Architectural Powder Coatings: A Review of World Technical and Market Status

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Powder coating is a rapidly growing segment of the surface finishing industry. Its advantages include relative ease of application, quick clean-up and less environmental regulatory pressure. The following article is an edited version of the text of just one of the many outstanding technical presentations made at Powder Coating '94, October 11–13, in Cincinnati, reprinted here with permission.

The use of powder coatings for the protection and decoration of architectural aluminum is continuing to grow in popularity worldwide. The recent introduction of new technologies is accelerating this growth in North American, Far Eastern and Australasian markets.

This article will review current world market position. Particular reference will be made to new powder developments, including high-durability systems, and the latest results from field experience will be presented, including information on corrosion prevention. Technical and economic benefits to end users will also be compared with competing technologies.

Architectural powder coatings have now been used around the world for more than 20 years. By providing excellent functional and cosmetic protection, powders have become increasingly popular. Architects appreciate the choice it gives them in design, and powder users like the relatively simple application process.

Until recently, the technology of thermosetting polyester powders had, in fact, changed relatively little. The last few years, however, have witnessed exciting advances in all the principle elements of the architectural powder coating system.

There have been developments in pretreatment (*e.g.*, non-chromium), new powder chemistries (*e.g.*, TGIC-free and super weatherability), new design and fabrication techniques (*e.g.*, thermal breaks and structural glazing) and novel powder application methods for aluminum extrusions (*e.g.*, vertical lines).

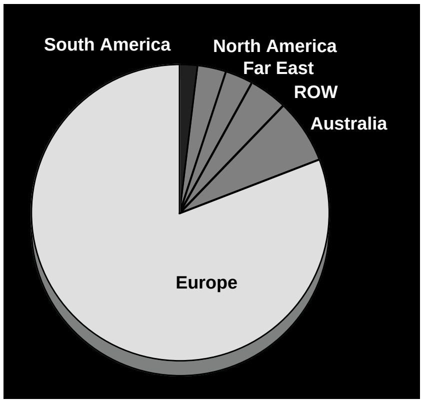

Fig. 1—World Architectural Powder Market 1994: 26,000 Tons

The Architectural Powder Coating System

To ensure the successful protection of architectural metal, it is important to consider the entire system. The aluminum, pretreatment, or finish cannot be considered in isolation. And, even though powder manufacturers can only directly control the paint formulation, they must work closely with other suppliers and also direct their research programs to take all factors into account.

The correct combination of these elements can then provide the appropriate corrosion resistance, exterior weatherability and the most economic method of finishing architectural aluminum extrusions and panels.

Environmental Issues

In the architectural sector, specific challenges are continuing to drive progress toward increased environmental acceptability of architectural systems. Aluminum, because of its recyclability, is preferable to PVC, and correctly designed, thermally insulated glazing systems save energy.

In this article, the study of environmental impact is split into two categories: The impact of the paint finish, itself, and influences from other stages of the finishing processes.

Atmospheric Pollution

Powder coatings have, in all markets, benefitted from their inherent advantage of being solvent-free. By virtually eliminating volatile organic compounds (VOCs), the atmospheric emissions are reduced, as are the health and safety risks associated with working with flammable solvents.

This key characteristic continues to assist the growth in the use of powder in such countries as the U.S. Restrictions on VOCs are increasing and, in certain states, local regulatory authorities now refuse to grant licenses for the operation of new plants applying solvent-containing paints. This is particularly relevant with the advent of the super-durable powders, which can now provide a technical option to replace relatively low-solids-fluorocarbon wet paints.

Non-chromium Pretreatment

In the case of architectural finishing, other aspects of the process are now coming under scrutiny. All leading architectural standards (Fig. 3) still require a multi-stage cleaning and conversion process. The use of chemical pretreatments containing either amorphous chromium phosphate or amorphous chromate is mandatory.

