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Evaluation of 3M™ Glass Bubbles in waterborne paints for reducing heat buildup on PVC based materials

Introduction

3M™ Glass Bubbles are currently used in many industrial and consumer products ranging from insulative pipe coatings and roof coatings to automotive light weighting of plastics and sealants. The chemistry and physical properties of 3M glass bubbles are such that they have shown benefits in reflecting incident solar radiation primarily in the near-infrared region, thus providing cooler surfaces. These cooler surfaces are attracting more interest as the market shifts to increasing volumes of durable, more user-friendly materials. One such material is PVC (polyvinyl chloride), which continues to be widely used in select regions for the decorative/building products markets. ASTM test method D4803[1] encompasses prediction of the heat build-up in rigid and flexible building products above ambient air temperature, which occurs due to absorption of the sun's energy. The method can be used on multiple colors of PVC, and testing is baselined against black PVC. This paper compares the heat buildup of painted versus unpainted black PVC, and the effects of the addition of 3M glass bubbles for heat reflective properties in a waterborne acrylic white low VOC latex paint. Further comments are made regarding their use in other colors.

Experimental Methods and Materials:

The baseline control paint formulation without 3M™ Glass Bubbles is listed in table 1.

Material	Amount (lbs.)	WPG	Amount	Vol %	Weight %
Water	206.50	8.34	24.76	24.76	17.71
Potassium tripolyphosphate	1.22	21.15	0.06	0.06	0.10
HMHEC cellulosic thickener	4.00	6.26	0.64	0.64	0.34
Vantex®- T amine additive	3.00	8.10	0.37	0.37	0.26
Defoamer	2.03	8.05	0.25	0.25	0.17
Copolymer dispersant	6.10	10.00	0.61	0.61	0.52
Nonionic surfactant (wetting agent)	2.03	8.97	0.23	0.23	0.17
Ti-Pure® R-706 TiO2	203.50	33.40	6.09	6.09	17.45
3M™ Ceramic Microspheres W-410	50.87	20.00	2.54	2.54	4.36
Nepheline syenite	101.75	21.70	4.69	4.69	8.73
Calcium carbonate	101.75	22.70	4.48	4.48	8.73
100% Acrylic resin	377.70	8.85	42.68	42.67	32.40
Water	101.75	8.34	12.20	12.20	8.73
Mix well, then add slowly under agitation					
3M™ Glass Bubbles iM16K	0.00	3.84	0.00	0.00	0.00
HASE thickener	3.68	8.83	0.42	0.42	0.32
TOTALS	**1165.9**		**100.0**	**100.0**	**100.0**

Table 1[2]

The standard control formulation listed in table 1 contained 6.1 volume % of TiO2, 2.5% 3M™ Ceramic Microspheres W-410, 4.7% nepheline syenite and 4.5% calcium carbonate. The paint had a pigment volume concentration of 47, and the volume solids were 39.5%. The starting point viscosity for this paint was adjusted to approximately 95KU's. The VOC for this basic formulation is <5 g/l, and the pH is 8-9. Subsequent formulations containing the 3M glass bubbles were made with iM16K, S28HS or iM30K grades. All bubbles were added near the end of the formulation to prevent breakage from the high shear cowles paste grind step. The formulation in table 1 includes iM16K as a placeholder. It has a true density of 3.84 lbs./gallon. Other 3M glass bubbles were substituted based on equivalent volume loadings, and the PVC's were varied to test heat buildup resistance properties per ASTM D-4803. These three grades of 3M glass bubbles were selected for this study based on many factors including isostatic crush strength and size. A minimum of a 3000-psi bubble is suggested for airless spray applications. Exterior PVC building materials could involve this type of application. The general properties of the 3M glass bubbles evaluated are shown in Table 2[2].

General properties of 3M™ Glass Bubbles

Product	Target Crush Strength, psi (90% survival)	True Density	Particle Size (50%) Microns by volume
iM16K	16,000	3.84	20
iM30K	27,000	5.0	18
S28HS	3,000	2.34	30

Table 2

All paints were matte in appearance (60°gloss <5)[3] due to the PVC and filler type/loading. ASTM method D4803-18 was followed for testing performance properties. Paints were applied with a brush in two coats on .060" black PVC(3×3"). The total dry film thickness ranged from 2-5 mils. The plaques were dried under ambient conditions for a minimum of seven days before testing. The general procedure calls for heating the plaque in a specially constructed box under an infrared 250W heat lamp for a given time. The temperature rise above ambient(lab) temperature relative to an unpainted black control sample is determined. This data can then be used to predict heat build-up, which could occur outdoors due to sun exposure. Calculations for temperature rise above ambient and heat buildup are referenced in section 11 of the ASTM method[1].

