ADHESIVES PORTFOLIO

Renewable Technology

The World Leader in Cashew Nutshell Liquid Technology

Cardolite
Chemistry for Tomorrow

CONTENT

ABOUT US

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 materials for coatings, adhesives, composites, foams and automotive and industrial applications.

LOCATIONS

Cardolite uses CNSL derivatives as key building blocks for most of its products to achieve unprecedented performance that solves today's problems in a sustainable manner.

Over 35 years supplying high quality specialty chemicals derived from Cashew Nutshell Liquid (CNSL), a renewable, non-food chain material.

The most advanced CNSL manufacturing facilities in the world located in Zhuhai (Guangdong), China and Mangalore, India

Dedicated sales force with local representation in over 30 countries. Warehouses set up in the USA, Latin America, Europe, China and India.

To further innovate with CNSL technology, Cardolite also operates three advanced research and technical service facilities in the USA, China and India.

PRODUCT OFFERING

To support our customers in solving industry challenges, Cardolite continues to invest heavily on innovation that leverages the unique properties of CNSL technology. Cardolite operates three advanced research and technical service laboratories in the USA, China and India that use CNSL as a primary building block to develop and evaluate performance of specialty materials with demonstrated advantages over some traditional chemistries.

ADHESIVE & SEALANTS APPLICATIONS

- Building & Construction
- Automotive & Transportation
- Industrial & Flooring
- Electronics & Potting
- Electric Vehicle Battery Systems
- Packaging

FOR EPOXY

Epoxy Curing Agents:
- Phenalkamines
- Phenalkamides
- Polyamides
- Modified Cycloaliphatic Amines

CNSL Epoxy Resins and Modifiers
CNSL Reactive and Non-reactive Diluents

FOR POLYURETHANE

Polyols:
- Mono-, di-, and multi-functional
- Polyester
- Polyether
- Mannich
- Novolac/Aromatic

CNSL NCO Blocking Agents
Reactive Diluents

CNSL SPECIALTIES

Ethoxylated Surfactants
Polymer Building Blocks
Hydrogenated Monomers
Hydrocarbon Resins
Friction Particles and Resins
Acrylates
FormuLITE™

CNSL TECHNOLOGY

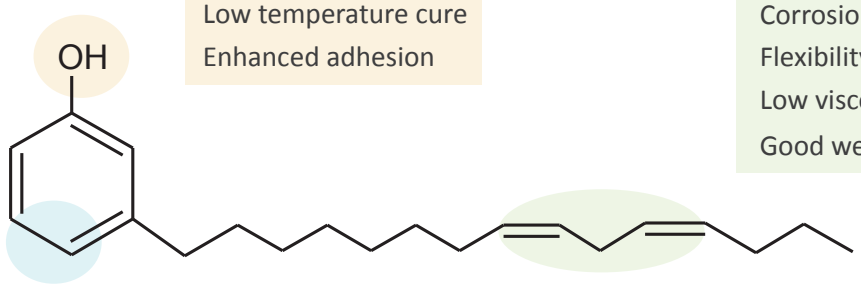
From the beginning, Cardolite products have been based on cashew nutshell liquid (CNSL), a natural, non-food chain, and annually renewable biomaterial. The technology has been widely adopted because there are inherent performance benefits gained from using this starting raw material without sacrificing other performance or cost.

Cardanol is a unique natural phenolic material obtained by distilling CNSL and serves as the primary building block for Cardolite's curing agents, diluents and resins. The molecule is composed of an aromatic ring with an OH group and a long aliphatic side chain, which bring valuable intrinsic benefits to adhesives.

CARDANOL AVERAGE STRUCTURE

Fast cure
Low temperature cure
Enhanced adhesion

Water resistance
Corrosion protection
Flexibility
Low viscosity
Good wetting properties



Chemical resistance
Thermal and fire resistance

USDA CERTIFIED BIOBASED PRODUCT
PRODUCT 98%

- Annually renewable with high bio-content
- Does not interfere with the food chain
- High performance
- Low viscosity for zero/low V.O.C.
- Better labeling compared to phenol-based materials
- Cost effective

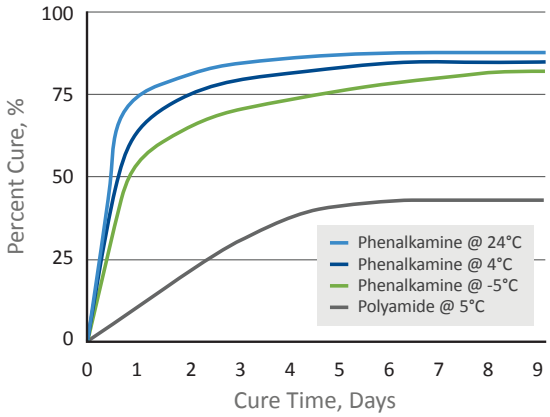
PHENALKAMINE & PHENALKAMIDE

CNSL-BASED EPOXY CURING AGENTS

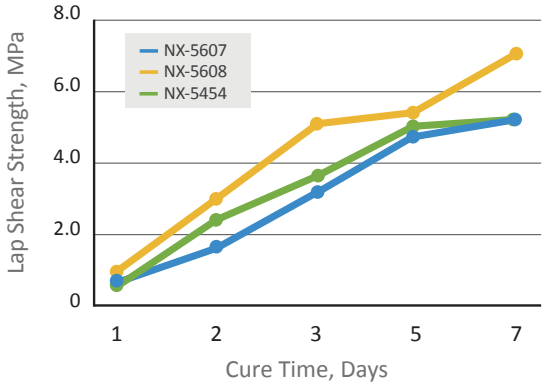
Cardolite phenalkamines and phenalkamides offer unique benefits over traditional petroleum-based and vegetable oil-based curing agents due to their CNSL backbone. These curing agents are high in bio-content and free of solvent to enable zero/low V.O.C. sustainable adhesives and sealants.

