

New Waterborne Coatings

Liquid EPDM

Liquid ethylene propylene diene rubber (L-EPDM) has been known in the coatings industry for many years. These elastomers have found utility in ambient cure liquid-applied roof coatings. These resins, formulated into waterborne liquid coatings, may be cured with peroxides, metal driers, or UV radiation and can be used in ambient maintenance coatings for flat or low-slope roofs.

Recently, formulations blending the L-EPDM (Figure 1) with other common coatings resins have been developed. Elastomeric acrylics, alkyds and polyurethanes have been blended with the L-EPDM without the use of compatibilizers. Each of these systems has seen unique property improvements, such as surface wetting, adhesion, impact strength, and more.

Additionally, industrial heat-cure formulations have been developed for a broad range of temperatures. This paper will discuss L-EPDM waterborne suspension and blend properties, coating formulation, application and curing methods, and final film properties.

INTRODUCTION

Ethylene-Propylene Diene (EPDM) rubber has been used extensively in automotive, wire and cable, roof membrane, and thermoplastic vulcanite (TPV) applications because of the ease of processing due to the polymer's unique structure.^{1,2}

Many of the properties of EPDM, notably, ozone and UV resistance, low-moisture permeability, and excellent high- and low-temperature properties, make it an ideal material for exterior coatings.

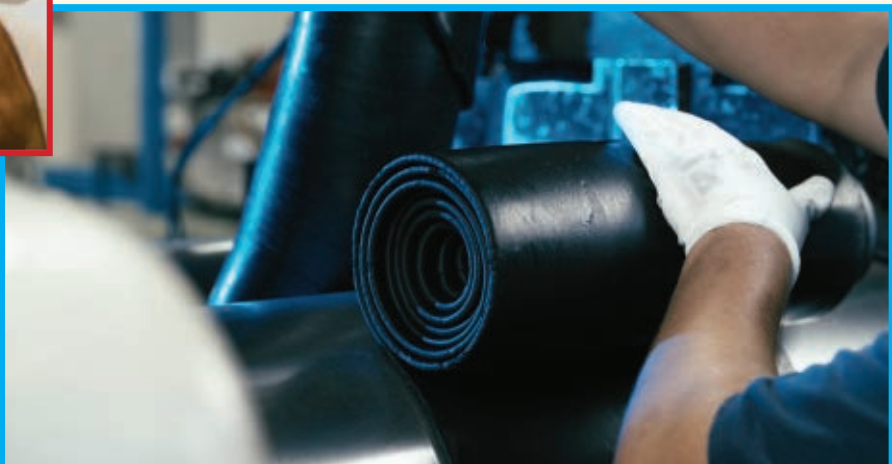
In recent studies, three coating formulations from a commercially available low-molecular-weight liquid EPDM (L-EPDM) were demonstrated; a peroxide crosslinking mechanism and a sunshine UV crosslinking mechanism, and a dual-cure system that uses both peroxide and UV.^{3,4,5}

These formulations all generate good EPDM rubber properties after crosslinking, including high mechanical strength, low-temperature flexibility, hydrophobicity, and adhesion to polar substrates. The formulations meet industrial requirements as protective coatings in solid content, rheology, curing speed, shelf life, pot life, and can be produced at a cost consistent with commercial elastomeric acrylic coatings.

These coatings were also formulated to be used as liquid roofing membranes



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Formulations With Dispersion

By Gregory J. Brust and John D. Jacquin
Lion Elastomers

and showed improved performance over solid EPDM sheets and elastomeric acrylic coatings in terms of ease of installation, solar reflectance, water resistance, and weather durability.

A previous paper reported on a waterborne dispersion of L-EPDM used for coatings and adhesives.^{6,7} L-EPDM dispersion used in this study is Trilene® 65D (T65D). T65 is a low-molecular-weight polymer of EPDM consisting of 45 wt % ethylene, 45 wt % propylene, and 10 wt % dicyclopentadiene monomers.

When blended with surfactants and dispersed in water at 50–55 wt % solids, it is designated T65D. Properties of T65D are shown in *Table 1*. The paths to formulating a peroxide-cured, a sunshine-UV cured, and an oxidatively cured system were discussed. The mechanical properties approach their solventborne counterparts.

