TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

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# TESTS ON DURALUMIN COLUMNS FOR AIRCRAFT CONSTRUCTION.

By John G. Lee

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## Introduction

The following paper is based on the results of tests, upon duralumin columns, contained in two theses presented to the Department of Civil and Sanitary Engineering of the Massachusetts Institute of Technology: one by Messrs. Erwin Harsch and E. P. Whitehead in 1920, and one by Messrs. R. H. Becker and G. A. Noveck in 1922. These theses were made at the request of certain officials of the United States Navy Department which was, at the time, preparing plans for the Shenandoah, and the materials were provided by that department. The tests were conducted under the general supervision of Professor Charles M. Spofford, head of the Civil and Sanitary Engineering Department of the Massachusetts Institute of Technology, through whose courtesy the publication of this paper is made possible. The actual testing was done with the advice and under the supervision of Professor Harrison W. Hayward, in charge of the Mechanical Testing Laboratories of the Institute. The curves shows in figures were plotted by the author from the data given in these theses; and the conclusions presented are also by the author.

Compression tests were made on four sets of heat-treated duralumin columns of different cross-section and varying thickness for different values of $L/r$. The specimens to be tested were cut to length, their ends machined square, and mounted between hemispherical bearing caps in an Olsen vertical testing machine (accurate to 20 lb.). In mounting the specimens a template was used to insure accurate centering. The load was applied by hand. Three individual tests were averaged for each point appearing on the plots.

The most interesting thing to be observed in the plots is the behavior of the columns at low values of $L/r$. While at the higher values ($L/r = 80$ and upwards) the points lie close to Euler's curve, at the lower values they do not break away in the parabolic form which we ordinarily expect. Instead, the curves break away rather earlier and in some instances remain concave upwards throughout their entire length. This tendency is most marked in thin sections with free edges far from the neutral axis, such sections being peculiarly liable to secondary failure by crinkling. Presumably, if the curves for such sections were continued below $L/r = 20$ they would continue rising more and more steeply until they reached the ultimate compressive strength (55,000 lb./sq.in.) at $L/r = 0$. As the sections are thickened up, the points lie closer to a straight line than to a curve. It may therefore be assumed that if we continued to increase the thickness the curve will eventually become convex upward, and take the more familiar form, the maximum value being at 55,000 lb./sq.in. at $L/r = 0$ as before. For two of the groups of sections (series A and B) the reversal in curvature actually appears.

This peculiar deviation from conventional column behavior appears to be due to local failure of the long unsupported flanges of the column. This failure is manifested in several ways. In the shorter columns it takes the form of direct local buckling. In the longer columns both flanges occasionally bend in the same direction, which amounts to giving the center of the column an angular displacement relative to the ends, and the failure is by twisting. Again, if the flanges bend in opposite directions, distortion takes place, and not infrequently the column fails about an axis which formerly had the greatest moment of inertia. In the case of the plain angle sections, where the outstanding legs receive the least support of any, the outer portions of these legs appeared to act as separate columns and buckle separately, as could be so noticed during the test.

It is useful to adopt a formula which will approximately fit all of the various column sections with which we have to deal. It is bound to be over-conservative in most cases, but the designer is constantly in need of some such formula for sections on which he has no tests. The following are accordingly suggested for pin-ended columns:

$$\text{From } L/r = 0 \text{ to } L/r = 90$$

$$f_c = 35{,}000 - 250\ L/r \qquad (1.$$

From $L/r = 90$ upwards

$$f_c = 100{,}000{,}000/(L/r)^2 \tag{2}$$

The first of these is an entirely empirical straight-line formula which is practically tangent to the second at $L/r = 90$. The second is Euler's formula $f_c = (\pi)^2 E/(L/r)^2$ where $E$ for duralumin has been taken as 10,130,000 lb./sq.in., which is a very reasonable value. Another formula which is of interest is that suggested by the Army of the form

$$f_c = .8\,[47{,}000 - 400(L/r)] \tag{3}$$

for values of $L/r$ from 0 to 80. The .8 factor disappears for tubes and bars, but is used for all other sections. For columns fixed at the ends, the 400 becomes 280 and the formula is good up to $L/r = 110$. The principal difficulty with the Army formula is that it does not come tangent to Euler's curve by a considerable amount. It fits the points almost as well as formula No. 1, however.