The catalytic effect of the phenolic hydroxyl coupled with the mobility offered by the long aliphatic side chain provide fast cure and bond strength development with epoxy resins even at low temperatures. The ability to crosslink at low temperature widens the adhesive application window year-round. The ability to cure fast lowers overall costs of a project by enabling quicker return-to-service in two-component field-applied adhesives or lower oven cure temperatures and higher production line speeds in forced-cure industrial applications. Moreover, CNSL-based curing agents are formulation-friendly due to their low viscosity, non-critical mix ratios, and good compatibility with epoxy resins (no induction time required for phenalkamines) and other adhesive raw materials.

Phenalkamine Low Temperature Cure



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



PHENALKAMINES

- Fast bond strength development at low temperatures
- High bond strength to wet, oil contaminated, and underwater substrates
- Excellent water and chemical resistance even at higher temperatures
- Very good thermal aging resistance
- High mechanical properties

PHENALKAMIDES

- High bond strength
- Increased flexibility and elongation
- Longer pot life with fast cure
- Excellent water resistance
- Better color stability and UV resistance

BONDING IN EXTREME CONDITIONS

The good adhesion properties derived from the phenolic hydroxyl and the good wetting properties inherited from the $C_{15}H_{27}$ side chain present in CNSL curing agents deliver good adhesion to oil-contaminated surfaces, wet metal or concrete, lightly rusted steel and lower surface tension or non-abraded materials (i.e. plastics).

In addition, the hydrophobic side chain increases water and moisture resistance in epoxy systems allowing for some CNSL curing agents-based formulations to cure and develop good bond strength even under water. Moreover, the combination of rigidity from the aromatic ring and flexibility and lower surface tension imparted by the CNSL aliphatic chain ensure good mechanical properties and high bond strength even to non-blasted surfaces.

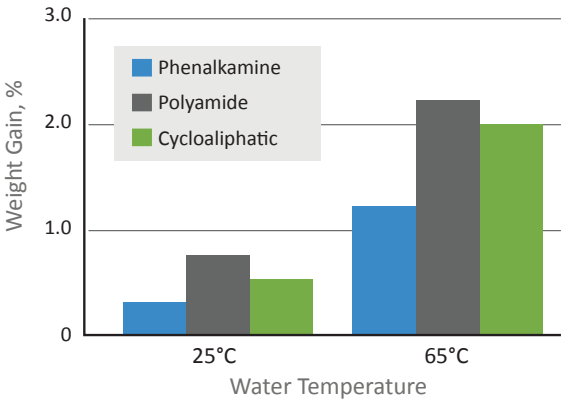
The non-critical mix ratios and fast cure under unfavorable conditions of CNSL-based curing agents combined with their ability to adhere to poorly prepared substrates helps to lower the risk of adhesive failure due to improper application.

Phenalkamine-based Epoxy Adhesion to Concrete

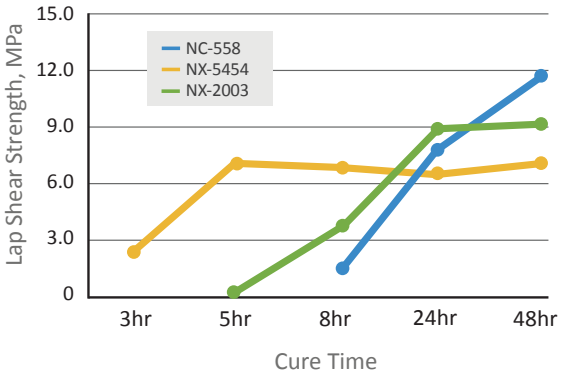
Epoxy Phenalkamine	Pull off Adhesion (psi/MPa)	Rupture Mode
24 hours dry concrete	1,000/6.90	50% dolly to adhesive 50% concrete
3 weeks dry concrete	1,000/6.90	Dolly to adhesive
3 weeks damp concrete	500/3.45	100% concrete

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

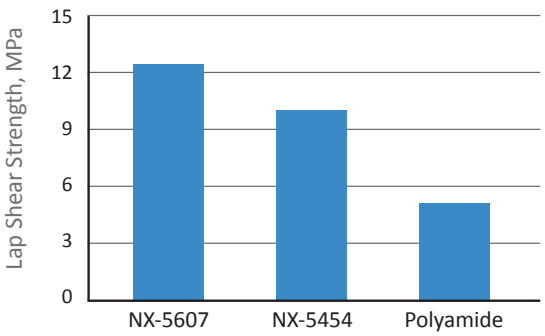
Comparative Water Resistance



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



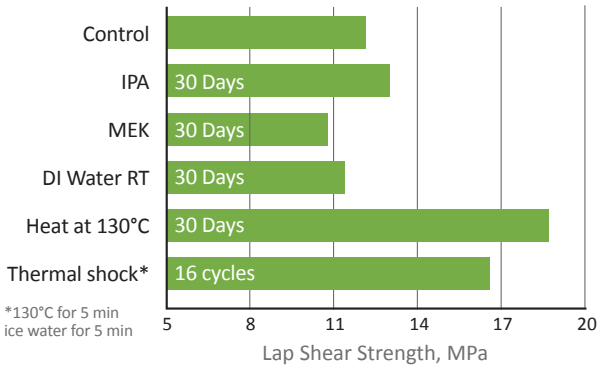
Bond Strength with Liquid Epoxy (EEW 190) on Wet Sand Blasted Steel Cured at 40°C for 16hr