These low-VOC coatings retain the low-temperature flexibility, hydrophobicity, excellent adhesion, and low-water vapor transmission. It was also shown that by blending this L-EPDM

dispersion with commercially available elastomeric acrylics, improved wetting over low-energy substrates and an increase in tensile modulus is achieved.

This work demonstrates the ability of this L-EPDM dispersion to be blended with other common waterborne

coatings resins. Several new formulations using this dispersion are also discussed, including direct to metal and high temperature industrial coatings. New formulations using the L-EPDM dispersion as a co-binder with waterborne acrylates and alkyds are also presented.

FIGURE 1—Simplified Structure of L-EPDM

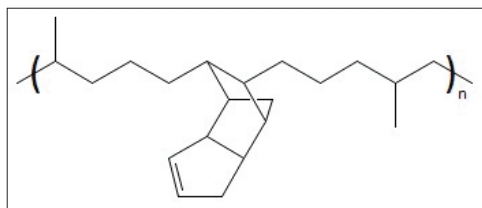


TABLE 1—Typical Properties of T65D

Property	Standard	Typical Value
Appearance		Milky white
Weight solids (%) in water	ASTM D3960	50–55
Brookfield Viscosity (cP @ 25 °C)	ASTM D2196	5,000–8,000
pH Value (@ 25 °C)	ASTM D7946	8–9
Specific Gravity (g/cc @ 25 °C)	ASTM D4052	0.95
Propylene Content (wt %)	ASTM D3960	45
Dicyclopentadiene (wt %)		10
VOC (g/l)		0
Typical particle size (microns)		1-2
Mw		~47,000
Tg (C)	DSC	-47
Solids wt loss (% @ 400 °C in air)	TGA	10
APEO		Not present
Shelf life (years)		2

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New Waterborne Coatings Formulations With Liquid EPDM Dispersion

EXPERIMENTAL

Blending L-EPDM Dispersion with Other Binders

T65D was weighed into a 100g MAX SpeedMixer cup. An amount of co-binder was then weighed into the cup to produce a 10 wt % co-binder to the L-EPDM blend. Samples were mixed at 2,000 rpm with a FlackTek high-speed mixer until a homogenous dispersion was formed. Of this blend, 10–15 g was transferred to a glass vial for stability testing. An additional amount of co-binder was added to the remaining blend to prepare a 20 wt % blend.

This process was repeated for blends in 10 wt % increments up to 90 wt % co-binder. No attempt was made to compatibilize the blends with added surfactants. Samples were left undisturbed at ambient conditions for 3 months to watch for separation/destabilization. Co-binders used in this paper included acrylic, acrylonitrile-acrylic, and styrene acrylic latexes, alkyd latex, and water-reducible alkyd, melamine formaldehyde resins, polyurethane dispersions, carboxylated styrene-butadiene, chloroprene rubber latexes, and wax dispersions. Co-binder product names can be found in *Table 2*.

Coating Formulation and Testing

Tables 3–7 list the formulations used in this study. *Table 3* is a clear formulation. *Table 4* is a T65D modified-acrylic coating. *Table 5* presents a series of T65D modified-alkyd coatings. *Tables 6* and *7* show peroxide-initiated, heat-cured T65D formulations for industrial coatings.

For all pigmented formulations, dispersant was dissolved in water before pigment was added. This was then mixed at 2,000 rpm with a FlackTek high-speed mixer until a homogenous dispersion was formed. Catalysts or peroxides, if used, were then added to the pigment dispersion, and mixed a further 2 minutes. Crosslinkers and coalescing solvents were mixed in a scintillation vial until fully dissolved, and then added to the L-EPDM polymer dispersion or T65D:co-binder blend and mixed at 2,000 rpm with a FlackTek high-speed mixer until a uniform mixture was achieved.

The pigment and polymer mixtures, where applicable, were then allowed sufficient mixing at 1,000 rpm to form a final smooth liquid paint. Coatings were allowed to equilibrate for 1 week at room temperature before testing. The paint properties were then measured for specific gravity, solid content and viscosity.

