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For the past several decades, coating suppliers have struggled to develop waterborne (WB) with comparable performance to solventborne (SB) coatings. Alkyds, in particular, have seen very little conversion to WB or lower volatile organic compound (VOC) options, primarily due to performance gaps related to dry time, gloss, adhesion, and corrosion resistance even though versions of WB alkyds have been available for more than 50 years. In fact, as of 2012, less than 10% of the overall alkyd market was converted to WB options.[1] Dow has developed novel technology

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Near-Zero VOC Waterborne Alkyd Dispersions with Solventborne Alkyd Performance

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that facilitates the dispersion of highly hydrophobic, high viscosity alkyd resins into water at near-zero VOC levels. These alkyd dispersions close the performance gaps of current WB alkyd options and offer formulators the opportunity to prepare high-performance WB alkyd paint at near-zero VOC.

CURRENT TECHNOLOGY

Solventborne alkyds continue to remain popular due to their low cost, ease of application, and great versatility. Nevertheless, alkyd coating volume has been forecasted to decline by two percent per year mainly due to the loss of share to coating technologies that can offer higher performance at lower VOC.[2] Paints based on waterborne acrylic emulsions have replaced certain SB alkyd coatings due to lower solvent content and faster dry. However, some coatings from acrylic emulsions can show worse adhesion, gloss, and corrosion resistance compared to SB alkyd coatings at thin film builds (*Figure 1*). Alkyds, which are typically applied at lower molecular weight than latex paints, display exceptional wetting of the substrate; consequently, their coating films offer higher gloss and corrosion resistance than those from latex paint. In addition, during air drying, alkyds crosslink via oxidation leading to very high molecular weight networks that further improves their resistance properties (*Scheme 1*). Another benefit of alkyds is their hydrophobicity, which contributes to excellent early water and humidity resistance.

Low-VOC alkyd options include high-solids alkyds, water-reducible alkyds, WB alkyd emulsions, and core-shell modified alkyd dispersions. The solids content of an SB alkyd can be practically increased by reducing the viscosity of the neat alkyd resin, thereby reducing the amount of solvent needed to bring the viscosity to a reasonable level. The viscosity can be reduced by decreasing the molecular weight of the alkyd resin by changing the dibasic acid/polyol ratio or by increasing the oil length. Although these changes result in VOC reduction, high-solids alkyds typically have longer dry times and reduced chemical/corrosion resistance properties compared to those from traditional SB alkyds.

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Water-reducible alkyds can be formulated to 250–350 g/L VOC. They are often made by incorporating trimellitic anhydride or other raw materials, including carboxylic acid groups, into the structure. The additional acid is neutralized with ammonia or other amine to provide hydrophilicity (*Figure 2*). The alkyds are typically supplied at 70–75 wt% solids in a hydrophilic glycol ether solvent and are dispersed into water by the formulator. They exhibit excellent application characteristics and high gloss, but tend to have long drying times and high yellowing.[1] In addition, the increased hydrophilicity often leads to limited paint storage stability due to ester hydrolysis, which causes a noticeable drop in performance.

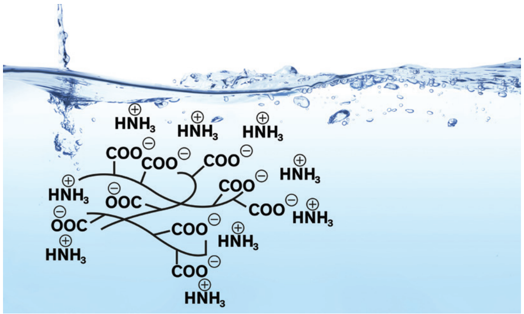
FIGURE 1—Corrosion resistance of commercial SB alkyd paint compared to commercial WB acrylic paint after 300 h salt spray exposure (1 mil dry film thickness, DFT).

Commercial SB Alkyd Paint

Commercial Premium Quality WB Acrylic Paint

Alkyd emulsions can be prepared with little, if any, volatile solvent and have improved hydrolytic stability. The resins are dispersed through the addition of 5–10% anionic and/or nonionic surfactants and do not require the incorporation of excess carboxylic acid groups. In this process, a neat alkyd is heated to a temperature high enough to reduce the viscosity. A surfactant package is then added to the molten alkyd followed by gradual water addition. As water is added, the mixture forms a water-in-oil emulsion. As the water content increases, the alkyd inverts to an oil-in-water emulsion (*Figure 3*). In general, the shorter the oil length of the alkyd resin, the higher the temperature required; therefore, this technique is typically limited to medium- and

FIGURE 2—Illustration of water-reducible alkyd dispersed in water.



SCHEME 1—Example of alkyd synthesis and oxidative drying.

