A FLICKER PHOTOMETER ATTACHMENT FOR THE LUMMER-BRODHUN CONTRAST PHOTOMETER.*

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EQUALITY-of-brightness photometers and flicker photometers have heretofore been built entirely separately from one another. In the literature of the measurement of light the design and use of the one has been a distinct problem from the design and use of the other, though the results the former gives are often used as a criterion for the practicability of the latter. Consequently, in constructing a flicker photometer, it has been built from the beginning just for the one purpose, notwithstanding the fact that about half of a flicker photometer is identical with an equality-of-brightness photometer in its essential requirements. It should be possible, by interchanging the two dissimilar parts on the part common to both, to make either one easily converted into the other type of photometer. The result should be a photometer that is simple, compact, and capable of measuring either lights of one color or lights of widely different colors with the best precision of the equality-of-brightness method in the one case and of the flicker method in the other.

At the same time it is felt that such an instrument should embody the latest approved features that are coming to be recognized as desirable in a flicker photometer.

It is the purpose of this paper to describe such an instrument which the author has devised in the shape of a flicker attachment to replace the telescope of the ordinary Lummer-Brodhun contrast photometer when it is desired to measure differently colored lights. The high precision and the wide distribution of this type of equality-of-brightness photometer justify its selection for this purpose, although there are other good instruments to which this idea could be even more easily applied with a slight modification of details.

The various details concerning this attachment will be better appreciated if, before describing it in detail, we briefly review the essential requirements of a flicker photometer.

* Communicated by the Author.

Wilde [1] says the desiderata for an ideal photometer are:

1. It must be sensitive and certain on lights of different color.

2. Rays must fall upon the illuminated surface perpendicularly to reduce angle errors.

3. Illuminated surfaces should be directly over pointer on the bar.

4. When balance is nearly obtained, it should be easy to perceive which way the head must be moved to improve the balance, without the necessity of rocking it to and fro.

5. If complete reversibility is required, both illuminated surfaces should be identical and must be the same distance from the eye.

6. In a flicker photometer, in order to secure sensitiveness, the transition from one surface to the other must be sudden and there must be no dark line crossing the field of view, such as an unilluminated edge of a card.

These requirements are subject to considerable modification and addition. They are given, however, as illustrating a certain viewpoint in the construction and use of flicker photometers and to emphasize the employment of a proper photometric procedure.

The use of the substitution method of photometry is strongly recommended with the direct measurement of distances wherever necessary.

This makes the second, third, and fifth requirements unnecessary.

The fourth requirement is misleading, because one cannot obtain a satisfactory balance with the flicker photometer by merely looking at it in one position. The proper method of obtaining a setting is rapidly to vary the light intensity back and forth over the no-flicker peak, at the same time gradually narrowing the range until the point of minimum or no-flicker is found. The essential requirements only will be outlined below. They will not be discussed in detail, as they have been fully covered elsewhere.[2]

The sensitiveness or precision requirements of a flicker photometer depend fundamentally upon one thing—the focusing of the observer's maximum attention upon the elimination of intensity flicker. The attention is secured in a rather negative way by eliminating all external factors that can divert it.

[1] *London Illuminating Engineer*, p. 825, i, 1908.

[2] *Phil. Mag.*, July–December, 1912, pp. 149, 352, 744, 845.

First, undue tiring of the eyes should be guarded against. This is secured mainly by making the field surrounding the flickering field light instead of leaving it dark. The intensity of this illumination should be equal to, or less than, the intensity of the comparison field. If brighter, it attracts the attention. The intensity and color of this field do not seem to influence the accuracy, at least within wide limits. This field should be illuminated uniformly and should be free from mechanical defects.

Secondly, there should be no mechanical flicker in the comparison field itself. This is secured by keeping the optical system clean and making its focus in space and not on a surface. The focus of the eye-piece lens, of course, should be on the plane of the opening through the external field just referred to.

Thirdly, in securing a balance, the color flicker (as distinguished from the intensity flicker) should be reduced to a minimum by a proper regulation of the speed of alternation of the colors.

