THE USE OF MSC/NASTRAN AND EMPIRICAL DATA TO VERIFY A DESIGN

PRESENTED AT
MSC/NASTRAN USER'S CONFERENCE
MARCH 22-23, 1984
PASADENA, CALIFORNIA

W. F. RAY, DESIGN ENGINEER
PPG INDUSTRIES, INC.
TECHNOLOGY DEVELOPMENT DEPARTMENT
AIRCRAFT PRODUCTS
HUNTSVILLE, ALABAMA

THE USE OF MSC/NASTRAN AND EMPIRICAL DATA TO VERIFY A DESIGN

W. F. Ray

ABSTRACT

Because of the radical behavior of some materials under certain loading conditions, it is sometimes impractical (or even impossible) to verify a finite element solution by empirical means. This is especially true if the material being analyzed is a uniformly loaded, flat shell with extreme elastic-mechanical properties. This paper describes an approach used by PPG Industries to determine and understand the deflection, stress, and in-plane loads developed in this flat elastic shell by incorporating the data from MSC/NASTRAN's Geometric Non-Linear Solution, known as SOL 64, with an actual pressurization test.

TABLE OF CONTENTS

1.0 INTRODUCTION

The purpose of this study is to provide the necessary stress analysis support to substantiate a PPG-designed interlayer system to be utilized in a laminated glass window.

An interlayer is considered to be a plastic transparent material used to laminate structural transparent materials (i.e. glass, acrylic, polycarbonate, etc.). Interlayers are unique in that they must be an adhesive, serve as an energy absorbing medium, provide failsafe features, and be of good optical quality. The primary reason for this study was to determine whether this interlayer design could withstand its intended loads.

The critical pressurization condition for which this interlayer system has been designed is the pressure applied during the failsafe situation. To meet this failsafe design requirement, all structural glass plies are considered failed. Thus, under this condition, the interlayer system must maintain its integrity without failure.

The two methods choosen to verify this design were the use of MSC/NASTRAN, a general purpose finite element program, and an actual pressurization test. Since the stress and strain calculations used in the finite element approach, are based on the calculated displacement results, it is extremely important to verify these deflection values. This was accomplished by correlating the MSC/NASTRAN model to the empirical pressurization study.

1.0 INTRODUCTION (Continued)

Neither the MSC/NASTRAN model nor the test specimen for this interlayer system incorporated any structural plies of glass. Thus, the worst possible situation for the interlayer was considered (i.e. maximum deflection and stress). This is a very conservative assumption since it has been documented that even though failure in the structural plies might occur, support is still provided by these plies.

2.0 SUMMARY

Based on the theoretical analysis and the empirical data presented in this report, the 0.290 inch interlayer system originally proposed is more than adequate for the various design requirements for this customer.

The interlayer system performed and behaved as expected with very little discrepancies present. A correlation between the MSC/NASTRAN model and the empirical data was established, thus assuring the validity of the model. A few of the highlights have been presented in this section.

For a more detailed understanding of how this interlayer system reacted to the applied load, the actual photos taken during the empirical testing, located in Appendix B, the MSC/NASTRAN generated plots, located in Appendix C, along with the summarized results from MSC/NASTRAN, located in Appendix D, should be referenced.

2.1 Overall Behavior

The behavior of this interlayer system was that of a large deflection (membrane) problem. In both the MSC/NASTRAN model and the empirical test, the maximum deflection occurred at the center of this window.

2.2 Maximum Stress Location

The maximum stress obtained from the MSC/NASTRAN model during this failsafe loading condition of 10.0 PSI, ranged between 393.0 PSI to 464.0 PSI along the row of elements between Element 1 (at the center) to Element 360 located at the middle edge of the long side of this window (Reference Figure 2.0 in Appendix A). Because these stress values are in tension with the magnitudes almost equal, the behavior of this model depicts one of a pure membrane.

Due to the associated problems inherent in strain gages (i.e., lack of accuracy during large deflection in plastic materials and their chemical reaction with the plastic itself), strain data was not recovered during the empirical testing of this interlayer system.

The maximum in-plane (membrane) load calculated in the MSC/NASTRAN model was 89.8 lbs. per fastener. It should be noted that there were no other means available to accurately predict, calculate, or approximate this load using standard plates and shells - type text-books (i.e., Timoshenko, Roark, Ugural, Flügge, etc.). Thus, the only theoretical information/solution, concerning this problem, would have to come from a finite element type solution.

2.2 Maximum Stress Location (Continued)

Verification for this particular finite element study could only be done with a pass/fail-type test.

2.3 Maximum Deflection Location

A maximum deflection of 3.34 inches at Grid Point-1 was observed in the MSC/NASTRAN model with the 10.0 PSI uniform pressure load applied. Grid Point-1 is located at the center of the window (Reference Figure 2.0 in Appendix A and Plot 5 in Appendix C).

The maximum deflection observed during the empirical test was 3.5 inches. This reading was taken once the interlayer had become static, (i.e., very little movement versus time). The internal pressure of the test fixture was maintained at a constant 10.0 PSI (Reference Photographs 1.0 through 4.0, in Appendix B).

3.0 MSC/NASTRAN MODEL DESCRIPTION

Because this window can be approximated using a rectangular shape, using appropriate symmetry conditions, only one-quarter of this window (interlayer system) was modeled.

This model was generated using CQUAD4 elements. The thickness of these elements was a uniform 0.290 inches. The material properties for this model depicted a weighted average between the different interlayers present. The PSHELL and MAT1 property cards were utilized to describe and reference the appropriate physical and material properties, respectively. For these properties, reference Figure 1.0 and Table I in Appendix A.

The "Local" coordinate system, utilized while describing the locations of the grid points for this model, was defined using the cartesian coordinate system. This, and all other "Local" coordinate systems used in this model, coincided with the basic or "Global" coordinate system. Hence, all input and output referenced throughout this MSC/NASTRAN model are defined in the same coordinate system.

The general orientation for this model with respect to the defined coordinate system is as follows:

1. The origin is located at the center of the windshield.

3.0 MSC/NASTRAN MODEL DESCRIPTION (Continued)

2. The X-axis is parallel to the long sides of the window.

3. The Z-axis is perpendicular to the plane of the window. Its positive direction can be defined going from the inboard surface towards the outboard surface of the window.

4. Using the right hand rule, the Y-axis is orthogonal to the X-Z plane.

Based on the above orientation, a positive deflection resulting from cabin pressurization is oriented in the positive Z - direction. In addition, the membrane stresses and forces are oriented in the X-Y plane of this model. (Reference Figure 2.0 in Appendix A).

The response of this shell model will involve primarily a membrane - type behavior. Thus, SPC1 (Single-Point Constraint) cards were utilized to define this specific behavior. The edge condition for this shell model was fixed with no in-plane movement allowed. The displacement conditions along the plane of symmetry specified that points on the plane do not displace out of the plane.

The actual frame and insert were not included in this model because the SPC1 cards simulated their existence with respect to the interlayer material.

3.0 MSC/NASTRAN MODEL DESCRIPTION (Continued)

The "Piecewise Linear Analysis" option of MSC/NASTRAN was used to solve this interlayer model. This solution sequence, known as SOL 64, allows for the solution of large deflection - type problems, typically called "Geometric Non-Linear" problems. For a better understanding of this analytical procedure, see Reference 4, Section 3.1, and Reference 5, Section 3.8.

In addition to the above feature, the uniform pressure load of 10.0 PSI was incrementally applied to this model. The load was applied in this fashion so that the stiffness properties for each element could be assumed constant for each iteration. While this incremental loading procedure and the geometric non-linear analysis was being performed, the increments in displacements and stresses were accumulated to produce the final, non-linear result. For this model, the final solution occurred during Subcase - 35.

3.0 MSC/NASTRAN MODEL DESCRIPTION (Continued)

The pressure load was applied to the individual elements by means of the PLOAD2 card. This load was applied to the inboard surface of this model with its direction in the positive Z-direction (i.e., from the inboard surface towards the outboard surface).

