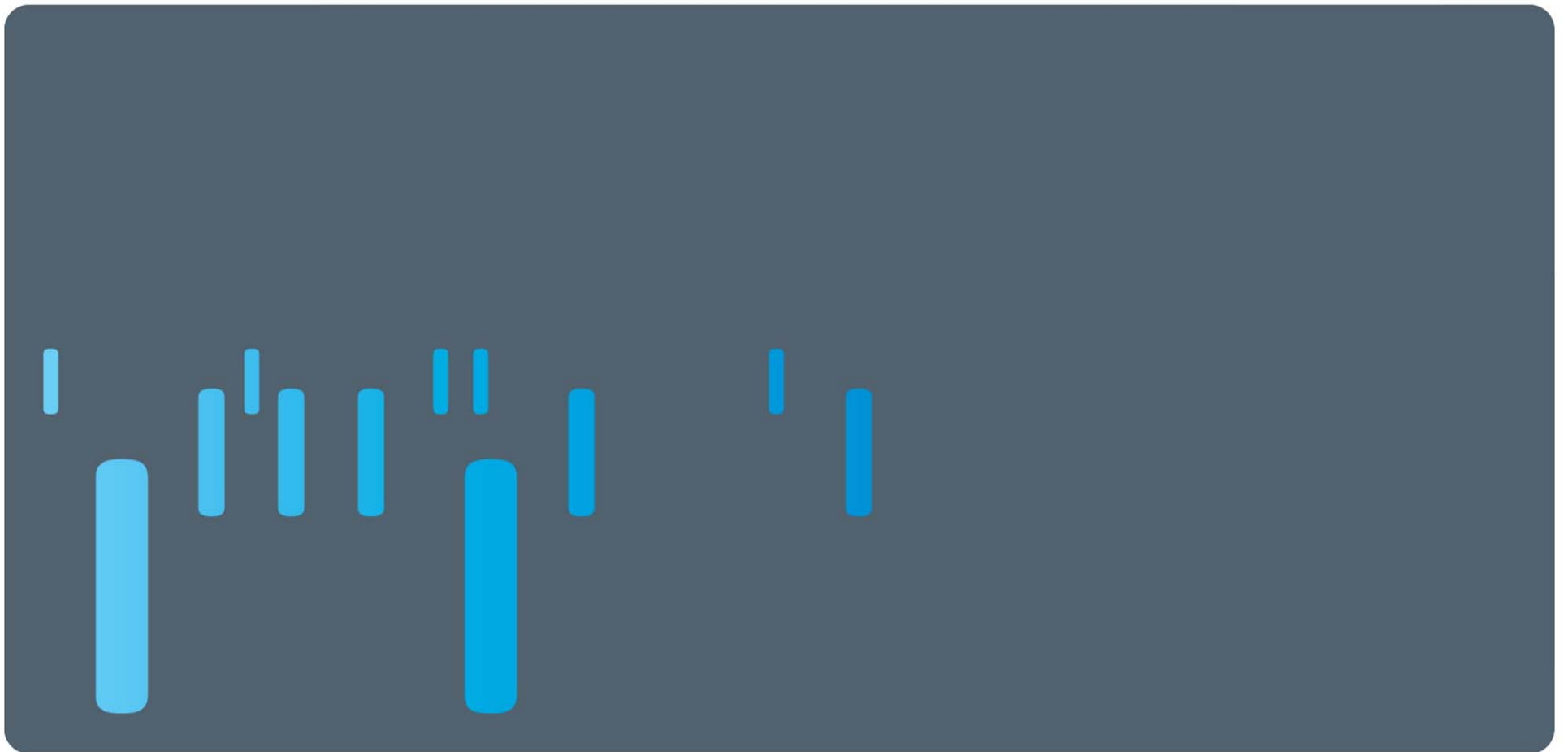


Tert-Butyl Acetate: VOC-Exempt Solvent for Coatings



Outline

- Solvent Use in Coatings
- Solvent Regulations
- Tert-Butyl Acetate as a VOC replacement
 - TBAC properties
 - Formulating compliant products with TBAC
 - Lacquers
 - Urethanes
 - Epoxies
 - Alkyds
- Conclusions

