Anodized Architectural Aluminum combined with an Organic Seal

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ABSTRACT

The performance levels for anodized architectural aluminum combined with an organic seal have recently been defined by the American Architectural Manufacturers Association's, AAMA, Voluntary Specification 612 (AAMA 612).[1] This surface coating yields a final finish that reveals the intrinsic luster of aluminum while also providing protection against corrosion, erosion, and other elements.

Aluminum articles are produced with a surface coating of high-durability by first electrolytically oxidizing the article in an acidic anodizing bath and after water washing, depositing the article in a solution of a thermosetting resin and passing a current through said article as the anode to cause the electrodeposition of resin particles to the oxidized porous surface. The article is then heated to cure the resinous film.[2]

INTRODUCTION

Anodizing is a reacted finish that is formed from oxidizing aluminum anodically in an electrolyte in order to produce a corrosion inhibiting film. This finish option has been preferred by many designers and architects for several decades because it satisfies many of the factors necessary when specifying a high performance coating for aluminum fenestration.

Anodized finishes reveal the natural luster of the aluminum material and provide a smooth metallic appearance. In addition to a natural "clear" aluminum finish, the two-step anodizing process allows various colors to be achieved by depositing different types of metal salt into the aluminum pores.

Anodized finishes are easier to handle than other finish options due to surface characteristics. Scratches and abrasions that are typically associated with the fabrication and installation of fenestration systems are minimized due to the hardness of the finish.

The two-step anodizing process is the most common process used in the anodizing of architectural aluminum. The basic process flow takes the aluminum material through degreasing, etching, neutralization, anodizing, coloring, and finally aqueous hydration. The aqueous hydration, hereafter referred to as conventional seal, is necessary to convert the anodic oxide pores to AL_2O_3-H_2O, Boehmite. This chemical seal increases the surface volume and attempts to bridge and close the anodic pores. Figure 1 illustrates the end result.

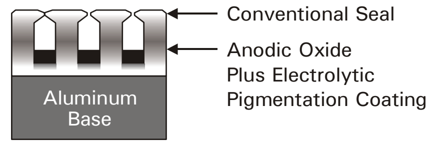

Figure 1. Anodized aluminum with a conventional seal

Various thicknesses of the anodic oxide film have been used in order to try to increase the corrosion resistance of anodizing. However, after a certain point, increasing the anodic film has little effect. "It must be remembered that coating thickness alone does not give aluminum its corrosion resistance. The most important factor for corrosion resistance is this sealing of anodic film."[4] Herein lies the issue with the conventional seal. It is generally not possible to close every pore of the porous anodic film with Boehmite. The small openings in the seal that remain allow acids, alkalies, or other corrosive materials to penetrate the conventional seal, degrade the finish, and corrode the aluminum. Therefore, a conventional seal provides inadequate protection for the anodic film against corrosion.

To improve the resistance to corrosion while maintaining the other benefits of the anodized finish, the conventional seal has been replaced with an organic seal. After the formation of the anodic oxide and the addition of coloring if required, the material is submerged in a solution of thermosetting resin. Then a current is passed through the material thereby electrodepositing the resin particles on the anodized oxide film by electrophoreses. The material is then heated to cure the resin adsorbed in and deposited on the anodic film which forms the physical seal. Figure 2 illustrates the end result.

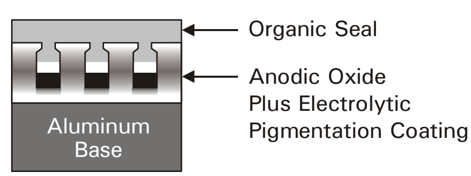

Figure 2. Anodized aluminum with an organic seal

ANODIC FILM WITH AN ORGANIC SEAL

History

In 1965, Honny Chemicals developed a coating to seal the anodic film through electrophoretic deposition, ED. This coating was developed to improve the corrosion performance of anodized aluminum. The Japanese Industrial Standards, JIS, Group, conducted a series of exposure tests on panels and performed building studies to analyze the performance of various sealing processes.

