Renewable and Zero VOC Solutions for Bio-based Epoxy and Polyurethane Floor Coatings

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Green solutions

CNSL Technology

- Renewable and sustainable
- Low VOC or zero VOC
- Non-toxic and better labeling
- Application-friendly
- Excellent performance
- Cost-efficient

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Cashew Nutshell Liquid (CNSL) Technology

Non-edible

Cashew Nutshell Liquid does not interfere with the food chain

Widely available

Cashew crops are annually renewable and widely grown in many tropical areas along the equator

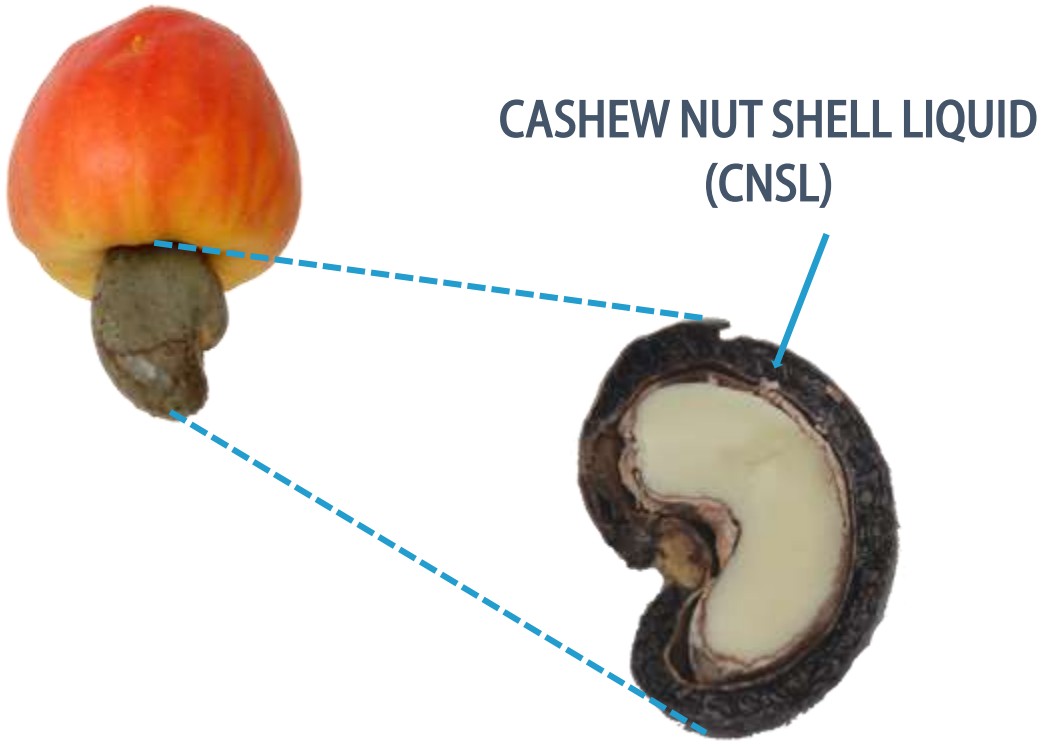
Versatile chemistry

CNSL can be processed into many functional materials with unique performances

Cost competitive

CNSL is a cost competitive resin with stable supply and a long history in the market

THE CASHEW



Cardanol Structure

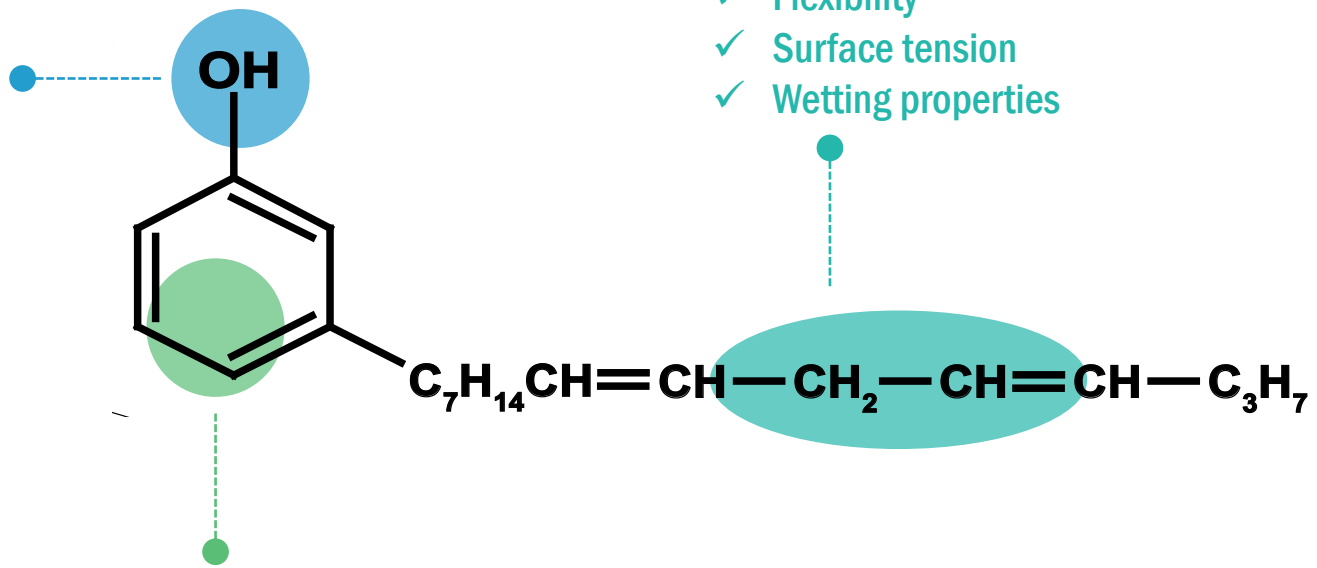
Average molecule represented on this slide

