Final Report on

Standard Agreement No. 01-307

Correlation Between Solids Content and Hiding as it Relates to Calculation of VOC Content in Architectural Coatings

Prepared for California Air Resources Board
and the California Environmental Protection Agency

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Disclaimer-

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ABSTRACT

The contractor designed a set of experiments to evaluate the effect of volume and type of solids on coverage and hiding for water-based and solvent-based architectural coatings. The experimental design was implemented by formulating thirty water-based and solvent-based coating samples with varying amounts and types of pigments and resins. Thirty unique formulations were prepared, corresponding to coatings commonly used in California. Coating classes included flat, eggshell, semigloss and gloss. Once formulated in agreement with the experimental design, the coatings were applied to well-defined surfaces, and evaluated by a series of standard tests for coverage, film thickness, hiding, and color, as appropriate to the coating type. A new potential measure for coatings, Hiding VOC, was proposed. This amounts to the grams of VOC associated with the formation of 1.00 square meter of a "hiding" film, as defined by ASTM Method D2805-96a. A comparison was made between selected solvent-based and water-based coatings, to explore the relative hiding abilities of each.

The contractor summarized and interpreted the results of the testing program.

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I. Introduction

A. Statement of Problem

Architectural coatings have been identified as a significant source of non-methane organic emissions in California. In recent years, these coatings have been subject to increased regulatory scrutiny, and these coatings have undergone dramatic changes in composition, with water-based systems replacing solvent-based systems in many application areas. Coating manufacturers must indicate the VOC content of their coatings, and environmentally conscious consumers have come to rely on the numerical values listed on the cans of paint they purchase. Ideally, these numerical values should allow for the easy comparison of the VOC content of disparate coatings. In practice, this is not so straightforward. The existence of "exempt" compounds and variable amounts of water in coatings may result in a significant difference between "actual VOC" and "regulatory VOC".

The U.S. EPA currently directs that the VOC of coating products be computed on a "less water and exempt compounds basis". This is more practical than a preferable alternative, such as the mass of VOC emitted per volume of coating solids applied. The difference between actual and regulatory VOC numbers becomes significant in the case of coatings with a high percentage of water. For such coatings, the regulatory VOC will be higher, sometimes dramatically higher, than the actual VOC. The regulatory definition implies that the volume of solids is directly related to coverage. If this is not the case with a selected class of coatings, the regulatory definition of VOC may impose an effective "penalty" on that coating. For example, it is theoretically possible for a low solids water-based formulation with a high regulatory VOC to provide the same coverage as a solvent based, higher solids content system with higher VOC actual. In such a case, the same coverage would result in different amounts of actual VOC emitted, favoring the water-based system, whereas the VOC regulatory definition would favor the solvent-based coating.

A term closely associated with coverage is "hiding". From the consumer's perspective, it is really the more important factor. If a particular coating "covers" but does not "hide" sufficiently, the consumer will repeat the application with additional paint. In such a case, the true VOC content of the paint becomes effectively multiplied by the number of gallons used to attain satisfactory hiding of the substrate. The hiding power for a series of coatings, even with constant percent by volume of solids, depends on the relative amounts of pigment and resin, as well as the nature and quality of the pigment. Ultimately, a method that could evaluate the amount of VOC required to adequately cover and hide a given surface would enable the REAL impact of a coating to be determined. Such a determination would amount to a performance-based characterization of the coating. This would be independent of carrier type (solvent- or water-borne), pigment amount and quality, resin, and other common coating parameters, and would facilitate comparison of coatings with different compositions.

B. Background

Currently, the VOC content of architectural coatings is regulated on a coating concentration basis (grams VOC/Liter of coating, for example), rather than a material concentration basis (grams of VOC/Liter of material, for example). Regulatory agencies define “coating VOC” (or regulatory VOC) as mass of VOC per unit volume of solids plus VOC (equivalent to the volume of paint minus water minus exempts), and defines “material VOC” (or actual VOC) as mass of VOC per unit volume of paint (including water and exempts). The existence of exempt compounds and variable amounts of water in coatings may result in a significant difference between “actual VOC” and “regulatory VOC”. The equations used for calculating these values are shown in Table 1.

When initial control strategies for VOC emissions from coatings were evaluated (in the 1970s), EPA would have preferred a set of regulations based on the mass of VOC per unit volume of paint solids. This is clearly the quantity of direct environmental significance. However, the lack of recognized acceptable methods for measuring the volume of the dried paint film (volume solids) precluded such a standard. The U.S. EPA currently directs that the VOC of coating products be computed on a “less water and exempt compounds basis” (regulatory VOC). The use of the expression “less water” was deemed critical to permit the comparison of the emissions from solvent-borne and waterborne

Table 1 - Equations for Computing VOC in Coatings

Actual (material) VOC includes all components.
Regulatory (coating) VOC excludes exempt solvents and water

Solvent borne coatings

$$actual\ VOC = \frac{g\ VOC}{L_{solids} + L_{VOC}}$$

$$L_{coating} = L_{solids} + L_{VOC}$$

$$regulatory\ VOC = \frac{g\ VOC}{L_{solids} + L_{VOC}} \quad or$$

$$regulatory\ VOC = \frac{g\ VOC}{L_{coating}}$$

Water borne coatings

$$actual\ VOC = \frac{g\ VOC}{L_{solids} + L_{VOC} + L_{water}}$$

$$L_{coating} = L_{solids} + L_{VOC} + L_{water}$$

$$L_{coating} - L_{water} = L_{solids} + L_{VOC}$$

$$regulatory\ VOC = \frac{g\ VOC}{L_{solids} + L_{VOC}} \quad or$$

$$regulatory\ VOC = \frac{g\ VOC}{L_{coating} - L_{water}}$$

coatings. The difference between actual (material) and regulatory (coating) VOC numbers becomes significant in the case of coatings with a high percentage of water, as exemplified by many contemporary architectural coatings. For these coatings, the regulatory (coating) VOC is higher, sometimes dramatically higher, than the actual (material) VOC. For example, contemporary latex paints have regulatory VOC values that are 2 to 5 times higher than their actual VOC.

Examination of the equations in Table 1 shows why this is so. The denominator of the regulatory VOC calculation of solvent borne coatings contains a term for the volume of coating. The corresponding expression for water-borne coatings is volume of coating minus volume of water. As the volume of water in a coating increases, its calculated regulatory VOC will increase. The regulatory definition is used because it is commonly assumed that coverage is proportional to the solids content, and the use of VOC regulatory helps ensure that the solids content of paints is not reduced when reductions in VOC actual are made by dilution with water. The regulatory VOC of a coating will not be affected by dilution, although the solids content (and hiding power) of the coating will be affected. While the regulatory VOC of a paint does not change as water or exempt solvent is added, the material VOC is obviously reduced by such changes. The addition of water or exempt solvent does not change the VOC-to volume paint solids ratio.

As discussed above, the amount of VOC emissions released from a coating product is determined by the VOC-to-volume solids ratio. This point is further illustrated by the data in Table 2. This table shows data for a series of hypothetical paints, both solventborne and waterborne, having the same pigment volume concentration (PVC), as well as identical hiding and extender pigment compositions. For the purpose of this exercise, it may be assumed that the density of the VOC component is 1000 grams/Liter.

For the solventborne paints 1-6 shown in Table 2, as the volume of solids is decreased incrementally from 0.75L to 0.125L, an incremental increase in the regulatory VOC content occurs. The mass of VOC emissions for a given dried film volume (volume solids), however, increases exponentially.

Paints 8-10 are hypothetical waterborne paints in which the volume solids is decreased incrementally simply by adding water. Since the ratio of VOC to volume solids remains constant in this series of paints, the regulatory VOC and total emissions per unit volume of paint solids both remain constant, in contrast to the effects seen with solventborne coatings. Paint 7 is intended to represent a paint identical in solids volume and VOC volume to Paint 3. It is duplicated in the table to show that the regulatory VOC for a solventborne paint and the corresponding waterborne paints having the same VOC to paint volume solids ratio, may be expressed on the same regulatory VOC basis.

C. Project Objectives

This report summarizes work performed on a project designed to investigate the relationship between total volume solids content, coverage, hiding, and VOC content as it pertains to common classes of architectural coatings. The project was intended to explore these relationships on the "effective" VOC content of architectural coatings.

While water-based coatings were originally the main focus of this study, discussions with ARB revealed that the hiding properties of both solvent- and water-based coatings could be addressed in this project. Unfortunately, it is not possible to prepare identical formulations of the same resin system in both solvent- and water-based systems. The hiding powers of selected water-based and solvent-based coatings were evaluated. Reflectance measurements on the dried films allowed for a direct comparison of hiding power, irrespective of the carrier from which the pigment was deposited. This approach should answer the question "Does a smaller volume of a solvent-based coating hide better than a water-based coating?"

These project objectives were met by implementing two main sub-tasks: formulating a set of coatings, and testing them for hiding power. We believed that we would have better control over experimental variables by formulating the coatings ourselves, rather than purchasing off-the-shelf coatings. Coatings proposed for investigation included a distribution of flat, eggshell, semigloss and gloss formulations. In response to the continued movement toward lower VOC coatings, we investigated emerging water-based coatings that make use of resin systems that do not require a coalescing agent. Resin systems were selected to be representative of current architectural coatings, and included

Table 2 – Effect of Varying Solids Volume on Regulatory VOC for Hypothetical Paints

Paint	Solids Volume, Liters	VOC Volume, Liters	Water Volume, Liters	Regulatory VOC, g/L-water	Solids Volume per Liter of Liquid Paint	VOC content, g per Liter of Paint Solids
1	0.75	0.25	0	250	0.75	333
2	0.625	0.375	0	375	0.625	600
3	0.5	0.5	0	500	0.5	1000
4	0.375	0.625	0	625	0.375	1667
5	0.25	0.75	0	750	0.25	3000
6	0.125	0.875	0	875	0.125	7000
7*	0.5	0.5	0	500	0.5	1000
8	0.375	0.375	0.25	500	0.375	1000
9	0.25	0.25	0.5	500	0.25	1000
10	0.125	0.125	0.75	500	0.125	1000

Hypothetical Paints 1-6 are solvent-based
Hypothetical Paints 8-10 are water-based
Paint 7 is identical to Paint 3

vinyl acrylic, vinyl acetate-ethylene copolymer, 100% acrylic, in conventional as well as low-VOC formulations, and a long oil soya alkyd. Additionally, the effect of pigment quality on coverage and hiding ability was investigated. Five commonly used pigment and extender materials were studied: titanium dioxide, calcium carbonate, and clay, nephelene syenite, and opaque polymer. Titanium dioxide was the main hiding pigment in these coatings, and was generally kept at or near 2.50 pounds per gallon for each of the paints prepared by us. In some of the water-based coatings, the TiO_2 content was varied, in accordance with manufacturer's specific formulation recommendations. All coatings were white in color (no colored pigments or tints). Part of the testing involved determination of color characteristics (using the CIE system).

The proposed composition of the formulated coatings is shown in Table 3. Detailed formulation information on these coatings may be found in Appendix A.

Table 3 – Proposed Test Formulations for Hiding/VOC Study

#	type	carrier	VOC	NVV	PVC	Resin	Extenders
1	flat	water	<100	33	40	vinyl acrylic	$CaCO_3$, clay
2	flat	water	<100	33	40	vinyl acrylic	neph.syn., clay
3	flat	water	<100	33	40	vinyl acrylic	$CaCO_3$, clay, opaque polymer
4	flat	water	<10	33	40	VAE	$CaCO_3$, clay
5	flat	water	<10	33	40	VAE	neph.syn., clay
6	flat	water	<10	33	40	VAE	$CaCO_3$, clay, opaque polymer
7	eggshell	water	<100	33	33	vinyl acrylic	neph.syn, opaque polymer
8	eggshell	water	<100	33	33	vinyl acrylic	clay, opaque polymer
9	eggshell	water	<100	33	33	vinyl acrylic	neph.syn., clay
10	eggshell	water	<10	33	33	vinyl acrylic/low VOC	neph.syn, opaque polymer
11	eggshell	water	<10	33	33	vinyl acrylic/low VOC	clay, opaque polymer
12	eggshell	water	<10	33	33	vinyl acrylic/low VOC	neph.syn., clay
13	semigloss	water	<100	33	25	vinyl acrylic	none
14	semigloss	water	<100	33	25	vinyl acrylic	opaque polymer
15	semigloss	water	<100	33	25	100% acrylic	none
16	semigloss	water	<100	33	25	100% acrylic	opaque polymer
17	semigloss	water	<10	33	25	100% acrylic, low VOC	none
18	semigloss	water	<10	33	25	100% acrylic, low VOC	opaque polymer
19	gloss	water	<10	33	20	100% acrylic, low VOC	none
20	gloss	water	<100	33	20	100% acrylic	none
21	flat	solvent	<400	42	50	long oil soya alkyd	neph.syn.,$CaCO_3$
22	flat	solvent	<400	42	50	long oil soya alkyd	clay,$CaCO_3$
23	eggshell	solvent	<400	42	40	long oil soya alkyd	neph.syn., $CaCO_3$
24	eggshell	solvent	<400	42	40	long oil soya alkyd	clay, $CaCO_3$
25	eggshell	solvent	<250	42	40	long oil soya alkyd, low VOC	neph.syn., $CaCO_3$
26	semigloss	solvent	<400	42	40	long oil tofa alkyd	none
27	semigloss	solvent	<400	42	40	long oil soya alkyd	none
28	semigloss	solvent	<250	42	40	long oil soya alkyd, low VOC	none
29	gloss	solvent	<400	42	20	long oil soya alkyd	none
30	gloss	solvent	<250	42	20	long oil soya alkyd, low VOC	none

Table Abbreviations:

VOC – volatile organic compound content, grams/Liter
NVV – volume percentage of non-volatiles
PVC - pigment-volume concentration (as percentage)
VAE – vinyl acetate-ethylene copolymer
neph.syn. - nephelene syenite

II. Project Methodologies

To obtain the desired information, standard methods for determining film thickness and coverage were used. A significant aspect of the study involved the determination of the hiding power, as a function of type and amounts of pigments. The method we used for this was ASTM D2805-96a, "Standard Method for Hiding Power of Paints by Reflectometry". An overview of this method is shown schematically in Figure 1. The method involves drawdowns on both glass and coated paper substrates. A sample drawdown on black glass is shown in Figure 2. A drawdown over coated paper substrate (Leneta chart) is shown in Figure 3.

This method enabled us to predict the contrast ratio for any film thickness from measurements made at only one film thickness. ASTM defines contrast ratio as "the ratio of the reflectance of a film on a black substrate to that of an identifcal film on a white substrate". This calculation facilitated determining the actual amount of VOC required to adequately cover and hide a surface. Results from this testing can be useful in comparing coatings with widely varying solids content.

Other ASTM methods used in this study included ASTM D 823 – "Standard Practices for Producing Films of Uniform Thickness of Paint, Varnish and Related Products on Test Panels", ASTM D 1005-95 "Standard Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers", ASTM D 1400-94 "Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base" , D1475-98(2003) "Standard Test Method for Density of Liquid Coatings, Inks, and Related Products" and D2369-04 "Standard Test Method for Volatile Content of Coatings".

A. Hiding vs. Coverage

The total surface area coverable by a liter of coating is dependent only on the thickness of the layer, since area = volume/thickness. A term closely associated with coverage is "hiding". From the ASTM's definition, the hiding power of a coating is defined as "the film area per unit volume (m^2/liter of coating) required to produce a dried film contrast ratio of 0.98, when applied identically over black and white substrates." From the consumer's perspective, it is really the more important factor. If a particular coating "covers" a given area but does not "hide" the surface sufficiently, the consumer will repeat the application with additional paint. In such a case, the true VOC content of the paint effectively becomes multiplied by the number of gallons used to attain satisfactory hiding of the substrate. The hiding power for a series of coatings, even with constant percent by volume of solids, depends on the relative amounts of pigment and resin, as well as the nature and quality of the pigment and resin. A consequence of these factors is that two paint films of identical composition will have identical hiding power if they are produced in a manner that produces identical coverage by the same volume of paint solids.

This forms the basis for a fundamental question addressed by this project:

Do equal volumes of paint solids obtained from different paints, give the same hiding power, when applied to surfaces of equal area, regardless of the carrier from which the solids were deposited?

This question requires answering several other related sub-questions. First, if it were possible to prepare solvent-based and water-based coatings at the same percent NVV resulting in identical films (thus prepared using identical resins and pigments), would these coatings have identical hiding powers? Second, if solvent-based and water-based coatings at the same percent NVV were prepared with different resins and pigments, would these coatings have identical hiding powers? Finally, does a smaller volume of one type of coating (e.g. solvent-based) generally provide better hiding than a larger volume of another type of coating (e.g. water-based) and thus some sort of VOC savings?

To help us answer these questions, we propose a new figure of merit for comparing coatings. Instead of comparing actual VOC or regulatory VOC, we propose the use of a term we refer to as "hiding VOC". This corresponds to the grams of VOC emitted per unit area (1.00 m^2) of a film producing a contrast ratio of 0.98. The defining equation for hiding VOC is:

$$hiding\ VOC = \frac{actual\ VOC}{H_{0.98}}$$

, where $H_{0.98}$ is the hiding power (as determined by ASTM D2805).

Ultimately, the use of "hiding VOC" could allow the amount of VOC required to adequately cover and hide a given surface to be evaluated, and would enable the real impact of a coating to be determined. Such a determination would amount to a performance-based characterization of the coating. This would be independent of carrier type (solvent- or water-borne), pigment amount and quality, resin, and other common coating parameters, and would facilitate comparison of coatings with widely varying compositions. Evaluating the effect of coating formulation on hiding, and hence, real VOC emitted during consumer use, is one goal of this project. To address this goal, two main sub-tasks will be performed: first, the preparation of selected coating formulations, followed by characterization of the hiding ability of the applied coatings.

Figure 1 - Hiding Power Determination Schematic

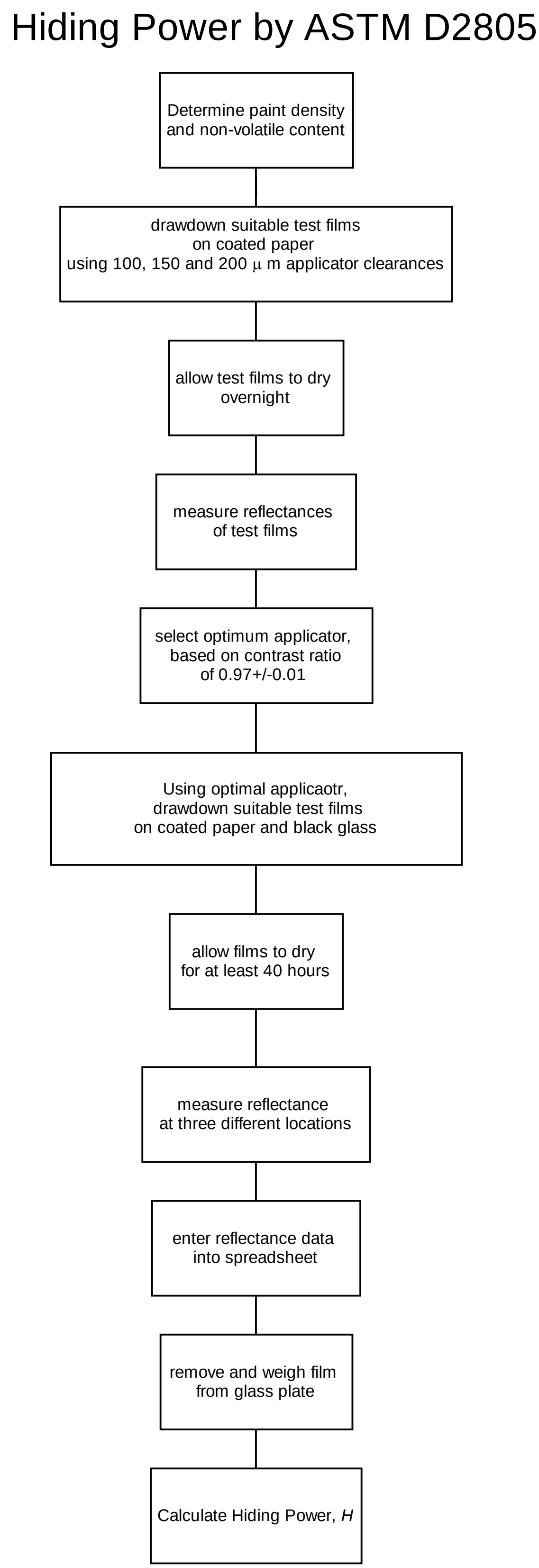


Figure 2 – Drawdown Bar and Drawdown on Black Glass

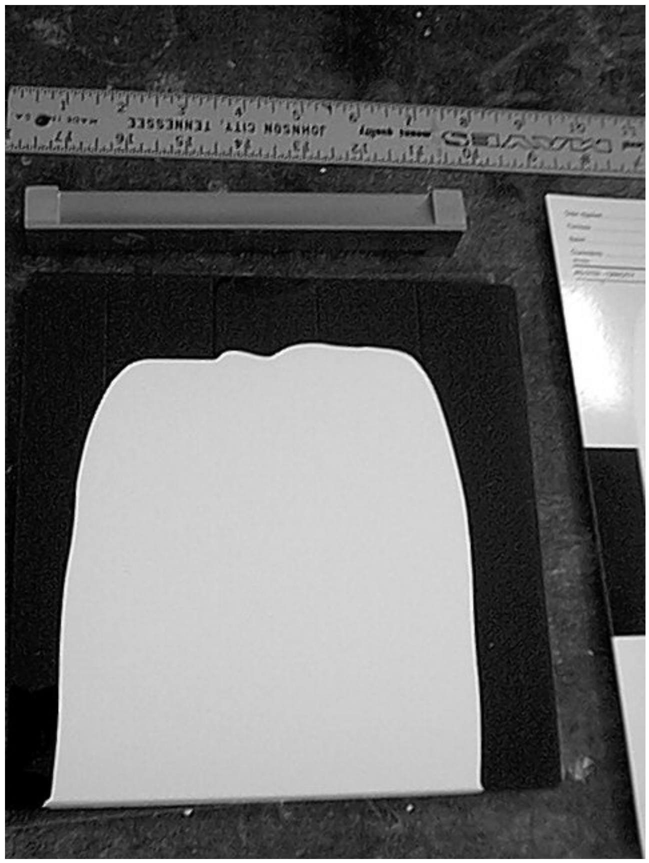
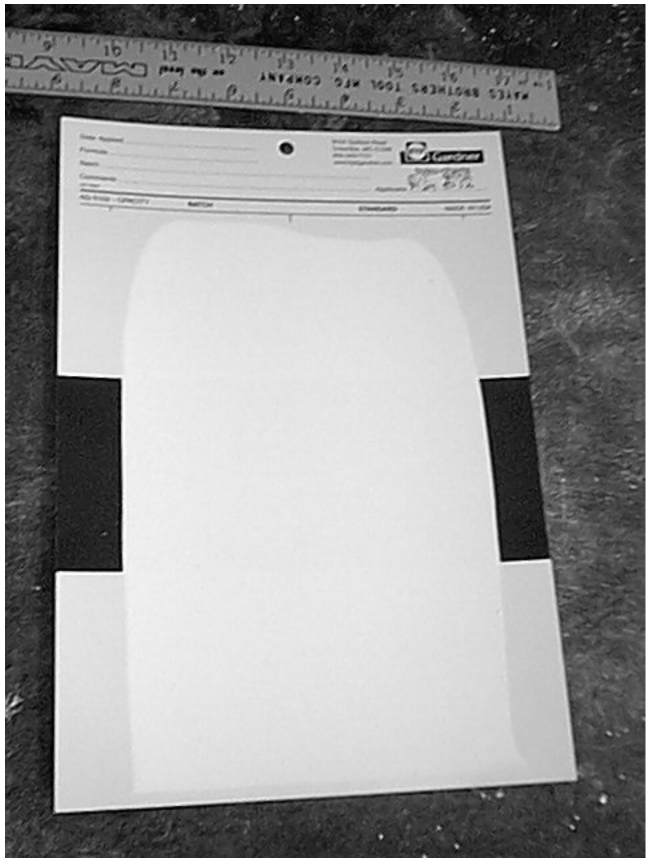


Figure 3 –Drawdown on Coated (Leneta) Chart



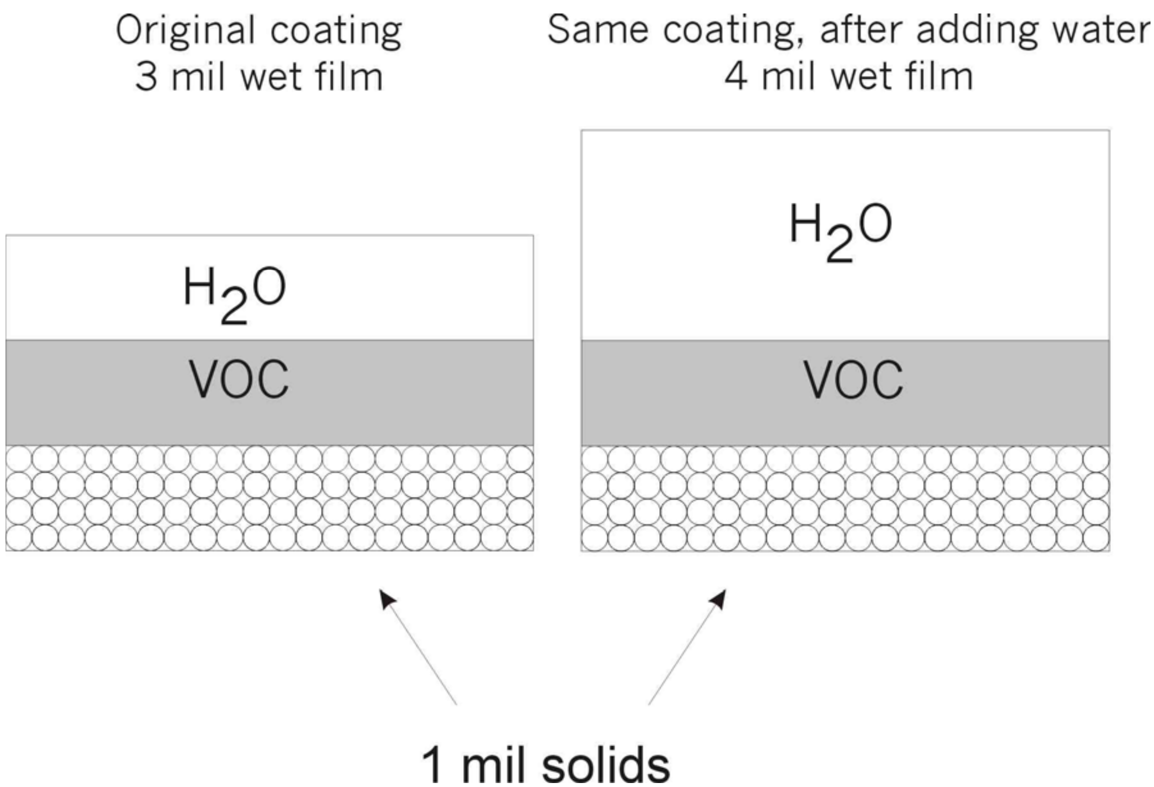
In accordance with ASTM D2805-96a method, coating samples were applied to the indicated substrates using a draw down bar. This assured the formation of a uniform wet film, and ultimately the formation of a uniform thickness of dried film for each individual sample. The method uses the Kubelka-Munk equations to allow for the calculation of the contrast ratio for any film thickness from measurements made at only one film thickness. Thus, the true hiding power, defined as the film thickness required to produce a contrast ratio of 0.98, may be computed by measuring the reflectance of a known film thickness. The contrast ratio is described by ASTM as "the ratio of the reflectance of a film on a black substrate to that of an identical film on a white substrate." A significant aspect of the study was determination of the hiding power, as a function of type and amounts of pigments. This should facilitate determining the actual amounts of VOC required to adequately cover and hide a surface. It should be useful in comparing coatings with widely varying solids content. As discussed earlier, this will be used to determine the "hiding VOC" of the coating samples.

While coatings were formulated to a single specific volume percent solids, corresponding to "typical" architectural coatings, the correlation between hiding power and percent solids was expanded through the use of the Kubelka-Munk equations. For example, the hiding power of "hypothetical" formulations with any desired range of percent solids may be investigated by such a simulation. As part of this simulation, the solids content of a "family" of coatings can be varied over whatever range is desired. The variation in solids content can be converted into corresponding changes in coating density and film mass. Of course, the properties of the deposited films are based solely on the light scattering properties of the solids, as based on the model for the coating family studied. Application of the simulated parameters into the Kubelka-Munk equations will produce the hiding power (and hiding VOC) of these simulated coatings. In this manner, it will be possible to prepare graphs of hiding power as a function of percent solids for each formulation, once the reflectance characteristics for that coating (e.g., scattering coefficient) have been determined at one film thickness and percent solids level. Such a family of graphs will enable comparisons between coatings of very different composition, even for coatings with different carriers. The scattering properties of the dried films will depend on the nature and amount of materials in the film. For each formulated coating, base scattering coefficients will be determined for a particular combination of pigments and extenders. From each base, a family of coatings, with variable percent solids will be investigated, as outlined previously.

To illustrate the effect of added water on hiding power, consider a family of water-based coatings prepared by adding or subtracting water from a base, or parent, coating. Figure 4 illustrates the solid films formed by the drying of two members of a coating family, differing only in the amount of water (or, equivalently, differing in volume solids content). The coatings depicted are presumed to consist of three major constituents: water, VOC and solids. In the case of the parent coating, a 33% volume solids coating, a three mil liquid film will produce a 1 mil film when dry. If the same coating is diluted with water to 25% volume solids, a 4 mil liquid film will be required to produce an identical 1 mil dry film. Clearly, the two dry films will be identical for these coatings. Hence, the reflectance characteristics of these films will be identical, dependent only on the composition of the solid, and not dependent on their percent volume in the coating.

Table 4 shows the data required to perform ASTM Method D2805-96a, "Standard Method for Hiding Power of Paints by Reflectometry". It also shows the definitions of the key parameters. The Kubelka-Munk equations forming the theoretical basis for the method are shown in Table 5.

Figure 4 – Comparison of Two Coatings Having Different Amounts of Water



representation of 33% volume solids

representation of 25% volume solids

Table 4 – ASTM D2805-96a Worksheet Definitions

	Definitions
Charts	
Ro	reflectance of film on black surface
Rw	reflectance of film on white surface of reflectance W
W	reflectance of white substrate
a	from eqn. A 1.2
R_{inf}	reflectivity of a film having the same reflectance over black and white substrates
Glass	
Ro	reflectance of film on black surface
A	film area, cm^2
N	non-volatile content of paint
D	paint density, g/mL
M	weight of film, g
Hx	Spread rate, m^2/L
b	from eqn. A 1.5
S	scattering coefficient
Hiding Power calcs	
a	from eqn. A 1.2
b	from eqn. A 1.5
U	from eqn. A 1.10
P	from eqn. A 1.11
$H_{0.98}$	hiding power, m^2/L, the spreading rate producing a contrast ratio of 0.98

Table 5 - Kubelka-Munk equations (ref. ASTM Method D2805)

$$R_\infty = f(R_0, R_W, W) \qquad \text{(A1.1)}$$

$$a = \frac{1}{2}\left(R_W + \frac{R_0 + W - R_W}{WR_0} \right) \qquad \text{(A1.2)}$$

$$R_\infty = f(a) = a - (a^2 - 1)^{1/2} \qquad \text{(A1.3)}$$

$$S = f(R_0, R_\infty, H_X) \qquad \text{(A1.4)}$$

$$b = f(R_\infty) = \frac{1}{2}\left(\frac{1}{R_\infty} - R_\infty \right) \qquad \text{(A1.5)}$$

$$\underline{S = \frac{H_X}{2b} \ln \left(\frac{1 - R_0 R_\infty}{1 - R_0/R_\infty} \right)} \qquad \text{(A1.6)}$$

$$H_C = f(S, C, R_\infty) \qquad \text{(A1.7)}$$

$$a = f(R_\infty) = \frac{1}{2}\left(\frac{1}{R_\infty} + R_\infty \right) \qquad \text{(A1.8)}$$

$$b = f(R_\infty) = \frac{1}{2}\left(\frac{1}{R_\infty} - R_\infty \right) \qquad \text{(A1.9)}$$

$$U = \left[\left(a + \frac{1 - C}{1.60\,C} \right)^2 - \frac{1}{C} \right]^{1/2} + \frac{1 - C}{1.60\,C} \qquad \text{(A1.10)}$$

$$P = f(U, R_\infty) = \frac{1}{2b} \ln \left(\frac{U + b}{U - b} \right) \qquad \text{(A1.11)}$$

$$\underline{H = S/P} \qquad \text{(A1.12)}$$

$$C = f(S, H, R_\infty) \qquad \text{(A1.13)}$$

$$P = S/H \qquad \text{(A1.14)}$$

$$a = f(R_\infty) = \frac{1}{2}\left(\frac{1}{R_\infty} + R_\infty \right) \qquad \text{(A1.15)}$$

$$b = f(R_\infty) = \frac{1}{2}\left(\frac{1}{R_\infty} - R_\infty \right) \qquad \text{(A1.16)}$$

$$C = \frac{a + b \coth bP - 0.80}{(a + b \coth bP)\,[1 - 0.80(a - b \coth bP)]} \qquad \text{(A1.17)}$$

Examination of the Kubelka-Munk equations shows that hiding power, $H_{0.98}$, is proportional to the scattering coefficient, *S*, of the solid film. In turn, *S* is proportional to the experimentally determined spread rate, H_x, which is dependent on the non-volatile content of the paint, *N*, and its density, *D*. In equation form,

Equation 1:

$$H_{0.98} \propto S \propto H_x \propto N \cdot D$$

$$\therefore$$

$$H_{0.98} \propto N \cdot D$$

From this relationship a useable equation for determining theoretical changes in hiding power as the amount of solids changes may now be developed. *N* and *D* may be expressed in a manner which reduces the entire equation to a single variable. *N* is the fraction of solids in a coating by mass,

Equation 2:

$$N = \frac{M_{solids}}{M_{solids} + M_{H20} + M_{VOC}}$$

and *D* , the density of the liquid coating, may be expressed as

Equation 3:

$$D = \frac{M_{solids} + M_{VOC} + M_{H20}}{V_{solids} + V_{VOC} + V_{H20}}$$

The product of N and D now becomes,

Equation 4:

$$\frac{M_{solids}}{V_{solids} + V_{VOC} + V_{H20}}$$

By varying only the volume of H_20 in the coating, $H_{0.98}$ may be expressed in terms of the single variable, VH_20

Equation 5:

$$H_{0.98} = \left[\frac{\left(A \cdot \ln\left(\frac{1 - R_0 R_\infty}{1 - R_0 / R_\infty} \right) \right)}{10 \cdot M \cdot \ln\left(\frac{U + b}{U - b} \right)} \right] \cdot \frac{M_{solids}}{V_{solids} + V_{VOC} + V_{H20}}$$

In equation 5, the quantities R_0 and R_∞ are derived from reflectance measurements on the dried film, and the quantities *A, M, U* and *b* are the same for all coatings in the family, since they depend only on the properties of the dried film. As shown in equation 1, $H_{0.98}$ is proportional to the volume of solids for a family of coatings. The magnitude of the proportionality constant is provided by application of the reflectance measurements and the Kubelka-Munk equations.

