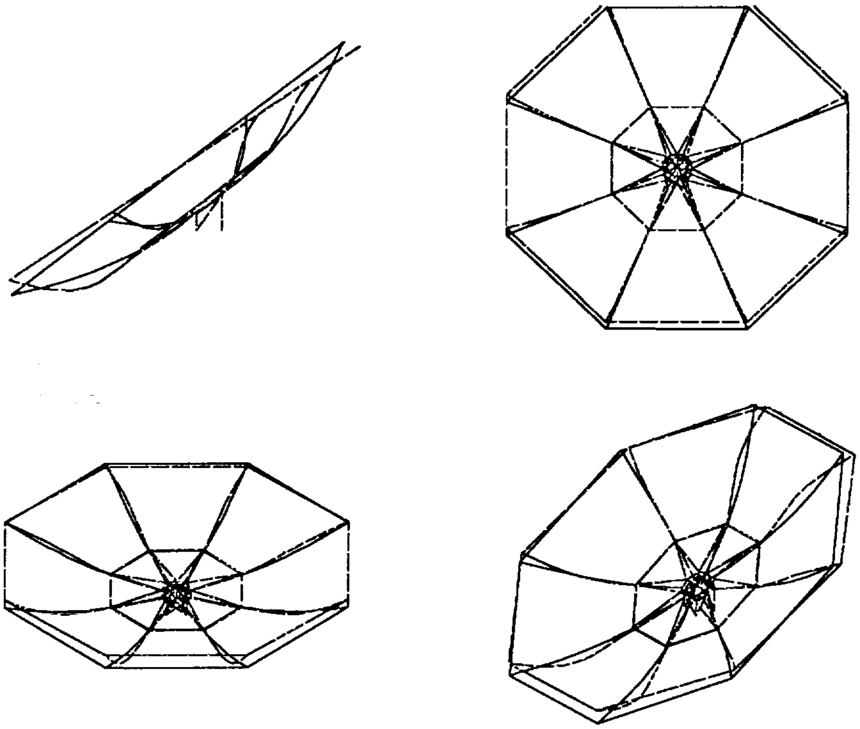


(j) Mode 10; 6.350 Hz.

Figure 16. Continued.

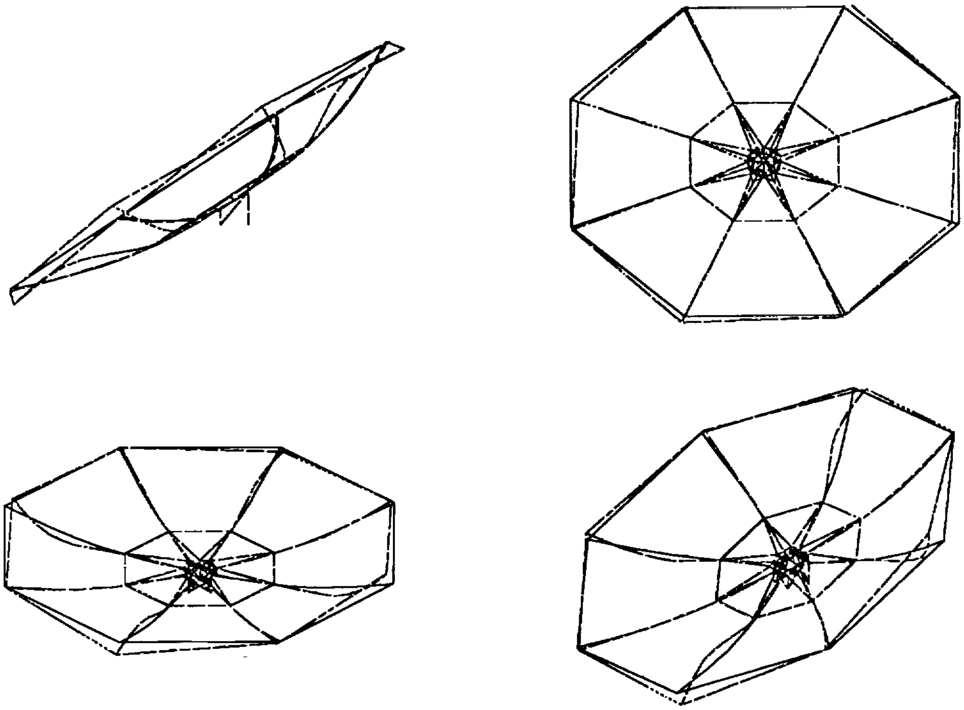


(k) Mode 11; 9.826 Hz.



