POWDER COATINGS BY DESIGN:

A Major Appliances OEM Design (and Materials Engineering) Perspective

Preview of the *U.S. Market Analysis for the Paint & Coatings Industry (2018–2023)*

By Aggie Lotz
The ChemQuest Group

In 2019, the American Coatings Association partnered with The ChemQuest Group, its international strategic consultant with a specialty chemicals' focus, to prepare the U.S. Market Analysis for the Paint & Coatings Industry (2018–2023) *and the* Global Market Analysis for the Paint & Coatings Industry (2018–2023).

ACA's U.S. *and* Global Market Analyses *characterize the use of all types of paint and coatings by region and end market (qualitative and quantitative data presented in comprehensive PowerPoint formats) through primary research conducted across the value chain with paint and coatings practitioners, including end users, as well as secondary research of industry-approved data sources.**

This article examines appliance finishes (with an emphasis on powder coatings). Powder coatings (Chapter 3) and Appliance Finishes (Chapter 10), are two of 24 chapters in the U.S. Market Analysis.

---

*For the first time in ACA's history, both *Market Analyses* will cover the same five-year period (2018 through 2023). They will be available for purchase by early September 2019 via *https://www.paint.org/publications-resources/market-analyses-benchmarking/*.

INTRODUCTION

This article focuses on the current design and materials engineering practices employed by major appliance manufacturers in the United States for developing a new suite of household appliances. Alternative finishes challenging stainless steel are emerging as a highly marketable feature. Today's unprecedented consumer demand for customizable appliance colors and textures (with decorative hardware finishes) that are integral to warm and inviting home interiors is likened to the wildly popular 1970s "harvest gold era." Years of above GDP growth in new construction and home remodeling are drivers. Remodeling demand, in particular, is partly driven by home renovation-themed TV shows featuring celebrity hosts who, year after year, inspire multigenerational audiences to improve and update their living spaces.

As outlined in the scope of the *U.S. Market Analysis' Chapter 10, Appliance Finishes*, original equipment manufacturer (OEM) appliance finishes include powder coatings, coil coatings, and liquid coatings. Appliance finishes are used to protect and decorate interior and exterior plastic and most metal substrates (e.g., ranges, freezers, washers), heating equipment (furnaces), industrial furnaces and ovens, and air conditioning equipment. Stainless steel, by comparison, was historically unpainted but is now commonly coated with an anti-fingerprint coating, while the newer black stainless appliances have a unique finish process that varies by OEM.

APPLIANCE DESIGN AND HOME INTERIORS

Customer Segmentation

Appliance OEMs are segmenting and tracking business trends that fall under three consumer categories: single appliance replacement (largest by volume), home renovation, and the U.S. builder distribution market comprising the design and construction of new homes.

Appliance shopping for most consumers is driven by a need to replace a single aging or unrepairable appliance. In this category, consumers are seeking to closely match the finish of a new kitchen or laundry appliance with their existing models, such as matching the color and finish of a new refrigerator to that of an existing stove and dishwasher. Far less frequently, consumers are investing in a suite of appliances for the kitchen and laundry either for a newly renovated space or in preparation for a move to a recently built or existing home. The move or renovation may entail a first-time appliance purchase or replacing existing (possibly aging) appliances that no longer fit the consumer's new space or must be left behind due to a real estate agreement. Buying factors will vary, but the appliance suite sale is king.

Timely interior design input from production builders as they build homes for a large, diverse audience across the United States is extremely valuable to appliance designers. Appliance designers walking alongside builders in each phase of a new home design springboards mutual creativity as builders conceptualize and design interior finishes for kitchens, laundry rooms, and adjoining spaces. Appliance design is required to fit in with the builders' vision for style, color palette, textures, and finishes. Beyond aesthetics, the appliance designer considers durability for the typical 10- to 15-year life of most major appliances.

Appliance Design and Finishes

In 2011–2012, GE embarked on a full year of consumer research, recognizing that the kitchen had become the hub of the home—that kitchen appliances, the refrigerator, stove/cooktop, dishwasher, and oven were integral to, and should complement, the surrounding décor. Wall coverings and cabinet finishes took on a warmer tone similar to a living room aesthetic. Moreover, the popularity of stainless steel was waning. GE set out to develop an alternative to stainless-steel in response to a gap in the market (an unmet need among consumers) for ease of wiping off, or ideally preventing, oily fingerprint smudges and water droplets that continually marred the surface of their stainless-steel appliances—otherwise known as "stainless steel fatigue."

