Cardolite Diols Introduction

Bristol, PA --- April, 2021

Content

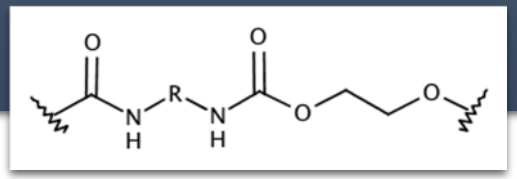
Diols: Typical Properties

Items	NX-9201	NX-9201LP	NX-9203	NX-9203LP	NX-9207	NX-9208	NX-9212
Polyol type	CNSL Diol	CNSL Diol	CNSL Diol	CNSL Diol	Non-CNSL (Polyester Diol)	CNSL Diol	CNSL Diol
Viscosity, (cps) @ 25°C	950-1850	950-1850	2200-5200	1800-3500	Waxy solid	Waxy solid	350-550
Hydroxyl value, (mg KOH/g)	65-80	65-80	80-115	90-125	120-145	70-85	45-60
Water content, %	≤ 0.1	≤ 0.1	≤ 0.1	≤ 0.1	≤ 0.05	≤ 0.05	≤ 0.1
Color, Gardener	14	≤ 17	14	≤ 14	Pale yellow solid	Pale brown solid	≤ 5
Bio content, calculated	87	87	69	69	-	36	13.8
Gel time (min) with PMDI	8	55	≤ 20	4hr	-	-	> 48hr
Recommended application	Binder	Binder Prepolymer	Binder	Binder Prepolymer	Binder Prepolymer	Binder Prepolymer	Binder Prepolymer

*Gel time for polyether diols cured with PMDI: >48hr

Applications for Cardolite Diols

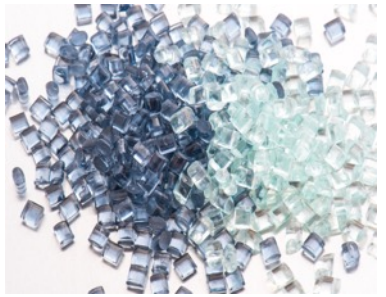
- One and two components PU
- Solvent-free or solvent-based PU and PUDs
- Suitable for thermoset and thermoplastic PU
- Used as binders or in prepolymers



Coatings

- Floor coatings
- PUD
- Building blocks (Acrylates)

Elastomers

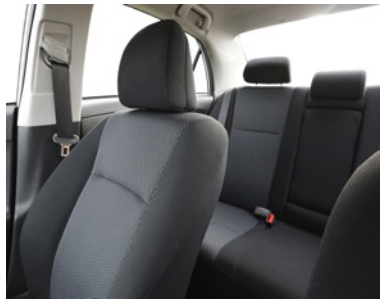


- TPU
- Thermal barrier
- Automotive noise, vibration and harshness (NVH) materials
- Seals

Adhesives

- Automotive sealants
- Building and construction
- Hot melt adhesives

Foams



- Flexible foams
- Injection foams
- Apparel foams

Textiles

- Coatings (e.g. leather, waterproofing)
- Adhesives
- TPU
- Shoe inserts

Diols: Compatibility with other PU raw materials

Items	NX-9201/ NX-9201LP	NX-9203/ NX-9203LP	NX-9207	NX-9208	NX-9212	Poly BD
PPG 1000	100% compatible	100% compatible	100% compatible	100% compatible	100% compatible	Max solubility: 55-60%
PPG 2000	100% compatible	100% compatible	100% compatible	100% compatible	100% compatible	Max solubility: 55-60%
Poly BD	compatible at <30%	100% compatible	incompatible	incompatible	compatible at <50%	-
EVA[1]	100% compatible, hazy	100% compatible, hazy	Incompatible	compatible at <50%	100% compatible	100% compatible, hazy
Tackifier (Wingtack 10[2])	compatible at <40%	100% compatible	incompatible	compatible at >50%	compatible at >30%	100% compatible
Tackifier (Indopol H300[3])	incompatible	incompatible	incompatible	compatible at 50%	incompatible	incompatible

[1] EVA: HANWHA 1528 ethylene vinyl acetate copolymer, [2] Wingtack 10: Cray Valley's Hydrocarbon, light yellow liquid, [3] Indopol H300: Indopol polybutane

- NX-9203 shows the best overall compatibility with other raw materials followed by NX-9208 and NX-9212.
- In terms of compatibility with PolyBD, NX-9203, NX-9212, NX-9201 are suitable diols.