The major assumptions considered for this model were as follows:

1. Although the actual windshield shape could be described as a modified parallelogram, a rectangular shape of an equal surface area was assumed for simplicity sake. For this type of problem (i.e., Geometric Non-Linear), using this rectangular shaped model did not decrease the over-all accuracy or results.
2. Due to the relative rigidity of the edge, the boundary condition around the edge was considered fixed.
3. Since this design incorporated a bolted-fastener system, no in-plane deflections were allowed along the window's edge.

4.0 EMPIRICAL TEST PROCEDURE

The basis used for correlating the MSC/NASTRAN model of this window was an actual test of the interlayer system with the structural plies (i.e., glass plies) removed. This unit was manufactured as if it was a production part. The only difference being the placement of a release film at the interlayer/glass interface. Once laminated, the glass plies (or in this case the pressing plates) and the film were removed, thus leaving only the interlayer system.

It should be noted that no additional materials were added to this part. Hence, a true failsafe situation was created.

The test apparatus consisted of the pressure chamber, pressure gauge, and deflection scale with marked indicator (Reference Figure 3.0 in Appendix B).

The test specimen was mounted into the test fixture. The temperature of this specimen was a uniform 73°F. Before the test was conducted, it was noted that the interlayer panel had sagged (crept) 0.5 inches. This creep could easily be explained once the interlayer's mechanical properties were considered.

Preliminary photographs were taken to document the initial test set-up. (Reference Photographs 1.0 and 2.0 in Appendix B). After the 10.0 PSI pressure was applied and the panel allowed to approach an equilibrium state (approximately ten minutes), another photograph was taken to document the deflection. (Reference Photograph 3.0).

4.0 EMPIRICAL TEST PROCEDURE (Continued)

From Photograph 2.0 and 3.0 the deflection could be determined by noting the differences in the position of the marked indicator with respect to the scale. Once this distance has been determined, 0.5 inches should be subtracted due to the initial creep as shown below:

Total Deflection Due to 10.0 PSI Pressure = Total Distance - Initial Creep.

or

$$\delta_{TOTAL} = 4.0 \text{ in.} - 0.5 \text{ in.} = 3.5 \text{ in.}$$

This panel was held at 10.0 psi for an additional ten minutes. No appreciable change in deflection occurred. The small deflection that did occur, however, could easily be explained by creep (Reference Photograph 4.0). Thus, for the failsafe condition at 10.0 PSI, held for ten minutes, the maximum deflection at the center was 3.5 inches.

After the pressure was released, a permanent set in the interlayer could be observed (Reference Photograph 5.0). After two weeks, this panel still had a 3/4-inch deflection.

5.0 REFERENCES

1. Schaeffer, H. G., MSC/NASTRAN Primer: Static and Normal Modes Analysis, Wallace Press, Inc., Milford, New Hampshire, Third Printing, 1982.

2. The MacNeal-Schwendler Corporation, MSC/NASTRAN: Handbook for Linear Static Analysis - Version 61, MSR-61, December 1981.

3. The MacNeal-Schwendler Corporation, MSC/NASTRAN: User's Manual - Volume I, MSR-39, February 1981.

4. The MacNeal-Schwendler Corporation, MSC/NASTRAN: User's Manual - Volume II, MSR-39, February 1981.

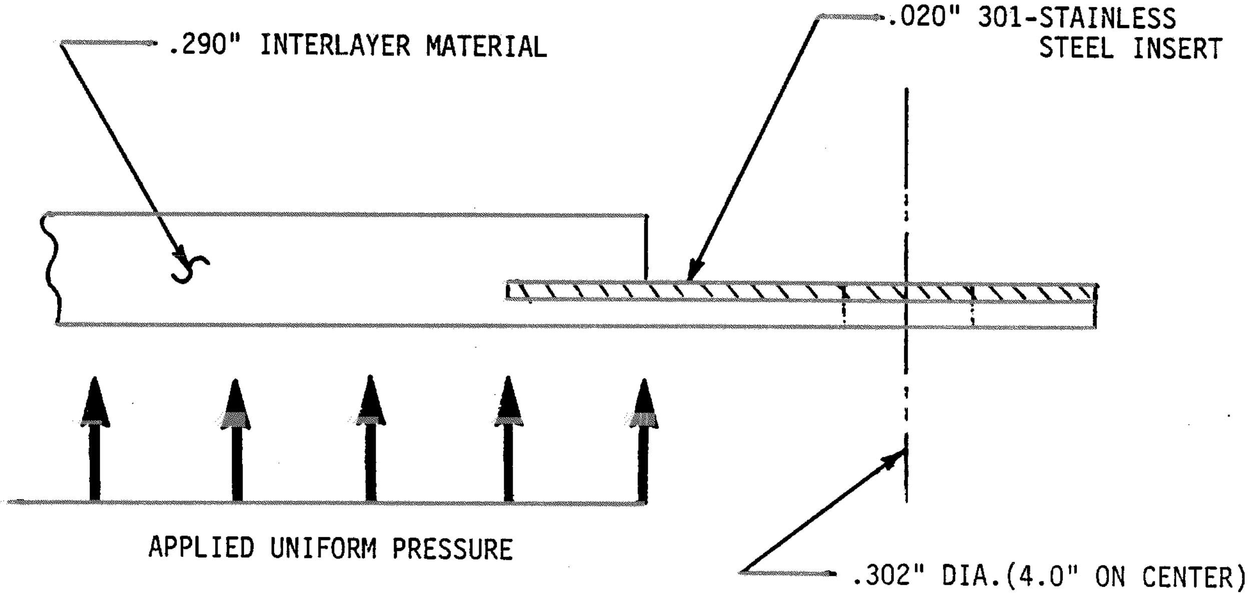
5. NASA and The MacNeal-Schwendler Corporation, NASTRAN Theoretical Manual, SP-221(03), December 1972.