In the mid 1970's anodized finishes with organic seals ultimately became the standard method for sealing the anodic film in Japan. The organic seal provided the increased corrosion protection required for the urban, industrial, and coastal environments. In 1977, the JIS released a performance standard for combined coatings of anodic oxide and organic coatings on aluminum and aluminum alloys, JIS H 8602.[3]

Organic Sealing Process

The highly porous nature of the anodic film provides an ideal substrate to absorb and anchor an organic seal. Figure 3 demonstrates the highly porous nature of the anodic film.

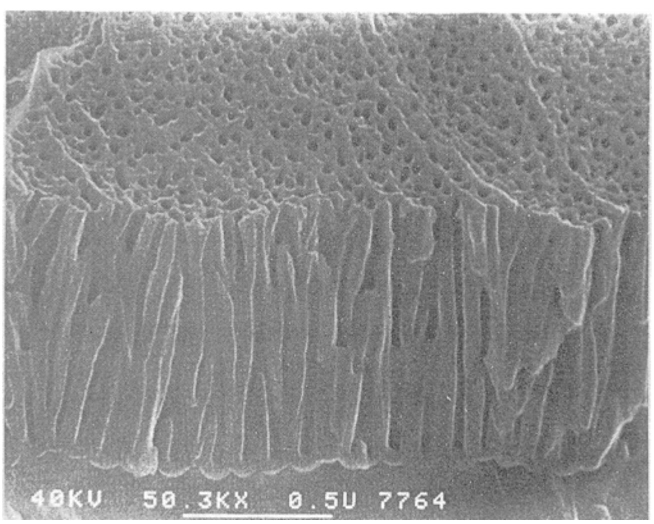

Figure 3. Anodic film prior to sealing.

Once the anodic film is submerged in the thermosetting resin, a charge is placed through the aluminum, as the anode, thereby electrodepositing the resin particles on the anodized oxide film by electrophoresis.

An important factor to consider is that this ED process is different than coating the anodic film with a resin by spray application or dipping process. In the ED process the resin grains are moved electrically and deposited on the surface of the anodic film. When this resin is set thermally, the structure of the anodic oxide is changed from Al_2O_3 to Boehmite. This thermal process simultaneously cross-links, cures the resin grains, and narrows the oxide pores to anchor the resin film. Figure 4 illustrates this condition.

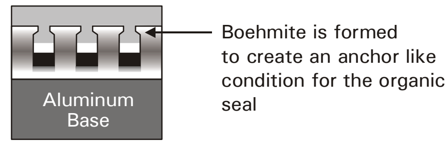

Figure 4. Anodized aluminum with an organic seal

As illustrated in Figure 4, the ED process provides a continuous and complete physical seal over the surface of the anodic film. This prevents acids and/or alkali, such as salt spray or mortar, from coming into contact with the anodic film that would result in corrosion. Conventional seals are susceptible to corrosion, as illustrated in Figure 5, because all of the pores cannot be completely closed.

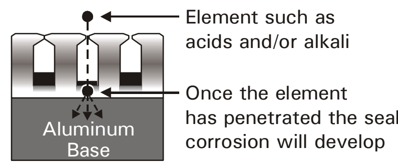

Figure 5. Illustration showing the penetration of acids and/or alkali on a conventionally sealed anodic surface

The ED process also applies the seal in a smooth and uniform coating which makes anodizing with an organic seal a better alternative when finishing complex shapes. In an electrostatic spray, such as the application of fluorocarbon paint, corners and recessed areas have less coverage due to the application process. Figure 6 illustrates this principle.

