

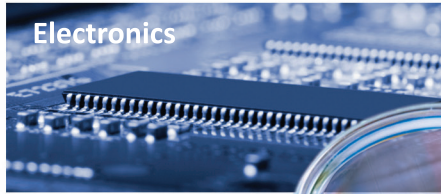
IVES



Cardolite



Construction

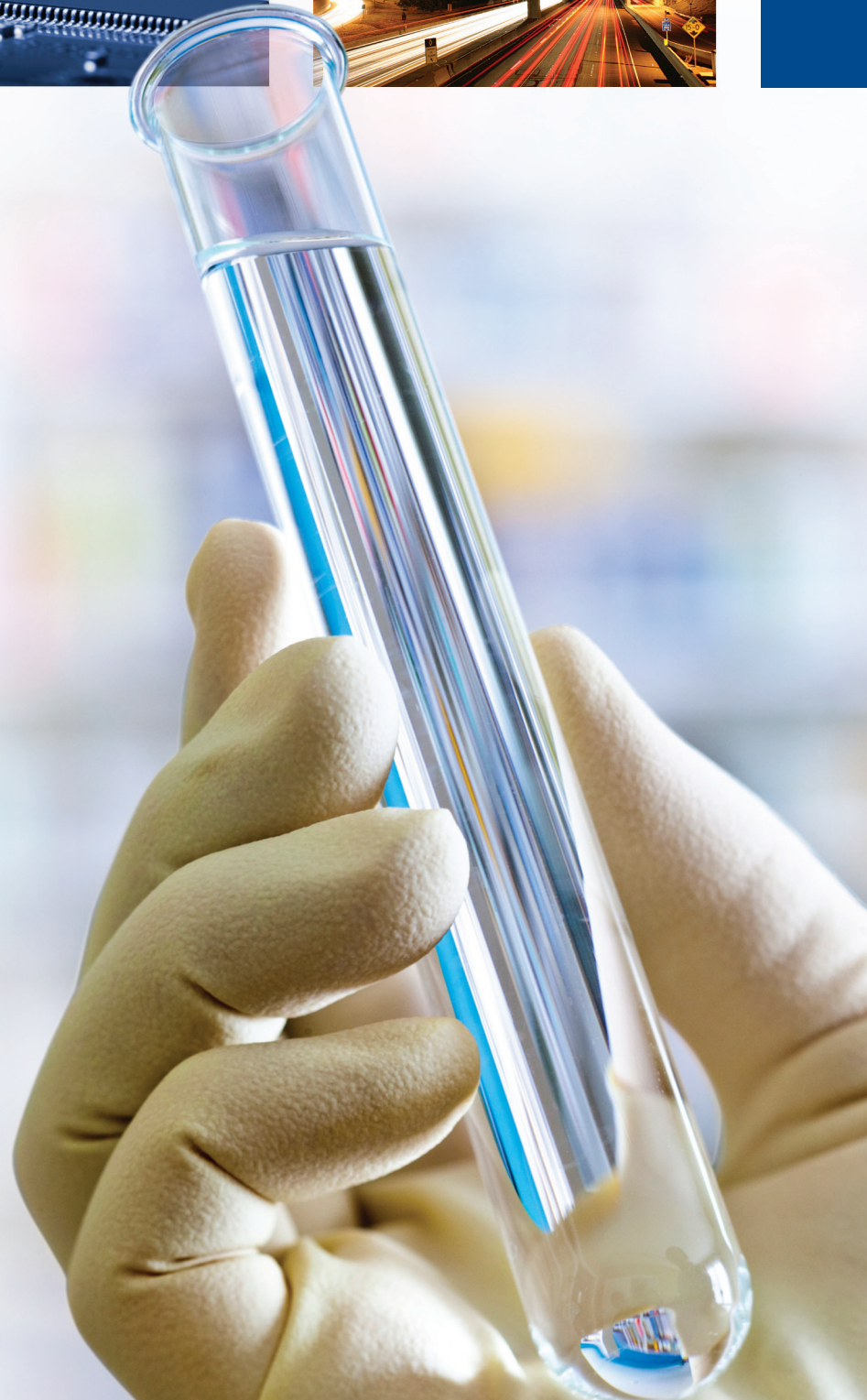


Electronics



Transportation

ADHESIVES



PRODUCT OVERVIEW

# CONTENTS



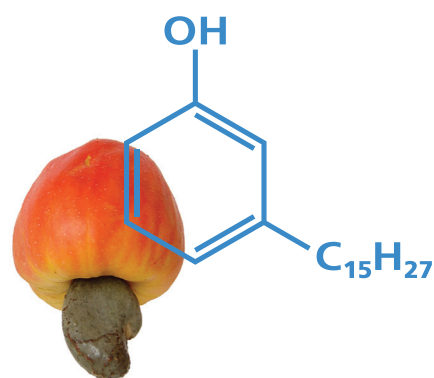
Company Introduction	P. 3
CNSL Technology	P. 3
Epoxy Curing Agents	P. 4-7
Epoxy Resins & Modifiers	P. 8-10
Polyol Resins	P. 11-12
Adhesive Applications	P. 13