APPENDIX A

FIGURE 1.0: PHYSICAL GEOMETRY

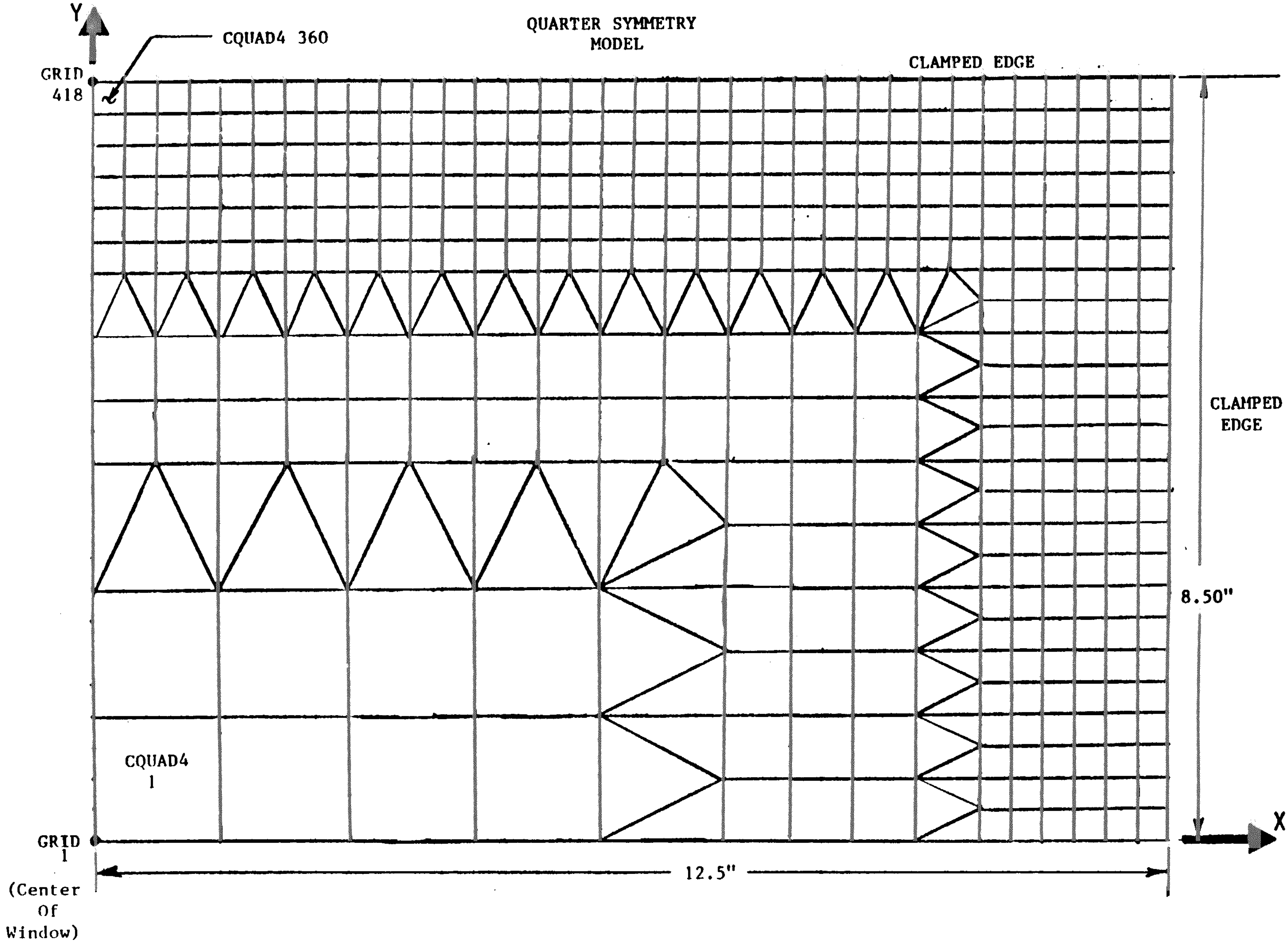
FIGURE 2.0: QUARTER SYMMETRY MODEL

TABLE I: MATERIAL PROPERTIES USED IN MSC/NASTRAN MODEL



CROSS-SECTION OF TESTED
INTERLAYER/INSERT SYSTEM

FIGURE 1.0



Y
CQUAD4 360
QUARTER SYMMETRY MODEL
CLAMPED EDGE
GRID 418
CLAMPED EDGE
8.50"
CQUAD4 1
GRID 1
X
12.5"
(Center Of Window)

FIGURE 2.0

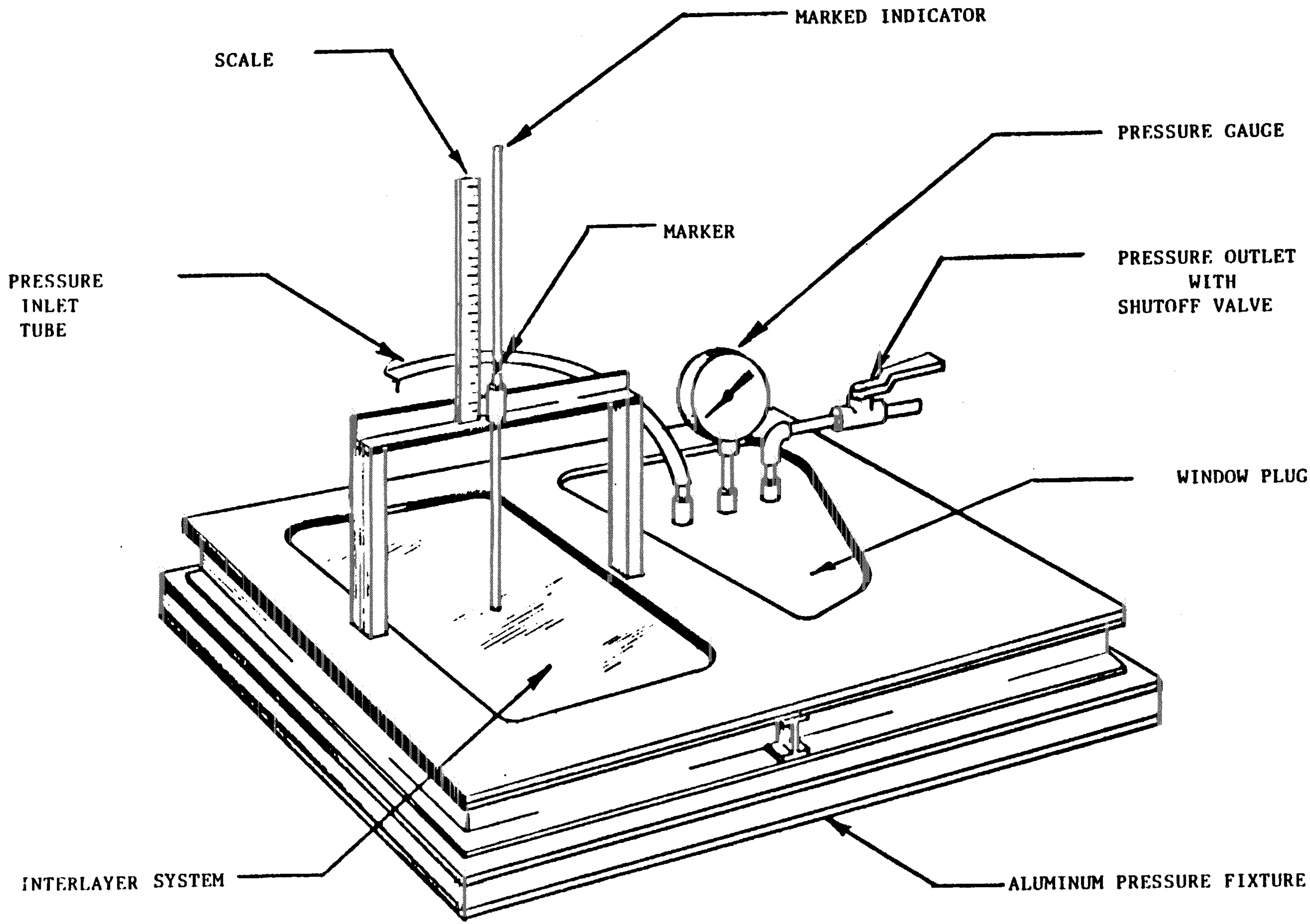
INTERLAYER MATERIAL PROPERTIES

USED IN THE MSC/NASTRAN MODEL

PROPERTY	VALUE
MATERIAL IDENTIFICATION NUMBER USED IN MODEL	41
MODULUS OF ELASTICITY (PSI)	3000.0
SHEAR MODULUS (PSI)	600.0
POISSON'S RATIO	.43
MASS DENSITY ($LB\text{-}SEC^2/IN^4$)	1.0×10^{-4}
COEFFICIENT OF THERMAL EXPANSION ($IN/IN\text{-}^{\circ}F$)	2.0×10^{-4}
REFERENCE TEMPERATURE FOR MATERIAL PROPERTIES ($^{\circ}F$)	70.0
STRESS ALLOWABLE FOR TENSION (PSI)	10,000.0
STRESS ALLOWABLE FOR COMPRESSION (PSI)	3,000.0
STRESS ALLOWABLE FOR SHEAR (PSI)	600.0

TABLE I.

