



Designation: **D3794 – 13 D3794 – 16**

## Standard Guide for Testing Coil Coatings<sup>1</sup>

This standard is issued under the fixed designation D3794; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the U.S. Department of Defense.*

### 1. Scope

1.1 This guide covers procedures for testing coil coatings. The test methods included are listed in Table 1. Where more than one test method is listed for the same characteristic, no attempt is made to indicate superiority of one method over another. Selection of test methods to be followed must be governed by the requirements in each individual case, together with agreement between the producer and user.

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

1.3 *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. Some specific hazards statements are given in Section 7 on Hazards.*

### 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

- [B177B117 Guide for Engineering Chromium Electroplating Practice for Operating Salt Spray \(Fog\) Apparatus](#)
- [B368 Test Method for Copper-Accelerated Acetic Acid-Salt Spray \(Fog\) Testing \(CASS Test\)](#)
- [C1371 Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers](#)
- [C1549 Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer](#)
- [D522 Test Methods for Mandrel Bend Test of Attached Organic Coatings](#)
- [D523 Test Method for Specular Gloss](#)
- [D610 Practice for Evaluating Degree of Rusting on Painted Steel Surfaces](#)
- [D660 Test Method for Evaluating Degree of Checking of Exterior Paints](#)
- [D661 Test Method for Evaluating Degree of Cracking of Exterior Paints](#)
- [D714 Test Method for Evaluating Degree of Blistering of Paints](#)
- [D822 Practice for Filtered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings](#)
- [D823 Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels](#)
- [D870 Practice for Testing Water Resistance of Coatings Using Water Immersion](#)
- [D968 Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive](#)
- [D1005 Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers](#)
- [D1014 Practice for Conducting Exterior Exposure Tests of Paints and Coatings on Metal Substrates](#)

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.53 on Coil Coated Metal.

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<sup>2</sup> 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.

- ~~D1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base (Withdrawn 2006)<sup>3</sup>~~
- D1193 Specification for Reagent Water
- D1200 Test Method for Viscosity by Ford Viscosity Cup
- D1210 Test Method for Fineness of Dispersion of Pigment-Vehicle Systems by Hegman-Type Gage
- D1212 Test Methods for Measurement of Wet Film Thickness of Organic Coatings
- D1308 Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes
- ~~D1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base (Withdrawn 2006)<sup>3</sup>~~
- D1474 Test Methods for Indentation Hardness of Organic Coatings
- D1475 Test Method For Density of Liquid Coatings, Inks, and Related Products
- D1654 Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments
- D1729 Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials
- D1735 Practice for Testing Water Resistance of Coatings Using Water Fog Apparatus
- D1823 Test Method for Apparent Viscosity of Plastisols and Organosols at High Shear Rates by Extrusion Viscometer
- D1824 Test Method for Apparent Viscosity of Plastisols and Organosols at Low Shear Rates
- D2092 Guide for Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting (Withdrawn 2008)<sup>3</sup>
- D2196 Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational Viscometer
- D2197 Test Method for Adhesion of Organic Coatings by Scrape Adhesion
- D2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
- D2247 Practice for Testing Water Resistance of Coatings in 100 % Relative Humidity
- D2248 Practice for Detergent Resistance of Organic Finishes
- D2369 Test Method for Volatile Content of Coatings
- D2454 Practice for Determining the Effect of Overbaking on Organic Coatings
- D2697 Test Method for Volume Nonvolatile Matter in Clear or Pigmented Coatings
- D2794 Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
- D2803 Guide for Testing Filiform Corrosion Resistance of Organic Coatings on Metal
- D3003 Test Method for Pressure Mottling and Blocking Resistance of Organic Coatings on Metal Substrates
- D3134 Practice for Establishing Color and Gloss Tolerances
- D3170 Test Method for Chipping Resistance of Coatings
- D3278 Test Methods for Flash Point of Liquids by Small Scale Closed-Cup Apparatus
- D3359 Test Methods for Measuring Adhesion by Tape Test
- D3361 Practice for Unfiltered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings
- D3363 Test Method for Film Hardness by Pencil Test
- D3960 Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings
- D4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
- D4138 Practices for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive, Cross-Sectioning Means
- D4141 Practice for Conducting Black Box and Solar Concentrating Exposures of Coatings
- D4145 Test Method for Coating Flexibility of Prepainted Sheet
- D4146 Test Method for Formability of Zinc-Rich Primer/Chromate Complex Coatings on Steel
- D4147 Practice for Applying Coil Coatings Using The Wire-Wound Drawdown Bar
- D4212 Test Method for Viscosity by Dip-Type Viscosity Cups
- D4214 Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films
- D4287 Test Method for High-Shear Viscosity Using a Cone/Plate Viscometer
- D4518 Test Methods for Measuring Static Friction of Coating Surfaces (Withdrawn 2000)<sup>3</sup>
- D4585 Practice for Testing Water Resistance of Coatings Using Controlled Condensation
- D4587 Practice for Fluorescent UV-Condensation Exposures of Paint and Related Coatings
- D5031 Practice for Enclosed Carbon-Arc Exposure Tests of Paint and Related Coatings
- D5178 Test Method for Mar Resistance of Organic Coatings
- D5402 Practice for Assessing the Solvent Resistance of Organic Coatings Using Solvent Rubs
- D5531 Guide for Preparation, Maintenance, and Distribution of Physical Product Standards for Color and Geometric Appearance of Coatings
- D5723 Practice for Determination of Chromium Treatment Weight on Metal Substrates by X-Ray Fluorescence
- D5796 Test Method for Measurement of Dry Film Thickness of Thin-Film Coil-Coated Systems by Destructive Means Using a Boring Device

