April 11, 1945

COLORIMETRY, SPECTROPHOTOMETRY, AND PHOTOMETRY
Publications by the staff of the National Bureau of Standards for
1941 to 1944

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GENERAL INFORMATION

This Letter Circular is a list of publications appearing during the years 1941 to 1944, inclusive, on colorimetry, spectrophotometry, photometry, lighting, and related subjects. For earlier publications see NBS Letter Circulars LC628 (1939-1940) and LC398 (prior to 1939). Copies of LC398, LC628, and other Letter Circulars may be obtained without charge from the National Bureau of Standards.

Some of the publications in this list have appeared in the regular series of publications of the Bureau, and others in various scientific and technical journals. Unless specifically stated, papers are not obtainable from the National Bureau of Standards. In those references preceded by an asterisk (*), the publication either is of joint authorship with an outside agency or has been issued by an outside agency with which the Bureau has cooperated.

In general, the order of arrangement within each of the major sections listed above is as follows: (1) formal Government publications listed in order of series number, (2) formal publications appearing in outside journals, listed approximately in order of date of issue, and (3) in the first section, published abstracts of papers presented before meetings of technical societies.

Where the price is stated, the publication can be purchased from the Superintendent of Documents, Government Printing Office, Washington 25, D.C. Remittance should accompany order and should be made either by coupons obtainable from the Superintendent of Documents in sets of 20 for $1.00 and good until used, or by check or money order payable to his order. The prices given in this Letter Circular are for delivery to addresses in the United States and its territories and possessions and in certain foreign countries which extend the franking privilege. In the case of all other countries, one-third the cost of the publication should be added to cover postage.
Series letters with serial numbers are used to designate Bureau publications:

RP = Research Paper. These are reprints of articles appearing in the Journal of Research of the National Bureau of Standards.
C = Circular.
FS = Federal Specification.
CS = Commercial Standard.
LC = Letter Circular. Letter Circulars are obtainable without charge from the National Bureau of Standards.

The List of available Publications of the Department of Commerce, which includes all publications of the National Bureau of Standards that are still in print, is obtainable without charge on application to the Bureau.

For papers in the other scientific or technical journals, the names of the journal or of the organization publishing the article is given in abbreviated form, together with (usually) the volume number (underlined), page, and year of publication in the order named. The Bureau cannot supply copies of these journals, although in some cases reprints of the papers are still available and may be obtained on request to the authors. The journals may usually be consulted in the leading libraries. Copies of the Journal of the Optical Society of America and the Review of Scientific Instruments may be obtained from the American Institute of Physics, 57 East 55th Street, New York 22, N. Y.; ASTM publications may be obtained from the American Society for Testing Materials (ASTM), 260 South Broad Street, Philadelphia 2, Pa. Addresses for other journals are given in the references.

Those who wish to keep informed concerning work at the National Bureau of Standards should subscribe to the "Technical News Bulletin". It is a monthly publication listing all papers published by members of the staff, whether appearing in Bureau publications or in other journals. It contains abstracts of papers appearing in the Journal of Research of the National Bureau of Standards, notes on progress of work in the laboratories, important conferences at the Bureau, and other items of general interest. Subscriptions should be sent to the Superintendent of Documents, Government Printing Office, Washington 25, D. C. The price is 50 cents a year.
COLORIMETRY AND SPECTROPHOTOMETRY


A method is described for determining the reflectance of a sheet of material indirectly from measurements of the transmission of one and two sheets of it. The reflectance, $R_a$, is found from the expression:

$$R_a = \sqrt{1 - \left(\frac{T_a}{T_{2a}}\right)^2},$$

where $T_a$ and $T_{2a}$ are the measured transmissions. Comparisons of reflectances found in this way with those obtained by the General Electric recording spectrophotometer are presented, and discussion of the effects of changes in angular conditions of illuminating and viewing the samples is given together with a discussion of fluorescence errors.

Measurement of the fading rate of paints.

Panels prepared from several paints were exposed in each of two accelerated-weathering machines and out-of-doors. The changes in color, gloss, and appearance of the different panels were followed. The rates at which fading occurred from artificial and natural weathering were measured numerically and compared.

Fresnel reflection of diffusely incident light.

