
Weston
# ENGINEERING NOTES

VOLUME 11 SEPTEMBER 1956 NUMBER 3

*In This Issue*

**25th Anniversary of the Weston Photronic® Cell**

**A Summary of the Technical Highlights of Its Development**

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## 25th ANNIVERSARY SUMMARY ON THE WESTON PHOTRONIC® CELL

*EDITOR'S NOTE: As of this year, the PHOTRONIC® Cell is twenty-five-years old. Now established as the preferred photocell in a wide variety of devices from exposure meters to airway beacon controls, its development history is replete with important technical papers. This issue of* ENGINEERING NOTES, *therefore, has been devoted to a summary of the highlights of those papers along with a few words on the early development.*

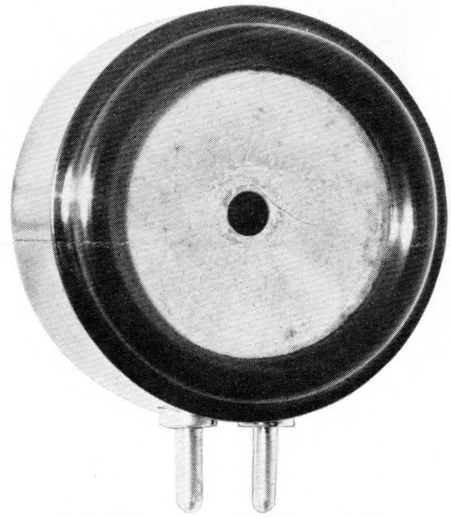
IN MAY, 1931, the Weston Photronic Cell was announced. It was the first commercially available selenium cell for the direct conversion of light into useful electrical energy. Over the intervening years, it has found wide usage and is today accepted as the ideal type of cell for light measurements of all kinds as well as for devices controlled by light.

Technically known as a barrier layer photovoltaic cell, it was developed by A. H. Lamb and C. H. Bartlett in the Weston Engineering Laboratories after several years of study of the general problem.

Weston Circular C-1 of January, 1932, "A New Dry Type Photoelectric Cell,"[1]* disclosed surprisingly complete data on the cell, along with a relay assembly for actual control of electric power by a light beam.

The first technical paper describing the cell was printed in *The Review of Scientific Instruments* for October, 1932,[4] where Bartlett presented comparative characteristics of the Photronic cell and the copper oxide photocell. Bartlett derived a number of equations to give the current, voltage and power sensitivity for the Photronic cell in terms of the incident light.

Mr. Lamb, in an article entitled "Historical Background of the Photoelectric Cell," published in WESTON ENGINEERING NOTES, April, 1948,[26] summarized the development from 1931 to 1948 as follows:



The Original Photronic Cell of 1931.

> "At first the copper oxide cell pushed to the fore, but further experiments conducted with tellurium, selenium and other materials soon indicated that a selenium alloy would offer the best possibilities. However, the going was not easy, as Mr. Fritts had predicted. The 1928-29-30 cells lacked sensitivity, or stability, or both, or were not reproducible commercially. Somewhat before this period, the Weston Company started an investigation of photoelectric cells including the liquid

*See Bibliography for all numbered references.

type, the dry-disc copper oxide and selenium type and others, but it was not until May, 1931, that the first satisfactory progress was achieved. Regarding this accomplishment, a booklet published by Weston in 1935 states 'Lamb and Bartlett, two Weston engineers, were first to produce barrier layer cells with apparently permanent characteristics. Their cell is known as the PHOTRONIC Photoelectric Cell.'

"In the past fifteen years, definite improvements in fundamental cell characteristics, particularly in the direction of providing increased current output without sacrificing stability, have been achieved. Knowledge of the photoelectric effects involved in cell design and manufacture has now reached a point permitting the creation of cells 'tailor-made' to the requirements where conditions limit the usefulness of the regular types. The entire operation from processing of the raw materials to the sensitization of the finished cell is performed under close technical control in the Weston plant. The material, skills and experience are available to move forward with new strides of progress in which even greater commercial utilization can be expected for the barrier layer cell."

In this paper, Mr. Lamb goes back to a reference by Becquerel, of France, who wrote, in 1839, of the effect of light on glass-enclosed batteries and showed that the voltage of one of his cells increased when a beam of light fell on the platinum electrode. The resistor type of cell was apparently discovered by Willoughby Smith in 1873; he found that selenium resistors used in checking telegraph lines varied in resistance, being higher when dark than in sunlight.

