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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON

Letter Circular LC-515 (Supersedes LC-199.)

(Revised March 8, 1938.)

SELENIUM CELLS; PHOTOCELLS; THERMOPILES

1. SELENIUM CELLS: A selenium cell consists of a thin, suitably annealed, deposit of selenium between two parallel conductors mounted on an insulating support. It functions through a change in the electrical conductivity of the selenium between the conductors when exposed to light. It requires for operation an electric battery in the circuit.

2. In the dark, the resistance of a selenium cell increases with decrease in temperature. Records show that, in the dark, a cell having a resistance of 1,000,000 ohms at 20°C, (68°F) had a resistance of three times that value (3,000,000 ohms) at 0°C (32°F).

3. Selenium cells usually have a resistance in the dark of 100,000 to 500,000 ohms. When exposed to full daylight, the resistance may be reduced to between 3,000 and 10,000 ohms. The decrease in resistance on exposure to light, and recovery after exposure, are not instantaneous, especially when the cell is exposed to light of long wave lengths.

4. The spectral response of a selenium cell to an equal energy stimulus depends upon heat treatment. A cell that has been annealed at 200°C, has its maximum sensitivity in the red part of the spectrum, while a cell annealed at 150°C has its maximum sensitivity in the blue-green part of the spectrum.

5. When exposed to light, the resistance of a good cell drops to from 1/10 to 1/50 of its value in the dark. This change in resistance is a function of the spectral quality (the color) of the light as well as the temperature of the cell. At low temperatures the light sensitivity is far greater than at 20°C.

6. Since the magnitude and the position of the maximum of the spectral sensitivity of a selenium cell depends upon heat treatment as well as upon temperature and perhaps humidity, and since the response (the change of resistance) of such a cell is not proportional to the illumination, it has been largely superseded by a wide variety of photoelectric cells of the electron emission type.

7. Information on the design, construction and characteristics of selenium cells may be found in the following publications:

"Selenium Cells (How Made)", by Thomas W. Benson (Spon and Chamberlain, 120 Liberty Street, New York, N. Y.);

"Selenium Cells and How They are Made", by Samuel Wein (Spon and Chamberlain, New York, N. Y.);

"The Moon Element", by E. F. Fournier d'Albe (D. van Nostrand Company, New York, N. Y.);

"The Selenium Cell, its Properties and Applications", by C. P. Barnard, (R.R. Smith, Inc., New York);

Bureau of Standards Scientific Papers (No. 319), vol. 14, p. 507; 1918. Reprints are not longer available. The original paper may be consulted in the nearest government depository library;

See also summary on Selenium Cells in a book on "Primary Batteries", by W. R. Cooper (D. van Nostrand Company, New York, N. Y.).

8. The element, Selenium, may be purchased from dealers in chemical supplies, e.g., Eimer and Amend, New York, N. Y.; or J. A. Samuel and Company, 220 Broadway, New York, N. Y.

9. Selenium Cells may be purchased from the following dealers:

James G. Biddle, Philadelphia, Pa.;
John J. Griffin and Sons, Ltd., London, England;
L. E. Knott Apparatus Company, Cambridge, Mass.

10. PHOTOELECTRIC CELLS: The photoelectric cell (sometimes called "Phototube") consists of a thin wire electrode (the anode) back of which is placed a relatively large plate of metal (the cathode, of Ni, Ag, etc.), both suitably supported within a spherical or cylindrical inclosure of glass (or glass with a quartz window) or, less commonly, of quartz. This inclosure is either highly evacuated or filled with an inert gas. The metal plate, which may be in contact with or on a separate support within the inclosure, is activated with a thin deposit of a metal (potassium, caesium, cadmium, titanium) that emits electrons when exposed to the spectral band of wave lengths which it is desired to measure.

Photoelectric cells are now obtainable commercially in which the long-wave-length limit of electron emission terminates at 2900A to 10,000A. By means of suitable glass filters that limit the short-wave-length response, it is possible to isolate and measure narrow bands of radiation throughout the spectral range, extending from 2500A to 9000A without employing a spectroscope.

11. Photoelectric cells function as a result of electron emission from the surface of the cathode when exposed to light. They require an electric battery in the circuit. In the highly evacuated type of photoelectric cell, if the applied voltage exceeds a certain critical value, the sensitivity (the number of electrons emitted) is not affected by a change in voltage across the cell.

12. The response of the photoelectric cell is practically instantaneous and is not appreciably affected by changes in temperature. In the highly evacuated types (also in some of the cells containing an inert gas) the response of the cell is closely proportional to the illumination, over a wide range of intensities.

When subjected to continuous usage, they are likely to become fatigued and, in some types, the sensitive surface may be destroyed. Further data are given in Bureau of Standards Scientific Papers (No. 319), vol. 14, p. 507; 1918, which may be consulted in any of the government depository libraries.

13. BARRIER LAYER PHOTOCELLS: These cells function as a result of electron emission in solids when exposed to the action of light. The phenomenon is practically a transformation of light into electricity. Hence, they require no external source of emf for operation, (Some New Thermoelectric and Actinoelectrical Properties of Molybdenite, Coblentz, BS Sci. Papers No. 486, vol. 19, p. 375; 1924, which may be consulted in any of the government depository libraries.)

This type of cell is regarded as being a dry plate rectifier. In commercial cells a metal plate is coated with a thin layer of a semi-conductor, such as cuprous oxide or selenium, upon which is deposited a thin film of metal that transmits light. On exposure of this thin metal surface to light, electrons tend to pass from the semi-conductor to the metal thus producing an electric current. Recent commercial developments are the "Photronic Cells" and the "Photox Cell".

