FEDERAL STANDARD

# COLORS, AERONAUTICAL LIGHTING

*This standard was approved on the above date by the Commissioner, Federal Supply Service, General Services Administration, for the use of all Federal agencies.*

## 1. SCOPE AND CLASSIFICATION

1.1 **Scope.**—This standard defines the color requirements for aeronautical lights, gives the requirements for primary standard filters, and describes techniques of inspection.

1.2 **Classification.**

1.2.1 *Categories.* — Colors shall be furnished in the following categories as specified:

Category I.—Aviation colors:
- Aviation red.
- Aviation yellow.
- ~~Aviation green.~~
- Aviation blue.
- Aviation white.

Category II.—Identification colors:
- Identification red.
- Identification yellow.
- Identification green.
- Identification lunar-white.

Category III.—Signal colors:
- Signal red.
- Signal green.

1.2.1.1 *Purpose of category I, aviation colors.*—Aviation colors are intended for high-intensity long-range signal lights in which the primary consideration is that the light be seen, the secondary consideration is that its color be identified. If aviation colors are used in situations requiring positive color identification, relatively few colors are used at a time. For example, aviation white is not intended to be distinguishable from aviation yellow unless it is in juxtaposition with it. On these accounts, the aviation colors are defined in such a way that they may be produced from incandescent lamps by means of ware of relatively high luminous transmittance. Since such high transmittance requires that the spectral band transmitted must be relatively broad, aviation colors must necessarily be perceived as relatively unsaturated.

1.2.1.2 *Purpose of category II, identification colors.*—Identification colors are intended for signal lights in which the primary object is the identification of the color. Each of the identification colors usually must be distinguishable from each of the remaining identification colors at ranges not much less than the maximum. The definitions of identification colors therefore provide for the maximum chromatic distinction obtainable from ware transmitting relatively narrow spectral bands.

1.2.1.3 *Purpose of category III, signal colors.*—Signal colors are intended for purposes, such as daytime signaling, generally requiring properties intermediate between those of aviation and identification colors.

Note 1—Signal-green chromaticity requirements are the same as those of identification green; the transmittance requirements are based upon the use of plastic ware.

1.2.2 *Grades.* — This standard covers the transmittance requirements of four grades of light-transmitting ware: A, B, C, and D, in descending order of transmittance as specified in table I.

1.2.2.1 *Purpose of grade A.*—Grade A is to be used only when the highest possible transmittance is essential.

1.2.2.2 *Purpose of grade B.*—Grade B is suitable for pressed ware of a uniform thickness of not more than 6 millimeters (0.2 inch) throughout the working area, such as position-light and identification-light covers, smooth-obstruction-light covers, and filters for carrier approach lights.

1.2.2.3 *Purpose of grade C.*—Grade C is suitable for such blown ware as code-beacon and contact-light filters.

1.2.2.4 *Purpose of grade D.*—Grade D is suitable for thick-sectioned ware such as beacon lenses, including course lights, obstruction-light lenses, and contact-light lenses and also for filters for airport approach lights.

## 2. APPLICABLE SPECIFICATIONS AND REFERENCE PUBLICATIONS

2.1 **Specifications.**—There are no Federal specifications applicable to this standard.

2.2 **Reference publications.**—The following publications contain basic material pertinent to this standard.

2.2.1 *Psychophysics of Color,* by Committee on Colorimetry, Journal of the Optical Society of America, volume 34, page 245 (1944).

2.2.2 *Quantative Data and Methods for Colorimetry,* by Committee on Colorimetry, Journal of the Optical Society of America, volume 34, page 633 (1944).

2.2.3 *1931 ICI Standard Observer and Coordinate System for Colorimetry,* D. B. Judd, Journal of the Optical Society of America, volume 23, page 359 (1933).

2.2.4 *Colorimetry,* National Bureau of Standards Circular 478 (1950).

2.2.5 *Rectangular Uniform-Chromaticity-Scale Coordinates,* F. C. Breckenridge and W. R. Schaub, Journal of the Optical Society of America, volume 29, page 370 (1939).

2.2.6 *Tables for Transforming Chromaticity Coordinates from the ICI System to the RUCS System,* National Bureau of Standards Letter Circular LC897 (1948).

## 3. DEFINITIONS

3.1 **General definitions.**—Each of the following technical terms is used in this standard in the sense in which the term is defined in this section.

3.1.1 *Standard observer.*—The standard observer and coordinate system is that adopted by the International Commission on Illumination (ICI) at its Eighth Session at Cambridge, England, in 1931. (See 2.2.1, 2.2.2, 2.2.3, and 2.2.4.) This standard observer refers essentially to cone vision. Darkness adaptation does not prevent correct recognition of colored lights if intense enough to be seen by a light-adapted observer.

3.1.2 *Chromaticity.* — Chromaticity of a color is a combined attribute determined by its dominant wavelength (3.1.3) and excitation purity (3.1.4). Chromaticity limits are usually given in terms of coordinates (x, y) in the ICI standard coordinate system.

3.1.3 *Dominant wavelength.* — Dominant wavelength of a color is that wavelength of spectrum light which, when combined with neutral light in suitable proportions, matches the color. Neutral light is light for which the chromaticity coordinates are x equals 0.333 and y equals 0.333. Colors of the same dominant wavelength are perceived under ordinary viewing conditions as of nearly the same hue. The chromaticity coordinates of colors described as having the same dominant wavelength in the ICI standard coordinate system lie on a straight line passing through the neutral point and the point on the spectrum locus which represents the spectrum component.

3.1.4 *Excitation purity.*—Excitation purity is the ratio of the distance on the ICI standard chromaticity diagram between the neutral point and the sample point to the distance in the same direction between the neutral point and the spectrum locus or the purple boundary. Excitation purity may be indicated by the word "purity" alone (see 3.1.6).

3.1.5 *Hue.*—Hue is that attribute of a color which determines whether the color is perceived as red, yellow, green, blue, purple, or as an intermediate color. Colors which have no hue are called neutral colors. A great variety of qualities of light are perceived as neutral under various circumstances. In general, colors represented in the region of the chromaticity diagram near x equals 0.333 and y equals 0.333 may be considered as neutral colors under ordinary conditions of observation.

3.1.6 *Saturation.*—Saturation is that attribute of a color which determines whether the color is perceived as greatly or slightly different from neutral. Colors of low saturation have less prominent hue. If dominant wavelength and luminance of a color be held constant, the saturation of the perceived color is found to correlate with purity; that is, if the purity of the color is low, it will be perceived to have low saturation, and if it is of high purity, it will yield a highly saturated color perception. To make sure that the hue of a signal is sufficiently distinct, it is usually sufficient to specify a minimum value for the purity of its color.

3.1.7 *Luminance.* — Luminance (formerly called brightness) of a specimen is the luminous flux emitted, reflected, or transmitted per unit solid angle and per unit projected area of the specimen.

3.1.8 *Luminance ratio.*—Luminance ratio is the ratio of the luminance of a portion of a test piece of diffusing ware to the luminance of a corresponding portion of a standard piece of diffusing ware of the same design made from white or nearly white material of the same type as the test piece, when each is illuminated by the same or an equivalent light source.

3.1.9 *Luminous transmittance.*—Luminous transmittance is the ratio of the light flux emitted from the test piece to that incident on the opposite surface. Luminous-transmittance requirements are applicable to light-transmitting ware bounded by plane parallel faces or by cylindrical or spherical faces concentric with the light source.