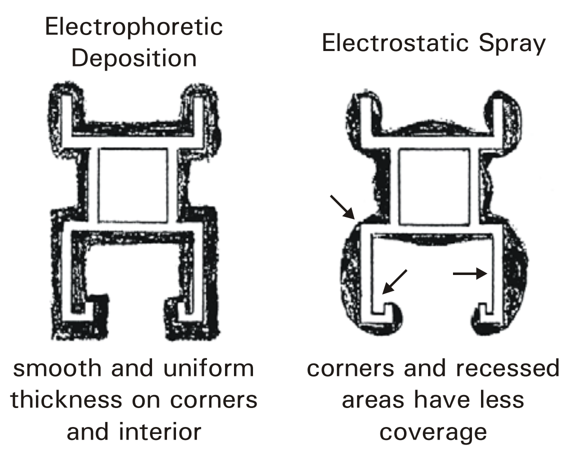

Figure 6. Electrophoretic deposition and electrostatic spray illustration

PERFORMANCE RESULTS

Mortar Resistance

Mortar, a highly corrosive alkaline, is a very common substance on construction sites. One of the primary benefits of using an organic sealing method is to provide corrosion resistance. As illustrated earlier in Figure 5, once the element has penetrated the seal the corrosive reaction begins. Figure 7 shows how well an organic seal protects the anodic film when tested in accordance with AAMA 612, section 7.9.2, and the results of the same test when applied to an anodic film with a conventional seal.

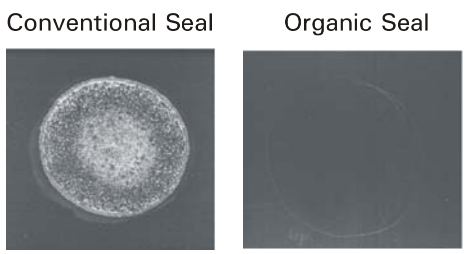

Figure 7. Photos taken after a mortar resistance test as specified in AAMA 612.

Corrosion Resistance

The high salt content in coastal environments can create a very corrosive environment for anodized finishes if the anodic film is not completely sealed. The images in Figure 8 display the results of a 4000 hour salt spray test as required in AAMA 612.

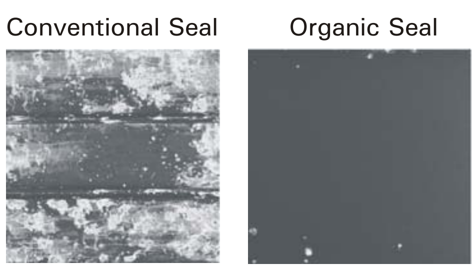

Figure 8. Photos taken after a corrosion resistance test as specified in AAMA 612.

Muriatic Acid Resistance

Muriatic acid is a highly corrosive acidic chemical. This acid is typically used to clean masonry on a construction site. The ability of fenestration to resist this acid is necessary due to the close proximity of the fenestration and masonry materials. Anodized aluminum with organic seal provides protection against this chemical due to its total seal of the anodic film. The ability to resist this chemical is required in accordance with AAMA 612.

Nitric Acid Resistance

According to the Environmental Protection Agency, EPA, acid rain is a serious environmental problem that affects large parts of the US and Canada. Acid rain occurs when sulfur dioxide (SO_2) and nitrogen oxides (NO_x) react in the atmosphere with water, oxygen, and other chemicals to form various acidic compounds. Sunlight increases the rate of most of these reactions. The result is a mild solution of sulfuric acid and nitric acid.

To determine a finishes ability to provide lasting protection from acid rain in urban environments, AAMA 612 requires the finish to pass a nitric acid resistance test. As shown in Figure 9, only the anodic film with the organic seal provides the protection from the acid required to pass the test.

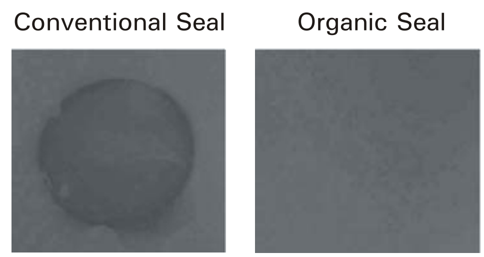

Figure 9. Photos taken after a nitric acid resistance test as specified in AAMA 612.

