bility of using photogrammetry in preserving geometric data of features for future research.

By the way, how about that historically interesting steeple in Boston, that was recently destroyed by a hurricane. Are there good drawings available for the reconstruction? If not, it will probably be very difficult to determine the real geometric shape of the steeple. If good photogrammetric pictures and the necessary control data are available, the reconstruction can be considerably facilitated.

Under present circumstaces, we should set out to establish, as quickly as possible, archives containing photogrammetric data of at least the most important cultural monuments. In this connection, it would be of undisputed value to maintain similar records of the human face.

We cannot prevent the present tendencies of general destruction in this way, but we certainly can give later generations important information about our own age. In this respect, photogrammetry has very much to offer.

AN APPLICATION OF PHOTOGRAMMETRY IN STRUCTURAL RESEARCH*

Professor K. B. Jackson, Dept. of Applied Physics, University of Toronto, Toronto, Canada

IT IS not surprising that those of us who use photographs for only one purpose lose sight of the *basic advantage of the photographic method of analysis* in the maze of accessories which we have accumulated to serve that purpose, and so fail to appreciate how radically *our* standard methods may be modified to meet very different requirements.

The *basic advantage* to which I refer lies in the capacity of a single photograph to provide a record of a multitude of simultaneous events. Whenever this is desirable the photographic method in one form or another is indicated.

The *accessories* may involve an aeroplane at 50,000 ft. or a collimated beam from a spark for a microsecond, or as in the case to be described, merely a few stretched wires. They enable us to obtain the particular kind of photograph we require; while other devices (from Multiplex projectors to micro comparators) may facilitate interpretation, it is the means adopted in *obtaining* the photograph that determine its significance in the solution of the problem in hand.

The problem to be described arose in a research project entitled "Curved Plates in Compression" which was carried out at the National Research Council, Ottawa, during the war. The purpose of the research was to *compare the performance* of curved plates subjected to axial loads, *with the predictions of various mathematical solutions.*

Probably the *only* simplicity in the mathematical approach lies in the assumption that the nominal dimensions of the "test specimens" do actually pertain. *Mathematically*, therefore, for one case there is *only one answer*. *Experimentally*, however, there will be a *different answer for each specimen* of the same case, due to unavoidable variations from the nominal dimensions and shape of the mathematician's prototype. It will be readily appreciated, for example, that the load carried by a slender column will be seriously affected by the slightest deviation from its nominal straightness.

* Presented at the Semi Annual Meeting of the Society, Philadelphia, Pa., Sept. 17, 1954.

