# AN INVESTIGATION OF INTER-RIVET BUCKLING OF AIRCRAFT PANELS IN COMPRESSION

A Thesis

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by

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Much credit is due the efforts of Messrs. W. J. Patton, W. Zukowsky, and Cornel Gross, who, as paid assistants under the above grant, participated in all phases of the experimental work as well as in the reduction and organization of test data.

# TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

# LIST OF FIGURES

LIST OF FIGURES (Continued)

# LIST OF TABLES

# ABSTRACT

The material presented herein is the result of a study of the buckling behaviour of stiffened flat panels, excluding the case of plate buckling. The test procedure is described and the values obtained, consisting of ultimate stress, critical buckling stress, stress at an arbitrary lack of smoothness, pin-end length of the principal buckle, and type of instability, are tabulated for each panel. These data are intended for use as a more comprehensive approach to the development of design charts than has been available in the past.

In addition, evidence is submitted from which the following conclusions are drawn.

1....... Conventional methods of loading with parallel platens cannot provide uniform stress distribution in test panels.

2....... Three separate regimes of buckling exist within the range of panels tested.

3....... Initial instability was always in the form of plate buckling.

# CHAPTER I

## INTRODUCTION

The successful structural design of a modern aircraft involves not only the provision of adequate strength and stiffness, but also demands that these be obtained with a minimum weight of material. In addition, aerodynamic efficiency at high speeds requires exceptional smoothness of all external surfaces.

Of particular importance is freedom from waviness in laminar flow wing construction. In present day stressed-skin design the compression loads resulting from bending of the wing are carried by the wing cover, which must be adequately stiffened to avoid buckling. Wing panels are normally stiffened by longitudinal stringers of suitable cross-section, riveted in place between transverse ribs spaced at intervals sufficiently small to prevent column buckling of the panel as a unit. The problem of designing structurally efficient skin-stiffener panels is a complex one, both because of the extremely large variation in loading conditions encountered with different aircraft, and because there are many panel proportions which meet the design conditions for almost any particular application reasonably well.[1]

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1 Norris F. Dow, Design Charts for Longitudinally Stiffened Wing Compression Panels, 1948.

Design methods. There have been many attempts to develop methods for predicting the strength of such panels. Of particular interest is the effective width concept of von Karman which has been widely used.[2]

The purely theoretical approach has been used by a few investigators. Generally speaking, however, theories sufficiently comprehensive to include more than narrowly restricted ranges of panel proportions and types of failure have not yet been evolved.[3]

The experimental, or possibly semi-empirical, approach has been far more extensively employed than presently available theory. Vast numbers of flat stiffened panels have been tested covering such a wide range of proportions, materials, and stiffener shapes, that it has been possible to produce design charts directly from experimental results. The work of Dow and Hickman at Langley Field has been phenomenal in this accomplishment. From these charts the most efficient panel proportions may be selected to carry a given load intensity over a given panel length with a given skin thickness.

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2 Th. von Karman, E. E. Sechler and L. H. Donnell, Transactions, American Society of Mechanical Engineers, volume 54, page 53, 1932.

3 George L. Gallaher and Rolla B. Bougham, NACA-TN 1482, A Method of Calculating the Compressive Strength of Z Stiffened Panels that Develop Local Instability, November 1947.

Limitations of present design data. Unfortunately it is becoming increasingly apparent that most of the work of Dow and Hickman and others falls somewhat short of providing the designer with sufficient information. Practically all of the design charts now available are based on loads at failure of the panels. Little information is available on the specific type of failure or the amplitude and wave form of the buckled sheet prior to ultimate failure. At airspeeds close to or above the velocity of sound, the accuracy of wing profile contour becomes of great importance. A slight waviness resulting from buckling in its initial stages, which would not be important from the standpoint of adequate strength, may seriously affect the aerodynamic characteristics of the wing. For this reason the critical buckling stress would seem to be assuming a position of greater importance than the actual failing load. Work on this phase of the problem is in progress at the National Research Council, Ottawa; and at Vickers-Armstrongs Ltd., (Weybridge Works), Messrs. Short Brothers and Harland, and Flight Refuelling Ltd. under contract to the Ministry of Supply, in England. It also forms a principal part of the investigation on which this thesis is based.

The results presented herein are those which have been obtained in connection with an assisted research project sponsored by the National Research Council at the University of Manitoba. In obtaining these results, an attempt was made to record as many details as possible concerning the buckling behaviour of the panels tested. More than ordinary care was exercised to secure accuracy, with the thought in mind that the results might be used at some future date as the basis for theoretical design.

# CHAPTER II

## STATEMENT OF PROBLEM

Behaviour of stiffened panels under load. On compression loading of a stiffened flat panel along two opposite edges, the load being parallel to the stiffeners as in Figure 1, a state of simple compression exists until a certain critical load is reached. At this point the sheet buckles, and further loading, by increasing the amplitude of the buckle, will result in decreased stiffness of the panel as a whole. The axial stiffness of the panel now changes continually with the load and an increasingly greater share of the total load is carried by the stiffeners. As the deflection of the sheet becomes comparable with its thickness both bending and membrane stresses of significant magnitude are developed in it. These stresses acting in both longitudinal and transverse directions, in general result in compound curvature of the sheet, flexural loading of the stiffener at its points of contact with the sheet, and twisting of the stiffener. Final failure occurs when one or more stiffeners fail by some form of instability. Four types of failure of stiffened panels are sketched in Figure 2 and may be described as follows:[1]

1 Norris F. Dow, Design Charts for Longitudinally Stiffened Wing Compression Panels.

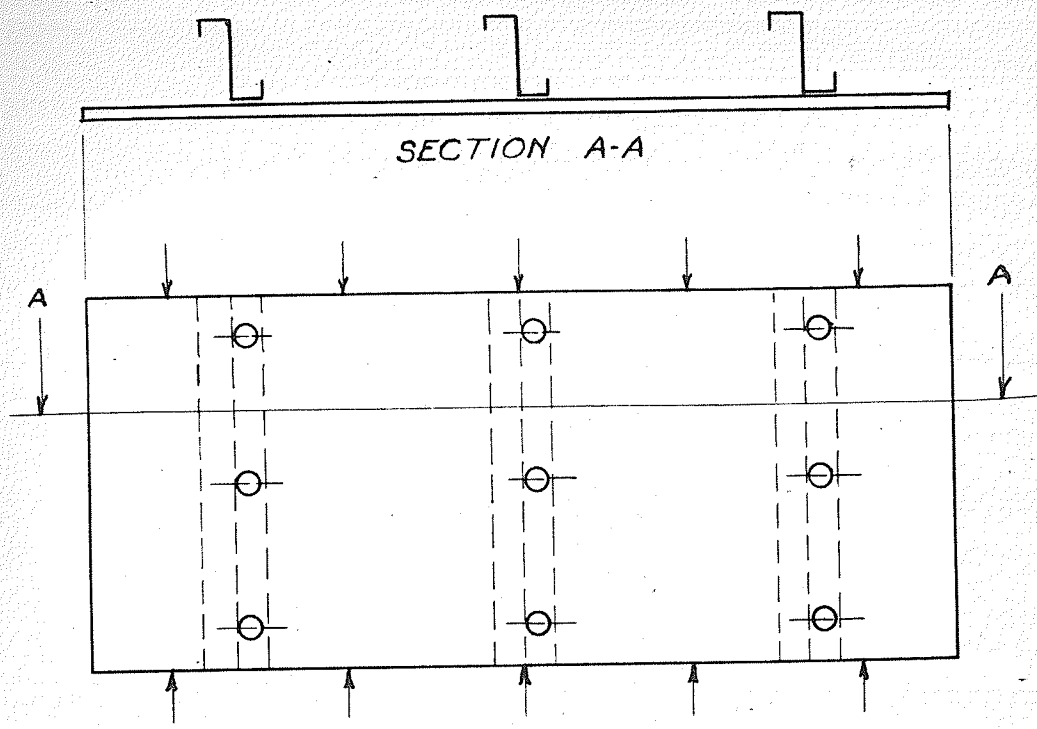
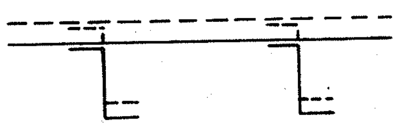
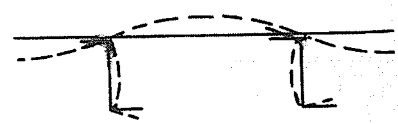


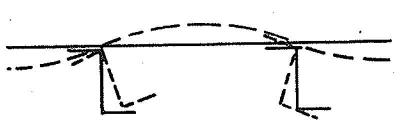

**FIGURE 1**



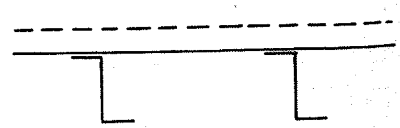
A- Column bending;- translation of entire cross section.



B- Local buckling:- distortion of cross section without translation of outstanding flanges.



C.- Stiffener twist:- distortion of section with translation of outstanding flanges.



D- Rivet failure:- separation of sheet and stiffeners.

**FIGURE 2**

A. Column bending, involving translation of the entire cross-section perpendicular to the plane of the sheet.

B. Local buckling, causing distortion of the cross-section without translation of the corners of the plate elements.

C. Stiffener twist, resulting in translation of the outstanding flange of the stiffener. This is primarily due to column failure of the stiffener in a plane parallel to that of the sheet, but, because of restraint of one flange at the sheet, the stiffener twists and "rolls over".

D. Rivet or inter-rivet failure, involving separation of sheet and stiffeners.

In addition to the above the buckling behaviour of the sheet alone may assume any of several modes. For example, the sheet may remain in full contact with the stiffeners but buckle in several waves between them. This is actually a case of plate buckling, but is more complicated than simple plate buckling because of the associated deformation of the stiffener. If the buckling pattern in adjacent bays is symmetrical with respect to the stiffener, bending of the stiffener will ensue. If anti-symmetrical, a torsional moment will be introduced into the stiffener. The latter case is well illustrated by the photo-grid picture of Panel 18 on page 111. In either case, the critical load for the stiffener alone is altered from its normal value by the addition of either lateral loads or twist, due to buckling of the sheet.

A second form of buckling which may occur at large rivet pitches involves buckling of the sheet as a fixed Euler column of length equal to the rivet pitch.

A third form involves buckling of the sheet between rivets, in such a manner that the deflection of the sheet is alternately towards and away from the stringer in consecutive rivet spaces.

A fourth mode seems to consist of a series of buckles predominantly along the stiffener, but not a function of rivet pitch. This type of instability appears to be analogous to buckling of a sheet supported on an elastic foundation.

With the exception of the first case of plate buckling all of these forms may be termed inter-rivet buckling. That is, they involve buckling along the line of rivets as well as in the plate between the stiffeners. Although the investigation described in this thesis was concerned with inter-rivet buckling only, it should be pointed out that it is seldom, if ever, that one form of instability occurs to the exclusion of all others. On the contrary, it is in fact difficult to ascertain in many cases which type of instability initiates failure.

The problem investigated and herein presented under the heading of "Inter-Rivet Buckling" may best be described as a study of the buckling behaviour of stiffened flat panels, excluding the case of plate buckling.

Variables of the problem. The main variables requiring investigation are:

a. Rivet pitch

b. Sheet thickness

c. Stiffener thickness

d. Stiffener form

e. Stiffener spacing

f. Rivet diameter and type

The major variables in the above list are rivet pitch and sheet thickness. Some indication of the importance of the variables c, d, e, and f, may be seen in the following paragraph.

It is reasonable to assume that the stress at which the plate buckles between the rivets is a function of the ratio of rivet pitch to sheet thickness. Considering a narrow element of sheet between rivets, one would expect it to buckle as a fixed ended strut having a length slightly less than the rivet pitch, because of the clamping action of the rivet heads. (Figure 3). Three factors tend to reduce the stress attainable under this assumption. Firstly, it depends upon the ability of the stiffener to keep the rivet heads in the initial plane of the sheet. Secondly, strut failure of the sheet midway between the stringers may occur over a length greater than the rivet pitch. Finally, the clamping effect of the rivet depends upon the size and shape of its head.

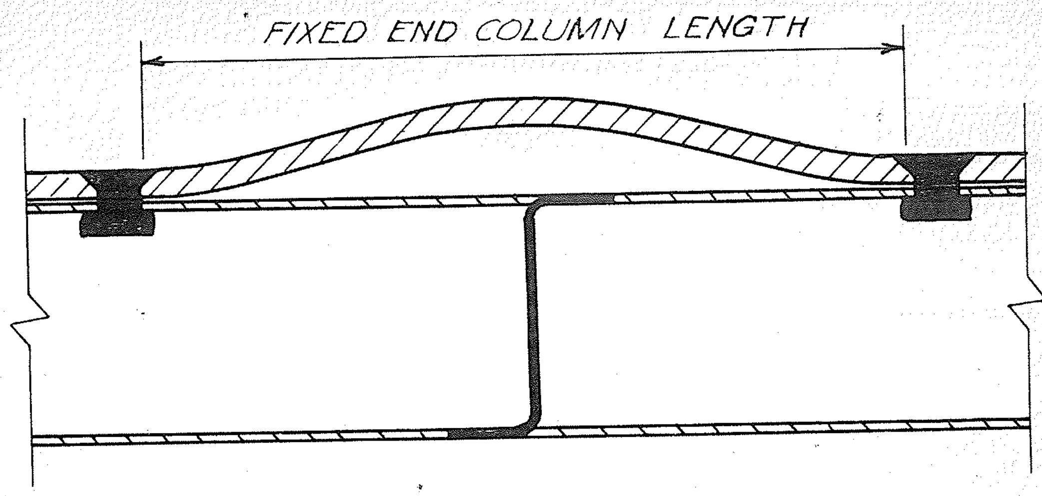
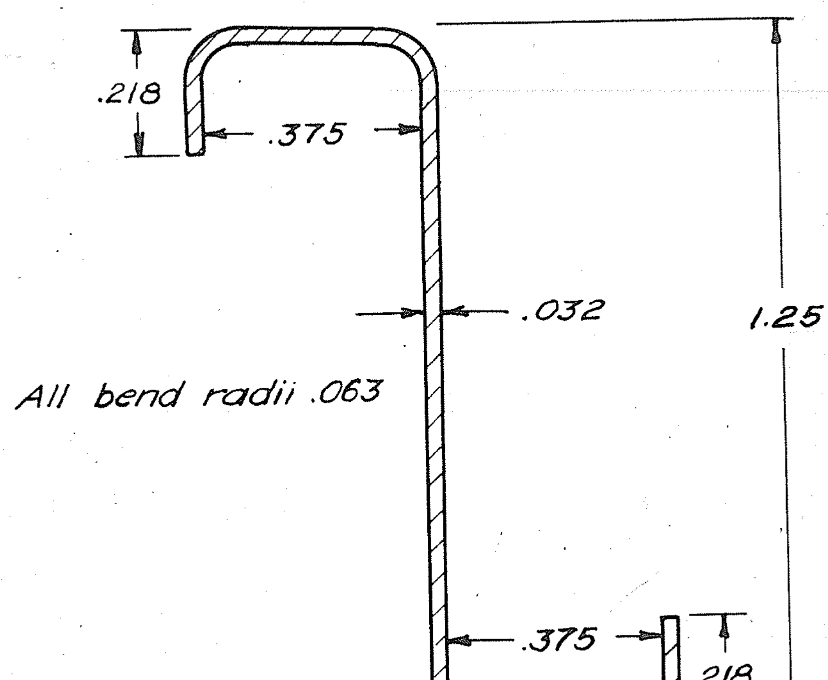



FIGURE 3




STIFFENER SECTION

FIGURE 4

Limitation of present investigation. Because of the large number of variables involved, it was decided to limit the investigation to one stringer size and form, a section of which is illustrated in Figure 4 on the previous page. All rivets used were 100° countersunk one-eighth inch diameter A17S-T rivets of one-quarter inch length, specified as AN-426-AD-4-4 by the aircraft industry. The sheets were of 24S-T Alclad material, all but a few being of .081 inch nominal thickness. The length of all sheets used in the panels tested was thirteen and one-half inches. The width varied between fifteen and seventeen inches. The stringer design was selected so as to conform with present design charts, and its form was purposely chosen to coincide closely with those used in other investigations so as to permit of easier comparison of test results. Test results for fifty-five panels are presented herein.

# CHAPTER III

## THEORETICAL CONSIDERATIONS

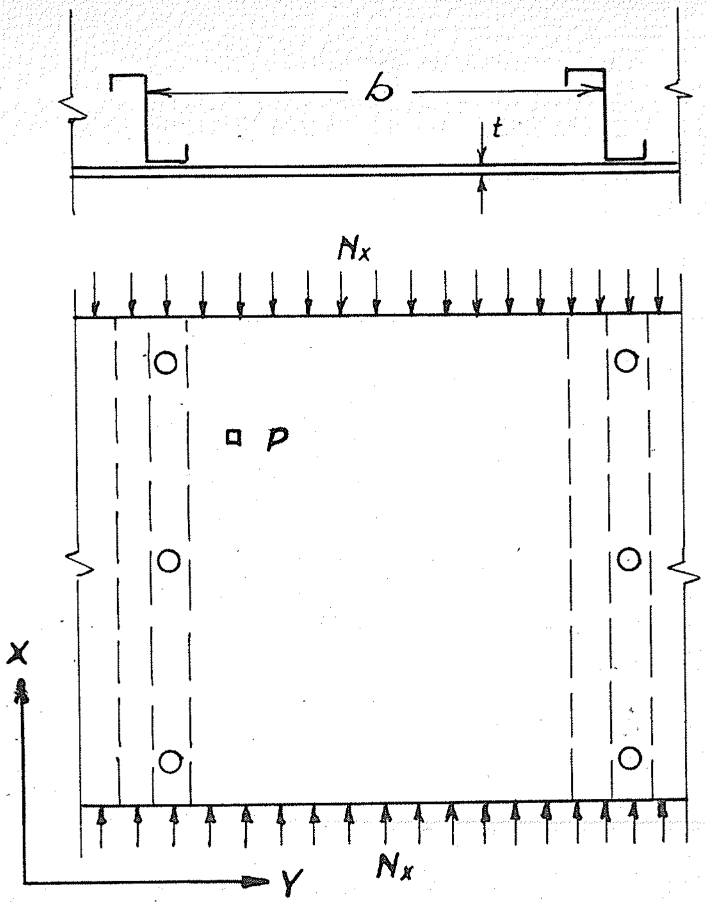
Although the approach to this problem was experimental with the principal aim of providing test results to be used in the construction of design charts, the effects of the variables may be better appreciated in the light of general thin plate theory.

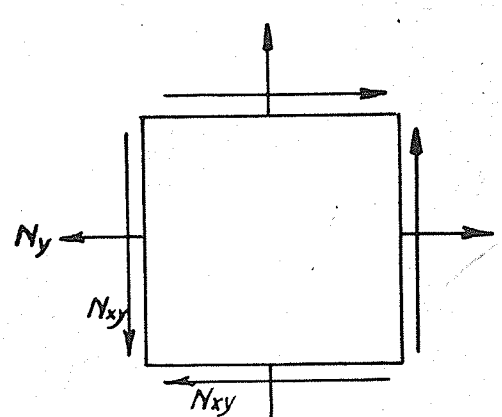
Small deflection theory. Referring to Figure 5, a thin plate having deflections, w, normal to its plane, of magnitude much less than the thickness, t, of the plate, and subjected to a force per unit width, Nx, applied in its plane, will be in equilibrium if the following relation is satisfied:

$$\nabla^4 w = \frac{Nx}{D} \cdot \frac{\partial^2 w}{\partial x^2} \qquad (1)^1$$

where $D = \frac{Et^3}{12(1-\nu^2)}$ the flexural rigidity. This relation is derived from the conditions of equilibrium of any element of the plate.

The axial load at which buckling of the plate occurs will be the smallest value of Nx which satisfies equation (1). The deflection, w, may be found directly as a solution of this equation and the critical value of Nx deduced. The deflection, w, must of course satisfy the boundary conditions at the edges of the plate. Energy, or variational methods may also be used to approximate the critical load. By any




ELEMENT OF PLATE, P
All stresses shown positive

**FIGURE 5**

one of these methods the critical load has been derived in the form[1]

$$Nx_{cr} = K_1 t \frac{\pi^2 E}{12(1-\nu^2)} (t/b)^2$$

where $\nu$ = Poisson's ratio and b is the width of the plate.

Or we may write this in the form

$$\sigma_{cr} = KE\ (t/b)^2 \tag{2}$$

where $\sigma_{cr}$ is the critical buckling stress.

At the edges of the plate, restraint against bending and torsion is provided by the stiffeners. The imposed conditions to be satisfied by the deflection, w, are of the form

$$D\left(\frac{\partial^2 w}{\partial x^2} + \nu \frac{\partial^2 w}{\partial y^2}\right) = C \frac{\partial^3 w}{\partial x^2 \partial y} \quad \text{for torsional restraint} \tag{3}$$ [2]

and $$D\left\{\frac{\partial^3 w}{\partial y^3} + (2-\nu)\frac{\partial^3 w}{\partial x^2 \partial y}\right\} - A\sigma_x \frac{\partial^2 w}{\partial x^2} = EI \frac{\partial^4 w}{\partial x^4} \tag{4}$$ [3]

for restraint against bending along the unloaded edge. In this expression $\sigma_x$ is the edge stress in the sheet, I the moment of inertia of the stiffener and C the torsional rigidity of the stiffener. Methods of calculating C for conventional stiffeners attached to plates are given by Lundquist and Stowell.[4] Solutions of equation (1) in the form (2) for the boundary conditions (3) and (4) have been found for several particular cases. It is common practice

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1 S. Timoshenko, Theory of Elastic Stability, page 337.
2 S. Timoshenko, Op. Cit., page 343.
3 S. Timoshenko, Op. Cit., page 346.
4 E. E. Lundquist and Stowell, Restraint Provided a Flat Rectangular Plate by a Sturdy Stiffener Along an Edge of the Plate. NACA TR Number 735, 1942.

to assume that the deflection $w = 0$ along all edges, but it is apparent that this procedure may introduce large errors on the unsafe side. Most theoretical and semi-empirical methods of design are based on solutions to these equations. As such they do not include the case of inter-rivet buckling since there is an implicit assumption that the plate remains in contact with, and fastened to, the stiffener continuously along its length.

Large deflection theory. Above the critical load equation (1) is not valid because it neglects membrane stresses which are not negligible when the deflection, w, is of the same order as the thickness, t.

For large deflections of the above type the expression

$$\nabla^4 w = \frac{1}{D}\left( N_x \frac{\partial^2 w}{\partial x^2} + 2 N_{xy} \frac{\partial^2 w}{\partial x \partial y} + N_y \frac{\partial^2 w}{\partial y^2} \right) \qquad (5)^5$$

must be satisfied. $N_x$, $N_y$, and $N_{xy}$, are direct and shear loads per lineal inch on elements of the sheet and depend not only on the external forces applied but also on the membrane stresses.

These stresses may be found by use of the Airy stress function. There is a function, F, such that

$$\sigma_x = \frac{\partial^2 F}{\partial y^2}$$
$$\sigma_y = \frac{\partial^2 F}{\partial x^2} \qquad (6)$$
$$\sigma_{xy} = -\frac{\partial^2 F}{\partial x \partial y}$$

From the large deflection compatibility of strains with the

5 S. Timoshenko, Theory of Elastic Stability, page 324.

above membrane stresses, it can be shown that

$$\nabla^4 F = E\left\{\left(\frac{\partial^2 w}{\partial x \partial y}\right)^2 - \frac{\partial^2 w}{\partial x^2} \cdot \frac{\partial^2 w}{\partial y^2}\right\} \qquad (7)^6$$

Functions F and w which satisfy equations (5), (6), and (7), have been determined for only a few practical cases, such as simply supported or clamped square, circular, and elliptical plates. For inter-rivet buckling the problem becomes non-linear to a high degree and therefore hopelessly complicated. In addition, isotropic material has been assumed in deriving the above equations, whereas aluminum alloys are definitely anisotropic, especially in the vicinity of the elastic limit.

In applying any of the equations (1) to (7) to the present case one has to face the difficult problem of mathematically expressing the boundary conditions imposed by the rivets. For example, with inter-rivet buckling, in alternate rivet spaces the sheet is in contact with the stiffener over one inter-rivet space, but in adjacent spaces it buckles away from the stiffener at some short distance from the rivet. This distance varies with the load on the panel, and therefore introduces a non-linear variation of the effective column length of the sheet between rivets. In some cases this has a pronounced effect on the buckling mode of the sheet. For example, the sheet may initially develop anti-symmetrical plate buckling. As the amplitude of the

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6 S. Timoshenko, Theory of Plates and Shells, page 343.

buckle increases the sheet may begin to buckle between rivets. Resulting membrane stresses modify the wave length and rivet restraint modifies the form of the initial buckle, which may eventually cause the plate buckling to be entirely replaced by inter-rivet buckling. This is well illustrated by Figures 76 and 77 of Panel 18 on page 111.

The analytic solution of the inter-rivet buckling problem is obviously not a simple one. An accurate knowledge of the manner in which buckling takes place would undoubtedly give material assistance to any one proposing to work on such a project. Data of this general nature have been collected for the present series of tests and are, in part, presented herein.

# CHAPTER IV

## LABORATORY TECHNIQUE

Construction of specimens. Material for all panels tested was 24S-T Alclad provided by MacDonald Brothers Aircraft Limited, Winnipeg. Sheet stock was inspected and culled for waviness, after which it was sheared and the stringers formed by the above company. One strip of one inch width was sheared from the stock adjacent to each panel for determination of physical constants. All panels and strips were numbered at this time for future identification.

Sheets and stringers were jig drilled for rivets and a series of five-sixteenth inch holes was provided in each end, for bond of the cerrobend caps. The rivet holes in the sheet were countersunk to a depth such that the rivet heads protruded about .005 inches from the sheet. Riveting of the stiffeners to the sheets was accomplished by assembling the unit under the head of the testing machine and loading an entire row of rivets simultaneously with a smooth steel bar. Heavy flat springs were used between the bar and stiffener to hold the stiffener and sheet in close contact while they were being riveted. A load of 1,900 pounds per rivet was found suitable and was used in all cases. By this means very uniform riveting was obtained leaving the sheet free from initial deformations which might have occurred if the rivets had been hand driven one by one.

After riveting, a cap three-quarters inch in thickness of a low melting alloy known as Cerrobend was cast at each end of the panel using a pouring temperature of 200°F. In order to reduce warping from thermal expansion, the panels were clamped between wooden blocks. In spite of this, a small amount of curvature was invariably introduced, the effect of which was probably negligible.

After capping, the panels were assembled in a fixture clamped to the table of a sixteen inch shaper and the ends were machined flat and parallel to within ± .001 inches.

Electrical resistance strain gauges were then cemented to sheet and stiffeners at desired locations using Duco cement. The locations used in most cases were the outstanding flanges of both the extreme and central stiffeners at mid-panel length, and at corresponding points on the outer surface of the sheet. Additional gauges were used in some instances for specific purposes to be mentioned later. The gauges were wired to a terminal block fastened to the cerrobend cap on the stiffener side of the panel. The outer sheet surface was then spray-painted with white Duco, and the rivets outlined with ink, making the panel complete and ready for testing.

Test equipment. The panels were tested in a 60,000 pound hydraulic testing machine accurate to within one-half of one per cent. To provide the necessary restraint against relative rotation of the panel ends, parallel platens, illustrated in Figure 6, were used. The surfaces of these platens were ground flat to within ± .001 inches. Supports, illustrated in Figure 7, were employed to prevent premature buckling at the panel edges. By clamping in these supports a strip of the sheet being tested, a clearance of .003 inches was maintained between the supports and the panel edge, providing a condition closely approximating that of simple support.

In the case of Panels 1 and 2, buckling of the sheet between rivets was measured with the dial gauge assembly shown in Figure 8, the fixed points being placed on the sheet adjacent to a pair of rivets. The instrument was initially adjusted by placing it on a surface plate and rotating the bezel until zero reading was obtained.

In all subsequent tests the deflection surfaces of the panels were recorded by means of the photo-grid method, shown in Figure 9. In this method, a grid of parallel black threads, accurately spaced in a plane parallel to the panel surface, is placed as indicated. An arc lamp and condensing lens illuminated the panel and grid. Shadows of the threads were thus cast upon the panel. A camera photographed both the threads and their shadows from the position shown in the sketch. The relative spacing of lamp, grid, and panel, were chosen so that shadows at one-quarter inch spacing were

PARALLEL PLATENS

Showing assembly of platens, test panel and edge supports.

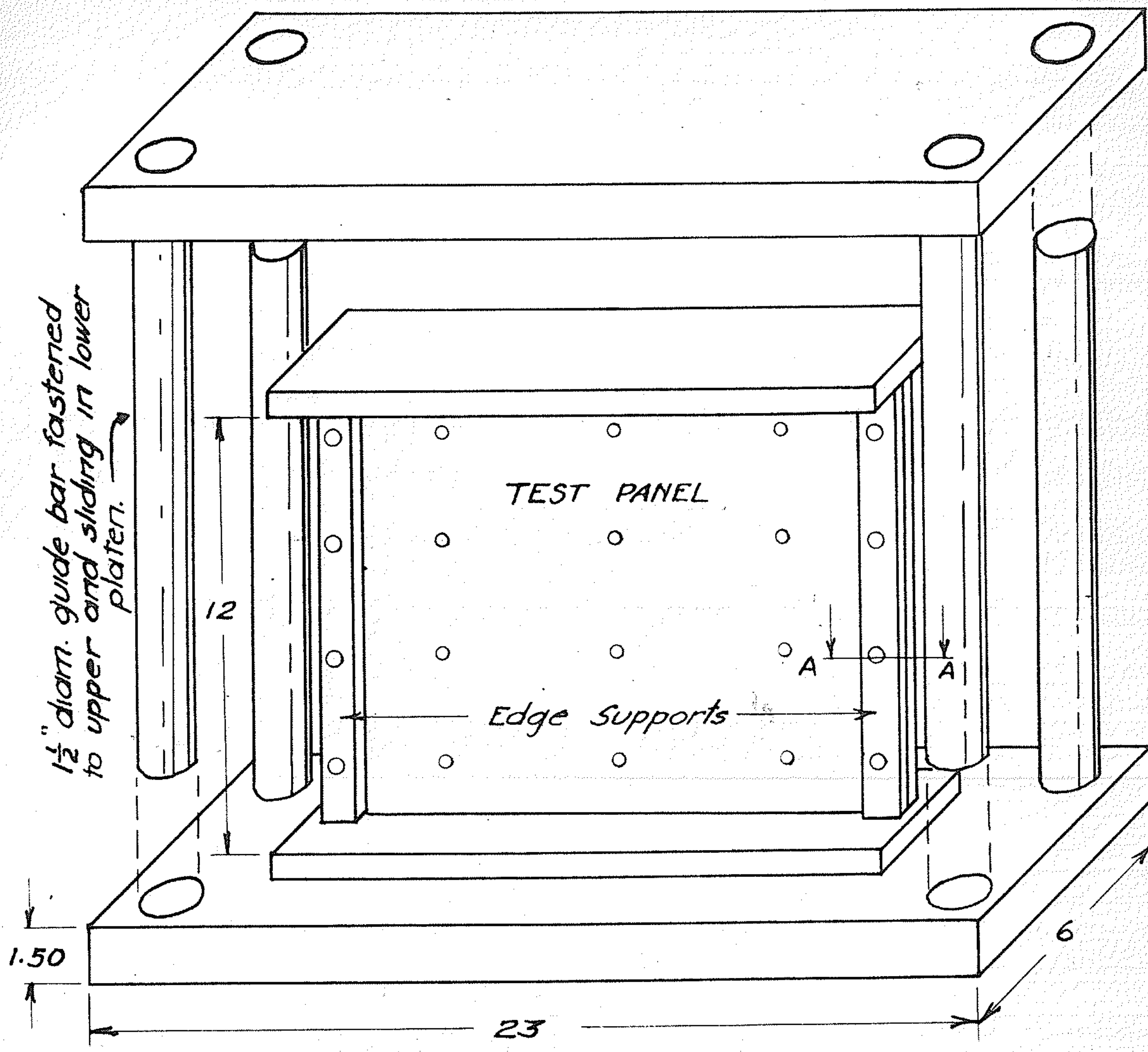
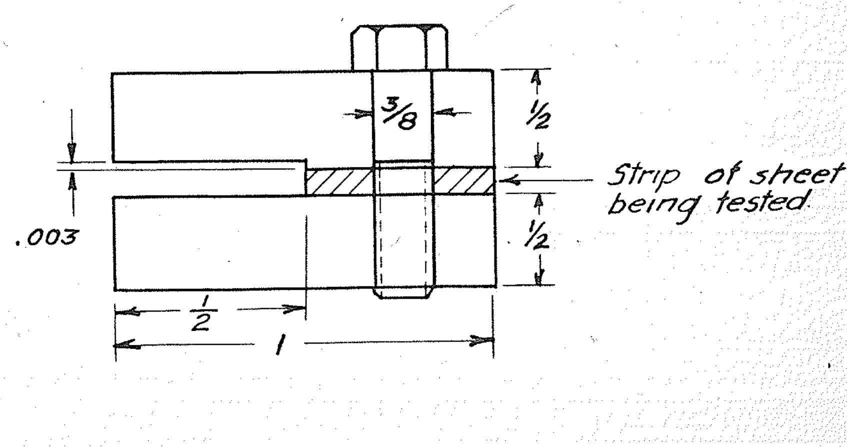



FIGURE 6

SECTION A-A THROUGH EDGE SUPPORT

FIGURE 7



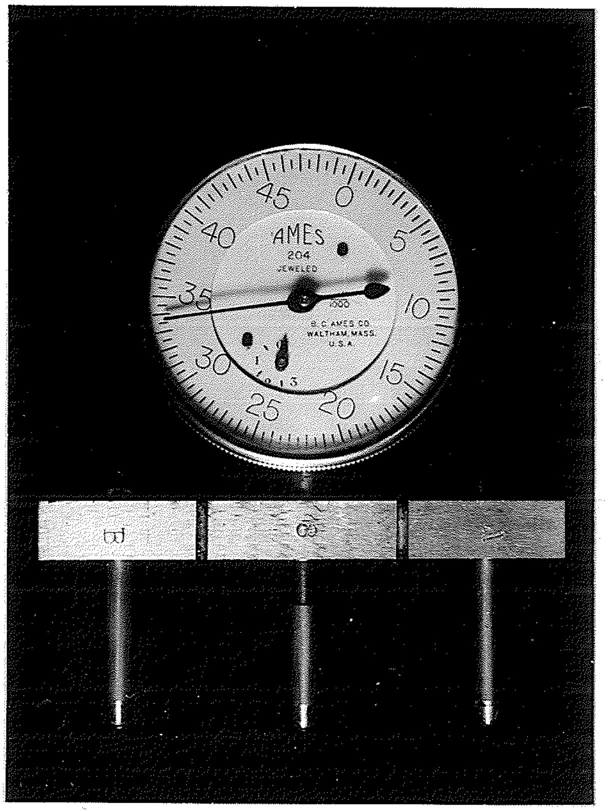



Figure 8.— Dial gauge used for measurement of inter-rivet buckle displacement.

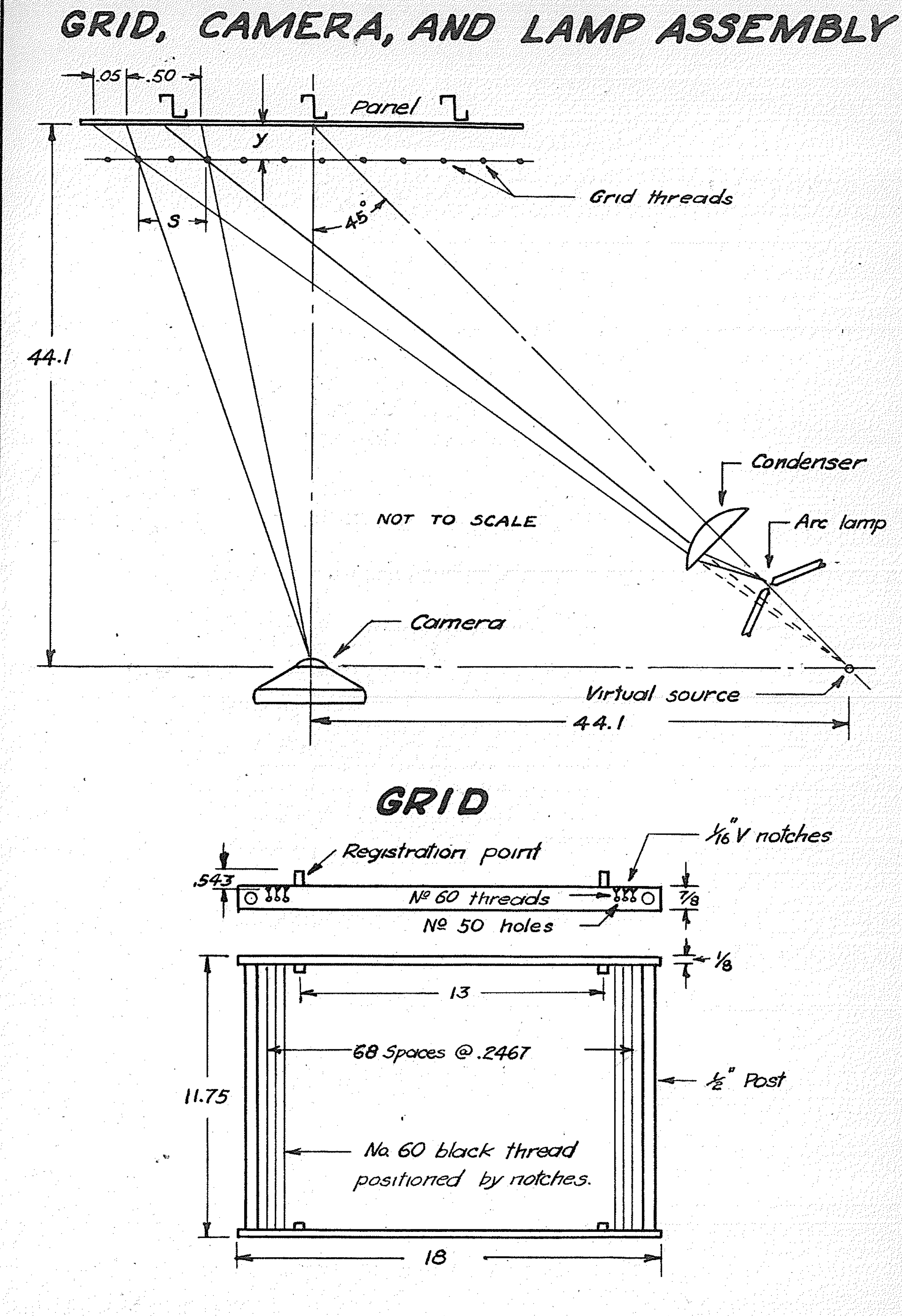



FIGURE 9 PHOTO-GRID EQUIPMENT

produced on a perfectly flat panel. Viewed from the camera location, the shadows were displaced one-twentieth inch to the left of the threads. Any deformation of the panel towards the grid resulted in an equal movement of the shadows to the right, and vice versa. A single photograph thus recorded the buckled form of the entire panel at any desired load. Deflections of the sheet at any point were subsequently determined by measurement of the shadow displacement recorded on the film. In the present investigation a thirty-five millimeter camera loaded with micro-file film was employed, and measurements of the negatives were accomplished with a microscope, using a thirty-two millimeter objective and a filar micrometer eyepiece. By suitable choice of camera and lamp positions, a calibration factor of .002 inches deflection per micrometer division was obtained. The actual dimensions used are indicated in Figure 9. Calculation of these distances is included in Chapter VI.