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

- D5894 Practice for Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet)
- D6093 Test Method for Percent Volume Nonvolatile Matter in Clear or Pigmented Coatings Using a Helium Gas Pycnometer
- D6491 Practice for Evaluation of Aging Resistance of Prestressed Prepainted Metal In a Dry Heat Test
- D6492 Practice for Detection of Hexavalent Chromium On Zinc and Zinc/Aluminum Alloy Coated Steel
- [D6578 Practice for Determination of Graffiti Resistance](#)
- [D6665 Practice for Evaluation of Aging Resistance of Pre-stressed Prepainted Metal in a Boiling Water Test](#)
- [D6695 Practice for Xenon-Arc Exposures of Paint and Related Coatings](#)
- D6906 Test Method for Determination of Titanium Treatment Weight on Metal Substrates by Wavelength Dispersive X-Ray Fluorescence
- [D6944 Practice for Determining the Resistance of Cured Coatings to Thermal Cycling](#)
- [D7091 Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals](#)
- D7376 Practice for Outdoor Evaluation of Wet Stack Storage Conditions on Coil-Coated Metals
- D7639 Test Method for Determination of Zirconium Treatment Weight or Thickness on Metal Substrates by X-Ray Fluorescence
- [D7869 Practice for Xenon Arc Exposure Test with Enhanced Light and Water Exposure for Transportation Coatings](#)
- [D7897 Practice for Laboratory Soiling and Weathering of Roofing Materials to Simulate Effects of Natural Exposure on Solar Reflectance and Thermal Emittance](#)
- E70 Test Method for pH of Aqueous Solutions With the Glass Electrode
- E84 Test Method for Surface Burning Characteristics of Building Materials
- E284 Terminology of Appearance
- E308 Practice for Computing the Colors of Objects by Using the CIE System
- E408 Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques
- E643 Test Method for Ball Punch Deformation of Metallic Sheet Material
- E903 Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres
- E1164 Practice for Obtaining Spectrometric Data for Object-Color Evaluation
- E1356 Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry
- E1541 Practice for Specifying and Matching Color Using the Colorcurve System (Withdrawn 2007)<sup>3</sup>
- E1545 Test Method for Assignment of the Glass Transition Temperature by Thermomechanical Analysis
- E1640 Test Method for Assignment of the Glass Transition Temperature By Dynamic Mechanical Analysis
- E1808 Guide for Designing and Conducting Visual Experiments
- E1918 Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field
- [E1980 Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces](#)
- G7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials
- G60 Practice for Conducting Cyclic Humidity Exposures
- G85 Practice for Modified Salt Spray (Fog) Testing
- G87 Practice for Conducting Moist SO<sub>2</sub> Tests
- G90 Practice for Performing Accelerated Outdoor Weathering of Nonmetallic Materials Using Concentrated Natural Sunlight
- G113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials
- G151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources
- G152 Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials
- G153 Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials
- G154 Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials
- G155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

### 3. Terminology

#### 3.1 Definitions:

- 3.1.1 *coil coating, n*—application of coatings or films to continuous metal coil stock.
- 3.1.2 *direct roller coat, n*—coating with the applicator or coating roll revolving in the same direction as the strip.
- 3.1.3 *metal pretreatment, n*—chemical treatment normally applied to the metal substrate prior to prime or finish coating.

