Designation: D4726 – 15

An American National Standard

Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Exterior-Profile Extrusions Used for Assembled Windows and Doors[1]

This standard is issued under the fixed designation D4726; 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 This specification establishes requirements for the material properties, including dimensional stability, weatherability, and extrusion quality, of rigid poly(vinyl chloride) (PVC) exterior profile extrusions used for assembled windows and doors. Methods for testing and for identifying exterior profile extrusions that comply with this specification are also provided.

1.2 The use of rigid PVC recycled plastic in this product shall be in accordance with the requirements in Section 6.

NOTE 1—Information with regard to application, assembly, and installation should be obtained from the manufacturers of the profiles and of the windows and doors.

NOTE 2—Refer to Specification D3678 for interior profile extrusions.

1.3 Color-hold guidelines are provided in an appendix for the manufacturer's product development and quality performance use.

1.4 Color-hold guidelines are presently limited to white, grey, beige, light brown, and dark brown (see Figs. X1.1 through X1.5). Additional colors will be added as color guidelines are developed.

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are for information only.

NOTE 3—There is no known ISO equivalent to this standard.

1.6 The text of this standard references notes and footnotes, which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this standard.

1.7 The following safety hazards caveat pertains only to the test methods portion, Section 11, of this specification: *This standard does not purport to address all of 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:*[2]

D618 Practice for Conditioning Plastics for Testing

D883 Terminology Relating to Plastics

D1042 Test Method for Linear Dimensional Changes of Plastics Caused by Exposure to Heat and Moisture

D1435 Practice for Outdoor Weathering of Plastics

D1600 Terminology for Abbreviated Terms Relating to Plastics

D2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates

D3678 Specification for Rigid Poly(Vinyl Chloride) (PVC) Interior-Profile Extrusions

D3892 Practice for Packaging/Packing of Plastics

D4216 Specification for Rigid Poly(Vinyl Chloride) (PVC) and Related PVC and Chlorinated Poly(Vinyl Chloride) (CPVC) Building Products Compounds

D4226 Test Methods for Impact Resistance of Rigid Poly-(Vinyl Chloride) (PVC) Building Products

D7209 Guide for Waste Reduction, Resource Recovery, and Use of Recycled Polymeric Materials and Products (Withdrawn 2015)[3]

E631 Terminology of Building Constructions

E805 Practice for Identification of Instrumental Methods of Color or Color-Difference Measurement of Materials

G147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests

3. Terminology

3.1 *General*—Definitions are in accordance with Terminologies D883 or E631 and D1600, unless otherwise indicated.

[1] This specification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.24 on Plastic Building Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

***A Summary of Changes section appears at the end of this standard**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *color-hold guidelines*—target color regions within a three-dimensional model which constitute acceptable appearance retention levels of color change resulting from weathering of a specific product type and color.

3.2.2 *temperate northern climate*—in weather testing, a North American metropolitan area testing site located within 73 to 100° W longitude and 37 to 45° N latitude.

4. Classification

4.1 *Color Regions*—The color region for a color is determined by measuring the Hunter L, a, b color values for a sample. Use the integer value (by truncating any fractional results) to determine the color region for the color using the following region boundaries.

4.1.1 *Region 1—Beige:*

L = 60 to 87
a = –2.5 to 4.0
b = 6.5 to 23

4.1.2 *Region 2—Dark Brown:*

L = 13 to 33
a = –1.0 to 6.0
b = 1.0 to 6.5

4.1.3 *Region 3—Gray:*

L = 33 to 74
a = –3 to 4
b = –5.5 to 5.5

4.1.4 *Region 4—Light Brown:*

L = 30 to 60
a = –1.5 to 12.5
b = 3.0 to 12.5

4.1.5 *Region 5—White:*

L = 83 to 100
a = –4 to 0
b = –5.5 to +5.5

NOTE 4—*L*, *a*, *b* is determined in accordance with the Hunter *L*, *a*, *b* opponent color space system in Test Method D2244.

5. Significance and Use

5.1 The purpose of this specification is to establish a recognized standard of quality for rigid poly(vinyl chloride) (PVC) exterior weatherable profile extrusions for use in assembling windows and doors. The information contained in this specification is intended to be helpful to producers, distributors, and users, and to promote understanding between buyers and sellers. It is also intended to serve as the basis for specification requirements of exterior windows and doors which are made from rigid PVC profile extrusions in their construction.

6. Materials and Manufacture

6.1 The profile extrusions used for assembled windows and doors shall be made principally of weatherable, rigid poly(vinyl chloride) (PVC) compounds meeting or exceeding the requirements of Class 1-20131-13 as defined in Specification D4216.

NOTE 5—Non-PVC materials may be used as a capstock.

6.2 Rigid PVC recycled plastic, as defined in Guide D7209, is acceptable for use in this product if all the requirements in the sections on Terminology (Section 3), Materials and Manufacture (Section 6), Physical Requirements (Section 7), and Performance Requirements (Section 8) are met by the extrusions containing PVC recycled plastic.

6.3 The PVC compound in the extruded section shall have uniform color and be free of any visual surface or structural changes, such as peeling, chipping, cracking, flaking, or pitting.

6.4 *Rework Material*—Clean, homogeneous PVC rework material or rework material containing PVC capstock generated from the manufacturer's own production of the same class compound is acceptable for use by the same manufacturer providing that the extruded profiles meet all the requirements of this specification. Clean principally PVC rework material containing non-PVC capstock is acceptable for use in the substrate of a capstocked product by the same manufacturer, providing that the extruded profiles meet all of the requirements of this specification.

