Finishes

There are many ways to finish the surface of an extruded aluminum component; the choice of finish depends upon a number of factors, most notably the desired appearance and (more importantly) the product's environment of use. Aluminum is naturally protected from many environmental stresses. As soon as unfinished aluminum is exposed to the atmosphere, a protective oxide coating naturally begins to form. For many applications, aluminum profiles require no more protection than this thin, transparent oxide film.

Aluminum profiles can be treated with a wide range of coatings wherever additional surface protection or an enhanced appearance is desired. Common finishes include liquid paint, powder coat, and anodized finishes.

Types of extrusion finishes are typically sorted as follows:

Liquid coatings. A broad range of paints (e.g., polyesters, acrylics, siliconized polyesters, and fluoropolymers) are available in a virtually unlimited array of colors.

Powder coatings. Wherever it is desirable to reduce emissions of volatile organic compounds, powder-coat finishes are available with little or no use of solvents. Whereas most applications in North America are on horizontal lines, vertical coating lines tend to be more prevalent in Europe. However, two new vertical powder coating lines recently have been installed in the United States.

Anodizing. Anodized aluminum profiles retain their metallic luster while accepting durable and vibrant color through an electro-chemical process.

Mechanical finishes. A wide variety of mechanical methods (e.g., sanding, polishing, grinding, buffing, blasting) can be used to obtain a wide variety of textures.

Chemical finishes. Etching yields a frosted, matte surface appearance, while bright-dipping produces a specular (mirror-like) finish.

Liquid Coatings

Liquid coatings contain three primary components:

- Resin serves as a binder that forms the paint film.
- Pigments provide characteristics such as color, opacity, and gloss.
- Solvents maintain the coating in a liquid state and influence application. Some liquid coatings also contain other additives.

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Taken together, the pigment and binder form the *solids* components of the coatings formulation. One way of classifying liquid coatings is based on the amount of *volume solids* they contain. Classification of liquid coatings by percent solids is expressed as follows:

Classification	***Percent Solids***
Conventional Solids	up to 40%
Medium Solids	40 to 55%
High Solids	55 to 70%

Apart from the solids, the remainder of the composition – the solvents – generally contain volatile organic compounds (VOCs), which are driven off during the curing or baking process. The volume solids form the actual coating left on the profile after the solvents have evaporated.

Commonly used liquid coatings – generally applied by spray – are differentiated by the types of resin they contain. The most commonly used spray technologies are:

Polyester coatings are typically applied in a single coat at 0.8 to 1.2 mils dry film thickness over properly pretreated aluminum. These are “high-solids” coatings, meaning they typically contain 55 to 70 percent solids. They may show slight chalking after one year of Florida exposure, but are resistant to muriatic acid and mortar. Polyester coatings can endure 1,500 hours salt spray and 1,500 hours of 100-percent humidity.

Acrylic coatings contain so-called “conventional solids” (a ratio of up to 40 percent) and are higher in volatile organic compounds (VOCs) than are polyester coatings, but are used for the same types of applications as polyesters. Acrylics are typically applied in a single coat at 0.8 to 1.2 mils dry film thickness and have excellent application and mar-resistance properties.

Silicone-modified polyester (SMP) coatings offer many of the same advantages as regular polyester, along with improved durability, but are typically “medium solids” coatings (containing 40 to 55 percent solids) and may require a two-coat application. These coatings show slightly better exterior durability and gloss retention than straight polyester and acrylic coatings.

Fluoropolymer coatings are typically two-coat applications, but depending on color can be three- or four-coat applications to obtain a minimum dry film thickness of 1.2 mils. High-end fluoropolymer coatings (those with at least 70 percent fluoropolymer resin) offer the highest levels of gloss- and color-retention. Fluoropolymer coatings can endure 4,000 hours of salt spray and 4,000 hours in a humidity cabinet.

