Factors Affecting Dirt Pickup in Latex Coatings

Alan Smith—BASF Corp.*
Oliver Wagner— BASF AG.

INTRODUCTION

Latex coatings are based on thermoplastic polymer. Their tendency to pick up dirt is greatly influenced by the glass transition temperature of the polymer. However, glass transition temperature is not the only polymer property influencing dirt pickup; hydrophobic modification has been found to be particularly beneficial in textured coatings while monomer selection and crosslinking chemistries have beneficial effects on paints and elastomeric coatings. Good correlation has been found between water sensitivity and water vapor permeability of polymer compositions, and the dirt pickup observed in coatings formulated with them.

The ability of painted exterior surfaces to remain relatively clean in appearance for long periods of exposure is a major performance issue in architectural coatings. The end user of architectural coatings perceives the primary function to be decorative, therefore, all factors affecting surface appearance dominate the perception of overall coating performance. A pronounced tendency to accumulate dirt can quickly negate any other positive attributes which an exterior coating may possess. Consequently, it is interesting and necessary to understand how coating properties influence dirt pickup.

Influence of Glass Transition Temperature

The characteristics which influence the extent to which a paint film picks up and retains dirt have been listed[1] as hardness, surface tackiness, surface resistivity, thermoplasticity, and gloss. Three of these characteristics are obviously closely interrelated, namely hardness, surface tackiness, and thermoplasticity. The hardness or tackiness of a thermoplastic polymer film at a given temperature is controlled largely by the glass transition temperature (T_g) of the polymer. Latex paints are typically based on thermoplastic polymer. It is generally accepted and confirmed by our work (*Figure* 1) that for a given polymer type dirt pickup decreases as polymer T_g increases. *Figure* 1 shows the difference in total reflectance (ΔL CIE-Lab) between exposed and unexposed areas of coated panels after three years vertical exposure in an agricultural/industrial area of central Germany. The panels were coated with 35% PVC white paints containing straight acrylic copolymer latices with T_g values of –20°, 0°, and +10°C.† The trend towards increased dirt pickup with decreasing T_g is shown clearly by the decrease in reflectance.

Holbrow[2] has shown that there is no correlation between hardness and dirt pickup between different coating types, but good correlation does exist for paints based on emulsion polymers. This is easily explained in terms of thermoplastic and non-thermoplastic behavior of resins. If the hardness of the coating is determined at room temperature the relative hardness of thermoplastic resins will have a good correlation with their T_g, the lower T_g resins will be tackier at the elevated temperatures experienced during the exposure period and, therefore, show more dirt pickup. A non-thermoplastic resin, such as a solvent-borne alkyd or epoxy, will not become tackier as the temperature increases so the hardness at room temperature is not a good indicator of its propensity to pick up dirt.

Dirt retention is a major concern in exterior textured coatings (synthetic stuccos), these coatings are being employed as the finish coat in the thermally insulating exterior cladding systems known as exterior insulation finishing systems (EIFS). Since these coatings are marketed as integral parts of the exterior cladding system, the expectation for their useful service life is very high. These coatings typically contain between 8% and 15% latex polymer solids on total solids by weight. A three-year vertical south exposure study (*Figure* 2) shows that at 10% polymer solids, the only polymer property which has a significant influence on dirt retention in textured coatings is MFFT* of the resin, and then only in extreme

*11501 Steele Creek Rd., Charlotte, NC 28273.

†T_g values, throughout the paper, are mid-point measured by differential scanning calorimetry (DSC).

*Resins MFFT = T_g (mid-point DSC) +/– 2°C.

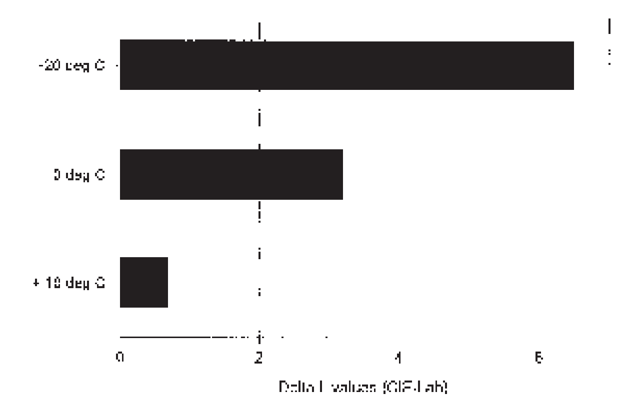

Figure 1—Dirt pickup after three years. Straight acrylic polymers—different T_g ranges.

