# NEW Acrylic Polymers for High Performance Interior Wall Paints

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As a result of requirements to lower VOC, polymers with low minimum film formation temperature (MFFT) are increasingly being utilized in waterborne architectural coatings. However, coating compositions based on these emulsion polymers suffer from poor durability, contributing to soft and tacky coating films. Performance compromises, including lower scrub resistance, high soiling tendency, poor wash, and burnish resistance are often the reported deficiencies of low-VOC paints.

The VOC reduction has raised significant technical challenges but also driven the development of durable, low-VOC waterborne coatings. This success has been enabled by innovative polymer and paint compositions. The progress towards greener products and higher performance standards is clearly demonstrated by the new paint products on the market, a strong

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# High Performance Interior Wall Paints

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testament to the coatings industry's continued commitment to better product quality and lower environmental impact. A recent survey on commercial semi-gloss (SG) and flat paints confirms that almost all interior paints are now formulated at VOC <50 g/L, with some products even claiming to be zero VOC and odorless.

For premium interior paints, the most sought-after attributes are stain resistance or easy clean, scrub durability, maximum hiding, and desired application characteristics. The latter two properties can be optimized by appropriate selections of $TiO_2$, polymeric opacifier, and rheology modifiers. This article will focus more on balancing stain removal or washability and scrub durability. Washability or stain removal is a coating's ability to withstand scrubbing to remove the staining materials with no changes to the coating's appearance or its protective functions. One mechanism of stain removal is mechanical erosion of paint films. Hence, a latex paint with good stain removal often exhibits poor scrub resistance. Adding to the challenge are the wide variations in chemical and physical characteristics of the stains encountered. A coating formulation is often optimized for hydrophobic stain washability at the expense of hydrophilic stain removal and vice versa. Stain resistance or easy clean is, therefore, a desirable property that is lacking in most latex paints and is more challenging to attain in flat interior paints as the types and amounts of pigments increase.

A benchmarking study examining the interior wall paints recently introduced into the market was conducted to understand the general trend and to baseline the stain resistance and washability performance of these new products. New acrylic polymers were also evaluated against the commercial interior SG and flat paints.

**TABLE 1—Commercial Interior Paints Selected for Benchmarking**

| | PAINT ID | VS (%) | VOC (g/L) |
|---|---|---|---|
| SG | SG1 | 41 | <50 |
| | SG2 | 38 | <50 |
| | SG3 | 37 | 0 |
| FLAT | FL1 | 46 | <50 |
| | FL2 | 44 | <50 |
| | FL3 | 40-50 | 0 |
| | FL4 | 40 | <50 |
| | FL5 | 41 | <50 |
| | FL6 | 44 | 0 |
| | FL7 | 46 | <50 |

## EXPERIMENTAL

### Commercial Paints

The commercial interior paints selected in this study are summarized in *Table 1*, including three SG and seven flat paints. The three premium SG paints were chosen because they represented the highest price points in the category, with SG1 and SG2 being the top product lines from the same manufacturer. Flat paints covering a wide price range were purchased from the "big-box" and independent company stores. The seven flat paints were produced by five different paint companies. The information on volume solids (VS) and VOC was taken from each product's technical datasheet.

### Paint Formulations

The SG and flat formulations used to evaluate the acrylic polymers are given in *Tables* 2 and *3*, respectively. The VS and pigment volume concentration (PVC) were 39.6% and 23.6%, respectively, for the SG formulation and 40.5% and 47.4%, respectively, for the flat formulation. Neither the SG nor flat paints contained any VOC, owing to the use of Optifilm™ 400 co-solvent.

### Gloss and Contrast Ratio of Dry Film

The test paints were prepared on the Leneta 3B opacity charts using a 3-mil bird drawdown bar. The films were allowed to dry overnight in a controlled temperature and controlled humidity (CT/CH at 77°F and 50% relative humidity) chamber. Gloss readings were taken after one-day dry using a BYK-Gardner Micro-tri-gloss meter. Three measurements were collected, and the average gloss values were reported. A BYK-Gardner Colorguide colorimeter was used to measure Y%-reflectance over the white and black parts of the opacity chart. Opacity or contrast ratio was calculated as the ratio of Y% reflectance over the black section to Y% reflectance over the white section.

