NATIONAL BUREAU OF STANDARDS REPORT

4296

SPECTROPHOTOMETRIC
AND
COLORIMETRIC
ANALYSIS
OF
SEVENTEEN GLASS FILTERS
DUPLICATING THE
RELOCATED AND RESPACED
UNION COLOR SCALE
FOR
LUBRICATING OIL AND PETROLATUM
FOR
ASTM COMMITTEE D-2
RESEARCH DIVISION IX
SUBMITTED BY
FISHER SCIENTIFIC CO.

by

John C. Schleter

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

AUTHENTICATED
U.S. GOVERNMENT
INFORMATION
GPO

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section is engaged in specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant reports and publications, appears on the inside of the back cover of this report.

Electricity and Electronics. Resistance and Reactance. Electron Tubes. Electrical Instruments. Magnetic Measurements. Process Technology. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat and Power. Temperature Measurements. Thermodynamics. Cryogenic Physics. Engines and Lubrication. Engine Fuels.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment. AEC Radiation Instruments.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Gas Chemistry. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Organic Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion.

Mineral Products. Porcelain and Pottery. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Heating and Air Conditioning. Floor, Roof, and Wall Coverings. Codes and Specifications.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. Components and Techniques. Digital Circuitry. Digital Systems. Analogue Systems.

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services.

Radio Propagation Engineering. Frequency Utilization Research. Tropospheric Propagation Research.

Radio Standards. High Frequency Standards. Microwave Standards.

- Office of Basic Instrumentation
- Office of Weights and Measures

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT 0201-20-0203

September 1955

NBS REPORT 4296

SPECTROPHOTOMETRIC
AND
COLORIMETRIC
ANALYSIS
OF
SEVENTEEN GLASS FILTERS
DUPLICATING THE
RELOCATED AND RESPACED
UNION COLOR SCALE
FOR
LUBRICATING OIL AND PETROLATUM
FOR
ASTM COMMITTEE D-2
RESEARCH DIVISION IX
SUBMITTED BY
FISHER SCIENTIFIC CO.

by

John C. Schleter
Photometry and Colorimetry Section
National Bureau of Standards

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

The publication, rep n part, is prohibited
unless permission is ndards, Washington
25, D.C. Such perm ort has been specifi-
cally prepared if th port for its own use.

Approved for public release by the director of the National Institute of Standards and Technology (NIST) on October 9, 2015

Spectrophotometric and Colorimetric Analysis of Seventeen Glass Filters Duplicating the Relocated and Respaced Union Color Scale for Lubricating Oil and Petrolatum

for
ASTM Committee D-2
Research Division IX

Submitted by
Fisher Scientific Co.

ABSTRACT

At the request of Research Division IX on Color, of ASTM Committee D-2 on Petroleum Products, a spectrophotometric and colorimetric analysis of a set of seventeen glass filters, submitted by the Fisher Scientific Co., has been carried out. These filters were manufactured to comply with the specifications of the relocated and respaced Union color scale. It was found that eight of the filters pass and eight of the filters fail to pass the specification. One single-component was too large to measure.

I. INTRODUCTION

In 1950, the National Bureau of Standards completed the derivation of a relocated and respaced Union color scale[1] (NBS Research Paper RP2103) to replace the original Union scale[2].

The Fisher Scientific Company procured several sets of glass filters manufactured to duplicate the relocated and respaced scale. One set of these filters, seventeen in number, were submitted to NBS through Research Division IX on Color, of ASTM Committe D-2 on Petroleum Products, to ascertain whether the filters complied with the specifications given in RP2103.

II. SPECTROPHOTOMETRIC MEASUREMENTS

Measurements of spectral transmittance of the glasses were made on a General Electric recording spectrophotometer[3,4] equipped with slits equivalent to approximately 10 millimicrons

of spectrum for the spectral region 400 to 750 millimicrons.