6.5 The PVC compound shall have a minimum impact resistance of 0.6 in.·lb/mil (2670 J/m) after weathering for six months and one year in a hot, dry climate such as Phoenix, AZ; a hot, humid climate, such as Miami, FL; and a temperate northern climate.

6.6 The PVC compound in the extruded section shall maintain uniform color and be free of any surface or structural changes, such as peeling, chipping, cracking, flaking, or pitting after weathering for six months, one year, and two years in a hot, dry climate, such as Phoenix, AZ; a hot, humid climate, such as Miami, FL; and a temperate northern climate when tested in accordance with Annex A1.

6.7 The PVC compound shall have successfully met the weathering requirements prescribed in 6.4 and 6.5 for six months at each climatic testing site prior to use in production of exterior-profile extrusions for either market development or sales.

NOTE 6—The six-month-test requirement constitutes a screening process to eliminate catastrophic failure in the marketplace.

7. Physical Requirements

7.1 *Dimensions*—The size, thickness, and dimensional tolerances of the exterior profiles shall be as agreed upon between the supplier and the purchaser in the purchase order, or by established internal process control standards.

7.2 *Dimensional Stability*—The dimensional stability of the exterior-profile extrusions shall be determined in accordance with 11.3. Extrusions over 0.040 in. (1.02 mm) shall have a maximum average shrinkage of 2.2 % for all sides measured, with no single value exceeding 2.4 %. Extrusions of 0.040 in. (1.02 mm) or less shall have a maximum average shrinkage of 3 %.

7.3 *Impact Resistance*—Flat sections of the exterior profile extrusion shall have a minimum brittle impact failure of 1.0 in.·lb/mil (4450 J/m) when tested in accordance with Test Methods D4226, Procedure B, using impactor C.125. Refer to 11.4.

8. Performance Requirements

8.1 *Weathering:*

8.1.1 The exposures listed in 6.6 shall be conducted in order to meet the requirements of this specification. All exposures shall be conducted at an angle of 45° S, plywood-backed, in accordance with Practice D1435 and Practice G147.

8.1.2 After six-month and 1-year exposure times, the minimum mean impact for 20 measurements conducted on the exposed specimens shall be at least 0.6 in·lb/mil (2670 J/m). Test impact in accordance with 11.4, A1.4, and A1.5.

8.1.3 After each exposure time, the tested specimens shall maintain a uniform color and be free of any visual surface or structural changes such as peeling, chipping, cracking, flaking, and pitting when tested in accordance with Annex A1.

NOTE 7—It is recommended that manufacturers use the color-hold guidelines in Appendix X1 to ensure quality performance.

8.1.4 Weatherability conformance testing requirements are to reflect performance of a "typical" extrusion system profile representing a specific PVC compound and a specific extrusion technology. In no case is there an implied requirement for testing all the various shaped profiles. The lengthy outdoor weatherability testing shall be performed concurrently with market development of new applications and sales of profiles to existing markets. Completion of weatherability testing prior to marketing of the product is not required. The profile extrusion producer shall immediately respond in terms of compound change or extrusion technology change to unsatisfactory weatherability behavior of the profiles under test in any climatic test site at any stage of the weatherability testing.

9. Workmanship, Finish, and Appearance

9.1 The extrusions shall be acceptable between the buyer and the seller or meet internal process control standards in section, color, and finish. The extrusions shall be substantially straight and free from defects that might affect appearance or serviceability.

10. Sampling

10.1 Select samples using a statistically acceptable procedure. The samples shall be representative of the compound used.

11. Test Methods

11.1 *General*—Use the inspection and test procedures contained in this section to determine the conformance of products to the requirements of this specification. A producer or distributor representing products as conforming to this specification shall use statistically based sampling plans that are appropriate to each manufacturing process. Keeping essential records are necessary to document with a high degree of assurance the claim that all of the requirements of this specification have been met. Additional sampling and testing of the product, as agreed upon between the supplier and the purchaser, is not precluded by this section.

11.2 *Conditioning of Specimens*—Condition the test specimens in accordance with Procedure A of Practice D618. For the purpose of quality control testing, the minimum conditioning time shall be four hours.

11.3 *Dimensional Stability:*

11.3.1 Determine the dimensional stability in accordance with Test Method D1042, except that one or more specimens shall be exposed to either of the following test cycles:

11.3.1.1 30 min immersed in water maintained at 180 ± 2°F (82 ± 1 °C), or

11.3.1.2 30 min conditioned in a forced-ventilation oven at 180 ± 2°F (82 ± 1 °C).

11.3.2 Specimens shall condition for no less than 1 h in accordance with Procedure A of Practice D618, prior to measurement. If a specimen were to fail, select and retest two additional specimens.

11.4 *Impact Test*—Determine the impact strength in accordance with Test Methods D4226, Procedure B, using the C.125 impactor.

12. Packing, Packaging, and Package Marking

12.1 The exterior profile extrusions shall be packaged in such a manner as to provide reasonable protection against damage in ordinary handling, transportation, and storage.

12.2 Provisions of Practice D3892 shall apply to this specification.

12.3 Marking on each package of extruded profile extrusions shall include the following:

12.3.1 Manufacturer's name or trademark;

12.3.2 Identity of code number of extrusion profiles;

12.3.3 Class of compound (Specification D4216) used in profiles;

12.3.4 The designation ASTM D4726, affirming that the product so marked has been qualified to all the provisions of this specification, and

12.3.5 The date and any other relevant information, such as factory, machine, production shift, and so forth, either directly or all or partly coded.

