TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 151

# TESTS ON BUILT-UP AIRPLANE STRUTS HAVING INITIAL TENSION IN OUTSIDE FIBERS.

By T. A. Schwamb and C. S. Smith.

Abstracted by John G. Lee.

August, 1923.

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# TESTS ON BUILT-UP AIRPLANE STRUTS HAVING INITIAL TENSION IN OUTSIDE FIBERS.*

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## Introduction.

The following paper is an abstract of a thesis performed by T. A. Schwamb and C. S. Smith, in June, 1922, as required for the Degree of Bachelor of Science at the Massachusetts Institute of Technology. The work was done in the Department of Mechanical Engineering, and is published by consent of that department.

The conventional airplane strut fails by buckling. The first signs of the failure usually are compression cracks on the concave side of bending, since wood is in general stronger in tension than in compression. It would therefore appear that if an initial tension could be introduced in the outside fibers, this tension would have to be relieved before the compression load could make itself felt. Such initially stressed struts have been used in certain airplanes.

The struts used in these tests were all of rectangular cross-section, 30" long and 3" wide, the thickness tapering 1" at the center, to $\frac{1}{2}$" at the ends along the curve of a circular arc. Certain of the specimens had a maximum thickness of 63/64" at the center and 7/16" at the end. The material was furnished in part

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* Abstracted by John G. Lee.

by the Bureau of Aeronautics, U.S.N., in part by the Engineering Division, Air Service, U.S.A., to whom the author's thanks are due.

## Construction of Struts.

The problem in making the struts was to devise some means whereby all hand work, with the exception of gluing, could be done away with, thus giving a more uniform product, and one capable of quantity production. The following methods appear applicable to production work.

### The Two-piece Strut.

This strut was made up from two identical pieces 30" long by 3" wide by $\frac{1}{2}$" thick at the center, and $\frac{1}{4}$" at the ends. The desired tapered curve was laid off upon a hard-wood template (Fig. 1), from which a hollow "shoe" was constructed from a block about 2" x 4" cross-section and 3 feet long (Fig. 2).

It will now be seen that if a $\frac{1}{2}$" slat of wood be placed on the shoe (Fig. 3) and run through a planer, the result will be that the slat will be bent down into the form and the top of the slat planed off straight (Fig. 4). When it has passed entirely through, the slat will bend back (Fig. 5), giving the desired curve.

To secure initial tension in the outside fibers, two of these "half-struts" were glued together with the curved sides in, thus making it necessary to bend them together. The gluing was all done under the present piano-manufacturing method. One-half of each strut was heated to $95^{\circ}$F while the glue was spread on the other and the two were then clamped together into the shoe, thus making certain that their center lines would be straight (Fig. 6). Sixteen clamps were necessary to hold a strut 30" long.

When the glue had set the clamps were removed and one edge of each strut squared off on a planer. The struts were then cut to a 3" width on a circular saw and sanded to dimensions. Next, the struts were placed in a jig and run between two circular saws set 30" apart (Fig. 7), which assured the ends being square and true. The strut was then ready for the test.

### Unstressed-Strut.

These struts were made up to secure a comparison. They were of two types, one-piece and two-piece. One-piece struts were cut nearly to form by a band saw and were then shaped by hand after which they were sawed to 3" width and cut off to 30" length. The two-piece struts were made by gluing two "half-struts" with the flat sides together.

### The Four-Piece Strut.

It is obvious from the construction of the two-piece struts that the magnitude of the initial tension is dependent upon the thickness of the strut so that in order to obtain a greater initial tension it is necessary to resort to a more elaborate construction. First, two quarter-inch slats were glued together over a form (Fig. 8), which gave them an initial curvature. When the glue had set these slats were placed upon the hollow shoe (Fig. 9), with the convex side upward and passed through the planer as before, the resulting "half-strut" is shown in Fig. 10, where it will be seen that one of the two slats has been planed down to zero thickness at the ends. Two of these "half-struts" were placed together as before (Figs. 10 and 11), and were finished up in precisely the same manner as the two-piece struts. Throughout their construction these struts showed no signs of failure either in the wood or the glued joints which indicates that excessive stress was not obtained.

