*Differences between Visual and Photographic Calibrations of Air Survey Cameras**

P. D. CARMAN AND H. BROWN,
National Research Council, Ottawa, Canada

SUMMARY: *Significant differences have been found between the calibration of air survey cameras by visual means and their calibration by a photographic procedure simulating conditions of use. The differences are chiefly of chromatic origin.*

THE logic of calibrating photogrammetric cameras by a photographic procedure was accepted by the Seventh International Congress of Photogrammetry in 1952. However, visual methods have continued in some use for reasons of tradition and of convenience of equipment. The Congress agreed that "a visual method will be permissible if it . . . gives the same values as the . . . photographic method to within the required accuracy." Until the present, both formal and fortuitous comparisons of the two methods have shown no discrepancies which significantly exceeded the uncertainties of measurement including those arising from definition limitations in the cameras tested.

During 1955, tests of Wild RC5A cameras on the National Research Council of Canada's new photographic calibrator were found to be showing consistent differences from the visual calibration data furnished by the manufacturer. Both the calibrated focal length and the shape of the radial distortion curve showed small but persistent discrepancies. For calibrated focal lengths, photographic values usually exceeded manufacturer's figures by .01 or .02 mm. Extreme values from the average radial measured distortion curves obtained photographically ranged from 10 to 17 microns, averaging 5 or 6 microns higher than the manufacturer's published data. The recognition of such small discrepancies was undoubtedly facilitated by the excellent definition of the Aviogon lens.

A number of special measurements were made on two RC5A cameras to explore the effects of the spectral differences involved in the two calibration methods.

These spectral differences are illustrated in Figure 1. Curve *A* shows the product $\bar{y}E_c$, that is the visibility function multiplied, wave-length by wave-length, by the spectral energy curve for *CIE* illuminant "*C*" which is a standardized approximation to daylight. This is reasonably representative of the source-receiver combinations used in visual calibrations. Curve *B* shows the product of photographic mean noon sunlight—that is the standard illuminant for photography—the sensitivity of Aero Super XX emulsion, and the transmission of a Wratten 13 filter. This is a photographic approximation to the visual condition of calibration. Curve *C* shows the combination used in photographic calibration. It is the product of mean noon sunlight, the sensitivity of Aero Super XX emulsion, and the transmission of a Wratten minus blue filter.

Results of the special measurements on the two cameras were essentially identical hence only one camera will be discussed here. Chromatic difference of distortion—also called chromatic difference of magnification or transverse colour—was measured at a number of field angles. The slit of a large collimator was illuminated by various wave-lengths of monochromatic light from filtered gas discharge lamps and the corresponding image positions in the focal plane of the RC5A Aviogon lens were measured with a microscope. Results plotted in Figure 2 immediately confirm that calibration results will be likely to vary with changes in spectral characteristics of the calibrating system.

To obtain further information on the

* Contribution from the Division of Applied Physics, National Research Council, Ottawa, Canada.

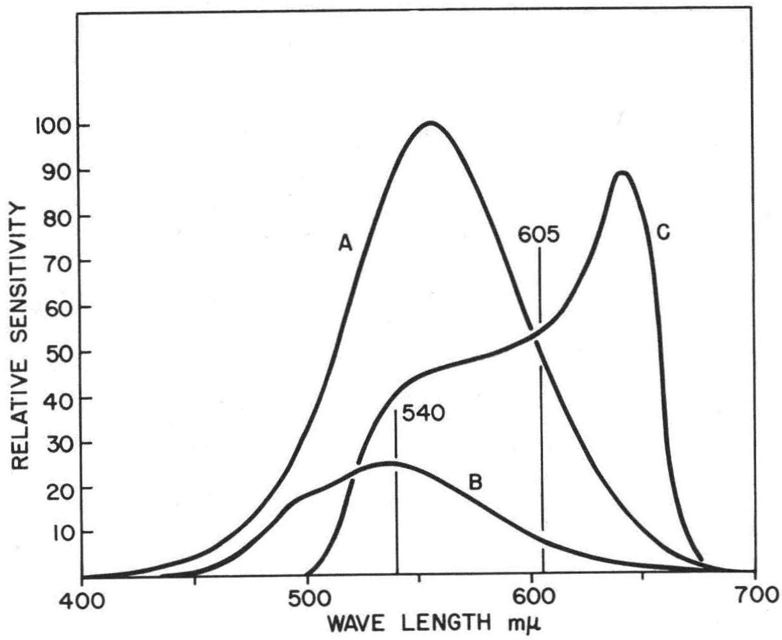

FIG. 1. Spectral response curves for the three receivers involved.
A—the eye to standard illuminant "C."
B—Super XX Aero emulsion with Wratten 13 filter to mean noon sunlight.
C—Super XX Aero emulsion with minus blue filter to mean noon sunlight.
B & C are on the same scale.