3.1.10 *Transmittance ratio.* — Transmittance ratio is the ratio of the light flux transmitted by a test piece to the light flux transmitted by a standard piece of the same design made from colorless material of the same type as the test piece when each is similarly illuminated and viewed. The intensity of a signal light with a colorless lens may be multiplied by the transmittance ratio of a colored lens to obtain the intensity of the unit when the colored lens is employed.

3.1.11 *Color temperature.*—Color temperature of a light source is the temperature of a total (Planckian) radiator which has the same color as the source. Color temperature is usually expressed in degrees Kelvin (°K). The numerical value will depend on the value assigned to $C_2$ in Planck's radiation equation for the total radiator. Color temperatures of 2842°K., 2848°K., and 2854°K. will have the same spectral distribution when computed with values of $C_2$ equal to 14,320; 14,350; and 14,380, respectively. In this standard, nominal values of color temperature are given to the nearest 10°K.

**3.2 Basic definitions of colors.**

3.2.1 *Basic principle of color definition by means of chromaticity coordinates.*—For the usual conditions of observation, the color perceived to belong to a source of adequate intensity is determined by its chromaticity coordinates. It is therefore feasible to state chromaticity requirements for light signals by bounding acceptable areas on the chromaticity diagram, and the colors in this standard are so defined. Because the ICI coordinate system does not represent chromaticity differences uniformly, it is often convenient to transform the limits to the Rectangular Uniform-Chromaticity-Scale system (see 2.2.5 and 2.2.6). The corresponding limits for the two coordinate systems are shown in figures 1 and 3 (ICI) and figures 2 and 4 (RUCS).

3.2.2 *Aviation colors.* — Aviation colors shall conform to the fundamental colorimetric definitions specified in 3.2.2.1 to 3.2.2.7, inclusive.

Note 2.—These definitions are identical with those adopted at the fourth session of the Aerodromes, Air Routes and Ground Aids (AGA) Division of the International Civil Aviation Organization (ICAO) in November 1949, with the following exceptions: (1) The tolerances allowed for the pale limit for red and yellow are less than the ICAO tolerances; (2) The limits for blue follow the ICAO "recommend practice" instead of the "standard"; (3) The greenish and pinkish limits for white lie within the range permitted by ICAO. The colors aviation variable-yellow and aviation variable-white are intended only for lights employing incandescent-lamp sources with intensities controlled by varying the lamp currents and consequently the colors of the light signals.

3.2.2.1 *Aviation red.*

y is not greater than 0.335
(yellow limit)
z is not greater than 0.003
(pale limit)

3.2.2.2 *Aviation yellow.*

y is not less than 0.400
(red limit)
x is not less than 0.560
(green limit)
z is not greater than 0.010
(pale limit)

3.2.2.3 *Aviation variable-yellow.*

y is not less than 0.385
(red limit)
x is not less than 0.550
(green limit)
z is not greater than 0.010
(pale limit)

(See 3.2.2.7 for additional requirements when used with aviation variable-white.)

3.2.2.4 *Aviation green.*

x is not greater than 0.390 – 0.171 y
(yellow limit)
x is not greater than 0.100 + 0.410 y
(pale limit)
y is not less than 0.390 – 0.171 x
(blue limit)

3.2.2.5 *Aviation blue.*

x is not greater than 0.390 – 0.171 y
(red limit)
y is not greater than 0.400 – x
(pale limit)
y is not greater than 0.060 + 0.820 x
(green limit)
$\phi_r$ divided by $\phi_w$ is not greater than 0.015.

$\phi_w$ is the total flux of the light under consideration, and $\phi_r$ is that part of $\phi_w$ consisting of radiant flux of wavelength longer than 600 m$\mu$.

Note 3.—Identification red pale-limit standard filter, NBS 3113A, may be used for determining $\phi_r$.

3.2.2.6 *Aviation white.*

x is not less than 0.350
(blue limit)
x is not greater than 0.470
(yellow limit)
y – $y_0$ is not numerically greater than 0.03 x
(pink and green limits)

($y_0$ is the y coordinate of the Planckian radiator for a given x.)

3.2.2.7 *Aviation variable-white.*

x is not less than 0.350
(blue limit)
x is not greater than 0.560
(yellow limit)
$y - y_0$ is not numerically greater than 0.03 x
(pink and green limits)

($y_0$ is the y coordinate of the Planckian radiator for a given x.)

Note 4.—For discrimination between the colors aviation yellow and aviation white obtained from incandescent-lamp sources whose intensities are controlled by varying the lamp currents and consequently the colors of the sources, the following additional requirements will apply:

(*a*) The chromaticity of the yellow lights shall be represented by coordinates such that y is not greater than x minus 0.160 at any time when the chromaticity of the white lights is represented by coordinates for which x is greater than 0.470.

(*b*) The yellow lights shall be displayed simultaneously with and in close proximity to the white lights.

3.2.3 *Identification colors.* — Identification colors shall conform to the fundamental colorimetric definitions specified in 3.2.3.1 to 3.2.3.4, inclusive. These limits are shown graphically in figure 3.

3.2.3.1 *Identification red.*

y is not greater than 0.287
(yellow limit)
z is not greater than 0.001
(pale limit)

3.2.3.2 *Identification yellow.*

y is not less than 0.370
(red limit)
x is not less than 0.570
(yellow limit)
z is not greater than 0.005
(pale limit)

3.2.3.3 *Identification green.*

x is not greater than 0.312
(yellow limit)
x is not less than 0.796 – 1.200 y
(blue limit)
y is not less than 0.257 + 1.200 x
(pale limit)

3.2.3.4 *Identification lunar-white.*

x is not less than 0.240
(blue limit)
x is not greater than 0.440
(yellow limit)
$y - y_0$ is not greater than 0.015
(green limit)
$y_0 - y$ is not greater than 0.045
(pink limit)

($y_0$ is the y coordinate of the Planckian radiator for a given x.)

3.2.4 *Signal colors.* — Signal colors shall conform to the fundamental colorimetric definitions specified in 3.2.4.1 and 3.2.4.2.

3.2.4.1 *Signal red.*

y is not greater than 0.304
(yellow limit)
z is not greater than 0.001
(pale limit)

3.2.4.2 *Signal green.*

x is not greater than 0.312
(yellow limit)
x is not less than 0.796 – 1.200 y
(blue limit)
y is not less than 0.257 + 1.200 x
(pale limit)

## 4. REQUIREMENTS

4.1 **Ranges of illuminants.**—The illuminant color-temperature range for each functional lighting application shall be as given in table II, unless otherwise stipulated in the procurement specification.

4.2 **Assembled equipment.**—When lighting units not utilizing light-transmitting ware

are purchased under specifications referencing this standard, or when lighting units using incandescent lamps as illuminants are so purchased, and it is not practicable to inspect the light-transmitting ware by itself, the requirements for color shall apply to the complete unit.

**4.3 Transmittance or luminance.**—Specifications shall indicate whether ware must meet the luminous-transmittance, transmittance-ratio, or luminance-ratio requirements of table I. Ware not intended to alter significantly the light-flux distribution should be specified by luminous transmittance, and by table I would have to meet a requirement more strict by about 8 percent, due to reflection losses, than ware specified by transmittance ratio or luminance ratio. The limits for aviation white ware refer to transmittance ratio only.

