Application of Powder Coating over Aluminum Product and Hardware Surfaces for Powder Coating

1. Scope

1.1 This practice describes methods of preparing surfaces of aluminum for powder coating and the application of powder coating materials.

1.1.1 Powder coating is a dry finishing process using finely ground particles of pigment and resin, electrostatically charged, and sprayed onto a part to be coated. The parts are electrically grounded so that the charged particles project at them adhere to the surface and are held there until melted and fused into a smooth coating in the curing oven. Powder coatings when properly applied, have been found to provide uniform, durable, high quality finish with superior film integrity. Because they contain little or no volatile emissions, they are fully regulatory compliant.

1.2 The values stated in SI units are to be regarded as the 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 to determine the application of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[1]

B 117 - 07a Standard Practice for Operating Salt Spray (Fog) Apparatus
D 2794 - 93(2004) Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
D 3363-05 Standard Test Method for Film Hardness by Pencil Test
D 3359 - 08 Standard Test Methods for Measuring Adhesion by Tape Test
E 376 Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods

2.2 *Society for Protective Coatings Specifications:*[2]

Surface Preparation Specification No. 1 Solvent Cleaning
Surface Preparation Specification No. 2 Hand Tool Cleaning
Surface Preparation Specification No. 3 Power Tool Cleaning
Surface Preparation Specification No. 7 Brush-Off Blast Cleaning

3. Summary of Practices

3.1 This practice describes the methods of preparation and application of powder coating. The key to achieving good adhesion between powder coatings and aluminum is surface preparation. The surface must be entirely free from aluminum oxides prior to powder coating. Any aluminum, or other metal oxides, that remain on the surface of the product can potentially retain air or moisture. Upon heating during the curing stages of the powder application, the oxides may release water vapor or air, which can expand and penetrate the powder coating, causing blisters or voids.

3.1.1The significant problem associated with the use of polyester powders on aluminum products is the adhesion of the coating to the aluminum surface. The aluminum surface is very resistant to atmospheric corrosion because the tight patina that is formed (aluminum oxide) is dense and tenacious this tight layer is usually self limiting and slows after initial formation. Aluminum oxide is recognized by its white appearance, giving rise to its name, white rust. However, the oxide layer must be removed to provide a pure metal surface for proper coating bond. This is a common problem in applying coatings on to aluminum surfaces whether paint or powder coating. The proper preparation of the aluminum substrate and application of the coating system can develop the adhesion and coverage necessary to overcome this problem and result a satisfactory service life.

[1] 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.

[2] Available from Society for Protective Coatings (SSPC), 40 24th St., 6th Floor, Pittsburgh, PA 15222-4656.

3.2 Variations in surface preparation produce end conditions that differ; hence they do not necessarily yield identical results when coatings are subsequently applied. Service conditions will dictate the type of surface preparation to be selected, although the quality produced by any individual process may vary with different compositions of the aluminum surface.

4. Significance and Use

4.1 The proper preparation and application of powder coating is dependent on the following steps: preparation, chemical pretreatment, thermal pretreatment, application of powder coating material, and curing.

5. Processes for Preparing Aluminum for Powder Coating

5.1 The key to preparing the substrate is removing the oxide layer, providing a pure metal surface for the coating to which to bond.

5.1.1 *Surface Cleaning*— Aluminum surfaces must be clean and free of oil and grease before they are powder coated. This can be accomplished by power washing the article to remove surface contaminants.

5.1.1.1 *Aqueous Alkaline cleaning*—the alkaline solution nominally is 2 to 5 % sodium compounds, with small additions of emulsifying, chelating, or sequestering agents, or a combination thereof. This solution can be applied through immersion in a tank filled with the solution, sprayed, or brushed with a soft bristle brush, usually nylon and not steel or copper. When dipping or spraying, the solution works best in the temperature range from 60 to 85°C. After cleaning, rinse thoroughly in hot water or water under pressure. Allow to dry completely before proceeding. Whenever aluminum is rinsed, it is desirable to use heated drying to accelerate the complete removal of water from the surface.

5.1.3.2 *Solvent cleaning*— typical cleaning solvents, such as mineral spirits or high-flash naphtha, can be used to remove oil and grease. The procedure to be used is as specified in SSPC Surface Preparation Specification 1. Proper rags or brushes should be used to wipe the parts.

NOTE 1—**Caution:** These rags or brushes should be cleaned or recycled often since oil can accumulate on their surfaces and be transferred back to the part. Small parts may be dipped or cleaned in ultrasonic baths of solvents. After cleaning, rinse thoroughly in hot water or water under pressure. Allow to dry completely before proceeding.

5.1.3.3 *Hand or Power Tool Cleaning* —Hand or power tool cleaning may be used to clean light deposits of aluminum reaction by products as specified in SSPC Surface Preparation Specification 2 or 3.