### Block Resistance

The test paints were prepared on the Leneta 3B opacity charts using a 3-mil bird drawdown bar. The films were dried in the CT/CH chamber for one day. In the room temperature (RT) block test, two square strips of 2.54 cm x 2.54 cm were placed together with paint film against paint film under a 454-g weight. After 24 h, the strips were separated and evaluated. For the elevated temperature (ET) block test, the paint strips after one-day drying at CT/CH were placed in a 120°F oven for 30 min. The weight load of 1000 g was transferred to the paint films via a 2.54-cm diameter rubber stopper. The films were allowed to cool for 30 min before the block ratings were given. One-day room (1d-RT) and elevated temperature (1d-ET) block were rated on the ASTM D-4946 scale from 0 (poorest) to 10 (best). The test was run in triplicate and the average value was reported.

### Wet Adhesion

Wet adhesion tests measure the adhesion of a coating under wet conditions to an aged alkyd substrate. Among the numerous wet adhesion tests, ASTM D-6900 was employed in this study. The gloss

**TABLE 2—SG Formulation**

| | WEIGHT | VOLUME |
|---|---|---|
| ***COMMON GRIND*** | | |
| WATER | 139.9 | 16.8 |
| TITANIUM DIOXIDE | 225.0 | 6.8 |
| DEFOAMER | 0.9 | 0.1 |
| DISPERSANT | 8.0 | 0.8 |
| NON-IONIC SURFACTANT | 2.0 | 0.2 |
| HEUR | 2.5 | 0.3 |
| AMMONIA [28%AQ] | 2.5 | 0.3 |
| THICKENER | 2.0 | 0.1 |
| EXTENDER | 54.6 | 2.5 |
| BIOCIDE | 8.0 | 0.8 |
| ***COMMON THINDOWN*** | | |
| OPACIFIER | 0.0 | 0.0 |
| DEFOAMER | 1.6 | 0.2 |
| WATER | 25.0 | 3.0 |
| HEUR | 1.0 | 0.1 |
| ***TOTAL OF COMMON PASTE*** | ***473.1*** | ***32.1*** |
| ***INDIVIDUAL THINDOWNS*** | | |
| GRIND | 473.1 | 32.1 |
| ACRYLIC POLYMER | 530.4 | 59.6 |
| CO-SOLVENT | 12.0 | 1.5 |
| HEUR | 1.5 | 0.2 |
| WATER | 56.0 | 6.7 |
| | ***1072.9*** | ***100.0*** |

| | |
|---|---|
| VOL SOLIDS | 39.6 |
| PVC | 23.6 |
| VOC (G/L) | 0 |

**TABLE 3—Flat Formulation**

| | WEIGHT | VOLUME |
|---|---|---|
| ***COMMON GRIND*** | | |
| WATER | 72.0 | 8.6 |
| TITANIUM DIOXIDE | 273.3 | 14.2 |
| DEFOAMER | 1.0 | 0.1 |
| DISPERSANT | 15.9 | 1.8 |
| NON-IONIC SURFACTANT | 2.9 | 0.3 |
| AMMONIA [28%AQ] | 0.5 | 0.1 |
| THICKENER | 2.9 | 0.2 |
| EXTENDER 1 | 93.6 | 4.2 |
| EXTENDER 2 | 163.8 | 7.5 |
| ***COMMON THINDOWN*** | | |
| WATER | 14.5 | 1.7 |
| HEUR | 14.3 | 1.6 |
| OPACIFIER | 39.2 | 4.6 |
| HEUR | 3.8 | 0.4 |
| ***TOTAL OF COMMON PASTE*** | ***697.5*** | ***45.4*** |
| ***INDIVIDUAL THINDOWNS*** | | |
| GRIND | 697.5 | 45.4 |
| ACRYLIC POLYMER | 347.4 | 39.5 |
| CO-SOLVENT | 12.7 | 1.6 |
| WATER | 112.7 | 13.5 |
| | ***1170.4*** | ***100.0*** |

| | |
|---|---|
| VOL SOLIDS | 40.5 |
| PVC | 47.4 |
| VOC (G/L) | 0 |

alkyd panels were prepared by casting 7-mil of Duvoe Duvguard 4308 Medium Green (4308-6650) Gloss Enamel paint onto a Leneta scrub chart and allowing it to cure for three to six weeks at CT/CH.