The requirements that make for agreement with the equality-of-brightness method are in each method:

First, a restricted field; and

Secondly, a high illumination on this field.

Dr. H. E. Ives has found that on a field size of about 2° and at an illumination of about 25-metre candles the flicker method and the equality-of-brightness method agree in their results, provided the same conditions are complied with in each case. A restricted field and a high illumination are somewhat interchangeable, but the candle-power of many standard lamps and other light sources places a limit on the illumination, so that the field is restricted to make it equivalent to a higher illumination.

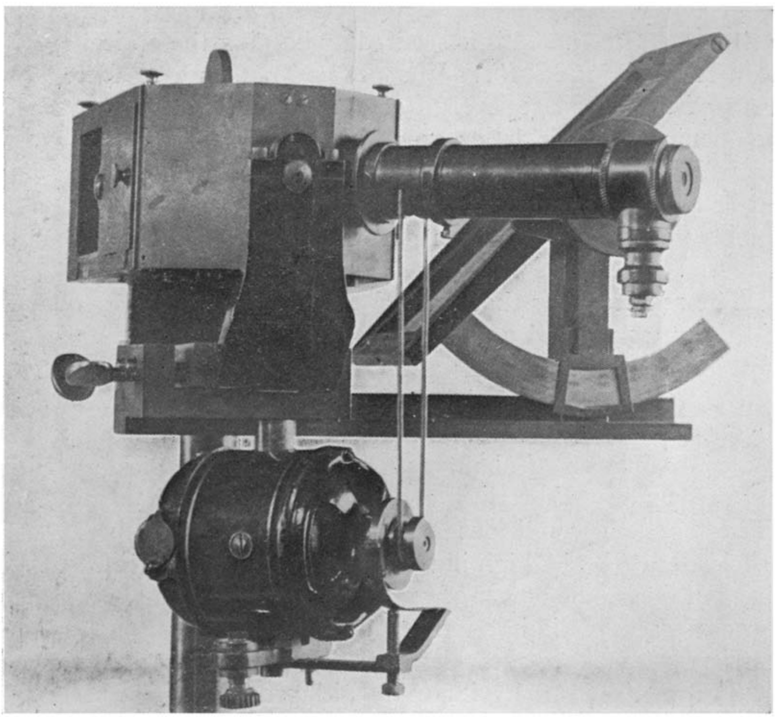
The requirements having to do with procedure have been mentioned; namely, that the substitution method be used with the direct measurement of distances. Where it cannot be done, care must be taken to reverse the comparison head and also the lamps under test, unless complete reversibility of each has been shown to yield identical results.

The method of securing a balance with the flicker photometer mentioned above should be emphasized here. The relative intensities of the two lights under test should be capable of being easily and quickly varied over a considerable range. One method of doing this is shown below.

In making a setting the light should be varied back and forth over the region of minimum or no-flicker, and the limits gradually narrowed down to a balance. It is impossible to obtain good precision or accuracy by leaving the setting at any one point and trying to decide whether it is the correct point. There is no criterion for the judgment unless the intensity is changed.

The last general requirement is one of convenience. The parts

FIG. 1.



The Lummer-Brodhun with flicker attachment, motor, and neutral tint-absorbing screen.