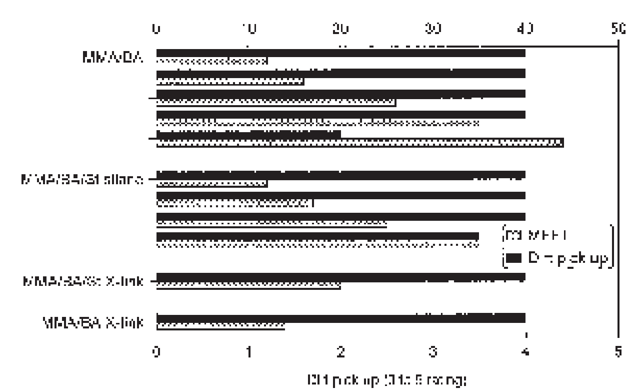

Figure 2—Polymer modifications have no effect at low polymer levels. Three years exposure of a 1.5 mm textured coating.

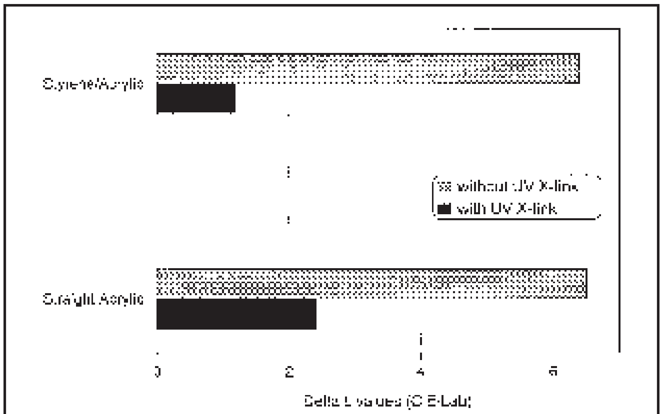

Figure 3—Dirt pickup after three years. Different polymers—low T_g range (–20°).

cases. The other polymer variations, chemical crosslinking, silane modification, and different acrylic monomers had no influence on the dirt pickup. The fact that the more subtle variations in polymer composition had no effect can be attributed to the low polymer content of the coating (textured coatings are formulated well above CPVC), large changes in the polymer properties are required in order to have any noticeable effect at this low level.

Influence of Crosslinking

Ultraviolet photoinitiators can be used as crosslinking agents for exterior latex coatings.[3] It has been our experience that this approach is only effective in reducing dirt pickup with low T_g resins in low PVC coatings. *Figure* 3 shows the effect of adding a UV initiator to low T_g (–20°C) acrylic and styrene acrylic latex in an elastomeric coating. The chart shows the change in total reflectance (ΔL CIE-Lab) between exposed and unexposed areas of the panels after three years of 45°S, the higher the ΔL value the higher the dirt pickup.

UV crosslinking in pigmented architectural coatings has the limitation that is purely a surface phenomenon, the underlying body of the coating is not crosslinked and therefore remains soft. Problems have been experienced with UV crosslinked elastomeric coatings, the crosslinked surface can erode away by chalking to expose the uncrosslinked tacky polymer beneath.[3] This has occurred in practice and has resulted in a sudden dramatic increase in dirt pickup as the coating ages. This problem does not occur with chemically crosslinked polymers since the crosslinking takes place throughout the coating, not only at the surface. A very practical approach to the use of UV crosslinkers in elastomeric coatings is to use them in combination with chemical crosslinkers; this ensures that degradation of the surface layer will not result in the exposure of a tacky uncrosslinked surface.

Figure 4 shows from left to right a UV crosslinked coating, a chemically crosslinked coating, and a coating using both UV and chemical crosslinking. All three elastomeric coatings are based on the same acrylic styrene resin which has a T_g of –25°C the coatings were all formulated at 30% PVC. The panels were exposed vertical south for 2.5 years. The combined crosslinking system does result in a significant reduction in dirt pickup.

Influence of Surface Morphology

As previously mentioned, surface resistivity is listed by Holbrow as a property influencing dirt pickup. A surface with high electrical resistance is capable of holding electrostatic charges and electrostatically charged surfaces (e.g., TV screen) have a tendency to attract air born dust and dirt particles. However, Holbrow concludes that this mechanism can only operate in very dry atmospheres since humid air will provide sufficient conductivity to prevent significant charge build-up. We have not found any evidence that surface resistivity is a significant factor influencing the dirt retention of coatings.