The curves determined by formulas Nos. 1 and 2 are drawn in on each of the four plots. It will be noticed in Figs. 2 and 3 that the channels B-1 and N-1 fall below the curve. These two channels are so exceedingly thin for their size that they are quite uneconomical sections; their ratio of thickness to perimeter is 1/60 and 1/40, respectively. The same thing may be said of the "S" sections in Fig. 4. Here we find all of the test specimens below the curve. If, however, we extrapolate from the test values, we conclude that the formula will hold for angles in which the thickness of plate is at least 1/10 of the length of a leg. Fig. 4 shows very clearly the inefficiency of the plain angle section.

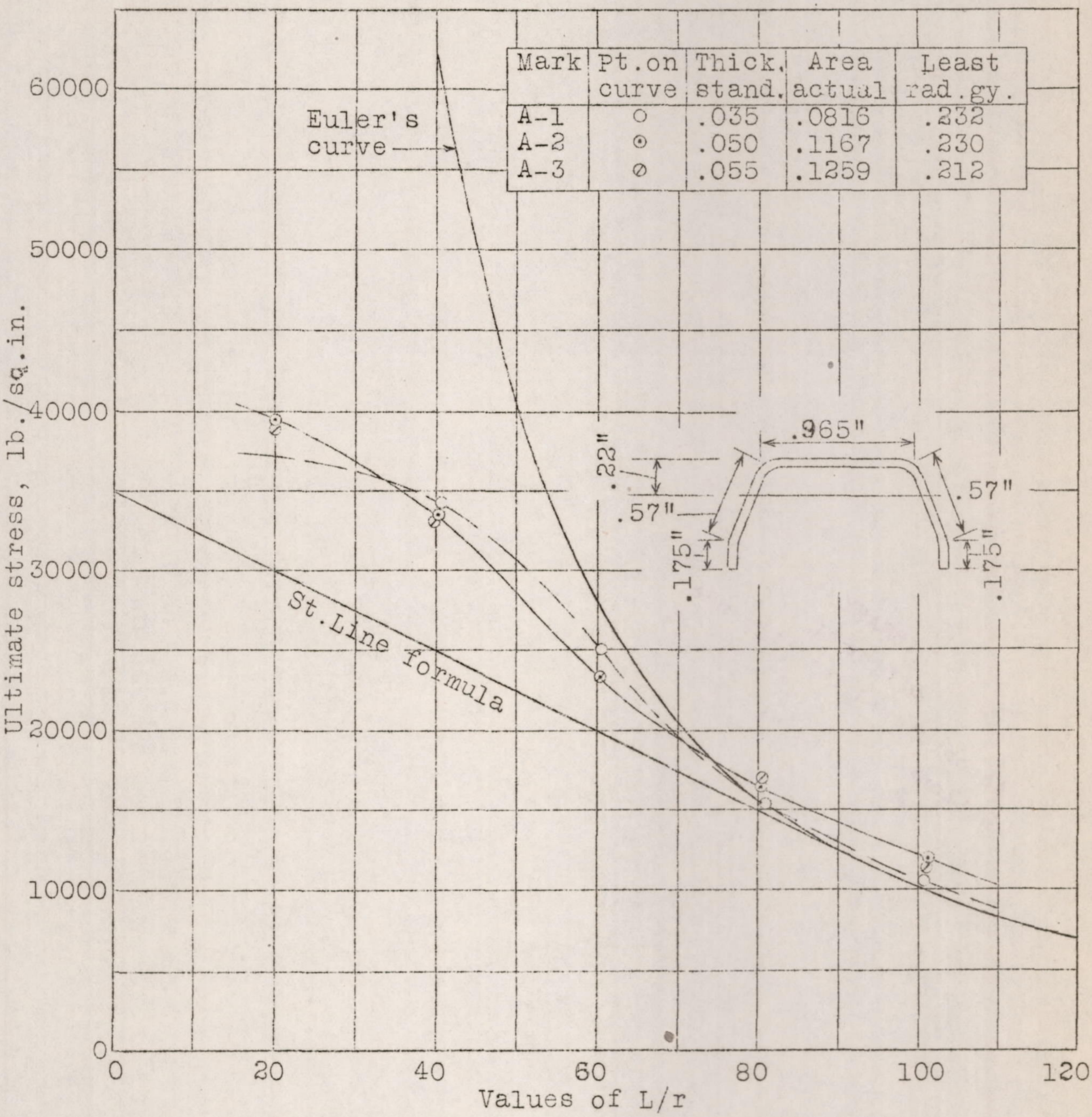



Fig.1 Compression tests mark "A" heat treated duralumin columns. Columns tested as pin ended struts. Least radius of gyration is about axis of non-symmetry.