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Comparison of Coatings Specifications

The following table is based on voluntary specifications developed by the American Architectural Manufacturers Association (AAMA). The specifications are identified as follows:

- AAMA 2603-02, Voluntary Specification, Performance Requirements and Test Procedures for Pigmented Organic Coatings on Aluminum Extrusions and Panels
- AAMA 2604-05, Voluntary Specification, Performance Requirements and Test Procedures for High Performance Organic Coatings on Aluminum Extrusions and Panels
- AAMA 2605-05, Voluntary Specification, Performance Requirements and Test Procedures for Superior Performing Organic Coatings on Aluminum Extrusions and Panels
- ASCA 96, Voluntary Specification for Superior Performance of Organic Coatings on Architectural Aluminum Curtainwall, Extrusions and Miscellaneous Aluminum Components

Test Parameter	AAMA 2603	AAMA 2604	AAMA 2605 and ASCA 96
PRETREATMENT REQUIREMENTS			
Metal preparation and pretreatment	Multi-stage cleaning and pretreatment	Multi-stage cleaning and pretreatment	Multi-stage cleaning and pretreatment
Pretreatment type	Chemical conversion coating	Chrome or non-chrome chemical conversion coating	Chrome or non-chrome chemical conversion coating
Pretreatment coating weight	none specified	chrome=30 mg/ft^2 minimum; non-chrome per supplier's specification	chrome=40 mg/ft^2 minimum; non-chrome per supplier's specification
PAINT FILM REQUIREMENTS			
Dry film thickness	0.8 mils minimum	1.2 mils (for multicoat, 1.0 mil topcoat minimum & 0.3 +/- 0.1 mil primer)	1.2 mils (for multicoat, 1.0 mil topcoat minimum & 0.3 +/- 0.1 mil primer) *(None specified under ASCA 96)*
Sealant compatibility	meets AAMA 800	meets AAMA 800	meets AAMA 800
Color uniformity	within established color range	within established color range	within established color range
Specular gloss	±5 units of specification (high=80+, medium= 20-79, low £19)	± 5 units of specification (high=80+, medium= 20-79, low £19)	± 5 units of specification (high=80+, medium= 20-79, low £19)
Dry film hardness	H minimum	F minimum	F minimum
ADHESION REQUIREMENTS			
Dry adhesion	0% failure (no loss)	0% failure (no loss)	0% failure (no loss)
Wet adhesion	0% failure (no loss)	0% failure (no loss)	0% failure (no loss)
Boiling water adhesion	none specified	0% failure (no loss)	0% failure (no loss)
Impact resistance	no removal of film from substrate	no removal of film from substrate	no removal of film from substrate
Abrasion resistance	none specified	abrasion coefficient value = 20 minimum	abrasion coefficient value = 40 minimum

Information courtesy of Aluminum Extruders Council

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Comparison of Coatings Specifications (continued)

Test Parameter	AAMA 2603	AAMA 2604	AAMA 2605 & ASCA 96
CHEMICAL RESISTANCE REQUIREMENTS			
Muriatic resistance	15-minute exposure: no blistering or visual change	15-minute exposure: no blistering or visual change	15-minute exposure: no blistering or visual change
Mortar resistance	24-hour exposure: no loss of film adhesion or visual change	24-hour exposure: no loss of film adhesion or visual change	24-hour exposure: no loss of film adhesion or visual change
Nitric acid resistance	none specified	30-minute exposure: 5 Delta E (Hunter) maximum color change	30-minute exposure: 5 Delta E (Hunter) maximum color change
Detergent resistance	72-hour exposure: no loss of adhesion, no blistering, no significant visual change	72-hour exposure: no loss of adhesion, no blistering, no significant visual change	72-hour exposure: no loss of adhesion, no blistering, no significant visual change
Window cleaner resistance	none specified	24-hour exposure: no blistering or appearance change	24-hour exposure: no blistering or appearance change *(None specified under ASCA 96)*
CORROSION RESISTANCE REQUIREMENTS			
Humidity resistance	1,500 hours: no more than “few” blisters size 8, figure no. 4, ASTM D 714	3,000 hours: no more than “few” blisters size 8, figure no. 4, ASTM D 714	4,000 hours: no more than “few” blisters size 8, figure no. 4, ASTM D 714
Salt spray resistance	1,500 hours of salt solution: minimum rating of 7 on scribe or cut edges; minimum blister rating of 8 in the field (ASTM D 1654)	3,000 hours of salt solution: minimum rating of 7 on scribe or cut edges; minimum blister rating of 8 in the field (ASTM D 1654)	4,000 hours of salt solution: minimum rating of 7 on scribe or cut edges; minimum blister rating of 8 in the field (ASTM D 1654)
WEATHERING RESISTANCE REQUIREMENTS			
Accelerated exposure	1,000 hours in Atlas Type “XW” weatherometer, no adhesion loss; slight chalking or color change	none specified	none specified
Outdoor exposure	1 year South Florida, 45^{m} south: no adhesion loss; slight chalking or fading	5 years South Florida, 45^{m} south: 5 Delta E (Hunter) maximum color change; chalking ≤ 8 (ASTM D 4214); gloss retention ≥ 30%; erosion resistance < 10% film loss	10 years South Florida, 45^{m} south: 5 Delta E (Hunter) maximum color change; chalking ≤ 8 (ASTM D 4214), gloss retention ≥ 50%; erosion resistance < 10% film loss

This table is a cursory comparison of some of the common elements of the referenced specifications. Far greater detail can be found in the specifications themselves. For copies of the specifications, please contact the issuing organizations.