It would be anticipated that the surface roughness of coatings would influence dirt pickup, with rougher sur-

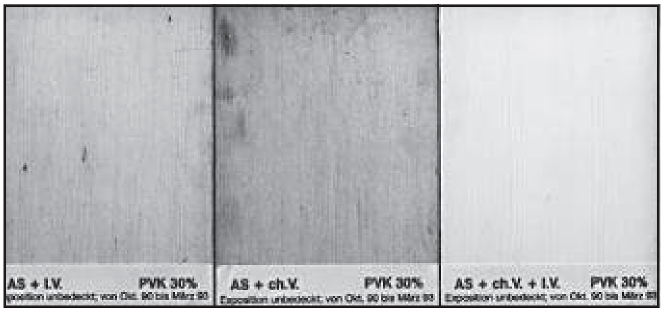

Figure 4—From left to right: UV crosslink coating; a chemically crosslinked coating; and a coating using both UV and chemical crosslinking.

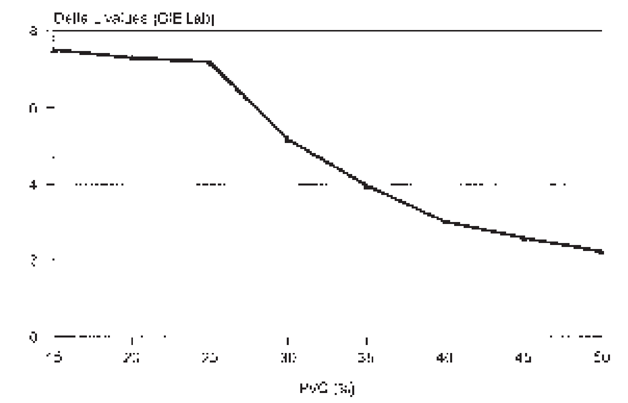

Figure 5—Straight acrylic PVC study.

faces collecting more dirt. It has been shown experimentally, however,[2] that when all other factors (PVC, resin, pigments, etc.) remain constant and only the roughness is varied by changing the particle size of large aggregates in the coating, the surface roughness does not influence the dirt pickup. This was demonstrated in both latex and alkyd paints. While the surface roughness may not influence dirt pickup in latex paints, PVC certainly does have an influence. *Figure* 5 shows ΔE values for a PVC ladder in an exterior acrylic house paint after 12 months of exposure at 45°S in Miami, FL. There is a clear trend towards lower dirt pickup as PVC increases. This is consistent with the observation that dirt pickup is caused by the tackiness of the thermoplastic polymer; as the PVC increases the amount of polymer at the coating surface decreases. This observation should not be confused with the well known phenomenon that porous surfaces are more difficult to clean than non-porous surfaces. First of all, the coatings in the PVC ladder did not exceed the CPVC and should not therefore demonstrate porosity. Secondly, no attempt was made to clean the coatings—measurement of ΔL values after cleaning may reveal a different trend.

Reduction of porosity has been employed as a means to reduce dirt pickup. A proprietary treatment[4] for painted surfaces to effect a reduction in dirt pickup consists of a low viscosity slurry of microfine silica. The paint is washed with the slurry, the theory being that the silica particles fill in the open pores in the paint thereby reducing dirt pickup. Holbrow[2] found this treatment to be very effective in sand filled latex paints, which are typically very porous as they are formulated well above CPVC.

Mechanism of Dirt Pickup

It has been shown[5] that the major mechanism for dirt pickup in exterior paints is carriage of the airborne dirt to the painted surface by rainwater. It has also been shown, by passing rainwater through filter paper and observing that it still soils the paint, that the dirt particles carried by rainwater are of colloidal dimensions. Such small particles can be carried by water into the pores in the paint surface. Pierce and Holsworth[6] have shown that latex paints contain air voids (pores) at all PVC levels, it has also been documented[7] that even unpigmented latex coatings contain pores. It is well known that films made from thermoplastic latex resins are softened by water saturation, so water plays a double role in causing dirt pickup. It carries the dirt to the surface and into the omnipresent pores, as well as softens the polymer making it hold on to the dirt more easily.