13. Keywords

13.1 color-hold guidelines; doors; exterior-profile extrusions; poly(vinyl chloride) (PVC); recycled plastic; windows

ANNEXES

(Mandatory Information)

A1. WEATHERABILITY PROCEDURE

A1.1 Summary of Procedure of Determining Weatherability

A1.1.1 Flat section specimens cut from finished product lineals or laboratory extruded samples are exposed in accordance with Practice D1435 and Practice G147 at 45° S, plywood-backed, in a hot, dry (desert) climate, such as Phoenix, AZ; a hot, humid climate such as Miami, FL; and in a northern temperate climate for periods of six months, one year and two years.

A1.1.2 Color change as a result of weather exposure at each climatic exposure site is measured after six months, one year and two years.

A1.1.3 Degree of retention of the original impact strength due to weather exposure in each exposure site is measured after six-months and one-year exposure.

A1.1.4 The acceptability of color uniformity, and surface or structural changes resulting from weathering at each test site and each exposure frequency is determined by visual observation in comparison to the unweathered specimens.

A1.2 Significance

A1.2.1 The processing of poly(vinyl chloride) (PVC) compounds has greater influence on impact retention and some influence on color retention. For this reason samples prepared for weathering must be processed in a manner similar to the commercial product while still permitting the use of laboratory scale equipment. Color hold guidelines are represented by ellipsoids or as an alternative, mathematical equations, both of which allow determination whether the product meets the performance criteria. The ellipsoids also allow determination of the direction of color change and, therefore, are useful in analyzing the weathering data.

A1.2.2 Poly(vinyl chloride) compounds undergo complex changes when exposed to the weather. Color changes are caused by chemical changes in the PVC, additives, or pigments. Color changes are caused by selective erosion of some pigments faster than others. Changes in impact strength are due to chemical changes in the PVC or additives, or due to physical changes on the surface as a result of erosion and crazing.

A1.3 Sampling and Specimen Preparation

A1.3.1 Select samples using a statistically acceptable procedure. The samples shall be representative of the product to be qualified.

A1.3.2 If commercial parts are used, cut them into sections so that flat test specimens at least 1.5 in. (38 mm) wide can be obtained. The back surface of the specimen must lay as flat as possible on the specimen support anvil. Cut the flat sections such that there are no ridges or raised areas remaining on the back surface of the specimen that would make contact with the specimen support anvil. The specimens shall be free of obvious imperfections, grooves, ribs, and so forth. Material prepared in the laboratory by a similar process is an alternate to a commercial part. If the commercial product is extruded, the laboratory specimen must be extruded; if the commercial product is a laminate of two materials, the laboratory specimen must be laminated with the two materials, and so forth.

A1.3.3 The number of specimens or the size of the specimen must be sufficient to obtain at least 20 impact locations of the dropped dart for each weathering interval.

A1.3.4 The thickness of any test specimen must differ from the average test specimen by no more than 10 %.

A1.4 Conditioning

A1.4.1 Condition the test specimens, including specimens removed from the weather exposure, at 73.4 ± 3.6°F (23.0 ± 2.0 °C) and 50 ± 10 % relative humidity for not less than 24 h before testing. In no case shall weathered specimens be oven-dried before testing.

A1.5 Procedure

A1.5.1 Obtain test specimens in accordance with A1.3.

A1.5.2 Measure the original tristimulus *X*, *Y*, and *Z* values in replicate for each specimen using 2° observer and Illuminant C, specular components included, in accordance with Practice E805. Calculate the Hunter *L*, *a*, *b* units in accordance with the equations in the Section on Hunter *L*, *a*, *b* Color Space and Color-Difference Equation in Test Method D2244. Average the calculated units from the replicate measurements and record them in a permanent record.

A1.5.3 Measure the impact resistance on an unweathered specimen in accordance with Test Methods D4226, Procedure B, with a C.125 impactor and record permanently.

A1.5.4 Mark the specimens permanently so as to not lose their identity during weathering. Weather specimens at 45°S, plywood-backed, in accordance with Practice D1435 in both a dry, hot (desert) climate such as Phoenix, AZ; a hot, humid climate such as Miami, FL; and a temperate northern climate. Remove specimens for testing after six-months, one-year, and two-year exposure. Further testing is optional. More frequent exposure increments are preferred to some applications.

A1.5.5 After exposure, measure the color and evaluate the appearance of the exposed specimens. Color measurement shall take place within seven days of specimen removal from the exposure test rack.

NOTE A1.1—Additional color development is known to occur for PVC products after removal from exposure to solar radiation. This color change is referred to as Dark Time Yellowing. For a hot, humid climate such as Miami, FL and in a northern temperate climate, color measurement within 48 h of removal is strongly recommended for PVC products. For a hot and dry (desert) climate, such as Arizona, it is strongly recommended the color

measurement be made within 8 h of removal from the exposure rack.

A1.5.6 Wash the exposed specimens in accordance with the procedure in Annex A2.

A1.5.7 Condition in accordance with A1.4.

A1.5.8 After removal from the exposure rack and within the time period specified in A1.5.5, measure color on the exposed specimen(s) in accordance with A1.5.2. Record color in *L*, *a*, *b* units and record the average change in color as compared to the unweathered specimen in *L*, *a*, *b* units.

A1.5.9 Note and record any nonuniform change in color.

A1.5.10 Measure average impact resistance of the weathered specimens, weathered side up, using the same method used for the unweathered specimen (A1.5.3).

A2. WASHING WEATHERED SPECIMENS

A2.1 Scope

A2.1.1 This procedure provides a consistent and reproducible practice for washing weathered specimens prior to instrumental color measurement. The procedure is designed to minimize any effects of altering the surface of the specimen in other than a predictable manner.

A2.2 Equipment

A2.2.1 *Mild Detergent,* such as Joy, Liquid Tide, or equivalent.