LyondellBasell: a new global leader

- Lyondell Chemical and Basell merged to form LyondellBasell Industries on Dec. 20, 2007
- LyondellBasell is...
 - One of the world's largest polymers, petrochemicals, and fuels companies with combined annual revenues of \$44.7 billion*
 - The global leader in polyolefins technology, production and marketing
 - A pioneer in propylene oxide and derivatives
 - A significant producer of advanced fuel products
 - Operator of one of North America's largest full-conversion refineries
 - A leading supplier of solvents
 - The developer and leading supplier of TBAC

****2007 pro forma combined revenues***

Solvent Uses in Coatings and Adhesives

- Resin Synthesis
 - Acrylics, alkyds
- Formulation
 - Resin solubilization
 - Pigment grinding
- Surface Preparation
 - Parts degreasing
- Application
 - Viscosity reduction
 - Surface wetting
 - Flow and leveling
 - Hardness development and curing
- Cleanup
 - Spray gun cleanup



Solvent Regulations Multiply...

- International Regulations
 - Montreal protocol on ozone depleting substances (ODS)
- National Regulations
 - Control of Volatile Organic Compounds (VOCs)
 - Control of Hazardous Air Pollutants (HAPs)
- State and local regulations
- Grass roots initiatives

Grass Roots: Green Building Initiatives

- **EPA lacks jurisdiction to regulate indoor air quality**
- **Health and environmental concerns:**
 - Indoor air quality (VOCs, HAPs, ozone, PM, mold, pollen, etc...)
 - Materials safety (lead, asbestos, phthalates)
 - Efficient use of resources (energy and materials)
 - Environmental impact of products (global warming, pollution, ozone depletion)
- **Leading to new product certification requirements:**
 - Leadership in Energy and Environmental Design (LEED rating)
 - Green Seal product standards:
 - Commercial Adhesives (GS-36)
 - Paints and Coatings (GS-11)
 - Stains and Finishes (GS-47)

Benefits of “Greener” Solvents

- Protect the environment, worker and consumer
- Reduce product liability
- Avoid impact of regulations
- Extend product life
- Expand markets and sales
- Promote a positive company image



Why Regulate VOCs in Coatings?