Results & Discussion:

Table 3 includes the results after a thirty-minute dwell under the heat lamp. Virgin PVC reached an equilibrium temperature at thirty minutes, but the painted samples were tested for one hour to reach a maximum specimen temperature. The ambient laboratory temperature was 70°F for this study. The formulations used for heat buildup calculations are included in the references[1].

					Predicted Heat Build Up °F			
Paint #	PVC[9] (pigment volume conc.)	3M Glass Bubble[2]	Wt.% GB)	Vol % GB	Vertical	Horizontal	Temp after 30min °F	Max Specimen Temp-Tm °F
0-virgin PVC	0	-	-	-	-	-	149	-
1	46.9	none	0	0	38.6	47.0	104	111.5
2	62.2	IM16K	5	13.8	36.3	44.2	103	109
3	71.4	IM16K	10	25.3	30.7	37.4	95.5	103
4	71.4	S28HS	6.4	25.3	34.0	41.3	102	106.5
5	71.4	IM30K	12.7	25.3	29.8	36.2	95	102
6	46.9	IM16K	4.7	11.7	34.4	41.9	104	107

Table 3

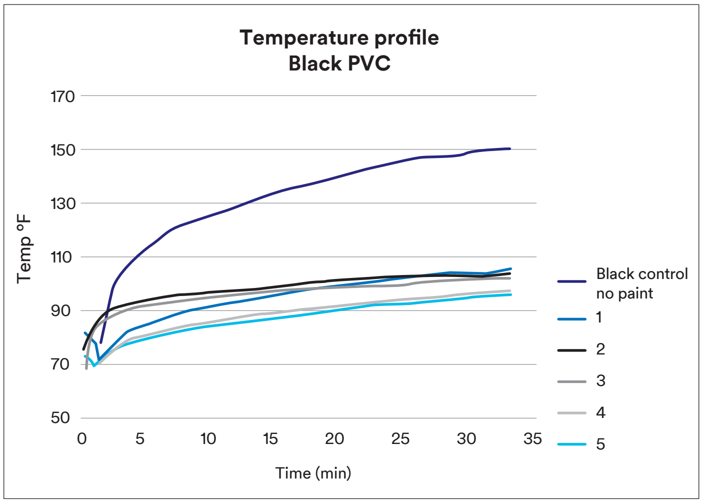
The initial study involved comparing baseline paint #1 with the unpainted virgin PVC. The maximum temperature dropped from 149 to 111.5°F by painting the surface. Paint #2 incorporated 13.8V% of 3M glass bubbles iM16K, and the temperature did not drop significantly. The heat buildup dropped approximately 2-3°F. Systems with the lowest heat build-up and temperature rise in theory should offer the lowest distortion potential.

The volume loading of 3M glass bubbles was increased to 25.3%, and samples 3-5 were made using three different grades of 3M glass bubbles. The corresponding PVC was 71.4 for these samples. These samples had a lower heat buildup and equilibrium temperature than paint #2, with iM30K exhibiting the lowest heat buildup. iM30K and iM16K performed similarly at the 25.3% volume loading. The higher loading of 3M glass bubbles reduced the heat buildup another 3-8 degrees.

One additional sample (paint #6) was made using only iM16K 3M glass bubbles as the filler. The nepheline syenite, ceramic microspheres and calcium carbonate were removed and replaced with an equal volume of 3M glass bubbles, and the PVC was held at 46.9. The maximum specimen temperature and HBU's did decrease by 4-5 units with the glass bubble containing paint. The temperature after thirty minutes and a maximum specimen temperature were recorded since the virgin PVC reached equilibrium and started to warp after 30 minutes while the painted samples reached equilibrium after approximately one hour.

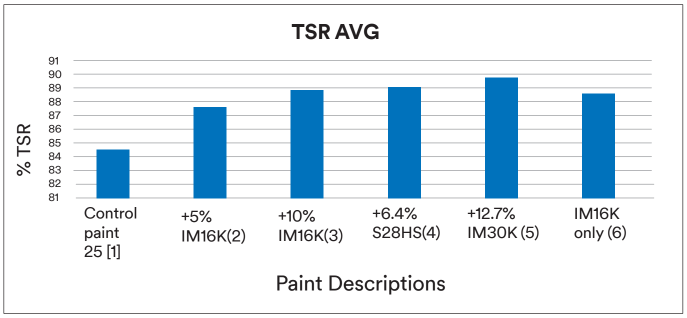
Graph 1 shows plots of each sample over a 30-minute period. Paints 3&5, (highest concentration and smallest bubbles), exhibit the lowest temperature rise over the test period.