This instrument is designed to measure transmitting samples with a diameter of 25 millimeters or greater. It was therefore necessary, because of the small size of these filters, 16 millimeters in diameter, to modify the optical path of the instrument to reduce the beam size. A double convex meniscus lens of approximately +3 diopters and large enough to intercept both beams, was inserted into the optical path before the decentered lens of the instrument. This supplementary lens converged all of the incident light of the sample beam onto the sample and produced a similar shape and convergence in the comparison beam. The supplementary lens was mounted in a blackened brass ring which fitted in the decentered lens mount of the spectrophotometer. The sample holder was made from blackened-brass to both hold and position the sample and also serve as a diaphragm in the sample compartment of the spectrophotometer. No diaphragm was used on the comparison side of the instrument.

The calibration curves recorded on each graph sheet were as follows: the curve of a sample of Corning 512 didymium glass for the wavelength calibration; and the zero curve, and "Lens 100% Curve" for calibration of the photometric scale. The "Lens 100% Curve" was recorded with the supplementary lens and sample holder in place.

The spectral transmittances of the 30 components of Filters B(0.5) through Q(8.0) were measured by using the "normal" cam of the spectrophotometer which gives 0% to 100% for full scale of the graph sheet. The single component of Filter A(0.0), which is clear glass, was too large to fit in the special holder and was not measured.

In an attempt to obtain improved values of spectral transmittance, for low values of transmittance, a series of measurements was made for the uranium and selenium components (yellow and red "cut-off" controlling components) of Filters D(1.5) through Q(8.0), by using the "X5" cam which gives 0% to 20% for full scale of the graph sheet.

Subsequently, components of Filters D(1.5) through Q(8.0), which all contain two components, were measured in combination to determine the spectral transmittances of the filters directly. Measurements were made by means of both the "normal" and "X5" cams. For these measurements, a ring-shaped spacer of celluloid approximately 0.1$_2$ millimeters in thickness was inserted between the individual components to maintain an air space and avoid the presence of interference patterns which would have occurred if the components had been placed in contact.

III. SPECTROPHOTOMETRIC RESULTS

The spectrophotometric curves of each graph sheet were read at 10-millimicron intervals between 400 and 750 millimicrons, corrections being made for wavelength errors by comparing the known wavelengths of minimum transmittance of a Corning 512 didymium glass with those recorded on the graph sheets. The photometric scale was corrected by means of the "Lens 100% Curve" and the zero curve.

When the "X5" cam was used with the supplementary lens system, the stray light in the optical system of the instrument caused the zero curve to be recorded on the graph sheets at approximately 0.2% rather than at 0.0%, with a slight decrease towards longer wavelengths. The values of spectral transmittance of this "X5" cam zero curve were read and extrapolations made for the remainder of the visible spectrum in which the filters were transmitting. These values of the "X5" cam zero curve were then subtracted from the values of spectral transmittance of the filters in the usual way for the zero correction.

It was found that for very low values of transmittance (0.00% to about 0.05%) the "normal" cam data generally indicated lower values than the "X5" cam data. For this transmittance range the "X5" cam data were adopted. In the transmittance range between about 0.05% and 20.00% the "normal" cam and "X5" cam data were found to be in generally good agreement; and for this transmittance range an average of the two sets of data were used. Above 20.00%, of course, only "normal" cam data were available.

IV. COMPUTATION OF SPECTRAL TRANSMITTANCE FROM COMPONENT DATA

The spectral transmittance data of the individual components of the filters having two components were combined by multiplying together, at each wavelength, the transmittance data of each component to obtain the "computed" spectral transmittances of the filters. In performing these computations, four decimals were maintained for Filters B(0.5) through L(5.5) and six decimals were maintained for Filters M(6.0) through Q(8.0).

V. COLORIMETRIC RESULTS

The values of spectral transmittance of each filter were converted to values of luminous transmittance, Y, and chromaticity coordinates (x,y), in accord with the 1931 CIE standard observer and coordinate system for colorimetry[5] for CIE Source C (representing average daylight). The values of the chromaticity coordinates (x,y) were then transformed into the uniform-chromaticity-scale (UCS) system[6] for correlation with the specifications given in RP2103, by means of Equations (4), page 566, RP2103.