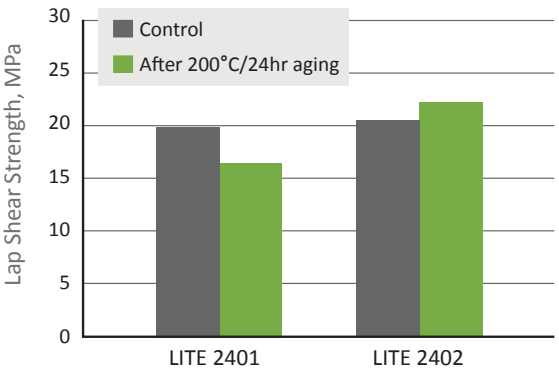
BONDING IN EXTREME CONDITIONS

The aromatic ring present in CNSL curing agents backbones enhances thermal, chemical and fire protection, which allows for adhesives to operate at high temperatures, up to 200°C. In addition, it provides good aging resistance under different strenuous conditions like immersion in water and chemicals. Additionally, the long hydrocarbon chain imparts flexibility, impact resistance and higher elongation to brittle epoxy adhesives and sealants.

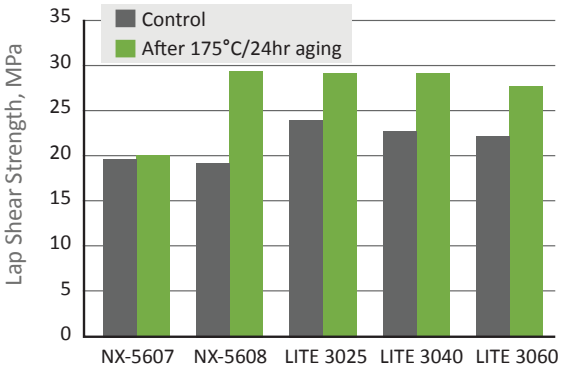
Different Aging Conditions (NC-558)



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



WATERBORNE TECHNOLOGY

The NX-8000 Series is the first CNSL-based waterborne curing agent product line available in the market. Phenalkamine NX-8101 is designed for water-based concrete grouts, mortars and adhesives that require fast hardness development, excellent bond strength to dry and wet concrete, high compression strength, and good compatibility with various solid and liquid epoxy resins. NX-8401 is an emulsion type CNSL curing agent that is easily reducible in water and provides very long pot life. NX-8101 and NX-8401 are supplied in water and do not contain or require any solvents in the formulation to deliver excellent performance. Other non-CNSL waterborne curing agents, such as NX-8501, are also available for applications that require lower color and better UV resistance.

Performance of Tile Grout based on NX-8101

Property	NX-8101 grout
Compression strength (MPa)	53.7
Shore D hardness at 25°C	
Day 1	77
Day 7	80
Shore D hardness at 10°C	
Day 1	44
Day 4	71
Working time at 25°C (min)	> 40

PHENALKAMINE SELECTION CHART

Product	Viscosity[1] at 25°C (cPs)	Type	Color[2] (Gardner)	Amine Value[3] (mgKOH/g)	AHEW[4]	Gel Time[5] (min)	Thin Film[6] Dry Hard Time (hrs)		
							25°C	5°C	0°C
NC-541	28,000	solvent-free	16	330	130	81	5	15.5	23
NC-641	25,000	solvent-free	16	304	130	61	4	13.5	21
LITE 2001	28,000	solvent-free	10	330	132	75	3	12.5	19
NC-541LV	2,300	solvent-free	15	340	125	61	6	24	29
NC-641LV	2,500	solvent-free	16	370	125	33	3.5	18	21
LITE 2001LV	2,500	solvent-free	10	340	125	75	7	17	29
LITE 2010LV	4,100	solvent-free	10	247	125	30	3	13.5	19
NC-540	2,000	solvent-free	15	535	81	42	3.5	13	19
NX-4943	1,800	solvent-free	14	488	82	41	4	14	23
NX-5567	770	solvent-free	15	561	66	22	3	10	15
NC-558	900	solvent-free	14	340	95	70	10	27	32
NC-658	1,000	solvent-free	14	300	95	90	6.5	22	28
NC-557	1,100	solvent-free	14	355	95	22	7	16.5	27.5
GX-6004	900	solvent-free	10	335	76	25	2.3	8.4	10.6
NX-2003	620	solvent-free	10	360	95	25	4.5	18.5	22
NX-2003D	700	solvent-free	13	357	95	25	4.5	15	24
NX-5454	1,080	solvent-free	11	275	133	18	2	7.5	10
NX-6019	1,100	solvent-free	11	275	133	22	2.5	10	11.5
NX-5653	1,100	solvent-free	11	366	132	33	2.1	6.6	10.3
NX-6654	1,500	solvent-free	11	325	132	37	2.3	8.8	12.6
LITE 2002	450	solvent-free	10	360	104	51	6	20	30.5
LITE 2002LP	700	solvent-free	10	360	104	85	7	21	39
NX-5352	2,500	solvent-free	14	390	104	35	2.5	10.5	17
NX-5607	2,490	solvent-free	10	405	95	14	2	9	14
NX-5608	3,350	solvent-free	10	405	95	13	2.5	12	15
NX-5594	950	solvent-free	14	395	76	16	2.5	8	11
LITE 2401	90	solvent-free	5	496	61	>90	6.5	24	n/a
LITE 2402	105	solvent-free	11	555	56	>85	5.2	17.1	n/a

