NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

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PERFORMANCE TESTS OF WIRE STRAIN GAGES

V - ERROR IN INDICATED BENDING STRAINS IN THIN SHEET METAL DUE TO THICKNESS AND RIGIDITY OF GAGE

By W. R. Campbell and A. F. Medbery
National Bureau of Standards

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SUMMARY

Results of tests to determine the combined effects of rigidity and thickness of wire strain gages on indicated bending strains in thin sheet metal are presented for 15 types of single-element multistrand wire strain gages. In most cases the indicated extreme-fiber bending strain was greater than the actual strain. It was concluded that the positive error caused by the finite thickness of the gage predominated over the negative error caused by the rigidity of the gage. The combined effect of thickness and rigidity was such as to increase the indicated strains of the different gages from 5 to 40 percent for a sheet thickness of 0.026 inch. Errors in indicated strain ranged from 0 to 9 percent for a sheet thickness of 0.125 inch.

INTRODUCTION

This report describes one of a series of performance tests on wire strain gages of types used in large numbers to measure stresses in aircraft structures. The purpose of the tests is to make available information on the properties, accuracy, and limitations of various multistrand, single-element gages.

The performance test program has been divided into several phases, the results of which are reported individually. The first four phases of the program have been reported in references 1 to 4. The present paper reports on the fifth phase, error in indicated extreme-fiber bending strain in thin sheet metal due to thickness and rigidity of gage.

This investigation, conducted at the National Bureau of Standards, was sponsored by and conducted with the financial assistance of the National Advisory Committee for Aeronautics.

The authors desire to acknowledge the cooperation of the organizations participating in the program. Wire strain gages for these tests

were contributed by the NACA Ames Aeronautical Laboratory, the Baldwin Locomotive Works, the Boeing Aircraft Company, the Chrysler Corporation, the Consolidated Vultee Aircraft Corporation, the Douglas Aircraft Company, the Lockheed Aircraft Corporation, North American Aviation, Inc., and Northrop Aircraft, Inc.

SYMBOLS

R gage resistance, ohms

ΔR change in gage resistance, ohms

ϵ_b extreme-fiber bending strain

$\Delta\epsilon_b$ change in extreme-fiber bending strain

K calibration factor of gage under axial tension

K_{mt} average calibration factor K for 8 gages of a given type at low tensile strains (Computed from table 2 of reference 1 as the average of 16 factors, 8 for strain increasing and 8 for strain decreasing.)

e difference between extreme-fiber bending strain indicated by wire strain gages and the actual strain as determined with Tuckerman strain gages, percent

t, w subscripts indicating measurements with Tuckerman strain gage and wire strain gage, respectively

DESCRIPTION OF STRAIN GAGES

Six aircraft companies, the NACA Ames Aeronautical Laboratory, the Baldwin Locomotive Works, and the Chrysler Corporation, contributed test gages of fifteen different types (A through G, H-1, I through O) which in all but one case are identical with the gage types reported in reference 1. Table 1 of reference 1 gives a description of all test gages except gage H-1 which was substituted for gage H. Data on gage type H-1 are given in appendix 1 of reference 2. Figures 1 and 2 of reference 1 show the gages attached to strips used in the calibrations at low tensile strains.

TESTS

The combined error caused by the thickness and rigidity of the wire strain gage was determined by comparing the extreme-fiber bending strains indicated by the wire strain gages with those measured with Tuckerman strain gages. The bending strains were produced in seven 24S-T aluminum-alloy cantilever beams of 1-inch width having thicknesses ranging from 0.026 to 0.125 inch (see fig. 1). Strains in each of the seven beams were measured with both types of strain gages with the gage centered at a point $1\frac{1}{2}$ inches from the fixed end. The measurements were made at several loads, all of them on the linear portion of the load-strain curve. The extreme-fiber bending strain ϵ_{bw} indicated by the wire strain gages were computed from

$$\epsilon_{bw} = \frac{\Delta R}{R} \times \frac{1}{K_{mt}} \qquad (1)$$

The change in extreme-fiber bending strain $\Delta\epsilon_{bt}$ which would have been observed at the gage line without the wire strain gage, for a given load increment, was taken from a curve of extreme-fiber strain against load determined for each beam with the Tuckerman gage. The percentage error e in strain indicated by the wire strain gage was then computed from

$$e = \left(\frac{\Delta\epsilon_{bw}}{\Delta\epsilon_{bt}} - 1\right) 100 \qquad (2)$$

The average error e for a given extreme-fiber distance (one-half the thickness of beam) was obtained by averaging values of e for several load increments on each beam.