B. Color Determinations

The determination of color was performed on all of these 30 coatings. Some background on the color determination will be presented here.

Color has been described as that characteristic of light by which an observer may distinguish between two structure-free fields of view of the same size and shape. Using this definition, color can be more accurately depicted as the chromatic appearance of an object under a certain set of conditions. The three conditions used to determine the "color" of an object are: the observer, the light source or illuminant, and the object itself.

The observer of an object views the outward chromatic appearance of an object interacting with an illuminant. Recognizing that the human interpretation of color is subjective, the need for a "standard observer", whose response to color is uniform and measurable, has been recognized. This "standard observer" embodies the measured response of the human eye to light at various wavelengths in the visible spectra. The development of the standard observer removes human bias from color determinations.

The second condition or component of color is the illuminant. Different light sources emit different amounts of light within the visible spectrum. As an example, an item of apparel viewed under the fluorescent light of a department store may have a different appearance when observed under normal daylight. The illuminant is characterized by measuring the intensity of light at each wavelength within the visible spectra. This characterization is known as the energy distribution of the illuminant. The three most prominent light sources are normal daylight, incandescent lights, and fluorescent lights. White light, more appropriately described as polychromatic light, can be characterized in terms of its "temperature", indicated in degrees Kelvin. The color temperature represents the continuous spectrum of energy emitted by a perfect black body radiator at the specified temperature. Some color temperatures for common illuminants are shown in the table below:

Illuminant	**color temperature, ^{o}Kelvin**
Tungsten filament lamp	2856
Medium daylight, without UV	6750
D65 standard lamp, with UV	6500
"cool white" fluorescent lamp	4100
"warm white" fluorescent lamp	3050
Candle	1900

It is curious to note that the "warmer" the source, the lower its temperature. In this context, warmth refers to the amount of red in the spectrum, and coolness describes the amount of blue color in the illuminant.

The third component in color determination is the object itself. An object's response to color is determined by the intensity of incident light at various wavelengths, and how much of that light is reflected from the surface of the object. In a color determination, this typically takes the form of a reflectance ratio of object to illuminant. By standardizing these three components a useful method for determining the color, or chromatic appearance of an object can be developed.

A number of scales for quantitating color have been developed. These are based on the fact that the human eye contains three different color receptors (cones), sensitive to each of the color primaries. One set of these receptors is responsive to red-orange (X), the second type to green(Y) and the third type to blue (Z). In the CIE (Commission International de L'Eclairage) XYZ system, the position of a color in “color space” may be represented by its (X,Y,Z) coordinates. Alternatively, a two-dimensional representation (X and Y only) may be used to describe all possible colors. The third coordinate is clearly related to the other two (if an object is neither red nor green, it will be blue).

A second scale, usually referred to as the CIE Lab scale, is a mathematical derivative of the CIE XYZ scale. In the Lab system, three “synthetic primaries” are derived: L*, which indicates lightness, a*, which indicates red-greenness, and b*, which indicates yellow-blueness.

In our color determination of the prepared coatings, each sample was analyzed using a standard D65 illuminant, over the white portion of the Leneta charts on which their hiding power was determined. The chromatic appearance of each coating was put into the L*a*b* format in which L* is a measure of the lightness of the coating, a* is the measure of green to red, where a positive a* is more red and negative a* is more green, and b* is blue to yellow, where positive b* is more yellow and negative b* is more blue. Low values of a* or b* indicate a lack of color, and high values of L* indicate a very light material. So a white coating will have a high L*, but low a* and b* values.

The need to consider a three dimensional color space has led to exploration of a simpler quantitative descriptor for color. One such descriptor, ΔE, is based on color difference between two samples. For example, if one defines a “reference, pure white” with coordinates of L*=100, a* = b* = 0, the length of the vector connecting a sample point with the reference point in color space can be defined as

$$\Delta E = \sqrt{\left(\Delta a^*\right)^2 + \left(\Delta b^*\right)^2 + \left(\Delta L^*\right)^2}$$

Effectively, this parameter describes “how far away” a given color is from a defined reference, but does not include the direction of the difference.

Results from color measurements are included in Table 6. The reference color was a hypothetical white with L* = 100 and a* =b* =0.

A graphical representation of these color values is shown in Figure 5.

C. Gloss Measurements

Gloss is the reflection of light from a surface, independent of color. Gloss may influence the visual color of a surface viewed from various angles. Gloss is usually measured at a prescribed angle measured from the vertical. The most common is the 60^o gloss value. If a sample has a 60^o gloss value greater than 70, a 20^o gloss value may also be reported. For non-glossy surfaces, the 85^o gloss value, or sheen, may also be reported. No absolute scale exists for distinguishing between coatings classified as flat, eggshell, satin, semigloss or gloss. Some possible suggested ranges are given below.

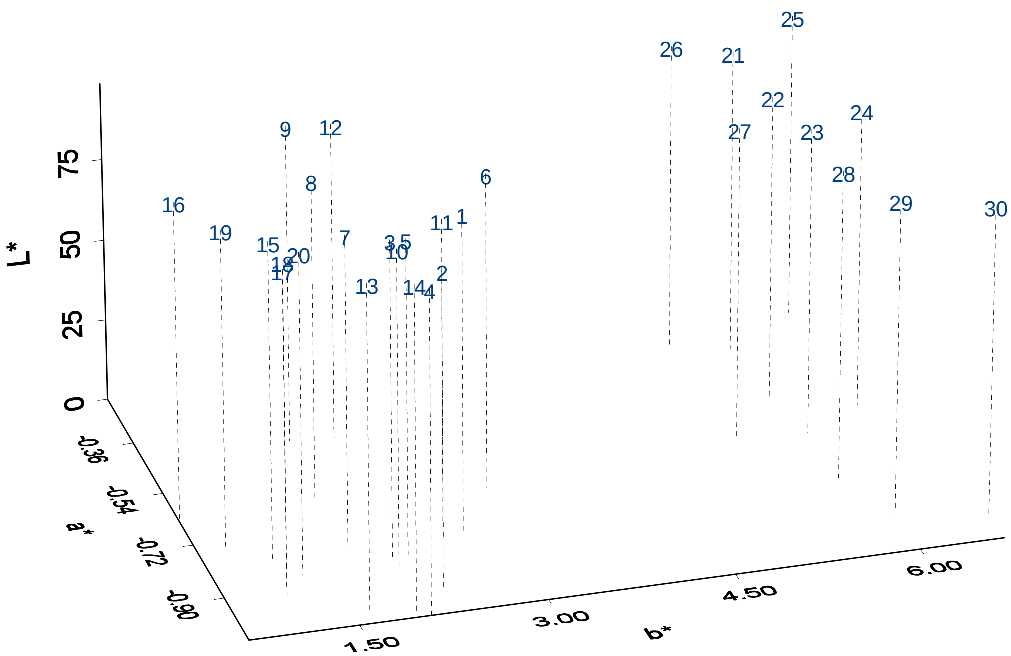
GLOSS RANGES

Type of Paint	20° Gloss	60° Gloss	85° Gloss (sheen)
Gloss	20-90	70 - 95+	--
Semi-gloss	5-45	25-75	--
Satin	--	5-25	0-40
Eggshell	--	2-15	5-25
Flat	--	0-10	0-15

Table 6 - Color values for Formulated Coatings

Formulation	type	solvent	L*	a*	b*	ΔE
1	flat	water	96.67	-0.79	2.70	4.36
2	flat	water	96.64	-0.97	2.27	4.17
3	flat	water	96.78	-0.85	2.04	3.91
4	flat	water	97.81	-1.04	2.07	3.19
5	flat	water	95.63	-0.84	2.18	4.96
6	flat	water	96.27	-0.66	3.09	4.89
7	eggshell	water	97.25	-0.82	1.73	3.35
8	eggshell	water	97.27	-0.62	1.75	3.31
9	eggshell	water	97.20	-0.42	1.83	3.37
10	eggshell	water	96.54	-0.88	2.05	4.12
11	eggshell	water	97.37	-0.81	2.51	3.72
12	eggshell	water	97.05	-0.43	2.18	3.69
13	semigloss	water	98.22	-1.00	1.64	2.62
14	semigloss	water	97.99	-1.02	1.98	3.00
15	semigloss	water	97.13	-0.81	1.14	3.19
16	semigloss	water	97.55	-0.64	0.63	2.61
17	semigloss	water	98.16	-0.92	1.10	2.33
18	semigloss	water	97.87	-0.89	1.14	2.57
19	gloss	water	97.13	-0.75	0.85	3.09
20	gloss	water	97.28	-0.86	1.31	3.14
21	flat	solvent	93.33	-0.30	5.70	8.78
22	flat	solvent	94.25	-0.49	5.71	8.12
23	eggshell	solvent	94.22	-0.62	5.81	8.22
24	eggshell	solvent	94.00	-0.57	6.31	8.73
25	eggshell	solvent	93.87	-0.20	6.37	8.84
26	semigloss	solvent	94.06	-0.26	5.25	7.93
27	semigloss	solvent	95.40	-0.60	5.25	7.01
28	semigloss	solvent	94.36	-0.78	5.79	8.12
29	gloss	solvent	95.93	-0.92	6.01	7.32
30	gloss	solvent	95.14	-0.97	6.69	8.33

Figure 5 - A Portion of Color Space for Prepared Coatings



notes:

ARB numbers identified for clarity
ARB numbers 21-30 are solvent-based coatings

Gloss is a function of the smoothness of a surface. Large pigment particles tend to produce flat coatings. The highest gloss coatings are almost always prepared with no extender pigments and gloss grades of titanium dioxide.

Gloss measurement has become very simple using modern hand-held gloss meters. The meter is first calibrated using a standard tile or glass. Readings are then taken at different angles depending on the level of gloss of the substrate.

Gloss measurements were taken for all formulations using drawdown samples on opacity charts. Readings were taken using the white sealed portion of the chart using a Byk-Gardner Micro Tri-Gloss meter. Results are given in Table 7. The values reported for these coatings are generally within the ranges given above. Three of the formulations had gloss readings outside their targeted ranges. Formulation ARB 8 (eggshell) is actually more of a semigloss and formulations ARB 26 and ARB 28 (semigloss) are more typical of satins or eggshells. These gloss values do not affect the VOC values or the hiding power of the coatings.

Coatings were originally classified into gloss categories by virtue of the information found in the formulations. Measured gloss values on the prepared coatings reinforced the original classifications.

Table 7 – Gloss measurements for All Coatings

Gloss Measurements at 20°, 60° and 85°					
#	type	solvent	20 deg	60 deg	85 deg
1	flat	water		5.3	24.3
2	flat	water		5.6	15.6
3	flat	water		4.3	48.7
4	flat	water		3.1	25.8
5	flat	water		4.1	19.2
6	flat	water		5.6	67.0
7	eggshell	water		11.5	24.8
8	eggshell	water		31.4	79.0
9	eggshell	water		10.9	27.6
10	eggshell	water		8.4	24.0
11	eggshell	water		7.4	69.4
12	eggshell	water		8.0	32.0
13	semigloss	water	16.0	59.5	
14	semigloss	water	25.0	65.9	
15	semigloss	water		37.0	81.6
16	semigloss	water		36.8	52.9
17	semigloss	water	22.5	59.1	
18	semigloss	water		38.2	60.3
19	gloss	water	21.1	63.3	
20	gloss	water	30.7	67.3	
21	flat	solvent		2.6	3.2
22	flat	solvent		3.8	13.4
23	eggshell	solvent		6.4	8.3
24	eggshell	solvent		3.7	7.3
25	eggshell	solvent		9.9	32.8
26	semigloss	solvent		12.2	22.7
27	semigloss	solvent	44.6	77.6	
28	semigloss	solvent		16.7	43.1
29	gloss	solvent	72.8	88.9	
30	gloss	solvent	59.2	78.3	

III. Results

A. Water-Borne Coatings

A number of water-borne coatings were prepared. Characteristics of these coatings are shown in Table 8. Detailed formulations for these coatings may be found in Appendix A.

In accordance with ASTM D2805, reflectance measurements were conducted on the dried films, using a Datacolor Mercury 2000 spectrophotometer and ColorSync analysis software.

In order to demonstrate the utility of the hiding power calculations approach, experimental data from a vinyl acrylic semigloss coating containing both TiO_2 and opaque polymer were acquired. Average values for reflectance (dimensionless fraction or decimal), dry film mass (grams), area of the dry film (cm^2), and Kubelka-Munk parameters *a, b* and *U* in the parent coating were calculated from the data, and held as constants in the model. Data for the parent coating and 7 simulated coatings in the same family are shown in Table 9. The members of this family of coatings were simulated by starting with the base coating, and adding or subtracting 100 pounds of water from the base formulation. Using the data from the base coating film, hiding values were calculated for 7 theoretical coatings based on the actual prepared coating, shown in **bold** in Table 9. While the $H_{0.98}$ varies, the hiding VOC values are the same for all coatings in the same family, as shown in Table 9.

The reproducibility of the technique was addressed in a number of quality assurance steps. As can be seen in Table 10, and as detailed in ASTM Method D2805, for each coating tested, four series of reflectance measurements are made. Table 10 shows the results of these four replicates range from about 1% to about 4%, expressed as relative standard deviation of the hiding power, $H_{0.98}$. Thus, the reproducibility of the method on a given coating sample was demonstrated to be quite good.

In order to address the effect of batch variation in the prepared coatings, three replicate batches of a paint formulation were prepared, and the hiding power was determined on all batches. Table 11 shows the results for three separate batches of ARB14. As is shown, batch-to-batch variation of hiding power and hiding VOC is not much greater than the within-batch variation. This verifies that the coatings are being formulated and tested in a consistent manner.

Finally, the potential variability of the technician performing the test was explored. A coating was analyzed by three separate individuals in our laboratory. The results of this series of tests are shown in Table 12. As can be seen, the between-operators variability was comparable to the variability seen with a single operator. This illustrates the impartiality and objectivity of the method.

Figure 6 shows a graph of $H_{0.98}$ vs. percent non-volatiles by volume (%NVV) for a family of coatings, with coating ARB14 serving as the “parent” of this family. This graph is linear, based on equation 1 above. The slope of the graph is a measure of the “effectiveness” of the coating to hide the substrate. It is important to keep in mind that this graph refers to the solid film. Any member of this coating family will produce the same film, if applied to a constant dry film thickness. The graph allows prediction of the hiding power as a function of %NVV, once the characteristics of the dried film have been established.

Table 8 - Water-Based Coating Characteristics

#	type	solvent	VOC*(reg)	VOC* (actual)	NVV	PVC	TiO_2 (lbs/100 gal)	H_{98} (m^2/L)	VOC H_{98} (g/m^2)	Resin	Extenders
1	flat	water	100	36	34	42	183	6.4	5.6	vinyl acrylic EPS 2911	$CaCO_3$, clay
2	flat	water	100	36	34	42	183	6.7	5.4	vinyl acrylic EPS 2911	neph.syn., clay
3	flat	water	105	39	33	40	117	5.1	7.6	vinyl acrylic EPS 2911	$CaCO_3$, clay, opaque polymer
4	flat	water	7.9	3	35	42	185	5.7	0.5	VAE Duravace FT-320	$CaCO_3$, clay
5	flat	water	8.1	3	34	42	185	6.7	0.4	VAE Duravace FT-320	neph.syn., clay
6	flat	water	7.8	3	34	42	145	6.3	0.5	VAE Duravace FT-320	$CaCO_3$, clay, opaque polymer
7	eggshell	water	14	5	33	38	213	6.6	0.8	vinyl acrylic Rovace 9900	clay
8	eggshell	water	80	29	33	33	190	7.3	4.0	vinyl acrylic Rovace 9900	clay, opaque polymer
9	eggshell	water	104	36	33	33	200	6.4	5.6	vinyl acrylic EPS 2911	neph.syn., clay
10	eggshell	water	8.2	3	33	33	173	5.4	0.6	VAE Duravace FT-320	clay
11	eggshell	water	8.8	3	34	33	185	6.9	0.4	VAE Duravace FT-320	clay, opaque polymer
12	eggshell	water	8.4	3	33	33	200	6.4	0.5	VAE Duravace FT-320	neph.syn., clay
13	semigloss	water	112	41	33	26	275	8	5.1	vinyl acrylic EPS 2911	none
14	semigloss	water	117	44	33	26	224	6.9	6.4	vinyl acrylic EPS 2911	opaque polymer
15	semigloss	water	68	25	33	25	275	6.5	3.8	100% acrylic Rhoplex SG-10M	none
16	semigloss	water	68	25	33	25	200	6.8	3.7	100% acrylic Rhoplex SG-10M	opaque polymer
17	semigloss	water	7.2	2	34	25	275	7.3	0.3	100% acrylic Rhoplex SG-10M	none
18	semigloss	water	225	96	32	26	271	6.2	15.5	100% acrylic Rhoplex SG-10M	opaque polymer
19	gloss	water	0	0	33	20	225	7.2	0	100% acrylic low VOC Rhoplex SF-012	none
20	gloss	water	156	62	33	20	220	7.2	8.6	100% acrylic Rhoplex HG-700	none

* VOC determined by formulation

Table 9 – Hiding VOC for a Family of Coatings

Constants

a	b	R_o	R_∞
1.002	0.05619	0.9197	0.9454

M (g)	Area (cm^2)	U	VOC (g/L)
1.2837	120	0.1048	117.09

Total Mass	Mass Solids	Total Volume	Non-volatiles by mass	Non-volatiles by volume	Density		H_x	$H_{0.98}$	Actual VOC	Hiding VOC
pounds	pounds	gallons	%	%	lb/gal	g/mL	m^2/L	m^2/L	g/L	g/m^2
740.61	476.34	64.79	64.32%	51.05%	11.432	1.3698	8.2359	10.78	67.78	6.29
840.61	476.34	76.79	56.67%	43.07%	10.947	1.3117	6.9483	9.09	57.18	6.29
940.61	476.34	88.80	50.64%	37.24%	10.593	1.2693	6.0089	7.86	49.45	6.29
1040.61	**476.34**	**100.80**	**45.78%**	**32.81%**	**10.324**	**1.2370**	**5.2933**	**6.93**	**43.56**	**6.29**
1140.61	476.34	112.80	41.76%	29.32%	10.111	1.2116	4.7300	6.19	38.93	6.29
1240.61	476.34	124.81	38.40%	26.50%	9.940	1.1911	4.2750	5.59	35.18	6.29
1340.61	476.34	136.81	35.53%	24.17%	9.799	1.1741	3.8999	5.10	32.10	6.29
1440.61	476.34	148.82	33.07%	22.22%	9.680	1.1600	3.5853	4.69	29.51	6.29

Bold values for formulated coating

Table 10 – Sample Data and Calculation Sheet

ARB 1a Batch 1			Nonvolatile Content		0.5078	VOC (Act)	36.141077
Paint Density 1.3453 (g/mL)			Template Film Area (cm^2)		120	Reg	100.39142

	Chart	Ro	Rw	W	a	b	Cw	Rinf
Test 1	1	0.9043	0.9129	0.8010	1.003	0.08232	0.9906	0.9206
	2	0.9022	0.9133	0.8026	1.003	0.08232	0.9878	0.9233
	3	0.9048	0.9134	0.8022	1.003	0.08232	0.9906	0.9210
	4	0.9065	0.9134	0.8039	1.004	0.08232	0.9924	0.9193
	Mean	**----**	**----**	**----**	**----**	**----**	**0.9904**	**0.9211**
	Panel	Ro	M (g)	Hx (m2/L)	S (m2/L)	U	P	H0.98 (m2/L)
	1	0.8984	1.4287	5.738	67.87	0.1233	9.7975	6.928
	2	0.8969	1.4287	5.738	65.92	0.1211	10.0725	6.544
	3	0.8972	1.4287	5.738	66.30	0.1229	9.8452	6.734
	4	0.8962	1.4287	5.738	65.05	0.1243	9.6795	6.721
	Mean	**0.897175**	**----**	**----**	**66.29**	**----**	**9.8486724**	**6.732**
Test 2	Chart	Ro	Rw	W	a	b	Cw	Rinf
	1	0.9016	0.9115	0.8030	1.003	0.08087	0.9891	0.9200
	2	0.9017	0.9124	0.8043	1.003	0.08087	0.9883	0.9216
	3	0.9014	0.9134	0.8046	1.003	0.08087	0.9869	0.9241
	4	0.9040	0.9144	0.8030	1.003	0.08087	0.9886	0.9239
	Mean	**----**	**----**	**----**	**----**	**----**	**0.9882**	**0.9224**
	Panel	Ro	M (g)	Hx (m2/L)	S (m2/L)	U	P	H0.98 (m2/L)
	1	0.8986	1.4475	5.663	66.26	0.1238	9.6568	6.861
	2	0.8965	1.4475	5.663	63.69	0.1224	9.8185	6.487
	3	0.8972	1.4475	5.663	64.52	0.1204	10.0596	6.414
	4	0.8975	1.4475	5.663	64.88	0.1206	10.0429	6.461
	Mean	**0.89745**	**----**	**----**	**64.84**	**----**	**9.8944672**	**6.556**
Test 3	Chart	Ro	Rw	W	a	b	Cw	Rinf
	1	0.9002	0.9130	0.8025	1.003	0.07690	0.9860	0.9246
	2	0.9021	0.9150	0.8032	1.003	0.07690	0.9859	0.9272
	3	0.9032	0.9154	0.8043	1.003	0.07690	0.9867	0.9268
	4	0.9024	0.9144	0.8022	1.003	0.07690	0.9869	0.9256
	Mean	**----**	**----**	**----**	**----**	**----**	**0.9864**	**0.9261**
	Panel	Ro	M (g)	Hx (m2/L)	S (m2/L)	U	P	H0.98 (m2/L)
	1	0.8968	1.4116	5.807	63.44	0.1200	9.8794	6.422
	2	0.8956	1.4116	5.807	62.17	0.1180	10.1261	6.140
	3	0.8951	1.4116	5.807	61.66	0.1182	10.0904	6.111
	4	0.8958	1.4116	5.807	62.38	0.1192	9.9738	6.254
	Mean	**0.895825**	**----**	**----**	**62.41**	**----**	**10.017434**	**6.232**
Test 4	Chart	Ro	Rw	W	a	b	Cw	Rinf
	1	0.9000	0.9162	0.8026	1.002	0.07332	0.9823	0.9325
	2	0.9012	0.9162	0.8027	1.003	0.07332	0.9836	0.9311
	3	0.8994	0.9142	0.8029	1.003	0.07332	0.9838	0.9282
	4	0.9025	0.9146	0.8046	1.003	0.07332	0.9868	0.9257
	Mean	**----**	**----**	**----**	**----**	**----**	**0.9841**	**0.9294**
	Panel	Ro	M (g)	Hx (m2/L)	S (m2/L)	U	P	H0.98 (m2/L)
	1	0.8985	1.4484	5.660	61.86	0.1138	10.4354	5.928
	2	0.8976	1.4484	5.660	60.95	0.1149	10.2979	5.919
	3	0.8966	1.4484	5.660	59.97	0.1172	10.0174	5.987
	4	0.8967	1.4484	5.660	60.07	0.1191	9.7857	6.138
	Mean	**0.89735**	**----**	**----**	**60.71**	**----**	**10.134094**	**5.993**

Table 11 – Batch variation in Hiding Power and Hiding VOC Determinations

ARB14 formulations

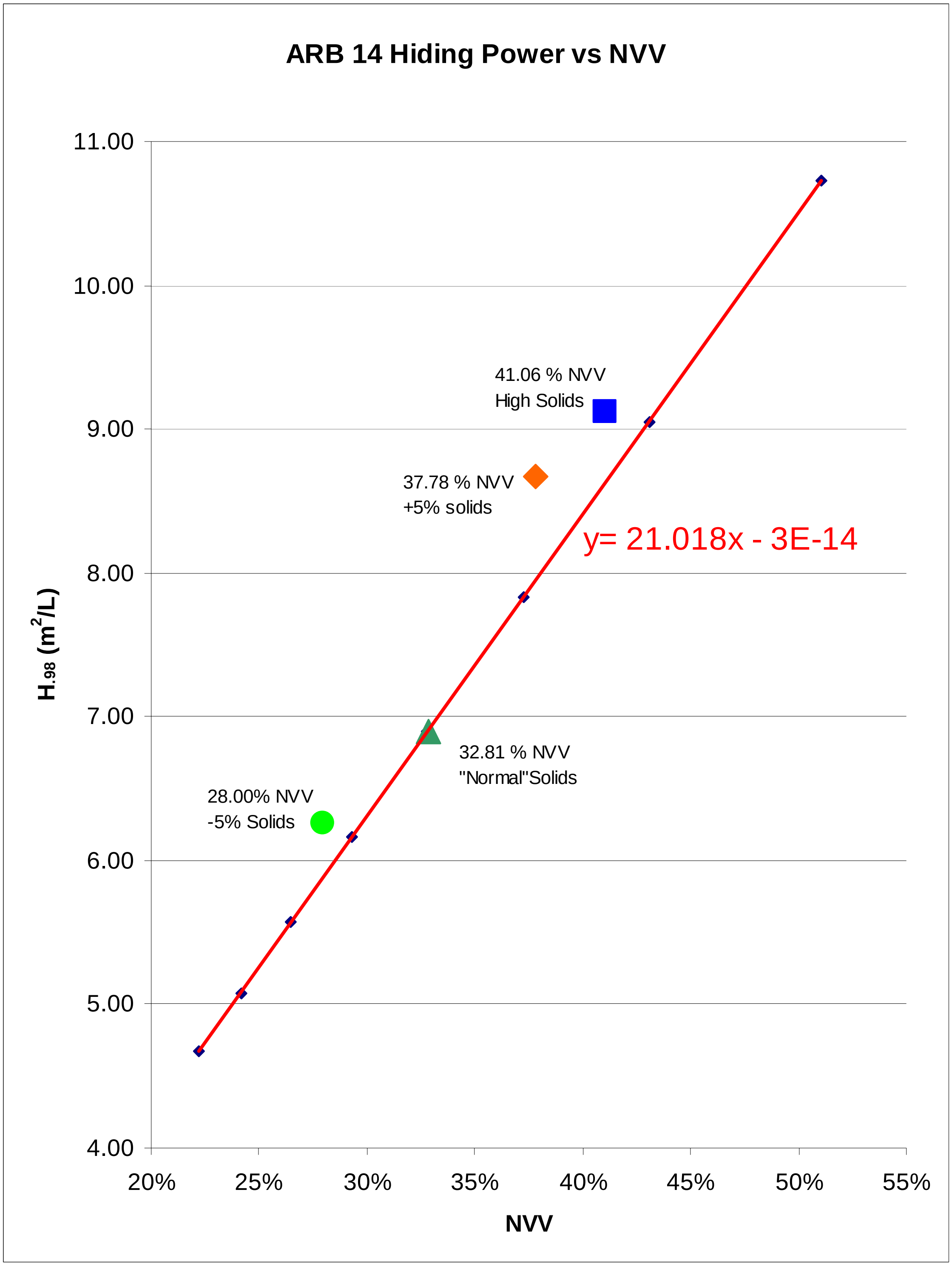
	$H_{0.98}$ (m^2/L)	Hiding VOC (g/m^2)
Batch 1	6.40	6.56
Batch 2	7.00	6.22
Batch 3	7.23	5.74
Average	**6.88**	**6.17**
Standard deviation	0.43	0.41
%RSD	6.2%	6.6%

Table 12 – Operator variability in Hiding Power Determinations

ARB7 formulations

	$H_{0.98}$ (m^2/L)
operator 1	6.0350
operator 2	6.600
operator 3	6.57
Average	**6.40**
Standard deviation	0.32
%RSD	5.0%

Figure 6 –Hiding Power vs. percent non-volatiles by volume (%NVV) for a Typical Coating Family for Coating ARB14



Notes: 1. Graph shows regression equation for "best-fit" line through simulated results.
2. Four large symbols (circle, triangle, diamond, and square) show location of actual formulated coatings.

To test the predictive ability of the graph shown in Figure 6, a series of coatings (in the same family) with varying %NVV was formulated. Four coatings were prepared, using varying amounts of water, to give 28.00, 32.81, 37.78 and 41.06 % NVV. The hiding power of these coatings was determined, using the method described previously. Results are shown below:

Comparison of Experimental and Predicted Hiding for a Family of Coatings

		$H_{0.98}$ (g/m^2)		
formulation	**%NVV**	**experimental**	**Predicted***	**difference**
High solids	41.06%	9.124	8.630	5.42%
+5% NVV	37.78%	8.670	7.941	8.41%
Original	**32.81%**	**6.895**	**6.896**	**-0.01%**
-5% NVV	28.00%	6.260	5.885	5.99%

*predicted value from regression equation shown in Figure 6

The predicted values were obtained from the regression equation of $H_{0.98}$ vs. %NVV for the formulated coating (which had 32.81%NVV). As is shown in the above table, predicting hiding power from %NVV using the Kubelka Munk equations produced values that agreed fairly closely with experimental values for members of this coating family.

Similar predictive graphs of $H_{0.98}$ vs. %NVV as well as Hiding VOC vs. %NVV for the all tested water-based coatings may be found in Appendix B. It should be noted that for these coatings, the hiding power was directly proportional to the percent non-voalitles, as dictated by the Kubelka-Munk equations. The Hiding VOC values for water-based coatings are independent of the percent non-volatiles. In this aspect, they are “immune” to changes due to dilution with water, as are $VOC_{regulatory}$ values.

B. Solvent-Borne Coatings

As with waterborne systems, a number of solventborne coatings were prepared and evaluated, using the methods described earlier. Characteristics of these coatings are shown in Table 13. Detailed formulations for these coatings may be found in Appendix A.

As with the water-based coatings, graphs of hiding VOC and $H_{0.98}$ are shown in Appendix C. As with water-based coatings, plots of $H_{0.98}$ vs. %NVV are linear, for the same reasons as was noted above. However, plots of Hiding VOC vs. %NVV are distinctly non-linear. The Hiding VOC is a complex function of the percent non-volatiles, since the addition of solvent affects the amount of VOC in the coating.

Table 13 - Solvent-Based Coating Characteristics

#	type	solvent	VOC*(reg)	VOC* (actual)	NVV	PVC	TiO_2 (lbs/100 gal)	H_{98} (m^2/L)	VOC H_{98} (g/m^2)	Resin	Extenders
21	flat	solvent	364	364	56	58	250	5.6	64	long oil soya alkyd EPS 6604	neph.syn., $CaCO_3$
22	flat	solvent	370	370	55	60	250	8.4	44	long oil soya alkyd EPS 6604	clay, $CaCO_3$
23	eggshell	solvent	344	344	61	50	250	6.5	53	long oil soya alkyd EPS 6604	neph.syn., $CaCO_3$
24	eggshell	solvent	331	331	58	50	250	8.6	39	long oil soya alkyd EPS 6604	clay, $CaCO_3$
25	eggshell	solvent	247	247	70	49	250	6.7	37	long oil soya alkyd, low VOC EPS 6611	neph.syn., $CaCO_3$
26	semigloss	solvent	331	331	60	40	250	7.5	44	long oil tofa alkyd Beckosol 10-029	none
27	semigloss	solvent	365	365	55	35	250	9.1	40	long oil soya alkyd EPS 6604	none
28	semigloss	solvent	200	200	77	37	250	8.8	23	long oil soya alkyd, low VOC EPS 6611	none
29	gloss	solvent	317	317	59	13	250	8.9	36	long oil soya alkyd EPS 6604 Dextrol OC70	none
30	gloss	solvent	207	207	73	10	250	9.1	23	long oil soya alkyd, low VOC EPS 6611 EPS 6604	none

* VOC values determined by Method 24

IV. Discussion of Results

A. Color

In our color determination of the prepared coatings, each sample was analyzed using a standard D65 illuminant, over the white sealed portion of the Leneta charts on which their hiding power was determined after storing the charts in the dark for three months. The chromatic appearance of each coating was put into the L*a*b* format in which L* is a measure of the lightness of the coating, a* is the measure of green to red, where a positive a* is more red and negative a* is more green, and b* is blue to yellow, where positive b* is more yellow and negative b* is more blue. Low values of a* or b* indicate a lack of color, and high values of L* indicate a very light material. So a white coating will have a high L*, but low a* and b* values. L*a*b* values were compared to those of a theoretical coating with a lightness of 100 (totally reflective) and a*=b*=0 (pure white). Using this theoretical coating as a "standard", values of $\Delta E = [(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{1/2}$ were calculated for each of the thirty formulations. ΔE is a measure of the overall color difference between two samples.

Results from these measurements are included in Table 6 and are represented in graphically in Figure 5.

As a group, the water-based coatings are lighter (higher L*) and significantly less yellow (smaller b*) than the solvent-based coatings, as is shown in the table below. Presumably, this is due to the characteristics of the resin, not the pigment in these coatings. This effect is shown clearly in Figure 5, in which the solvent-based coatings (ARB numbers greater than 20) appear to "cluster" in a "more yellow" region than the water-based coatings. The overall ΔE values for the water-based coatings were also significantly smaller than those for the solvent-based coatings. In general, formulations containing only TiO_2 as pigment were closest in color to the "theoretical" pure white coating, especially for water-based coatings.

	Averages		
	L*	a*	b*
Water-based coatings	97.19	-0.80	1.81
Solvent-based coatings	94.46	-0.57	5.89

As the hiding power of a coating does not depend explicitly on its color the results from the color determinations do not affect either the calculated values of $H_{0.98}$ or the Hiding VOC. They serve merely as an objective, comparative check on the whiteness of the prepared coatings.

B. Gloss

Gloss results for the formulated coatings are shown in Table 7. The gloss values reported for these coatings are generally within the ranges given earlier. Three of the formulations had gloss readings outside their targeted ranges. Formulation ARB 8 (eggshell) is actually more of a semigloss and formulations ARB 26 and ARB 28 (semigloss) are more typical of satins or eggshells. These gloss values do not affect the VOC or hiding values of the coatings, and are merely provided for reference.

C. Water-Based Coatings

As a group, all water based paints were formulated at 34 ±1 percent NVV. The NVV was kept roughly constant, to reflect current practice with water-based coatings sold in California, and to follow manufacturers' recommendations as presented in the formulations used. Thus all water based paints had similar total solids content. The TiO_2 levels ranged from 117 lbs/100 gallons for one of the flats to 275 lbs/100 gallons for some of the semigloss formulations. The amount of TiO_2 in each of the formulated coatings was varied, in accordance with the formulation guidelines. This variation in TiO_2 levels makes hiding comparisons within the group somewhat more difficult. $H_{0.98}$ values ranged from 5.1 (for the flat with the lowest TiO_2 level) to 8.0 for a semigloss with 275 lbs TiO_2/100 gallons. For other coatings in the group, hiding was primarily determined by TiO_2 level and secondarily by opaque polymer level. Opaque polymer acts like a hiding pigment and can replace some of the TiO_2 in a formulation as is evident from the hiding results. The combination of the extenders nepheline syenite and clay produced better hiding than $CaCO_3$ and clay in water based formulations. This is just the opposite of the result found for solvent based coatings. Overall, the water based coatings have lower $H_{0.98}$ values as formulated than the solvent based coatings. However, the solvent based coatings were all formulated at significantly higher NVV levels, as is typical in industrial production.