A2.2.2 *Sponge or Soft Cloth.*

A2.3 Procedure

A2.3.1 Flush the exposed specimen with distilled or deionized water.

A2.3.2 Wash the specimen lightly with mild detergent using a sponge or soft cloth.

A2.3.2.1 The scrubbing action shall not be excessive and shall be limited to back and forth scrubbing along the grain or pattern, if one exists.

A2.3.2.2 Avoid circular scrubbing.

A2.3.3 Evaluate specimen visually to determine if the specimen is "soil free."

A2.3.4 If not "soil free," lightly wipe the specimen once over the surface with a "sopping wet" sponge in the direction of the grain or pattern, if one exists.

A2.3.5 Reflush the specimen with distilled or deionized water and dry in a vertical position, placed so that water will run off with the grain or pattern, if one exists.

APPENDIX

(Nonmandatory Information)

X1. COLOR-HOLD GUIDELINES WEATHERING TEST

X1.1 Scope

X1.1.1 Color-hold guideline weatherability testing provides a method for estimating the acceptability of color change in a window and door profile product over an extended period of service.

X1.1.2 It has been shown that commercial window and door profile products which demonstrate weathering behavior that approximates these target guidelines during a two-year test program exhibit acceptability for the marketplace in terms of color change.

X1.1.3 These tests are designed for the window and door manufacturer's product development and quality performance use only and are not for regulatory use.

X1.2 Significance and Use

X1.2.1 Color-hold guidelines provide boundary target color regions within a three-dimensional model, which constitutes acceptable appearance retention levels of color change resulting from weathering of a specific window or door profile product type, formulation, and color.

X1.2.2 Each color region is defined by the manufacturers of vinyl window and door profiles as specific color-hold guidelines (see Note X1.1). Regardless of where a specific color falls within the region, it becomes the control on each of the three graphs plotting color difference of each manufacturer's formulation and color.

NOTE X1.1—Five color regions are presently defined as specific color-hold guidelines.

X1.2.3 Color-hold guidelines are unique and specific to a product application, such as window and door profiles and may not be transposable for use on other product applications.

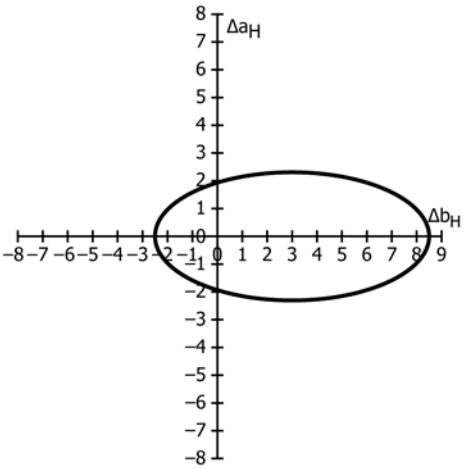
NOTE X1.2—In any product application, color-hold guidelines are related to a perceived acceptable level of color change. Therefore, window and door color-hold guidelines may be acceptable for transposition for

building railings or fence profile applications, but not for siding applications.

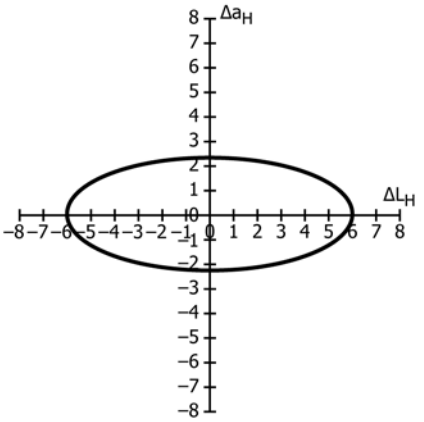
X1.3 Establishing Window and Door Color Regions

X1.3.1 The window and door manufacturer's color panel uses the following steps to establish the window and door color regions.

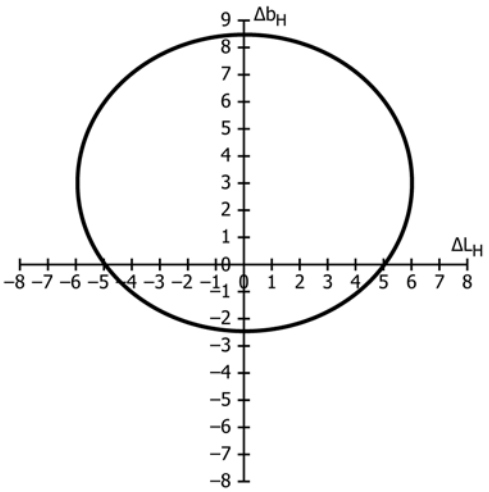
Step 1—All commercial unweathered window and door profile colors are divided into rational similar color regions representing a visibly definable hue (white, beige, dark brown, gray, and light brown). See Figs. X1.1-X1.5. Each color is then measured in Hunter *L*, *a*, *b* units and plotted in color space.