PROCEDURE

The tests were started by determining load-strain curves for the beams with Tuckerman strain gages at the point where the wire gages were to be attached. Two Tuckerman gages were attached to the beams, one to the upper surface and one to the lower surface. The extreme-fiber bending strain was then obtained by taking one-half the numerical sum of the strains observed with the two gages, thus eliminating errors due to curvature of the test beam. Two calibrations were made on each beam with intervening removal of the beam from the clamps in order to check that the strain was not affected by the changes in the clamping condition. It was found the strains observed in the two calibrations differed by less than 1 percent.

Measurements on the beams with Tuckerman gages over the area to be occupied by the wire gage showed that the strain varied linearly with the distance from the fixed end. The wire strain gages were attached to the tensile extreme fiber of the beams, following the manufacturers' instructions. The beams were then clamped and loaded as in figure 1. Unit change in gage resistance $\Delta R/R$ for each load was measured with a Wenner ratio set (reference 1) in a direct-current Wheatstone bridge. The values of $\Delta R/R$ were then converted to indicated strain increments using equation (1). The percentage difference between these strain increments and the true extreme-fiber strain increment was computed using equation (2). The values of e for a given sheet thickness were then averaged for the various loads to obtain the average error due to the combined effect of rigidity and gage thickness.

RESULTS AND DISCUSSION

The average error e in the extreme-fiber strain indicated by the wire gages is plotted against sheet thickness in figures 2 to 6. Examination of these curves shows that for most gages the error increases rapidly as the sheet thickness decreases. The bending strains indicated by the wire gages for the thinnest sheet (0.026 in.) exceeded the actual strains by 5 to 40 percent.

Since the indicated strains were in most cases higher than the strains to be measured it may be concluded that the error in indicated strain caused by the finite thickness of the gage predominated over that caused by the rigidity of the gage; the first effect tends to increase the extreme-fiber distance while the second tends to decrease the indicated strains because of a reduction of the strain under the gage.

The data in figures 2 to 6 are of comparative value only, since they give numerical errors which are dependent on the flexural rigidities and dimensions of the specimen to which the gages were attached.

CONCLUSIONS

Results of tests to determine the combined effects of rigidity and thickness of wire strain gages on indicated bending strains in thin sheet metal show that each of the 15 types of wire strain gages used indicate larger extreme-fiber strains than those observed with Tuckerman strain gages. Errors in indicated bending strain on cantilever strips in bending averaged 14 percent for the thinnest sheet (0.026 in.) and 3 percent for the thickest (0.125 in.). The errors for individual types of gages on the 0.026-inch strips ranged from 5 to 40 percent in the following sequence of increasing error; type J, A, E, C, O, K, H-1, I, B, G, M, F, D, L, and N.

In general, the tests showed that wire strain gages indicate bending strains on thin sections with considerably less accuracy than that normally realized in the measurement of axial strains. For given applications it may be possible to make corrections for the error in indicated strain. The corrections would have to be determined under the particular conditions of the test.

National Bureau of Standards,
Washington, D. C., June 20, 1946.

REFERENCES

1. Campbell, William R.: Performance Tests of Wire Strain Gages. I - Calibration Factors in Tension. NACA TN No. 954, 1944.

2. Campbell, William R.: Performance Tests of Wire Strain Gages. II - Calibration Factors in Compression. NACA TN No. 978, 1945.

3. Campbell, William R.: Performance Tests of Wire Strain Gages. III - Calibrations at High Tensile Strains. NACA TN No. 997, 1945.

4. Campbell, William R.: Performance Tests of Wire Strain Gages. IV - Axial and Transverse Sensitivities. NACA TN No. 1042, 1946.

