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

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Spectrophotometric
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Analysis
of
Seventeen Glass Filters
Duplicating the
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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 Min.	b Max.		b Min.	Luminous Transmittance Y Max.		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.

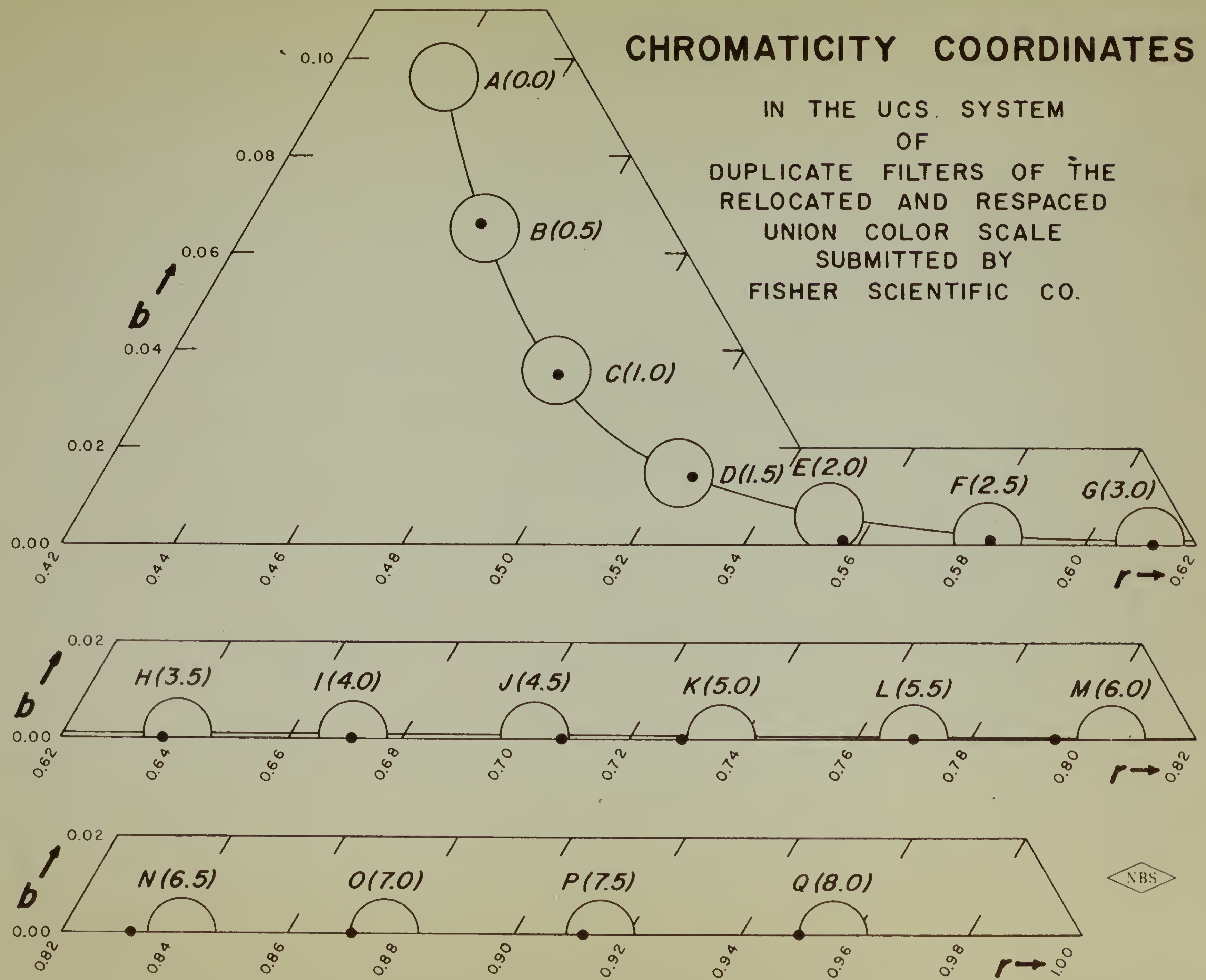