1(a) ($\Delta a_H - \Delta b_H$)

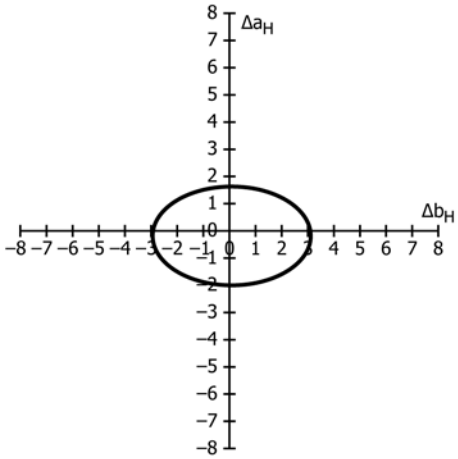


1(b) ($\Delta a_H - \Delta L_H$)

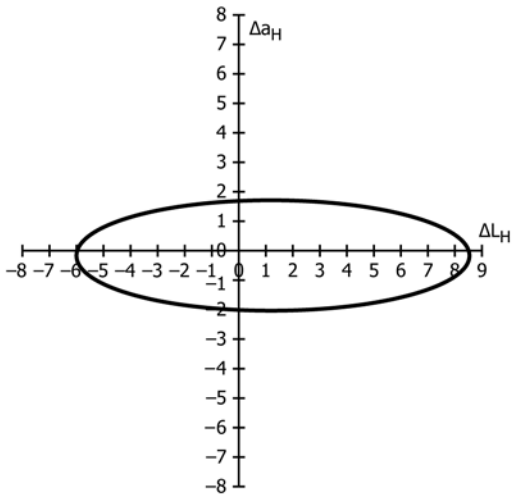


1(c) ($\Delta b_H - \Delta L_H$)

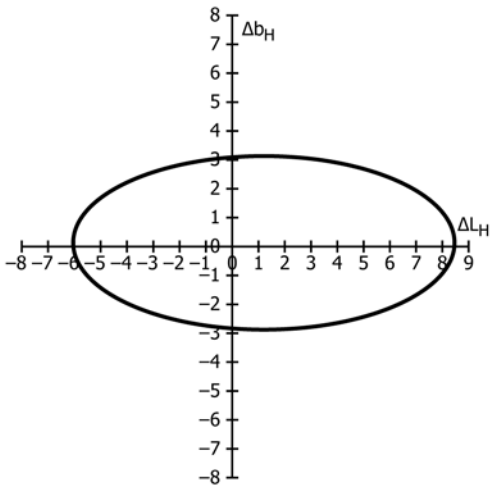
FIG. X1.1 White Color-Hold Guidelines



2(a) ($\Delta a_H - \Delta b_H$)



2(b) ($\Delta a_H - \Delta L_H$)



2(c) ($\Delta b_H - \Delta L_H$)

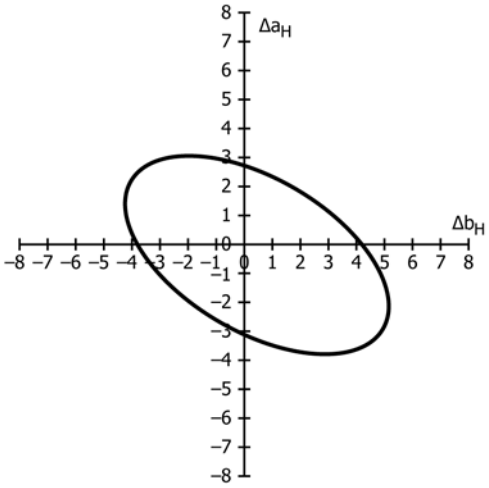
FIG. X1.2 Gray Color-Hold Guidelines

Step 2—The color region itself is then defined by the extreme Hunter *L*, *a*, *b* units within the population of colors.

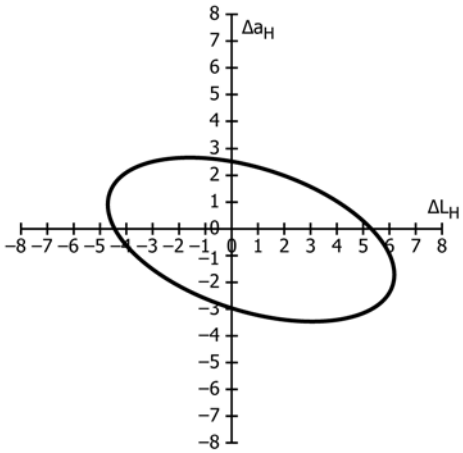
Step 3—Any specific color being evaluated within the color region becomes the control for color-difference studies. Refer to X1.3.

Step 4—Simulated two-year weathered samples for each color region encompassing areas within that region are prepared.

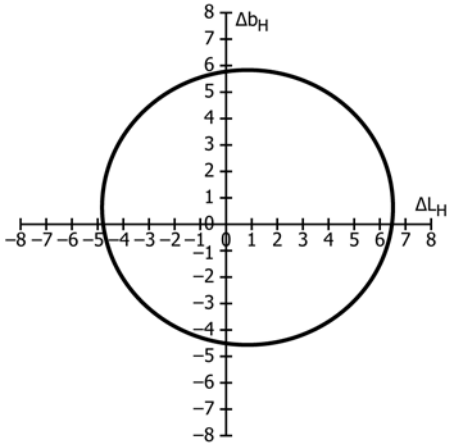
Step 5—A visual examination and rating of each simulated weathered sample is conducted by a panel of window and door



3(a) ($\Delta a_H - \Delta b_H$)



3(b) ($\Delta a_H - \Delta L_H$)



3(c) ($\Delta b_H - \Delta L_H$)

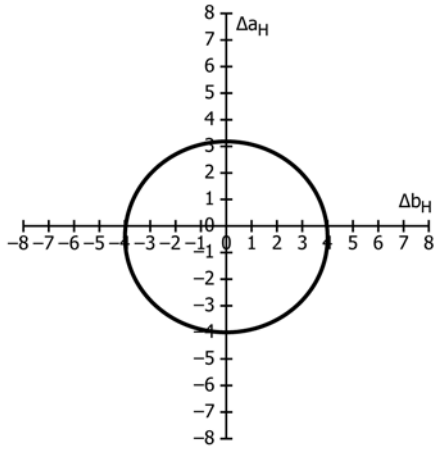
FIG. X1.3 Beige Color-Hold Guidelines

manufacturers and color specialists to establish a visual average rating of limits of acceptability of color change for the window and door application. After visual examination, the acceptable delta (Δ) limits are plotted three dimensionally and considered preliminary limits.