Cardanol is biobased certified by the USDA

Cardanol showed 96% biodegradation after 28 days*

*according to OECD Guideline No. 301D – Closed Bottle Test

- ✓ Fast cure
- ✓ Low temperature
- ✓ Adhesion



- ✓ Water and moisture resistance
- ✓ Low viscosity
- ✓ Flexibility
- ✓ Surface tension
- ✓ Wetting properties

- ✓ Thermal and fire resistance
- ✓ Chemical resistance

Cardanol Derivatives

Phenalkamines

Phenalkamides

Waterborne phenalkamines

CNSL ethoxylates

Polyols/diols

NCO Blocking Agents

Epoxy modifiers/diluents

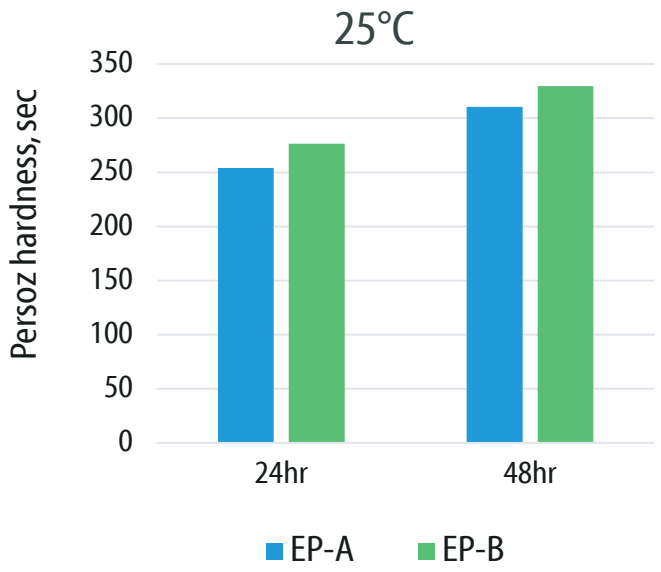
CNSL Specialties

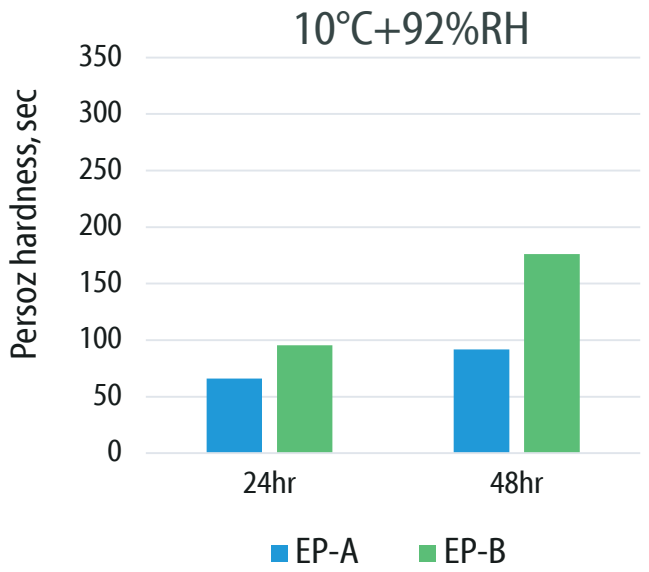
Solvent-free Epoxy Floor Coatings

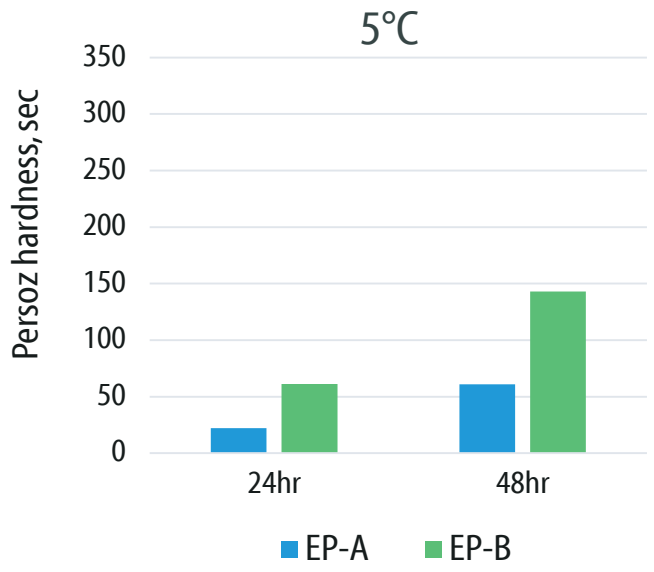
Phenalkamine Curing Agents

Properties	EP-A	EP-B
Viscosity @ 25°C (cPs)	800-1600	1064
Amine value (mg KOH/g)	300-350	366
Color (Gardner)	≤ 14	8
Recommended (phr, EEW 190)	50 - 70	50 - 70
Gel time @ 25°C (min) with standard liquid epoxy resin	37 (70 phr)	33 (70 phr)
Solvent/benzyl alcohol	No/No	No/No
Free phenol	No	No