Chromium pretreatment has a long and proven track record around the world. After thorough cleaning of the aluminum, the conversion of its surface with chromate ions provides both enhanced paint adhesion and resistance to under-film corrosion, if subse-

Process	Key Factors Affecting Performance
Aluminum	***Aluminum*** *• Grade and Flexibility* *• Impurities and Trace Elements*
Chemical Cleaning & Pretreatment	***Pretreatment Type*** *• Chromium (Yellow or Green)* *• Non-chromium Method* *• Spray or Dip Rinse* *• Use of Demineralized Water*
Spray Application	***Powder*** *• Electrostatic Charge Properties* *• Particle Size Application* *• Vertical or Horizontal* *• Tribostatic*
Baking	***Cure Properties*** *• Low Bake* *• Universal Bake* *• Over-bake Resistance*
Fabrication	***Use of Pre- or Post-thermal Breaks*** *• Temperature Stability of Thermal Break* *• Temperature Stability of Finish* *• Adhesion of Thermal Break* ***Structural Glazing Adhesives*** *• Adhesion of Sealant*
Building	***Weatherability of Finishing*** *• Polymer Backbone* *• Curing Agent* *• Pigments* ***Durability of Finish*** *• Resistance to Damage* *• Flexibility*

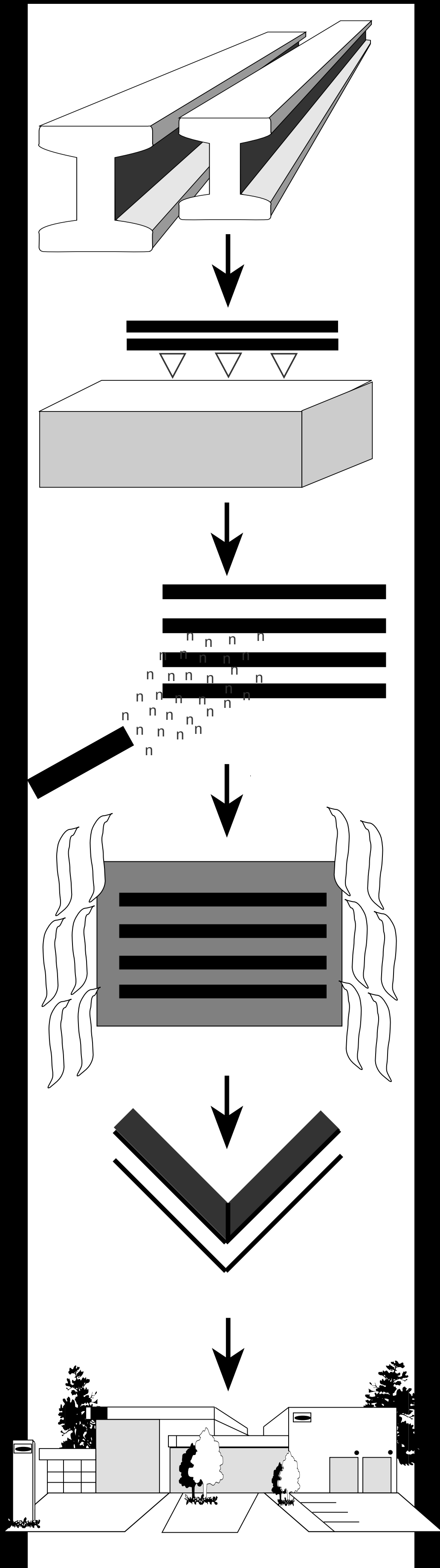

Fig. 2—The Thermoset Powder Coating Process.

Australia	:	Australian Standard AS3715-1989[1]
Europe	:	British Standard BS6496 : 1984[2]
	:	GSB RAL RG631 : 1994[3]
	:	Qualicoat : 1994 [4]
South Africa	:	SABS-1993[5]
U.S.	:	AAMA 603.8-92[6]
	:	AAMA 605.2-92[6]

Fig. 3—World Architectural Standards.

quent damage occurs. Traditional processes use hexavalent chromium, either as chromium chromate (yellow) or chromium phosphate (green).