The test and control paints were drawn down in parallel on the same alkyd panel with a 7-mil Dow bar. After the panels were dried for 4 h at CT/CH, the films were cross hatched through to the gloss alkyd substrate layer. The test panels were then soaked in water for 30 min. Size and density of blisters were reported. Before scrubbing, 20 mL of 50% Lava soap solution and 5 mL of water were added to the paint panels on the scrub machine. The number of the cross hatched squares not removed after 1000 scrub cycles was reported as percent film remaining.

### Scrub Resistance

Relative scrub resistance was evaluated on the Garner Straight Line Washability and Wear Abrasion Machine. The coatings were applied at a wet film thickness of 7 mil over Leneta black plastic charts and allowed to dry for seven days in the CT/CH chamber. The nylon bristle brushes were conditioned by running 400 cycles before the test began. A standardized abrasive scrub media (#SC-2 from the Leneta Company) was used. The test included the addition of 7 mL of scrub media and 5 mL of water at the beginning and after every 400 cycles. The experimental latex was drawn down and scrubbed side-by-side with an internal scrub control. The test was done in triplicate and the number of cycles to failure was recorded.

### Tannin Blocking

The tannin stain solution was prepared by neutralizing the 10% aqueous tannic acid to pH of 7.0 using ammonium hydroxide and then equilibrated overnight. A coat of a commercial control paint was applied 6 in. wide on the sealed portion of the Leneta WB card using a 6-mil drawdown bar and allowed to dry overnight in the CT/CH chamber. Approximately 10 mL of the tannin solution was deposited from a dropper onto the paper towel covering the dried control paint. A foam brush after dipping into tannin sample (excess tannin was wiped off) was used to evenly distribute the tannin over the paper towel. The WB chart with the control paint in contact with tannin solution was placed back in the CT/CH chamber to dry overnight. The test paint along with the control paint was prepared side-by-side using a 10-mil square bar, dried overnight at CT/CH, and then coated with the control paint on top. After overnight drying of the control topcoat, a BYK-Gardner Colorguide colorimeter was used to measure $\Delta E$ as an indication of color change due to tannin bleeding through.

### Stain Resistance and Washability

A quantitative, multi-stain test method was employed to assess the removal of both hydrophilic and hydrophobic stains. The hydrophilic soilants are common household stains: mustard, ketchup, hot coffee, grape juice, and blue fountain ink. The hydrophobic stains include ball point pen, #2 pencil, blue crayon, red grease pencil, and two brands of red lipsticks (lipsticks #1 and #2). The paint films were prepared on white Leneta Scrub Test Panels (P122-10N, B#4311) using a 7-mil Dow bar and allowed to dry for a minimum of three days in the CT/CH chamber. The test paints formulated with experimental latexes were drawn down side-by-side with a control paint.

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Mustard and ketchup were applied using a 20-mil square drawdown bar. For liquid stains such as coffee, grape juice, and fountain ink, a strip of single-ply paper towel was used to hold the liquid stains in place. Hydrophobic, solid stains were directly marked on the white panels. All stains were allowed to sit on the paint film for two hours. The films were washed for 100 cycles using ASTM standard sponges and Leneta standardized non-abrasive scrub medium as the cleaning solution. The panels contacted by hydrophilic stains were gently rinsed under running tap water to remove excess stains before sponge wash.

Degree of staining was determined using the ΔE values of unstained versus stained and then washed portions of the paint film measured by a BYK-Gardner colorimeter. Resistance against hydrophilic stains was visually assessed by comparing the water-rinsed section to the sponge-washed section.

## RESULTS AND DISCUSSION

### Commercial Interior SG and Flat Paints

*Table 1* shows that all commercial products selected in this study were formulated at VOC less than 50 g/L. *Figure 1* displays the tiered advertisements for the commercial SG and flat paints. Common themes can be extracted from the frequency analysis of product features highlighted by paint manufacturers:

1. Stain resistance and easy clean (3/3 of SG paints and 7/7 of flat paints)
2. Exceptional hide and self-priming (3/3 of SG paints and 6/7 of flat paints)
3. Scrub/scuff/mar resistance (2/3 of SG paints and 5/7 of flat paints)
4. Antimicrobial-mildew resistant (2/3 of SG paints and 4/7 of flat paints)

These key performance characteristics reflect consumers' expectations and, therefore, define the quality standards for premium, low-VOC interior paints.

