CANDLEPOWER DISTRIBUTION AND COLOR CHARACTERISTICS OF A DOUBLE OBSTRUCTION LIGHT

by

Robert T. Vaughan

to

Airways Engineering Division
Office of Federal Airways
Civil Aeronautics Administration
THE NATIONAL BUREAU OF STANDARDS

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- Office of Basic Instrumentation
- Office of Weights and Measures
CANDLEPOWER DISTRIBUTION AND COLOR CHARACTERISTICS
OF A DOUBLE OBSTRUCTION LIGHT

by

Robert T. Vaughan
Photometry and Colorimetry Section
Optics and Metrology Division

NBS Test 21A-7/55

to

Airways Engineering Division
Office of Federal Airways
Civil Aeronautics Administration
Department of Commerce

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
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1. SCOPE

This report presents the results of a study of the candlepower distribution and color characteristics of a double obstruction light. The study was made primarily to provide a basis for evaluating the performance of a neon obstruction light relative to that of the incandescent obstruction lights in common use. The characteristics of the neon obstruction light, designed for use on the catenary of a transmission line, have been reported in NBS Report 4441.

2. DESCRIPTION OF EQUIPMENT TESTED

The equipment tested, shown in figure 1, was taken from stock at Washington National Airport and consists of:

(A) A double obstruction light fitting manufactured by the A.G.A. division of the Elastic Stop Nut Corporation, Elizabeth, N. J. The fitting bears the following marking: "ELIZABETH A'G' A NEW JERSEY."

(B) Two red cover glasses, each a cylindrical fresnel lens closed at the top.

One glass, designated for the purposes of this test as "lens A", is marked

"AP 3522-2-R
K
Made in U.S.A."

This glass was presumably manufactured by Kopp Glass, Inc., Swissvale, Pa. It has inside vertical prisms designed to eliminate the shadows of the lamp filament supports, and it is approximately 4 inches in effective height and 3 1/2 inches in outside diameter at the center belt.
The other glass, designated as "lens E", is marked "PYREX T.M.REG." On the underside of the flange the following marking appears:

"PYREX T.M. REG. U.S. PAT. OFF. MADE IN U.S.A. 530018"

This glass was presumably manufactured by the Corning Glass Works, Corning, N. Y. It is approximately 4" in effective height and 4" in outside diameter at the center belt.

(C) Three G.E. 111A 21/TS traffic signal lamps rated at 111 watts, 120 volts.

3. TEST PROCEDURE

The three lamps were seasoned at their rated voltage, 120 volts, and the total luminous flux from each was measured in a 60-inch integrating sphere at energizing voltages of 110 volts, 115 volts, and 120 volts. The values recorded were converted to "lumens per watt", and, as shown in figure 2, a graph of lumens per watt vs. energizing voltage was plotted for each lamp. The abscissa of the intersection of each of these curves with the curve representing the rated lumens per watt indicates the voltage at which each lamp should be operated to assure that it would be operating at its rated efficiency and hence at its normal color temperature. All candlepower and color measurements were made with each lamp operating at the test voltage so determined. Since no method is provided for focussing the unit, it was tested as received.

To provide measured horizontal and vertical rotations of the test unit, the unit was mounted in a special fixture on the table of a goniometer. The primary axis of rotation was horizontal and normal to the photometric axis. With the goniometer set at the 0°.0° position the fitting was mounted with the axes of the lenses lying in a plane perpendicular to the photometric axis, and with the axis of the right-hand lens, as viewed from the photocell, coincident with the vertical axis of the goniometer. The lenses were oriented so that the notches in the flange of each were in the transverse plane and the lettering on the top of the lenses was right side up when viewed from the photometer side of the goniometer. The lamp-lens combination to be measured was mounted in the right-hand position on the fitting, and the remaining lens, with no lamp, was mounted in the left-hand position.
The measurements were made with an automatic photometer, the recording element of which is a Leeds & Northrup recording potentiometer driven in synchronism with the goniometer table on which the unit under test is mounted. The photometric distance was 10.0 meters.

The photometer was calibrated with standard filter No. 3639 and with standard lamp No. NBS 3315 at a distance of 2.0 meters. The calibration includes a correction factor which is the ratio of the rated lumens of the lamp to the lumens produced by it when operating under the test conditions at its rated color temperature. This calibration has been recorded on the candlepower distribution chart as a line showing the candlepower of the test unit which would give an illumination at the photocell equivalent to that given by the standard lamp multiplied by the correction factor.

Since the luminous transmittance of the type of red glass of which the lenses are made is a function of its temperature, a record was made to determine the time required after the lamp was energized for the transmittance of the lens to reach equilibrium. This record, shown in figure 3, indicates that at an ambient temperature of 75°F the transmittance of the lens became stabilized after the lamp had been operated at its test voltage for a period of about 40 minutes. Each lamp-lens combination was operated, therefore, at its test voltage for a period of at least one hour before the candlepower measurements were recorded.