The fraction of incident light which is reflected at an interface between two media whose relative index of refraction is $n$ has been computed from the Fresnel formula for three angular conditions: (1) perpendicular incidence, (2) diffuse external incidence and (3) diffuse internal incidence. These results have been amplified by suitable interpolation and are tabulated for intervals of 0.01 throughout the range of $1.00 \leq n \leq 1.60$. 
Title

*Tristimulus specification of the Munsell Book of Color from spectrophotometric measurements.
Also J. Optical Soc. Am. 33, 355 (1943).

Tristimulus values X, Y, Z, and trilinear coordinates, x and y, are given for each of the 421 standards of the Munsell Book of Color for each of four illuminants - ICI Illuminants A and C, representative of incandescent-lamp light and average daylight, respectively, Illuminant "D" (lightly overcast north sky), and Illuminant "S" (extremely blue sky). Values of x and y for ICI Illuminant C are also plotted in large diagrams which serve as means for determining the Munsell notation and thereby the ISCC-NBS color name for any color whose trilinear coordinates and apparent reflectance are given.

Also J. Optical Soc. Am. 33, 627 (1943).

The color names consist of hue names such as red, pink, yellowish green, or purple without further modifiers since they are intended to differentiate lights chiefly according to hue. The hue names are among those used in the ISCC-NBS system (see RP1239) and carry the same meaning. The chromaticity ranges identified by each of these hue names are defined by areas on the ICI chromaticity diagram.

Also J. Optical Soc. Am. 32, 509 (1942), and (in abridged form) as part of Symposium on Color, published by the ASTM, March 5, 1941.

Three filters are described for use with a particular source and photocell to give a close approximation to an ideal artificial eye for color measurement. The resulting three source-filter-photocell combinations can be used to measure approximate tristimulus specifications, magnitudes of color difference, and values for whiteness and yellowness. A new uniform-chromaticness-scale coordinate system is described and typical data and work sheets show the use of the photoelectric tristimulus method for six different types of measurement.
Color charts: A descriptive list. NBS Letter Circular (September, 1941). (Supersedes LC526).

Color and legibility. NBS Letter Circular (August 1943). (Supersedes LC526).


This is a condensed version of the paper which first appeared as NBS Research Paper RP1545 in 1940. A null-type photoelectric instrument is described which is suitable for a number of uses.


Films of liquids can be flowed onto depolished plaques of black glass and used as standards of specular reflectance. The specular reflectances of these liquid films at 45°, 60° and 75° were computed as a function of refractive index by Fresnel's equation and are plotted on a large graph.


This paper is part of a Symposium on Color. The color systems whose inter-relations are indicated include: (1) the ICI standard coordinate system (2) linear homogeneous transformations thereof (a) for simplicity in computation, (b) for uniform chromaticity scales, and (c) for theories of color vision, (3) polar coordinate specifications such as that by dominant wavelength and purity, (4) systems of transparent color standards such as the Lovibond glasses and the Arny solutions, (5) systems of opaque color standards such as Lunsell, Ostwald, Maerz and Paul, and Ridgway, and (6) the ISCC-NBS method of designating color.

Introduction to color. Deane B. Judd. Part of Symposium on Color, published by the ASTM, March 5, 1941.

The following topics are treated briefly in the paper: psychological definition of color, attributes of
object color (hue, lightness, and saturation), modes of appearance (surface, transparent volume), technical definition of color, instrumentation (goniophotometer, spectrophotometer), color specification by combinations of lights (ICI standard observer and coordinate system, uniform-chromaticity-scale system, dominant wavelength and purity), and color specification by material standards.


Argument is presented to support the view that black and white are the terminal members of any series of gray colors perceived to belong to opaque surfaces, providing only that the apparent reflectances of these surfaces vary by a factor sufficiently large (between 10 and 100).


The proposed method is based upon the (α,β)-diagram which is related to the standard ICI coordinate system, yields approximately uniform chromaticity scales, and is conveniently adaptable to expressions of results obtained by any one of several recently developed photoelectric tristimulus colorimeters.

Methods of designating color. Deane B. Judd. The Bulletin of the American Ceramic Society (2525 N. High Street, Columbus 2, Ohio) 20, 375 (1941).

This paper is part of a Symposium on Color Standards and Measurements. The topics discussed in the paper are definitions of ideas of color, attributes of color perception, modes of appearance of object colors, limitations of color standards, and tristimulus specifications.