## Materials Used in Making Struts.

The wood available for these struts was first-class kiln-dried spruce, supplied as already noted, by the Army and the Navy, which had been carefully picked and sawed so that it was very straight-grained and free from all knots and season cracks. The spruce came about 36" x $1\frac{3}{8}$" x $3\frac{1}{4}$" and approximately half of both the Army and Navy shipments were slash, and the other half quarter-sawed. In choosing wood for individual specimens it was attempted to get as nearly uniform grain as possible so that the results would be reliable. The wood used for struts Nos. 23 and 30, had the grain evenly matched so that the pieces were all from the same section of the same tree, giving about as great uniformity as possible.

## Method of Test.

The testing was all done in a 20,000-pound Riehle testing machine. The struts were centered upon hemispherical caps which in turn rested upon hardened steel plates as is shown in the photograph (Fig. 12). The load was applied by hand in order to obtain more accurate deflection readings. The deflection was measured by a steel scale placed across the column of the testing machine. The scale is visible in the photograph.

## Results and Conclusions.

Throughout the tests all of the primary failures occurred in the middle third of the strut. With struts having $\frac{1}{2}$" end thickness the failures were directly in the center, while with those having 7/16" end thickness the failure tended to be nearer the extremities. In one or two cases a secondary failure appeared in splitting at the ends, although this always took place after the maximum load had been reached. This was prevented in the case of the four-piece struts by placing small clamps on the end of the struts as soon as the load had passed the maximum.

All of the failures were preceded by compression cracks ranging throughout the central third of the strut, which indicates that at no time was the initial stress great enough to cause failure in tension. After the compression failure had worked pretty well across the section, the strut gave way in shear or tension, the latter being more frequent in the four-piece struts. In only one instance did glue show up in the break, and that was in a specimen which sheared off at the end. The failure is shown in the photograph (Fig. 13) and is the fourth from the left.

From the accompanying load-deflection curves of the two-piece struts (Fig. 14) it appears that there is no appreciable change in strength, in going from the stressed to the unstressed members, although the stressed struts appear to be somewhat stiffer, and they also possess the advantage, not apparent from the curves, of being more uniform. It is interesting to note that the one-piece struts are stronger than both the two-piece stressed and the two-piece unstressed struts. This is accounted forrby the reduced central cross-section of the two-piece struts, and consequent reduction of the moment of inertia. Taking this into consideration, the one-piece and two-piece struts appear to have approximately the same strength. This is rather opposed to the popular idea, that the laminated member is the stronger.

The results for the four-piece struts are much more promising. Here we have an increase in maximum strength of 8.4% and a decrease in deflection at three-fourths maximum load of approximately 50%. As in the case of the two-piece struts, this is accompanied by much greater uniformity. The variation of individual specimens from the average for the one-piece struts was 34%; for the two-piece struts, 25%; and for the four-piece struts, 16%.

Just what initial tension was actually present in the struts and how that tension would affect a strut of streamline form, it is difficult to say, but from the foregoing it may be concluded that the increased rigidity and dependability of the four-piece strut would warrant further investigation.

Figs.1,2.

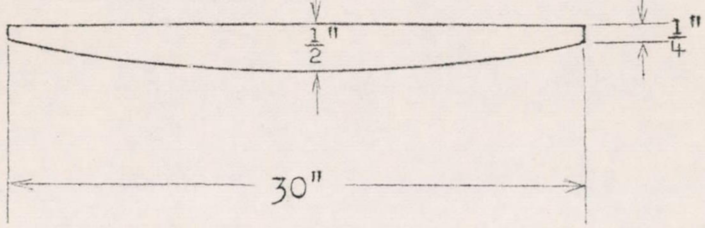
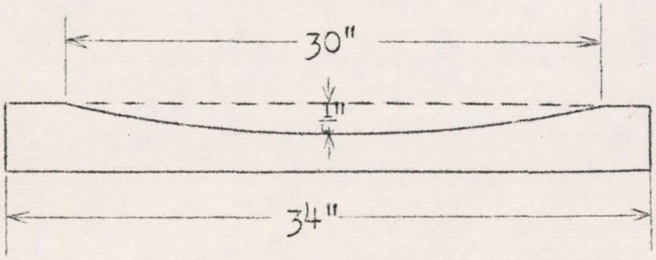


Fig.1 (Template)



Fig,2 (Shoe)

Figs. 3,4,5.