*From the beginning, Cardolite products have been based on cashew nutshell liquid (CNSL), a natural, and annually renewable biomaterial. CNSL can be found in the honeycomb structure of the cashew nutshell and is considered a by-product (non-food chain material) of the cashew nut industry. CNSL-based technology has been widely adopted because there are inherent performance benefits gained from using this starting raw material, unlike using other natural raw materials that can sacrifice performance or cost.*

**Cardolite Corporation** is a privately held manufacturer of the world's largest variety of products derived from cashew nutshell liquid (CNSL), a renewable natural resource. The unique properties of CNSL are used to develop and produce a wide range of specialty curing agents, resins, and diluents for coatings, adhesives, composites and friction applications.

With over 30 years of experience, Cardolite is the leader in the production of high quality CNSL-based products with the most advanced CNSL technology manufacturing facilities in the world located in Zhuhai, Guangdong (China), and Mangalore, Karnataka (India). Cardolite facilities are ISO 9000 registered and strictly adhere to local and best practice health, safety, environmental, and security standards. With sales offices, representatives, and distribution facilities in the Americas, Europe, and Asia, Cardolite prides itself on delivering high quality products and services across the globe.

To further advance CNSL technology, Cardolite also operates two advanced research and technical service facilities in the USA and China. By using CNSL as a primary building block, these labs are able to develop adhesive materials that have unique advantages over some traditional adhesive chemistries. Cardolite continues to invest heavily in research, technical support, manufacturing, and market development to meet the ongoing needs of the adhesives industry with innovative, natural, renewable CNSL-based products.



## CNSL TECHNOLOGY

Cardanol is a unique natural phenolic material obtained by distilling CNSL and serves as the primary building block for Cardolite products. The molecule is composed of an aromatic ring with an OH group and a long aliphatic side chain, which bring valuable intrinsic benefits to adhesive materials. The aromatic ring provides a strong chemical resistant backbone while the OH group gives high bond strength and good reactivity for fast and low temperature cure. The side chain provides excellent water resistance, good flexibility, low viscosity, and extended pot life. Most Cardolite products have high bio-content of >65%.

# Epoxy Curing Agents

## FAST BONDING IN EXTREME CONDITIONS

Cardolite phenalkamines and phenalkamides exhibit fast cure even at low temperatures, enable non-critical mix ratios, and show nice film appearance due to good compatibility with epoxy resins. However, due to the long aliphatic side chain of cardanol, CNSL curing agents also provide extended pot life and good flexibility.

The fast and low temperature cure combined with the good pot life properties of CNSL hardeners allow for wider adhesive application window and increased productivity. Faster cure means quicker return to service for two-component field-applied adhesives. In forced cure industrial applications, phenalkamines and phenalkamides can help save energy by lowering oven cure temperatures, or improving process efficiency via increased production line speeds. Finally, by reaching a high level of crosslinking very quickly and not having a narrow mix ratio, failure risks are lowered and problems avoided when environmental conditions change after application.

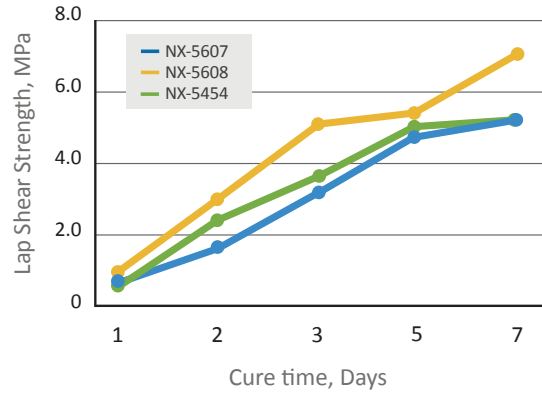
### Phenalkamine based Epoxy Adhesion to Concrete

Epoxy Phenalkamine	Pull off Adhesion (psi/MPa)	Rupture Mode
24 hours dry concrete	1,000/6.90	50% dolly to adhesive 50% concrete
3 weeks dry concrete	1,000/6.90	Dolly to adhesive
3 weeks damp concrete	500/3.45	100% concrete

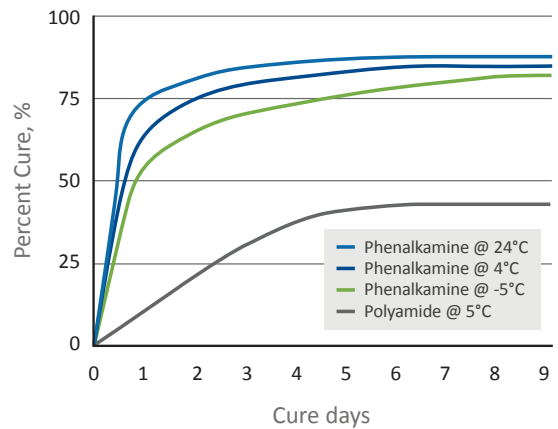


This image shows failure occurs in the concrete and not between dolly/coating and concrete.