[1]ASTM D2196 [2]ASTM D1544 [3]ASTM D2074 [4]Theoretical based on total product weight [5]50g at 25°C
[6]ASTM D5895 @ 200 micron with LER (EEW 190)

PHENALKAMINE SELECTION CHART

Product	Viscosity[1] at 25°C (cPs)	Type	Color[2] (Gardner)	Amine Value[3] (mgKOH/g)	AHEW[4]	Gel Time[5] (min)	Thin Film[6] Dry Hard Time (hrs)		
							25°C	5°C	0°C
NX-2007	265	benzyl alcohol	4	310	113	50	2	16	23.5
NX-2009	370	benzyl alcohol	7	310	95	31	4	12	20.5
Ultra LITE 2009	330	benzyl alcohol	1	277	95	34	6	22	32
Ultra LITE 2009SF	5,900	solvent-free	1	404	62	43	7	22	n/a
Ultra LITE 2009H	150	benzyl alcohol	1	355	95	29	5	19	30
Ultra LITE 2009HSF	500	solvent-free	2	550	57	39	6	17.2	n/a
Ultra LITE 2012	150	benzyl alcohol	1	330	95	100	6.5	n/a	n/a
NX-6032	1,200	benzyl alcohol	10	325	133	20	2	11	16
NX-8101	35,000	waterborne	8	160	270	45	3	9	n/a
NX-8401	8,000	waterborne	emulsion	135	290	n/a	2.8[7]	n/a	n/a

PHENALKAMIDE SELECTION CHART

Product	Viscosity[1] at 25°C (cPs)	Type	Color[2] (Gardner)	Amine Value[3] (mgKOH/g)	AHEW[4]	Gel Time[5] (min)	Thin Film[6] Dry Hard Time (hrs)	
							25°C	5°C
NX-5052	> 150,000	solvent-free	11	220	179	69	4.5	18
LITE 3025	34,000	solvent-free	8	345	103	200	8.5	n/a
LITE 3040	5,000	solvent-free	8	380	118	110	7.3	29
LITE 3060	850	solvent-free	8	455	104	48	5	17.5
GX-3090	520	solvent-free	7	598	69	47	4.3	19.2

POLYAMIDE SELECTION CHART

Product	Viscosity[1] at 25°C (cPs)	Type	Color[2] (Gardner)	Amine Value[3] (mgKOH/g)	AHEW[4]	Thin Film[6] Dry Hard Time (hrs)
						25°C
NT-1541	5,000 @ 75°C	solvent-free	9	215	198	n/a
NT-1515	4,000 @ 75°C	solvent-free	8	235	198	n/a
NT-1542	40,000	solvent-free	7	350	103	8
NT-1544	10,000	solvent-free	8	380	97	9
NT-1545	3,000	solvent-free	8	380	103	11

[1]ASTM D2196 [2]ASTM D1544 [3]ASTM D2074 [4]Theoretical based on total product weight [5]50g at 25°C
[6]ASTM D5895 @ 200 micron with LER (EEW 190) [7]Measured with epoxy dispersion

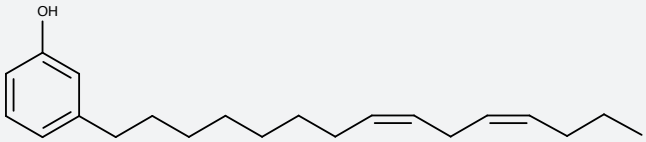
CURING AGENT MECHANICAL PROPERTIES

Curing Agent	Tg[7] (°C)	Tensile Strength (MPa)	Flexural Strength (MPa)	Compressive Strength (MPa)	Elastic Modulus (MPa)	Lap Shear[8] (MPa)
GX-3090	98	57	122	105	2,931	15
GX-6004	80	62	114	102	2,765	17
LITE 2001	87	48	78	61	1537.3	18
LITE 2002	77	56	115	78	2,314	15
LITE 2401*	126	71	112	91	2,450	19
LITE 2402*	138	68	106	92	2,670	20
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
NC-540	105	54	98	81	2,457	16
NC-558	61	41	105	56	1,985	21
NT-1542	88	54	99	83	2307	23
NT-1544	102	57	105	86	2409	24
NX-2003	74	55	94	76	2,384	20
NX-2003D	79	51	108	75	2,309	20
NX-2007	70	57	105	88	3,200	14
NX-2009	57	51	101	80	2,500	20
NX-4943	94	61	111	87	2,785	17
NX-5352	75	58	101	83	2413	18
NX-5454	60	47	88	72	2,019	12
NX-5567	113	65	117	97	2,681	17
NX-5594	95	73	127	105	2,560	14
NX-5607	93	51	123	97	2,811	18
NX-5608	99	62	114	92	2,647	16
NX-6032	52	49	92	75	2,515	20
Ultra LITE 2009HSF	127	61	93	109	3,349	14
Ultra LITE 2009SF	73	65	119	112	3,159	15

[7]DSC [8]Sand blasted substrate Test specimen cured at 40°C for 16 hours with liquid epoxy (EEW 190) *cured at RT/8hr + 120°C/2hr