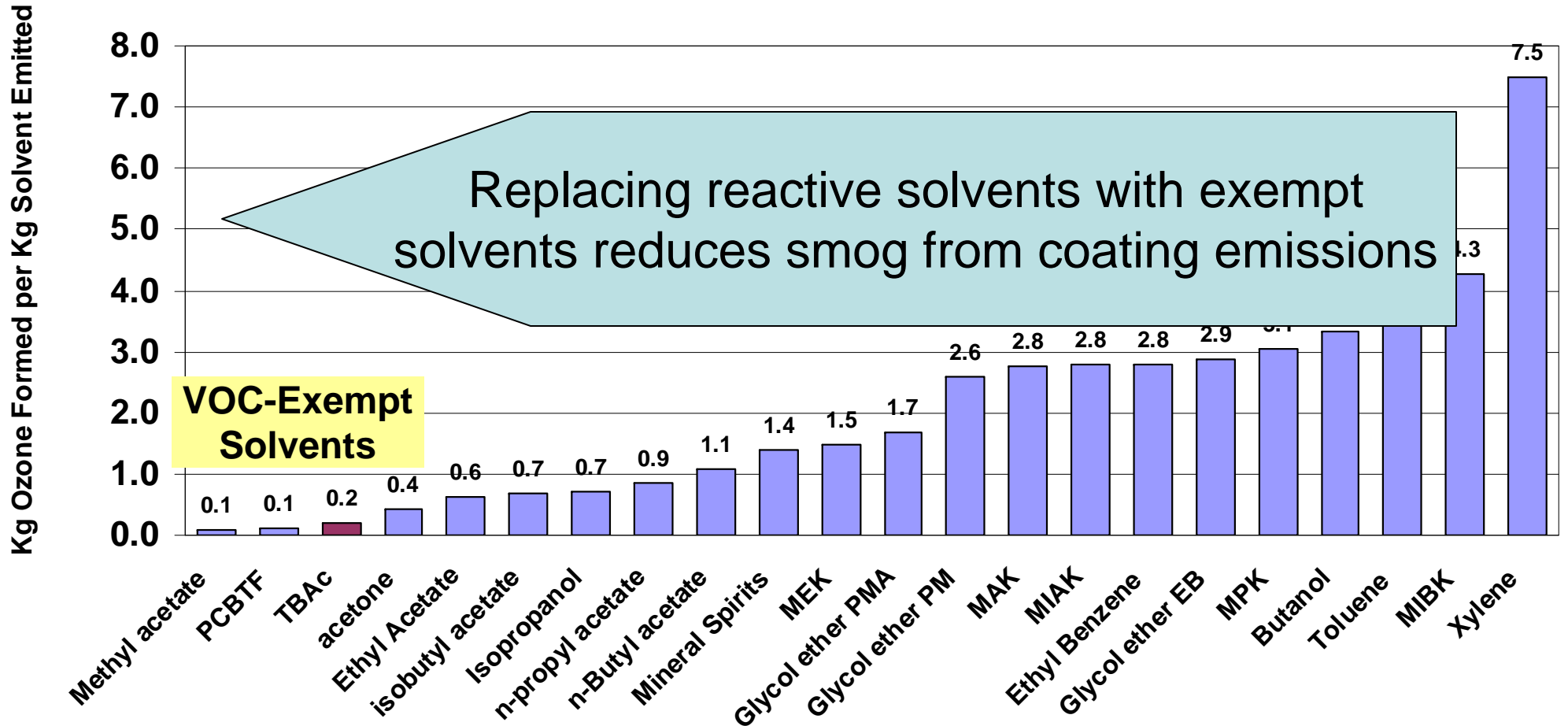
- Volatile Organic Compounds (VOCs) contribute to ground level ozone (smog) formation
- Ozone is a lung irritant and criteria pollutant
- Major sources (biogenic, cars and truck) are difficult to reduce
- Coating operations are a minor but visible source of VOCs
- Low-VOC coating technologies exist
 - Water-based
 - Energy curable (UV and powder)
 - High solids
 - Exempt solvents

VOC Regulations in the US and Canada



- US lowers ozone standard to 75 ppb in 2008
- Effective 9/30/09, TBAC is VOC-exempt in Canada for architectural and automotive coatings
- US and Canadian Regulations based on photochemical reactivity
 - Only photochemically reactive compounds are regulated
 - Negligibly reactive compounds are exempt:
 - Acetone, methyl acetate, TBAC, many halogenated solvents.
 - Many halogenated compounds are regulated under the Montreal protocol because they deplete stratospheric ozone.

Reactivity of Solvents Varies Greatly



Based on Dr. William Carter's SAPRC-99 model
<http://pah.cert.ucr.edu/~carter/reactdat.htm>

Formulating with TBAC

- TBAC is a medium-fast evaporating solvent (2.8 times n-BuAc)
- Solvent blend must contain ~30% slow solvent for optimum flow, leveling and appearance (e.g. MAK, EEP, PMA, xylene)
- TBAC blush resistance superior to acetone and methyl acetate
- Slow solvents should be used for pigment grinding
- TBAC can be used with isocyanates and amido curatives
- TBAC is stable in acid-catalyzed varnishes
- Coating properties are unaffected because TBAC evaporates first

Resins Soluble in TBAC

- Acrylics and styrene acrylics
- Urethanes and isocyanates
- Alkyds and polyesters
- Modified alkyds (silicone, oil-modified urethanes, acrylic and phenolic)
- Nitrocellulose and other cellulosic resins
- Some chlorinated resins (not PVC)
- Epoxies and their amino and amido-amine curatives
- Melamine and urea-formaldehyde
- Phenolic and styrenated
- Silicones and silanes

