Designation: D 4303 – 03

Standard Test Methods for Lightfastness of Colorants Used in Artists' Materials[1]

This standard is issued under the fixed designation D 4303; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 Four test methods to accelerate the effects of long term indoor illumination on artists' paints are described as follows:

1.1.1 *Test Method A*—Exposure to natural daylight filtered through glass,

1.1.2 *Test Method B*—Exposure to irradiance from daylight fluorescent lamps,

1.1.3 *Test Method C*—Exposure in xenon-arc irradiance simulating daylight filtered through glass, and

1.1.4 *Test Method D*—Exposure to irradiance from cool white fluorescent lamps and soda-lime glass filtered fluorescent UV sunlamps.

1.2 These test methods are used to approximate the color change that can be expected over time in pigments used in artists' paints in normal indoor exposure.

NOTE 1—The color changes that result from accelerated exposure may not duplicate the results of normal indoor exposure in a home or gallery. The relative resistance to change, however, can be established so pigments can be assigned to categories of relative lightfastness.

1.3 Lightfastness categories are established to which pigments are assigned based on the color difference between specimens before and after exposure.

1.4 Color difference units are calculated by the CIE 1976 L*a*b* color difference equation.

1.5 These test methods apply to artists' oil, resin-oil, acrylic emulsion, alkyd, watercolor paints, and gouache paints.

1.6 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.7 *This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates[2]

D 4302 Specification for Artists' Oil, Resin–Oil, and Alkyd Paints[3]

D 4674 Practice for Accelerated Testing for Color Stability of Plastics Exposed to Indoor Office Environment[4]

D 5067 Specification for Artists' Watercolor Paints[3]

D 5098 Specification for Artists' Acrylic Emulsion Paints[3]

D 5724 Specification for Gouache Paints[3]

E 284 Terminology of Appearance[2]

E 1347 Test Method for Color and Color–Difference Measurement by Tristimulus (Filter) Colorimetry[2]

E 1348 Test Method for Transmittance and Color by Spectrophotometry Using Hemispherical Geometry[2]

E 1349 Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional Geometry[2]

G 24 Practice for Conducting Exposures to Daylight Filtered Through Glass[5]

G 113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials[5]

G 151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources[5]

G 155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-metallic Materials[5]

3. Terminology

3.1 *Definitions*—Appearance terms used in these test methods are defined in Definitions E 284. Terms relating to natural and artificial lightfastness tests are defined in Definitions G 113.

3.1.1 *glass*—as used in these test methods, glass refers to single-strength window glass.

4. Summary of Test Methods

4.1 Color measurements are made on specimens that have been prepared as directed in Specification D 4302, D 5067, D 5098 or D 5724 depending on the vehicle. The measurements are recorded for comparison with readings made after the specimens have been exposed.

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[1] These test methods are under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and are the direct responsibility of Subcommittee D01.57 on Artist Paints and Related Materials.

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[2] *Annual Book of ASTM Standards*, Vol 06.01.
[3] *Annual Book of ASTM Standards*, Vol 06.02.
[4] *Annual Book of ASTM Standards*, Vol 08.03.
[5] *Annual Book of ASTM Standards*, Vol 14.04.

4.2 Specimens are exposed to daylight filtered through glass or to laboratory test sources to simulate and accelerate the effects of indoor illumination using at least two of the four test methods described in Section 7.

4.3 The pigments are classified by color difference calculated in accordance with Practice D 2244.

5. Significance and Use

5.1 The retention of chromatic properties by a pigment over a long period of years is essential in an artistic painting. Accelerated exposure simulates color changes that may reasonably be expected. The producer and the user of artists' paints, therefore, can be apprised of suitable pigments.

5.2 There can be significant variations in results between the different exposure procedures used in these test methods. In addition, there can also be significant differences in results between exposures conducted in accordance with a single procedure because of variability inherent within the procedures themselves.

6. Apparatus

6.1 *Sun Exposure Facilities* as described in Practice G 24, using an exposure angle of 45°, facing the equator.

6.2 *Xenon-Arc Lightfastness Apparatus* as described in Practice G 155.

6.3 *Daylight Fluorescent Lamp Apparatus*, [6] as described in Annex A1.

6.4 *Fluorescent Cool White Lamp/Filtered Sunlamp Lightfastness Apparatus*, using very high output cool white fluorescent lamps and soda-lime glass filtered fluorescent UV sunlamps as described in Practice D 4674.

6.5 *Spectrophotometer*, abridged spectrophotometer or colorimeter capable of excluding specular reflectance in its measurement.