CNSL DILUENTS AND MODIFIERS

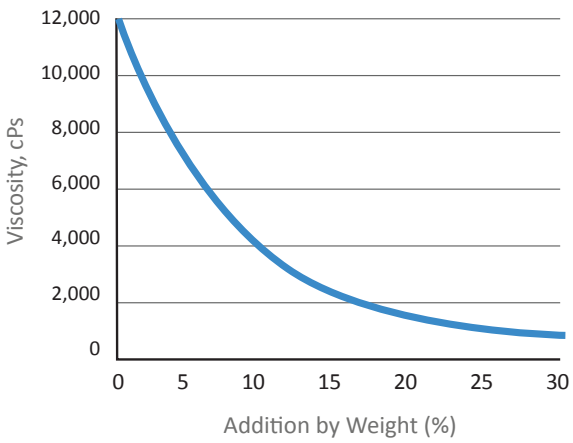
FOR EPOXY AND POLYURETHANES



NX-202x Product Family

Cardolite NX-202x products are low viscosity multipurpose resin modifiers. The long hydrophobic aliphatic side chain of the cardanol gives these products a very low viscosity and provides excellent early water and moisture resistance. Used as epoxy and polyurethane diluents and epoxy-amine accelerators, these materials enable lower V.O.C. and better workability, without sacrificing other performance properties. NX-2021 is the standard modifier grade while NX-2022 is higher in purity. NX-2024 and NX-2025 are the lower odor and lighter initial color versions of NX-2021 and NX-2022 respectively. Ultra LITE 2023, NX-2023(D), and NX-2026 are the wet color stable versions of the NX-202x product family. These products are a good alternative to synthetic phenolic diluents and modifiers that have unfavorable labeling.

NX-202x and LITE/UL 2020 Dilution Curve (25°C with Liquid Epoxy Resin, EEW=190)



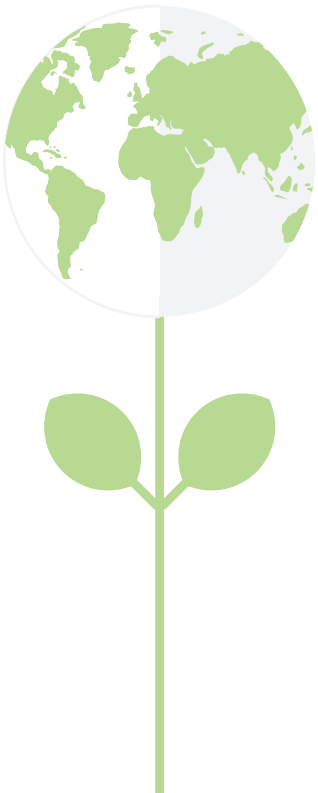
LITE 2100* & LITE 2100R - HYDROCARBON RESINS

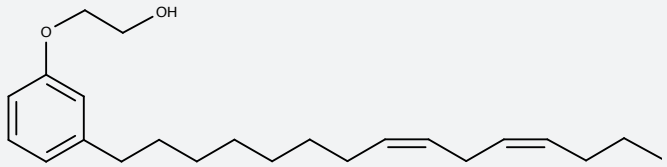
Cardolite LITE 2100(R) are low color and low viscosity CNSL modified hydrocarbon resins. They are designed to enable high solids and solvent-free formulations by lowering the viscosity of epoxy resins more efficiently than typical phenol-based hydrocarbon resins and by improving overall system compatibility for better film formation. These products show good hardness development while providing improved flexibility and impact resistance. Their high hydrophobicity results in excellent water resistance, and more importantly, excellent corrosion protection on immersed and vapor exposed surfaces. Both products show very good UV resistance with excellent gloss retention for use in lighter color coatings and adhesives.

DILUENTS AND MODIFIERS TYPICAL PROPERTIES

Product	Type	Color[1] (Gardner)	Viscosity[2] at 25°C (cPs)
LITE 2020*	Resin diluent and modifier	≤ 14	30-115
Ultra LITE 2020*	Resin diluent and modifier	≤ 2	60
LITE 2100*	Hydrocarbon resin modifier	≤ 4	450-750
LITE 2100R**	Hydrocarbon resin modifier	≤ 4	500-1,500
NX-2021	Resin diluent and modifier	≤ 18	45-75
NX-2022	Resin diluent and modifier	5 - 8	40-60
Ultra LITE 2023	Resin diluent and modifier	≤ 1	40-100
NX-2023	Resin diluent and modifier	≤ 6	40-100
NX-2023D	Resin diluent and modifier	≤ 15	80-140
NX-2024	Resin diluent and modifier	4 - 9	45-60
NX-2025	Resin diluent and modifier	≤ 5	≤ 60
NX-2026	Resin diluent and modifier	≤ 2	≤ 60

[1]ASTM D1544, [2]ASTM D2196
*LITE/Ultra LITE 2020 and LITE 2100 are not approved for sale in Europe. **LITE 2100R is the REACH version of LITE 2100



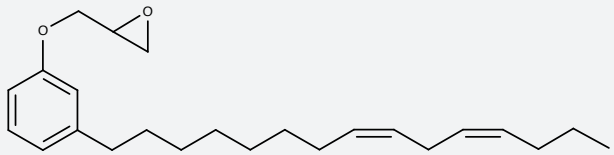


LITE 2020/Ultra LITE 2020*

Cardolite LITE 2020 and Ultra LITE 2020 are low viscosity multi-purpose resin modifiers. These resins are ideal for formulating environmentally friendly high solids or solvent free adhesives. Due to their unique chemical structure, they are more efficient than traditional hydrocarbon resins in reducing viscosity despite being higher in viscosity. Their hydrophobic nature allows for good corrosion resistance and early water resistance. Ultra LITE 2020 is a lower color version of LITE 2020.

