As a corollary to the use of the first Laplacean curve, it may be added that no longer the arithmetic mean and the standard deviation, but the median, and the arithmetic mean error u are the significant constants of the distribution. The value of u is found from k, since $u = 1/k = 1.76$, giving a standard deviation of $u\sqrt{2} = 2.49$, whereas computation from the moments direct gave $\sigma = 2.36$ (class intervals).

It might be added that possibly a dissection of the observed frequency curve into two normal curves, by means of Pearson's nonic might give a good representation, but the minimum number of constants required in that case is three (if the curve is considered symmetrical), as against only one for the first Laplacean.

[1] These PROCEEDINGS, **15**, 120–125 (1929).

[2] Cf. Stromberg, *Mt. Wilson Contrib.* No. 210, 1921; Luyten, these PROCEEDINGS, **9**, 317 (1923); also *Harvard Annals*, **85**, 97 (1923).

THE APPLICATION OF PHOTOELECTRIC CELLS SENSITIVE IN THE INFRA-RED TO STELLAR PHOTOMETRY

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During the past fifteen months I have been investigating the possibility of using caesium oxide on silver photo-cells in stellar photometry. I have found that these cells may be used to measure very small light intensities with a high degree of precision when sufficiently cooled.

Caesium oxide on silver photo-cells having the two electrodes at the same end were found to have an extremely large leak at room temperature. Dr. C. H. Prescott, Jr., of the Bell Telephone Laboratories in New York, who made the cells I am now using, very kindly made up one with the electrodes coming out at opposite ends. It was noticed that this leak was apparently unchanged but when the polarity was reversed it was very greatly reduced. Dr. Prescott then suggested that perhaps cooling would help decrease the current, which flowed when no visible radiation was incident on the cathode of the photo-cell. We will define this current as "dark current."

I was given the opportunity to follow up this suggestion at the Sloane Physics Laboratory in January, 1931. When the cell was cooled to $-10°$C. the dark current was reduced to less than the sensitivity limit of the galvanometer used. This limit was 3×10^{-11} amperes. Kingsbury and Stilwell, also of the Bell Laboratories (*Phys. Rev.*, **37**, 1549 (1931)) obtained very similar results using a sensitive galvanometer. Koller (*Phys. Rev.*, **33,** 1082(1929)) measured this dark current from caesium oxide on silver in a higher range of temperatures, 100° to 170°C.

A photoelectric photometer was then constructed in such a way that either liquid air or solid carbon dioxide could be used to cool the cell. Complete details of this photometer, together with astronomical data accumulated since last October will be given at a later date. It differs radically from former types in several respects. The photo-cell is made of soda-lime glass instead of fused quartz and is mounted in a thermos bottle. All drying is done quite simply with phosphorus pentoxide. Since the apparatus is attached to the Loomis telescope (a coelostat, the eye end of which is stationary) the task of mounting the apparatus was relatively simple. A specially sensitive Lindemann electrometer is used. It was then found that this dark current could be reduced, in some cases by a factor of more than ten thousand, by cooling the photo-cell with "dry ice." Aside from reducing this dark current to a value which would make stellar measurements possible, cooling stabilizes the photo-current and apparently raises the glow potential. This latter effect has not been thoroughly investigated from fear of damaging a good cell. No appreciable change in sensitivity occurs when the particular cell used is cooled from +5°C. to −40°C. The dark current increases with the voltage impressed on this cell in much the same way as does the photo-current. This would indicate that the two are similar in character. All the cells that I have used, and these include several different makes, reach a steady state in less than a half hour after icing.

None of these cells has a dark current greater than one division in six seconds after it has been cooled to approximately −40° when the cathode potential is a few volts under the glow potential for the cell in question. Since the capacity of the anode-electrometer system was found to be in the neighborhood of 9 cm., and one division per second corresponds to 0.028 volt/sec., this dark current is less than 5×10^{-14} amps. The cell which I am now using, by far the best in this respect, has a dark current which is less than 5×10^{-16} amps. at 135 volts, the highest voltage yet applied to this cell. The important feature of this dark current is that it seems to be very constant as long as the cell is in thermal equilibrium. In the case of the cell mentioned above, higher sensitivity than that obtained with a Lindemann electrometer could undoubtedly be used as far as trouble from the dark current is concerned.

The lens of the Loomis telescope has an aperture of 15 inches. An A0 star of the fourth visual magnitude will give 1 division per second. A fifth magnitude K0 star will give about the same deflection. However, the stability of the apparatus enables one to measure the intensities of fifth magnitude white stars or sixth magnitude red stars with considerable accuracy. The fact that the atmospheric absorption in the red is much less than that in the blue is obviously also an advantage. Readings taken over a period of a minute have an average deviation of about one second. Somewhat greater sensitivity could undoubtedly be attained by raising the cell voltage. However, until the need arises, this will not be done since it would involve some risk of spoiling an excellent photo-cell.

The point of maximum sensitivity for equal spectral energy is near 8000 Å. After the light from an A0 (white) star has penetrated the atmosphere, been reflected from a mirror and passed through several glass surfaces, about 55 per cent of the total effective energy is of longer wave-length than 6800 Å. For a K0 (yellow) star this ratio is about 75 per cent. When a filter is used which cuts off the energy at approximately 7800 Å, the total effective energy of a white star is reduced by about 80 per cent while that of a red star is reduced by approximately 64 per cent.

Actual observations have shown that the photoelectric current is at least very nearly proportional to the incident light intensity over a range of magnitudes extending from 3.0 to 6.5. The important point at present is that the same relative magnitudes are found for the same stars on different nights to within a high degree of accuracy.

I am very grateful to Dr. Schilt, then at Yale Observatory, now at Columbia University, for his many helpful suggestions and constant encouragement. The coöperation of the Bell Laboratories in general and of Dr. Prescott in particular made this work possible. The G-M Laboratories, Inc., in Chicago and the Westinghouse Laboratory in Pittsburgh also showed noteworthy spirit of coöperation.

THE ROTATIONAL STRUCTURE OF THE ULTRA-VIOLET ABSORPTION BANDS OF FORMALDEHYDE

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We have photographed the ultra-violet absorption bands of formaldehyde in the third order of the 40 ft. spectrograph of the Loomis Laboratory at Tuxedo[3] with a dispersion of about 0.4 Å per mm. The bands are practically completely resolved, and the lines are very sharp. Until now we have measured and studied the bands at 3520, 3430 and 3390 Å. Although not all details of the analysis have been completed yet, we think that the results obtained so far are of sufficient interest to justify their publication. Some of the minor details may require modification