In late 2012, on a limited basis, the appliance industry introduced new alternative finishes like frost white and black stainless. From GE's perspective, their year-long consumer research uncovered a preference for metallic surfaces with fingerprint resistance, while the traditional pure white, almond, and glossy black finishes had faded in popularity. Flooring such as laminates featured a warmer wood tone. In response to changing interiors and consumer preferences, GE landed on what it called Slate, marketed as "a rich matte appearance that naturally hides fingerprints and smudges to maintain its beauty," and GE sales took off. During shipping, however, the low-gloss, slate coating soon began to burnish around the appliance corners. According to ChemQuest vice president David Cocuzzi, this burnishing effect is an inherent concern with low-gloss (matte) coatings technology.

At about the same time, LG launched a brushed stainless finish that caught on.

By 2014, "black stainless" was introduced—a brush metal effect that shines through a translucent darker color. While a year earlier Slate was designed to complement cabinets and other features in a kitchen, by contrast, black stainless was designed to make a bold statement. The "black" in black stainless is a coating with a small amount of black pigment to create a transparent, dark coating.

Shortly thereafter, the Café line of high-end GE appliances with customizable hardware was introduced, featuring new colors such as pearl bright white.

GE's Monogram series followed. These appliances use physical vapor deposition (PVD) technology, which produces an exceptionally hard, scratch-resistant coating. PVD coatings are, by end user's standards, exceptionally expensive. PVD technology is principally nitride coatings, according to Cocuzzi, comparable to tungsten carbide in toughness, and equally tough to work with. After all, appliances, with a relatively long life verses consumer electronics and smartphones, are subjected not only to a fair number of fingerprints and smudges, but also door slams and other use considerations.

The net effect is that consumers and interior designers have a great deal more to work with to create their very own "dream kitchen." Moreover, anti-fingerprint coatings are now commonly used on stainless-steel appliances.

Top photo: Matte black kitchen suite
Second photo: Wi-fi enabled wall oven
Left, corner photo: Dual fuel range with baking drawer
Middle photo: Glass kitchen suite
Right photo: Refrigerator with hot-water dispenser

In-home Consumer Research

"We did consumer research the old fashion way," says Lou Lenzi, recently retired design director for GE Appliances. "GE Appliances' design research team spent time with consumers in their homes during daily activities like meal preparation. It's one thing to observe and ask questions through the one-way glass in a focus group setting, but quite another to actually go into the consumer's home and observe and witness how people live their lives in the kitchen and how they congregate."

Designers bring miniature versions of appliance designs under development in the form of paper models, reminiscent of paper doll fashion accessories with foldable tabs for attachment. This was one of many methods GE used to obtain consumer feedback—adhering paper models to the front surfaces of a refrigerator, dishwasher, and wall oven. The consumer stood in front of their current appliances and offered feedback. GE dedicates a lot of time, attention, and detail to its in-home consumer research because the outcomes drive the company's understanding of where consumers are headed. Consumers are certainly influenced by magazines, social media, and cable TV shows, and that crossover effect is experienced in homes.

APPLIANCE DESIGN AND ENGINEERING

Appliance OEMs' materials engineers focus on materials, materials processes, application of finishes, testing, validation, and qualifying the finishes, to meet internal specifications and industry standards. At GE and Electrolux, designers work with materials engineers who are part of the R&D team, and materials engineers work hand-in-hand with the production engineer in kitchen (especially dishwashing) and laundry products. Electrolux's material engineer also interacts with Purchasing, Manufacturing, and Quality Assurance, according to Tim Jones, recently retired after 40 years as Electrolux's materials engineer.

Lenzi would accompany GE's materials engineers to meetings with coating suppliers occasionally for a firsthand understanding of their world. Design leaders are like sponges when it comes to information—they track consumer interest, trends and durable goods, automobile design, and fashion design. Beyond design, they seek to understand what is on the leading edge with supplier partners who are challenging their own R&D teams to innovate new approaches. In the appliance OEM's design studio, coating suppliers (and major retailers) are exposed to design and material concepts, and observations are exchanged on the appliance suite from every angle, which ensures a good leg up on the development process. The consumer's need for aesthetic attributes is a top priority, followed by the technical properties and processes recommended by materials engineers. Appliance designers must understand color coating, powder coating, and films while leaving technical decisions to the engineering team.

The laundry room is, much like the kitchen, becoming a softer, more inviting environment. Here, the industrial design team works closely with the design research team, the materials engineers, and, of course, the production engineers, to ensure that a specified finish will reflect an appliance brand and its values.

Certain properties such as scratch resistance and burnish require packaging engineers' expertise. From a packaging engineer's perspective, safely delivering a 21½-cubic-foot refrigerator to the consumer's home without scratches requires an appropriate package design including core blocks, the inner packed materials, and the corrugated carton, that collectively become a critical component of the finish specification. Otherwise, during delivery, if a finish burnishes due to rubbing inside the container, the team turns to the manufacturing engineer. Obviously, no team member wants to hear of their new appliance unboxed in the home with the customer's first reaction being, "What is this scratch or discoloration?." On the front of the refrigerator, you have injectable to plastic patch overlays for the control services. The side panels are often color-coated or powder-coated. How do you achieve consistent visual harmony across multiple materials and processes? The short answer is that it is a team effort to pull off.

