A Recording Photoelectric Photometer

by

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Letters To The Editor

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A RECORDING PHOTOELECTRIC PHOTOMETER.

During the last couple of decades a considerable amount of work has been done on the study of profiles of Fraunhofer lines using photographic photometry. However, there are certain inherent disadvantages in the technique employing photographic plates, such as the necessity of determining the characteristic curve of each plate for converting the density-curve, as directly obtained from the plate with the help of a recording microphotometer, into an intensity-curve. Apart from being laborious the procedure also involves uncertain factors like the Eberhard effect, so that workers in this field have felt it desirable to evolve a spectrophotometric technique independent of the photographic process. For this purpose, naturally the thermocouple and the photoelectric cell appear to be the most obvious choices of light-receiver to replace the photographic plate ; for these have been extensively used in photometric work of various kinds. But the thermocouple in its most sensitive form devised by Moll does not appear to be adequate (even in conjunction with the Moll thermo-relay) for directly determining the contours of the absorption lines in the solar spectrum produced by a high-dispersion spectrograph of the types currently used in solar observatories. The photoelectric cell in the form of a " multiplier tube " or in combination with a separate amplifying system therefore seems to be at present the only practicable alternative for solar line-contour measurements. Some years ago Brück at Cambridge Observatory succeeded in building a recording photoelectric spectrophotometer using a vaccum photo-cell in conjunction with an electrometer triode, but he does not seem to have published his results of line-profile measurements with this instrument. The recording spectrophotometer, which we describe briefly in the present note, has been built at the Kodaikanal Observatory on essentially the lines indicated by Brück.

The spectrum is provided by a high-dispersion prism spectrograph - a seven-prism instrument with a focal length of about 21 feet giving a dispersion of 2.4 Å per mm in the region of the D lines. The spectrograph is fed by an 18-inch siderostat through a 12-inch photovisual lens of 21 feet focal length. The upper half of the spectrum is focussed on to the photographic plate and is used in the usual way, while the lower half is deflected towards the side of the spectrograph camera by means of a right-angle prism which is adjusted so that the deflected spectrum is also in focus at the scanning slit of the photometer. The light from this slit, which is about .03 mm wide, is received by a short-focus convex lens fixed at a distance from the slit equal to its focal length. The parallel beam of light so obtained from a narrow section of the spectrum is directed again by a second right-angle prism to the photo-cell.

The photo-cell P, electrometer triode T and high-meg resistor R_1 are contained in a heavy cast-iron cylindrical chamber (A in Fig. 2, p 159) with a glass window. The chamber is connected to a Cenco pump through a drying tube containing calcium chloride and is exhausted to a pressure of about 10 mm of mercury. The chamber, which must be moved to scan the spectrum, rests on a carriage (B) mounted on three steel balls which travel in straight channels in an iron base. The carriage and the recording drum with photographic paper are driven by the same motor through a reduction gear and a common shaft (C) having at one end a worm attached to the carriage and at the other end two pairs of pulleys of different diameters for turning the drum. The paper-carrying drum is provided with two pairs of circular flangs which rest on one or the other pair of pulleys on the shaft so that two different speeds of recording are available. The light from the galvanometer mirror is focussed on to the photographic paper by a cylindrical lens. The drum takes standard 12×50 cm bromide paper and is mounted inside—a light tight cylinder (D) equipped with a shutter, the whole system consisting of galvanometer and recording drum being