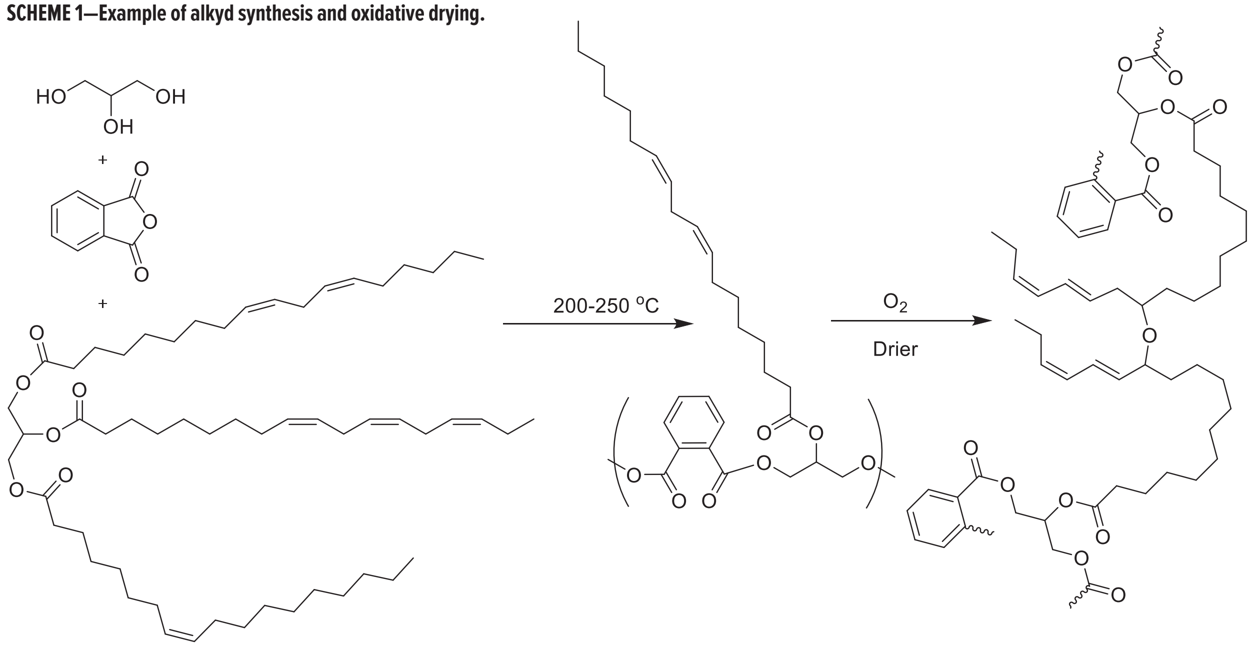


FIGURE 3—Illustration of WB alkyd emulsion.

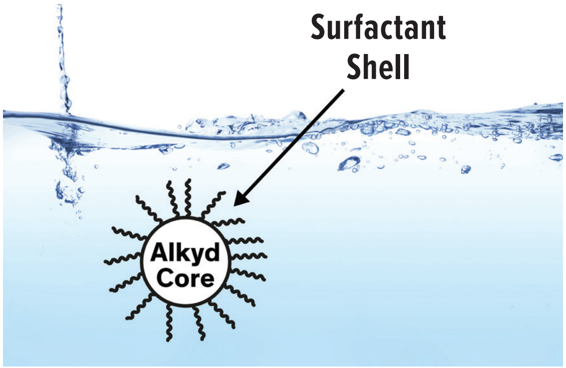
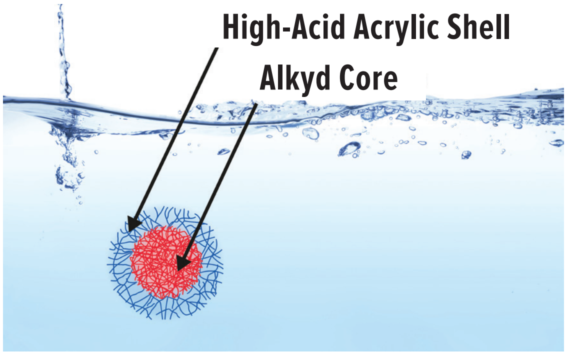


FIGURE 4—Illustration of core-shell modified alkyd dispersion



long-oil alkyds. The emulsions typically have low storage stability and inferior performance due to the presence of high levels of surfactant, which can also migrate to the surface of the coating and lead to early water resistance or corrosion resistance failures.

To improve the hydrolytic stability of WB alkyds, core-shell alkyd-acrylic hybrids have been introduced. During manufacture, an alkyd of deliberately low molecular weight is copolymerized with a "hydrolysis-resistant" acrylic monomer, grafting the acrylic to the alkyd. The acrylic shell is made hydrophilic by neutralizing the acid groups with an amine. The alkyd is then dispersed into water. The acrylic shell extends into the water phase and helps protect the alkyd core from hydrolysis, making the hybrid more shelf stable than water-reducible alkyds (*Figure 4*). The hybrids also have fast drying time and high gloss at VOC levels that tend to be <100 g/L.[1] Unfortunately, during copolymerization, a considerable amount of acrylic homopolymerization (i.e., not grafted to alkyd) also occurs.[3] High levels of ungrafted acrylic polymer detract from the properties of the modified alkyd and often result in considerable water sensitivity due to the high acid value acrylic polymers.

In all the examples mentioned above, low VOC was achieved through chemically or physically modifying the alkyd resin—reducing molecular weight, increasing the acid value and neutralizing, increasing the oil length, or adding a significant amount of surfactant—all of which cause a reduction in overall alkyd performance. In addition, modification steps or the use of specialty monomers/materials in the synthesis increases the cost of production of these resins.

So, the question remains, if a modified WB alkyd resin cannot offer the same performance as an SB system, why not disperse traditional SB resins in water? Until very recently, the answer to this question was that traditional "solvent-borne" alkyd resins are too hydrophobic to disperse in water or to remain stable as an alkyd emulsion. A novel, mechanical dispersion technology changes the rules and attacks the problem in a new way. The mechanical dispersion process enables the dispersion of very hydrophobic alkyd resins into water without polymer modification or significant amount of surfactant.

NOVEL TECHNOLOGY

When choosing to develop WB alkyd technology, a route to disperse hydrophobic, high-molecular weight/viscosity resins into water without any hydrophilic modification of the alkyd was implemented. It was hypothesized that these dispersions would yield WB alkyd coatings that maintained the excellent gloss, adhesion, and resistance properties associated with SB alkyd coatings. Thorough process studies demonstrated that mechanical dispersion could disperse unmodified alkyd resins of various compositions. Formulation work showed that these dispersions could be used to formulate WB alkyd coatings that mirrored the performance of SB alkyd coatings and decoupled performance from VOC level.

