THE BRIGHTNESS OF THE LIGHT OF THE WEST INDIAN ELATERID BEETLE, PYROPHORUS.

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The West Indian elaterid beetle, *Pyrophorus*, is one of the brightest of luminous organisms. Pickering, by comparing its light with stars of various magnitudes, believed its intensity to be .004 candle. As Ives has pointed out, it is not so much the intensity, but the specific luminous emission or brightness which is the important quantity in measuring luminescences. The relation between intensity (measured in candles), brightness (measured in lamberts) and specific luminous emission or light flux (measured in lumens) per sq. cm. area of luminescent surface is given by:

$$\frac{\text{candles}}{\text{cm}^2} \times \pi = \frac{\text{lumens}}{\text{cm}^2} \text{ or lamberts.}$$

From Pickering's value, .004 candle, and an assumed light organ area of 1.5 cm.^{2}, which is certainly too large, Ives calculated a specific luminous emission of .0084 lumen per sq. cm. or .0084 lambert brightness. By direct measurement, Ives and Jordan obtained .0144 lambert for the glowworm, and Nichols .016 lambert for luminescence of *Cypridina* (an ostracod crustacean) while Dufford, Nightingale and Calvert found .002 lambert for *Cypridina*.

Thanks to Dr. J. S. Dexter of the University of Porto Rico, Rio Piedras, Porto Rico, and to Mr. R. M. Grey, Soledad, Cienfuegos, Cuba, we have recently received some living *Pyrophorus* beetles (Fig. 1), and have measured the brightness of the prothoracic organ by a modified Macbeth illuminometer. Some of the beetles from Porto Rico were 3 cm. long while those from Cuba were 2.5 cm. or less.

Fig. 2 shows one end of a Macbeth illuminometer. A green filter (*G*) of 24 per cent transmission (measured at the proper color tem-

perature of the illuminometer lamp (I)) is placed before the illuminometer lamp (I) and a neutral filter (N) of 9 per cent transmission before the *Pyrophorus* light organ (P). The green filter allows a good color match, while the neutral filter cuts down the light of *Pyrophorus* to a point where readings can be obtained. In addition, a lens (L_1), placed so as to focus the *Pyrophorus* light at the eye (E), serves to fill the comparison field of the illuminometer, a method suggested by

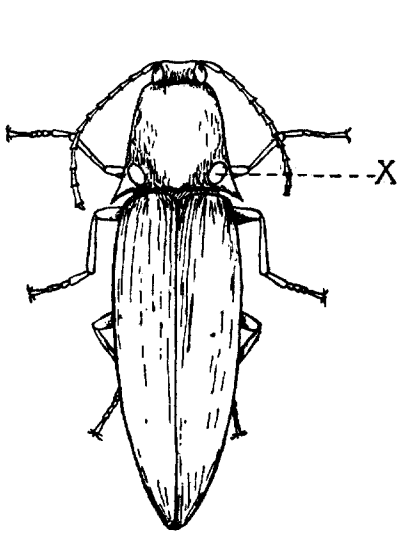

FIG. 1.

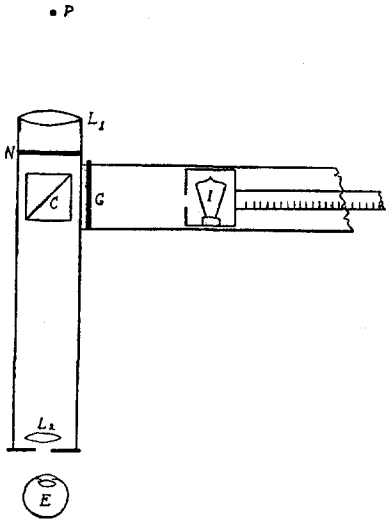

FIG. 2.

FIG. 1. *Pyrophorus* beetle. X, one of the prothoracic light organs.

FIG. 2. P, *Pyrophorus* light organ; N, neutral filter of 9 per cent transmission; G, green glass filter of 24 per cent transmission; C, cube of illuminometer; I, calibrated lamp of illuminometer; L_1, lens which forms a real image of P at eye E; L_2 lens for sharp focussing in illuminometer.

Dr. A. H. Pfund, and serving to make determination of equality in brightness of the two fields easy. About half the measurements were made without the lens, but judgment of equality of brightness is not so easy in this case, as the light organ is small.

When the *Pyrophorus* beetles are squeezed between the fingers, their prothoracic organs glow brilliantly for a considerable period of time, long enough to obtain very good readings. There is much varia-

tion in the brightness of various individuals. About 100 observations on 25 beetles gave values on the inverse square scale of the illuminometer of 4 to 22 foot candles, with an average of 8.5 foot candles. Twenty-two observations on 6 beetles which had been fed sugar water and which gave an unusually bright luminescence, averaged 14.3 foot candles with a maximum of 20 foot candles. Taking a high value frequently observed, 20 foot candles, we calculate the lamberts by making allowance for the screens and the reflection factor of the testplate used to calibrate the Macbeth illuminometer, as follows:

20 foot candles × .79 (reflection factor*) × 1.076 (conversion factor for foot candles to millilamberts) × 11.11 (reciprocal of .09, the transmission of the neutral filter) × .24 (transmission of the green filter) = 45 millilamberts.

This value may be taken as nearly correct for an active brightly luminescing beetle. It may be used to calculate the candle power of one organ by the relation given above, if we measure the area of a luminous organ. In the beetle giving the greatest brightness the organ was an irregular ellipse with diameters of .147 cm. and .119 cm. The average diameter is .133 cm. and projected area .0137 cm.^{2} Hence .045 lambert or .045 lumen per sq. cm. × .0137 = .00062 lumen. Divided by π lumens per candle this = .0002 candle.

SUMMARY.

The maximum brightness of one of the prothoracic light organs of the West Indian elaterid beetles, *Pyrophorus* (measured at Princeton, New Jersey) was found to be .045 lambert, or .045 lumen per sq. cm. at 20°C. This corresponds to .0002 candle for one organ, or .0004 candle for the pair of prothoracic organs.

* Foot candles is an illumination unit. Multiplied by the conversion factor, 1.076, the illuminated surface would have a brightness expressed in millilamberts, if it reflected 100 per cent of the light. Since no surface does this, the reflection factor (79 per cent) of the particular surface must be used in calculating brightness (millilamberts) when the illuminometer is calibrated in illumination units (foot candles).

BIBLIOGRAPHY.

Dufford, R. T., Nightingale, D., and Calvert, S., *J. Am. Chem. Soc.*, 1925, xlvii, 95.
Ives, H. E., *J. Franklin Inst.*, 1922, cxciv, 213.
Ives, H. E., and Jordan, C. W., *Lighting J.*, 1913, 47.
Nichols, E. L., *Science*, 1922, lv, 157.
Pfund, A. H., *Nat. Research Council Bull. 59*, 1927, 27.
Pickering, W. H., *Nature*, 1916, xcvii, 180.