NATIONAL BUREAU OF STANDARDS REPORT

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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 HELLIGE, INC.

by

John C. Schleter

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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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 HELLIGE, INC.

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NBS

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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 Hellige, Inc.

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 Hellige, Inc., has been carried out. These filters were manufactured to the specifications given in NBS Report 2012, modified in regard to the last two filters by letter to Research Division IX. From the data of this analysis, it is found that all of the seventeen filters now pass the required tolerance limits, both for chromaticity and transmittance.

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 glass filters of the original Union color scale were measured by the Bureau in 1929[3].

In the attempt to obtain glass filters meeting the specifications given in RP2103, Hellige, Inc. was contacted early in 1951, and agreed to submit to the Bureau, at the request of Research Division IX, twelve glass filters which were to be close matches to the original Union color scale. From the data of spectral transmittance of the components of these filters, the author formulated the designs for sixteen filters to satisfy the specifications for the relocated and respaced color scale. These design data were given in NBS Report 2012[4].

Using these design data, Hellige, Inc. prepared a set of seventeen filters (sixteen filters of the color scale and one modified filter) and submitted them, through Research Division IX, to NBS in June 1953, to ascertain whether these

filters complied with the specifications of RP2103. The filters were submitted in uncemented component form with the exception of components whose thicknesses were greater than that of the stock glasses. For these components several pieces of the same type of glass were submitted in cemented form.

II. SPECTROPHOTOMETRIC MEASUREMENTS

The measurements of spectral transmittance of the glasses were made on a General Electric recording spectrophotometer[5,6], equipped with slits equivalent to approximately 10 millimicrons of spectrum for the spectral region 400 to 750 millimicrons.

These measurements were made on the filters by the procedure given in Section III, pages 2 and 3, NBS Report 2012. The components of the filters were combined to give results equivalent to cemented filters by using a film of glycerine between individual components to remove the light losses due to reflections at the surfaces. When the spectrophotometric data were reduced and the colorimetric analysis completed, it appeared that half of the filters failed to pass the specifications of RP2103. These results were given in NBS Report 2935[7].

Spectrophotometric measurements were then made on the individual components, in order to obtain data from which to make the modifications to the filters. Measurements for each filter were made on the same spectrophotometric graph sheet, both for the separate components and also for the combined filter with a glycerine film between components. These measurements served as a check on the previous measurements.

By using the data of these measurements, modifications of the designs were attempted. It was found that the results obtained by computation, from the individual components, of the chromaticity coordinates and luminous transmittances of the filters which appeared to fail, did not agree with the data obtained from direct measurements of the combined filters with a glycerine film between components.

The discrepancies were believed to be caused by the following: - (1) incomplete coverage of the glycerine film between the individual components, (2) the reduction in the sensitivity of measurements for low values of transmittance when the two supplementary lenses were used, and (3) the difficulty in reproducing the same positioning of the two lenses in the optical path of the spectrophotometer for successive measurements.

A new supplementary lens system was developed using only one double convex menicus lens of approximately +3 diopters, placed before the decentered lens of the spectrophotometer, and large enough to intercept both beams. This supplementary lens was mounted in a blackened brass ring which fitted in the decentered lens mount of the spectrophotometer. A new 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.

Tests of this new single supplementary lens system were made by using glass samples large enough to be measured with and without the supplementary lens system and having spectral transmittances similar to the components of the filters of the color scale. Measurements were also made on these same glasses by means of a Beckman Model DU quartz spectrophotometer. The analysis of these data showed good agreement, within the experimental error, between measurements made with and without the single supplementary lens system in place. Furthermore an improved sensitivity of measurement for low values of transmittance seems to have resulted from the use of this single supplementary lens system. For these reasons, the single supplementary lens system was used for the remainder of the measurements.

The procedure as given in Section III, pages 2 and 3, NBS Report 2012, was further modified by the omission of the measurement of the "True 100% Curve", as the "Lens 100% Curve" only was used for the calibration of the spectrophotometric graph sheets.

The components of the eight filters, which seemed to fail the specifications, submitted in cemented form were taken apart and cleaned previous to making further measurements. The spectral transmittances of all of the filters, whether or not they appeared to fail or pass the specifications were remeasured by the new procedure.

Subsequently, the components of the filters were cemented together with Canada balsalm to form the set of 17 filters. Measurements of spectral transmittance were then made on the cemented filters. The procedure used for these measurements was the same as that used for the components, with the addition of a series of measurements made with a "X5" cam, which gives 0% to 20% for full scale of graph sheet, rather than 0% to 100% full scale as obtained with the "normal" cam.

This series of measurements was made in an attempt to obtain improved values of spectral transmittance of the cemented filters in the range between 0% and 2%.

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, as previous described, 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 for very low values of transmittance (0.0% to about 0.2%) that 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 0.2% and 20.0% 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 20.0%, of course, only "normal" cam data were available.