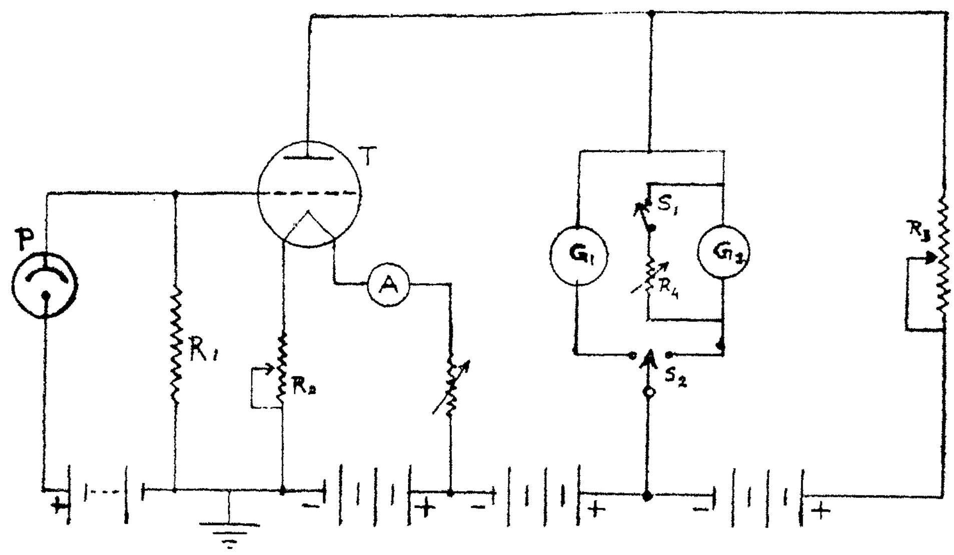

Fig. 1. Circuit diagram of Amplifier.

enclosed in a light-tight box (E) so that the instrument works in a well-lighted room.

The single-stage amplifier employs an "Osram Electrometer Triode, type ET-1" and a Dubilier 5×10^{10} grid-leak resistor (R_1). A plate voltage of 5 volts and a negative bias of 3·5 volts are used. A common battery provides the filament current and negative bias for the grid through a drop across resistor R_2. Under these conditions a steady-state current of about 200 μa flows in the plate circuit and anode slope resistance of about 25,000Ω is obtained. The cathode of the photo-cell (Osram type KMV 6) is connected to the grid and anode voltage of about 22.5 volts is supplied by a dry battery. The steady plate current flowing through the galvanometer is balanced out by an auxiliary circuit consisting of three Nickel-Cadmium cells and resistance R_3 consisting of a fixed 17,500 ohms resistor and three rheostats of 5000, 500 and 20 ohms respectively. Preliminary balancing adjustments are made using a Weston panel galvanometer G_1. The recording galvanometer G_2—Cambridge d'Arsonval type of resistance 450Ω, period 2 sec., current sensitivity · 10^{-9} amp/mm and external resistance for critical damping 14,000 ohms—is then thrown in the plate circuit by switch S_2 and fine balancing is obtained while the shunt resistance R_4 (20,000Ω) is gradually increased and finally disconnected by the switch S_1.

Using a grid-leak of 5×10^{10} ohms a current amplification of over 2 million is obtained with the amplifier. With the scanning slit about ·03 mm wide and the spectrograph slit also about ·03 mm wide the continuous solar spectrum near the D lines gives a galvanometer deflection of the order of 10-12 cm, when the sky is perfectly clear. The instrument is naturally exceedingly sensitive to varying sky conditions. All potentials for the working of the amplifier and the balancing circuit are supplied by one battery of 4 NIFE cells and one battery of 5 Nickel-Iron cells. A shielded box (F) contains different resistances for adjustment and has meters, rheostats and switches on the front. All wires leading from this box to the cylinder (A) containing the photo-cell, the electrometer triode and the grid-leak resistor, and to the shielded box (G) containing batteries, are very thoroughly shielded. A schematic diagram of the amplifier is shown in Fig. 1.

A length of 12 mm or 20 mm of the spectrum is covered by one complete turn of the drum, depending upon the choice of drum speed. With the faster speed a length of 12 mm of the spectrum is recorded in about 7 minutes. Preliminary records