Fritts, an American, developed the first self-generating dry disc barrier layer photocell, of selenium, which was referred to in an article by Dr. Siemans in the *Electrical World* for April 25, 1885, and further described by Fritts himself in the *Scientific American Supplement* of June 6, 1885.

## Romain's Circuit Analysis

After the initial work by Lamb and Bartlett on the Photronic Cell, studies were made as to how the cell operated, and how it could best be used. Apparently its internal resistance and its output voltage and current all varied with the illumination and with the connected load. B. P. Romain, a Weston engineer, evolved an equivalent circuit for the cell which allowed for the evaluation of these factors. He showed,[6] that an equivalent circuit for the cell could be synthesized using several resistances in parallel, each a simple function of illumination and load resistance. More specifically, he considered the cell as having several *conductance* parameters, and states,

> "The purpose of this paper is to show that the internal leakage path in the Photronic Cell may be regarded as consisting of three conductances which are: (1) a conductance which is a constant for a given cell; (2) a conductance which is directly proportional to the illumination of the cell; (3) a conductance which is directly proportional to the total internal leakage current in the cell."

Romain developed the plot, Figure 2 of the paper, showing the amount of current which would flow in load circuits of varying resistances at certain values of illumination.

Romain further states,

> "The data so far accumulated point to the conclusion that the total generated current $I$ is very nearly proportional to the illumination over a wide range and is little affected by the varying conditions encountered in ordinary use but that the leakage resistance is subject to very appreciable variations under similar conditions.
>
> "If the resistance of the external circuit is kept small, in comparison with the leakage resistance variations in current output for any given illumination will be correspondingly small, because relatively large variations in leakage resistance only cause small variations in the current shunted away from the external circuit."

Having available a photocell which would give current in terms of the light incident on its surface, engineers immediately began the

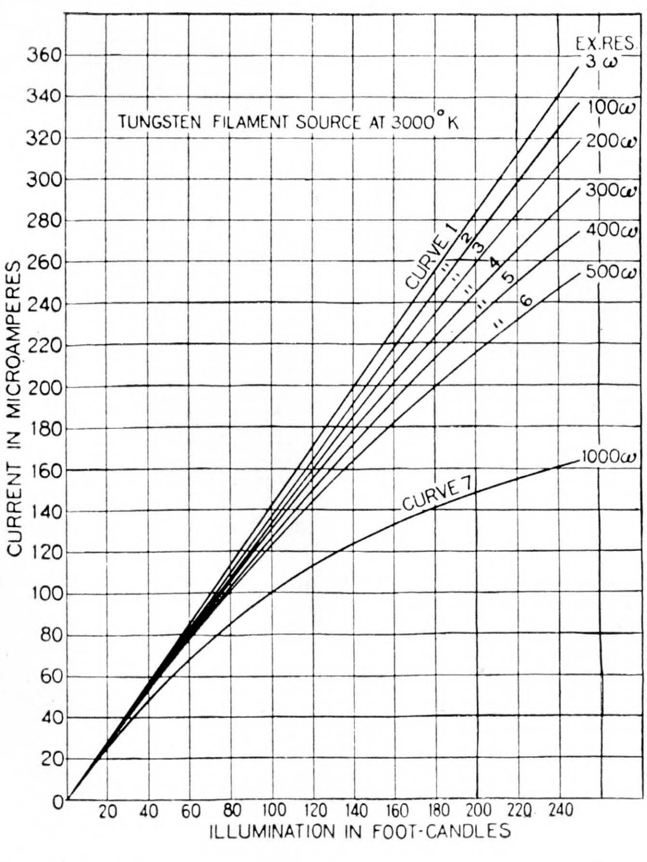



**Figure 2.**

***(From Romain paper, Reference No. 6.)***

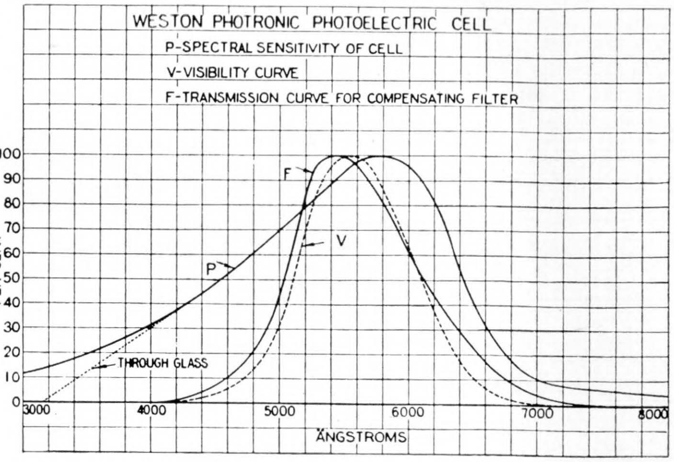



**Figure 4—Spectral Response of Photronic Photoelectric Cell.**

*(From Goodwin paper, Reference No. 5.)*

work of applying the photocell to the various problems of light measurement which had existed for many years.

