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Technical Paper

The use of 3M™ Glass Bubbles to increase time until condensation forms on painted surfaces

Introduction

The use of paints which can minimize or control condensation is quickly gaining popularity among homeowners who are looking to reduce moisture buildup in specific areas of their homes such as bathrooms, kitchens, basements, garages, sheds, and entry areas. Many different manufacturers are starting to develop these paints using newer technologies involving more durable binders.

Another key raw material which could be utilized to delay the onset of condensation is 3M™ Glass Bubbles.

Condensation and Related Issues

There is always some moisture in the air, even if it is not readily visible. If air gets cold, it cannot hold all the moisture produced by everyday activities and some of this moisture appears as tiny droplets of water. This is readily noticeable on windows on a cold morning. This phenomenon is condensation. It can also be seen on mirrors when you have a bath or shower, and on cold surfaces such as tiles or cold walls.

Condensation occurs in cold weather, even when the atmosphere is dry. In homes, condensation may be visible on or near windows, in corners, and near wardrobes and cupboards. Condensation forms on cold surfaces and places where there is little movement of air. Excessive condensation can produce long-term dampness which can lead to mold growth on walls and ceilings, and mildew which can result in rotting wooden window frames.

Condensation Formation

Condensation forms more easily on cold surfaces in the home, for example walls and ceilings. In some cases, those surfaces can be made warmer by improving the thermal insulation. In many cases, thermal insulation is not possible due to the house configuration or the cost of refurbishment.

An efficient way of combating condensation is to cover walls and ceilings with a specially formulated paint to reduce condensation.

Anti-Condensation Paint

There are various kinds of anti-condensation paints. Some of them are formulated above CPVC (Critical Pigment Volume Concentration), making the dry paint film highly porous. These paints act as a sponge, absorbing water from condensation. Typically, these paints have lower quality, resulting in lower scrub and stain resistance. Over time, these paints may promote mold and mildew growth resulting in fungi, black stains, and rapid degradation of the wall:

Higher quality anti-condensation paints are formulated below CPVC, making the dry paint film non-porous, and impervious to water with good scrub and stain resistance. The use of fungicides can also help enhance the durability of the paint.

In addition to those physical and chemical properties, another important property for a good anti-condensation paint is a low thermal conductivity to provide some degree of thermal insulation, in order to increase surface temperature of the wall. If the temperature of the wall is greater than the dew point of the surrounding ambient moist atmosphere, condensation will not appear. If the temperature of the wall is lower than the dew point of the surrounding atmosphere, the time for condensation to form will be longer when the wall is warmer (close to the dew point) rather than colder (far away from the dew point).

3M™ Glass Bubbles

3M™ Glass Bubbles are a high-strength, low-density, inorganic additives made from a water resistant and chemically-stable soda-lime-borosilicate glass. They are used in a variety of applications, including automotive, marine, oil and gas, and construction.

Because of their hollow shape, 3M™ Glass Bubbles have been used in various applications for many years to provide thermal insulation. Thermal conductivity (K Value) is proportional to the bubble density as shown in Table 1. The largest glass bubble, K1, has a thermal conductivity as low as 0.044 W/m-K at 20°C. For comparison purposes, the thermal conductivity of calcium carbonate, the most common filler/extender used in paint, has a thermal conductivity 88 times greater than the K1 grade. The K value is also affected by the temperature of the resulting matrix.