Measurements were then made of the following lamp-lens combinations in the order indicated.

<table>
<thead>
<tr>
<th>Measurement No.</th>
<th>Lamp No.</th>
<th>Lens</th>
<th>Traverse</th>
<th>Figure No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>A</td>
<td>Vertical at 0° Horiz.</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>A</td>
<td>Horizontal at +7.0° Vert.</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>A</td>
<td>Vertical at 0°</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>A</td>
<td>Horizontal at +7.0° Vert.</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>A</td>
<td>Vertical at 0°</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>A</td>
<td>Horizontal at +9.5° Vert.</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>B</td>
<td>Vertical at +8.5° Vert.</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>B</td>
<td>Vertical at 0°</td>
<td>11</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>B</td>
<td>Horizontal at +9.7° Vert.</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>B</td>
<td>Vertical at 0°</td>
<td>13</td>
</tr>
<tr>
<td>11</td>
<td>3</td>
<td>B</td>
<td>Horizontal at +8.8° Vert.</td>
<td>14</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>B</td>
<td>Set of 8 Vert. traverses</td>
<td>15</td>
</tr>
<tr>
<td>13</td>
<td>3</td>
<td>B</td>
<td>at 45° Horiz. intervals</td>
<td>16</td>
</tr>
<tr>
<td>14</td>
<td>3</td>
<td>A</td>
<td>Set of 8 Vert. traverses</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>at 45° Horiz. intervals</td>
<td></td>
</tr>
</tbody>
</table>
Because lamp No. 3 was found to most nearly approximate the *average* of the three lamps, it was selected for the two sets of vertical traverses, measurements No. 13 and 14. Vertical angles above the horizon were considered as positive angles; those below the horizon, as negative angles.

Using a Lummer-Brodhun photometer head, trained observers compared the chromaticity of the light from the test unit with that transmitted from a standard lamp at 2350°K through standard filters whose chromaticity coordinates for light of that color temperature are known.

4. RESULTS

The maximum candlepower for each lamp-lens combination was found to be as follows:

<table>
<thead>
<tr>
<th>Lamp</th>
<th>Lens</th>
<th>Max cp.</th>
<th>Vert.</th>
<th>Horiz.</th>
<th>Fig. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>104</td>
<td>+7.0°</td>
<td>0°</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>102</td>
<td>+7.9°</td>
<td>172°</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>115</td>
<td>+6.5°</td>
<td>225°</td>
<td>17</td>
</tr>
<tr>
<td>1</td>
<td>B</td>
<td>90</td>
<td>+8.5°</td>
<td>30°</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>63</td>
<td>+9.7°</td>
<td>177°</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>B</td>
<td>78</td>
<td>+8.8°</td>
<td>348°</td>
<td>15</td>
</tr>
</tbody>
</table>

On the candlepower distribution charts, there is a small discrepancy between the calibration marks and the grids, amounting at most to 1.9%, but this can be disregarded in view of the large variations in the candlepower of the unit with different lamps and lenses.

In figure 17, the narrow peaks in the candlepower distribution curves occurring between the vertical angles +82° and +85° are due to an image of the C-9 filament formed by the top section of lens A. Since this region is one of little importance, the variations in the candlepower due to the image are of little significance.

The results of the chromaticity comparisons are shown in figures 13 and 19. The chromaticities of the standard filter and lamp combinations are shown in the figures as circles. The chromaticity of the test unit differs from each of the known chromaticities in the sense indicated by the arrow in each case.
The chromaticity of the light transmitted by each of the lenses using a lamp of the recommended type at its rated lumens per watt was found to be within the limits for aviation red as defined in Specifications AN-C-56, Fed. Std. No. 3, and MIL-C-25050 (ASG).

5. DISCUSSION

There is a considerable difference between the transmittance of pale-limit red glassware and that of ware of minimum acceptable transmittance. This difference in transmittance causes a corresponding difference in the candlepower of the units on which the glassware is used. It is desirable, therefore, to know how the two lenses measured compare in transmittance with the average for each type to be expected in service in order to know how to interpret the measured values given in this report.

A good approximation to the transmittances for the measured lenses can be estimated from the results of the color tests. Studies of the characteristics of selenium glass filters have shown a correlation between their redness and transmittance, the relationship depending upon the color temperature of the light source. The color temperature, in turn, is a function of the lamp efficiency. The normal color temperature for a gas-filled tungsten lamp operating at the rated lumens per watt of the test lamp (11.7 lpw) is 2750°K. For a light source of this color temperature, the color of lens A is characteristic of glass having a transmittance ratio of 0.18 and that of lens B corresponds to glass having a transmittance ratio of 0.12.