D. Solvent-Based Coatings

All formulated solvent-based coatings contained 250 lbs TiO_2 per 100 gallons of paint. The use of solvent-based coatings allowed greater flexibility in preparing suitable coatings for investigation, while staying within the target ranges of solids recommended in the formulations. For flats and eggshells, the combination of clay and $CaCO_3$ extenders provided slightly better hiding than nepheline syenite and $CaCO_3$. The semigloss and gloss solvent-based coatings (which contained no extenders) showed the highest $H_{0.98}$ values as formulated of any of the thirty formulations, both solvent based and water based. These coatings had relatively low PVC values. Traditionally, semigloss and gloss solvent based alkyds have been praised for their high hiding ability. This is evident in the results obtained here.

E. Comparison of Coatings by Class

The thirty prepared coatings consisted of four separate classes: flat, eggshell, gloss, and semigloss. Figures 7, 8, 9, and 10 show graphical representations of hiding power as a function of %NVV for coatings in each of these four classes. These figures show that in many cases, a 35% NVV water-based coating hides as well as a 60% NVV solvent-based coating.

To facilitate comparison of coatings from different classes and carriers, three graphs were prepared, showing the hiding power of all the coatings, when expressed on an equivalent %NVV basis. Recall the Kubelka-Munk equations, or the associated graphs of hiding vs. %NVV, may be used to deduce the hiding that would occur from a coating at any value of %NVV. When compared on an equal NVV basis, the water based coatings had higher $H_{0.98}$ values as shown in Figures 11, 12 and 13.

These latter three graphs reveal that for the coatings tested, the water-based coatings hide better than solvent-based coatings, at equivalent %NVV. This is an unexpected result, since the hiding would presume to originate from the characteristics of the hiding pigment(s). The cause for this observation may be found in the more efficient dispersion of the pigment in the water-based carrier. Perhaps the reason for the good hiding associated with solvent based alkyd coatings is their high NVV as formulated as compared to water based coatings. The higher resin/TiO_2 ratio in these coatings may provide better spacing of the TiO_2 and thus higher hiding.

In order to explore if some of these differences in hiding VOC can be explained in terms of varying hiding power, a plot of Hiding VOC for all coatings, adjusted to a hiding power of 9.0 was prepared (Figure 14). It should not be surprising that at constant Hiding power, the solvent-based coatings exhibited higher Hiding VOC values than the water-based coatings.

F. Hiding VOC

Table 14 shows a comparison of three VOC measures: regulatory VOC, Actual VOC, and Hiding VOC. It should be noted that the hiding VOC is the only one of these measures that is performance-based. As such, it reflects the amount of VOC that is likely to be released in a successful consumer application of the coating.

To place these concepts into a practical setting, it may be helpful to consider the following scenario:

Consider a room with dimensions 10 feet x 12 feet, with 8 foot ceiling height. Assume a consumer will paint the walls of this room. Further assume that the "end-point" of this task will be reached when the consumer is satisfied that the walls have been adequately "hidden" by the paint. The area to be covered amounts to 2(10x8) + 2(12x8) = 354 ft2, or 32.9 m^2. The volume of paint required to achieve this depends on the hiding power of the coating, according to the equation: Volume (in liters) = Area/$H_{0.98}$. Once this volume is known, the amount of VOC emissions released during the painting process may be calculated easily.

Table 14 shows the results of these calculations for all the prepared coatings. Note that the volume of coating required varies from about 3 to about 6 liters (dependent on hiding power). For solvent based coatings, total VOC emissions are the same, regardless of which VOC measure is used to calculate them.

For water –based coatings, VOC emissions based on VOC actual are identical to those calculated from hiding VOC ($VOC_{H0.98}$). Note that the VOC emissions calculated from Regulatory VOC are larger (often MUCH larger) than the "real" VOC emissions.

These relationships may be seen more clearly when a series of graphs is prepared from the data in Table 14. The total VOC emissions released during the painting can be calculated from the product of coating volume and actual VOC (grams VOC = L x VOC_{actual}). Figure 15 shows how well each of the three VOC measures correlates with the total VOC emissions. The upper graph of Figure 15 shows a poor correlation between emitted VOC and regulatory VOC. The middle graph shows an improved correlation between emitted VOC and VOC actual, due mostly to the improved correlation for the water-based coatings. The lower graph shows a perfect correlation between grams emitted VOC and hiding VOC for both water-based and solvent-based coatings.

Since one of the major reasons for applying a coating is to hide the substrate, hiding is an important performance factor for any coating. Coatings manufacturers often advertise coatings as being "one-coat". Traditional practice shows this is often not the case, since hiding depends on several factors including resin, amounts of hiding pigments, amounts of non-hiding pigments, and color. A consumer might purchase a white or very lightly tinted coating and a dark highly tinted coating of the same brand from the same manufacturer with identical regulatory VOC levels and find one coat of the white coating hides sufficiently while three coats of the highly tinted coating are required to provide the same level of hiding. Current VOC regulations are based entirely on the VOC content of the coating and are not tied to any performance characteristics. This study has shown it is possible to relate VOC to hiding quantitatively for both waterborne and solventborne white coatings. Similar results should be obtainable for colored coatings.

Figure 7 – Predicted Hiding Power for Flat Coatings

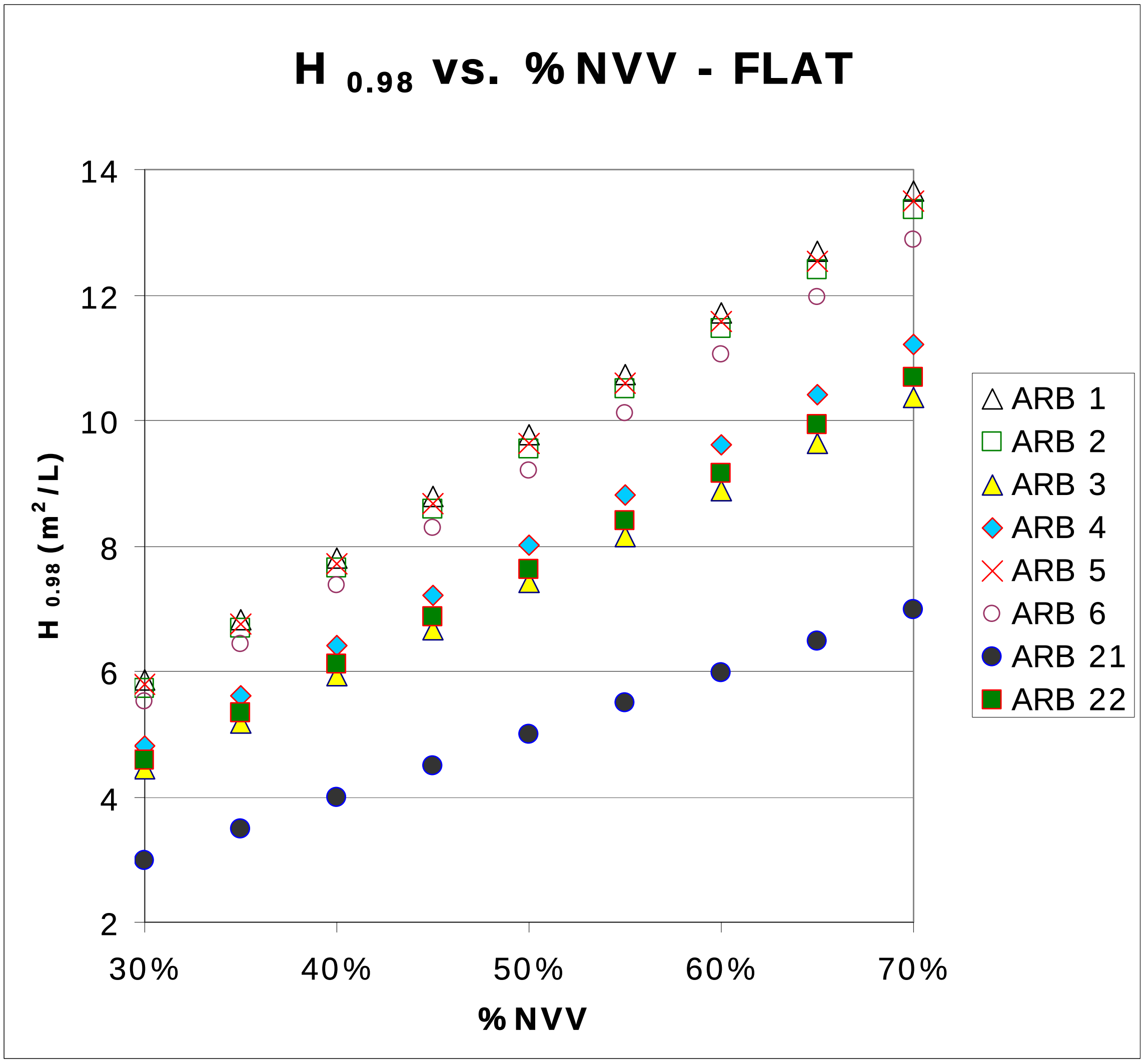


Figure 8 – Predicted Hiding Power for Eggshell Coatings

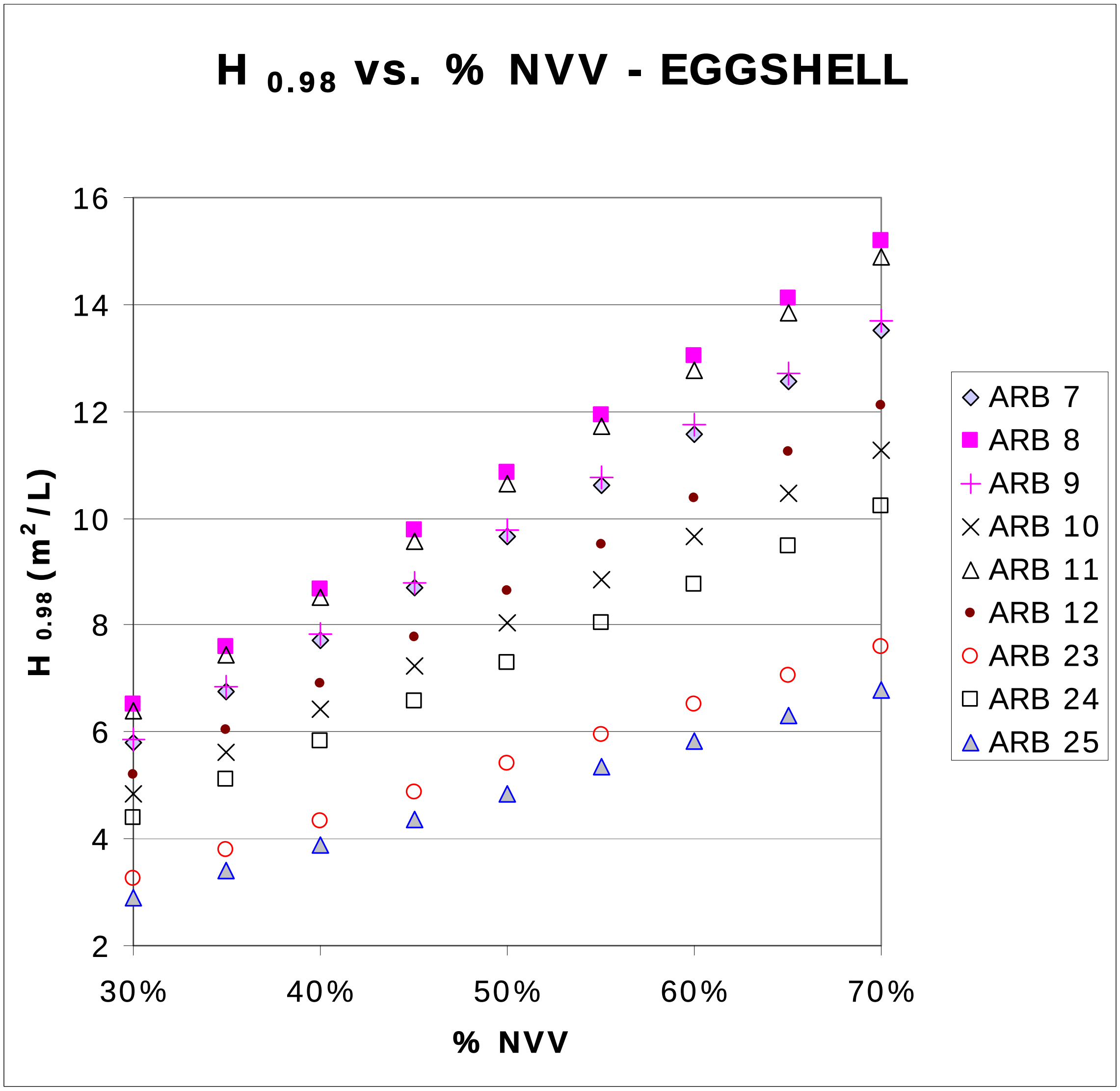


Figure 9 – Predicted Hiding Power for Semigloss Coatings

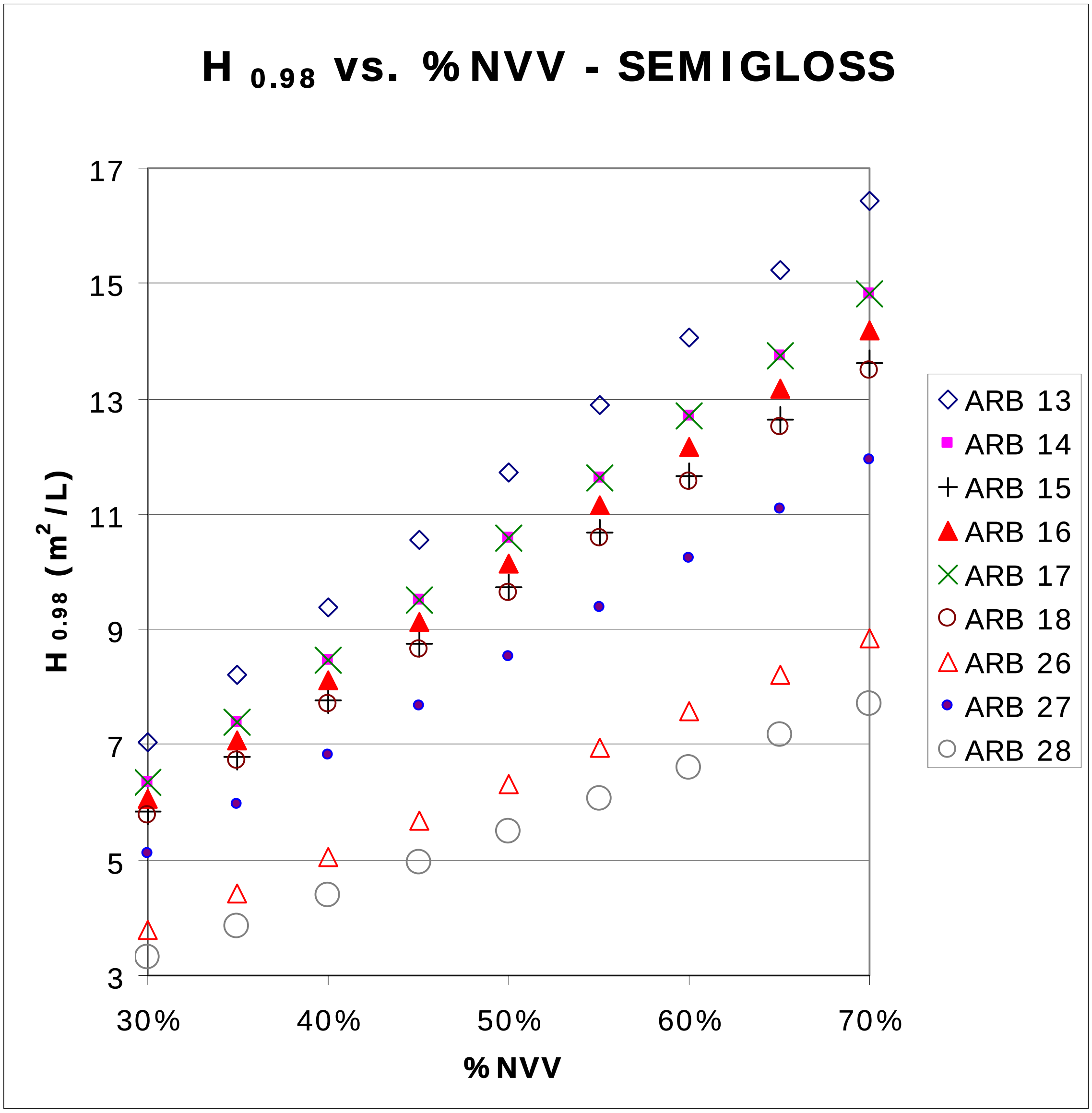


Figure 10 – Predicted Hiding Power for Gloss Coatings

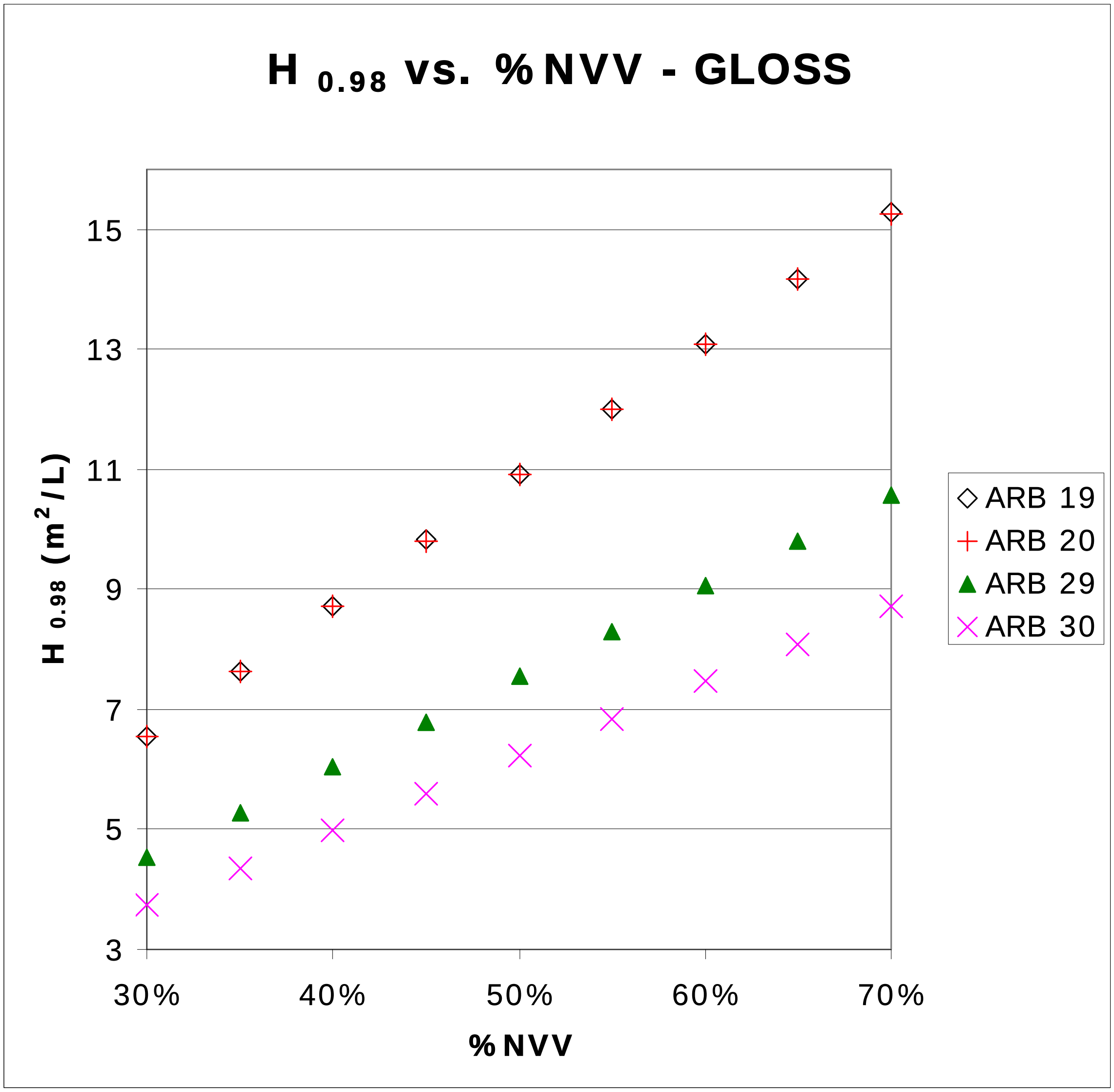


Figure 11 – Predicted Hiding Power for all coatings, at hypothetical 35% Solids

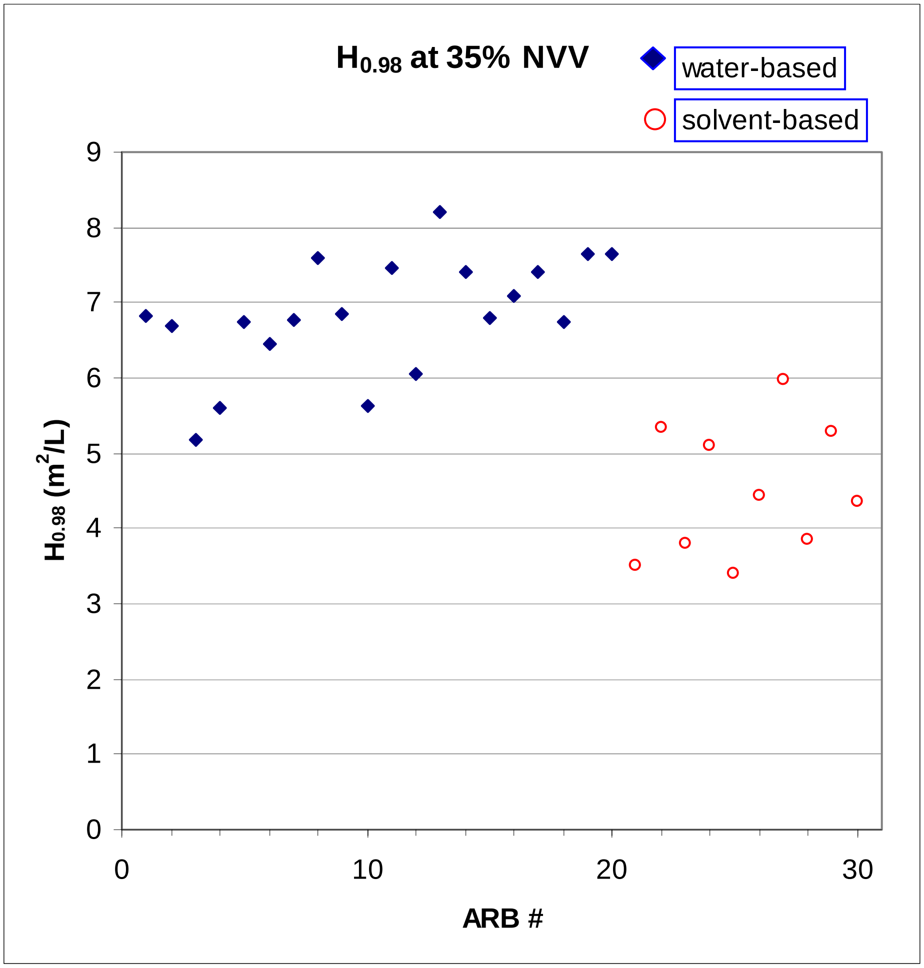


Figure 12 – Predicted Hiding Power for all coatings, at hypothetical 50% Solids

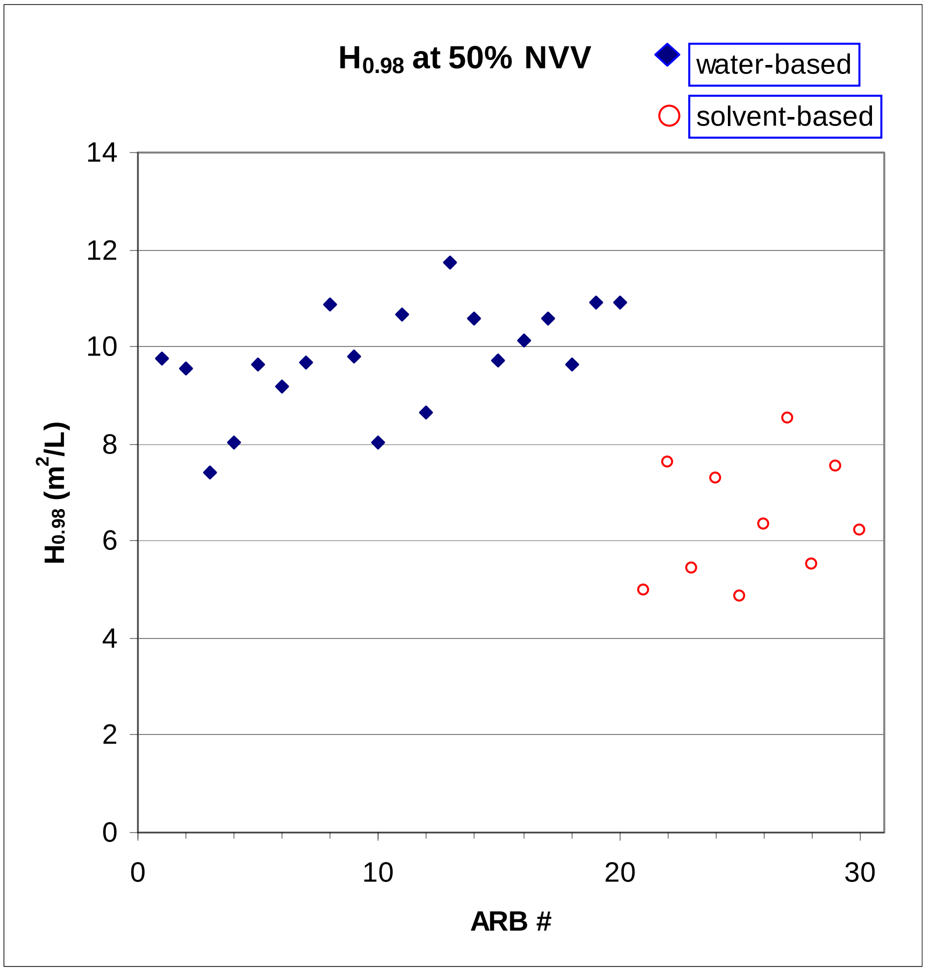


Figure 13 – Predicted Hiding Power for all coatings, at hypothetical 65% Solids

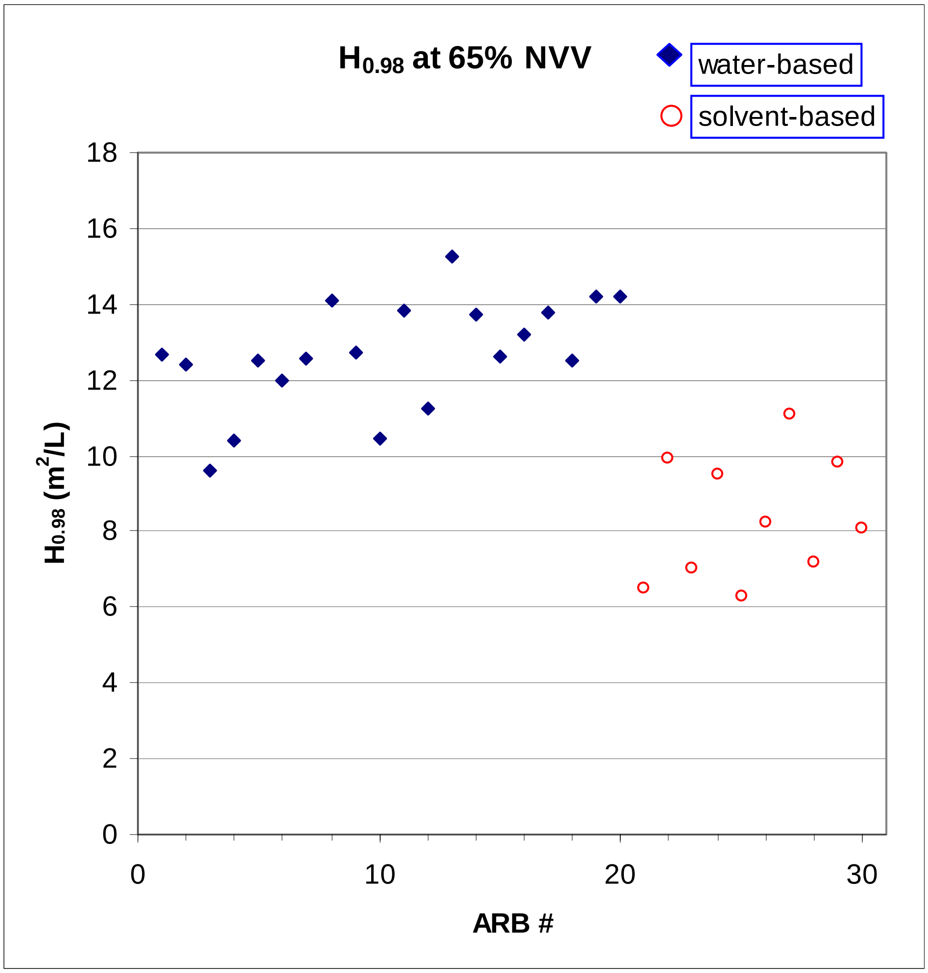


Figure 14 –Hiding VOC for All Coatings, Adjusted to Common Hiding Power of 9.0

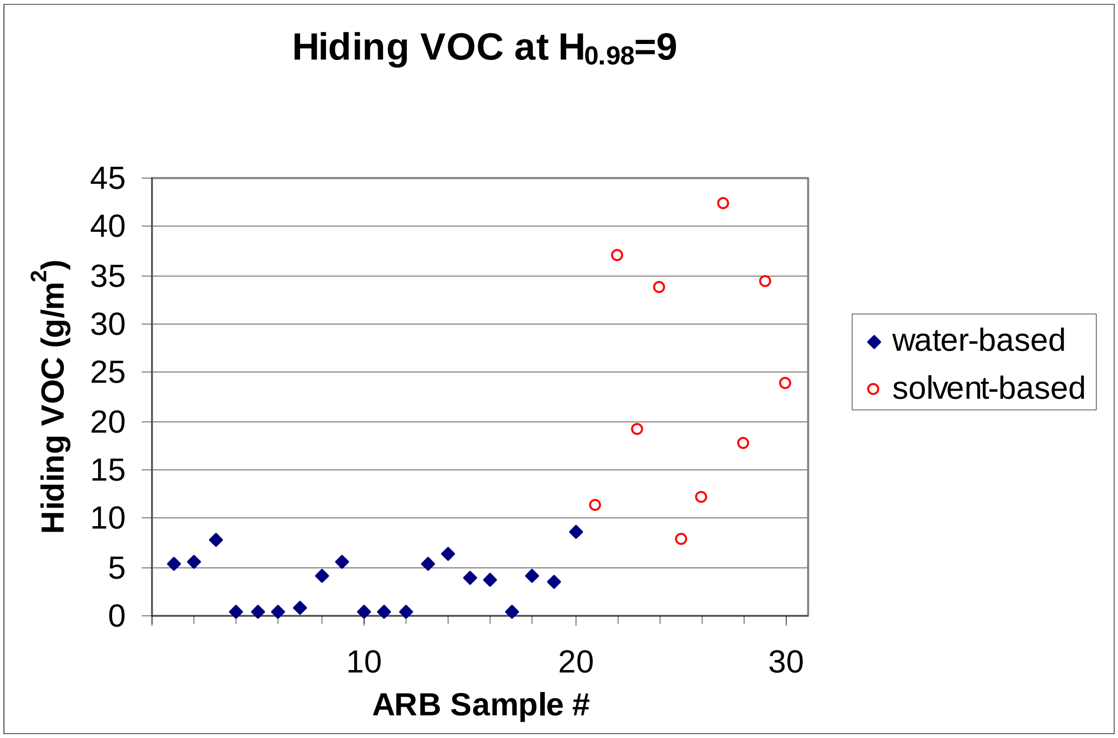
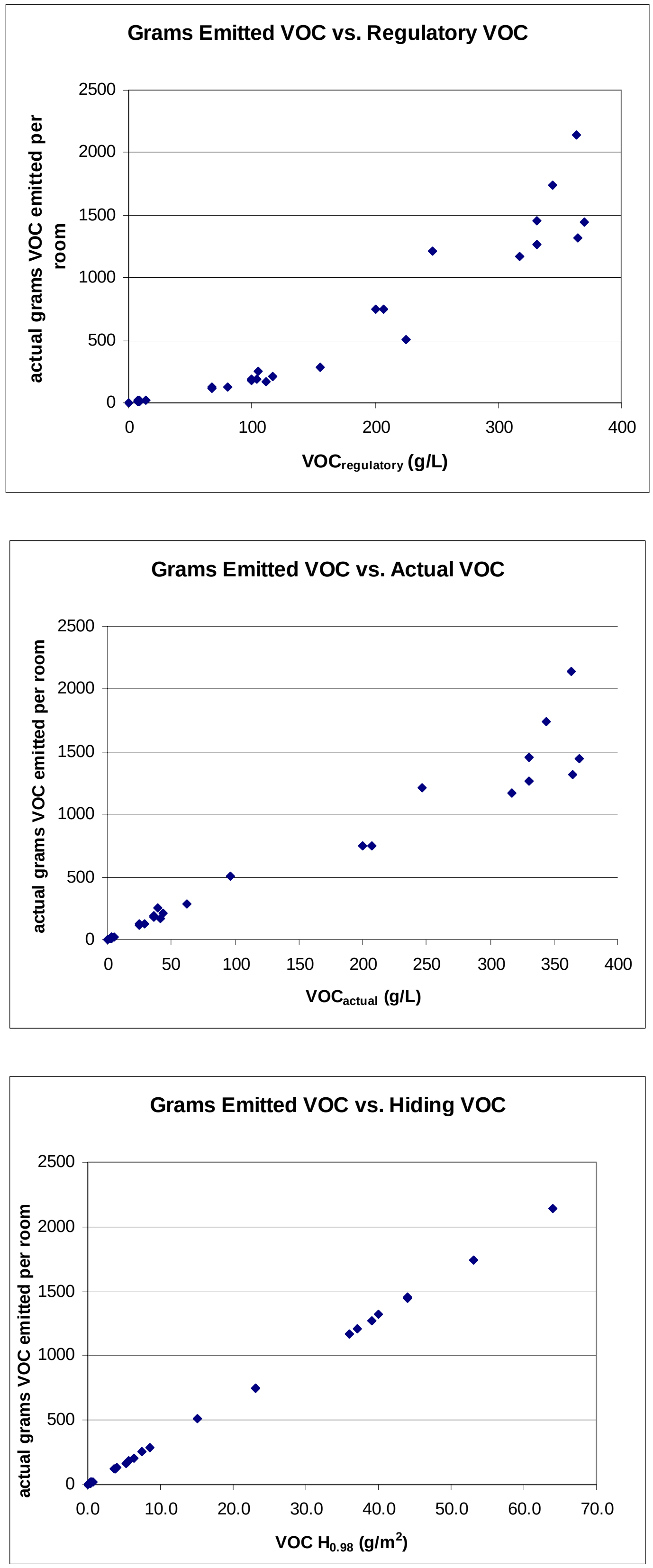


Table 14 - Comparison of VOC Measures

ARB #	type	solvent	$H_{0.98}$ m²/L	VOC Measures VOC_{reg} g/L	VOC_{actual} g/L	$VOCH_{0.98}$ g/m²	liters to hide* 32.9 m²	VOC Emissions (grams) based on VOC_{reg}	VOC_{actual}	$VOCH_{0.98}$
1	flat	water	6.4	100	36	5.6	5.14	514	**185**	185
2	flat	water	6.7	100	36	5.4	4.91	491	**177**	177
3	flat	water	5.1	105	39	7.6	6.45	677	**252**	252
4	flat	water	5.7	7.9	3	0.5	5.77	46	**17**	17
5	flat	water	6.7	8.1	3	0.4	4.91	40	**15**	15
6	flat	water	6.3	7.8	3	0.5	5.22	41	**16**	16
7	eggshell	water	6.6	14	5	0.8	4.98	70	**25**	25
8	eggshell	water	7.3	80	29	4.0	4.51	361	**131**	131
9	eggshell	water	6.4	104	36	5.6	5.14	535	**185**	185
10	eggshell	water	5.4	8.2	3	0.6	6.09	50	**18**	18
11	eggshell	water	6.9	8.8	3	0.4	4.77	42	**14**	14
12	eggshell	water	6.4	8.4	3	0.5	5.14	43	**15**	15
13	semigloss	water	8	112	41	5.1	4.11	461	**169**	169
14	semigloss	water	6.9	117	44	6.4	4.77	558	**210**	210
15	semigloss	water	6.5	68	25	3.8	5.06	344	**127**	127
16	semigloss	water	6.8	68	25	3.7	4.84	329	**121**	121
17	semigloss	water	7.3	7.2	2	0.3	4.51	32	**9**	9
18	semigloss	water	6.2	225	96	15.5	5.31	1194	**509**	509
19	gloss	water	7.2	0	0	0.0	4.57	0	**0**	0
20	gloss	water	7.2	156	62	8.6	4.57	713	**283**	283
21	flat	solvent	5.6	364	364	65.0	5.88	2139	**2139**	2139
22	flat	solvent	8.4	370	370	44.0	3.92	1449	**1449**	1449
23	eggshell	solvent	6.5	344	344	52.9	5.06	1741	**1741**	1741
24	eggshell	solvent	8.6	331	331	38.5	3.83	1266	**1266**	1266
25	eggshell	solvent	6.7	247	247	36.9	4.91	1213	**1213**	1213
26	semigloss	solvent	7.5	331	331	44.1	4.39	1452	**1452**	1452
27	semigloss	solvent	9.1	365	365	40.1	3.62	1320	**1320**	1320
28	semigloss	solvent	8.8	200	200	22.7	3.74	748	**748**	748
29	gloss	solvent	8.9	317	317	35.6	3.70	1172	**1172**	1172
30	gloss	solvent	9.1	207	207	22.7	3.62	748	**748**	748

* 10' x 12' room, 8 ' ceiling = 354 ft² = 32.9 m²

Figure 15 –Correlation between Grams Emitted VOC (per 354 ft^2) and Various VOC Measures



V. Conclusions

This study involved the use of an ASTM method (D2805) to study the effect of pigment and resin on the hiding ability of formulated architectural coatings. One of the key questions this project addressed was stated on page 7 of this report:

Do equal volumes of paint solids obtained from different paints, give the same hiding power, when applied to surfaces of equal area, regardless of the carrier from which the solids were deposited?