As in the computations of spectral transmittance of the filters from the data obtained from the individual components, four decimals were maintained for the computations of the chromaticity coordinates (x,y) of Filters B(0.5) through L(5.5), and six decimals were maintained for Filters M(6.0) through Q(8.0), to eliminate significant errors of rejection in the dark and red end of the scale. All of the computations of the chromaticity coordinates (r,b) were made with four decimals since in the final analysis only three decimals were reported.

When corrections for light losses due to reflections at the surfaces were attempted, it was noted that the corrected luminous transmittances of the filters having two components were all corrected to values higher than the maximum allowed in the specifications. The uncorrected values of luminous transmittance, however, generally were within the limits of the specification. Apparently, these filters were designed by the manufacturer to be used in uncemented combinations. It was for this reason that the direct measurements of spectral transmittance of the filters were made with the thin ring-shaped spacer between the components.

VI. ADOPTED VALUES

The values of the chromaticity coordinates (r,b), and luminous transmittances, Y, adopted for the set of filters were those obtained from values of spectral transmittance computed from the components rather than from the measured values obtained directly from the combined filters because the precision of the results was found to be greater.

The values the chromaticity coordinates (r,b), and the luminous transmittances, Y, for Filters B(0.5) through Q(8.0), obtained by the two methods, generally agree to within one in the last place for fifteen of the sixteen filters, the greatest deviation being 0.002 for the chromaticity coordinate, r, of Filter N(6.5).

The adopted values of the chromaticity coordinates (r,b), and the luminous transmittances, Y, together with the limits for each filter, are given in Table I.

Figure 1 shows the chromaticity coordinates, in the UCS system, of the duplicate filters of the relocated and respaced Union color scale. In this figure, it should be noted, the red axis, r, has been divided into three sections. The large open circles indicate the chromaticity tolerances.

Figure 2 shows, on a square-root scale, the luminous transmittances, Y, plotted against Union number. The open circles of varying size indicate the transmittance tolerances. The tolerance limits and luminous transmittances of Filters P(7.5) and Q(8.0) are plotted on an enlarged ordinate scale at the right-hand side of the figure.

From Table I and Figures 1 and 2, it can be seen that Filters E(2.0), F(2.5), G(3.0), H(3.5), I(4.0), J(4.5), and L(5.5) pass the specifications for both chromaticity and luminous transmittance. Filter B(0.5) is considered to pass the specifications even though the luminous transmittance is the maximum allowed. Note that the viewing conditions present in the ASTM Union Colorimeter require strict adherence to the chromaticity tolerances, but that the transmittance tolerances are probably more strict than necessary. Filters K(5.0), M(6.0), and N(6.5) fail to meet the chromaticity tolerances, and of these, Filters K(5.0) and N(6.5) fail to meet the transmittance tolerances while Filter M(6.0) falls at the transmittance limit. Filters C(1.0), D(1.5), and P(7.5) fail to meet the transmittance tolerances but pass the chromaticity tolerances. Filters O(7.0) and Q(8.0) fall at both the chromaticity and transmittance tolerance limits. Filter A(0.0) was not measured.

VII. SUMMARY

At the request of Research Division IX on Color, of ASTM Committee D-2 on Petroleum Products, a spectrophotometric and colorimetric analysis of a set of seventeen glass filters, submitted by the Fisher Scientific Co., has been carried out. From this study, it has been found that eight of the filters pass the specification for the relocated and respaced Union color scale, as given in NBS Research Paper RP2103. Three of the filters fail to meet the chromaticity tolerances, and of these three, two fail to meet the transmittance tolerances while one falls at the transmittance limit. Three filters fail to meet the transmittance tolerances but pass the chromaticity tolerances. Two of the filters fall at both the chromaticity and transmittance limits. The component of one single-component filter was not included in the measurements because of size.

The author wishes to express his thanks to Messrs. W. A. Hall and K. L. Kelly for their assistance in checking the data.

Table I

Chromaticity Coordinates in the UCS System (r,b), and Luminous Transmittances, Y, of Sixteen Glass Filters Submitted by the Fisher Scientific Co. Duplicating the Relocated and Respaced Union Color Scale for Lubricating Oil and Petrolatum.