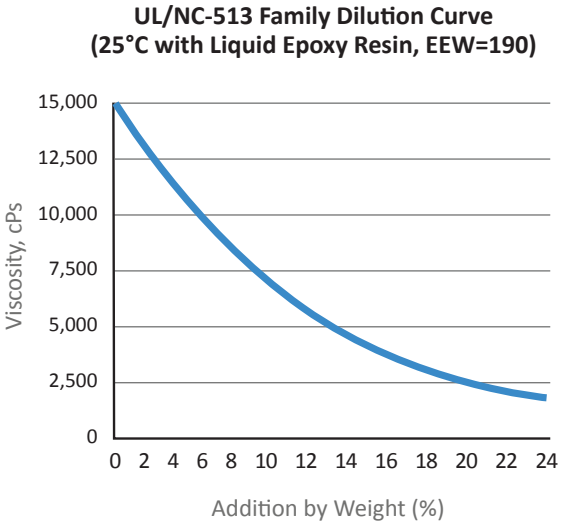
CNSL EPOXY

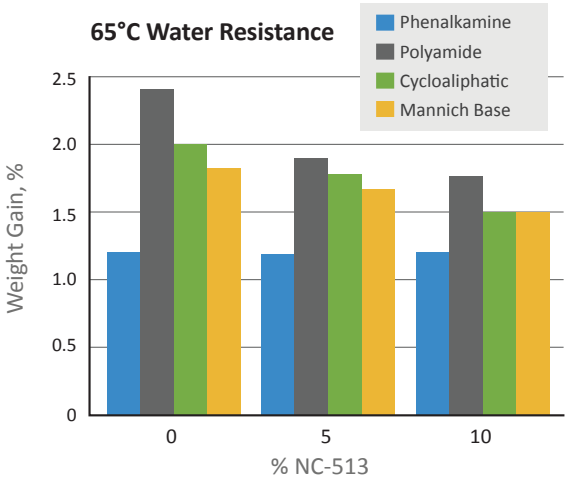
DILUENTS AND MODIFIERS

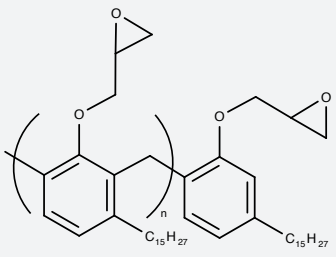


NC-513/Ultra LITE 513/LITE 513E

Cardolite NC-513, Ultra LITE 513, and LITE 513E 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. LITE 513E is a very low total chlorine version of NC-513 suitable for electronic applications.

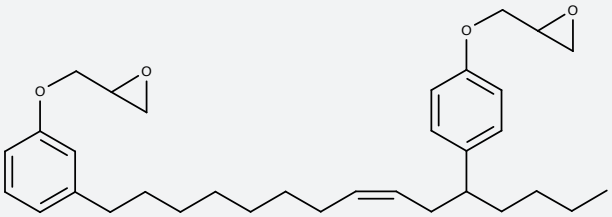






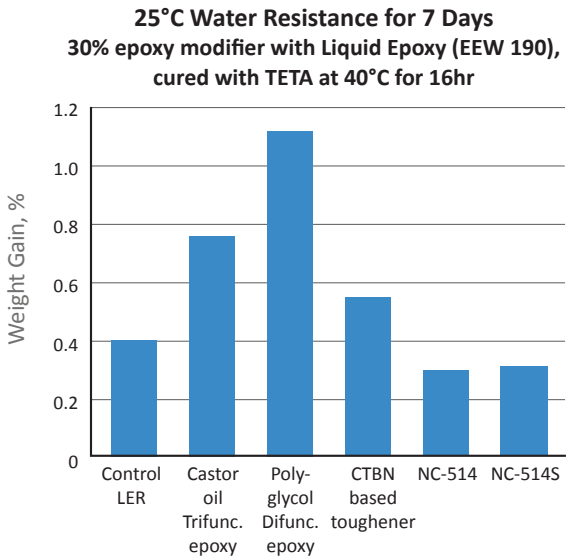
NC-547

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.



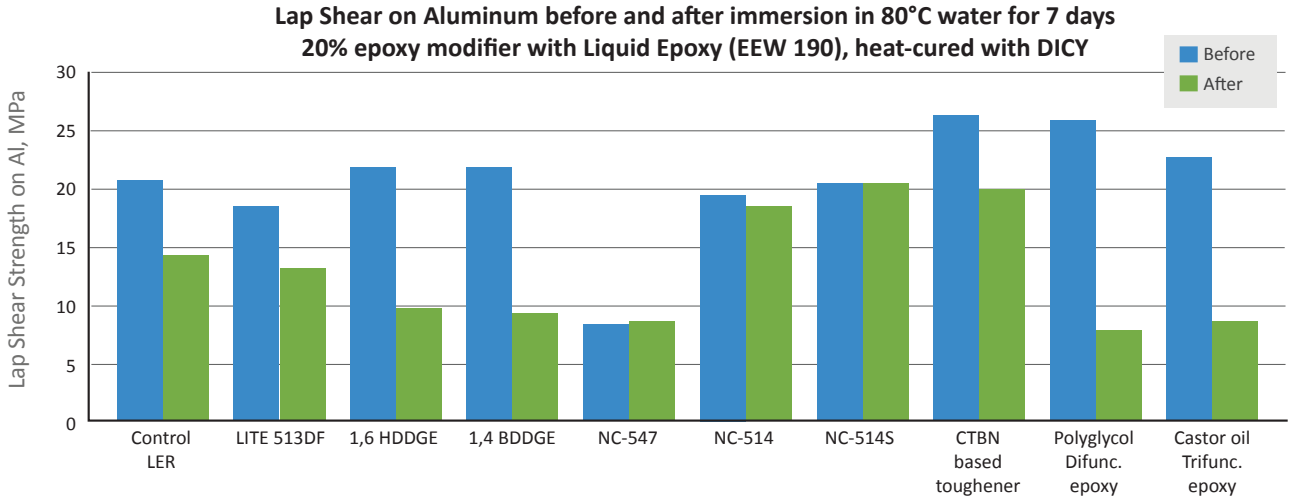
NC-514/NC-514S

Cardolite NC-514 and NC-514S are flexible difunctional glycidyl ether epoxy resins. NC-514S is lower in viscosity. The chain of 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.