Mechanical dispersion is a continuous emulsification process in which a metered alkyd stream and a metered aqueous stream are combined under shear to create an emulsion of specified quality. The resulting dispersions are solvent-free (manufactured without added solvent), typically 50–65 wt% solids with a viscosity range of 500–5000 cP and a narrow particle

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size distribution between 100–300 nm. *Figure 5* shows a schematic of the process. The process is well suited for quick product turnarounds, is easily adjustable, and economically scalable (1–100 kg/min resin flow). It effectively disperses neat alkyd resins with a range of acid values (2–30 mg KOH/g), oil lengths (short, chain-stopped, medium, and long), molecular weights (up to ~250 kg/mol), and viscosities (up to ~250,000 cP) with little to no surfactant (0–4%). Examples of the characteristics of short-oil (SO) and medium-oil (MO) alkyd resin dispersions are shown in *Table 1*.

Unlike the previous WB alkyds described where resin modification decreased coating performance, the performance of this enhanced class of WB alkyd dispersions is comparable to commercial SB alkyds (*Figure 6*).

In 2011, a Voice of the Market (VOM) study was conducted to help understand the growing trends in WB alkyd coatings. The major conclusions from the study were that (1) despite shortcomings in current WB alkyd technology, formulators still use it, and (2) a great majority of formulators desire to use WB alkyds provided that the performance gaps around gloss, adhesion, and corrosion resistance are closed.

To demonstrate the utility of this technology, the performance of an SO alkyd resin formulated at 560 g/L VOC in solvent was compared vs the same

FIGURE 5—Schematic of mechanical dispersion process and illustration of narrow particle size distribution of alkyd dispersion.

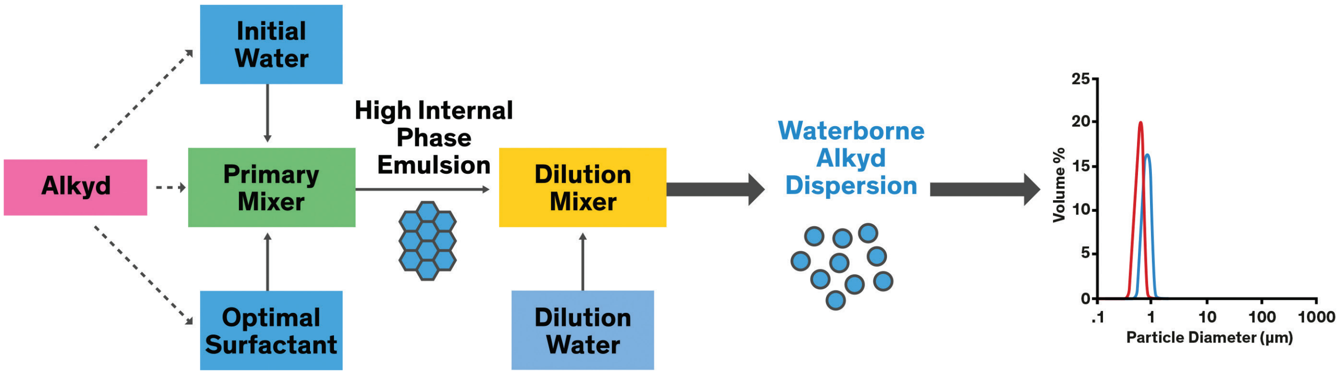
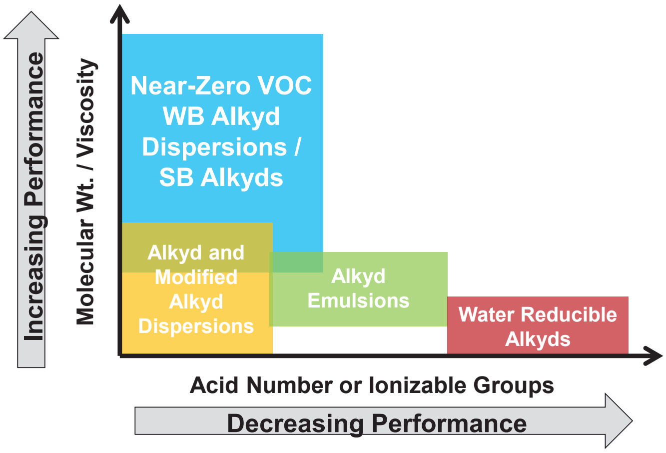


TABLE 1—Dispersion Characteristics of an SO and MO Alkyd Dispersed into Water via Novel Mechanical Dispersion Process

PROPERTY[a]	WB SO ALKYD DISPERSION	WB MO ALKYD DISPERSION
APPEARANCE	MILKY WHITE LIQUID	MILKY WHITE LIQUID
SOLIDS (%)	58	55
PARTICLE SIZE (NM)	165	150
VISCOSITY[b] (CP)	3,000	1,800
PH	9.0	7.0

(a) These are typical properties, not to be construed as specifications.
(b) Viscosity measured with Brookfield Viscometer: Spindle #4, 10 rpm.

FIGURE 6—Pictorial representation of new compositional space available for WB alkyd dispersions enabled by mechanical dispersion.



alkyd dispersed via mechanical dispersion and formulated at near-zero VOC (<5 g/L) (*Table 2*). Clear coatings were drawn down on cold rolled steel (CRS) targeting 1 mil dry film thickness (DFT) and cured for 14 days at 23°C and 50% relative humidity (RH). Gloss, adhesion, hardness, and MEK resistance were measured after 14 days of curing and are reported in *Table 3*. The corrosion resistance of the coatings after 200 h salt spray exposure is shown in *Figure 7*. Notably, the two coatings had very similar performance, although the corrosion resistance of the WB alkyd coating was improved compared to the SB alkyd coating, even at lower VOC.