All tests were conducted following ASTM standards with standard lab equipment.

Each coating was applied to desired substrates including cold-rolled steel (CRS), Lineta charts, and release paper, using a Gardco® wet-film applicator to 0.2–0.5 mm thickness. Dry times for formulations in *Tables 2–4* were

TABLE 2—Co-Binders Used for Blends with T65D

Material	Type	Manufacturer
Rovene® 6120	100% Acrylic latex	Mallard Creek Polymers
Acronal® PLUS 4230	Acrylonitrile-acrylic latex	BASF
UCAR® 3176 A	Styrene-acrylic latex	Dow Chemical
Rhoplex® 2100-EC	Styrene-acrylic latex	Dow Chemical
Beckosol® AQ 206	Alkyd latex	Polynt
5060-BC-70	Water-reducible alkyd	Gabriel
Resimine® 745	Hexamethoxymethyl-melamine-formaldehyde resin	Prefere Melamines
Resimine AQ7551	High-imino methylated melamine-formaldehyde resin	Prefere Melamines
Urotuf® F108	Polyurethane dispersion	Polynt
Urotuf F982	Polyurethane dispersion	Polynt
Styrofan® 4215	Carboxylated SBR latex	BASF
Neoprene Latex	Polychloroprene latex	Denka Performance Materials
Michem® dispersion	Maleated polypropylene wax dispersion	Michelman

TABLE 3—Clear Coating Formulation

Ingredient	Material	Manufacturer	grams
Trilene® 65D	EPDM dispersion	Lion Elastomers	58.51
Mineral Spirits	Coalescing solvent		2.60
Ricon® 156	Liquid polybutadiene	Cray Valley	0.52
SR-350	TMPTMA Crosslinker	Sartomer	1.56
10% Co Hydro-Cure IV	Metal drier catalyst	Borchers	0.13
12% Zr Hydro-Cem	Metal drier catalyst	Borchers	0.71
Halox® FlashX® 150	Rust Inhibitor	ICL Phosphate Specialty	0.32
Total			64.35

TABLE 4—Pigmented, 65:35 Acrylic:T65D Modified Coating Formulation

Ingredient	Material	Manufacturer	grams
Trilene® 65D	EPDM Dispersion	Lion Elastomers	85.7
Rovene® 6120	Pure acrylic emulsion	Mallard Creek Polymers	151.2
Mineral Spirits	Coalescing solvent		3.8
Ricon® 156	Liquid polybutadiene	Cray Valley	0.8
SR-350	TMPTMA crosslinker	Sartomer	2.3
10% Co Hydro-Cure IV	Metal drier catalyst	Borchers	0.2
12% Zr Hydro-Cem	Metal drier catalyst	Borchers	1.0
DI H ₂ O	Diluent		47.7
DisperBYK® 2055	Pigment dispersant	BYK	3.2
Atomite EP7705	Calcium carbonate filler	Eager Polymers	77.5
Ti-Pure® R-706	TiO ₂ pigment	Chemours	68.9
ZnO	Pigment	U.S. Zinc	19.9
Total			462.2

measured following ASTM D1640 using a Gardco Ultracycle dry-time recorder and then allowed to cure indoors at ambient conditions for 7 days to achieve final properties before testing.

Formulations in *Table 5* were placed in an 80 °C oven for 5 minutes to flash off water and then placed in a 170 °C

oven for 15–30 minutes. The 50:50 formulation from *Table 4* was also cured at 60 °C and 80 °C for 1 hour with a dry timer. The formulation in *Table 6* was coated in triplicate and placed in an 80 °C oven for 5 minutes to flash off water and then placed in three ovens at 160 °C, 180 °C, or 200 °C for 5–30 minutes. A

sample was removed from each oven every 5 minutes to check degree of cure.

After drying, the coating film was used to measure physical properties including pencil hardness, crosshatch adhesion, impact strength, and flexural strength. All the tests were conducted following related ASTM standards with standard lab equipment.