Similarly, retailers display a lineup of various brands of appliances on the show floor, which prompts appliance manufacturers to assess their competitor's features, brands, and price points against their own in a mock shopping exercise. All the design criteria, material qualifications, and manufacturing decisions are on full display by their channel customer—the retailer. Still, the moment of truth is when the product is unboxed in the consumer's kitchen—here an appliance manufacturer strives to deliver on its promises to retailer customers.

Otherwise, the retailer hears from the customer, and the complaint runs down the line, but the buck stops with the appliance manufacturer's internal design and engineering team.

THE TECHNICAL SIDE OF APPLIANCE FINISHES

Qualification of a New Powder Paint Supplier: at the OEM or Job Shop

In his tenure with Electrolux, Jones' role overseeing supplier and material qualification in the St. Cloud, MN plant was a high priority.

From a logistics standpoint, Electrolux's newest plant is in Memphis, TN (slated to close by end of 2020). Electrolux manufactures dishwashers in Kinston, NC; freezers in St. Cloud, MN (closing in late 2019); and refrigerators in Anderson, SC and Ciudad Juárez, Mexico. Charlotte, NC is a major hub for Electrolux appliance design, fabric care R&D, and its Global Technology Center, and is its corporate headquarters in North America.

Jones perfected the following steps, over many years of trial and error, to qualify a new powder paint supplier. The qualification is being driven by the appliance manufacturer, usually for a cost advantage.

Qualification of a New Powder Paint Supplier

1. Purchasing agent or project manager initiates interest in new powder paint suppliers
   A. Criteria for appliance finishing system is communicated in order of importance, as follows:
      i) Price
      ii) Need for new technology, coating properties
      iii) Paint application optimization (improving equipment or methods)
      iv) Mitigate or eliminate unfavorable dynamics with incumbent supplier
      v) New appliance design requirements (appliance suites, individual appliance design enhancements)

B. Meet with powder paint supplier candidates individually
   i) Initial phone interview (communicate above criteria)
   ii) Face-to-face follow-up (if needed)

C. Request for Quote (RFQ) is prepared at the OEM or job shop
   i) Documentation includes:
      a) Material
      b) Test
      c) Finish
      d) Agency specifications (when applicable)
   ii) Identify substrates to be powder painted: cold-rolled steel, galvanized steel, etc.
   iii) Identify type of parts to be painted
   iv) Disclose annual volume of paint in use
   v) Identify packaging for paint/coatings: supersacks, gaylords, drums, 50-lb boxes
   vi) Disclose current resin types such as epoxy, polyester, hybrid, etc.
   vii) Disclose application and curing methods (spray-applied; cure oven fueled by Natural Gas or LPG; some cure ovens can utilize UV elements to enhance the curing operation)
   viii) Present pictures and CAD drawings (if available)
   ix) Disclose powder paint labeling requirements: part number, barcode, etc.
   x) Disclose shipping/transportation requirements (refrigerated or non-refrigerated truck)

D. Exchange pre-bid information with suppliers
   i) OEM color requirements
      a) Provide a color specification identifying DL, DA, DB, DE Tolerances
      b) Log color standards into a spectrophotometer for periodic color evaluations

2. Receive quotes from one or more powder paint suppliers

3. Schedule onsite full day plant audit → powder paint suppliers come to appliance factory

   A. Request that powder paint supplier representatives be present during audit
      i) Sales representative
      ii) Technical manager
      iii) Formulator/chemist

   B. Conduct audit, comprised of, but not limited to:
      i) Supplier's corresponding powder-coated color sample for each issued color standard
      ii) Evaluate each color sample against previously issued standards
         a) Identify adjustments needed, if any
         b) Bake panels using appliance OEM ovens to authenticate color matching
      iii) Audit the pretreatment system (example results are shown in *Tables 1* and *2*)
         a) Schedule the current pretreatment chemical supplier to attend audit to answer questions

TABLE 1—Pretreatment Audit Support Documentation (2014)

PRETREATMENT CRITERIA	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	STAGE 6	STAGE 7
Material	Bonderite C-AK ZX-2	Bonderite C-AK ZX-2	City Water	City Water	Bonderite M-NT 1	Rinse	Empty
Product Function	Alkaline Cleaner	Alkaline Cleaner	Rinse	Rinse	Pretreatment	Rinse	
Temperature Specification	120–150°F	120–150°F	< 110°F	< 85° F	< 85°F	< 85°F	
Actual	125	128	107	85	84	80	
Testing	Free Alkalinity (mLs)	Free Alkalinity (mLs)	Conductivity (uS)	Conductivity (uS)	pH	Conductivity (uS)	
Operating Range	18–20	18–20	< 750	< 400	4.7–5.2	< 380	
Actual	21.3	19.4	571	288	4.9	245	
Testing	Total Alkalinity (mLs)	Total Alkalinity (mLs)			Hach Meter (ABS)		
Operating Range	18–60	18–60			0.22–0.30		
Actual	42.9	40.5			0.226		
Testing	Total/Free Alkalinity Ratio	Total/Free Alkalinity Ratio					
Operating Range	< 3.0	< 3.0					
Actual	2.01	2.09					
PSI	5 to 10	5 to 10	5 to 15	5 to 10	5 to 10	5 to 10	
Actual	10	10	10	10	10	10	
Sample Taken							