Influence of Hydrophobicity

The realization that water plays a significant role in the soiling of latex paints suggests that hydrophobic surfaces should stay cleaner than hydrophilic surfaces. The Paint Research Association[8] has shown that post treatment of a coating with a five percent solution of a silicone water repellent does result in a significant reduction in dirt pickup. However, incorporation of one percent of the same silicone water repellent into the paint formulation had no noticeable effect. The Norwegian Paint and Varnish Association[5] has reported con-

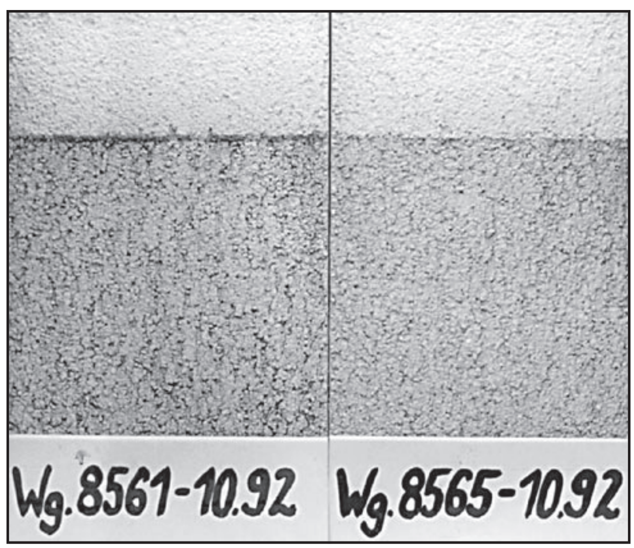

Figure 6—Two textured coating panels after 2.5 years exposure at 45°S. Panel on the left is a traditional styrene/acrylic coating; panel on the right has 33% of the styrene/acrylic copolymer replaced with a silicone emulsion. (Formulations 1 & 2 in appendix.)

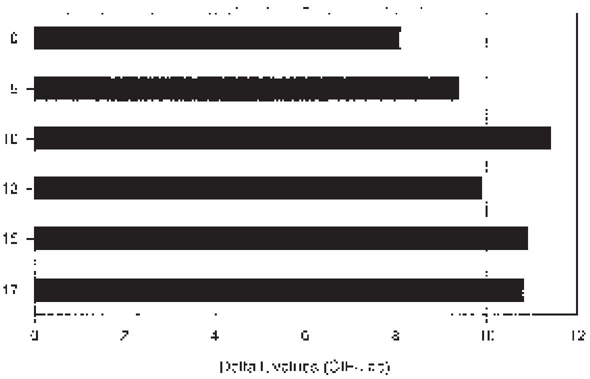

Figure 7—Dirt pickup after 2.5 years. Different amounts of silicone emulsion.

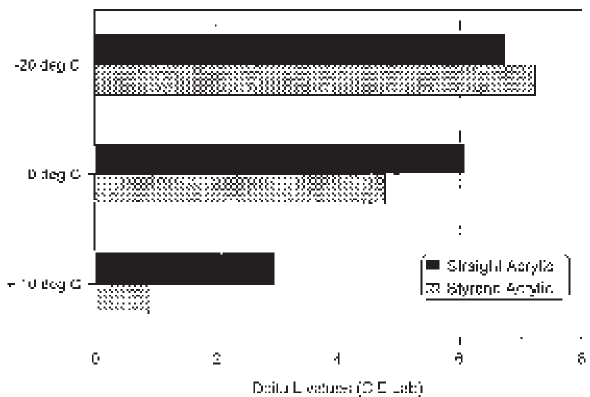

Figure 8—Dirt pickup after three years. Different polymers—different T_g ranges.

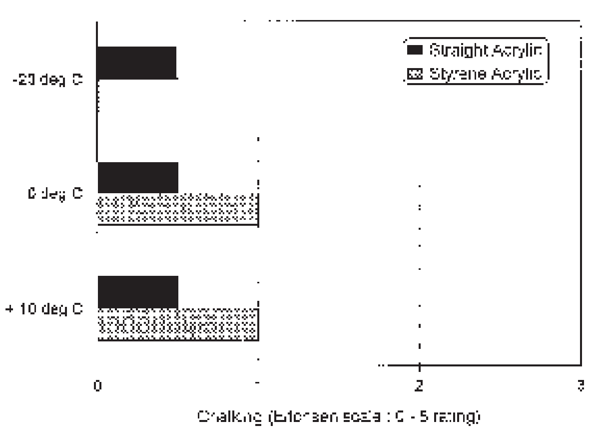

Figure 9—Chalking after three years. Different polymers—different T_g ranges.