4.3.1 *Filters.* — Nondiffusing ware (such as filters) whose shape does not affect significantly the light-flux distribution shall have luminous transmittance within the limits shown in table I for the grade and color specified.

4.3.2 *Refracting ware.*—Ware whose shape or surface character affects significantly the candlepower distribution, shall have a transmittance ratio within the limits shown in table I for the grade and color specified.

4.3.3 *Diffusing ware.*—Diffusing ware shall have a luminance ratio within the limits shown in table I for the grade and color specified.

TABLE I.—*Transmittance and luminance limits*
(Illuminant at 2850° K.)

| Grade | Red | Yellow and variable yellow | Green | Blue | Lunar white | White and variable white |
|---|---|---|---|---|---|---|
| A. Minimum acceptable luminous transmittance or transmittance ratio (for filters and refracting ware). | | | | | | |
| Aviation colors: | | | | | | |
| A | 0.200 | 0.600 | 0.225 | 0.026 | ------------- | ------------- |
| B | 0.175 | 0.500 | 0.200 | 0.022 | ------------- | 0.950 |
| C | 0.150 | 0.400 | 0.175 | 0.016 | ------------- | 0.925 |
| D | 0.130 | 0.300 | 0.150 | 0.008 | ------------- | 0.900 |
| Identification colors: | | | | | | |
| B | 0.048 | 0.400 | 0.048 | ------------- | 0.120 | ------------- |
| Signal colors: | | | | | | |
| B | 0.095 | ------------- | *0.190 | ------------- | ------------- | ------------- |
| B. Luminance-ratio limits (for diffusing ware). | | | | | | |
| Aviation colors: | | | | | | |
| B (min.) | ------------- | ------------- | ------------- | ------------- | ------------- | 0.800 |
| B (max.) | ------------- | ------------- | ------------- | ------------- | ------------- | 1.200 |
| Identification colors: | | | | | | |
| B (min.) | 0.048 | 0.400 | 0.048 | ------------- | 0.120 | ------------- |
| B (max.) | 0.120 | 1.000 | 0.120 | ------------- | 0.300 | ------------- |

* Can be met at present only with plastic ware.

TABLE II.—*Ranges of illuminants*

| Equipment | Color temperature range (°K.) |
|---|---|
| Approach lights, airport | 3200 to 1500 |
| Approach lights, carrier | 2850 to 1900 |
| Beacons | 3000 to 2850 |
| Boundary lights | 2850 to 2100 |
| Code beacons | 3000 to 2850 |
| Course lights | 3000 to 2850 |
| Contact lights | 2850 to 1500 |
| Identification lights | 2850 to 1900 |
| Obstruction lights | 2850 to 2100 |
| Position (running) lights | 2850 to 2360 |
| Range lights | 2850 to 2100 |
| Traffic-control lights | 2850 to 2360 |
| Signal lights | 2850 to 2360 |
| Special lights | Optional. |

## 5. SAMPLING, INSPECTION, AND TEST PROCEDURES

**5.1 General.**—Generally applicable methods of sampling, inspection, and tests are given below for use as a guide in the drafting of procurement specifications which will specify the exact procedures to be used.

**5.2 Sampling.**—Whenever practicable each piece should be inspected for conformity to the color requirements. Whenever it is impracticable to inspect each piece, the sampling should be done in such a manner as to include extremes of chromaticity and transmittance rather than in a random manner.

**5.3 Technique of inspection and test by means of working standards.**

5.3.1 *Basic principle of the method.*

5.3.1.1 *Chromaticity.*—The chromaticity of the light emitted by the equipment or transmitted by the cover under test may be determined by comparing the chromaticity of the emitted or transmitted light with light of known chromaticity, provided the directions and amounts of the perceived hue and saturation differences are such as to indicate definitely whether the cover conforms or does not conform to the color requirements. For example, a lamp-filter combination known to have chromaticity coordinates x = 0.157, y = 0.533 could be used to judge the conformity to identification green of equipment yielding either a close chromaticity match or a chromaticity perceived as both slightly yellower and slightly more saturated; this equipment would conform. But this source-filter combination would not permit a decision to be made regarding equipment yielding chromaticities perceived as less saturated, because the inspector would have no basis for judging whether the chromaticity departure is great enough to cause the chromaticity point (x, y) of the equipment to fall outside the area on the chromaticity diagram permitted by 3.2.3.3. A source-filter combination for which x = 0.200, y = 0.497 would serve as a saturation and hue-limit standard (called pale and blue limit) for identification green. It would permit an inspector to judge conformity or nonconformity of equipment yielding chromaticities both greener and slightly yellower than the standard, but if he perceived that the chromaticity of the test piece was considerably yellower and of about the same saturation he would not know whether it met the requirement that y be not less than 0.257 + 1.200 x. Several working standards of chromaticity are likely to be required by the inspector for each color.

5.3.1.2 *Transmittance.*—A standard filter of known luminous transmittance and of spectral characteristics similar to the test cover may be used in conjunction with a visual or photoelectric photometer to test a cover for conformity to the requirements of 4.3. The inspector has essentially to set the visual photometer to equality of luminance, or to use the photoelectric photometer for an analogous purpose.

5.3.2 *Selection of working standards.*—Working standard filters and color temperatures of sources to be employed for inspection should be specified in each procurement document. The chromaticity coordinates of the lamp-filter combination must lie within the

TABLE III.— *Primary standard filters*

| Color | Grades | Limit | Filter | Illuminant color temperature °K. | x | y | z | T. (2850° K.) |
|---|---|---|---|---|---|---|---|---|
| Aviation red | All | Pale and yellow | 3647A | 3000 | 0.665 | 0.335 | 0.000 | |
| | | Pale and yellow | 3647A | 2850 | 0.666 | 0.334 | 0.000 | 0.310 |
| | | * | 3647A | 2360 | 0.669 | 0.331 | 0.000 | |
| | | * | 3647A | 1900 | 0.674 | 0.326 | 0.000 | |
| | All | Pale and yellow | 3656A | 3000 | 0.666 | 0.334 | 0.000 | |
| | | Pale and yellow | 3656A | 2100 | 0.673 | 0.327 | 0.000 | |
| | All | Transmittance | 3218A | 2850 | 0.696 | 0.304 | 0.000 | 0.178 |
| | All | Transmittance | 3172A | 2850 | 0.702 | 0.297 | 0.001 | 0.150 |
| Aviation yellow | | Pale and green | (Filters not yet selected) | | | | | |
| | | Transmittance | | | | | | |
| | | Red | | | | | | |
| Aviation variable-yellow. | | Pale and green | (Filters not yet selected) | | | | | |
| | | Transmittance | | | | | | |
| | | Red | | | | | | |
| Aviation green | All | Pale | 7044A | 2850 | 0.258 | 0.437 | 0.305 | 0.243 |
| | | Yellow | 7044A | 2360 | 0.289 | 0.473 | 0.238 | |
| | All | Pale | 7346A | 2850 | 0.243 | 0.414 | 0.343 | 0.271 |
| | | * | 7346A | 2360 | 0.272 | 0.455 | 0.273 | |
| | All | Pale | 7356A | 3000 | 0.226 | 0.399 | 0.375 | |
| | | Yellow | 7356A | 2100 | 0.281 | 0.478 | 0.241 | |
| | All | Blue | 7321A | 2850 | 0.156 | 0.363 | 0.481 | 0.106 |
| | | * | 7321A | 2360 | 0.166 | 0.413 | 0.421 | |
| | All | Blue | 7327A | 3000 | 0.166 | 0.362 | 0.472 | |
| | | * | 7327A | 2100 | 0.195 | 0.457 | 0.348 | |
| | B, C, and D | Transmittance | 7322A | 2850 | 0.166 | 0.370 | 0.464 | 0.132 |
| | All | Transmittance | 7342A | 2850 | 0.205 | 0.400 | 0.395 | 0.200 |
| Aviation blue | All | * | 8219A | 3000 | 0.158 | 0.125 | 0.717 | |
| | | * | 8219A | 2850 | 0.160 | 0.133 | 0.707 | 0.039 |
| | | Pale and green | 8219A | 2360 | 0.169 | 0.167 | 0.664 | |
| | All | Transmittance | 8213A | 2850 | 0.148 | 0.084 | 0.768 | 0.020 |
| Identification red | All | Pale and yellow | 3113A | 2850 | 0.713 | 0.287 | 0.000 | 0.107 |
| | | * | 3113A | 1900 | 0.715 | 0.285 | 0.000 | |
| | B | Transmittance | 3055A | 2850 | 0.723 | 0.277 | 0.000 | 0.056 |