Persoz Hardness Development







- Clear coat systems based on C_{12}-C_{14} aliphatic glycidyl ether modified bisphenol A/F type epoxy resin
- Curing agents: 70 phr
- WFT = 15mils over QD-36 panel

- EP-A and EP-B showed fast hardness development at different cure conditions, especially at low temperatures

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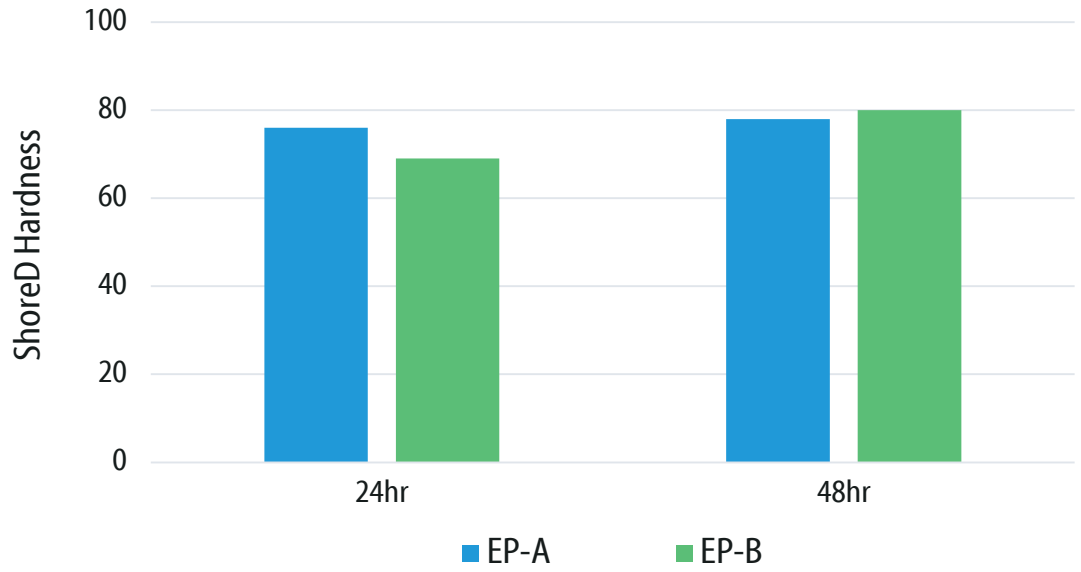
Shore D Hardness Development @ 25°C



- Clear coat system based on C_{12}-C_{14} aliphatic glycidyl ether modified bisphenol A/F type epoxy resin
- Curing agents: 70 phr
- 8 grams of mixture in Al pan

- EP-A and EP-B showed fast Shore D hardness development which good for floor applications

Film Appearance @ 10°C / 96%RH Condition

- Clear coat system based on C_{12}-C_{14} aliphatic glycidyl ether modified bisphenol A/F type epoxy resin
- Curing agents: 70 phr

EP-A

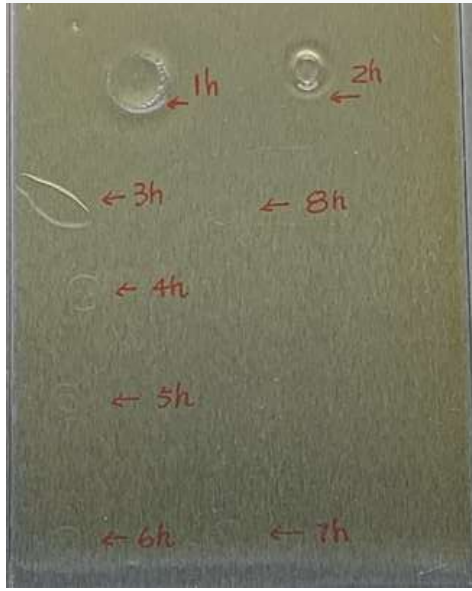
EP-B

- EP-A and EP-B showed excellent film appearance and no blush at low temperature and high humidity cure condition