Information courtesy of Aluminum Extruders Council

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Spray Coatings Specifications For Aluminum

Specifications	AAMA 2603*	AAMA 2604*	AAMA 2605*
CHEMICAL RESISTANCE REQUIREMENTS			
	Voluntary specification, performance requirements and test procedures for pigmented organic coatings on aluminum extrusions and panels	Voluntary specification, performance requirements and test Procedures for high performance organic coatings on aluminum extrusions and panels	Voluntary specification, performance requirements and test procedures for superior performing organic coatings on aluminum extrusions and panels
Suggested uses	Residential, all interior applications	Commercial/industrial, high-end residential, high traffic areas	High performance, architectural and monumental applications
South Florida exposure	1 Year	5 Years	10 Years
Color retention	1 Year – Fade	5 yrs. – Fade = 5 Delta E	10 yrs. – Fade = 5 Delta E
Chalk resistance	1 Year – Chalk	5 yrs. – Chalk = 8	10 yrs. – Chalk = 8 (colors) 10 yrs. – Chalk = 6 (whites)
Gloss retention	No Specification	5 yrs. – 30% Retention	10 yrs. – 50% Retention
Erosion resistance	No Specification	5 yrs. – 10% Loss	10 yrs. – 10% Loss
Dry film thickness	0.80 mils minimum	1.20 mils minimum	1.20 mils minimum (2-coats)
Pretreatment system	Chrome or chrome free	Chrome or chrome free	Chrome = 40mg/sq. ft.
ACCELERATED TESTING			
Salt spray	1,500 hours	3,000 hours	4,000 hours
Humidity	1,500 hours	3,000 hours	4,000 hours
Color uniformity	Final color approval should be made with applicator prepared production lines samples	Final color approval should be made with applicator prepared production lines samples	Final color approval should be made with applicator prepared production lines samples

**Contact AAMA for latest revisions/changes to AAMA specifications - www.aamanet.org*

Powder Coatings

Powder coatings are applied electrostatically from an air fluidized hopper. Electrostatic application enables positively charged powder particles to adhere to a negatively charged (or grounded) aluminum profile. After the proper amount of powder is applied, the profile is baked in an oven where the powder particles are melted to a liquid state, fusing together to form a homogenous film. Most applications in North America are on horizontal lines.

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The primary powder ingredients are as follows:

- **Binders** consist of the resin, polymer, and crosslinker. This ingredient provides the powder with its fundamental film properties.
- **Prime Color Pigments** can be either organic or inorganic and provide the paint with its color.
- **Additives** serve numerous functions but generally affect fluidization and application properties.

Powder coatings perform comparably to liquid coatings of the same resin chemistry and are available in an increasingly wide range of colors.

Because powder coatings contain little or no volatile organic compounds (VOCs), they offer an environmentally friendly coating alternative. Powder coating serves a growing market and is expected to play a significant part in the finishing of aluminum profiles in the years to come.

Typical anodizing tank layout

Anodizing

Anodizing is an electrochemical process that enhances aluminum's natural oxide surface layer by forming an even more durable oxide film that can accept a variety of (usually translucent) colors. The resultant finish shows off the natural luster of the aluminum substrate. Anodic coatings can yield a wide range of characteristics; features such as thickness, hardness, porosity, and protective value are dependent upon on the specific process used, the alloy being anodized, and the length of treatment time.

What's Underneath the Finish Matters

All aluminum alloys that can be extruded may also be anodized; variables such as color and film density depend upon the alloy of the product being anodized.

The anodic finish greatly increases the resistance to corrosion and abrasion over a mill-finished product, without altering the texture of the metal's surface.