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Diols: Reactivity

Diol	Isocyanate	Gel time @ 25°C
PPG 1000	HDI	> 18 h
PPG 2000	HDI	> 18 h
PolyBD	HDI	7 h 10’
NX-9201	**HDI**	**58’ 33"**
NX-9203	**HDI**	**16’ 31"**
PPG 1000	IPDI	> 18 h
PPG 2000	IPDI	> 18 h
NX-9201	**IPDI**	**4 h 45'**
NX-9203	**IPDI**	**3 h 43'**

Diol	Isocyanate	Gel time @ 25°C
PPG 1000	MDI	10 h 33'
PPG 2000	MDI	11 h 56'
PolyBD	MDI	2 h 06’
NX-9201	**MDI**	**3 h 36'**
NX-9203	**MDI**	**2 h 21'**
NX-9201LP	**PMDI**	**55 min**
NX-9203LP	**PMDI**	**4 h**
NX-9207	**PMDI**	**(solid)**
NX-9208	**PMDI**	**(solid)**

- 2K systems, NCO Index 100
- No catalyst has been used

- CNSL diols show greater reactivity to aliphatic and aromatic isocyanates compared to PPG diols.
- CNSL diols show similar reactivity to aromatic isocyanates, but greater reactivity to aliphatic isocyanates compared to PolyBD diols.

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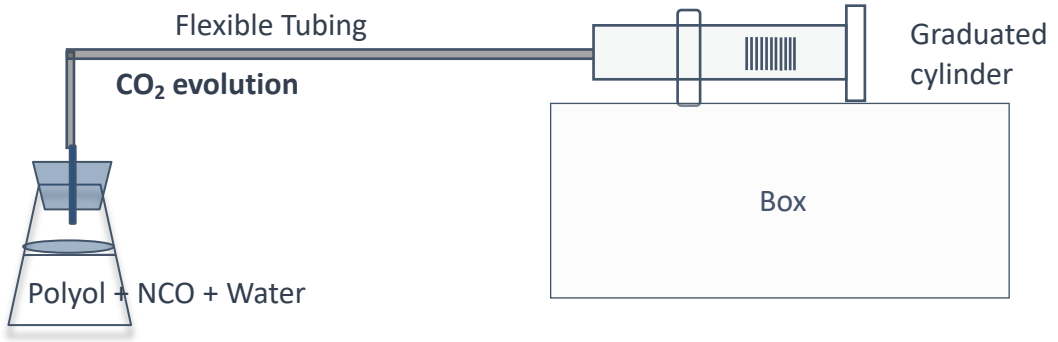
Moisture Sensitivity: CO_2 Evolution

Formula 100g of diol/NCO (Index 100) +100g of water)	OH value (mg KOH/g)	CO_2 (ml) after 24hr	
		Monomeric MDI	Polymeric MDI
PPG2000	57	>75*	>75*
PPG1000	114	>75*	>75*
PolyBD	48	18	14
NX-9201/NX-9201LP	**72**	**19**	**23**
NX-9203/NX-9201LP	**92**	**34**	**37**
NX-9207	**147**	**-**	**52**
NX-9208	**78**	**-**	**49**
NX-9212	**50**	**-**	**30**

*75 ml is the maximum volume of the syringe used in the test

Test Schematics



- PolyBD, NX-9201, NX-9203, NX-9212 showed the lowest sensitivity to moisture due to their hydrophobicity.
- NX-9208 showed slightly less moisture sensitivity than NX-9207.

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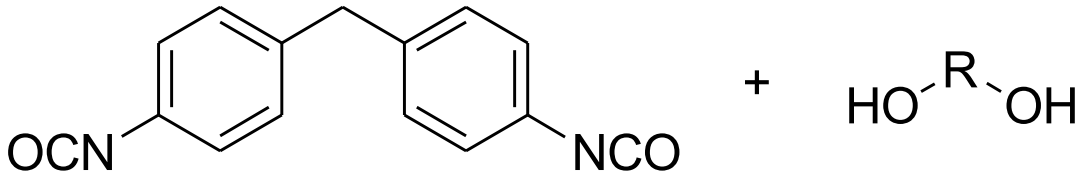
Prepolymer Preparation