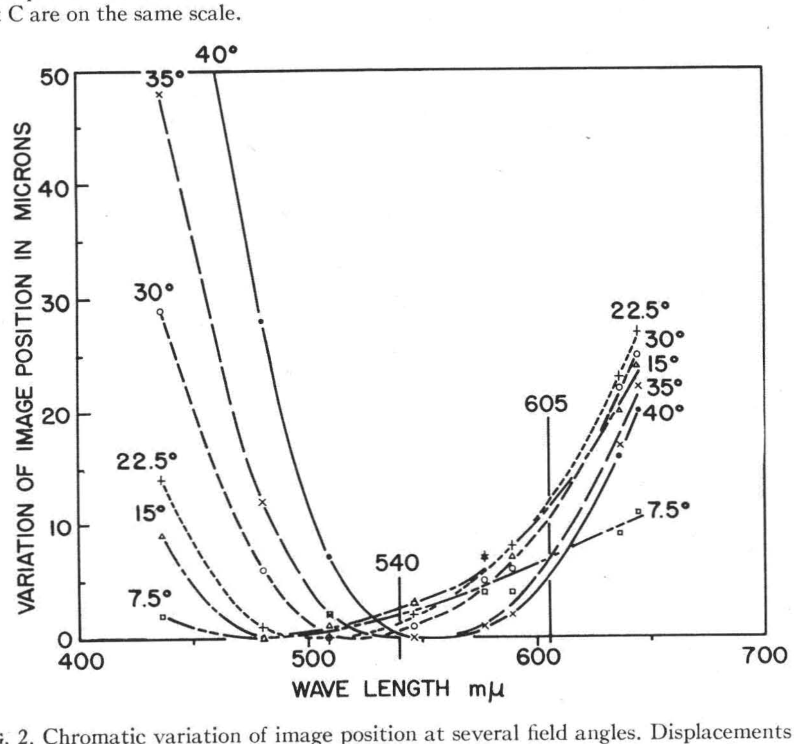

FIG. 2. Chromatic variation of image position at several field angles. Displacements are positive away from the lens axis and for each field angle are relative to the monochromatic image formed closest to the axis.

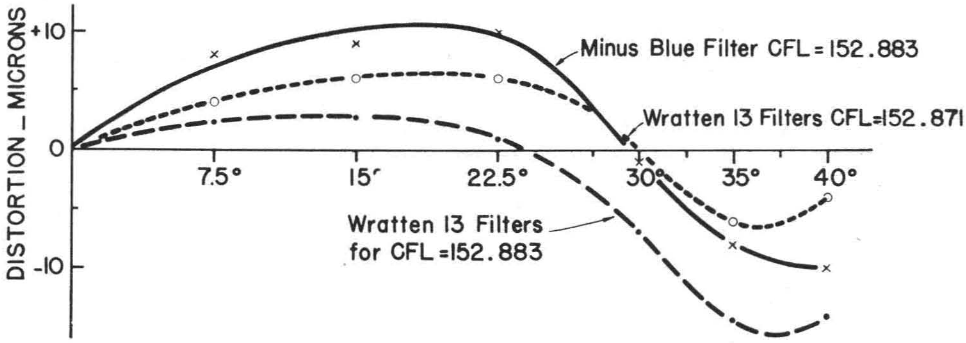

FIG. 3. Average radial measured distortion.

magnitude of such a variation, the camera was tested on the photographic calibrator using two different filter arrangements with the usual "mean noon sunlight" light sources and flattened Aero Super XX plates.[2] The first filter was the commonly used Wild 2X yellow filter. For the second calibration no filter was on the camera but all the collimator light sources were screened with Wratten 13 filters to transform the effective spectral sensitivity to about that of the human eye. Results of these calibrations are shown in Figure 3. The two upper curves show each set of distortion data plotted from its own best calibrated focal length, that is the focal length which makes distortion a minimum. The C.F.L. for normal photographic calibration exceeds that for the simulated visual calibration by 0.012 mm., agreeing with the differences of 0.01 to 0.02 mm. found between photographic and manufacturer's calibrations. The third and lowest curve of Figure 3 shows the data from the simulated visual calibration plotted on the photographic calibrated focal length. Putting this curve on the same basis as the photographic distortion curve provides a direct indication of the differences in image positions occurring between the two calibration methods.

