temporaries abroad are the degree of LL.D. from the University of Glasgow in 1896, and the Symons Gold Medal of the Royal Meteorological Society in 1912.

CHARLES F. BROOKS

YALE UNIVERSITY

SPECIAL ARTICLES

A NEW FORM OF PHOSPHOROSCOPE[1]

EXISTING phosphoroscopes are of two types, those with a periodically interrupted source of light and those employing a steady source.

To the first type belongs the classical instrument of E. Becquerel,[2] subsequently modified by E. Wiedemann,[3] in which the object is placed between two parallel revolving disks and is alternately illuminated and observed through properly placed and adjustable openings.

In 1908 Merritt,[4] devised a phosphoroscope in which the phosphorescent surface P, Fig. 1, was illuminated periodically by the passage

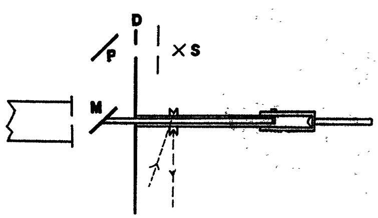

FIG. 1.

of an opening in a revolving disk D mounted between it and a source of light S. The phosphorescence was observed at the desired time after exposure by means of a small revolving mirror, M, mounted obliquely on the end of the shaft. The disk was carried upon a hollow sleeve revolving with the shaft and the angle between the opening in the disk and the plane of reflection of the mirror could be varied during rotation.

With this apparatus curves of decay of numerous cases of phosphorescence of short duration were determined by Messrs. Waggoner[5] and Zeller.[6]

In these phosphoroscopes, the source of light is not in itself necessarily intermittent, the periodic interruption of excitation being produced by the use of a revolving sectored disk. Another group of instruments of this general type employs the intermittent discharge from an induction coil or transformer, as in the spark-phosphoroscope briefly described by Laborde in 1869,[7] Crookes's device with sectored disk and commutator for observing the afterglow of substances subjected to kathode discharge,[8] Lenard's[9] phosphoroscope of 1892 and de Watteville's[10] apparatus for the spectroscopic study of phosphorescence (1906). Lenard's instrument differs from the others of this group in that the eclipse of the exciting spark is produced by the linear movement of a screen mounted upon the plunger of a Ruhmkorff mercury interrupter in the primary circuit of the induction coil.

The other type of phosphoroscope, in which an uninterrupted source of light is used, likewise had its origin with Becquerel.[11] It was later used for lecture demonstrations at the Royal Institution by Tyndall[12] and for measurements by Kester,[13] Waggoner[14] and others. It consists simply of a cylinder revolving on a

[1] A paper presented at the April meeting of the American Physical Society, 1916.

[2] E. Becquerel, *Annales de Chimie et de Physique* (3), 55, p. 5, 1859.

[3] E. Wiedemann, *Wiedemann's Annalen*, 34, p. 446 (1888).

[4] Nichols and Merritt, "Studies in Luminescence," Carnegie Institute of Washington, Publication No. 152.

[5] C. W. Waggoner, *Physical Review* (1), XXVII., p. 209.

[6] Carl Zeller, *Physical Review* (1), XXX., p. 367.

[7] Laborde, *Comptes Rendus*, 68, p. 1,576.

[8] Crookes, *Proc. of the Royal Society*, 42, p. 111 (1887).

[9] Lenard, *Wiedemann's Annalen*, 46, p. 637.

[10] C. de Watteville, *Comptes Rendus*, 142, p. 1,078.

[11] E. Becquerel, *Ann. de Chimie et de Physique* (3), 62, p. 5 (1861).

[12] See Lewis Wright, "Light," London, 1882, p. 152.

[13] Kester, *Physical Review* (1), IX., p. 164.

[14] Waggoner, Publications of the Carnegie Institution of Washington, No. 152, p. 120.

vertical axis, A, Fig. 2, and carrying a layer

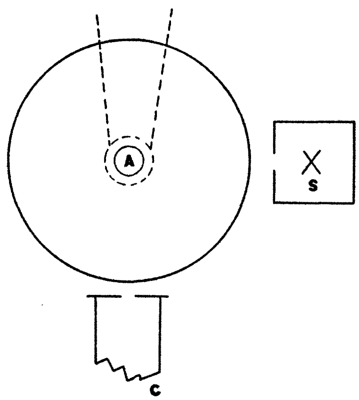

FIG. 2.

of the phosphorescent substance on its periphery.

A source of light, S, illuminates the traveling surface through a fixed vertical slit and the various stages of the phosphorescent glow may be studied by observing at different angles from this opening. In the form used by Waggoner, where a wheel of 45 cm. diameter was used instead of the small drum of Tyndall and of Kester this instrument has many advantages over other forms provided the substance is available in sufficient quantity to coat the entire rim of the wheel. With a speed suit-

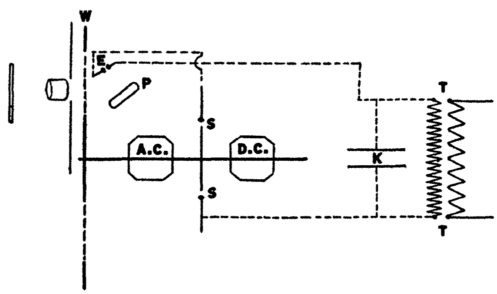

FIG. 3.

able to the substance under observation the whole phenomenon of the decay of phosphorescence may be viewed at a glance, including progressive changes of intensity and color.