Coating Applications

- Coatings – Solvent-based
 - Automotive refinish clearcoats
 - Industrial maintenance coatings
 - Wood lacquers and enamels
 - Aerospace coatings
 - Metal coatings
 - Concrete coatings
 - Traffic paints
- Resin solvent: alkyds, acrylic resins
- Spray equipment cleanup, thinners, degreasers



Wood Lacquer Reformulations

Components	Conventional Formulation	TBAc/n-BuAc Formulation	TBAc/PMAc Formulation	
RS 1/2 Nitrocellulose	14.3	14.3	14.3	<p>Replaced xylene, MEK, and BuAc with TBAC and PMA</p>
Beckosol 12-035	11.7	11.7	11.7	
Diisononyl phthalate	3.0	3.0	3.0	
xylene	30.5	0.0	0.0	
MEK	10.7	0.0	0.0	
n-butyl acetate	22.7	13.9	0.0	
n-butanol	7.1	7.1	7.1	
PM Acetate	0.0	0.0	13.9	
TBAc Solvent	0.0	50.0	50.0	
Total lbs	100.0	100.0	100.0	
lbs VOC/lb solids*	3.99		1.50	<p>Lower HAPs & VOCs</p>
lbs HAP/lb solids	2.29		0.23	
Viscosity, cps	146	185	102	<p>Dry time is reduced/ coating properties unchanged</p>
Dry Time, min	20	10	10	
20 degree gloss	42	47	49	
60 degree gloss	86	87	89	
Whiteness index	65	67	67	
Yellowness index	6.0	5.4	5.4	

Beckosol® is a registered trademark of Reichhold Chemical.

2K Urethane Clearcoat Formulations

Components	Conventional	TBAC-Based	Conventional High-solids	TBAC-Based
G-Cure 105 P70	100.0	100.0	50.0	50.0
JONCRYL 920	0.0	0.0	50.0	50.0
T-12 (1% in toluene)	1.9	1.9	0.3	0.3
FC 430 (10% in toluene)	0.3	0.3	0.3	0.3
HDI Trimer	28.3	28.3	33.9	25.4
IPDI Trimer	0.0	0.0	0.0	15.6
MAK	25.0	25.0	24.0	24.0
n-Butyl acetate	25.0	0.0	24.0	0.0
TBAc Solvent	0.0	25.0	0.0	24.0
Total lbs	205.5	205.5	206.5	213.6
% solids	46%	46%	51%	51%
lbs VOC/gal*	4.40	3.28	3.96	2.86

- Significant VOC reductions are possible

G-Cure® is a registered trademark of the Cognis Corporation

JONCRYL® is a registered trademark of Johnson Polymers (BASF)