## The Photronic Illumination Meter

The most obvious problem was that of measuring illumination. The first direct reading illumination meter requiring no batteries or other auxiliary source of power was the Weston Model 603, described in the paper "The Photronic Illumination Meter," of 1932.[5] The meter is shown in Figure 1 of the paper, and is described in the summary as follows:

> "This instrument utilizes for its light-measuring element a Weston Photronic Photoelectric Cell, which is a direct-action disc type, requiring no external emf, and is mounted in a light target, connected to an electrical measuring instrument by a flexible lead.
>
> "Its current response is linear from less than 0.3 foot-candle to above 10,000 foot-candles for relatively low external resistance. Its spectral response extends from below 2,500 Å in the ultraviolet to above 8,000 Å in the infrared, and has a single peak of 5,800 Å near the visibility peak. A yellow-green filter for eye sensitivity compensation is described as well as means for correcting for light incident at angles other than normal."

More specifically:

> "The instrument which is the subject of this paper utilizes for its light-measuring element the new Weston Photronic Photoelectric Cell. This cell is the direct-action disc type which transforms light energy directly into electrical energy, without the use of any external source of electromotive force.
>
> "The cells are mounted in a light target provided with a handle which is connected electrically by a flexible lead to an indicating instrument of the permanent-magnet, movable-coil type as shown in Figure 1. The instrument is usually calibrated to indicate directly in units of illumination, foot-candles or lux, incident upon the cells in the light target.
>
> "To measure illumination at any point, it is only necessary to hold the light target close to and parallel to the plane in which the value of the illumination desired is to be measured, and read the value directly from the scale of the instrument."

Having a foot-candle meter, the obvious question as to its spectral response was analyzed with the findings as in Figure 4 of the paper and the following discussion:

### Spectral Response

"Curve P in Figure 4 shows the spectral sensitivity of the Photronic Photoelectric Cell. Curve V is the visibility or eye sensitivity curve. It will be noted that the response of the Photronic Photoelectric Cell extends well into the ultraviolet and into the infrared regions. When used under glass, which cuts off radiation of shorter wave-length than about 3,100 Ångstroms, the cell curve follows the dotted line as shown. When used under quartz windows, the curve extends to 2,500 Ångstroms and below.

"The curve is quite similar to the visibility curve but has its maximum at about 5,800 Å, whereas the visibility curve peaks at about 5,500 Å. The cell is considerably more sensitive than the eye in the blue, blue-green and red regions.

"On account of this difference in sensitivity of the cell and eye, illumination measurements made by the cell without a filter, in general, will be accurate only for one particular quality of light to which it was adjusted.

"The sensitivities are so related, however, that if the cell is adjusted to tungsten illumination at about 3,000 degrees K, it will give, within experimental errors, the same accuracy when used to measure a quality of light equivalent to mean noon sunlight, which has a color temperature of about 5,400 degrees K."

The paper further states:

"A yellow-green filter has been developed which changes the response of the cell to match the sensitivity of the normal eye very closely. With its use, measurements of illumination of various

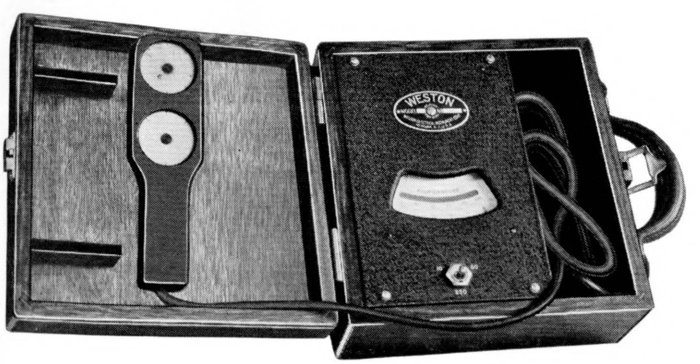



**Figure 1—Photronic Illumination Meter.**

*(From Goodwin paper, Reference No. 5.)*

color values can be made to a comparatively high accuracy even on illuminants differing so widely as neon and mercury vapor lamps.