These actual differences in image position are replotted in the lower solid curve of Figure 4. To illustrate how they arise from the transverse colour, they are compared there with a curve computed from Figures 1 and 2. From Figure 1, a median wave-length of 605 mμ was obtained from the curve for Super XX with minus blue filter and a median wave-length of 540 mμ

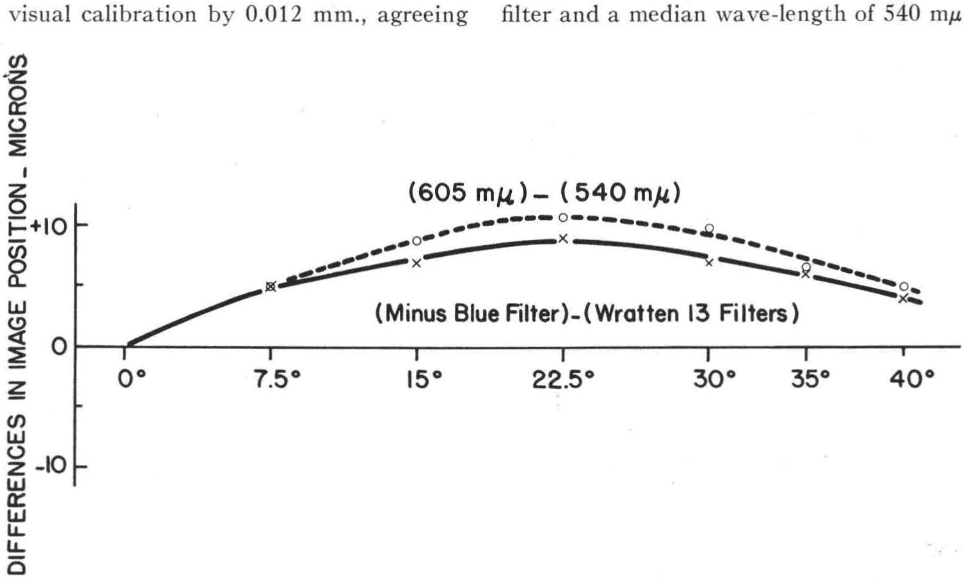

FIG. 4. Differences in image position.

from the curve for Super XX corrected to eye sensitivity with a Wratten 13 filter. Image shifts between these two wave-lengths were then read from the curves of Figure 2 and plotted to give the comparison curve in Figure 4.

This procedure is only a rough approximation to the theoretically correct one which would require emulsion characteristic curve data for all wave-lengths and complicated integration. However, the agreement between the two curves is sufficient to confirm that the differences found between the two calibration procedures can be attributed chiefly to the chromatic differences of distortion of the lens as seen by two spectrally different receivers.

These results emphasize the necessity of calibrating air survey cameras by a procedure which closely simulates conditions of use. The error investigated here arose primarily from the visual test procedure having the wrong chromatic sensitivity. It is also highly probable that similar errors would arise from other departures from normal conditions of use.

References

1. International Society of Photogrammetry, Commission I, Specification of Methods of Calibrating Photogrammetric Cameras and Measuring their Resolution, Image Illumination, and Veiling Glare.
2. Carman, P. D., "Control and Interferometric Measurement of Plate Flatness," J.O.S.A., 45, 1009–1010, 1955.

*The Future of Your Profession Rests With You**

DR. JOHN J. THEOBALD, *President, Queens College and Deputy Mayor, City of New York*

When I ended my formal association with Federal mapping efforts in 1941 or 2, the American Society of Photogrammetry was less than ten years old, and the American Congress on Surveying and Mapping had just been started. We were talking about the photoalidade, Tom Pendleton and the Geological Survey's relatively recent applications of multiplex equipment to precision mapping and the new nine-lens camera of the Coast and Geodetic Survey. At TVA George Whitmore and his colleagues had been demonstrating the effectiveness of aerial methods for property surveys and the big debate centered around the relative merits of glass and copper plate engraving.

This seems a long time ago. When I scanned your present program, I was particularly interested in identifying what new trends it indicated. This is what I found. First there were the usual technical papers—"Pendulous Cantilever Principles Applied to Self-leveling Instrument Design", "Distortion Tolerance Specifications for Mapping—Camera Lenses" and the like. A little more complicated, more varied, but basically marked evidence of the same scientific advances which were being made 15 years ago and which are obviously being continued at a thoroughly healthy rate.

Two other types of papers are amply represented. One group includes those devoted primarily to the service functions of mapping and photogrammetry—"Use of Topographic Maps in Flood Disaster Areas," "Correlations Between Terrain and Human Activity Which May Be Analyzed by Photo Interpretation," "Control Surveys and Photogrammetric Maps for Superhighways and Toll Roads," "Several Uses of Air Photo Interpretation to the Soils Engineer," "What Topographic Maps Mean to California." Papers of this type, if written twenty years ago would probably have consisted largely of attempts by one

* This was the principal address at the ACSM-ASP Consecutive Meetings, March 18–24, 1956 at Hotel Shoreham, Washington, D. C. It was presented at the General Assembly.