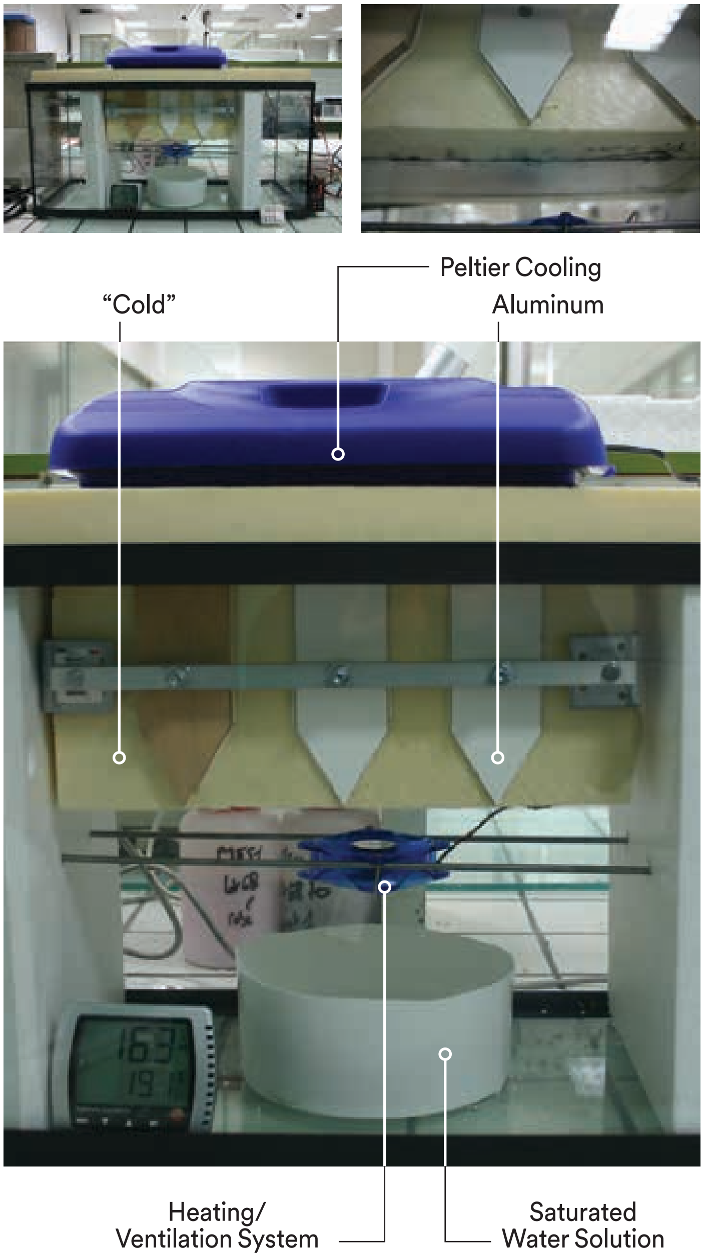
Table 1. Typical Physical Properties

Bubble type	Density (g/cc)	Pressure strength (bar)	Bubble void volume %	Calculated K value bubble (W/m-K)
K1	0.125	17	95.1%	0.044
K15	0.15	21	94.1%	0.051
K20	0.20	34	92.1%	0.065
S22	0.22	28	91.3%	0.071
XLD3000	0.23	210*	90.9%	0.074
K25	0.25	52	90.2%	0.080
S28HS	0.28	210*	89.0%	0.088
S32LD	0.29	103	88.6%	0.091
S32	0.32	140	87.4%	0.100
S32HS	0.32	420*	87.4%	0.100
S35	0.35	210	86.2%	0.109
K37	0.37	210	85.4%	0.115
S38	0.38	280	85.0%	0.118
S38HS	0.38	385	85.0%	0.118
S38XHS	0.38	385*	85.0%	0.118
S42XHS	0.42	550*	83.5%	0.131
K46	0.46	420	81.9%	0.143
iM16K	0.46	1100*	81.9%	0.143
S60	0.60	690	76.4%	0.187
S60HS	0.60	1240*	76.4%	0.187
iM30K	0.60	1930*	76.4%	0.187

* Minimum 90% survival at specified pressure
** @ 20°C

In order to address the common problem of condensation on interior painted surfaces, a test method to determine the condensation time was developed. No standard method for measure condensation on surfaces is known, and this method allows differentiation between formulations of condensation resistant paints.