Crosshatch adhesion testing was conducted on the samples, and the results showed 100% adhesion(5B) rating with both single and multiple coats[5].



Graph 1

Additional testing for total solar reflectance (TSR)[4] was conducted on flat painted black PVC plaques, and the results are shown in graph 2.



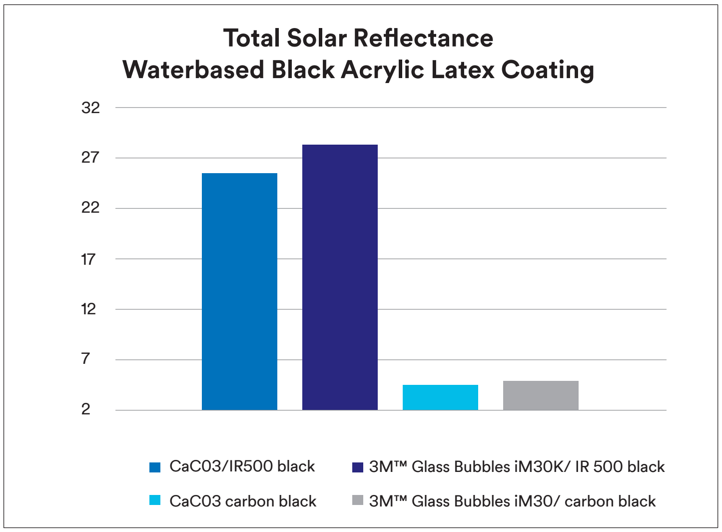
Graph 2

In general, the addition of 3M glass bubbles to this white paint formulation increased the TSR values on an average of 3-5.2%.

Additional Experiment-Evaluation of Additional Colors:

A series of final experiments examined the effects of using 3M glass bubbles iM30K in combination with infrared reflecting iron oxide black and yellow pigments in relation to solar reflectance and heat buildup on aluminum. For this study, a different waterbased acrylic elastomeric latex low gloss paint was formulated at a PVC of 43%. The iM30K 3M glass bubbles were added directly to the grind phase with the other fillers and pigments. Coatings were applied at twenty dry mils to aluminum and tested for total solar reflectance and heat profiles on aluminum. A 250-watt infrared lamp was used, and the temperature was measured on the back side of the aluminum for a one-hour period. The ASTM method was not used for this heat profile test.

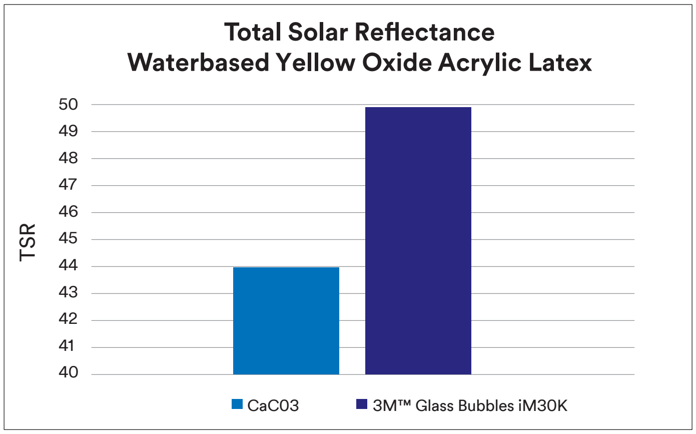
For the black color, a comparison was made between a standard PB#7 and an infrared reflecting black IR5006. A standard formulation using calcium carbonate filler was compared to a formulation containing an equal volume loading (18.7%) of iM30K 3M glass bubbles. The TSR results are shown in graph 3.



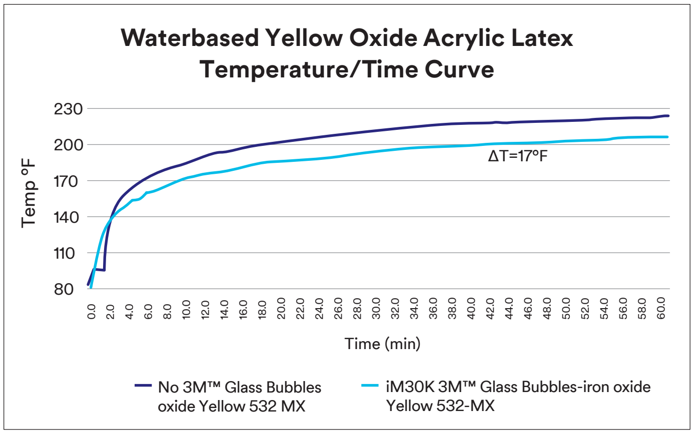
Graph 3

In general, the paints containing the infrared reflecting black pigment and the 3M glass bubbles have higher TSR values. The heat profiles on aluminum are shown in graph 4. The heat profiles indicate much lower temperatures with the paints containing the IR500 iron oxide pigment and 3M glass bubbles as shown with the green line.