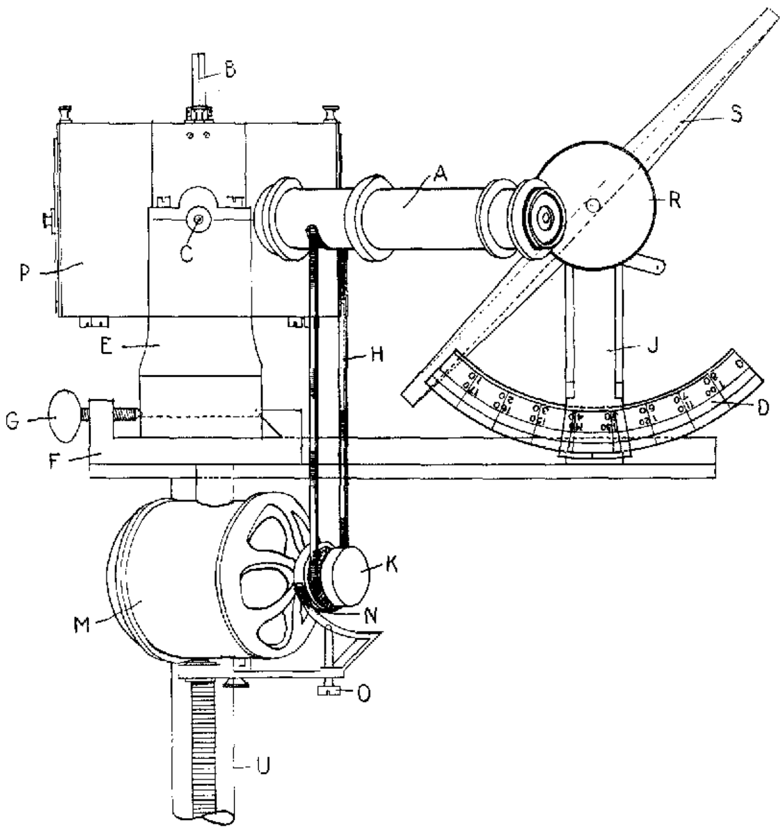
should be easily accessible for cleaning, repairing, and demonstration.

The attachment, with the motor and a neutral tint-absorbing screen, is shown in position on a Lummer-Brodhun head in Fig. 1.

Fig. 2 shows an elevation of the same.

The attachment (*A*) screws into the head in place of the regular telescope. The only other change necessary in the Lummer-Brodhun is the removal of the contrast glasses, which the heads are built to permit readily. A belt (*H*) runs from the rotator within the tube to the motor (*M*), which is fastened to a clamp (*F*) that fastens to the horizontal casting beneath the box. The belt (*H*) is made of spirally-wound steel wire. It acts

FIG. 2.

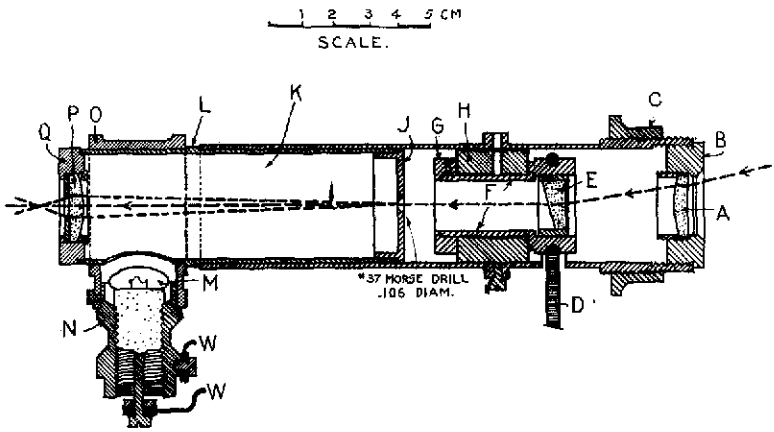


Elevation of Lummer-Brodhun with flicker attachment, motor, and neutral tint-absorbing screen, showing the method of clamping it to the head.

A. Flicker attachment.	*J*. Index.
B. Comparison disk.	*K*. Pulley.
C. Axis of head.	*M*. Motor.
D. Scale.	*N*. Friction brake.
E. Casting supporting head.	*O*. Brake screw.
F. Clamp.	*P*. Lummer-Brodhun box.
G. Clamp screws.	*R*. Screen knob.
H. Belt.	*U*. Support.

as a spring to take up any slack, and allows of the belt being easily slipped off the motor pulley. The part shown to the right is an addition, proposed by Dr. H. E. Ives, to facilitate reading, in the shape of a neutral tint-absorbing screen formed of parallel wires in the frame (S). The frame is turned by knob (R) and the transmission read on the scale (D). This screen permits the light intensity to be easily and quickly varied over a considerable range, the desirability of which was mentioned above. In most cases it is more convenient to use such a screen than to move the light or the photometer head, though originally the attachment was intended to be used as the Lummer-Brodhun contrast head would otherwise be. Dr. Hugo Kruss[3] has a screen attached to his contrast photometer that would likewise undoubtedly work nicely with the flicker

FIG. 3.