2K Urethane Clearcoat Properties

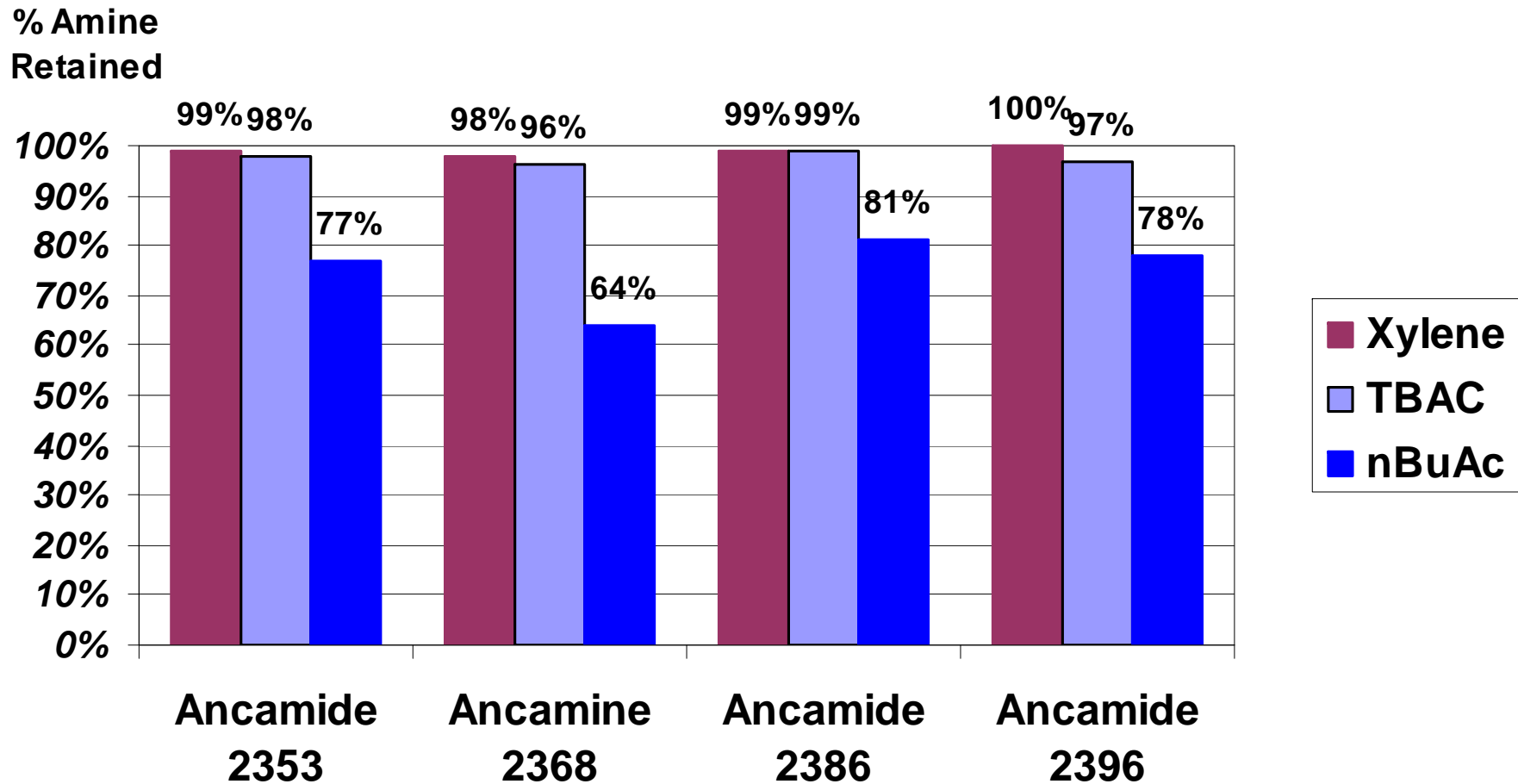
Properties	Conventional	TBAC- Based	High-solids	TBAC- Based
lbs VOC/gal*	4.40	3.28	3.96	2.86
Viscosity, sec #2 Zahn	21.2	21.1	20.9	20.8
Dry Time, hours	3.2	3.5	7	4
20 degree gloss	88	88	90	90
60 degree gloss	95	95	95	95
DOI	90	90	90	90
Reverse Impact, lbs	160	160	160	160
Direct Impact, lbs	160	160	160	160
Cross hatch adhesion, %	100%	100%	100%	100%
10% acid resistance (30 min)	pass	pass	pass	pass
100 MEK double rubs	pass	pass	pass	pass

- No change in coating performance

TBAC: Not Your Typical Ester Solvent

- Other esters react with amino and amido epoxy curatives
- Studied four types of amine and amido curatives
- Compared stability in xylene, TBAC, n-Butyl acetate
- Accelerated aging at 60°C for 30 days
 - Equivalent to one year at ambient temperature
- Measured residual amine using ASTM D2896

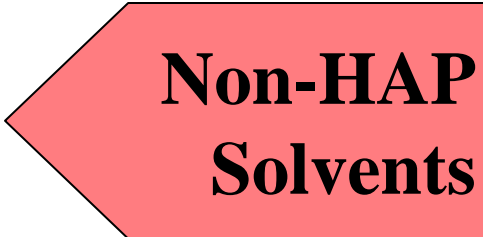
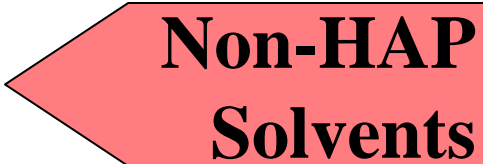
Storage Stability of Amine and Amido Curatives



