NATIONAL BUREAU OF STANDARDS REPORT

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LUMINOSITY FILTER AND THERMOPILE FOR A PHYSICAL PHOTOMETER

by

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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● Office of Basic Instrumentation ● Office of Weights and Measures.

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Photometry and Colorimetry Section
Optics and Metrology Division

Sponsored by
Signal Corps Engineering Laboratories
Fort Monmouth, New Jersey

NBS

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This report describes development work on a luminosity filter and thermopile for a physical photometer in accordance with correspondence and Signal Corps Supply Agency purchase order 15618-PH-53-92(11419). National Bureau of Standards test number G-12419 covers this work.

1. MATERIAL

The Signal Corps furnished the following materials:

2 absorption cells
2 uranium glass filters
2 infrared-absorbing glass filters
1 thermopile, Eppley #2177

The National Bureau of Standards supplied the following materials:

1 liter of the liquid component. (one absorption cell was filled and the remainder sealed in a bottle).
1 circuit diagram
3 calibrated standard lamps

The measured glass filters and the thermopile have been marked G-12419.

2. MEASUREMENTS

The National Bureau of Standards made spectrophotometric measurements on one of each type of glass, determined the composition of a liquid component which, used with the two glass filters, would duplicate closely the luminosity curve of the CIE standard observer. Three standard lamps calibrated for luminous intensity in a specified direction were supplied by the NBS. The response of the thermopile when used with the luminosity filter was determined.

2.1 Spectrophotometric Data

The glass filters were measured on the General Electric and Beckman quartz photoelectric spectrophotometers. Measurements on the General Electric recording spectrophotometer were made with an effective spectral band of approximately 10 millimicrons of spectrum from 400 to 750 millimicrons and 20 millimicrons of spectrum from 730 to 1300 millimicrons. A comparable set of measurements was made on the Beckman spectrophotometer, but with much narrower slit widths. A hydrogen source was used for measurements below 400 millimicrons to the extinction point in the ultraviolet for each filter. The infrared absorbing glass was measured in the infrared to 1300 millimicrons, with use of a stray energy filter above 960 millimicrons.

The marked absorption cell was measured on the General Electric recording spectrophotometer only at wavelengths of 400 $m\mu$ and above because the strong absorption of the other components of the complete filter makes unimportant the values for the cell below 400 $m\mu$. Repeat measurements were made with the cell reversed in the sample compartment.

Values obtained at each 10 millimicron interval, corrected for wavelength, zero, and 100 percent errors, are given in Table 1.

2.2 Photometric Data

The three standard lamps were supplied by the National Bureau of Standards and their luminous intensity was measured by means of a calibrated physical photometer. The physical photometer is calibrated at periodic intervals against the basic lamp standards. This photometer, consisting of a thermopile and luminosity filter, is a modified form of the one described in NBS J. Research 27, 217 (September, 1941) RP1415.

The lamps were standardized while burning base down. The orientation was such that the plane containing the two lines etched on opposite sides of the bulb was parallel to the photometer axis, the line having the etched circle being turned away from the photometer. A diaphragm having an opening 2 1/2 centimeters high and 9 1/2 centimeters wide, centered with respect to the filament and located 4 1/2 centimeters from the center of the socket, was placed between the lamp and the photometer. The photometric distance was 1 meter. With the voltage held constant at the designated value, readings were taken of current and luminous intensity. The measurements were made in the order of the designated lamp numbers, the lowest lamp number being taken first. Three such sets of measurements were taken, the order of taking the readings being reversed in the second set and the results given in Table 2 are the averages of the 3 sets.

2.3 Thermopile Calibration

The luminosity filter was mounted immediately in front of the thermopile and the response in microvolts determined by using standard lamps. Corrections were made for the change in optical path caused by the complete luminosity filter and for the distance between the receiving surface and the cover glass. These corrections are of opposite sign. The total correction amounts to 1.13 centimeters and must be subtracted from the distance between the cover glass and source in determining the effective photometric distance when using the complete physical photometer. The receiving surface is 0.50 centimeter behind the cover glass. The calibration data for the luminosity filter and thermopile used together are given below in Section 3, Results, under 3.3 Response of Thermopile.

2.4 The Luminosity Filter

The complete luminosity filter consists of an infrared absorbing glass, a uranium glass, and the solution component used in the absorption cell of 5.00 centimeters length. The infrared absorbing glass is placed on the source side to reduce the heating effect of the radiant flux on the other components, while the uranium glass is placed on the thermopile side to minimize any fluorescence caused by radiant flux transmitted by the infrared absorbing glass and the solution component in the near ultraviolet range of the spectrum.

The composition of the solution to be used with the two glass components was determined from the data for copper sulfate and cobalt ammonium sulfate given in previous publications of the Bureau [1,2] and from unpublished data for the potassium dichromate. The

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1 Filters for the Reproduction of Sunlight and Daylight and the Determination of Color Temperature, Raymond Davis and K. S. Gibson. Miscellaneous Publication, Bureau of Standards, No. 114 (1931).