* See note at end of table.

TABLE III.—*Primary standard filters—Continued*

| Color | Grades | Limit | Filter | Illuminant color temperature °K. | x | y | z | $T_s$ (2850° K.) |
|---|---|---|---|---|---|---|---|---|
| Identification yellow. | All | Pale and green | 3955A | 2850 | 0.577 | 0.422 | 0.001 | 0.535 |
| | | * | 3955A | 1900 | 0.606 | 0.393 | 0.001 | |
| | All | Pale and green | 3964A | 2850 | 0.577 | 0.421 | 0.002 | 0.649 |
| | | * | 3964A | 1900 | 0.604 | 0.395 | 0.001 | |
| | All | Transmittance | 3840A | 2850 | 0.609 | 0.390 | 0.001 | 0.500 |
| | | Red | 3840A | 1900 | 0.627 | 0.372 | 0.001 | |
| Identification green. | | * | 6319A | 2850 | 0.273 | 0.639 | 0.088 | 0.134 |
| | All | Pale (yellow) and yellow | 6319A | 1900 | 0.312 | 0.631 | 0.057 | |
| | | * | 6327A | 2850 | 0.268 | 0.637 | 0.095 | 0.139 |
| | All | Pale (yellow) and yellow | 6327A | 1900 | 0.309 | 0.630 | 0.061 | |
| | B | Transmittance (yellow) | 6310A | 2850 | 0.216 | 0.699 | 0.085 | 0.054 |
| | All | Transmittance (yellow) | 6306A | 2850 | 0.212 | 0.693 | 0.095 | 0.049 |
| | All | Pale | 6700A | 2850 | 0.220 | 0.520 | 0.260 | 0.103 |
| | | Pale | 6700A | 1900 | 0.269 | 0.578 | 0.153 | |
| | All | Pale (blue) | 6916J-A | 2850 | 0.202 | 0.498 | 0.300 | 0.086 |
| | | * | 6916J-A | 1900 | 0.238 | 0.577 | 0.185 | |
| | All | Pale (blue) | 6917A | 2850 | 0.201 | 0.501 | 0.298 | 0.109 |
| | | * | 6917A | 1900 | 0.243 | 0.582 | 0.175 | |
| | All | Blue | 6905A | 2850 | 0.157 | 0.533 | 0.310 | 0.031 |
| | | * | 6905A | 1900 | 0.182 | 0.610 | 0.208 | |
| | B | Transmittance (blue) | 6905A | 2850 | 0.157 | 0.533 | 0.310 | 0.031 |
| Identification lunar-white. | All | * | 8449A | 2850 | 0.312 | 0.328 | 0.360 | 0.250 |
| | | Yellow | 8449A | 1900 | 0.440 | 0.398 | 0.162 | |
| | B | Transmittance | 8430A | 2850 | 0.270 | 0.286 | 0.444 | 0.167 |
| | | * | 8430A | 1900 | 0.398 | 0.378 | 0.224 | |
| Signal red | B | Pale and yellow | 3218A | 2850 | 0.696 | 0.304 | 0.000 | 0.178 |
| | | Transmittance | 3113A | 2850 | 0.713 | 0.287 | 0.000 | 0.107 |
| Signal green | B | Pale (yellow) and yellow | 6319A | 2850 | 0.273 | 0.639 | 0.088 | 0.134 |
| | B | Pale | 6700A | 2850 | 0.220 | 0.520 | 0.260 | 0.103 |
| | B | Pale (blue) | 6916J-A | 2850 | 0.202 | 0.498 | 0.300 | 0.086 |
| | B | Blue | 6905A | 2850 | 0.157 | 0.533 | 0.310 | 0.031 |
| | B | Transmittance | 6319A | 2850 | 0.273 | 0.639 | 0.088 | 0.134 |

* Although the filter is not a limit standard at this color temperature, the chromaticity coordinates are listed for information.

TABLE IV.—*Chromaticity tolerances for duplicates of primary standard filters*

| Color | Limit | Filter | Chromaticity tolerances (Illuminant 2850° K.) x | y |
|---|---|---|---|---|
| Aviation red | Pale and yellow | 3647A | 0.6635 ≤ x ≤ 0.6665* | 0.3335 ≤ y ≤ 0.3360* |
| | Pale and yellow | 3656A | 0.6660 ≤ x ≤ 0.6680 | 0.3317 ≤ y ≤ 0.3337 |
| Aviation yellow | Pale and green | | (Tolerances not yet determined) | |
| | Red and transmittance | | | |
| Aviation variable-yellow | Pale and green | | (Tolerances not yet determined) | |
| | Red and transmittance | | | |
| Aviation green | Pale | 7044A | 0.2575 ≤ x ≤ 0.2590 | 0.4365 ≤ y ≤ 0.4380 |
| | Yellow | 7356A | 0.2315 ≤ x ≤ 0.2335 | 0.4095 ≤ y ≤ 0.4115 |
| | Pale | 7346A | 0.2430 ≤ x ≤ 0.2445* | 0.4140 ≤ y ≤ 0.4155 |
| | Blue | 7321A | 0.1550 ≤ x ≤ 0.1570 | 0.3630 ≤ y ≤ 0.3640* |
| | Blue | 7327A | 0.168 ≤ x ≤ 0.172 | 0.374 ≤ y ≤ 0.378 |
| Aviation blue | Pale and green | 8219A | 0.159 ≤ x ≤ 0.161 | 0.130 ≤ y ≤ 0.133 |
| Identification red | Pale and yellow | 3113A | 0.7125 ≤ x ≤ 0.7150 | 0.2850 ≤ y ≤ 0.2870 |
| Identification yellow | Pale and yellow | 3955A | 0.5765 ≤ x ≤ 0.5770 | 0.4215 ≤ y ≤ 0.4235 |
| | Pale and yellow | 3964A | 0.5750 ≤ x ≤ 0.5785 | 0.4210 ≤ y ≤ 0.4223 |
| | Red and transmittance | 3840A | 0.6090 ≤ x ≤ 0.6105 | 0.3890 ≤ y ≤ 0.3905 |
| Identification green | Pale (yellow) and yellow | 6319A | 0.2710 ≤ x ≤ 0.2750 | 0.6335 ≤ y ≤ 0.6420 |
| | | 6327A | 0.267 ≤ x ≤ 0.269 | 0.636 ≤ y ≤ 0.638 |
| | Pale (blue) | 6916J-A | 0.1995 ≤ x ≤ 0.2020 | 0.4950 ≤ y ≤ 0.4980* |
| | Pale (blue) | 6917A | 0.2005 ≤ x ≤ 0.2025 | 0.500 ≤ y ≤ 0.502 |
| | Blue and transmittance | 6905A | 0.1570 ≤ x ≤ 0.1590 | 0.5315 ≤ y ≤ 0.5345 |
| Identification lunar-white | Yellow | 8449A | 0.3105 ≤ x ≤ 0.3125 | 0.3265 ≤ y ≤ 0.3285 |
| | Transmittance | 8430A | 0.2700 ≤ x ≤ 0.2715 | 0.2860 ≤ y ≤ 0.2885 |