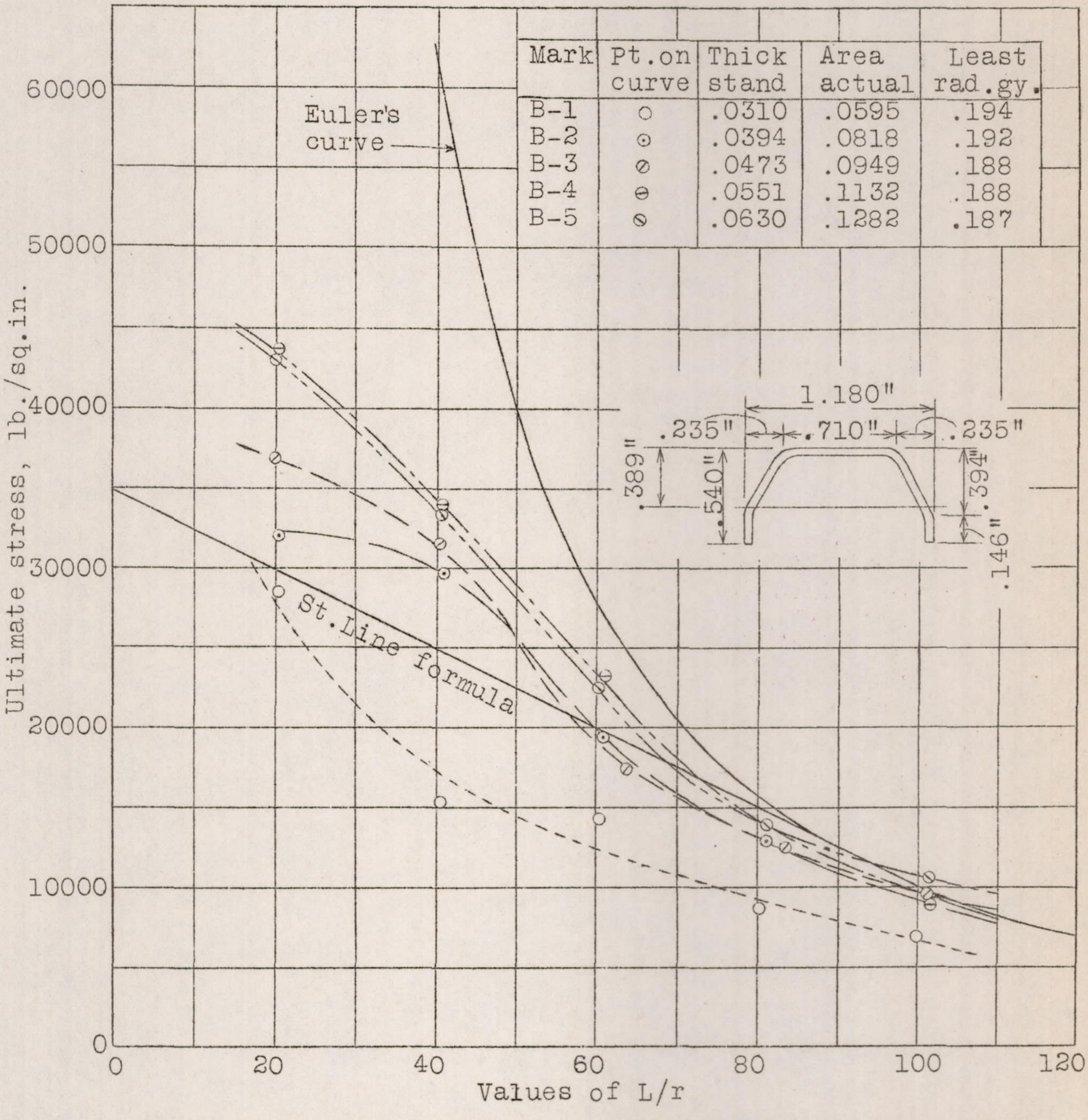