After validating the hypotheses, the next step was to develop an exceptional alkyd resin for metal protection in industrial applications. Both SO and MO alkyd resins were explored using design of experiments (DoE) methodology. The optimal composition of the MO alkyd resin was determined through the completion of DoEs varying the oil length, degree of branching, effects of molecular structure, and acid content (*Table 4*). Coatings were evaluated on resistance to yellowing, hardness, flexibility, gloss, adhesion, block resistance, scrub resistance, and flow and leveling. Based on the results, an MO alkyd resin showing the best balance of coating properties was chosen as the candidate to move forward.

The results from the first sets of DoEs led to extending the design into the SO alkyd space, hypothesizing that a SO alkyd would offer improved corrosion resistance. A Box-Behnken design for three variables at three levels was laid out to explore the effect of polyol type, fatty acid type, and aromatic acid type on coating performance in clear coatings (*Figure 8*).[4] Coatings were evaluated on resistance to yellowing, hardness, flexibility, gloss, chemical resistance, adhesion, and resistance to corrosion. Based on our results, the MO and SO probes were scaled up and dispersed for additional formulation work.

TABLE 2—Clear Coating Formulations for the Developmental SO Alkyd Resin at 560 g/L and <5 g/L VOC

MATERIAL NAME	wt%
ALKYD IN XYLENE	54
XYLENE	22
MINERAL SPIRITS	23
CO DRIER	0.3
ZR DRIER	0.9
ANTI-SKIN AGENT	0.01
TOTALS	100%
PROPERTY	**VALUE**
TOTAL PVC	0%
VOLUME SOLIDS	34%
WEIGHT SOLIDS	38%
VOC GENERIC WATER EXCL.	**560 G/L**

MATERIAL NAME	wt%
ALKYD IN WATER	97
RHEOLOGY MODIFIER	0.2
DEFOAMER	0
WATER	0
CO DRIER	0.8
ZR DRIER	2.1
TOTALS	100%
PROPERTY	**VALUE**
TOTAL PVC	0%
VOLUME SOLIDS	51%
WEIGHT SOLIDS	54%
VOC GENERIC WATER EXCL.	**<5 G/L**

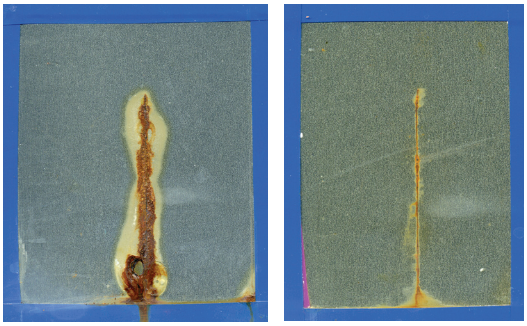
TABLE 3—Gloss, Adhesion, Hardness, and MEK Resistance Data for Clear SB and WB SO Alkyd Coatings (1 mil DFT on CRS); Cured for 14 days at 23°C and 50% RH)

DESCRIPTION	FORMULATION VOC (g/L)	20° GLOSS	60° GLOSS	ADHESION	PENCIL HARDNESS	MEK DOUBLE RUBS
SB SO ALKYD COATING	560	89	103	5B	B	45
WB SO ALKYD COATING	<5	96	105	5B	B	47

TABLE 4—Path to MO Alkyd Probe Using DoE Methodology

DOE	DESIGN SPACE	OUTPUT
1	OIL LENGTH DEGREE OF BRANCHING	1ST GENERATION PROBE
AUGMENTED DESIGN 1	EXPAND DESIGN TO SHORTER OIL LENGTHS	1ST GENERATION PROBE IS STILL BEST PERFORMER
2	DECOUPLE MW AND ACID VALUE	2ND GENERATION PROBE

FIGURE 7—Corrosion resistance of clear SB and WB SO alkyd coatings (200 h salt spray exposure, 1 mil DFT on CRS).



SB Alkyd Coating
VOC = 560 g/L

WB Alkyd Coating
VOC = < 5 g/L

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FIGURE 8—Schematic of Box-Behnken design for SO alkyd.

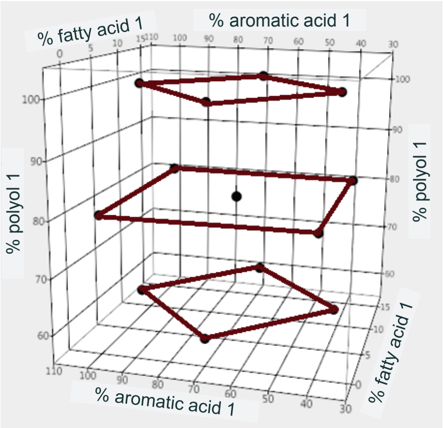


TABLE 5—Pigmented Formulation Used for SO and MO Alkyd Dispersion Coatings

MATERIAL NAME	POUNDS	GALLONS
GRIND		
WATER	5.50	0.66
DEFOAMER	0.20	0.02
DISPERSANT	1.30	0.15
BASE	0.20	0.03
RHEOLOGY MODIFIER	0.40	0.05
TIO$_2$	24.00	0.72
CA DRIER	1.60	0.20
GRIND SUB-TOTAL	33.20	1.82
LETDOWN		
SO OR MO WB ALKYD DISP.	71.42	8.15
FE DRIER	0.60	0.07
FLASH RUST INHIBITOR	1.20	0.13
TOTALS	106.42	10.18

PROPERTY	VALUE
TOTAL PVC	14%
VOLUME SOLIDS	50%
WEIGHT SOLIDS	61%
VOC GENERIC WATER EXCL.	**<5 G/L**

FIGURE 9—Corrosion resistance of SO alkyd dispersion coatings formulated with various dispersants (~1 mil DFT, 300 h salt spray exposure).