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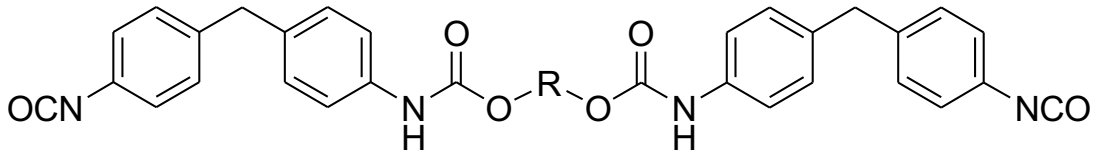
Total amount of MDI needed = X + {N(X+Y)/[(42/X)-N]}

N: desired NCO of the prepolymer (expressed as a fraction)

X: equivalent weight of the diisocyanate

Y: equivalent weight of the polyol (or average equivalent weight of the polyol blend)

- Isocyanate is added to reactor under Nitrogen
- Diol is slowly added to isocyantes at **65-70°C/2-4hr** (reaction temperature around 80-85°C for TDI based prepolymers)
- Conversion has been monitored by **NCO titration.**
- **No catalyst** (if any, Tin or Bismuth based)



Guidelines for making stable prepolymers using Cardolite Diols

Prepolymer synthesis: factors	NX-9212	NX-9207	NX-9208	NX-9201	NX-9201LP	NX-9203	NX-9203LP
Type of Isocyanates	Ok for any isocyanate	Ok for any isocyanate	Ok for any isocyanate	Only aliphatic isocyanates, i.e. IPDI, HDI	Aliphatic isocyanates and MDI	Only aliphatic isocyanates, i.e. IPDI, HDI	Aliphatic isocyanates and MDI
Isocyanate percent	No limitation	No limitation	No limitation	>3-4%	For MDI >7%, For aliphatic NCOs >3-4%	>3-4%	For MDI >7%, For aliphatic NCOs >3-4%
Catalysts used in prepolymer reaction	No limitation	No limitation	No limitation	More stable with no additional catalyst, but minimum is ok	More stable with no additional catalyst, but minimum is ok	More stable with no additional catalyst, but minimum is ok	More stable with no additional catalyst, but minimum is ok
Comments	Fully recommended for prepolymer synthesis	Fully recommended for prepolymer synthesis	Fully recommended for prepolymer synthesis	Suitable if above conditions are met and our guideline procedure is followed	Suitable if above conditions are met and our guideline procedure is followed	Suitable if above conditions are met and our guideline procedure is followed	Suitable if above conditions are met and our guideline procedure is followed

Thermal Stability: Prepolymer

CNSL Diols: 3% NCO prepolymer (Monomeric MDI)	RT	80ºC	120ºC
NX-9201	x	x	x
NX-9203	x	x	x
NX-9201LP	>6 month	x	x
NX-9203LP	>6 month	x	x
NX-9207	>6 month	ok for 48hr	After 24hr, skinning occurs
NX-9208	>6 month	ok for 48hr	After 24hr, skinning occurs
NX-9212	>6 month	ok for 48hr	After 24hr, thin skinning occurs

Suggestions for improvement on thermal stability:

1. No catalyst
2. Benzyol chloride as stabilizer
3. Nitrogen atmosphere

NX-9207, NX-9208 and NX-9212 exhibit the best prepolymer thermal stability at room temperature and elevated temperatures.

Prepolymers (NCO 7%): Physical Properties

7% NCO Prepolymer	Prepolymer Viscosity (cps at 25°C)	Tensile strength (MPa)	Elongation (%)	Modulus (MPa)	Hardness Shore A
PPG 1000	29617	9.3	245.9	20.4	81.4
PPG 2000	26617	8.4	249.4	18.0	79
PTMEG 1000	21583	11.5	342.0	29.9	81.5
PTMEG 2000	25694	3.6	114.6	22.4	83
Aliphatic polycarbonate diol	28631	27.0	202.2	55.8	91.2
PolyBD (mw 4000)	20365	5.4	101.4	24.9	88.4
NX-9201/NX-9201LP	19868	2.2/4.2	30.6/83	19.3	75.4
NX-9203/NX-9203LP	21056	5.1/6.5	82.8/96	32.6	82
NX-9207	97400	**26.8**	**302**	43.5	91
NX-9208	57700	**11**	**197**	24.5	87
NX-9212	5250	4.65	**295.3**	8.08	73

*NCO: MDI, 1,4-BDO extended prepolymers cured at RT for 18 h (T12 and Dabco 8154 have been used as catalysts and BYK 054 as air release additive)

- NX-9207 shows the best mechanical performances followed by NX-9208.
- NX-9212 provides lower viscosity prepolymers.