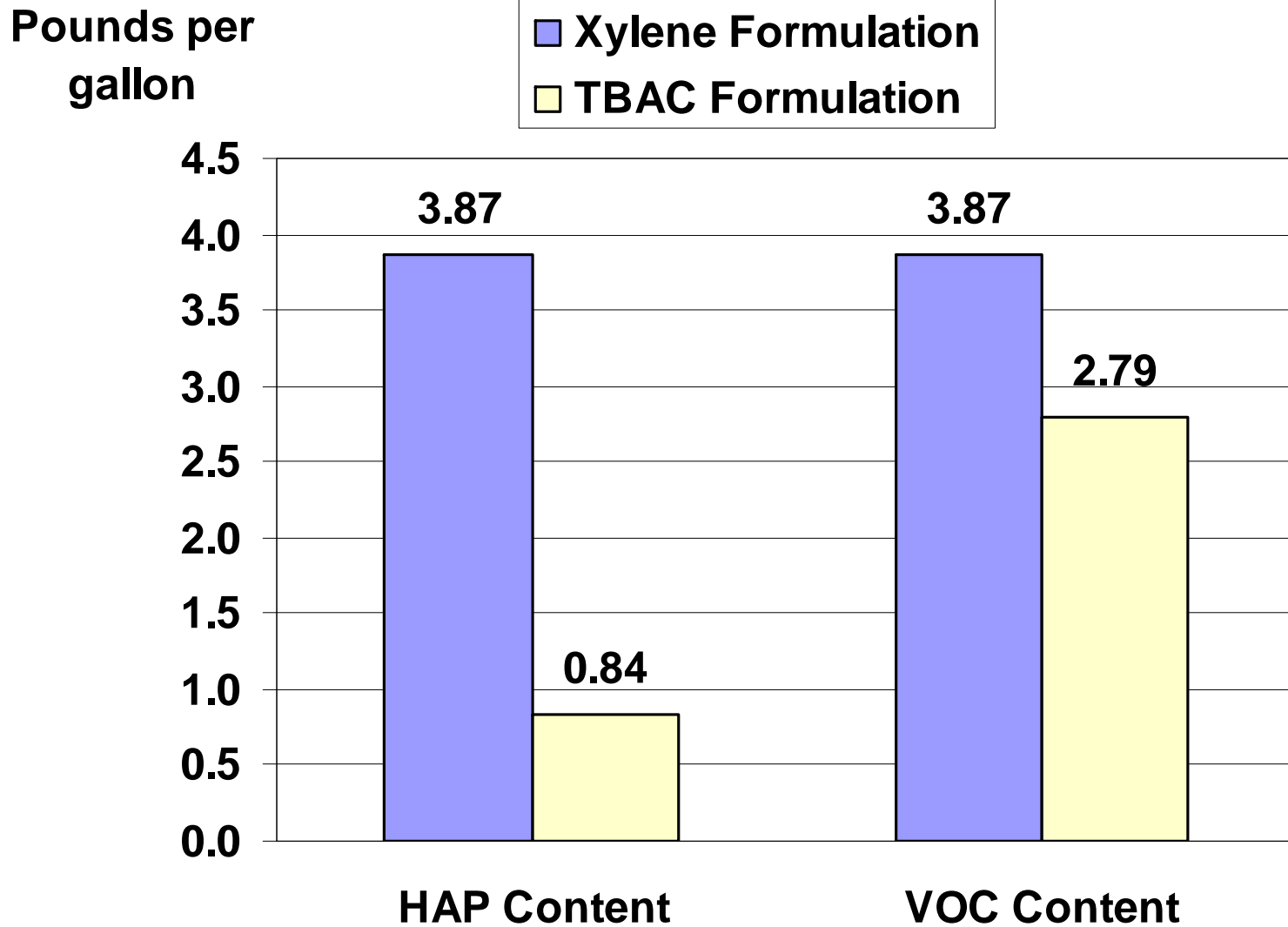
- Xylene and TBAC show similar stability

Ancamide and Ancamine are trademarks of Air Products & Chemicals.