Of all materials used in metal pretreatment, those containing hexavalent chromium probably require the most-stringent treatment, as the amount of hexavalent chromium allowed in discharges by most authorities varies from 0 to less than one ppm.[7]

The treatment of chromate-containing wastewater can very successfully process chromate ions and minimize effluent. It is a two-stage process, involving the reduction of hexavalent chromium to the trivalent state, which is then precipitated by adding alkali.

As with all environmental issues, however, the ultimate target should be to remove the initial hazard. Pretreatment suppliers have, therefore, been working on alternative chemistries (*e.g.*, based on titanium or zirconium) that do not rely on the use of chromium. To date, a number of potential systems have been developed. Though current standards still do not allow their use, the soon-to-be-published European Standard (CEN) will allow an option for suitable non-chromium products.

Determining long-term life expectancy of the new systems has been the key problem so far. Direct comparisons with chromium systems using, for example, acetic acid salt spray or pressure cooker tests, have identified potential candidates.

It has been found with some of the new systems, however, that, although laboratory-prepared samples give good results, it has proven difficult to replicate the performance on actual plants.

Standard authorities are also evaluating potential candidate systems with a view to modifying their specification. It is also likely, because of the variety of chemistries being suggested, that specific proprietary systems will be tested and approved (as with finishes), instead of generic recommendations. Also, tests are to be included in evaluations of all pretreatment systems for the reported phenomenon of filiform corrosion,[8] currently of concern to the European coating industry.

Advances in Technology

TGIC-free Systems

The most popular powder coatings used for architectural finishes are of the thermosetting type. They are formulated with exterior-grade polymers that react with chemical co-reactants during baking, to form a hard, tough, durable finish.

	Acetic Acid Salt Spray ISO 9227	Humidity DIN 50017KK	Pressure Cooker BS6496 : 1984
Chromium Standard System	**10/10** (8,000 hr)	**10/10** (8,000 hr)	**10/10** (25 hr)
Non-chromium System 1			
Laboratory Sample	**10/9** (8,000 hr)	**10/10** (8,000 hr)	**9/9** (25 hr)
Plant Sample	**5/10** (3,000 hr)	**10/10** (8,000 hr)	**9/9** (1925 hr)
System 2	**0/0** (5,000 hr)	**4/6** (5,000 hr)	—
System 3	**4/7** (3,000 hr)	**10/10** (3,000 hr)	**10/10** (2 hr)

Rating based on ASTM D1654
First Figure: Result from scribe   Second Figure: Result on rest of panel
0 = Failure   10 = Excellent

Fig. 4—Results for standard chromium systems, compared with various non-chromium products.

The main chemical components used to form the film are based on carboxyl-functional polyester resins, cured with triglycidyl isocyanurate (TGIC). This use of a very-low-molecular-weight epoxy-functional co-reactant allows a relatively high proportion of the ultra-violet (UV)-resistant polyester to be included in the powder formulation.

TGIC, a tri-functional epoxy, reacts with the carboxyl group on the polyester, to form an ester linkage. A typical ratio of components is 93:7 polyester and TGIC, respectively. After addition of pigments and other additives, TGIC is, therefore, typically contained in the powder at less than five percent by weight.

As part of ongoing work to confirm the suitability of all raw materials, information became available from raw material suppliers on the toxicology of TGIC and powders that contain TGIC. These findings indicated that TGIC, when tested on laboratory animals, can be toxic or can cause mutations in the male's reproductive system. If suitable handling precautions are observed and good practice applied during powder application, powders containing TGIC can be used safely. To sustain and enhance powder coating's rightly deserved reputation as environmentally sound, however, powder manufacturers have developed systems that do not rely on the use of TGIC.