Considering the small size of the image on the film, which was less than one-twentieth of the panel size, the accuracy and sensitivity of the method was amazing. Panel deflections of .001 inches could be detected easily. The results of a calibration test of this equipment are given on page 30.

In some cases, dial gauges were used at the four corners of the platens to measure the over all compression strain of the panel. In one case, the lateral movement of the top platen relative to the lower one was also measured with a dial gauge to check the fixity of the entire loading assembly.

The electrical resistance strain gauges used were connected to a Baldwin Type K Strain Indicator through a twenty point switching and balancing unit constructed for this particular project.

Tension and compression test specimens from sheet and stiffener stock were tested in a 10,000 pound Tinius Olsen testing machine, accurate to less than one-half of one per-cent. Strain readings were made with a pair of Tuckerman strain gauges having a certified accuracy of one-tenth of one per cent, and a reading sensitivity of two micro-inches on a one inch gauge length. The Tuckerman gauge is well described by B. L. Wilson, National Bureau of Standards, Washington.[1] Compression tests of the sheet stock were accomplished with the use of a guiding fixture constructed especially for the work. The design of the fixture was substantially in accordance with one developed by the U. S. National Bureau of Standards.[2] The device, with specimen and strain gauges attached, is shown in Figure 10.

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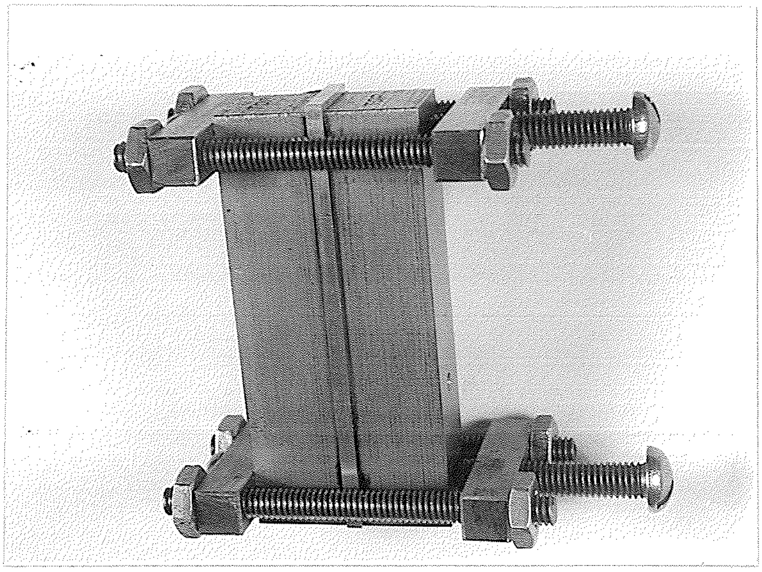
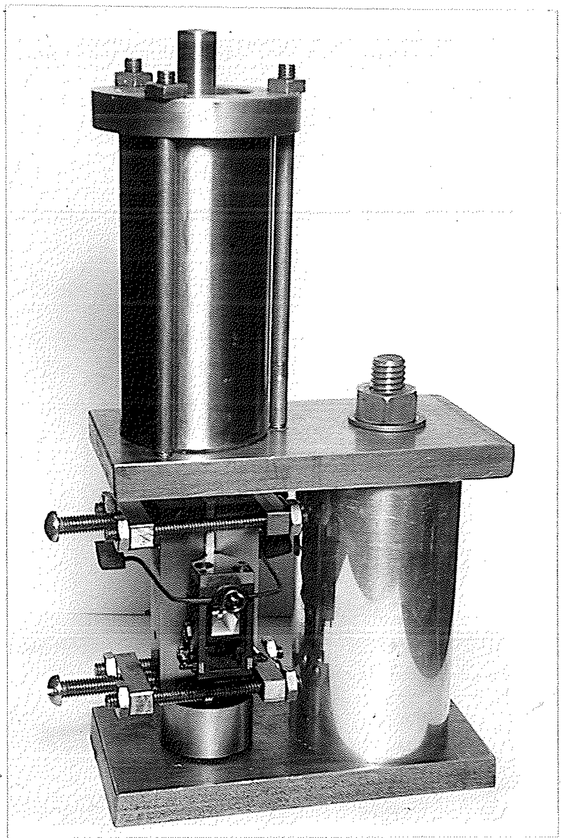
1 B. L. Wilson, Characteristics of the Tuckerman Strain Gage, ASTM Proceedings, volume 44, 1944, page 1017.
2 Op. Cit., page 683.



Specimen supported in compression testing guide.



Specimen, guide, and Tuckerman gauges, assembled in subpress ready for test.

FIGURE 10

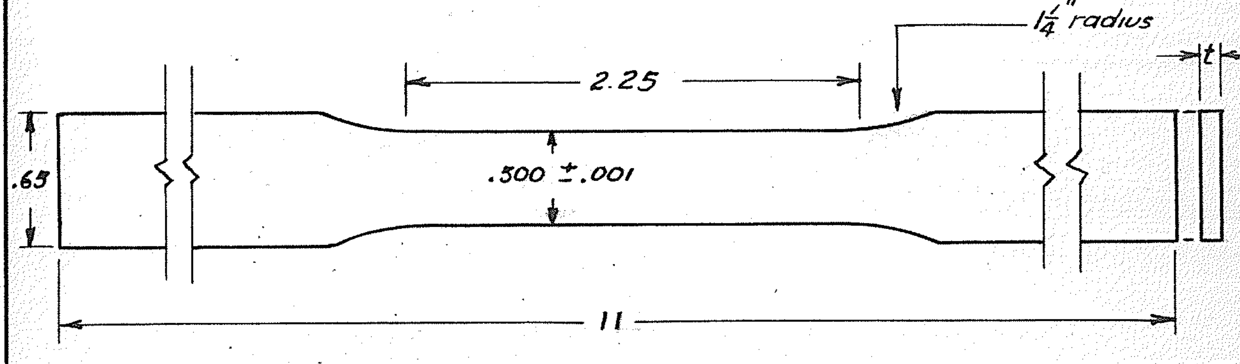
Test procedure. In general, the following sequence of operations was performed in testing a completed panel. The panel ends were first carefully cleaned and lightly scraped to remove accidental burrs or foreign matter adhering to them. The platens were then placed around the panel and the edge supports assembled, after which the entire assembly was centred in the testing machine. The electrical strain gauges were then connected, balanced to a predetermined initial reading and an initial load of 2,000 pounds was applied to the panel through a spherical loading head. Strain gauge readings were recorded at this load and at loads of 4,000 and 6,000 pounds. At loads of these magnitudes the strain readings should have indicated a condition of pure compression; that is, all strain readings should have been identical. Some adjustment of the panel laterally or front to back was usually necessary before uniform strain readings over this range of load were closely approached. When a satisfactory condition of uniform loading was attained, the photo-grid was fastened to the panel with rubber bands and the test proper was started. Strain readings, dial gauge readings, and photographs, were taken at 2,000 pound increments or less until the panel failed. The failing load and any peculiarities noticed during the test were recorded. After developing the film, the displacements of the sheet between rivets and occasionally at other points, were measured using the micrometer eyepiece of the microscope.

Standard procedure was followed in testing the tension and compression samples for determining physical properties of the sheet. The specimen dimensions for these tests are shown in Figure 11.

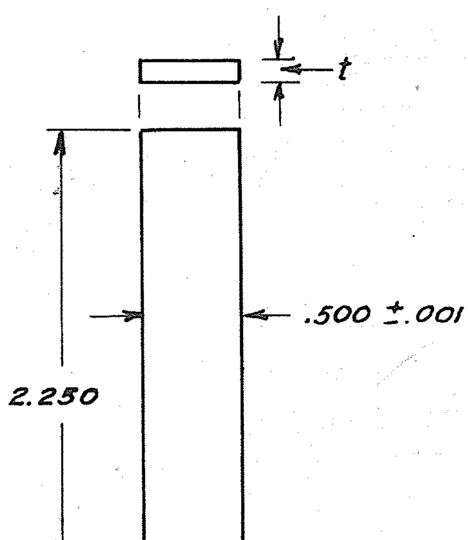
Suitability of laboratory methods. The test equipment and laboratory technique which have been described were carefully thought out and thoroughly checked before actual testing of panels was begun. Considerable time, skill, and care, were required in the preparation of test specimens. For this reason alone, a procedure of testing which would adequately and consistently produce all the necessary data was absolutely necessary in order to avoid waste of time and material in the event of unsatisfactory behaviour of equipment during an actual test.

No difficulty resulting in invalidation of the test data was encountered in any test with any of the equipment. It can therefore be said, without question, that the equipment and technique used were entirely satisfactory at all times. The wealth of data accumulated, part of which is given in Chapter V is a confirmation of this statement.

## TENSION SPECIMEN




## COMPRESSION SPECIMEN




Ends to be flat, square, and parallel within ±.0001"

FIGURE 11 CONTROL SAMPLES

# CHAPTER V

## RECORDED TEST DATA

Organization of material. As many as possible of the experimental test data are presented in this chapter, including a calibration check of the photo-grid equipment. Strain readings of the electrical resistance gauges, as well as dial gauge readings, are given in tabular form, so that future investigators may use them directly for various determinations not included in the present work. Results of tension and compression tests of the sheet stock are given in graphical form. Because of the very large number of displacement readings from photo-grid measurements, these have been omitted, and this phase of the work is covered by only a few examples presented graphically. It is intended to file the micro-file film records along with this thesis so that a complete record of data will be available to any one interested.

Photo-grid calibration. The photo-grid equipment was calibrated by photographing a spray-painted sheet of plate glass in place of the usual test panel. Glass was used because of its superior surface flatness and rigidity. Shims of various thicknesses were placed under the grid registration points to displace it definite amounts from glass surface. Photographs were taken with each set of shims in place, and without any shims. The shim thickness was then computed from measurements on the film negatives and compared with the actual values obtained by direct measurement. In addition, the grid spacing was determined and compared with the theoretical spacing. Film measurements were made at five points in each case. The results obtained are given in Table I.

TABLE I

CALIBRATION OF PHOTO-GRID EQUIPMENT

| Point | Readings for shims in inches | | |
|---|---|---|---|
| | No. 1 | No. 2 | No. 3 |
| 1 | .0135 | .0355 | .0025 |
| 2 | .0137 | .0357 | .0032 |
| 3 | .0153 | .0358 | .0038 |
| 4 | .0157 | .0357 | .0042 |
| 5 | .0143 | .0373 | .0053 |
| Mean Reading . . . | .0145 | .0360 | .0038 |
| Actual Value . . . | .0138 | .0343 | .0038 |

It can be seen from the above Table that the accuracy of grid measurements is of the order of .001 inches.

A check of the grid spacing at five points gave a mean reading of 0.249 inches compared with a theoretical value of 0.250 inches.

<u>Strain and dial gauge readings</u>. Tables II to LVI contain the electrical resistance strain gauge and dial gauge readings, and dimensions of each panel tested. The gauge positions are given by reference to the appropriate sketch shown in Figure 12. Terminology for panel dimensions is as follows:

t = sheet thickness
L = rivet pitch
b = stiffener pitch
W = panel width
N = number of stiffeners

All dimensions are given in inches, loads in pounds, strain gauge readings in micro-inches per inch, and dial gauge readings in inches. The strain gauges are designated by number and dial gauges by lower case letters.

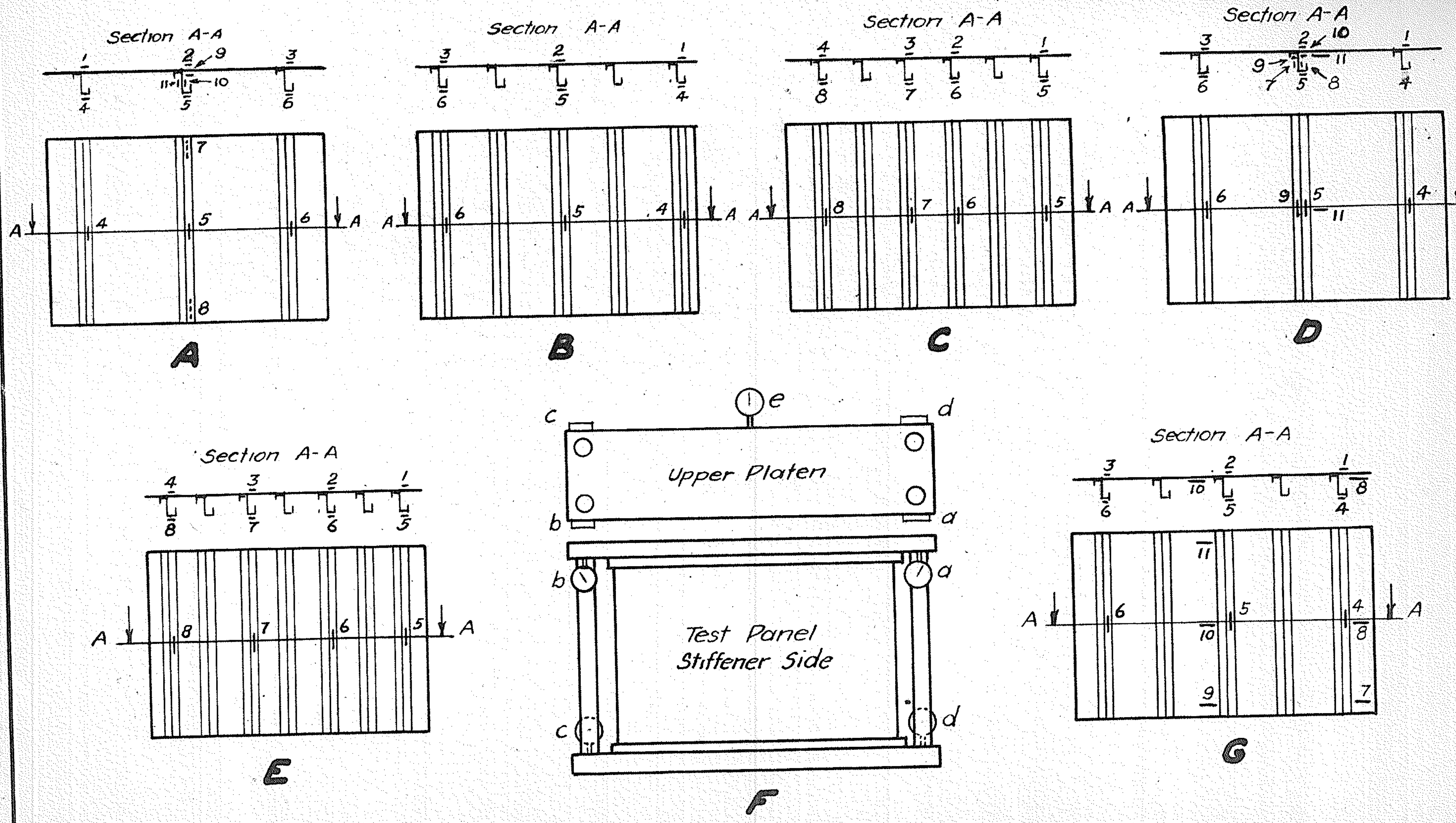



FIGURE 12 ARRANGEMENTS OF STRAIN GAUGES AND DIALS

# TABLE II

## STRAIN READINGS FOR PANEL 1

t = .0830 in. L = 2.00 in. b = 4.00 in.
W = 16 in. N = 3

Gauge arrangement A, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 118 | 117 | 120 | 107 | 131 | 124 | 77 | 128 | 120 | 124 | 126 |
| 4000 | 246 | 239 | 241 | 222 | 258 | 227 | 167 | 248 | 243 | 250 | 253 |
| 6000 | 363 | 357 | 360 | 332 | 384 | 342 | 254 | 366 | 362 | 367 | 378 |
| 8000 | 487 | 478 | 475 | 447 | 514 | 474 | 358 | 479 | 488 | 494 | 506 |
| 10000 | 620 | 617 | 599 | 590 | 666 | 621 | 480 | 606 | 620 | 632 | 648 |
| 12000 | 753 | 749 | 715 | 734 | 811 | 770 | 588 | 726 | 748 | 762 | 788 |
| 14000 | 891 | 881 | 832 | 882 | 960 | 912 | 703 | 848 | 879 | 895 | 928 |
| 16000 | 1030 | 1015 | 942 | 1015 | 1091 | 1023 | 820 | 970 | 1007 | 1021 | 1071 |
| 18000 | 1176 | 1152 | 1043 | 1143 | 1215 | 1147 | 942 | 1095 | 1137 | 1146 | 1213 |
| 20000 | 1328 | 1287 | 1132 | 1277 | 1356 | 1304 | 1060 | 1222 | 1270 | 1271 | 1360 |
| 22000 | 1498 | 1420 | 1212 | 1411 | 1508 | 1450 | 1172 | 1351 | 1402 | 1387 | 1520 |
| 24000 | 1748 | 1542 | 1322 | 1527 | 1671 | 1634 | 1262 | 1496 | 1563 | 1481 | 1713 |
| 24650 | Ultimate load | | | | | | | | | | |

TABLE III

STRAIN READING FOR PANEL 2

t = .0820 in. L = 2.50 in. b = 2.50 in.
W = 15 in. N = 5

Gauge arrangement B, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 94 | 106 | 107 | 130 | 148 | 153 |
| 4000 | 212 | 240 | 228 | 245 | 262 | 260 |
| 6000 | 332 | 362 | 343 | 365 | 382 | 373 |
| 8000 | 441 | 492 | 456 | 477 | 494 | 500 |
| 10000 | 554 | 620 | 568 | 590 | 610 | 600 |
| 12000 | 674 | 722 | 673 | 703 | 730 | 705 |
| 14000 | 782 | 832 | 776 | 815 | 850 | 817 |
| 16000 | 887 | 960 | 880 | 935 | 970 | 915 |
| 18000 | 977 | 1075 | 973 | 1060 | 1090 | 1020 |
| 20000 | 1074 | 1138 | 1046 | 1160 | 1202 | 1113 |
| 22000 | 1132 | 1130 | 1100 | 1283 | 1330 | 1217 |
| 24000 | 1132 | 950 | 1104 | 1430 | 1478 | 1350 |
| 25000 | 1084 | 745 | 1070 | 1505 | 1565 | 1420 |
| 26000 | 902 | 252 | 970 | 1575 | 1692 | 1500 |
| 26500 | 512 | -458 | 800 | 1663 | 1849 | 1587 |
| 26700 | 260 | -1152 | 608 | 1720 | 1990 | 1667 |
| 27000 | -1353[a] | -2875 | -182 | 1997 | 2548 | 2003 |
| 27500 | -1413 | -3625 | -812 | 2293 | 3015 | 2295 |
| 28000 | -3450 | -4445 | -1487 | 2605 | 3528 | 2610 |
| 28500 | -4113 | -4901 | -1992 | 2855 | 4110 | 2910 |
| 29000 | -5103 | -5720 | -3022 | 3625 | 6035 | 3665 |
| 29300 | Ultimate load | | | | | |

a Negative readings indicate tension strains.

# TABLE IV

## STRAIN READING FOR PANEL 3

t = .0830 in. L = 2.00 in. b = 3.20 in.
W = 16 in. N = 4

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 108 | 114 | 108 | 103 | 119 | 130 | 120 | 124 |
| 4000 | 234 | 241 | 235 | 214 | 219 | 244 | 250 | 248 |
| 6000 | 348 | 371 | 358 | 318 | 330 | 374 | 384 | 369 |
| 8000 | 467 | 495 | 480 | 421 | 443 | 503 | 512 | 481 |
| 10000 | 586 | 616 | 603 | 523 | 557 | 626 | 637 | 591 |
| 12000 | 709 | 744 | 732 | 628 | 677 | 758 | 767 | 709 |
| 14000 | 821 | 860 | 854 | 728 | 794 | 886 | 893 | 817 |
| 16000 | 939 | 981 | 982 | 828 | 914 | 1022 | 1023 | 934 |
| 18000 | 1055 | 1097 | 1104 | 928 | 1034 | 1155 | 1162 | 1057 |
| 20000 | 1166 | 1205 | 1222 | 1018 | 1159 | 1292 | 1302 | 1179 |
| 22000 | 1257 | 1297 | 1320 | 1090 | 1278 | 1426 | 1442 | 1300 |
| 24000 | 1334 | 1347 | 1385 | 1138 | 1409 | 1574 | 1590 | 1428 |
| 26000 | 1336 | 1245 | 1307 | 1107 | 1560 | 1753 | 1766 | 1569 |
| 27000 | 1186 | 859 | 990 | 973 | 1679 | 1903 | 1900 | 1654 |
| 27500 | Ultimate Load | | | | | | | |

# TABLE V

## STRAIN READING FOR PANEL 4

t = .0830 in. L = 2.50 in. b = 4.00 in.
W = 16 in. N = 3

Gauge arrangement B, Figure 12

| Load | Gauge readings in micro-inches per inch | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5000 | 268 | 248 | 230 | 215 | 192 | 120 |
| 10000 | 570 | 528 | 502 | 540 | 520 | 386 |
| 15000 | 795 | 713 | 730 | 875 | 863 | 671 |
| 17000 | 760 | 723 | 770 | 1025 | 1017 | 796 |
| 18000 | 650 | 540 | 740 | 1125 | 1123 | 861 |
| 19000 | 390 | 163 | 620 | 1565 | 1270 | 951 |
| 20000 | -300[a] | -942 | 75 | 1865 | 1615 | --- |
| 23360 | Ultimate Load | | | | | |

a Negative readings indicate tension strains

# TABLE VI

## STRAIN READING FOR PANEL 5

t = .0810 in. L = 3.00 in. b = 2.50 in.
W = 15 in. N = 5

Gauge arrangement D, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 46 | 50 | 63 | 70 | 70 | 65 | 45 | 60 | 45 | 48 | -10 |
| 3000 | 101 | 105 | 130 | 130 | 140 | 120 | 100 | 110 | 95 | 108 | 0 |
| 4000 | 141 | 160 | 185 | 180 | 188 | 165 | 155 | 160 | 140 | 170 | -30 |
| 5000 | 188 | 215 | 250 | 232 | 228 | 205 | 219 | 205 | 175 | 223 | -48 |
| 6000 | 221 | 270 | 300 | 280 | 270 | 245 | 273 | 255 | 220 | 278 | -60 |
| 7000 | 271 | 332 | 363 | 340 | 332 | 295 | 335 | 315 | 272 | 333 | -71 |
| 8000 | 314 | 395 | 420 | 395 | 392 | 345 | 387 | 375 | 322 | 398 | -90 |
| 9000 | 356 | 455 | 475 | 448 | 470 | 390 | 440 | 430 | 375 | 463 | -110 |
| 10000 | 396 | 515 | 530 | 500 | 540 | 440 | 500 | 485 | 425 | 526 | -115 |
| 11000 | 436 | 550 | 590 | 555 | 630 | 490 | 560 | 545 | 475 | 590 | -132 |
| 12000 | 471 | 640 | 640 | 605 | 690 | 535 | 615 | 595 | 525 | 648 | -150 |
| 13000 | 514 | 700 | 695 | 655 | 730 | 583 | 665 | 655 | 576 | 718 | -180 |
| 14000 | 551 | 765 | 745 | 705 | 770 | 630 | 723 | 710 | 620 | 778 | -208 |
| 15000 | 591 | 830 | 800 | 755 | 800 | 675 | 785 | 765 | 670 | 848 | -235 |
| 16000 | 626 | 890 | 850 | 803 | 848 | 725 | 840 | 820 | 722 | 913 | -262 |
| 17000 | 656 | 945 | 895 | 850 | 920 | 773 | 895 | 875 | 780 | 976 | -282 |
| 18000 | 701 | 1010 | 945 | 905 | 985 | 822 | 945 | 935 | 832 | 1043 | -302 |
| 19000 | 731 | 1070 | 987 | 955 | 1070 | 870 | 1000 | 988 | 885 | 1113 | -320 |
| 20000 | 766 | 1135 | 1025 | 1010 | 1128 | 917 | 1040 | 1045 | 935 | 1178 | -340 |
| 21000 | 791 | 1185 | 1057 | 1065 | 1180 | 967 | 1125 | 1100 | 990 | 1248 | -362 |
| 22000 | 804 | 1240 | 1077 | 1107 | 1215 | 1012 | 1167 | 1155 | 1040 | 1316 | -382 |
| 23000 | 796 | 1295 | 1090 | 1160 | 1260 | 1059 | 1230 | 1205 | 1098 | 1391 | -407 |
| 24000 | 761 | 1345 | 1087 | 1210 | 1302 | 1107 | 1275 | 1255 | 1145 | 1461 | -432 |
| 25000 | 661 | 1390 | 1065 | 1265 | 1378 | 1157 | 1325 | 1308 | 1215 | 1546 | -467 |
| 29780 | Ultimate | Load | | | | | | | | | |

TABLE VII

STRAIN READING FOR PANEL 6

t = .0820 in. L = 2.00 in. b = 2.14 in.
W = 15 in. N = 6
Gauge arrangement E, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 108 | 107 | 100 | 98 | 114 | 108 | 101 | 128 | 90 | 150 | 128 | 105 | 96 | 82 |
| 4000 | 215 | 223 | 212 | 203 | 239 | 215 | 201 | 228 | 189 | 267 | 246 | 223 | 176 | 210 |
| 6000 | 322 | 339 | 332 | 310 | 363 | 345 | 316 | 313 | 284 | 393 | 358 | 325 | 238 | 331 |
| 8000 | 422 | 455 | 445 | 413 | 479 | 462 | 436 | 400 | 378 | 510 | 467 | 430 | 296 | 449 |
| 10000 | 532 | 573 | 540 | 518 | 589 | 576 | 557 | 499 | 470 | 633 | 580 | 545 | 358 | 562 |
| 12000 | 640 | 679 | 632 | 616 | 711 | 693 | 687 | 605 | 558 | 751 | 698 | 655 | 413 | 669 |
| 14000 | 754 | 785 | 715 | 715 | 837 | 813 | 818 | 716 | 650 | 871 | 820 | 777 | 473 | 782 |
| 16000 | 867 | 905 | 820 | 814 | 969 | 931 | 944 | 813 | 738 | 981 | 942 | 893 | 523 | 885 |
| 18000 | 974 | 1012 | 925 | 906 | 1089 | 1054 | 1079 | 9906 | 827 | 1103 | 1076 | 1015 | 569 | 992 |
| 20000 | 1054 | 1143 | 1036 | 1008 | 1214 | 1171 | 1207 | 1002 | 915 | 1216 | 1206 | 1137 | 618 | 1094 |
| 22000 | 1130 | 1265 | 1152 | 1106 | 1341 | 1294 | 1335 | 1106 | 1004 | 1333 | 1340 | 1260 | 663 | 1198 |
| 24000 | 1232 | 1393 | 1258 | 1206 | 1461 | 1414 | 1459 | 1216 | 1090 | 1446 | 1583 | 1380 | 713 | 1295 |
| 26000 | 1321 | 1499 | 1355 | 1298 | 1584 | 1526 | 1557 | 1310 | 1168 | 1546 | 1728 | 1495 | 733 | 1385 |
| 27000 | 1364 | 1557 | 1415 | 1346 | 1646 | 1579 | 1607 | 1363 | 1205 | 1598 | 1798 | 1550 | 750 | 1432 |
| 28000 | 1417 | 1635 | 1480 | 1404 | 1719 | 1649 | 1667 | 1426 | 1254 | 1661 | 1893 | 1620 | 773 | 1490 |
| 29000 | 1467 | 1695 | 1515 | 1444 | 1774 | 1689 | 1703 | 1468 | 1289 | 1708 | 1960 | 1667 | 790 | 1532 |
| 30000 | 1499 | 1784 | 1562 | 1500 | 1837 | 1746 | 1756 | 1525 | 1332 | 1786 | 2040 | 1730 | 816 | 1587 |
| 31000 | 1557 | 1883 | 1604 | 1558 | 1904 | 1804 | 1807 | 1577 | 1375 | 1824 | 2113 | 1787 | 838 | 1643 |
| 32000 | 1622 | 1985 | 1597 | 1616 | 1967 | 1871 | 1859 | 1636 | 1420 | 1890 | 2203 | 1847 | 866 | 1695 |
| 33000 | 1704 | 2104 | 1692 | 1674 | 2038 | 1912 | 1901 | 1680 | 1454 | 1936 | 2268 | 1887 | 872 | 1731 |
| 34000 | 1799 | 2255 | 1818 | 1743 | 2089 | 1963 | 1944 | 1735 | 1494 | 1995 | 2315 | 1929 | 893 | 1782 |
| 35000 | 1912 | 2370 | 1885 | 1825 | 2149 | 2001 | 1977 | 1788 | 1532 | 2053 | 2396 | 1970 | 918 | 1852 |
| 36000 | 2027 | 2465 | 1932 | 1976 | 2189 | 2034 | 1989 | 1852 | 1580 | 2141 | 2466 | 2015 | 923 | 1892 |
| 36120 | Ultimate load | | | | | | | | | | | | | |

TABLE VIII

STRAIN READING FOR PANEL 7

t = .0800 in. L = 2.00 in. b = 2.50 in.
W = 15 in. N = 5

Gauge arrangement B, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 115 | 115 | 85 | 78 | 102 |
| 4000 | 240 | 230 | 204 | 206 | 210 |
| 6000 | 370 | 330 | 325 | 333 | 322 |
| 8000 | 495 | 430 | 435 | 458 | 444 |
| 10000 | 598 | 518 | 560 | 586 | 560 |
| 12000 | 724 | 614 | 695 | 718 | 679 |
| 14000 | 848 | 714 | 825 | 848 | 790 |
| 16000 | 980 | 807 | 860 | 988 | 905 |
| 18000 | 1120 | 880 | 905 | 1120 | 1020 |
| 20000 | 1250 | 932 | 1030 | 1253 | 1127 |
| 22000 | 1382 | 980 | 1160 | 1388 | 1238 |
| 24000 | 1522 | 1012 | 1285 | 1516 | 1340 |
| 26000 | 1655 | 962 | 1415 | 1652 | 1452 |
| 28000 | 1795 | 864 | 1540 | 1790 | 1560 |
| 30000 | 1955 | 871 | 1657 | 1910 | 1657 |
| 32000 | 2210 | 1046 | 1755 | 2003 | 1765 |
| 33200 | Ultimate load | | | | |

TABLE IX

STRAIN READINGS FOR PANEL 8

t = .0665 in. L = 1.50 in. b = 3.20 in.
W = 16 in. N = 4

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3000 | 142 | 143 | 141 | 140 | 139 | 142 | 146 | 150 |
| 5000 | 288 | 288 | 282 | 280 | 289 | 282 | 284 | 292 |
| 7000 | 432 | 440 | 430 | 417 | 420 | 421 | 426 | 410 |
| 9000 | 578 | 603 | 582 | 552 | 557 | 566 | 571 | 547 |
| 11000 | 722 | 776 | 722 | 688 | 696 | 702 | 712 | 680 |
| 13000 | 873 | 898 | 837 | 827 | 844 | 817 | 861 | 835 |
| 15000 | 1011 | 1043 | 940 | 957 | 989 | 944 | 1010 | 985 |
| 17000 | 1160 | 1140 | 1057 | 1090 | 1116 | 1082 | 1165 | 1141 |
| 19000 | 1305 | 1258 | 1131 | 1220 | 1256 | 1222 | 1327 | 1300 |
| 20000 | 1385 | 1318 | 1254 | 1288 | 1322 | 1295 | 1405 | 1380 |
| 21000 | 1455 | 1340 | 1263 | 1358 | 1385 | 1377 | 1494 | 1462 |
| 22000 | 1558 | 1288 | 1253 | 1499 | 1546 | 1483 | 1605 | 1555 |
| 26050 | Ultimate load | | | | | | | |

# TABLE X

## STRAIN READINGS FOR PANEL 9

t = .064 in. L = 2.00 in. b = 3.2 in.
W = 16 in. N = 4

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3000 | 136 | 132 | 144 | 158 | 139 | 138 | 114 | 110 |
| 5000 | 272 | 269 | 288 | 310 | 283 | 275 | 246 | 246 |
| 7000 | 409 | 403 | 428 | 458 | 424 | 411 | 376 | 401 |
| 9000 | 545 | 542 | 569 | 608 | 570 | 548 | 480 | 558 |
| 11000 | 475 | 678 | 710 | 758 | 707 | 682 | 601 | 712 |
| 13000 | 810 | 825 | 870 | 923 | 854 | 820 | 737 | 878 |
| 15000 | 960 | 997 | 1053 | 1108 | 1006 | 969 | 882 | 1045 |
| 17000 | 1140 | 1133 | 1198 | 1238 | 1148 | 1106 | 1014 | 1200 |
| 18000 | 1288 | 1336 | 1412 | 1443 | 1223 | 1176 | 1079 | 1270 |
| 19000 | 1560 | 1646 | 1703 | 1708 | 1285 | 1242 | 1134 | 1340 |
| 20000 | 1880 | 2018 | 2063 | 2113 | 1373 | 1337 | 1220 | 1430 |
| 23075 | Ultimate load | | | | | | | |

TABLE XI

STRAIN READINGS FOR PANEL 10

t = .0650 in. L = 2.50 in. b = 3.20 in.
W = 16 in. N = 4

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3000 | 132 | 141 | 141 | 154 | 123 | 117 | 109 | 113 |
| 5000 | 262 | 273 | 273 | 295 | 253 | 245 | 228 | 233 |
| 7000 | 362 | 401 | 407 | 425 | 386 | 375 | 356 | 473 |
| 9000 | 440 | 520 | 525 | 552 | 516 | 487 | 471 | 613 |
| 11000 | 471 | 609 | 615 | 652 | 645 | 601 | 608 | 755 |
| 13000 | 452 | 608 | 611 | 684 | 781 | 732 | 751 | 906 |
| 14000 | 400 | 512 | 506 | 615 | 851 | 805 | 827 | 985 |
| 15000 | | | | | 935 | 895 | 921 | 1080 |
| 16000 | | | | | 1049 | 1034 | 1051 | 1197 |
| 17000 | | | | | 1226 | 1237 | 1241 | 1387 |
| 18000 | | | | | 1431 | 1485 | 1481 | 1630 |
| 19000 | | | | | 1693 | 1815 | 1761 | 1745 |
| 20000 | | | | | 1996 | 2167 | 2106 | 2074 |
| 21000 | | | | | 2384 | 2575 | 2668 | 2570 |
| 21750 | Ultimate load | | | | | | | |

# TABLE XII

## STRAIN READINGS FOR PANEL 11

t = .0655 in. L = 3.00 in. b = 3.20 in.
W = 16 in. N = 4

Gauge arrangement C, Figure 12

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 63 | 68 | 69 | 65 | 61 | 78 | 75 | 71 |
| 3000 | 130 | 132 | 137 | 135 | 140 | 142 | 144 | 137 |
| 4000 | 201 | 200 | 206 | 203 | 227 | 209 | 206 | 195 |
| 5000 | 267 | 265 | 272 | 271 | 309 | 280 | 274 | 256 |
| 6000 | 333 | 328 | 339 | 327 | 390 | 355 | 341 | 321 |
| 7000 | 398 | 390 | 400 | 378 | 462 | 437 | 413 | 390 |
| 8000 | 457 | 450 | 457 | 423 | 539 | 519 | 486 | 470 |
| 9000 | 507 | 498 | 508 | 463 | 617 | 600 | 556 | 549 |
| 10000 | 547 | 531 | 532 | 483 | 699 | 688 | 626 | 633 |
| 11000 | 570 | 530 | 530 | 463 | 769 | 765 | 694 | 711 |
| 12000 | 553 | 430 | 383 | 362 | 851 | 850 | 774 | 801 |
| 13000 | 358 | -80[a] | -260 | -67 | 954 | 985 | 896 | 929 |
| 18000 | Ultimate load | | | | | | | |

a Negative readings indicate tension strains.