LITE 513DF - CNSL REACTIVE DILUENT & MODIFIER

Cardolite LITE 513DF is a high bio-content diluent and modifier with lower epoxy equivalent weight than standard 513. This material is low in viscosity providing good dilution efficiency to epoxy resins, good water resistance and increased flexibility. In adhesive applications, LITE 513DF has demonstrated good tensile strength and Tg while still improving elongation and bond strength. Moreover, this CNSL epoxy exhibited good dielectric properties and insulating performance. LITE 513DF is an excellent alternative to petroleum-based difunctional diluents (e.g., 1,6 hexanediol diglycidyl ether and 1,4 butanediol diglycidyl ether).



CNSL EPOXY TYPICAL PROPERTIES

Product	Type	Color[1] (Gardner)	Viscosity[2] (cPs)	EEW[3]	HyCl[4] (%)
NC-513	Reactive diluent	9	40-70	425-575	≤ 2
LITE 513E	Reactive diluent	5	20-40	360-410	≤ 1000ppm
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	350-500	≤ 0.5
NC-547	Epoxy novolac resin	18	28,000	550-850	≤ 2.5
LITE 513DF	Reactive diluent	6	90-200	250-300	≤ 2

[1]ASTM D1544, [2]ASTM D2196 at 25°C, [3]ASTM D1652, [4]ASTM D1726 HyCl (total for LITE 513E)

Excellent water and moisture resistance

Low viscosity diluents for lower V.O.C.

Toughness, flexibility, increased bond strength

Better labeling compared to phenol-based materials

CNSL EPOXY MECHANICAL PROPERTIES

Formulations LER:Modifier 70:30, cured with TETA	Tensile Strength (MPa)	Elongation at Break (%)	Tg[1] (°C)	Lap Shear Strength[2] (MPa)
LER	65.0	3.0	120.0	11.7
LER:NC-514	67.3	4.0	85.9	16.1
LER:NC-514S	61.8	4.9	83.4	20.0
LER:LITE 513DF	58.7	6.2	88.0	18.3
LER:Castor oil Trifunc. epoxy	45.2	6.0	73.9	22.2
LER:Polyglycol Difunc. epoxy	41.8	6.1	63.5	n/a
LER:CTBN toughener	53.1	3.4	114.4	23.0
LER:1,6 HDDGE	61.7	4.1	79.2	17.5
LER:1,4 BDDGE	58.7	3.1	80.1	18.8

[1]DSC [2]Sand blasted substrate Test specimen cured at 25°C/16 hrs + 60°C/1 hr + 100°C/2 hrs

CNSL NOVOLACS

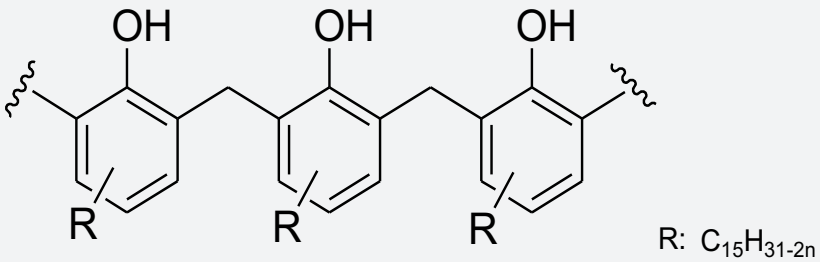
CNSL Novolacs have very high bio-content and degree of aromaticity as seen in their average structure. These materials carry similar benefits to other CNSL resins such as excellent water and moisture resistance, increased flexibility and impact protection, and high thermal, fire, and chemical resistance.

These bio-renewable novolac resins can function as an epoxy crosslinker in heat-cured one-component and two-component epoxy formulations as renewable alternatives for dicyandiamide and phenolic compounds. Hydroxyl groups can react with isocyanates forming polyurethane linkages as well. They are excellent sustainable alternatives to petroleum-based phenolic resins.

Product	Hydroxyl equivalent weight[1] (g/eq)	Hydroxyl value[2] (mg KOH/g)	Viscosity[3] (cPs)	Color[4] (Gardner)
NX-4001	280-350	160-200	70,000-140,000 at 40°C	≤ 18
NX-4005	290-325	173-193	800-1300 at 25°C	≤ 18

[1] Calculated [2] ASTM D4274 [3] ASTM D2196 [4] ASTM 1544

CNSL NOVOLAC AVERAGE STRUCTURE



POLYOLS 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 compared to typical commercially available polyols. This hydrophobicity provides excellent water resistance and less moisture sensitivity during cure with isocyanate for increased durability of the final polyurethane system. In addition, CNSL polyols show fast cure with isocyanates minimizing the amount of catalysts required and allowing for quick return-to-service.

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.

Cardolite diols offer a wide range of mechanical properties to meet different application requirements. Diol grades suitable as building blocks for prepolymers show excellent compatibility with polyether diols, polyBD, tackifier, and EVA giving formulators greater latitude to achieve desired properties and meet cost targets. For both uses as binders or as part of prepolymers, Cardolite diols provide excellent hydrolytic stability and reduced moisture sensitivity.