APPENDIX B

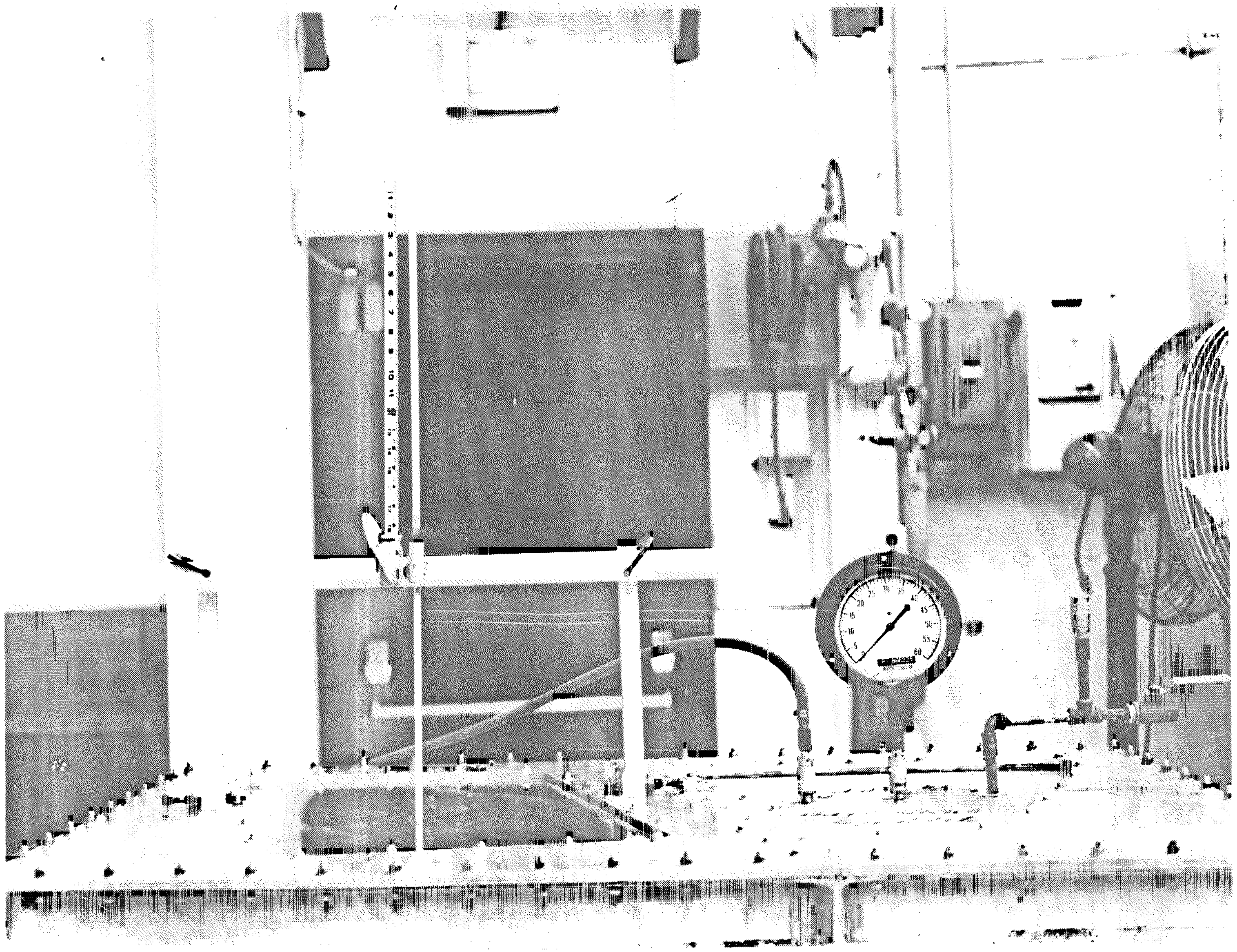


PRESSURE TEST APPARATUS

FIGURE 3.0

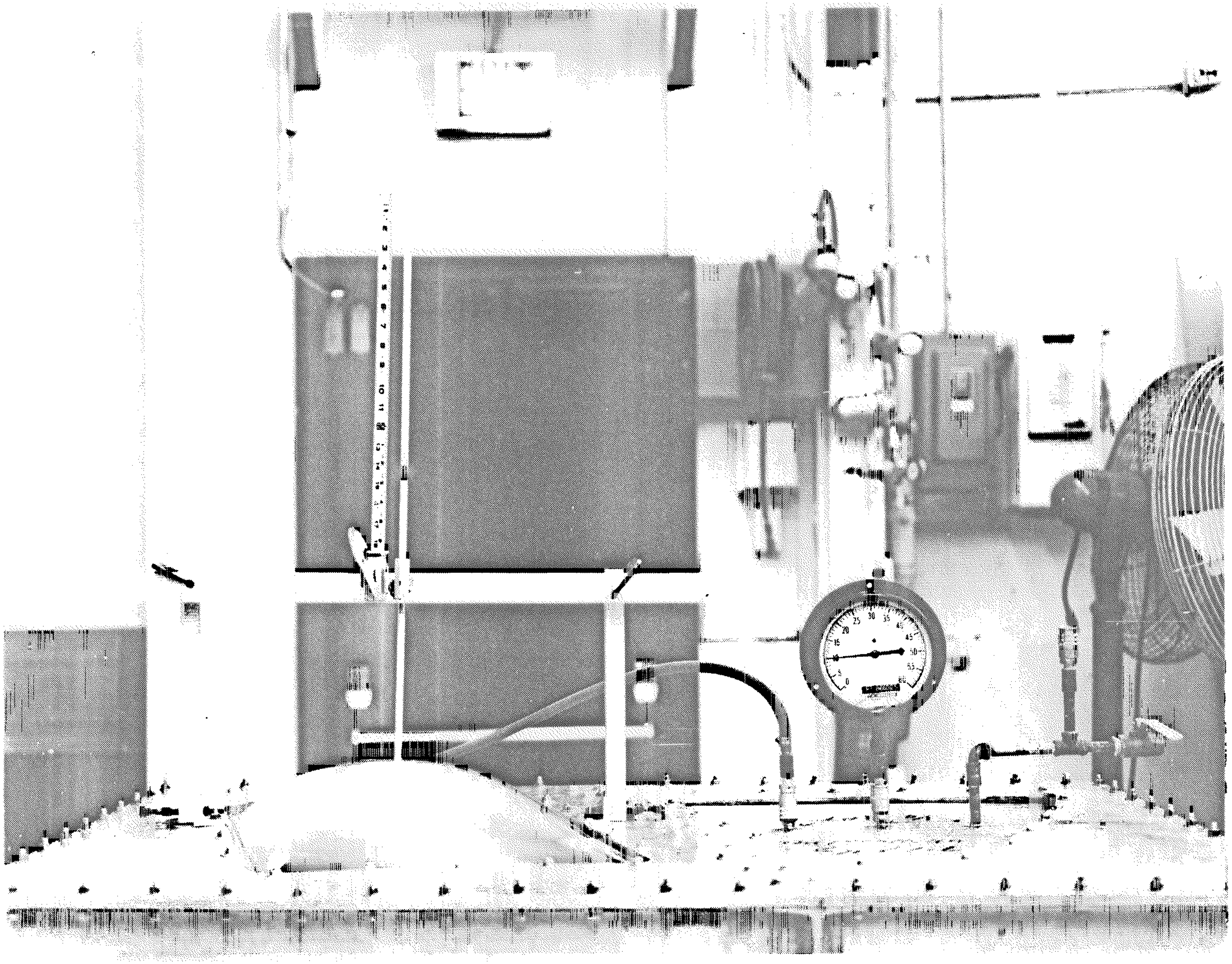
INITIAL INSTALLATION

PHOTOGRAPH 1.0



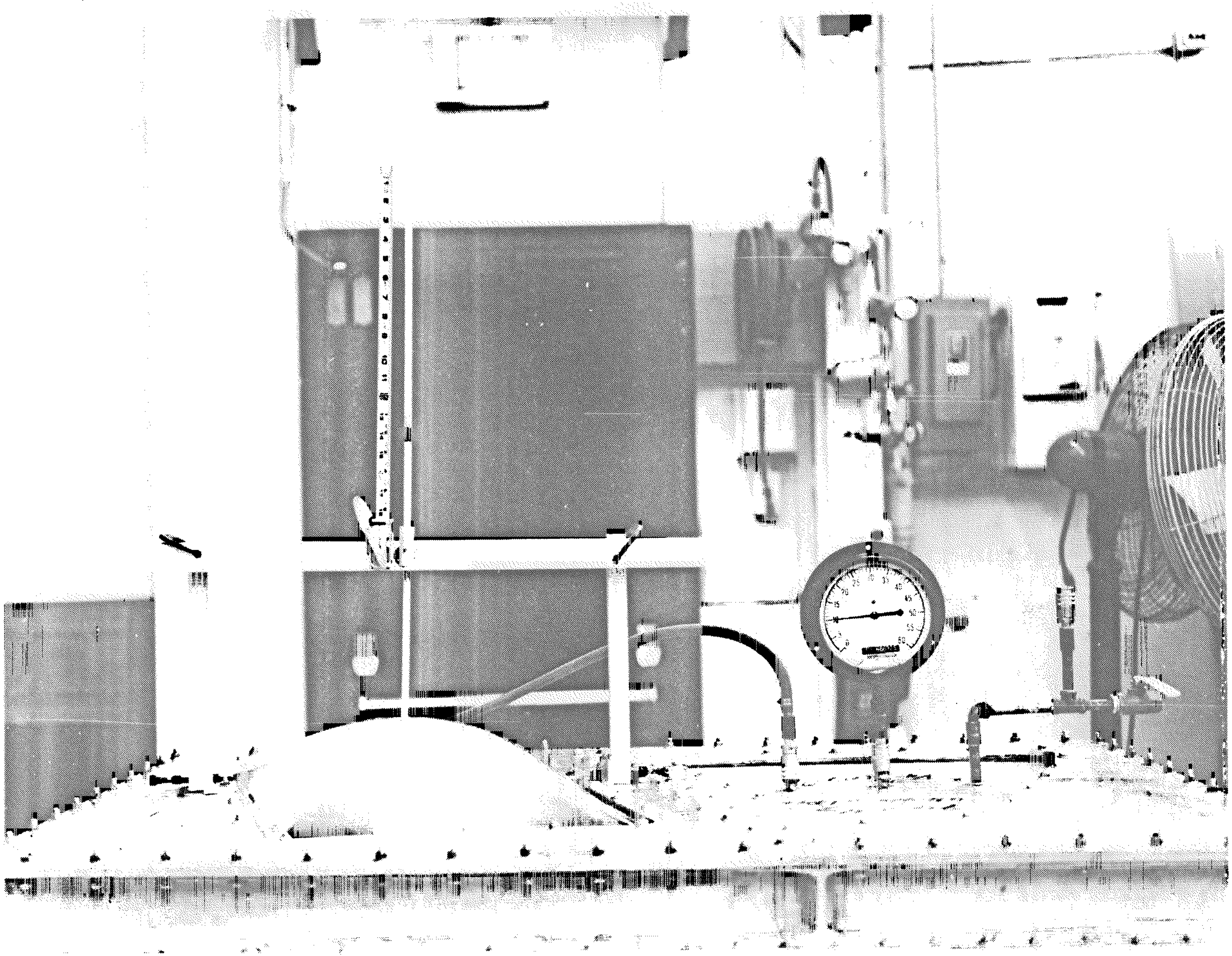
INITIAL TEST SETUP
SHOWING TEST APPARATUS