TABLE 5—Pigmented Alkyd: T65D Coating Formulation

Ingredient	Material	Manufacturer	100:0	90:10	75:25	50:50	25:75	10:90
DI H ₂ O	Diluent		15.21	15.19	14.94	14.94	14.94	14.93
DisperBYK® 2055	Pigment dispersant	BYK	1.01	1.02	1.01	1.01	1.01	1.00
Ti-Pure® R-706	TiO ₂ pigment	Chemours	29.93	29.92	29.44	29.44	29.43	29.41
Beckosol® AQ 206	Medium oil alkyd emulsion	Polynt	53.06	47.20	40.23	26.36	13.43	5.33
Trilene® 65D	EPDM dispersion	Lion Elastomers		5.75	13.32	27.02	39.65	47.57
Mineral Spirits	Coalescing solvent			0.11	0.25	0.51	0.75	0.90
Borchi® OXY-Coat1101	Metal drier catalyst	Borchers	0.39	0.39	0.38	0.37	0.37	0.41
Halox® FlashX® 150	Rust inhibitor	ICL phosphate specialty	0.40	0.41	0.44	0.36	0.41	0.44
Total			100	100	100	100	100	100

TABLE 6—Heat-cured T65D Formulations for Industrial Coatings

Ingredient	Material	Manufacturer	Pigmented grams	Clearcoat grams
Trilene® 65D	EPDM dispersion	Lion Elastomers	31.21	58.51
Mineral Spirits	Coalescing solvent		3.56	2.40
SR-350	TMPTMA crosslinker	Sartomer	1.34	0.92
VUL-CUP® 40KE	Peroxide catalyst	Arkema	0.46	0.86
DI H ₂ O	Diluent		5.64	
DisperBYK® 2055	Pigment dispersant	BYK	0.40	
Atomite EP7705	Calcium carbonate filler	Eager Polymers	13.62	
Ti-Pure® R-706	TiO ₂ pigment	Chemours	2.70	
ZnO	Pigment	U.S. Zinc	1.72	
Total			60.64	62.69

TABLE 7—Low-PVC Heat-cured T65D Formulation for Industrial Coatings

Ingredient	Material	Manufacturer	grams
Trilene® 65D	EPDM dispersion	Lion Elastomers	52.09
Mineral Spirits	Coalescing solvent		5.93
SR-350	TMPTMA crosslinker	Sartomer	2.26
Dicumyl Proxide 40KE	Peroxide catalyst	Arkema	2.08
DI H ₂ O	Diluent		8.51
DisperBYK® 2055	Pigment dispersant	BYK	0.22
Ti-Pure® R-706	TiO ₂ pigment	Chemours	9.97
Total			81.05

New Waterborne Coatings Formulations With Liquid EPDM Dispersion

RESULTS AND DISCUSSION

Blends of Trilene 65D with other binders

T65D is exceptionally compatible with a wide range of waterborne binders. An example of a good blend and a partially destabilized blend are shown in *Images*

1 and 2, respectively. These images show blends of increasing T65D content from 10–90 wt % from left to right. *Table 8* shows the results of blending for each binder.

No attempt was made to compatibilize the blends with added surfactants. T65D

blends well with all the acrylic containing dispersions and makes an excellent blend with the alkyd dispersion. With excellent blending at all loadings, the L-EPDM could be used as a modifier, co-binder, or as the primary resin, with the other binder for performance enhancement or used for cost reduction.