#### 3.1.3.1 Discussion—

The treatment is designed to react with and modify the metal substrate to produce a surface suitable for coating or adhesive bonding.

- 3.1.4 *reverse roller coat, n*—coating with the applicator or coating roll revolving in a direction opposite to that of the strip.

3.2 The definitions given in Terminology **G113** are applicable to this guide.

**TABLE 1 List of Test Methods and Recommended Practices**

	Section	ASTM Standard
Liquid Coatings Properties:	7	
Viscosity:	7.1	
Ford cup viscosity	7.1.2	D1200
Zahn cup viscosity	7.1.2	D4212
High-Shear extrusion viscometer	7.1.3	D1823
Plastisol and organosol low-shear viscosity	7.1.4	D1824
Brookfield-type viscometer	7.1.5	D2196
Cone and Plate viscometer	7.1.6	D4287
Weight Solids	7.2	D2369
Volatile Content	7.2	D2369
Volume Solids	7.3	D2697, D6093
Fineness of dispersion	7.4	D1210
Density (weight per gallon)	7.5	D1475
VOC Determination	7.6	D3960
pH	7.7	E70
Flash Point	7.8	D3278
Metal Pretreatment:	8	
Preparation of galvanized steel for painting	8.2	D2092
Detecting Cr+6	8.3.1	D6492
X-ray fluorescence, chrome determination	8.3.2	D5723
X-ray fluorescence, titanium determination	8.3.3	D6906
X-ray fluorescence, zirconium determination	8.3.4	D7639
Panel Preparation:	9	
Wire-wound drawdown bars	9.4.1.1	D4147
Blade film applicator	9.4.1.2	D823
Wet film thickness	9.5	D1212
Material Properties of a Cured Coil Coating System:	10	
Dry film thickness (DFT)	10.1	
DFT, destructive methods	10.1.1	
DFT, micrometer	10.1.1.1	D1005
DFT, microscope	10.1.1.2	D4138
DFT, boring method	10.1.1.3	D5796
DFT, non-destructive methods	10.1.2	
DFT, eddy current, non-ferrous base	10.1.2.1	D1400
DFT, eddy current, non-ferrous base	10.1.2.1	D7091
DFT, magnetic flux, ferrous base	10.1.2.2	D1186
DFT, magnetic flux, ferrous base	10.1.2.2	D7091
Color:	10.2	
Glossary of color	10.2.1	E284
Preparation and control of color standards	10.2.1	D5531
Color and gloss tolerances	10.2.1	D3134
Conducting visual experiments	10.2.1	E1808
Color differences by visual evaluation	10.2.2	
Visual evaluation of color and color difference	10.2.2.1	D1729
Color differences by instrumental evaluation	10.2.3	
Color matching, color curve system	10.2.3	E1541
CIE color difference	10.2.3	E308
Obtaining special data	10.2.3	E1164
Calculation of color differences	10.2.3	D2244
Specular gloss measurement	10.3	D523
Hardness:	10.4	
Pencil hardness	10.4.1	D3363
Indentation hardness	10.4.2	D1474
Flexibility:	10.5	
Impact resistance	10.5.2	D2794
Mandrel bend	10.5.3	D522
T bends	10.5.4	D4145
Ball punch deformation	10.5.5	E643
Draw test	10.5.6	D4146
Adhesion:	10.6	
Cross hatch tape adhesion	10.6.2	D3359
Scrape adhesion	10.6.3	D2197
Degree of Cure:	10.7	
Glass transition, TMA	10.7.2	E1545
Glass transition, DMA	10.7.2	E1640
Glass transition, DSC	10.7.2	E1356
Solvent resistance	10.7.3	D5402
Dry heat test	10.7.4	D6491
Boiling water test	10.7.5	D6665
Other tests:	10.8	
Pressure mottling/blocking resistance	10.8.1	D3003
Effect of overbaking	10.8.2	D2454