Designation of Filter	Chromaticity Coordinates r Max.	r	r Min.	b Max.	b	b Min.	Luminous Transmittance Y Max.	Y	Y Min.
A(0.0)	0.445	----	0.433	0.102	----	0.090	0.95	----	0.89
B(0.5)	.468	0.461	.456	.071	0.066	.059	.89	0.89(*)	.83
C(1.0)	.495	.490	.483	.042	.035	.030	.80	.82 *	.74
D(1.5)	.527	.524	.515	.021	.012	.009	.70	.62 *	.64
E(2.0)	.558	.557	.546	.012	.001	.000	.58	.57	.52
F(2.5)	.588	.583	.576	.008	.001	-.004	.46	.45	.42
G(3.0)	.617	.612	.605	.007	.000	-.005	.33	.31	.29
H(3.5)	.646	.638	.634	.007	.000	-.005	.24	.23	.20
I(4.0)	.677	.671	.665	.007	.000	-.005	.163	.159	.141
J(4.5)	.709	.708	.697	.007	.000	-.005	.117	.109	.101
K(5.0)	.742	.729 *	.730	.006	.000	-.006	.087	.088 *	.075
L(5.5)	.776	.770	.764	.006	.000	-.006	.063	.059	.053
M(6.0)	.811	.795 *	.799	.006	.000	-.006	.044	.044(*)	.036
N(6.5)	.847	.832 *	.835	.006	.000	-.006	.029	.030 *	.023
O(7.0)	.883	.871(*)	.871	.006	.000	-.006	.018	.018(*)	.014
P(7.5)	.921	.912	.909	.006	.000	-.006	.0089	.0098 *	.0073
Q(8.0)	.962	.950(*)	.950	.006	.000	-.006	.0028	.0028(*)	.0022

* Filter fails to fall within tolerance limits.

(*) Filter falls on tolerance limit.