2K Epoxy Reformulation

	Xylene Formulation	TBAC Formulation	
<u>Part A</u>			
Epon 1001X75	301	301	
Pigment & fillers	260	260	
Beetle 216-8	12	12	
Xylene	221		
Aromatic 100		30	
ARCOSOLV PM		76	
TBAC Solvent		115	
MAK		15	
<u>Part B</u>			
Epicure 3115	131	131	
Xylene	70		
Aromatic 100		15	
TBAC Solvent		55	
<u>Formulation constants</u>			
Volume Ratio A/B	75/25	75/25	
Wt % Solids mixed	62	62	

Effect on HAP and VOC Contents



Epoxy Coating Properties

	Xylene Formulation	TBAC Formulation
<u>Film Properties after 7 days</u>		
Thickness, mils	1.93	1.94
Direct Impact, in.lb	160	160
Reverse Impact, in.lb	160	160
Crosshatch adhesion	100%	100%
1/8 Mandrel bend	pass	pass
800 hours Salt Spray ASTM B117	<1 mm creep 7 VF blisters	<1 mm creep 7 VF blisters

Cure speed & film properties were identical

Other Coating Uses for TBAC

- **Alkyd coatings for general industrial and decorative coatings**
- **Conversion varnishes for wood**
- **Resin suppliers now offering alkyd resins in TBAC:**
 - Reichhold, CCP, Hexion, Nuplex
- **Acrylic polyols in TBAC also available from:**
 - CCP, Cognis, Rohm & Haas, BASF (Johnson Polymer)

Clear Catalyzed Conversion Varnish

- Used on kitchen cabinets, furniture and flooring
- Resin System:
 - Coconut alkyd: Beckosol® 12035-E2 (65% NV in 32/4 TBAC/A100)
 - Polyol: SAA-100 (100% NV)
 - Crosslinker: Cymel U80 (98% NV)
- Solvents used:
 - TBAC, n-butanol, MAK
 - Small amounts of Aromatic 100 and Isopropanol
- Varnish formulation
 - 209 grams VOC/L
 - 50wt% solids
 - Viscosity = 75 Cps
- Varnish applied to unprimed oak boards