Various approaches for the removal of TGIC were considered. Polyurethanes appeared to be an obvious solution, but, because of the presence of isocyanate co-reactant, neither external "blocking," using caprolactam, nor internally blocked isocyanates can entirely remove the hazard of free isocyanates.[9]

Acrylics could be used, also, but, these films are generally brittle, so they offer no solution where any degree of flexibility or mechanical performance is required.

As a result of these findings, new systems have been introduced using new co-reactant chemistry, where TGIC has been replaced by a ß-hydroxyalkylamide. When this is used in conjunction with specially adapted polymers, no potentially dangerous volatile compounds are released.

Of course, when originally developed, the system's overall performance had to be confirmed (Fig. 6). Since then, the systems have been independently approved to the requirements of the key architectural finishing standards.

Interestingly, although the original driving force behind the development of

TGIC-free systems was health and safety, coaters have found that the new chemistry can give greatly enhanced application characteristics. Excellent first-time transfer efficiency and penetration (because of reduced Faraday cage effects) have been noted, as well as good tribo-electric charging qualities.

In Australia, for example, where TGIC-free products have almost completely replaced previous architectural products, coaters have found an increase in powder use of up to 20 percent. Development continues in this area, and other new cross-linkers are under evaluation.

	Gardner Impact	Conical Mandrel	Erichsen	T-Bend Flexibility
Polyester/TGIC	7.5J	<3 mm	8 mm	1T
TGIC-free Chemistry	7.5J	<3 mm	8 mm	1T
Polyurethane—“Caprolactam Blocked”	7.5J	<3 mm	8 mm	1T
Polyurethane—“Internally Blocked”	5J	<3 mm	7 mm	2T

Fig. 5—Mechanical Performance Table.

Exterior Weatherability

The main purpose of an architectural finish is to create the image inspired by the architect’s imagination ... and to maintain that image for as long as possible, without the coating’s degrading.

Standard high-performance architectural powders, based on polyester polymers cured with triglycidylisocyanurate or the alternatives previously discussed, have outstanding toughness and weatherability attributes. Products are assessed against the European Standards, where performance is measured after 12 months’ Florida exposure, and more than 26,000 tons are used worldwide, today.

As with any technology, there is always a drive to improve performance, and, in the case of architectural powders, this has focused on enhancing exterior weatherability and, specifically, gloss retention, color retention and chalking resistance. In more-severe environments, such as the Middle East, Far East, North America and Australasia, such alternative technologies as fluorocarbon-wet paints (PVDF) and anodizing are widely used. But powder is rapidly establishing a strong position, particularly with the advent of new, super-durable powders.

Using the benchmark standard of the American Architectural Manufacturers’ Association Standard AAMA605.2-92, the new powder systems are formulated to meet—after five years’ exposure in Florida—the key requirements of:

Gloss Retention : Greater than 50 %
Chalking : Rating 8 or higher
Color Change : Maximum ΔE of 5

Because the Florida test is, by definition, a long-term test, it has been necessary to use and understand all available accelerated weathering techniques. The use of the Fresnel Solar Reflecting Concentrator*, in particular, has proven extremely useful. The background to this technique has been published previously.[10] Perhaps more important, the predictions made are now being confirmed by the actual, real-time Florida data (Fig. 8).

Comparison with Alternative Technologies

The original AAMA 605 Standard was written around the performance of fluorocarbon or polyvinylidine difluoride (PVDF) wet paints. Together with inorganic anodizing, these finishes dominated the commercial finishing of aluminum, in the past.

In Europe, powder has replaced almost all wet painting, and at least 50 percent of anodizing. In other markets, such as the U.S. and the Far East, the use of standard architectural powders is growing rapidly, but it is now expected to accelerate even more, with the introduction of the new, super-durable powders.

In addition to the recognized benefits of powder—in terms of film toughness, ease of application and cost (Fig. 10)—the new powders can now offer greatly enhanced exterior performance as shown in Fig. 9.