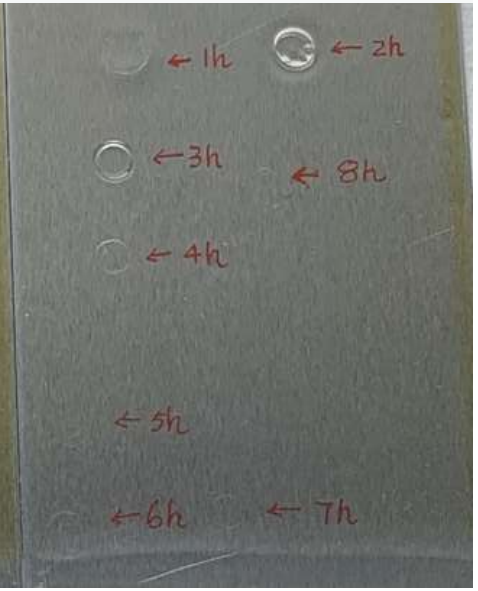
Early Water Resistance

- Clear coat system based on C_{12}-C_{14} aliphatic glycidyl ether modified bisphenol A/F type epoxy resin
- Curing agents: 70 phr
- WFT = 15 mils over QD-36 panel
- Add one droplet of water over films every hour
- Very tiny marks at 4 hours
- No marks after 4 hours

EP-A



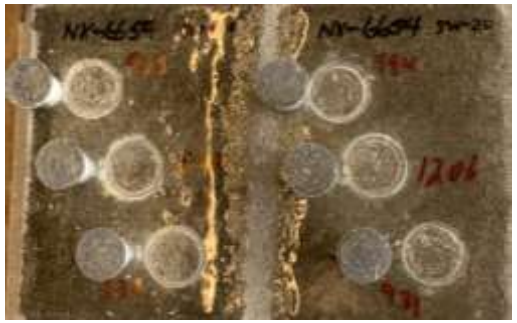
EP-B



- EP-A and EP-B systems showed excellent early water resistance, no water marks after 4-hour cure at 25°C condition

Pull-Off Adhesion to Various Concrete Substrates

EP-A



15W-40 5W-40

Different concrete surfaces	Pull-off adhesion (psi/MPa)	
	EP-A	EP-B
Dry concrete @ RT	1030/7.10	1134/7.82
Damp concrete @ RT	760/5.24	730/5.03
15W-40 oil contaminated concrete @ 15°C	741/5.11	794/5.47
5W-20 oil contaminated concrete @ 15°C	838/5.78	1043/7.19

- EP-A and EP-B primer systems showed excellent adhesions to damp and contaminated concrete substrates

Underwater Cure Properties

Composition	Underwater cure system/g
Liquid epoxy (Bis A type)	28.27
Diluent 2	5.65
Dispersant 2	1.47
Extender 2	11.31
Extender 3	7.12
Extender 4	28.27
EP-A/EP-B	17.91
Total	100.00

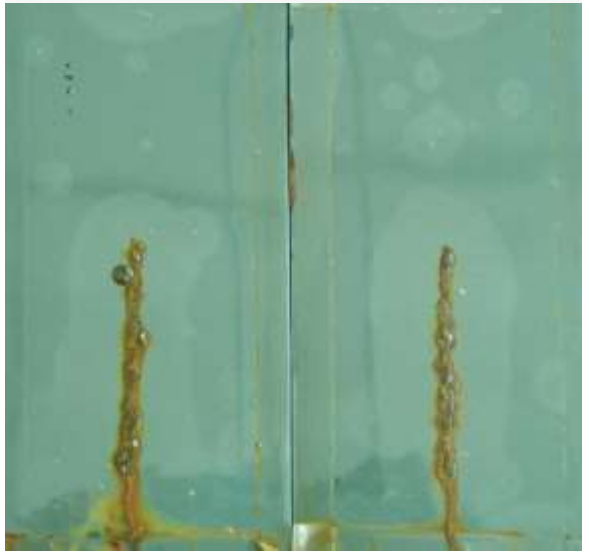
After 24 hrs underwater cure @ 15°C	Pull-off adhesion (psi/MPa)	Failure mode
EP-A	689/4.75	100% concrete cohesion
EP-B	804/5.54	100% concrete cohesion

EP-A and EP-B primer systems could cure well underwater and provide excellent adhesions to the underwater concrete

Salt Spray Test - 1000 hrs

- Clear coating systems based on C_{12}-C_{14} aliphatic glycidyl ether modified bisphenol A/F type epoxy resin
- Curing agents: 70phr
- DFT ~ 2 mils over SA2.5 steel
- 7 days RT cure before exposure