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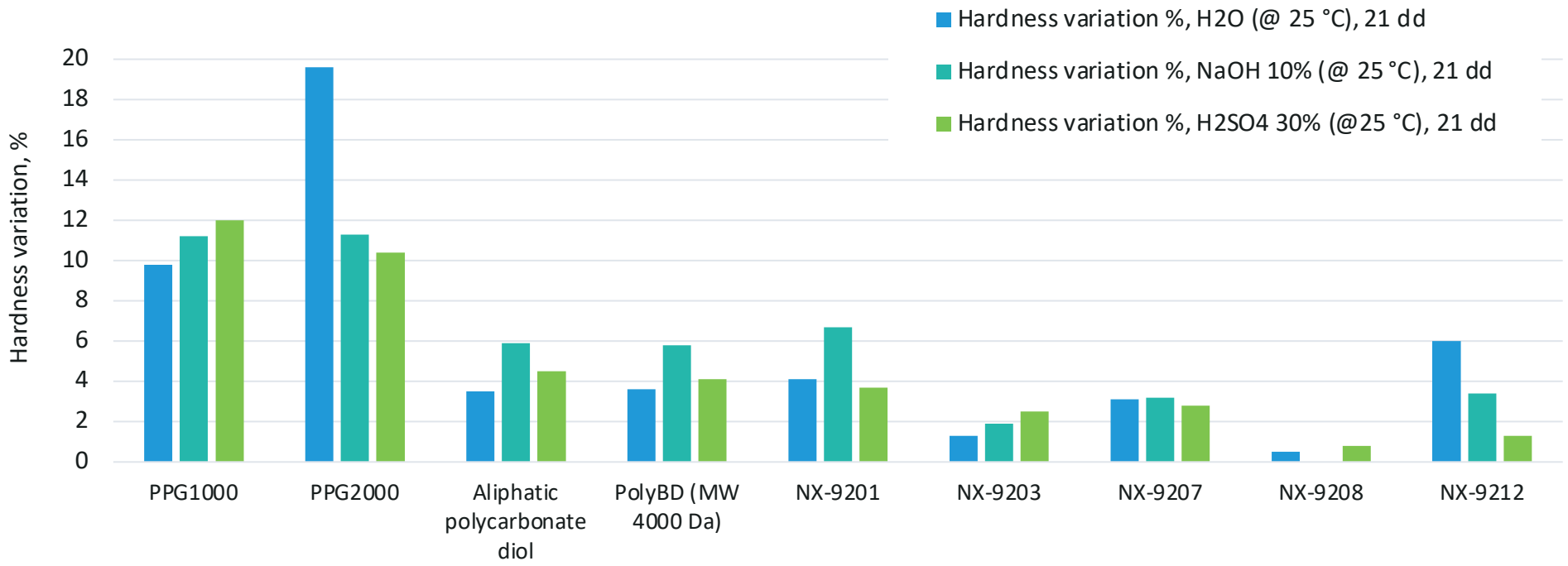
Prepolymers (7% NCO): Hydrolytic Stability

*NCO: Monomeric MDI, 1,4-BDO extended prepolymers cured at RT for 18 h (T12 and Dabco 8154 have been used as catalysts and BYK 054 as air release additive)



NX-9208 demonstrates excellent hydrolytic stability followed by NX-9203, NX-9207, NX-9212 and NX-9201.