Figure 1.- Method of producing bending strains.

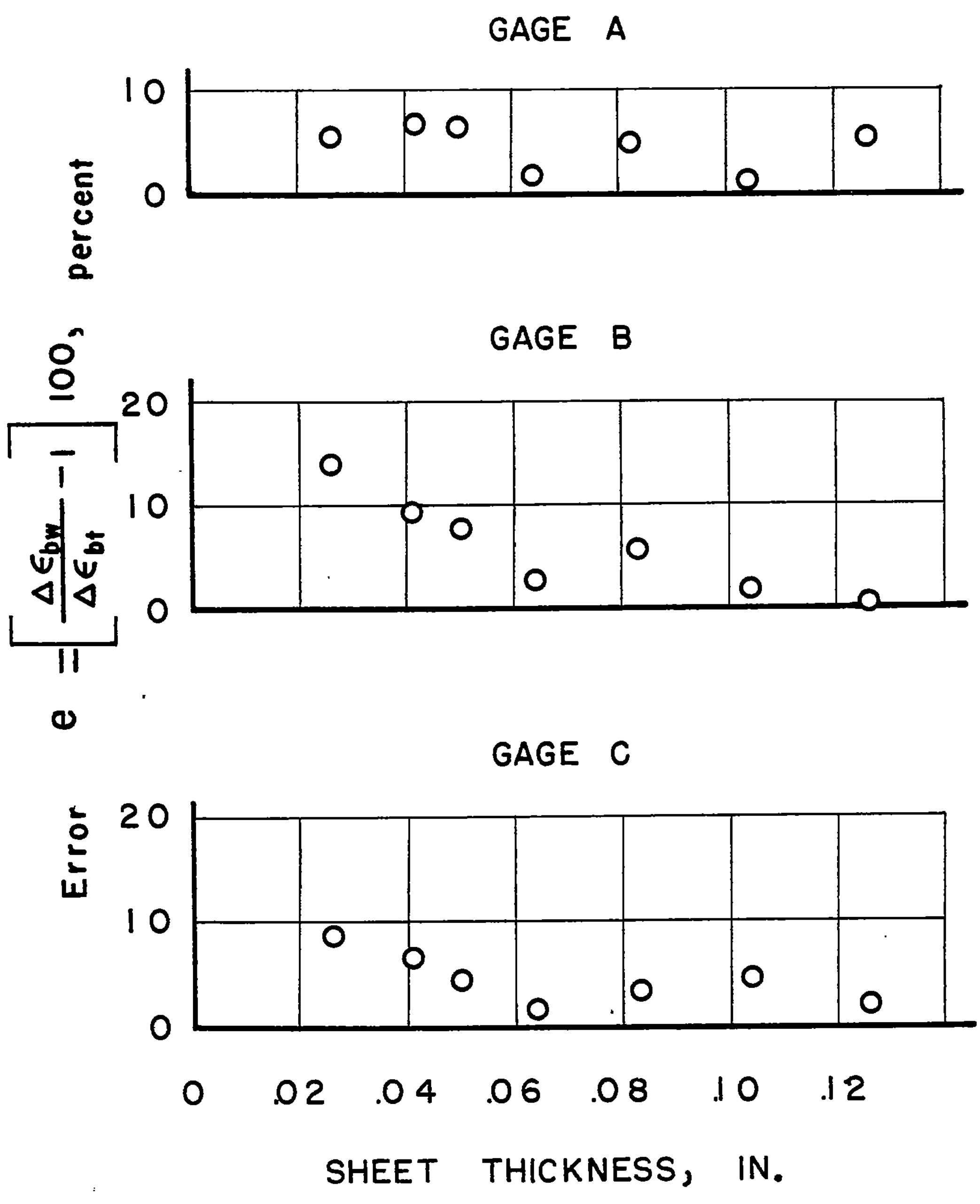

Figure 2.- Average error in the extreme-fiber strain, indicated by wire gages A, B, and C, plotted against sheet thickness.