Pretreat for Success

The anodizing process typically includes three or four pretreatment steps:

- Alkaline cleaning removes organic contaminants like oils, greases, marking pens, fingerprints, or shop dirt.
- Acid cleaning (optional) is used to remove inorganic contaminants like oxide films and intermetallics, which might interfere with a quality finish.
- Etching takes place in a hot caustic solution and yields a matte or satin finish that can diminish the effect of die lines.
- Deoxidize and desmut steps remove oxides and intermetallics, which appear as loose particles (gray to black in color) on the surface of the etched aluminum.

Here's How it Happens

The aluminum profile is immersed in a tank that holds an acid-based electrolyte solution. Electrical current is passed through the solution while the temperature is carefully controlled. The electrically-conductive aluminum profile serves as an anode, the result of which is that oxygen ions are released from the electrolyte and drawn to the surface of the aluminum. The oxygen immediately combines with the surface aluminum to form a hard aluminum oxide film.

Unlike other finishes, in which a separate coating is applied, the anodic coating is an integral part of the aluminum surface, since it is formed by oxidation of the surface atoms themselves.

There are several types of anodizing

Anodizing processes differ by type of electrolyte solution used, voltage and current density applied, and bath temperature. There are several general types of anodizing processes, each of which yields distinctive performance characteristics or a unique appearance:

Sulfuric (the most common process) can produce thin films suitable as pretreatment for organic coatings, but is more commonly used to produce comparatively thick, transparent and absorptive oxide films that can be dyed or electrolytically colored.

Chromic produces gray or greenishgray coatings with excellent corrosion resistance. It is also suitable for dyeing, producing opaque colors, and provides an excellent base for organic coatings.

Oxalic provides a hard, nonporous coating with a slightly golden tone. Oxalic acid anodic coatings, like sulfuric acid coatings, may be colored with organic, inorganic, and electrolytic coloring processes.

Phosphoric produces porous anodic coatings sometimes used as a base for electroplated coatings and for bonding, especially in aerospace applications.

Boric provides a hard, impervious, nonabsorptive film with exceptionally high electrical resistance. This process is used for highly specialized electrical applications.

Hardcoating produces a much thicker film. Functional hardcoating, or hard anodizing, is a modification of sulfuric anodizing, performed at high current densities and low temperatures. Sometimes additives are mixed into the electrolyte to produce a denser, more abrasion-resistant oxide film, imparting high wear resistance to the product; typical coating thickness is 1.5 to 7.0 mils.

The Sealing Step

Sealing the anodic pore enhances the beauty and durability of the anodic coating. A properly sealed anodic film is nonabsorbent and nonreactive, thoroughly resistant to stains and corrosion. Many sealing processes are available, depending on the anodic finish, substrate alloy, and environment of use. A few common examples follow:

Hot water, with or without additives. Deionized, high quality water free of silica is used at or near the boiling point (212°F, 100°C). Additives may be used to prevent seal bloom, smut, and powdering.

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Mid-temperature seals. This common sealing method employs immersion of the anodized profile in a solution containing nickel acetate or other metal ion at 170-190°F (77-88°C).

Room-temperature seals. Not suitable for organic dyes, this system makes use of nickel fluoride at 85-95°F (29-35°C).

Non-nickel seals. In place of nickel, other metal salts are available for use as a mid-temperature seal.

Mechanical finishes

The surface of an aluminum profile can be buffed and burnished to a mirror finish or scored and blasted to a rough texture. Blasting methods include abrasive blasting, shot blasting, and glass-bead blasting. Other mechanical finishing methods (in addition to the buffing and burnishing already mentioned) include sanding, polishing, and tumbling.

Any of these methods may be applied as a final surface finish, or to enhance surface quality, or in preparation for a final cosmetic finish.

Chemical finishes

Etching

A silvery-white, frosted appearance can be given to an aluminum profile by applying a caustic solution to its surface in a process known as chemical etching. The aluminum profile is passed through a hot bath, rinsed, and then immersed in what is called a deoxidizedesmut bath that removes undissolved alloy constituents or surface impurities. To complete the process, further rinses are usually required.

Bright Dipping

Bright dipping is a specialized kind of chemical-finishing that yields a bright, mirror-like finish (known as a specular finish). The bath usually contains both phosphoric acid and nitric acid, heated to an elevated temperature. The profile to be bright-dipped must first be polished to remove fine scratches, and afterwards is usually anodized. Anodizing the bright-dipped part serves two purposes: it protects the surface finish, and can be used to apply color to the profile.