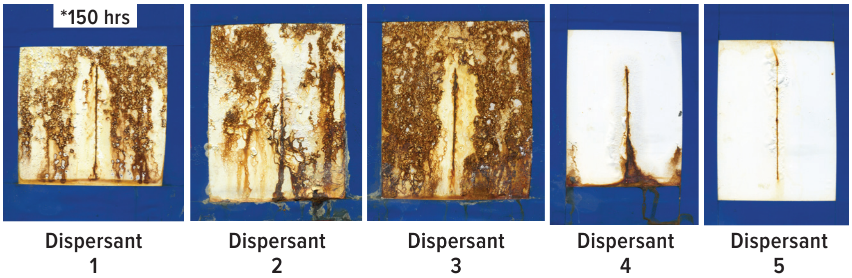


FIGURE 10—Top-down SEM images of 14% PVC coatings formulated with various dispersants (~1 mil DFT on CRS).

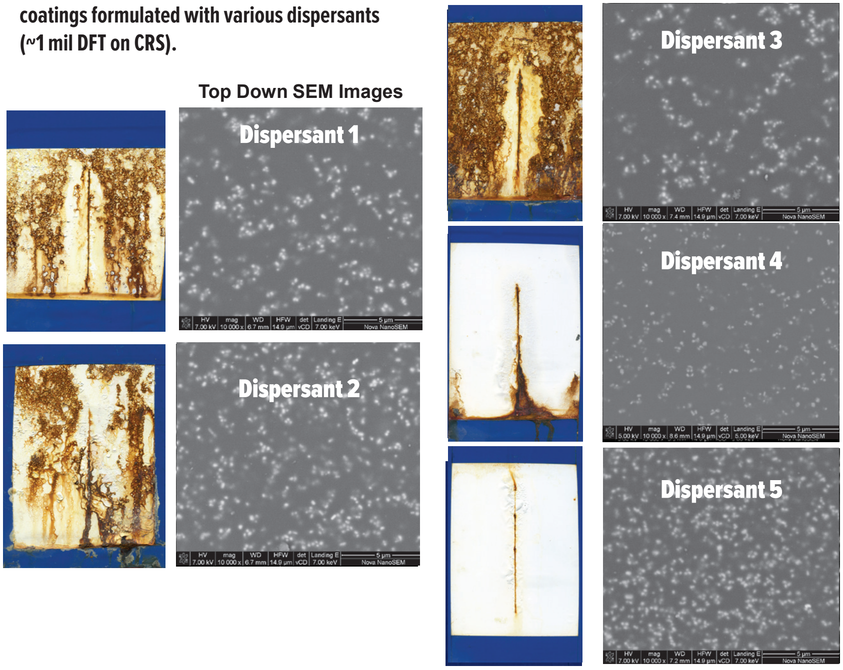
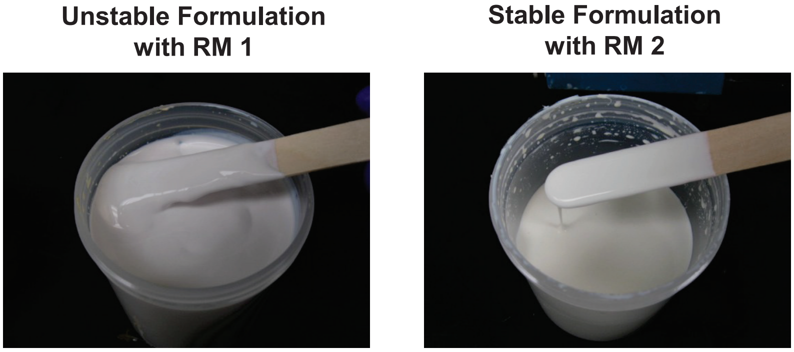


FIGURE 11—Effect of rheology modifier on paint stability.



Unstable Formulation with RM 1

Stable Formulation with RM 2

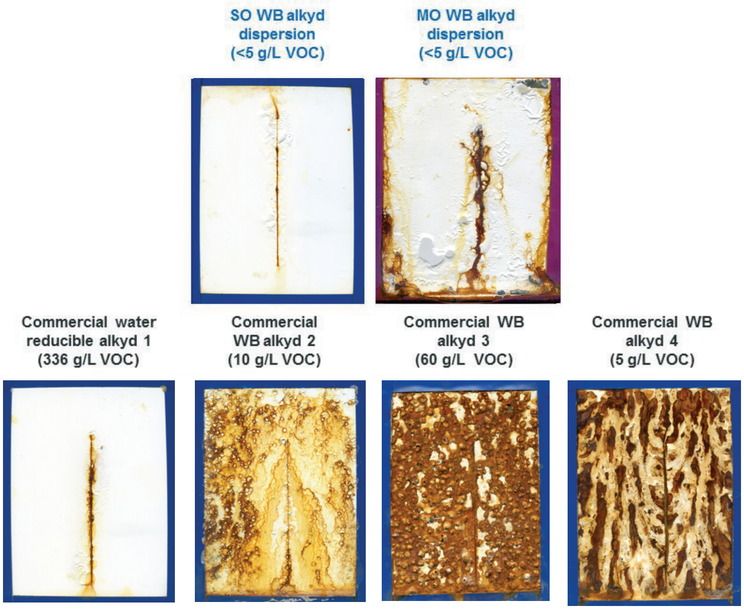
FORMULATION DEVELOPMENT

Early into formulation development of the mechanically dispersed alkyd resins, it was discovered that traditional WB alkyd coating formulation strategies did not give acceptable coating performance with this new class of WB alkyd dispersions. Since additives recommended for WB alkyds were designed to work with more hydrophilic resins, it was necessary to evaluate different additives that could be more compatible with the hydrophobic resin chemistry. For example, evaluation of five different dispersants in the grind led to dramatically different corrosion-resistance properties (*Figure 9*). To understand this observation, the paints were evaluated using top-down SEM (*Figure 10*). The results were striking. The more hydrophobic dispersants showed a much better distribution of TiO_2 within the alkyd, which corresponded with improved corrosion protection. The necessity of proper additive selection was consistent across the other additives including rheology modifiers (RM) and defoamers. *Figure 11* shows how RM 1 caused the formulation to become unstable and crash, whereas RM 2 thickened the paint to a usable viscosity without causing agglomeration.