A number of sub-questions were formulated under this general query:

1. Were it possible to prepare solvent-based and water-based coatings at the same percent NVV resulting in identical films, would these coatings have identical hiding powers?
2. If solvent-based and water-based coatings at the same percent NVV were prepared with different resins and pigments, would these coatings have identical hiding powers?
3. Does a smaller volume of one type of coating (e.g. solvent-based) generally provide better hiding than a larger volume of another type of coating (e.g. water-based) and thus some sort of VOC savings?

These issues were resolved by the work described in this study. Specifically:

1. The use of the Kubelka-Munk equations permitted the comparison of water-based and solvent-based coatings at the same volume percent solids to be made. At equivalent %NVV (percent non-volatile by volume), water-based coatings provided better hiding power (as measured objectively) than solvent-based coatings for all gloss categories.
2. A series of coatings formulated with different resin and pigment, adjusted to a common %NVV were shown to not have identical hiding powers. This refutes the oft-stated maxim that "%NVV dictates the hiding power of a coating". The percent solids of a coating is one of the factors that determines its hiding ability, but it is not the only factor.
3. A smaller volume of a solvent-based paint does not necessarily hide better than a larger volume of a water-based paint. In many cases, a 35% NVV water-based coating was shown to hide as well as a 60% NVV solvent-based coating

Additional major findings of the study included:

- Demonstrated the reliability and reproducibility of ASTM Method D2805 to determine the hiding power of coatings
    - Hiding, $H_{0.98}$ defined as area of hiding film produced by 1 liter of coating (units of m^2/L)
    - Hiding film is one that produces a contrast ratio of 0.98, when applied over suitable black and white substrates.
- Verified the ability of the Kubelka-Munk equations to predict hiding power in a family of coatings with varying percent non volatile volume content
    - Within a family of coatings, hiding is directly proportional to %NVV
- Demonstrated the differences in hiding power of different paints with equal volumes of solids when applied to surfaces of equal area
    - Among coatings with the same carrier, hiding depends on both the %NVV and the nature of the solids (pigment plus resin)
    - Across carriers (e.g., comparing water-borne and solvent-borne coatings), hiding is not consistently related to only %NVV, but also depends on the nature of the solids (pigment plus resin)

- for both solvent based and water based paints the nature of the pigments affects the hiding power as demonstrated by the differing slopes of the hiding power versus percent NVV plots
- in general, water based paints hide better than solvent based paints at the same percent NVV
- higher solids content does not necessarily equate to better hiding

- Introduced and developed a proposed new measure to describe VOC content of coatings
    - hiding VOC, VOC $H_{0.98}$ defined as the grams of VOC associated with the production of 1 square meter of a "hiding film" (units of grams/m^2)
    - hiding VOC calculated from relationship: $hiding\ VOC = \frac{actual\ VOC}{H_{0.98}}$
    - this is a performance-based measure, which determines the amount of VOC emissions likely to result from the application of the coating
    - using this measure, a smaller volume of a higher hiding solvent based paint still produces much more VOC than a larger volume of a lower hiding water based paint and thus provides no VOC savings
- Compared the ability of each of three VOC measures to describe VOC emissions from a typical painting application
    - For water-based coatings, regulatory VOC of the coatings is poorly correlated with actual VOC emissions
    - For water-based coatings, actual VOC of the coatings is more closely correlated with actual VOC emissions
    - For solvent-based coatings, neither actual nor regulatory VOC of the coatings correlate well with actual VOC emissions
    - For both classes of coatings, hiding VOC is the only measure that correlates perfectly with VOC emissions in real applications
- The suitability of VOC regulatory was called into question
    - Since the basis of VOC regulatory was that a consistent relationship between solids and hiding (or coverage) existed, and this relationship was found to be absent in this study, VOC regulatory does not appear to be the ideal measure for the type of architectural coatings investigated

As the results in Table 14 (and the associated graphs in Figure 15) show, existing measures of the VOC content of liquid coatings, VOC Regulatory and VOC Actual, do not provide reliable estimates for VOC emissions that result from the application of the coatings. There are two factors that contribute to the amount of VOC emissions from a coating. The first of these is, of course, the VOC content in the liquid coating itself. The second, often ignored, factor is the volume of liquid coating that will be used for a particular application. This is related to the ability of the coating to hide (not simply "cover") the substrate to which it is applied. The volume of liquid coating used for a particular application is thus tied to the hiding power of the coating. Coatings with higher hiding power will require less volume to hide a substrate than coatings with poorer hiding power. Neither VOC regulatory nor VOC actual address the amount of coating that will be used in an application. Hence, neither of these two measures can be used to adequately describe the magnitude of VOC emissions arising from the use of coatings. The figure of merit described in this study, Hiding VOC, is the only measure that is directly related to the amount of emissions produced by the application of the coating. The basis for the VOC regulatory calculation, that the volume of solids dictates hiding, seems to be not supported by this study. In general, comparable levels of solids do not necessarily provide identical hiding for coatings formulated within the same carrier type or in different carriers.

The predictive use of the Kubelka-Munk equations (on which ASTM Method D2805 is based) represented another novel aspect of this work. In order to address the question of whether identical dried paint films offer identical hiding powers, a series of coatings with varying percent solids volume would need to be prepared, in both water and solvent-borne systems. Based on physico-chemical properties of the resins systems, truly identical coatings could not be prepared both in water- and solvent-based formulations. Further, coatings in both solvent systems differ widely in percent solids content.

In water-based architectural coatings sold in California, the %non-volatile (by volume) averages to around 33-34%. The percent NVV is much higher in solvent-based systems, with values of 40%, 50%, or even higher being typical. It would be difficult to prepare formulations of water-based coatings with %NVV in this range, so comparability of coatings with different percent NVV represented a challenge. To address this, each coating investigated was presumed to represent one member (the "parent") of a coating family. Individual family members differed in %NVV. By studying the hiding power of the dried film produced by the parent coating, application of the Kubelka-Munk equations allowed the hiding power of other related coatings to be determined. In this manner, all coatings could be compared on the same percent NVV. Based on the results of this study, comparison at any level of NVV is possible.

Figures 11, 12, and 13 show the comparison of hiding power for all coatings, normalized to a percent NVV of 35, 50 and 65%, respectively. At each of these percent NVV, water-based coatings exhibited higher hiding power than solvent-based coatings, at equivalent percent NVV. In general, the best of the solvent-based coatings had hiding powers comparable to the worst of the water-based coatings. This was an unexpected result, since the hiding was presumed to originate from the characteristics of the hiding pigment. These results suggest that the nature of the resin may have some effect on either the final film formation, or effect the dispersion and/or orientation of the pigment particles in the dried film. As discussed earlier, it is not possible to prepare water and solvent-based coatings which have EXACTLY the same pigment/resin combination. Within a given solvent system, hiding is dependent on the nature of the solids, as well as the percent solids by volume (%NVV). When compared on an equal percent NVV basis, hiding is still dependent on the nature of the pigment and resin.

This project was not undertaken for the purpose of providing a new regulatory measure for the VOC content of architectural coatings. It was based on exploring the phenomenon of hiding power, based on the premise that this was an important aspect of coatings, which has not received as much attention as the more obvious VOC content of the coatings. It certainly offers a new way to think about improving coatings that is performance-based, not based on simply reducing the VOC content of the coating. Enhancing the hiding power of a coating will automatically lower the hiding VOC levels, without necessarily changing the actual (or regulatory) VOC. Total emissions for the coating could be reduced without reducing the VOC content of the coating. It is hoped that this project sparks interest in further use of the Hiding VOC concept.

Appendix A – Formulations

Paint Test Formula:		ARB1						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	166.70	20.01	0.00	0.00		20.01
100	19.70	Attagel 50	7.00	0.36	7.00	0.36		0.00
34.6	10.20	Tamol 1254	10.22	1.00	3.54	0.20	0.00	0.80
100	8.84	Triton CF-10	2.21	0.25	2.21	0.25		0.00
0	8.64	Propylene glycol	20.41	2.36	0.00	0.00	20.41	0.00
4.5	8.33	Kathon LX 1.5%	1.50	0.18	0.07	0.01		0.17
100	7.77	Drew L-475	2.00	0.26	2.00	0.26		0.00
0	7.85	AMP-95	2.00	0.25	0.00	0.00	2.00	0.00
100	33.33	Ti Pure R-900	185	5.55	185.00	5.55		0.00
100	22.60	Vicron 15-15	79.90	3.54	79.90	3.54		0.00
100	21.50	ASP NC	37.20	1.73	37.20	1.73		0.00
100	21.50	ASP Ultrafine	69.10	3.21	69.10	3.21		
Grind Total			583.24	38.70	386.01	15.10	22.41	23.60
Pigment Total					378.20	14.39		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	583.24	38.70	378.20	14.39	22.41	23.60
100	7.77	Drew L-475	2.00	0.26	2.00	0.26		0.00
55	9.05	EPS 2911	340.00	37.57	187.00	19.20	0.00	18.37
0	7.92	Texanol	7.66	0.97	0.00	0.00	7.66	0.00
64	8.70	Triton GR7M	1.00	0.11	0.64	0.07	0.36	
0	8.33	Water	175.00	21.01	0.00	0.00	0.00	21.01
30	8.80	Acrysol DR3(premix w eq/.H2O)	20.00	2.27	6.00	0.59	0.00	1.59
TOTAL			1128.90	100.89	573.84	34.51	30.43	64.57
Paint properties					**VOC**			
Weight per gallon		11.189			Lbs/gal		0.3016	
% NV by weight		50.83			Lbs/gal-water		0.8378	
% NV by volume		34.20			Grams /L*		36.14	
PVC		41.69			Grams/L-water*		100.39	

Paint Test Formula:		ARB2						
GRIND :								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	166.70	20.01	0.00	0.00		20.01
100	19.70	Attagel 50	7.00	0.36	7.00	0.36		0.00
34.6	10.20	Tamol 1254	10.22	1.00	3.54	0.20	0.00	0.80
100	8.84	Triton CF-10	2.21	0.25	2.21	0.25		0.00
0	8.64	Propylene glycol	20.41	2.36	0.00	0.00	20.41	0.00
4.5	8.33	Kathon LX 1.5%	1.50	0.18	0.07	0.01		0.17
100	7.77	Drew L-475	2.00	0.26	2.00	0.26		0.00
0	7.85	AMP-95	2.00	0.25	0.00	0.00	2.00	0.00
100	33.33	Ti Pure R-900	185	5.55	185.00	5.55		0.00
100	21.70	Minex 4	77.00	3.55	77.00	3.55		0.00
100	21.50	ASP NC	37.20	1.73	37.20	1.73		0.00
100	21.50	ASP Ultrafine	69.10	3.21	69.10	3.21		
Grind Total			580.34	38.72	383.11	15.11	22.41	23.60
Pigment Total					375.30	14.40		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	580.34	38.72	375.30	14.40	22.41	23.60
100	7.77	Drew L-475	2.00	0.26	2.00	0.26		0.00
55	9.05	EPS 2911	340.00	37.57	187.00	19.20	0.00	18.37
0	7.92	Texanol	7.66	0.97	0.00	0.00	7.66	0.00
64	8.70	Triton GR7M	1.00	0.11	0.64	0.07	0.36	
0	8.33	Water	175.00	21.01	0.00	0.00	0.00	21.01
30	8.80	Acrysol DR3(premix w eq/.H2O)	20.00	2.27	6.00	0.59	0.00	1.59
TOTAL			1126.00	100.91	570.94	34.52	30.43	64.57
Paint properties					**VOC**			
Weight per gallon		11.159			Lbs/gal		0.3016	
% NV by weight		50.71			Lbs/gal-water		0.8375	
% NV by volume		34.21			Grams/ L*		36.14	
PVC		41.71			Grams/L-water*		100.36	

Paint Test Formula:		ARB3							
GRIND :									
			Formula		Non-Volatile				
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal	
0	8.33	Water	117.38	14.09	0.00	0.00		14.09	
0	8.64	Propylene glycol	20.41	2.36	0.00	0.00	20.41	0.00	
0	7.85	AMP-95	2.04	0.26	0.00	0.00	2.04	0.00	
100	7.77	Drew L-475	2.04	0.26	2.04	0.26		0.00	
4.5	8.33	Kathon LX 1.5%	1.53	0.18	0.07	0.01		0.18	
30	9.92	Tamol 850	7.35	0.74	2.20	0.22		0.52	
100	33.33	Ti Pure R-900	117.38	3.52	117.38	3.52		0.00	
100	18.35	Optiwhite	112.28	6.12	112.28	6.12		0.00	
100	22.50	Duramite	54.10	2.40	54.10	2.40		0	
Grind Total			434.52	29.95	288.08	12.54	22.46	14.79	
Pigment Total			117.38	3.52	294.66	13.24			
LETDOWN:									
			Formula		Non-Volatile				
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal	
		Grind	434.52	29.95	288.08	12.54	22.46	14.79	
0	8.33	Water	219.45	26.35	0.00	0.00	0.00	26.35	
55	9.05	EPS 2911	328.67	36.32	180.77	18.56	0.00	17.76	
0	7.92	Texanol	7.66	0.97	0.00	0.00	7.66	0.00	
100	7.77	Drew L-475	2.04	0.26	2.04	0.26	0.00	0.00	
30.5	8.55	OP 96	35.73	4.18	10.90	1.20	0.00	2.98	
0	7.85	AMP-95	2.04	0.26	0.00	0.00	2.04	0.00	
30	8.88	Acrysol TT-935	15.31	1.72	4.59	0.44		1.29	
TOTAL			1045.42	100.00	486.38	33.00	32.15	63.15	
Paint properties					**VOC**				
Weight per gallon		10.45			Lbs/gal		0.3215		
% NV by weight		46.52			Lbs/gal-water		0.8726		
% NV by volume		33.00			Grams/L*		38.53		
PVC		40.13			Grams/L-water*		104.56		

Paint Test Formula:		ARB4						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	166.70	20.01	0.00	0.00		20.01
100	19.70	Attagel 50	7.00	0.36	7.00	0.36		0.00
34.6	10.20	Tamol 1254	10.22	1.00	3.54	0.20	0.00	0.80
100	8.84	Triton CF-10	2.21	0.25	2.21	0.25		0.00
4.5	8.33	Kathon LX 1.5%	1.50	0.18	0.07	0.01		0.17
25	7.69	Tego Foamex 8030	2.00	0.26	0.50	0.08	0.00	0.18
0	7.85	AMP-95	2.00	0.25	0.00	0.00	2.00	0.00
100	33.33	Ti Pure R-900	185	5.55	185.00	5.55		0.00
100	22.60	Vicron 15-15	79.90	3.54	79.90	3.54		0.00
100	21.70	Polygloss 90	37.20	1.71	37.20	1.71		0.00
100	21.50	ASP Ultrafine	69.10	3.21	69.10	3.21		
Grind Total			562.83	36.33	384.51	14.91	2.00	21.42
Pigment Total					378.20	14.37		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	562.83	36.33	378.20	14.37	2.00	21.42
25	7.69	Tego Foamex 8030	2.00	0.26	0.50	0.08	0.00	0.18
64	9.02	Duravace FT-320	284.10	31.50	181.82	19.22	0.00	12.28
64	8.70	Triton GR7M	1.00	0.11	0.64	0.07	0.36	
0	8.33	Water	228.00	27.37	0.00	0.00	0.00	27.37
21.5	8.70	Acrysol RM8W	38.90	4.47	8.36	0.81	0.00	3.13
TOTAL			1116.83	100.04	569.53	34.55	2.36	64.38
Paint properties					**VOC**			
Weight per gallon		11.164			Lbs/gal		0.0236	
% NV by weight		51.00			Lbs/gal-water		0.0662	
% NV by volume		34.53			Grams/ L*		2.83	
PVC		41.60			Grams/L-water*		7.93	

Paint Test Formula:		ARB5							
GRIND:									
			Formula		Non-Volatile				
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal	
0	8.33	Water	166.70	20.01	0.00	0.00		20.01	
100	19.70	Attagel 50	7.00	0.36	7.00	0.36		0.00	
34.6	10.20	Tamol 1254	10.22	1.00	3.54	0.20	0.00	0.80	
100	8.84	Triton CF-10	2.21	0.25	2.21	0.25		0.00	
4.5	8.33	Kathon LX 1.5%	1.50	0.18	0.07	0.01		0.17	
25	7.69	Tego Foamex 8030	2.00	0.26	0.50	0.08	0.00	0.18	
0	7.85	AMP-95	2.00	0.25	0.00	0.00	2.00	0.00	
100	33.33	Ti Pure R-900	185	5.55	185.00	5.55		0.00	
100	21.70	Minex 4	77.00	3.55	77.00	3.55		0.00	
100	21.70	Polygloss 90	37.20	1.71	37.20	1.71		0.00	
100	21.50	ASP Ultrafine	69.10	3.21	69.10	3.21			
Grind Total			559.93	36.34	381.61	14.92	2.00	21.42	
Pigment Total					375.30	14.38			
LETDOWN:									
			Formula		Non-Volatile				
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal	
		Grind	559.93	36.34	375.30	14.38	2.00	21.42	
25	7.69	Tego Foamex 8030	2.00	0.26	0.50	0.08	0.00	0.18	
64	9.02	Duravace FT-320	284.10	31.50	181.82	19.22	0.00	12.28	
64	8.70	Triton GR7M	1.00	0.11	0.64	0.07	0.36		
0	8.33	Water	246.00	29.53	0.00	0.00	0.00	29.53	
30	8.80	Acrysol DR3(premix w eq/.H2O)	20.00	2.27	6.00	0.59	0.00	1.59	
TOTAL			1113.03	100.02	564.26	34.34	2.36	65.00	
Paint properties					**VOC**				
Weight per gallon		11.128			Lbs/gal		0.0236		
% NV by weight		50.70			Lbs/gal-water		0.0674		
% NV by volume		34.34			Grams/L*		2.83		
PVC		41.88			Grams/L-water*		8.08		

Paint Test Formula:		ARB6						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	166.70	20.01	0.00	0.00		20.01
100	19.70	Attagel 50	7.00	0.36	7.00	0.36		0.00
34.6	10.20	Tamol 1254	10.22	1.00	3.54	0.20	0.00	0.80
100	8.84	Triton CF-10	2.21	0.25	2.21	0.25		0.00
4.5	8.33	Kathon LX 1.5%	1.50	0.18	0.07	0.01		0.17
25	7.69	Tego Foamex 8030	2.00	0.26	0.50	0.08	0.00	0.18
0	7.85	AMP-95	2.00	0.25	0.00	0.00	2.00	0.00
100	33.33	Ti Pure R-900	157.25	4.72	157.25	4.72		0.00
100	22.60	Vicron 15-15	0.00	0.00	0.00	0.00		0.00
100	21.70	Polygloss 90	122.00	5.62	122.00	5.62		0.00
100	21.50	ASP Ultrafine	69.10	3.21	69.10	3.21		
Grind Total			539.98	35.87	361.66	14.45	2.00	21.42
Pigment Total					355.35	15.59		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	539.98	35.87	355.35	15.59	2.00	21.42
25	7.69	Tego Foamex 8030	2.00	0.26	0.50	0.08	0.00	0.18
64	9.02	Duravace FT-320	284.10	31.50	181.82	19.22	0.00	12.28
30.5	8.55	Ropaque OP-96	50.00	5.85	15.25	1.68	0.00	4.17
64	8.70	Triton GR7M	1.00	0.11	0.64	0.07	0.36	
0	8.33	Water	271.00	32.53	0.00	0.00	0.00	32.53
30	8.80	Acrysol DR3	20.00	2.27	6.00	0.59	0.00	1.59
TOTAL			1168.08	108.39	559.56	37.22	2.36	72.18
Paint properties					**VOC**			
Weight per gallon		10.776			Lbs/gal		0.0218	
% NV by weight		47.90			Lbs/gal-water		0.0652	
% NV by volume		34.34			Grams/L*		2.61	
PVC		41.87			Grams/L-water*		7.81	

Paint Test Formula:		ARB7						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/ Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	106.42	12.78	0.00	0.00		12.78
34.6	10.20	Tamol 1254	10.88	1.07	3.76	0.21	0.00	0.85
100	8.84	Triton CF-10	2.35	0.27	2.35	0.27		0.00
4.5	8.33	Kathon LX 1.5%	1.60	0.19	0.07	0.01		0.18
25	7.69	Tego Foamex 8030	1.06	0.14	0.27	0.04	0.00	0.10
0	7.85	AMP-95	2.13	0.27	0.00	0.00	2.13	0.00
100	33.33	Ti Pure R-900	212.84	6.39	212.84	6.39		0.00
100	23.30	Nicron 503	42.57	1.83	42.57	1.83		0.00
100	21.70	Minex 4	47.89	2.21	47.89	2.21		
Grind Total			427.73	25.13	309.75	10.95	2.13	13.91
Pigment Total					322.77	12.56		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/ Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	455.19	25.13	309.75	10.95	2.13	13.91
25	7.69	Tego Foamex 8030	2.13	0.28	0.53	0.09	0.00	0.19
30.5	8.55	Ropaque OP-96	63.85	7.47	19.47	2.14	0.00	5.33
55	8.98	Rovace 9900	333.63	37.15	183.49	19.13	0.00	18.02
0	8.33	Water	228.80	27.47	0.00	0.00	0.00	27.47
30	8.80	Acrysol DR3	19.95	2.27	5.99	0.59	0.00	1.59
0	7.85	AMP-95	1.86	0.24	0.00	0.01	1.86	0.00
TOTAL			1105.42	100.00	519.24	32.91	3.99	66.51
Paint properties					**VOC**			
Weight per gallon		11.054			Lbs/gal		0.0399	
% NV by weight		46.97			Lbs/gal-water		0.1192	
% NV by volume		32.91			Grams/L*		4.78	
PVC		38.17			Grams/L-water*		14.28	

Paint Test Formula:		ARB8						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/ Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	210.00	25.21	0.00	0.00		25.21
34.6	10.20	Tamol 1254	11.85	1.16	4.10	0.23	0.00	0.93
100	8.84	Triton CF-10	2.56	0.29	2.56	0.29		0.00
4.5	8.33	Kathon LX 1.5%	1.74	0.21	0.08	0.01		0.20
25	7.69	Tego Foamex 8030	1.16	0.15	0.29	0.05	0.00	0.10
0	8.64	Propylene glycol	10.00	1.16	0.00	0.00	10.00	0.00
0	7.85	AMP-95	2.32	0.30	0.00	0.00	2.32	0.00
100	33.33	Ti Pure R-900	190.00	5.70	190.00	5.70		0.00
100	21.50	ASP NC	21.80	1.01	21.80	1.01		0.00
100	21.50	ASP Ultrafine	49.05	2.28	49.05	2.28		
Grind Total			427.73	37.47	267.88	9.57	12.32	26.44
Pigment Total					280.67	11.17		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/ Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	455.19	37.47	267.88	9.57	12.32	26.44
25	7.69	Tego Foamex 8030	2.32	0.30	0.58	0.09	0.00	0.21
0	7.92	Texanol	10.00	1.26	0.00	0.00	10.00	0.00
30.5	8.55	Ropaque OP-96	65.00	7.60	19.83	2.18	0.00	5.42
55	8.98	Rovace 9900	365.12	40.66	200.82	20.94	0.00	19.72
0	8.33	Water	85.00	10.20	0.00	0.00	0.00	10.20
30	8.80	Acrysol DR3	21.75	2.47	6.52	0.64	0.00	1.73
0	7.85	AMP-95	2.03	0.26	0.00	0.01	2.03	0.00
TOTAL			1006.41	100.23	495.62	33.44	24.35	63.74
Paint properties					**VOC**			
Weight per gallon		10.041			Lbs/gal		0.2429	
% NV by weight		49.25			Lbs/gal-water		0.6672	
% NV by volume		33.36			Grams/L*		29.11	
PVC		33.42			Grams/L-water*		79.95	

Paint Test Formula:		ARB9						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	155.00	18.61	0.00	0.00		18.61
100	19.70	Attagel 50	7.00	0.36	7.00	0.36		0.00
34.6	10.20	Tamol 1254	10.00	0.98	3.46	0.20	0.00	0.79
100	8.84	Triton CF-10	2.20	0.25	2.20	0.25		0.00
0	8.64	Propylene glycol	20.00	2.31	0.00	0.00	20.00	0.00
4.5	8.33	Kathon LX 1.5%	1.50	0.18	0.07	0.01		0.17
100	7.77	Drew L-475	2.00	0.26	2.00	0.26		0.00
0	7.85	AMP-95	2.00	0.25	0.00	0.00	2.00	0.00
100	33.33	Ti Pure R-900	200	6.00	200.00	6.00		0.00
100	21.70	Minex 4	50.00	2.30	50.00	2.30		0.00
100	21.50	ASP NC	27.00	1.26	27.00	1.26		0.00
100	21.50	ASP Ultrafine	23.00	1.07	23.00	1.07		
Grind Total			499.70	33.83	314.73	11.70	22.00	22.13
Pigment Total					307.00	10.99		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	499.70	33.83	307.00	10.99	22.00	22.13
100	7.77	Drew L-475	2.00	0.26	2.00	0.26		0.00
55	9.05	EPS 2911	375.00	41.44	206.25	21.18	0.00	20.26
0	7.92	Texanol	8.00	1.01	0.00	0.00	8.00	0.00
64	8.70	Triton GR7M	1.00	0.11	0.64	0.07	0.36	
0	8.33	Water	175.00	21.01	0.00	0.00	0.00	21.01
30	8.80	Acrysol DR3	20.00	2.27	6.00	0.59	0.00	1.59
TOTAL			1080.70	99.93	521.89	33.09	30.36	64.99
Paint properties					**VOC**			
Weight per gallon		10.815			Lbs/gal		0.3038	
% NV by weight		48.29			Lbs/gal-water		0.8690	
% NV by volume		33.11			Grams/L*		36.41	
PVC		33.20			Grams/L-water*		104.13	

Paint Test Formula:		ARB10						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	248.05	29.78	0.00	0.00		29.78
100	19.70	Attagel 50	7.00	0.36	7.00	0.36		0.00
34.6	10.20	Tamol 1254	9.73	0.95	3.37	0.19	0.00	0.76
100	8.84	Triton CF-10	2.14	0.24	2.14	0.24		0.00
4.5	8.33	Kathon LX 1.5%	1.46	0.18	0.07	0.01		0.17
25	7.69	Tego Foamex 8030	1.95	0.25	0.49	0.08	0.00	0.18
0	7.85	AMP-95	1.95	0.25	0.00	0.00	1.95	0.00
100	33.33	Ti Pure R-900	174	5.22	174.00	5.22		0.00
100	21.70	Minex 4	77.00	3.55	77.00	3.55		0.00
Grind Total			523.27	40.77	264.06	9.64	1.95	31.13
Pigment Total					275.39	11.04		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	523.27	40.77	264.06	9.64	1.95	31.13
25	7.69	Tego Foamex 8030	1.95	0.25	0.49	0.08	0.00	0.18
30.5	8.55	Ropaque OP-96	57.00	6.67	17.39	1.91	0.00	4.76
64	9.02	Duravace FT-320	310.00	34.37	198.40	20.97	0.00	13.40
64	8.70	Triton GR7M	0.97	0.11	0.62	0.07	0.35	
0	8.33	Water	136.19	16.35	0.00	0.00	0.00	16.35
30	8.80	Acrysol DR3	19.46	2.21	5.84	0.58	0.00	1.55
TOTAL			1048.83	100.73	486.79	33.25	2.30	67.36
Paint properties					**VOC**			
Weight per gallon		10.412			Lbs/gal		0.0228	
% NV by weight		46.41			Lbs/gal-water		0.0688	
% NV by volume		33.00			Grams/L*		2.73	
PVC		33.19			Grams/L-water*		8.24	

Paint Test Formula:		ARB11						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	150.84	18.11	0.00	0.00		18.11
100	19.70	Attagel 50	6.47	0.33	6.47	0.33		0.00
34.6	10.20	Tamol 1254	9.24	0.91	3.20	0.18	0.00	0.73
100	8.84	Triton CF-10	2.03	0.23	2.03	0.23		0.00
4.5	8.33	Kathon LX 1.5%	1.39	0.17	0.06	0.01		0.16
25	7.69	Tego Foamex 8030	1.85	0.24	0.46	0.07	0.00	0.17
0	7.85	AMP-95	2.05	0.26	0.00	0.00	2.05	0.00
100	33.33	Ti Pure R-900	187	5.61	187.00	5.61		0.00
100	21.70	Polygloss 90	36.97	1.70	36.97	1.70		0.00
100	21.50	ASP Ultrafine	29.57	1.38	29.57	1.38		
Grind Total			427.40	28.93	265.76	9.51	2.05	19.42
Pigment Total					278.71	11.07		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	427.40	28.93	278.71	11.07	2.05	19.42
25	7.69	Tego Foamex 8030	1.85	0.24	0.46	0.07	0.00	0.17
30.5	8.55	Ropaque OP-96	61.31	7.17	18.70	2.06	0.00	5.12
64	9.02	Duravace FT-320	299.00	33.15	191.36	20.23	0.00	12.92
64	8.70	Triton GR7M	0.92	0.11	0.59	0.07	0.33	
0	8.33	Water	243.29	29.21	0.00	0.00	0.00	29.21
30	8.80	Acrysol DR3	18.48	2.10	5.54	0.55	0.00	1.47
TOTAL			1052.25	100.90	495.37	34.04	2.38	68.30
Paint properties					**VOC**			
Weight per gallon		10.429			Lbs/gal		0.0236	
% NV by weight		47.08			Lbs/gal-water		0.0731	
% NV by volume		33.74			Grams/L*		2.83	
PVC		32.53			Grams/L-water*		8.76	

Paint Test Formula:		ARB12						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	155.00	18.61	0.00	0.00		18.61
100	19.70	Attagel 50	7.00	0.36	7.00	0.36		0.00
34.6	10.20	Tamol 1254	10.00	0.98	3.46	0.20	0.00	0.79
100	8.84	Triton CF-10	2.20	0.25	2.20	0.25		0.00
4.5	8.33	Kathon LX 1.5%	1.50	0.18	0.07	0.01		0.17
25	7.69	Tego Foamex 8030	2.00	0.26	0.50	0.08	0.00	0.18
0	7.85	AMP-95	2.00	0.25	0.00	0.00	2.00	0.00
100	33.33	Ti Pure R-900	200	6.00	200.00	6.00		0.00
100	21.70	Minex 4	50.00	2.30	50.00	2.30		0.00
100	21.70	Polygloss 90	27.00	1.24	27.00	1.24		0.00
100	21.50	ASP Ultrafine	23.00	1.07	23.00	1.07		
Grind Total			479.70	31.51	313.23	11.51	2.00	20.00
Pigment Total					307.00	10.97		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	479.70	31.51	307.00	10.97	2.00	20.00
25	7.69	Tego Foamex 8030	2.00	0.26	0.50	0.08	0.00	0.18
64	9.02	Duravace FT-320	315.00	34.92	201.60	21.31	0.00	13.61
64	8.70	Triton GR7M	1.00	0.11	0.64	0.07	0.36	
0	8.33	Water	257.00	30.85	0.00	0.00	0.00	30.85
30	8.80	Acrysol DR3	20.00	2.27	6.00	0.59	0.00	1.59
TOTAL			1074.70	99.93	515.74	33.03	2.36	66.24
Paint properties					**VOC**			
Weight per gallon		10.755			Lbs/gal		0.0236	
% NV by weight		47.99			Lbs/gal-water		0.0700	
% NV by volume		33.05			Grams/ L*		2.83	
PVC		33.23			Grams/L-water*		8.39	

Paint Test Formula:		ARB13						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	224.49	26.95	0.00	0.00		26.95
0	8.64	Propylene glycol	10.25	1.19	0.00	0.00	10.25	0.00
0	7.85	AMP-95	4.23	0.54	0.00	0.00	4.23	0.00
100	7.77	Drew L-475	2.07	0.27	2.07	0.27		0.00
4.5	8.33	Kathon LX 1.5%	1.01	0.12	0.05	0.01		0.12
76.7	19.4	Ti Pure R-746	358.5	18.48	274.97	8.45		10.03
100	9.18	Igepal CO-630	2.08	0.23	2.08	0.23		0.00
100	11.50	Natrosol 250 HBr	5.06	0.44	5.06	0.44		0.00
Grind Total			607.69	48.21	284.22	9.39	14.48	37.09
Pigment Total			358.5	18.48	274.97	8.45		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	607.69	48.21	284.22	9.39	14.48	37.09
0	8.33	Water	30.00	3.60	0.00	0.00	0.00	3.60
0	8.64	Propylene glycol	10.10	1.17	0.00	0.00	10.10	0.00
0	7.92	Texanol	10.02	1.27	0.00	0.00	10.02	0.00
100	7.77	Drew L-475	2.08	0.27	2.08	0.27		0.00
55	9.01	EPS 2911	407.00	45.18	223.85	23.20	0.00	21.99
30	8.88	Acrysol TT-935	5.06	0.57	1.52	0.14		0.43
TOTAL			1071.95	100.26	511.67	33.00	34.60	63.11
Paint properties					**VOC**			
Weight per gallon		10.69			Lbs/gal		0.3451	
% NV by weight		47.73			Lbs/gal-water		0.9312	
% NV by volume		32.91			Grams/ L*		41.35	
PVC		25.61			Grams/L-water*		111.58	