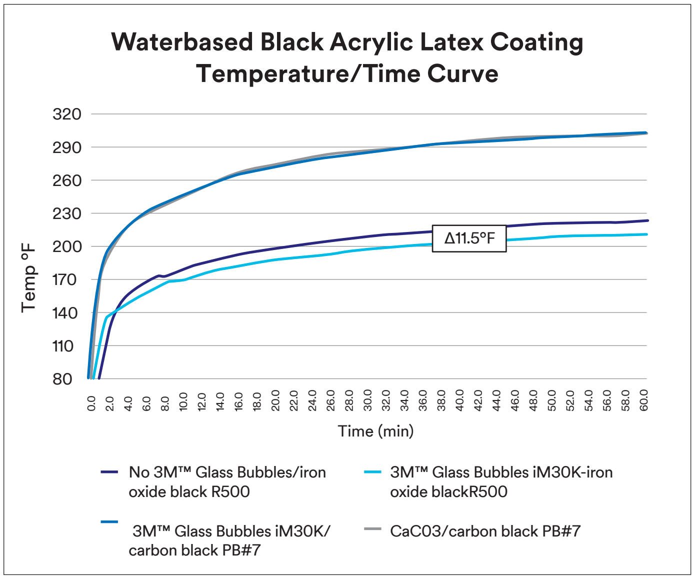
A second paint series was formulated in a tan color using an infrared reflecting yellow oxide dispersion[7]. For this study, comparisons were made between the calcium carbonate and 3M glass bubbles only. The PVC's and volume loadings were comparable to the black paints. The results shown in graph 5 indicate increases in TSR of 5% when using iM30K 3M glass bubbles. Graph 6 indicates temperatures up to 17°F lower are achievable when using 3M glass bubbles.



Graph 5



Graph 6



Graph 4

Summary:

In this study, the inclusion of 3M glass bubbles in flat white latex paints has exhibited benefits for reducing the heat build-up and increasing the total solar reflectance on PVC. These parameters could be important for increasing the longevity of the substrate in decorative paint applications. Further studies could be conducted to optimize the formulation package for bubble type and concentration, and to examine effects on other paint properties. Additional studies have shown that 3M glass bubbles could provide similar benefits in other colors as well, especially when optimizing the formulations for pigment and filler packages. Future studies could include the evaluation of heat build-up units with respect to deformation of the PVC siding due to window reflection.

References:

Note[1]: ASTM method D4803-18, ASTM International

Temperature rise above ambient temperature:
$\Delta Tlu = Tm - Ta$
where:
ΔTlu = temperature rise above ambient temperature in the laboratory under the heat lamp,
Tm = maximum temperature of the specimen, as read from the digital temperature meter, and
Ta = ambient air temperature in the laboratory.

Heat buildup:
$\Delta T = \Delta Tlu / \Delta Tlb * \Delta Tb$
where:
ΔT = predicted heat buildup of the specimen under study due to heating by the sun,
ΔTlu = temperature rise above ambient temperature in the laboratory for the specimen under study,
ΔTlb = temperature rise above ambient temperature in the laboratory for a black control sample,
ΔTb = heat buildup for a black control sample under controlled conditions due to absorption of the sun's energy (found experimentally),
ΔTb = for vertical position, 74°F or 41°C, and
ΔTb = for horizontal position, 90°F or 50°C.

Note[2]: Vantex is a trademark of Eastman Chemical, Ti-Pure is a trademark of Chemours, 3M Ceramic Microspheres W-410, 3M glass bubbles S28HS, iM16K and iM30K are trademarks of 3M

Note[3]: Gloss measured with a BYK Micro-TRI-gloss instrument

Note[4]: ASTM C1549-Solar Spectrum Reflectometer

Note[5]: ASTM D-3359 method B crosshatch 2mm spacing

Note[6]: Colanyl Oxide Black IR 500 is a registered product of Clariant-PG17

Note[7]: Colanyl Oxide yellow R-532-MX is a registered product of Clariant- PY42

Note[8]: Calculation for PVC (Pigment Volume Concentration):

PVC = volume of pigment / volume total solids = Vp / (Vp + Vb)

Vp - volume of pigment

Vb - volume of binder

Acknowledgements and Special Note:

The author would like to thank Zachary Vonberg for experimental testing and data collection.

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Issued: 7/18 14046HB
98-0212-4284-1