TABLE 6—Paint Performance of WB Alkyd Dispersion Coatings and Commercial WB Alkyd Paints

SAMPLE	WB SO ALKYD DISPERSION	WB MO ALKYD DISPERSION	COMMERCIAL WATER-REDUCIBLE ALKYD 1	COMMERCIAL WB ALKYD 2	COMMERCIAL WB ALKYD 3	COMMERCIAL WB ALKYD PRIMER 4
VOC (G/L)	**<5**	**<5**	>330	<10	>50	<5
DFT (MIL)	**1.1**	**0.8**	1.0	1.2	1.1	1.4
TACK FREE (H)	**0.6**	**0.4**	1.7	0.2	0.3	0.05
20° GLOSS	**86**	**85**	56	38	9	1
60° GLOSS	**95**	**110**	83	79	42	2
KÖNIG HARDNESS	**40**	**38**	39	21	25	35
PENCIL HARDNESS	**B**	**B**	B	B	B	B
ADHESION	**5B**	**5B**	2B	3B	4B	4B
DIRECT IMPACT	**20**	**160**	20	20	20	0

FIGURE 12—Corrosion resistance of paints from enhanced WB alkyd dispersions compared to commercial WB alkyd paints after 300 h salt spray exposure (~1 mil DFT on CRS).



SO WB alkyd dispersion (<5 g/L VOC)

MO WB alkyd dispersion (<5 g/L VOC)

Commercial water reducible alkyd 1 (336 g/L VOC)

Commercial WB alkyd 2 (10 g/L VOC)

Commercial WB alkyd 3 (60 g/L VOC)

Commercial WB alkyd 4 (5 g/L VOC)

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BENCHMARK STUDY

Once satisfied with a near-zero VOC (<5 g/L) formulation (*Table 5*), we compared the performance of the SO and MO WB alkyd dispersions, formulated at 14% PVC, with six commercial solventborne alkyd paints (VOC range 330–600 g/L) and four commercial waterborne alkyd paints (VOC range <5–350 g/L).

All the paints were applied at a targeted 1 mil DFT on CRS panels. After curing for 14 days at 23°C and 50% RH, the paints were evaluated for dry time, gloss, hardness, adhesion, flexibility, and corrosion resistance.

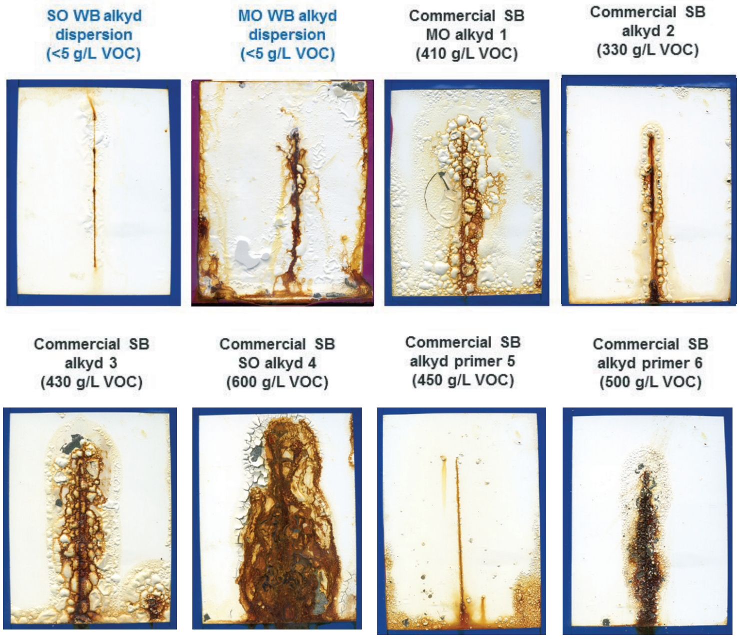
As discussed earlier, the common techniques used to formulate low-VOC alkyd coatings often compromise coating performance such as reduced gloss, adhesion, and corrosion resistance.

Table 6 shows the performance of the paints based on the enhanced WB alkyd dispersions as compared to the commercial WB alkyd paints. Notably, all the commercial WB alkyd paints have lower gloss and worse adhesion compared to the paints derived from the enhanced alkyd dispersions. Hardness and impact resistance were comparable across the data set, with the exception of the paint formulated with the MO

TABLE 7—Performance of Paints from the WB Alkyd Dispersions and Commercial SB Alkyd Paints

SAMPLE	WB SO ALKYD DISPERSION	WB MO ALKYD DISPERSION	COMM. SB MO ALKYD 1	COMM. SB ALKYD 2	COMM. SB ALKYD 3	COMM. SB SO ALKYD 4	COMM. SB ALKYD PRIMER 5	COMM. SB ALKYD PRIMER 6
VOC (G/L)	**<5**	**<5**	410	330	430	600	450	500
DFT (MIL)	**1.1**	**0.8**	1.0	1.5	1.1	1.1	1.2	1.1
TACK FREE (H)	**0.6**	**0.4**	0.5	3.2	2.4	0.2	0.4	0.2
20° GLOSS	**86**	**85**	51	66	71	31	7	53
60° GLOSS	**95**	**110**	87	88	89	76	37	90
KÖNIG HARDNESS	**40**	**38**	24	18	25	61	29	37
PENCIL HARDNESS	**B**	**B**	5B	3B	3B	H	3B	B
ADHESION	**5B**	**5B**	3B	4B	3B	5B	4B	3B
DIRECT IMPACT	**20**	**160**	40	80	100	20	80	60

FIGURE 13—Corrosion resistance of paints derived from the WB alkyd dispersions compared to commercial SB alkyd paints after 300 h salt spray exposure (~1 mil DFT on CRS).