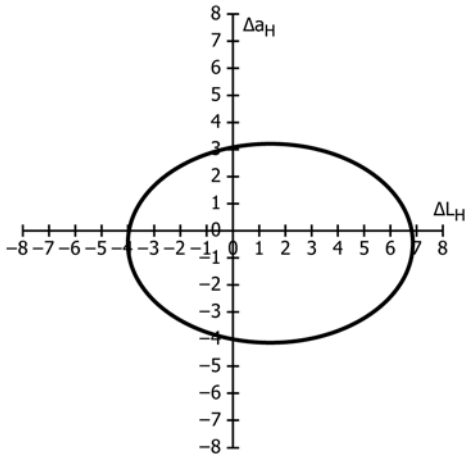
Step 6—Real world data from two-year weathering studies in Florida, Arizona, and temperate northern climate test sites are then plotted in terms of change of Hunter *L*, *a*, *b* from the control for each of the colors within that region.

Step 7—The final reference ellipses of color-hold guidelines for each region are then established by adjustment of the preliminary data by use of the real world data. Refer to X1.3. The ellipses are then normalized and the mathematical equations for each set of ellipses are developed.

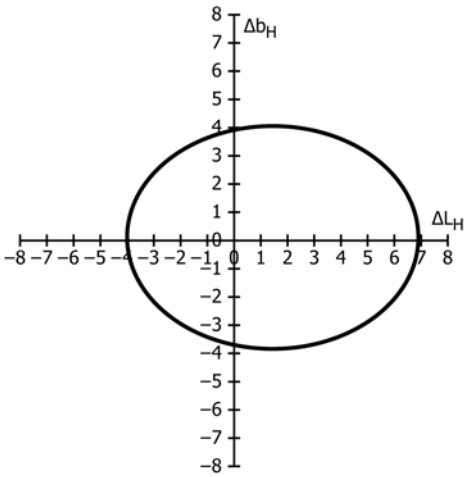
Step 8—Concurrent with development of the color-hold guidelines for each color region, outdoor weathering of all commercial window and door profile samples will be continued in Florida, Arizona, and northern temperate climate sites in



4(a) ($\Delta a_H - \Delta b_H$)



4(b) ($\Delta a_H - \Delta L_H$)



4(c) ($\Delta b_H - \Delta L_H$)

FIG. X1.4 Light Brown Color-Hold Guidelines

a five-year program followed each five years by a new study, including new colors and formulations representing current commercial products.

X1.4 Summary of Procedure for Determining Weathering

X1.4.1 Flat section specimens cut from finished product window and door profiles are exposed in a dry, hot climate such as Phoenix, AZ; a hot, humid climate such as Miami, FL; and a temperate Northern climate.

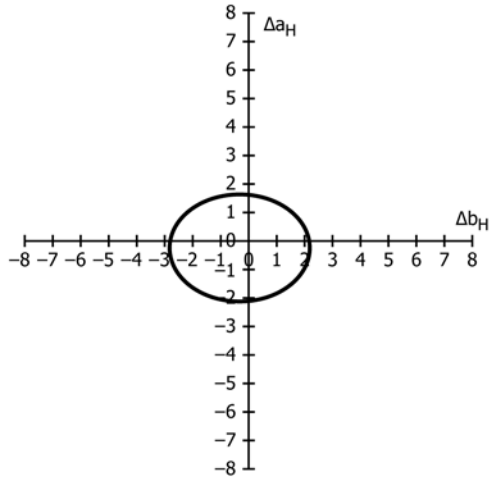
X1.4.2 Color change caused by weather exposure at each exposure site is measured after six months, one year, and two years of exposure.

X1.4.3 The acceptability in the change in color resulting from weathering at each test site and exposure frequency is determined by reference to the appropriate color-hold guideline ellipses for that specific color or, as an alternative, by reference to the appropriate color-hold guideline equation for that specific color.

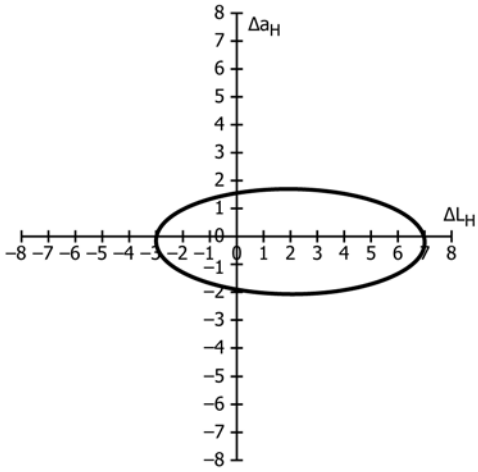
X1.5 Sampling and Specimen Preparation

X1.5.1 Select samples using a statistically acceptable procedure. The samples shall be representative of the window and door profile product to be qualified.

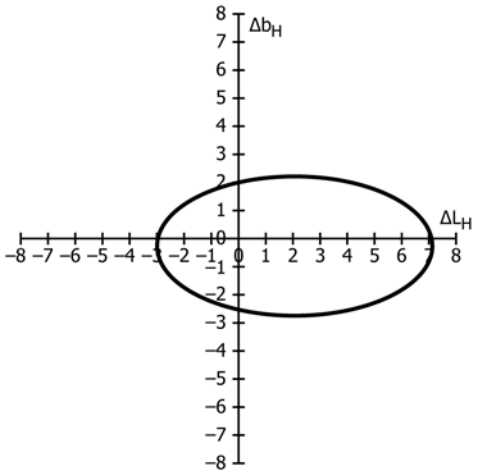
X1.5.2 If commercial parts are to be used, they shall be cut into specimens that are flat and are free of any imperfections.