TABLE XIII

STRAIN READINGS FOR PANEL 12

t = .0403 in. L = 1.00 in. b = 3.20 in.
W = 16 in. N = 4

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 96 | 104 | 108 | 101 | 90 | 90 | 77 | 76 |
| 3000 | 192 | 208 | 212 | 205 | 182 | 205 | 182 | 160 |
| 4000 | 282 | 305 | 312 | 302 | 270 | 310 | 281 | 246 |
| 5000 | 377 | 407 | 414 | 402 | 363 | 420 | 382 | 343 |
| 6000 | 469 | 508 | 509 | 503 | 464 | 527 | 500 | 439 |
| 7000 | 557 | 623 | 580 | 634 | 578 | 640 | 614 | 554 |
| 8000 | 662 | 925 | 569 | 896 | 696 | 769 | 749 | --- |
| 9000 | 752 | 1165 | 614 | 1114 | 816 | 913 | 881 | 846 |
| 18975 | Ultimate load | | | | | | | |

# TABLE XIV

## STRAIN READINGS FOR PANEL 13

t = .082 in.   L = 1.50 in.   b = 2.50 in.
W = 15 in.   N = 5

Gauge arrangement B, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1000 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3000 | 115 | 118 | 104 | 108 | 115 | 90 |
| 5000 | 233 | 240 | 222 | 232 | 235 | 205 |
| 7000 | 352 | 365 | 339 | 371 | 355 | 324 |
| 9000 | 464 | 485 | 453 | 508 | 470 | 448 |
| 11000 | 575 | 602 | 571 | 647 | 582 | 579 |
| 13000 | 687 | 723 | 684 | 792 | 703 | 722 |
| 15000 | 795 | 848 | 806 | 938 | 823 | 867 |
| 17000 | 910 | 976 | 932 | 1100 | 955 | 1020 |
| 19000 | 1018 | 1094 | 1042 | 1242 | 1070 | 1160 |
| 21000 | 1122 | 1213 | 1162 | 1393 | 1177 | 1310 |
| 22000 | 1179 | 1276 | 1221 | 1468 | 1234 | 1384 |
| 23000 | 1238 | 1337 | 1282 | 1541 | 1292 | 1458 |
| 24000 | 1294 | 1396 | 1339 | 1619 | 1345 | 1535 |
| 25000 | 1347 | 1458 | 1401 | 1696 | 1400 | 1606 |
| 26000 | 1394 | 1516 | 1459 | 1768 | 1457 | 1681 |
| 27000 | 1450 | 1579 | 1522 | 1837 | 1505 | 1745 |
| 28000 | 1501 | 1646 | 1591 | 1923 | 1563 | 1829 |
| 29000 | 1546 | 1703 | 1642 | 1990 | 1615 | 1899 |
| 30000 | 1600 | 1769 | 1712 | 2073 | 1675 | 1975 |
| 31000 | 1644 | 1828 | 1770 | 2143 | 1730 | 2045 |
| 32000 | 1750 | 1888 | 1830 | 2217 | 1785 | 2120 |
| 33000 | 1790 | 1952 | 1898 | 2298 | 1845 | 2194 |
| 34000 | 1834 | 1923 | 1962 | 2377 | 1906 | 2266 |
| 35000 | 1872 | 2075 | 2032 | 2458 | 1970 | 2340 |
| 36000 | 1905 | 2131 | 2092 | 2533 | 2027 | 2414 |
| 37000 | 1927 | 2193 | 2154 | 2603 | 2083 | 2480 |
| 38000 | 1934 | 2248 | 2222 | 2639 | 2134 | 2547 |
| 39000 | 1934 | 2302 | 2294 | 2763 | 2195 | 2620 |
| 40000 | 1904 | 2332 | 2377 | 2853 | 2273 | 2698 |
| 41080 | Ultimate load -- sudden failure | | | | | |

TABLE XV

STRAIN READINGS FOR PANEL 14

t = .0810 in. L = 2.25 in. b = 2.50 in.
W = 15 in. N = 5

Gauge arrangement B, Figure 12

| | Gauge readings in micro-inches per inch | | | | | |
|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 4 | 5 | 6 |
| 1000 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3000 | 120 | 120 | 113 | 100 | 101 | 119 |
| 5000 | 240 | 242 | 233 | 215 | 220 | 248 |
| 7000 | 357 | 363 | 350 | 342 | 335 | 369 |
| 9000 | 470 | 468 | 468 | 363 | 453 | 496 |
| 11000 | 585 | 570 | 588 | 454 | 570 | 624 |
| 13000 | 704 | 665 | 718 | 543 | 698 | 759 |
| 15000 | 820 | 727 | 848 | 674 | 823 | 901 |
| 17000 | 935 | 850 | 968 | 808 | 948 | 1029 |
| 18000 | 990 | 904 | 1030 | 868 | 1010 | 1096 |
| 19000 | 1071 | 952 | 1093 | 942 | 1077 | 1164 |
| 20000 | 1121 | 984 | 1152 | 999 | 1138 | 1232 |
| 21000 | 1175 | 1018 | 1212 | 1047 | 1206 | 1302 |
| 22000 | 1225 | 1046 | 1268 | 1107 | 1267 | 1367 |
| 23000 | 1267 | 1069 | 1318 | 1165 | 1325 | 1429 |
| 24000 | 1308 | 1099 | 1373 | 1230 | 1388 | 1497 |
| 25000 | 1345 | 1122 | 1421 | 1300 | 1356 | 1564 |
| 26000 | 1375 | 1129 | 1460 | 1365 | 1428 | 1634 |
| 27000 | 1400 | 1139 | 1498 | 1430 | 1488 | 1697 |
| 28000 | 1395 | 1108 | 1502 | 1498 | 1663 | 1767 |
| 29000 | 1369 | 1017 | 1357 | 1570 | 1748 | 1849 |
| 30000 | 1300 | 829 | 1263 | 1645 | 1848 | 1929 |
| 30940 | Ultimate load | | | | | |

TABLE XVI

STRAIN READINGS FOR PANEL 15

t = .0820 in. L = 2.00 in. b = 2.00 in.
W = 16 in. N = 7

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3000 | 99 | 109 | 98 | 103 | 57 | 58 | 72 | 73 |
| 5000 | 217 | 214 | 193 | 200 | 142 | 138 | 161 | 183 |
| 7000 | 319 | 312 | 278 | 290 | 245 | 270 | 251 | 297 |
| 9000 | 409 | 415 | 368 | 382 | 353 | 352 | 350 | 413 |
| 11000 | 506 | 515 | 443 | 467 | 457 | 445 | 449 | 518 |
| 13000 | 589 | 612 | 530 | 550 | 563 | 552 | 558 | 628 |
| 15000 | 675 | 712 | 616 | 632 | 664 | 657 | 660 | 733 |
| 17000 | 766 | 815 | 695 | 721 | 772 | 770 | 778 | 848 |
| 19000 | 842 | 910 | 761 | 802 | 872 | 869 | 880 | 950 |
| 21000 | 922 | 1015 | 840 | 889 | 980 | 987 | 994 | 1059 |
| 23000 | 1031 | 1113 | 918 | 972 | 1085 | 1098 | 1100 | 1168 |
| 25000 | 1119 | 1210 | 981 | 1052 | 1187 | 1205 | 1210 | 1269 |
| 27000 | 1192 | 1305 | 1060 | 1142 | 1290 | 1312 | 1318 | 1373 |
| 29000 | 1287 | 1400 | 1126 | 1210 | 1394 | 1420 | 1433 | 1481 |
| 31000 | 1374 | 1496 | 1195 | 1287 | 1496 | 1530 | 1540 | 1578 |
| 33000 | 1457 | 1595 | 1268 | 1363 | 1600 | 1643 | 1657 | 1685 |
| 35000 | 1525 | 1685 | 1336 | 1433 | 1697 | 1750 | 1767 | 1785 |
| 37000 | 1609 | 1782 | 1398 | 1502 | 1800 | 1860 | 1877 | 1883 |
| 39000 | 1684 | 1877 | 1463 | 1569 | 1895 | 1970 | 1998 | 1991 |
| 41000 | 1752 | 1973 | 1508 | 1624 | 1995 | 2087 | 2118 | 2073 |
| 42000 | 1792 | 2010 | 1520 | 1647 | 2034 | 2127 | 2160 | 2105 |
| 43000 | 1804 | 2046 | 1537 | 1662 | 2078 | 2180 | 2220 | 2132 |
| 44000 | 1842 | 2094 | 1555 | 1679 | 2122 | 2230 | 2280 | 2163 |
| 45000 | 1874 | 2129 | 1564 | 1686 | 2127 | 2295 | 2347 | 2178 |
| 46000 | 1912 | 2169 | 1566 | 1677 | 2210 | 2340 | 2405 | 2193 |
| 47000 | 1950 | 2202 | 1548 | 1650 | 2252 | 2393 | 2470 | 2208 |
| 48000 | 1967 | 2234 | 1488 | 1574 | 2291 | 2437 | 2530 | 2213 |
| 48950 | Ultimate load | | | | | | | |

TABLE XVII

STRAIN READINGS FOR PANEL 16

t = .0405 in. L = 0.75 b = 3.20 in.
W = 16 in. N = 4

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 74 | 86 | 94 | 98 | 62 | 60 | 75 | 90 |
| 3000 | 173 | 188 | 199 | 205 | 155 | 154 | 170 | 189 |
| 4000 | 268 | 285 | 299 | 305 | 262 | 252 | 263 | 292 |
| 5000 | 368 | 385 | 409 | 413 | 337 | 361 | 365 | 407 |
| 6000 | 462 | 460 | 524 | 495 | 574 | 465 | 473 | 524 |
| 7000 | 585 | 504 | 791 | 540 | 787 | 575 | 603 | 657 |
| 7500 | 658 | 523 | 843 | 590 | 875 | 637 | 679 | 732 |
| 8000 | 740 | 545 | 940 | 634 | 945 | 689 | 743 | 793 |
| 8500 | 838 | 580 | 1056 | 647 | 998 | 761 | 822 | 865 |
| 20520 | Ultimate load | | | | | | | |

TABLE XVIII

STRAIN READING FOR PANEL 17

t = .0405 L = 1.25 in. b = 3.20 in.
W = 16 in. N = 4

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 102 | 110 | 105 | 109 | 86 | 80 | 92 | 84 |
| 3000 | 195 | 205 | 208 | 206 | 178 | 173 | 200 | 177 |
| 4000 | 289 | 305 | 310 | 304 | 271 | 268 | 292 | 267 |
| 5000 | 378 | 403 | 408 | 402 | 366 | 365 | 396 | 369 |
| 6000 | 477 | 505 | 521 | 516 | 466 | 471 | 504 | 465 |
| 7000 | 627 | 598 | 603 | 659 | 572 | 580 | 612 | 567 |
| 7500 | 700 | 660 | 743 | 757 | 636 | 643 | 675 | 627 |
| 8000 | 740 | 718 | 813 | 849 | 696 | 708 | 736 | 682 |
| 9000 | 876 | 853 | 963 | 1054 | 818 | 843 | 869 | 805 |
| 10000 | 1033 | 998 | 1123 | 1279 | 956 | 995 | 1020 | 940 |
| 11000 | 1192 | 1140 | 1308 | 1479 | 1982 | 1143 | 1160 | 1074 |
| 12000 | 1368 | 1281 | 1543 | 1689 | 1230 | 1298 | 1304 | 1187 |
| 13000 | 1580 | 1423 | 1732 | 1889 | 1372 | 1445 | 1453 | 1310 |
| 14000 | 1815 | 1598 | 1900 | 1993 | 1531 | 1598 | 1619 | 1428 |
| 15000 | 2047 | 1852 | 2343 | 2281 | 1694 | 1745 | 1772 | 1542 |
| 16490 | Ultimate load | | | | | | | |

# TABLE XIX

## STRAIN READINGS FOR PANEL 18

t = .0405 in. L = 1.75 in. b = 3.20 in.
W = 16 in. N = 4

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 102 | 109 | 101 | 101 | 75 | 77 | 81 | 79 |
| 3000 | 197 | 206 | 195 | 194 | 162 | 169 | 183 | 169 |
| 4000 | 293 | 299 | 284 | 272 | 260 | 275 | 289 | 262 |
| 5000 | 392 | 380 | 371 | 351 | 362 | 378 | 392 | 349 |
| 6000 | 547 | 415 | 451 | 428 | 467 | 486 | 504 | 437 |
| 6500 | 705 | 410 | 543 | 476 | 530 | 539 | 566 | 484 |
| 7000 | 816 | 427 | 640 | 521 | 590 | 596 | 626 | 535 |
| 7500 | 915 | 460 | 732 | 578 | 652 | 652 | 686 | 591 |
| 16200 | Ultimate load | | | | | | | |

TABLE XX

STRAIN READINGS FOR PANEL 19

t = .0800 in. L = 1.75 in. b = 2.50 in.
W = 15 in. N = 5

Gauge arrangement B, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 110 | 115 | 131 | 95 | 110 | 122 |
| 6000 | 217 | 230 | 256 | 205 | 231 | 248 |
| 8000 | 324 | 340 | 377 | 323 | 352 | 382 |
| 10000 | 432 | 455 | 496 | 443 | 477 | 519 |
| 12000 | 540 | 567 | 613 | 563 | 599 | 656 |
| 14000 | 642 | 675 | 728 | 683 | 721 | 791 |
| 16000 | 749 | 790 | 844 | 803 | 845 | 930 |
| 18000 | 849 | 1100 | 966 | 931 | 978 | 1077 |
| 20000 | 947 | 1015 | 1082 | 1048 | 1098 | 1213 |
| 22000 | 1050 | 1133 | 1207 | 1175 | 1230 | 1360 |
| 24000 | 1150 | 1250 | 1328 | 1304 | 1360 | 1507 |
| 26000 | 1249 | 1368 | 1444 | 1424 | 1488 | 1639 |
| 28000 | 1342 | 1495 | 1592 | 1553 | 1627 | 1767 |
| 30000 | 1435 | 1620 | 1715 | 1673 | 1755 | 1897 |
| 31000 | 1480 | 1688 | 1778 | 1733 | 1820 | 1962 |
| 32000 | 1532 | 1762 | 1855 | 1801 | 1895 | 2028 |
| 33000 | 1580 | 1840 | 1930 | 1863 | 1965 | 2088 |
| 34000 | 1623 | 1926 | 2017 | 1925 | 2031 | 2145 |
| 35000 | 1666 | 2012 | 2099 | 1983 | 2090 | 2190 |
| 36000 | 1715 | 2155 | 2112 | 2043 | 2147 | 2230 |
| 37010 | Ultimate load | | | | | |

TABLE XXI

STRAIN READINGS FOR PANEL 20

t = .0815 in. L = 2.50 in. b = 3.00 in.
W = 15 in. N = 4

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 129 | 122 | 117 | 120 | 117 | 122 | 114 | 112 |
| 6000 | 252 | 237 | 235 | 234 | 244 | 248 | 239 | 222 |
| 8000 | 374 | 355 | 348 | 342 | 362 | 368 | 360 | 333 |
| 10000 | 496 | 470 | 457 | 452 | 492 | 492 | 482 | 455 |
| 12000 | 619 | 589 | 576 | 561 | 622 | 618 | 609 | 582 |
| 14000 | 741 | 707 | 686 | 670 | 762 | 744 | 739 | 710 |
| 15000 | 801 | 767 | 747 | 726 | 832 | 807 | 802 | 770 |
| 16000 | 859 | 822 | 797 | 774 | 892 | 823 | 862 | 828 |
| 17000 | 922 | 883 | 857 | 831 | 965 | 928 | 931 | 895 |
| 18000 | 979 | 938 | 911 | 882 | 1032 | 990 | 992 | 955 |
| 19000 | 1037 | 993 | 964 | 932 | 1100 | 1053 | 1054 | 1015 |
| 20000 | 1092 | 1045 | 1017 | 981 | 1170 | 1113 | 1120 | 1079 |
| 21000 | 1149 | 1100 | 1068 | 1031 | 1240 | 1177 | 1184 | 1142 |
| 22000 | 1201 | 1153 | 1122 | 1081 | 1312 | 1245 | 1255 | 1210 |
| 23000 | 1256 | 1203 | 1171 | 1127 | 1382 | 1301 | 1319 | 1272 |
| 24000 | 1304 | 1245 | 1214 | 1170 | 1449 | 1366 | 1382 | 1332 |
| 25000 | 1347 | 1284 | 1254 | 1211 | 1522 | 1433 | 1449 | 1396 |
| 26000 | 1384 | 1315 | 1289 | 1251 | 1597 | 1500 | 1519 | 1465 |
| 27000 | 1408 | 1332 | 1314 | 1282 | 1667 | 1562 | 1583 | 1525 |
| 28000 | 1396 | 1315 | 1313 | 1310 | 1750 | 1638 | 1662 | 1597 |
| 29000 | 1309 | 1230 | 1279 | 1318 | 1832 | 1703 | 1735 | 1660 |
| 30750 | Ultimate load | | | | | | | |

TABLE XXII

STRAIN READINGS FOR PANEL 21

t = .0800 in. L = 3.00 in. b = 3.00 in.
W = 15 in. N = 4

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 129 | 125 | 119 | 120 | 67 | 96 | 103 | 110 |
| 6000 | 246 | 237 | 237 | 232 | 190 | 220 | 224 | 230 |
| 8000 | 363 | 355 | 350 | 342 | 309 | 345 | 358 | 359 |
| 10000 | 476 | 472 | 462 | 443 | 457 | 475 | 491 | 481 |
| 12000 | 586 | 587 | 569 | 537 | 587 | 609 | 622 | 610 |
| 14000 | 689 | 697 | 677 | 624 | 712 | 746 | 758 | 740 |
| 15000 | 731 | 743 | 720 | 662 | 795 | 815 | 823 | 805 |
| 16000 | 769 | 787 | 757 | 694 | 857 | 885 | 893 | 875 |
| 17000 | 801 | 819 | 786 | 722 | 928 | 961 | 960 | 931 |
| 18000 | 816 | 834 | 792 | 719 | 1004 | 1032 | 1026 | 1010 |
| 19000 | 792 | 804 | 768 | 708 | 1085 | 1113 | 1102 | 1080 |
| 26500 | Ultimate load | | | | | | | |

TABLE XXIII

STRAIN READINGS FOR PANEL 22

t = .0810 in.   L = 1.50 in.   b = 2.00 in.
W = 16 in.   N = 7

Gauge arrangement E, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 94 | 118 | 96 | 85 | 90 | 80 | 88 | 70 |
| 6000 | 184 | 215 | 187 | 163 | 203 | 182 | 141 | 164 |
| 8000 | 270 | 314 | 277 | 241 | 328 | 293 | 221 | 265 |
| 10000 | 354 | 411 | 368 | 315 | 455 | 408 | 316 | 371 |
| 12000 | 441 | 508 | 462 | 392 | 582 | 521 | 401 | 476 |
| 14000 | 527 | 594 | 550 | 464 | 707 | 635 | 558 | 584 |
| 16000 | 616 | 685 | 648 | 543 | 835 | 752 | 761 | 693 |
| 18000 | 704 | 767 | 744 | 621 | 963 | 870 | 978 | 806 |
| 20000 | 786 | 851 | 837 | 693 | 1093 | 985 | 1022 | 919 |
| 22000 | 872 | 935 | 932 | 770 | 1218 | 1105 | 1163 | 1036 |
| 24000 | 956 | 1016 | 1027 | 845 | 1348 | 1222 | 1202 | 1143 |
| 26000 | 1038 | 1094 | 1119 | 920 | 1470 | 1338 | 1228 | 1259 |
| 28000 | 1121 | 1174 | 1211 | 993 | 1593 | 1458 | 1445 | 1372 |
| 30000 | 1203 | 1254 | 1307 | 1068 | 1723 | 1583 | 1345 | 1489 |
| 32000 | 1278 | 1326 | 1395 | 1133 | 1843 | 1698 | 1371 | 1600 |
| 34000 | 1355 | 1397 | 1487 | 1203 | 1968 | 1825 | 1475 | 1725 |
| 36000 | 1426 | 1467 | 1577 | 1271 | 2078 | 1942 | 1566 | 1831 |
| 38000 | 1496 | 1534 | 1666 | 1336 | 2213 | 2067 | 1672 | 1949 |
| 40000 | 1560 | 1596 | 1754 | 1399 | 2349 | 2197 | 1778 | 2063 |
| 42000 | 1614 | 1654 | 1832 | 1456 | 2482 | 2322 | 1878 | 2169 |
| 44000 | 1648 | 1697 | 1902 | 1503 | 2615 | 2448 | 1978 | 2283 |
| 45000 | 1664 | 1722 | 1936 | 1528 | 2674 | 2518 | 2033 | 2341 |
| 46000 | 1657 | 1733 | 1959 | 1548 | 2743 | 2587 | 2084 | 2398 |
| 47000 | 1626 | 1733 | 1971 | 1564 | 2792 | 2663 | 2133 | 2454 |
| 48000 | 1564 | 1708 | 1968 | 1579 | 2866 | 2748 | 2190 | 2509 |
| 49000 | 1446 | 1681 | 1942 | 1588 | 2959 | 2852 | 2225 | 2567 |
| 50000 | Ultimate load | | | | | | | |

TABLE XXIV

STRAIN READINGS FOR PANEL 23

t = .0810 in. L = 2.50 in. b = 3.00 in.
W = 15 in. N = 4

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 143 | 135 | 123 | 88 | 94 | 100 | 86 |
| 6000 | 260 | 258 | 237 | 197 | 212 | 213 | 191 |
| 8000 | 330 | 387 | 353 | 320 | 344 | 341 | 304 |
| 10000 | 437 | 518 | 473 | 455 | 473 | 473 | 421 |
| 12000 | 545 | 640 | 583 | 585 | 612 | 598 | 527 |
| 14000 | 650 | 768 | 700 | 725 | 736 | 735 | 648 |
| 16000 | 750 | 890 | 807 | 853 | 868 | 869 | 765 |
| 18000 | 820 | 997 | 891 | 983 | 1000 | 1000 | 886 |
| 20000 | 885 | 1085 | 959 | 1113 | 1154 | 1135 | 1013 |
| 21000 | 902 | 1104 | 984 | 1185 | 1229 | 1213 | 1078 |
| 22000 | 890 | 1085 | 981 | 1260 | 1392 | 1289 | 1143 |
| 23000 | 802 | 950 | 916 | 1353 | 1481 | 1302 | 1213 |
| 24000 | 398 | --- | --- | ---- | ---- | ---- | ---- |
| 26280 | Ultimate load | | | | | | |

TABLE XXV

STRAIN READINGS FOR PANEL 24

t = .0805 in. L = 1.75 in. b = 3.00 in.
W = 15 in. N = 4

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 136 | 130 | 129 | 136 | 138 | 112 | 97 |
| 6000 | 255 | 250 | 244 | 259 | 265 | 237 | 208 |
| 8000 | 384 | 376 | 364 | 388 | 396 | 368 | 336 |
| 10000 | 514 | 503 | 486 | 518 | 528 | 500 | 469 |
| 12000 | 641 | 628 | 608 | 649 | 659 | 631 | 600 |
| 14000 | 764 | 751 | 726 | 776 | 795 | 767 | 733 |
| 16000 | 888 | 873 | 843 | 897 | 918 | 891 | 860 |
| 18000 | 1026 | 1008 | 971 | 1032 | 1058 | 1032 | 1002 |
| 20000 | 1156 | 1138 | 1096 | 1164 | 1195 | 1174 | 1148 |
| 22000 | 1293 | 1270 | 1219 | 1288 | 1323 | 1307 | 1279 |
| 24000 | 1433 | 1405 | 1341 | 1420 | 1451 | 1440 | 1416 |
| 26000 | 1576 | 1540 | 1468 | 1556 | 1585 | 1582 | 1560 |
| 28000 | 1735 | 1690 | 1600 | 1693 | 1718 | 1725 | 1703 |
| 29000 | 1821 | 1768 | 1668 | 1759 | 1782 | 1792 | 1774 |
| 30000 | 1927 | 1856 | 1749 | 1827 | 1848 | 1862 | 1850 |
| 31000 | 2039 | 1943 | 1821 | 1886 | 1904 | 1926 | 1925 |
| 32000 | 2187 | 2048 | 1912 | 1943 | 1955 | 1987 | 2000 |
| 33000 | 2316 | 2166 | 2024 | 1996 | 1993 | 2035 | 2062 |
| 34000 | 2558 | 2383 | 2271 | 2044 | 2000 | 2044 | 2108 |
| 34350 | Ultimate load | | | | | | |

TABLE XXVI

STRAIN READING FOR PANEL 25

t = .0805 in. L = 1.75 in. b = 3.00 in.
W = 15 in. N = 4

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 120 | 118 | 125 | 122 | 105 | 111 | 136 | 121 |
| 6000 | 233 | 238 | 257 | 249 | 225 | 239 | 263 | 241 |
| 8000 | 337 | 346 | 375 | 363 | 351 | 358 | 384 | 360 |
| 10000 | 448 | 552 | 502 | 490 | 468 | 492 | 521 | 492 |
| 12000 | 551 | 647 | 622 | 606 | 581 | 618 | 655 | 617 |
| 14000 | 657 | 746 | 748 | 730 | 681 | 748 | 789 | 747 |
| 16000 | 761 | 840 | 870 | 852 | 786 | 879 | 925 | 880 |
| 18000 | 862 | 923 | 992 | 967 | 898 | 1011 | 1066 | 1019 |
| 20000 | 959 | 1016 | 1132 | 1100 | 1025 | 1143 | 1200 | 1151 |
| 22000 | 1062 | 1105 | 1275 | 1231 | 1147 | 1277 | 1348 | 1212 |
| 23000 | 1107 | 1144 | 1352 | 1295 | 1193 | 1332 | 1412 | 1356 |
| 24000 | 1150 | 1185 | 1432 | 1363 | 1249 | 1395 | 1485 | 1425 |
| 25000 | 1198 | 1228 | 1508 | 1438 | 1306 | 1464 | 1564 | 1496 |
| 26000 | 1248 | 1272 | 1598 | 1521 | 1331 | 1532 | 1640 | 1565 |
| 27000 | 1297 | 1313 | 1692 | 1613 | 1381 | 1603 | 1721 | 1637 |
| 28000 | 1356 | 1362 | 1783 | 1722 | 1453 | 1665 | 1794 | 1706 |
| 29000 | 1416 | 1412 | 1895 | 1839 | 1511 | 1736 | 1885 | 1774 |
| 30000 | 1553 | 1546 | ---- | ---- | ---- | ---- | ---- | ---- |
| 30000 | Ultimate load | | | | | | | |

## TABLE XXVII

### STRAIN READINGS FOR PANEL 26

t = .0810 in. L = 1.75 in. b = 2.00 in.
W = 16 in. N = 7

Gauge arrangement E, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 124 | 104 | 118 | 117 | 91 | 97 | 99 | 94 |
| 6000 | 194 | 193 | 220 | 210 | 175 | 196 | 202 | 186 |
| 8000 | 277 | 282 | 317 | 300 | 254 | 291 | 301 | 267 |
| 10000 | 366 | 372 | 417 | 393 | 336 | 389 | 401 | 350 |
| 12000 | 440 | 454 | 508 | 479 | 410 | 478 | 492 | 432 |
| 14000 | 519 | 542 | 606 | 568 | 508 | 571 | 591 | 519 |
| 16000 | 602 | 631 | 707 | 660 | 578 | 672 | 696 | 617 |
| 18000 | 674 | 716 | 804 | 753 | 656 | 763 | 789 | 707 |
| 20000 | 759 | 802 | 903 | 828 | 753 | 861 | 890 | 799 |
| 22000 | 841 | 890 | 1003 | 897 | 847 | 959 | 994 | 894 |
| 24000 | 919 | 973 | 1100 | 981 | 945 | 1054 | 1099 | 992 |
| 26000 | 1001 | 1061 | 1202 | 1076 | 1015 | 1154 | 1200 | 1077 |
| 28000 | 1079 | 1140 | 1298 | 1164 | 1092 | 1246 | 1300 | 1169 |
| 30000 | 1164 | 1227 | 1395 | 1256 | 1176 | 1344 | 1403 | 1267 |
| 32000 | 1242 | 1315 | 1485 | 1353 | 1202 | 1359 | 1508 | 1358 |
| 34000 | 1326 | 1402 | 1588 | 1444 | 1172 | 1330 | 1608 | 1447 |
| 36000 | 1402 | 1488 | 1691 | 1535 | 1319 | 1421 | 1705 | 1536 |
| 37000 | 1442 | 1528 | 1740 | 1579 | 1333 | 1466 | 1753 | 1577 |
| 38000 | 1481 | 1572 | 1783 | 1628 | 1367 | 1515 | 1805 | 1617 |
| 39000 | 1524 | 1620 | 1833 | 1673 | 1401 | 1559 | 1851 | 1667 |
| 40000 | 1555 | 1670 | 1885 | 1720 | 1436 | 1604 | 1893 | 1697 |
| 41000 | 1599 | 1649 | 1940 | 1776 | 1429 | 1649 | 1938 | 1737 |
| 42000 | 1644 | 1696 | 1945 | 1826 | ---- | 1696 | 1986 | 1779 |
| 43000 | 1677 | 1758 | 2055 | 1978 | ---- | 1741 | 2024 | 1815 |
| 44000 | 1723 | 1828 | 2139 | 2033 | ---- | 1779 | 2055 | 1850 |
| 45000 | 1760 | 1913 | 2246 | 2098 | ---- | 1821 | 2079 | 1892 |
| 45900 | Ultimate load | | | | | | | |

TABLE XXVIII

STRAIN READINGS FOR PANEL 27

t = .0815 in.   L = 2.50 in.   b = 2.286 in.
W = 16 in.   N = 6

Gauge arrangement C, Figure 12

| Load | Gauge readings in micro-inches per inch | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 108 | 111 | 99 | 80 | 88 | 87 | 98 | 82 |
| 6000 | 209 | 220 | 193 | 158 | 189 | 182 | 204 | 171 |
| 8000 | 305 | 323 | 292 | 241 | 293 | 283 | 313 | 261 |
| 10000 | 397 | 407 | 383 | 324 | 401 | 384 | 422 | 351 |
| 12000 | 490 | 477 | 472 | 399 | 503 | 480 | 523 | 434 |
| 14000 | 588 | 539 | 561 | 478 | 611 | 579 | 629 | 521 |
| 16000 | 682 | 608 | 647 | 554 | 717 | 673 | 731 | 593 |
| 18000 | 773 | 670 | 724 | 627 | 818 | 762 | 831 | 676 |
| 19000 | 822 | 701 | 762 | 667 | 878 | 805 | 884 | 707 |
| 20000 | 855 | 731 | 795 | 696 | 918 | 841 | 932 | 744 |
| 21000 | 898 | 768 | 829 | 734 | 966 | 880 | 981 | 982 |
| 22000 | 946 | 803 | 860 | 771 | 1020 | 923 | 1038 | 824 |
| 23000 | 990 | 828 | 891 | 804 | 1067 | 962 | 1084 | 864 |
| 24000 | 1033 | 848 | 917 | 834 | 1120 | 1007 | 1137 | 902 |
| 25000 | 1075 | 865 | 935 | 864 | 1172 | 1049 | 1192 | 944 |
| 26000 | 1102 | 873 | 948 | 891 | 1221 | 1079 | 1239 | 980 |
| 27000 | 1142 | 883 | 950 | 916 | 1274 | 1121 | 1292 | 1021 |
| 28000 | 1165 | 871 | 938 | 935 | 1324 | 1161 | 1344 | 1064 |
| 29000 | 1165 | 830 | 902 | 946 | 1381 | 1203 | 1403 | 1103 |
| 30000 | 1151 | 759 | 832 | 956 | 1438 | 1248 | 1466 | 1148 |
| 33210 | Ultimate load | | | | | | | |

# TABLE XXIX

## STRAIN READINGS FOR PANEL 28

t = .0805 in. L = 2.00 in. b = 2.286 in.
W = 16 in. N = 6

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 91 | 109 | 107 | 108 | 94 | 103 | 109 | 98 |
| 6000 | 179 | 219 | 214 | 216 | 198 | 204 | 219 | 195 |
| 8000 | 264 | 329 | 324 | 324 | 303 | 314 | 330 | 289 |
| 10000 | 349 | 441 | 431 | 411 | 406 | 433 | 445 | 396 |
| 12000 | 433 | 553 | 539 | 477 | 511 | 554 | 578 | 518 |
| 14000 | 515 | 661 | 644 | 561 | 612 | 678 | 704 | 644 |
| 16000 | 599 | 774 | 751 | 657 | 714 | 801 | 829 | 770 |
| 18000 | 685 | 887 | 858 | 753 | 816 | 927 | 959 | 897 |
| 20000 | 770 | 1000 | 969 | 851 | 924 | 1052 | 1084 | 1025 |
| 22000 | 856 | 1110 | 1071 | 940 | 1020 | 1172 | 1201 | 1150 |
| 24000 | 942 | 1227 | 1181 | 1039 | 1126 | 1300 | 1330 | 1281 |
| 26000 | 1029 | 1342 | 1290 | 1135 | 1231 | 1423 | 1455 | 1411 |
| 28000 | 1118 | 1459 | 1397 | 1229 | 1332 | 1544 | 1579 | 1539 |
| 30000 | 1207 | 1581 | 1508 | 1322 | 1437 | 1671 | 1709 | 1674 |
| 32000 | 1287 | 1710 | 1629 | 1422 | 1544 | 1789 | 1832 | 1804 |
| 33000 | 1320 | 1776 | 1688 | 1477 | 1597 | 1851 | 1893 | 1864 |
| 34000 | 1360 | 1849 | 1749 | 1531 | 1645 | 1905 | 1949 | 1929 |
| 35000 | 1405 | 1929 | 1821 | 1601 | 1695 | 1957 | 2000 | 1991 |
| 36000 | 1450 | 2009 | 1909 | 1692 | 1746 | 2010 | 2050 | 2054 |
| 37000 | 1503 | 2112 | 2043 | 1750 | 1804 | 2057 | 2090 | 2114 |
| 37950 | Ultimate load | | | | | | | |

TABLE XXX

STRESS READINGS FOR PANEL 29

t = .0825 in. L = 3.00 in. b = 2.00 in.
W = 16 in. N = 7

Gauge arrangement E, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 87 | 88 | 100 | 98 | 103 | 98 | 94 | 88 |
| 6000 | 177 | 182 | 205 | 200 | 216 | 205 | 190 | 183 |
| 8000 | 261 | 270 | 310 | 292 | 318 | 302 | 295 | 275 |
| 10000 | 349 | 360 | 413 | 395 | 423 | 415 | 405 | 373 |
| 12000 | 429 | 452 | 515 | 493 | 521 | 515 | 508 | 463 |
| 14000 | 509 | 543 | 620 | 587 | 626 | 618 | 617 | 564 |
| 16000 | 589 | 635 | 727 | 685 | 728 | 723 | 725 | 665 |
| 18000 | 669 | 724 | 829 | 776 | 826 | 823 | 830 | 763 |
| 20000 | 745 | 818 | 935 | 874 | 928 | 923 | 931 | 860 |
| 22000 | 817 | 903 | 1042 | 966 | 1027 | 1023 | 1033 | 952 |
| 24000 | 887 | 995 | 1145 | 1060 | 1128 | 1124 | 1135 | 1046 |
| 26000 | 954 | 1080 | 1255 | 1155 | 1226 | 1226 | 1239 | 1143 |
| 28000 | 1016 | 1162 | 1363 | 1242 | 1321 | 1323 | 1339 | 1238 |
| 30000 | 1061 | 1249 | 1488 | 1340 | 1425 | 1422 | 1435 | 1332 |
| 32000 | 1084 | 1313 | 1598 | 1435 | 1520 | 1518 | 1525 | 1420 |
| 33000 | 1080 | 1347 | 1660 | 1496 | 1576 | 1569 | 1573 | 1468 |
| 34000 | 1073 | 1381 | 1737 | 1584 | 1631 | 1615 | 1604 | 1513 |
| 35000 | 929 | 752 | 1333 | 1450 | ---- | ---- | ---- | ---- |
| 36460 | Ultimate load | | | | | | | |

TABLE XXXI

STRAIN READINGS FOR PANEL 30

t = .0815 in. L = 3.00 in. b = 2.286 in.
W = 16 in. N = 6

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 114 | 112 | 108 | 93 | 93 | 103 | 101 | 89 |
| 6000 | 230 | 221 | 212 | 185 | 194 | 217 | 215 | 197 |
| 8000 | 336 | 325 | 315 | 276 | 307 | 339 | 336 | 308 |
| 10000 | 442 | 420 | 414 | 364 | 425 | 456 | 459 | 415 |
| 12000 | 550 | 520 | 509 | 453 | 544 | 576 | 580 | 519 |
| 14000 | 655 | 620 | 607 | 545 | 663 | 700 | 703 | 626 |
| 16000 | 757 | 710 | 696 | 633 | 781 | 822 | 822 | 729 |
| 18000 | 862 | 745 | 777 | 721 | 894 | 939 | 935 | 829 |
| 20000 | 967 | 866 | 854 | 813 | 1012 | 1062 | 1058 | 935 |
| 21000 | 1012 | 889 | 981 | 857 | 1071 | 1123 | 1118 | 971 |
| 22000 | 1053 | 897 | 998 | 902 | 1129 | 1180 | 1179 | 1041 |
| 23000 | 1093 | 890 | 1004 | 941 | 1185 | 1240 | 1237 | 1089 |
| 24000 | 1111 | 847 | 979 | 981 | 1247 | 1305 | 1298 | 1142 |
| 25000 | 1096 | 729 | 895 | 1009 | 1307 | 1374 | 1367 | 1199 |
| 32400 | Ultimate load | | | | | | | |

TABLE XXXII

STRAIN READINGS FOR PANEL 31

t = .0815 in. L = 2.50 in. b = 2.00 in.
W = 16 in. N = 7

Gauge arrangement E, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 78 | 106 | 108 | 97 | 109 | 122 | 108 | 95 |
| 6000 | 153 | 208 | 213 | 191 | 209 | 230 | 221 | 200 |
| 8000 | 226 | 309 | 320 | 284 | 307 | 334 | 334 | 305 |
| 10000 | 298 | 410 | 427 | 378 | 404 | 437 | 452 | 415 |
| 12000 | 366 | 504 | 523 | 463 | 494 | 541 | 561 | 519 |
| 14000 | 436 | 603 | 628 | 554 | 584 | 642 | 672 | 625 |
| 16000 | 503 | 702 | 730 | 642 | 674 | 742 | 783 | 731 |
| 18000 | 571 | 801 | 834 | 734 | 766 | 845 | 895 | 835 |
| 20000 | 638 | 901 | 939 | 822 | 856 | 945 | 1006 | 935 |
| 22000 | 708 | 1001 | 1042 | 916 | 948 | 1044 | 1117 | 1043 |
| 24000 | 772 | 1101 | 1149 | 1002 | 1034 | 1147 | 1225 | 1143 |
| 26000 | 839 | 1201 | 1259 | 1096 | 1124 | 1259 | 1341 | 1253 |
| 28000 | 902 | 1309 | 1379 | 1191 | 1213 | 1362 | 1447 | 1358 |
| 29000 | 928 | 1355 | 1431 | 1231 | 1259 | 1416 | 1500 | 1404 |
| 30000 | 956 | 1402 | 1485 | 1272 | 1299 | 1467 | 1554 | 1450 |
| 31000 | 989 | 1461 | 1555 | 1319 | 1343 | 1519 | 1606 | 1500 |
| 32000 | 1018 | 1519 | 1625 | 1369 | 1385 | 1568 | 1649 | 1547 |
| 33000 | 1051 | 1585 | 1708 | 1419 | 1429 | 1613 | 1690 | 1593 |
| 34000 | 1081 | 1671 | 1820 | 1477 | 1474 | 1647 | 1715 | 1637 |
| 35000 | 1119 | 1789 | 1970 | 1552 | 1514 | 1675 | 1731 | 1677 |
| 35720 | Ultimate load | | | | | | | |

TABLE XXXIII

STRAIN READINGS FOR PANEL 32

t = .0825 in.   L = 2.25 in.   b = 2.00 in.
W = 16 in.   N = 7

Gauge arrangement E, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 92 | 101 | 97 | 97 | 88 | 98 | 105 | 91 |
| 6000 | 177 | 202 | 196 | 193 | 181 | 199 | 214 | 191 |
| 8000 | 262 | 304 | 292 | 288 | 271 | 307 | 329 | 297 |
| 10000 | 338 | 401 | 398 | 386 | 373 | 420 | 445 | 406 |
| 12000 | 428 | 511 | 493 | 457 | 459 | 530 | 540 | 511 |
| 14000 | 514 | 614 | 587 | 585 | 557 | 646 | 678 | 616 |
| 16000 | 596 | 718 | 679 | 675 | 648 | 752 | 787 | 712 |
| 18000 | 680 | 821 | 769 | 767 | 744 | 866 | 904 | 819 |
| 20000 | 764 | 926 | 864 | 859 | 840 | 978 | 1017 | 919 |
| 22000 | 842 | 1012 | 961 | 951 | 937 | 1094 | 1134 | 1024 |
| 24000 | 924 | 1098 | 1060 | 1048 | 1038 | 1209 | 1249 | 1125 |
| 26000 | 1007 | 1190 | 1150 | 1148 | 1133 | 1322 | 1362 | 1225 |
| 28000 | 1088 | 1290 | 1257 | 1248 | 1230 | 1434 | 1472 | 1325 |
| 30000 | 1170 | 1383 | 1354 | 1340 | 1328 | 1549 | 1587 | 1427 |
| 32000 | 1245 | 1486 | 1461 | 1438 | 1423 | 1659 | 1695 | 1522 |
| 33000 | 1284 | 1534 | 1501 | 1486 | 1467 | 1718 | 1749 | 1572 |
| 34000 | 1315 | 1585 | 1540 | 1536 | 1509 | 1767 | 1798 | 1614 |
| 35000 | 1353 | 1638 | 1601 | 1588 | 1555 | 1820 | 1847 | 1661 |
| 36000 | 1388 | 1693 | 1664 | 1643 | 1601 | 1877 | 1898 | 1710 |
| 37000 | 1428 | 1747 | 1732 | 1700 | 1649 | 1933 | 1945 | 1757 |
| 38000 | 1461 | 1819 | 1812 | 1762 | 1697 | 1981 | 1987 | 1801 |
| 39000 | 1511 | 1846 | 1925 | 1528 | 1738 | 2022 | 2015 | 1839 |
| 40000 | 1570 | 2005 | 2076 | 1886 | 1786 | 2058 | 2035 | 1879 |
| 40900 | Ultimate load | | | | | | | |