7. Procedure

7.1 Specimens of pigments to be tested in oil, resin-oil, or alkyd panels shall be prepared as directed in Specification D 4302. Specimens of pigments to be tested in acrylic emulsion paints shall be prepared as directed in Specification D 5098. Specimens of pigments to be tested in watercolors shall be prepared as directed in Specification D 5067.

7.2 Immediately before exposure, measure all test specimens on a spectrophotometer or spectrocolorimeter (see Test Method E 1348 or E 1349) or colorimeter (see Test Method E 1347) using Illuminant C and the 1931 2° observer and excluding specular reflection from the measurement. Record the measurements.

7.2.1 Read specimen panels always with any brush marks in the same direction and with panels in the same position so that the same area of the panel is measured before and after each exposure interval. If the design of the instrument allows, three readings at different locations on the panel should be made and the mean calculated. If feasible, mark on the back of the specimen the spot(s) measured, and remeasure these same spots following exposure.

7.2.2 If it is necessary to store specimens in the dark for a period of time, prior to measurement and exposure, those that contain oil in the vehicle shall be placed in subdued light for seven days to eliminate any yellowing of the oil due to storage.

7.2.3 Compare these pre-exposure measurements with subsequent measurements of the test specimens made at the end of exposure to calculate the amount of any color change. If feasible, measure the test specimens at regular, frequent intervals during exposure to calculate the rate of any color change.

7.2.4 Retain a specimen of each paint in the dark. After the test is complete, measure these retained specimens and compare with the pre-exposure measurement of the test specimens to verify that the retained specimens have not changed color significantly during storage.

7.2.5 Compare visually the retained, unexposed specimens with the exposed test specimens to verify that the measured color difference agrees with the perceived color change between the exposed and unexposed specimens. These retained specimens may also be needed for an additional test as described in 7.7.1 and 7.7.2.

7.3 Expose specimen panels in at least two of the four test methods described. Oil, resin-oil alkyd, and acrylic emulsion paint specimens shall be exposed by Test Method A and either Test Method B, Test Method C or Test Method D. Watercolors, gouache, and other paints sensitive to moisture shall be exposed by Test Methods C and either Test Method B or Test Method D.

7.3.1 *Test Method A—Exposure to Natural Daylight Filtered Through Glass*:

7.3.1.1 Mount the specimens on an open-type rack and expose at 45° angle to the vertical to a total radiation dose of 1260 MJ/m ^{2} in accordance with Practice G 24.

7.3.1.2 For tests in southern Florida expose panels during the months of October through May.

7.3.2 *Test Method B— Exposure to Irradiance from Daylight Fluorescent Lamps:*

7.3.2.1 Mount the specimens with the test face 3 in. (75 mm) from the plane of the lamps.

7.3.2.2 Unless specified otherwise, expose the specimens to a repeating cycle of 8 h light followed by 4 h dark until the specimen has been exposed to a total radiant energy dose of 1260 MJ/m^2. Rotate the specimen panels two positions to the right after each 100-MJ/m ^{2} dose. This test method takes approximately nine months to complete.

7.3.2.3 Maintain the ambient room temperature at 24 ± 3°C and prevent the test chamber from exceeding room temperature by more than 6°C.

7.3.2.4 Monitor irradiance at the specimen location for total radiation for each rotation period. Measure radiation 1 h after

[6] The Verlilux lamps F48T12VLX/HO, manufactured by Verilux, Inc., 9 Viaduct Rd., Stamford, CT 06906, used in the apparatus described in Annex A1 are not available. Other fluorescent lamps that closely simulate daylight may be suitable, and Subcommittee D01.57 seeks information that will allow these fluorescent lamps to be recommended. Lamps should have a related color temperature of 6000 ± 500 K and a color rendering index of at least 90 as calculated by Method of Measuring and Specifying Colour-Rendering Properties of Light Sources, International Commission of Illumination (CIE) publication No. 13.2 (TC-3.2) 1974. Available from the U.S. National Committee of the CIE, *c/o* Director of Marketing, OEM Division, North American Philips Lighting Corp., Philip Square CN8800, Somerset, NJ 08873.

the lamps are turned on and at the end of the period. The mean of these readings in joules per square centimetre (J/cm^2) per hour multiplied by the number of hours of radiation gives the J/cm^2 for that period.

7.3.3 *Test Method C— Exposure to Xenon-Arc Irradiance Simulating Daylight Filtered Through Glass:*

7.3.3.1 Mount specimens in unbacked holders avoiding positions that place specimens at the extreme top or bottom of the specimen rack.