(l) Mode 12; 9.995 Hz.

Figure 16. Continued.



(m) Mode 13; 10.601 Hz.

Figure 16. Concluded.

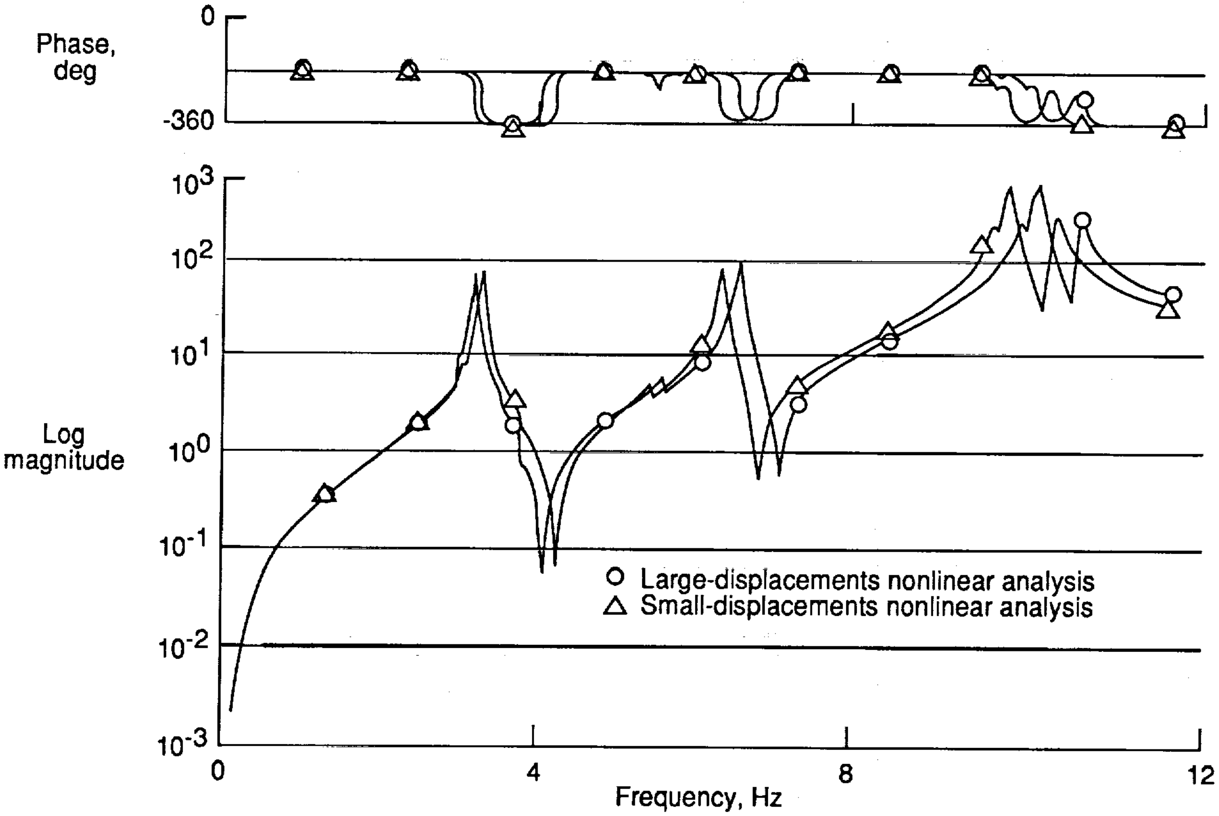


Figure 17. Vertical frequency-response function for rib 2.