5(a) ($\Delta a_H - \Delta b_H$)



5(b) ($\Delta a_H - \Delta L_H$)



5(c) ($\Delta b_H - \Delta L_H$)

FIG. X1.5 Dark Brown Color-Hold Guideline

Cut a sufficient number of specimens to allow removal of a specimen at each weathering time interval specified at each testing site, plus retained unweathered specimens. Alternatively, samples may be washed, measured, and returned to the test site.

X1.5.3 Samples prepared in the laboratory by the same process (extrusion) and melt temperature may be used as an alternative to a commercial sample. The laboratory sample must be extruded under similar conditions to those used to prepare the commercial product.

X1.5.4 The thickness of any test specimen shall be the same thickness as the window and door profile commercial product, differing from the average test specimen by no more than 10 %.

X1.6 Weathering Practice

X1.6.1 Prepare test specimens in accordance with X1.5.

X1.6.2 Mark each specimen permanently so as to ensure retention of identity during and after weathering.

X1.6.3 Measure in replicate the original tristimulus *X*, *Y*, and *Z* values for each specimen using 2° observer and

Illuminant C, specular components included, in accordance with Practice E805. Calculate the Hunter *L*, *a*, *b* units in accordance with the equations in the section on Hunter *L*, *a*, *b* Color Space and Color-Difference Equation in Test Method D2244, using the average of the replicate measurements and record them in a permanent record.

X1.6.4 Weather specimens at an angle of 45° S, plywood-backed, in accordance with Practice D1435 in a hot, dry climate, such as Phoenix, AZ; a hot, humid climate, such as Miami, FL; and in a temperate northern climate.

X1.6.5 Remove specimens for testing after six months, one year, and two years of exposure.

X1.6.6 It is recommended that exposed specimens be evaluated for color characterization at the test site. If this is not possible, use an expedient shipping procedure to minimize time between exposure and testing. Color measurement shall be completed within seven days after removal from the exposure rack.

NOTE X1.3—Additional color development is known to occur for PVC products after removal from exposure to solar radiation. This color change is referred to as Dark Time Yellowing. For a hot, humid climate such as Miami, FL and in a northern temperate climate, color measurement within 48 h of removal is strongly recommended for PVC products. For a hot and dry (desert) climate, such as Arizona, it is strongly recommended the color measurement be made within 8 h of removal from the exposure rack.

X1.6.7 Wash the exposed specimens in accordance with the procedure in Annex A2.

X1.6.8 Measure and record the color of the exposed specimens in accordance with X1.4.3 after each exposure frequency.

X1.6.9 Calculate and record the change in *L*, *a*, *b* color coordinates for each specimen exposure frequency by reference to the original color (X1.6.3) and the exposed color (X1.6.8).

X1.6.10 Note and record any nonuniform change in color on any specimen.

X1.6.11 Determine the acceptability of the change in color resulting from weathering at each test site and exposure frequency by reference to the appropriate series of color-hold guideline ellipses for that specific color. The target three-dimension color space is plotted as guideline ellipses for each color (Δa versus Δb), (Δa versus ΔL), and (Δb versus ΔL) in Fig. X1.1(*a*) to 5(*c*). For example, in the case of white window and door profiles, use Fig. X1.1(*a*), 1(*b*), and 1(*c*).

X1.6.12 Plot the specific change in the color coordinates when compared to the unweathered specimen color coordinates (X1.6.3) by plotting on each of the guideline ellipses for that color. To meet the color-hold guidelines, the plotted change in color for Δa, Δb, and ΔL will fall essentially within the acceptance regions in all three color ellipses.

X1.6.13 Report any deviation and extent of deviation from the target guideline ellipses by Δa, Δb, and ΔL for any test site and exposure frequency. Report any deviation from uniform color change in any specimen. Report any other appearance change in any specimen. As an alternative to plotting the color change data on the color hold guideline ellipses, the equations for the corresponding guidelines set of ellipses may be used. The calculations are performed by inserting the delta L, delta a and delta b values into the equation and solving for the value on the left side of the equation. If the left side of the equation is less than or equal to 1, the product meets the color-hold guidelines.

X1.6.14 *An Example of an Ellipsoid Calculation:*

X1.6.14.1 Take an initial color reading of the specimen.

Example: L = 75.25, a = 0.50, b = 2.85

By definition, this specimen is in the Gray Color Region.

X1.6.14.2 Take a color reading after an outdoor exposure.

Example: L = 79.45, a = 0.25, b = 1.95

The color difference (exposed - initial) is: $\Delta L = 4.20$, $\Delta a = -0.25$, $\Delta b = -0.90$

X1.6.14.3 Insert the ΔL, Δa, and Δb values into the Gray Colorhold Ellipsoid Equation to calculate the ellipsoid value.

Gray Colorhold Ellipsoid:

$$\frac{(\Delta L - 1.20)^2}{(7.30)^2} + \frac{(\Delta a + 0.15)^2}{(1.85)^2} + \frac{(\Delta b - 0.10)^2}{(3.00)^2} = 1 \quad \text{(X1.1)}$$

$$\frac{(4.20 - 1.20)^2}{(7.30)^2} + \frac{(-0.25 + 0.15)^2}{(1.85)^2} + \frac{(-0.90 - 0.10)^2}{(3.00)^2}$$

$$= 0.169 + 0.03 + 0.111$$

$$= 0.283$$

The ellipsoid value is less than 1.00, so the outdoor exposure specimen is within the gray colorhold guideline.