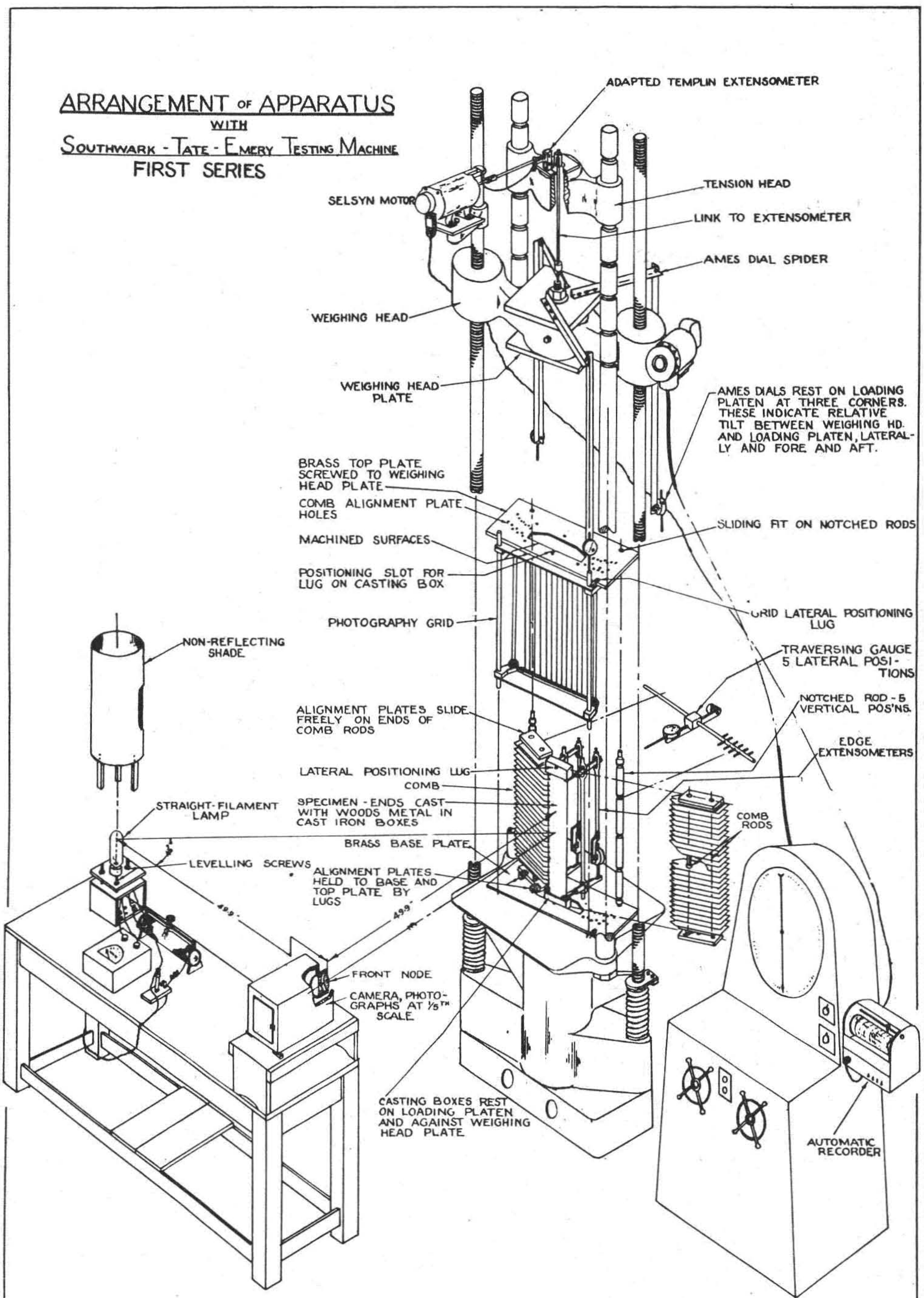

FIG. 1.—Exploded view of apparatus.

Every effort was made to obtain nominal conditions during the tests, but it soon became obvious that *residual variations were still significant* and therefore had to be *measured* and *related*, if possible, *to the variations* in performance obtained.

The specimens, simulating a portion of the skin of an aircraft, were thin sheets of aluminum alloy 18 inches long, 4, 6 or 8 inches wide, and .018, .028 or .036 inch thick, with radii of curvature of 24 or 48 inches. They were located in the testing machine by clamps on the four edges and subjected to a compressive load parallel to the axis of the cylinder of which they formed a part.

A load was applied and released four times, to increasing limits and finally to failure. An automatic load-strain recorder indicated the over-all shortening of the specimen under load. But it was necessary to determine the actual form of the nominally cylindrical surface of the specimen, both before and during the application of the loads, and to an accuracy which would be sensitive to the cause of any measurable effects of deformation on load carrying performance. It looked as if "spot heights" to .001 inch on $\frac{1}{2}$ inch centers would be required *five, ten or more* times *during each test*, and there were *150 tests to be performed.* (Such a multitude of multitudes of simultaneous events!) They demanded a photographic method which would be *quick*, and *particularly sensitive in the "third dimension"*—in depth.

The apparatus with its arrangement involved in the photographic method of measuring the surface form of the specimen to .001 inch is shown on Figure 1. It and the selected method are briefly described as follows:

A (vertical) line-filament lamp, 50 inches to the left of the camera, casts sharp shadows, of a series of straight vertical wires, on the surface of the specimen, 50 inches in front of the camera, at $\frac{1}{2}$ inch chordwise intervals. The camera, 17 cm. Zeiss Tessar at f/16, $3\frac{1}{4} \times 4\frac{1}{4}$ inches format, photographs the shadows and wires on a fine grain photographic plate.