**TABLE 1** *Continued*

	Section	ASTM Standard
Detergent resistance	10.8.3	D2248
Effect of household chemicals	10.8.4	D1308
Abrasion and mar resistance	10.8.5	
Taber abramer	10.8.5.1	D4060
Falling (sand) abrasive	10.8.5.2	D968
Mar resistance	10.8.5.3	D5178
Flame spread	10.8.6	E84
Chip resistance	10.8.7	D3170
Coefficient of friction	10.8.9	D4518
Resistance to thermal cycling	10.8.10	D6944
Graffiti resistance	10.8.11	D6578
<b>Radiative Properties of Cured Coil Coating Systems:</b>	<b>11</b>	
Solar Reflectance:	11.1	
Measuring solar reflectance of horizontal and low-slope surfaces in the field	11.1.1.1	E1918
Measuring solar reflectance in laboratory and field	11.1.1.2	C1549
Method for solar absorbance, reflectance, and transmittance	11.1.1.3	E903
Practice for calculating solar reflectance index of horizontal and low-sloped opaque surfaces	11.1.1.4	E1980
Laboratory soiling test to simulate natural exposure	11.1.1.5	D7897
Thermal emittance:	11.2	
Measuring hemispherical emittance	11.2.1.1	C1371
Measuring total normal emittance	11.2.1.2	E408
<b>Weathering and Corrosion Resistance Properties of a Cured Coil Coating System:</b>	<b>12</b>	
Real-time weathering:	12.1	
Conducting exterior weathering tests	12.1.1	D1014, G7
Chalk resistance	12.1.2.2	D4214
Degree of rusting	12.1.2.5	D610
Degree of blistering:	12.1.2.1	D714
Checking	12.1.2.3	D660
Cracking	12.1.2.4	D661
Corrosion creepage	12.1.2.6	D1654
Wet storage resistance	12.1.3.1	D7376
Accelerated corrosion and environmental resistance characteristics:	12.2	
Salt spray	12.2.1	B477
Salt spray	12.2.1	B117
Water fog	12.2.2	D1735
100 % Relative humidity	12.2.2	D2247
Condensation humidity	12.2.3	D4585
Water immersion	12.2.4	D870
Cyclic salt spray	12.2.5	G85
Cyclic salt fog/UV condensation:	12.2.5.6	D5894
Cyclic humidity	12.2.5	G60
Moist SO <sub>2</sub> testing (Kesternich)	12.2.6	G87
Copper-accelerated salt spray (CASS)	12.2.7	B368
Filliform corrosion	12.2.8	D2803
Specification for reagent water	12.2.9	D1193
Accelerated weathering tests:	12.3	
Dew cycle (Unfiltered open-flame carbon arc)	12.3.2	D3361, G151
Filtered, open-flame carbon arc	12.3.3	D822, G151, G152
Fluorescent UV-condensation	12.3.4	D4587, G151, G154
Enclosed carbon arc	12.3.5	D5031, G153, G151
Xenon arc	12.3.6	G151, G155, D6695, D7869
Accelerated outdoor tests (black box, heated black box, Fresnel)	12.3.7	D4141, G7, G90
Accelerated outdoor tests (black box, heated black box, Fresnel)	12.3.7	D4141, G90

#### 4. Significance and Use

4.1 This guide represents a collection of pertinent ASTM test methods used within the coil coatings industry. In the past coil coaters world wide depended on industry standards written by the National Coil Coaters Association. That association, working cooperatively with ASTM, will no longer issue new, nor update old, standards.

#### 5. General Requirements

5.1 All standard tests shall be made at  $25 \pm 3^\circ\text{C}$  ( $77 \pm 25^\circ\text{F}$ ) and  $50 \pm 5\%$  relative humidity, immediately after baking unless otherwise specified.

#### 6. Sampling

6.1 The number of samples per unit of production shall be agreed upon between the producer and user.

## 7. Liquid Coating Properties

### 7.1 Viscosity:

7.1.1 It is common to measure the viscosity of coil coatings using an efflux technique (Ford or Zahn cup). This provides a simple, rapid technique for controlling the viscosity of a product, either in a paint production facility, or on-line at a coil coating facility. Coatings in the coil industry, however, cover a wide range of generic qualities, with many of them having non-Newtonian rheological characteristics. It is important, therefore, to consider the behavior of these coatings under different shear conditions, as well as measuring efflux viscosity. Some of the test methods require little expertise, where other test methods involve costly equipment and a high level of experience to run and interpret the rheological data.