Improved application characteristics and significant advances in exterior durability continue to make powder finishes more attractive.

When considered in conjunction with the overall architectural system advances in powder performance, combined with advances in pretreatment, fabrication methods and environmental acceptability, an exciting and prosperous future is indicated for architectural powders, worldwide. ❑

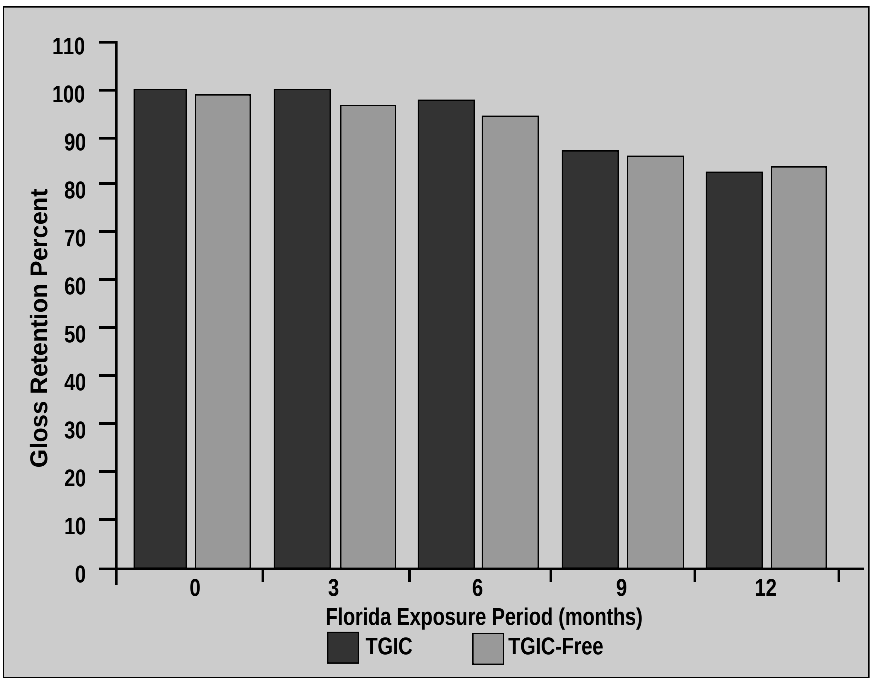

Fig. 6—Comparison of TGIC and TGIC-free chemistries.

*EMMAQUA , DSET Laboratories, Inc., Phoenix, AZ.