* Some glasses complying with this tolerance are not strictly applicable to ware illuminated by a 2850° K. source, but may be used over a lower color temperature range.

fundamental limits set forth in 3.2 for the applicable range of permissible variation in color temperature of source, or the use of the filter must be restricted to color temperatures for which the chromaticity coordinates of the combination lie within the limits. Certain primary standard filters already selected by, and on deposit at, the National Bureau of Standards are listed in table III. This table gives the limits for which the filters are used, the chromaticity coordinates (x, y, z) for illuminants at certain color temperatures, and the luminous transmittances ($T_s$) for source-color temperature 2850°K. These filters conform to the chromaticity requirements of 3.2 as indicated, many of them falling well within the fundamental limits. Duplicates of most of these filters have been certified and are in use for inspection of lighting equipment purchased by the Department of Defense and the Civil Aeronautics Administration. Table IV gives the chromaticity tolerances used in the selection of such duplicates, and may serve as a guide in future certification of duplicates as to how closely the chromaticity coordinates of a working standard need be evaluated. Working standards other than those listed in table III may be employed. For certification by the National Bureau of Standards they must meet the requirements of 5.3.2.1 through 5.3.2.7.

5.3.2.1 *Material.* — The working standard shall be a filter of material known to be permanent. Working standards shall be made of glass for the sake of permanence.

5.3.2.2 *Uniformity of coloring.* — Coloring matter shall be uniformly distributed throughout the material except in the case of selenium-red- and yellow-glass filters for which a slight variation shall be accepted as unavoidable. Flashed glasses consisting of a thin layer of highly selective glass attached to a clear-body glass shall be avoided not only because of probable nonuniformity from spot to spot but also because slight scratches may alter the chromaticity significantly.

5.3.2.3 *Dimensions.*—The standard filters should be cut square, not more than 5.05 centimeters (1.99 inches) nor less than 4.90 centimeters (1.93 inches) on each side, and shall not be less than 1.5 millimeters (0.059 inch) thick. Filters of other dimensions may be used as standards in lieu of the above. These dimensions are suggested because they have been found convenient, and to adhere to them would make the various standard filters applicable to testing equipment already available. The minimum thickness serves to relieve the inspector of the worry of having to care for unduly fragile standards.

5.3.2.4 *Optical quality.* — Standard filters shall have sufficiently plane, parallel, and well-polished faces, and shall be sufficiently free from bubbles, striae, scratches, and other defects to be suitable for use as standards. Any defect sufficient to alter appreciably the judgment of an inspector in his use of the specimen as a standard shall be avoided.

5.3.2.5 *Chromaticity.*—The standard filter, in combination with all light sources with which it is to be used, shall conform to the chromaticity requirements of the color to be represented. The transmittance-standard filters shall also conform to the further chromaticity requirements specified in table V.

TABLE V.—*Chromaticity limits for transmittance standards*
(Illuminant 2850°K.)

| Color | Limit | Color | Limit | Color | Limit |
|---|---|---|---|---|---|
| Aviation red | $y<0.310$ | Identification red | $y<0.280$ | Signal red | $y<0.295$ |
| Aviation yellow and aviation variable-yellow. | $y<0.435$ | Identification yellow | $y<0.405$ | | |
| Aviation green | $x<0.210$ | Identification green | $y>0.150 +2.000x$ | Signal green | $y>0.080 +2.000x$ |
| Aviation blue | $y<0.086$ | | | | |
| | | Identification lunar-white | $x<0.285$ | | |

The chromaticity requirements in table V have been found to be necessary for the purpose of making the transmittance standard closely similar in chromaticity to that of the darker ware to be tested so that the inspector can easily set the photometric fields to equality of luminance. Ideally, the chromaticity of the transmittance standard should be intermediate to that of the pale limit standard and that for ware just meeting the transmittance requirement. It is to be expected that a transmittance standard satisfactory for ware colored with one combination of coloring constituents will seldom be satisfactory for ware colored with some other combination of coloring constituents, particularly if there is a considerable hue difference. Each new colorant material will ordinarily require a new choice of transmittance standard.

5.3.2.6 *Transmittance.*—The transmittance of the standard filters for 2850° K. shall be not less than 0.60 times the minimium transmittance specified for the ware. This requirement has been found useful in the selection of standard filters because of the convenience of pairs of polaroid filters to adjust the photometric field to equality of brightness in both chromaticity and transmittance inspections. If the standard filter is very dark, the photometric scale may not be sufficiently reliable and the luminance adjustment often cannot be made without appreciable change in chromaticity introduced by failure of the chromaticity of the pair of polarizing filters to stay constant independent of angle between them.

5.3.2.7 *Selection of correlated pairs of working standards.*—Standard filters shall be selected in pairs, a chromaticity (pale-limit) standard being made, if feasible, of the same glass as the transmittance standard. If such selection is not feasible, the members of a pair of standard filters shall be selected so as to have the same chromaticity characteristics within a tolerance of 0.010. The transmittance standard shall be considered as having the same chromaticity characteristics as the pale-limit standard for a stated range of illuminants if it is possible to obtain, by increasing the thickness of the material of the pale-limit standard, a specimen whose chromaticity coordinates (x, y) for every illuminant within the range differ from those of the pale-limit standard with the same illuminant by less than a stated tolerance. Such ranges of illuminants are specified in table II. In the manufacture of glass or plastic ware, the chromaticity variation most difficult to control is that corresponding to the amount of the coloring constituents in a unit cross-section of the light beam being transmitted. This variation occurs because the effectiveness of coloring constituents of both glass and plastic ware is affected by heat treatment and by other aspects of the molding process. If the volume density of the coloring constituents within the body of the ware is too slight, the ware will ordinarily fail by being too pale; if too great, it will fail by not transmitting enough light.

5.3.3 *Inspection and test procedure.*

5.3.3.1 Illuminate one side of a photometric field with light from the equipment under test. If the test piece is light-transmitting ware, illuminate it with incandescent lamp light of color temperature corresponding to one of the extremes, usually the upper extreme, of color temperature such as specified in table II.

5.3.3.2 Illuminate the other side of the photometric field with light from a standard-light source and chromaticity-limit filter of the nominal color of the test piece. If the test piece is light-transmitting ware, the color temperature of the lamp illuminating the standard should be checked in a preliminary setting against that of the test piece by a comparison in which both working standard filter and test piece are removed.