PHOTOGRAPH 2.0

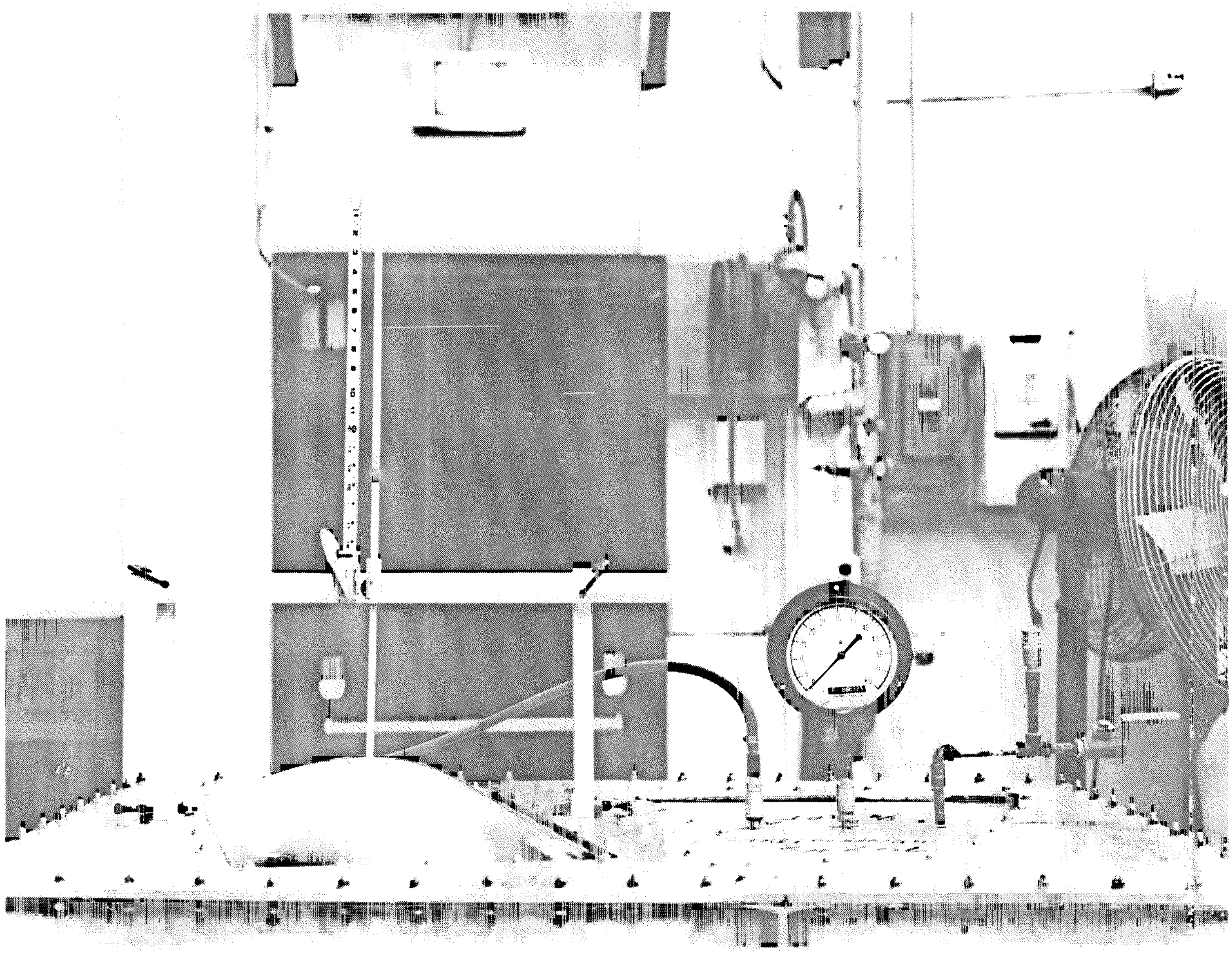


DEFLECTED PANEL AFTER TEN MINUTES
WITH 10.0 PSI PRESSURE APPLIED

PHOTOGRAPH 3.0



DEFLECTED PANEL AFTER TWENTY MINUTES
WITH 10.0 PSI PRESSURE APPLIED



PERMANENT SET IN PANEL AFTER
PRESSURE WAS RELEASED

PHOTOGRAPH 5.0

APPENDIX C

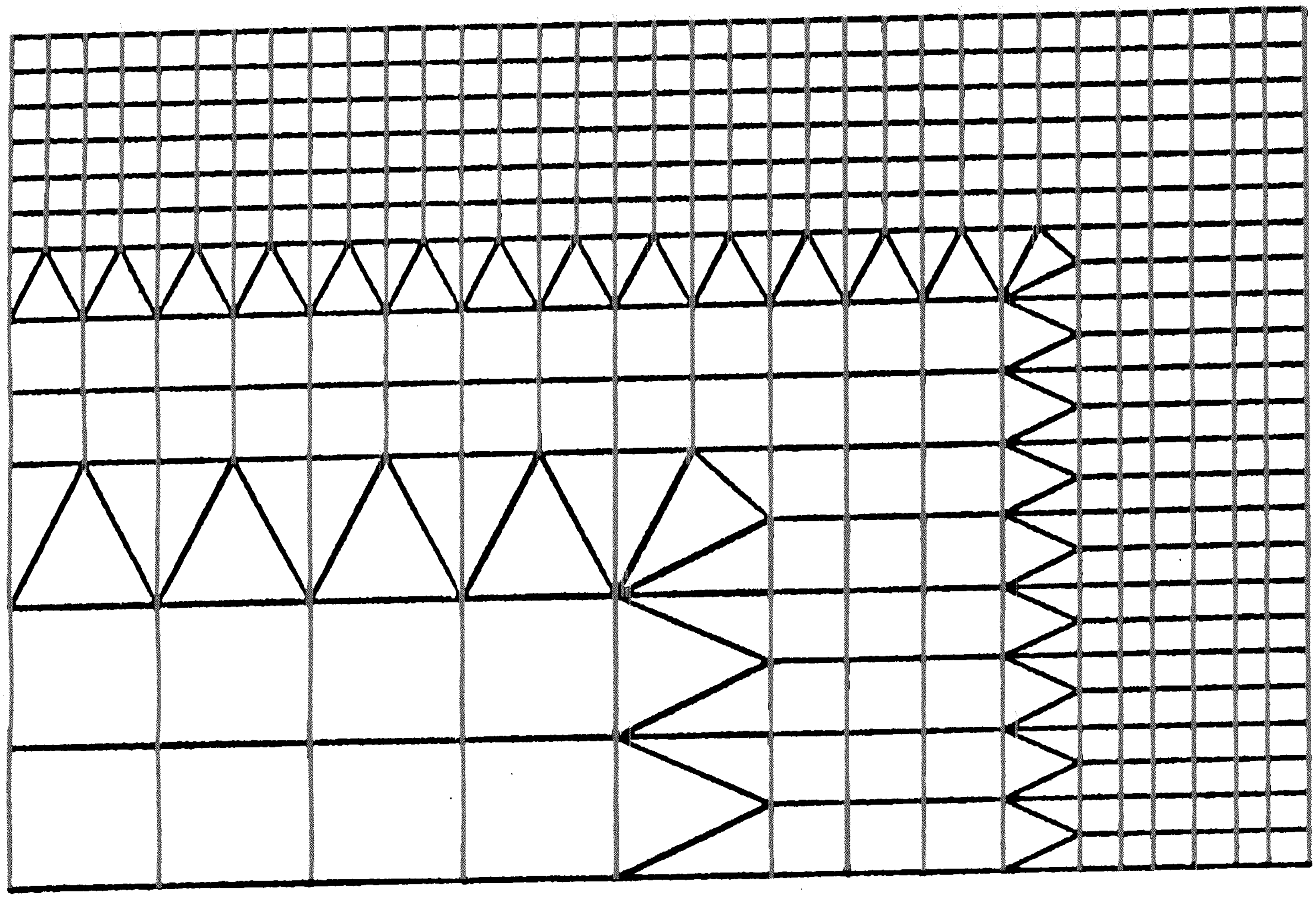
MSC/NASTRAN GENERATED PLOTS

PLOT 1: UN-DEFORMED PLOT, PLAN VIEW

PLOTS 2-5: GEOMETRIC NON-LINEAR SOLUTION, SIDE VIEW

- PLOT 2: SUBCASE 12, 0.1 PSI PRESSURE APPLIED
- PLOT 3: SUBCASE 17, 1.0 PSI PRESSURE APPLIED
- PLOT 4: SUBCASE 25, 5.0 PSI PRESSURE APPLIED