Elevation of flicker attachment.

A. Front lens.
B. Collar for lens.
C. Collar to hold telescope rigid in head.
D. Belt.
E. Rotating prism.
F. Rotator bearing.
H. Stationary bearing for rotator.
J. Front of eye-piece.
K. Eye-piece.
L. Collar on eye-piece.
N. Lamp socket.
O. Rotating collar for lamp.
P. Eye-lens.
Q. Collar for lens.
W. Wires to lamp.

attachment, if the micrometer thread is not too fine. O on the motor is a friction brake designed to allow the speed to be changed quickly and easily over a wide range.

The attachment is shown internally in elevation in Fig. 3.

The right end of the tube screws into the Lummer-Brodhun, and when the tube is in position, with the belt (D) downward to the motor, the collar (C) is screwed tightly against the box. This brings the attachment central and square on the head and at the same time renders it rigid. A is a lens setting in a collar (B) that magnifies the Lummer-Brodhun field properly. E is a prism

[3] *Jnl. f. Gasbel.*, p. 437, 1914.

that sets in a cylindrical piece (G), the whole being rotated in bearing (H) by the belt (D). The bearing (H) is held in position by a screw beneath the tube. Upon loosening this screw the bearing with the rotating piece containing the prism can be slipped out of the tube either way if the belt (D) is first unhooked and pulled out. K is the eye-piece, which consists of a brass tube covered at the far end with a disk (J), in the centre of which is the hole making the 2° field mentioned above. The eye lens is at P, set in a collar (Q). The entire interior of this eye-piece (K) is painted white, and at M is placed a small 2-volt pocket torch-light which, when lighted, sends its rays up in the eye-piece. This, in turn, being a matt white, acts as an integrating sphere and diffuses the light so well that in looking into the eye-piece through the lens one sees surrounding the 2° opening a uniformly-illuminated surface. To allow the adjustment of the brightness of this surface to suit the observer, the socket (N) into which the light sets is fastened to a collar (O) which turns on the eye-piece (K) and moves the lamp over the solid part of the eye-piece, the whole arrangement acting as a shutter. It allows of the illumination being changed from too bright to absolute darkness and at the same time always keeping it uniform. A spring in the collar (O) pressing on the eye-piece insures the collar always turning smoothly. This collar can be slipped off the head of the eye-piece. The lamp socket (N) can be slipped out of the collar on loosening a set screw to allow the replacement of the lamp. L is a small collar fastened to the eye-piece that limits the distance which it can be slipped into the attachment tube, and at the same time the turning collar (O) bears against it on the opposite side. When it is desired to remove the eye-piece (K) it is simply pulled out of the other tube, bringing J with it. The white surface is thus never exposed to careless handling. Fixed resistances, not shown, go in series with the lamp and motor. They both are intended to operate on 110-volt line to the head.

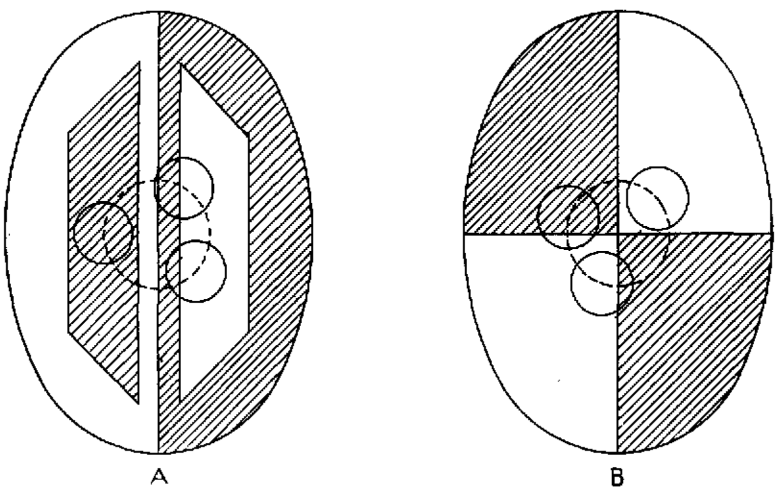
The method of cutting the Lummer-Brodhun field is shown in Fig. 4 A. The dotted line shows how it goes from trapezoid to trapezoid, the circles representing three different positions of the rotating prism. B shows the four-part field used in the laboratory flicker photometer recently built in this laboratory.[4] This four-part cube can be easily put in a Lummer-Brodhun box to