TABLE XXXIV

STRAIN READINGS FOR PANEL 33

t = .0810 in.  L = 2.00 in.  b = 3.75 in.
W = 15 in.  N = 3

Gauge arrangement B, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 122 | 131 | 130 | 148 | 130 | 129 |
| 6000 | 241 | 259 | 255 | 303 | 280 | 275 |
| 8000 | 356 | 381 | 375 | 455 | 429 | 420 |
| 10000 | 477 | 510 | 500 | 608 | 585 | 571 |
| 12000 | 574 | 639 | 625 | 758 | 735 | 618 |
| 14000 | 708 | 761 | 745 | 909 | 888 | 766 |
| 15000 | 755 | 812 | 800 | 985 | 968 | 841 |
| 16000 | 812 | 872 | 860 | 1068 | 1049 | 914 |
| 17000 | 871 | 934 | 925 | 1147 | 1136 | 994 |
| 18000 | 929 | 1002 | 992 | 1234 | 1218 | 1070 |
| 19000 | 992 | 1070 | 1058 | 1315 | 1297 | 1149 |
| 20000 | 1052 | 1151 | 1132 | 1397 | 1370 | 1219 |
| 21000 | 1119 | 1232 | 1213 | 1487 | 1451 | 1397 |
| 22000 | 1192 | 1328 | 1310 | 1583 | 1540 | 1472 |
| 23000 | 1282 | 1470 | 1430 | 1689 | 1637 | 1559 |
| 24000 | 1689 | 2012 | 1838 | 1927 | 1903 | 1774 |
| 24300 | Ultimate load | | | | | |

TABLE XXXV

STRAIN READINGS FOR PANEL 34

t = .0830 in. L = 3.50 in. b = 2.00 in.
W = 16 in. N = 7

Gauge arrangement E, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 94 | 82 | 88 | 91 | 86 | 85 | 77 | 101 |
| 6000 | 188 | 165 | 169 | 183 | 192 | 173 | 159 | 214 |
| 8000 | 277 | 242 | 248 | 271 | 294 | 257 | 243 | 336 |
| 10000 | 356 | 334 | 346 | 351 | 385 | 356 | 350 | 448 |
| 12000 | 424 | 425 | 444 | 420 | 465 | 464 | 464 | 553 |
| 14000 | 492 | 520 | 544 | 492 | 550 | 575 | 584 | 658 |
| 16000 | 557 | 611 | 638 | 556 | 630 | 688 | 699 | 766 |
| 18000 | 618 | 689 | 714 | 611 | 712 | 805 | 806 | 873 |
| 20000 | 675 | 737 | 741 | 642 | 794 | 918 | 913 | 978 |
| 22000 | 709 | 695 | 619 | 598 | 879 | 1037 | 1080 | 1088 |
| 23000 | 712 | 585 | 416 | 515 | 920 | 1097 | 1020 | 1144 |
| 24000 | 680 | 295 | -46[a] | 328 | 965 | 1161 | 1184 | 1210 |
| 34200 | Ultimate load | | | | | | | |

a Negative value incicates tension strain

TABLE XXXVI

STRAIN READINGS FOR PANEL 35

t = .0805 in. L = 1.00 in. b = 3.00 in.
W = 15 in. N = 4

Gauge arrangement C, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 121 | 127 | 123 | 120 | 129 | 129 | 131 | 125 |
| 6000 | 247 | 257 | 249 | 240 | 270 | 240 | 257 | 245 |
| 8000 | 372 | 386 | 375 | 361 | 418 | 403 | 390 | 363 |
| 10000 | 500 | 516 | 500 | 477 | 549 | 548 | 529 | 488 |
| 12000 | 622 | 639 | 620 | 587 | 677 | 678 | 671 | 616 |
| 14000 | 750 | 767 | 742 | 686 | 815 | 789 | 810 | 745 |
| 16000 | 873 | 892 | 862 | 798 | 963 | 958 | 953 | 875 |
| 18000 | 996 | 919 | 986 | 909 | 1125 | 1088 | 1097 | 1005 |
| 20000 | 1114 | 1041 | 1103 | 1028 | 1282 | 1235 | 1243 | 1141 |
| 22000 | 1242 | 1168 | 1223 | 1136 | 1459 | 1410 | 1385 | 1271 |
| 23000 | 1299 | 1226 | 1279 | 1186 | 1549 | 1484 | 1453 | 1333 |
| 24000 | 1359 | 1287 | 1337 | 1229 | 1635 | 1561 | 1531 | 1407 |
| 25000 | 1421 | 1351 | 1395 | 1291 | 1713 | 1622 | 1600 | 1471 |
| 26000 | 1484 | 1416 | 1457 | 1346 | 1996 | 1680 | 1676 | 1541 |
| 27000 | 1542 | 1574 | 1511 | 1398 | 1877 | 1736 | 1752 | 1609 |
| 28000 | 1598 | 1632 | 1564 | 1442 | 1945 | 1801 | 1816 | 1671 |
| 29000 | 1659 | 1698 | 1620 | 1493 | 2028 | 1898 | 1899 | 1748 |
| 30000 | 1720 | 1765 | 1681 | 1544 | 2101 | 1974 | 1971 | 1813 |
| 31000 | 1779 | 1825 | 1737 | 1589 | 2172 | 2063 | 2042 | 1881 |
| 32000 | 1839 | 1887 | 1793 | 1632 | 2252 | 2158 | 2124 | 1956 |
| 33000 | 1899 | 1955 | 1850 | 1672 | 2324 | 2224 | 2197 | 2027 |
| 34000 | 1958 | 2023 | 1907 | 1705 | 2402 | 2298 | 2274 | 2097 |
| 35000 | 2017 | 2095 | 1964 | 1752 | 2482 | 2411 | 2359 | 2181 |
| 36000 | 2087 | 2185 | 2025 | 1804 | 2560 | 2494 | 2441 | 2262 |
| 37000 | 2191 | 2321 | 2102 | 1853 | 2634 | 2556 | 2513 | 2356 |
| 38000 | 2454 | 2627 | 2297 | 1923 | 2687 | 2473 | 2541 | 2477 |
| 38500 | Ultimate load | | | | | | | |

TABLE XXXVII

STRAIN READINGS FOR PANEL 36

t = .0830 in. L = 3.25 in. b = 2.00 in.
W = 16 in. N = 7

Gauge arrangement E, Figure 12

Gauge readings in micro-inches per inch

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 95 | 104 | 93 | 86 | 90 | 99 | 101 | 187 |
| 6000 | 195 | 209 | 191 | 173 | 195 | 209 | 206 | 187 |
| 8000 | 286 | 309 | 281 | 256 | 301 | 318 | 311 | 284 |
| 10000 | 380 | 415 | 381 | 343 | 417 | 433 | 424 | 385 |
| 12000 | 473 | 521 | 472 | 423 | 530 | 545 | 536 | 485 |
| 14000 | 562 | 623 | 558 | 498 | 639 | 659 | 643 | 580 |
| 16000 | 647 | 728 | 641 | 575 | 753 | 778 | 756 | 680 |
| 18000 | 734 | 821 | 723 | 647 | 869 | 888 | 861 | 779 |
| 20000 | 821 | 919 | 801 | 718 | 977 | 1002 | 965 | 878 |
| 22000 | 906 | 1014 | 876 | 788 | 1089 | 1118 | 1074 | 980 |
| 24000 | 986 | 1099 | 945 | 854 | 1207 | 1238 | 1188 | 1086 |
| 26000 | 1010 | 1046 | 915 | 889 | 1319 | 1369 | 1316 | 1196 |
| 27000 | 974 | 903 | 805 | 877 | 1366 | 1450 | 1392 | 1255 |
| 28000 | 813 | 640 | 443 | 793 | 1443 | 1548 | 1478 | 1325 |
| 36180 | Ultimate load | | | | | | | |

TABLE XXXVIII

STRAIN READINGS FOR PANEL 37

t = .0830 in. L = 1.25 in. b = 2.50 in. W = 15 in. N = 5

Gauge arrangement BF, Figure 12

| | Gauge readings in micro-inches per inch | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 5 | 6 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 103 | 123 | 123 | 87 | 88 | 16 | 18 | 16 | 14 |
| 6000 | 214 | 260 | 242 | 193 | 171 | 30 | 33 | 29 | 26 |
| 8000 | 327 | 388 | 332 | 310 | 258 | 44 | 47 | 43 | 37 |
| 10000 | 435 | 509 | 449 | 430 | 345 | 57 | 61 | 56 | 51 |
| 12000 | 543 | 611 | 568 | 548 | 439 | 71 | 73 | 70 | 64 |
| 14000 | 652 | 694 | 690 | 670 | 541 | 84 | 86 | 81 | 76 |
| 16000 | 760 | 775 | 808 | 787 | 646 | 97 | 99 | 94 | 91 |
| 18000 | 865 | 890 | 932 | 914 | 764 | 110 | 112 | 106 | 103 |
| 20000 | 980 | 1026 | 1055 | 1033 | 873 | 124 | 125 | 122 | 117 |
| 22000 | 1085 | 1138 | 1177 | 1155 | 991 | 137 | 140 | 136 | 131 |
| 24000 | 1200 | 1253 | 1296 | 1275 | 1102 | 150 | 155 | 152 | 143 |
| 26000 | 1307 | 1377 | 1313 | 1394 | 1216 | 166 | 170 | 167 | 156 |
| 28000 | 1417 | 1493 | 1436 | 1517 | 1334 | 181 | 184 | 180 | 170 |
| 29000 | 1476 | 1539 | 1506 | 1580 | 1359 | 176 | 187 | 192 | 188 |
| 30000 | 1533 | 1580 | 1665 | 1633 | 1442 | 195 | 199 | 194 | 182 |
| 31000 | 1590 | 1622 | 1723 | 1692 | 1500 | 202 | 206 | 201 | 189 |
| 32000 | 1646 | 1647 | 1788 | 1754 | 1558 | 210 | 214 | 209 | 195 |
| 33000 | 1705 | 1687 | 1850 | 1807 | 1609 | 218 | 221 | 215 | 201 |
| 34000 | 1766 | 1729 | 1918 | 1865 | 1663 | 226 | 227 | 222 | 208 |
| 35000 | 1825 | 1791 | 1985 | 1919 | 1719 | 233 | 235 | 229 | 215 |
| 36000 | 1885 | 1868 | 2049 | 1971 | 1770 | 240 | 243 | 235 | 222 |
| 37000 | 1947 | 1948 | 2118 | 2023 | 1828 | 247 | 240 | 243 | 228 |
| 38000 | 2017 | 2033 | 2193 | 2070 | 1879 | 254 | 256 | 250 | 235 |
| 39000 | 2083 | 2120 | 2260 | 2114 | 1931 | 263 | 264 | 256 | 242 |
| 40000 | 2155 | 2216 | 2318 | 2143 | 1971 | 270 | 271 | 264 | 250 |
| 41000 | 2245 | 2340 | 2418 | 2158 | 2013 | 278 | 279 | 271 | 257 |
| 42000 | 2333 | 2496 | 2528 | 2140 | 2051 | 286 | 287 | 278 | 265 |
| 42680 | Ultimate load | | | | | | | | |

TABLE XXXIX

STRAIN READINGS FOR PANEL 38

t = .0825 in. L = 2.75 in. b = 2.50 in.
W = 15 in. N = 5

Gauge arrangement BF, Figure 12

| Load | Gauge readings in micro-inches per inch | | | | | | Dial readings in inches x 10-4 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 110 | 119 | 112 | 117 | 135 | 118 | 20 | 18 | 11 | 10 |
| 6000 | 218 | 228 | 217 | 231 | 260 | 239 | 36 | 35 | 24 | 21 |
| 8000 | 326 | 337 | 328 | 347 | 386 | 360 | 54 | 50 | 35 | 34 |
| 10000 | 428 | 441 | 431 | 457 | 500 | 470 | 71 | 64 | 46 | 49 |
| 12000 | 533 | 547 | 535 | 572 | 619 | 583 | 86 | 77 | 58 | 63 |
| 14000 | 638 | 648 | 640 | 683 | 737 | 702 | 104 | 91 | 70 | 76 |
| 16000 | 753 | 749 | 742 | 793 | 850 | 812 | 118 | 104 | 82 | 90 |
| 18000 | 858 | 849 | 848 | 906 | 959 | 927 | 134 | 117 | 93 | 105 |
| 20000 | 957 | 944 | 955 | 1411 | 1072 | 1037 | 149 | 130 | 104 | 120 |
| 21000 | 1002 | 987 | 1013 | 1071 | 1134 | 1098 | 158 | 136 | 111 | 126 |
| 22000 | 1043 | 1031 | 1068 | 1124 | 1189 | 1151 | 165 | 143 | 116 | 134 |
| 23000 | 1080 | 1084 | 1128 | 1183 | 1250 | 1212 | 172 | 148 | 123 | 142 |
| 24000 | 1110 | 1134 | 1189 | 1240 | 1302 | 1265 | 180 | 155 | 129 | 150 |
| 25000 | 1128 | 1176 | 1253 | 1298 | 1361 | 1320 | 187 | 162 | 135 | 159 |
| 26000 | 1128 | 1212 | 1330 | 1365 | 1430 | 1375 | 195 | 168 | 141 | 165 |
| 27000 | 1029 | 1088 | 1395 | 1431 | 1495 | 1425 | 204 | 175 | 146 | 172 |
| 28000 | ---- | ---- | ---- | ---- | ---- | ---- | 266 | 239 | 215 | 243 |
| 29500 | Ultimate load | | | | | | 332 | 310 | 290 | 315 |

TABLE XL

STRAIN READINGS FOR PANEL 39

t = .0840 in. L = 2.75 in. b = 2.00 in.
W = 16 in. N = 7

Gauge arrangement DF, Figure 12

| | Gauge readings in micro-inches per inch | | | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 110 | 109 | 102 | 90 | 97 | 117 | 115 | 98 | 20 | 14 | 6 | 6 |
| 6000 | 200 | 214 | 203 | 175 | 186 | 227 | 224 | 195 | 34 | 26 | 15 | 18 |
| 8000 | 295 | 318 | 303 | 262 | 274 | 337 | 334 | 291 | 48 | 36 | 24 | 30 |
| 10000 | 390 | 421 | 401 | 346 | 359 | 428 | 439 | 383 | 62 | 49 | 33 | 41 |
| 12000 | 485 | 526 | 499 | 432 | 443 | 485 | 548 | 478 | 75 | 60 | 40 | 53 |
| 14000 | 582 | 630 | 594 | 519 | 530 | 564 | 657 | 578 | 89 | 71 | 50 | 65 |
| 16000 | 679 | 733 | 684 | 603 | 611 | 611 | 762 | 671 | 103 | 82 | 58 | 76 |
| 18000 | 778 | 840 | 779 | 690 | 694 | 720 | 879 | 771 | 118 | 95 | 66 | 88 |
| 20000 | 872 | 943 | 874 | 777 | 781 | 838 | 994 | 871 | 132 | 106 | 75 | 97 |
| 22000 | 970 | 1046 | 963 | 858 | 862 | 951 | 1107 | 967 | 146 | 118 | 83 | 109 |
| 24000 | 1066 | 1145 | 1042 | 945 | 942 | 1070 | 1218 | 1061 | 160 | 130 | 91 | 120 |
| 26000 | 1162 | 1242 | 1120 | 1025 | 1016 | 1183 | 1337 | 1165 | 174 | 142 | 100 | 131 |
| 28000 | 1257 | 1330 | 1179 | 1098 | 1087 | 1296 | 1447 | 1256 | 190 | 155 | 109 | 142 |
| 29000 | 1310 | 1366 | 1195 | 1135 | 1130 | 1360 | 1509 | 1307 | 198 | 161 | 115 | 148 |
| 30000 | 1352 | 1399 | 1207 | 1166 | 1171 | 1425 | 1567 | 1353 | 203 | 165 | 118 | 152 |
| 31000 | 1402 | 1396 | 1181 | 1180 | 1209 | 1486 | 1635 | 1401 | 210 | 171 | 124 | 157 |
| 32000 | 1442 | 1321 | 1091 | 1178 | 1250 | 1559 | 1704 | 1449 | 218 | 176 | 128 | 162 |
| 33000 | 1445 | 1053 | 813 | 1125 | 1301 | 1659 | 1784 | 1501 | 225 | 183 | 133 | 169 |
| 34000 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 234 | 191 | 140 | 176 |
| 35000 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 297 | 244 | 208 | 253 |
| 35970 | Ultimate load | | | | | | | | 574 | 364 | 340 | 548 |

# TABLE XLI

## STRAIN READINGS FOR PANEL 40

t = .0815 in. L = 2.00 in. b = 2.66 in. W = 15.95 in. N = 5

Gauge arrangement BF, Figure 12

| | Gauge readings in micro-inches per inch | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 4 | 5 | 6 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 96 | 107 | 110 | 110 | 115 | 115 | 14 | 17 | 10 | 7 |
| 6000 | 200 | 211 | 199 | 212 | 230 | 215 | 28 | 30 | 21 | 20 |
| 8000 | 307 | 321 | 278 | 312 | 309 | 318 | 42 | 40 | 31 | 33 |
| 10000 | 407 | 422 | 397 | 436 | 438 | 423 | 54 | 51 | 41 | 45 |
| 12000 | 515 | 536 | 508 | 536 | 537 | 519 | 67 | 63 | 52 | 57 |
| 14000 | 622 | 651 | 638 | 525 | 659 | 626 | 80 | 77 | 63 | 69 |
| 16000 | 712 | 756 | 743 | 621 | 777 | 726 | 93 | 89 | 73 | 81 |
| 18000 | 807 | 864 | 880 | 729 | 935 | 841 | 107 | 101 | 83 | 93 |
| 19000 | 852 | 900 | 972 | 786 | 1036 | 891 | 114 | 108 | 88 | 98 |
| 20000 | 910 | 961 | 1019 | 838 | 1126 | 942 | 121 | 115 | 93 | 103 |
| 21000 | 960 | 1015 | 1082 | 990 | 1216 | 995 | 128 | 122 | 998 | 107 |
| 22000 | 1011 | 1067 | 1145 | 1044 | 1303 | 1056 | 134 | 130 | 103 | 112 |
| 23000 | 1063 | 1119 | 1218 | 1107 | 1380 | 1108 | 141 | 136 | 108 | 118 |
| 24000 | 1113 | 1175 | 1287 | 1157 | 1353 | 1158 | 148 | 142 | 112 | 123 |
| 25000 | 1166 | 1231 | 1340 | 1210 | 1525 | 1213 | 154 | 149 | 118 | 128 |
| 26000 | 1221 | 1288 | 1407 | 1267 | 1609 | 1281 | 162 | 153 | 124 | 134 |
| 27000 | 1273 | 1346 | 1462 | 1323 | 1673 | 1326 | 169 | 162 | 130 | 139 |
| 28000 | 1331 | 1412 | 1515 | 1374 | 1728 | 1380 | 175 | 169 | 136 | 145 |
| 29000 | 1392 | 1492 | 1584 | 1422 | 1795 | 1437 | 182 | 176 | 142 | 150 |
| 30000 | 1451 | 1573 | 1653 | 1487 | 1865 | 1492 | 189 | 183 | 148 | 155 |
| 31000 | 1513 | 1664 | 1728 | 1539 | 1919 | 1544 | 196 | 190 | 153 | 160 |
| 32000 | 1581 | 1762 | 1808 | 1596 | 1986 | 1603 | 204 | 196 | 160 | 166 |
| 33000 | 1655 | 1862 | 1903 | 1648 | 2041 | 1656 | 211 | 203 | 166 | 172 |
| 34000 | 1739 | 1942 | 2026 | 1706 | 2095 | 1721 | 219 | 210 | 172 | 178 |
| 35000 | 1849 | 2193 | 2167 | 1753 | 2101 | 1774 | 227 | 218 | 179 | 185 |
| 35650 | Ultimate load | | | | | | | | | |

TABLE XLII

STRAIN READINGS FOR PANEL 41

t = .0820 in. L = 3.25 in. b = 2.286 in. W = 16 in. N = 6

Gauge arrangement CF, Figure 12

| | Gauge readings in micro-inches per inch | | | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 94 | 118 | 111 | 94 | 78 | 114 | 115 | 102 | 10 | 10 | 9 | 8 |
| 6000 | 183 | 198 | 220 | 187 | 160 | 212 | 222 | 196 | 22 | 22 | 20 | 19 |
| 8000 | 276 | 261 | 329 | 281 | 232 | 342 | 336 | 300 | 32 | 30 | 32 | 31 |
| 10000 | 378 | 369 | 438 | 373 | 301 | 478 | 471 | 400 | 42 | 38 | 44 | 44 |
| 12000 | 480 | 477 | 551 | 470 | 372 | 621 | 583 | 499 | 52 | 48 | 55 | 57 |
| 14000 | 575 | 581 | 667 | 571 | 438 | 758 | 694 | 598 | 63 | 57 | 67 | 69 |
| 16000 | 667 | 688 | 771 | 659 | 495 | 882 | 804 | 700 | 73 | 66 | 78 | 83 |
| 18000 | 750 | 786 | 871 | 756 | 582 | 1023 | 925 | 805 | 84 | 76 | 91 | 96 |
| 20000 | 831 | 865 | 971 | 850 | 672 | 1152 | 1037 | 906 | 93 | 89 | 101 | 107 |
| 22000 | 893 | 912 | 1058 | 950 | 761 | 1289 | 1155 | 1009 | 103 | 94 | 112 | 120 |
| 23000 | 895 | 878 | 1061 | 998 | 806 | 1359 | 1214 | 1060 | 109 | 99 | 118 | 128 |
| 24000 | 850 | 730 | 986 | 1043 | 851 | 1429 | 1276 | 1112 | 114 | 104 | 124 | 135 |
| 32800 | Ultimate load | | | | | | | | | | | |

TABLE XLIII

STRAIN READINGS FOR PANEL 42

t = .0815 in. L = 3.50 in. b = 2.50 in.
W = 14.97 in. N = 5

Gauge arrangement BF, Figure 12

| | Gauge readings in micro-inches per inch | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 4 | 5 | 6 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 111 | 112 | 103 | 124 | 128 | 110 | 15 | 15 | 14 | 12 |
| 6000 | 227 | 225 | 213 | 238 | 245 | 216 | 29 | 29 | 25 | 25 |
| 8000 | 339 | 349 | 324 | 363 | 372 | 333 | 45 | 44 | 39 | 39 |
| 10000 | 449 | 469 | 436 | 489 | 502 | 450 | 60 | 58 | 52 | 53 |
| 12000 | 549 | 568 | 545 | 609 | 629 | 566 | 72 | 72 | 65 | 65 |
| 13000 | 591 | 588 | 595 | 661 | 680 | 614 | 78 | 79 | 70 | 70 |
| 14000 | 633 | 615 | 654 | 721 | 750 | 681 | 85 | 85 | 77 | 77 |
| 15000 | 670 | 631 | 713 | 782 | 811 | 740 | 92 | 92 | 84 | 84 |
| 16000 | 691 | 630 | 770 | 843 | 883 | 805 | 99 | 99 | 90 | 90 |
| 17000 | 692 | 585 | 813 | 895 | 940 | 862 | 103 | 108 | 97 | 96 |
| 18000 | 641 | 377 | 663 | 961 | 1020 | 912 | 113 | 116 | 104 | 102 |
| 19000 | 501 | 18 | 565 | 1028 | 1104 | 984 | 120 | 124 | 113 | 111 |
| 28000 | --- | --- | --- | ---- | ---- | --- | 450 | 455 | 475 | 480 |
| 28950 | Ultimate load | | | | | | | | | |

TABLE XLIV

STRAIN READINGS FOR PANEL 43

t = .0825 in.   L = 3.25 in.   b = 2.50 in.
W = 15 in.   N = 5

Gauge arrangement BF, Figure 12

| Load | Gauge readings in micro-inches per inch: 1 | 2 | 3 | 4 | 5 | 6 | Dial readings in inches x $10^{-4}$: a | b | c | d |
|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 96 | 120 | 123 | 123 | 118 | 93 | 19 | 17 | 14 | 9 |
| 6000 | 225 | 228 | 217 | 237 | 237 | 191 | 34 | 34 | 26 | 21 |
| 8000 | 343 | 330 | 303 | 359 | 369 | 299 | 50 | 41 | 39 | 32 |
| 10000 | 445 | 440 | 408 | 469 | 479 | 403 | 63 | 67 | 51 | 44 |
| 12000 | 565 | 555 | 530 | 584 | 598 | 519 | 78 | 83 | 64 | 56 |
| 13000 | 623 | 614 | 590 | 659 | 676 | 579 | 85 | 90 | 70 | 62 |
| 14000 | 676 | 658 | 643 | 709 | 734 | 638 | 91 | 98 | 76 | 67 |
| 15000 | 735 | 707 | 698 | 769 | 797 | 698 | 99 | 106 | 84 | 72 |
| 16000 | 787 | 745 | 745 | 823 | 857 | 753 | 105 | 115 | 91 | 77 |
| 17000 | 840 | 780 | 785 | 881 | 921 | 816 | 111 | 122 | 100 | 83 |
| 18000 | 883 | 792 | 815 | 946 | 989 | 884 | 119 | 130 | 108 | 89 |
| 19000 | 933 | 770 | 885 | 1001 | 1054 | 941 | 125 | 136 | 115 | 94 |
| 20000 | 975 | 681 | 792 | 1066 | 1131 | 1013 | 131 | 145 | 122 | 100 |
| 21000 | 965 | 440 | 678 | 1176 | 1212 | 1091 | 136 | 154 | 132 | 105 |
| 22000 | 780 | -89 | 407 | 1241 | 1320 | 1183 | 144 | 165 | 142 | 110 |
| 29000 | --- | --- | --- | ---- | ---- | ---- | 312 | 362 | 358 | 280 |
| 29810 | Ultimate load | | | | | | | | | |

# TABLE XLV

## STRAIN READINGS FOR PANEL 44

t = .0815 in. L = 1.00 in. b = 2.50 in. W = 15 in. N = 5

Gauge arrangement BF, Figure 12

| | Gauge readings in micro-inches per inch | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 4 | 5 | 6 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 116 | 100 | 93 | 76 | 97 | 81 | 30 | 21 | 18 | 15 |
| 6000 | 217 | 202 | 190 | 159 | 197 | 172 | 52 | 38 | 32 | 30 |
| 8000 | 315 | 295 | 276 | 246 | 298 | 279 | 71 | 55 | 46 | 44 |
| 10000 | 415 | 388 | 361 | 336 | 408 | 374 | 90 | 71 | 59 | 58 |
| 12000 | 514 | 477 | 446 | 426 | 514 | 475 | 107 | 86 | 74 | 69 |
| 14000 | 604 | 570 | 531 | 519 | 629 | 581 | 124 | 101 | 88 | 82 |
| 16000 | 695 | 658 | 621 | 616 | 740 | 680 | 142 | 117 | 91 | 93 |
| 18000 | 785 | 742 | 704 | 710 | 858 | 787 | 159 | 135 | 116 | 108 |
| 20000 | 867 | 828 | 782 | 805 | 967 | 886 | 178 | 146 | 125 | 117 |
| 22000 | 953 | 897 | 854 | 895 | 1080 | 993 | 197 | 163 | 138 | 130 |
| 24000 | 1048 | 981 | 932 | 937 | 1190 | 1093 | 214 | 179 | 147 | 143 |
| 26000 | 1142 | 1071 | 1014 | 1088 | 1310 | 1202 | 232 | 194 | 161 | 155 |
| 28000 | 1234 | 1151 | 1081 | 1187 | 1421 | 1301 | 252 | 212 | 172 | 168 |
| 29000 | 1283 | 1180 | 1121 | 1239 | 1482 | 1357 | 262 | 222 | 176 | 174 |
| 30000 | 1327 | 1208 | 1152 | 1279 | 1529 | 1402 | 270 | 229 | 182 | 180 |
| 31000 | 1373 | 1232 | 1187 | 1325 | 1581 | 1455 | 281 | 238 | 187 | 187 |
| 32000 | 1418 | 1265 | 1223 | 1375 | 1633 | 1502 | 290 | 246 | 192 | 193 |
| 33000 | 1468 | 1300 | 1263 | 1426 | 1688 | 1557 | 300 | 256 | 199 | 199 |
| 34000 | 1523 | 1335 | 1301 | 1476 | 1740 | 1603 | 310 | 264 | 204 | 205 |
| 35000 | 1573 | 1361 | 1337 | 1521 | 1790 | 1653 | 320 | 273 | 210 | 210 |
| 36000 | 1630 | 1390 | 1372 | 1565 | 1835 | 1699 | 329 | 281 | 215 | 216 |
| 37000 | 1690 | 1428 | 1410 | 1609 | 1885 | 1751 | 340 | 290 | 220 | 223 |
| 38000 | 1745 | 1462 | 1443 | 1649 | 1924 | 1792 | 350 | 299 | 225 | 229 |
| 39000 | 1802 | 1498 | 1486 | 1697 | 1974 | 1844 | 361 | 308 | 230 | 236 |
| 40000 | 1857 | 1532 | 1422 | 1726 | 2000 | 1883 | 371 | 319 | 235 | 243 |
| 41000 | 1955 | 1592 | 1464 | 1756 | 2016 | 1927 | 387 | 329 | 243 | 251 |
| 42000 | 2005 | 1629 | 1491 | 1775 | 2026 | 1956 | 394 | 335 | 246 | 255 |
| 43000 | 2105 | 1702 | 1539 | 1788 | 2006 | 1994 | 406 | 344 | 252 | 263 |
| 44000 | 2325 | 1881 | 1616 | 1723 | ---- | ---- | --- | --- | --- | --- |
| 44000 | Ultimate load | | | | | | | | | |

## TABLE XLVI

### STRAIN READINGS FOR PANEL 45

t = .0835 in. L = 1.25 in. b = 2.00 in.
W = 16 in. N = 7

Gauge arrangement EF, Figure 12

| | Gauge readings in micro-inches per inch | | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 4 | 6 | 7 | 8 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 105 | 92 | 102 | 93 | 60 | 52 | 61 | 26 | 25 | 15 | 13 |
| 6000 | 189 | 182 | 201 | 170 | 160 | 117 | 125 | 43 | 40 | 28 | 26 |
| 8000 | 275 | 273 | 298 | 243 | 248 | 204 | 190 | 57 | 52 | 38 | 36 |
| 10000 | 355 | 462 | 393 | 315 | 332 | 294 | 263 | 69 | 65 | 48 | 46 |
| 12000 | 434 | 454 | 492 | 392 | 420 | 382 | 338 | 81 | 77 | 58 | 56 |
| 14000 | 511 | 541 | 585 | 468 | 519 | 468 | 419 | 94 | 97 | 69 | 66 |
| 16000 | 588 | 627 | 678 | 538 | 603 | 541 | 494 | 108 | 101 | 79 | 78 |
| 18000 | 662 | 718 | 773 | 615 | 703 | 624 | 564 | 118 | 115 | 88 | 89 |
| 20000 | 741 | 810 | 874 | 693 | 801 | 688 | 650 | 131 | 127 | 97 | 100 |
| 22000 | 813 | 899 | 966 | 770 | 896 | 765 | 728 | 144 | 140 | 106 | 110 |
| 24000 | 883 | 984 | 1058 | 840 | 991 | 813 | 807 | 157 | 154 | 116 | 121 |
| 26000 | 955 | 1012 | 1153 | 910 | 1086 | 871 | 887 | 169 | 168 | 126 | 131 |
| 28000 | 1032 | 1165 | 1254 | 990 | 1201 | 977 | 979 | 183 | 182 | 135 | 141 |
| 30000 | 1102 | 1254 | 1348 | 1063 | 1293 | 1068 | 1058 | 196 | 194 | 144 | 151 |
| 31000 | 1142 | 1301 | 1397 | 1109 | 1349 | 1117 | 1108 | 207 | 207 | 153 | 162 |
| 32000 | 1169 | 1340 | 1442 | 1142 | 1401 | 1164 | 1145 | 211 | 211 | 154 | 163 |
| 33000 | 1202 | 1383 | 1491 | 1178 | 1453 | 1207 | 1181 | 217 | 217 | 158 | 167 |
| 34000 | 1236 | 1421 | 1538 | 1212 | 1508 | 1257 | 1224 | 224 | 224 | 164 | 173 |
| 35000 | 1272 | 1464 | 1583 | 1248 | 1551 | 1297 | 1257 | 230 | 230 | 168 | 177 |
| 36000 | 1307 | 1512 | 1633 | 1285 | 1599 | 1347 | 1300 | 238 | 237 | 173 | 182 |
| 37000 | 1334 | 1550 | 1678 | 1319 | 1642 | 1384 | 1328 | 246 | 243 | 177 | 187 |
| 38000 | 1370 | 1598 | 1731 | 1358 | 1703 | 1430 | 1370 | 254 | 250 | 182 | 192 |
| 39000 | 1403 | 1637 | 1779 | 1395 | 1752 | 1472 | 1408 | 261 | 257 | 187 | 197 |
| 40000 | 1439 | 1687 | 1831 | 1423 | 1803 | 1516 | 1448 | 268 | 264 | 191 | 201 |
| 41000 | 1471 | 1734 | 1881 | 1459 | 1854 | 1559 | 1488 | 276 | 272 | 197 | 207 |
| 42000 | 1504 | 1777 | 1930 | 1493 | 1893 | 1604 | 1528 | 283 | 278 | 202 | 211 |
| 43000 | 1539 | 1831 | 1982 | 1531 | 1951 | 1647 | 1570 | 291 | 285 | 207 | 217 |
| 44000 | 1570 | 1882 | 2038 | 1573 | 2006 | 1688 | 1607 | 299 | 292 | 213 | 222 |
| 45000 | 1600 | 1934 | 2091 | 1608 | 2033 | 1718 | 1639 | 305 | 298 | 217 | 227 |
| 46000 | 1632 | 1985 | 2151 | 1648 | 2068 | 1754 | 1672 | 312 | 306 | 222 | 231 |

TABLE XLVI (continued)

| Load | Gauge readings in micro-inches per inch | | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | a | b | c | d |
| 47000 | 1659 | 2031 | 2211 | 1685 | 2104 | 1780 | 1800 | 319 | 314 | 227 | 236 |
| 48000 | 1692 | 2084 | 2281 | 1708 | 2166 | 1816 | 1736 | 327 | 321 | 233 | 241 |
| 49000 | 1723 | 2139 | 2351 | 1744 | 2220 | 1845 | 1770 | 335 | 328 | 238 | 247 |
| 50000 | 1755 | 2202 | 2435 | 1790 | 2276 | 1866 | 1807 | 344 | 335 | 243 | 250 |
| 51000 | 1788 | 2270 | 2525 | 1838 | 2333 | 1875 | 1840 | 352 | 344 | 249 | 256 |
| 52000 | 1828 | 2367 | 2650 | 1900 | 2352 | 1847 | 1876 | 360 | 351 | 254 | 261 |
| 52760 | Ultimate load | | | | | | | | | | |

# TABLE XLVII

## STRAIN READINGS FOR PANEL 46

t = .0820 in. L = 2.75 in. b = 3.00 in.
W = 15 in. N = 4

Gauge arrangement CF, Figure 12

| | Gauge readings in micro-inches per inch | | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 4 | 6 | 7 | 8 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 103 | 106 | 131 | 130 | 87 | 83 | 66 | 23 | 28 | 20 | 11 |
| 6000 | 202 | 214 | 263 | 251 | 183 | 189 | 149 | 39 | 41 | 38 | 20 |
| 8000 | 296 | 316 | 388 | 368 | 289 | 304 | 260 | 55 | 71 | 54 | 31 |
| 10000 | 389 | 421 | 505 | 481 | 396 | 420 | 376 | 70 | 94 | 70 | 42 |
| 12000 | 483 | 527 | 631 | 596 | 509 | 541 | 487 | 85 | 114 | 85 | 53 |
| 14000 | 576 | 632 | 752 | 708 | 632 | 665 | 598 | 101 | 136 | 98 | 64 |
| 16000 | 663 | 736 | 875 | 816 | 756 | 783 | 708 | 118 | 156 | 115 | 74 |
| 17000 | 708 | 789 | 938 | 869 | 820 | 845 | 772 | 127 | 166 | 121 | 79 |
| 18000 | 746 | 837 | 997 | 920 | 880 | 907 | 836 | 135 | 178 | 130 | 85 |
| 19000 | 783 | 885 | 1061 | 976 | 947 | 963 | 892 | 144 | 188 | 136 | 89 |
| 20000 | 821 | 924 | 1124 | 1028 | 1014 | 1021 | 953 | 152 | 198 | 143 | 94 |
| 21000 | 856 | 974 | 1182 | 1078 | 1077 | 1079 | 1017 | 160 | 208 | 150 | 100 |
| 22000 | 883 | 1014 | 1243 | 1128 | 1142 | 1139 | 1080 | 168 | 217 | 156 | 105 |
| 23000 | 909 | 1049 | 1310 | 1184 | 1217 | 1199 | 1149 | 176 | 229 | 163 | 110 |
| 24000 | 923 | 1072 | 1384 | 1233 | 1280 | 1246 | 1213 | 183 | 239 | 170 | 115 |
| 25000 | 916 | 1076 | 1468 | 1303 | 1350 | 1294 | 1270 | 190 | 247 | 176 | 120 |
| 26000 | 879 | 1046 | 1556 | 1405 | 1435 | 1351 | 1346 | 200 | 258 | 185 | 125 |
| 26620 | Ultimate load | | | | | | | | | | |

TABLE XLVIII

STRAIN READINGS FOR PANEL 47

t = .0820 in. L = 3.50 in. b = 2.286 in.
W = 16 in. N = 6

Gauge arrangement CF, Figure 12

| | Gauge readings in micro-inches per inch | | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 5 | 6 | 7 | 8 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 88 | 84 | 97 | 80 | 101 | 110 | 77 | 20 | 16 | 11 | 11 |
| 6000 | 186 | 181 | 192 | 170 | 198 | 217 | 147 | 36 | 30 | 19 | 21 |
| 8000 | 285 | 176 | 285 | 274 | 297 | 331 | 224 | 54 | 43 | 28 | 33 |
| 10000 | 380 | 267 | 380 | 389 | 406 | 451 | 304 | 72 | 54 | 36 | 45 |
| 12000 | 470 | 344 | 462 | 503 | 519 | 574 | 392 | 90 | 66 | 45 | 58 |
| 14000 | 551 | 404 | 531 | 625 | 638 | 680 | 478 | 108 | 77 | 51 | 70 |
| 16000 | 606 | 421 | 567 | 746 | 768 | 815 | 576 | 126 | 90 | 59 | 83 |
| 17000 | 608 | 382 | 558 | 799 | 819 | 873 | 617 | 135 | 96 | 63 | 89 |
| 18000 | 601 | 336 | 528 | 864 | 880 | 934 | 658 | 144 | 100 | 65 | 95 |
| 19000 | 552 | 288 | 428 | 932 | 950 | 1001 | 707 | 155 | 107 | 70 | 103 |
| 20000 | 438 | 44 | 242 | 1002 | 1026 | 1070 | 755 | 165 | 112 | 74 | 112 |
| 21000 | 210 | -421[a] | -135 | 1089 | 1111 | 1157 | 817 | 176 | 119 | 80 | 124 |
| 31000 | --- | --- | --- | ---- | ---- | ---- | --- | 424 | 273 | 225 | 375 |
| 31960 | Ultimate load | | | | | | | | | | |

a Negative values indicate tension strains.