### Properties of SG Commercial Paints

*Table 4* summarizes the lab evaluation of the three SG paints. All three paints formed relatively glossy films yielding high gloss readings. For SG3, its gloss readings of 33.8 at 20° and 71.4 at 60° approached those of high gloss products.[1] Substrate adhesion, although not promoted on the product feature list, is a basic but critical requirement. The three SG paints, as expected, all passed the four-hour wet adhesion test with 100% film remaining. SG1 and SG2, formulated for the highest quality by the same paint manufacturer, provided durable finishes. The scrub resistance of these two paint samples exceeded 2500 cycles. Comparatively, SG3 was weak in scrub durability, and its paint film failed before reaching 1000 cycles. Among the three paints, only SG2 exhibited acceptable one-day block resistance. Block resistance was not one of the featured properties shown in *Figure 1,* which was confirmed by the test results.

Premium paints are expected to deliver a smooth, uniform appearance with a minimum number of coats. This is why hiding ranked so high in *Figure 1*. Contrast ratio of the drawdown film is a simple measure of intrinsic hiding. The three commercial SG paints spanned the normal range for contrast ratio, from 97.1% to 99.4%. Tannin blocking was also tested to assess these products for the claimed attribute of "self-priming" or "primer and paint in one." Varying degrees of tannin staining were observed, as indicated by the ΔE values, from ~2.4 for SG2 and SG3 to 5.5 for SG1. A lower ΔE value is desired, indicating good tannin blocking performance of the test paint. Among the

**FIGURE 1—Advertised product features of commercial interior paints.**

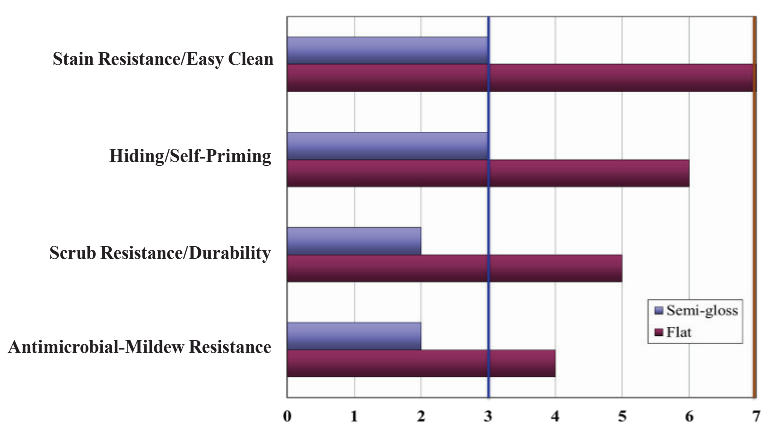



**TABLE 4—Performance Summary of Commercial SG Paints**

| PAINT ID | 20° GLOSS | 60° GLOSS | SCRUB CYCLES | 1D-RT BLOCK | 1D-ET BLOCK | 4-h WET ADHESION | CONTRAST RATIO % | TANNIN ΔE |
|---|---|---|---|---|---|---|---|---|
| SG1 | 16.1 | 49.2 | 2637 | 5 | 4 | 100 | 98.7 | 5.48 |
| SG2 | 16.8 | 50.7 | 3040 | 7 | 6 | 100 | 97.1 | 2.35 |
| SG3 | 33.8 | 71.4 | 860 | 4 | 0 | 100 | 99.4 | 2.45 |

TABLE 5—Performance Summary of Commercial Flat Paints

| PAINT ID | 60° GLOSS | 85° GLOSS | SCRUB CYCLES | 4-h WET ADHESION | CONTRAST RATIO, % | TANNIN ΔE |
|---|---|---|---|---|---|---|
| FL1 | 5.0 | 4.0 | 1527 | 100 | 98.6 | 4.96 |
| FL2 | 4.5 | 3.5 | 1543 | 100 | 98.5 | 3.25 |
| FL3 | 3.8 | 3.2 | 860 | 100 | 99.7 | 0.88 |
| FL4 | 2.3 | 5.8 | 733 | 72 | 99.1 | 2.02 |
| FL5 | 5.9 | 4.4 | 1010 | 100 | 97.5 | 2.75 |
| FL6 | 4.6 | 3.2 | 1540 | 100 | 98.3 | 6.15 |
| FL7 | 3.9 | 3.6 | 1423 | 100 | 98.6 | 3.89 |

FIGURE 2—Washability of commercial interior paints against hydrophilic stains.