X1.7 Color Hold Guideline Equations

X1.7.1 *White:*

$$\frac{(\Delta L - 0.00)^2}{(6.00)^2} + \frac{(\Delta a - 0.00)^2}{(2.30)^2} + \frac{(\Delta b - 3.00)^2}{(5.50)^2} = 1 \quad \text{(X1.2)}$$

X1.7.2 *Gray:*

$$\frac{(\Delta L - 1.20)^2}{(7.30)^2} + \frac{(\Delta a + 0.15)^2}{(1.85)^2} + \frac{(\Delta b - 0.10)^2}{(3.00)^2} = 1 \quad \text{(X1.3)}$$

X1.7.3 *Beige:*

$$\frac{(\Delta L' - 0.85)^2}{(5.65)^2} + \frac{(\Delta a'' + 0.15)^2}{(2.65)^2} + \frac{(\Delta b' - 0.60)^2}{(5.20)^2} = 1 \quad \text{(X1.4)}$$

X1.7.3.1 In order to duplicate the original hand-drawn ellipses for Beige, two axes rotations were made to the ellipsoid equation. The $\Delta b - \Delta a$ plane was rotated –0.50 radians, and the $\Delta L - \Delta a$ plane was rotated –0.30 radians.

X1.7.3.2 To calculate the ellipsoid value for Beige, counter-rotations of the ΔL, Δa, and Δb data must be made. Note that Δa is rotated twice, and $\Delta a''$ is used to calculate the ellipsoid value.

$$\Delta a' = (\Delta b^2 + \Delta a^2)^{0.5}\ (\sin(\arctan(\Delta a/\Delta b) + 0.5))$$

X1.7.3.3 Calculations for $\Delta L'$, $\Delta a''$, and $\Delta b'$ used in the ellipsoid equation for Beige:

$$\Delta L' = (\Delta L^2 + \Delta a'^2)^{0.5}\ (\cos(\arctan(\Delta a'/\Delta L) + 0.3)) \quad \text{(X1.5)}$$

$$\Delta a'' = (\Delta L^2 + \Delta a'^2)^{0.5}\ (\sin(\arctan(\Delta a'/\Delta L) + 0.3)) \quad \text{(X1.6)}$$

$$\Delta b' = (\Delta b^2 + \Delta a^2)^{0.5}\ (\cos(\arctan(\Delta a/\Delta b) + 0.5)) \quad \text{(X1.7)}$$

X1.7.4 *Lt. Brown:*

$$\frac{(\Delta L - 1.45)^2}{(5.45)^2} + \frac{(\Delta a + 0.45)^2}{(3.65)^2} + \frac{(\Delta b - 0.05)^2}{(3.95)^2} = 1 \quad (X1.8)$$

$$\frac{(\Delta L - 2.05)^2}{(5.05)^2} + \frac{(\Delta a - 0.20)^2}{(1.90)^2} + \frac{(\Delta b + 0.30)^2}{(2.50)^2} = 1 \quad (X1.9)$$

X1.7.5 *Dk. Brown:*

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D4726–09) that may impact the use of this standard. (May 1, 2015)

(1) Reworded 1.2 to remove non-mandatory language.
(2) Reworded Note 3, ISO equivalency in accordance with D 4969-08.
(3) Removed D 1898, D 4099, D5033 references and added D 7209 reference to Referenced Documents.
(4) Removed color regions from Section 3.
(5) Reworded 3.2.1.
(6) Deleted old Note 4.
(7) Removed sub "H's" in Note 5.
(8) Added Section 4, "Classification," for color regions, renumbered all sections.
(9) Section 4.1.1: Region 1 – Beige: Set L = 60 – 87 from L = 61 – 87. Closed gap with light brown, L = 30 - 60.
(10) Delete old Note 6, D4099 reference.
(11) Replaced D5033 reference with D 7209 in 5.3.
(12) Reworded 5.6 to add a two-year weathering period for white and all colors
(13) Section 5.7 – Renumbered 5.4 to 5.5 and 5.5 to 5.6
(14) Reworded 6.2, 6.3, and 6.4 to remove non-mandatory language.
(15) Deleted Table 1.
(16) Replaced Table 1 reference in 7.1.1 with 5.6.
(17) Reworded 8.1.3.
(18) Reworded 9.1 to delete D 1898 reference.
(19) Reworded 10.1 and 10.3.2 to remove passive language.
(20) Reworded A1.1 and A1.1.4.
(21) Reworded A1.1.1 and A1.1.2 to add a two-year weathering period for white and all colors.
(22) Reworded A1.2.1 and A1.2.2 to remove passive language.
(23) Reworded A1.2.3 and moved to A1.5.5.
(24) Added Note 10, recommendation for color measurement within 48 hours and eight hours for a hot and dry climate, such as Arizona and reworded.
(25) Reworded A1.3.1 to delete D 1898 reference.
(26) Reworded A1.3.2, added wording about flatness of test specimen.
(27) Adjusted temperature and humidity values in A1.4.1 in accordance with D618.
(28) Changed A1.5 to "Procedure" from "Practice."
(29) Reworded A1.5.4 to add a two-year weathering period for white and all colors.
(30) Reworded A1.5.8 to clarify time period specified in A1.2.3 for color measurement.
(31) Reworded A2 and A2.1.1.
(32) Reworded X1.1.1.
(33) Reworded X1.1.2.
(34) Reworded X1.1.3.
(35) Reworded X1.5.1 to delete D1898 reference.
(36) Adjusted unit spacing in accordance with ASTM SI-10 (American National Standard for Metric Practice) in various sections.
(37) Corrected Equation X1.6 in X1.7.3.3, replaced A with Δ.
(38) Updated "Summary of Changes" at end of document.