5.3.3.3 Adjust the photometric fields to equal luminance and note the character of the chromaticity difference between the two fields. If the choice of chromaticity standard filter has been good, the inspector will be able to judge compliance of the test piece with the particular chromaticity limit represented by the filter. If he is not able to judge compliance, another filter must be chosen, or the test piece set aside for a referree test.

5.3.3.4 Repeat 5.3.3.1 to 5.3.3.3, above, using a light source for the test piece corresponding to the other (usually lower) extreme of color temperature (often to be obtained by means of a color-temperature-reducing filter). If the test piece passes the chromaticity requirements for both upper and lower extremes of color temperature such as specified in table II, it is usually safe to assume that it passes for the intermediate color temperatures. If the spectral characteristics of the ware are such that this assumption cannot be made, the inspector will have to be given special instructions to test at intermediate color temperatures also.

5.3.3.5 *Measurement of luminous transmittance.*—First, adjust the photometric fields to equality of luminance with the light sources set at color temperature 2850°K. and with no test piece or transmittance standard in place, and read the photometric scale setting. Second, insert both transmittance standard and test piece, reset to equality of luminance, and read the photometric scale setting. Third, obtain the ratio of luminous transmittance of test piece to that of standard by dividing the second photometric scale reading by the first. Fourth, from this ratio compute the luminous transmittance of the test piece by multiplying by the luminous transmittance of the transmittance standard. Fifth, determine compliance or noncompliance with the specification by comparing the transmittance of the test piece with the transmittance requirements of table I.

5.3.3.6 *Measurement of transmittance ratio.*—First, set both light sources to color temperature 2850°K. and adjust the photometric fields to equal luminance with a colorless prism or lens of the same design as the test piece on the test side of the photometer, and read the photometric scale setting. Second, substitute the test piece for the colorless piece on the test side, insert the transmittance standard on the other side of the photometer, set the photometer to equality of luminance, and read the photometric scale setting. Third, obtain the relative transmittance ratio of the test piece to the luminous transmittance of the standard by dividing the second photometric scale setting by the first. Fourth, from the relative transmittance ratio, compute the transmittance ratio itself by multiplying the former by the luminous transmittance of the standard. Fifth, determine compliance or noncompliance with the specification by comparing the transmittance ratio of the test piece with the transmittance-ratio requirements of table I. This test, or its equivalent, shall be carried out over the whole solid angle into which light is supposed to be transmitted by the test piece in its intended use. If, as is usual, the photometer does not take in the whole of this angle, the test must be repeated for other orientations of test piece and colorless analogue until the inspector is satisfied that the requirements of table I are met over the whole solid angle or until he has found a portion of the solid angle within which the test piece does not comply. If repeated tests are required for this purpose or for testing many pieces in succession, it is useful to set up on the photometer the setting corresponding to the requirement of minimum transmittance ratio; noncompliance is then revealed by the test piece appearing darker than the standard.

5.3.3.7 *Measurement of luminance ratio.*—First, set both light sources to color temperature 2850°K, insert a white cover of the same design and material (except for coloring constituents) as the test piece in both beams, and read the photometric scale setting. Second, substitute the test piece for its white analogue in the test beam, insert the transmittance standard in the standard beam, and read the photometric scale setting. Third, from the two photometric settings compute the ratio of the luminance ratio of the test piece to the luminous transmittance of the standard. Fourth, from this ratio and the known luminous transmittance of the standard, compute the luminance ratio of the test piece. Fifth, determine compliance or noncompliance by comparing the luminance ratio of the test piece with the luminance-ratio requirements of table I. This test must be repeated until the inspector is convinced that the whole area of the test piece transmitting light for the intended purpose satisfies the requirements. If many pieces are to be tested in succession, it is useful to set up on the photometer the setting corresponding to one of the limiting luminance ratios of table I; then noncompliance is revealed by noting whether the test piece is darker than the white analogue plus the transmittance standard.

(See following figures 1 through 4.)

*This standard is a part of Section III, Part 4, of the Federal Standard Stock Catalog.*

★ U. S. GOVERNMENT PRINTING OFFICE: 1951

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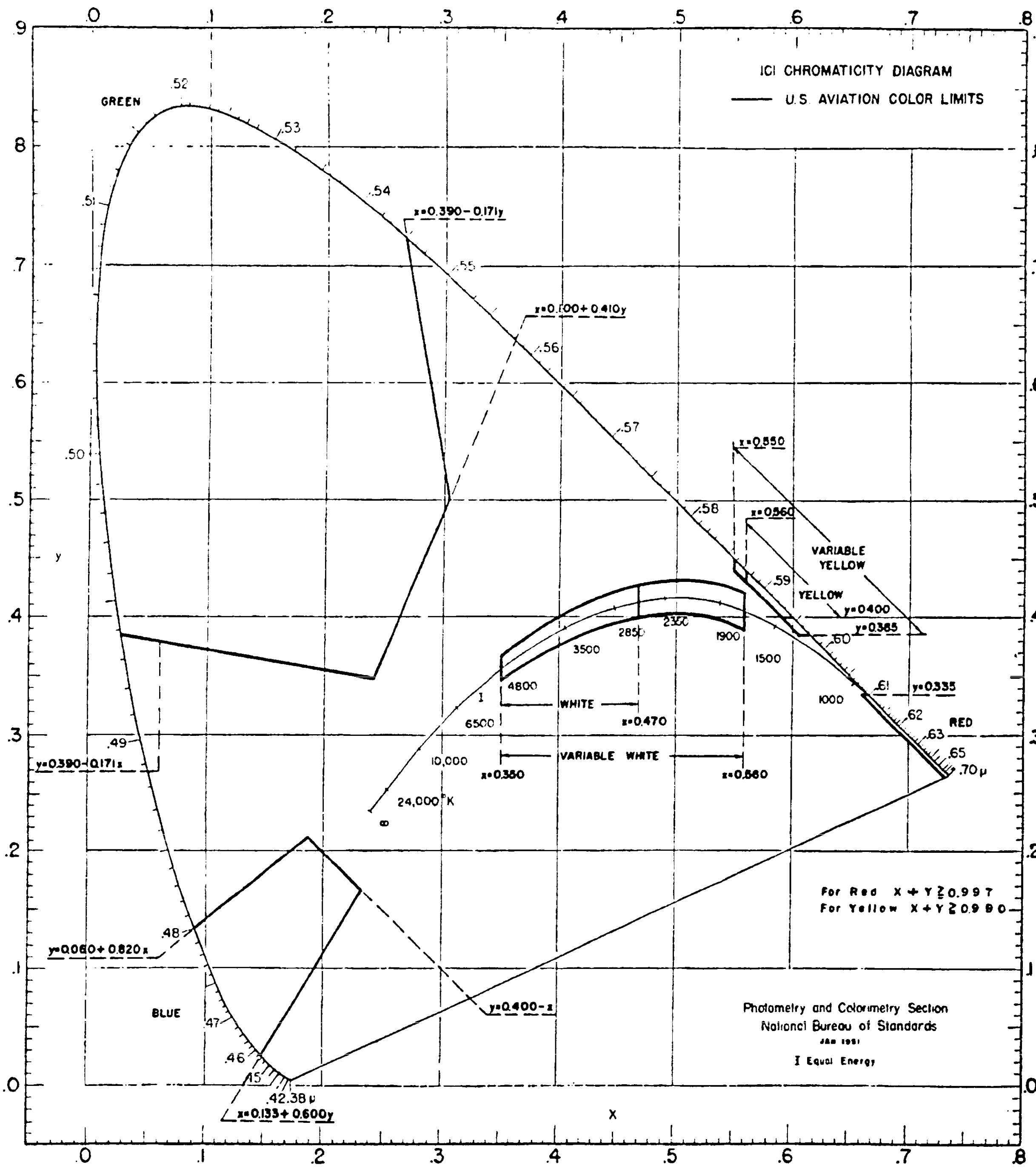
ICI CHROMATICITY DIAGRAM
U.S. AVIATION COLOR LIMITS
GREEN
BLUE
RED
YELLOW
VARIABLE YELLOW
WHITE
VARIABLE WHITE
x=0.390−0.171y
x=0.100+0.410y
y=0.390−0.171x
y=0.060+0.820x
x=0.133+0.600y
y=0.400−x
x=0.550
x=0.560
y=0.400
y=0.385
y=0.335
x=0.350
x=0.470
x=0.560
For Red X+Y ≧ 0.997
For Yellow X+Y ≧ 0.990
Photometry and Colorimetry Section
National Bureau of Standards
Jan 1951
I Equal Energy