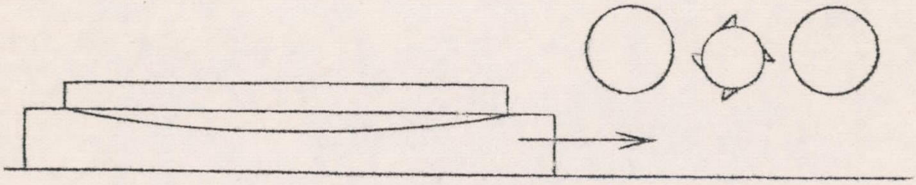


Fig. 3

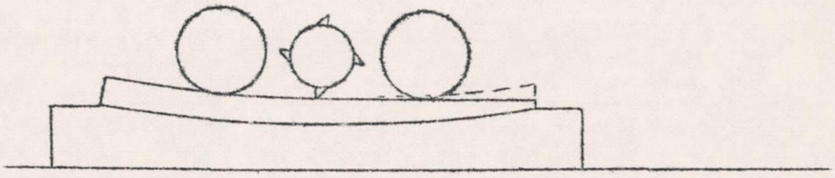


Fig. 4

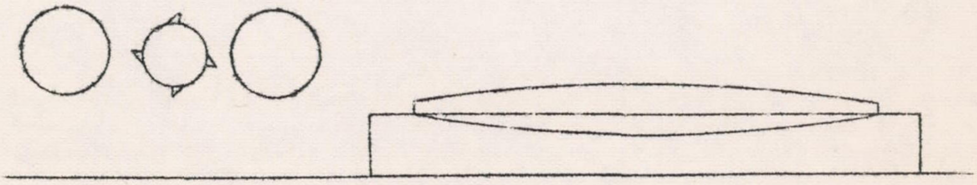


Fig. 5

Figs.6,7,8.

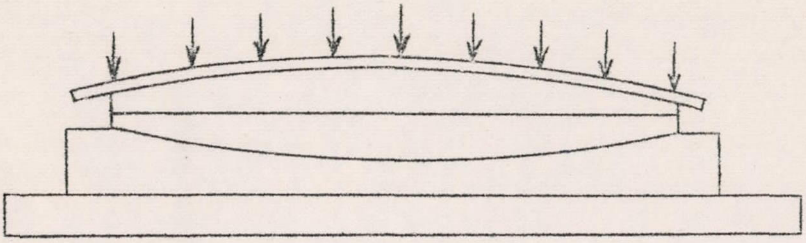


Fig.6

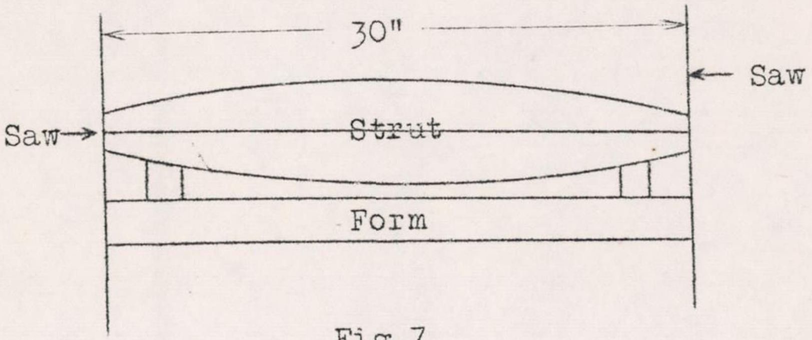


Fig.7

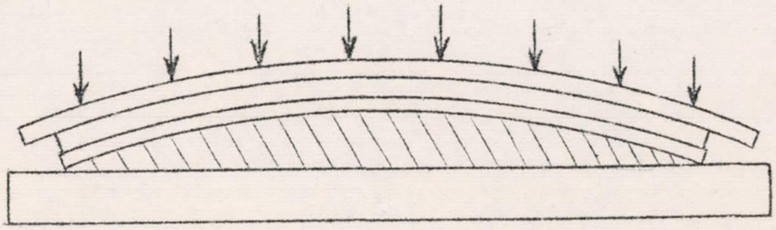


Fig.8

Figs.9,10,11.