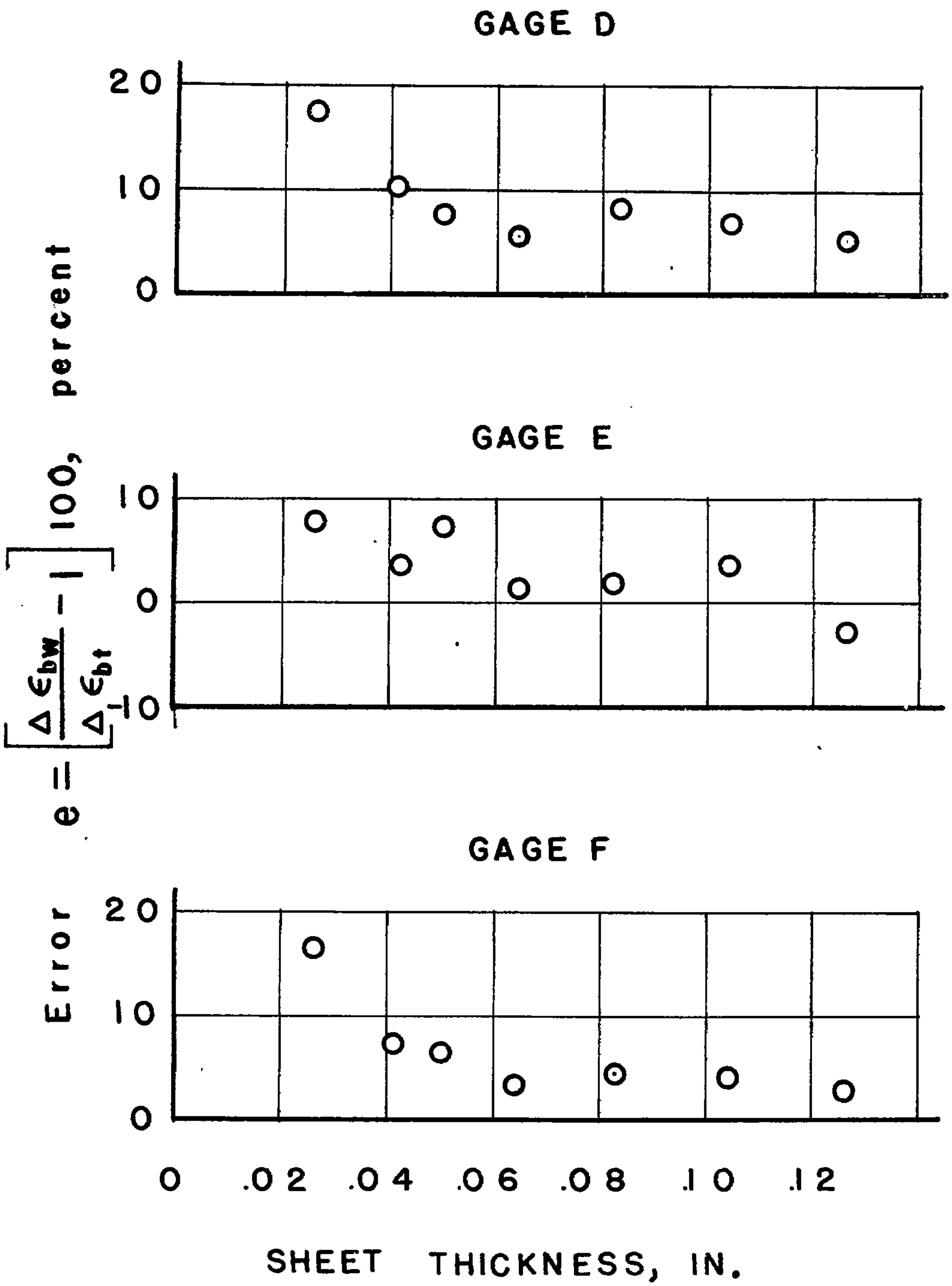

Figure 3.- Average error in the extreme-fiber strain, indicated by wire gages D, E, and F, plotted against sheet thickness.