7.3.3.2 Unless agreed otherwise, expose specimens in accordance with Practices G 151and G 155 to total radiation from the filtered xenon arc to reach a radiant exposure of 510 kJ/m^2 measured at 340 nm. Expose the specimens to 100 % light from the xenon arc apparatus equipped with window glass filters. Set the machine to maintain an irradiance level at 0.35 W/m^2/nm at 340 nm and maintain the relative humidity in the test chamber at 55 ± 5 % RH. The black panel temperature shall be 63 ± 2°C. This radiant exposure measured at 340 nm has been calculated to provide total UV radiant exposure equivalent to the total UV behind glass-filtered daylight when total spectral radiant exposure to glass-filtered daylight is 1260 MJ/m^2. See Appendix X1.

NOTE 2—When mutually agreed upon, the following alternative light and dark cycle may be employed in accordance with Practices G 151 and G 155. Expose test specimens to the following cycle:

Set the xenon arc apparatus equipped with window glass filters to maintain an irradiance level of 0.35 W/m^2/nm at 340 nm.

Light Cycle: 3.8 h light, at 35 ± 5 % RH. The black panel temperature shall be 63 ± 2°C. Followed by:

Dark Cycle: 1 h dark, at 90 ± 5 % RH. The black panel temperature shall be 35 ± 3°C.

It has been found that Alizarin Crimson, and possibly other pigments, are affected by a light and dark cycle, owing to the oxidation-reduction effect of titanium dioxide changing valence with the changes from light to dark and vice-versa, characteristic of daylight and indoor light.

Any variance from the specified test cycle must be detailed in the Report section.

7.3.4 *Test Method D—Exposure to Irradiance From Very High Output Cool White Fluorescent Lamps and Intermittent Exposure to Soda-Lime Glass Filtered Fluorescent UV Sunlamps Representative of Illumination in an Indoor Environment*:

7.3.4.1 Two suitable reference pigments must be determined and agreed to for each vehicle type[7]. To establish reference pigments, formulate two suitable pigments in the relevant vehicle, prepare test specimens and expose them using both Method A and Method C. Both test specimens must show a color difference before and after exposure that places them in Lightfastness Category II (ΔE*>4 and >8) in both the Method A and Method C tests. To conform to Test Method D, these reference pigments, purchased from the same manufacturer(s) and dispersed in the vehicle used to establish their lightfastness, must be included as controls when testing colors in that vehicle. Test Method D is complete when test specimens of both or the two reference paints show a color difference greater than four and less than 8 CIELAB units (CIELAB ΔE*>4.0 and >8).

7.3.4.2 Verify proper lamp function before starting test. Pre-age the lamps by leaving them on for a minimum of 48 h prior to the initial test. Radiometer readings at the start of the test shall not be less than 8.0 W/m^2 for the 1500-mA lamps and 1.0 W/m^2 for the 430-mA lamps.

7.3.4.3 Adjust the specimens or specimen table so that the surface of all test specimens are within 3 mm of being coplanar with the cosine receptor.

7.3.4.4 Close the specimen drawer and verify lamp irradiance in accordance with 7.3.4.2.

7.3.4.5 Turn on both sets of lamps. After 20 min turn off fluorescent sunlamps (FS) and record the cool white (CW) irradiance (radiometer reading) in W/m^2.

7.3.4.6 Turn off the CW lamps and turn on the FS lamps. Record the radiometer reading (W/m^2). Calculate the off-time internal cycle of the FS lamp so the average nominal sunlamp UV actinic exposure is set at 12 % of the value of the VHO lamps. An example calculation is as follows:
Radiometer readings:

$$CW = 10.3 \text{ W/m}^2, FS = 2.4 \text{ W/m}^2 \tag{1}$$

In 1 h:

$$CW \text{ radiation} = 10.3 \text{ W/m}^2 \times 3600 \tag{2}$$

$$= s\ 37\,080 \text{ J/m}^2 \times 0.12 = 4450$$

$$FS \text{ radiation} = 2.4 \text{ W/m}^2 \times 3600 \text{ s} = 8640 \text{ J/m}^2$$

The On-Time required for the FS lamps is 4450/ 8640 = 0.515 h.
The Off-Time interval is 0.485 h/h total operation of the unit.