TABLE XLIX

STRAIN READINGS FOR PANEL 48

t = .0830 in. L = 1.25 in. b = 3.00 in. W = 15 in. N = 4

| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | a | b | c | d |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 100 | 119 | 120 | 112 | 67 | 62 | 72 | 34 | 22 | 27 | 15 | 9 |
| 6000 | 186 | 234 | 241 | 219 | 154 | 154 | 200 | 136 | 43 | 50 | 28 | 18 |
| 8000 | 266 | 335 | 349 | 317 | 253 | 255 | 320 | 252 | 63 | 74 | 40 | 30 |
| 10000 | 347 | 437 | 453 | 413 | 353 | 355 | 451 | 372 | 83 | 94 | 52 | 41 |
| 12000 | 427 | 535 | 559 | 510 | 463 | 456 | 585 | 491 | 104 | 114 | 62 | 52 |
| 14000 | 501 | 630 | 663 | 607 | 575 | 546 | 717 | 616 | 125 | 136 | 73 | 65 |
| 16000 | 583 | 711 | 770 | 688 | 682 | 632 | 836 | 740 | 146 | 156 | 84 | 79 |
| 18000 | 660 | 802 | 874 | 779 | 792 | 715 | 942 | 854 | 167 | 177 | 95 | 93 |
| 20000 | 742 | 901 | 981 | 879 | 900 | 794 | 1069 | 980 | 193 | 196 | 106 | 107 |
| 22000 | 810 | 970 | 1079 | 953 | 996 | 853 | 1195 | 1091 | 213 | 214 | 116 | 119 |
| 23000 | 849 | 1020 | 1131 | 998 | 1051 | 886 | 1264 | 1152 | 225 | 225 | 122 | 126 |
| 24000 | 878 | 1069 | 1176 | 1035 | 1093 | 912 | 1330 | 1214 | 236 | 235 | 128 | 133 |
| 25000 | 917 | 1128 | 1231 | 1078 | 1143 | 940 | 1392 | 1268 | 245 | 244 | 133 | 140 |
| 26000 | 944 | 1179 | 1277 | 1116 | 1190 | 963 | 1459 | 1325 | 256 | 252 | 139 | 147 |
| 28000 | 1032 | 1301 | 1382 | 1208 | 1293 | 1033 | 1595 | 1445 | 280 | 272 | 150 | 161 |
| 29000 | 1056 | 1353 | 1428 | 1245 | 1335 | 1058 | 1656 | 1500 | 291 | 280 | 155 | 168 |
| 30000 | 1094 | 1415 | 1481 | 1285 | 1383 | 1087 | 1718 | 1554 | 300 | 289 | 160 | 174 |
| 31000 | 1129 | 1480 | 1538 | 1327 | 1428 | 1113 | 1785 | 1615 | 311 | 299 | 165 | 181 |
| 32000 | 1173 | 1550 | 1600 | 1370 | 1574 | 1142 | 1852 | 1672 | 322 | 307 | 170 | 188 |
| 33000 | 1216 | 1630 | 1667 | 1415 | 1517 | 1168 | 1920 | 1731 | 333 | 317 | 175 | 195 |
| 34000 | 1256 | 1719 | 1741 | 1457 | 1553 | 1192 | 1975 | 1784 | 343 | 327 | 180 | 202 |
| 35000 | 1309 | 1856 | 1848 | 1513 | 1591 | 1205 | 2028 | 1837 | 353 | 336 | 186 | 208 |
| 36000 | 1384 | 2055 | 2011 | 1588 | 1616 | 1211 | 2068 | 1895 | 365 | 346 | 191 | 217 |
| 36700 | Ultimate load | | | | | | | | | | | |

TABLE L

STRAIN READINGS FOR PANEL 49

t = .0815 in. L = 1.50 in. b = 2.286 in. W = 16 in. N = 6

Gauge arrangement CF, Figure 12

| Load | Gauge readings in micro-inches per inch | | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 8 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 66 | 71 | 68 | 92 | 86 | 109 | 70 | 15 | 21 | 7 | 0 |
| 6000 | 149 | 163 | 146 | 189 | 167 | 197 | 132 | 36 | 45 | 18 | 6 |
| 8000 | 232 | 256 | 224 | 252 | 240 | 278 | 190 | 53 | 66 | 29 | 13 |
| 10000 | 311 | 352 | 304 | 380 | 303 | 354 | 262 | 70 | 90 | 42 | 17 |
| 12000 | 393 | 446 | 383 | 469 | 368 | 431 | 331 | 86 | 109 | 52 | 24 |
| 14000 | 482 | 541 | 461 | 555 | 434 | 509 | 395 | 104 | 128 | 61 | 32 |
| 16000 | 577 | 644 | 544 | 640 | 496 | 584 | 455 | 122 | 148 | 71 | 41 |
| 18000 | 666 | 742 | 620 | 721 | 560 | 661 | 512 | 139 | 164 | 81 | 50 |
| 20000 | 759 | 843 | 695 | 798 | 623 | 734 | 589 | 156 | 181 | 90 | 61 |
| 22000 | 853 | 944 | 771 | 858 | 687 | 813 | 680 | 173 | 199 | 100 | 72 |
| 24000 | 945 | 1043 | 843 | 915 | 750 | 891 | 774 | 190 | 214 | 110 | 84 |
| 26000 | 1041 | 1151 | 919 | 982 | 820 | 982 | 875 | 209 | 232 | 117 | 94 |
| 27000 | 1089 | 1196 | 951 | 1007 | 855 | 1026 | 920 | 219 | 241 | 122 | 100 |
| 28000 | 1136 | 1251 | 988 | 1029 | 880 | 1066 | 967 | 228 | 248 | 126 | 105 |
| 29000 | 1181 | 1301 | 1024 | 1060 | 915 | 1110 | 1016 | 237 | 255 | 131 | 110 |
| 30000 | 1229 | 1356 | 1061 | 1092 | 953 | 1160 | 1062 | 246 | 263 | 136 | 116 |
| 31000 | 1278 | 1408 | 1098 | 1120 | 985 | 1206 | 1113 | 255 | 271 | 141 | 122 |
| 32000 | 1326 | 1464 | 1138 | 1152 | 1023 | 1261 | 1165 | 265 | 280 | 146 | 129 |
| 33000 | 1370 | 1516 | 1171 | 1182 | 1064 | 1311 | 1210 | 274 | 288 | 151 | 134 |
| 34000 | 1419 | 1571 | 1206 | 1207 | 1095 | 1354 | 1250 | 292 | 295 | 155 | 140 |
| 35000 | 1469 | 1634 | 1246 | 1238 | 1140 | 1411 | 1310 | 291 | 304 | 162 | 147 |
| 36000 | 1513 | 1689 | 1281 | 1263 | 1178 | 1459 | 1351 | 300 | 311 | 166 | 152 |
| 37000 | 1561 | 1748 | 1321 | 1290 | 1220 | 1508 | 1401 | 310 | 319 | 171 | 158 |
| 38000 | 1610 | 1803 | 1353 | 1311 | 1255 | 1553 | 1445 | 319 | 328 | 177 | 165 |
| 39000 | 1656 | 1864 | 1391 | 1337 | 1296 | 1596 | 1492 | 328 | 336 | 182 | 170 |
| 40000 | 1707 | 1923 | 1434 | 1367 | 1347 | 1648 | 1547 | 337 | 345 | 187 | 176 |
| 41000 | 1756 | 1983 | 1472 | 1390 | 1388 | 1683 | 1587 | 345 | 353 | 192 | 181 |
| 42000 | 1803 | 2050 | 1518 | 1420 | 1435 | 1724 | 1635 | 354 | 361 | 198 | 187 |
| 43000 | 1852 | 2119 | 1562 | 1449 | 1480 | 1763 | 1687 | 364 | 370 | 203 | 194 |
| 44000 | 1908 | 2196 | 1613 | 1529 | 1523 | 1791 | 1728 | 373 | 380 | 208 | 200 |
| 45000 | 1960 | 2284 | 1673 | 1585 | 1570 | 1822 | 1770 | 383 | 390 | 213 | 207 |
| 46050 | Ultimate load | | | | | | | | | | |

TABLE LI

STRAIN READINGS FOR PANEL 50

t = .0815 in. L = 2.50 in. b = 2.00 in. W = 16 in. N = 7

Gauge arrangement EF, Figure 12

| | Gauge readings in micro-inches per inch | | | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 94 | 110 | 108 | 94 | 101 | 112 | 83 | 60 | 23 | 22 | 6 | 6 |
| 6000 | 182 | 211 | 206 | 182 | 205 | 224 | 172 | 143 | 40 | 36 | 12 | 14 |
| 8000 | 269 | 317 | 308 | 268 | 308 | 345 | 261 | 237 | 57 | 50 | 19 | 22 |
| 10000 | 354 | 418 | 407 | 353 | 410 | 455 | 345 | 322 | 72 | 64 | 26 | 31 |
| 12000 | 450 | 521 | 509 | 440 | 513 | 568 | 430 | 410 | 89 | 78 | 34 | 41 |
| 14000 | 544 | 627 | 611 | 527 | 618 | 684 | 516 | 507 | 106 | 92 | 41 | 56 |
| 16000 | 624 | 734 | 718 | 620 | 728 | 803 | 597 | 598 | 123 | 106 | 49 | 60 |
| 18000 | 727 | 834 | 815 | 705 | 826 | 910 | 686 | 707 | 140 | 121 | 56 | 69 |
| 20000 | 822 | 946 | 928 | 803 | 940 | 1035 | 763 | 800 | 156 | 135 | 62 | 78 |
| 22000 | 912 | 1051 | 1033 | 892 | 1040 | 1170 | 845 | 888 | 172 | 149 | 69 | 87 |
| 24000 | 1006 | 1156 | 1135 | 984 | 1143 | 1287 | 924 | 985 | 188 | 165 | 77 | 95 |
| 26000 | 1099 | 1261 | 1240 | 1075 | 1248 | 1407 | 1006 | 1087 | 206 | 182 | 85 | 104 |
| 28000 | 1192 | 1375 | 1346 | 1164 | 1350 | 1500 | 1080 | 1182 | 222 | 198 | 93 | 113 |
| 30000 | 1284 | 1484 | 1452 | 1255 | 1452 | 1613 | 1154 | 1280 | 238 | 214 | 101 | 121 |
| 32000 | 1384 | 1604 | 1560 | 1345 | 1553 | 1730 | 1232 | 1388 | 255 | 230 | 110 | 131 |
| 34000 | 1480 | 1751 | 1688 | 1444 | 1660 | 1852 | 1301 | 1480 | 271 | 245 | 119 | 140 |
| 35000 | 1527 | 1826 | 1756 | 1492 | 1712 | 1908 | 1335 | 1534 | 280 | 254 | 124 | 145 |
| 36000 | 1577 | 1928 | 1858 | 1547 | 1765 | 1975 | 1372 | 1582 | 289 | 261 | 129 | 149 |
| 37000 | 1672 | 2137 | 2036 | 1625 | 1825 | 2063 | 1412 | 1639 | 300 | 271 | 134 | 154 |
| 37950 | Ultimate load | | | | | | | | | | | |

TABLE LII

STRAIN READINGS FOR PANEL 51

t = .0830 in. L = 2.00 in. b = 2.00 in. W = 16 in. N = 7

Gauge arrangement EF, Figure 12

| | Gauge readings in micro-inches per inch | | | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 104 | 110 | 81 | 90 | 95 | 128 | 94 | 67 | 22 | 22 | 9 | 7 |
| 6000 | 202 | 204 | 157 | 173 | 188 | 254 | 204 | 134 | 38 | 38 | 16 | 14 |
| 8000 | 302 | 320 | 243 | 248 | 269 | 370 | 310 | 212 | 52 | 51 | 24 | 22 |
| 10000 | 401 | 429 | 314 | 339 | 340 | 490 | 417 | 297 | 66 | 64 | 32 | 32 |
| 12000 | 502 | 532 | 386 | 406 | 403 | 510 | 527 | 385 | 81 | 77 | 40 | 39 |
| 14000 | 599 | 642 | 477 | 470 | 481 | 727 | 634 | 478 | 96 | 91 | 48 | 48 |
| 16000 | 693 | 750 | 563 | 535 | 566 | 846 | 741 | 572 | 110 | 114 | 56 | 56 |
| 18000 | 787 | 857 | 658 | 553 | 648 | 965 | 851 | 672 | 128 | 118 | 65 | 67 |
| 20000 | 881 | 967 | 751 | 586 | 730 | 1080 | 958 | 766 | 144 | 131 | 72 | 77 |
| 22000 | 981 | 1079 | 837 | 669 | 839 | 1202 | 1071 | 867 | 160 | 145 | 81 | 87 |
| 24000 | 1072 | 1189 | 929 | 708 | 944 | 1317 | 1178 | 964 | 175 | 158 | 89 | 97 |
| 26000 | 1165 | 1299 | 1012 | 788 | 1043 | 1433 | 1283 | 1059 | 190 | 171 | 98 | 107 |
| 28000 | 1264 | 1410 | 1099 | 876 | 1151 | 1555 | 1398 | 1160 | 206 | 185 | 106 | 118 |
| 30000 | 1360 | 1528 | 1203 | 978 | 1250 | 1663 | 1498 | 1253 | 222 | 199 | 115 | 128 |
| 32000 | 1451 | 1638 | 1283 | 1086 | 1352 | 1782 | 1608 | 1353 | 239 | 213 | 124 | 138 |
| 33000 | 1499 | 1495 | 1316 | 1146 | 1400 | 1837 | 1662 | 1399 | 245 | 219 | 127 | 142 |
| 34000 | 1549 | 1552 | 1361 | 1195 | 1456 | 1900 | 1717 | 1449 | 253 | 226 | 131 | 148 |
| 35000 | 1597 | 1613 | 1414 | 1238 | 1507 | 1954 | 1767 | 1495 | 260 | 234 | 134 | 152 |
| 36000 | 1647 | 1772 | 1451 | 1276 | 1555 | 2010 | 1818 | 1541 | 268 | 242 | 138 | 158 |
| 37000 | 1694 | 1835 | 1487 | 1326 | 1606 | 2065 | 1870 | 1590 | 276 | 249 | 143 | 162 |

TABLE LII (continued)

| Load | Gauge readings in micro-inches per inch | | | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | a | b | c | d |
| 38000 | 1745 | 1999 | 1532 | 1355 | 1657 | 2120 | 1923 | 1639 | 285 | 256 | 146 | 168 |
| 39000 | 1797 | 2064 | 1581 | 1396 | 1706 | 2175 | 1973 | 1689 | 292 | 264 | 150 | 173 |
| 40000 | 1850 | 2133 | 1632 | 1438 | 1760 | 2235 | 2027 | 1740 | 300 | 272 | 155 | 178 |
| 41000 | 1902 | 2205 | 1686 | 1480 | 1805 | 2277 | 2073 | 1787 | 307 | 279 | 159 | 184 |
| 42000 | 1957 | 2278 | 1705 | 1513 | 1843 | 2317 | 2107 | 1828 | 316 | 288 | 163 | 188 |
| 43000 | 2010 | 2375 | 1783 | 1546 | 1896 | 2364 | 2157 | 1879 | 324 | 296 | 167 | 194 |
| 44000 | 2080 | 2487 | 1855 | 1591 | 1947 | 2397 | 2197 | 1929 | 333 | 303 | 172 | 200 |
| 45000 | 2161 | 2635 | 1952 | 1636 | 1987 | 2404 | 2225 | 1976 | 340 | 310 | 176 | 205 |
| 46000 | Ultimate load | | | | | | | | | | | |

TABLE LIII

STRAIN READINGS FOR PANEL 52

t = .0830 in.  L = 2.25 in.  b = 3.00 in.
W = 15 in.  N = 4

Gauge arrangement CF, Figure 12

| Load | 2 | 3 | 4 | 5 | 6 | 7 | 8 | a | b | c | d |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 136 | 134 | 126 | 77 | 84 | 87 | 83 | 27 | 29 | 10 | 9 |
| 6000 | 266 | 258 | 245 | 174 | 190 | 202 | 183 | 48 | 50 | 20 | 22 |
| 8000 | 404 | 391 | 367 | 281 | 306 | 335 | 282 | 68 | 68 | 31 | 34 |
| 10000 | 536 | 418 | 484 | 402 | 430 | 476 | 410 | 85 | 86 | 44 | 44 |
| 12000 | 673 | 651 | 606 | 532 | 554 | 623 | 544 | 104 | 104 | 55 | 56 |
| 14000 | 816 | 778 | 724 | 667 | 684 | 773 | 691 | 124 | 122 | 65 | 67 |
| 16000 | 957 | 908 | 839 | 805 | 812 | 923 | 841 | 141 | 142 | 78 | 80 |
| 18000 | 1094 | 1038 | 956 | 944 | 947 | 1074 | 984 | 163 | 160 | 90 | 93 |
| 19000 | 1177 | 1116 | 1025 | 1027 | 1020 | 1163 | 1071 | 176 | 172 | 96 | 101 |
| 20000 | 1223 | 1171 | 1069 | 1084 | 1077 | 1231 | 1135 | 184 | 179 | 100 | 105 |
| 21000 | 1296 | 1241 | 1127 | 1150 | 1140 | 1303 | 1204 | 192 | 188 | 106 | 111 |
| 22000 | 1376 | 1317 | 1187 | 1224 | 1207 | 1383 | 1283 | 203 | 198 | 113 | 118 |
| 23000 | 1443 | 1386 | 1241 | 1287 | 1270 | 1457 | 1359 | 213 | 206 | 118 | 124 |
| 24000 | 1525 | 1478 | 1308 | 1357 | 1311 | 1531 | 1430 | 222 | 215 | 125 | 130 |
| 25000 | 1610 | 1621 | 1408 | 1424 | 1392 | 1615 | 1513 | 233 | 226 | 132 | 138 |
| 26000 | 1705 | 1768 | 1547 | 1491 | 1444 | 1674 | 1580 | 241 | 235 | 137 | 143 |
| 27000 | 1823 | 1908 | 1705 | 1560 | 1501 | 1735 | 1657 | 252 | 244 | 144 | 150 |
| 28000 | 1975 | 2086 | 1876 | 1626 | 1544 | 1776 | 1725 | 264 | 254 | 150 | 156 |
| 29000 | 2303 | 2463 | 2154 | 1867 | 1540 | 1755 | 1770 | 276 | 265 | 159 | 165 |
| 29300 | Ultimate load | | | | | | | | | | |

TABLE LIV

STRAIN READINGS FOR PANEL 53

t = .0820 in. L = 1.75 in. b = 2.00 in. W = 16 in. N = 7

Gauge arrangement EF, Figure 12

| | Gauge readings in micro-inches per inch | | | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 108 | 120 | 120 | 110 | 59 | 79 | 47 | 31 | 20 | 21 | 9 | 8 |
| 6000 | 208 | 235 | 240 | 218 | 136 | 172 | 205 | 95 | 37 | 40 | 19 | 18 |
| 8000 | 300 | 342 | 349 | 316 | 231 | 277 | 318 | 188 | 50 | 55 | 28 | 26 |
| 10000 | 390 | 449 | 461 | 417 | 329 | 383 | 434 | 294 | 64 | 70 | 38 | 36 |
| 12000 | 482 | 560 | 578 | 521 | 431 | 497 | 558 | 407 | 78 | 86 | 48 | 44 |
| 14000 | 570 | 667 | 690 | 620 | 529 | 602 | 673 | 520 | 92 | 102 | 59 | 52 |
| 16000 | 661 | 778 | 810 | 725 | 632 | 718 | 797 | 636 | 107 | 118 | 70 | 61 |
| 18000 | 750 | 885 | 924 | 827 | 738 | 832 | 922 | 754 | 121 | 134 | 82 | 71 |
| 20000 | 846 | 1000 | 1047 | 934 | 845 | 945 | 1044 | 874 | 135 | 151 | 95 | 81 |
| 22000 | 939 | 1114 | 1167 | 1038 | 949 | 1059 | 1170 | 994 | 151 | 168 | 107 | 90 |
| 24000 | 1027 | 1222 | 1285 | 1142 | 1053 | 1170 | 1290 | 1112 | 165 | 184 | 119 | 98 |
| 26000 | 1119 | 1339 | 1408 | 1250 | 1161 | 1281 | 1411 | 1232 | 179 | 201 | 130 | 106 |
| 28000 | 1211 | 1450 | 1525 | 1352 | 1262 | 1390 | 1530 | 1350 | 195 | 216 | 142 | 115 |
| 30000 | 1301 | 1564 | 1650 | 1460 | 1371 | 1509 | 1653 | 1474 | 212 | 233 | 154 | 124 |
| 32000 | 1396 | 1682 | 1780 | 1571 | 1481 | 1615 | 1774 | 1597 | 227 | 250 | 166 | 132 |
| 33000 | 1446 | 1795 | 1840 | 1622 | 1530 | 1665 | 1829 | 1653 | 235 | 259 | 172 | 136 |
| 34000 | 1486 | 1795 | 1898 | 1672 | 1575 | 1715 | 1882 | 1712 | 243 | 266 | 177 | 140 |
| 35000 | 1533 | 1858 | 1970 | 1733 | 1632 | 1772 | 1946 | 1777 | 250 | 275 | 184 | 145 |
| 36000 | 1581 | 1915 | 2029 | 1782 | 1681 | 1819 | 1998 | 1833 | 258 | 283 | 189 | 149 |

TABLE LIV (continued)

| Load | Gauge readings in micro-inches per inch 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Dial readings in inches x $10^{-4}$ a | b | c | d |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 37000 | 1628 | 1978 | 2091 | 1837 | 1736 | 1870 | 2051 | 1893 | 265 | 291 | 194 | 132 |
| 38000 | 1673 | 2039 | 2159 | 1893 | 1788 | 1922 | 2109 | 1957 | 273 | 300 | 200 | 156 |
| 39000 | 1721 | 2103 | 2231 | 1953 | 1893 | 1975 | 2161 | 2020 | 281 | 308 | 206 | 161 |
| 40000 | 1768 | 2168 | 2301 | 2011 | 1896 | 2022 | 2212 | 2082 | 289 | 317 | 212 | 166 |
| 41000 | 1815 | 2230 | 2370 | 2067 | 1946 | 2065 | 2259 | 2142 | 297 | 325 | 218 | 169 |
| 42000 | 1861 | 2298 | 2448 | 2127 | 1999 | 2108 | 2301 | 2202 | 305 | 334 | 224 | 174 |
| 43000 | 1908 | 2368 | 2529 | 2190 | 2051 | 2146 | 2339 | 2359 | 312 | 343 | 229 | 178 |
| 44000 | 1960 | 2450 | 2627 | 2264 | 2106 | 2180 | 2369 | 2317 | 320 | 352 | 235 | 182 |
| 45000 | 2010 | 2528 | 2720 | 2334 | 2153 | 2207 | 2389 | 2372 | 328 | 360 | 240 | 186 |
| 46000 | 2069 | 2642 | 2869 | 2440 | 2197 | 2208 | 2363 | 2422 | 336 | 370 | 248 | 191 |
| 46710 | Ultimate load | | | | | | | | | | | |

TABLE LV

STRAIN READINGS FOR PANEL 54

t = .0825 in. L = 1.50 in. b = 2.50 in. W = 15 in. N = 5

Gauge arrangement GF, Figure 12

| | Gauge readings in micro-inches per inch | | | | | | | | | | | Dial readings in inches x $10^{-4}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | a | b | c | d |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 115 | 113 | 81 | 76 | 109 | 67 | -20[a] | -41 | -8 | -42 | -17 | 16 | 10 | 3 | 12 |
| 6000 | 241 | 235 | 183 | 163 | 221 | 147 | -41 | -82 | -16 | -83 | -30 | 35 | 20 | 11 | 24 |
| 8000 | 362 | 358 | 293 | 266 | 335 | 274 | -58 | -119 | -26 | -122 | -41 | 52 | 32 | 21 | 38 |
| 10000 | 479 | 478 | 399 | 370 | 450 | 347 | -77 | -155 | -34 | -164 | -54 | 69 | 46 | 32 | 50 |
| 12000 | 597 | 601 | 511 | 495 | 594 | 468 | -99 | -194 | -43 | -202 | -64 | 86 | 61 | 44 | 63 |
| 14000 | 714 | 717 | 620 | 616 | 727 | 581 | -120 | -227 | -54 | -245 | -80 | 104 | 76 | 56 | 74 |
| 16000 | 833 | 837 | 723 | 749 | 874 | 707 | -145 | -262 | -63 | -282 | -92 | 120 | 92 | 67 | 86 |
| 18000 | 952 | 954 | 844 | 877 | 1018 | 831 | -169 | -294 | -74 | -323 | -105 | 140 | 107 | 79 | 100 |
| 20000 | 1072 | 1068 | 951 | 1003 | 1157 | 950 | -198 | -330 | -83 | -363 | -119 | 157 | 123 | 90 | 112 |
| 22000 | 1194 | 1188 | 1066 | 1139 | 1307 | 1080 | -226 | -362 | -93 | -402 | -132 | 174 | 139 | 100 | 124 |
| 24000 | 1316 | 1301 | 1178 | 1270 | 1454 | 1210 | -254 | -397 | -101 | -442 | -144 | 193 | 155 | 111 | 138 |
| 26000 | 1441 | 1413 | 1291 | 1406 | 1607 | 1342 | -285 | -434 | -111 | -482 | -159 | 211 | 170 | 122 | 151 |
| 28000 | 1565 | 1523 | 1399 | 1539 | 1756 | 1470 | -316 | -468 | -122 | -522 | -173 | 230 | 186 | 132 | 163 |
| 30000 | 1690 | 1630 | 1509 | 1672 | 1909 | 1602 | -354 | -504 | -132 | -561 | -189 | 250 | 203 | 144 | 163 |
| 32000 | 1822 | 1729 | 1619 | 1806 | 2064 | 1733 | -387 | -541 | -144 | -600 | -198 | 270 | 218 | 155 | 187 |
| 34000 | 1954 | 1823 | 1724 | 1932 | 2222 | 1866 | -421 | -575 | -156 | -645 | -212 | 291 | 235 | 167 | 201 |
| 35000 | 2022 | 1867 | 1779 | 1997 | 2306 | 1934 | -444 | -594 | -159 | -662 | -219 | 300 | 240 | 171 | 207 |
| 36000 | 2097 | 1900 | 1833 | 2063 | 2389 | 2000 | -462 | -609 | -166 | -681 | -225 | 310 | 251 | 177 | 214 |
| 37000 | 2168 | 1932 | 1885 | 2123 | 2478 | 2072 | -481 | -628 | -173 | -698 | -232 | 320 | 260 | 182 | 220 |
| 38000 | 2243 | 1953 | 1928 | 2177 | 2568 | 2142 | -501 | -645 | -177 | -713 | -241 | 331 | 267 | 188 | 236 |
| 39000 | 2327 | 1955 | 1963 | 2230 | 2584 | 2226 | -518 | -664 | -183 | -720 | -249 | 342 | 275 | 194 | 235 |
| 39900 | Ultimate load | | | | | | | | | | | | | | |

a Negative values indicate tension strains.

TABLE LVI

STRAIN READINGS FOR PANEL 55

t = .0825 in. L = 1.50 in. b = 3.20 in. W = 16 in. N = 4

Gauge arrangement CF, Figure 12

| | Gauge readings in micro-inches per inch | | | | | | | | Dial readings in inches x $10^{-4}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | a | b | c | d | e |
| 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4000 | 112 | 129 | 129 | 124 | 83 | 111 | 98 | 47 | 20 | 20 | 13 | 9 | 18 |
| 6000 | 222 | 255 | 251 | 241 | 184 | 252 | 233 | 154 | 36 | 37 | 26 | 22 | 38 |
| 8000 | 333 | 381 | 371 | 351 | 300 | 388 | 367 | 273 | 53 | 53 | 39 | 32 | 48 |
| 10000 | 444 | 514 | 496 | 469 | 425 | 529 | 512 | 405 | 67 | 68 | 51 | 42 | 61 |
| 12000 | 558 | 643 | 616 | 581 | 551 | 667 | 652 | 533 | 82 | 84 | 63 | 52 | 71 |
| 14000 | 670 | 776 | 745 | 699 | 686 | 818 | 803 | 673 | 99 | 101 | 76 | 62 | 87 |
| 16000 | 783 | 904 | 865 | 809 | 813 | 960 | 948 | 806 | 114 | 117 | 86 | 74 | 99 |
| 18000 | 892 | 1032 | 984 | 921 | 943 | 1107 | 1097 | 950 | 128 | 133 | 98 | 74 | 118 |
| 19000 | 947 | 1100 | 1051 | 979 | 1009 | 1183 | 1164 | 1016 | 135 | 141 | 104 | 88 | 124 |
| 20000 | 1002 | 1162 | 1109 | 1032 | 1071 | 1257 | 1239 | 1090 | 143 | 150 | 109 | 92 | 140 |
| 21000 | 1054 | 1223 | 1168 | 1087 | 1138 | 1328 | 1307 | 1154 | 150 | 158 | 114 | 97 | 145 |
| 22000 | 1110 | 1290 | 1227 | 1140 | 1201 | 1405 | 1384 | 1226 | 159 | 166 | 120 | 101 | 153 |
| 23000 | 1162 | 1357 | 1290 | 1197 | 1271 | 1481 | 1454 | 1292 | 165 | 174 | 125 | 106 | 166 |
| 24000 | 1220 | 1424 | 1354 | 1254 | 1343 | 1558 | 1534 | 1367 | 174 | 183 | 131 | 111 | 170 |
| 25000 | 1279 | 1592 | 1414 | 1311 | 1414 | 1647 | 1612 | 1446 | 182 | 192 | 137 | 116 | 186 |
| 26000 | 1334 | 1660 | 1472 | 1362 | 1476 | 1714 | 1685 | 1521 | 190 | 200 | 143 | 121 | 195 |
| 27000 | 1395 | 1735 | 1542 | 1426 | 1554 | 1803 | 1768 | 1600 | 198 | 210 | 149 | 126 | 200 |
| 28000 | 1450 | 1807 | 1604 | 1480 | 1619 | 1882 | 1842 | 1672 | 205 | 218 | 155 | 131 | 211 |
| 29000 | 1512 | 1888 | 1676 | 1541 | 1691 | 1967 | 1922 | 1752 | 213 | 227 | 160 | 135 | 216 |
| 30000 | 1574 | 1982 | 1763 | 1604 | 1764 | 2040 | 2002 | 1835 | 221 | 237 | 166 | 140 | 222 |
| 31000 | 1630 | 2064 | 1843 | 1666 | 1832 | 2123 | 2085 | 1918 | 230 | 248 | 171 | 143 | 242 |
| 32000 | 1702 | 2172 | 1955 | 1733 | 1896 | 2198 | 2157 | 2003 | 239 | 259 | 178 | 148 | 246 |
| 33000 | 1787 | 2220 | 2082 | 1805 | 1963 | 2300 | 2259 | 2107 | 249 | 269 | 185 | 152 | 264 |
| 33540 | Ultimate load | | | | | | | | | | | | |

Buckled form of stiffeners. Figures 13 to 67 inclusive show the stiffener sides of each panel after failure and removal of the load. The form of stringer failure is clearly indicated, and, in practically every case involved torsion or rolling over of the outstanding flange. Local failure of the stringer lip at the rivets adjacent to the principal buckle will be observed, but in all cases this occurred after the primary failure. Of particular interest is the similarity of the buckled form of each stringer in any one panel.

Control test data. A few representative stress-strain curves for tension and compression control test specimens of the sheet stock are given in Figures 68 to 71 inclusive. The values of E, the modulus of elasticity, are written in on each curve. The curve numbers indicate the corresponding panel, and the letter S signifies stringer stock. The ordinate at the intersection of the dashed line with the curve gives the 0.2 per cent yield strength. It will be noticed that all of these curves have a steeper slope up to 10,000 pounds per square inch than beyond this stress. This is due to the fact that the pure aluminum "Alclad" coating approximately .003 inches thick reaches its elastic limit at about 10,000 pounds per square inch, and the coating

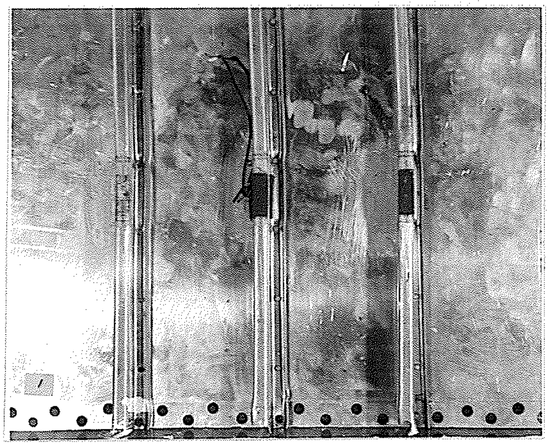



Figure 13 Panel 1

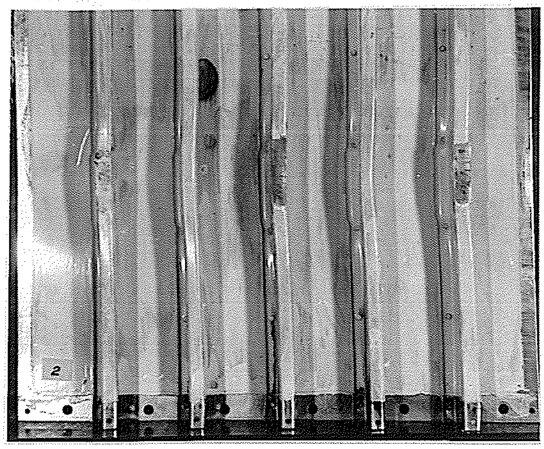



Figure 14 Panel 2

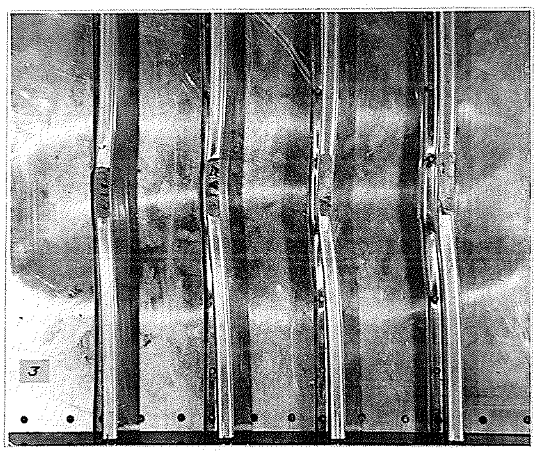
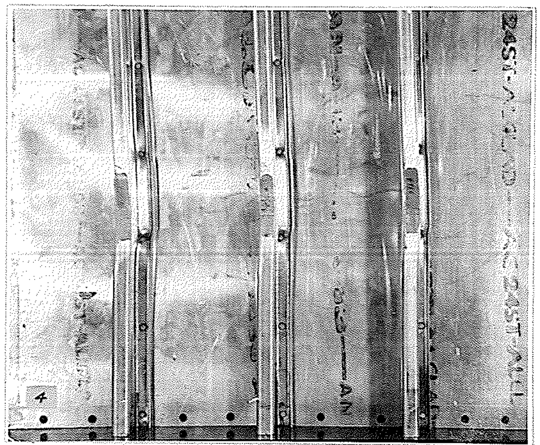



Figure 15 Panel 3

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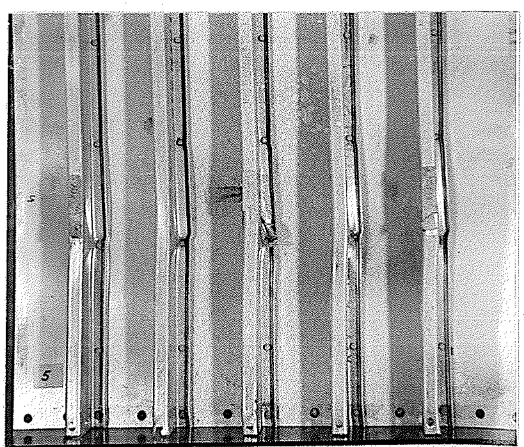


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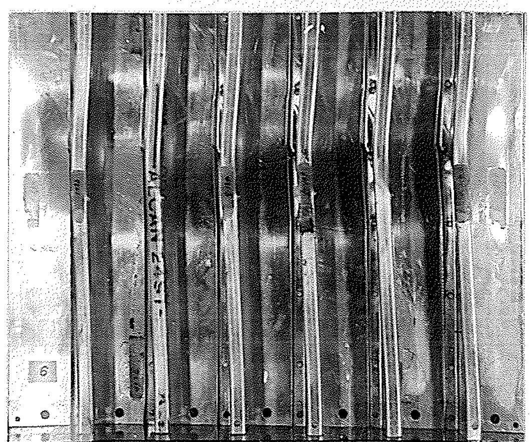


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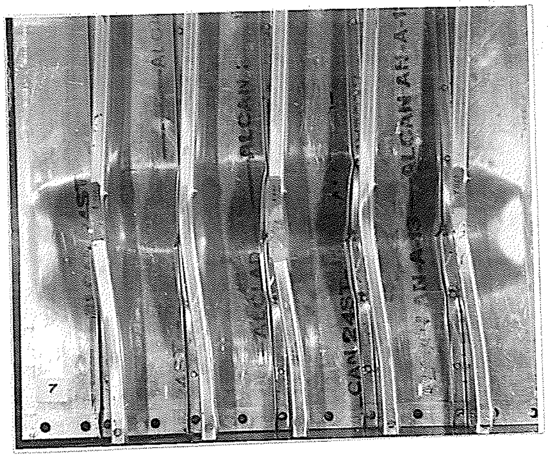

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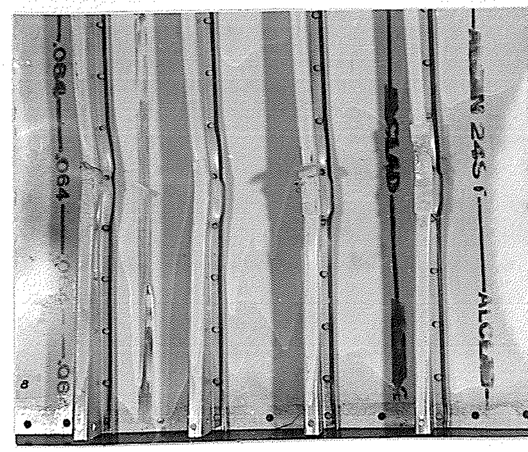

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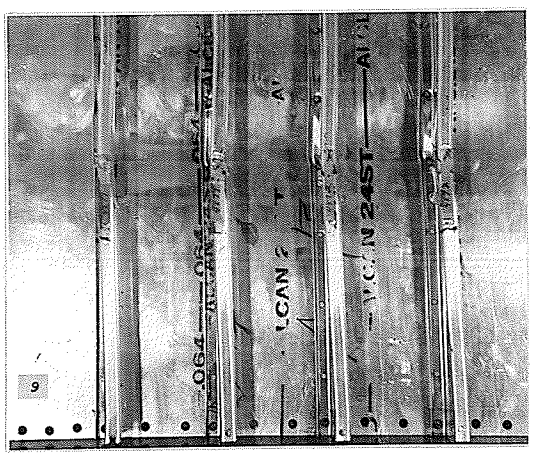

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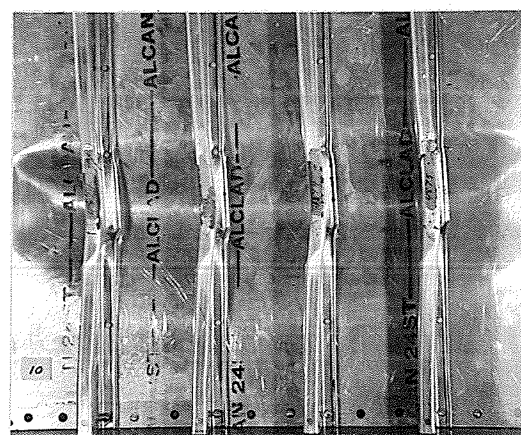