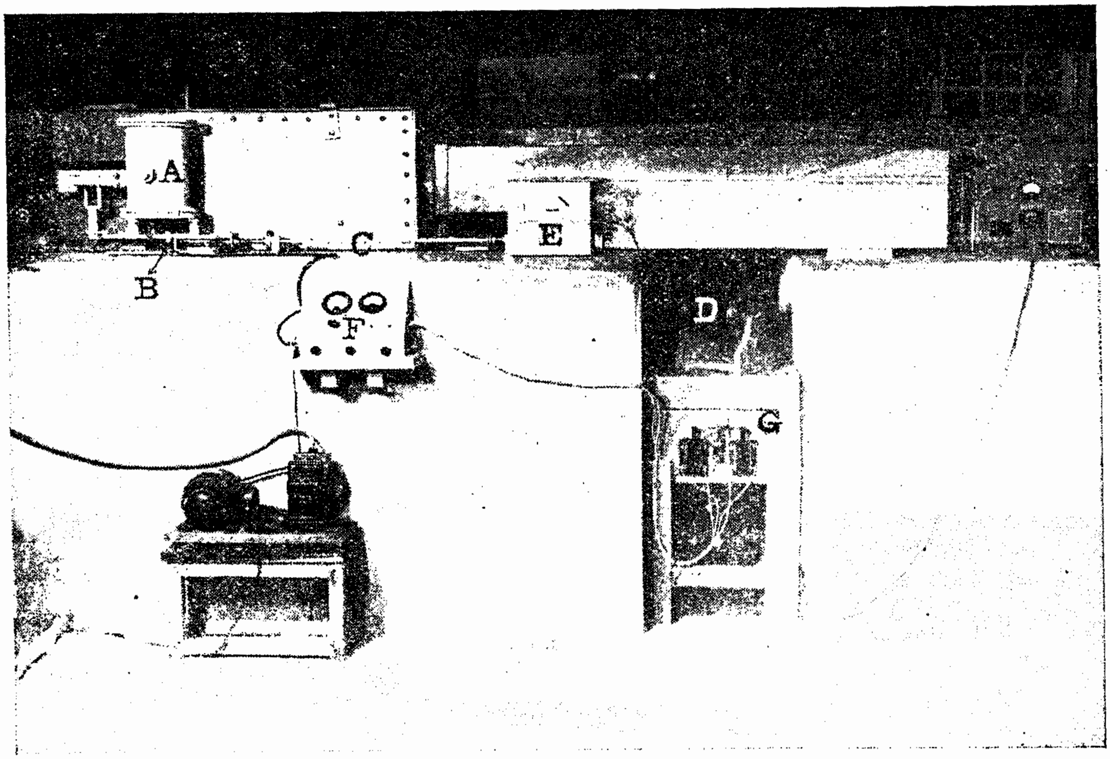

Fig. 2. General view of the equipment.

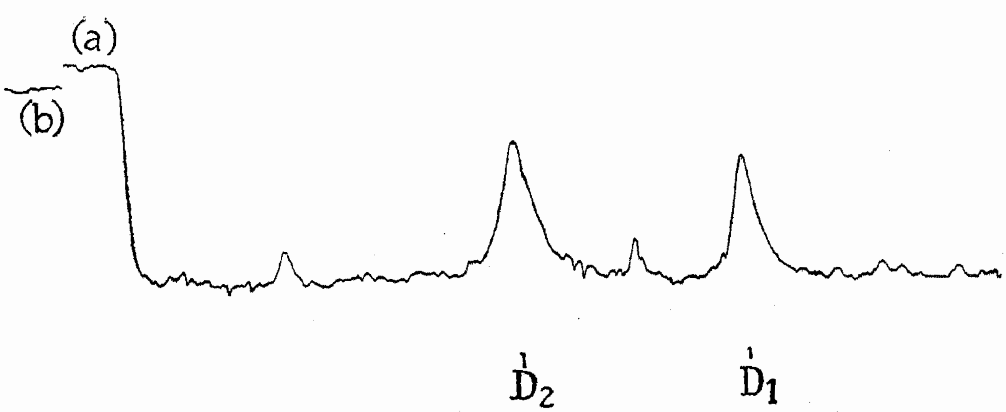

Fig. 3. Record of Solar Spectrum

(a) Beginning of record in darkness.
(b) End of record in darkness.

taken with the instrument indicate satisfactory performance. The drift of the recording spot of light is less than 1 cm in one single complete record with the faster speed of the drum and random fluctuations are less than ± 2 mm. A sample record reduced to about five-sixteenth of the original is reproduced in Fig. 3.

Although the instrument described above is designed specially for use in solar line-contour work and therefore works almost at the limit of its capacity, it is evidently easy to reduce its sensitivity and thus increase its stability. A less sensitive prototype of the instrument without the recording part has in fact also been constructed at this observatory for certain visual observations. No doubt a photometer of the type here described would be capable of dealing with a variety of problems of interest to geophysicists.

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