5.1.4 *Surface Preparation*—Aluminum surfaces have a layer of aluminum oxide that must be removed before powder coating will adhere to the aluminum. Aluminum is generally smooth and may be slightly roughened prior to powder coating. The following two methods may be used to prepare the aluminum surface for powder coating.

5.1.4.1 *Sweep Blasting*— Abrasive sweep or brush blasting, which uses a rapid nozzle movement will roughen the aluminum surface profile. The abrasive material that has been used successfully is aluminum/magnesium silicate. Particle size should be in the range of 200 to 500 µm (8 to 20 mils). Other materials that can be used are soft mineral sands with MOH hardness of five or less, organic media, such as corn cobs or walnut shells, corundum, and limestone. Depending on the value of hardness for the abrasive medium, blasting pressure may need to be determined for the appropriate nozzle to work-piece distance, geometry of the component, and blasting medium. For some all-alloy coatings, even the relatively low-pressure blast of 0.15 to 0.25 MPa (20 to 40 psi) can be too great, causing cohesion problems. Oil contamination of the compressed air will degrade adhesion to sweep-blasted aluminum surfaces. Care is needed in averting this type of contamination. The purpose of sweep blasting is to deform the metal. The procedure for this process can be found in SSPC Surface Preparation Specification 7. Sweep blasting of aluminum should be not less than 110 m^2 /h (1200 ft^2/h) using these abrasive materials. The substrate should be maintained at a temperature greater than 3°C (5°F) above the dew point temperature. Following abrasive blast cleaning, surfaces should be blown down with clean, compressed air. In some atmospheric conditions, such as high humidity, or high temperature, or both, the formation of aluminum oxide on the blasted surface will begin very quickly, so the powder coating should be applied immediately, within 60 min, after sweep blasting. Aluminum oxide formation is not visible to the naked eye; therefore, in any atmosphere, powder coating should be stated as soon as possible after surface preparation.

5.1.4.2 *Phosphate Treatment*—this conversion-coating process consists of reacting the aluminum surface in a phosphate solution containing oxidizing agents and other salts for accelerating the coating action. The aluminum surface is converted to a crystalline phosphate coating of the proper texture to inhibit corrosion and increase the adherence and durability of the powder coating. This process may be applied by immersion, spray, or soft bristle brush application. After a time period of 3 to 6 min, the surface should be washed with clean water and allowed to completely dry before application of the powder coating system. Powder coating should take place soon after treatment to avoid pick up of surface contaminants.

5.1.4.3 *Notification of Surface Treatment* —the powder coating shop must be notified as to any surface treatment methods were used to prepare the surface.

6.0 Chemical Pretreatment of Aluminum Prior to Powder Coating

6.1 Chemical pretreatment is necessary to promote powder coating adhesion by providing a proper substrate on the aluminum surface to passivate the aluminum surface by providing a conversion coating to receive the powder coating material. Presently, the most common method of chemical pretreatment is to use a phosphoric acid to provide the conversion coating. However, phosphates are injurious to the environment and if found in wastewater streams, lead to algae growth in and eutrification of receiving waters. There are emerging methods of providing an appropriate substrate on which to place the powder coating material which eliminate the need for use of phosphate acids. As these materials are developed and placed into use, manufacturer's directions, as stated in the Product Data Sheet must be followed.

6.2 Pretreatment consists of three main stages with rinses between each stage. These are: cleaning, creation of a conversion coating, and sealing.

6.2.1 Subsequent to the preparation process described in Section 5, the surface must receive additional cleaning to achieve maximum performance. The cleaning stage is accomplished by applying a surface active agent to loosen the bond between any residual soil-surface bond by reducing surface tension.

6.1.1.1 Subsequent to application of the cleaning agent, the surface is rinsed with a water rinse to neutralize the surface.

6.2.2 After the first rinse, an agent to promote a proper conversion coating, usually a phosphoric acid is applied. These agents may include iron, zinc, zirconium, or other material. The phosphate coating promotes the bonding of the powder coating to the aluminum. When the clean metal comes in contact with the slightly acidic phosphating solution, pickling occurs. This results in a reduction of the acid concentration at the liquid/metal interface, iron is dissolved, hydrogen evolved, and the phosphate coating is deposited. The coating weight should be in the range of from 35 to 70 mg/ft^2. Coating weights for other solutions will be determined by the phosphating agent supplier.

6.2.3 After phosphatizing, the surface is again rinsed to flush any remaining phosphate solution, stop the phosphatizing process, and cleanse the surface for final seal rinsing.

6.3.4 The final pretreatment stage is seal rinsing. The purpose of the sealing rinse is to enhance the coating's resistance to surface corrosion and paint adhesion. The sealing rinse consists of a sealing agent and water. As a rule of thumb, water with hardness above the moderately high range (i. e. greater than 250 ppm as $CaCO_3$) should not be used as make up water for the final rinse. Likewise water with a level of combined chlorides and sulfates greater than 100 ppm should not be used. In these cases, demineralized water should be substituted. The most common methods for demineralized water are ion exchange or reverse osmosis.