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Diol blends: Viscosity

Diols	Viscosity (cps, @ 25°C)	Viscosity (cps, @ 40°C)
NX-9201	1,441	614
NX-9203	2,950	843
NX-9207	solid	261
NX-9208	solid	527
Diol blends	**Viscosity (cps, @ 25°C)**	**Viscosity (cps, @ 40°C)**
NX-9207/9201LP 20/80	solid	633
NX-9207/9203LP 80/20	solid	451
NX-9207/9203LP 50/50	solid	576
NX-9207/9203LP 20/80	solid	779
NX-9208/9201LP 80/20	solid	1,057
NX-9208/9201LP 50/50	solid	901
NX-9208/9201LP 20/80	**2,248**	**759**
NX-9208/9203LP 80/20	solid	1,138
NX-9208/9203LP 50/50	**14,649**	**1,083**
NX-9208/9203LP 20/80	**2,923**	**1,000**

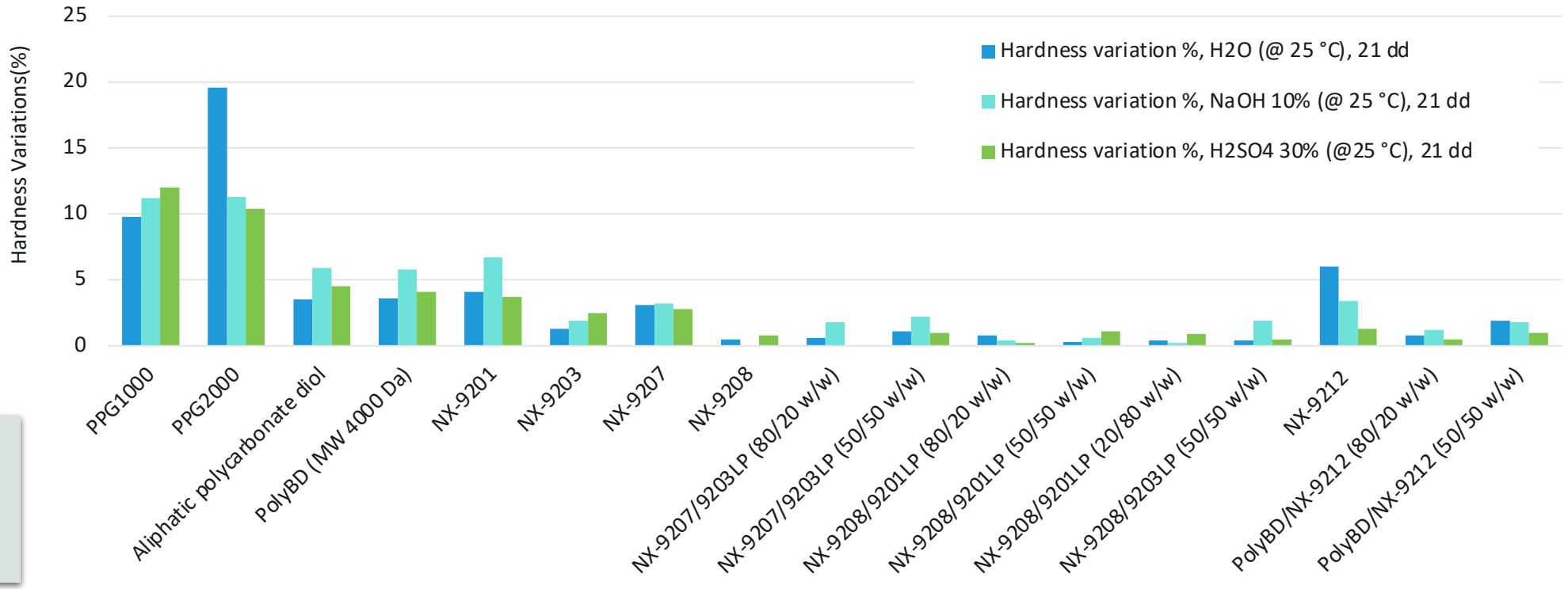
Diol Blends: Mechanical Properties and Stability

Diols (7% NCO prepolymer)	Hardness (Shore A)	Tensile strength (MPa)	Elongation (%)
NX-9201LP	75	4.2	83
NX-9203LP	82	6.5	96
NX-9207	91	26.8	302
NX-9208	87	11.0	197
NX-9212	73	4.65	295
PolyBD	88.4	5.4	101.4
NX-9207/9201LP 20/80 (solid)	84	6.0	94
NX-9207/9203LP 80/20 (solid)	**89**	**13.9**	**270**
NX-9207/9203LP 50/50 (solid)	90	5.6	111
NX-9207/9203LP 20/80 (solid)	84	3.1	37
NX-9208/9201LP 80/20 (solid)	**84**	**10.5**	**187**
NX-9208/9201LP 50/50 (solid)	86	9.0	148
NX-9208/9201LP 20/80 (2,248cps)	80	6.0	111
NX-9208/9203LP 80/20 (solid)	**85**	**10.2**	**180**
NX-9208/9203LP 50/50 (14,649cps)	**85**	**11.7**	**200**
NX-9208/9203LP 20/80 (2,923)	87	6.1	106
PolyBD/NX-9212 80/20	**82.4**	**4.4**	**98.1**
PolyBD/NX-9212 50/50	**81**	**4.3**	**151.3**