[4] *Phys. Review,* iv, p. 222, 1914.

replace the present one, if this type of field is preferred with the attachment. A question to be answered by the construction of this instrument was whether the irregular type of alternation given by the Lummer-Brodhun field would result in less precision or accuracy than the four-part field. No difference was found on trial, the irregular alternation of fields apparently calling merely for a lower speed.

The real value of such an instrument as described is best shown in actually measuring large color differences. A deep red monochromatic signal glass whose transmission was accurately known was measured against a 1.15 w.p.c. tungsten light on the

FIG. 4.



To show how the Lummer-Brodhun field (A) is cut by the attachment; also a four-part field (B).

other side; likewise a green signal glass and a 4 w.p.c. carbon lamp against the tungsten. In each case it has been found equal in precision and accuracy to the large laboratory instrument just referred to. The focus of the optical system of the attachment is in space and not on a surface, and, although the attachment was tested on a photometer head whose mirrors were badly corroded and needed replacing, no trouble was experienced from mechanical flicker.

It should be made plain that this attachment does not obviate the necessity of a proper selection of observers if the result is to represent that of an average eye. At least five observers should be used in this case, as has been carefully explained in a paper recently published concerning this point, to which the reader is referred.[5] This is required of all flicker photometers.

In addition to the above point, care should be taken to remove the contrast glasses of the Lummer-Brodhun in using the attachment. If this is not done there will always be an outstanding intensity flicker. This point has been mentioned previously, but it is repeated here for emphasis.

The thanks of the author are due to Dr. H. E. Ives for many helpful suggestions, and especially to Mr. C. B. Smith, the laboratory's mechanic, who has taken a deep interest in perfecting many mechanical details.

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The United Gas Improvement Company,
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Electroplating with Cobalt. C. H. BUCHANAN and THOMAS HADDOW. (*The Metal Industry,* vol. 13, No. 6.)—This paper, prepared for the New York Branch of the Electroplaters' Society, contains data and results of experiments covering a long period, made by the writer, C. H. Buchanan, and a report of experiments of recent data in collaboration with Thomas Haddow. Early experience showed that a chloride-cobalt solution deposited more rapidly than did a nickel solution. Subsequent work done with cobalt proved so satisfactory that if the cobalt metal could have been obtained in sufficient quantities from commercial sources, even at a cost higher than paid for nickel, it would have been adopted for general work. The results of recent tests are summarized as follows: Cobalt plating has a beautiful bluish-white color. The deposit does not tarnish as readily as nickel; it is homogeneous, with a fine, close grain; it is smooth and not brittle, and will easily withstand bending tests. The time required in order to secure a satisfactory deposit is much less with cobalt than with nickel, and the current density with cobalt may be greater. Metallic cobalt costs more than nickel, but the cost of the salts is of small importance in a comparison of the two as to economy in results. Because of the greater conductivity of cobalt as compared with nickel, a current of higher density may be used in combination with a solution of less concentration. The time required in the solution is, with cobalt, one-third that required for nickel, and there is a similar saving of time in the buffing-room. The substitution of cobalt for nickel would thus greatly increase the speed of production in any established plant.

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[5] *Trans. Ill. Eng. Soc.,* 1915; *Phys. Review,* v, p. 230, March, 1915.