- PLOT 5: SUBCASE 35, 10.0 PSI PRESSURE APPLIED

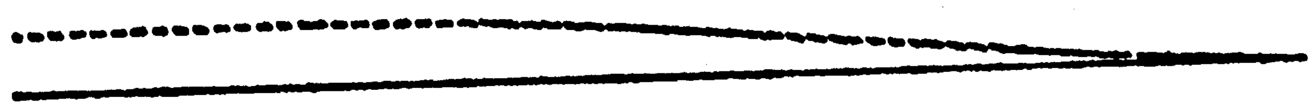
11/11/83
UNDEFORMED PLOT WITH ELEMENTS LABELED



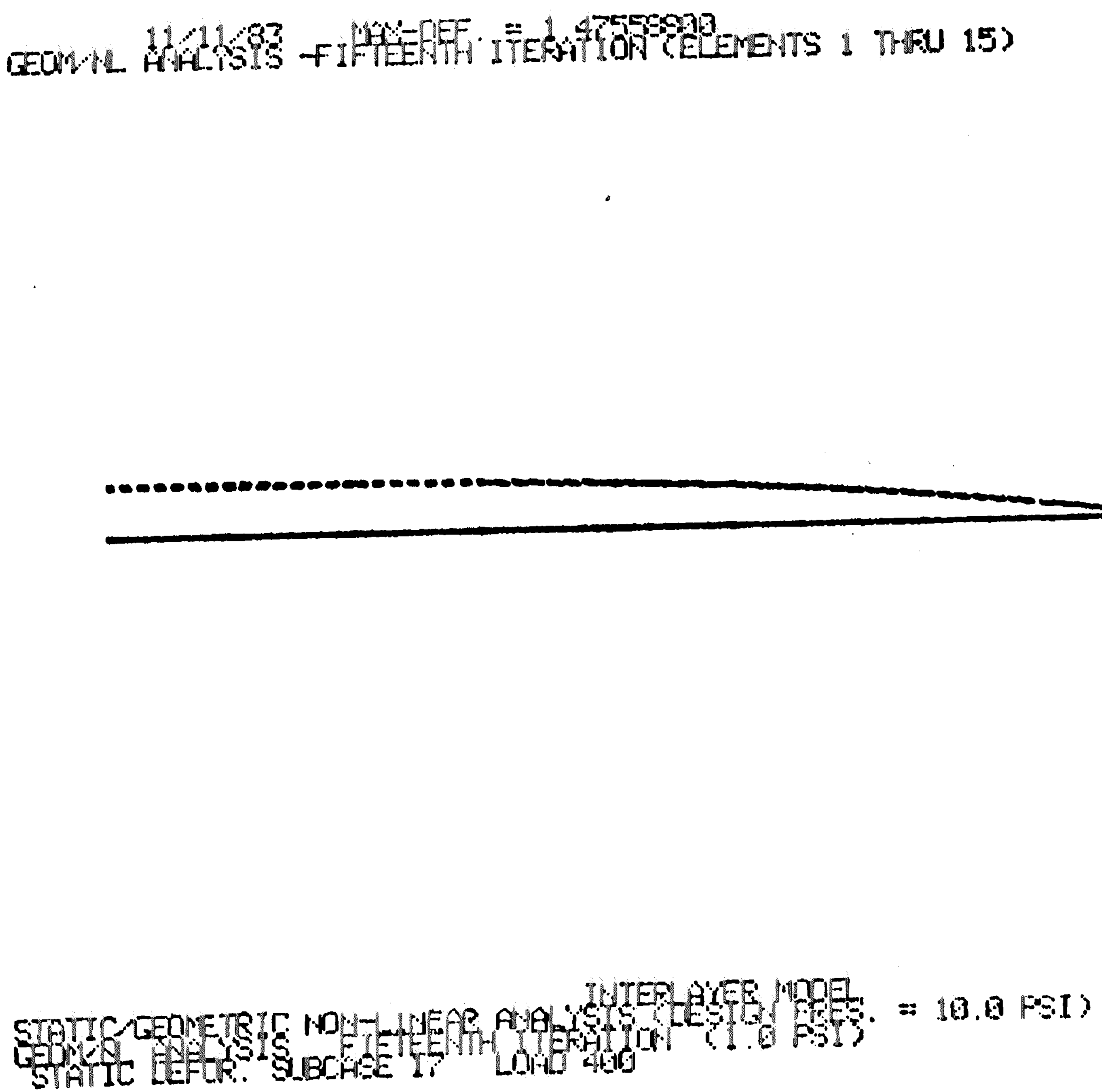
INTERLAYER MODEL
STATIC/GEOMETRIC NON-LINEAR ANALYSIS (DESIGN PRES. = 10.0 PSI)
UNDEFORMED SHAPE

PLOT 1.0

11/11/83 MAX-DEF = 0.50973679
GEOM/NL ANALYSIS -TENTH ITERATION (ELEMENTS 1 THRU 15)



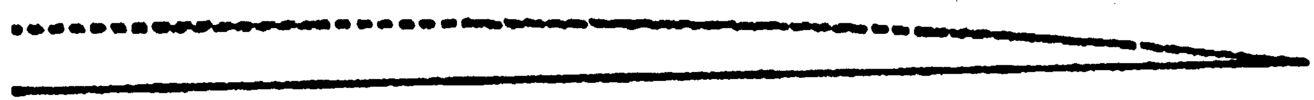
INTERLAYER MODEL
STATIC/GEOMETRIC NON-LINEAR ANALYSIS (DESIGN PRES. = 10.0 PSI)
GEOM/NL ANALYSIS TENTH ITERATION (0.1 PSI)
STATIC DEFOR. SUBCASE 12 LOAD 300