SO WB alkyd dispersion (<5 g/L VOC)

MO WB alkyd dispersion (<5 g/L VOC)

Commercial SB MO alkyd 1 (410 g/L VOC)

Commercial SB alkyd 2 (330 g/L VOC)

Commercial SB alkyd 3 (430 g/L VOC)

Commercial SB SO alkyd 4 (600 g/L VOC)

Commercial SB alkyd primer 5 (450 g/L VOC)

Commercial SB alkyd primer 6 (500 g/L VOC) alkyd dispersion, which showed superior impact resistance. As expected, the corrosion resistance of paints from an unmodified, hydrophobic alkyd resin was higher than those from resins that have hydrophilic modification. This is evident in *Figure 12*, which compares the corrosion resistance of the paints derived from the enhanced WB alkyd dispersions to the commercial WB alkyd paints after 300 h salt spray. The paint based on the SO alkyd dispersion clearly outperforms all the commercial WB alkyd emulsion paints and matches the performance of the water-reducible alkyd which was formulated at >300 g/L VOC and enhanced for corrosion protection.

To demonstrate the distinct value of these WB alkyd dispersions, we also compared the performance of WB paints formulated from them to the performance of commercial SB alkyd paints. The same test protocols as described earlier were followed; all paints were drawn down on CRS, targeting 1 mil DFT. The biggest difference between the paints was VOC levels, although the PVC level for the paints was unknown. Compared with the commercial SB topcoat alkyd coatings, the enhanced WB alkyd dispersion coatings displayed very good gloss and adhesion (*Table 7*). However, the most impressive comparison is the corrosion resistance of the paints from these WB alkyd dispersions with that of the commercial SB alkyd paints at 1 mil DFT after 300 h salt spray exposure (*Figure 13*). The paint based on the enhanced SO alkyd dispersion matched the corrosion resistance performance of the best SB alkyd paint evaluated.

SHORT-OIL—MEDIUM-OIL ALKYD COMPARISON

Clearly both paints formulated with the SO and MO alkyd dispersions performed very well compared to the commercial options available. In addition, the performance of the SO and MO alkyd dispersions were complementary. Both the SO and MO paints from the developmental dispersions had very high gloss (>85 at the 20° gloss reading) and excellent adhesion across a variety of substrates. However, the most noticeable difference between the coatings from the two resins was the balance of flexibility, MEK resistance, and corrosion resistance (*Table 8*). Paint formulated with the MO alkyd dispersion paint was significantly more flexible and had better solvent resistance (MEK double rubs) than the paint formulated with the SO alkyd dispersion. The paint formulated with the SO alkyd dispersion, however, provided extended corrosion resistance (>300 h) (*Figure 14*).

The next logical step was to evaluate the performance of blends of the SO and MO WB alkyd dispersions. The dispersions were pre-blended and then formulated according to the pigmented starting point formulas described earlier. The paints were drawn down on CRS panels targeting 1.5 mil DFT. The coatings were cured for 14 days at 21°C and 50% RH prior to evaluation. *Table 9* shows the performance of the coatings. From the data, it is evident that the degree of flexibility and corrosion resistance can be tailored to meet specific application targets without sacrificing gloss or adhesion properties. The corrosion resistance of the paints to 200 h of salt spray exposure is excellent, slightly favoring blends with more SO alkyd dispersion (*Figure 15*).

DRY TIME IMPROVEMENTS

One documented gap between SB and WB alkyd systems is the increased drying times of WB alkyd coatings. This was noticed in the SOA–MOA dispersion blend work. To improve the dry times of formulations containing these

TABLE 8—Performance of Coatings Formulated with SO and MO Alkyd Dispersions

NAME	WB SO ALKYD DISPERSION	WB MO ALKYD DISPERSION
VOC (G/L)	<5	<5
DFT (MIL)	1.1	0.8
TACK FREE (H)	0.6	0.4
20° GLOSS	86	85
60° GLOSS	85	110
KÖNIG HARDNESS	40	38
PENCIL HARDNESS	B	B
ADHESION	5B	5B
MEK DOUBLE RUBS	15	75
DIRECT IMPACT	20	160
INDIRECT IMPACT	0	160

FIGURE 14—Corrosion resistance of coatings formulated with SO and MO alkyd dispersions after 150 and 300 h salt spray exposure (~1 mil DFT on CRS).