IV. COMPUTATION OF SPECTRAL TRANSMITTANCE FROM COMPONENT DATA

The data of spectral transmittance of the individual components of the filters were combined by means of Equation (10), page 5, NBS Report 2012, to obtain the "computed" spectral transmittances of the various filters. In performing the 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), for reasons given below.

V. COLORIMETRIC RESULTS

The values of spectral transmittance for 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[8] 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[9] for correlation with the previous data, by means of the equations given on page 3, NBS Report 2935.

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 chromaticity coordinates (x,y) of Filters B(0.5) through L(5.5), and six decimals were maintained for the computations 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 3 decimals were reported.

VI. MODIFICATIONS TO DESIGN DATA

As a result of the measurements made on the components and the cemented filters, it was found that only the last two filters of the scale, Filters P(7.5) and Q(8.0), failed to pass the specifications. The design data for these two filters were modified by increasing the thickness of the red component of each filter as follows: Filter P(7.5), 0.663_3 mm rather than 0.457 mm; and Filter Q(8.0), 1.13_2 mm rather than 0.87_1 mm. These modified thicknesses were reported to Research Division IX at the meeting of October 4, 1954, and also by letter to the secretary on November 30, 1954.

The new components were received in February, 1955, and measurements made on them later in the year.

VII. ADOPTED VALUES

The values of the chromaticity coordinates (r,b), and luminous transmittance, Y, adopted for the set of seventeen glass filters of the color scale were those obtained from values of spectral transmittance computed from the components rather than from the measured values obtained directly from the cemented filters because the precision of the results was found to be greater. The values of the chromaticity coordinate, r, for Filters B(0.5) through O(7.0), obtained by the two methods,

generally agree to within 0.001 for twelve of the fifteen filters, the greatest deviation being 0.003 for Filter L(5.5). No measurements were made on cemented Filters P(7.5) and Q(8.0), since measurements made directly with similar cemented filters were found to be not reproducible.

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 all seventeen of the filters pass the chromaticity specifications as given in RP2103. The luminous transmittances of all of the filters fall within the transmittance specifications, with the exceptions of Filters H(3.5) and J(4.5) which are considered to pass even though the value of transmittance are the maximum allowed in the specification. 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.

VIII. SUMMARY

At the request of Research Division IX on Color, ASTM Committee D-2 on Petroleum Products, a spectrophotometric and colorimetric analysis of a set of seventeen glass filters, submitted by Hellige, Inc., has been carried out. From this study, it has been found that all seventeen glass filters pass the specifications for the relocated and respaced Union color scale as given in NBS Research Paper RP2103. It is planned that these filters will be retained at this Bureau as the master standards of this color scale.

The author wishes to express his thanks to Miss M.A. Belknap for making all of the measurements by means of the Beckman Model DU spectrophotometer, and to Dr. G. Wyszecki, guest worker at the National Bureau of Standards, Miss G. M. Haas, and Messrs. K. L. Kelly and W. A. Hall for their assistance in computing and checking the data.

Table I

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

Designation of Filter	Chromaticity Coordinates r			b			Luminous Transmittance Y		
	Max.		Min.	Max.		Min.	Max.		Min.
B(0.5)	0.468	0.461	0.456	0.071	0.066	0.059	0.89	0.88	0.83
C(1.0)	.495	.488	.483	.042	.035	.030	.80	.77	.74
D(1.5)	.527	.518	.515	.021	.016	.009	.70	.66	.64
E(2.0)	.558	.550	.546	.012	.008	.000	.58	.55	.52
F(2.5)	.588	.576	.576	.008	.004	-.004	.46	.43	.42
G(3.0)	.617	.609	.605	.007	.002	-.005	.33	.32	.29
H(3.5)	.646	.639	.634	.007	.002	-.005	.24	.24	.20
I(4.0)	.677	.668	.665	.007	.001	-.005	.163	.162	.141
J(4.5)	.709	.700	.697	.007	.000	-.005	.117	.117	.101
K(5.0)	.742	.733	.730	.006	.000	-.006	.087	.086	.075
L(5.5)	.776	.766	.764	.006	.000	-.006	.063	.060	.053
M(6.0)	.811	.804	.799	.006	.000	-.006	.044	.042	.036
N(6.5)	.847	.840	.835	.006	.000	-.006	.029	.027	.023
O(7.0)	.883	.874	.871	.006	.000	-.006	.018	.016	.014
O(7.0)**		.875			.000			.017	
P(7.5)	.921	.914	.909	.006	.000	-.006	.0089	.0078	.0073
Q(8.0)	.962	.956	.950	.006	.000	-.006	.0028	.0025	.0022

**Modified filter submitted by Hellige, Inc. to reduce overall thickness.

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