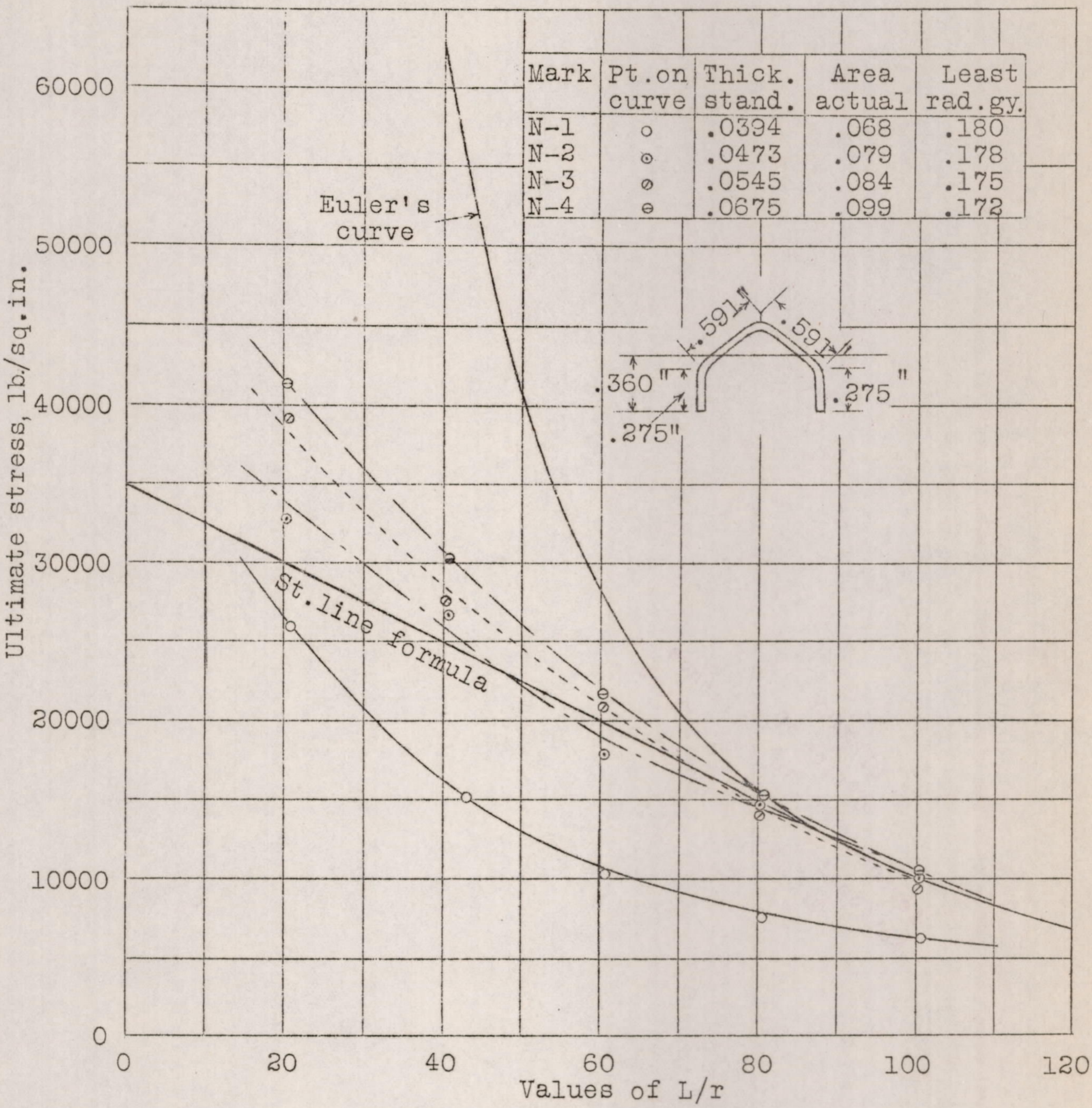