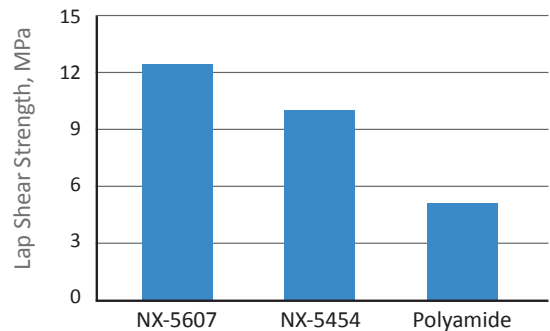
Bond Strength Development with Liquid Epoxy (EEW 190) on Sand Blasted Steel at 0°C



Phenalkamine Low Temperature Cure Data and Comparison



Bond Strength with Liquid Epoxy (EEW 190) on Wet Sand Blasted Steel at 40°C for 16hr Cure

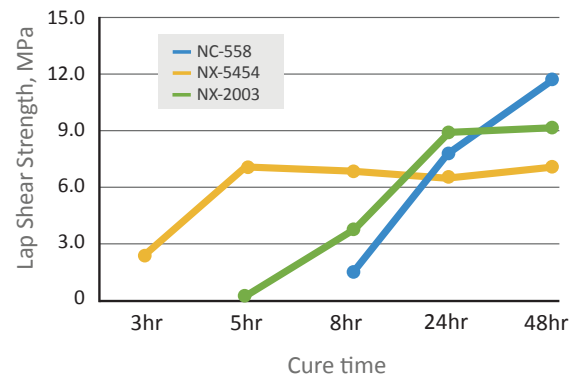




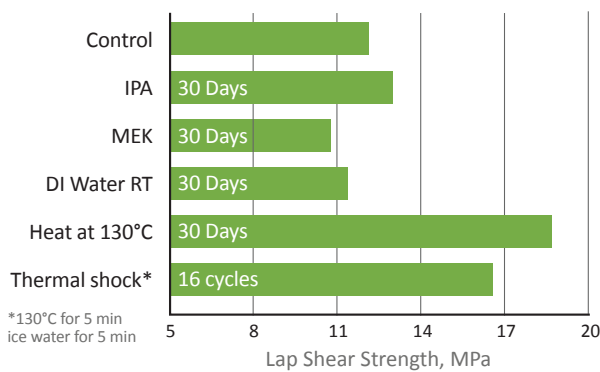
## BONDING UNDER WATER

Cardolite curing agents are very hydrophobic due to the long aliphatic chain of the cardanol, which provides excellent water resistance compared to other amine curing agents commonly used in the adhesive industry. The hydrophobicity of CNSL products coupled with their fast cure allows adhesives to quickly develop strong bonds to wet metal, damp concrete, and under water structures. Moreover, CNSL curing agents exhibit excellent chemical resistance due to its aromatic ring, which in combination with their other properties such as high bond strength, result in very good aging properties under different strenuous conditions.

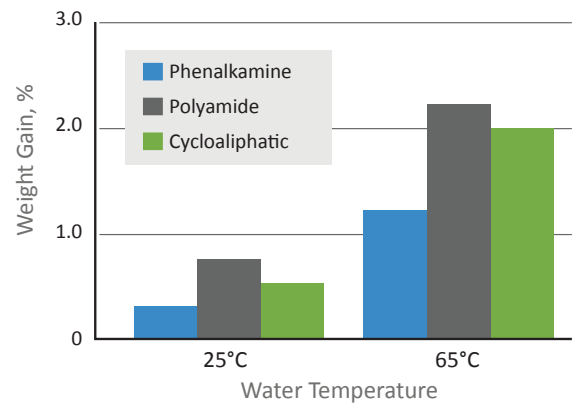
**Bond Strength with Liquid Epoxy (EEW 190) on Non-abraded Steel Cured at 22°C Under Water**



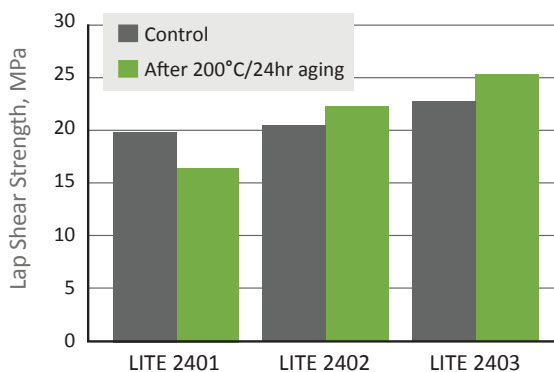
**Different Aging Conditions**



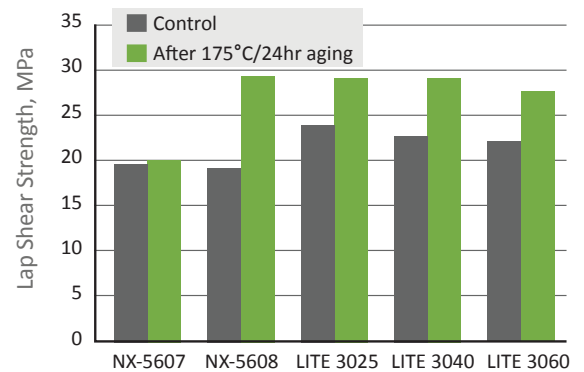
**Comparative Water Resistance of CNSL Curing Agents**