"Curve F in Figure 4 shows the computed transmission curve of such a compensating filter."

When light strikes the cell at a sharp angle, reflection from the glass window as well as the shadowing from the cell housing creates a so-called cosine error. Mr. Goodwin evaluated this factor experimentally, obtaining curve C of Figure 6 of the paper below, and also devised a compensating means giving the result as in curve D.

Modern cosine correcting means follow this original design approach, using a truncated cone-shaped cell cover of translucent glass.

## The "VISCOR"® Filter

Reference was made to the color correcting filter in the work of Goodwin. However, the advent of colored gaseous tube lamps—neon and mercury—seemed to require a more permanent filter with a more exact compensation. Dr. M. E. Fogle, then of the Weston engineering staff, studied the requirement and in collaboration with Dr. H. P. Gage, of the Corning Glass Works, devised the visual correction filter which has been used since that time. Fogle's paper of 1936,[16] explores the requirement and states:

"The obvious method of making the cell agree with the human eye is to use a color filter (a selective radiation filter) in front of the cell to filter out or remove that part, or all, of the rays of any given wave-length necessary to make the response of the cell to the remainder just equal the eye sensitivity at that wave-length. With a cell and filter combination having an effective sensitivity identical to that of the average human eye, it matters not what the spectral composition of the light may be because the sum total response to all the different wave-lengths will be the same for the cell plus filter as for the eye.

"The transmission of the ideal visual correction filter for a Photronic Cell is given by Curve 1 in Figure 5. A visual correction filter consisting of two pieces of colored glass cemented together with balsam has just been developed which closely approximates this ideal. The spectral calculations for this new filter were made by the author working in conjunction with Dr. H. P. Gage of the Corning Glass Works who developed the special blue glass component after existing glasses proved inadequate.

"A colored-liquid filter and a dyed-gelatin filter were previously developed, both of which also quite closely approximate the ideal correction filter. A liquid filter is undesirable for most commercial applications; and the gelatin filter used in the past being transparent to infrared rays sometimes led to an appreciable error because of the infrared response of the cell. Calculations and measurements indicate that the new glass filter is by far the best one yet developed for this purpose and that it is entirely satisfactory for commercial use."

Fogle described the filter in detail as follows:

"One component of the new correction filter is a yellow glass which removes the excess blue response of the Photronic Cell, and the other is a blue-green glass which removes the excess red response. The spectrophotometric curve of the glass visual correction filter and the calculated ideal filter are compared in Figure 5. It is possible to make the two curves conform more closely, by altering the thickness of the component glasses, and thereby increase the accuracy on continuous light sources.

"The total transmission of the filter is about 37.5 per cent for light from tungsten at 3,000 K—measured as cell response. The peak of the transmission is about 72 per cent (78 per cent of the theoretical maximum) at 545 millimicrons. This is quite high for a filter having complete cut-