Beckosol® is a registered trademark of Reichhold Chemical

Cymel® is a registered trademark of Cytec Industries

White Alkyd Enamel Paint*

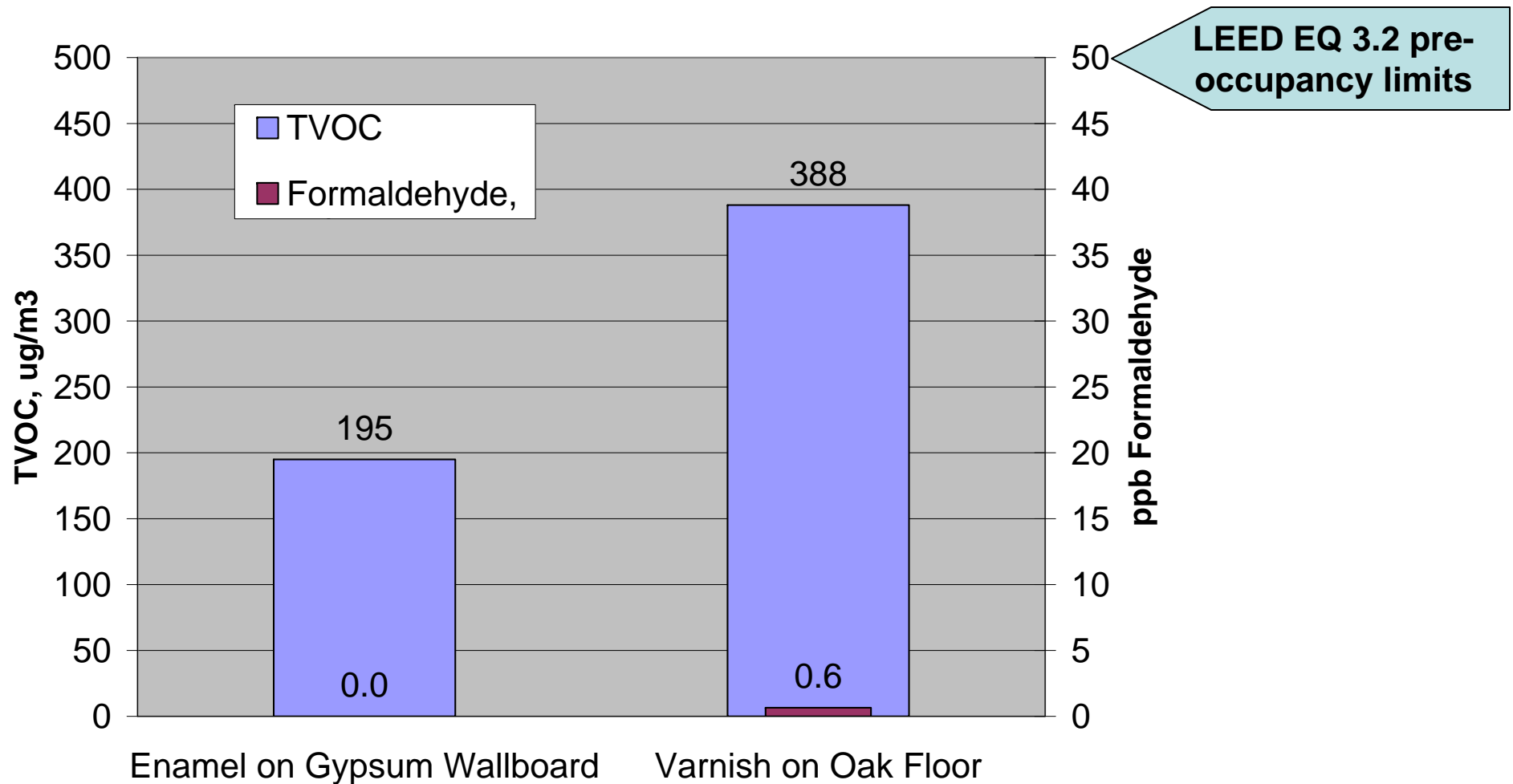
- Used on wood trim, cabinets, walls
- Resin System:
 - Soy alkyd: Beckosol® 11081-E2 (70% NV in 26/4 TBAC/A100)
- White pigment: TiO_2
- Solvents used:
 - TBAC/mineral spirits 26/10, 2% methanol
- Enamel properties
 - 250 grams VOC/L
 - 62 wt% solids
 - Viscosity = 68 KU
 - PVC: 21%
 - Pigment to binder weight ratio: 0.93
- Enamel applied to unprimed gypsum wallboard

***Enamel paint prepared by Jeff Danneman, Reichhold Chemical.**

TBAC Indoor Air Concentrations After Painting

- Model classroom parameters:
 - Room volume 231 m³
 - Area painted: walls = 94.6 m²; flooring = 89.2 m²
 - Air exchange rate = 0.9 hr⁻¹
- Conversion varnish on floor (960 sf)
 - TBAC concentration safe (below acute RfC) after 24 hours
 - TBAC below odor detection threshold after 200 hours (8.3 days)
- White enamel on walls (1,018 sf)
 - TBAC concentration safe (below acute RfC) after 5 hours
 - TBAC below odor detection threshold within a week

TVOCs and Formaldehyde in Classroom @14 Days



- Both paints qualify for LEED credits EQ 3.2 and EQ 4.2

Conclusions

- Coating VOC regulations are spreading and becoming stricter
- VOC-exempt solvents like TBAC are useful formulating tools for cost-effective, high performance coatings
- TBAC is suitable for a wide range of coating technologies
- Solvent-based coatings require less energy to produce, apply, and cure than other low-VOC coatings
- Solvent-based coatings with TBAC can meet stringent VOC-content limits as well as qualify for green building environmental credits

3385-V2-1009

supersedes 3385-V1-0908