Colorblindness is of various types, and there is a greater or lesser adherence of groups of observers to these types. The most common are the two types of red-green blindness, protanopia and deuteranopia, and the corresponding types
of anomalous vision, protanomaly and deuteranomaly. Color blindness is usually congenital, but it may also be acquired as a result of injury or disease. Congenital red-green blindness and anomalous vision are much more prevalent among males than among females, and are regarded as sex-linked characteristics. Methods of predicting precisely the appearance of colors to red-green-blind observers are described with a view to their possible usefulness in the design and development of color-blindness tests.


Observers of both of the two common types of abnormal color vision might detect a position perfectly camouflaged for normal vision. The first type of observer, the anomalous trichromat, might detect spectral differences between object and background invisible to the normal observer. The second type of observer, the red-green-blind dichromat, might detect the position hidden in a pattern of exhibiting red-green differences more confusing to the normal observer than to the red-green-blind observer.


Colorimetry of pulp and paper by the spectrophotometer and by the photoelectric tristimulus method are discussed, together with the use of Munsell and Ostwald color systems. Evaluation of "whiteness" of paper and its relation to reflectivity of pulp for blue light is treated in some detail because of its connection with the saving of chlorine used as a bleach.

*Chapters from the forthcoming report of the Optical Society of America Committee on Colorimetry, J. Optical Soc. Am., as follows:

Chapter 2, The concept of color, 33, 544 (1943).
Chapter 5, Physical concepts: Radiant energy and its measurement, 34, 183 (1944).
Chapter 6, The psychophysics of color, 34, 245 (1944).
Chapter 7, Quantitative data and methods for colorimetry, 34, 633 (1944).
Chapter 8, Colorimeters and color standards, 35, 1 (1945).

This paper discusses the problem of obtaining agreement between different instruments built to measure 60° specular gloss. It is shown that differences in source and receptor field angles will cause differences in the results which such instruments give. These differences can be minimized in the low-gloss range by the use of uniformly calibrated low-gloss standards.


This is a condensed introduction to color vision including treatment of metamer, anomalous trichromatism, color-blindness, standard observer, visual colorimetry, photoelectric colorimetry, trichromatic production of pictures, tri-receptor mechanism and color theories (Young-Helmholtz, Ladd-Franklin, Hering, Müller), modes and attributes of color perception, retinal zones (perimetry), retinal adaptation (negative after-image, Bezold-Brücke phenomenon), and post-retinal adaptation (simultaneous color contrast, color transformation, memory color).


Different methods of aiming sunlight reflected from mirrors are described, and the effectiveness of each is discussed.

Abstracts on Colorimetry and Spectrophotometry:


The wavelengths given are superseded by those in the eighth reference below.


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**PHOTOELECTRY AND LIGHTING**

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<tr>
<th>Title</th>
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<tr>
<td>The daytime photoelectric measurement of cloud heights. Maurice K. Laufer and Laurence W. Foskett. J. Research NBS 26, 331 (1941).</td>
<td>RP1379</td>
<td>5¢</td>
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A photoelectric detector is described which was used with a modulated beam of light for the measurement by triangulation of the height of clouds during the daytime. An a-c mercury-arc lamp was used to obtain the modulated beam. The shot noise of the phototube, resulting from the relatively high brightness of daytime clouds, limits the detection. Dark overcast clouds at an elevation of 9,000 feet were detected.


A physical photometer has been constructed, consisting of a thermopile, a potentiometer, and a filter which has at each wavelength a transmission closely proportional to the ICI luminosity factor for that wavelength. This photometer gives results for colored lights or filters which are consistent with the ICI luminosity factors and which are more accurate than those obtained by visual observers when the photometric fields are not closely color-matched.

Fluorescent lamps. NBS Letter Circular (June 1941) LC652 Free

Incandescent electric lamps: Photometric standards distributed by the National Bureau of Standards. NBS Letter Circular (February 1942). (Supersedes LC220.) LC680 Free

Luminous and fluorescent paints. NBS Letter Circular (September 1942). (Supersedes LC678) LC703 Free


NBS letter discussing possible effects of fluorescent lighting upon vision. Lighting and Lamps 44, 14 (February 1944).


Airport lighting in the United States and Europe. F.C. Breckenridge. Illuminating Engineering (51 Madison Avenue, New York 10, N.Y.) 36, 1157 (December 1941).


Work is described leading to the use of flashing position lights for commercial aircraft. The National Bureau of Standards cooperated in this development.

SPECIFICATIONS AND STANDARDS CONTAINING COLORIMETRIC OR PHOTOMETRIC DATA.