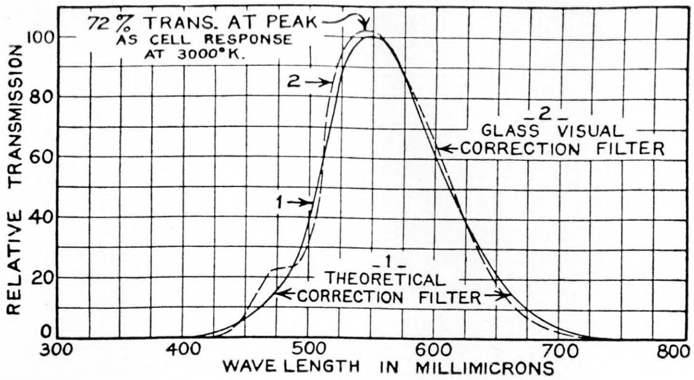



**Figure 5— Theoretical and Glass Visual Correction Filters for Photronic Cell.**

*(From Fogle paper, Reference No. 16.)*

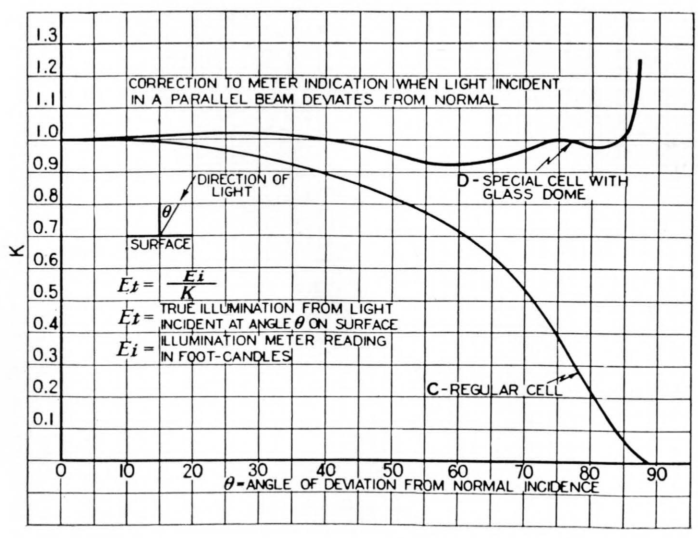



**Figure 6— Effect of Angle of Incidence of Light on Cell Mounted in Target.**

*(From Goodwin paper, Reference No. 5.)*

offs at both ends of the visible spectrum.

"The infrared sensitivity of the Photronic Cell (a sensitivity which may produce a response as large as 10 per cent of the total for light rich in the near infrared rays) is eliminated by the glass correction filter. This also tends to retard heating of the cell, since only a portion of the heat is able to reach the disc by conduction, and thereby reduces errors caused by changing temperature.

"Glass is quite stable chemically and therefore the filter does not affect the sensitive surface of the cells disc. The blue-green component, being more easily scratched and fogged by moisture than the yellow component, is placed inside of the cell for protection.

"Calculations were made in order to predict the accuracy of a filter in use with the Photronic Cell when measuring light from tungsten lamps, acetylene flame, gas mantle, daylight, neon, sodium, and mercury lamps.

"The reliability of such calculations can be judged by the close agreement between calculated values obtained in a similar manner for a cell without a filter, and actual measurements listed in Table I."

TABLE I—ILLUMINATION MEASUREMENTS WITH THE PHOTRONIC CELL

*(From Fogle paper, Reference No. 16.)*

| Light Source | Photronic Cell Without Filter | | | Cell With Glass Visual Correction Filter | |
|---|---|---|---|---|---|
| | Measured Output* | Calc. Output* | Calc. Correction Factor | Calc. Output* | Effect of Filter Variations |
| | | | | | % |
| 2200 K | | 106.2 | .94 | 99.7 | ± .3 |
| 2300 | 106.7 | 105.5 | .95 | 99.8 | ± .2 |
| 2600 | | 102.0 | .98 | 100.0 | ± .1 |
| 2700 | 100.0 | 100.0 | 1.00 | 100.0 | ± .0 |
| 2848 (Ill. A) | | 98.3 | 1.02 | 100.0 | ± .0 |
| 3000 | 97.6 | 97.2 | 1.03 | 100.1 | ± .1 |
| 4000 | | 95.7 | 1.04 | 100.4 | ± .3 |
| 4800 (Ill. B) | | 98.6 | 1.01 | 100.5 | ± .5 |
| 6000 | | 101.5 | .99 | 100.7 | ± .6 |
| 6500 (Ill. C) Daylight | 101.0 | 103.0 | .97 | 100.7 | ± .7 |
| Acetylene | | 105.5 | .95 | 99.9 | ± .2 |
| Gas Mantle | 90.0 | 86.0 | 1.16 | 100.4 | ± .3 |
| Sodium | 74.0 | 70.0 | 1.43 | 100.7 | ± 2.0 |
| Neon | 106.0 | 107.0 | .94 | 99.5 | ± 2.0 |
| Mercury: High Pres. | 71.0 | 74.0 | 1.35 | 99.3 | ± 2.0 |
| Mercury: Inter. Pres. | 77.0 | 82.0 | 1.22 | 99.4 | ± 2.0 |
| Mercury: Low Pres. | | 87.0 | 1.15 | 99.6 | ± 2.0 |

* Relative values of current output based on tungsten light source at 2,700° K.