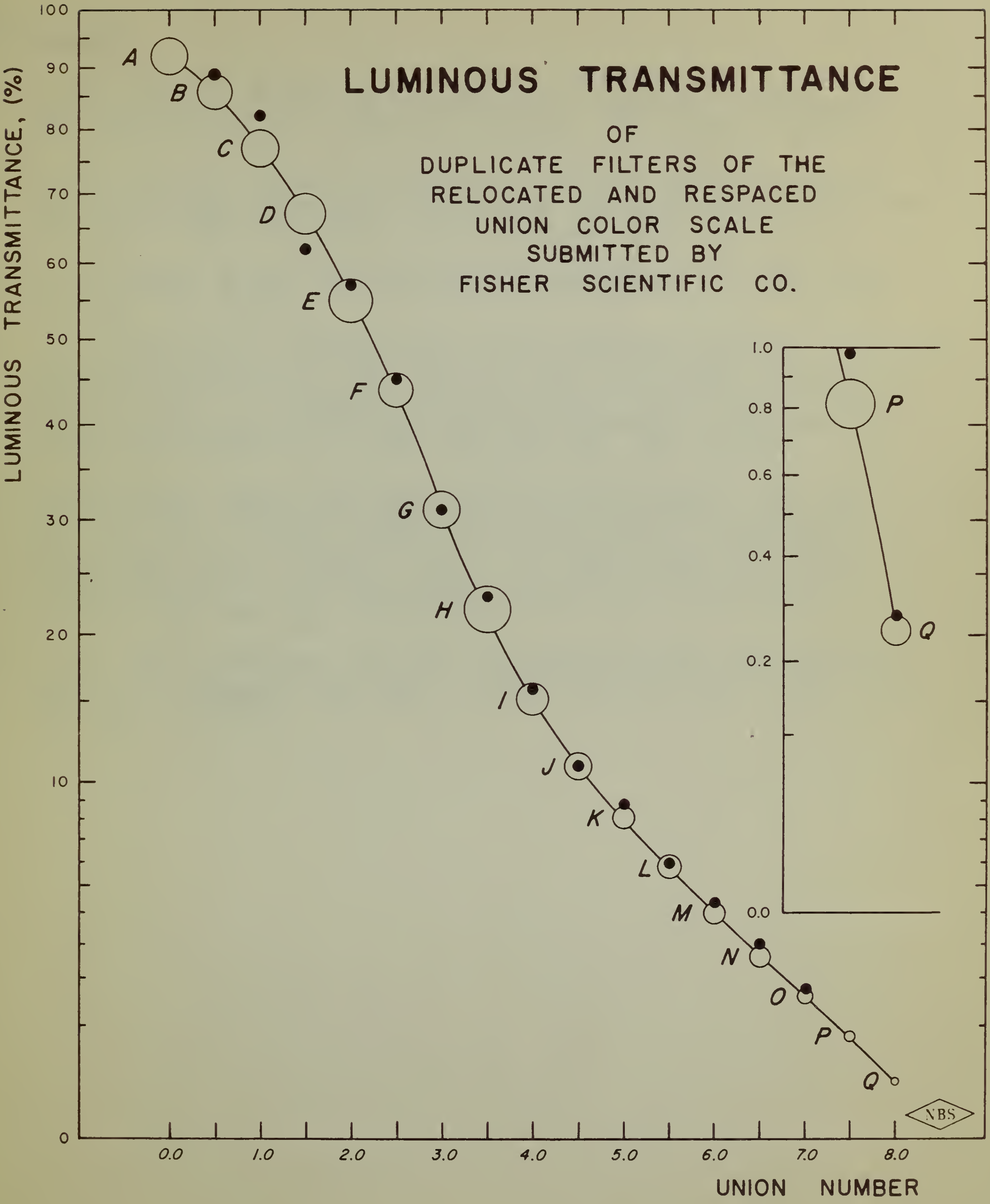


FIGURE 2



LUMINOUS TRANSMITTANCE
OF
DUPLICATE FILTERS OF THE
RELOCATED AND RESPACED
UNION COLOR SCALE
SUBMITTED BY
FISHER SCIENTIFIC CO.
LUMINOUS TRANSMITTANCE, (%)
UNION NUMBER
100
90
80
70
60
50
40
30
20
10
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
1.0
0.8
0.6
0.4
0.2
0.0
NBS

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THE NATIONAL BUREAU OF STANDARDS

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