**Thermal Resistance at 200°C, Cured with Liquid Epoxy (EEW 190) at 80°C/16hr + 120°C/2hr**



**Thermal Resistance at 175°C Cured with Liquid Epoxy (EEW 190) at 40°C/16hr**





## Curing Agent Property Selection Chart

Product	Viscosity <sup>1</sup> @ 25°C (cPs)	Technology	Type	Color <sup>2</sup> (Gardner)	Amine Value <sup>3</sup> (mgKOH/g)	AHEW <sup>4</sup>	Gel Time <sup>5</sup> (min)	Thin Film <sup>6</sup> Dry Hard Time (hours)		
								25°C	5°C	0°C
NC-541	28,000	phenalkamine	solvent free	16	330	130	81	4.5	11	20.5
LITE 2001	28,000	phenalkamine	solvent free	10	330	132	75	3	12.5	19
NC-541LV	2,300	phenalkamine	solvent free	15	340	125	61	7	24+	36
LITE 2001LV	2,500	phenalkamine	solvent free	10	340	125	75	7	17	29
LITE 2010LV	4,100	phenalkamine	solvent free	10	247	125	30	3	13.5	19
NC-540	2,000	phenalkamine	solvent free	15	535	81	42	3.5	13	19
NC-558	900	phenalkamine	solvent free	17	340	95	40	10	22	32
NC-557	1,100	phenalkamine	solvent free	14	355	95	22	7	16.5	27.5
NC-566	1,800	phenalkamine	solvent free	14	380	95	25	3.5	9	14
NX-2003	620	phenalkamine	solvent free	10	360	95	25	4.5	18.5	22
NX-2003D	700	phenalkamine	solvent free	13	357	95	25	4.5	15	24
NX-5454	1,080	phenalkamine	solvent free	11	275	133	18	2	7.5	10
NX-5198	140	phenalkamine	solvent free	11	300	179	15	2.4	13	n/a
LITE 2002	450	phenalkamine	solvent free	10	360	104	51	6	20	30.5
LITE 2002LP	650	phenalkamine	solvent free	10	360	104	85	7	21	39
NX-2007	265	phenalkamine	benzyl alcohol	4	310	113	50	2	16	23.5
NX-2009	370	phenalkamine	benzyl alcohol	7	310	95	31	4	12	20.5
Ultra LITE 2009	330	phenalkamine	benzyl alcohol	1	277	95	34	6	19	27
NX-4943	1,800	phenalkamine	solvent free	14	488	82	41	4	14	23
NX-5567	770	phenalkamine	solvent free	15	561	66	22	3	10	15
NX-6032	1,200	phenalkamine	benzyl alcohol	10	325	133	20	2	11	16
NX-5607	2,490	phenalkamine	solvent free	10	405	95	14	2	9	14
NX-5608	3,350	phenalkamine	solvent free	10	405	95	13	2.5	12	15
NX-5594	1,000	phenalkamine	solvent free	14	414	76	16	2.5	8	11
LITE 3025	34,000	phenalkamide	solvent free	10	345	103	200	8.5	29	n/a
LITE 3040	5,000	phenalkamide	solvent free	10	380	118	110	7.3	29	n/a
LITE 3060	850	phenalkamide	solvent free	10	460	104	48	5	17.5	n/a
GX-3090	520	phenalkamide	solvent free	7	598	69	45	4.3	19.2	n/a
LITE 2401	90	phenalkamine	solvent free	5	496	61	>90	n/a	n/a	n/a
LITE 2402	105	phenalkamine	solvent free	11	555	56	>85	n/a	n/a	n/a
LITE 2403	230	phenalkamine	solvent free	5	526	58	>170	n/a	n/a	n/a

<sup>1</sup>ASTM D2196 <sup>2</sup>ASTM D1544 <sup>3</sup>ASTM D2074 <sup>4</sup>Theoretical based on total product weight <sup>5</sup>50g at 25°C <sup>6</sup>ASTM D5895 @ 200 micron <sup>7</sup>ASTM D2369-98

## Curing Agent Mechanical Properties Selection Chart

Curing Agent	T <sub>g</sub> <sup>7</sup> (°C)	Tensile Strength (MPa)	Flexural Strength (MPa)	Compressive Strength (MPa)	Elastic Modulus (MPa)	Lap Shear <sup>8</sup> (MPa)
NC-540	105	54	98	81	2,457	16
NC-558	61	41	105	56	1,985	21
NX-2003	74	55	94	76	2,384	20
NX-2003D	79	51	108	75	2,309	20
NX-5454	60	47	88	72	2,019	12
NX-5198	38	13	27	23	581	11
LITE 2002	77	56	115	78	2,314	15
NX-2007	70	57	105	88	3,170	14
NX-2009	57	51	101	80	2,500	20
NX-4943	94	61	111	87	2,785	17
NX-6032	52	49	92	75	2,515	20
NX-5607	93	51	123	97	2,811	18
NX-5608	99	62	114	92	2,647	16
NX-5594	95	73	127	105	3,098	14
LITE 3025	87	57	105	86	2,397	23
LITE 3040	75	52	97	77	2,173	23
LITE 3060	76	66	110	89	2,696	18
GX-3090	98	57	122	105	2,931	15
LITE 2401*	126	70	105	91	2,902	19
LITE 2402*	130	68	112	92	2,670	20
LITE 2403*	145**	63	97	81	2,568	23