Gloss Retention

Direct sunshine and environmental elements can degrade the original luster of a finish. While all types of finishes will lose some degree of luster over time, the anodic film with an organic seal maintains a high percentage of its original gloss. After five (5) years of exposure as shown in Figure 10, the gloss retention for anodized aluminum with an organic seal approaches that of aluminum finished with fluorocarbon paint. These samples were tested in accordance with AAMA 612.

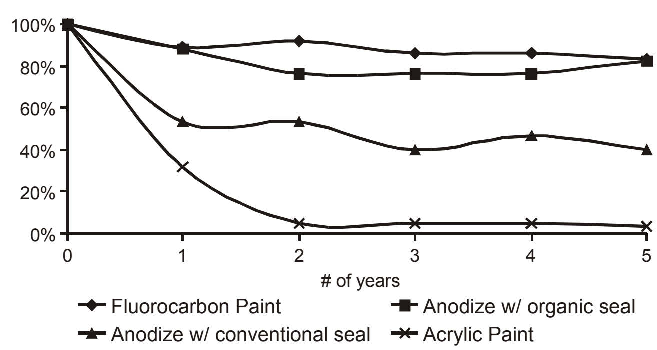

Figure 10. Gloss retention results, Appendix A

Color Retention

Anodized aluminum with an organic seal provides the highest level of color retention as shown in Figure 11. The natural beauty of the aluminum material is maintained for many years because the anodic film is protected from environmental elements by the organic seal.

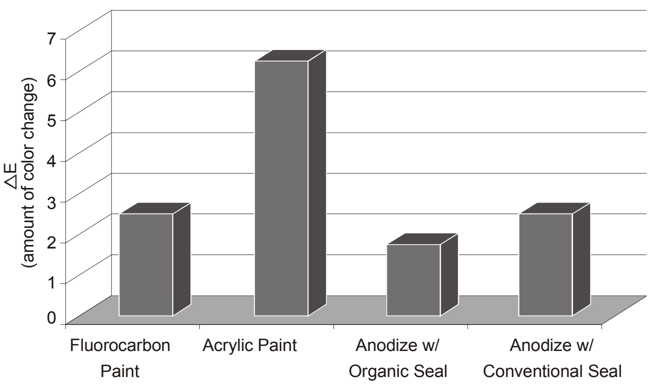

Figure 11. Color retention results as specified by AAMA 612. Appendix B.

Seal Hardness

Measuring the hardness of the film helps to determine the finish's ability to resist damage during the fabrication and installation of the aluminum fenestration systems when they are most susceptible to abrasions. An anodized finish with an organic seal provides a finish hardness of no less than 3H when measured in accordance with AAMA 612, as shown in Figure 12. This hardness allows the finish to withstand abrasions and scratches that might be encountered during the construction process while providing the protection needed from environmental elements and cleaning compounds once the fenestration is installed on the building.

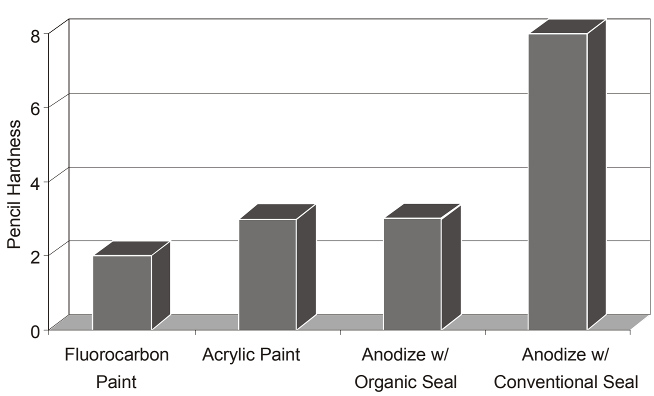

Figure 12. Finish hardness as specified by AAMA finish standards.