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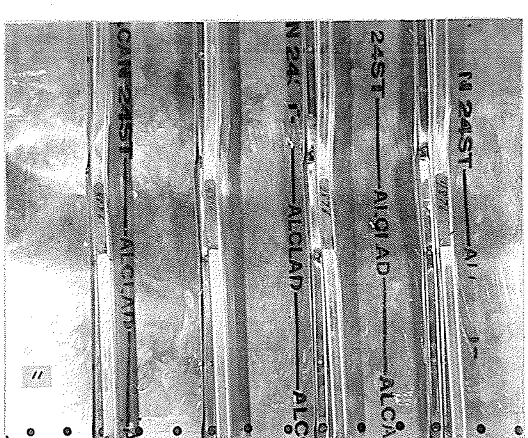

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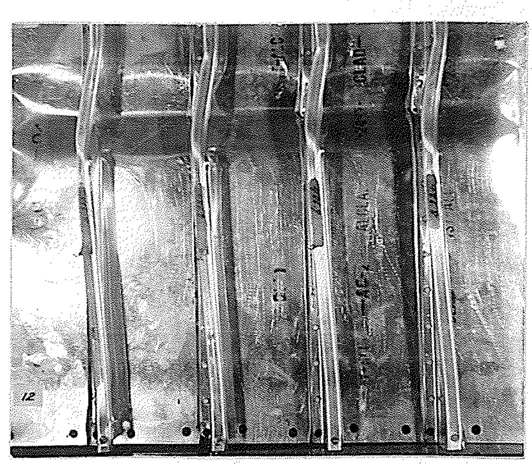

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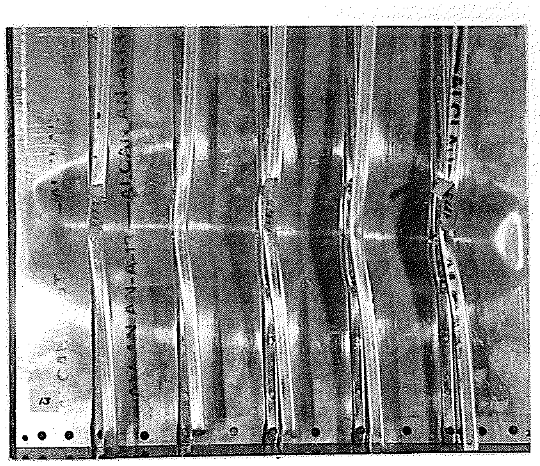

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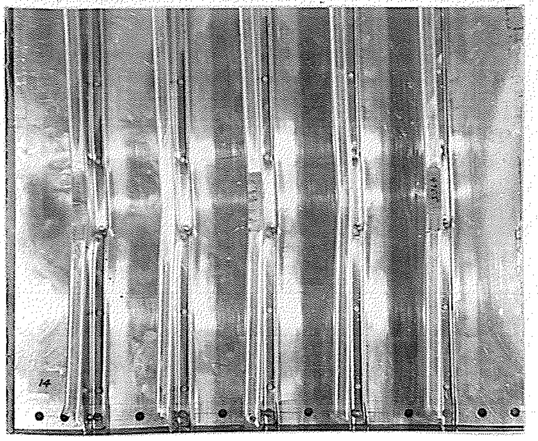

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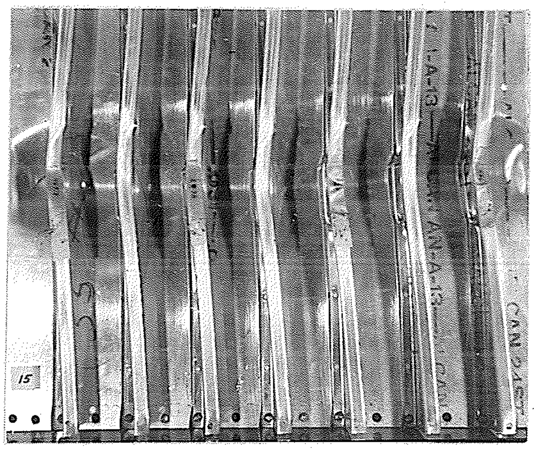

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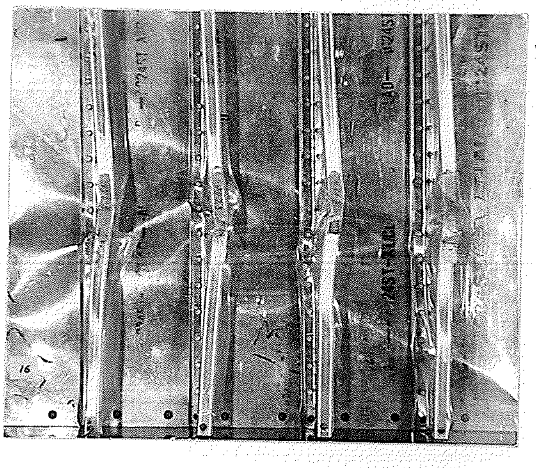

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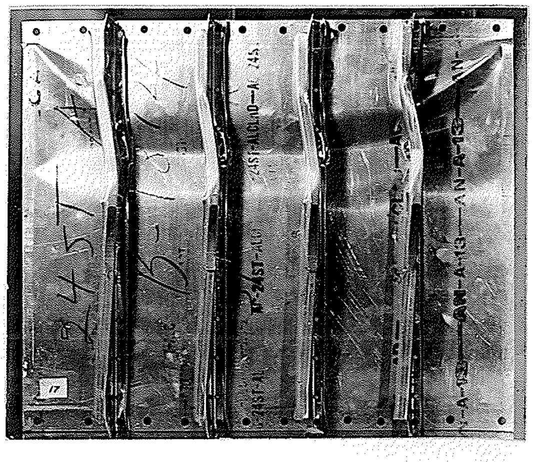

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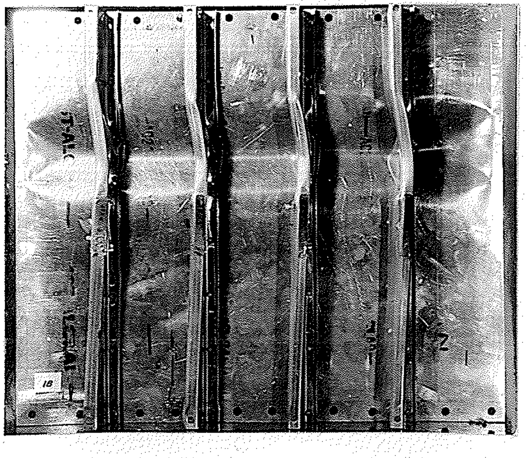

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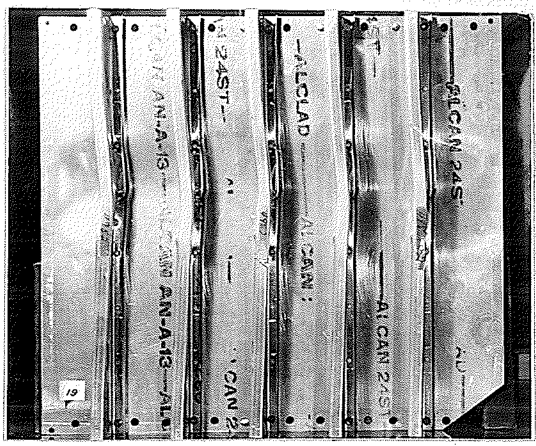



Figure 31 Panel 19

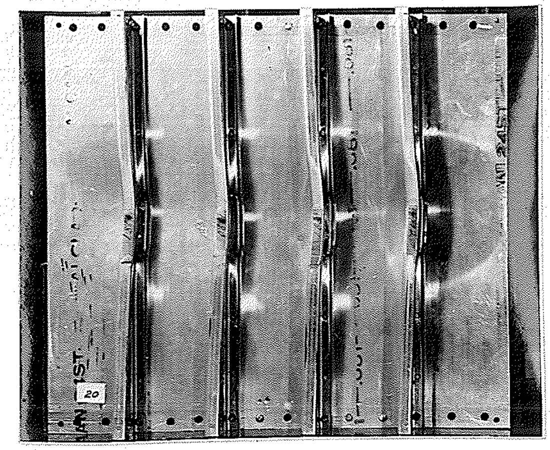



Figure 32 Panel 20

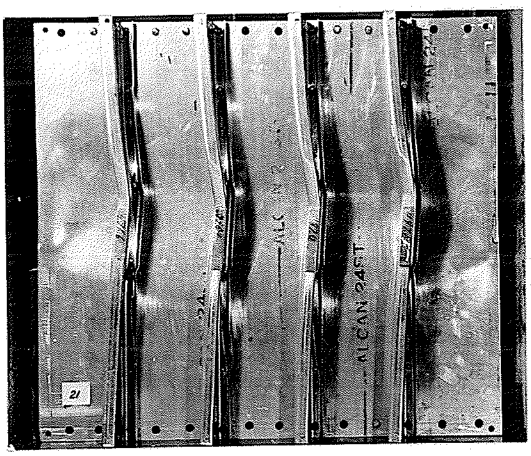



Figure 33 Panel 21

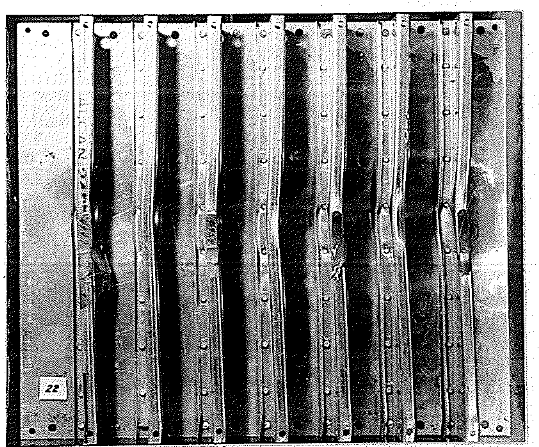



Figure 34 Panel 22

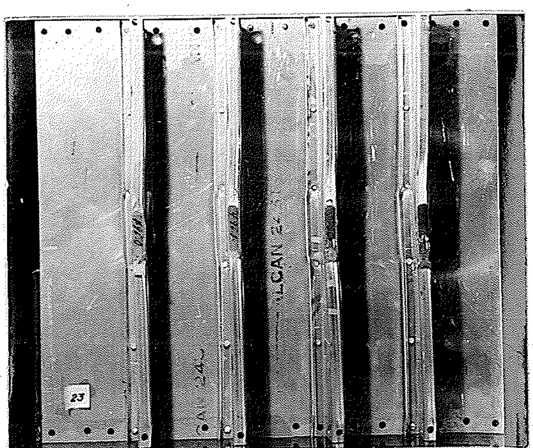
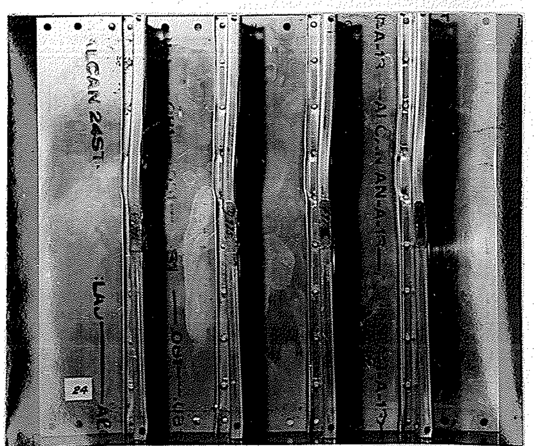



Figure 35 Panel 23

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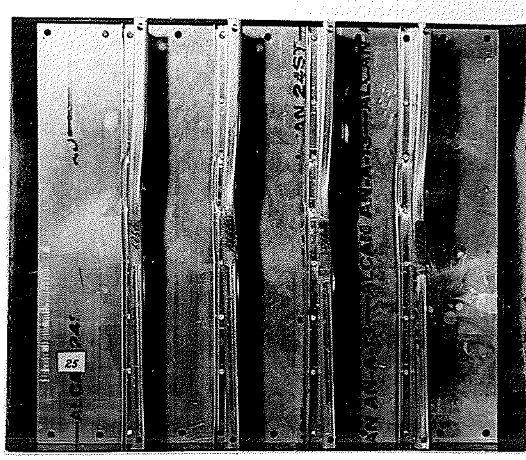
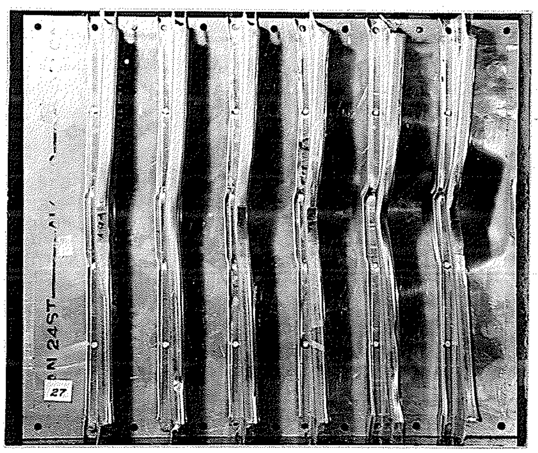



Figure 37 Panel 25


Figure 38 Panel 26

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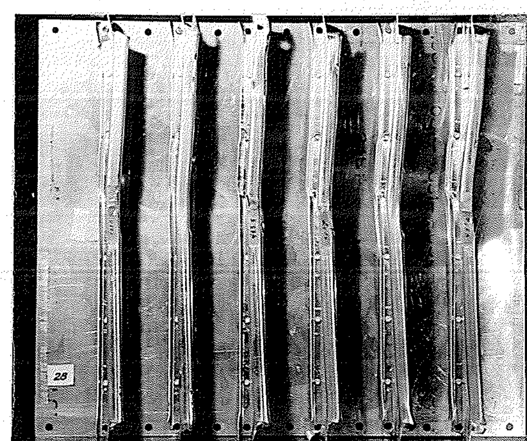


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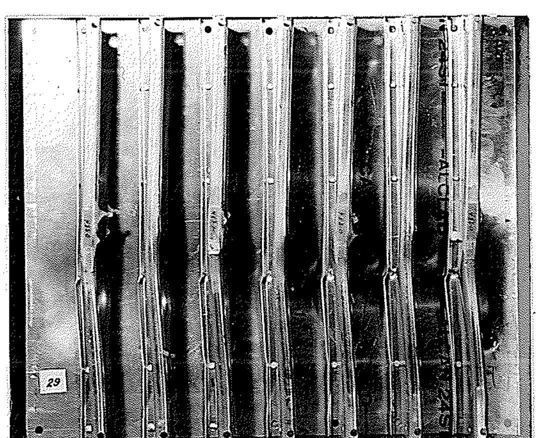


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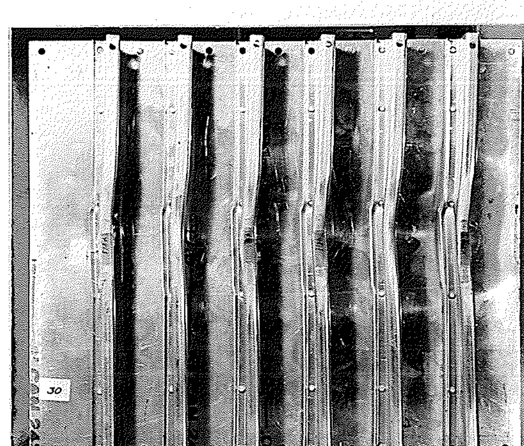


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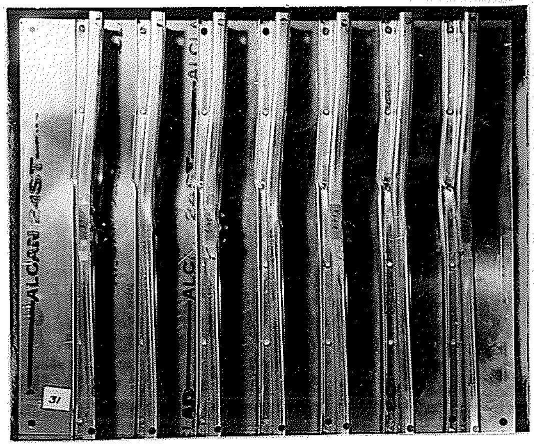

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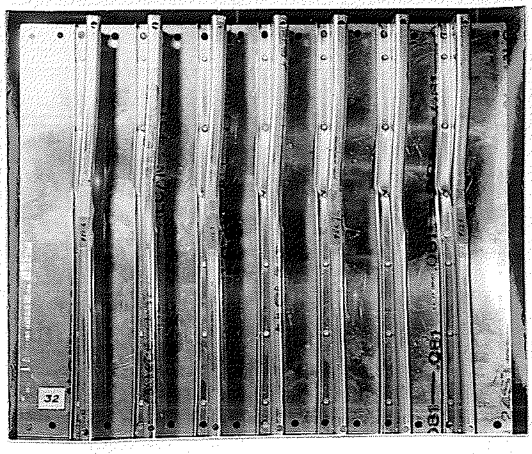

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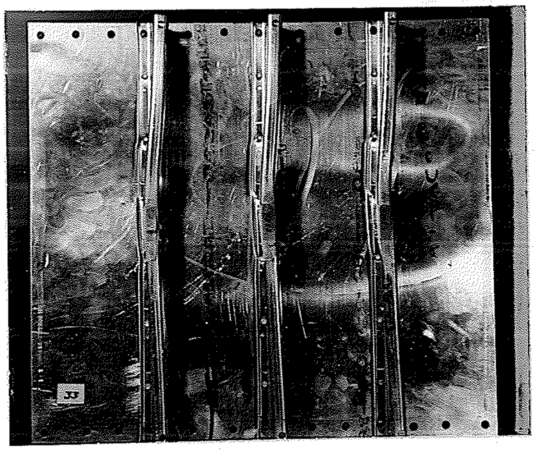

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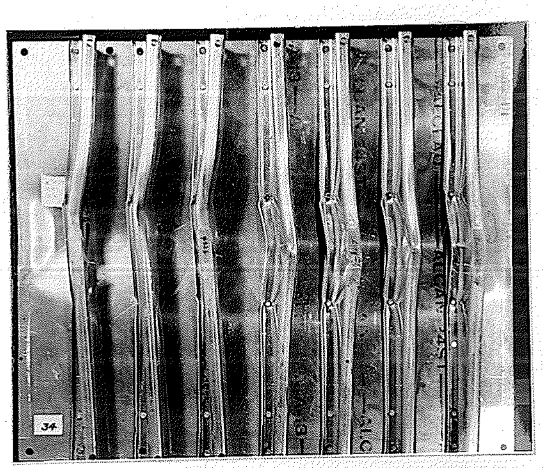

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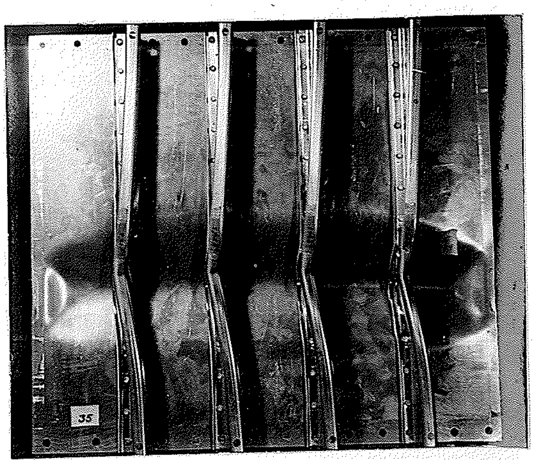

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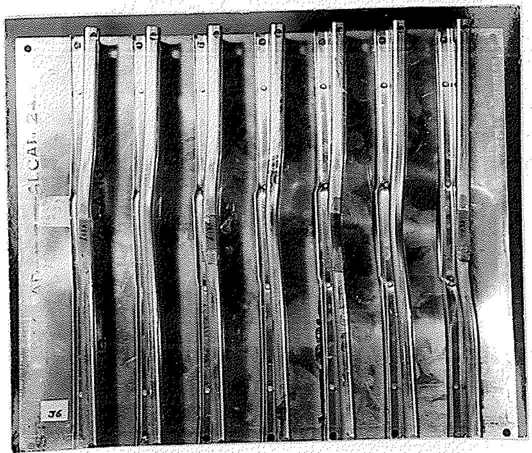

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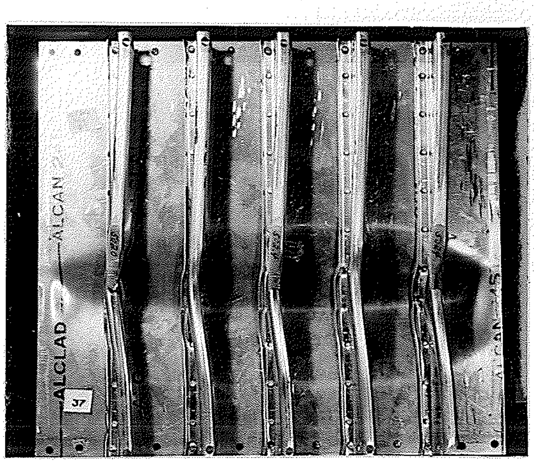


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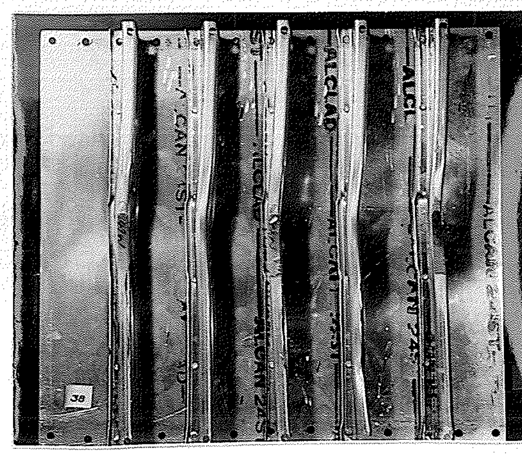

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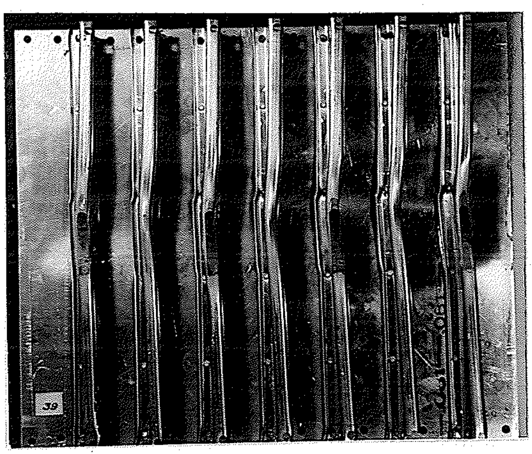

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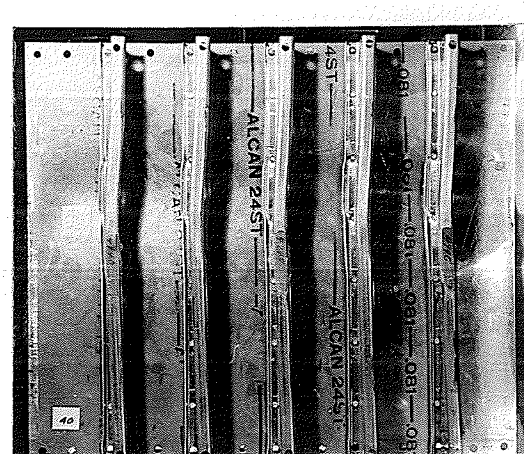
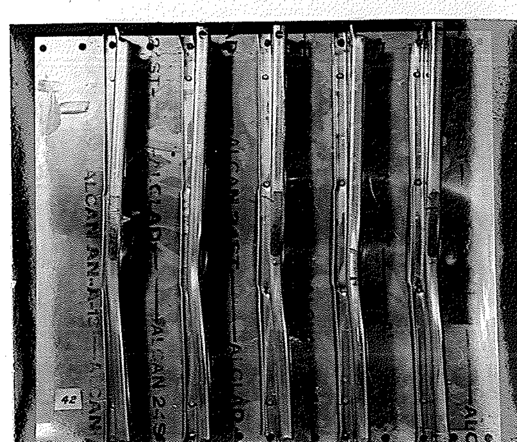



Figure 52 Panel 40


Figure 53 Panel 41



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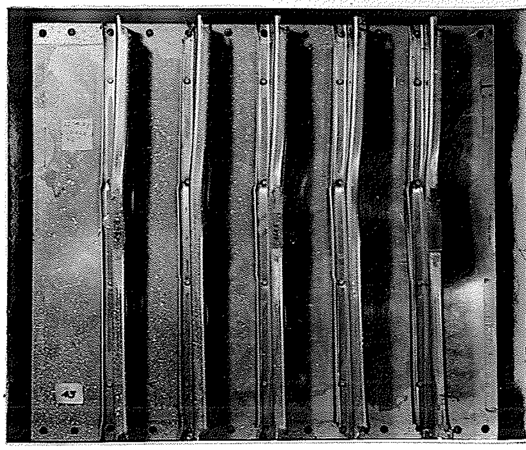

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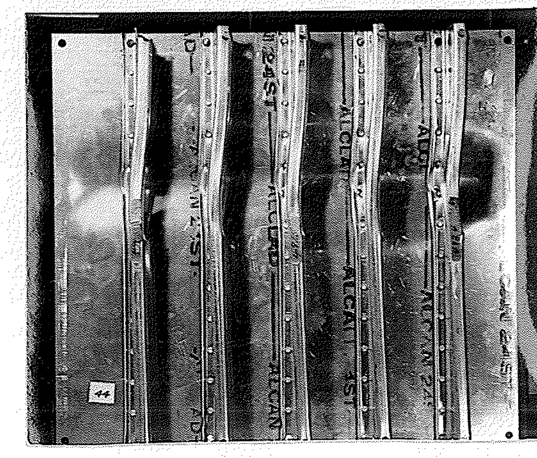

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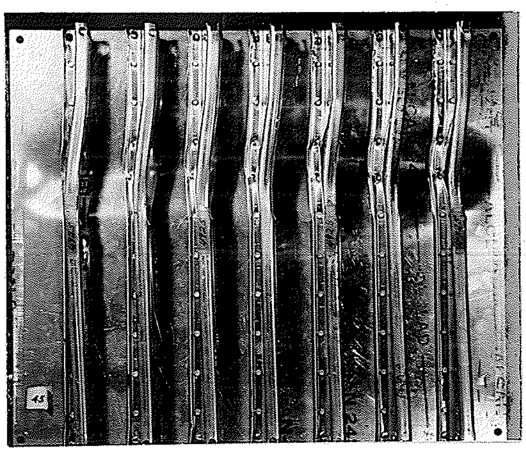

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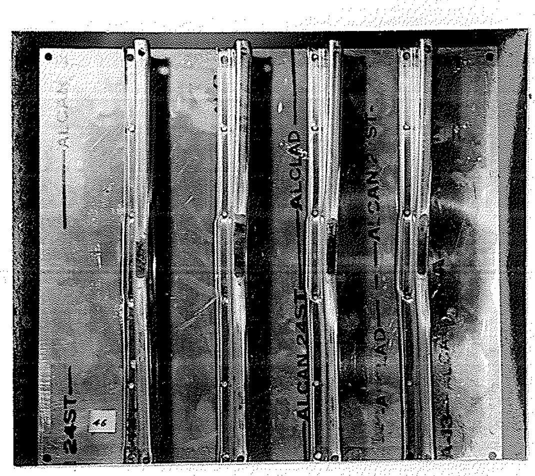
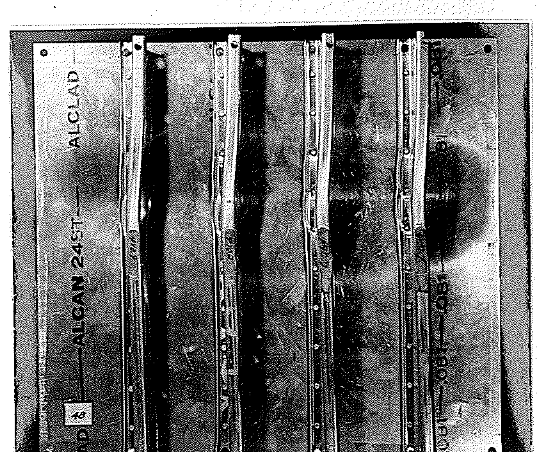


Figure 58 Panel 46

Figure 59 Panel 47



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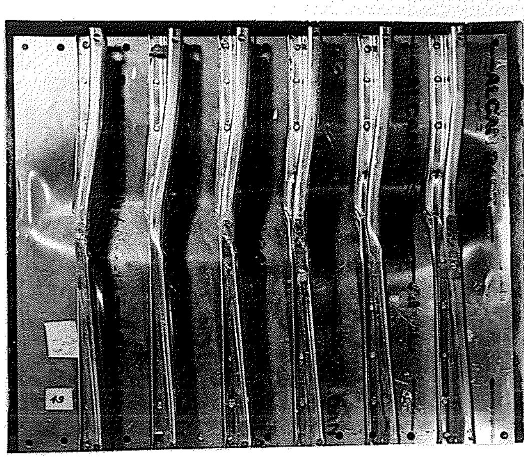

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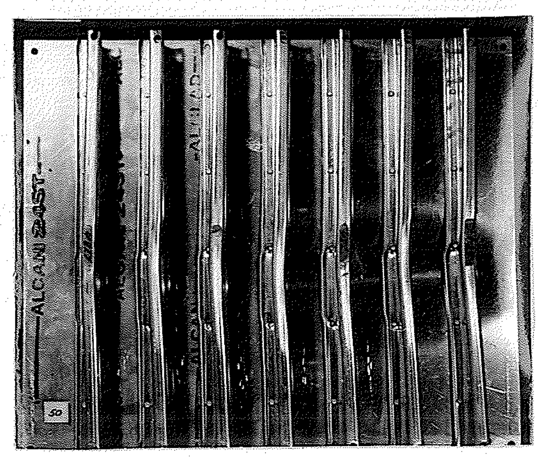

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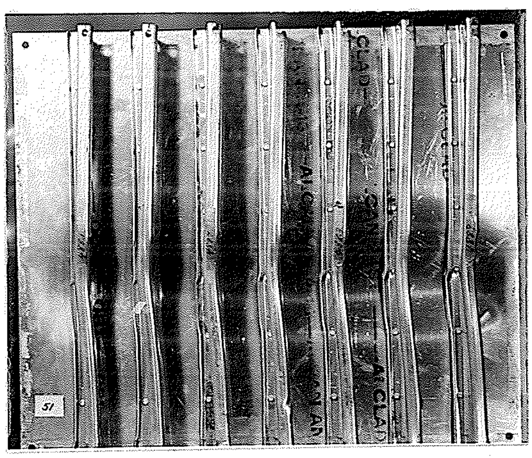

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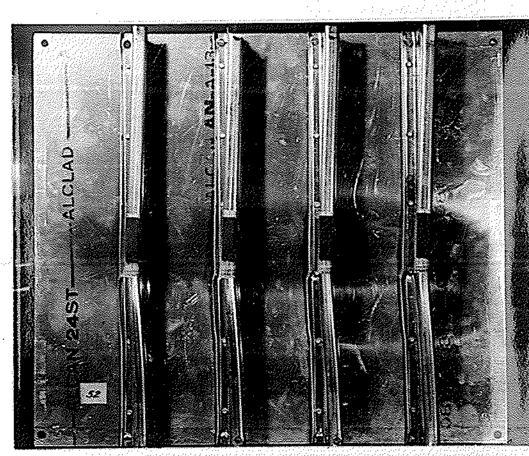

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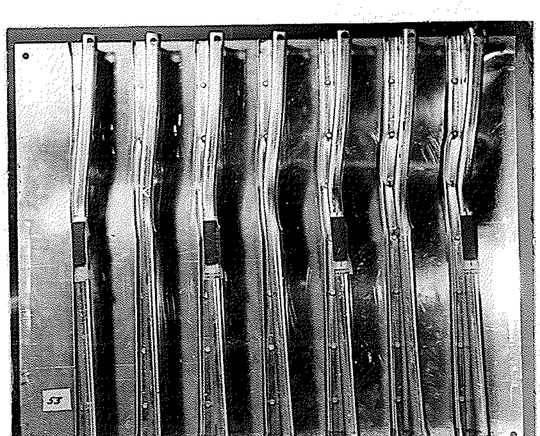

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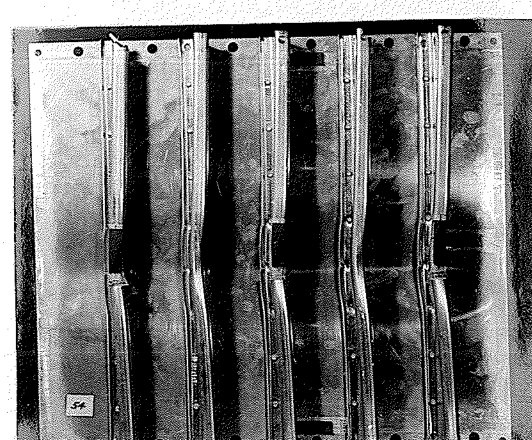


Figure 66 Panel 54

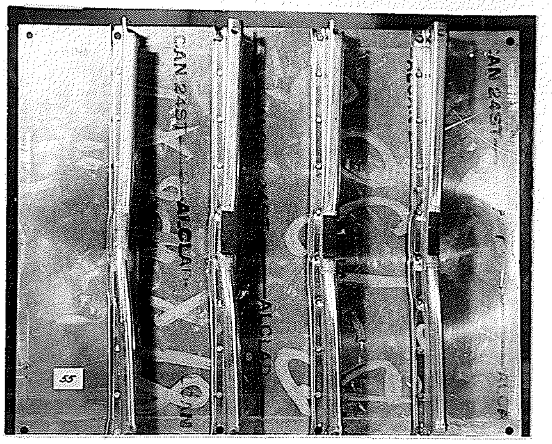


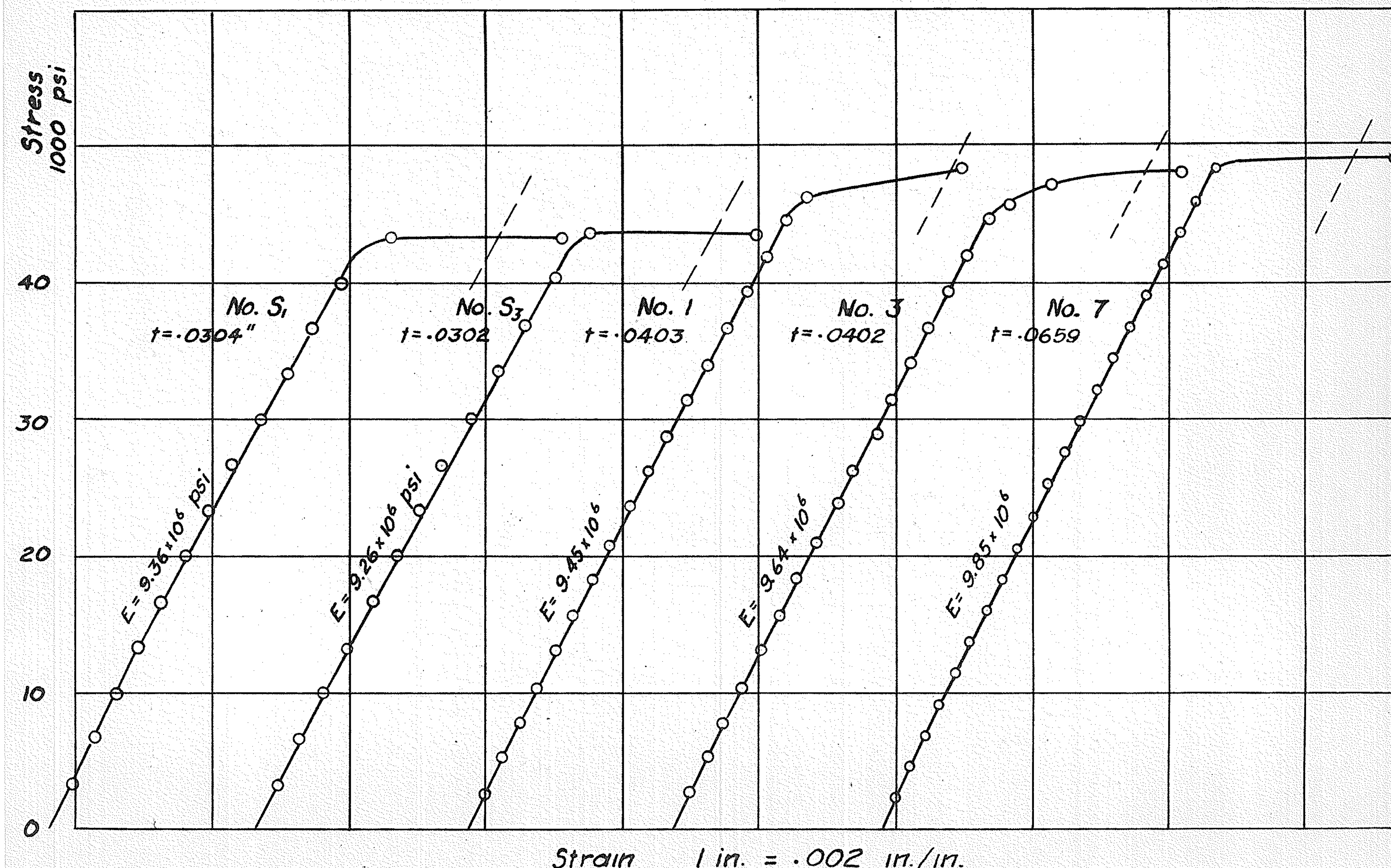
Figure 67 Panel 55

thereafter deforms plastically at more or less constant stress. The modulus recorded is that of the second part of the curve and is known as the secondary value. Since the aluminum coating is the same thickness for all sheet sizes, the secondary modulus is lower for the thinner sheets. Average values of E in tension were found to be 9.98, 9.88, 9.65, and 9.33, million pounds per square inch for sheet thicknesses of .081, .066, .040, and .032, inches respectively. The modulus in compression was in general about four per cent higher than the tension value. Average value of the 0.2 per cent yield strength was 48,500 pounds per square inch in tension, and 45,000 pounds per square inch in compression.