7.3.4.7 Program the FS lamp cycling to a 1-h time on interval/cycle.

7.3.4.8 Program the FS lamp timer to the off-time interval calculated in the example in 7.3.4.6.

7.3.4.9 Start the test. Do not add specimens once the test has begun.

7.3.4.10 Rotate specimens every 200 h by moving those in the innermost row (adjacent to median) to the outermost row of the same specimen tray, move all remaining rows one row closer to the median.

7.3.4.11 Test is complete when reference pigment specimens show a CIELAB ΔE*>4.0.

7.4 Measure test specimens immediately after exposure with specular reflection excluded in the measurement and record.

7.5 Calculate the color difference between the specimen before exposure *and* after exposure in accordance with the CIE 1976 L*a*b* color difference equation in Practice D 2244. State the color change in total color difference units (ΔE^*_{ab}).

7.6 Visually check the exposed specimen against the unexposed specimen of the same paint kept in subdued light, in order to verify that the color difference stated in ΔE^*_{ab} units agrees with visual assessment. Make this check also following any subsequent exposures.

7.7 Since all test methods can produce aberrant results in pigments that are sensitive to some aspect of a particular type

[7] PR 170 (F5RK)-Novaperm Red F5RK, manufactured by Clariant Corp., and PY 3-Arylide Yellow 272-1007, manufactured by Sun Chemical Corp., have been found satisfactory in both oil and acrylic vehicles.

of exposure, assign pigments to lightfastness categories based on results from a minimum of two of the test methods described in 7.3.1-7.3.4:

7.7.1 Unless specified otherwise, expose one specimen inland outdoors under glass to daylight in southern Florida below 27° latitude following Test Method A and expose the second specimen indoors to simulated daylight behind glass following either Test Method B, Test Method C, or Test Method D. Place pigment in the appropriate category if both tests indicate the same category and neither result is within ±0.5 ΔE^*_{ab} of the borderline between categories.

7.7.2 If the results from the first two tests place the pigment in different lightfastness categories, or if either of the test results fall within ±0.5 ΔE^*_{ab} of the dividing line between two categories, either assign the pigment to the poorer of the two categories involved or for a more accurate rating, proceed with the third exposure. The third exposure may use either the test method not used in the two previous exposures, or may repeat the exposure which gave the poorer result, providing the two test results are within 4 ΔE^*_{ab} of one another. To guard against accepting an aberrant test result, if there is more than 4 ΔE^*_{ab} difference between the first two test results, use the test method not employed in the first two tests for the third exposure.

7.7.3 Calculate the mean of the color differences from the three exposures to determine the appropriate lightfastness category unless one of them differs from the nearest test result by more than 4 ΔE^*_{ab}, or the mean is within ±0.5 ΔE^*_{ab} of the dividing line between categories. In these cases make a fourth exposure.

7.7.4 For the fourth exposure use the test method not previously employed, or repeat the test method with poorest result, unless the results from that test method differ from the nearest other test result by more than 4 ΔE^*_{ab}. In this case, discard this one test result. Calculate the mean of the test results from the four exposures, or three exposures if one has been discarded, to determine the lightfastness category.

8. Interpretation of Results

8.1 *Lightfastness I*—Assign pigments that exhibit a mean color change of 4 or less ΔE^*_{ab} to Lightfastness Category I.

8.2 *Lightfastness II*—Assign pigments that exhibit a mean color change of more than 4.0 but not more than 8.0 ΔE^*_{ab} to Lightfastness Category II.

8.3 *Lightfastness III*—Assign pigments that exhibit a mean color change of more than 8.0 but not more than 16.0 to Lightfastness Category III.

8.4 *Lightfastness IV*—Assign pigments that exhibit a mean color change of more than 16.0 but not more than 24.0 to Lightfastness Category IV.

8.5 *Lightfastness V*—Assign pigments that exhibit a mean color change of more than 24.0 to Lightfastness Category V.

9. Report

9.1 The following applies to reports for all test methods:

9.1.1 Name of company,

9.1.2 ASTM test methods used,

9.1.3 Vehicle used,

9.1.4 Colour Index Names and Constitution Numbers for all pigments tested,

9.1.5 Date when exposure began,

9.1.6 CIELAB notation for test specimens prior to exposure,

9.1.7 Date when test specimens were removed from exposure and total exposure time,

9.1.8 CIELAB notation for test specimens following exposure. If it is not possible to measure specimens immediately after removal from exposure, give the date when rated,

9.1.9 Give the color difference in CIELAB ΔE^* for reference and test specimens prior to and following exposure, and

9.1.10 Lightfastness category for all test specimens as determined in 7.7.

9.2 The following is specific information required for each of the test methods:

9.2.1 *Test Method A*:

9.2.1.1 Total spectral radiant exposure, MJ/m^2.

9.2.2 *Test Method B*:

9.2.2.1 Total spectral radiant exposure, MJ/m^2, and

9.2.2.2 If the program includes a dark period, specify the light/dark periods.

9.2.3 *Test Method C*:

9.2.3.1 Name and model of apparatus used,

9.2.3.2 Irradiance level, W/m^2, for the control point or spectral range being measured,

9.2.3.3 Radiant exposure at 340 nm, kJ/m^2,

9.2.3.4 Relative humidity,

9.2.3.5 Black panel temperature,

9.2.3.6 Dry bulb temperature, and

9.2.3.7 Panel rotation schedule.

9.2.4 *Test Method D*:

9.2.4.1 Initial CW UV irradiance, W/m^2,

9.2.4.2 Final CW UV irradiance, W/m^2,

9.2.4.3 Initial FS UV irradiance, W/m^2,

9.2.4.4 Final FS UV irradiance, W/m^2,

9.2.4.5 FS On Time, and

9.2.4.6 Panel rotation schedule.

10. Precision and Bias

10.1 *Precision*—Variation in test results can result from differences in pigment manufacture from time to time within a company, different varieties of a pigment from company to company, specimen preparation, different instruments and instrumental readings, variations in the surface of the specimen, and the conditions of exposure. Allowance for these variables is made by requiring more than one test and by establishing lightfastness categories that include a range of color differences.

10.2 To establish the relationship between test methods, 5 sets of 172 paint specimens, 90 in oil and 82 in acrylic emulsion vehicle, were made at the same time by one person and exposed in four sets of lightfastness tests: southern Florida sun filtered through glass, Kansas sun filtered through glass, fluorescent apparatus, and xenon-arc apparatus.[8]

[8] Supporting data are available from ASTM International Headquarters. Request RR: D01–1036.

10.2.1 All four test methods placed 73 % of the pigments in the same category. When 12 aberrant test results were dropped from consideration and the third and fourth exposures conducted as required in cases where test results are near the border line between lightfastness categories (see 8.2), all combinations of the test results placed 99 % of the pigments in the same category.

10.3 *Bias*—Since there is no accepted reference material suitable for determining bias for the procedure in these test methods for measuring lightfastness, bias has not been determined.

11. Keywords

11.1 daylight filtered through glass exposure test; daylight fluorescent lamp exposure test; indoor fluorescent exposure test; lightfastness; lightfastness categories; pigments

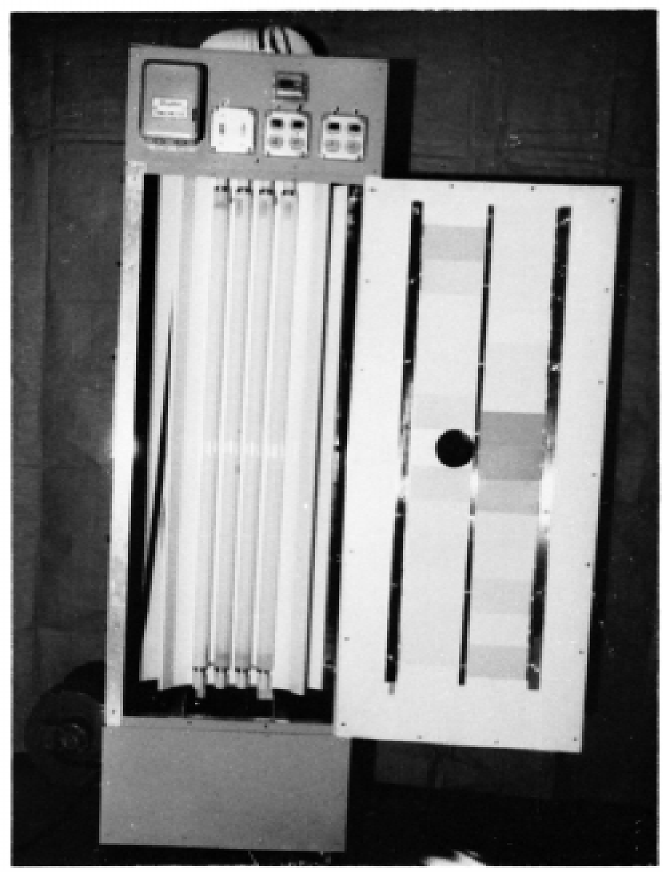
ANNEX

(Mandatory Information)