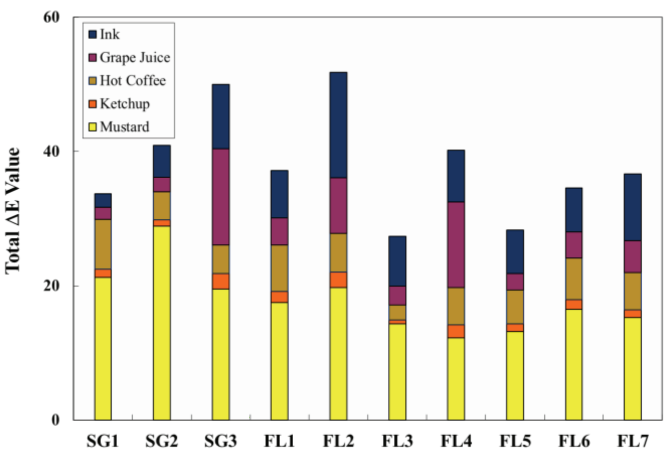
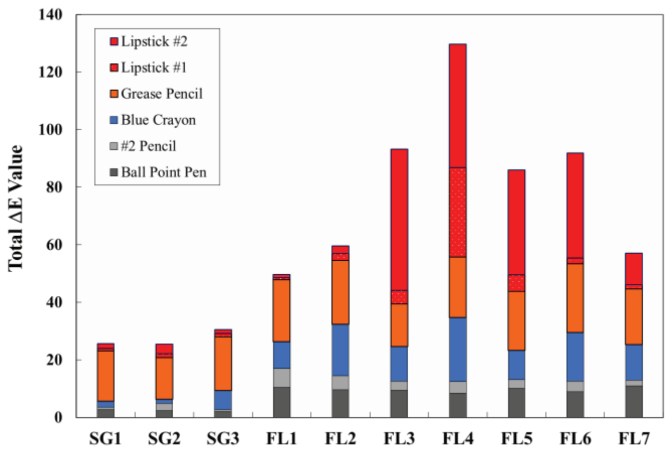



FIGURE 3—Washability of commercial interior paints against hydrophobic stains.




three products, SG2 provided the lowest contrast ratio but the best tannin blocking performance, suggesting that there is no direct correlation between the contrast ratio and tannin blocking.

## Properties of Flat Commercial Paints

A larger number of flat paints are included in this study since many paint properties deteriorate as the PVC increases and polymer binder usage decreases. New binder technologies and formulation approaches are required to deliver the promise of durable and washable flat finishes. *Table 5* compiles the performance properties of the seven commercial flat paints. Block resistance is not listed because it is less important given the fact that block resistance is generally enhanced by the extender pigments used in flat paint formulations.

The low 60°and 85° gloss values confirmed that all seven paints produce matte finishes. All except FL4 exhibited good wet adhesion to the aged gloss alkyd substrate. The flat paints display smaller variations in scrub resistance than the SG paints. However, they can be divided into two performance groups: four products scrubbing greater than 1400 cycles while the other three failing between 700~1000 scrub cycles. Similar to the SG paints, the flat paints yielded contrast ratios in a typical range, from 97.5% to 99.7%. The ΔE values measured after tannin blocking tests ranged from 0.88 to 6.15. FL3 and FL4 were not the best in class for scrub durability. They did, however, deliver the maximum intrinsic hiding (highest contrast ratios) and tannin blocking (least color change or ΔE) as self-priming paints. The applied hiding by using other application tools such as brushes and rollers were not evaluated in this work.

## Stain Resistance and Washability of Commercial Interior Paints

As shown in *Figure 1,* stain resistance and/or easy clean is clearly the number one claimed property of the interior paints across the sheen or PVC range.

Five hydrophilic stains and six hydrophobic stains were used to test the washability of commercial interior paints. Residual color from each stain was measured by ΔE. Small ΔE values are desirable, denoting slight or no staining of the paint surface. The total ΔE value for the hydrophilic stains and the hydrophobic stains are plotted in *Figures 2* and *3*, respectively.

Stain resistance and washability are affected by the composition and surface characteristics of the paint film in addition to the chemical and physical properties of the stain. Wetting, adhesion, and penetration of stains on the coating surface are influenced by surface tension and viscosity of the stain, as well as the surface energy and porosity of the coating film. The data in *Figure 2* shows that mustard tends to cause the heaviest discoloration on the paint surface. Depending on the paint formulation, grape juice and blue ink sometimes left high amounts of staining compounds behind (SG3, FL2, and FL4). Visual inspection of the stained



and water-rinsed sections revealed that good washability or low ΔE value generally corresponded well to the paints possessing high resistance to the water-based household stains. Most stains were removed during the water-rinse step, and the subsequent sponge wash did not further reduce the color of the stained area significantly.