IMAGE 1—Example of a Good T65D Blend—Styrene-acrylic Dispersion



IMAGE 2—Example of a Partially Destabilized T65D Blend—Polyurethane Dispersion



TABLE 8—Results of Blending Waterborne Resins with T65D

Binder Resin Type	% T65D in Blend								
	10	20	30	40	50	60	70	80	90
Styrene acrylic latex	Green	Green	Green	Green	Green	Green	Green	Green	Green
Pure acrylic latex	Green	Green	Green	Green	Green	Green	Green	Green	Green
Acrylonitrile-acrylic latex	Green	Green	Green	Green	Green	Green	Green	Green	Green
Alkyd latex	Green	Green	Green	Green	Green	Green	Green	Green	Green
Water reducible alkyd	Green	Green	Green	Green	Green	Green	Green	Yellow	Yellow
Hexamethoxymethyl-melamine formaldehyde	Green	Green	Green	Yellow	Yellow	Orange	Orange	Orange	Orange
High-Imino-methylated-melamine formaldehyde	Green	Yellow	Yellow	Yellow	Orange	Orange	Orange	Orange	Orange
Polyurethane dispersion	Green	Green	Green	Green	Yellow	Yellow	Yellow	Green	Green
Maleated polypropylene wax emulsion	Green	Green	Green	Yellow	Yellow	Yellow	Green	Green	Green
Carboxylated styrene butadiene latex	Green	Green	Green	Green	Green	Green	Green	Green	Green
Styrene butadiene latex	Green	Green	Green	Green	Green	Green	Green	Green	Green
Polychloroprene latex	Green	Green	Green	Green	Green	Green	Green	Green	Green
Natural rubber latex	Green	Green	Green	Green	Green	Green	Green	Green	Green
Blend Compatibility as Supplied	Full:	Green	Green	Partial:	Yellow	Yellow	Poor:	Orange	Orange

Coatings Formulation Properties

The properties of the clear T65D based coating are shown in *Table 9*. While the solids in this formulation are 50 wt %, the viscosity is somewhat high at low-shear rates. This formulation is sheer thinning, however, which allows for easy application and the dry time is sufficient for complete flow and leveling.

This low-VOC coating is completely dry after overnight drying at ambient conditions (~22 °C, 55% RH). This elastomeric coating is understandably soft but has great impact and excellent

adhesion and flexibility over a steel substrate.

A pigmented 100% acrylic coating was modified with 35 wt % of T65D (*Table 10*). The solids of this coating are much higher than the previous formulation due to the high pigment volume concentration (PVC), but the viscosity is much lower. The VOC is also lower, as the acrylic does not require a coalescing solvent like the L-EPDM. The dry time of this modified acrylic/L-EPDM blend coating is much shorter than the pure T65D coating, greatly reducing time to recoat or use. While still soft, the

coating does not lose any of its adhesion or flexibility and is slightly improved in its reverse impact resistance.

Compared to the 100% acrylic formulation, the L-EPDM modified acrylic coating provides better adhesion to cold rolled steel. Thus, the addition of L-EPDM affords enhanced wettability properties to the acrylic coating. As shown in a previous paper⁷, the L-EPDM also improves the tensile properties in acrylic coatings. With improved wetting and increased tensile strength, L-EPDM can improve the performance of elastomeric acrylic roof coatings.

TABLE 9—Properties of Clear Coating

Characteristic	Test Standard	Result
Formulation Properties		
Solids (wt %)	ASTM D3960	50
Brookfield Viscosity @ 25°C (cP)	ASTM D2196	14,000
VOC (g/l)	ASTM D3960	43
Performance Properties at Ambient Cure on CRS		
Dry film thickness (mils)		2.5
Dry-to-touch (h)	ASTM D1640	8
Through dry (h)	ASTM D1640	12
Pencil hardness	ASTM D3363	6b
Crosshatch adhesion	ASTM D3359	5B
Impact strength—Forward (in-lb)	ASTM D2794	>100
Impact strength—Reverse (in-lb)	ASTM D2794	70
Flex (conical mandrel)	ASTM D522	Highest (38°)

TABLE 10—Properties of Pigmented Acrylic Coating Modified with T65D

Characteristic	Test Standard	100% Acrylic Results	65:35 Blend Results
Formulation Properties			
Solids (wt%)	ASTM D3960	60	63
Brookfield Viscosity@ 25°C (cP)	ASTM D2196	1800	2600
VOC (g/l)	ASTM D3960	3	9
Performance Properties—Ambient cure on CRS			
Dry film thickness (mils)		2.5	2.5
Dry-to-touch (h)	ASTM D1640	3.5	4
Through dry (h)	ASTM D1640	4	6
Pencil hardness	ASTM D3363	6b	6b
Crosshatch adhesion	ASTM D3359	2B	5B
Impact strength—Forward (in-lb on CRS)	ASTM D2794	>100	>100
Impact strength—Reverse (in-lb on CRS)	ASTM D2794	>100	>100
Flex (conical mandrel)	ASTM D522	Max (38°)	Max (38°)