FIGURE 1

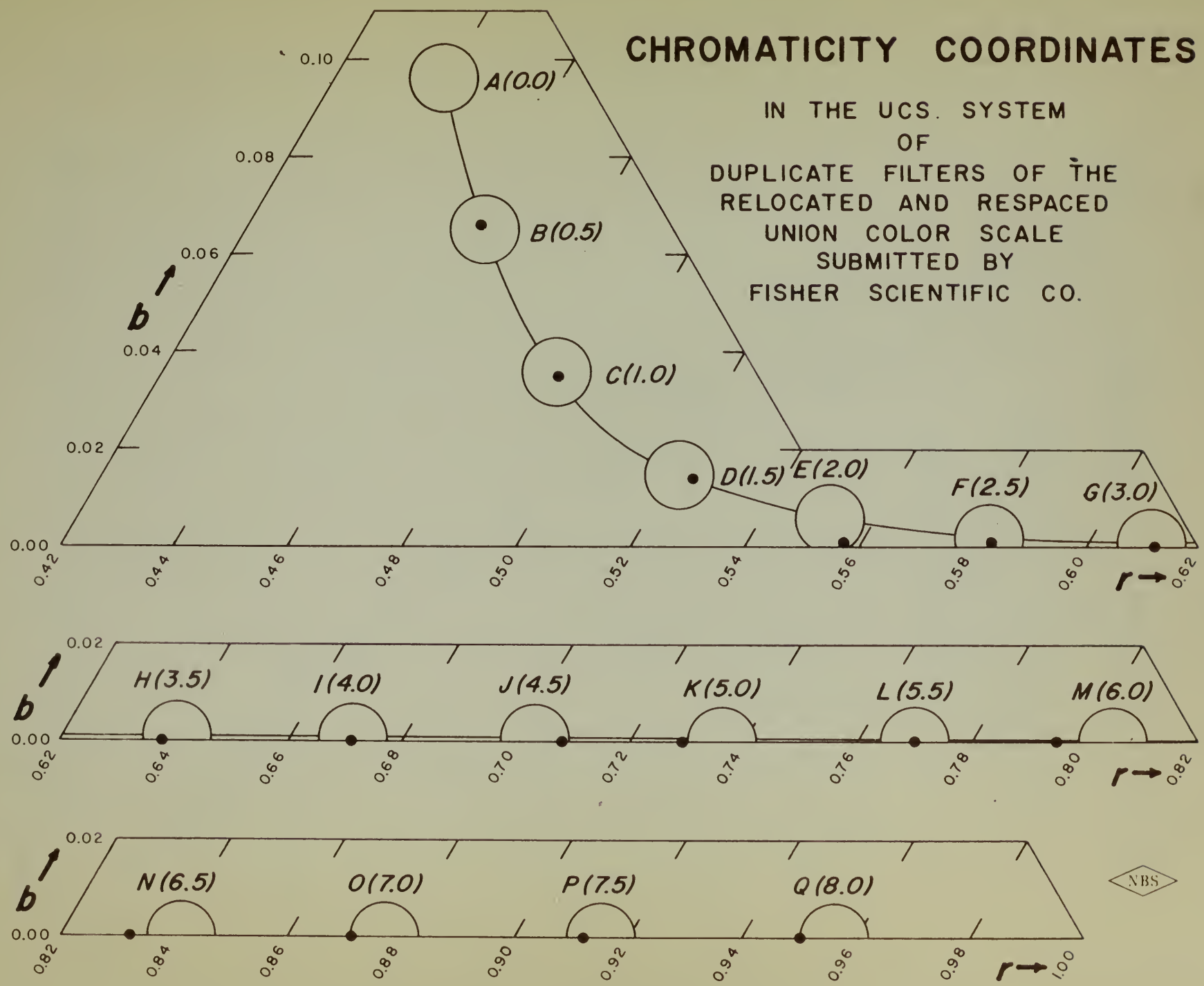
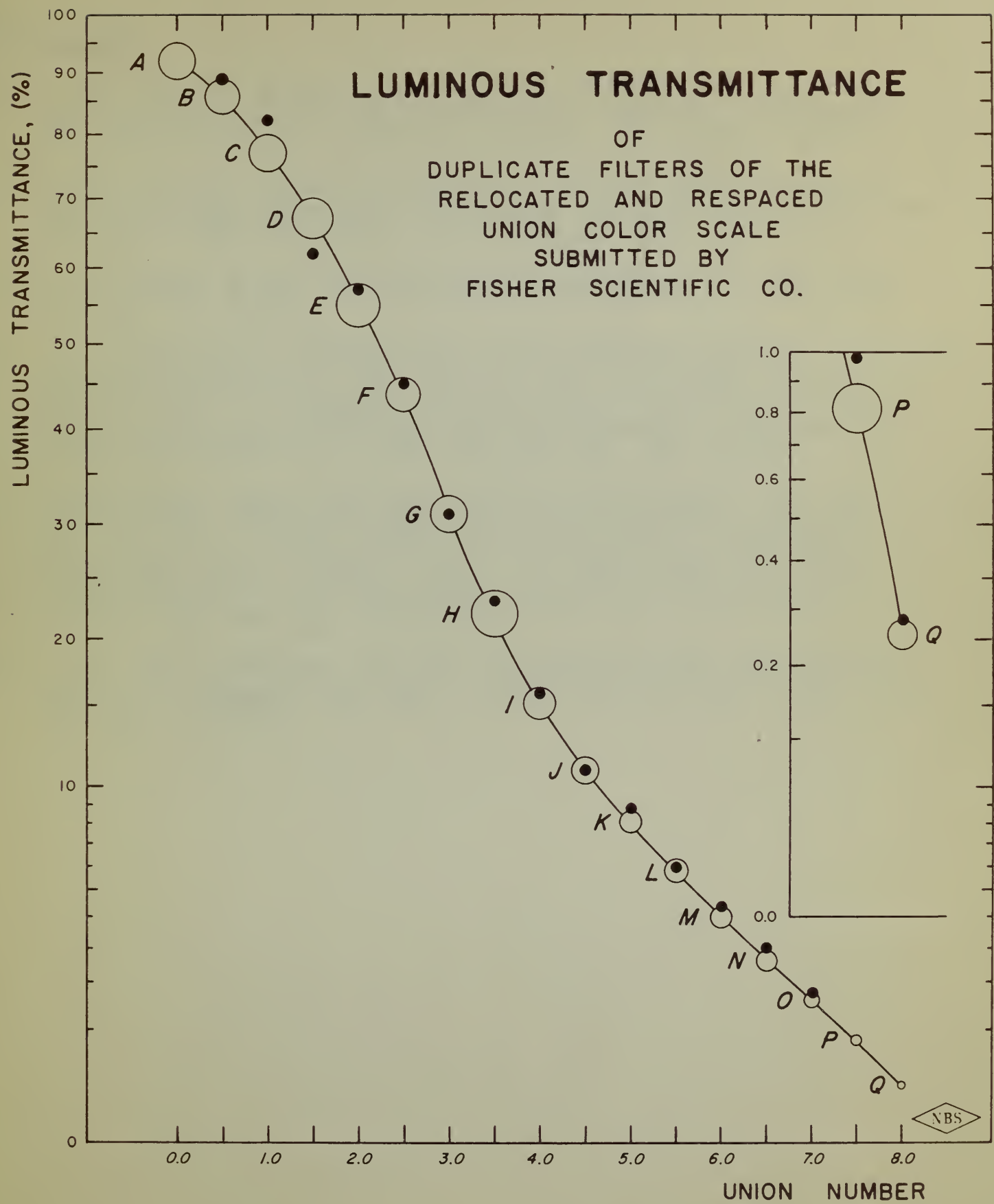