<sup>7</sup>DSC <sup>8</sup>Sand blasted substrate Test specimen cured at 40°C for 16 hours with liquid epoxy (EEW 190) \*cured at RT/8hr + 120°C/2hr \*\*cured at 80°C/10hr + 140°C/6hr

## WATERBORNE TECHNOLOGY

The NX-8100 Series is the first CNSL-based waterborne curing agent product line available in the market. Phenalkamine grade NX-8101 is designed for cost effective water-based concrete grouts, mortars and adhesives that require fast hardness development, excellent bond strength to dry and wet concrete, and high compression strength. NX-8101 is supplied in water and does not contain or require any solvents in the formulation to deliver excellent performance. Moreover, its good compatibility with various epoxy resins, easy reducibility in water, and visible end of pot life makes NX-8101 friendly to use.

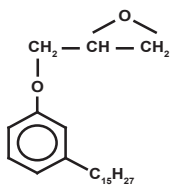
## Waterborne Curing Agent Property Chart

Product	Viscosity <sup>1</sup> @ 25°C (cPs)	Solids <sup>7</sup> (%)	Color <sup>2</sup> (Gardner)	Amine Value <sup>3</sup> (mgKOH/g)	AHEW <sup>4</sup>	Gel Time <sup>5</sup> (min)	Thin Film <sup>6</sup> Dry Hard Time (hours)	
							25°C	5°C
NX-8101	35,000	50	8	160	270	45	3	9

# Epoxy Resins, Diluents, and Modifiers

In addition to epoxy curing agents, Cardolite offers a line of cardanol derived epoxy resins, diluents, and modifiers that provide tools to formulators looking to add unique properties to their adhesives.

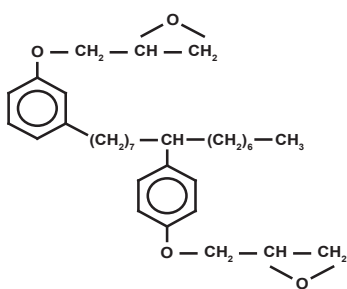
## CARDOLITE NC-513/ULTRA LITE 513



Cardolite NC-513 and Ultra LITE 513 are monofunctional reactive epoxy diluents that can be used to increase flexibility, impact resistance, water resistance, and

flexural strength. These reactive diluents have very low viscosities and low volatilities, which make them ideal for helping formulate solvent-free adhesives. As for other cardanol based products, these diluents are hydrophobic and exhibit very good water resistance. Good reactivity means these diluents react completely into the epoxy network which can increase the bond strength. Ultra LITE 513 is a lower viscosity, higher purity, and lighter colored version of NC-513; they are both identical in chemical make-up.

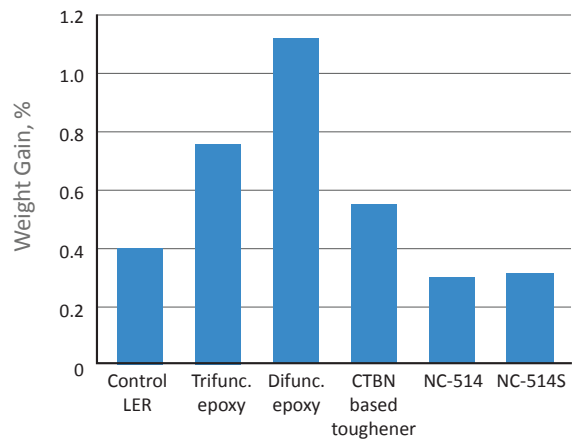
## CARDOLITE NC-514/NC-514S



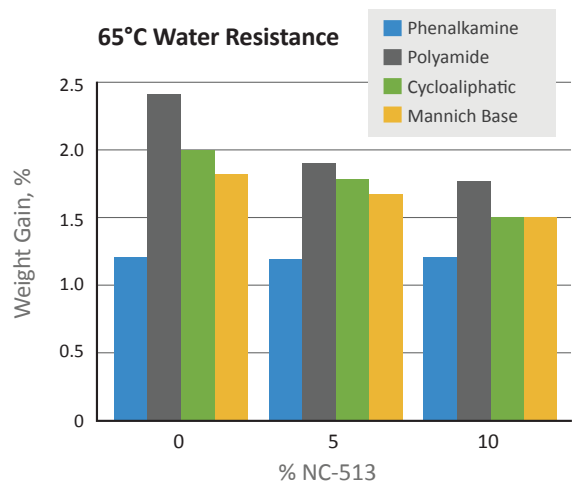
Cardolite NC-514 and NC-514S are flexible difunctional glycidyl ether epoxy resins. NC-514S is lower in viscosity. The chain of 8 carbons separating the aromatic groups allows this

resin to be used in conjunction with traditional epoxy resins or as a sole resin to increase adhesive flexibility, water resistance, and bond strength while minimizing reduction in mechanical strengths.