tradictory results, observing that hydrophilic paints stayed cleaner than hydrophobic paints. These observations were made on oil-based white house paints and are inconsistent with our observations on latex paints. *Figure* 6 shows two textured coating panels after 2.5 years exposure at 45°S, one panel is a traditional styrene/acrylic coating, the other has 33% of the stryrene/acrylic copolymer replaced with a silicone emulsion (Formulations 1 & 2 in the Appendix). The silicone modified coating shows significantly reduced dirt pickup, which is attributed to the hydrophobic character of the silicone resulting in reduced wet time and reduced water penetration into the porous coating. The fact that the water beads up on the coating surface and cannot wet out and enter the pores prevents the water from carrying the suspended colloidal dirt into the porous matrix of the coating.

We have also evaluated silicone modified paints. *Figure* 7 shows ΔL values for a series of styrene acrylic latex paints in which silicone emulsion addition was varied from 0% to 17% (Formulation 3 in Appendix). No benefit is seen for modifying the coating with silicone emulsion. These results are not consistent with those seen in the textured coating (*Figure* 6). This is probably because the paint is much less porous than the textured coating, so it does not derive the added benefit of preventing dirt penetration below the surface. We have, however, noted in the same series of silicone modified paints that algae growth decreased with increasing amounts of silicone. This can be attributed to reduced wet time caused by the hydrophobic silicone. A similar correlation should also exist for mildew growth, but we have not noticed this phenomenon in our work to date.

Our studies show that hydrophobicity and associated rate of water run-off play a significant role in controlling coating cleanliness in textured coatings. The advantages of hydrophobic modification would probably be even more apparent if we had exposed the panels vertically instead of at 45°.

Influence of Monomer Type

Figure 8 shows ΔL values (CIE Lab) for a series of 35% PVC white latex paints after three years vertical exposure. The paints were made with latex resins having two different monomer combinations, a straight acrylic (MMA/BA), and a styrene acrylic (Sty/BA). For each monomer combination, the monomer ratios were adjusted to produce polymers with three different glass transition temperatures, +10°C, 0°C, and –20°C. The trend toward reduced dirt pickup with increasing T_g is clear and consistent for both monomer combinations. More interesting however is the fact that at 0°C and 10°C T_g, the dirt pickup is strongly influenced by the monomer composition, whereas at –20°C all the polymers perform poorly as the resin is too tacky and soft.

One possible reason for the difference in dirt pickup could be chalking. It is well known and reported[9,10] that moderate controlled chalking can have a beneficial self-cleaning effect in latex paints. However, this was not the case in this exposure series none of the polymers showed any significant chalking (*Figure* 9). Chalking is rated using the Erichsen scale of 0 to 5 where 0 is no chalking. The differences in dirt pickup must be associated with other properties which are influenced by the monomer composition.

In order to further investigate the influence of monomer composition on film properties, a series of model dispersions was produced[11] which varied from one another only in the nature and amount of the main monomers. In other words, the emulsifying agents, the secondary monomers, the auxiliaries, and the method of production were identical in all cases. Monomer ratios were adjusted to yield roughly the same T_g for each composition. *Figure* 10 shows the water absorption and water vapor permeability values (ISO DIS 7783 paints and varnishes—determination of water vapor permeability) for these acrylic and styrene acrylic copolymers. Water absorption (DIN 53495 determination of water uptake, Procedure 3) is shown as % weight. Water vapor permeability is expressed as the standard equivalent thickness in meters of stationary air cushion that would yield the same results as a polymer film of 1 g/m^2 coat weight. The results show that the resistance to diffusion of water vapor rises with an increase in the length of the carbon chain in the alcohol of the acrylic ester employed a corresponding decrease in water absorption is also observed. The values for the water absorbed and the water permeability of the straight acrylic copolymers lie systematically above those for the styrene acrylic copolymers.