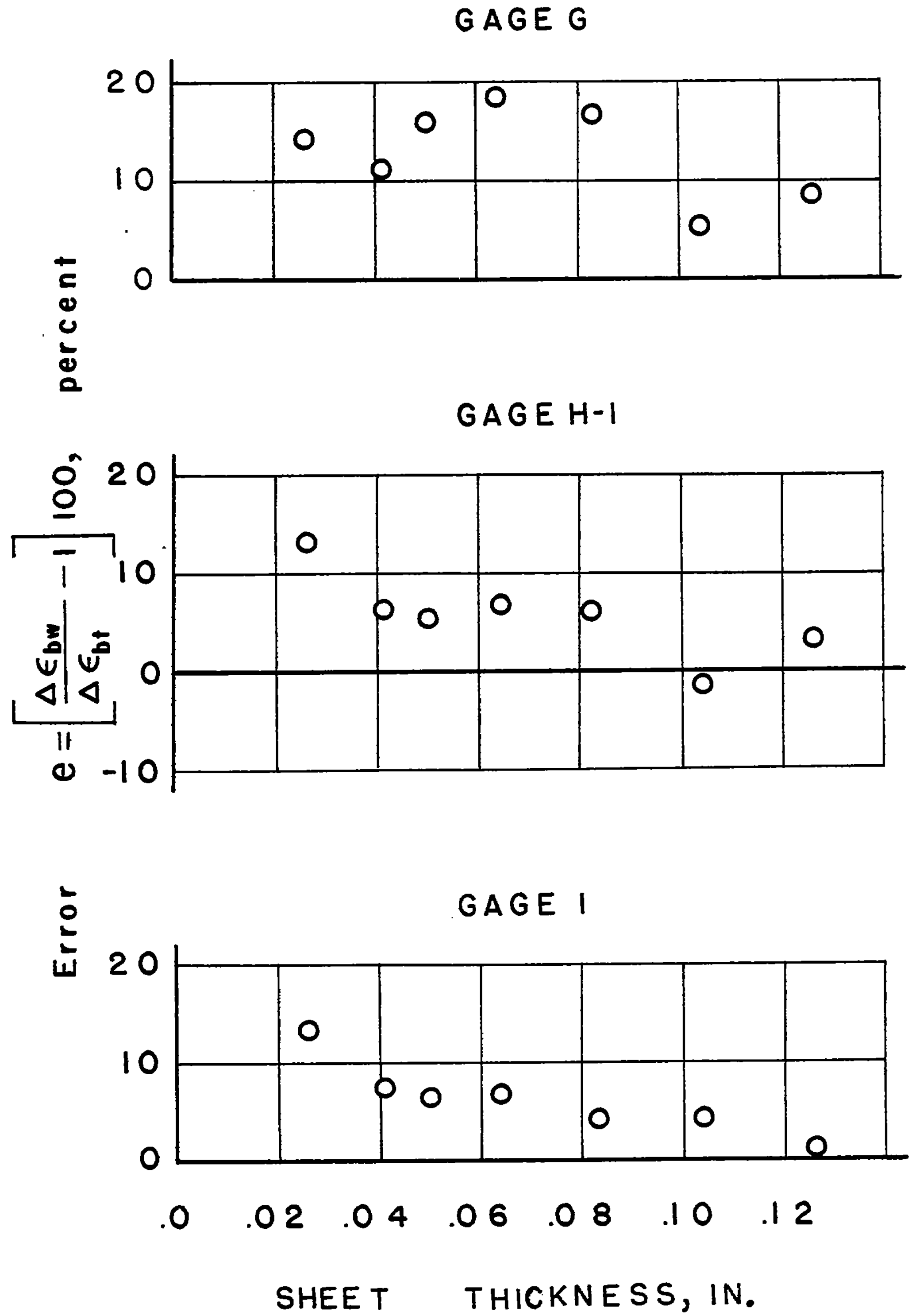

Figure 4.- Average error in the extreme-fiber strain, indicated by wire gages G, H-1, and I, plotted against sheet thickness.