Fig.2 Compression tests mark "B" heat treated duralumin columns. Columns tested as pin ended struts. Least radius of gyration is about axis of non-symmetry.




| Mark | Pt.on curve | Thick. stand. | Area actual | Least rad.gy. |
|---|---|---|---|---|
| N-1 | ○ | .0394 | .068 | .180 |
| N-2 | ⊙ | .0473 | .079 | .178 |
| N-3 | ⊘ | .0545 | .084 | .175 |
| N-4 | ⊖ | .0675 | .099 | .172 |

Fig.3 columns. Compression tests mark "N" heat treated duralumin Columns tesred as pin ended struts. Least radius of gyration is about axis of nom-symmetry.

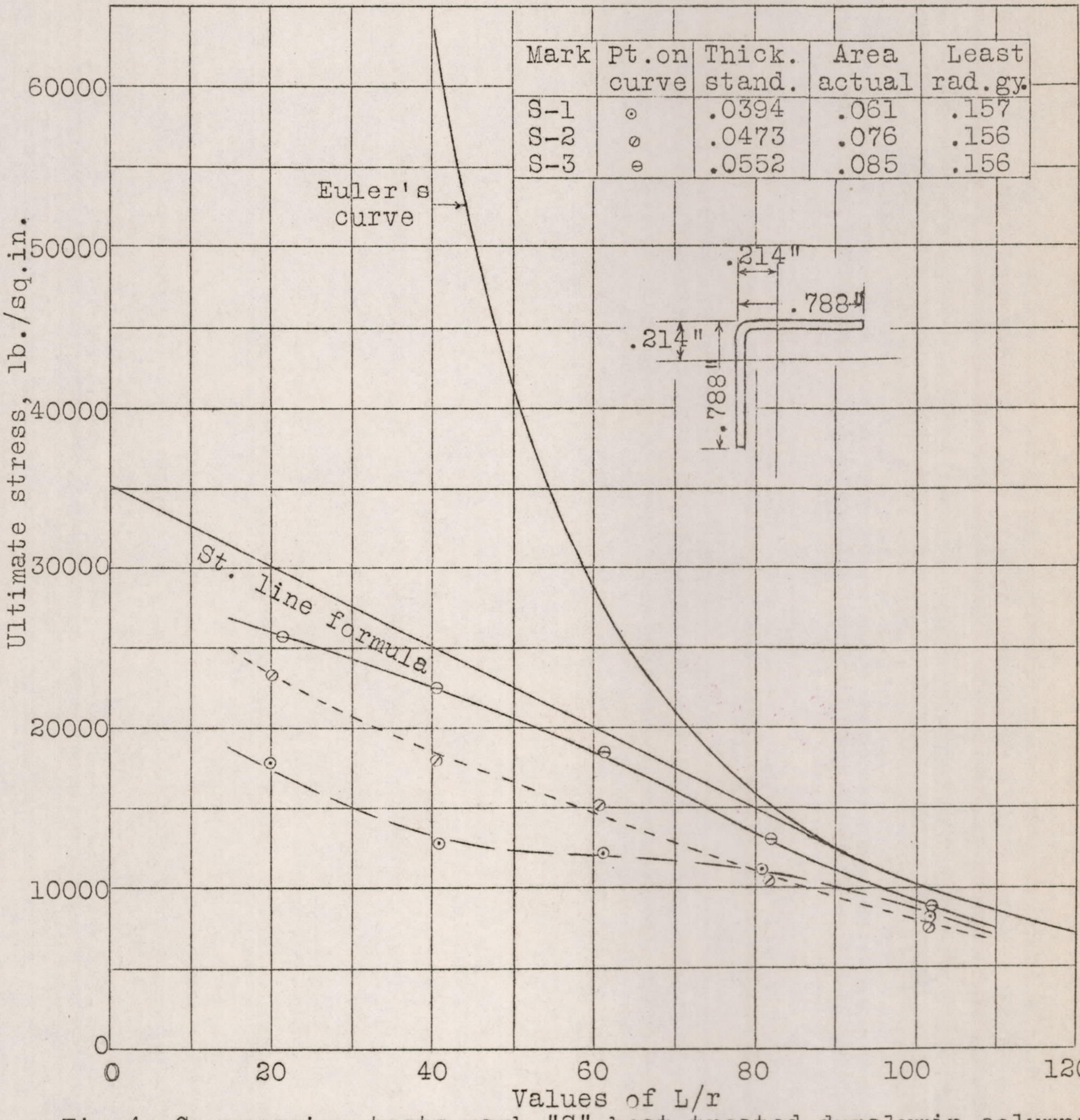



Fig.4 Compression tests mark "S" heat treated duralumin columns. Columns tested as pin ended struts. Least radius of gyration is about axis of non-symmetry.