MEASUREMENTS ON FOUR CELLS WITH GLASS VISUAL CORRECTION FILTERS[a]

| Light Source | Relative Measured Output of Cells[b] | | | | Average |
|---|---|---|---|---|---|
| | #1 | #2 | #3 | #4 | |
| 2360 K | 98.9 | 98.8 | 99.1 | 99.1 | 99.0 |
| 2855 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 4820 | 100.0 | 100.9 | 100.7 | 98.7 | 100.7 |
| 6535 | 103.2 | 103.3 | 105.6 | 104.1 | 104.0 |
| Mercury | 101.0 | 100.6 | 99.4 | 96.7 | 99.6 |

[a] Measurements by Electrical Testing Laboratories.
[b] Basis of comparison 2,855° K. These four cells were purposely selected as being dissimilar in regard to time of preparation and physical characteristics. Even so, their spectral characteristics appear to be quite uniform.

Fogle summarizes his work by stating that it seemed quite probable that the Photronic Cell, corrected by the new "VISCOR" filter, would allow for the measurement of light from tungsten lamps with an accuracy of 2 per cent, with a possible accuracy of 3.5 per cent for all continuous sources and within 5 per cent from commercial monochromatic sources. Over the intervening years there have been no findings outside these limits and the filtered cells have found excellent acceptance in illumination meters for all applications.

We should also make specific reference to the paper,[17] published by Dr. Gage on the development of the VISCOR filter from the point of view of the glass maker. In this paper, Gage states:

"The specific data for the Photronic Cells used in this calculation were supplied by Dr. M. E. Fogle of the Weston Electrical Instrument Corporation and the calculations used in the filters finally specified were made by him. The filters are composed from two glasses, *b* and *y*, illustrated in Figure 4. These were first made in small experimental melts of one pound or less. Glasses obviously unsuitable were rejected; likely candidates were plane polished and spectrophotometered by the Electrical Testing Laboratories under the direct supervision of Dr. Roger S. Estey. A yellow glass was soon selected having the spectral transmission shown in Figure 4*Y* and a melt of the smallest commercial size was made. The pale blue-green glass (Figure 4*B*) was more difficult to obtain as the coloring agent dissolved in glasses of known commercial types did not have as sharp a spectral cut-off as was required and in general absorbed too far toward the shorter wavelengths resulting in a low transmission for the finished filter, the maximum point of which is at 0.546$\mu$. The ideal filter should not absorb anything at this wavelength.

"It was found that a special type of glass to which was added the coloring agent did give very nearly the theoretically desirable spectral transmission and this combined with the yellow glass gives the transmission curve, Figure 4. Inasmuch as the blue-green element did not give the desired result when dissolved in the yellow glass, the yellow element was tried in the special glass. This combination did not work at all as the resulting color had no resemblance to what was desired, another instance of the profound influence of the solvent upon the material dissolved."

After a discussion of the unavoidable variations in transmission of the glass from melt to melt, Gage summarizes his paper by indicating the procedure for determining the specific thickness of each of the two elements—the blue and the yellow glass—in terms of their specific absorption of light to attain the optimum correction.

## Photometer Committee Report

One of the most important documents on photometry is the report of the Committee on Photoelectric Portable Photometers of the Illuminating Engineering Society,[15] presented at the annual convention of that Society in the fall of 1936, and published in April, 1937. This forty page report states:

> "The measurement of illumination has been revolutionized since 1931 by the introduction of photoelectric portable photometers employing barrier-layer cells. These instruments eliminate the tedious visual comparison required with previous portable photometers and simplify illumination measurements to such an extent that such measurements can be made by the layman."

The report summarizes the work of Goodwin, Fogle, Pierce and others of the Weston Engineering staff, and also includes many foreign references. It concludes with suggested calibrating methods, and recommends:

> ". . . that portable photometers employing barrier-layer photoelectric cells be calibrated by the use of unmodified radiation from an incandescent lamp operating at a color temperature of 2,700° K."

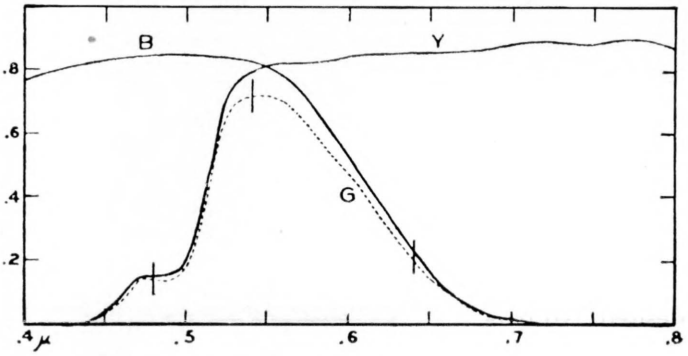



Figure 4.