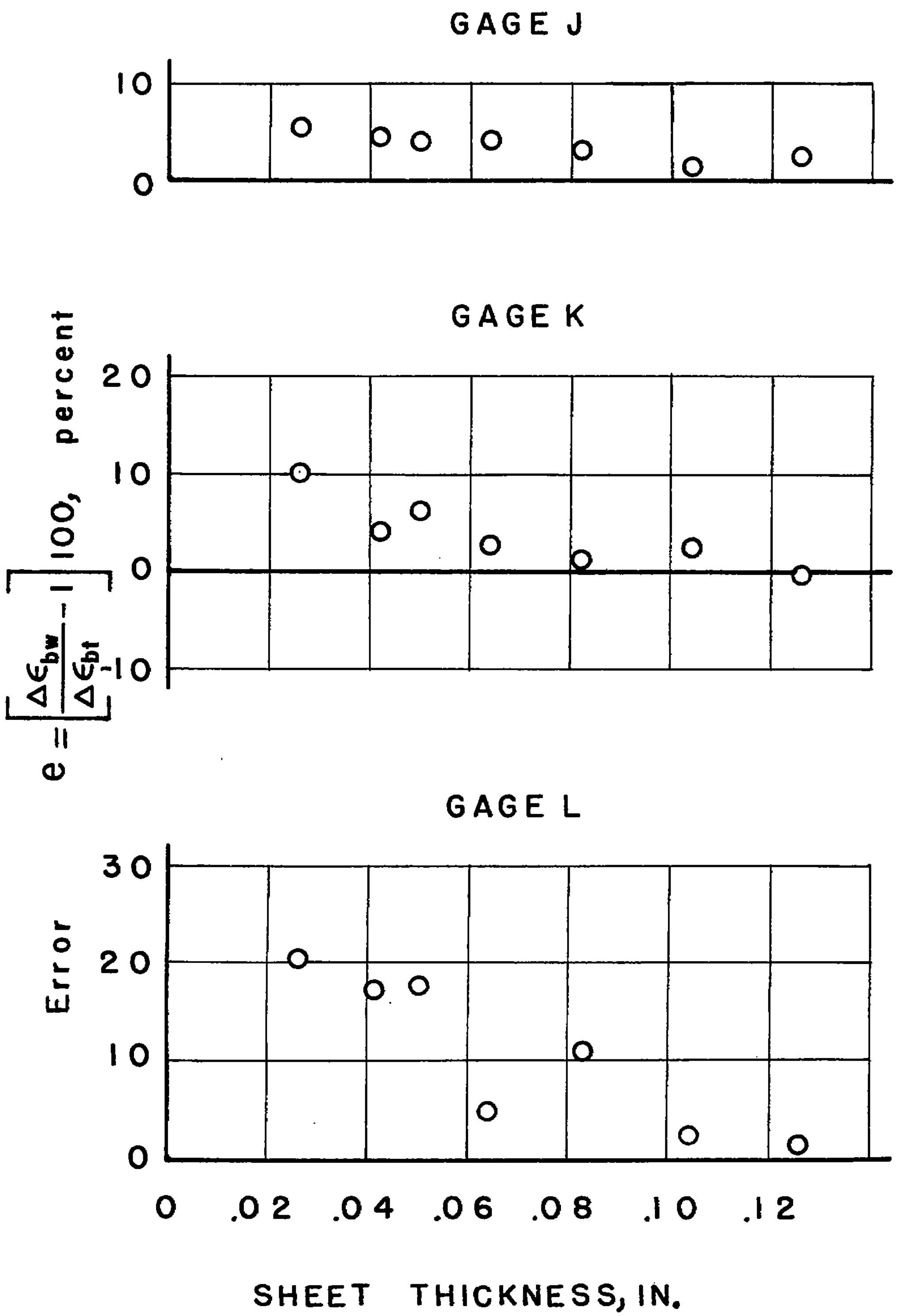

Figure 5.- Average error in the extreme-fiber strain, indicated by wire gages J, K, and L, plotted against sheet thickness.