Paint Test Formula:		ARB14						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	186.17	22.35	0.00	0.00		22.35
0	8.64	Propylene glycol	10.10	1.17	0.00	0.00	10.10	0.00
0	7.85	2-amino-2-methyl-1-propanol	4.14	0.53	0.00	0.00	4.14	0.00
100	7.77	Defoamer	2.15	0.28	2.15	0.28		0.00
4.5	8.33	Biocide	1.01	0.12	0.05	0.01		0.12
76.5	19.4	TiO2 slurry gloss grade	293.2	15.11	224.30	6.84		8.27
100	9.18	Nonoxynol-9	2.06	0.22	2.06	0.22		0.00
100	11.50	Hydroxyethylcellulose	5.06	0.44	5.06	0.44		0.00
Grind Total			503.89	40.22	233.61	7.79	14.24	30.74
Pigment Total			293.2	15.11	224.30	8.53		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	503.89	40.22	233.61	7.79	14.24	30.74
0	8.33	Water	50.00	6.00	0.00	0.00	0.00	6.00
30.5	8.55	Opaque polymer	50.27	5.88	15.33	1.69	0.00	4.19
0	8.64	Propylene glycol	13.11	1.52	0.00	0.00	13.11	0.00
0	7.92	Texanol	9.25	1.17	0.00	0.00	9.25	0.00
100	7.77	Defoamer	2.03	0.26	2.03	0.26		0.00
55	9.01	Vinyl acrylic resin	407.00	45.18	223.85	23.20	0.00	21.99
30	8.88	Associative thickener	5.06	0.57	1.52	0.14		0.43
TOTAL			######	100.80	476.34	33.07	36.60	63.35
Paint properties					**VOC**			
Weight per gallon		10.32			Lbs/gal		0.3631	
% NV by weight		45.78			Lbs/gal-water		0.9771	
% NV by volume		32.81			Grams/L*		43.51	
PVC		25.78			Grams/L-water*		117.09	

Paint Test Formula:		ARB15						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	200.00	24.01	0.00	0.00		24.01
0	8.64	Propylene glycol	10.00	1.16	0.00	0.00	10.00	0.00
25	9.20	Tamol 731	12.86	1.40	3.22	0.35	0.00	0.00
86	7.69	Tego Foamex 8050	1.89	0.25	1.63	0.21	0.00	0.03
100	7.77	Drew L-475	2.00	0.26	2.00	0.26		0.00
4.5	8.33	Kathon LX 1.5%	1.70	0.20	0.08	0.01		0.20
100	33.3	Ti Pure R-706	275	8.26	275.00	8.26		0.00
Grind Total			503.45	35.53	281.92	9.09	10.00	24.24
Pigment Total			275	8.26	275.00	8.26		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	503.45	35.53	281.92	9.09	10.00	24.24
0	8.33	Water	82.00	9.84	0.00	0.00	0.00	9.84
0	7.92	Texanol	10.00	1.26	0.00	0.00	10.00	0.00
100	7.77	Drew L-475	2.00	0.26	2.00	0.26	0.00	0.00
50	8.82	Rhoplex SG-10M	430.00	48.75	215.00	22.94	0.00	25.81
20	8.70	RM-2020NPR	35.00	4.02	7.00	0.66	0.00	3.36
25	8.70	RM-825	3.00	0.34	0.75	0.07	0.57	0.27
TOTAL			1065.45	100.02	506.67	33.02	20.57	63.52
Paint properties					**VOC**			
Weight per gallon		10.65			Lbs/gal		0.2057	
% NV by weight		47.55			Lbs/gal-water		0.5637	
% NV by volume		33.02			Grams/L*		24.65	
PVC		25.01			Grams/L-water*		67.54	

Paint Test Formula:		ARB16						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	200.00	24.01	0.00	0.00		24.01
0	8.64	Propylene glycol	10.00	1.16	0.00	0.00	10.00	0.00
25	9.20	Tamol 731	12.86	1.40	3.22	0.35	0.00	0.00
100	7.77	Drew L-475	5.00	0.64	5.00	0.64		0.00
4.5	8.33	Kathon LX 1.5%	1.70	0.20	0.08	0.01		0.20
100	33.3	Ti Pure R-706	200	6.01	200.00	6.01		0.00
Grind Total			429.56	33.42	208.29	7.01	10.00	24.20
Pigment Total			200	6.01	220.74	8.29		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	429.56	33.42	208.29	7.01	10.00	24.20
0	8.33	Water	35.00	4.20	0.00	0.00	0.00	4.20
30.5	8.55	Ropaque OP-96	68.00	7.95	20.74	2.28	0.00	5.67
0	7.92	Texanol	10.00	1.26	0.00	0.00	10.00	0.00
100	7.77	Drew L-475	0.95	0.12	0.95	0.12	0.00	0.00
50	8.82	Rhoplex SG-10M	430.00	48.75	215.00	22.94	0.00	25.81
20	8.70	RM-2020NPR	32.25	3.71	6.45	0.61	0.00	3.10
25	8.70	RM-825	3.00	0.34	0.75	0.07	0.57	0.27
TOTAL			1008.75	99.76	452.18	33.04	20.57	63.26
Paint properties					**VOC**			
Weight per gallon		10.11			Lbs/gal		0.2062	
% NV by weight		44.83			Lbs/gal-water		0.5635	
% NV by volume		33.12			Grams/L*		24.71	
PVC		25.08			Grams/L-water*		67.52	

Paint Test Formula:		ARB17							
GRIND:									
			Formula		Non-Volatile				
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	164.56	19.76	0.00	0.00		19.76
34.6	9.50	Tamol 1254	4.75	0.50	1.64	0.13	0.00	0.37
100	8.84	Triton CF-10	0.68	0.08	0.68	0.08		0.00
4.5	8.33	Kathon LX 1.5%	1.50	0.18	0.07	0.01		0.17
86	7.69	Tego Foamex 8050	1.18	0.15	1.01	0.13	0.00	0.02
0	7.85	AMP-95	2.00	0.25	0.00	0.00	2.00	0.00
76.7	19.4	Ti Pure R-746	353.3	18.21	270.98	8.33		9.88
30	8.80	Acrysol DR3	5.00	0.57	1.50	0.15	0.00	0.42
0	8.33	Water Premix	5.00	0.60	0.00	0.00	0.00	0.60
Grind Total			537.97	40.30	275.89	8.82	2.00	31.48
Pigment Total			353.30	18.21	270.98	8.33		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	537.97	40.30	275.89	8.82	2.00	31.48
86	7.69	Tego Foamex 8050	1.74	0.23	1.50	0.20	0.00	0.03
50	8.82	Rhoplex SG-10M	450.00	51.02	225.00	24.01	0.00	27.01
0	8.33	Water	50.00	6.00	0.00	0.00	0.00	6.00
30	8.80	Acrysol DR3	5.00	0.57	1.50	0.15	0.00	0.40
0	8.33	Water Premix	5.00	0.60	0.00	0.00	0.00	0.60
TOTAL			1049.71	98.72	503.88	33.18	2.00	65.52
Paint properties					**VOC**			
Weight per gallon		10.633			Lbs/gal		0.0203	
% NV by weight		48.00			Lbs/gal-water		0.0602	
% NV by volume		33.61			Grams/L*		2.43	
PVC		25.10			Grams/L-water*		7.22	

Paint Test Formula:		ARB18						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	100.00	12.00	0.00	0.00		12.00
0	8.64	Propylene glycol	30.00	3.47	0.00	0.00	30.00	0.00
25	9.20	Tamol 731	12.86	1.40	3.22	0.35	0.00	0.00
86	7.69	Tego Foamex 8050	1.89	0.25	1.63	0.21	0.00	0.03
100	7.77	Drew L-475	0.95	0.12	0.95	0.12		0.00
4.5	8.33	Kathon LX 1.5%	1.70	0.20	0.08	0.01		0.20
76.7	19.4	Ti Pure R-746	354.6	18.28	271.98	8.36		9.92
Grind Total			502.00	35.73	277.84	9.05	30.00	22.15
Pigment Total			354.6	18.28	271.98	8.36		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	502.00	35.73	277.84	9.05	30.00	22.15
0	8.33	Water	60.00	7.20	0.00	0.00	0.00	7.20
0	7.92	Texanol	50.00	6.31	0.00	0.00	50.00	0.00
100	7.77	Drew L-475	0.95	0.12	0.95	0.12	0.00	0.00
50	8.82	Rhoplex SG-10M	415.00	47.05	207.50	22.14	0.00	24.91
20	8.70	RM-2020NPR	32.25	3.71	6.45	0.61	0.00	3.10
25	8.70	RM-825	0.95	0.11	0.24	0.02	0.18	0.09
TOTAL			1061.14	100.23	492.97	31.95	80.18	57.45
Paint properties					**VOC**			
Weight per gallon		10.59			Lbs/gal		0.8000	
% NV by weight		46.46			Lbs/gal-water		1.8740	
% NV by volume		31.88			Grams/L*		95.86	
PVC		26.16			Grams/L-water*		224.56	

Paint Test Formula:	ARB19								
GRIND:			Formula		Non-Volatile				
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	155.00	18.61	0.00	0.00		18.61
50	9.90	Tamol 1124	3.40	0.34	1.70	0.17	0.00	0.00
100	8.9	Triton X-100	5.00	0.56	5.00	0.56		0.00
100	21.20	KTPP	2.00	0.09	2.00	0.09	0.00	0.00
4.5	8.33	Kathon LX 1.5%	1.00	0.12	0.05	0.01		0.11
86	7.69	Tego 8050	2.00	0.26	1.72	0.23	0.00	0.03
0	8.33	Ammonia (20%)	5.00	0.60	0.00	0.00	0.00	0.48
100	33.3	Ti Pure R-706	220	6.61	220.00	6.61		0.00
Grind Total			393.40	27.19	230.47	7.67	0.00	19.24
Pigment Total			220	6.61	220.00	6.61		
LETDOWN:			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	393.40	27.19	230.47	7.67	0.00	19.24
0	8.33	Water	100.00	12.00	0.00	0.00	0.00	12.00
86	7.69	Tego 8050	2.00	0.26	1.72	0.23	0.00	0.03
30	8.77	Acrysol RM-5	10.00	1.14	3.00	0.30	0.00	0.84
43.5	8.61	Rhoplex SF-012	515.00	59.81	224.03	24.88	0.00	34.93
TOTAL			1020.40	100.41	459.21	33.08	0.00	67.05

Paint properties	
Weight per gallon	10.16
% NV by weight	45.00
% NV by volume	32.94
PVC	19.97

VOC	
Lbs/gal	0.0000
Lbs/gal-water	0.0000
Grams/L*	0.00
Grams/L-water*	0.00

Paint Test Formula:		ARB20						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
0	8.33	Water	150.00	18.01	0.00	0.00		18.01
50	9.90	Tamol 1124	5.50	0.56	2.75	0.28	0.00	0.00
4.5	8.33	Kathon LX 1.5%	1.00	0.12	0.05	0.01		0.11
97	8.28	Byk-22	2.00	0.24	1.94	0.23	0.00	0.01
0	8.64	Propylene glycol	30.00	3.47	0.00	0.00	30.00	0.00
0	8.33	Ammonia (20%)	5.00	0.60	0.00	0.00	0.00	0.48
100	33.3	Ti Pure R-706	220	6.61	220.00	6.61		0.00
Grind Total			413.50	29.60	224.74	7.12	30.00	18.61
Pigment Total			220	6.61	220.00	6.61		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	413.50	29.60	224.74	7.12	30.00	18.61
0	7.92	Texanol	21.50	2.71	0.00	0.00	21.50	0.00
0	8.33	Water	45.00	5.40	0.00	0.00	0.00	5.40
97	8.28	Byk-22	2.00	0.24	1.94	0.23	0.00	0.01
30	8.77	Acrysol RM-5	20.00	2.28	6.00	0.60	0.00	1.68
45	8.84	Rhoplex HG-700	530.00	59.95	238.50	24.96	0.00	34.99
TOTAL			1032.00	100.20	471.18	32.92	51.50	60.69
Paint properties					**VOC**			
Weight per gallon		10.30			Lbs/gal		0.5140	
% NV by weight		45.66			Lbs/gal-water		1.3037	
% NV by volume		32.85			Grams/L *		61.59	
PVC		20.07			Grams/L-water*		156.22	

Paint Test Formula:		ARB21						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
70	8.00	EPS 6604	200.00	25.00	140.00	17.50	60.00	0.00
100	8.70	SOYA Lecithin	32.56	3.74	32.56	3.74	0.00	0.00
100	8.83	Dextrol OC70	15.34	1.74	15.34	1.74	0.00	0.00
100	33.3	Ti Pure R-706	250.00	7.51	250.00	7.51	0.00	0.00
100	22.6	Vicron 15-15	340.00	15.04	340.00	15.04	0.00	0.00
100	21.7	Minex 4	220.00	10.14	220.00	10.14	0.00	0.00
100	12.3	Bentone SD-1	0.00	0.00	0.00	0.00	0.00	0.00
0	6.68	Mineral Spirits	180.00	26.94	0.00	0.00	180.00	0.00
0.7	6.74	BYK -066	6.65	0.99	0.05	0.01	6.60	0.00
31	7.50	calcium 6% drier	3.89	0.52	1.21	0.16	2.68	0.00
Grind Total			1248.44	91.61	999.15	55.84	249.29	0.00
Pigment Total			810.00	32.69	810.00	32.69		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	1248.44	91.61	999.15	55.84	249.29	0.00
0	6.68	Mineral Spirits	50.00	7.48	0.00	0.00	50.00	0.00
57	8.60	Cobalt 12% Drier	0.82	0.09	0.47	0.05	0.35	0.00
61	9.20	Zirconium 18 % drier	3.89	0.42	2.37	0.26	1.52	0.00
100	7.66	Exkin #2	2.13	0.28	2.13	0.28	0.00	0.00
70	8.00	EPS 6604	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL			1305.27	99.89	1004.12	56.43	301.15	0.00
Paint properties		Theory			**VOC**			
Weight per gallon		13.07			Lbs/gal		3.0149	
% NV by weight		76.93			Lbs/gal-water		3.0149	
% NV by volume		56.49			Grams/L*		361.27	
PVC		57.93			Grams/L-water*		361.27	

Paint Test Formula:		ARB22						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
70	8.00	EPS 6604	180.00	22.50	126.00	15.75	54.00	0.00
100	8.70	SOYA Lecithin	32.56	3.74	32.56	3.74	0.00	0.00
100	8.83	Dextrol OC70	15.34	1.74	15.34	1.74	0.00	0.00
100	33.3	Ti Pure R-706	250.00	7.51	250.00	7.51	0.00	0.00
100	12.3	Bentone SD-1	0.00	0.00	0.00	0.00	0.00	0.00
100	21.5	ASP NC	120.00	5.58	120.00	5.58	0.00	0.00
100	21.5	ASP Untrafine	120.00	5.58	120.00	5.58	0.00	0.00
100	22.6	Vicron 15-15	320.00	14.16	320.00	14.16	0.00	0.00
0	6.68	Mineral Spirits	197.00	29.48	0.00	0.00	197.00	0.00
0.7	6.74	BYK -066	6.65	0.99	0.05	0.01	6.60	0.00
31	7.50	calcium 6% drier	3.50	0.47	1.09	0.14	2.42	0.00
Grind Total			1245.05	91.74	985.03	54.21	260.02	0.00
Pigment Total			810.00	32.83	810.00	32.83		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	1245.05	91.74	985.03	54.21	260.02	0.00
0	6.68	Mineral Spirits	50.00	7.48	0.00	0.00	50.00	0.00
57	8.60	Cobalt 12% Drier	0.74	0.09	0.42	0.05	0.32	0.00
61	9.20	Zirconium 18 % drier	3.50	0.38	2.14	0.23	1.37	0.00
100	7.66	Exkin #2	2.17	0.28	2.17	0.28	0.00	0.00
0.7	6.74	BYK -066	0.00	0.00	0.00	0.00	0.00	0.00
70	8.00	EPS 6604	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL			1301.45	99.97	989.75	54.77	311.70	0.00
Paint properties		Theory			**VOC**			
Weight per gallon		13.02			Lbs/gal		3.1178	
% NV by weight		76.05			Lbs/gal-water		3.1178	
% NV by volume		54.79			Grams/L *		373.60	
PVC		59.94			Grams/L-water*		373.60	

Paint Test Formula:		ARB23						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
70	8.00	EPS 6604	280.00	35.00	196.00	24.50	84.00	0.00
100	8.70	SOYA Lecithin	32.56	3.74	32.56	3.74	0.00	0.00
100	8.83	Dextrol OC70	14.40	1.63	14.40	1.63	0.00	0.00
100	33.3	Ti Pure R-706	250.00	7.51	250.00	7.51	0.00	0.00
100	21.7	Minex 4	250.00	11.52	250.00	11.52	0.00	0.00
100	22.6	Vicron 15-15	255.00	11.28	255.00	11.28	0.00	0.00
0	6.68	Mineral Spirits	135.00	20.20	0.00	0.00	135.00	0.00
0.7	6.74	BYK -066	6.65	0.99	0.05	0.01	6.60	0.00
31	7.50	calcium 6% drier	5.44	0.73	1.69	0.23	3.76	0.00
Grind Total			1216.96	90.89	997.96	60.19	219.00	0.00
Pigment Total			755.00	30.31	755.00	30.31		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	1216.96	90.89	997.96	60.19	219.00	0.00
0	7.31	Aromatic 100	60.00	8.21	0.00	0.00	60.00	0.00
57	8.60	Cobalt 12% Drier	1.14	0.13	0.65	0.08	0.49	0.00
61	9.20	Zirconium 18 % drier	5.44	0.59	3.32	0.36	2.12	0.00
100	7.66	Exkin #2	2.00	0.26	2.00	0.26	0.00	0.00
70	8.00	EPS 6604	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL			1285.55	100.08	1003.94	60.88	281.61	0.00
Paint properties		Theory			**VOC**			
Weight per gallon		12.85			Lbs/gal		2.8139	
% NV by weight		78.09			Lbs/gal-water		2.8139	
% NV by volume		60.83			Grams/L*		337.19	
PVC		49.79			Grams/L-water*		337.19	

Paint Test Formula:		ARB24						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
70	8.00	EPS 6604	260.00	32.50	182.00	22.75	78.00	0.00
100	8.70	SOYA Lecithin	32.56	3.74	32.56	3.74	0.00	0.00
100	8.83	Dextrol OC70	14.40	1.63	14.40	1.63	0.00	0.00
100	33.3	Ti Pure R-706	250.00	7.51	250.00	7.51	0.00	0.00
100	21.5	ASP NC	120.00	5.58	120.00	5.58	0.00	0.00
100	21.5	ASP Untrafine	120.00	5.58	120.00	5.58	0.00	0.00
100	22.6	Vicron 15-15	230.00	10.18	230.00	10.18	0.00	0.00
0	6.68	Mineral Spirits	160.00	23.94	0.00	0.00	160.00	0.00
0.7	6.74	BYK -066	6.65	0.99	0.05	0.01	6.60	0.00
31	7.50	calcium 6% drier	5.06	0.67	1.57	0.21	3.49	0.00
Grind Total			######	92.33	950.58	57.19	248.09	0.00
Pigment Total			720.00	28.85	720.00	28.85		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	######	92.33	950.58	57.19	248.09	0.00
0	7.31	Aromatic 100	50.00	6.84	0.00	0.00	50.00	0.00
57	8.60	Cobalt 12% Drier	1.06	0.12	0.61	0.07	0.46	0.00
61	9.20	Zirconium 18 % drier	5.06	0.55	3.08	0.34	1.97	0.00
100	7.66	Exkin #2	2.04	0.27	2.04	0.27	0.00	0.00
70	8.00	EPS 6604	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL			######	100.10	956.30	57.86	300.52	0.00
Paint properties		Theory			**VOC**			
Weight per gallon		12.56			Lbs/gal		3.0021	
% NV by weight		76.09			Lbs/gal-water		3.0021	
% NV by volume		57.80			Grams/L*		359.74	
PVC		49.86			Grams/L-water*		359.74	

Paint Test Formula:		ARB25							
GRIND:									
			Formula		Non-Volatile				
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
100	8.17	EPS 6611	250.00	30.60	250.00	30.60	0.00	0.00
100	8.70	R&R 557	20.00	2.30	20.00	2.30	0.00	0.00
100	8.83	Dextrol OC70	15.33	1.74	15.33	1.74	0.00	0.00
100	33.3	Ti Pure R-706	250.00	7.51	250.00	7.51	0.00	0.00
100	22.6	Vicron 15-15	300.00	13.27	300.00	13.27	0.00	0.00
100	21.7	Minex 4	300.00	13.82	300.00	13.82	0.00	0.00
0	6.68	Mineral Spirits	140.00	20.95	0.00	0.00	140.00	0.00
0.7	6.74	BYK -066	6.65	0.99	0.05	0.01	6.60	0.00
31	7.50	calcium 6% drier	6.94	0.93	2.15	0.29	4.79	0.00
Grind Total			1288.92	92.10	1137.53	69.54	151.40	0.00
Pigment Total			850.00	34.61	850.00	34.61		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	1288.92	92.10	1137.53	69.54	151.40	0.00
0	7.31	Aromatic 100	50.00	6.84	0.00	0.00	50.00	0.00
57	8.60	Cobalt 12% Drier	1.46	0.17	0.83	0.10	0.63	0.00
61	9.20	Zirconium 18 % drier	6.94	0.75	4.24	0.46	2.71	0.00
100	7.66	Exkin #2	2.17	0.28	2.17	0.28	0.00	0.00
100	8.17	EPS 6611	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL			1349.50	100.15	1144.77	70.38	204.73	0.00
Paint properties		Theory			**VOC**			
Weight per gallon		13.47			Lbs/gal		2.0442	
% NV by weight		84.83			Lbs/gal-water		2.0442	
% NV by volume		70.27			Grams/L*		244.96	
PVC		49.17			Grams/L-water*		244.96	

Paint Test Formula:		ARB26						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
70	7.90	Beckosol 10-029	275.00	34.81	192.50	24.37	82.50	0.00
100	8.70	SOYA Lecithin	22.00	2.53	22.00	2.53	0.00	0.00
100	8.83	Dextrol OC70	16.62	1.88	16.62	1.88	0.00	0.00
100	33.3	Ti Pure R-706	250.00	7.51	250.00	7.51	0.00	0.00
100	21.7	Minex 4	355.00	16.36	355.00	16.36	0.00	0.00
0	6.68	Mineral Spirits	106.00	15.86	0.00	0.00	106.00	0.00
0.7	6.74	BYK -066	16.81	2.49	0.12	0.02	16.70	0.00
31	7.50	calcium 6% drier	6.63	0.88	2.06	0.27	4.58	0.00
Grind Total			1048.06	82.33	838.29	52.94	209.77	0.00
Pigment Total			605.00	23.86695	605.00	23.87		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	1048.06	82.33	838.29	52.94	209.77	0.00
0	6.68	Mineral Spirits	55.00	8.23	0.00	0.00	55.00	0.00
57	8.60	Cobalt 12% Drier	1.39	0.16	0.79	0.09	0.60	0.00
61	9.20	Zirconium 18 % drier	6.63	0.72	4.04	0.44	2.59	0.00
100	7.66	Exkin #2	2.20	0.29	2.20	0.29	0.00	0.00
70	7.90	Beckosol 10-029	66.00	8.35	46.20	5.85	19.80	0.00
TOTAL			1179.29	100.08	891.53	59.60	287.76	0.00
Paint properties		Theory			**VOC**			
Weight per gallon		11.78			Lbs/gal		2.8751	
% NV by weight		75.60			Lbs/gal-water		2.8751	
% NV by volume		59.55			Grams/L*		344.53	
PVC		40.04			Grams/L-water*		344.53	

Paint Test Formula:		ARB27						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
70	8.00	EPS 6604	250.00	31.25	175.00	21.88	75.00	0.00
100	8.70	SOYA Lecithin	20.00	2.30	20.00	2.30	0.00	0.00
100	8.83	Dextrol OC70	15.11	1.71	15.11	1.71	0.00	0.00
100	33.3	Ti Pure R-706	250.00	7.51	250.00	7.51	0.00	0.00
100	21.7	Polygloss 90	255.00	11.75	255.00	11.75	0.00	0.00
0	6.68	Mineral Spirits	165.00	24.69	0.00	0.00	165.00	0.00
0.7	6.74	BYK -066	6.65	0.99	0.05	0.01	6.60	0.00
31	7.50	calcium 6% drier	6.81	0.91	2.11	0.28	4.70	0.00
Grind Total			968.56	79.21	715.11	45.14	240.00	0.00
Pigment Total			505.00	19.2587	505.00	19.2587		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	968.56	79.21	715.11	45.14	240.00	0.00
0	6.68	Mineral Spirits	48.00	7.18	0.00	0.00	48.00	0.00
57	8.60	Cobalt 12% Drier	1.43	0.17	0.81	0.09	0.61	0.00
61	9.20	Zirconium 18 % drier	6.81	0.74	4.15	0.45	2.65	0.00
100	7.66	Exkin #2	2.00	0.26	2.00	0.26	0.00	0.00
70	8.00	EPS 6604	100.00	12.50	70.00	8.75	30.00	0.00
TOTAL			1126.80	100.06	792.07	54.70	321.27	0.00
Paint properties		Theory			**VOC**			
Weight per gallon		11.26			Lbs/gal		3.2107	
% NV by weight		70.29			Lbs/gal-water		3.2107	
% NV by volume		54.67			Grams/L*		384.74	
PVC		35.21			Grams/L-water*		384.74	

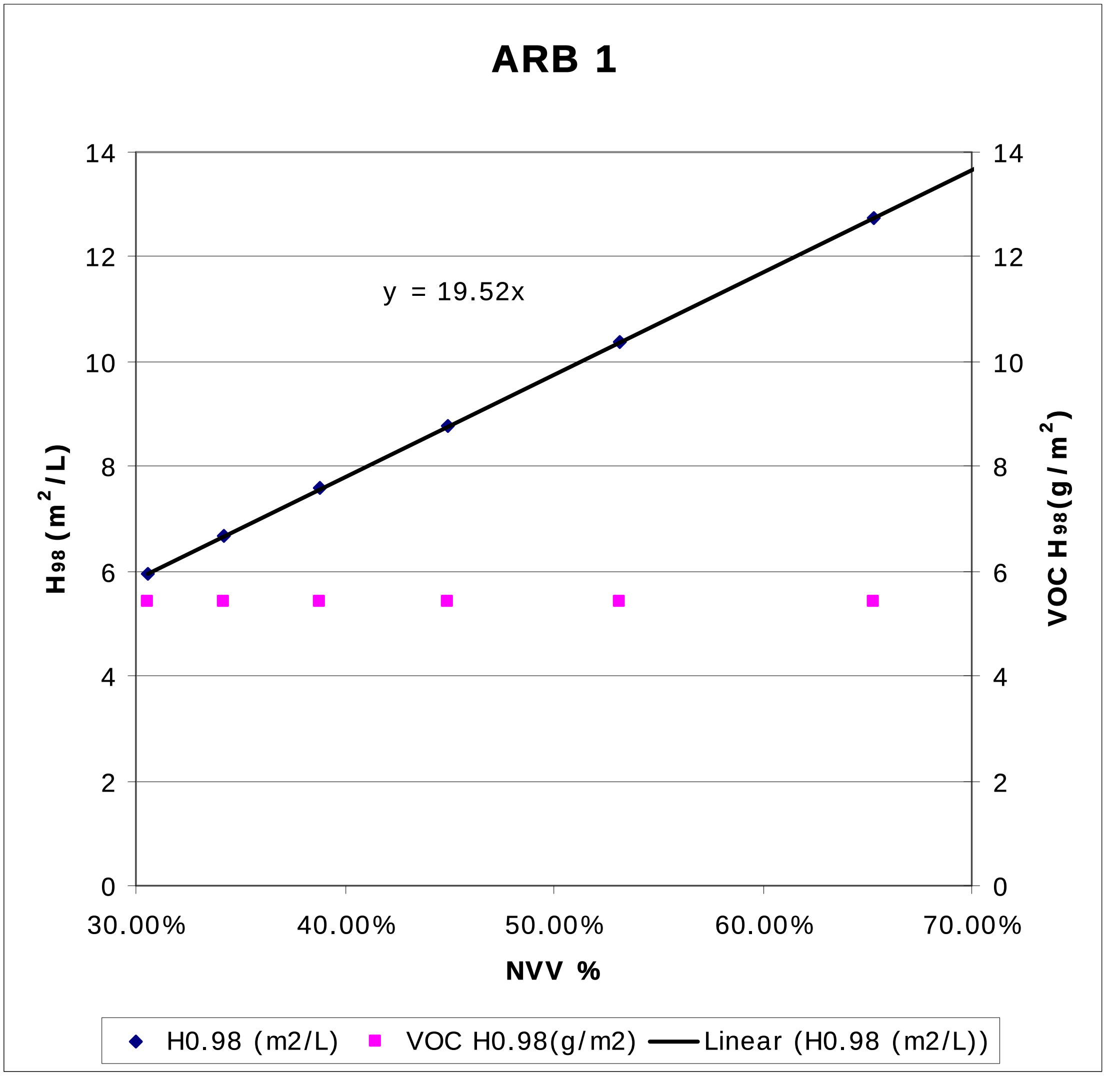
Paint Test Formula:		ARB28						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
70	8	EPS 6604	0	0.00	0.00	0.00	0.00	0
100	8.17	EPS 6611	300	36.72	300.00	36.72	0.00	0
100	8.7	SOYA Lecithin	20	2.30	20.00	2.30	0.00	0
100	8.83	Dextrol OC70	15.11	1.71	15.11	1.71	0.00	0
100	33.3	Ti Pure R-706	250.00	7.51	250.00	7.51	0.00	0
100	21.7	Polygloss 90	0.00	0.00	0.00	0.00	0.00	0
100	21.7	Minex 4	450.00	20.74	450.00	20.74	0.00	0
0	6.68	Mineral Spirits	140	20.96	0.00	0.00	140.00	0
0.7	6.74	BYK -066	6.65	0.99	0.05	0.01	6.60	0
Grind Total			1181.76	90.92	1035.16	68.98	146.60	0
Pigment Total			700.00	28.24	700.00	28.24		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	1181.76	90.92	1035.16	68.98	146.60	0
70	8	EPS 6604	0	0.00	0.00	0.00	0.00	0
100	8.17	EPS 6611	50	6.12	50.00	6.12	0.00	0
0	6.68	Mineral Spirits	0	0.00	0.00	0.00		0
57	8.6	Cobalt 12% Drier	2.04	0.24	1.16	0.14	0.92	0
61	9.2	Zirconium 18 % drier	9.72	1.06	5.93	0.64	2.08	0
31	7.5	calcium 6% drier	9.72	1.30	3.01	0.40	3.69	0
100	7.66	Exkin #2	2	0.26	2.00	0.26	0	0
TOTAL			1255.25	99.89	1097.26	76.54	153.29	0.00
Paint properties		Theory			**VOC**			
Weight per gallon		12.57			Lbs/gal		1.5346	1.58154
% NV by weight		87.41			Lbs/gal-water		1.5346	
% NV by volume		76.63			Grams/L*		183.89	
PVC		36.90			Grams/L-water*		183.89	

Paint Test Formula:		ARB29						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
70	8.00	EPS 6604	250.00	31.25	175.00	21.88	75.00	0.00
100	8.83	Dextrol OC70	12.20	1.38	12.20	1.38	0.00	0.00
100	8.70	SOYA Lecithin	20.00	2.30	20.00	2.30	0.00	0.00
100	33.3	Ti Pure R-706	250	7.51	250.00	7.51	0.00	0.00
0	6.68	Mineral Spirits	20.00	2.99	0.00	0.00	20.00	0.00
0.7	6.74	BYK -066	6.65	0.99	0.05	0.00	6.60	0.00
Grind to 7.5 Hegman								
Grind Total			558.85	46.42	457.24	33.06	101.60	0.00
Pigment Total			250	7.51	250.00	7.51		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	558.85	46.42	457.24	33.06	101.60	0.00
70	8.00	EPS 6604	280.00	35.00	196.00	24.50	84.00	0.00
0	6.68	Mineral Spirits	105.00	15.71	0.00	0.00	105.00	0.00
57	8.60	Cobalt 12% Drier	2.16	0.25	1.23	0.14	0.93	0.00
61	9.20	Zirconium 18 % drier	10.31	1.12	6.29	0.68	4.02	0.00
31	7.50	calcium 6% drier	10.31	1.37	3.19	0.31	7.11	0.00
100	7.66	Exkin #2	2.00	0.26	2.00	0.26	0.00	0.00
TOTAL			968.62	100.14	665.96	58.96	302.66	0.00
Paint properties		Theory			**VOC**			
Weight per gallon		9.67			Lbs/gal		3.0225	
% NV by weight		68.75			Lbs/gal-water		3.0225	
% NV by volume		58.88			Grams/L*		362.19	
PVC		12.73			Grams/L-water*		362.19	