Porosity of paint films generally increases as the PVC increases from SG to flat formulations. Higher porosity allows greater stain penetration and consequently "easy-clean" is more difficult to attain with flat paints. However, this expected decline was not observed for the penetrating liquid stains shown in *Figure 2*. The group of flat paints exhibited similar overall washability of hydrophilic stains. In some cases, the flat paints even rendered improved removal of hydrophilic stains compared to the SG paints. This is presumably because the paint manufacturers optimized the surface characteristics to minimize the negative effect of increasing film porosity on staining and stain removal.

However, the formulation strategy that enabled good hydrophilic stain removal did not yield similar results for the hydrophobic stains on flat paint surfaces. *Figure 3* shows that most hydrophobic stains were completely removable from the SG finishes. The flat paints as a product category recorded higher total ΔE values in general. Red grease pencil once marked on the painted surfaces seemed to be tenacious and difficult to remove even from SG paint films. This appears to be the case for blue crayon on the flat paint films as well. Additionally, ballpoint pen and #2 pencil were not the biggest contributors to the total ΔE value and their removability was almost unaffected by different flat paint formulations that most likely were based on different binder technologies. The two red lipsticks were the biggest contributors and differentiators of washability performance. For these reasons, the five hydrophilic stains and the two lipsticks were considered in the evaluation of experimental acrylic polymers.

**FIGURE 4—Washability of SG experimental paints vs commercial SG paints.**

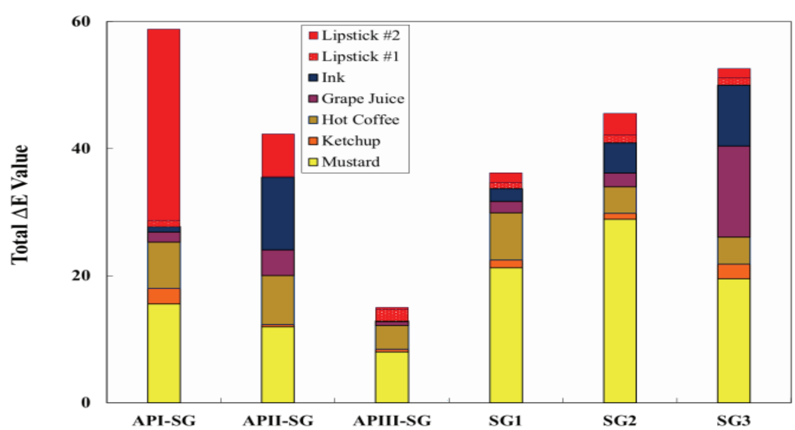
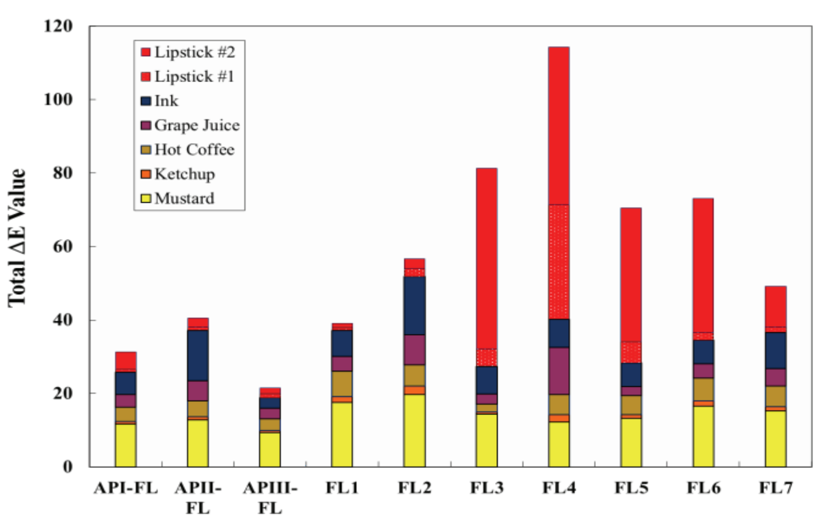



**FIGURE 5—Washability of flat experimental paints vs commercial flat paints.**




### High Performance Acrylic Polymers

Three acrylic polymers, denoted as API, APII, and APIII, were evaluated in SG and flat paints using the formulations shown in *Tables 2* and *3*. The following designation was used to describe the experimental paint samples, for example, API-SG indicating the SG paint sample based on API and API-FL indicating API in the flat formulation.