TABLE 2—Pretreatment Audit Support Documentation (2015)

PRETREATMENT CRITERIA	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	STAGE 6	STAGE 7
Material	Bonderite C-AK ZX-2	Bonderite C-AK ZX-2	City Water	City Water	Bonderite M-NT 1	Rinse	Empty
Product Function	Alkaline Cleaner	Alkaline Cleaner	Rinse	Rinse	Pretreatment	Rinse	
Tank Volume (Gallons)	**1500**	**2800**	**1925**	**2020**	**1410**	**965**	**600**
Last Dump or Decant	7/18/15	7/18/15			8/17/14		
Amount Dumped or Decanted							
Tank Condition (note any leaks)	OK	OK	OK	OK	OK	OK	
Pump Condition (note any leaks)	OK	OK	OK	OK	OK	OK	
Screen Condition	OK	OK	OK	OK	OK	OK	
Heater Condition	OK	OK	NA	NA	NA	NA	
Riser Condition	OK	OK	OK	OK	OK	OK	
Nozzle Condition	OK	OK	OK	OK	OK	OK	
Spray Pattern	OK	OK	OK	OK	OK	OK	
Chemical Feed Pump Settings	Manual	Manual	Manual	Manual	Manual	Manual	

iv) Audit the dry-off oven
   a) Run Datapaq® to profile the oven at the proposed line rate (see *Figure 1* and *Table 3*)

v) Audit the powder paint room with paint-room supervisor and lead present
   a) Review cleanliness of paint room
   b) Review temperature and humidity controls
   c) Review transfer efficiencies of powder paint to parts
   d) Review reclaim systems to ensure efficiency (low volume of waste reclaimed is preferred result)
   e) Review airflow in the powder paint booth
      - Check electrostatic spray gun placements
      - Check for paint deposits outside paint booth (powder paint escaping the paint booth points to a likely flaw in booth design)
   f) Review air movement surrounding the paint booth
      - Misdirected air movement outside the booth can affect powder paint applications

vi) Audit the cure oven
   a) Run a Datapaq to profile the oven at the proposed line rate (see *Figure 1* and *Table 3*)

vii) Review the inspection area
   a) Determine rework rates
   b) Review powder paint coverage on parts
   c) Review powder paint usage on parts by measuring coating thickness and powder paint usage weights

viii) Recap audit results with Powder Paint Supplier and internal team

4. Decision: do audit results favor next step with the new powder paint supplier?
   A. Purchasing agent and project manager submit formal approvals

5. Request for standard supplier documentation
   A. SDS, PDS, VOC, RoHS, and Agency requirements such as FDA or NSF if needed for each coating being qualified

6. Request a ~20-lb sample box of powder paint for each qualified color
   A. Batch production quality/production-grade sample

7. Samples are received, and qualification process begins
   A. Conduct physical property testing (manually spray test panels, see *Table 4* and *Figure 2*)
   B. Conduct compatibility testing with incumbent powder paint (depicted in *Table 5*)
      i) 1% incumbent to 99% new supplier (evaluate for color, gloss, surface defects, fish-eyes, craters)
      ii) 5% incumbent to 99% new supplier (evaluate for color, gloss, surface defects, fish-eyes, craters)
      iii) Assess results-to-date, and determine next steps
         a) Results will help assess relative cleanliness of powder paint booth during a potential change-over
   C. Conduct tier panel evaluation of graduating film thicknesses for current and proposed powder paints. Determine minimal film thickness that meets physical property requirements
   D. Determine color stability of powder paints with 100% overbake (i.e., twice baked)
      i) Includes all paint lines stop, which adds cure time
      ii) Evaluate for color at the normal cure-rate; re-bake then re-evaluate for color
   E. Powder paint sample test results that do not meet the appliance OEM's physical property requirements → powder paint manufacturer must reformulate.
      i) If applicable, submit new samples with the reformulated product, and repeat the above tests for quality assurance.

FIGURE 1—DataPaq® for dry-off and cure oven with line speed and set points.