The instrument, which we have called the *synchronophosphoroscope* and which is to be described in the present note, was devised for various studies in phosphorescence to which the previous types are not easily adaptable. It consists of a small synchronous, alternating-current motor A. C., Fig. 3, and a small direct-current motor D. C. upon a common shaft. To one end of the shaft is attached a sectored disk, WW, Figs. 3 and 4, with four equal open and four closed sectors, corresponding to the four poles of the A. C. motor. On a circuit of 60 cycles this machine, when brought to speed by the D. C. motor and released, runs steadily at 30 revolutions per second. A "step up" transformer TT, in the same alternating current circuit produces discharges at the spark gap, or series of gaps (E), at each alternation, *i. e.,* 120 times a second. This discharge may be reduced to a single spark by proper adjustment of the resistance and capacity of the circuit or more conveniently for many purposes the discharge may be confined to the peak of the wave by means of the four-pointed star-wheel, SS (Figs. 3 and 4), which is mounted

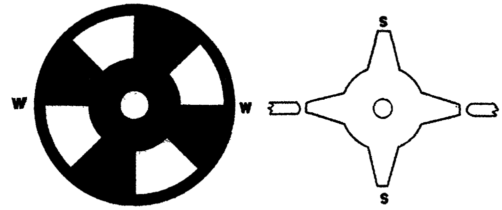

FIG. 4.

on the shaft and carefully adjusted as to phase.

The direct-current motor may also be used to drive the sectored disk at other speeds, in which case the circuit of the motor A. C. is broken and the discharge is derived from any convenient source capable of producing a proper spark at each quarter revolution.

When the sectored disk WW is so adjusted on the shaft that the closed sectors conceal the phosphorescent surface during excitation by the spark, an observer, looking through the open sectors as they pass, sees the phosphorescence as it appears a few ten thousandths of a second after. The apparatus is thus suitable for the study of phosphorescence of very short duration or of the earliest stages in cases of slow decay. By shifting the sector on the shaft it is possible without variation in the rate of rotation to make observations at the very beginnings of phosphorescence and to compare by simultaneous vision, the appearances, just before and immediately after the close of excitation, or on the other hand the earlier with the later stages, up to about .004 second. The photometer, spectroscope, spectrophotometer, camera, etc., may all readily be used with this form of phosphoroscope and studies of the most varied character become possible.

The instrument has already been employed in various determinations, some of the results of which have been reported elsewhere.

To study the change of color during the decay of phosphorescence in the case of certain sulphides, color photographs[15] by the Lumière process were taken, first of the glowing surface as it appeared through the sectored disk at full speed and then for comparison with the disk revolving very slowly.

To determine the effect of temperature the tube containing the sulphide was mounted within a cylindrical dewar bulb, and the lower end cooled to the temperature of liquid air. By keeping the upper end of the tube at + 20° C. a sharp temperature gradient along the axis of the tube was maintained and the very striking changes of color when the substance, under these circumstances, was excited to phosphorescence were photographically recorded.

Spectroscopic comparisons of the spectrum of the light emitted by the uranyl salts during fluorescence and at various stages during phosphorescence have been made with this phosphoroscope[16] and it has been found especially well adapted to the determination of the decay of phosphorescence in cases where, as in that of the uranyl salts, the entire process occupies only a few thousandths of a second.

EDWARD L. NICHOLS,
H. L. HOWES

PHYSICAL LABORATORY OF
CORNELL UNIVERSITY,
May, 1916

[15] Paper read at the April meeting of the American Philosophical Society, 1916.

[16] Nichols, *Proc. Nat. Acad. of Sciences*, 1916.

SCIENTIFIC QUEEN REARING

HAVING been engaged for several years in practical breeding of thoroughbred queens for commercial use, and realizing the certainty and definiteness of results if "Mendel's laws of heredity could be applied to bee breeding, I undertook to determine, if possible, the manner in which some of the most valuable traits of the different races of bees were transmitted through heredity, with the idea of combining in one strain of bees those qualities of recognized desirability, such as hardiness, prolificness, longevity, length of tongue and wing expanse. Color also was brought under observation as a means by which segregation could be more readily seen if it occurred in the second filial generation, as observed by Mendel in coat color of peas when a green-seeded variety was crossed on a yellow-seeded sort, in his experiments with the garden pea.

I was therefore much interested to see that Professor Newell, of College Station, Texas, was working along the same lines.[1] The conclusions at which he arrives, in some instances, do not accord with the facts brought out in a series of breeding tests that were conducted to determine certain (the same) characteristics.

Dzierzon was the first, I believe, to point out that drones were of the same zygotic constitution as the mother alone, and were produced parthenogenetically, the correctness of which is supported by some very convincing evidence, obtained by other reliable experimenters in the same field. Professor Newell says:

> Pure Italian queens mated to Carniolan drones produce only Italian drones, and Carniolan queens mated to Italian drones produce only Carniolan drones. This is strictly in accordance with the theory of Dzierzon, the daughters of Italian queens which have mated to Carniolan drones produce both Italian and Carniolan drones, produce them in equal numbers, and do not produce any other kind. (?) This is in accordance with the theoretical expectation under Mendelian law. (?)

[1] See "Inheritance in the Honey Bee," SCIENCE, N. S., No. 1049, pages 218–219, February 5, 1915.