New Waterborne Coatings Formulations With Liquid EPDM Dispersion

TABLE 11—Properties of T65D Modified-Alkyd Coating

Characteristic	Test Standard	Ratio of Alkyd : L-EPDM					
		100:0	90:10	75:25	50:50	25:75	10:90
Formulation Properties							
Solids (wt %)	ASTM D3960	60	60	60	60	60	60
Brookfield Viscosity@ 25 °C (cP)	ASTM D2196	15226	17274	25466	60768	62905	65323
VOC (g/l)	ASTM D3960	0	2.9	6.6	13.4	19.8	23.7
Performance Properties—Ambient cure—Substrate: CRS							
Dry film thickness (mils)		1	1	1	1	1	1
Dry-to-touch/surface dry (h)	ASTM D1640	0.70	0.76	1	0.8	0.71	1.08
Through dry/hard dry (h)	ASTM D1640	0.85	0.98	1.42	1.02	2.62	~18
Gloss at 20/60/85 degrees	ASTM D523	7/49/80	20/66/78	10/48/60	3/23/31	2/12/30	2/12/28
Pendulum hardness (König-oscillations)	ASTM D4366	34	25	16	15	13	20
Color—L/a/b	L	91.33	94.86	93.96	90.36	89.77	88.7
	a	-1.93	-1.71	-1.77	-1.91	-1.91	-1.81
	b	-1.26	-0.08	-0.73	-2.72	-2.72	-2.58
Pencil hardness	ASTM D3363	H	HB	2B	3B	4B	5B
Crosshatch adhesion	ASTM D3359	5B	5B	5B	5B	5B	5B
Impact strength—Forward (in-lb)	ASTM D2794	18	20	20	>100	>100	>100
Impact strength—Reverse (in-lb)	ASTM D2794	nil	Nil	20	>100	>100	>100
Flex (conical mandrel)	ASTM D522	Max (38°)	Max (38°)	Max (38°)	Max (38°)	Max (38°)	Max (38°)

IMAGE 3—Alkyd:T65D Blend Coatings—Wetting of Low-Surface Energy Substrates



Table 11 describes the effect of increasing T65D addition to an alkyd-dispersion-based coating. While the solids content stays consistent across all formulations, the viscosity increases with T65D loading, but begins to plateau at approximately 50 wt % T65D. The drying time in ambient conditions also increases as

more T65D is added to the formulation. However, in all blends, the dry times are significantly shorter than coatings prepared with T65D alone.

This is due to the increased unsaturation in the system from the alkyd resin and its higher mobility compared to the L-EPDM polymer which allows reactive groups to come in contact more

often. The gloss and color of the coating is decreased somewhat as T65D is increased, but like viscosity reaches and inflection point at 50 wt %. Most significantly, the impact strength of the coatings hit a maximum at 50 wt % T65D as well. This is likely due to the formation of an interpenetrating polymer network in the coating at this loading that fully reinforces the alkyd system.