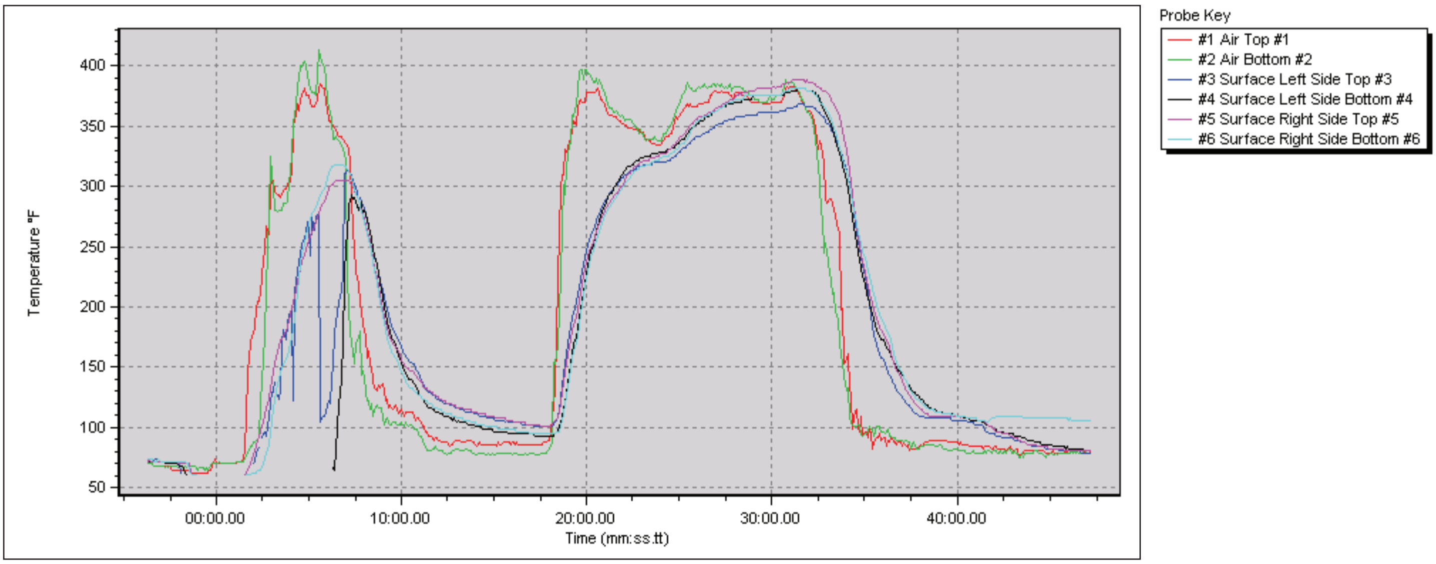

TABLE 3—DataPaq for Dry-off and Cure Oven

Maximum/Minimum

Probe	Maximum (°F)	Max. Reached (mm:ss.tt)	Minimum (°F)	Min. Reached (mm:ss.tt)
#1 (°F)	384.8	05:40.00	62.6	-01:15.00
#2 (°F)	413.6	05:35.00	64.4	-01:00.00
#3 (°F)	368.6	31:25.00	60.8	-01:50.00
#4 (°F)	381.2	31:25.00	60.8	-01:35.00
#5 (°F)	388.4	31:05.00	60.8	01:35.00
#6 (°F)	381.2	31:00.00	60.8	-01:15.00

Datapaq Value | Max / Min | Time at Temperature | View Data

8. Determine if powder paint meets physical property testing
   - A. Schedule meeting to evaluate progress-to-date
   - B. Determine paint trial timing (one week, one month, etc.)
9. Agree upon and commence one-week trial
   - A. Newly qualified powder paint manufacturer is required to produce the appropriate quantity of powder paint based on typical usage for trial period plus 20% for safety
   - B. Pre-trial sample: New supplier ships a 20-lb box of powder paint to run through the proposed OEM or job shop manufacturing process
   - C. Conduct tests on production-grade powder paint
     - i) Color, Gloss, Compatibility, and Tier panels for hide-ability
     - ii) Test results evaluated, OEM and supplier consensus required on test results to move forward with final approval
   - D. Final approval: Trial powder coatings is shipped, and trial commences
10. Back-up protocol: In the event of a major failure during the new powder paint trial, an inventory of the incumbent's powder paint is on hand to prevent downtime
11. OEM or job shop receives trial quantity of new powder paint
    - A. Confirm that the labeling on incoming paint packages is correct
    - B. Allow new powder paint to stabilize for two to three days in climate-controlled powder paint room prior to trial, until the paint reaches room temperature between 70–75°F
12. Schedule the changeover on a weekend to avoid overlap with manufacturing operations
    - A. Run reclaim units and hoppers on lowest setting to minimize scrap
13. Weekend of the New Powder Paint trial run
    - A. Schedule New Powder Paint Supplier to be present during the weekend changeover and testing
    - B. Based on the compatibility testing results, clean the powder paint booth(s), guns, hoppers, and reclaim unit(s) as needed
    - C. Load the stabilized powder paint (trial quantity)
      - i) Season the paint by turning all powder paint guns on and reclaiming the paint
      - ii) Run for 30–60 min (to avoid or minimize cross contamination of new/old paint)
    - D. Start powder painting parts and a few test panels
      - i) Evaluate for color and gloss to ensure both are within your specification
      - ii) Weigh parts before powder painting and after to determine paint usage
      - iii) Conduct film thickness evaluations on parts and compare with data collected from current supplier
    - E. After running the powder paint for a few hours, assess whether all testing and manufacturing requirements have been met