CONCLUSION

Anodized aluminum combined with an organic seal provides the long-term protection desired by architects, designers, and building owners while still allowing the beauty of the aluminum to shine through. This finish combines the benefits of excellent corrosion resistance to chemicals at construction sites with increased protection against salt spray in coastal environments while maintaining superior color and gloss retention and enhanced protection of the aluminum base.

REFERENCES

[1] "Voluntary Specification, Performance Requirements, and Test Procedures for Anodized Architectural Aluminum Combined with a Transparent Organic Coating", American Architectural Manufacturers Association, 2002

[2] "Method of Providing Aluminum Surfaces with Coatings", United States Patent 3,622,473

[3] "Combined coatings of anodic oxide and organic coatings on aluminum and aluminum alloys", JIS H 8602, Japanese Industrial Standard, 1992

[4] "Selection Guide for Anodic Coating on Architectural Aluminum", Association of Architectural Aluminum Manufacturers of South Africa, January 2000

Gloss Retention

Specimens were tested in accordance with procedures outlined in the AAMA 612 Voluntary Specification, Section 7.12.1.4, as summarized below. In order for the coating to obtain its integrity, it should at the minimum meet the requirements as outlined within the specification.

Specimens were exposed in Florida south of latitude 27° North at a 45° angle facing south for a minimum of five (5) years. Time elapsed when the coating was off the test fence for evaluation, or other purposes, was not counted as part of the 5-year exposure minimum.

Procedure: After weathering exposure, measure 60° gloss of exposed and unexposed areas of a test site exposure panel following ASTM D 523. The exposure panel may be washed lightly with clear water and a soft cloth to remove loose surface dirt. Heavy scrubbing or any polishing to restore the surface is not permitted where gloss measurements are made.

Performance: Gloss retention shall be a minimum of 50% after the 5-year exposure test expressed as:

$$\%\ \text{Retention}\ (\triangle E) = \left(\frac{60^\circ\ \text{gloss exposed}}{60^\circ\ \text{gloss unexposed}}\right) x100$$

	# of Years Exposed					
	0	1	2	3	4	5
Fluorocarbon Paint	100%	88.9%	91.7%	86.1%	86.1%	83.3%
Acrylic Paint	100%	31.7%	5.0%	5.0%	5.0%	3.3%
Anodize w/ Organic Seal	100%	88.2%	76.5%	76.5%	76.5%	82.4%
Anodize w/ Conventional Seal	100%	53.3%	53.3%	40.0%	46.7%	40.0%

Tests performed by DSET Laboratories, Inc.

Color Retention

Specimens were tested in accordance with procedures outlined in the AAMA 612 Voluntary Specification, Section 7.12.1.2, as summarized below. In order for the coating to obtain its integrity, it should at the minimum meet the requirements as outlined within the specification.

Specimens were exposed in Florida south of latitude 27° North at a 45° angle facing south for a minimum of five (5) years. Time elapsed when the coating was off the test fence for evaluation, or other purposes, was not counted as part of the 5-year exposure minimum.

Performance: Maximum of 5 ΔE Units (Hunter) color change as calculated in accordance with ASTM D 2244, Section 6.3 after the minimum 5-year exposure test. Color change shall be measured on the exposed coated surface, which has been cleaned of external deposits with clear water and a soft cloth and corresponding values, shall be measured on the original retained panel or the unexposed flap area of the panel. A portion of the exposed panel may be washed lightly to remove surface dirt only. Heavy scrubbing or any polishing to remove chalk formation or restore the surface is not permitted where color measurements are made.

	Color Change
	ΔE
Fluorocarbon Paint	2.50
Acrylic Paint	6.25
Anodize w/ Organic Seal	1.75
Anodize w/ Conventional Seal	2.50

Tests performed by DSET Laboratories, Inc.