Development of Condensation Time Test Method

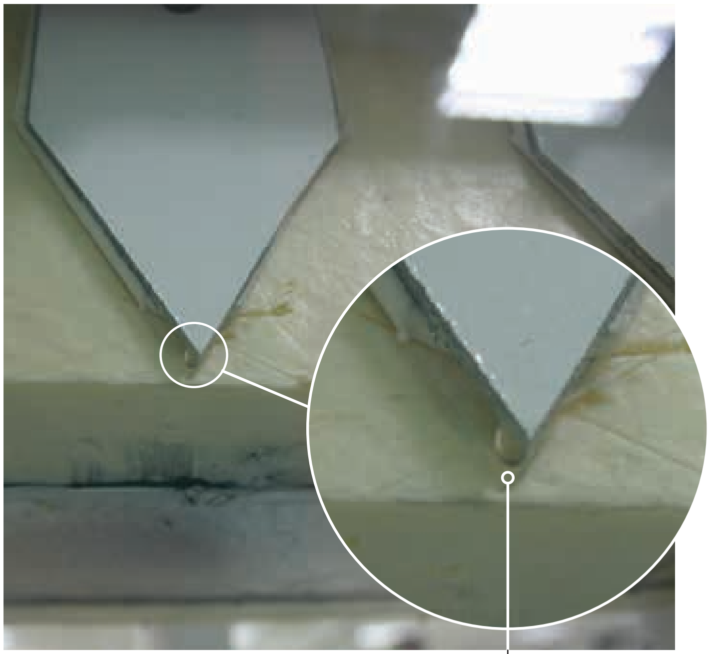


Description of the Test Method

One enclosure consists of a fish tank. Humidity and temperature is regulated inside the enclosure.

A second enclosure made of polystyrene foam board is set on top of the first enclosure. The temperature inside the second enclosure is regulated at low temperature.

Painted aluminum panels are mounted at the interface between the two enclosures, so the surface of the paint is exposed to high humidity and room temperature, while the back side of the painted panel is exposed to low temperature.



First Drop of Condensation

Due to the temperature gradient and high humidity in the first enclosure, condensation occurs on the painted surface as small droplets. These droplets increase in size and coalesce with each other.

They finally slip down the painted surface, and the time for the first drop of condensation to fall is recorded

Test Method Settings

Fish Tank:

Temperature = 22°C

Dew Point = 19 – 20°C

Cool box:

Temperature = 3°C

Measure of the first drop of condensation

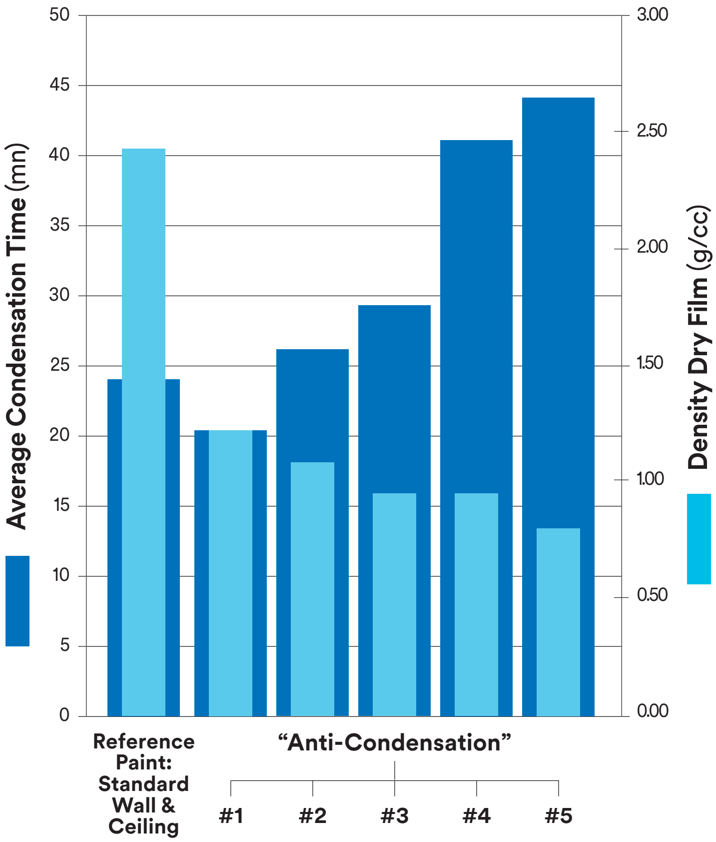
Various anti-condensation paints from the European market were selected along with a regular wall/ceiling paint for reference (Table 2).