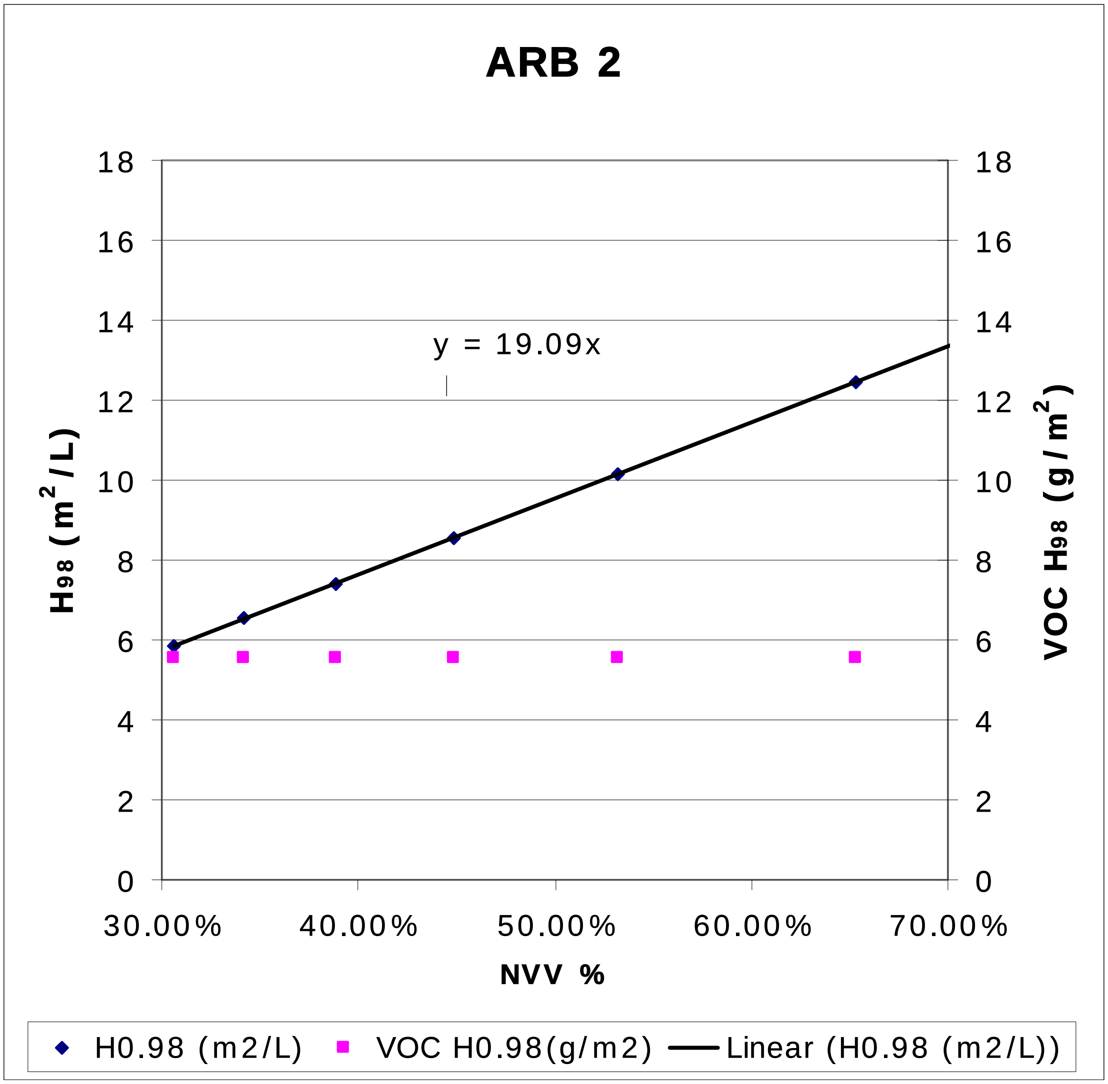
Paint Test Formula:		ARB30						
GRIND:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
100	8.17	EPS 6611	125.00	15.30	125.00	15.30	0.00	0.00
70	8.00	EPS 6604	125.00	15.63	87.50	10.01	37.50	0.00
100	8.83	Dextrol OC70	12.20	1.38	12.20	1.38	0.00	0.00
100	8.70	SOYA Lecithin	20.00	2.30	20.00	2.30	0.00	0.00
100	33.3	Ti Pure R-706	250	7.51	250.00	7.51	0.00	0.00
0	6.68	Mineral Spirits	50.00	7.48	0.00	0.00	50.00	0.00
0.7	6.74	BYK -066	6.65	0.99	0.05	0.00	6.60	0.00
Grind to 7.5 Hegman								
Grind Total			588.85	50.58	494.74	36.50	94.10	0.00
Pigment Total			250	7.51	250.00	7.51		
LETDOWN:								
			Formula		Non-Volatile			
% NV	Lbs/Gal	Material	Lbs	Gal	Lbs	Gal	VOC, lbs	Water, gal
		Grind	588.85	50.58	494.74	36.50	94.10	0.00
100	8.17	EPS 6611	140.00	17.14	140.00	17.14	0.00	0.00
70	8.00	EPS 6604	230.00	28.75	161.00	18.42	69.00	0.00
0	6.68	Mineral Spirits	0.00	0.00	0.00	0.00	0.00	0.00
57	8.60	Cobalt 12% Drier	3.00	0.35	1.71	0.20	1.29	0.00
61	9.20	Zirconium 18 % drier	14.26	1.55	8.70	0.95	5.56	0.00
31	7.50	calcium 6% drier	14.26	1.90	4.42	0.43	9.84	0.00
100	7.66	Exkin #2	2.00	0.26	2.00	0.26	0.00	0.00
TOTAL			992.37	100.53	812.57	73.89	179.80	0.00
Paint properties		Theory			**VOC**			
Weight per gallon		9.87			Lbs/gal		1.7885	
% NV by weight		81.88			Lbs/gal-water		1.7885	
% NV by volume		73.50			Grams/L *		214.32	
PVC		10.16			Grams/L-water*		214.32	

Appendix B – Hiding Power Graphs for Water-based Coatings

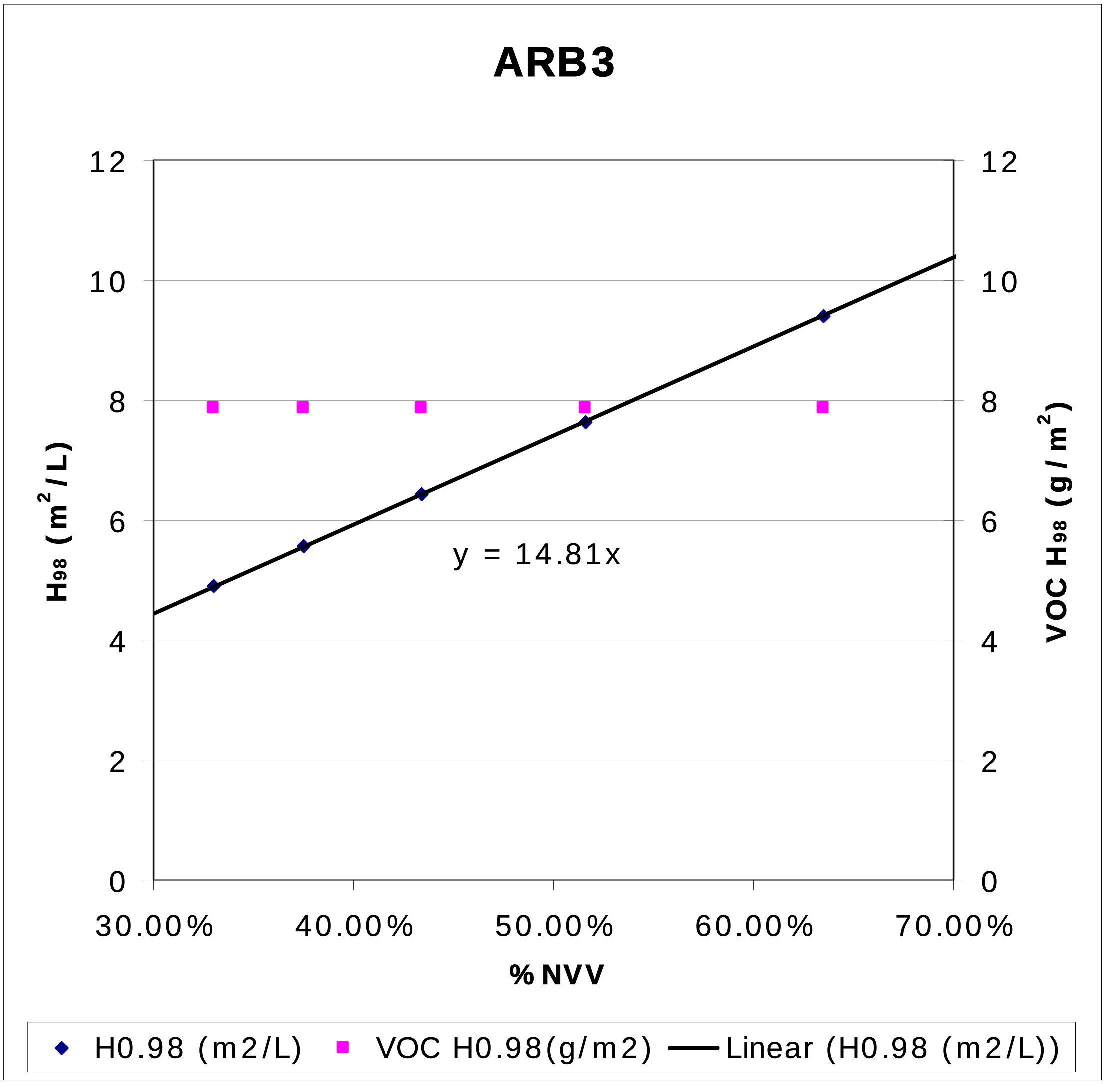
Predicted Hiding Power and Hiding VOC for ARB 1



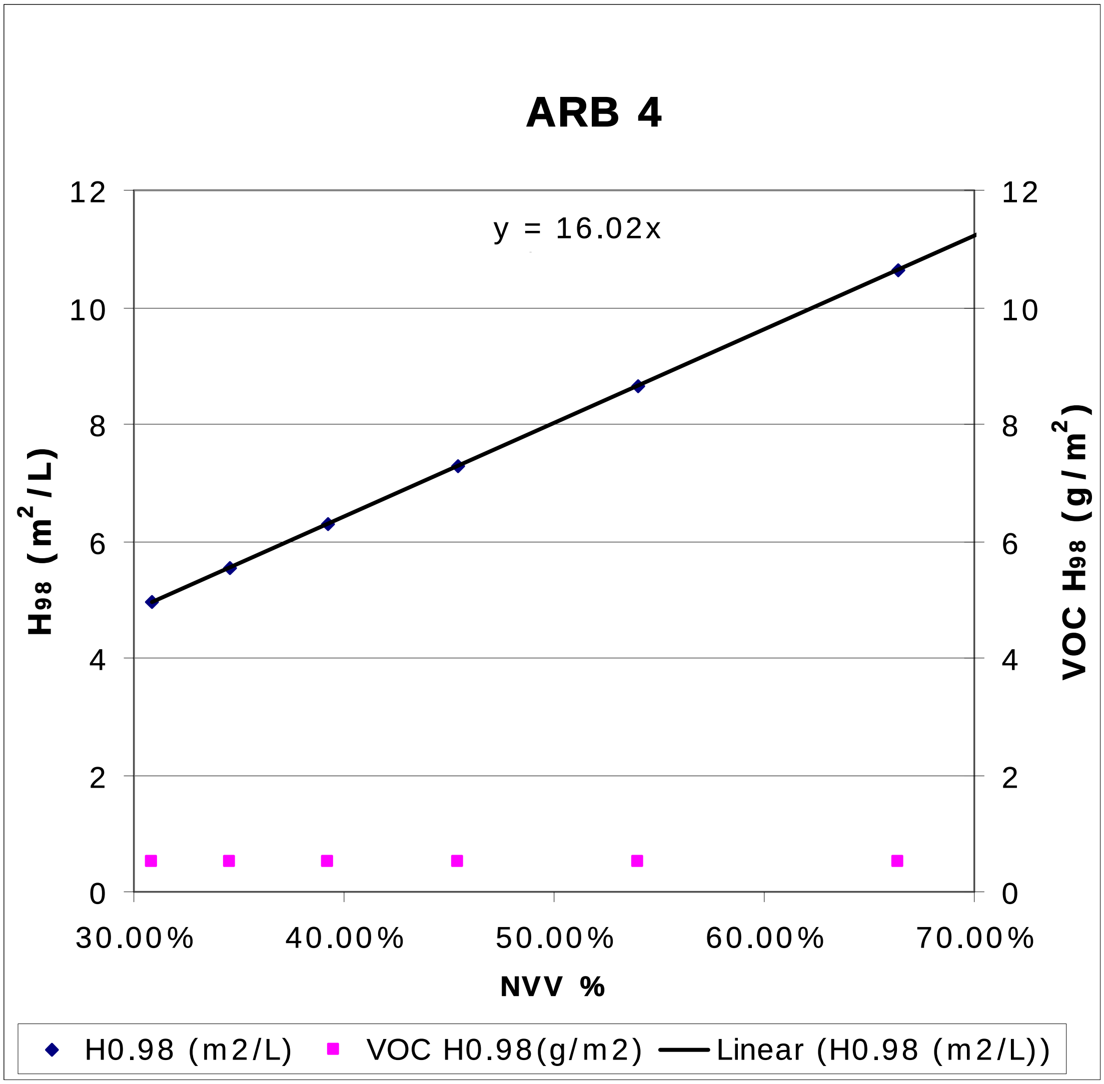
Predicted Hiding Power and Hiding VOC for ARB 2



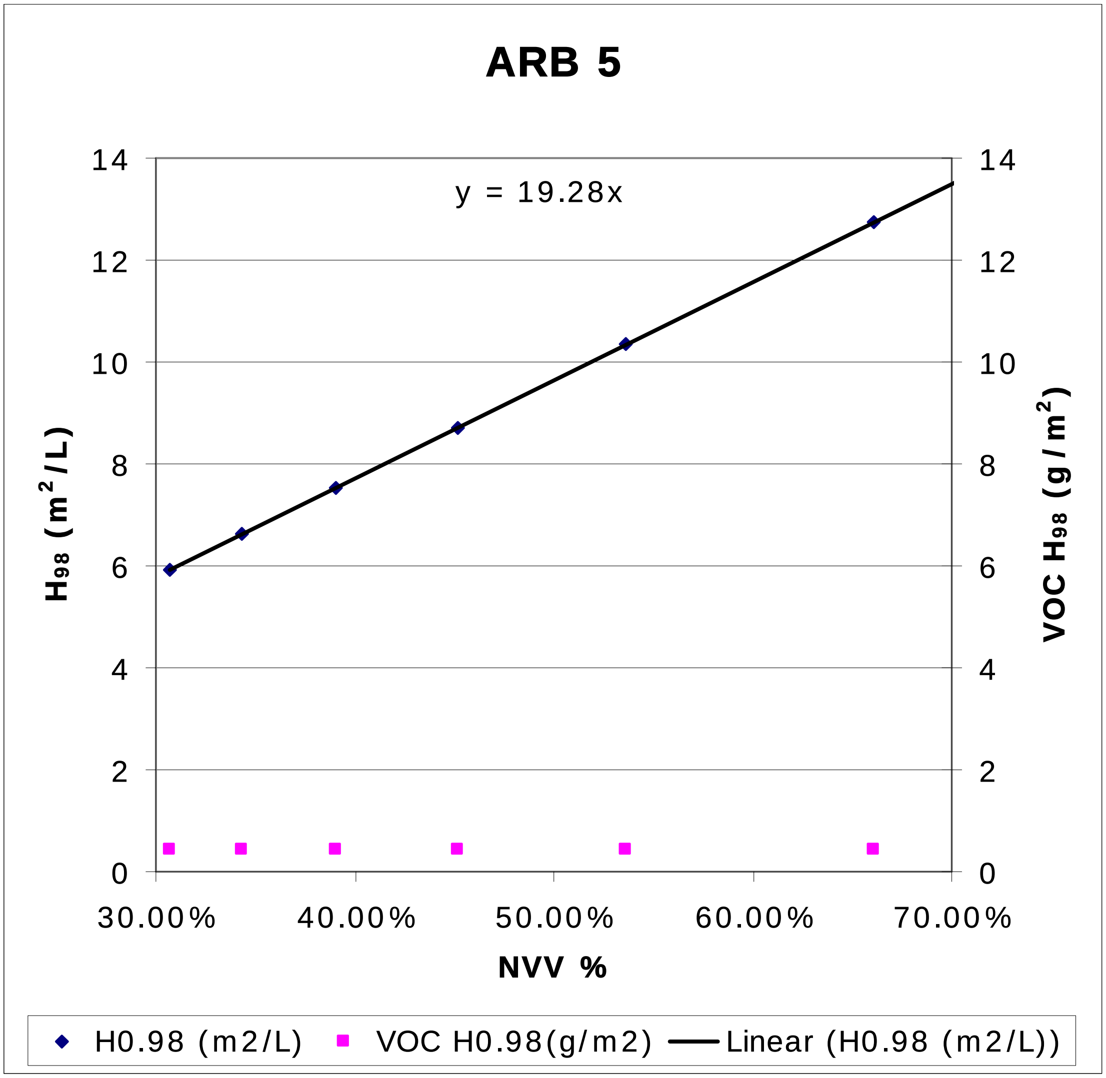
Predicted Hiding Power and Hiding VOC for ARB 3



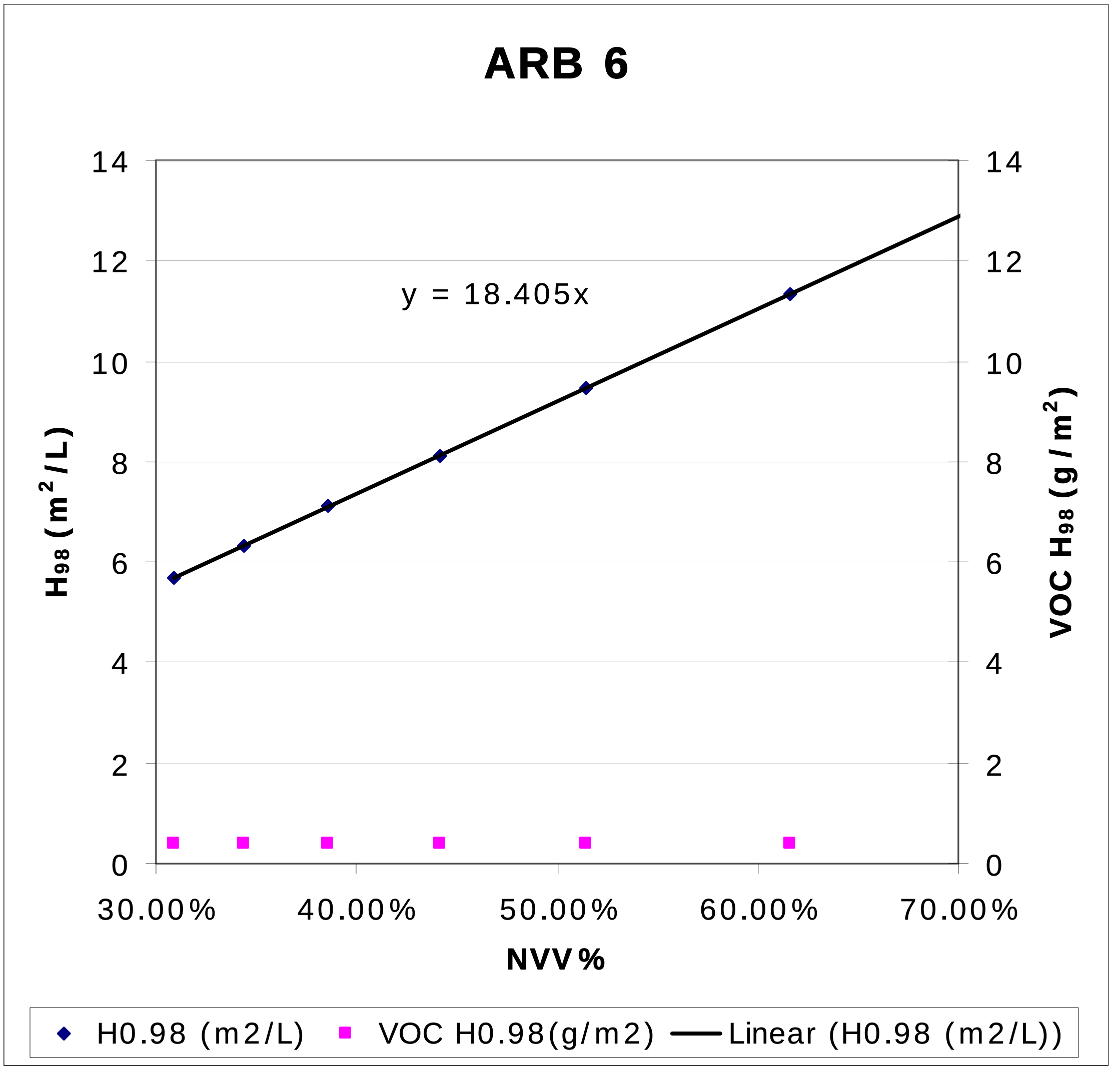
Predicted Hiding Power and Hiding VOC for ARB 4



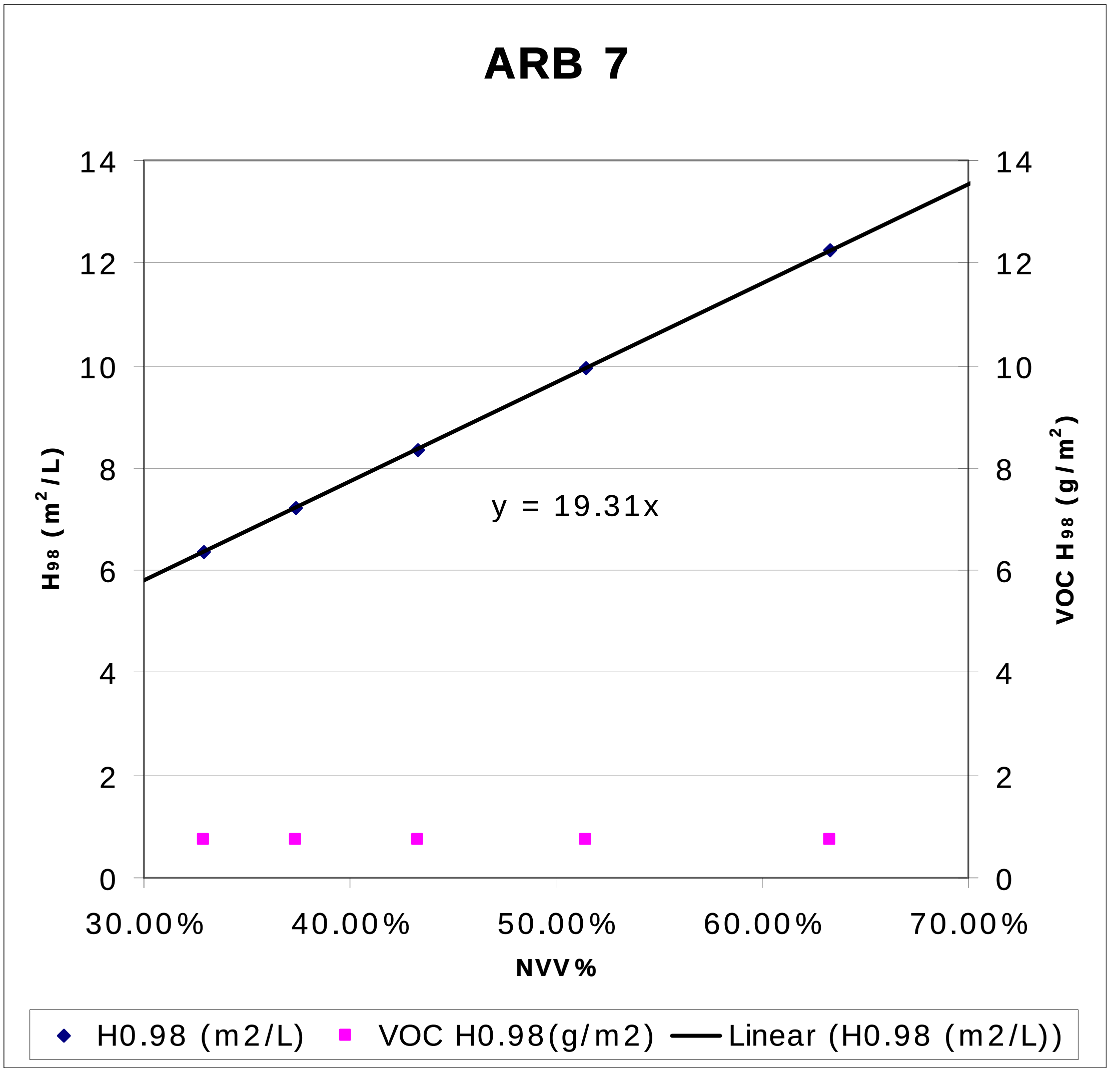
Predicted Hiding Power and Hiding VOC for ARB 5



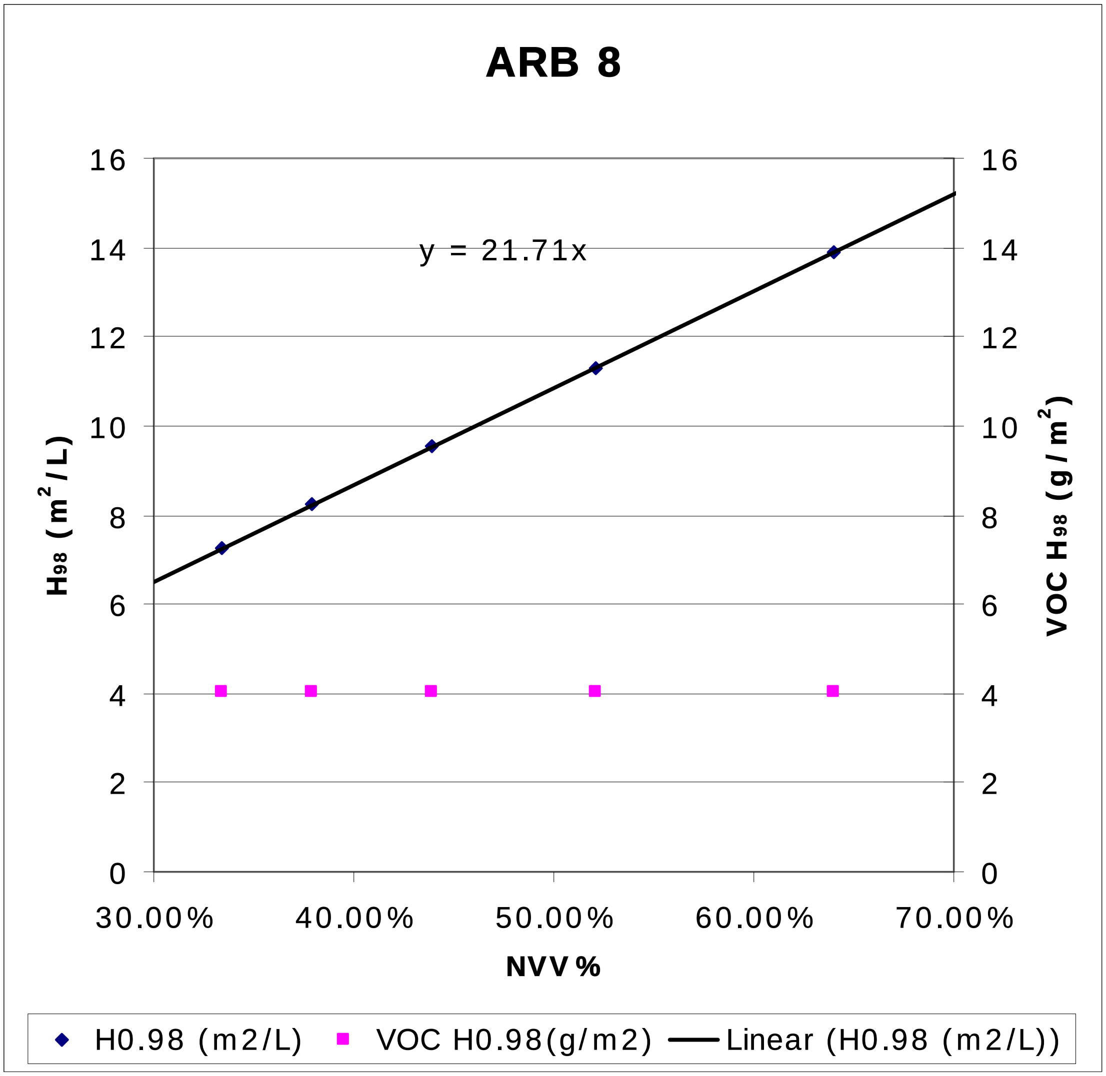
Predicted Hiding Power and Hiding VOC for ARB 6



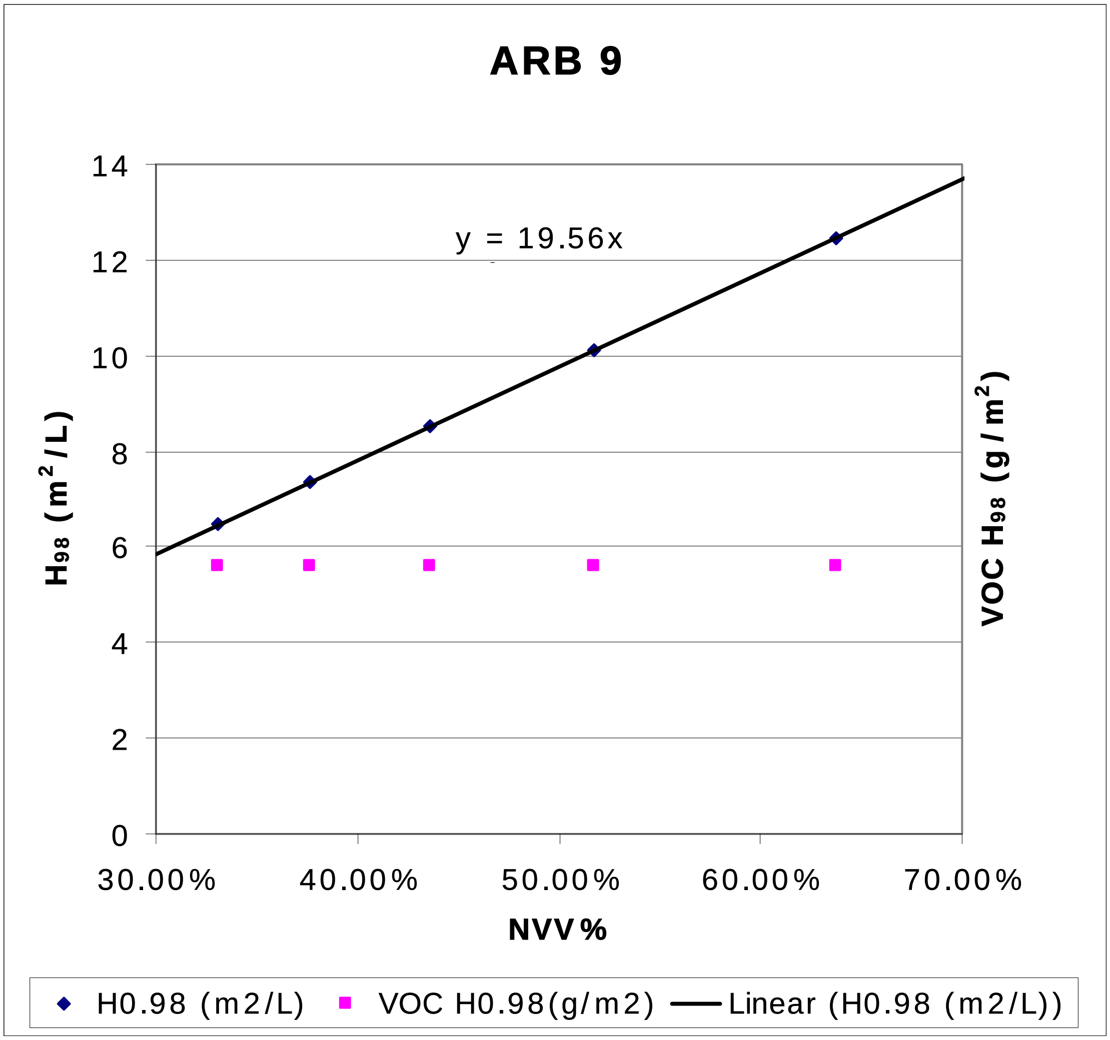
Predicted Hiding Power and Hiding VOC for ARB 7



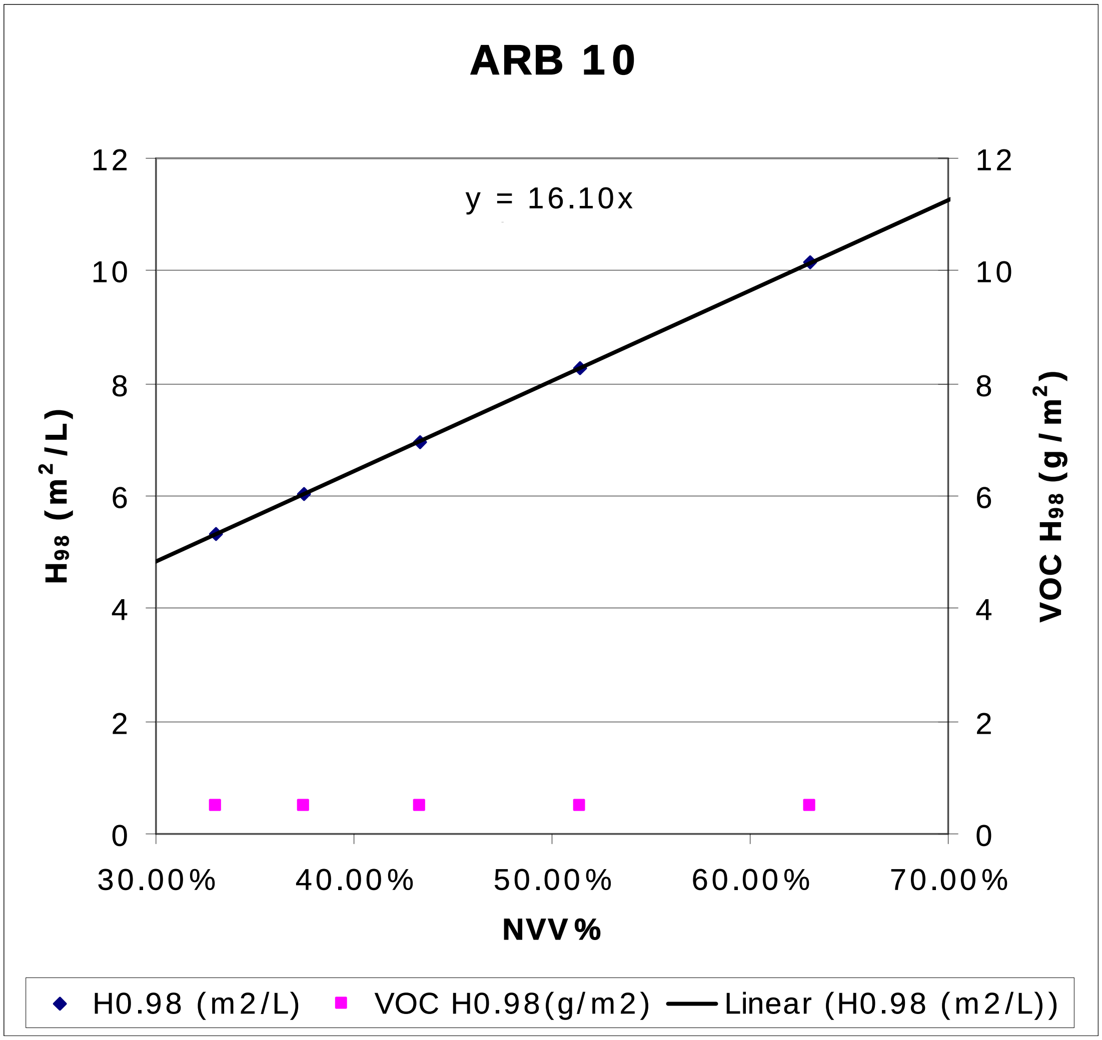
Predicted Hiding Power and Hiding VOC for ARB 8