TABLE 4—Powder Paint Physical Property Testing *(see Figure 2)*

SPEC	PROPERTY	REQUIREMENT	CONTROL STEEL CONTROL PRETREATMENT	CONTROL STEEL SUPPLIER PRETREATMENT	SUPPLIER STEEL	SUPPLIER STEEL
	Compatibility **– Film thickness** **– Gloss** **– Fish eyes** **– Orange peel**		**– 2.1 to 2.8 mils** **– 86 to 89 Units** **– None** **– Slight**	–	–	–
#	**Pencil Hardness**	2H minimum	**>2H**	**>2H**	**>2H**	**>2H**
#	**Adhesion**	4B minimum	**5B**	**5B**	**5B**	**5B**
#	**Grease Resistance** – Pencil – Color DE – Swelling			–	–	–
		H minimum	**2H**	–	–	–
		.4 DE max. difference from original reading	**0.4**	–	–	–
		2 minimum, slight swelling	**4**	–	–	–
#	**Stain Resistance**	8 minimum (average)	**9.0**	–	–	–
#	**Film Thickness**	1.2 mils minimum	**1.2 to 1.4**			
	Hideability **– Smooth** **– Textured**		**1.2 to 1.4**	–	–	–
#	**Gloss 60**	80 gloss units minimum	**64.9**	–	–	–
#	**Flexibility**	1/8" max.	**0**	0	**0**	0
#	**Direct Impact** **Reverse Impact**	60 in. lb	**>60**	**>60**	**>60**	**>60**
		30 in. lb	**>30**	**>30**	**>30**	**>30**
#	**Taber Abrasion (1000 g/100 cycles)**	12 mg wt. Loss max.	**0.3**	–	–	–
#	**Salt Spray 504 h** – avg. creep – 336 h blistering – 504 h blistering	1/16" max. 336 h	**0.004"**	**0.0"**	**.004"**	.150"
		1/16" max. 504 h	**.012"**	**.016"**	**.004"**	.256" (Looks like panel had some type of contamination)*
		Few #8-size max.	**None**	**None**	**None**	**Few #8**
		Few #8-size max.	**None**	**Few #8**	**Few #8**	Few #4, #6, #8
#	**UV Stability** (500 h QUVA 340) – Color – Gloss			–	–	–
				–	–	–
#		DE 1.5 max. difference	**0.45**	–	–	–
		45 gloss units minimum	**78**	–	–	–
#	**Heat Stability DL/DE (100% Time @ Temp)** – Color – Gloss			–	–	–
				–	–	–
		DE .50 max. difference	**0.1**	–	–	–
		80 gloss units minimum	**81.3**	–	–	–
#	**Odor** – Cold test – Hot test			–	–	–
		4.0 max.	**0.5**	–	–	–
		4.0 max.	**1.0**	–	–	–
#	**Color**	Max. DE 1.0	**0.1**	–	–	–

*Statement in parentheses is engineer's testing notation.

FIGURE 2—Salt spray test panels.

F. Consensus requirement: Paint Supervisor, Lead Person, Project Manager, Purchasing Agent, Quality Assurance Representative, and New Paint Supplier must review results and agree to move forward with one-week trial

14. Commence one-week trial after all responsible parties have agreed to proceed
15. Monday morning: Start-up of New Powder Paint trial in manufacturing
    A. New Powder Paint technical representative arrives at facility 30 min before production line starts
    B. Conduct periodic evaluations of color, gloss, and powder paint usage weights on parts for the entire week
16. Friday morning: Evaluate week-long trial with team and thoroughly review positive and negative outcomes
17. Purchasing Agent/Project Manager Decision: determine if trial-run results favor replacing incumbent with the new powder paint supplier. Inform team.
18. Saturday changeover back to incumbent powder paint product
19. Based on the compatibility testing results, clean the powder paint booth(s), guns, and hoppers, and reclaim unit(s) as needed
20. Load incumbent's powder paint
    A. Season the paint by turning on powder paint guns to reclaim the paint
    B. Run for 30–60 min (to avoid or minimize cross contamination of new/old paint)
    C. Start powder painting parts and a few test panels with the incumbent's powder paint
    D. Evaluate for color and gloss to ensure that both are within your specification