Fig.9

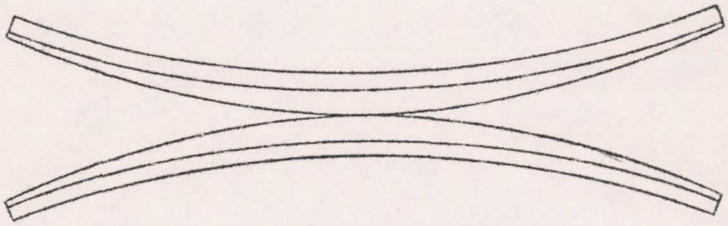


Fig.10

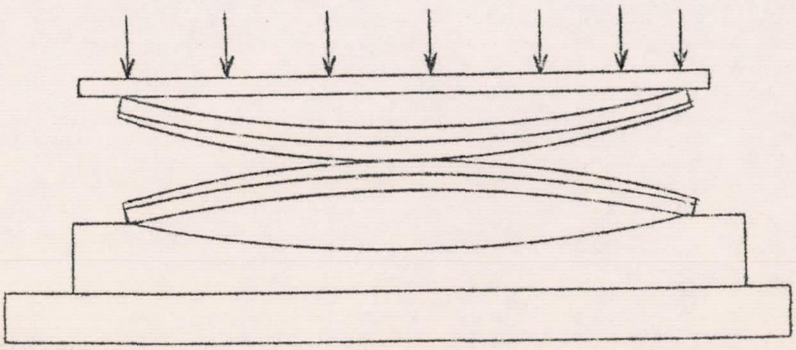


Fig.11

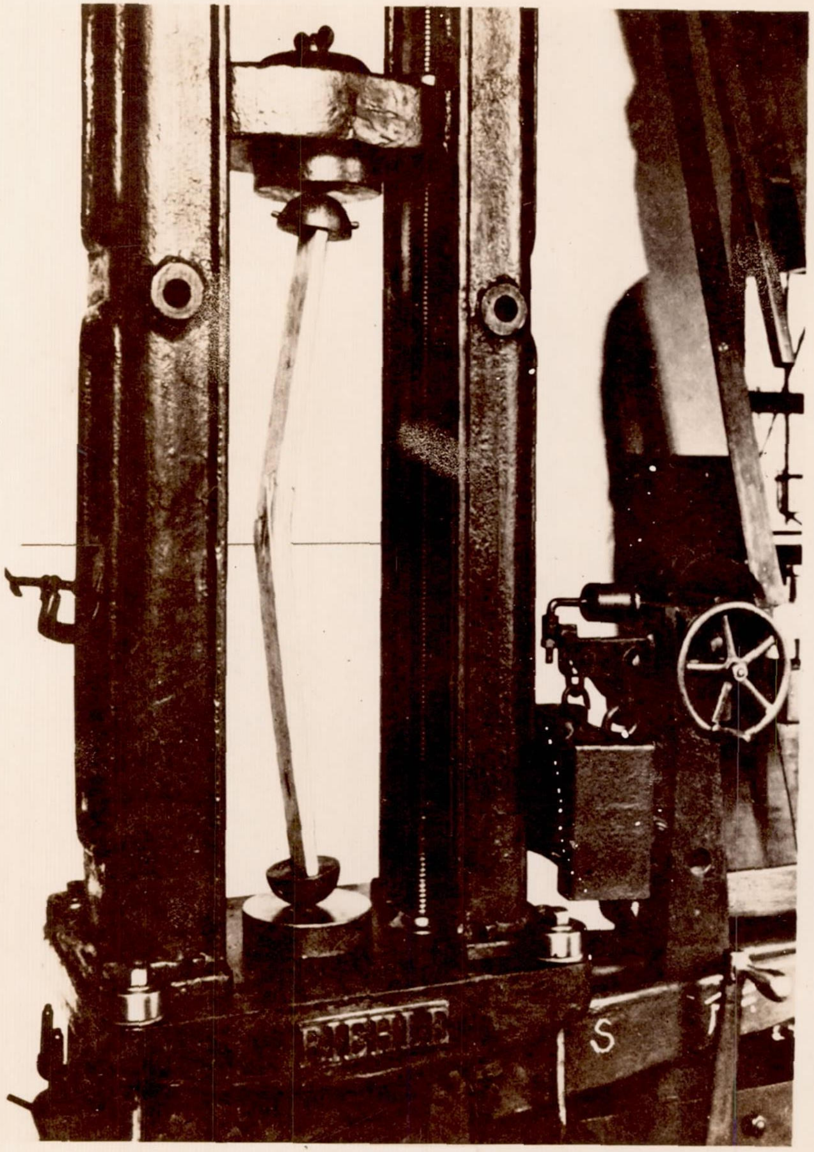


Fig. 12

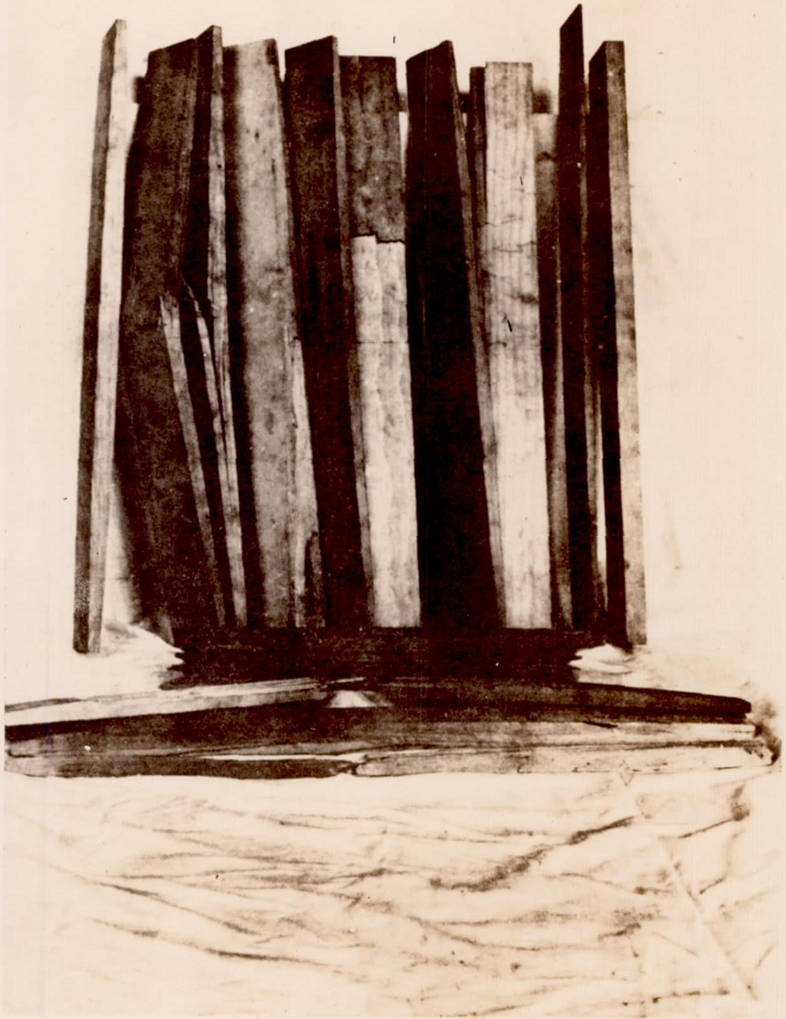


Fig. 13

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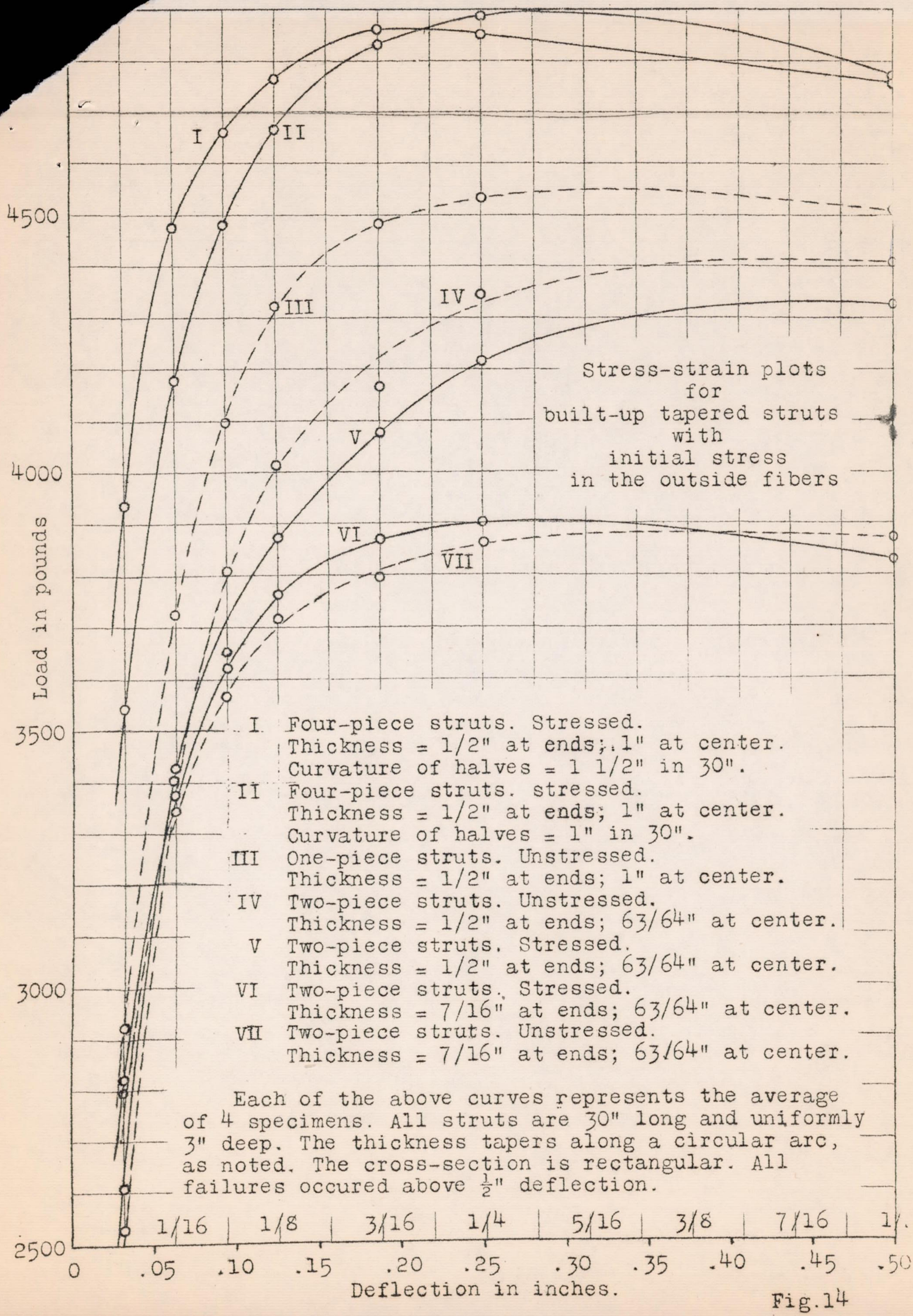

Stress-strain plots
for
built-up tapered struts
with
initial stress
in the outside fibers

I Four-piece struts. Stressed.
Thickness = 1/2" at ends; 1" at center.
Curvature of halves = 1 1/2" in 30".
II Four-piece struts. stressed.
Thickness = 1/2" at ends; 1" at center.
Curvature of halves = 1" in 30".
III One-piece struts. Unstressed.
Thickness = 1/2" at ends; 1" at center.
IV Two-piece struts. Unstressed.
Thickness = 1/2" at ends; 63/64" at center.
V Two-piece struts. Stressed.
Thickness = 1/2" at ends; 63/64" at center.
VI Two-piece struts. Stressed.
Thickness = 7/16" at ends; 63/64" at center.
VII Two-piece struts. Unstressed.
Thickness = 7/16" at ends; 63/64" at center.

Each of the above curves represents the average of 4 specimens. All struts are 30" long and uniformly 3" deep. The thickness tapers along a circular arc, as noted. The cross-section is rectangular. All failures occured above ½" deflection.

Fig. 14