A1. FLUORESCENT DAYLIGHT LAMP LIGHTFASTNESS APPARATUS

NOTE 1—Pyranometer, recorder, and demand readout meter in place. (*a*) Four-Bank Fluorescent Exposure Apparatus that Handles One Hundred and Eight 3 by 6-in. Panels

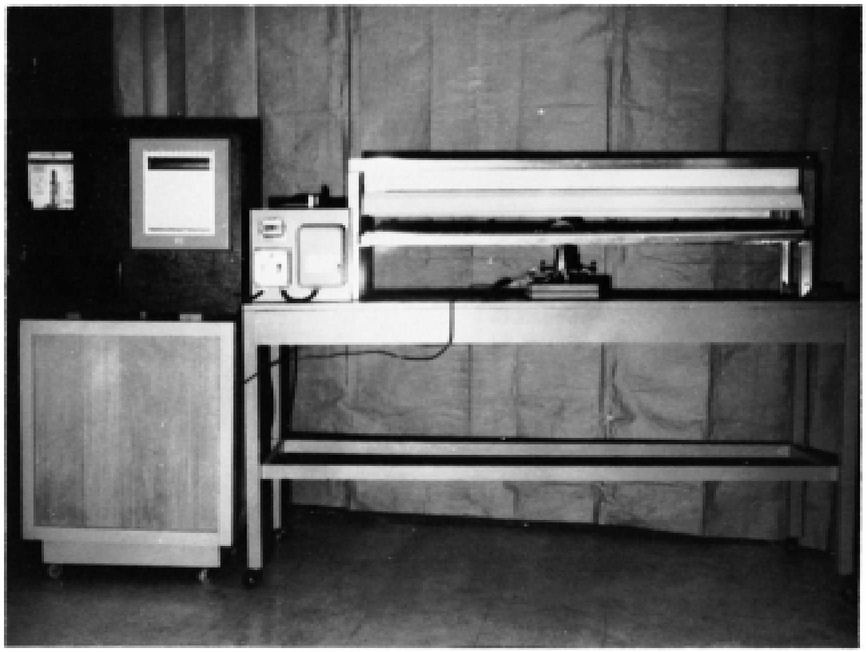
FIG. A1.1 Apparatus for Exposing Paint Specimens to Fluorescent Irradiation



NOTE 1—Notice hole for mounting Eppley pyranometer which is attached at right. (*b*) Four-Bank Verilux Fluorescent Exposure Apparatus with One Panel Open

FIG. A1.2 Apparatus for Exposing Paint Specimens to Fluorescent Irradiation

A1.1 The apparatus for exposing paint specimens to fluorescent irradiation is shown in a large-size version in Fig. A1.1 and Fig. A1.2. A smaller version is shown in Fig. A1.3. Fig. A1.4 provides the dimensions and arrangement for constructing the larger size apparatus out of materials that are easily available.



NOTE 1—Pyranometer, recorder, and demand readout meter in place.

FIG. A1.3 Single-Bank Device of Four Verilux Daylight Fluorescent Lamps [6] that Handles Twenty-seven 3 by 6-in. Panels

A1.2 *Cabinet Construction*—Make framework for the apparatus out of 1½ by 1½ by ⅛-in. (40 by 40 by 3.2-mm) aluminum angle available in hardware stores. The supports and the remainder of the enclosure are ⅛-in. tempered hardboard. The exposure panel supports, which are also the apparatus sides, are made removable by being fastened by reversed bolts with wing nuts. Coat them on the interior side with a non-yellowing white paint. Four reflectors, which each can hold four fluorescent lamps, are fastened together by the 1½-in. angles, back to back, to form a square in the center of the cabinet facing the specimens, which are attached to the hardboard panels support as shown in Fig. A1.4. Construct the framework so that the lamps are 3 in. (75 mm) from the test specimens. Cut holes in each side adjacent to the center and centered on a panel location to accommodate an Eppley pyranometer. With one panel space missing on each panel bank, the cabinet accommodates 108 test panels.

A1.3 *Irradiation*—The reflector fixtures hold sixteen 48-in. (1.2-m) long high-powered lamps with a correlated color temperature of 6000 K and a spectral irradiance simulating sunlight.