FIGURE 2—Oscillatory Rheology of Alkyd:T65D Blend Coatings at 25 °C

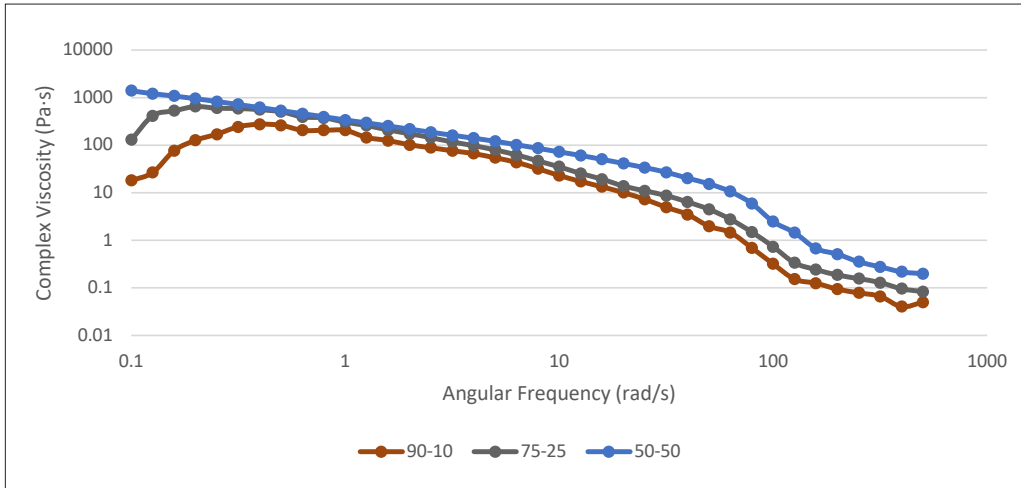


TABLE 12—Properties of Heat-cured T65D Modified-Alkyd Coating

Characteristic	Test Standard	60°C	80°C
Solids (wt %)	ASTM D3960	60	60
Brookfield Viscosity@ 25 °C (cP)	ASTM D2196	60768	60768
VOC (g/l)	ASTM D3960	13.4	13.4
Performance Properties—Substrate: CRS			
Dry film thickness (mils)		2.5	2.5
Dry-to-touch/surface dry (min)	ASTM D1640	3.5	1.7
Through dry/hard dry (min)	ASTM D1640	18.5	16.7
Gloss at 20/60/85 degrees	ASTM D523	18/66/82	17/64/82
Pendulum Hardness (König–oscillations)	ASTM D4366	13	15
Color – L/a/b	L	93.13	93.97
	a	-1.83	-1.86
	b	-0.18	0.37
Pencil hardness	ASTM D3363	3B	3B
Crosshatch adhesion	ASTM D3359	4B	5B
Impact strength—Forward (in-lb)	ASTM D2794	>100	>100
Impact strength—Reverse (in-lb)	ASTM D2794	>100	>100
Flex (conical mandrel)	ASTM D522	Max (38°)	Max (38°)

As with the acrylic blends mentioned in a previous paper⁶, the alkyd blends have improved wetting over low-surface energy substrates as the T65D loading increases (*Image 3*). This is partly due to the low-polarity of the T65D resin but is also related to viscosity. *Figure 2* shows the complex viscosity of the 90:10, 75:25, and 50:50 alkyd:T65D coatings as measured by oscillatory rheology.

All the formulations are shear thinning, and viscosity increases slightly with T65D content, but the most interesting difference occurs at very

low-shear. At the lowest shear, which a coating might experience while leveling and drying, the high-alkyd sample has a much lower viscosity. This allows the coating to crawl and bead on the low-surface energy substrate.

By increasing the T65D loading by 15 wt %, the low-shear viscosity increases by nearly an order of magnitude. An additional 25 wt % increase in T65D increases the low-shear viscosity by another order of magnitude and eliminates the low-shear viscosity drop. This, in addition to the decreased polarity, leads to the improved wetting over low-energy substrates.

Heat-Cured Industrial Coatings Properties

The effect of heat on the cure and properties of the 50:50 T65:alkyd dispersion were studied (*Table 12*). These coatings cure very rapidly and were tack free in under 5 minutes. The coating cures twice as fast at 80 °C as at 60 °C. Each coating did require 15 minutes of cooling time to achieve a mar-free hard surface. The color and gloss of these heat cured coatings were improved over the ambient cured alkyd blend coating, and the mechanical properties were similar. This shows that this improved alkyd coating can be used in a heat-cured industrial coating process.

New Waterborne Coatings Formulations With Liquid EPDM Dispersion

Table 13 shows the properties of pigmented and clear coatings of T65D formulated with VUL-CUP 40KE as the crosslinking initiator. We chose to use a peroxide in place of the metal driers here as it is a much more efficient radical generator at these temperatures. As this peroxide is stable at room temperature, this is a 1K system. 10mil WFT samples were cured with a 20-minute water flash at 80 °C followed by a 30-minute cure at 170 °C.