EP-A



EP-B

- EP-A and EP-B primer systems showed excellent anti-corrosion performance

Bio-based SF Phenalkamines

- Low viscosity, true solvent free, no benzyl alcohol, no free phenol
- High bio-content
- Fast cure at different cure conditions, especially at low temperatures
- Excellent film appearance, no blush at high humidity condition
- Good adhesions over damp or oil-contaminated concrete substrates
- Excellent underwater cure properties
- Good corrosion resistance
  - EP-A: Compliance with EU-REACH
  - EP-B: Compliance with TSCA

Solvent-free Polyurethane Floor Coatings

Key Components

Polyols	PLO-A	PLO-B	PLO-C
OH value (mg KOH/g)	170	224	256
Viscosity at 25°C (cPs)	3000	1710	1200
Average Functionality	3.2	3.1	4.3
Color (Gardner)	≤ 5	≤ 5	≤ 5
Bio-content* (%, calculated)	79	62	64

*Calculated values are estimated based on the amount of renewable raw materials used and processing conditions. They should be considered as approximate values. Cardolite makes no representations or warranties, expressed or implied, as to the accuracy of these calculations

Isocyanates	Polymeric MDI	Aliphatic polyisocynate HDI
NCO content (%)	30.5 - 32.5	21.7 - 22.2
Viscosity at 25°C (cPs)	160 - 240	2,500 ± 750
NCO equivalent value	133.3	200
Density at 25°C (g/cm^3)	1.22 - 1.25	/

- PLO-A, PLO-B and PLO-C provide a range of desirable pot life, viscosity, cure speed and color stability

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2K Clear PU Formulations

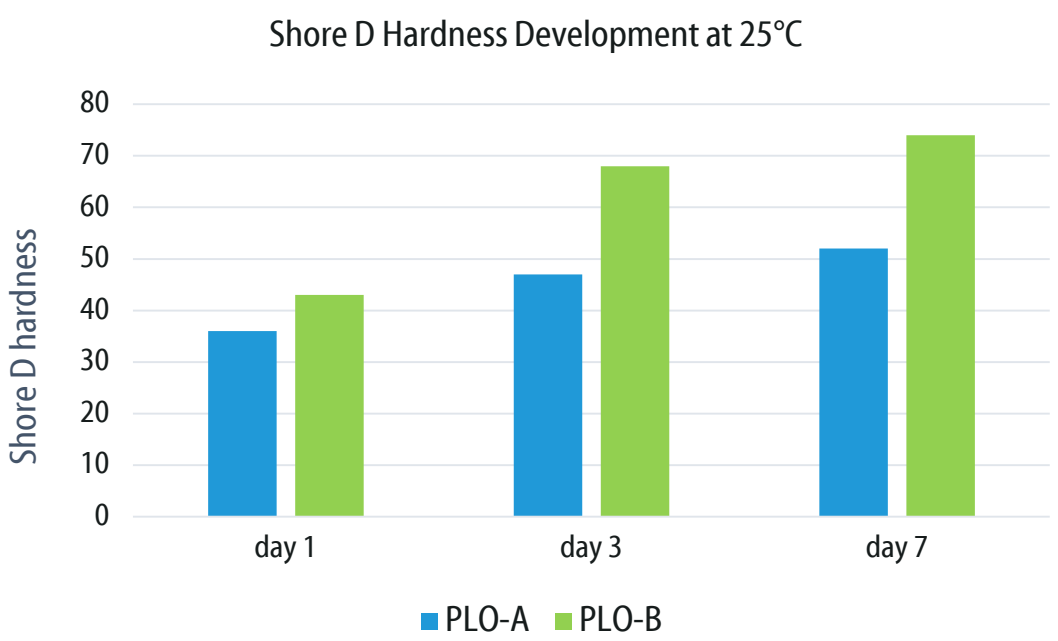
Targets:

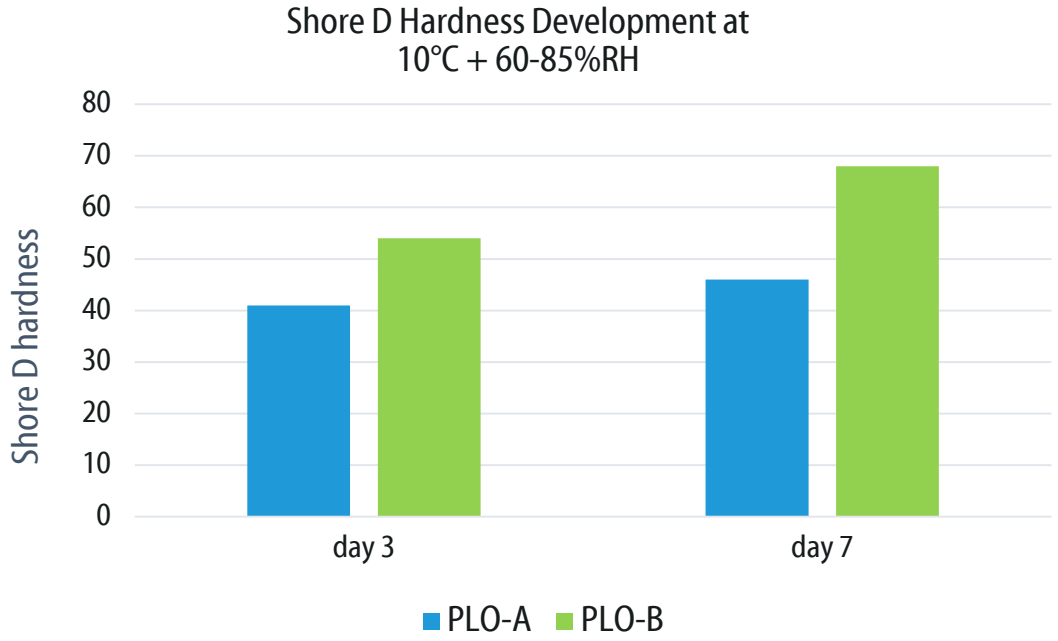
- Solvent-free systems
- Low viscosity
- Fast hardness development
- Good mechanical properties
- Good chemical resistance

Part A	PLO-A (g)	PLO-B (g)
PLO-A	95.7	/
PLO-B	/	95.7
Defoamer	0.5	0.5
Moisture scavenger	3.0	3.0
Leveling agent	0.5	0.5
Subtotal	99.7	99.7
Polymeric MDI	42.7	56.9
Total	142.4	156.6
Admixing viscosity (cPs)	1866	953
Gel time (mins)	45	52

NCO index 110

Hardness Development





- PLO-A and PLO-B showed fast hardness development
- PLO-A and PLO-B exhibited good hardness development at low temperature and high humidity

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Mechanical Properties

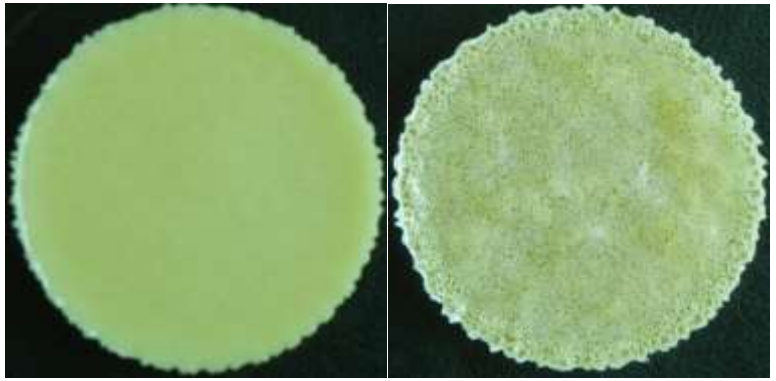
- Polymeric MDI
- NCO index: 110
- Cure condition: 7 days at 25°C/40-60%RH

Mechanical Properties		PLO-A	PLO-B
Mandrel Bend		1/8″ pass	1/8″ pass
Impact resistance (Kg · cm)	Direct	200	200
Impact resistance (Kg · cm)	Reverse	200	200
Cross-hatch adhesion (over QD-36 CRS)		5B	5B
Compression strength (MPa, at yield point)		No yield points detected, elastomeric PU system	25

- PLO-A and PLO-B systems exhibited very good flexibility and adhesion performance.
- PLO-A based PU system demonstrated excellent elastomeric performance at room temperature (compression test did not show measurable yield points)