The position of the lamp and the wire grid, and the scale of the photographs, are such that, for a perfect specimen in correct position, the images of the shadows are straight and are at a constant distance, .50 mm., from the adjacent images of the wires. If any vertical section of the specimen is bent *backwards*, the image of the shadow on that section will be similarly bent but to the *right*. And vice versa.

Deviations of the shadow images can be measured to ± 5 microns, representing displacements of the specimen of $\pm .001$ inch in depth.

Measurements were made at $\frac{1}{2}$ inch intervals on each shadow, i.e. on $\frac{1}{2}$ inch centers over the whole area of the specimen; appropriate contours of initial deformation, and deflection under load, were plotted.

The information obtained from the photographs fully justified the work involved. In fact it proved to be much more widely applicable than was originally anticipated. It provided an independent solution to the problem of post-buckling behavior as well as evidence which satisfactorily accounted for the variations in the experimental values for the buckling load, or critical buckling stress.

Figure 2 includes the first and last photographs during a test, and the contours plotted from them. Heights are indicated in thousandths of an inch.

Figure 3 illustrates a rather specialized form of photo interpretation.

In closing I express my appreciation of the opportunity to present this paper, my indebtedness to the National Research Council for permission to do so, and my acknowledgement of the cooperation of my colleague Mr. A. H. Hall of the National Research Council throughout three years of trial and error. I make no apology for presenting material that has already been published in technical

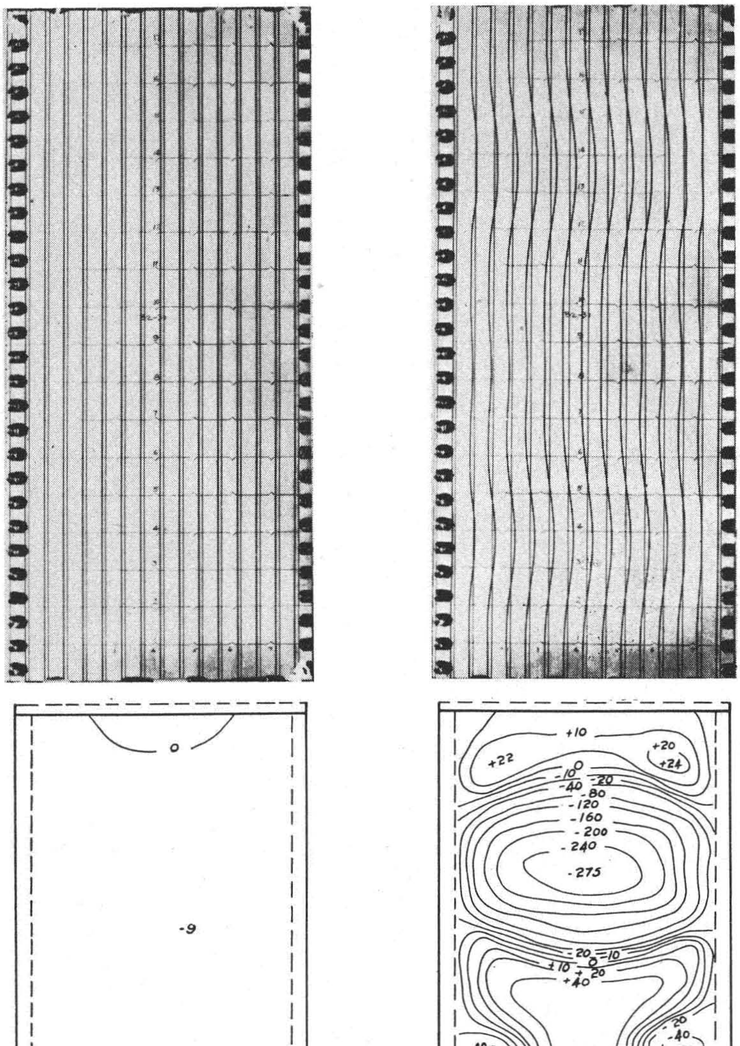

FIG. 2.—Photographs and contours.

reports because I think I can safely assume that those reports have not come to the attention of this audience. I hope that the subject will be of some interest, at least as an example of adding a zero to the right end of the "*c*" factor.