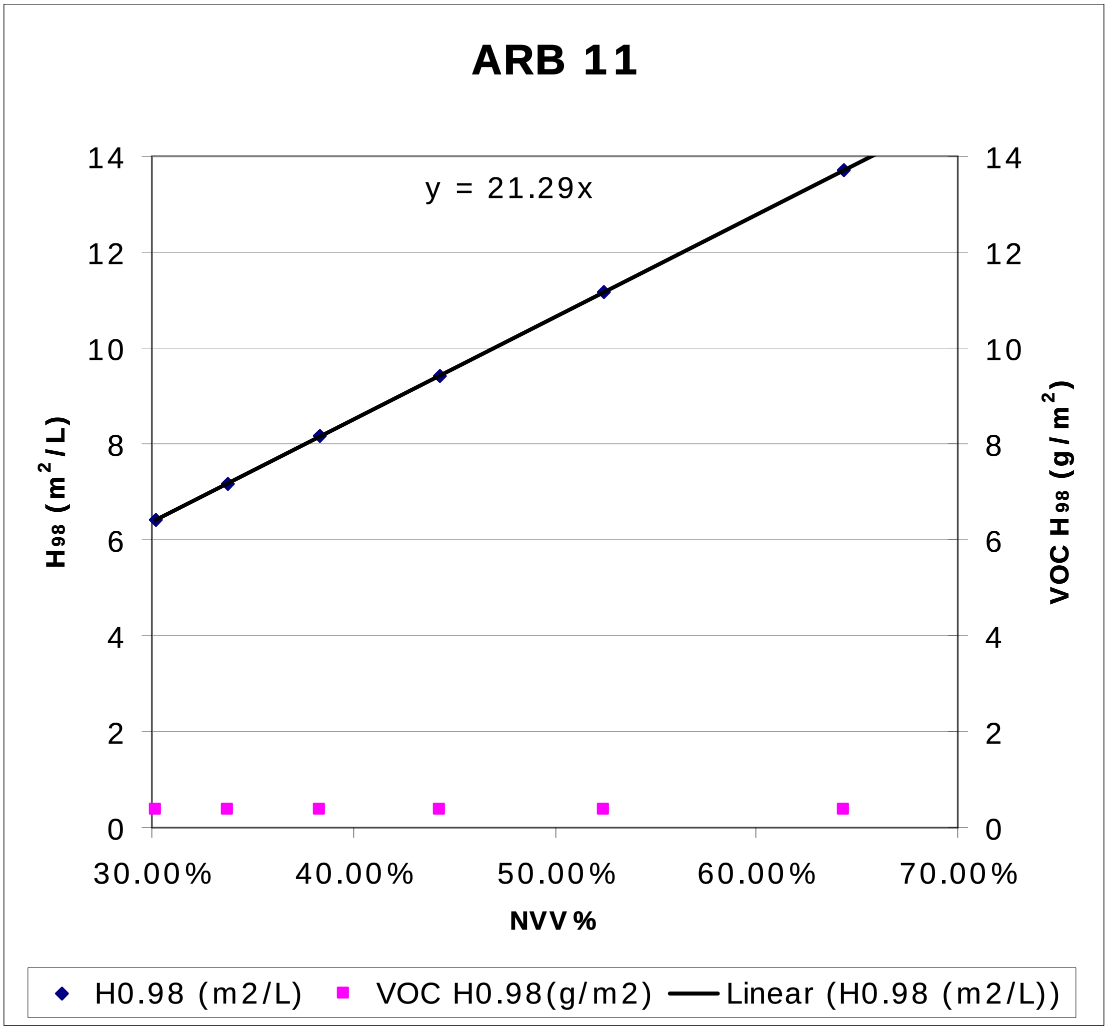
Predicted Hiding Power and Hiding VOC for ARB 9



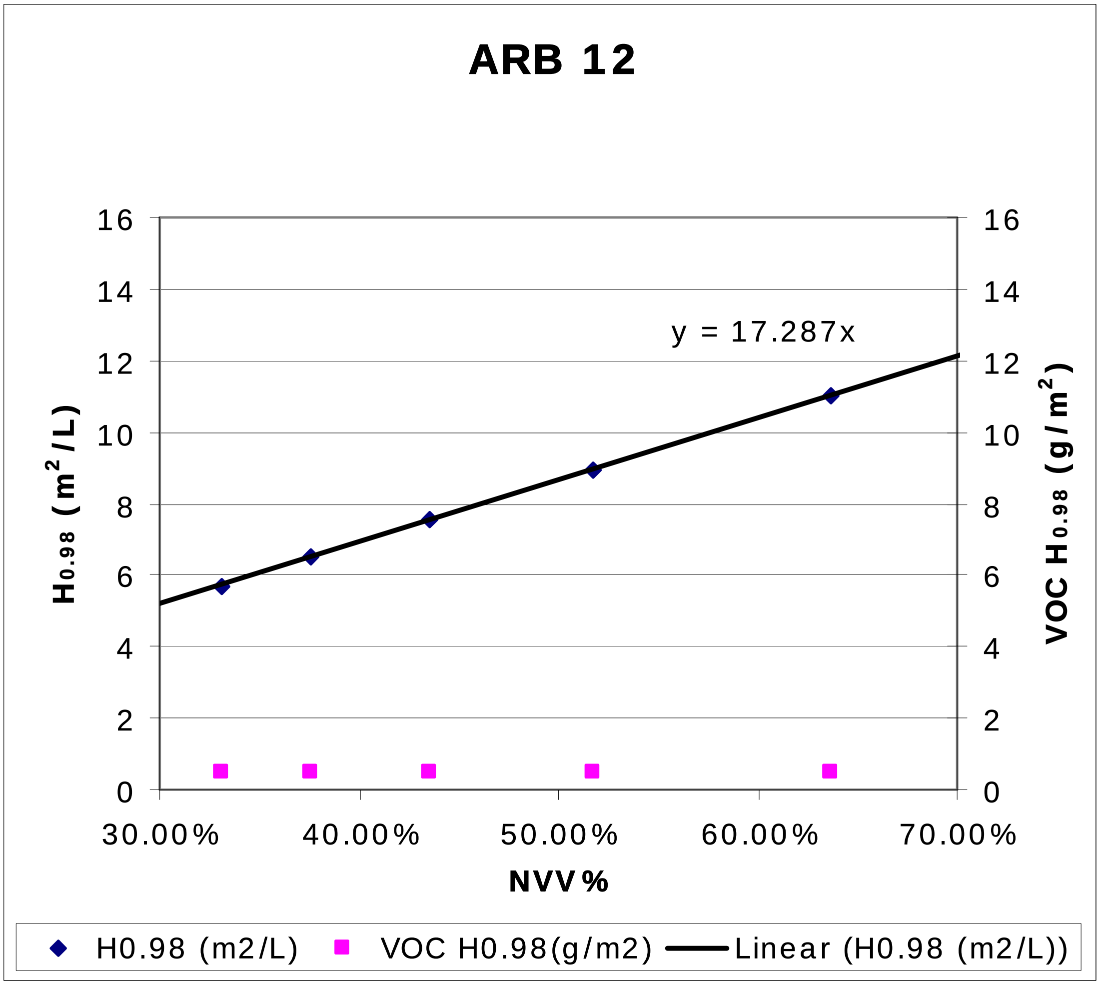
Predicted Hiding Power and Hiding VOC for ARB 10



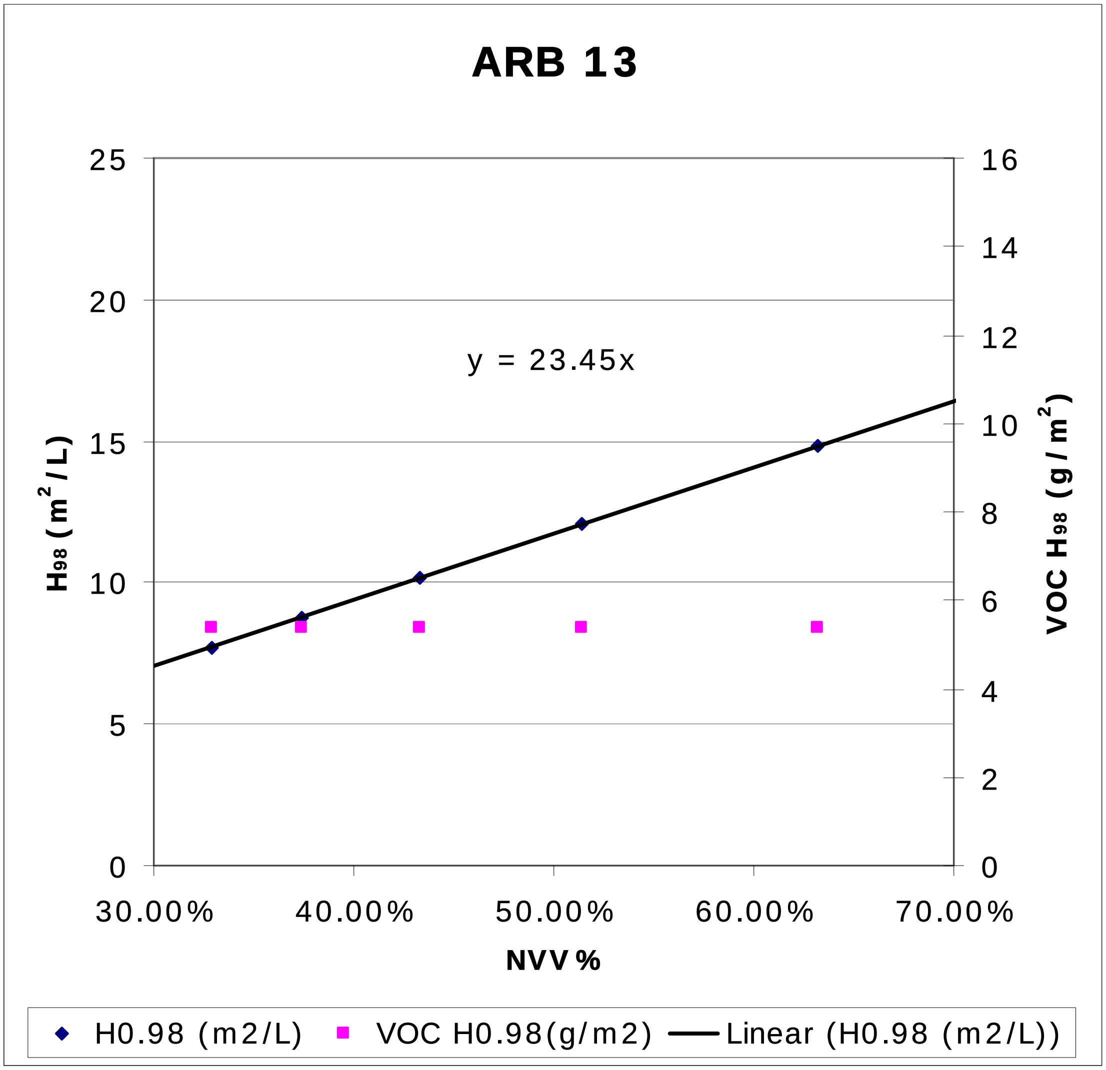
Predicted Hiding Power and Hiding VOC for ARB 11



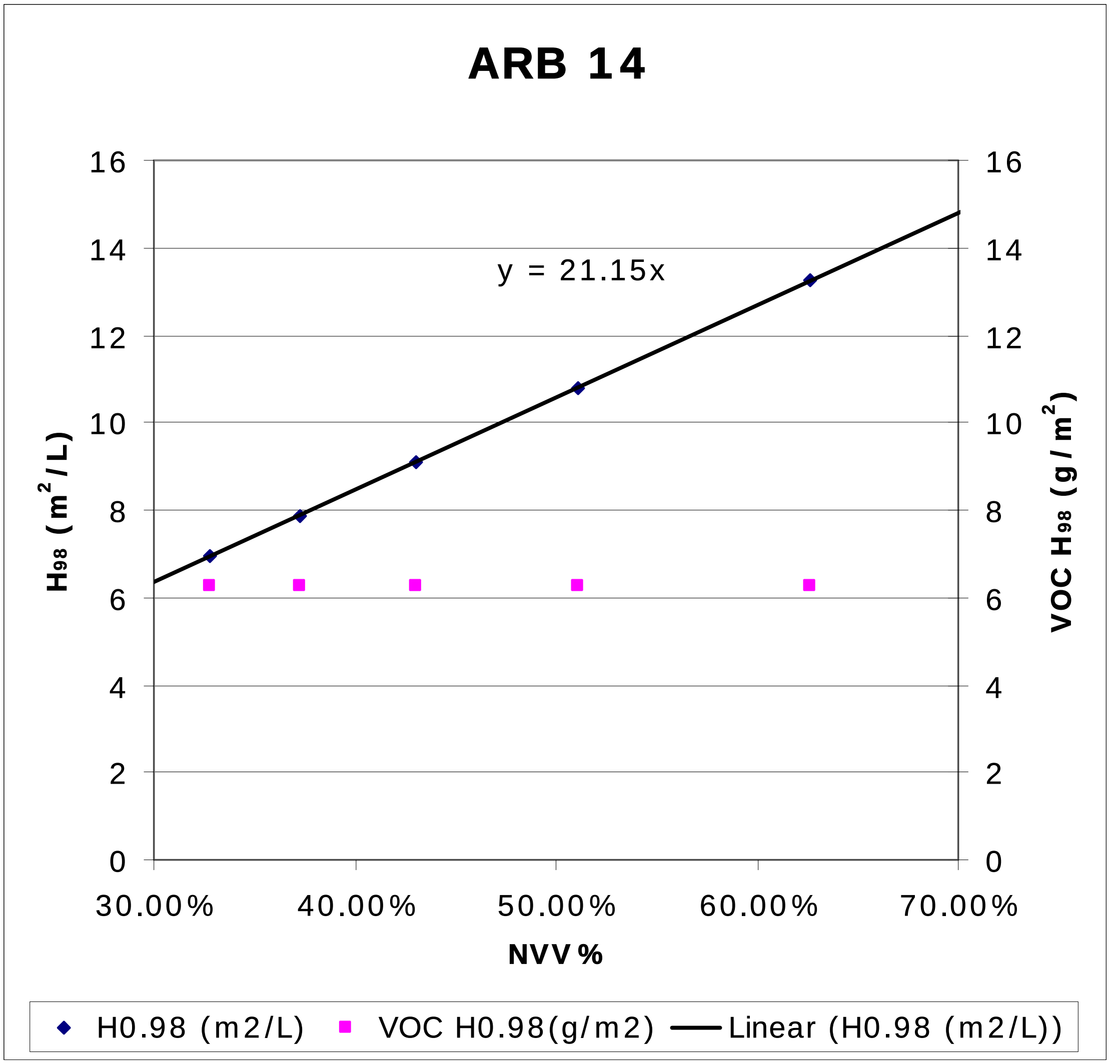
Predicted Hiding Power and Hiding VOC for ARB 12



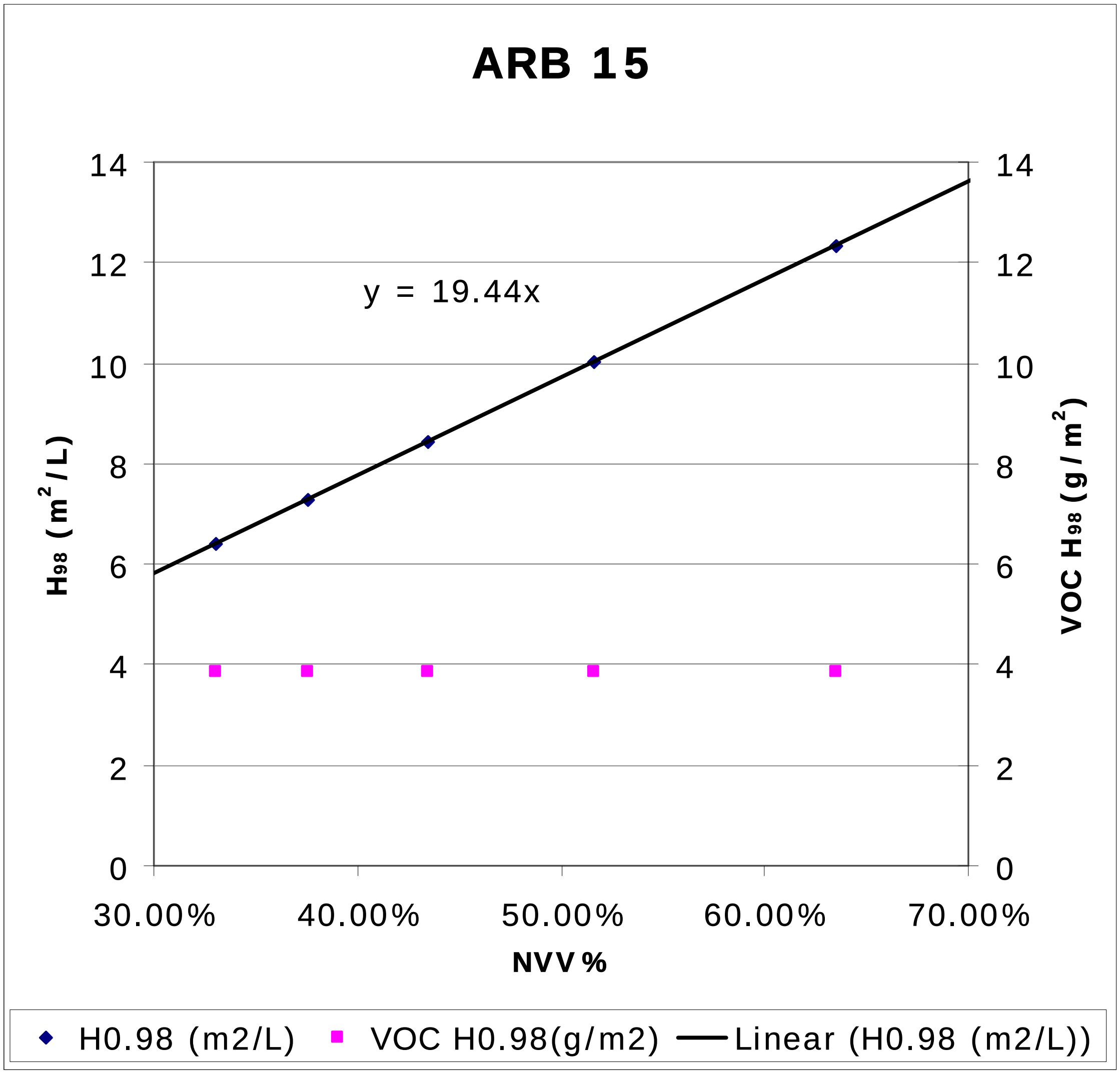
Predicted Hiding Power and Hiding VOC for ARB 13



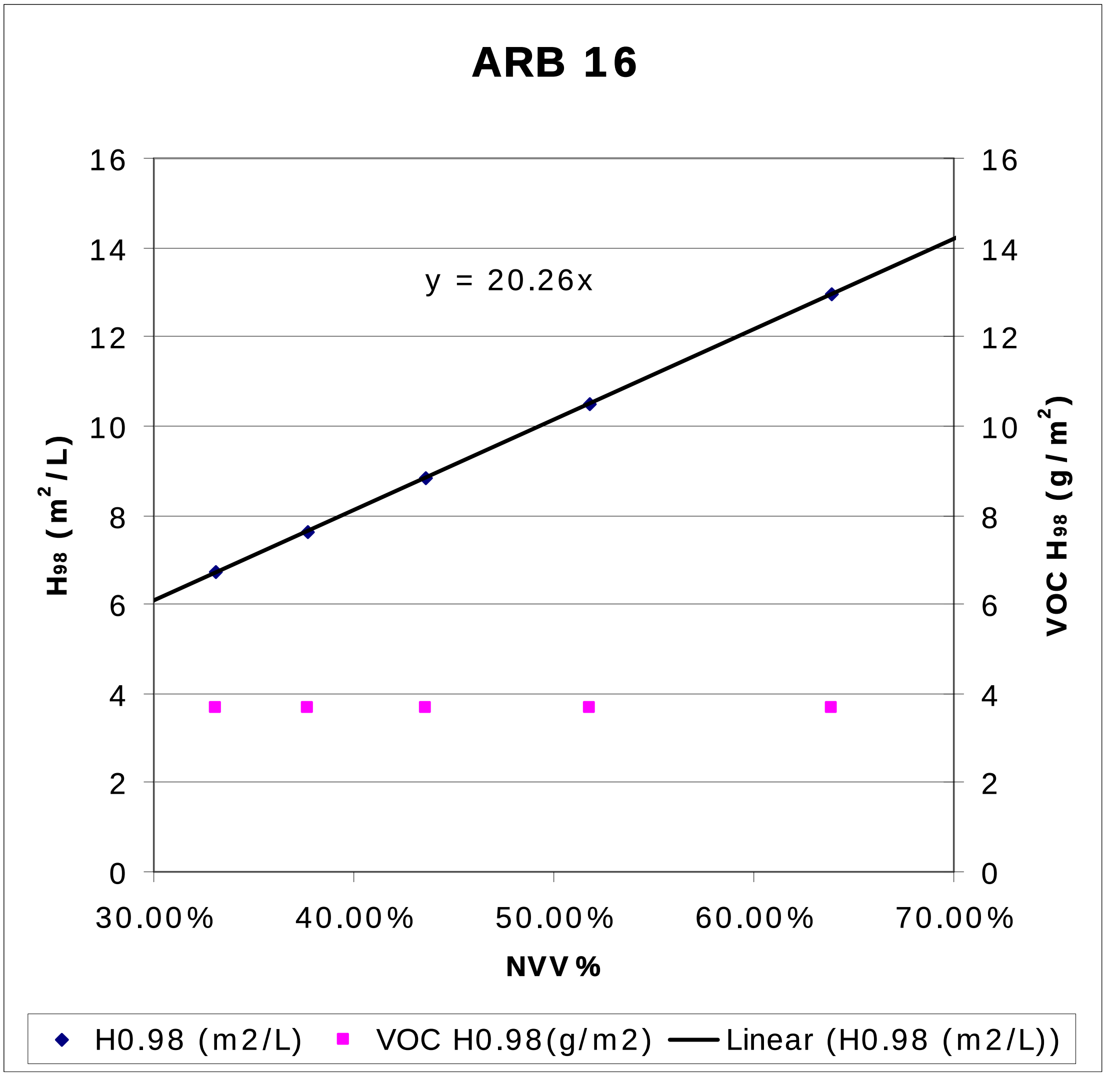
Predicted Hiding Power and Hiding VOC for ARB 14



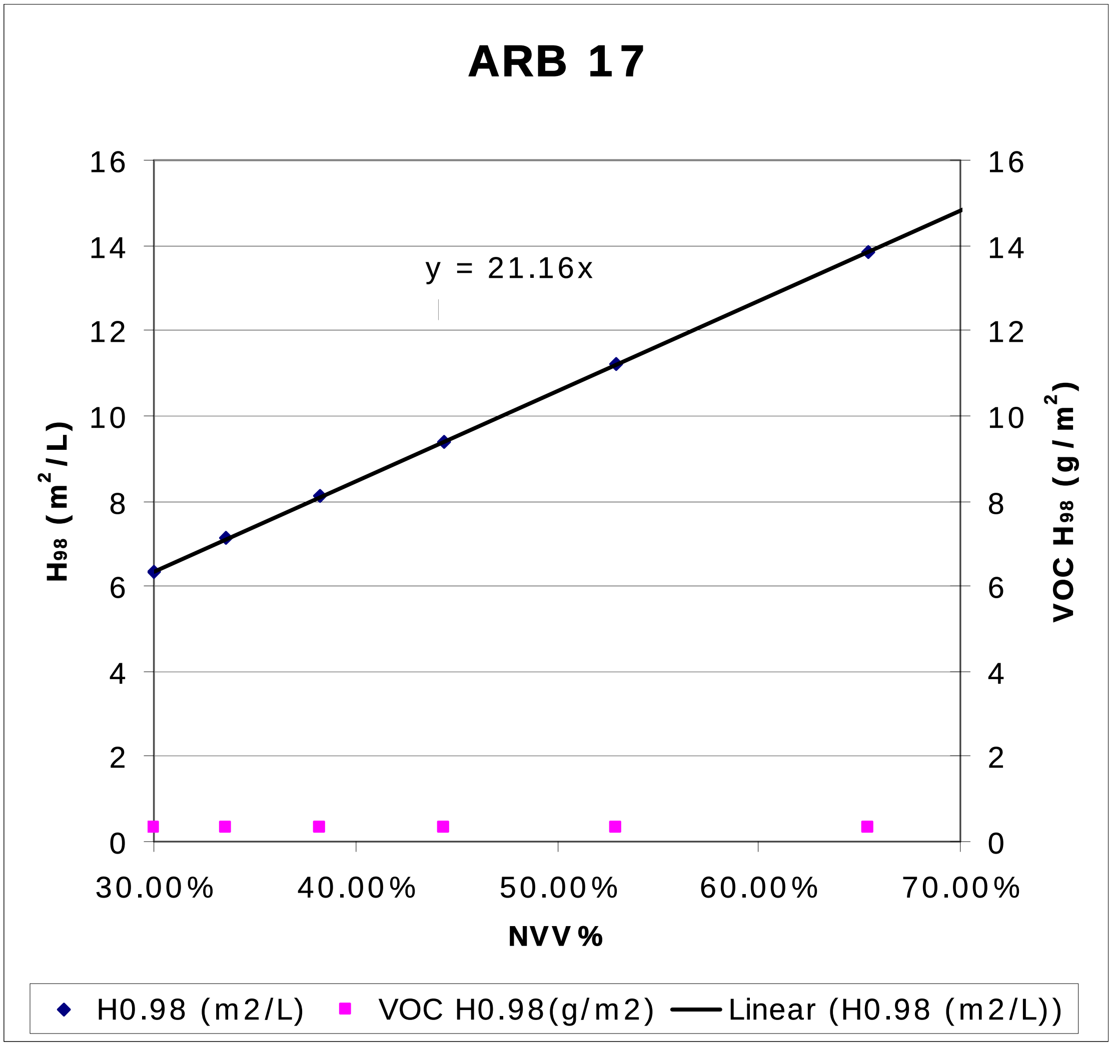
Predicted Hiding Power and Hiding VOC for ARB 15



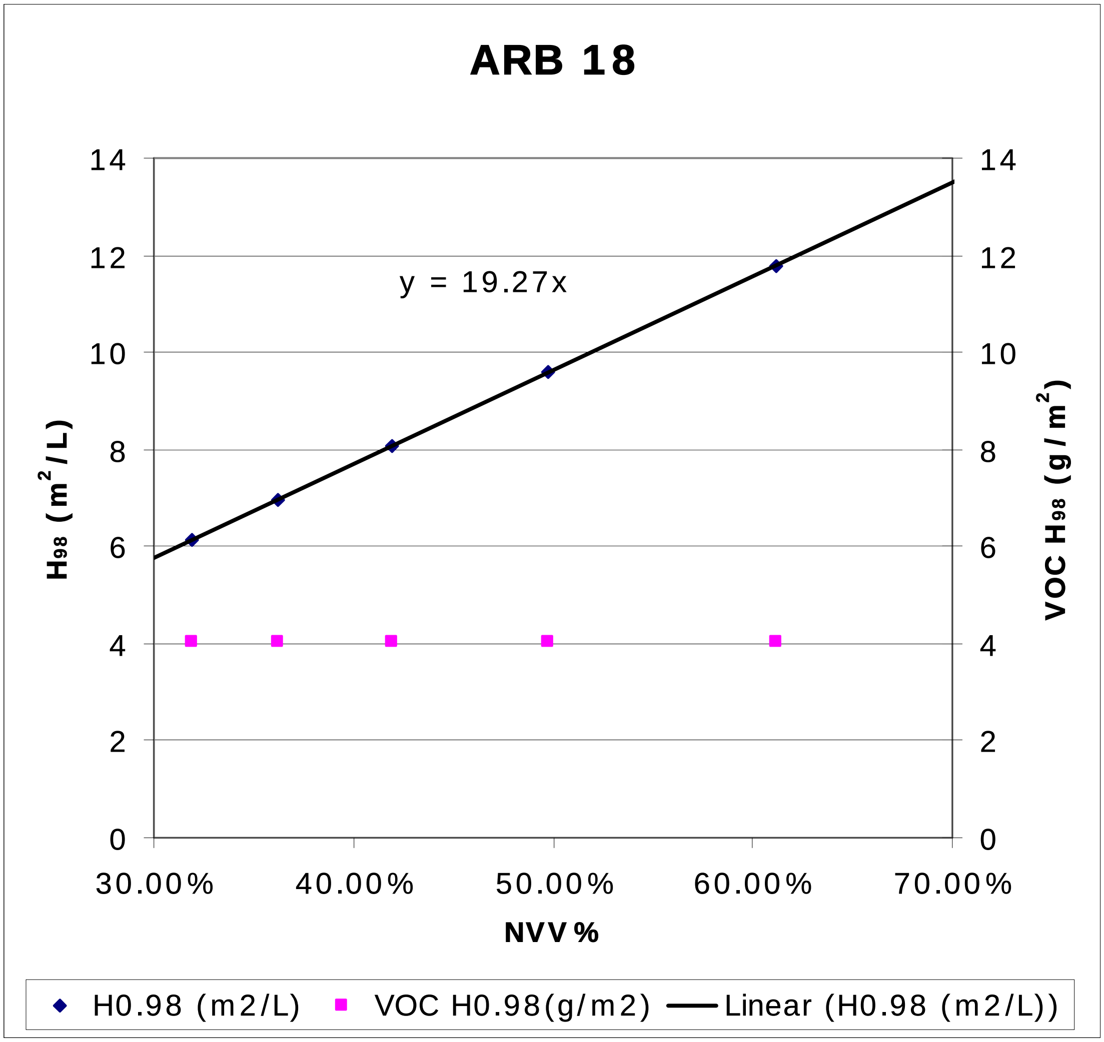
Predicted Hiding Power and Hiding VOC for ARB 16



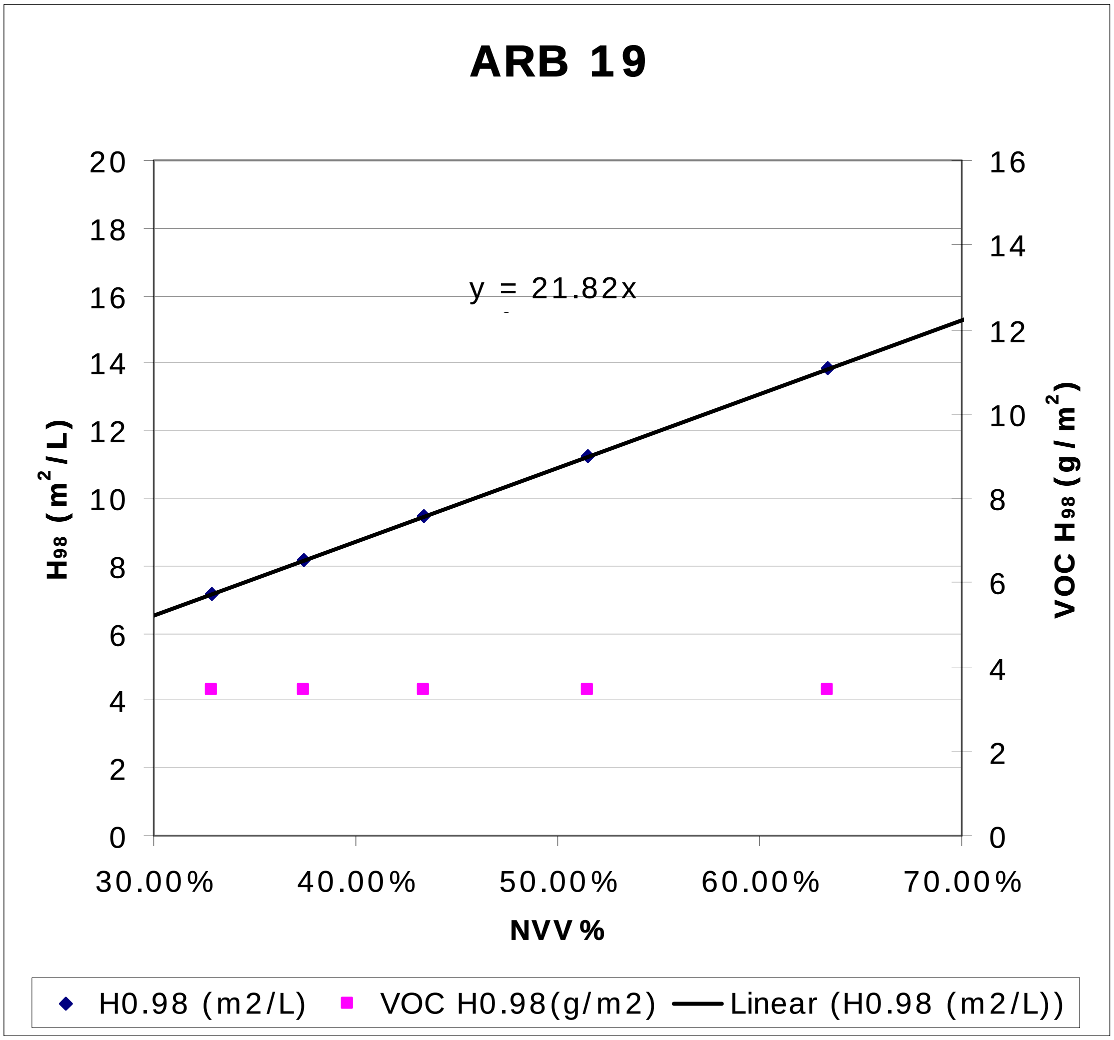
Predicted Hiding Power and Hiding VOC for ARB 17



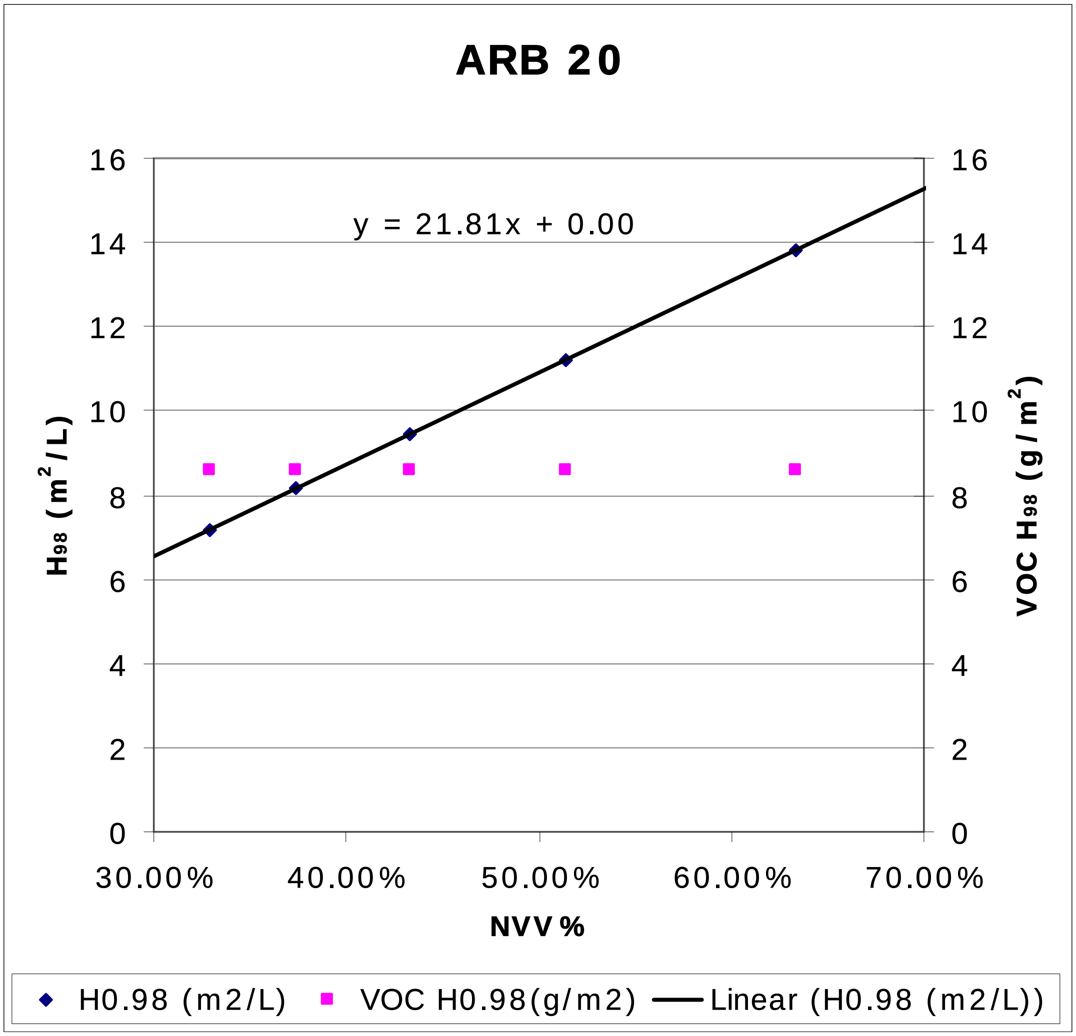
Predicted Hiding Power and Hiding VOC for ARB 18