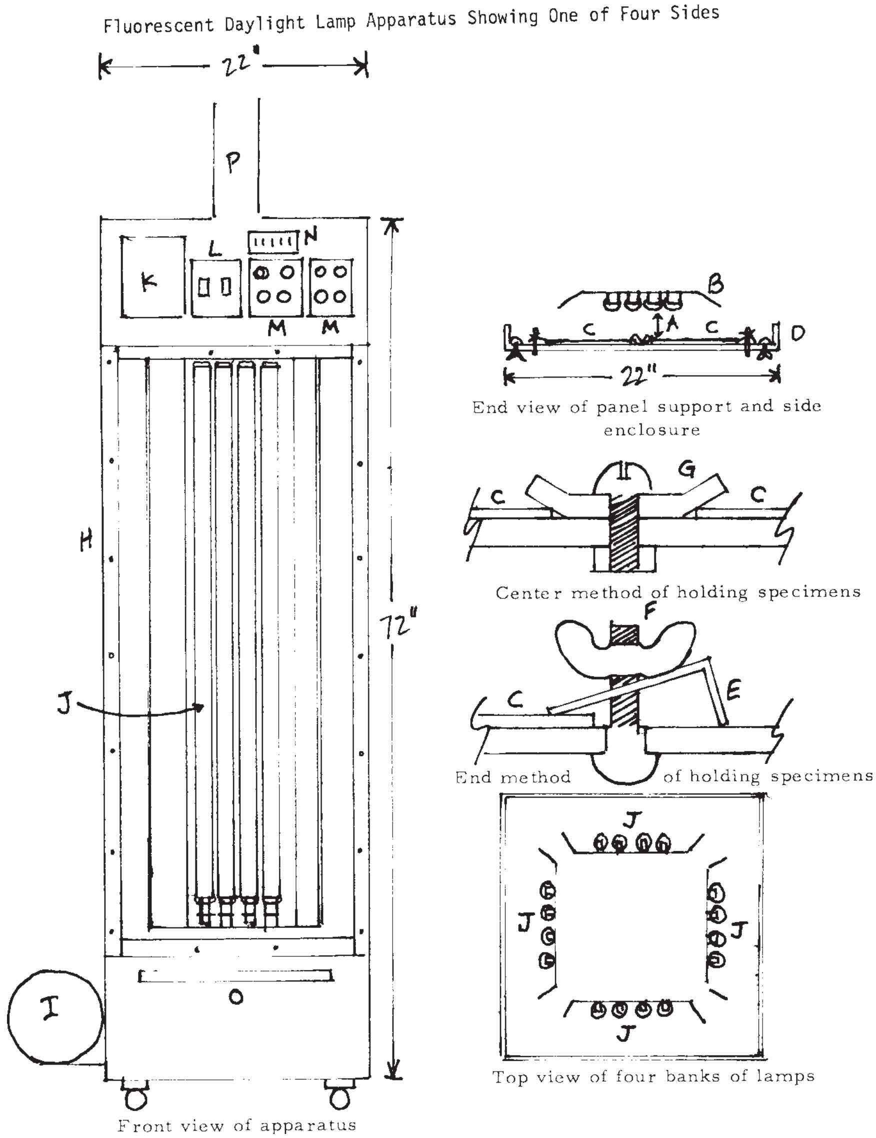
A1.3.1 Irradiance can be monitored by a spectral radiometer or a filter radiometer which has been calibrated to provide information on the total spectral radiant exposure.

A1.3.2 Install a timer, shown as K in Fig. A1.4, to cycle exposure for 8 h of light followed by 4 h of dark.

A1.3.3 Install an electric time meter in the circuit, shown as N in Fig. A1.4 to record the total amount of time the lamps are turned on.

A1.4 *Temperature and Humidity Control*—Install a centrifugal blower unit at the base of the cabinet, shown as I in Fig. A1.4. The air from the blower passes immediately through an air filter O and, after passing through the specimen exposure area, is vented out through the top of the cabinet. The blower furnishes the filtered air draft that keeps the temperature in the cabinet to within 6°C of the ambient temperature of the room. The small 6°C temperature rise is sufficient to limit the humidity in the cabinet to about 60 % relative humidity even when the general humidity is very high. Install a thermometer in the top of the cabinet near the vent and away from any direct illumination from the lights.

A1.5 If preferred, a smaller open apparatus holding a single bank of four daylight fluorescent lamps may be constructed as shown in Fig. A1.3. A small fan blowing through the unit from one end furnishes the air draft, but otherwise the apparatus must have the same distance between lamps and specimens and the same monitoring equipment described in A1.2 and A1.3.



Drawing: 1 in. = 25 mm.