TABLE 5—New Powder Paint vs Incumbent Powder Paint Compatibility Study

NEW POWDER (%)	INCUMBENT POWDER (%)	60 GLOSS	20 GLOSS	APPEARANCE
100.00	0.00	85–88	63–66	—
99.00	1.00	83–86	55–60	No craters or fish-eyes
95.00	5.00	82–85	49–54	No craters or fish-eyes
0	100	86–89	62–68	—

Finding one or two new powder paint manufacturers may hinge on formulator expertise. Materials engineers can learn from application equipment suppliers who specialize in and use large quantities of powder paint, but chemists formulating new powder paint products have a deeper knowledge not only of their own portfolio, but of technology in general. Appliance OEMs are trying to learn from their supplier partners how to improve performance/cost through innovative materials, new technology, and application methods.

According to the Powder Coating Institute, electrostatic spray deposition (ESD) is commonly used to achieve the application of the powder coating to a metal substrate. This application method uses a spray gun, which applies an electrostatic charge to the powder particles that are then attracted to the grounded part. After application of the powder coating, the parts enter a curing oven where, with the addition of heat, the coating chemically reacts to produce long molecular chains, resulting in high crosslink density. These molecular chains are resistant to breakdown. Sometimes a powder coating is applied during a fluidized bed application. Preheated parts are dipped in a hopper of fluidizing powder—the coating melts and flows out on the part. Post cure may be needed depending on the mass and temperature of the part and the type of powder used.

In a week-long trial of a new powder coating for appliances, Jones' ideal is to use two or three separate batches of production-grade paint to ensure the quality of the new powder paint manufacturer's process and end product is consistent batch to batch. Climatizing, which takes up to three days, cannot be overlooked—so the three batches can be received on the same day before the trial begins. Humidity is an equally important consideration albeit difficult to control. Excessive heat and moisture can cause powder paint to clump, gel, or otherwise affect its quality. Powder paint exposed to seasonal cold temperatures and low humidity during winter also requires climatization for quality control. Most jobs shops have little, if any, ability to control humidity. Typically, humidity is best controlled in the appliance OEM's powder paint room using a very sophisticated humidifier.

Whenever possible, appliance suites are manufactured without changing the type of powder paint, hardware, and accessories for design and bulk pricing considerations. Qualifying the same technology for use in multiple facilities in and outside North America can be a strategy, depending on logistics. Standardizing physical property requirements such as material specifications, test specifications, and the finished specification may warrant using the same powder paint coating design and specific powder paint formula. A paint manufacturer who has plant locations and a reliable channel strategy in the same countries as the appliance OEM may have an advantage for this reason.

The volume of powder paint varies by plant, depending on the type of appliance manufactured at that location. When manufacturing, for example, in the United States and Europe, an appliance OEM may invest $10,000 to $20,000 to qualify a new powder paint product in the United States to gain a modest cost savings of $50,000 in their U.S. location and a $200,000 savings in Europe.

Job shops will vary in their approach. One job shop may use an appliance OEM's qualified powder paint product to gain bulk pricing (often the powder paint manufacturer will even accommodate the job shop's packaging preference), while other shops with multiple OEM customers would not be able to satisfy all of their customers' requirements using one OEM's qualified product.

Managing Efficiency in the Major Appliances Supply Chain

Managing efficiency at the factory and among the many tier suppliers is challenging for material engineers. Cost reduction strategies that resonate with coatings practitioners involve the substitution of parts and technologies with lower priced versions or qualifying new suppliers and unseating an incumbent supplier with a low-bid rival. Implementing newer, more efficient application equipment is another strategy employed at the OEM and in job shops. Sometimes, it is a matter of periodically inspecting job shops to ensure compliance with an appliance OEM's methods and painting practices. When a red flag is encountered, corrective action must be taken or the job shop risks losing its OEM contract. At minimum, improving efficiency reduces operating expenses by significantly reducing scrap and waste. Appliance OEMs prioritize worker health and safety throughout their supply chain. Avoiding downtime on the appliance OEM's own lines due to inferior parts is critical.

Historically, smaller parts have been outsourced, with wired goods as one of those examples. Poor practices discovered in job shops may involve a prolonged search for reliable and efficient wire suppliers with powder paint capabilities to meet best practices in powder paint booth management, equipment maintenance, part manufacturing including pre-trim surface preparation and painting, and worker safety and training.

A ~$500,000 capital expense for equipment was once recouped in less than a year. To illustrate the savings, consider a wire goods part produced in a job shop. The unpainted part weighs about a half pound. Measuring the pure powder paint coating on the wire part with a film thickness gage, film thickness coverage was in the range of 10 to 20 mils of powder paint. For the Faraday Cage areas film thickness should be around 3 to 5 mils by comparison. In a mismanaged job shop, the total output of powder paint for that part exceeded the acceptable film thickness by three to four times.