11/11/83 MAX-DEF. = 1.47556830
GEOM/NL ANALYSIS -FIFTEENTH ITERATION (ELEMENTS 1 THRU 15)
INTERLAYER MODEL
STATIC/GEOMETRIC NON-LINEAR ANALYSIS (DESIGN PRES. = 10.0 PSI)
GEOM/NL ANALYSIS - FIFTEENTH ITERATION (1.0 PSI)
STATIC DEFOR. SUBCASE 17 LOAD 400

PLOT 3.0

11/11/93 MAX-DEF = 2.59606500

GEOM/NL ANALYSIS -TWENTIETH ITERATION (ELEMENTS 1 THRU 15)



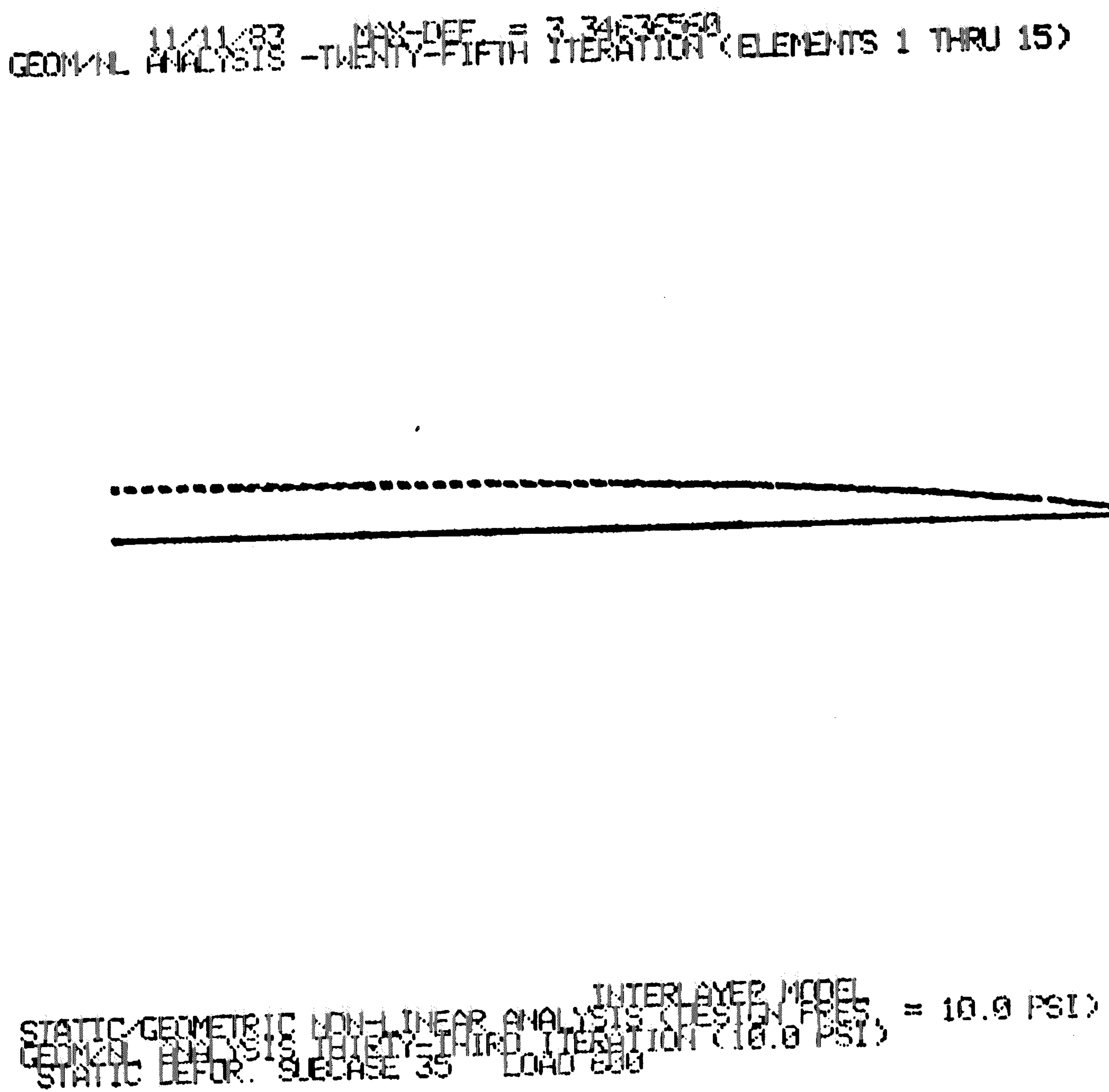
INTERLAYER MODEL

STATIC/GEOMETRIC NON-LINEAR ANALYSIS (DESIGN PRES. = 10.0 PSI)

GEOM/NL ANALYSIS - TWENTY-THIRD ITERATION (5.0 PSI)

STATIC DEFOR. SUBCASE 25 LOAD 500

PLOT 40


11/11/83 MAX-DEF =
GEOM/NL ANALYSIS -TWENTY-FIFTH ITERATION (ELEMENTS 1 THRU 15)
INTERLAYER MODEL
STATIC/GEOMETRIC NON-LINEAR ANALYSIS (DESIGN PRES. = 10.0 PSI)
GEOM/NL ANALYSIS THIRTY-THIRD ITERATION (10.0 PSI)
STATIC DEFOR. SUBCASE 35 LOAD

PLOT 5.0

APPENDIX D

MSC/NASTRAN BULK DATA

N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

```
ID RAY
TIME 3000
SOL 64
CEND
```


C A S E   C O N T R O L   D E C K   E C H O

```
CARD
COUNT
  1      ECHO=SORT
  2      MAXLINES=63000
  3      TITLE=                                    INTERLAYER MODEL
  4      SUBTITLE=STATIC/GEOMETRIC NON-LINEAR ANALYSIS (DESIGN PRES. = 10.0 PSI)
  5      SPC 100
  6      PARAM NOMEIN 1
  7      SUBCASE 1
  8      LOAD 200
  9      LABEL=STATIC/LINEAR ANALYSIS  (.001 PSI)
 10      DISPLACEMENT=ALL
 11      SPCFORCE=ALL
 12      OLOAD(SORT1)=ALL
 13      STRESS=ALL
 14      FORCE=ALL
 15      SUBCASE 2
 16      LOAD 200
 17      LABEL=DIFFERENTIAL STIFFNESS SOLUTION  (.001 PSI)
 18      DISPL=ALL
 19      SPCFO=ALL
 20      OLOAD=ALL
 21      STRESS=ALL
 22      FORCE=ALL
 23      SUBCASE 3
 24      LOAD 200
 25      LABEL=GEOM/NL ANALYSIS   FIRST ITERATION  (.001 PSI)
 26      DISPL=ALL
 27      SPCFO=ALL
 28      OLOAD=ALL
 29      STRESS=ALL
 30      FORCE=ALL
 31      SUBCASE 4        $SECOND ITERATION
 32      LOAD 200
 33      SUBCASE 5        $THIRD ITERATION
 34      LOAD 200
 35      SUBCASE 6        $FOURTH ITERATION
 36      LOAD 200
 37      SUBCASE 7        $FIFTH ITERATION
 38      LOAD 200
 39      LABEL=GEOM/NL ANALYSIS   FIFTH ITERATION  (.001 PSI)
 40      DISPL=ALL
 41      SPCFO=ALL
 42      OLOAD=ALL
 43      STRESS=ALL
 44      SUBCASE 8        $6TH ITERATION
 45      LOAD 300
 46      SUBCASE 9        $7TH ITERATION
 47      LOAD 300
 48      SUBCASE 10       $8TH ITERATION
 49      LOAD 300
 50      SUBCASE 11       $9TH ITERATION
 51      LOAD 300
 52      SUBCASE 12       $10TH ITERATION
 53      LOAD 300
 54      LABEL=GEOM/NL ANALYSIS   TENTH ITERATION  (0.1 PSI)
 55      DISPL=ALL
 56      SPCFO=ALL
 57      OLOAD=ALL
 58      FORCE=ALL
 59      STRESS=ALL
 60      SUBCASE 13       $11TH ITERATION
 61      LOAD 400
 62      SUBCASE 14       $12TH ITERATION
 63      LOAD 400
 64      SUBCASE 15       $13TH ITERATION
 65      LOAD 400
 66      SUBCASE 16       $14TH ITERATION
 67      LOAD 400
 68      SUBCASE 17       $15TH ITERATION
 69      LOAD 400
```