Moisture Sensitivity at High Humidity

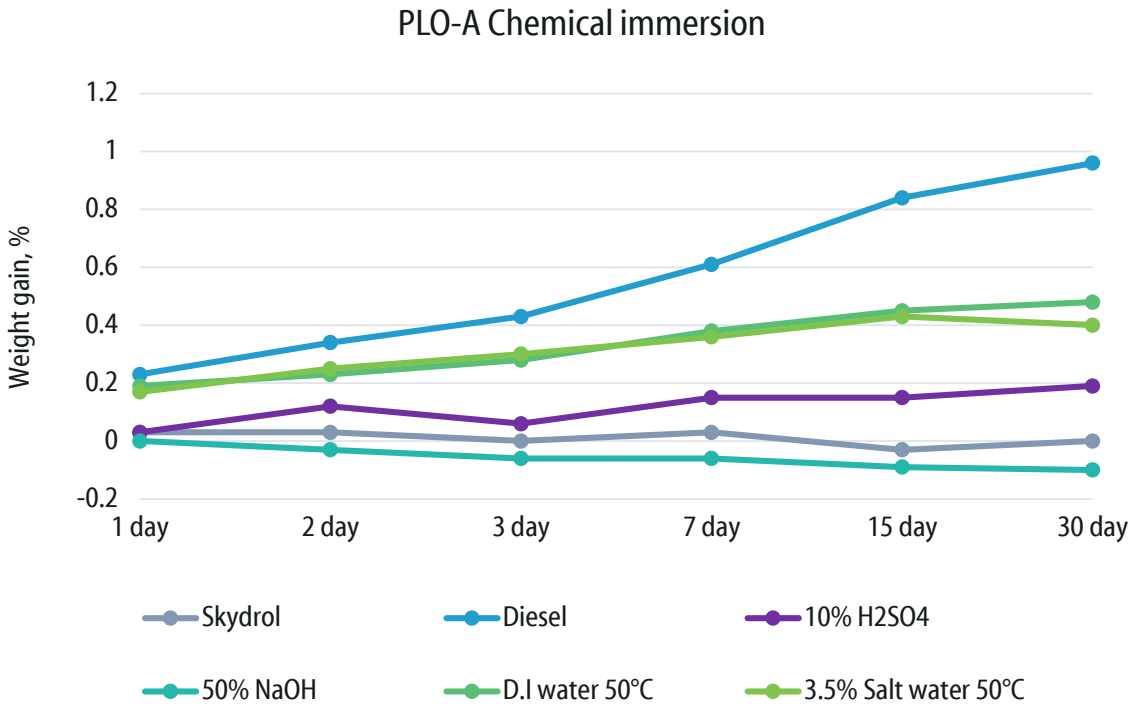
PLO-A PLO-B

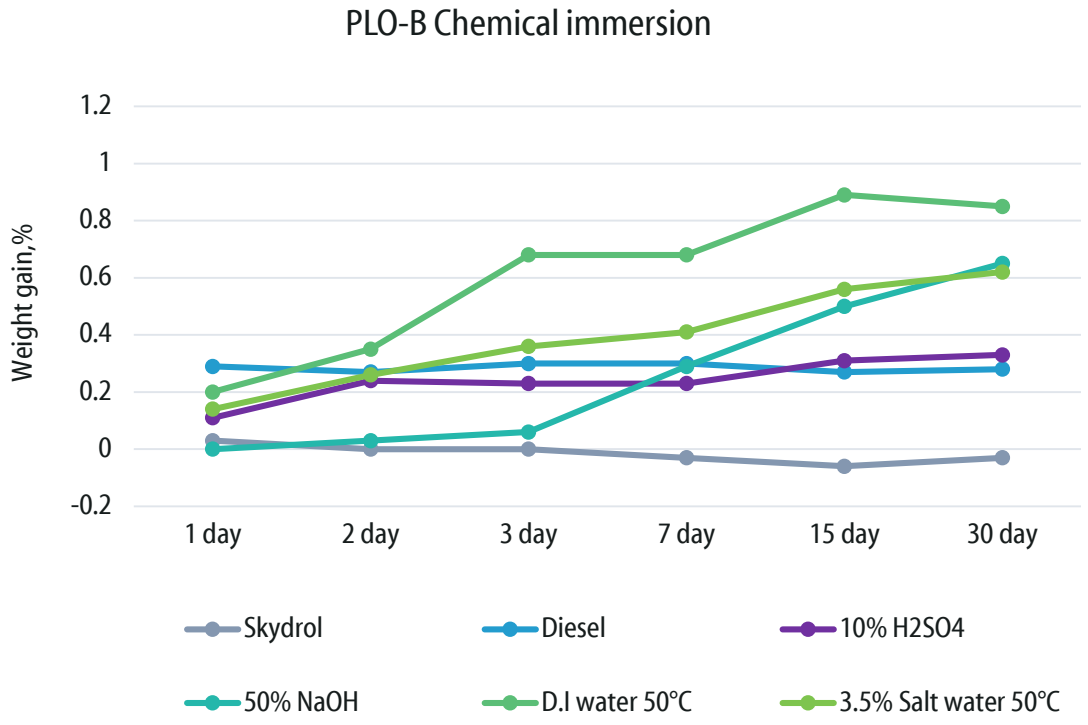


Cured at 28-34°C, 65-95%RH

- PLO-A is more hydrophobic than PLO-B which results in reduced moisture sensitivity during cure under high humidity.