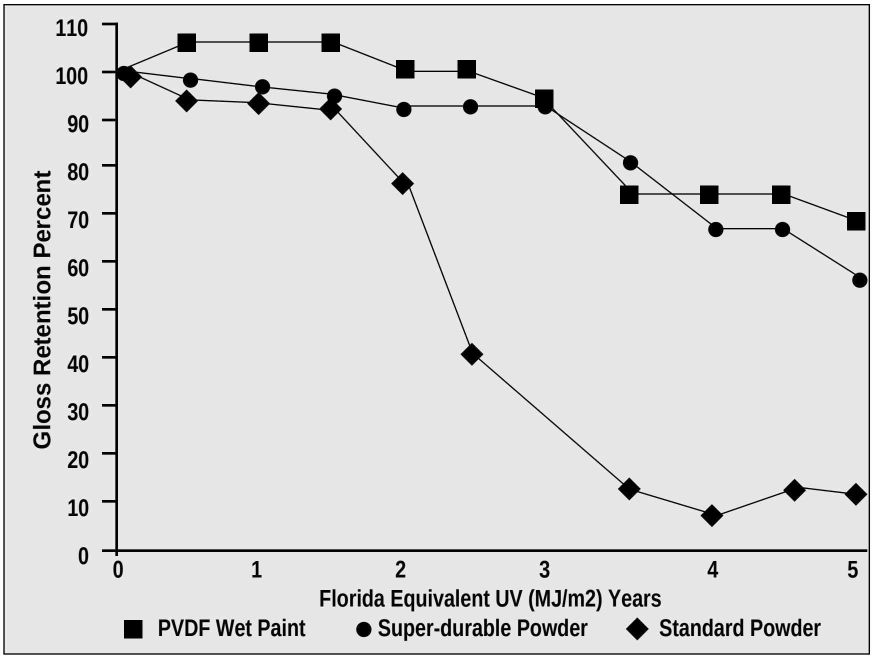

Fig. 7—Gloss retention curves for various coating systems from EMMAQUA accelerated method.

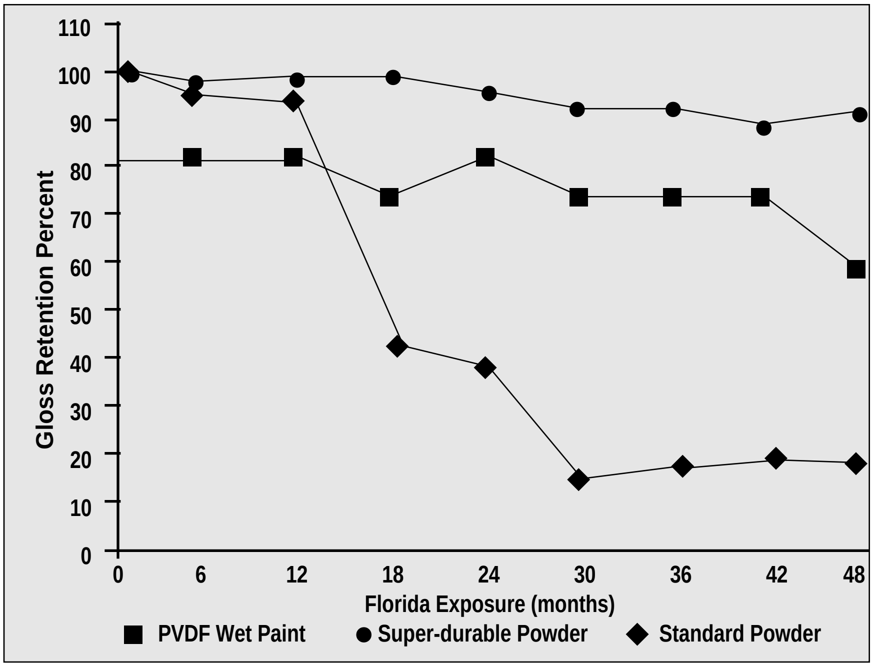

Fig. 8—Gloss retention curves for various coating systems from actual Florida exposure.

	Anodizing	Architectural Powders		PVDF (Spray)
		Standard	Super-durable	
Film Thickness	12–25	60–80	60–80	25–40
Number of Coats	N/A	1	1	2,3, or 4
Color Range	1	5	3	3
Choice of Gloss	1	5	4	2
Toughness	5	5	5	3
Weatherability	4	3	5	5
Health & Safety	4	5	5	2
Environmental Impact	2	4	4	1
Cost	5	5	4	1

5 = Excellent 4 = Very Good 3 = Good 2 = Fair 1 = Poor

Fig. 9—Architectural finishes: Guide to comparative performance.

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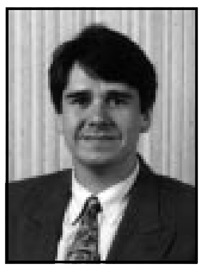

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Matthew Osmond graduated in 1981 with a BS in chemical sciences from Leeds University (U.K.). Since then, he has worked in various divisions of Courtaulds Coatings (Holdings), Ltd., Felling, U.K. For six years, he was responsible for the development of the market for architectural powder coatings and is now marketing and commercial manager in the central support function of the Courtaulds Coatings powder business.