7.0 Application of Powder Coating Material

7.1 *Powder Coat Material*- Powder coating types can be broadly categorized into two divisions, thermoplastic and thermosetting. Thermoplastic powders do not chemically react during application or baking, therefore, these materials will remelt after cooling when heat is re-applied. Thermosetting powder coatings will chemically react during baking to form a polymer network which is more resistant to coating breakdown. In addition, thermosetting powder coatings will not remelt after cooling when heat is re-applied. There is a wide variety of powder coating materials in production. The powder coating material manufacturer shall supply a Product Data Sheet specifying application and curing techniques. Materials shall be used that are specified by the product manufacturer to be compatible as an overcoat to a aluminum substrate. Also, if the piece in use will be subject to ultraviolet radiation, a super durable formula shall be used to preserve color integrity.

7.2 *Powder Application*- Polyester powder is applied through electrostatic application guns. These can be either using the corona charging method operating at voltages from 50 kV to 100 kV or tribostatic (frictional) charging. The powder particles acquire an electrostatic charge as they pass through the gun transported by low pressure, dehumidified air at a discharge rate of 100-600 g/min, depending on the application. The work being coated is grounded and the charged powder particles are attracted to the surface of the work, where they electrostatically adhere in a uniform layer typically 4 to 10 mils (100-250 microns) thick. (Greater thicknesses, up to 30 mils (750 microns) can be obtained using fluidized bed techniques.) The location and motion of the guns, the transport air pressure, and the types of nozzles used will determine the uniformity of distribution of powder. Complex shapes generally require localized hand spraying to ensure that powder is adequately deposited in all necessary areas on the work.

7.3 *Polymer Performance*- Due to the wide variety of powder coating materials that are available, depending on the type of powder coating material used, the application process should be tailored to the specific powder requirements recommended by the manufacturer. Polyester powders are available in a variety of grades and their performance is generally reflected in the cost of the powders. The highest grades of powders designed for exterior use have excellent UV resistance and as a result have very good gloss and color retention in atmospheric exposure conditions. The higher grades of polyester powders can be expected to pass 1000 hour Salt Spray (ASTM B 117). TCIG (triglycidyl isocyanurate) containing powders provide the best long-term durability. Polyester powders, while performing well in normal atmospheric exposure conditions, may not perform satisfactorily in chemical environments where epoxy powders may be more appropriate. As a rule, the polyester powders should be considered for high performance architectural applications rather than industrial exposures. Epoxies are unsuitable for architectural applications because of their chalking tendencies when exposed to UV radiation.

7.3.1 Like most applied coatings, failures associated with polyester powder coatings that have otherwise been correctly specified are related to the integrity of application. Coating integrity of polyester powder coated aluminum surfaces is most often affected by inadequate powder coverage in the cured polyester film. Problems associated with powder coverage are not unique to aluminum products, but are a function of the design of the product being coated and the techniques and equipment used to apply the powder to ensure adequate penetration of the charged powder particles onto all surfaces of the work. It is very difficult for any applied coating less than 4 mils (100 microns) in thickness, applied in a single coat, to be free of holidays in the coating.

8.0 Curing

8.1 Powder coatings cross link at specific temperatures. In general, thermoplastic resins tend to be of higher molecular weight and require relatively higher temperatures to cure than thermosetting resins. However, the specific temperature and cure schedule as provided by the manufacturer shall be followed as these curing parameters will vary among manufacturers.

8.2 The curing oven shall be capable of attaining temperatures required by the powder coating material supplier as defined by the manufacturer’s Product Data Sheet. This is typically 350 to 450°F (175 to 230°F). The oven shall sustain the temperature for a sufficient time to insure the coating material is cured as per manufacturer’s specifications.

8.3 The cure oven temperature should be operated as low as possible. Best results are achieved with lower oven temperatures and longer times as opposed to higher temperatures with shorter times. The lower temperatures will result in longer curing times that will lead to the resealing of any craters that may have formed.

8.4 Polyester powders are thermosetting resins that cross link at a specific temperature. For these powders to be fully cured, this temperature must be maintained until the reaction is complete. Elevating the curing temperature above the minimum level will shorten the curing time at the risk of burning the powder. A typical polyester powder will cure in 10 minutes at a metal temperature of 390° F (200°C). At 375°F (190°C), curing time must be extended to 15 minutes, or may be shortened to 8 minutes at 410°F (210°C).

9.0 Inspection

9.1 The power coating component of the duplex coating shall, at a minimum, meet the following requirements:

Direct impact	: ASTM D 2794	160 in./lb (9.0 m/kg)
Reverse impact	: ASTM D 2794	160 in./lb (9.0 m/kg)
Pencil hardness (scratch/gouge)	: ASTM D 3363	2H
Flexibility (Mandrel test)	: ASTM D 522	1/8 in. (3m mm)
Minimum adhesion	: ASTM D 3359	5A,5B (100% crosshatch)
Salt spray	: ASTM B 117	+ 1000 hrs < 2mm