*Figure 4* compares the overall washability of the experimental SG paints with the threecommercial SG paints. API offered slightly cleaner removal of five hydrophilic stains than the best performing commercial paint SG1. However, API displayed extremely poor washability for lipstick #2. The DE reading of 30.1 caused by the staining of lipstick #2 alone accounted for more than half of the total DE value. The compositions of API were modified in the development of APII to specifically enhance the removal of lipstick #2. The goal was successfully achieved

TABLE 6—Performance Summary of Experimental Paints Based on API, APII, and APIII

| PAINT ID | SCRUB CYCLES | 1D-RT BLOCK | 1D-ET BLOCK | 4-h WET ADHESION | CONTRAST RATIO % |
|---|---|---|---|---|---|
| API-SG | 6460 | 0 | 0 | 100 | 98.5 |
| APII-SG | 3193 | 9 | 8 | 100 | 94.7 |
| APIII-SG | 1713 | 4 | 0 | 100 | 99.1 |
| | | | | | |
| API-FL | 1363 | 9 | 9 | 100 | 98.2 |
| APII-FL | 1420 | 9 | 10 | 100 | 98.1 |
| APIII-FL | 1090 | 9 | 10 | 100 | 98.6 |

with APII: a dramatic reduction of residual color (DE value from to 6.6) from lipstick #2 resulted in an acrylic polymer that delivered comparable washability to the premium commercial paints (*Figure 4*). The most remarkable improvement in overall stain washability was realized with APIII. The seven stains left minimal residual colors on the APIII-SG paint film. The total DE value combining seven stains was 15, which was less than the single DE value corresponding to the mustard discoloration on the commercial paints.

*Figure 5* presents the comparison between the experimental and commercial flat paints. The stain removal property of the three experimental acrylic polymers did not differ as much as seen in the SG formulation or as the wide spread demonstrated by the commercial flat paints. In the flat formulation, all three acrylic polymers offered outstanding overall washability performance, more competitive than all the commercial flat paints. Without any special additive for the "easy-clean" paint property,[2] APIII provided a step-change in washability performance and excellent balance of hydrophilic and hydrophobic stain removal. Moreover, the data in *Figures 4* and *5* demonstrate that APIII can afford the best stain resistance and washability for a wide PVC range from SG to flat formulations.

Other performance properties of the three acrylic polymers are summarized in *Table 6*. All three polymers demonstrated good four-hour wet adhesion. The experimental paints provided comparable intrinsic hiding or contrast ratios to the commercial paints. AP2-SG exhibited exceptional block resistance, a desired property for SG paints. AP1 and AP2 delivered excellent scrub durability in both SG and flat formulations. All three acrylic polymers maintained over 1000 cycles of scrub durability even in the flat formulation, suggesting that good washability was not the result of surface erosion due to poor scrub resistance. It should be noted that the two paint formulations are screening tools for the experimental polymers and it is therefore possible to optimize a given performance property with changes of paint formulations.

## CONCLUSIONS

The coatings industry has made substantial progress in reducing VOC and enhancing performance of waterborne coatings. This article examines the performance of commercial semi-gloss and flat paints recently introduced into the market. For interior applications, the most valued product attributes are stain resistance or easy clean and hiding followed by durability, antimicrobial, and mildew resistance. The benchmarking results have validated the successful development of higher performance, greener products. Three acrylic polymers are highlighted in this article. They offer improved stain washability while providing comparable scrub resistance and hiding to the state-of-the-art commercial products. These new acrylic polymers can thus enable coatings formulators to develop durable and washable, high performance flat to non-flat interior paints. ❊

## REFERENCES


1. Wu, W., "Structured Nano-Acrylic Polymers, Low-VOC, Excellent Block Resistance, Hardnessand Film Formation," *Paint & Coat. Ind.,* 20-27 (November 2013).
2. Meng, J., Guo, C., Zhou, W., and Liao, R., "Novel Application of Fluorosurfactants in Easy-Clean Architectural Paints," *Paint & Coat. Ind.,* 30-37 (July 2013).



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