Predicted Hiding Power and Hiding VOC for ARB 19

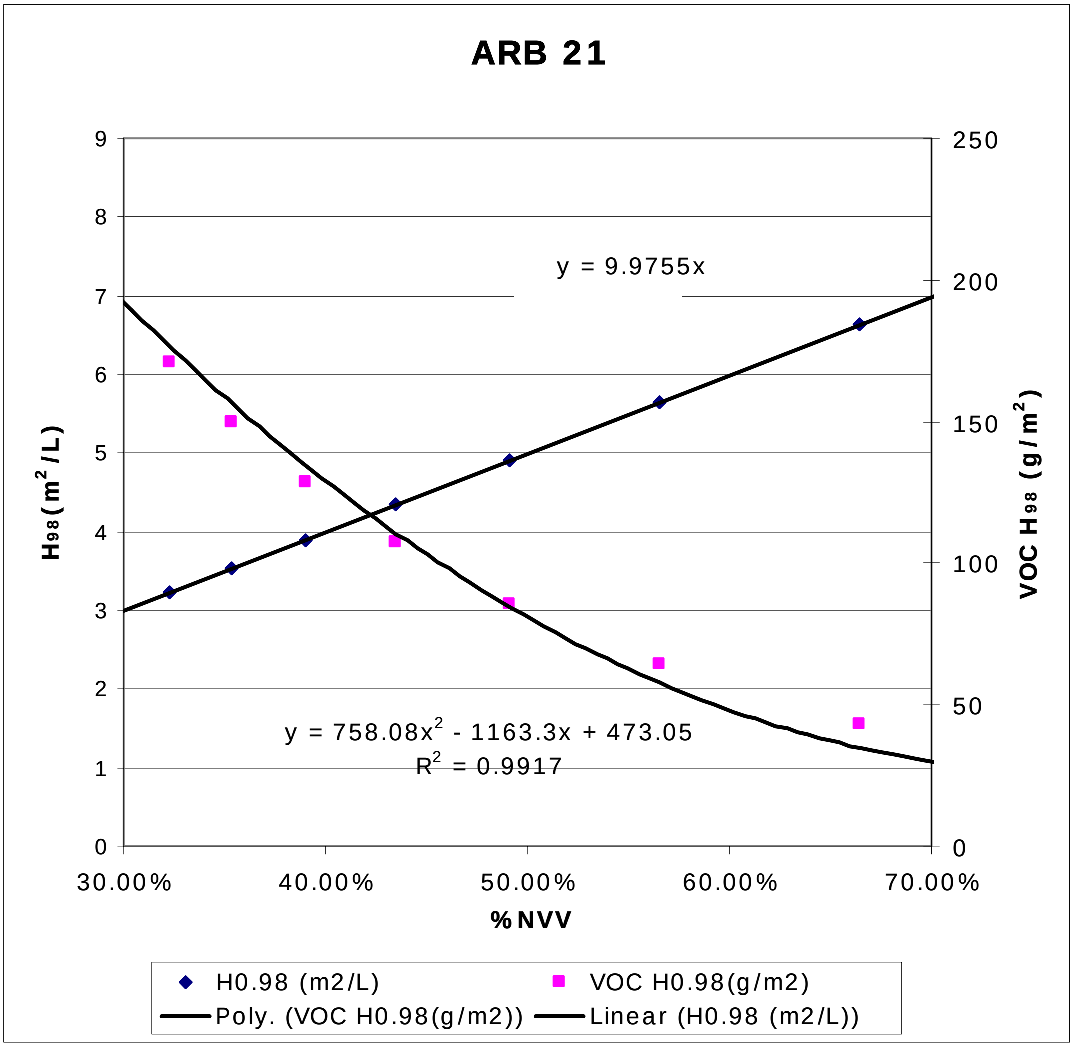


Predicted Hiding Power and Hiding VOC for ARB 20

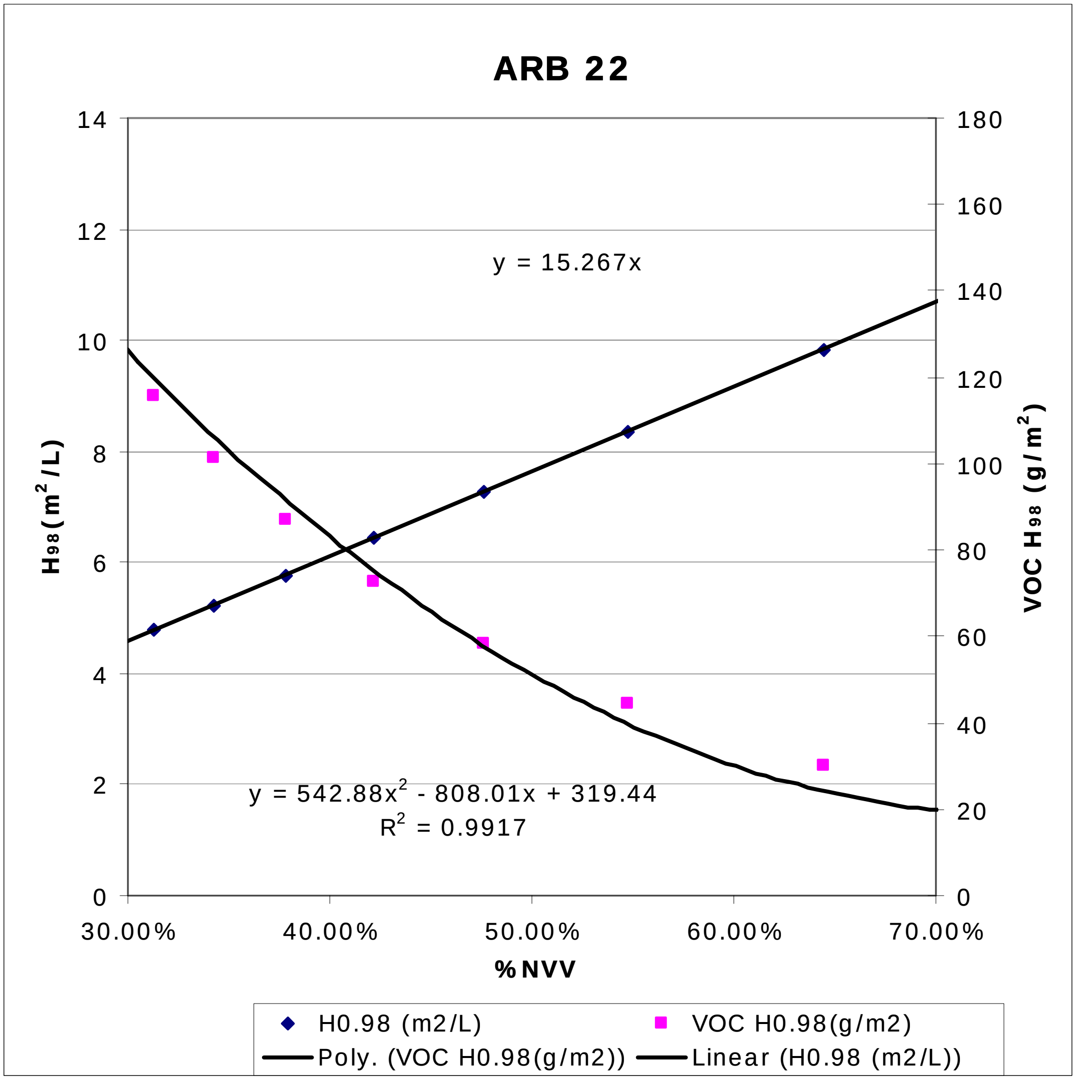


Appendix C – Hiding Power Graphs for Solvent-based Coatings

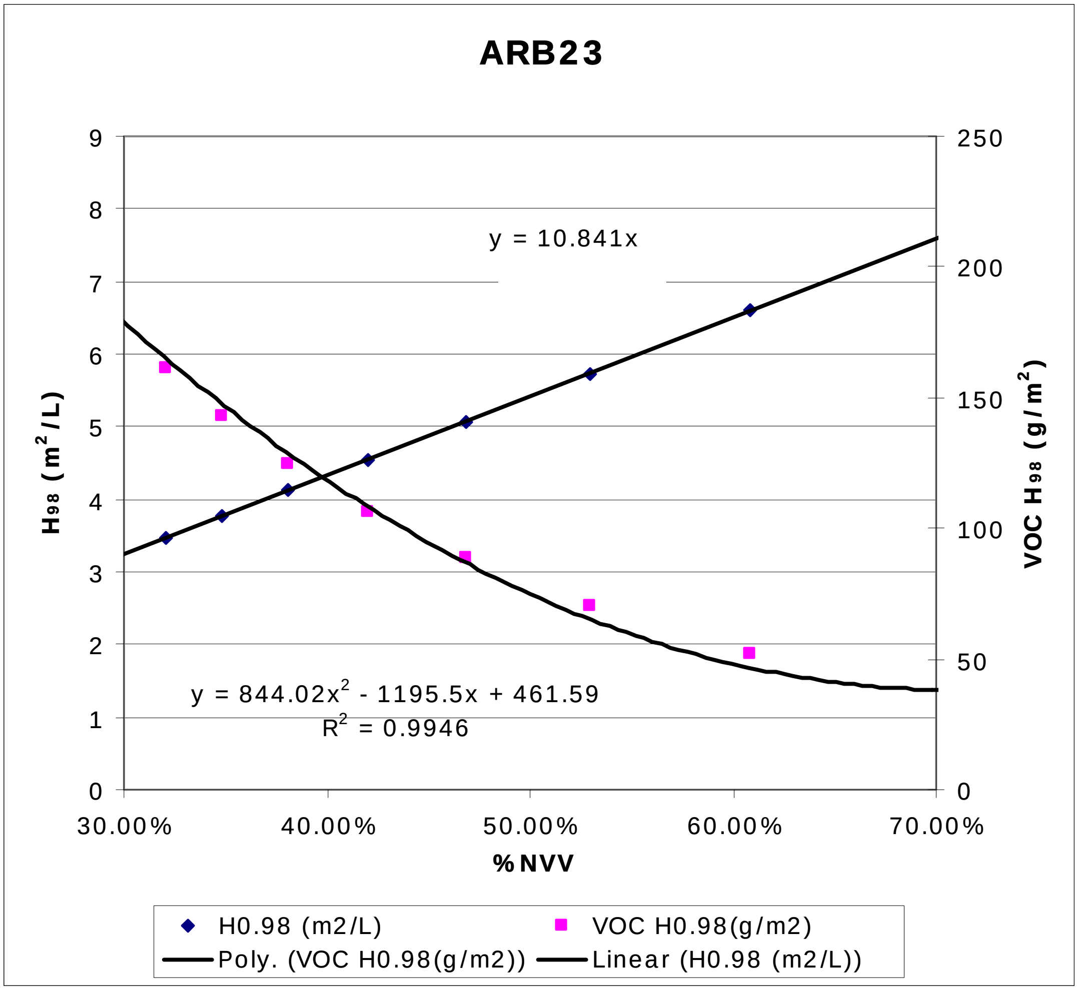
Predicted Hiding Power and Hiding VOC for ARB 21



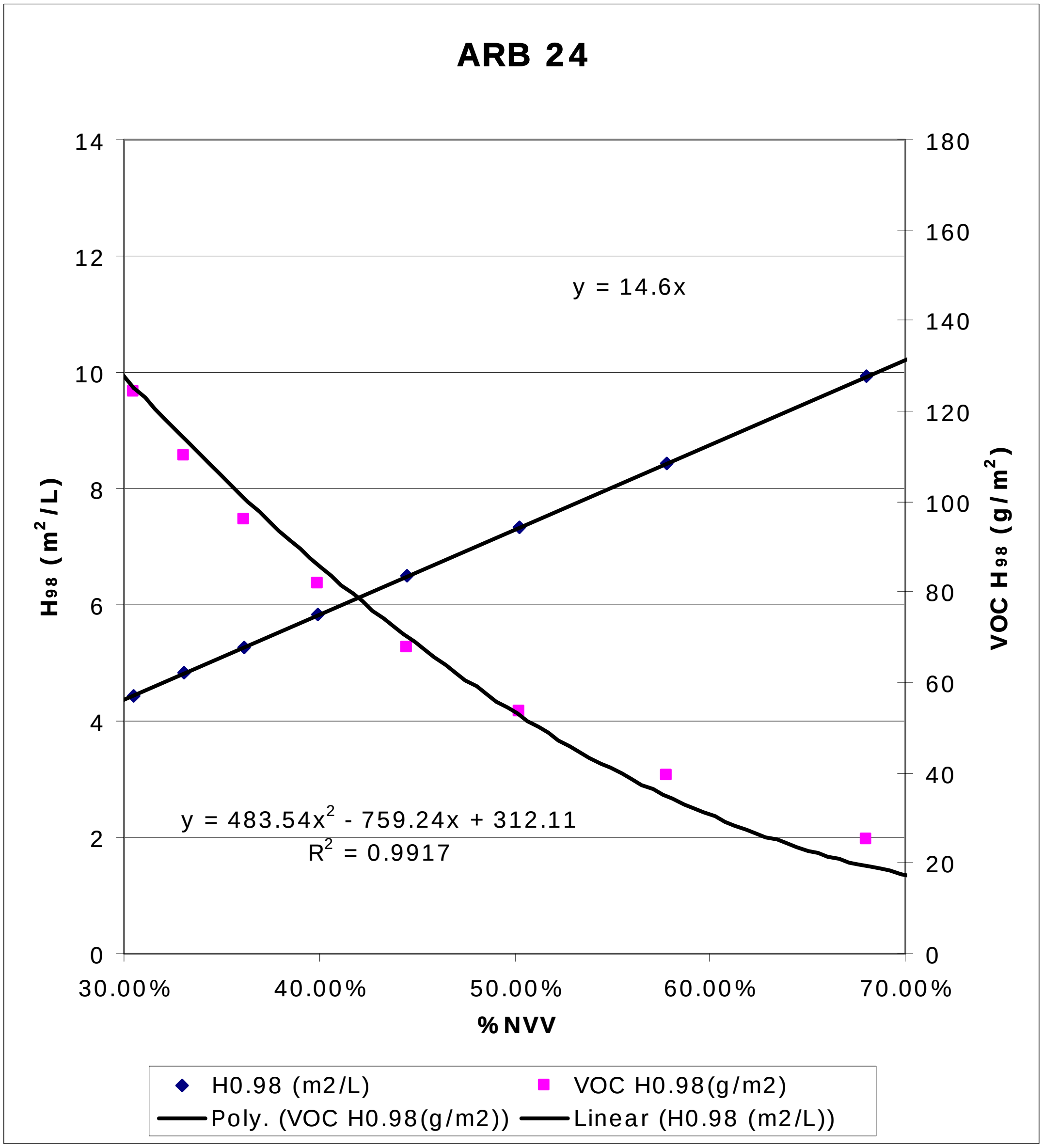
Predicted Hiding Power and Hiding VOC for ARB 22



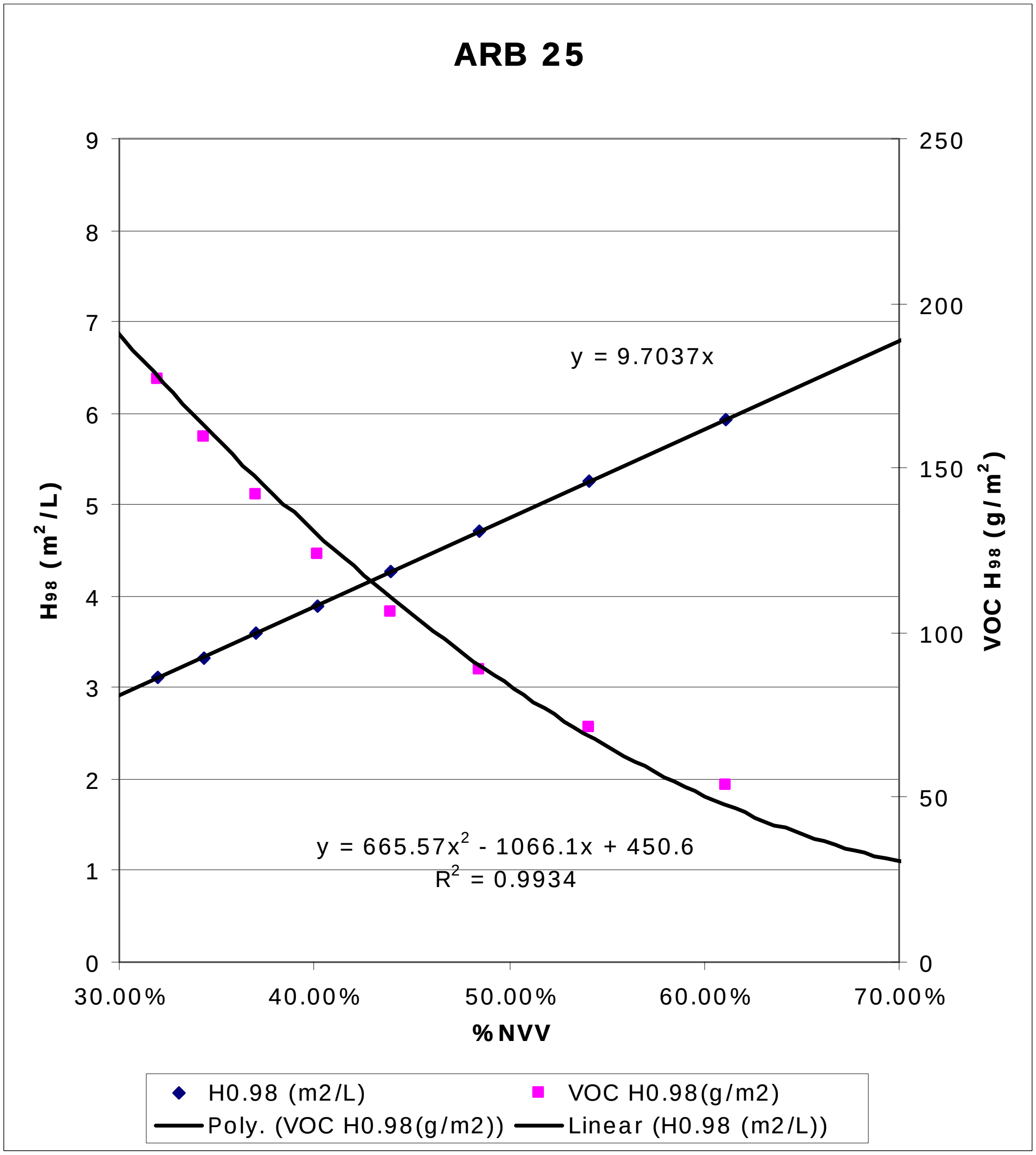
Predicted Hiding Power and Hiding VOC for ARB 23



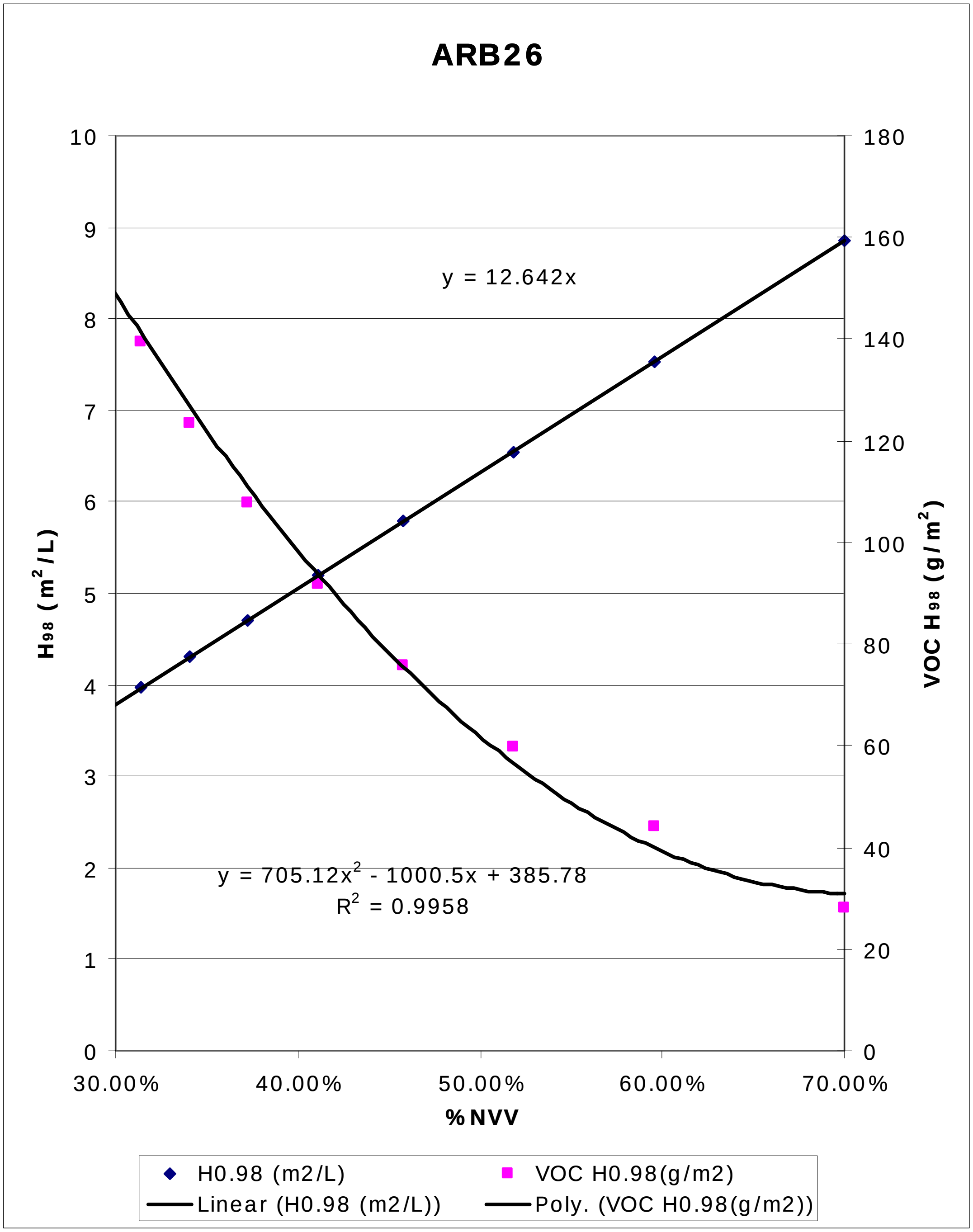
Predicted Hiding Power and Hiding VOC for ARB 24



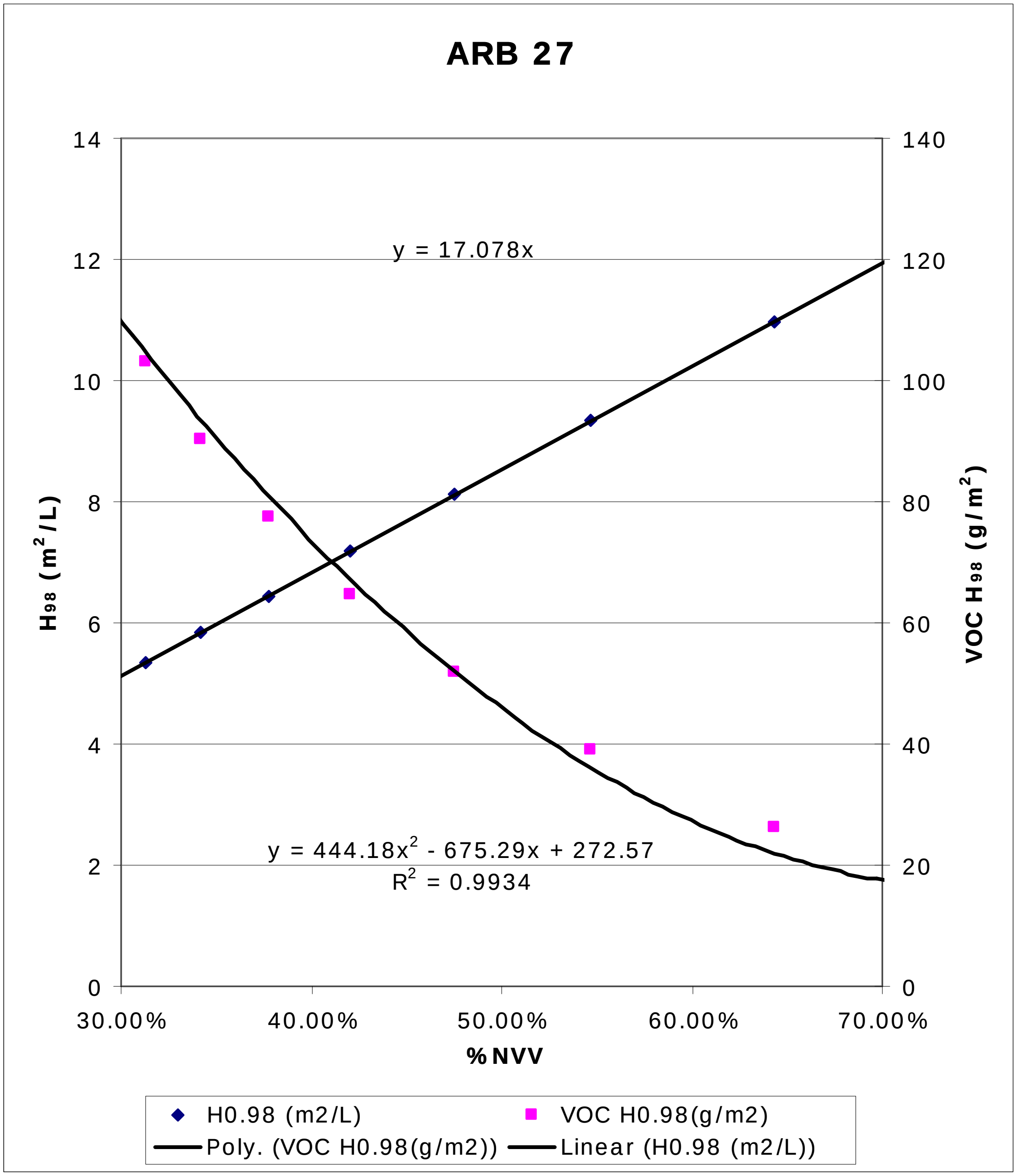
Predicted Hiding Power and Hiding VOC for ARB 25



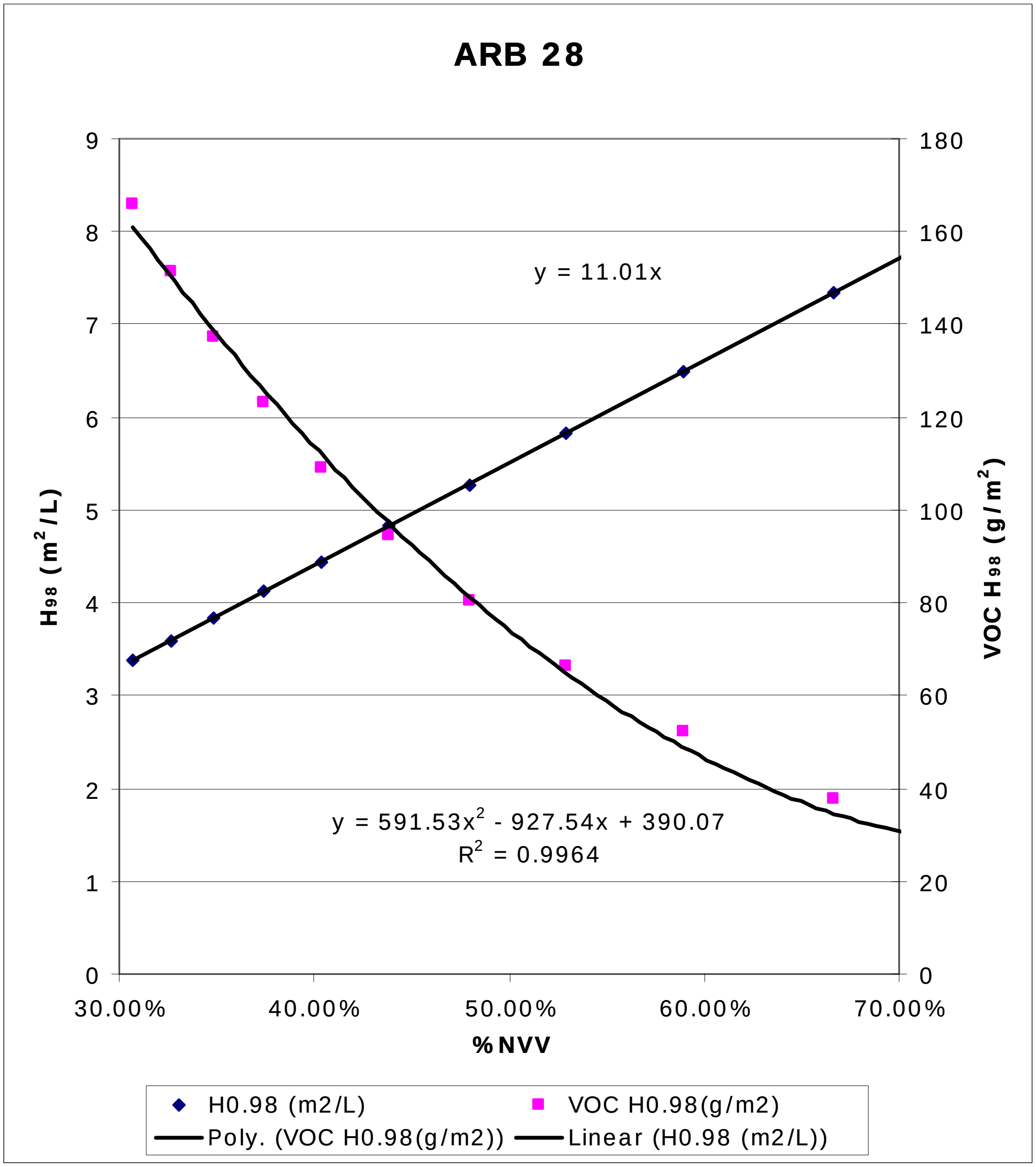
Predicted Hiding Power and Hiding VOC for ARB 26



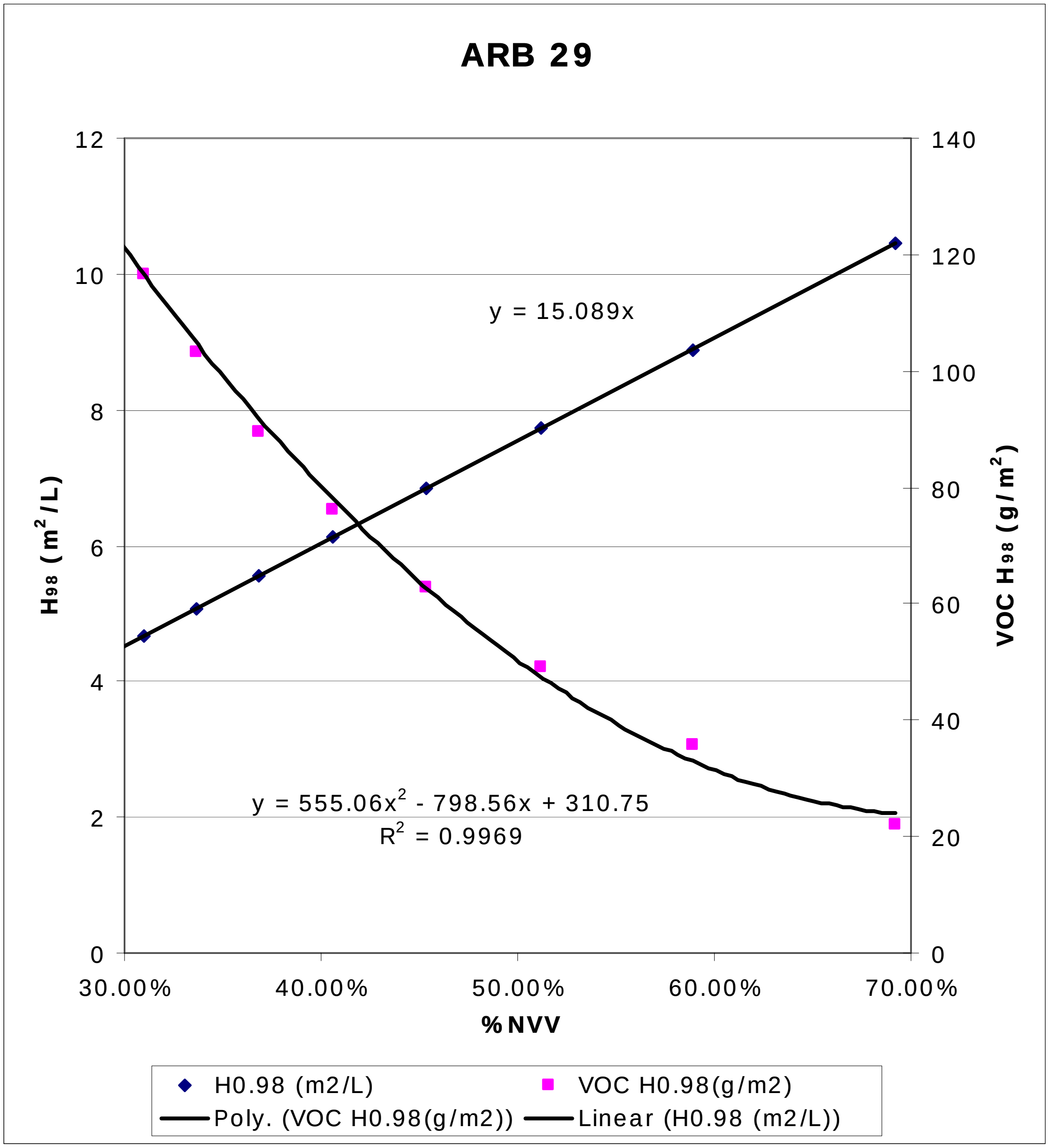
Predicted Hiding Power and Hiding VOC for ARB 27



Predicted Hiding Power and Hiding VOC for ARB 28



Predicted Hiding Power and Hiding VOC for ARB 29



Predicted Hiding Power and Hiding VOC for ARB 30