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<td>Federal Specifications</td>
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<td>*Federal Specification for lamps; electric incandescent, large, tungsten-filament. April 8, 1942.</td>
<td>W-L-10le</td>
<td>5¢</td>
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<tr>
<td>*Current annual supplement to W-L-10le</td>
<td></td>
<td>5¢</td>
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<tr>
<td>*Current annual supplement to W-L-111b</td>
<td></td>
<td>5¢</td>
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<tr>
<td>*Federal Specification for flashlights; electric, hand.</td>
<td>W-F-421a</td>
<td>5¢</td>
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<tr>
<td>*Federal Specification for lamp-auxiliaries; fluorescent.</td>
<td>W-L-131</td>
<td>5¢</td>
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<tr>
<td>*Current supplement to W-L-131.</td>
<td></td>
<td>5¢</td>
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<tr>
<td>*Procurement Division Specification for lamps, electric, fluorescent; No. 570 (Obtainable from the Procurement Division, Treasury Department, Washington 25, D.C.)</td>
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Title | Series | Price
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*Federal Specification for enamel; interior, gloss, light-tints and white. | TT-E-506a | 5¢
*Federal Specification for paint, paste, resin emulsion, interior, light tints and white. | TT-P-88 | 5¢
*Federal Specification for paint, varnish, lacquer, and related materials; general specification for sampling and test methods. | TT-P-141a | 20¢

National Bureau of Standards

NBS Simplified Practice Recommendation, Color marking for anesthetic gas cylinders. | R176-41 | 5¢

Army and Navy Specifications

*Army-Navy Aeronautical Specification. Colors; aeronautical lights and lighting equipment; AN-C-56, July 25, 1942. (Obtainable from the Air Technical Service Command, Army Air Forces, Wright Field, Dayton, Ohio, the Bureau of Aeronautics, Navy Department, Washington 25, D. C. or The Airways Engineering Division, Civil Aeronautics Administration, Washington 25, D.C.)

This specification was approved by joint action of the War and Navy Departments and the Civil Aeronautics Administration for use in the procurement of aeronautical supplies; it covers the chromaticity and transmission requirements of equipment and lighting ware in four grades, A, B, C, and D, in descending order of transmission.


This specification was approved by the joint action of the War and Navy Departments and the Civil Aeronautics Administration for use in the procurement of aeronautical supplies. Specifications are given for general requirements of Class A, B, C, and D covers for allowable imperfections, chromaticity and transmission, heat resistance, impact strength, specific gravity, water absorption, etc., and references are made to
other specifications wherein detailed requirements are given for these particular properties.

*Army-Navy Aeronautical Specification. Lamps; all-glass sealed reflector; AN-L-23a. (Obtainable from either the Air Technical Service Command, Army Air Forces, Wright Field, Dayton, Ohio or the Bureau of Aeronautics, Navy Department, Washington 25, D.C.).

This specification was approved by joint action of the War and Navy Departments for use in the procurement of aeronautical supplies; it covers photometric measurements for candlepower performance and life tests of "sealed-beam" type lamps. Detailed requirements are covered by Army-Navy Aeronautical Standard drawings AN3126, AN3128, AN3129, and AN3130.


Specifications are given for total luminous transmission and cone-to-rod luminosity ratios for red silicate-enameled and transparent red lacquered globes.

*Navy Aeronautical Specification. Inspection of light-transmitting covers for aircraft lights; M-540, November 15, 1942. (Obtainable from the Bureau of Aeronautics, Navy Department, Washington 25, D.C.)

This specification supplements Specifications AN-C-56 and AN-C-70 and is primarily a set of instructions for the use of inspection equipment (comparator-photometers) provided by the Bureau of Aeronautics.

*Navy Aeronautical Specification. Emergency signaling mirror; NAVAER M-580a, June 20, 1944. (Obtainable from Bureau of Aeronautics, Navy Department, Washington 25, D.C.)

*Navy Aeronautical Specification. Tri-color approach light filter; NAVAER M-599, February 1, 1944. (Obtainable from the Bureau of Aeronautics, Navy Department, Washington 25, D.C.)

Chromaticity and transmission requirements are given for identification red, yellow and green, in accordance with
Specification AN-C-56; optical equipment for determining the width of one component of the filter is described.


*Corps of Engineers. Reflectorized coating systems (retro-directive); tentative specification No. T-1290, February 22, 1943. (Obtainable from the Office of the Chief of Engineers, War Dept., Washington 25, D.C.)