*(From Gage paper, Reference No. 17.)*

## The Photographic Exposure Meter

Parallel with the development of illumination measuring instruments came the intriguing study of their application to photography. In 1931 there were several types of devices marketed for determining the correct camera exposure for a given scene. In "Wynne's Infallible Exposure Meter," made in England from about 1903 to 1932, a small segment of sensitized paper was exposed to the available light, and the time taken for it to change color to match an adjacent color standard was used in calculating the exposure. And there were two devices on the market measuring light using selenium resistive cells, but they required continual dry cell replacement and were bulky and of limited utility.

W. N. Goodwin, Jr., studied the over-all exposure problem intensively. To obtain a negative with the best gradation of density it appeared necessary to know two factors—scene illumination and film sensitivity—and to appropriately set the other two factors—lens opening or f/stop, and exposure time.

Goodwin developed the modern dry disc self-contained exposure meter, showing the necessity for measuring the scene brightness, in foot-candles per square meter, averaged over a 60-degree acceptance angle as representative of a typical camera. The entire theory of the exposure meter is given in Goodwin's classic paper,[7] "The Photronic Photographic Exposure Meter," of 1933, in which he also shows the possibility of measuring the brightness of the brightest and the darkest object, and so exposing the negative to include both shadow detail and detail in the highlights. The summary of the paper indicates its broad coverage as follows:

> "Summary—This paper describes a new photographic exposure meter, which measures the brightness of the scene to be photographed. It utilizes for its light measuring element two Weston Photronic Photoelectric Cells connected in parallel to, and mounted in the same case with, a permanent magnet movable coil indicating instrument calibrated in units of brightness: candles per sq. ft. The cells are of the direct action dry disc type, which transform light energy directly into electrical energy, requiring no battery, and having an unlimited life. They are mounted in tubular depressions to limit the area of the scene covered.
>
> "A simple mechanical dial calculator attached to the meter case translates light values into exposure values by a single setting of a dial, after having set the calculator once for all for the speed of the film being used. The calculator has the novel feature of providing means for fitting the brightness range of a scene as determined by its darkest and brightest objects, to the correct film range indicated on the dial as lying between the darkest and brightest objects which the film will correctly expose, for the indicated shutter speed and aperture."

Having a means for measuring scene brightness, and the spread from darkest to brightest objects, it remained to consider the method of film rating. Goodwin found that methods of analyzing film sensitivity were available but that prior methods of evaluation were concerned only with obtaining a very limited criterion to obtain a fair picture on a film. Thus, *H* and *D* values as well as Scheiner values concern themselves primarily with the least amount of light which would start to register on a film. But with a true brightness meter as a tool with which the photographer could explore brightness values in his pictorial composition and determine the mean value, it appeared important to determine not only that value of light which would start registering on the film but also the degree to which the film would respond to the various levels of illumination forming the whole picture. Goodwin therefore took the classical *H* and *D* curve and selected the center point of the straight line portion as the "Weston Point." This represented the average of the film and could well correspond to the average brightness of the scene. It allowed for placing the average scene density at its middle value and, with a single number as the film speed description, it allowed for the best possible negative to be taken of the scene in question.

Goodwin assigned the film speed number of 16 to Verichrome and Plenachrome films in daylight as they then existed, and formulated the necessary techniques to rate all black and white films. A complete sensitometric laboratory was then installed with all the necessary apparatus for exposing and developing film and determining the resulting density of the various exposed sections. Weston continues to purchase, on the open market, films offered to the photographer which are exposed and processed under controlled conditions in an area conditioned to 68° F. From the plot of light versus density—the *H* and *D* curve—the "Weston Point" and the corresponding film speed is obtained.

Thus the Weston exposure meter was accompanied from the first with appropriate film speed data. Indeed, Weston Film Speed sheets were demanded in such large quantities in later years that printing enough of them, not to mention the scientific rating of new films, became a problem of the first magnitude.

In a very few years, the matter of film rating became so important to both the photographer and the film maker that others concerned began to offer alternate ratings and the American Standards Association was called upon to assist in formulating a standard procedure. Such a standard exists today, differing slightly from the original method devised by Goodwin, but essentially with the same result, and today most films are rated directly on their containers with an appropriate "Exposure Index."