Chemical Resistance





- Polymeric MDI, NCO index 110
- 7-day RT cure before immersion test

- PLO-A and PLO-B systems showed good chemical resistance to acid, alkaline, salt solutions, skydrol and Diesel

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2K Pigmented PU Systems

Targets:

- Balanced cure properties
- Good mechanical properties
- Improved color stability

PLO-B

PLO-C

Cure condition: 7 days at 25°C/40-60%RH

Part A	PLO-B (g)	PLO-C (g)
PLO-B	36.7	/
PLO-C	/	36.7
Dispersant	4.0	4.0
Defoamer	0.5	0.5
Moisture scavenger	3.0	3.0
White pigment	6.0	6.0
Barium sulfate filler	16.5	16.5
Silica sand filler	11.0	11.0
DBTDL (catalyst)	0.03	0.03
Leveling agent	1.0	1.0
Rheological additive	0.5	0.5
Part B: Aliphatic polyisocyanate (HDI) (NCO index:110)	30.9	36.1
Total	113.0	119.7

2K Pigmented PU Systems: Cure Properties

Properties	Admixing viscosity at 25°C (cPs)	Gel time at 25°C (mins)
PLO-B	5309	289
PLO-C	5549	154

- PLO-B and PLO-C showed medium admixing viscosities and long gel times

Systems	Cure Temperature	Hardness (Shore A/D)*		
		Day 1	Day 3	Day 7
PLO-B	25°C	67(A)	16(D)	23(D)
PLO-C	25°C	75(A)	21(D)	27(D)
PLO-B	10°C	Soft	75(A)	23(D)
PLO-C	10°C	49(A)	81(A)	28(D)

*A = Shore A, D = Shore D

- PLO-B and PLO-C systems exhibited good hardness development when combined with HDI type isocyanate

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Mechanical Properties

Mechanical properties		PLO-B	PLO-C
Mandrel Bend		1/8" pass	1/8" pass
Impact resistance (Kg · cm)	Direct	200	200
Impact resistance (Kg · cm)	Reverse	200	200
Cross-hatch adhesion (over QD-36 CRS substrate)		5B	4B
Abrasion (1000 cycle/mg)		78	80

- NCO index:110
- Cure condition: 7 days at 25℃/40-60%RH

- PLO-B and PLO-C showed very good flexibility and adhesion
- Good abrasion resistance can be achieved by PLO-B and PLO-C

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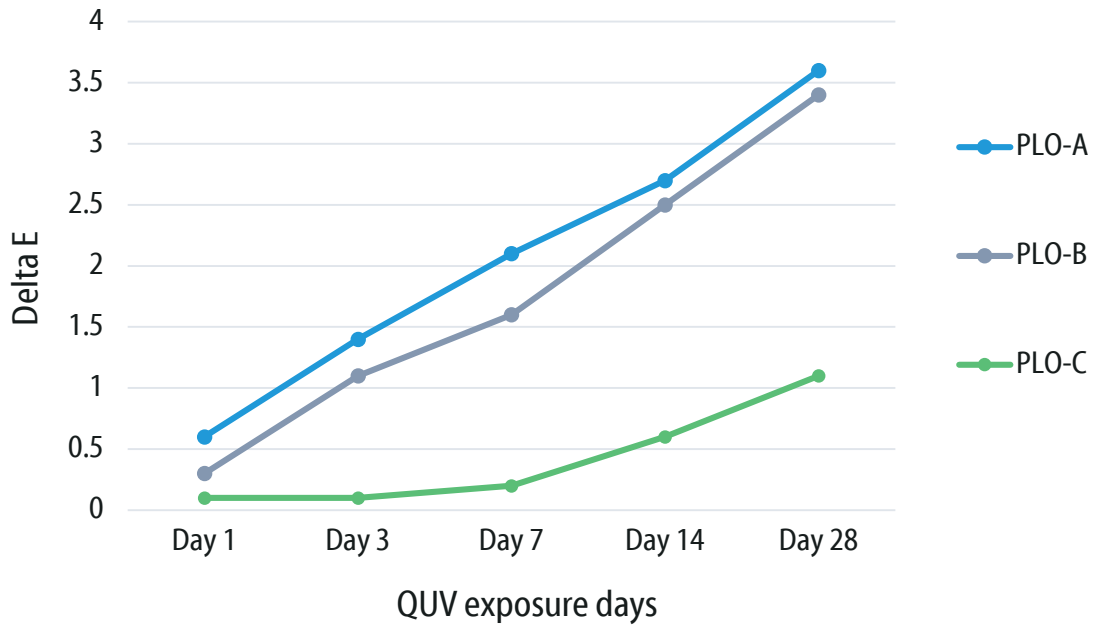
Color Stability: QUV-A Exposure



Part A	Weight (g)
Polyols (PLO-A, PLO-B or PLO-C)	38.94
BYK-163	0.56
Titanium Dioxide	22.32
MICA	28.08
Barium Sulfate	10.10
Total	100.00
HDI*	25.37/33.43/38.20

* Aliphatic polyisocyanate (HDI trimer)
Weight (%) polyol order: PLO-A, PLO-B, PLO-C

- PLO-C showed the best color stability after QUV-A exposure

Renewable SF Polyols

- PLO-A and PLO-B combined with polymeric MDI could offer fast cure, good hardness development, and excellent chemical resistance
- PLO-B and PLO-C combined with HDI could provide medium admixing viscosity, long pot life, reasonable cure speed, and excellent flexibility, adhesion and abrasion resistance
- PLO-C could display excellent color stability when exposed to UV light

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Thank you!

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