CHROMATICITY COORDINATES
IN THE UCS. SYSTEM
OF
DUPLICATE FILTERS OF THE
RELOCATED AND RESPACED
UNION COLOR SCALE
SUBMITTED BY
FISHER SCIENTIFIC CO.
A(0.0)
B(0.5)
C(1.0)
D(1.5)
E(2.0)
F(2.5)
G(3.0)
H(3.5)
I(4.0)
J(4.5)
K(5.0)
L(5.5)
M(6.0)
N(6.5)
O(7.0)
P(7.5)
Q(8.0)
b
r
0.00
0.02
0.04
0.06
0.08
0.10
0.42
0.44
0.46
0.48
0.50
0.52
0.54
0.56
0.58
0.60
0.62
0.64
0.66
0.68
0.70
0.72
0.74
0.76
0.78
0.80
0.82
0.84
0.86
0.88
0.90
0.92
0.94
0.96
0.98
1.00
NBS

FIGURE 2


LUMINOUS TRANSMITTANCE
OF
DUPLICATE FILTERS OF THE
RELOCATED AND RESPACED
UNION COLOR SCALE
SUBMITTED BY
FISHER SCIENTIFIC CO.
LUMINOUS TRANSMITTANCE, (%)
UNION NUMBER
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
NBS

REFERENCES

1. D. B. Judd, L. Plaza, M. A. Belknap, A suggested relocation and respacing of the Union Colorimeter scale for lubricating oil and petrolatum, J. Research NBS 44, 559 (1950), RP2103.

2. ASTM Tentative method of tests for color of lubricating oil and petrolatum by means of ASTM colorimeter, ASTM Designation: D155-45T, ASTM standards, part III-A, p. 839, (1946).

3. A. C. Hardy, A new recording spectrophotometer, J. Opt. Soc. Am. 25, 305 (1935).

4. J. L. Michaelson, Construction of the General Electric recording spectrophotometer, J. Opt. Soc. Am. 28, 365(1938); also K. S. Gibson, and H. J. Keegan, Calibration and operation of the General Electric recording spectrophotometer of the National Bureau of Standards, J. Opt. Soc. Am. 28, 372 (1938).

5. Proceedings, Eighth Session, Commission Internationale de L'Eclairage, Cambridge, England, September 1931, p. 19 to 29; also A. C. Hardy, Handbook of Colorimetry, Cambridge, Technology Press, (1936); also D. B. Judd, The 1931 I.C.I. standard observer and coordinate system for colorimetry, J. Opt. Soc. Am. 23, 359 (1933).

6. D. B. Judd, A Maxwell triangle yielding uniform chromaticity scales, J. Research NBS 14, 41 (1935) RP756; also J. Opt. Soc. Am. 25, 24 (1935).

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 ($1.25) and its Supplement ($0.75), available from the Superintendent of Documents, 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.

NBS