7.1.2 *Efflux Viscosity*—Determine efflux viscosity in accordance with Test Method [D4212](#) (Zahn cup) or [D1200](#) (Ford cup).

7.1.3 *High-Shear Extrusion Viscosity*—Determine the high-shear extrusion viscosity for plastisols and organosols in accordance with Test Method [D1823](#).

7.1.4 *Low-Shear Viscosity for Plastisols and Organosols*—Test in accordance with Test Method [D1824](#).

7.1.5 *Brookfield-type Viscosity*—Determine the Brookfield viscosity with a rotational viscometer in accordance with Test Method [D2196](#).

7.1.6 *Cone and Plate Viscometer*—Determine the viscosity using a cone and plate viscometer in accordance with Test Method [D4287](#).

7.2 *Weight Solids*—Determine the level of nonvolatile mass in accordance with Test Method [D2369](#).

7.3 *Volume Solids*—Determine the level of nonvolatile volume in accordance with Test Method [D2697](#) or [D6093](#).

7.4 *Fineness of Dispersion*—Determine the fineness of grind of a coating in accordance with Test Method [D1210](#).

7.5 *Density*—Determine the density (weight per gallon) in accordance with Test Method [D1475](#).

7.6 *VOC*—Determine the VOC (volatile organic component) content in accordance with Practice [D3960](#).

7.7 *pH*—Controlling the level of acidity or alkalinity (pH) in the pretreatment section of a coil line, as well as that of waterborne coatings, is important. Determine pH in accordance with Test Method [E70](#).

7.8 *Flash Point*—Test the flash point of a coating in accordance with Test Methods [D3278](#).

## 8. Metal Pretreatment

8.1 The successful performance of any coil-coated system is dependent on metal substrate preparation. Metal preparation in the coil coating industry usually consists of one of the following methodologies: clean, rinse, formation of conversion coating, rinse, post-treatment of conversion coating, and dry; or, clean, rinse, application of a roll-on pretreatment, and dry. The metal pretreatment promotes maximum formability and adhesion of the organic coatings to the substrate, as well as promoting environmental exposure resistance, including anti-corrosive properties, of the coil coated system. Cleaners, conversion coating treatments, dried-in-place roll-on pretreatments, and post-treatments vary with the performance desired, the coating system used, and the metal substrate. Because there is an interdependency between the cleaning, pretreating, and post-treatment steps, in order to obtain acceptable performance, it is necessary that the reaction times, concentrations, temperatures, and application methods used in the laboratory be as close as possible to those encountered under production condition, and that both laboratory and production conditions be in strict accordance with the pretreatment suppliers' specifications.

8.2 In the case of zinc coated steel surfaces, Guide [D2092](#), Methods A, B, C, D, and F illustrate the variety of pretreatments available.

8.3 *Coating Weight of Metal Pretreatment*—The one parameter to ensure that a substrate is properly cleaned and pretreated is the measurement of the level of pretreatment and post-treatment.

8.3.1 Determine the presence of hexavalent chromium on zinc and zinc/aluminum alloy coated steel in accordance with Practice [D6492](#).

8.3.2 *X-ray Fluorescence*—Determine the chromium weight in accordance with Practice [D5723](#).

8.3.3 *X-ray Fluorescence*—Determine the titanium weight in accordance with Test Method [D6906](#).

8.3.4 *X-ray Fluorescence*—Determine the zirconium weight or thickness with Test Method [D7639](#).

## 9. Panel Preparation

9.1 *Summary of Method*—This method includes substrate and pretreatment selection for application of coatings by wire wound draw-down bars on laboratory panels.

9.2 *Choice of Substrate*—The substrate to be coated, substrate size, gage, temper, alloy, and pretreatment to be used shall be agreed upon between the producer and user. Avoid using substrates that have been contaminated by handling.

9.3 *Degassing of Substrate*—Some galvanized substrates tend to absorb gasses on aging. To avoid blistering when the substrate is coated and baked it may be necessary to de-gas the substrate by heating and cooling to room temperature prior to application of the coating. The time and temperature of the degassing cycle shall be agreed upon between the producer and user.