These results help to explain the differences in dirt pickup observed with the different monomer combinations in *Figure* 8. The results are fully consistent with the theory that hydrophobicity reduces dirt pickup. Styrene acrylic copolymers being more hydrophobic than straight acrylic copolymers yield films having lower water take-up, higher resistance to water vapor permeability, and ultimately lower dirt pickup. Concerns over increased chalking and yellowing with styrene acrylics versus straight acrylics are in our experience unjustified at PVC levels of 30% and higher; at low PVC levels straight acrylics do offer advantages. The excellent exterior durability of styrene has also been reported by Stevens[12] who notes that styrene acrylics show no chalking or yellowing disadvantage in exterior house paints when compared with straight acrylic copolymers.

CONCLUSION

Our work indicates that the dominance of styrene acrylics in textured coatings and exterior house paints in Europe, and the emergence of silicone modified textured coatings may be technically justified by the potential of these systems to stay cleaner for longer. Our work also indicates that styrene acrylic copolymers may be better suited to address the requirements for zero VOC and elastomeric coatings than straight acrylics, given that both these applications require low T_g polymers which also exhibit a low tendency to pick up dirt.

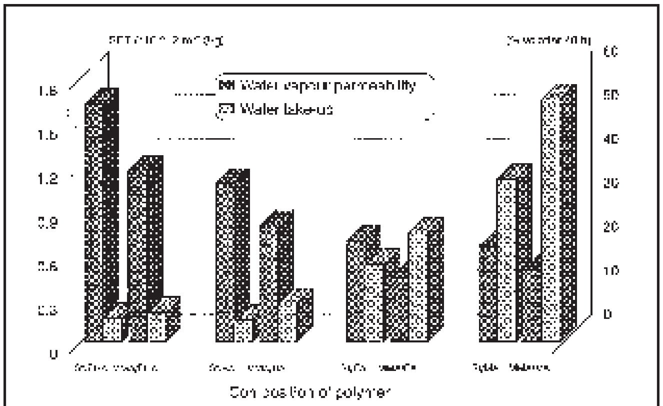

Figure 10—Water take-up and vapor permeability. Styrene/acrylics vs. straight acrylics same T_g.

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Appendix

Formulation 1

Styrene Acrylic Textured Coating	Parts by Weight
Latex resin (Sty. Acr.) 50%	121
Acrylic thickener 8%	5
Bentonite thickener 4%	28
TKPP, 50%	5
Defoamer	4
Biocide	2
Mineral spirits 180-210°C	9
Coalescent	9
Silicone emulsion 44%	0
Water	60
Titanium dioxide	32
Cellulosic thickener	7
Calcium carbonate	297
Mica	49
Calcium carbonate 1 mm	93
Calcium carbonate 1.5 mm	279
Total	1000

Formulation 2

Silicone Modified Textured Coatings	Parts by Weight
Latex resin (Sty. Acr.) 50%	80
Acrylic thickener 8%	5
Bentonite thickener 4%	28
TKPP, 50%	5
Defoamer	4
Biocide	2
Mineral spirits 180-210°C	9
Coalescent	9
Silicone emulsion 44%	80
Water	21
Titanium dioxide	32
Cellulosic thickener	7
Calcium carbonate	297
Mica	49
Calcium carbonate 1 mm	93
Calcium carbonate 1.5 mm	279
Total	1000

ALAN SMITH graduated with a Degree in Chemistry from the University of Liverpool, England, in 1976. Upon graduation, he joined the International Paint Co., as a Chemist in their marine coatings division. In 1981, Mr. Smith joined NL Chemicals as a Research Scientist working in coatings applications. Since 1991, he has been employed as Technical Manager/Coatings Raw Materials, for the polymer dispersion business of BASF Corp.

OLIVER WAGNER studies Chemistry in Darmstadt and has worked in BASF Dispersions Technical Group since 1987. From 1993 until 1995, Mr. Wagner worked for BASF Corp. in Charlotte, NC, as Technical Marketing Manager. Since October 1996, he holds the position of Regional Manager for Coatings Raw Materials for BASF South East Asia in Singapore.

Formulation 3

Silicone Modified Latex Paint	
Water	220.0
Sodiumpolyphosphate	0.5
Dispersant	2.5
Bentonite thickener	1.5
Biocide	1.5
Defoamer	2.0
Titanium dioxide	110.0
China clay	15.0
Mica	30.0
Calcium carbonate	355.0
Latex resin (sty. acr.) 50%	96.0
Silicone emulsion 50%	Variable[a]
Diurethane thickener	8.0
Total	842 + Silicone

(a) Silicone emulsion added = 5%, 10%, 13%, 15%, 17% by weight.