Office of Civilian Defense

*OCD standard specifications for window obscuration. Prepared by the Office of Civilian Defense Committee on Window Obscuration and the Protective Lighting Unit, Engineer Section (December 1943).

American Standards Association


The standard provides (1) for the use of a spectrophotometer, (2) for the reduction of spectrophotometric data by means of the ICI standard observer to luminous reflectance (or transmission) and to chromaticity coordinates (either x and y or dominant wavelength and purity), (3) for the use of the Munsell system of working standards of color, and (4) for the use of ISCC-NBS color designations wherever precision is not required.

*Photographic Flash Lamps. American War Standard of the American Standards Association (70 East 45th Street, New York 17, N.Y.), ASA-Z52.43-1944.

This standard has also been approved as Federal Specification W-L-122 and 1945 Supplement thereto, copies of which are obtainable from the Superintendent of Documents, Washington 25, D.C.

*Illuminating Engineering Nomenclature and Photometric Standards. (See under Illuminating Engineering Society, below.)
American Society for Testing Materials


*Specular gloss of paint finishes, tentative method of test for. ASTM designation D528-44T (revised from previous tentative methods published in 1939 and 1941).

*Daylight 45-degree, 0-degree apparent reflectance of paint finishes, tentative method of test for. ASTM designation D771-44T.

Illuminating Engineering Society


Association of American Railroads


Colorimetric specifications are given for red (including highway-crossing red), yellow, green, blue, purple, and lunar-white railroad signal colors, lenses, and standard glasses. Corresponding specifications for hand lantern globes are given in AAR Signal Section Specification 59-59.

Institute of Traffic Engineers


Colorimetric specifications are given for red, yellow, and green traffic signal colors, lenses, and standard glasses.
APPLICATIONS OF COLORIMETRY, FILTER PHOTOMETRY, OR SPECTROPHOTOMETRY TO CHEMICAL ANALYSIS

Title


Series RP1364 Price 5¢


Series RP1386 Price 5¢


Spectral transmittancy curves are given (350 to 1000 millimicrons) of nitrate solutions of lanthanum, cerium, praseodymium, neodymium, samarium, europium and gadolinium.


Series RP1424 Price 5¢

Spectral transmittancy curves from 400 to 750 millimicrons are shown.


Series RP1456 Price 10¢

Transmittancy curves are given from 350 to 1000 millimicrons.


Series RP1558 Price 5¢
Title

Basic ionization constant of metacresol-sulfonphthalein; pH values and salt effects.

Spectral transmittancy or absorption curves in the visible and ultraviolet are given for metacresol-sulfonphthalein in neutral, acid, and alkaline aqueous solutions.

MISCELLANEOUS

Distribution of ozone in the stratosphere:


Rate of oxidation of typical nonferrous metals as determined by interference colors of oxide films.

Spectral reflection curves are given of oxide films of various colors on nickel and copper.


Planckian distributions of radiant energy, relative to that for 350 millimicrons, are given at every 5 millimicrons from 230 to 350 millimicrons, at every 50°K from 2500° to 2900°K.

Series: RP1593  Price: 10¢

Title: Radiometry: Publications by the Staff of the National Bureau of Standards. NBS Letter Circular (February 1941). (Supersedes LC462).  

Series: LC0631  Price: Free

Title: Sun lamps, health lamps; carbon and mercury arc lamps. NBS Letter Circular (February 1941). (Supersedes LC462).  

Series: LC0631  Price: Free

Title: Sources of information on paint and related materials. NBS Letter Circular (November 1941).  

Series: LC0671  Price: Free

Title: Photoelectric cells; selenium cells; thermopiles. NBS Letter Circular (June 1942). (Supersedes LC515).  

Series: LC0686  Price: Free

Title: The standard samples of the National Bureau of Standards. H. A. Bright, Industrial Standardization and Commercial Standards Monthly (American Standards Association, 70 East 45th Street, New York 17, N. Y.) 12, 268 (October 1941).  

Series: LC0789  Price: Free


Series: LC0789  Price: Free

Title: The spectral transmission of several specimens of rubber are included.  

Series: LC0789  Price: Free


Series: LC0789  Price: Free

Title: The spectral absorption of butter oil, lard, cottonseed oil, and corn oil are illustrated.  

Series: LC0789  Price: Free