CASE CONTROL DECK ECHO (CONT.)

```
CARD
COUNT
 70      LABEL=GEOM/NL ANALYSIS   FIFTEENTH ITERATION  (1.0 PSI)
 71      DISPL=ALL
 72      SPCFO=ALL
 73      OLOAD=ALL
 74      FORCE=ALL
 75      STRESS=ALL
 76      SUBCASE 18      $16TH ITERATION
 77      LOAD 500
 78      SUBCASE 19      $17TH ITERATION
 79      LOAD 500
 80      SUBCASE 20      $18TH ITERATION
 81      LOAD 500
 82      SUBCASE 21      $19TH ITERATION
 83      LOAD 500
 84      SUBCASE 22      $20TH ITERATION
 85      LOAD 500
 86      SUBCASE 23      $21ST ITERATION
 87      LOAD 500
 88      SUBCASE 24      $22ND ITERATION
 89      LOAD 500
 90      SUBCASE 25      $23RD ITERATION
 91      LOAD 500
 92      LABEL=GEOM/NL ANALYSIS      TWENTY-THIRD ITERATION (5.0 PSI)
 93      DISPL=ALL
 94      SPCFO=ALL
 95      OLOAD=ALL
 96      STRESS=ALL
 97      FORCE=ALL
 98      SUBCASE 26      $24TH ITERATION
 99      LOAD 600
100      SUBCASE 27      $25TH ITERATION
101      LOAD 600
102      SUBCASE 28      $26TH ITERATION
103      LOAD 600
104      SUBCASE 29      $27TH ITERATION
105      LOAD 600
106      SUBCASE 30      $28TH ITERATION
107      LOAD 600
108      SUBCASE 31      $29TH ITERATION
109      LOAD 600
110      SUBCASE 32      $30TH ITERATION
111      LOAD 600
112      SUBCASE 33      $31ST ITERATION
113      LOAD 600
114      SUBCASE 34      $32ND ITERATION
115      LOAD 600
116      SUBCASE 35      $33RD ITERATION
117      LOAD 600
118      LABEL=GEOM/NL ANALYSIS THIRTY-THIRD ITERATION (10.0 PSI)
119      DISPL=ALL
120      SPCFO=ALL
121      OLOAD=ALL
122      STRESS=ALL
123      FORCE=ALL
124      PLOT ID EF3712
125      OUTPUT(PLOT)
126      PLOTTER NAST
127      CSCALE = 1.8
128      PAPER SIZE = 26.0 X 20.0
129      SET 1=ALL
130      SET 2=1,38,394,395,112,138,416,417,190,224,258,292,326,360
131      SET 3=1,2,3,4,414,415,6,7,8,176,177,10,11,12,13,14,15
132      PTITLE=UNDEFORMED PLOT WITH GRID POINTS LABELED
133      AXES Z,X,Y
134      VIEW 0.0,0.0,0.0
135      FIND SCALE,ORIGIN 1,SET 1
136      PLOT SET 1,ORIGIN 1,LABEL GRID POINTS
137      PTITLE=UNDEFORMED PLOT WITH ELEMENTS LABELED
138      AXES Z,X,Y
139      VIEW 0.0,0.0,0.0
140      FIND SCALE,ORIGIN 1,SET 1
141      PLOT SET 1,ORIGIN 1,LABEL ELEMENTS
142      PTITLE=DEFORMED WINDSHIELD-EDGE VIEW WITH .001 PSI PRESURE LOAD
143      AXES X,Y,Z
144      VIEW 0.0,0.0,0.0
145      FIND SCALE,ORIGIN 2,SET 2
146      PLOT STATIC DEFORMATION 0,1,SET 2,ORIGIN 2,LABEL ELEMENTS
147      PTITLE=DEFORMED WINDSHIELD-EDGE VIEW WITH .001 PSI PRESSURE LOAD
148      AXES Y,X,Z
149      VIEW 0.0,0.0,0.0
150      FIND SCALE,ORIGIN 3,SET 3
```

```
                    C A S E   C O N T R O L   D E C K   E C H O (CONT.)
CARD
COUNT
 151      PLOT STATIC DEFORMATION 0,1,SET 3,ORIGIN 3,LABEL ELEMENTS
 152      AXES Y,X,Z
 153      VIEW 0.0,0.0,0.0
 154      FIND SCALE,ORIGIN 3,SET 3
 155      PTITLE=DIFFERENTIAL STIFFNESS ANALYSIS (ELEMENTS 1 THRU 15)
 156      PLOT STATIC DEFORMATION 0,2,SET 3,ORIGIN 3,LABEL ELEMENTS
 157      PTITLE=GEOM/NL ANALYSIS -FIRST ITERATION (ELEMENTS 1 THRU 15)
 158      PLOT STATIC DEFORMATION 0,3,SET 3,ORIGIN 3,LABEL ELEMENTS
 159      PTITLE=GEOM/NL ANALYSIS -FIFTH ITERATION (ELEMENTS 1 THRU 15)
 160      PLOT STATIC DEFORMATION 0,7,SET 3,ORIGIN 3,LABEL ELEMENTS
 161      PTITLE=GEOM/NL ANALYSIS -TENTH ITERATION (ELEMENTS 1 THRU 15)
 162      PLOT STATIC DEFORMATION 0,12,SET 3,ORIGIN 3,LABEL ELEMENTS
 163      PTITLE=GEOM/NL ANALYSIS -FIFTEENTH ITERATION (ELEMENTS 1 THRU 15)
 164      PLOT STATIC DEFORMATION 0,17,SET 3,ORIGIN 3,LABEL ELEMENTS
 165      PTITLE=GEOM/NL ANALYSIS -TWENTIETH ITERATION (ELEMENTS 1 THRU 15)
 166      PLOT STATIC DEFORMATION 0,25,SET 3,ORIGIN 3,LABEL ELEMENTS
 167      PTITLE=GEOM/NL ANALYSIS -TWENTY-FIFTH ITERATION (ELEMENTS 1 THRU 15)
 168      PLOT STATIC DEFORMATION 0,35,SET 3,ORIGIN 3,LABEL ELEMENTS
 169      PTITLE=GEOM/NL ANALYSIS-TWENTY-FIFTH ITERATION (PLAN VIEW)
 170      AXES Z,X,Y
 171      VIEW 0.0,0.0,0.0
 172      FIND SCALE,ORIGIN 1,SET 1
 173      PLOT STATIC DEFORMATION 0,35,SET 1,ORIGIN 1
 174      BEGIN BULK

               INPUT BULK DATA CARD COUNT =      928
```

NOTE: The CQUAD4, CTRIA3, and GRID cards have been ommitted due to space limitation

```
 906-      MAT1     41       3300.             .43      .00010   2.00E-4  70.0              +M4
 907-      +M4      10000.   3000.    600.
 908-      MAT1     51       100.              .45      .00010   2.00E-4  70.0              +M5
 909-      +M5      5000.    2000.    600.
 910-      PARAM    KDIAG    1.0      0.0
 911-      PARAM    SSG3     0
 912-      PARAM    TESTNEG  -2
 913-      PLOAD2   200      .301     1        THRU     453
 914-      PLOAD2   300      .1       1        THRU     453
 915-      PLOAD2   400      1.0      1        THRU     453
 916-      PLOAD2   500      5.0      1        THRU     453
 917-      PLOAD2   600      10.0     1        THRU     453
 918-      PSHELL   1        41       .290     51
 919-      SPC1     10       2        1        THRU     16
 920-      SPC1     20       1        1        42       83       124      152      180      +SPCA
 921-      +SPCA    208      243      313      348      383      418
 922-      SPC1     30       135      16       23       34       41       57       64       +SPCB
 923-      +SPCB    75       82       98       105      116      123      144      151      +SPCC
 924-      +SPCC    172      179      200      207      242      277      312      347      +SPCD
 925-      +SPCD    382      417      452
 926-      SPC1     40       234      418      THRU     452
 927-      SPCADD   100      10       20       30       40
           ENDDATA

        TOTAL COUNT=   928
```