Heavy and inconsistent coating thicknesses can lead to surface defects such as orange peel, and the paint may become more brittle and chip during assembly. (Note: orange peel is a surface defect, a non-smooth surface, which creates a poor overall finish appearance. Orange peel has multiple causes and can occur with powder or liquid coatings.) Part fitting into the application can be thrown off. For example, a wire part may not fit into its stud application due to excessive film thickness. In other cases, poorly painted parts may no longer fit into a cabinet.

The new piece of equipment increased a semi-automated operation to 100% automated, which decreased time, materials, labor, waste, and clean-up expenses, and optimized the coating application. Improved quality paid off by producing consistently good coating systems vs the shop's prior inconsistent results. Not only did the equipment pay for itself in under one year, but these gains compounded every year thereafter.

Part of the qualification process determines the efficiency of the powder paint itself—not only by volume and transfer efficiency to the substrate but also by the degree of hideability achieved for each mil of film thickness. For instance, one powder paint product may produce a level of coverage at 1 mil film thickness achieving a certain level of color and gloss and other physical properties, while a new paint supplier's product may require 1.5 mils to achieve identical results.

Seasonal energy variations also affect quality and efficiency. The demand for natural gas peaks during winter months for heating in most parts of the United States. In some areas, industrial users may be forced to curtail their use of natural gas when pressure is low, at which point a manufacturer will turn to its Liquefied Petroleum Gas (LPG) source. Material engineers in appliance manufacturing have observed that a change from Natural Gas to LPG as its energy source may cause color changes (often yellowing) with certain chemistries of powder paint. White powder paint is reportedly the most sensitive.

THE FUTURE OF APPLIANCES

Buying appliances online is also a growing trend: the changing dynamic between brick and mortar and e-commerce sales is fast paced, even though buying an appliance for many consumers is one of the largest investments they will make in their home, and well worth doing in person.

Is Alexa waiting to unveil her hidden talent for preparing fine cuisine? Not that we know of. But the trend towards voice control is thought to be the next big thing in appliances. You may see fewer physical controls on your appliance in the not-so-distant future, which will open the door to more opportunities for new finishes. Eliminating all the buttons and knobs on a high-end front-load washing machine is unlikely anytime soon. However, reducing the number to two or three key buttons combined with more advance controls enabled by a voice mechanism is feasible. As a smartphone technology begins translating controls into a voice interface, the technology will open up these clean, simple, sleek surfaces, making the kitchen feel more like a living space and less like a mechanical environment.

Customization and personalization will continue to transform appliances. Today, GE's Café line of appliances is customized with mix and match hardware. A consumer may prefer a handle design that has a certain finish and a certain end-cap aesthetic that they want to extend to virtually every appliance.

The kitchen seems destined for an era of video screens popping up (i.e., touch a screen on your refrigerator to shop online), more furniture, larger islands that become the focal point—truly the living area of the home. Any finish or material compatible with the kitchen's multiple functions—cooking, entertaining, congregating at the end of the day—that adds warmth, functionality, and appeal, will likely be in demand. Yet, coming full circle in a few decades, the dining room and living room may take center stage and the kitchen may once again be relegated to a mere utility room. For now, the kitchen is the hub of the home.

These trends are obvious for appliance designers who attend three important annual trade shows: the annual Consumer Electronic Show (CES), The Kitchen & Bath Industry Show, and The NAHB International Builders' Show® (IBS).

GE Appliances, according to Lenzi, has relied on powder coatings for years because "you can't beat the durability and the ease of application; powder coated is a well-liked process." In 2010, GE put a billion-dollar investment into GE Appliances business unit to reshore its major manufacturing in the United States. Its Louisville, KY site is a 900-acre complex producing refrigerators, dishwashers, and laundry products. In 2018–2019, GE Appliances (acquired by Haier in 2016) invested another $200 million in upgrades to expand the laundry and dishwasher manufacturing in Louisville.

ACKNOWLEDGMENTS

The author extends her special thanks to co-contributors, Tim Jones and Lou Lenzi, FIDSA. Jones retired in April 2018. Over his more than 40-year career with Electrolux Major Appliances, he was involved in qualifying new paint colors and paint products and new application equipment, to satisfy diverse Electrolux internal requirements from its Design Group as well as Purchasing, Manufacturing Engineering, Accounting, and its Quality teams, while working with various paint and coatings vendors seeking qualifications and approval for U.S.-based appliance and part finishes.

Lenzi retired in July 2016 as design director of GE Appliances, where he and his team were responsible for all industrial design, user interface design, and user experience design activities for all GE and GE Monogram-branded major appliance products. ❊

AGGIE LOTZ, vice president, The ChemQuest Group, Inc. (8150 Corporate Dr., Ste. 250, Cincinnati, OH) and ChemQuest Technology Institute (South Boston, VA); alotz@chemquest.com.