A	3-in. distance from lamp to exposure specimen	I	Centrifugal blower
B	Four-gang fixture for fluorescent lamps	J	Fluorescent lamps in 4-gang fixture
C	Exposure specimens	K	Timer to control cycles
D	1½by 1½ by ⅛-in. aluminum angle frame	L	Two 2-way switches for off-on and interval-on
E	1 by ⅛-in. metal trim strip	M	Individual switches for each bank
F	3⁄16-in. carriage bolt, ¾-in. long, spaced 6 in. apart, with wing nut	N	Time meter
G	Metal corner moulding reversed	O	Air Filter, inside
H	Aluminum angle frame throughout	P	Vent

NOTE 1—Frame is 1½ by 1½ by ⅛-in. aluminum angle. Enclosure and removable panel support sides are tempered hardboard.

FIG. A1.4 Dimensions for Constructing Apparatus

TABLE X1.1 Radiant Exposure Values[A]

Source	Radiant Exposure Values over Different Wavelength Ranges			
	420 nm	340 nm	300–400 nm[B]	250–3000 nm
Sunlight Through Window Glass	1940 kJ/m^2	303 kJ/m^2	61.7 MJ/m^2	1260.0 MJ/m^2
Xenon with Type "S" Borosilicate Inner and Soda-Lime Outer Filters	1330 kJ/m^2	510 kJ/m^2	61.7 MJ/m^2	

[A]This information is included for reference purposes only.
[B]Xenon and sunlight were equated over this range.

APPENDIX

(Nonmandatory Information)

X1. RADIANT EXPOSURE CALCULATION

X1.1 The amount of exposure required by these test methods, 1260 MJ/m^2, was determined in a study of test specimens exposed outdoors behind window glass as described in ASTM RR: D01-1036.[8] Test specimens were prepared in oil and acrylic emulsion vehicles from ninety-two pigments, including a set of control pigments with known lightfastness. Color difference measurements, verified by visual comparison of exposed and unexposed specimens of the same paints, determined that at 1260 MJ/m^2 the color changes had occurred that have historically been seen in the control pigments following normal indoor exposure for a great many years, while beyond that point many specimens had bleached sufficiently to make measurements misleading.

X1.2 A standard for sunlight was selected, in this case CIE Number 85, Table 4. This CIE standard is for direct sunlight; therefore, the CIE data was multiplied by the spectral reflectance of typical window glass to arrive at a standard for sunlight through window glass.

X1.3 Since the xenon arc and sunlight spectra are quite different in the IR range, the glass-filtered spectrum was divided into radiant dosages calculated for different wavelength ranges (subsets of the total radiant dosage) based on the total spectral radiant exposure of 1260 MJ/m^2.

X1.4 Radiant dosages for sunlight through window glass were calculated for the wavelength ranges typically used for xenon-arc control: 340 nm, 420 nm, and 300 to 400 nm. These values are shown in Table X1.1.

X1.5 A xenon spectrum with Type "S" borosilicate inner and soda-lime outer filters was equated with the sunlight radiant dosage from 300 to 400 nm. This value (61.7 MJ/m^2) is shown in Table X1.1, equal for both the sunlight and xenon sources.

X1.6 The xenon radiant dosages were calculated for the other xenon control points (340 and 420 nm) based on 61.7 MJ/m^2 for the 300 to 400-nm spectral range. These values are listed in Table X1.1.

X1.7 Targeting the radiant dosages calculated in Table X1.1 for the xenon control points, two radiance levels were selected appropriate for xenon testing in Atlas equipment with the Type "S" borosilicate inner and soda-lime outer filter combination. These irradiance levels are shown in Table X1.2 along with the target radiant dosage for each xenon control point.

X1.8 From the radiant dosage and irradiance levels, the xenon exposure time was calculated. These times are listed in Table X1.2 and represent the final results of these calculations. For each xenon irradiance control point and controlled irradiance level, the time listed is the required exposure period to produce total UV radiant exposure equivalent to the total UV of glass-filtered sunlight when the exposure to total spectral radiant energy of the sun through window glass is 1260 MJ/m^2.

TABLE X1.2 Exposure Times[A]

Xenon Control Point, nm	Radiant Exposure Equivalent to 61.7 MJ/m^2 Total UV in Glass-Filtered Sunlight	Irradiance Level, W/m^2	Exposure Time Required to Achieve the Radiant Exposure in Column 2, h
340	510 kJ/m^2	0.35	410.5
		0.50	283.3
420	1330 kJ/m^2	0.90	410.5
		1.30	283.3
300–400	61.7 MJ/m^2	42.3	410.5
		60.5	283.3

[A]This information is included for reference purposes only.