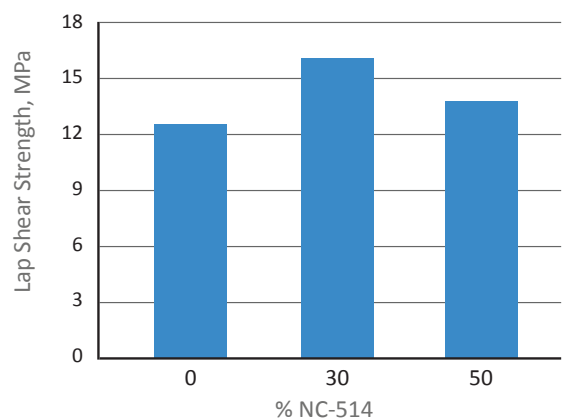
**25°C Water Resistance for 7 Days**  
30% epoxy modifier with Liquid Epoxy (EEW 190), cured with TETA at 40°C for 16hr



**65°C Water Resistance**

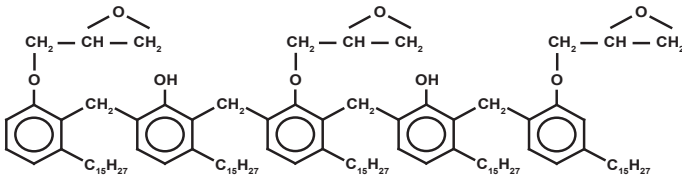


**NC-514 Effect on Bond Strength**  
Added to Liquid Epoxy (EEW 190) and cured with NX-2003 on non-abraded carbon steel



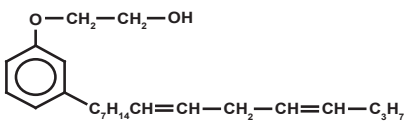


## CARDOLITE NC-547



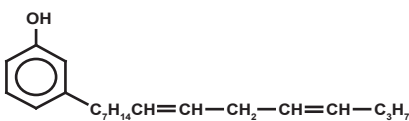
Cardolite NC-547 is a polyglycidyl ether epoxy novolac resin derived from cardanol. This resin can be used in conjunction with standard epoxy resins to bring additional flexibility and longer pot life to adhesives without adversely affecting chemical and water resistance.

## CARDOLITE LITE 2020\*



Cardolite LITE 2020 is a low viscosity multipurpose resin modifier. This resin is 100% non-volatile and is therefore useful for formulating environmentally friendly solvent free adhesives. Due to its unique chemical structure, LITE 2020 is more efficient than traditional hydrocarbon resins in reducing viscosity despite being higher in viscosity. Its hydrophobic nature allows for good corrosion resistance and early water resistance.

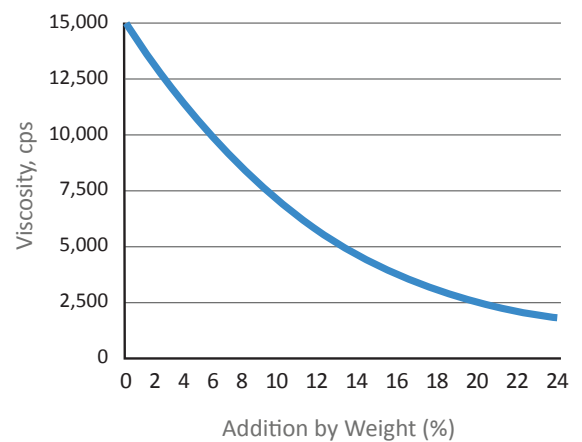
## CARDOLITE NX-202X SERIES



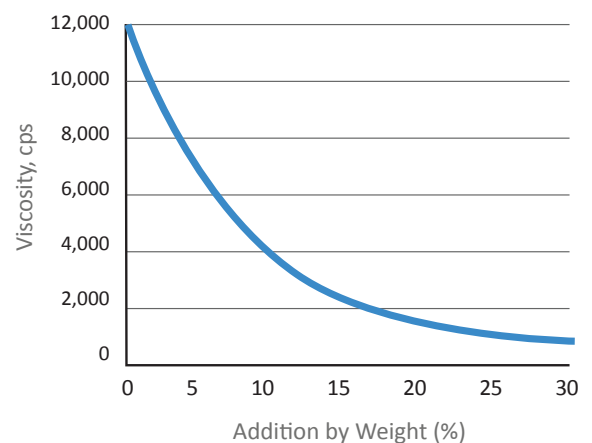
Cardolite NX-202x products are low viscosity multipurpose resin modifiers. The long hydrophobic aliphatic side chain of the cardanol molecule gives these products a very low viscosity and provides excellent early water resistance and corrosion protection. By using NX-202x products as epoxy diluents and accelerators, high solids or solvent-free formulations can be achieved with enhanced workability and faster cure without sacrificing other performance properties. Ultra LITE 2023, NX-2023(D), and NX-2026 are light color stable. NX-2024 and NX-2025 are less color stable and more cost effective. These products are a good alternative to synthetic phenolic diluents and modifiers that have unfavorable labeling.