Obstruction light lenses are classed in the color specifications as thicksectioned ware for which the transmittance requirements of Grade D are stipulated. This requirement allows a minimum transmittance ratio of 0.130 for a light source of 2854°K (Spec. AN-C-56, Table IV, Non-diffusing ware, Type I.) With pale-limit ware, the transmittance ratio may be as high as 0.31 which is 2.4 times the minimum.

The transmittance value estimated for lens B would drop even more below the minimum permitted by the specifications if the transmittance measurements were made with a light source of color temperature 2850°K as prescribed in the specifications.
On the basis of the approximate estimates made above, the candlepower of lens B should be regarded as a minimum for incandescent obstruction light units of its design, while the candlepower of lens A is approximately 0.6 of the maximum to be expected from the palest acceptable lenses of its type.
DOUBLE DESTRUCTION LIGHT CHARACTERISTICS OF THREE G.E. 111A-21/T8 LAMPS Lumens vs. Voltage Lumens Per Watt vs. Voltage

Hundreds of Lumens

- Lumens Per Watt

Ran No. 1  Lamps No. 2 & 3

Ran No. 1  Lamps No. 2 & 3

Ran.

110  112  114  116  118  120

Applied Voltage: Volts

NBS Test 21A-7/55 Figure 2
DOUBLE OBSTRUCTION LIGHT
DECREASE IN CANDLEPOWER DURING FIRST HOUR OF OPERATION

Lamp 3, Lens A

Calibration
113.4 C

Candlepower (Candles)

Time: Minutes

NBS Test 21A-7/55

Figure 3
DOUBLE OBSTRUCTION LIGHT
VERTICAL CANDLEPOWER DISTRIBUTION
Lamp 1  Lens A
Horizontal Angle: 0°

Candlepower: Candles

Vertical Angle

NBS Test 21A-7/55  Figure 4
Figure 5
DOUBLE OBSTRUCTION LIGHT
VERTICAL CANDLEPOWER DISTRIBUTION
Lamp 2 Lens A
Horizontal Angle: 0°

NBS Test 21A-7/55
Figure 6
DOUBLE CONSTRUCTION LIGHT
HORIZONTAL CANDLEPOWER DISTRIBUTION
Lamp 2, Lamp 3
Vertical Angle: 7.9°

Calibration: 113.4°

Figure 7
DOUBLE CONSTRUCTION LIGHT
HORIZONTAL CANDLEPOWER DISTRIBUTION
Lamp 3, Lens A
Vertical Angle: 9.5°

Calibration
113.4 C

Figure 9

Horizontal Angle
DOUBLE OBSTRUCTION LIGHT
VERTICAL CANDLEPOWER DISTRIBUTION
Lamp I, Lens B
Horizontal Angle: 0°

Candlepower: Candles

-40° -20° 0° +20° +40° +60° +80°

NBS Test 21A-7/55
Vertical Angle

Figure 10
Double Obstruction Light
Vertical Candlepower Distribution
Lamp 2  Lens B
Horizontal Angle: 0°

Calibration

113.4 C.

Candlepower: Candles

Vertical Angle

NBS Test 21A-7/55

Figure 12
DOUBLE OBSTRUCTION LIGHT
VERTICAL CANDLEPOWER DISTRIBUTION
Lamp 3  Lens B
Horizontal Angle: 90°

Candlepower: Candles

Vertical Angle

NBS Test 21A-7/55 Figure 14

Calibration
113.4 C
DOUBLE OBSTRUCTION LIGHT
HORIZONTAL CANDLEPOWER DISTRIBUTION
Lamp 5 Lens B
Vertical Angle: 8.66

Figure 15
DOUBLE OBSTRUCTION LIGHT
EIGHT VERTICAL CANDLEPOWER DISTRIBUTIONS
Lamp 3  Lens B
Horizontal Interval: 45°

Calibration
113.4 C

Candlepower: Candela

Vertical Angle

NBS Test 21A-7/55

Figure 16
DOUBLE OBSTRUCTION LIGHT
EIGHT VERTICAL CANDLEPOWER DISTRIBUTIONS
Lamp 3  Lens A
Horizontal Interval: $45^\circ$

Calibration
113.4 C

NBS Test 21A-7/55

Figure 17
DOUBLE OBSTRUCTION LIGHT
CHROMATICITY OF LENS A
Red Portion of C.I.E. Diagram

NBS 3201 (Near Match)
NBS 3151
NBS 3503
NBS 3502
AN-C-56
MIL-C-25050 (ASC)
Fed. Spec. No. 7

NBS Test 22A-7/55 Figure 18
DOUBLE DESTRUCTION LIGHT
CHROMATICITY OF LENS B
Red Portion of C.I.E. Diagram

NBS 3503
NBS 3151 (Near Match)
NBS 3128

AN-C-556
MIL-C-25250 Q (ASG)
Fed. Std. No. 3

NBS Test 21A-7/55
Figure 19
THE NATIONAL BUREAU OF STANDARDS

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