* NCO: Monomeric MDI. All prepolymers have an approx. 7% NCO content prior to extension with BDO

- Highlighted blends in green show better mechanical properties than neat NX-9201LP and NX-9203LP and not too far from neat NX-9207 and NX-9208. Blends show good stability after exposure at 50°C for 14 days.
- PolyBD/NX-9212 50/50 blend can be used to improve neat PolyBD elongation.

Diol Blends: Prepolymers (7% NCO) Hydrolytic Stability



*NCO: Monomeric MDI, 1,4-BDO extended prepolymers cured at RT for 18 h (T12 and Dabco 8154 have been used as catalysts and BYK 054 as air release additive)

- Prepolymers based on most blends show good resistance after exposure for 21 days in different aqueous media compared to industry benchmarks.
- Blending NX-9212 and PolyBD helps to improve hydrolytic stability.

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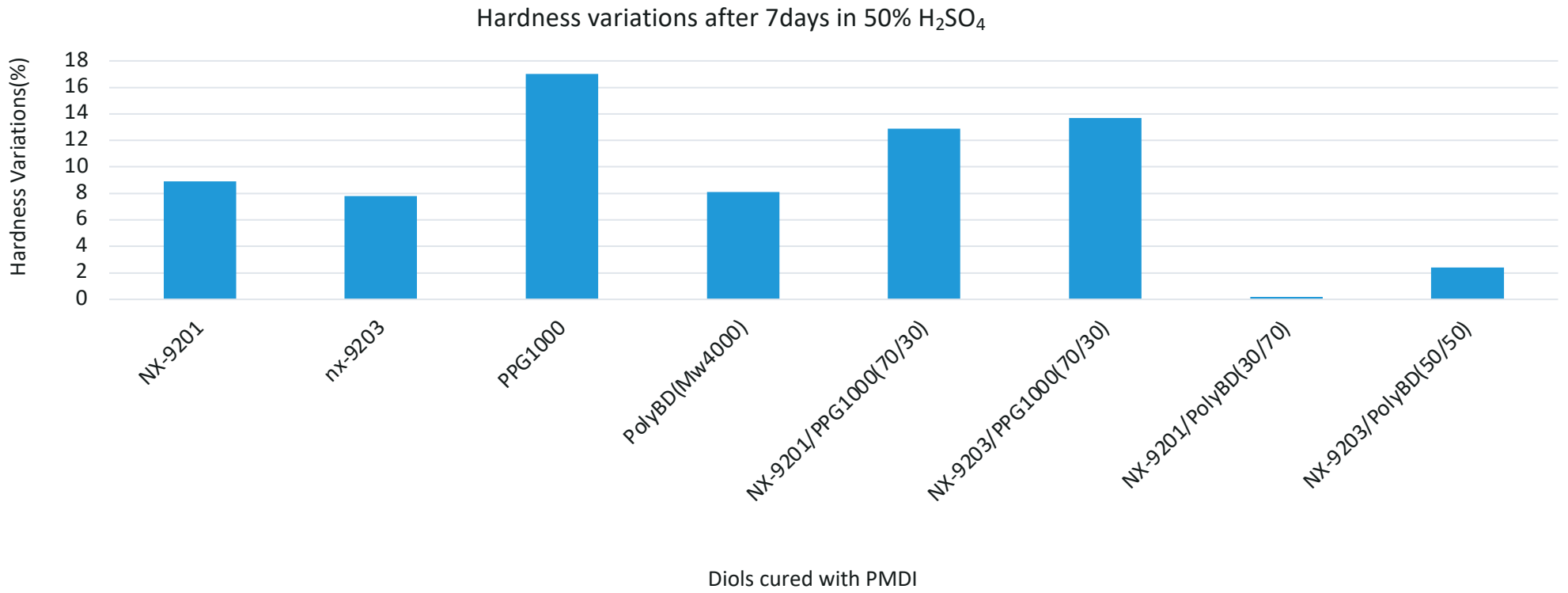
2K PU Properties