**FIGURE 1.**

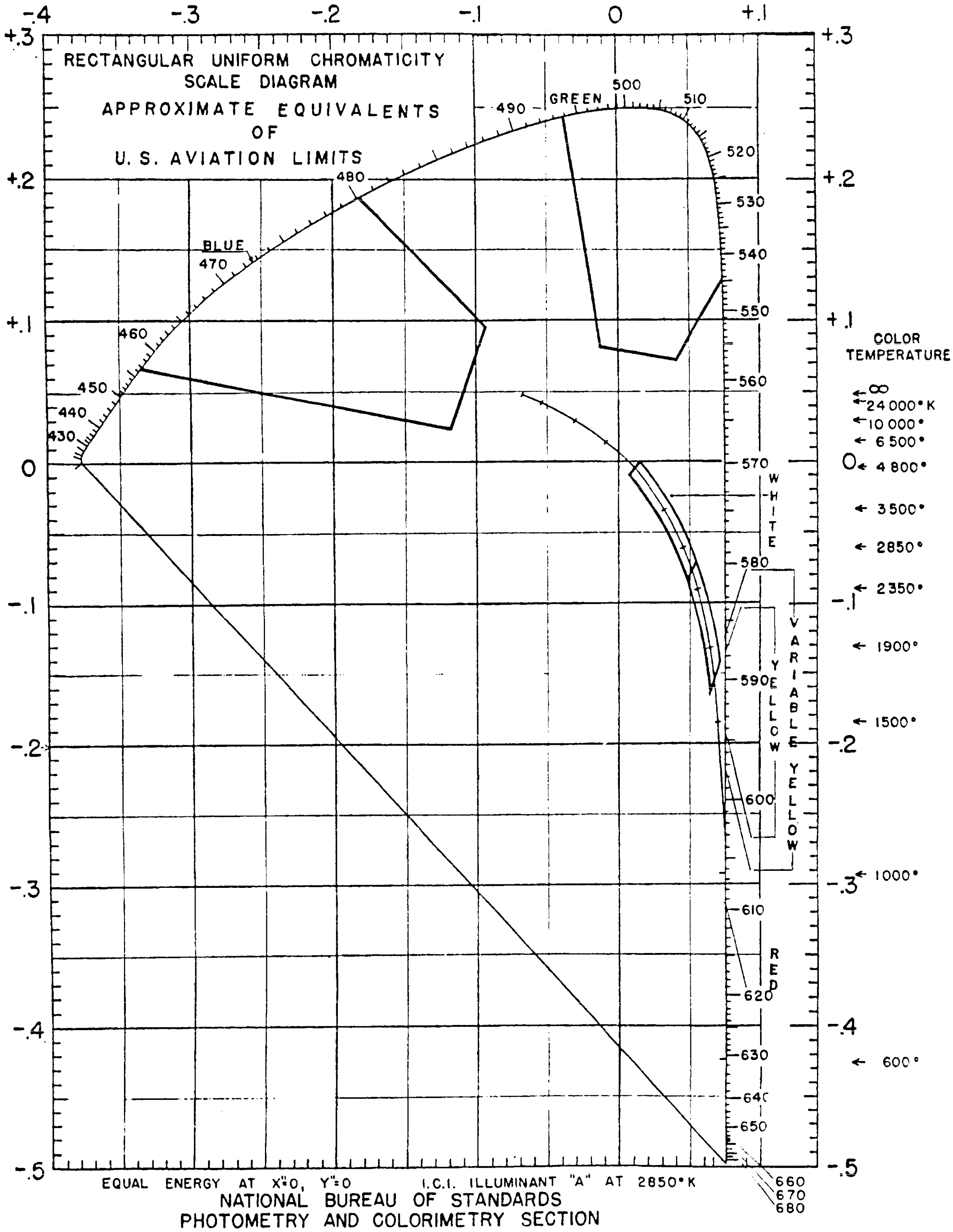
RECTANGULAR UNIFORM CHROMATICITY SCALE DIAGRAM
APPROXIMATE EQUIVALENTS OF U. S. AVIATION LIMITS
GREEN
BLUE
WHITE
YELLOW
VARIABLE YELLOW
RED
COLOR TEMPERATURE
∞
24 000°K
10 000°
6 500°
4 800°
3 500°
2850°
2350°
1900°
1500°
1000°
600°
EQUAL ENERGY AT X"=0, Y"=0
I.C.I. ILLUMINANT "A" AT 2850°K
NATIONAL BUREAU OF STANDARDS
PHOTOMETRY AND COLORIMETRY SECTION
JAN 1951

FIGURE 2.