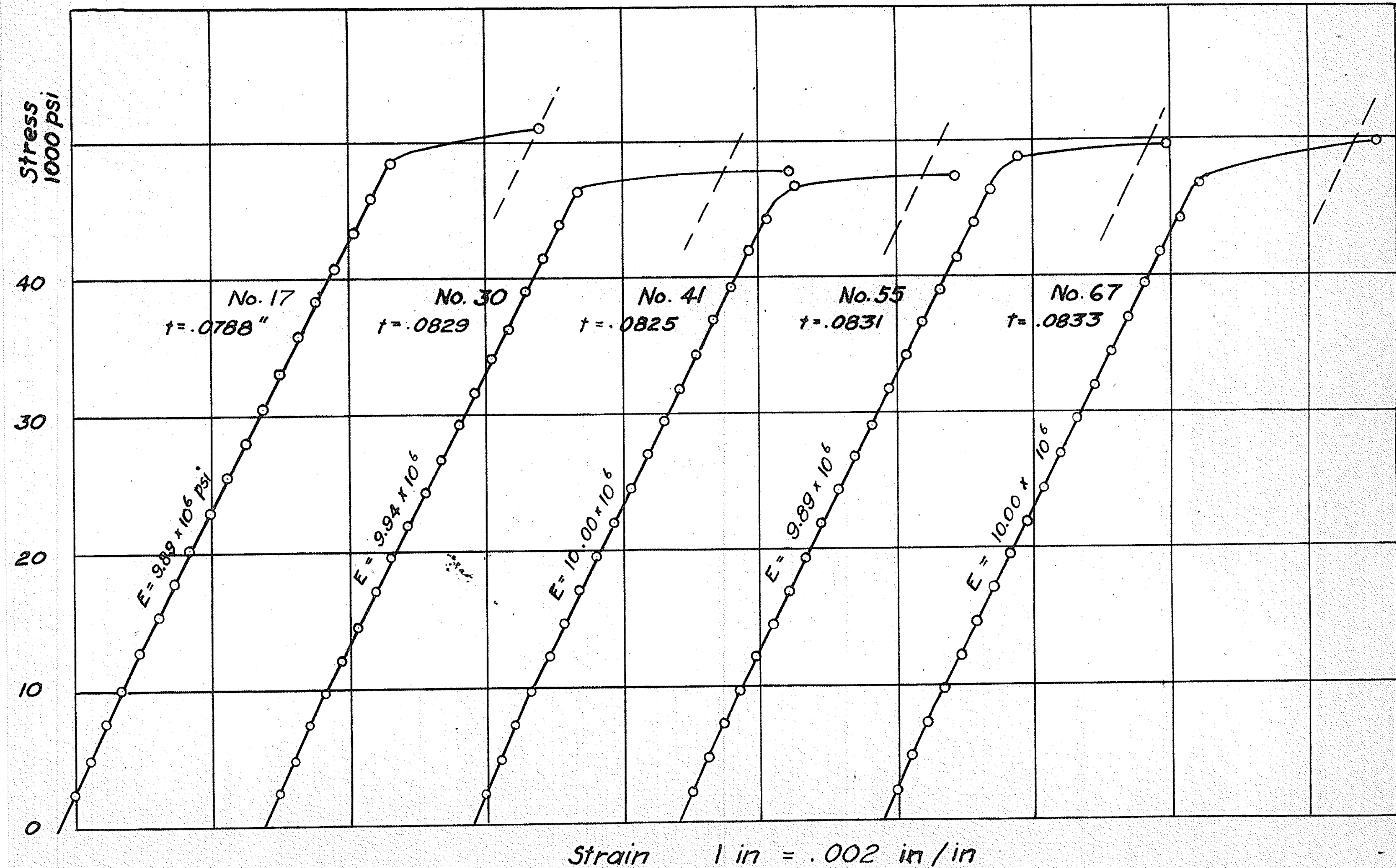
Grid displacement readings. A typical set of photogrid readings is plotted graphically on Figure 72. This shows the vertical profile of the sheet at each stiffener. Horizontal dashed lines indicate the rivet locations. From similar curves the pin-end length of the major buckle, the number of half-waves, and the type of buckling were deduced for each panel. Data for determining the critical buckling stress were also obtained from the displacement readings.

Figures 73 and 74 show sheet profiles at stringers and at lines midway between stringers for one of the panels tested. It is apparent from Figure 73 that anti-symmetrical plate buckling has taken place to a small degree at the

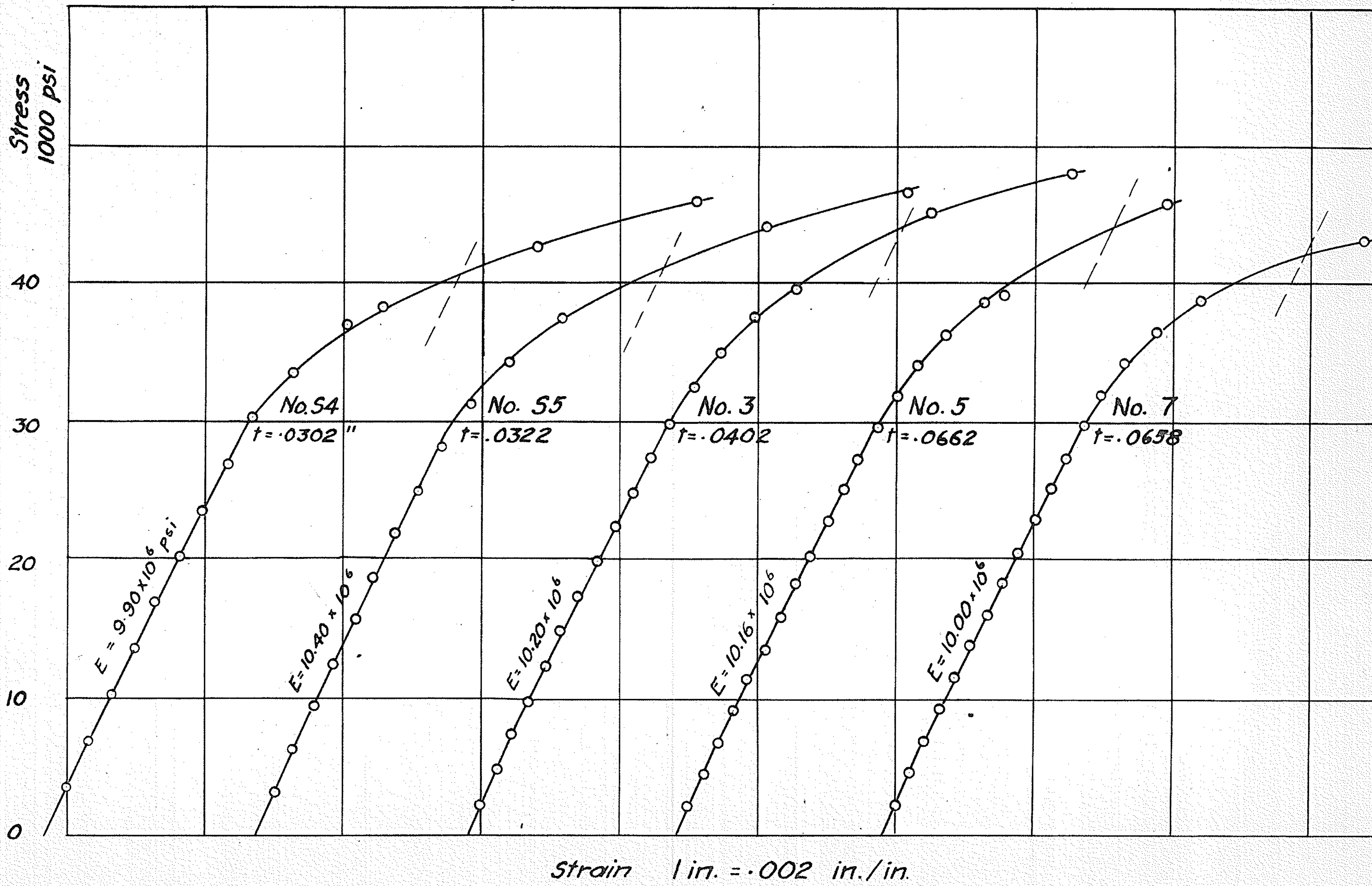
# FIGURE 68 TENSION STRESS STRAIN CURVES



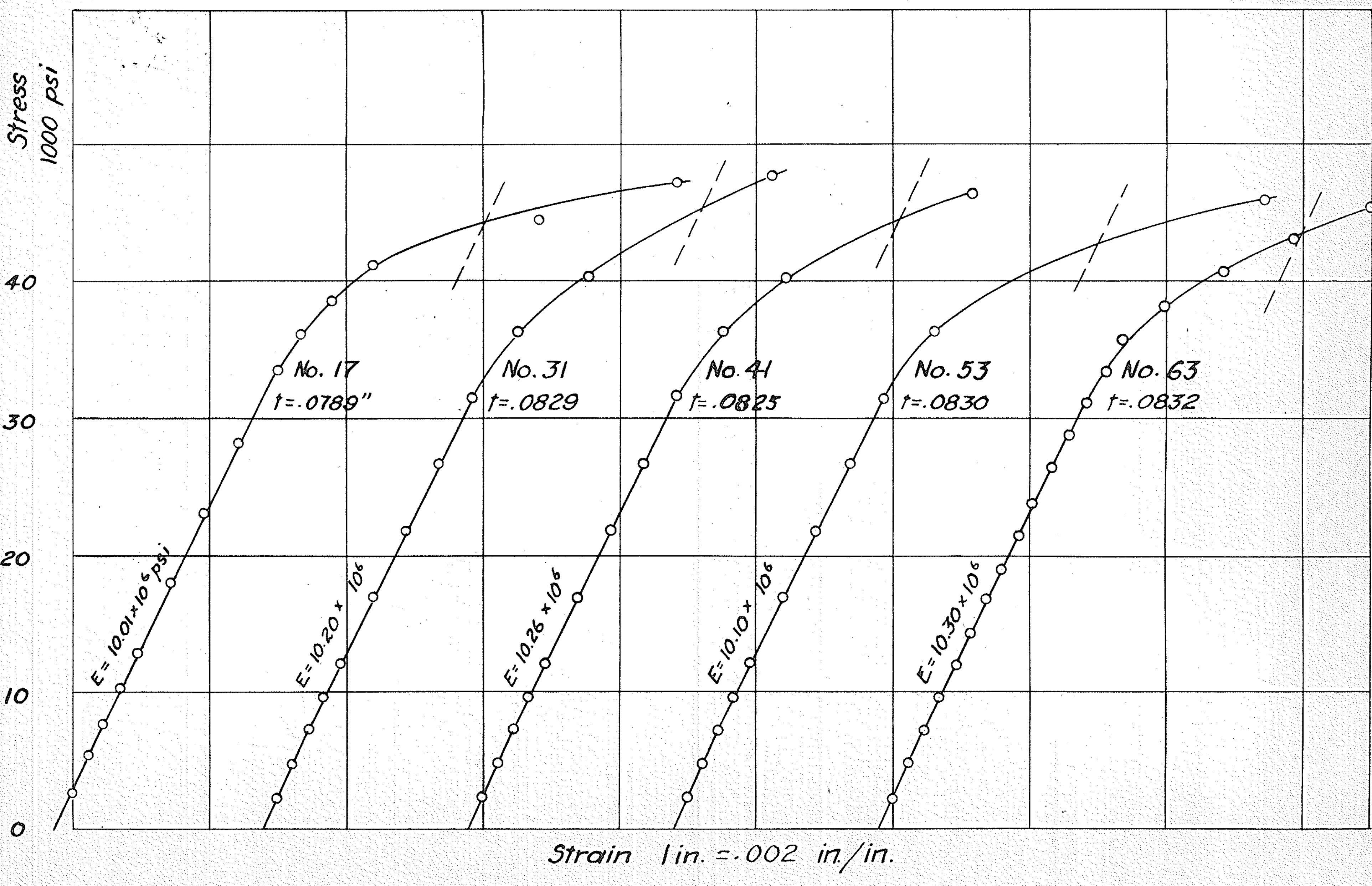
# FIGURE 69 TENSION STRESS STRAIN CURVES



# FIGURE 70 COMPRESSION STRESS-STRAIN CURVES



# FIGURE 71 COMPRESSION STRESS STRAIN CURVES



# FIGURE 72
## PANEL 32

Sheet profiles at each stiffener for 40.000 load.
Horizontal Scale 1 in = .02 in

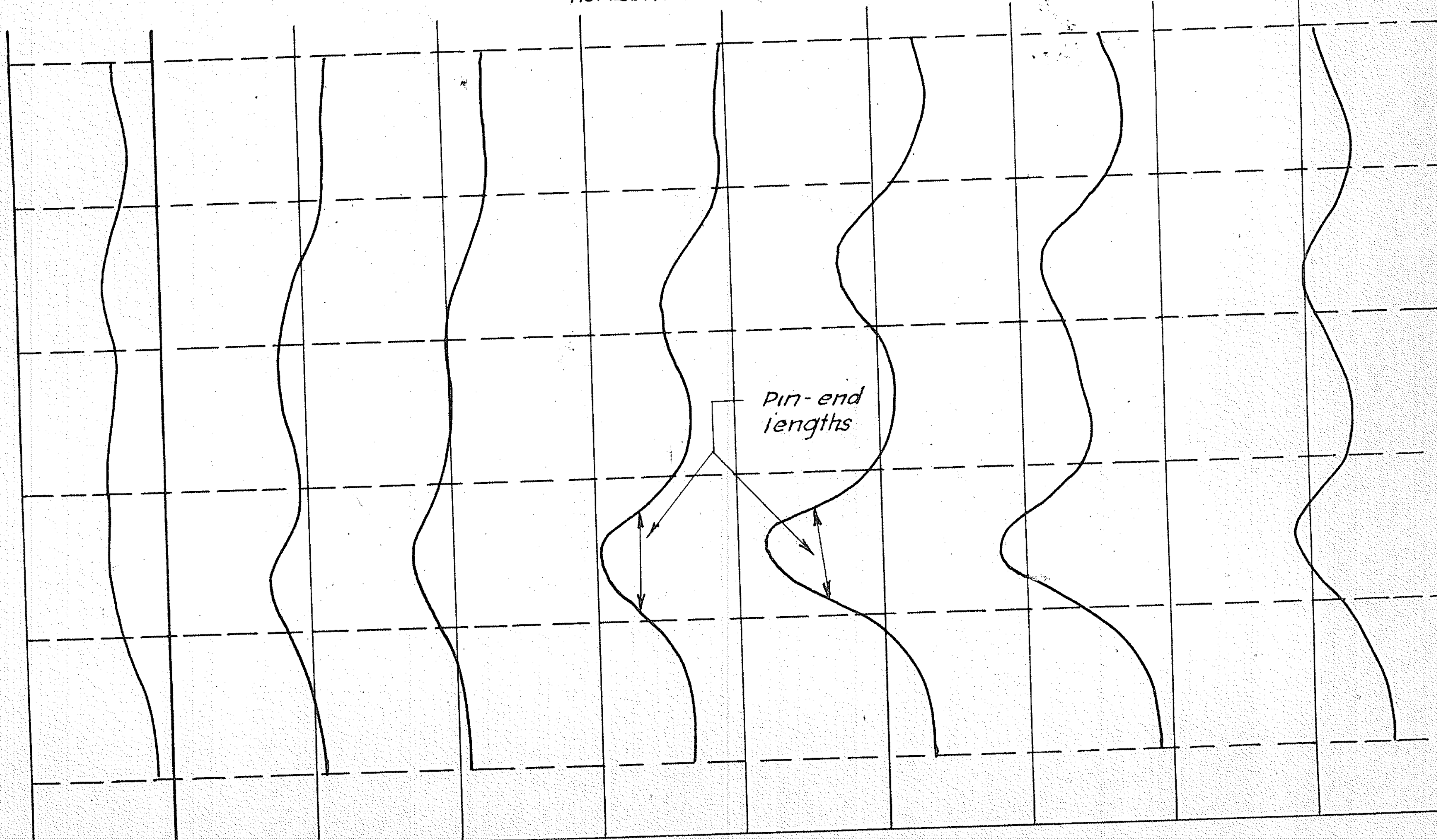
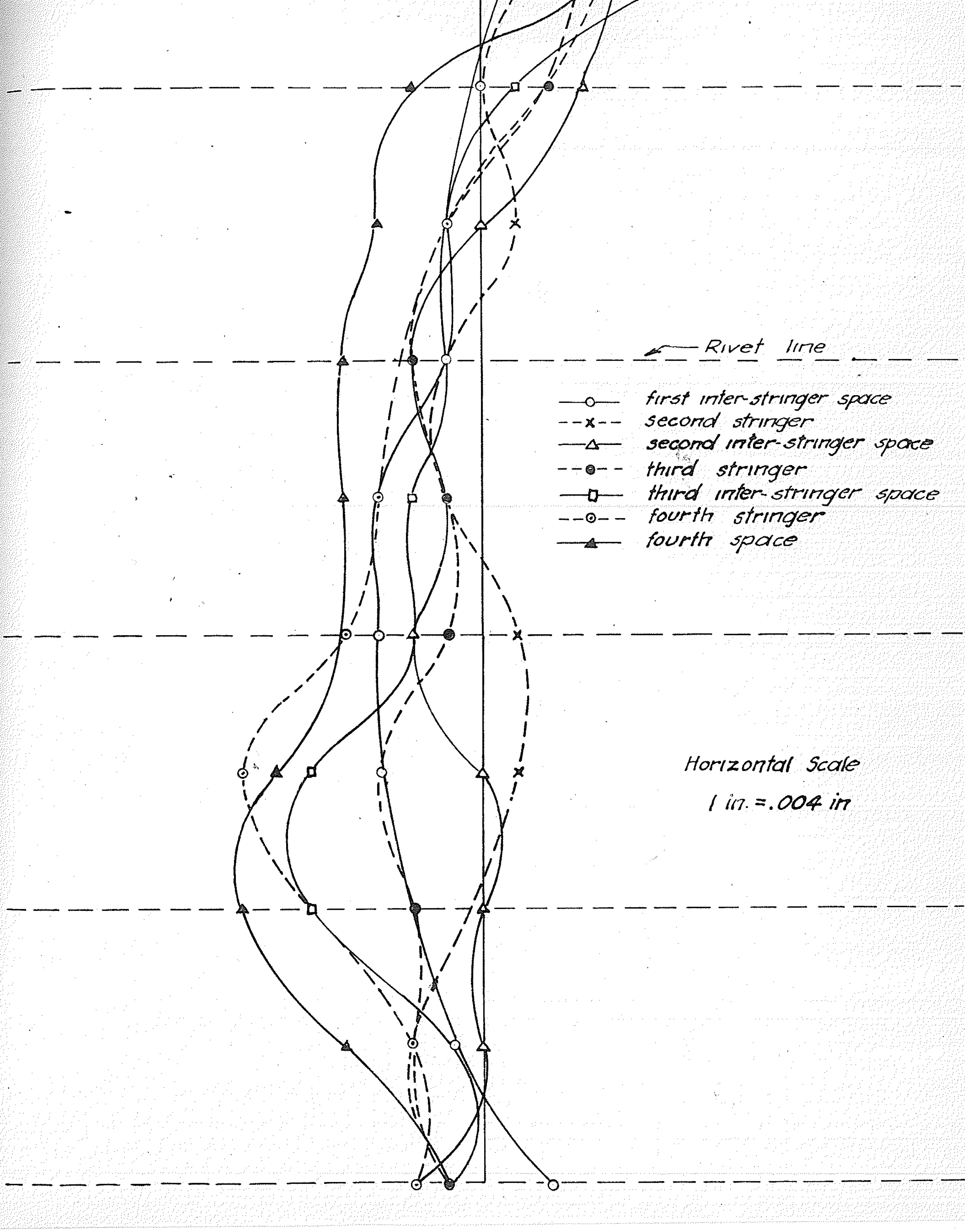


**FIGURE 73**
**PANEL 19**

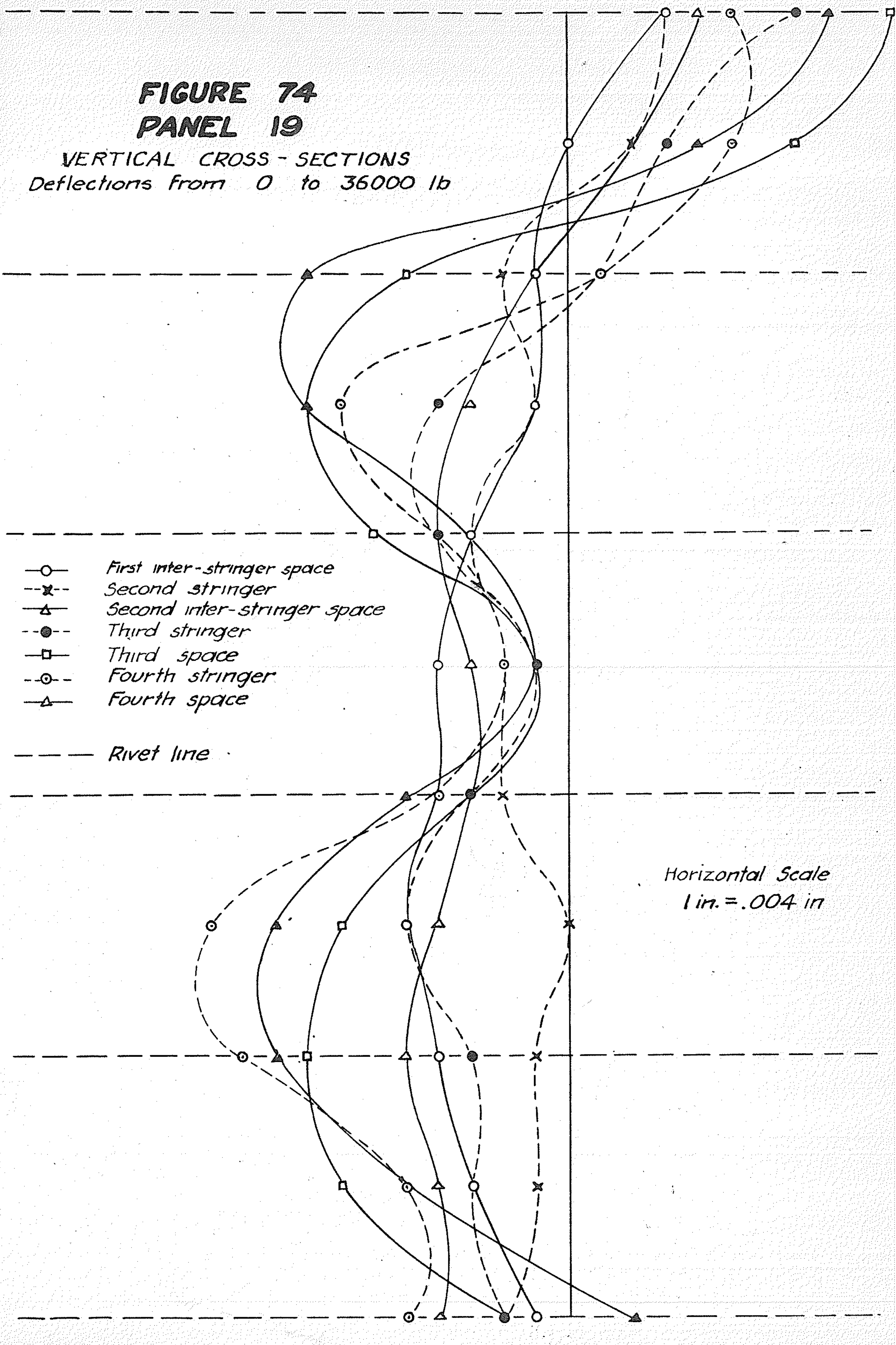
VERTICAL CROSS-SECTIONS

Deflections from 0 to 32,000 lb.



# FIGURE 74
# PANEL 19

VERTICAL CROSS - SECTIONS
Deflections from 0 to 36000 lb



lower load. At higher loads this has disappeared, and has been replaced by inter-rivet buckling as shown in Figure 74. The amount of plate buckling developed in this and similar panels .081 inches thick is so small that it could not be detected except by precise measurement. This phenomenon was observed in many of the panels tested, and will be considered further in discussion of test results.

The effective way in which the photo-grid method delineates buckling behaviour is illustrated in Figure 75. It should be pointed out that this photograph was taken at failure, and that the second line of rivets had pulled through the stiffeners. This explains the large wavelength of the principal buckle. Figures 76 and 77 again illustrate the transition from plate buckling to inter-rivet buckling for increased loads. In this case, however, the sheet thickness was only .040 inches, and the panel design was such that well-developed plate buckling was to be expected.

The general arrangement of photo-grid equipment is illustrated in Figure 78, which shows a panel set up for test. The arc lamp may be seen supported on a tube clamped to the right-hand testing machine column. The tube fixed to the left-hand column is the camera support. The method used for carrying the lamp and camera was necessitated by the fact that the testing machine table rises as load is applied. In order to obtain pictures from a fixed position relative

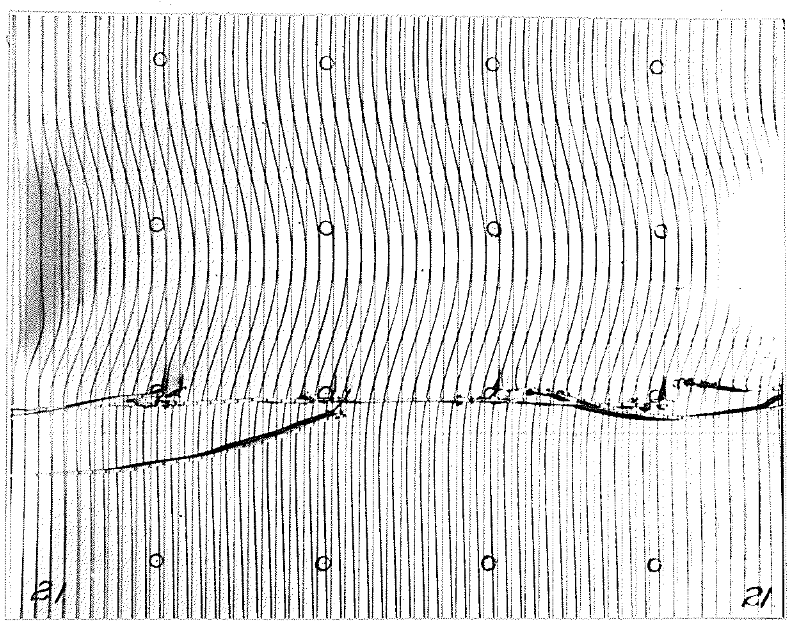



Figure 75.— Typical appearance of a photo-grid record. The irregular horizontal lines are strain gauge lead wires.

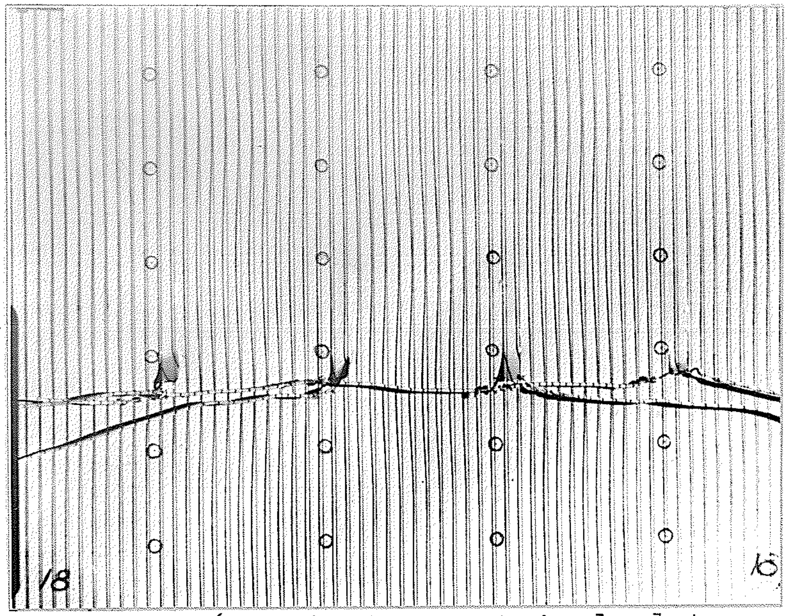



Figure 76.— Anti-symmetrical plate buckling of panel 18 at 9,000 lb. load.

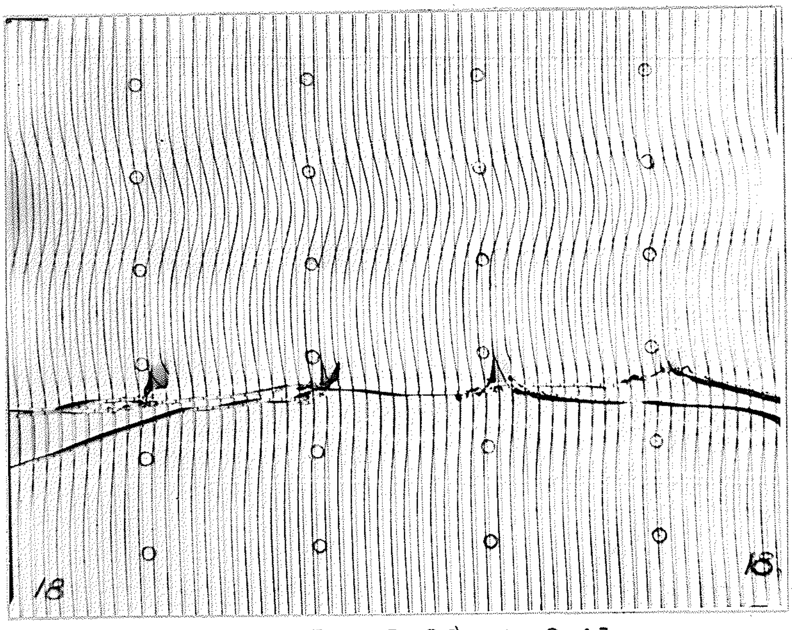



Figure 77.— Panel 18 at failure. Plate buckling has been replaced by inter-rivet buckling.

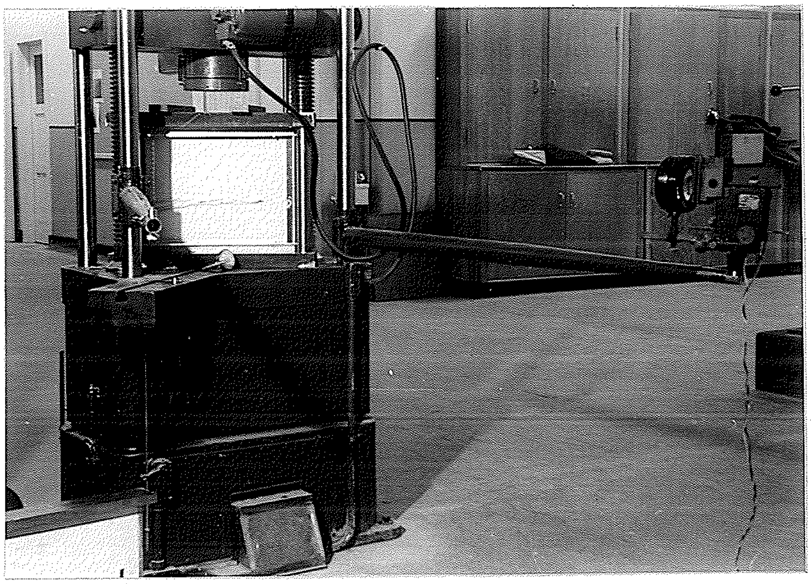


Figure 78.— Panel set up for test. The arc lamp may be seen at the extreme right. The end of the camera support tube appears at the lower left corner of the panel.

to the panel it was therefore necessary to support the equipment on the machine columns, which are attached to the table.

# CHAPTER VI

## CALCULATIONS

Determination of photo-grid dimensions. In designing the photo-grid equipment, it was deemed desirable to set it up so that readings of panel deformations could be taken directly without the use of one or more calibration constants. A reading sensitivity of at least .002 inches was required. Because of the large number of photographs involved, the use of a 35 millimeter camera taking 36 exposures on one loading was considered for obvious reasons. On account of the small negative size, a microscope was necessary for reading to the required sensitivity. Preliminary investigation of images on micro-file film showed that a visual magnification of about 60X was most suitable, because at this value the full resolution of the film was clearly readable. At greater magnifications, the individual grains in the film became objectionably large, interfering with ease of reading image displacement. Films of finer grain and greater resolution than micro-file have not yet been produced. A Bausch and Lomb metallurgical microscope, fitted with a 32 millimeter objective and bi-filar micrometer eyepiece, was selected for film measurement. This eyepiece and objective combination gave a visual magnification of 58x.

The first step in designing the equipment was to determine the calibration constant for the eyepiece. Using a stage micrometer having .01 millimeter graduations, the eyepiece constant was found to be 4.21 divisions for .01 millimeter image displacement.

That is $\quad 1 \text{ division} = \frac{.01}{4.21} = .002375 \text{ mm.}$

For one division to be equivalent to .002 inches panel displacement, the film magnification must be

$$\frac{.002375}{.002 \times 25.4} = \frac{1}{21.4}$$

The camera, a Kine Exacta, was equipped with a Tessar type lens of 50 millimeters nominal focal length. The optical properties of a simple lens system give the following relations:

$$\frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{f} \quad \text{and}$$

$$\frac{d_o}{d_i} = \frac{1}{M}$$

where $d_i$ and $d_o$ are image and object distances from the nodal planes of the lens respectively, and M is the magnification.

Hence on substitution we have

$$\frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{50}$$

$$\frac{d_o}{d_i} = 21.4$$

$$\frac{21.4}{d_o} + \frac{1}{d_o} = \frac{1}{50}$$

i.e. $d_o$ = 1120 mm. or 44.1 inches

The distance from the front nodal plane of the camera lens to the face of the panel was thus fixed in all tests at 44.1 inches.

A shadow spacing of one-quarter inch with shadows appearing one-twentieth inch to the left of the grid threads was selected as being most suitable. Referring to Figure 9, on page 23, by similar triangles

$$\frac{0.55}{44.1} = \frac{y}{44.1 - y}$$

from which the grid distance, y = 0.543 inches.

Also $$\frac{S}{0.5} = \frac{44.1 - y}{44.1} = \frac{43.557}{44.1}$$

from which S = .4933 inches. The grid spacing = $\frac{S}{2}$ = .2467 inches.

These distances were used in all panel tests. It should be observed that the camera was focused on the plate, and that the grid threads appear at one-quarter inch spacing, as do their shadows, at this lens setting, in spite of the fact that they are actually spaced at less than one-quarter inch.

Pin-end lengths. From the photo-grid negatives, the length between inflection points of the principal buckle was measured and recorded as the pin-end length. This information will be of considerable value in checking the validity of any theoretical method of design which may be developed. The figures tabulated in the summary of results are the best approximations that could be made of this parameter at loads close to the critical buckling value. Great personal error is involved in the pin-end length determination because of the small amplitude of the wave form, and the fact that it varied in magnitude across the width of the panel. The values reported are the average of measurements made at each stiffener location. Any measurements which appeared inconsistent were disregarded.

0.2 per cent buckle amplitude. The importance of wing smoothness has been previously mentioned. An obvious criterion of design is therefore the stress beyond which an arbitrary acceptable buckling amplitude is exceeded. A buckling amplitude of 0.2 per cent of the rivet pitch was chosen as a reasonable upper limit. The stress at this value was determined from the photo-grid measurements and will be found in the tabulation of results. Again, some personal error is involved in its determination. It is not surprising to find that the value so determined was close to the critical buckling stress.

Critical buckling stress. The value of $P_{cr}$, the critical buckling load, was determined by three different methods as follows:

1. The load was plotted against the readings of the strain gauges attached to the sheet at mid-panel length as shown in Figure 79. The ordinate, at the point of intersection of the initial straight-line portion of the curve with a tangent to the curve at a point just beyond the knee, was taken as the critical buckling load. The values for each gauge were averaged and divided by the cross-sectional area of the panel to obtain the critical buckling stress. This method is very satisfactory when the principal buckle occurs in the zone of gauge attachment, but may give inaccurate results if the buckle occurs outside this area.

2. $P_{cr}$ was determined by Southwell's[1] method. This method assumes a small initial curvature of the panel under a load below the critical value. A general expression for the column deflection in the form of a trigonometric series is employed, the first term of which is predominant at loads close to the critical value. Assuming that the deflection is given with sufficient accuracy by the first term alone we have

$$\delta = \frac{a_1}{(P_{cr} / P) - 1}$$

in which $\delta$ is the deflection, $a_1$ the initial deflection, and P the load on the panel. Rearranging terms we obtain

$$\frac{\delta}{P} P_{cr} - \delta = a_1$$

1 S. Timoshenko, Theory of Elastic Stability, McGraw Hill, 1936, page 177.

# LOAD - STRAIN CURVES
## PANEL 43

$P_{cr}$ :- Gauge 1 : 21800 lb
Gauge 2 : 20300 lb
Gauge 3 : 21000 lb

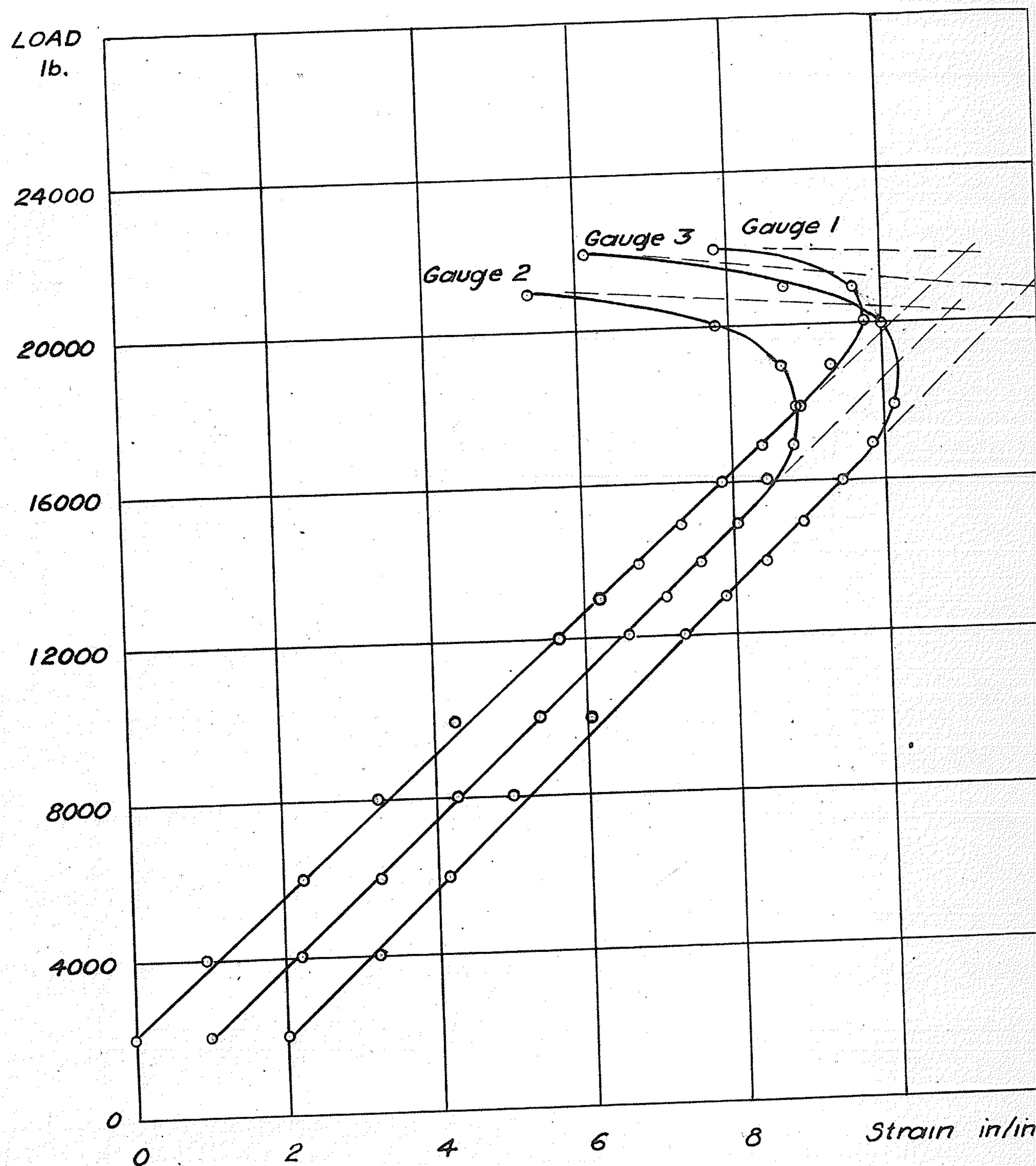



FIGURE 79

This indicates that, if $\delta/P$ is plotted against $\delta$ the points will fall on a straight line. The equation is now seen to be that of a straight line in terms of the inverse slope and x intercept. The x intercept gives $a_1$, and $P_{cr}$ is found as the inverse slope of the line.