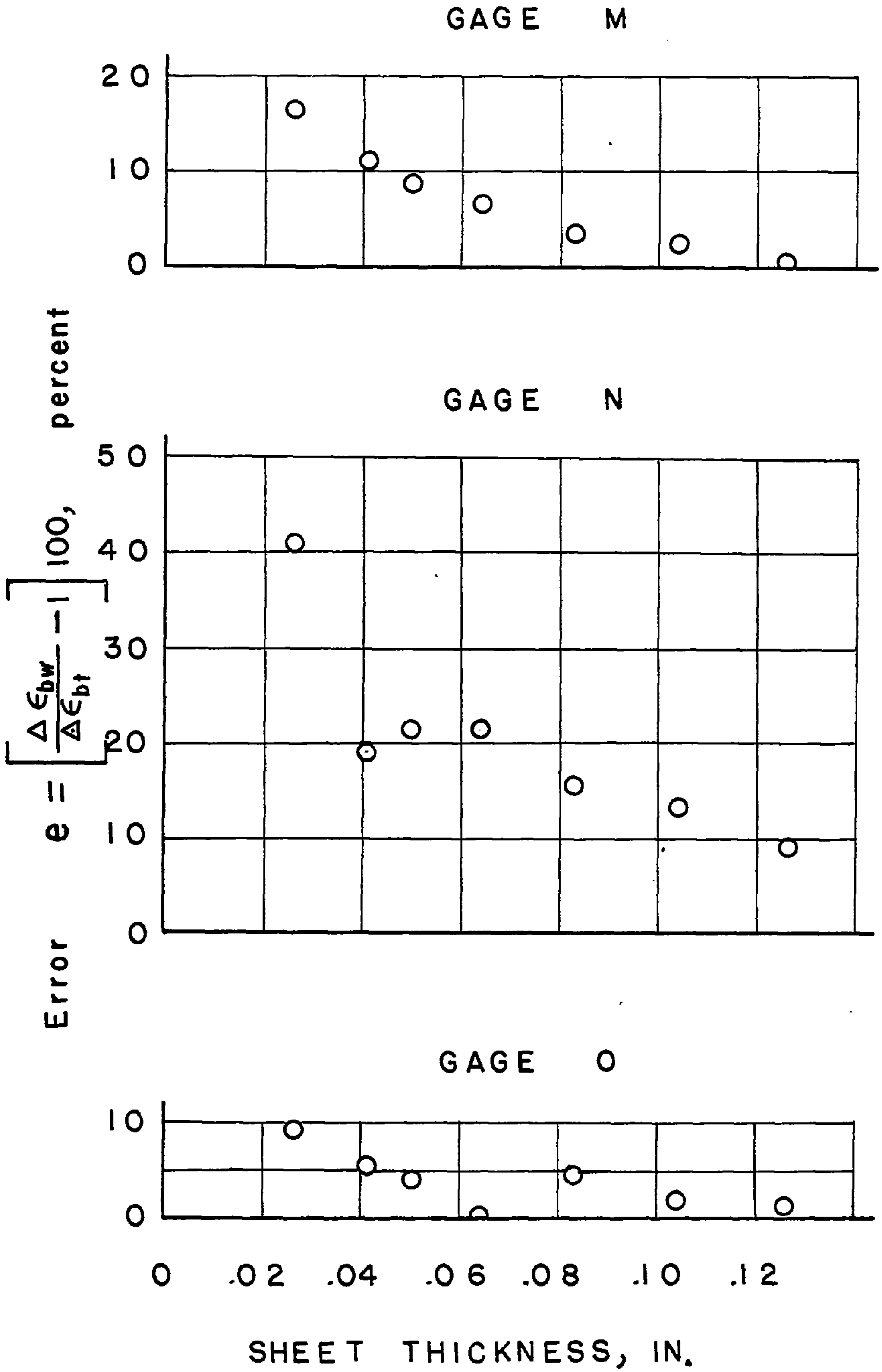

Figure 6.- Average error in the extreme-fiber strain, indicated by wire gages M, N, and O, plotted against sheet thickness.

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ABSTRACT

Fifteen types of multi-strand, single-element, wire strain gages underwent tests to establish the degree of accuracy obtained by this equipment. Generally, the indicated extreme fiber bending strain was greater than the actual strain. It was concluded that positive error caused by finite thickness of the gage predominated over negative error caused by gage rigidity. Total error for sheet thickness 0.026 inches ranged from 5 to 40%, and up to 9% for sheet thickness of 0.125 inches.

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