**NC-513 and Ultra LITE 513 Dilution Curve (25°C with Liquid Epoxy Resin, EEW=191)**



**NX-202x and LITE 2020 Dilution Curve (25°C with Liquid Epoxy Resin, EEW=191)**



## CARDOLITE LITE 2100\*/LITE 2100R

Cardolite LITE 2100 and LITE 2100R are low color and low viscosity cashew nutshell liquid modified hydrocarbon resins. They are recommended as an epoxy modifier for use in adhesives, coatings, and tar replacement. These products are designed to enable high solids and solvent free formulations by lowering the viscosity of epoxy resins more efficiently than typical phenol based hydrocarbon resins and by improving overall system compatibility for better film formation and protective performance. In addition, LITE 2100 and LITE 2100R show less effect on dry time than competitive chemistries and they can increase hardness development of the final product while providing improved flexibility and impact resistance. The high hydrophobicity of this product results in excellent water and moisture resistance, and more importantly, excellent corrosion protection on immersed and vapor exposed surfaces. Moreover, both products show very good UV resistance with excellent gloss retention for use in lighter color products.

### Epoxy Resin, Diluent, and Modifier Property Selection Chart

Product	Type	Color <sup>1</sup> (Gardner)	Viscosity <sup>2</sup> (cPs)	EEW <sup>3</sup>	Hydrolyzable Chlorine <sup>4</sup> (%)
NC-513	Reactive diluent	9	40 - 70	425 - 575	≤ 2
Ultra LITE 513	Reactive diluent	1	20 - 35	350 - 425	≤ 0.5
NC-514	Epoxy resin	17	25,000	350 - 500	≤ 2
NC-514S	Epoxy resin	12	2,000	320 - 420	≤ 0.5
NC-547	Epoxy novolac resin	18	28,000	550 - 850	≤ 2.5
LITE 2020	Nonreactive resin modifier	≤ 14	30 - 115	-	-
LITE 2100	Hydrocarbon resin modifier	≤ 4	450 - 750	-	-
LITE 2100R	Hydrocarbon resin modifier	≤ 4	500 - 1,000	-	-
NX-2023D	Nonreactive resin modifier	≤ 15	80 - 140	-	-
NX-2023	Nonreactive resin modifier	≤ 6	40 - 100	-	-
Ultra LITE 2023	Nonreactive resin modifier	1	40 - 100	-	-
NX-2024	Nonreactive resin modifier	4 - 9	45 - 60	-	-
NX-2025	Nonreactive resin modifier	≤ 5	≤ 60	-	-
NX-2026	Nonreactive resin modifier	≤ 2	≤ 60	-	-

<sup>1</sup> ASTM D1544    <sup>2</sup> ASTM D2196 at 25°C    <sup>3</sup> ASTM D1652    <sup>4</sup> ASTM D1726 Hydrolyzable chlorine

\* LITE 2020 and LITE 2100 are not approved for sale in Europe

# CNSL Polyols, Diols, and Blocking Agents

## POLYOL AND DIOLS

Cardolite CNSL-based polyols have unique qualities compared to widely known polyester and polyether polyols, and other natural oil based polyols. CNSL polyols are very hydrophobic because of the long aliphatic chain of cardanol, the absence of ester bonds (hydrolyzable), and fewer ether oxygen atoms compared to typical polyether polyols (less hydrophilic). This hydrophobicity provides excellent water resistance and less moisture sensitivity during cure with isocyanate for increased durability of the final polyurethane system.

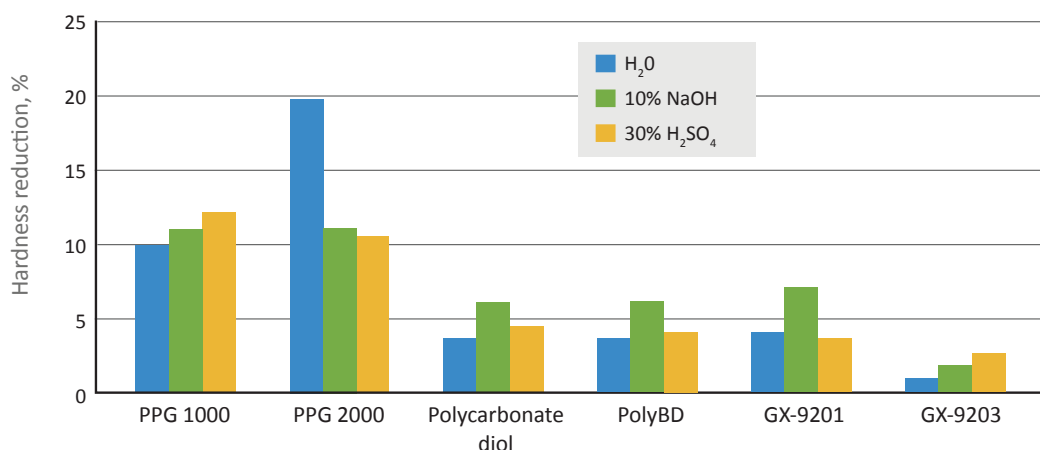
Different from other renewable polyols obtained from soy and castor oil, CNSL polyols have an aromatic structure that translates into excellent thermal resistance and chemical resistance to acid and alkaline solutions. Moreover, the combination of aromaticity and long aliphatic chain delivers hydrolytic stability and mechanical strength to CNSL-based polyols.