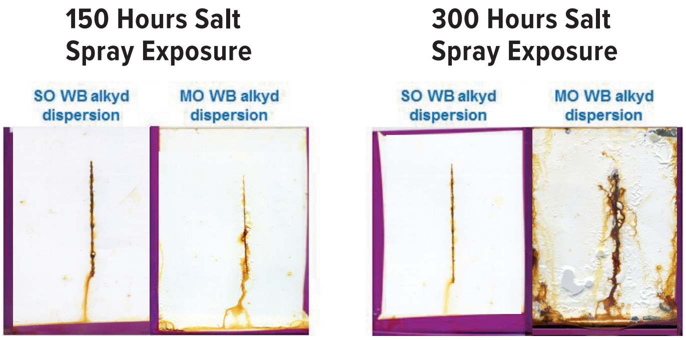


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TABLE 9—Paint Performance of Coatings Formulated with Blends of SO and MO Alkyd Dispersions

wt% MO IN BLEND	100%	80%	60%	40%	20%	0%
DFT	1.3	1.9	1.3	1.4	1.6	1.5
20° GLOSS	87	86	87	87	88	89
60° GLOSS	86	90	94	90	88	97
SET TO TOUCH (H)	0.5	0.4	0.2	0.2	0.5	0.5
TACK FREE (H)	0.7	0.8	0.8	0.6	1.2	1.1
DRY HARD (H)	10	16	18	>24	>24	>24
KÖNIG (SEC)	27	30	27	31	24	24
PENCIL GOUGE	HB	B	HB	B	B	HB
ADHESION	5B	5B	5B	5B	5B	5B
DIRECT IMPACT	160	60	40	20	20	20
REVERSE IMPACT	160	80	<10	<10	<10	<10

FIGURE 15—Corrosion resistance of coatings formulated with blends of SO and MO alkyd dispersions after 200 h salt spray exposure (caption denotes amount of medium-oil alkyd (MOA) dispersion in blend, balanced by short-oil alkyd (SOA) dispersion, by resin weight).

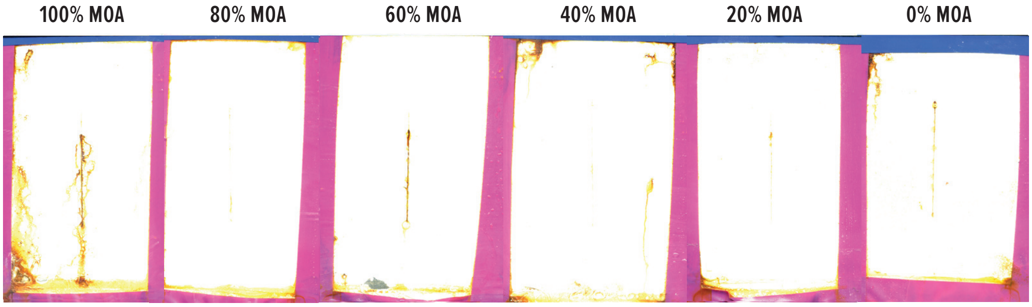

FIGURE 16—Results from drier DoE that show improved drying time and hardness with combination of three or four driers.

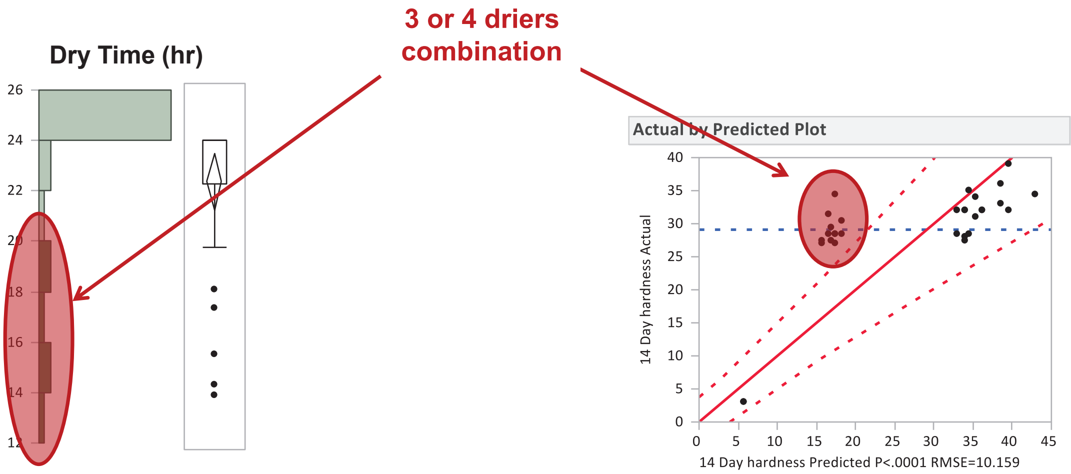

TABLE 10—Drying Time Improvements Realized in 14% PVC Formulation using Co/Zr as Primary Driers

VOLUME SOLIDS (%)	DISPERSANT	SOLVENT	VOC (g/L)	SET-TO-TOUCH TIME (h)	TACK-FREE TIME (h)	DRY HARD TIME (h)
50	1	N	<5	0.1	0.2	>24
40	1	N	<5	0.2	0.4	16
50	1	Y	<35	0.1	1.6	19
50	2	Y	<35	0.1	0.4	19
40	1	Y	<35	0.3	1.0	12
40	2	Y	<35	0.1	0.4	7

alkyd dispersions, an evaluation of drier package in clear coatings was completed using the SO alkyd dispersion. The mixture design included Co, Zr, Mn, and Fe driers at low to high levels. Interestingly, combinations of three or four driers gave the shortest drying times and the hardest films (*Figure 16*). Further work was done with a 14% PVC formulation, optimizing around Co/Zr as the primary driers. Inclusion of Ca as an auxiliary drier improved drying times. *Table 10* highlights a few of the improvements realized upon reducing volume solids, solvent addition (<35 g/L VOC), and proper additive selection.

CONCLUSIONS

Mechanical dispersion technology facilitates the dispersion of hydrophobic, unmodified, alkyd resins. Formulation of these dispersions into waterborne alkyd paints at near-zero VOC can generate coatings with performance mirroring and, in some cases, exceeding that obtained from solventborne alkyd coatings. Short-oil and medium-oil alkyd dispersions can be blended to achieve one of the best balance of overall properties for a given application. These waterborne alkyd dispersions show that they can close the performance gap between commercial waterborne alkyd technology and commercial solventborne alkyd technologies with regards to gloss, adhesion, and corrosion resistance. ❊

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