2 Spectral Energy Distribution of the International Commission on Illumination Light Sources A, B, and C, Raymond Davis, K. S. Gibson, G. W. Haupt, Journal of Research of the National Bureau of Standards, Vol. 50, No. 1, January 1953, RP2384.

solution component is made up as follows:

Copper sulfate ($CuSO_4 \cdot 5\ H_2O$)	17.00 grams
Cobalt ammonium sulphate ($CoSo_4(NH_4)_4SO_4 \cdot 6H_2O$)	2.10 grams
Potassium Dichromate ($K_2Cr_2O_7$)	.140 grams
Sulfuric acid (1.835 sp.g.)	10.00 cc
Distilled water to make 1 liter of solution	

3. RESULTS

3.1 Luminosity Filter

The measured values of transmittance for the two glass components and the absorption cell are given in the second, third and fourth columns of Table 1. The fifth column gives the calculated relative transmittance of the complete luminosity filter, and the CIE luminosity values appear in the last column of the Table. The values from column five are plotted in Figure I where the solid line is the CIE luminosity curve.

Table 1. Spectral Transmittance of Luminosity Filter.

Wavelength in millimicrons	Transmittance: Cell with distilled water	Transmittance: Infrared absorbing glass	Transmittance: Uranium glass	Transmittance: Luminosity filter (Relative to 555 mμ)	CIE luminosity curve (Relative to 555 mμ)
270	not meas-	0.000	0.000	0.000	0.000
280	ured below	.001	.000	.000	.000
290	400 mμ	.005	.000	.000	.000
300	--	.022	.000	.000	.000
310	--	.076	.000	.000	.000
320	--	.174	.000	.000	.000
330	--	.305	.000	.000	.000
340	--	.44	.000	.000	.000
350	--	.56	.001	.000	.000
360	--	.66	.020	.000	.000
370	--	.735	.110	.000	.000
380	--	.785	.145	.00009	.000
390	--	.809	.079	.0004	.000
400	0.910	.813	.021	.0012	.0004
410	.910	.812	.010	.0013	.0012
420	.910	.808	.013	.0021	.0040
430	.911	.811	.039	.0058	.0116
440	.912	.815	.127	.018	.023

450	.912	.817	.245	.037	.038
460	.913	.812	.320	.059	.060
470	.913	.821	.407	.105	.091
480	.914	.830	.399	.148	.139
490	.914	.838	.402	.211	.208
500	.914	.840	.47	.310	.323
510	.914	.838	.62	.492	.503
520	.914	.830	.78	.707	.710
530	.915	.826	.84	.849	.862
540	.915	.829	.859	.942	.954
550	.915	.835	.867	.996	.995
560	.915	.832	.872	.998	.995
570	.914	.822	.874	.950	.952
580	.913	.810	.876	.868	.870
590	.911	.793	.879	.757	.757
600	.908	.774	.883	.634	.631
610	.905	.751	.887	.505	.503
620	.905	.724	.890	.387 +	.381
630	.905	.692	.892	.275	.265
640	.904	.660	.894	.183	.175
650	.903	.628	.896	.113	.107
660	.902	.594	.898	.066	.061
670	.901	.557	.900	.035	.032
680	.900	.521	.903	.018	.017
690	.898	.478	.905	.0087	.0082
700	.893	.436	.907	.0041	.0041
710	.882	.395	.908	.0019	.0021
720	.864	.356	.908	.00092	.00105
730	.832	.321	.908	.00045	.00052
740	.808	.285	.907	.00023	.00025
750	.802	.250	.907	.00012	.00012
760	.802	.220	.908	.00007	.00006
770	.804	.192	.909		
780	.810	.165	.907		
790	.818	.140	.904		
800	.826	.119	.900		
810	.830	.100	.898		
820	.823	.084	.896		
830	.799	.069	.896		
840	.773	.056	.896		

850	.754	.045	.898
860	.744	.037	.900
870	.735	.029	.901
880	.720	.022	.900
890	.704	.018	.899
900	.682	.015	.897
910	.653	.012	.895
920	.602	.009	.893
930	.508	.008	.892
940	.378	.007	.893
950	.234	.006	.896
960		.005	.898
970		.004	.902
980		.003	.906
990		.002	.909
1000		.001	.911
1010		.000	.912
1020		.000	.914
1030		.000	.916
1040		.000	.917
1050		.000	.917
1060		.000	.917
1070		.000	.917
1080		.000	.917
1090		.000	
1100		.000	
to		.000	
1300		.000	

3.2 Values for Standard Lamps

The values for the standard lamps when aligned and diaphragmed as described above in Section 2. Measurements, under 2.2, Photometric Data, are given in Table 2.

Table 2. Values for Standard Lamps

Lamp Number	Volts (set)	Amperes	Candles in Specified Direction
NBS2882	105.00	3.985	975
NBS2883	105.00	3.985	991
NBS2884	105.00	4.115	1015

The values of candlepower are estimated to be uncertain by less than 3/4 percent.

3.3 Response of Thermopile

With the luminosity filter immediately in front of the thermopile the response was found to be .00229 microvolts per incident meter candle.

4. MEASURING CIRCUIT

A measuring circuit suitable for use with the thermopile was described in a paper presented at the Fall 1953 meeting of the Optical Society of America. A copy of the manuscript is attached and is considered to be part of this report but is not released for publication at this time.

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.00). Information on calibration services and fees can be found in NBS Circular 483, Testing by the National Bureau of Standards (25 cents). Both are available from the Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

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