A complete description of our procedures and data is available in mimeographed form upon request.

* This research was done under Contract N5-ori-166, Task Order I, between the Systems Coordination Division, Naval Research Laboratory, Office of Naval Research, and The Johns Hopkins University. This is Report No. 166-I-162, Project Designation No. NR 507–470, under that contract. An abstract of this paper appears in J. Opt. Soc. Am. 39, 1057 (1949).

1 R. W. Pickford, J. Psychol. 27, 153 (1949).
2 D. Farnsworth, J. Opt. Soc. Am. 39, 1056 (1949).
3 W. D. Wright, *Researches on Normal and Defective Colour Vision* (C. V. Mosby Company, St. Louis, Missouri, 1947), pp. 305–309.
4 A. Chapanis, J. Opt. Soc. Am. 39, 242 (1949).
5 G. L. Walls and R. W. Matthews, Univ. Calif. Publ. in Psychology 7, 1–172 (1952).
6 R. M. Halsey and A. Chapanis, J. Opt. Soc. Am. 42, 722 (1952).
7 S. Hecht, Documenta Ophthalmologica 3, 289 (1949).

An Isophotal Contour Densitometer*

F. E. Fowler, D. S. Johnson, and D. E. Billings
High Altitude Observatory, Harvard University and University of Colorado, Boulder, Colorado
(Received June 24, 1952)

A CONTOUR densitometer is a device for rapidly tracing the lines of equal optical density in a photograph. Its end product is a contour map of the distribution of density in a photograph analogous in principle to a topographic map. Within the limits of accuracy inherent in photographic photometry, the contour lines represent isophotes in the object photographed, the brightness levels of which can be determined if the characteristic curve of the photograph is known.

The High Altitude Observatory has needed such a device for the study of a large number of 35-mm photographs of solar prominences and flares—the specific requirements for the instrument being that it not only give contour mapping of these solar features, but that it measure the areas within the contours and that it carry out the operation much more rapidly than other available isophotal contour devices. The data thereby obtained, in addition to being helpful in the understanding of the solar phenomena, are of particular importance for the correlation of solar flares with the ionospheric disturbances which affect radio propagation, and with meter-wavelength solar radio noise.

To meet these needs the Observatory has designed and constructed a working breadboard model of an isophotal contour densitometer which follows in some respects that suggested by Babcock.[1] The basic operation is as follows (see Fig. 1).

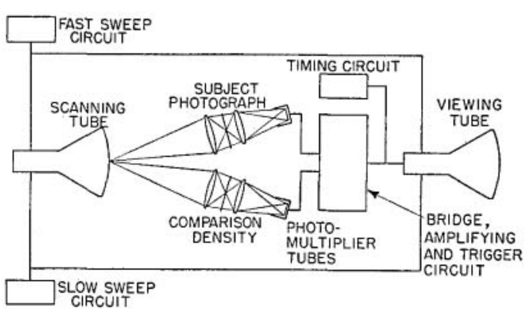

Fig. 1. Block diagram of contour densitometer.

The moving spot on a cathode-ray tube (called the scanning tube) screen traces out a rectangular pattern. (In the present breadboard model this spot has a 60-cycle/sec vertical sweep and a 7-sec horizontal sweep.) Two optical systems receive light from this spot. Light which enters one system passes through an objective lens which forms an image of the spot on the film to be studied and thence through the film and a field lens to the cathode of a photomultiplier tube. The field lens is positioned to form an image of the objective aperture on the photocathode. The second optical system is identical to the first except that a comparison density is used in place of the film.

The two photomultiplier tubes are connected in a bridge, amplifying, and trigger circuit in such a way that the difference in their output signals, amplified, actuates the trigger circuit whenever the image of the scanning spot, as it passes over the subject film, falls on a density less than the comparison density. The trigger circuit, in turn, blocks the beam on a second cathode-ray tube called the viewing tube. Since the horizontal and vertical motions of the beam on the viewing tube are synchronized with those of the scanning tube, the viewing tube traces out on its screen a bright facsimile of all densities on the subject photograph which are greater than the comparison density. The outline of this bright area is an isophotal contour. A timing circuit which is actuated only when the viewing tube is unblocked gives, at the end of a scan, a measure of the area within the contour.

A condenser, charged through a pentode and discharged through a triode by pulses obtained from the 60-cycle line, supplies the fast sweep signal. Another condenser, similarly charged through a pentode but discharged through a switch operated by a synchronous motor, supplies the slow sweep signal.

The scanning and viewing tubes are 5FP7s which are of the magnetic type. The screens have two phosphors—one which emits an intense, short-lived, blue light, and the other a low intensity yellow light which lasts for more than 7 sec after the electron beam has passed. The blue light is adequate for making a photographic record of a facsimile in a single scan, while the yellow lasts long enough to show on the screen a complete pattern bounded by an isophotal contour.

The use of two photomultiplier tubes has certain disadvantages in that the two tubes are not likely to have identical response over their entire ranges, and that they may experience unequal fatigue. An alternative which avoids these difficulties is to chop the light from the two optical systems at a rate of the order of 100 000 per second (either mechanically or electro-optically) in such a way that a single phototube receives light first from one optical system, then from the other. In such a system the amplified net ac signal from the phototube undergoes a change in phase when the scanning spot image on the subject photograph passes from a density below to a density above the comparison density.

With either design the instrument is essentially a null instrument in which irregularities of the scanning tube phosphor and variations in power line voltage cancel out. The breadboard now in use is somewhat simpler in that the comparison optical system is replaced by a potentiometer which supplies an arbitrary voltage to simulate the output of the comparison photomultiplier tube. Experience with this arrangement emphasizes the desirability of the null system.

In its present breadboard form the instrument can be used in a density range from 0 to 2.3, with a density discrimination of the order of 0.01. Each scan has approximately 250 resolvable lines in each direction—a number which can be improved by better focusing coils. The experimental optical system is rather rudimentary and has small apertures with poor light efficiency. We can readily increase the light by a factor of 10 by using an optical system of larger aperture. This would permit the use of a less intense scanning spot which could be made smaller to give better resolution; or the range of the measurable densities could be increased. In practice the operator chooses the compromise between density range and resolution best suited to his particular problem. The actual area of film scanned depends on the magnification of the optical system which projects the image of the scanning spot on the film. This optical system is conveniently modified to fit the particular problem.

Although this densitometer was developed by High Altitude Observatory primarily for the study of solar flares and prominences, it should have, because of its high speed, its versatility as to types of film which it will analyze, and its integrating feature for measurement of total areas above a given density, many other applications both in and outside the field of astronomy.

* The work of design and development of the Isophotal Contour Densitometer has been supported by the Office of Naval Research under Contract No. N8onr-64801.
1 H. W. Babcock, Pubs. Astron. Soc. Pacific 62, 18 (1950).