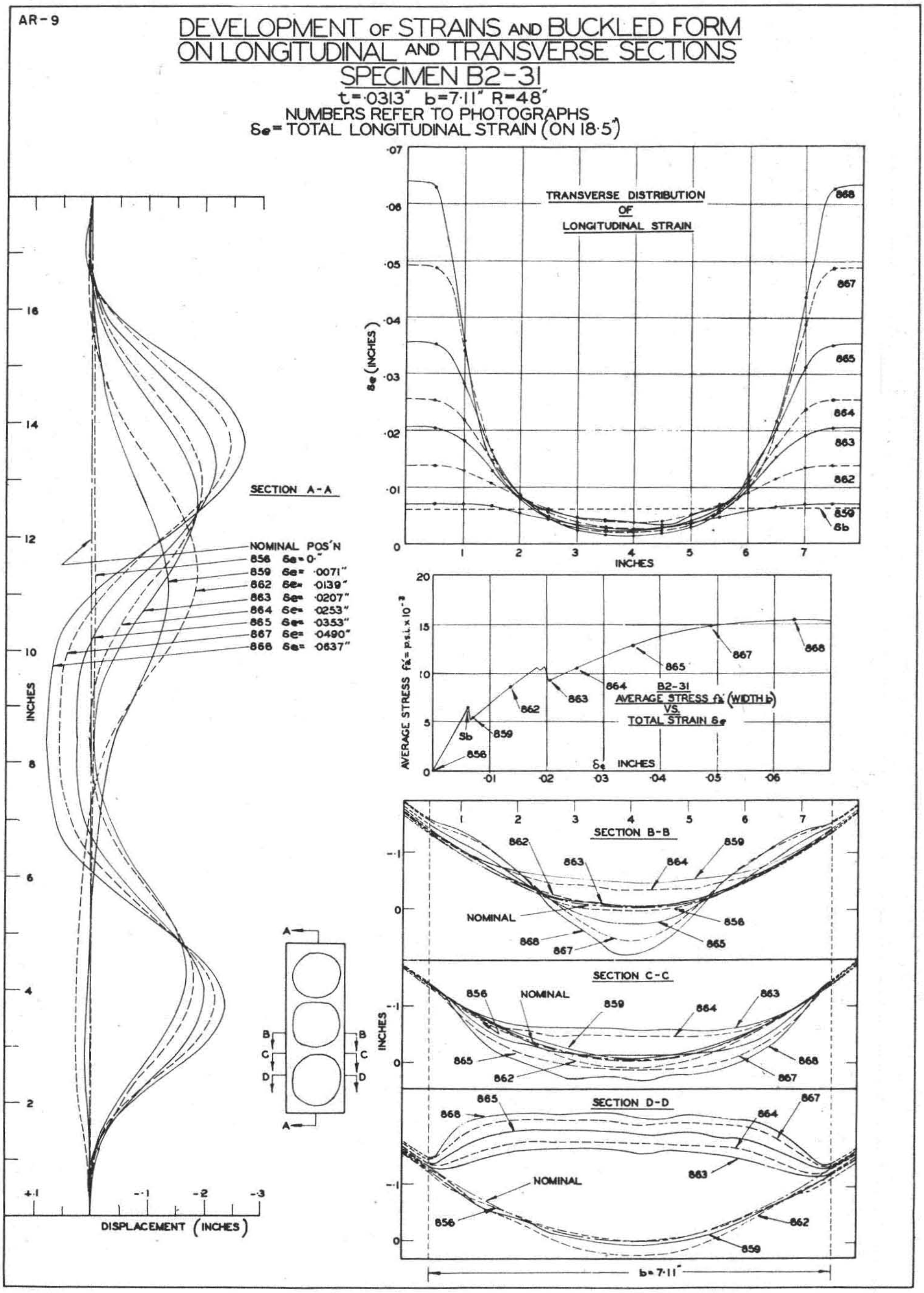

Fig. 3.—Interpretation.

I have abbreviated the description of the method to the bare essentials. Those who are interested in the details should consult Report No. NRC-AR1, National Research Council, Ottawa.