Diols	Lap shear (40°C/114hr cure) on blasted steel, MPa	Tensile strength (40°C/114hr cure), MPa	Elongation at break (40°C/114hr cure), %	Tg (40°C/4hr+80°C/2hr+ 120°C/4hr), °C
NX-9207	1.31	-	-	-31
NX-9208	0.79	0.23	76	-45
Diols	Lap shear (60°C/4hr) on blasted Al, MPa	Tensile strength (4h/70°C+1hr/120°C), MPa	Elongation at break (4h/70°C+1hr/120°C), %	Tg (4h/70°C+1hr/120°C), °C
NX-9201	0.21	0.2	29	-55
NX-9203	0.72	0.57	62	-18
PolyBD (Mw=2800)	0.44	0.59	46	-74

NCO index = 100, cured with polymeric MDI

*NX-9207, NX-9208 are preheated at 60ºC prior to mixing with isocyanate

Diols in 2K PU: Hydrolytic Stability



*cured 4hr/70°C + 1hr/120°C

- CNSL diols show good hydrolytic stability in 50% H_2SO_4.
- CNSL diols and PolyBD blends exhibit significantly improved hydrolytic stability in 50% H_2SO_4.

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2K PU Adhesive and Sealants: Formulation

Part A	Formulation 1	Formulation 2	Formulation 3
PolyBD R45V	100		50
NX-9203LP		100	50
V260 (OH value 660)	17.15	17.15	17.15
Filler (Calcium carbonate powder)	100	100	100
Epoxy silane adhesion promoter	1.086	1.086	1.086
Antifoam agent	0.1	0.1	0.1
Part B			
143LP (modified MDI)	43.3 (1.05 NCO index)	61.9 (1.05 NCO index)	52.6 (1.05 NCO index)

2K Performance Comparison

Formulations	Tensile strength (Mpa) 40°C/3day cure	Elongation at break (%) 40°C/3day cure	Hardness(A) 40°C/ 3day cure	Tg (℃) 40°C/3day cure	Water absorption (%) 25°C 7day /14day	Adhesion strength (MPa), Al	Adhesion strength on plastics, MPa		
							PC	PVC	Nylon
Formulation 1 (PolyBD)	3.5	42.5	92	-75	0.78/1.05	3.2	4.0	3.6	1.4
Formulation 2 (NX-9203LP)	4.0	14.7	97	n/a	0.30/0.36	3.5	0.4	0.3	0.1
Formulation 3 (PolyBD/ NX-9203LP)	**7.0**	**77.2**	**93**	**-77**	**0.17/0.19**	**6.1**	1.9	2.7	1.0

*Pretreatment on substrates for adhesion: Alcohol wipe
*Adhesion failure mode: cohesion failure

- CNSL diol and PolyBD are compatible.
- Combining PolyBD and CNSL diol at 50:50 provides significantly improved water resistance, increased tensile and elongation, and better bonding on Aluminum substrate.

Cardolite Diols Summary

- One and two components PU
- Solvent-free or solvent-based PU and PUDs
- Suitable for thermoset and thermoplastic PU
- Used as binders or in prepolymers
- Applications: Adhesives and Sealants, TPU and Hot melt, Coatings, PU Foams, Textiles, Elastomers

NX-9201(LP)

- **Lowest moisture sensitivity**
- Good hydrolytic stability
- Good compatibility
- Low Tg (better performance at low temperature)
- NX-9201LP suitable for prepolymer synthesis

NX-9203(LP)

- **Best compatibility**
- Excellent hydrolytic stability
- Low moisture sensitivity
- Good synergy effect with PolyBD
- NX-9203LP suitable for prepolymer synthesis

NX-9207

- **Best mechanical properties**
- Lighter color
- Reduced odor
- Good hydrolytic stability
- Better prepolymer stability at room and elevated temperatures

NX-9208

- **Best hydrolytic stability**
- Higher mechanical properties
- Good compatibility: Blend with NX-9203LP or NX-9201LP for balanced performance
- Better prepolymer stability at room and elevated temperatures

NX-9212

- **Low viscosity**
- Light color
- High elongation
- Good hydrolytic stability
- Better prepolymer stability at room and elevated temperatures

Thank you!

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