In using this method the displacements at the centre of the principal buckle were measured from the photo-grid negatives, and plotted as illustrated in Figure 80, for the sheet at each stringer location. The average value of the inverse slopes was divided by the panel sectional area, and recorded as the critical buckling stress.

This method is always applicable except that in a few cases the points do not lie on a straight line, due possibly to initial lack of straightness.

3. The third method employed consisted of plotting the load against the deflection at the principal buckle. This curve, theoretically, should have a sharply defined knee at $P_{cr}$. Actually, for various reasons, the knee is not sharp. The curve is therefore idealized by projecting a tangent to the second part of the curve backward to intersect the load axis. The ordinate at this point of intersection was taken as $P_{cr}$ and the values so obtained were converted to the critical buckling stress as in the previous methods. A typical curve illustrating this method is given in Figure 81.

# SOUTHWELL CURVES

## PANEL 43

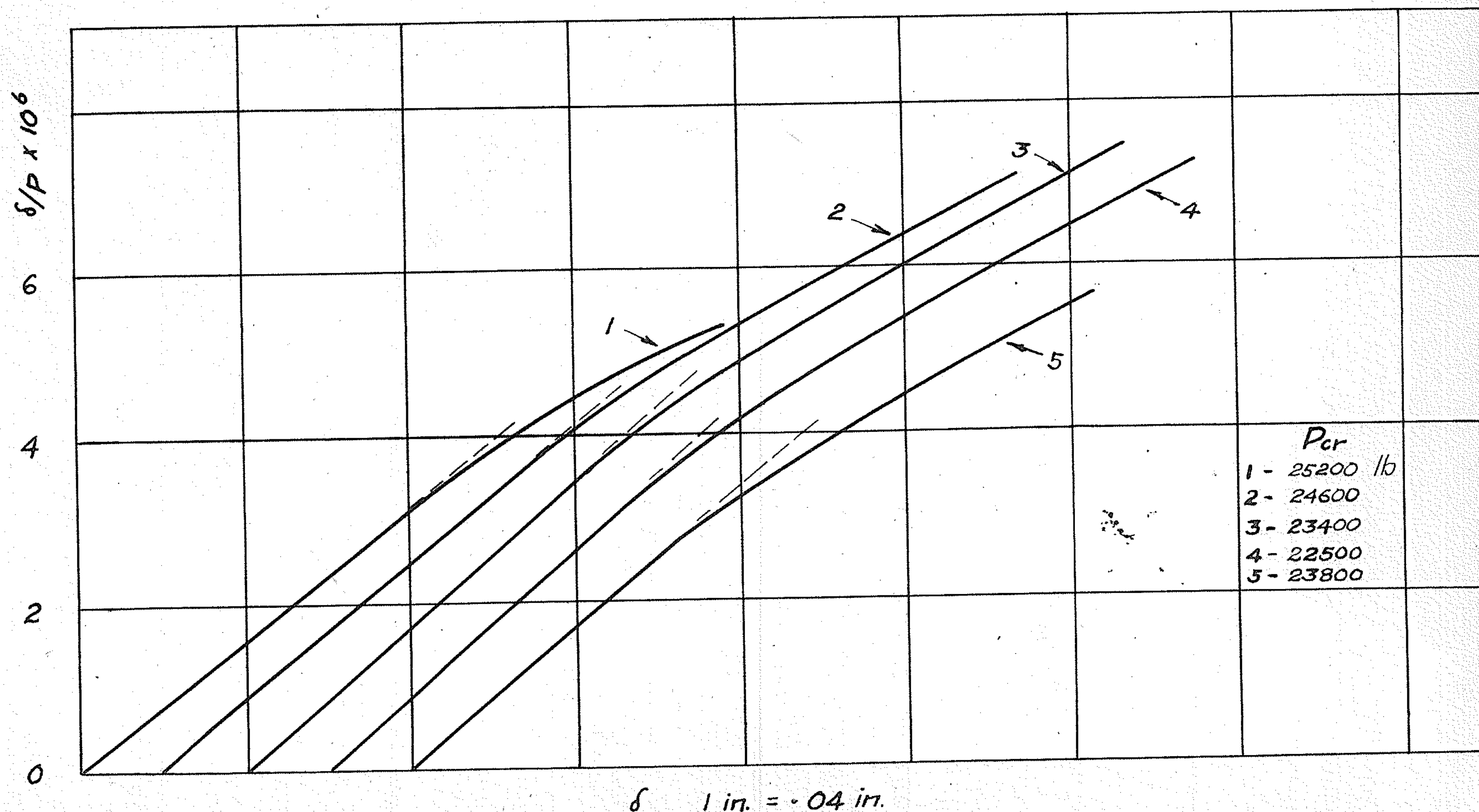



FIGURE 80

# LOAD-DEFLECTION CURVES

## PANEL 43

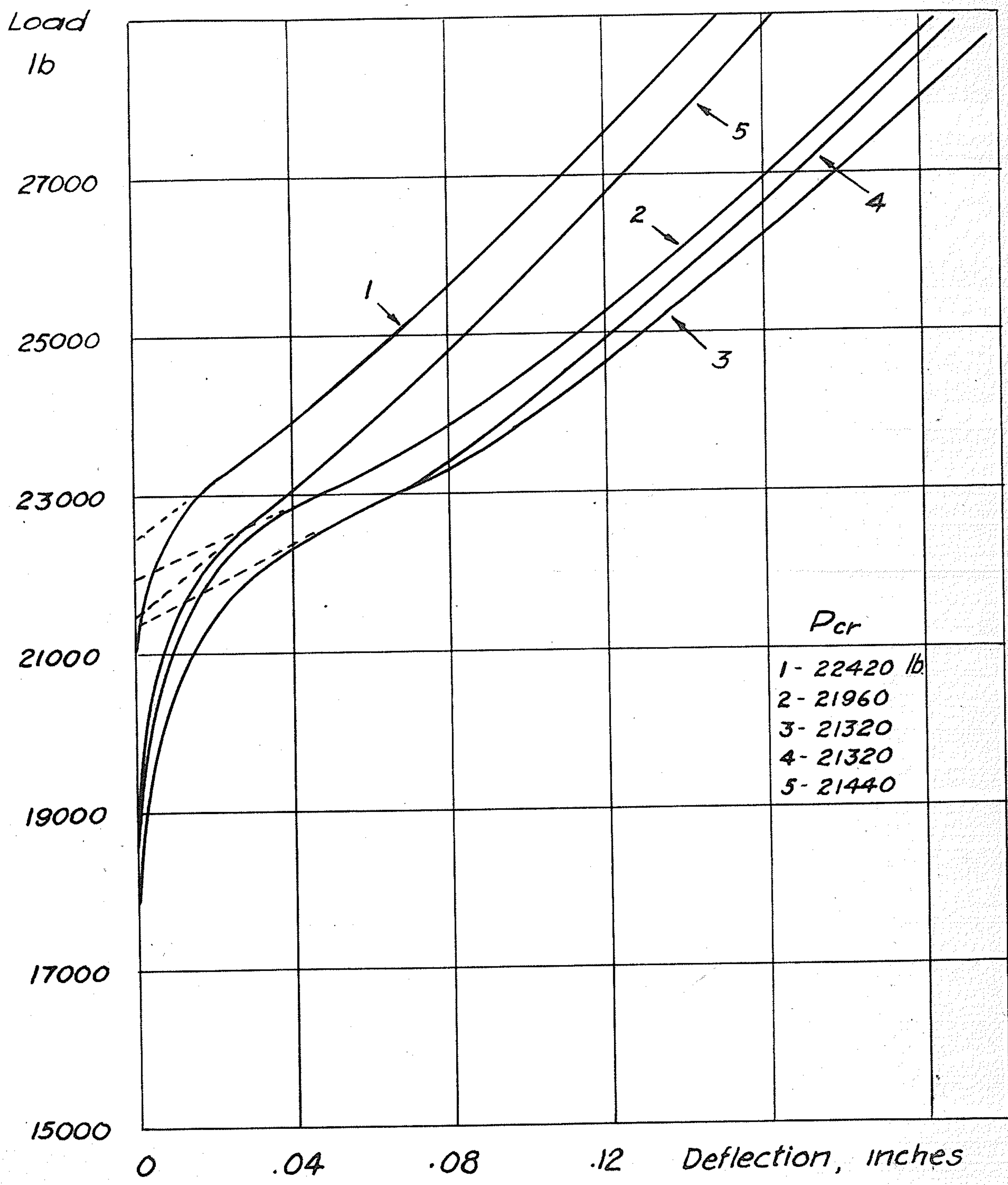



FIGURE 81

Additional calculations. Values of the non-dimensional parameters, $A_{str}/bt$ (stiffener area over sectional area of sheet between stiffeners) and L/t (rivet pitch over sheet thickness) were calculated and have been recorded. These values are commonly used for graphical presentation by other investigators, and have been included for this reason only.

# CHAPTER VII

## PRESENTATION AND DISCUSSION OF RESULTS

Presentation. A tabulation of the results obtained from the fifty-five panels tested is given in Table LVII. In a few cases it will be observed that some of the values have been omitted. In these instances it was not possible to determine the figure with reasonable accuracy. Included in the table are values of the number of half waves into which the panel buckled, and also the type of instability. With respect to the number of half waves, it should be pointed out that it is incorrect to assume that these were of uniform length. The rivet spacing seldom coincided with the half-wavelengths and this effect, together with the necessarily small buckle amplitude toward the stiffener, caused differences in the lengths of each half wave.

The type of instability is indicated by letter as follows:

R—inter-rivet buckling
P—plate buckling of such magnitude as to be clearly visible to the unaided eye.
W—wrinkling of the sheet into five or more half-waves. In this type of failure the half-wavelength appeared to be independent of rivet pitch, the form of instability being somewhat analogous to sandwich buckling.

PR—plate buckling initially, followed by inter-rivet buckling at failure.

The critical buckling stress tabulated is that value

# SUMMARY OF RESULTS

| PANEL NUMBER | PANEL WIDTH | SHEET THICKNESS | NUMBER OF STRINGERS | CROSS-SECTIONAL AREA OF PANEL | RIVET PITCH | STRINGER PITCH | PIN-END LENGTH OF HALF-WAVE | NO. OF HALF WAVES PARALLEL TO LOAD | $\frac{A_{str}}{bt}$ | $\frac{L}{t}$ | CRITICAL BUCKLING STRESS | C.B.S. for d = 0.2 % L | ULTIMATE LOAD | AVERAGE ULTIMATE STRESS | $\frac{P_{ult}}{P_{cr}}$ | TYPE OF INSTABILITY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PANELS WITH SEVEN STRINGERS. b = 2" | | | | | | | | | | | | | | | | |
| 45 | 16 | .0835 | 7 | 1.851 | 1.25 | 2.00 | 2.0 | 5 | 0.440 | 14.97 | 27800 | 27000 | 52760 | 28500 | 1.024 | W |
| 22 | 16 | .081 | 7 | 1.810 | 1.50 | 2.00 | 1.5 | 8 | 0.454 | 18.5 | 25200 | 25200 | 50 000 | 27650 | 1.095 | R |
| 26 | 16 | .081 | 7 | 1.810 | 1.75 | 2.00 | 1.75 | 7 | 0.454 | 21.6 | 24500 | 24300 | 45900 | 25400 | 1.036 | W |
| 15 | 16 | .082 | 7 | 1.827 | 2.00 | 2.00 | 2.0 | 6 | 0.448 | 24.4 | failure | failure | 48950 | 26850 | 1.00 | R |
| 32 | 16 | .0825 | 7 | 1.836 | 2.25 | 2.00 | 1.7 | 5 | 0.445 | 27.3 | 21200 | 21200 | 40900 | 22300 | 1.052 | R |
| 31 | 16 | .0815 | 7 | 1.819 | 2.50 | 2.00 | 2.50 | 5 | 0.451 | 30.5 | 19000 | 17000 | 35720 | 19640 | 1.035 | R |
| 39 | 16 | .084 | 7 | 1.858 | 2.75 | 2.00 | 2.75 | 4 | 0.438 | 32.7 | 18150 | 17100 | 35970 | 19370 | 1.067 | R |
| 29 | 16 | .0825 | 7 | 1.836 | 3.00 | 2.00 | 3.00 | 4 | 0.445 | 36.4 | 18500 | 18500 | 36450 | 19870 | 1.074 | R |
| 36 | 16 | .083 | 7 | 1.843 | 3.25 | 2.00 | 2.00 | | 0.443 | 39.2 | 15700 | 13600 | 36180 | 19610 | 1.25 | R |
| 34 | 16 | .083 | 7 | 1.843 | 3.50 | 2.00 | 1.75 | | 0.443 | 42.2 | 12500 | 11400 | 34200 | 18670 | 1.493 | R |
| PANELS WITH FIVE STRINGERS. b = 2.5" | | | | | | | | | | | | | | | | |
| 44 | 15 | .0815 | 5 | 1.588 | 1.00 | 2.50 | | 4 | 0.361 | 12.3 | 27700 | | 44000 | 27700 | 1.00 | W |
| 37 | 15 | .083 | 5 | 1.613 | 1.25 | 2.50 | | | 0.354 | 15.05 | 25300 | | 42680 | 26450 | 1.045 | |
| 13 | 15 | .082 | 5 | 1.599 | 1.50 | 2.50 | 2.2 | 5 | 0.358 | 18.3 | 25000 | 25000 | 41080 | 25700 | 1.03 | W |
| 19 | 15 | .080 | 5 | 1.568 | 1.75 | 2.50 | 2.2 | 5 | 0.368 | 21.9 | 23200 | 23200 | 37010 | 23450 | 1.01 | W |
| 7 | 15 | .080 | 5 | 1.568 | 2.00 | 2.50 | 2.0 | 6 | 0.368 | 25.0 | 19200 | 19150 | 33200 | 21200 | 1.105 | R |
| 14 | 15 | .081 | 5 | 1.584 | 2.25 | 2.50 | 1.8 | 5 | 0.363 | 27.8 | 18800 | 17000 | 30940 | 19520 | 1.037 | R |
| 2 | 15 | .082 | 5 | 1.598 | 2.50 | 2.50 | 2.5 | 5 | 0.358 | 30.5 | 16500 | 15200 | 29300 | 18300 | 1.11 | R |
| 38 | 15 | .0825 | 5 | 1.605 | 2.75 | 2.50 | 2.75 | 4 | 0.356 | 33.3 | 14900 | 14900 | 29500 | 18380 | 1.235 | R |
| 5 | 15 | .081 | 5 | 1.583 | 3.00 | 2.50 | 1.5 | 4 | 0.363 | 37.0 | 15700 | 14500 | 29780 | 18700 | 1.19 | R |
| 43 | 15 | .0825 | 5 | 1.605 | 3.25 | 2.50 | 1.7 | 4 | 0.356 | 39.4 | 13600 | 12500 | 29810 | 18500 | 1.365 | R |
| 42 | 15 | .0815 | 5 | 1.605 | 3.50 | 2.50 | 1.75 | | 0.361 | 42.9 | 11600 | 8800 | 28950 | 18220 | 1.57 | R |

TABLE LVII

## SUMMARY OF RESULTS. Cont'd.

| PANEL NUMBER | PANEL WIDTH | SHEET THICKNESS | NUMBER OF STRINGERS | CROSS-SECTIONAL AREA OF PANEL | RIVET PITCH | STRINGER PITCH | PIN-END LENGTH OF HALF-WAVE | NO. OF HALF WAVES PARALLEL TO LOAD. | $\frac{A_{str}}{bt}$ | $\frac{L}{t}$ | CRITICAL BUCKLING STRESS | C. B. S. for d = 0.2% L | ULTIMATE LOAD | AVERAGE ULTIMATE STRESS | $\frac{P_{ult}}{P_{cr}}$ | TYPE OF INSTABILITY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PANELS WITH SIX STRINGERS. b = 2.286" | | | | | | | | | | | | | | | | |
| 49 | 16 | .0825 | 6 | 1.761 | 1.50 | 2.286 | 2.0 | 5 | 0.39 | 18.2 | 25600 | 25600 | 46050 | 26200 | 1.02 | W |
| 28 | 16 | .0805 | 6 | 1.729 | 2.00 | 2.286 | | | 0.40 | 24.85 | 19700 | 19700 | 37950 | 21950 | 1.115 | W |
| 27 | 16 | .0815 | 6 | 1.745 | 2.50 | 2.286 | 1.8 | 4 | 0.395 | 30.7 | 18300 | 15500 | 33210 | 19020 | 1.04 | R |
| 30 | 16 | .0815 | 6 | 1.745 | 3.00 | 2.286 | 1.5 | 4 | 0.395 | 36.8 | 15800 | 14330 | 32400 | 18590 | 1.177 | R |
| 41 | 16 | .082 | 6 | 1.753 | 3.25 | 2.286 | 1.6 | | 0.392 | 39.6 | 14000 | 13700 | 32800 | 18710 | 1.336 | R |
| 47 | 16 | .082 | 6 | 1.753 | 3.50 | 2.286 | 1.8 | | 0.392 | 42.7 | 10600 | 9200 | 31960 | 18220 | 1.72 | R |
| PANELS WITH FOUR STRINGERS. b = 3" | | | | | | | | | | | | | | | | |
| 35 | 15 | .0805 | 4 | 1.501 | 1.00 | 3.00 | 2.0 | 6 | 0.304 | 12.4 | 24700 | 22000 | 38500 | 25650 | 1.037 | W |
| 48 | 15 | .083 | 4 | 1.538 | 1.25 | 3.00 | 2.0 | 6 | 0.295 | 15.07 | 23200 | 20500 | 36700 | 23850 | 1.028 | W. |
| 24 | 15 | .082 | 4 | 1.524 | 1.50 | 3.00 | 2.25 | | 0.299 | 18.3 | 22000 | 21000 | 34350 | 22530 | 1.024 | W |
| 25 | 15 | .0805 | 4 | 1.501 | 1.75 | 3.00 | 1.75 | | 0.304 | 21.75. | 20000 | | 30000 | 20000 | 1.00 | W |
| 20 | 15 | .0815 | 4 | 1.517 | 2.00 | 3.00 | 2.0 | 6 | 0.300 | 24.55 | 20100 | 19000 | 30750 | 20300 | 1.01 | W |
| 52 | 15 | .083 | 4 | 1.544 | 2.25 | 3.00 | 2.25 | 6 | 0.295 | 27.1 | 17500 | 16000 | 29300 | 18950 | 1.083 | R |
| 23 | 15 | .081 | 4 | 1.509 | 2.50 | 3.00 | 2.50 | 5 | 0.302 | 30.9 | 16100 | 15000 | 26280 | 17430 | 1.08 | R |
| 46 | 15 | .082 | 4 | 1.524 | 2.75 | 3.00 | 2.75 | 4 | 0.299 | 33.6 | 17100 | 16800 | 26620 | 17440 | 1.02 | R |
| 21 | 15 | .080 | 4 | 1.494 | 3.00 | 3.00 | 2.0 | 4 | 0.306 | 37.5 | 14100 | 12700 | 26500 | 17720 | 1.257 | R |

# SUMMARY OF RESULTS. Cont'd.

| PANEL NUMBER | PANEL WIDTH | SHEET THICKNESS | NUMBER OF STRINGERS | CROSS-SECTIONAL AREA OF PANEL | RIVET PITCH | STRINGER PITCH | PIN-END LENGTH OF HALF-WAVE | NO. OF HALF WAVES PARALLEL TO LOAD | $\frac{A_{str}}{bt}$ | $\frac{L}{t}$ | CRITICAL BUCKLING STRESS | C.B.S. for d = 0.2% L | ULTIMATE LOAD | AVERAGE ULTIMATE STRESS | $\frac{P_{ult}}{P_{cr}}$ | TYPE OF INSTABILITY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MISCELLANEOUS PANELS. | | | | | | | | | | | | | | | | |
| 6 | 15 | .082 | 6 | 1.672 | 2.00 | 2.14 | 2.00 | 6 | 0.419 | 24.4 | 21500 | 18200 | 36120 | 21600 | 1.005 | R |
| 40 | 15.95 | .0815 | 5 | 1.669 | 2.00 | 2.66 | 2.0 | 6 | 0.339 | 24.5 | 21000 | 19800 | 35650 | 21350 | 1.015 | R |
| 55 | 16 | .0825 | 4 | 1.521 | 1.50 | 3.20 | 2.25 | 5 | 0.278 | 18.2 | 21650 | | 33540 | 20700 | 1.0 | W |
| 3 | 16 | .083 | 4 | 1.622 | 2.00 | 3.20 | | 4 | 0:284 | 24.1 | 16800 | 14800 | 27500 | 16950 | 1.01 | W |
| 33 | 15 | .081 | 3 | 1.436 | 2.00 | 3.75 | 2.00 | 6 | 0.244 | 24.7 | 15800 | 14600 | 24300 | 16910 | 1.07 | R |
| 1 | 16 | .083 | 3 | 1.549 | 2.00 | 4.00 | | 6 | 0.2215 | 24.1 | 15800 | 15500 | 24650 | 15900 | 1.005 | R |
| 4 | 16 | .083 | 3 | 1.549 | 2.50 | 4.00 | 2.00 | 5 | 0.2215 | 30.1 | 12300 | 11600 | 23360 | 15100 | 1.23 | |
| DUPLICATE PANELS. | | | | | | | | | | | | | | | | |
| 50 | 16 | .0815 | 7 | 1.821 | 2.50 | 2.00 | 2.50 | | 0.450 | 30.6 | 19600 | 20300 | 39750 | 20800 | 1.06 | R |
| 51 | 16 | .083 | 7 | 1.844 | 2.00 | 2.00 | 2.00 | 6 | 0.443 | 24.1 | 24400 | 22800 | 46000 | 25000 | 1.025 | R |
| 53 | 16 | .082 | 7 | 1.825 | 1.75 | 2.00 | 1.75 | 5 | 0.448 | 21.4 | 24300 | 24100 | 46710 | 25600 | 1.055 | W |
| 54 | 15 | .0825 | 5 | 1.607 | 1.50 | 2.50 | 2.6 | 5 | 0.356 | 18.2 | 24250 | 24200 | 39900 | 24800 | 1.02 | W |
| THIN PANELS. | | | | | | | | | | | | | | | | |
| 8 | 16 | .0665 | 4 | 1.359 | 1.50 | 3.20 | 3.0 | 4 | 0.345 | 22.6 | 15500 | 9500 | 26050 | 19180 | 1.24 | P |
| 9 | 16 | .0655 | 4 | 1.342 | 2.00 | 3.20 | 2.0 | 6 | 0.350 | 30.6 | 14150 | 11200 | 23075 | 17200 | 1.215 | R |
| 10 | 16 | .065 | 4 | 1.335 | 2.50 | 3.20 | 2.5 | 4 | 0.353 | 38.5 | 11700 | 10500 | 21750 | 16300 | 1.39 | R |
| 11 | 16 | .0655 | 4 | 1.342 | 3.00 | 3.20 | 3.0 | 4 | 0.350 | 45.8 | 9400 | 8200 | 21490 | 16000 | 1.70 | R |
| 16 | 16 | .0405 | 4 | 0.942 | 0.75 | 3.20 | 3.0 | 4 | 0.565 | 18.5 | 6500 | 5000 | 20520 | 21750 | 3.35 | P |
| 12 | 16 | .0405 | 4 | 0.942 | 1.00 | 3.20 | 2.5 | 4 | 0.565 | 24.7 | 6250 | | 18975 | 20130 | 3.22 | P |
| 17 | 16 | .0405 | 4 | 0.942 | 1.25 | 3.20 | 2.5 | 5 | 0.565 | 30.85 | 6100 | | 16490 | 17490 | 2.87 | P |
| 18 | 16 | .0405 | 4 | 0.942 | 1.75 | 3.20 | 2.5 | 4 | 0.565 | 43.2 | 6100 | 6000 | 16200 | 17180 | 2.82 | P, R |

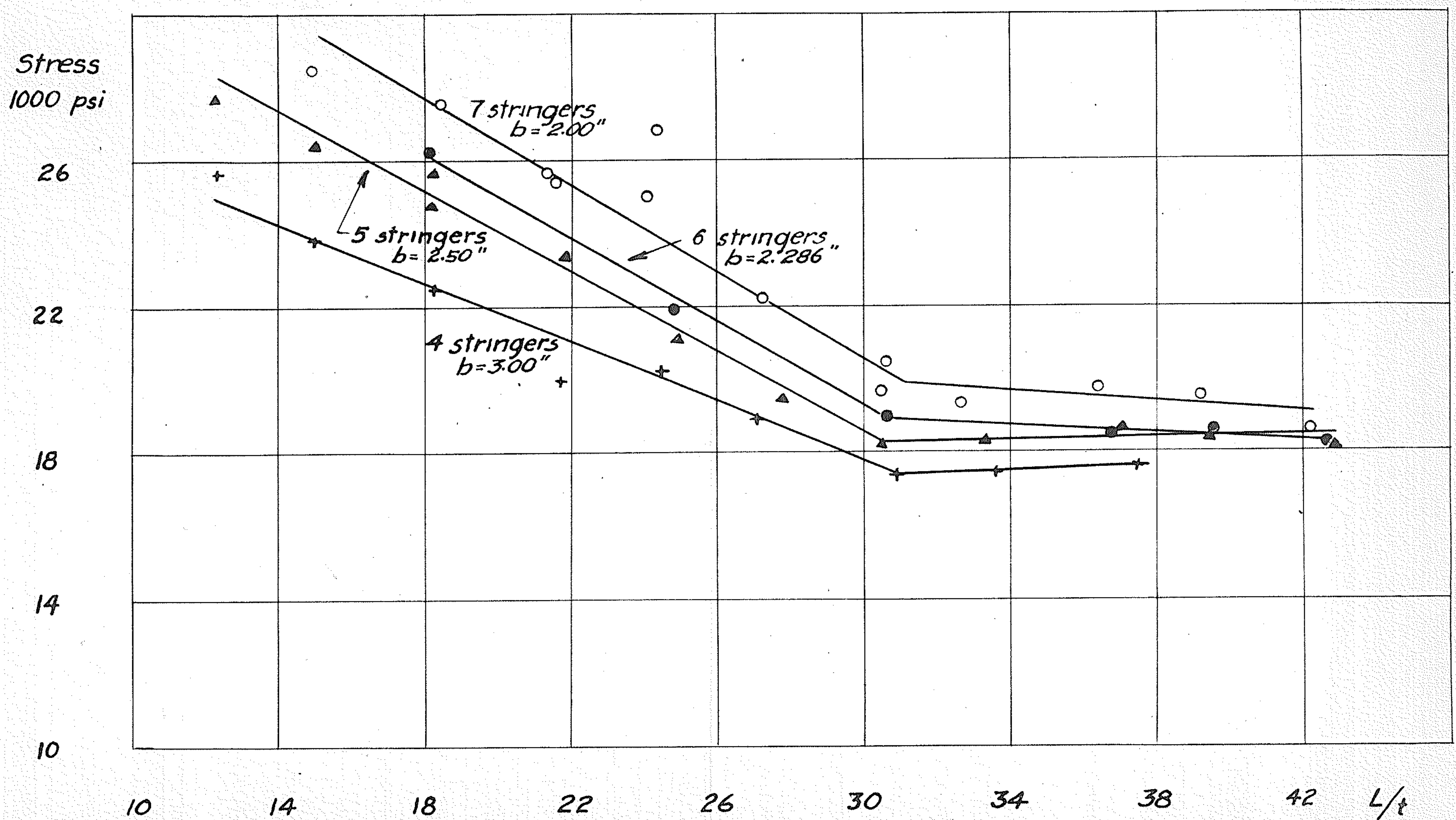
which was thought to be the most reliable from the three methods used for its determination. In most cases the three values were in close agreement. For the few panels in which inconsistencies occurred, there was usually at least one value which appeared to be well-defined.

The ultimate stresses for panels of nominal thickness .081 inch, with 4, 5, 6, and 7, stiffeners, are shown plotted against L/t in Figure 82. Figure 83 shows the variation of critical buckling stress with rivet pitch L, for panels having 4, 5, and 7, stiffeners. In the latter case, the tabulated critical buckling stress values have been adjusted, to compensate for variations from the nominal .081 inch sheet thickness. The curve for six stiffeners is of similar shape, but has been omitted for the sake of clarity.

## DISCUSSION OF RESULTS

Load distribution. Trustworthy laboratory results from an investigation of this nature depend primarily on the attainment of uniform load distribution at the ends of the panel. In compression testing of any type, this requirement is difficult to satisfy since a small eccentricity of load application causes bending of the specimen, which, in turn, increases the eccentricity. Nearly all panel buckling investigators have employed some type of sliding parallel platen arrangement similar to the one shown in Figure 6, and have

# FIGURE 82 VARIATION OF ULTIMATE STRESS WITH L/t



# VARIATION OF CRITICAL BUCKLING STRESS WITH RIVET PITCH - L

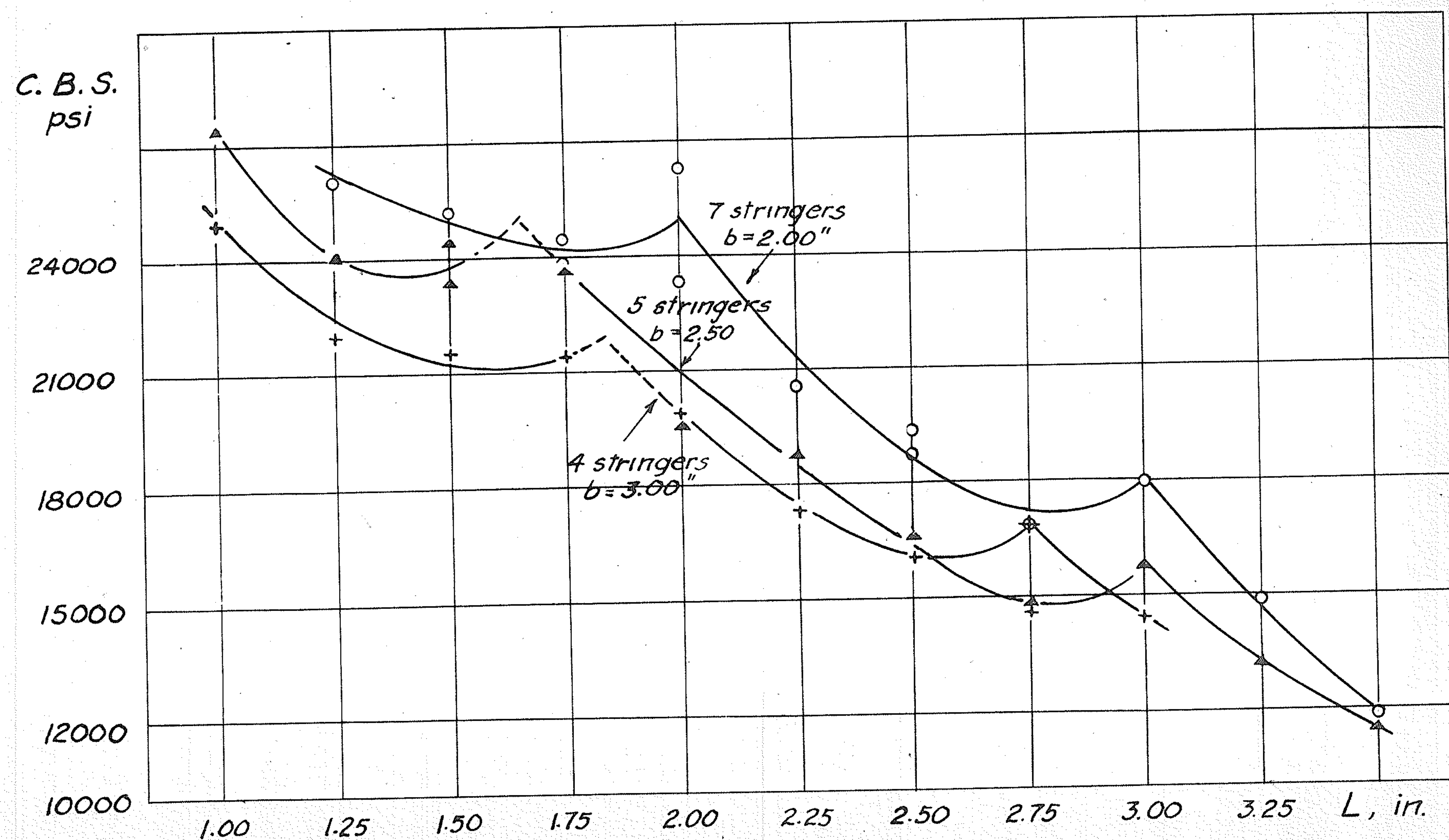



FIGURE 83

attempted to obtain uniform load distribution by providing accurately machined flat and parallel surfaces at the panel ends. Many reports have been published in which dial gauges at the four corners of the platen, as in Figure 12F, were used as an indication of uniform loading. In these cases, the panels were loaded so that all four dials gave the same reading during the test, that is, the panel ends were, at all times, parallel. This method does not result in uniform stress distribution at any point in the panel. The reason for this is due principally to the large width of the panel relative to its length. Considering, for the moment, the sheet alone, it is evident that its ends are almost completely restrained from lateral expansion in accordance with Poisson's ratio by the cerrobend cap, and by frictional resistance to sliding at the platen surface. The usual practical interpretation of St. Venant's principle indicates that the effects of this end restraint should die away more or less completely at a distance from the end of about half the width, that is, about eight inches in the present case. Since the panel length is only twelve inches, no part of it will be free from the effects of end restraint. For complete restraint the effective value of the modulus of elasticity in compression is $\frac{E}{1-\gamma^2}$. It may be stated, then, that the compressive stiffness varies from $\frac{E}{1-\gamma^2}$ at the ends, to approximately E at mid-length, for the sheet alone. This, of course, will result in a corresponding variation of the unit strain along the panel length.

Considering the stiffener alone, it is logical, from the above discussion, to expect that the effects of end restraint should disappear at about five-eighths of an inch from each end. In other words, the effects of end restraint on the stiffener alone are negligible, and its effective compression stiffness is E for almost its entire length. When sheet and stiffener are attached, and considered as a unit, it is apparent that there will be incompatibility between the stiffener and sheet stresses or strains, or both. If the platens remain parallel during loading, then the stress in the sheet will be higher than that in the stringer at all points, since the average effective modulus is higher.

More recent investigations have employed resistance strain gauges on the sheet and stiffeners, and have tried to establish uniform stress distribution across the mid-panel section. This was the procedure followed in the present series of tests. If uniform stress in stiffeners and sheet are maintained during loading, it is obvious from the previous discussion that the panel ends cannot remain parallel, but must approach each other more rapidly on the stiffener side of the panel. There is thus rotation of the panel ends, resulting in bending of the stiffeners and hence the panel as a whole.

One more effect should be mentioned. The edge of the sheet, say up to the first stiffener, is not so greatly affected by the end restraint as is the central portion. This is partly due to the fact that the stiffeners mechanically anchor the central portion of the sheet in the cerrobend cap. As a result, the stiffness and therefore the stresses in the end bays of the sheet may be expected to be lower than in the centre.

Difficulties in obtaining uniform stress without rotation of the platens has been frequently reported, but it is believed that the above is the first reasonable explanation of the phenomenon.

As a check on its validity, several transverse gauges were installed on panel No. 54. An examination of Table LV will reveal the following information, all of which corroborates the above analysis. Transverse gauges 9 and 11, near the panel ends at the centre line, gave very low readings, indicating nearly complete fixity at these points. Gauge 7, also at the panel end, but at the edge instead of the centre, gave much higher readings, indicating that end restraint was not as effective in the end bays. Gauges 8 and 10 at panel mid-length showed the highest readings, approximately thirty per cent of the longitudinal strains at the same points. Since Poisson's ratio is 0.30, this indicates that the horizontal mid-section of the panel was practically free from the effects of end restraint. Further, the dial gauge readings a and b, on the stiffener side of the panel, are larger than c and d, on the sheet side, indicating platen rotation.

One of the best panels from the standpoint of strain distribution was panel 55. A glance at the gauge readings of Table LVI will show the readings in the end bays to be lower than the central readings. This condition, as well as platen rotation, was evident in nearly all tests.

A conclusion which may be drawn from the above is that it is not possible with flat platens to load a stiffened panel in such a way as to obtain either a condition of uniform stress or strain.

Since failure of the panel usually occurs at mid-length, it is believed that the closest possible approach to uniform strain at this position is better than maintaining parallelism of the platens.

Pin-end lengths. The pin-end lengths of half-waves included in the summary of results should prove to be of value in developing and checking theoretical aspects of this problem. A few observations are of interest. Considering the .081 inch panels, it will be noticed that in those panels which fail by wrinkling, the pin-end length is approximately 2.00 inches, regardless of rivet pitch, stiffener pitch, or number of stiffeners. Wrinkling did not occur at rivet pitches greater than 2.50 inches. At rivet pitches greater than 3.00 inches, the pin-end length was about half the rivet pitch, the sheet failing like a fixed Euler column between rivets, as in Figure 3. At rivet pitches between 2.00 and 3.00 inches, the pin-end length was nearly equal to the rivet pitch. This, of course, involves distortion of the rivets and stiffeners.

Ultimate stresses. These values, plotted on Figure 82, have been checked as far as possible with other data, and have been found to be in close agreement, especially at the higher stresses. Duplicate panels were tested in a few cases, and will be found in Table LVII. The results checked remarkably well with the original values.

Critical buckling stresses. Figure 83 shows curves of some of these values. The most striking part of these curves is the appearance of cusps, dividing each curve into three parts. This suggests that there are three buckling regimes depending on rivet pitch, and this is borne out by the three varieties of pin-end lengths previously mentioned. Curves of this nature have not been previously reported, and are definitely of interest from the theoretical standpoint. A great deal of time has been spent on photo-grid readings in an attempt to find some definite type of buckling corresponding to these regimes, but without success. About all that can be said at present is that they correspond with the pin-end lengths associated with wrinkling, Euler sheet buckling, and the phase in between these two. At the peaks of the cusps, the critical stress will be found to be very close to the ultimate stress.

0.2 per cent L buckle amplitude. The smoothness criterion of specifying critical stresses will be seen to give results which are close to the critical buckling stress, but which are in general somewhat lower. This is an indication that if a high degree of skin smoothness is desired, even the critical buckling stress is on the unsafe side. If this statement is accepted as true, then no theoretical solution to the problem is possible by existing methods, since all of these methods involve determinations of $P_{cr}$.

Plate buckling. According to published data, panel 19 should have failed by "pure inter-rivet buckling", unaffected by plate buckling. It is difficult to visualize just how the sheet could buckle between rivets before buckling between the stiffeners, but this has been presumed to be the case by most authorities. Careful measurement of photo-grid negatives has revealed the fact that panel 19 developed slight, but well-defined, anti-symmetrical plate buckling initially, after which inter-rivet buckling occurred, causing disappearance of the plate buckling. This is illustrated in Figures 73 and 74. This condition was observed in many of the panels tested, and is believed to have occurred in all of them.

The original problem, namely, buckling of stiffened panels excluding the case of plate buckling is, in the above light, an impossibility. The difference between thin and thick panels in this regard appears to be only one of degree, the plate buckling in the latter case being of such small amplitude as to have escaped notice. This perhaps is a statement which would only interest the theorist, because the amount of plate buckling is so small as to be practically negligible.

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