## Control Applications

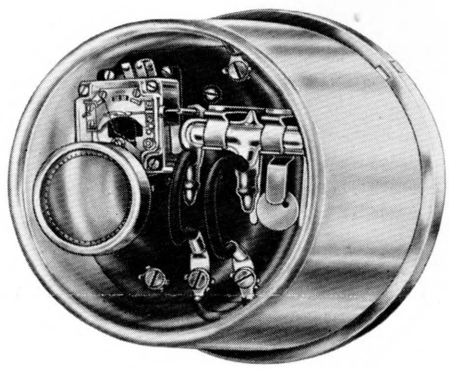
While the basic designs for the illumination and exposure meters were being processed, much thought was also being given to connecting a Photronic Cell and a relay together. Indeed, the first circular[1] on the cell listed relays for control use along with an assembly of a Photronic Cell, a sensitive moving coil relay and a secondary power relay for control through the medium of an intercepted light beam. In Lamb's paper,[2] in the *Electrical World* for April 16, 1932, he states:

> "For automatic control of illumination, industrial processes, etc., the 'Photronic Cell' allows the construction of simple, trouble-free devices. One or more cells can be directly connected to a sensitive relay which, in turn, can control a large power relay suitable for controlling the particular electrical circuit desired. No battery or amplifier tubes are required; all control is performed by a simple relay circuit. The relay is simply connected to the 110 volt, 60 cycle line and to the circuit to be controlled and is then ready for operation. It is suitable for control or counting up to 200 operations per minute. A relay for the control of outdoor illumination such as signs, floodlights, street lights, airports, etc., is another application of the cell."

In succeeding years, assembled gear was designed and offered for automatic control of street lights and school lighting, for smoke determination and for counting items passing a beam of light. Automatic door openers were installed and burglar alarms came on the market, all using the barrier layer cell. See references [3], [9], [11], [12], [13], [14], [20], [22] and [25]. Of particular interest is the Airway Beacon Control described in reference,[24] where Lamb states:

> "Finally after a series of developments and later experiments conducted during 1932-1933 at an emergency landing field at Bowie, Md., and at Newark Airport, the Government airway engineers using the then newly developed Weston Photoelectric Cell and Photoelectric Lightmeter arrived at the required safe illumination values which were ultimately written into Bureau of Aeronautics Specification #BA 224. The Weston Model 709 Type BA 224, Beacon Light Control was then produced to meet the requirements of this specification and after passing the Government tests was approved for use along all airways."

The most modern version of street light control is the Weston Model 1089 of 1953, shown below, and



Weston Plug-in Illumination Control.

which incorporates the Photronic Cell, a primary moving coil relay, and a clock motor to rotate a 30 ampere mercury switch, all within the glass housing of a standard small watt-hour meter case. Thousands of these are in use across the United States, automatically turning on street lights and sign lights at dusk and turning them off in the morning. Hazard markings on chimneys and other airway hazards are automatically controlled for the safety of everyone.

## Summary

Thus, in a quarter century, the barrier layer cell, the Photronic Cell, has been developed from a scientific curiosity into a commonly used component, known to everyone by its impact on the arts of photography and illumination as well as contributing to the safety of the general public.

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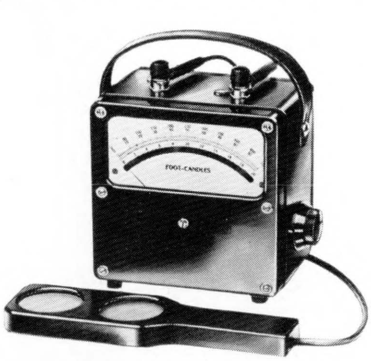
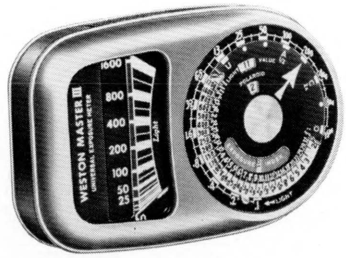
*Note: In the above, there are listed some items that are not referenced in the text. They are included to make the bibliography complete and for future reference.*

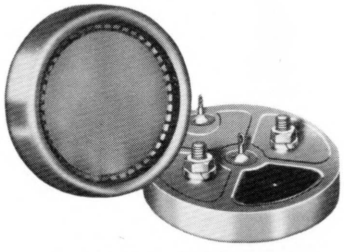
## SOME PHOTOELECTRIC CELL APPLICATIONS




**Industrial Foot-Candle Meter.**




**Photographic Exposure Meter.**



**Sealed Photoelectric Cell.**

**Photographic Analyzer.**

**Precision Illumination Meter.**