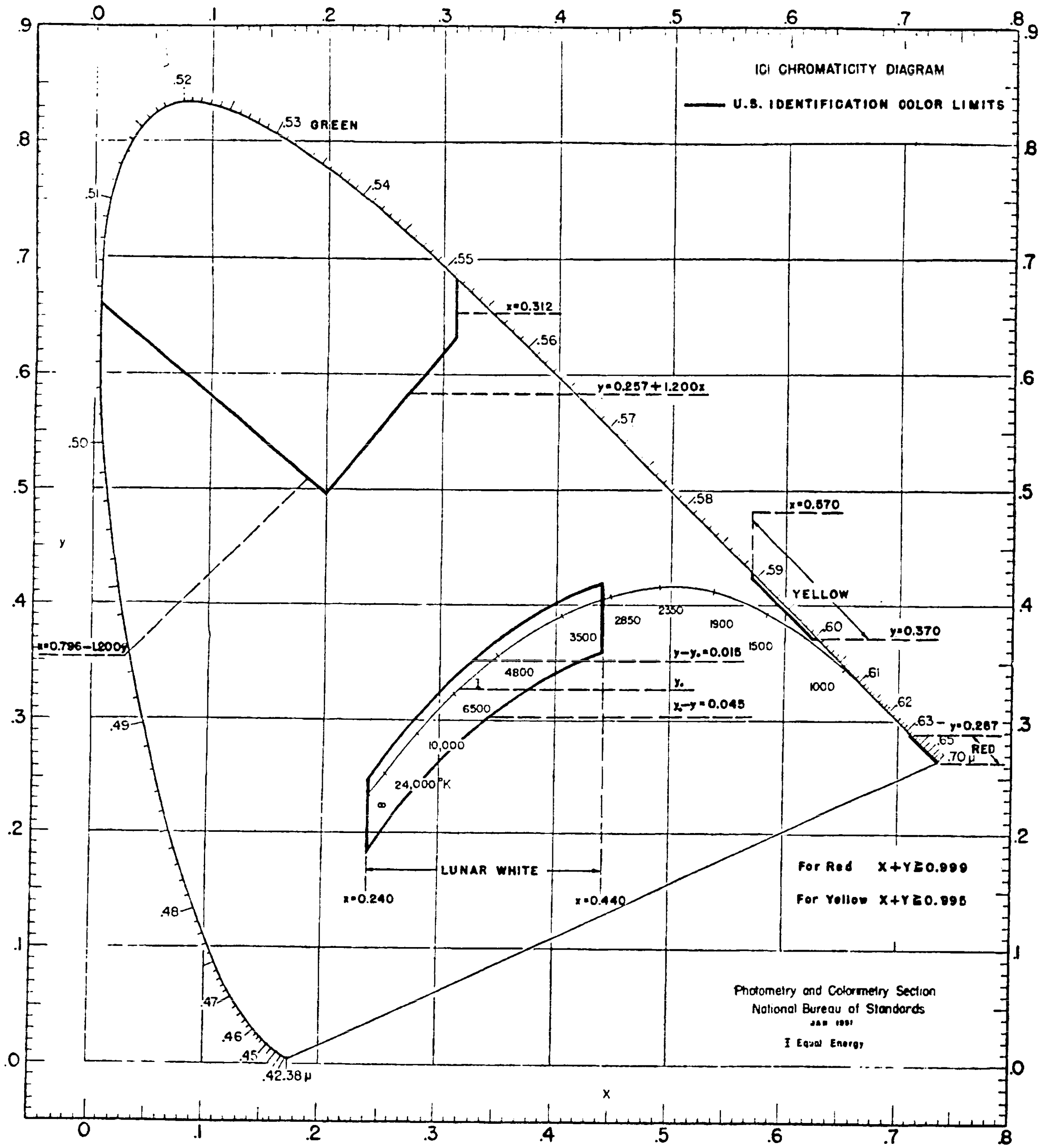
ICI CHROMATICITY DIAGRAM
U.S. IDENTIFICATION COLOR LIMITS
GREEN
YELLOW
RED
LUNAR WHITE
x=0.312
y=0.257+1.200x
x=0.570
y=0.370
y=0.287
x=0.796−1.200y
y−y₀=0.018
y₀
y₀−y=0.045
x=0.240
x=0.440
For Red X+Y≧0.999
For Yellow X+Y≧0.995
Photometry and Colorimetry Section
National Bureau of Standards
Equal Energy

FIGURE 8.

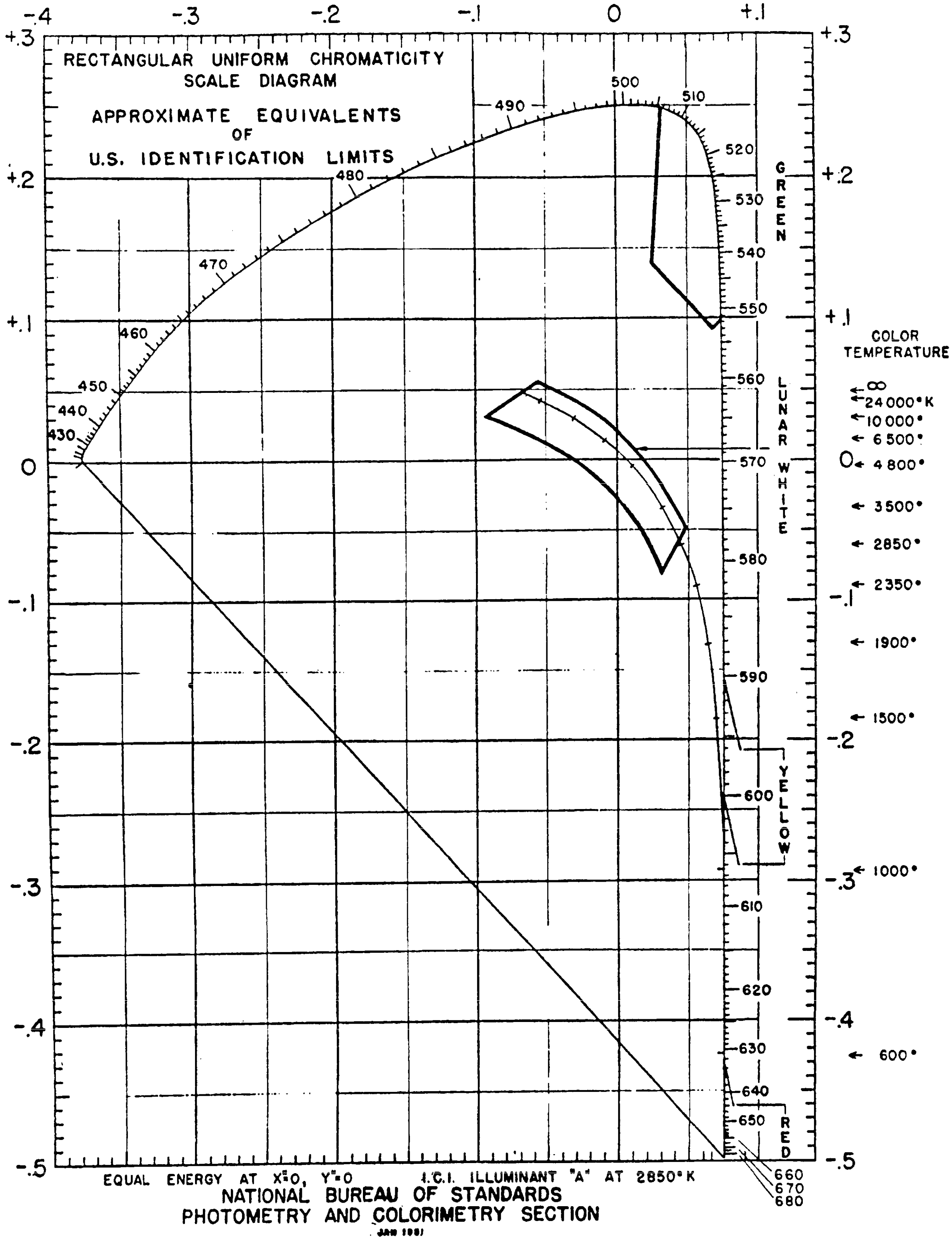
RECTANGULAR UNIFORM CHROMATICITY SCALE DIAGRAM
APPROXIMATE EQUIVALENTS OF U.S. IDENTIFICATION LIMITS
GREEN
LUNAR WHITE
YELLOW
RED
COLOR TEMPERATURE
∞
24 000°K
10 000°
6 500°
4 800°
3 500°
2850°
2350°
1900°
1500°
1000°
600°
EQUAL ENERGY AT X=0, Y=0
I.C.I. ILLUMINANT "A" AT 2850°K
NATIONAL BUREAU OF STANDARDS
PHOTOMETRY AND COLORIMETRY SECTION

FIGURE 4.