A second set of tests looked at a thinner 5 mil WFT film with a 5-minute water flash and 15-minute cure at the same temperatures. Pigmented coatings took slightly longer to fully dry due to the absorption of water into the pigment. While the pigment loadings, film thickness, and cure times varied between each of these samples, the final properties of each of these films was the same. This demonstrates a flexibility in film thickness and cure profile of industrial coatings made with T65D.

Finally, we investigated the effect of various cure temperatures on coatings properties (Table 14). In this case, dicumyl peroxide was used as the crosslinking initiator. As this peroxide is stable at room temperature, this is a 1K system. As the cure temperature was increased, the curing time was shortened by 5 minutes for each 20 °C increase.

The additional 5 minutes for dry-to-touch was the time it took for the film to come to room temperature and lose enough molecular motion to become non-tacky. An additional 10 minutes was usually needed for the substrate to cool enough for the coating to avoid deformation by thumb twist. In each case the physical properties of the coating were the same, showing that the required process time can be controlled by increasing the temperature.

CONCLUSIONS

T65D is a new waterborne resin for coatings applications with unique properties and is exceptionally compatible with a wide range of waterborne binders. Blends of T65D with these other resins form highly flexible and impact resistant coatings with improved wetting over low-energy surfaces.

TABLE 13—Properties of Heat-cured T65D Industrial Coatings

Characteristic	Test Standard	Pigmented Result	Clearcoat Result	Pigmented Result	Clearcoat Result
Formulation Properties					
Solids (wt %)	ASTM D3960	58	50	58	50
Brookfield Viscosity@ 25°C (cP)	ASTM D2196	19,000	14,000	19,000	14,000
VOC (g/l)	ASTM D3960	52	55	52	55
Flash @ 80 °C (min)		20	20	5	5
Oven condition (min @ °C)		30 @ 170	30 @ 170	15 @ 170	15 @ 170
Performance Properties—applied over CRS					
Dry film thickness (mils)		5	5	2.5	2.5
Dry-to-touch (h)	ASTM D1640	2	oven exit	0.5	oven exit
Through dry (h)	ASTM D1640	4	oven exit	1.0	oven exit
Pencil hardness	ASTM D3363	6b (softest)	6b	6b	6b
Crosshatch adhesion	ASTM D3359	5B (highest)	5B	5B	5B
Impact strength	ASTM D2794	>90 in-lb	>90 in-lb	>90 in-lb	>90 in-lb
Flex (conical mandrel)	ASTM D522	Max (38°)	Max (38°)	Max (38°)	Max (38°)

TABLE 14—Properties of Low-PVC Heat-cured T65D Industrial Coatings

Characteristic	Test Standard	Result	Result	Result
Formulation Properties				
Solids (wt %)	ASTM D3960	48	48	48
Brookfield Viscosity@ 25°C (cP)	ASTM D2196	4,700	4,700	4,700
VOC (g/l)	ASTM D3960	74	74	74
Flash @ 80 °C (min)		5	5	5
Oven condition (min @ °C)		15 @ 160	10 @ 180	5 @ 200
Performance Properties—applied over CRS				
Dry Film Thickness (mils)		2.5	2.5	2.5
Dry-to-touch (min)	ASTM D1640	20	15	10
Through dry (min)	ASTM D1640	30	25	20
Pencil hardness	ASTM D3363	F	F	F
Crosshatch adhesion	ASTM D3359	5B	5B	5B
Impact strength—Forward (in-lb)	ASTM D2794	>100 in-lb	>100 in-lb	>100 in-lb
Impact strength—Reverse (in-lb)	ASTM D2794	>100 in-lb	>100 in-lb	>100 in-lb
Flex (conical mandrel)	ASTM D522	Max (38°)	Max (38°)	Max (38°)

These coatings can be cured at ambient conditions or at elevated temperatures to achieve shorter cure times without sacrificing mechanical properties. ❄️

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GREGORY J. BRUST and JOHN D. JACQUIN,
Lion Elastomers, 36191 Hwy. 30, Geismar, LA 70734;
greg.brust@lionelastomers.com and
john.jacquin@lionelastomers.com.