14. The spectral response of selenium barrier-layer photocells extends from the ultraviolet (3100A) throughout the visible into the short wave lengths infrared (to about 9000A), the maximum sensitivity being in the visible. By covering the sensitive surface of the cell with a suitable glass filter, the resulting spectral response may be made to closely simulate the spectral luminosity curve of the "average eye". Such a photocell and filter combination may be used as a photometer.

The spectral response curve of copper-oxide barrier-layer photocells follows the general shape of the spectral luminosity curve of the "average eye". The response of this type of cell is low in red, however, being zero for wave lengths longer than 6500A.

The current response of barrier-layer cells depends upon the external resistance and is approximately proportional to the illumination for low values of external resistance. For high values of external resistance, the current response curve of such cells deviates markedly from proportionality to the illumination.

15. Information on the design, construction and characteristics of light-sensitive cells is to be found in the following publications:

Anderson, John S. (editor), Photoelectric Cells and Their Applications, London, The Physical Society and The Optical Society, 1930.

Campbell, N. R., and Ritchie, Dorothy, Photoelectric Cells; their Properties, Use and Applications, London and New York, Pitman and Sons, Ltd., 1929.

Hughes, A. L. and DuBridge, L. A., Photoelectric Phenomena, McGraw-Hill Book Company, Inc., New York, 1932.

Zworykin, V. K. and Wilson, E. D., Photocells and Their Applications J. Wiley & Sons, New York, 1930.

J. H. Morecraft, Electron Tubes and Their Applications, J. Wiley & Sons, 1937.

W. G. Dow, Fundamentals of Engineering Electronics, J. Wiley & Sons, 1937.

Koller, L. R., The Physics of Electron Tubes, McGraw-Hill Book Company, Inc., New York, 1937.

T. J. Fielding, Photoelectric and Selenium Cells, Instruments Publishing Company, Pittsburgh, Pa.

The monthly journal, "Electronics", published by McGraw-Hill Publishing Company, Inc., New York, covers the whole field of photoelectric devices.

The literature on photoelectric devices and their properties is extensive; important papers have been published in the following journals:

Electric Journal (1936); Jour. A.I.E.E. (1929); Trans. I.E.S. (1932 and 1937); Proc. Inst. Radio Engineers (1929); Rev. Sci. Inst. (1930, 1931, 1932); Journal Opt. Soc. Amer. (1929); Phys. Rev. (1928); Jour. I.E.E. (London, 1936, full bibliography on barrier-layer cells.

16. Photoelectric Cells, commonly called "Photocells" or "Phototubes" may be purchased from the following dealers:

The Case Research Laboratory, Auburn, New York ("Thalofide Cells");
General Radio Company, Cambridge, Mass.;
Robert C. Burt, Scientific Laboratories, Pasadena, Calif., (Na-cells);
The General Electric Company, Schenectady, New York (Cd-cells);
The G-M Laboratories, Inc., 1731 Belmont Ave., Chicago, Ill., (K-cells);
National Carbon Company, New York, N. Y. (Raytheon Fotocells);
Watson and Sons, Parker Street, London, England;
Westinghouse Lamp Company, Bloomfield, N. J., (Ti-cells);
Weston Electric Instrument Co., Newark, N. J. (barrier-layer photronic cells);
Pfaltz & Bauer, Empire State Bldg., New York, N. Y.;
Research & Development Company, 8 West 40th Street, New York, N. Y.

17. PHOTOLYTIC CELLS: These cells function as a result of a change in electromotive force that occurs when a certain kind of electrode is immersed in an electrolyte and exposed to light. They require no external battery. In the early models, first the one then the other electrode was exposed to light to reduce polarization. In recent models, a non-polarizing electrode is used. This type of photoelectric response device seems to have fallen into disuse.

Reference: "Cuprous Oxide Photochemical Cells", T. W. Case, Trans-Amer. Electrochem. Soc. 31, pp. 351 and 364; 1917.

18. THERMOPILES. These are sources of electromotive force which are maintained by temperature differences in an electric circuit. The method of construction, and properties of thermopiles are given in Bureau of Standards Scientific Papers No. 229, vol. 11, p. 131, 1914, on file in government depository libraries. Linear thermopiles (also pyrheliometers) are obtainable from the Eppley Laboratory, Inc., Newport, Rhode Island. Western Electric Vacuum thermocouples (for measuring feeble alternating currents) are obtainable from Graybar Electric Company, 420 Lexington Avenue, New York, N. Y. High sensitivity vacuum thermocouples are obtainable from R. C. Burt Scientific Laboratories, Pasadena, California.

19. MISCELLANEOUS: Bolometers are obtainable from the S. O. Hoffman Company, 835 Howard St., San Francisco, California.

Iron-Clad Thomson Galvanometers are obtainable from Leeds and Northrup Company, Philadelphia, Pa. This firm (also the Weston Electrical Instrument Corporation, Newark, N. J.) makes sensitive d'Arsonval galvanometers.

Measurements of Radiant Energy: Edited by W.E. Forsythe (McGraw-Hill Book Co., Inc., New York). This publication gives general information on instruments and methods of radiometry.

20. New types and designs of the above described photoelectric and radiometric instruments are frequently to be found in the literature and in the advertisements published in "The Physical Review", the "Journal of the Optical Society of America", "The Review of Scientific Instruments", "Science", "Electronics", the "Journal of Scientific Instruments" (London). A very complete list of names of manufacturers and distributors of radiometric apparatus is published in "Instruments, The Magazine of Measurement and Control" (see the yearly index), published by The Instruments Publishing Company, Pittsburgh, Pa.

WASHINGTON, D.C.,
March 5, 1938.