Paint performance was measured in terms of resistance to condensation and other physical properties such as wet and dry density and solids content.

Table 2.

	Reference Paint: Standard Wall & Ceiling	"Anti-Condensation"				
		#1	#2	#3	#4	#5
Paint Density (g/cc)	**1.49**	1.11	1.04	.98	0.97	0.90
Density Dry Film (g/cc)	**2.42**	1.21	1.08	0.95	0.94	0.79
W% Solids	**56.0%**	58.0%	54.0%	37.0%	52.0%	43.0%
Volume % Solids	**34.4%**	53.4%	52.2%	38.3%	53.4%	48.7%
Average Condensation Time (min)	**24**	20	26	29	41	44

A plot of condensation time versus density of the dry film showed there is a direct correlation. Lower density dry films yield longer condensation times. One way to achieve lower density involves formulating higher PVC paints. Exceeding the CPVC, however, may produce porous films which will reduce film durability properties such as scrub resistance.



Lab Formulations with 3M™ Glass Bubbles

The second step of the technical study was to develop a good anti-condensation starting formulation for customers to model.

An extreme vertices mixture design involving three parameters (resin, calcium carbonate and 3M™ Glass Bubbles S22) was conducted. This involved a linear regression, a paint formula model, and an optimized formulation. The resulting optimization produced the following formulation:

Table 3.

Raw Material	Weight	Weight %	Volume	Volume %	Dry Volume	Dry Volume %
Water	52.44	26.91	52.44	26.22		0.00
Dispersant	0.80	0.41	0.69	0.35	0.21	0.21
TiO_2	41.00	21.04	10.00	5.00	10.00	10.00
$CaCO_3$	0.00	0.00	0.00	0.00	0.00	0.00
Styrene-Acrylic Dispersion	77.28	39.66	75.03	37.52	36.39	36.39
Preservative	.039	0.20	0.35	0.18	0.35	0.35
Glass Bubbles S22	11.00	5.64	50.00	25.00	50.00	50.00
Thickener 1	2.21	1.13	2.11	1.05	1.00	1.00
Thickener 2	9.45	4.85	9.09	4.55	2.00	2.00
Anti-Foam	0.29	0.15	0.29	0.15	0.05	0.05
Totals	194.87	100.00	200.00	100.00	100.00	100.00

This paint does not contain any ground filler such as calcium carbonate which is highly thermally conductive.

The paint is formulated below CPVC (Critical Pigment Volume Concentration) meaning that the paint is a closed film and not porous. The S22 bubble grade was chosen for its lower density and thermal conductivity, although other bubble grades could be evaluated depending on processing and application conditions. The weight loading did not exceed 6% in the optimized formulation. The density of the dried film was <1 g/cc. This paint produced an average condensation time of 45 minutes, which is comparable or better than many of the commercially available paints tested in this study (reference Table 2, paint #3 which has same dry density but much lower condensation time).

Weight % Solids	48.7%
Volume % Solids	50.0%
Wet Density	0.97
Dry Density	0.95
Condensation Time	**45 min**

Volume Pigment	60.00
Volume Binder	40.00
PVC	60.0%
CPVC	69.5%
CPVC/PVC	1.16

Conclusions

Large performance variability was noticed among the various commercially tested anti-condensation paints, with some so-called "anti-condensation paints" offering no extension of condensation time versus standard wall paints (Table 2, paint #1).

The use of 3M™ Glass Bubbles allows formulators to make low density-low thermally conductive paints below the critical pigment volume concentration, which in turn should produce durable paints with longer condensation times. Further studies showed that a film conductivity of 0.10 – 0.15 W/m-°K yielded a longer condensation time paint versus a standard paint which had a film thermal conductivity of 0.50 W/m-°K.

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