CNSL diols exhibit excellent compatibility with polyether diols, polyBD, tackifier, and EVA giving formulators greater latitude to achieve desired properties and meet cost targets. In addition, CNSL diols provide faster cure compared to other diols reducing the need of catalysts. These diols are suitable for use as a binder or building block for pre-polymers in one-component adhesives.

## CNSL Diols Compatibility Chart

Diol	GX-9201	GX-9203	PolyBD
PPG 1000	100% compatible	100% compatible	Max solubility 55-60%
PPG 2000	100% compatible	100% compatible	Max solubility 55-60%
PolyBD	Max solubility 30%	100% compatible	na
Ethylene vinyl acetate (EVA)	Hazy, 100% compatible	Hazy, 100% compatible	Hazy, 100% compatible
Tackifier (aliphatic hydrocarbon)	Max solubility 40%	100% compatible	100% compatible
Tackifier (polybutane)	Incompatible	Incompatible	Incompatible

Hydrolytic Stability after 21 Days in 25°C Immersion, Cured prepolymer (7% NCO)



## CNSL Polyols Property Selection Chart

Product	Type	Color <sup>1</sup> (Gardner)	Viscosity <sup>2</sup> (cPs)	Hydroxyl Value <sup>3</sup> (mg KOH/g)	Hydroxyl Eq. Weight <sup>3</sup> (g/mole)
NX-9001	CNSL Polyol	18	2,000	175	320
NX-9001LV	Low Viscosity CNSL Polyol	18	1,000	175	320
NX-9004	CNSL Polyol	18	5,000	212	265
LITE 9001	Low color CNSL Polyol	6	2,000	175	320
GX-9005	Non-CNSL Branched Polyol	5	3,000	170	330
GX-9007	CNSL Branched Polyol	14	2,900	175	320
GX-9201	CNSL Polyester Diol	14	1,400	75	748
GX-9203	CNSL Polyester Diol	14	3,000	85	660

<sup>1</sup> ASTM D1544   <sup>2</sup> ASTM D2196 at 25°C   <sup>3</sup> GPC

## NCO BLOCKING AGENT

High purity and light color cardanol, NX-2026, is an effective isocyanate blocking agent that can be used to replace petro-based phenols. NX-2026 blocked NCO systems should be lower in viscosity and require lower deblocking temperatures than phenol. Moreover, cardanol can act as a flexibilizer in the final matrix.



Blocking Agent	NCO Type	Deblock Temperature (°C)
NX-2026*	PPG prepolymer (10.4% NCO)	128
Phenol	PPG prepolymer (10.4% NCO)	140

\*Properties on page 10

# Adhesive Applications

Technology	Application Industry	End Use	Key Products
Epoxy	Construction	Grouts, tile adhesives, anchoring adhesives, dry hanging, potting, concrete bonding, construction joints	NX-5607, NX-5608, LITE 2002, NX-2003, NC-558, NX-2021, NX-2026, NX-8101
	Transportation	Car body adhesives, auto body patch, automobile assembly (1k and 2k adhesives), interior sealants (acoustics), composite bonding, plastic bonding, boat building adhesives, underwater repair for marine	NX-5607, NX-5608, LITE 3040, LITE 2010LV, NC-558, NC-513, UL-513, NC-514, NC-547, NX-5454, NX-2003, NX-2021
	Infrastructure	Road repairs, pipe bonding, potable water filters, rail track grout, underwater repair	NX-6032, LITE 3060, NC-558, NX-5454
	Industrial	Potable water, engineering adhesive, solar cell adhesive, aluminum bonding, putty adhesive, honeycomb panel bonding	NC-558, NC-557, LITE 2002, NX-5608, NX-5607, LITE 3040, NX-6032, GX-6004
	Electronics	Chip adhesives, electronic encapsulation	Ultra LITE, NC-513
Polyurethane	Building and Construction	Glass sealant, potting, sealant, water proofing	NX-9001, LITE 9001, GX-9201, GX-9203, GX-9005, GX-9007
	Automotive	Structural adhesives	NX-2021
	Packaging	Cork adhesive, prepolymers, NCO blocking agents	GX-9201, GX-9203, NX-2026
	Industrial	Honeycomb panel bonding, wind blades	GX-9005, NX-9004

Notes



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