CNSL DIOL COMPATIBILITY CHART

Material Compatibility Percent*	NX-9201 (LP)	NX-9203 (LP)	NX-9208	NX-9212	PolyBD
PPG 1000	100%	100%	100%	100%	< 55-60%
PPG 2000	100%	100%	100%	100%	< 55-60%
PolyBD	< 30%	100%	0%	< 50%	na
Ethylene vinyl acetate (EVA)	Hazy, 100%	Hazy, 100%	< 50%	100%	Hazy, 100%
Tackifier (aliphatic hydrocarbon)	< 40%	100%	> 50%	> 30%	100%
Tackifier (polybutane)	0%	0%	Compatible at 50%	0%	0%

* Percent in the blend of the diol shown in each column header

POLYOL AND DIOLS TYPICAL PROPERTIES

Product	Description	Average Functionality	Color[1] (Gardner)	Viscosity[2] (cPs)	Hydroxyl Value[3] (mg KOH/g)	Hydroxyl Eq. Weight[4] (g/mole)
NX-9001	CNSL Novolac Polyol	4.3	18	2,000	175	320
NX-9001LV	Low viscosity NX-9001	3.8	18	1,000	175	320
NX-9004	CNSL Polyol	4.1	18	5,000	198	283
LITE 9001	Light color NX-9001	4.3	6	2,000	175	320
NX-9005	Non-CNSL Branched Polyol	3.2	≤ 5	3,000	170	330
NX-9006	CNSL Novolac Polyol	4.4	18	3,000	190	295
LITE 9006	Light color NX-9006	3.3	12	2,000	180	312
NX-9007	CNSL Branched Polyol	3.3	14	2,900	175	320
NX-9008	High Strength CNSL Polyol	3.0	10	3,000	320	175
NX-9011	Tough non-CNSL Polyol	3.1	≤ 5	1,800	224	250
NX-9014	High UV Resistance non-CNSL Polyol	4.3	≤ 5	1,200	256	219
NX-9016	Multifunctional Aromatic CNSL Polyol	4.7	14	22,000	180	312
NX-9018	High Strength non-CNSL Polyol	4.1	≤ 3	1,000	370	152
NX-9201	CNSL Polyester Diol	2.0	14	1,400	75	748
NX-9203	CNSL Polyester Diol	2.0	14	3,000	85	660
NX-9201LP	Lower reactivity NX-9201	2.0	14	1,300	70	801
NX-9203LP	Lower reactivity NX-9203	2.0	14	2,000	115	488
NX-9207	High Strength Non-CNSL Polyester Diol	2.0	Pale yellow	Waxy solid	132	425
NX-9208	High Strength CNSL Polyester Diol	2.0	Pale brown	Waxy solid	78	719
NX-9212	CNSL Polyether Diol	2.0	≤ 5	450	55	1020

[1] ASTM D1544 [2] ASTM D2196 at 25°C [3] ASTM D4274 [4] Calculated

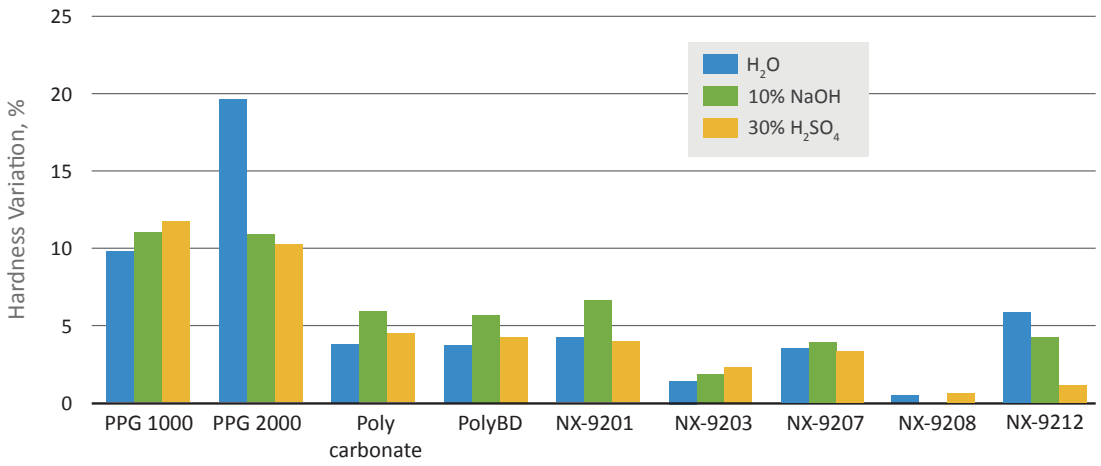
Grades suitable for two-component ambient cured and one-component blocked or moisture cured Polyurethanes and as building block for prepolymers

POLYOLS MECHANICAL PROPERTIES

Polyol	Tensile Strength (MPa)	Elongation at Break (%)	Tg[1] (°C)	Lap Shear[2] (MPa)
NX-9001	8.4	28.3	40.0	7.4
LITE 9001	11.2	22.0	54.0	9.0
NX-9001LV	3.7	41	26.0	5.4
NX-9005	24.4	103.6	24.5	11.2
NX-9007	17.2	92.7	23.2	10.7
NX-9008	40.0	16.0	98.0	14.3
NX-9011	30.0	72.3	46.0	11.5
NX-9014	26.8	49.4	37.0	13.7
NX-9018	37.0	3.7	84.0	15.1

[1]DSC [2]Sand blasted substrate Cured with Polymeric MDI, NCO Index: 100

Hydrolytic Stability of Diols in cured prepolymer (7% NCO) exposed for 21 days at 25°C



NCO BLOCKING AGENT TECHNOLOGY

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

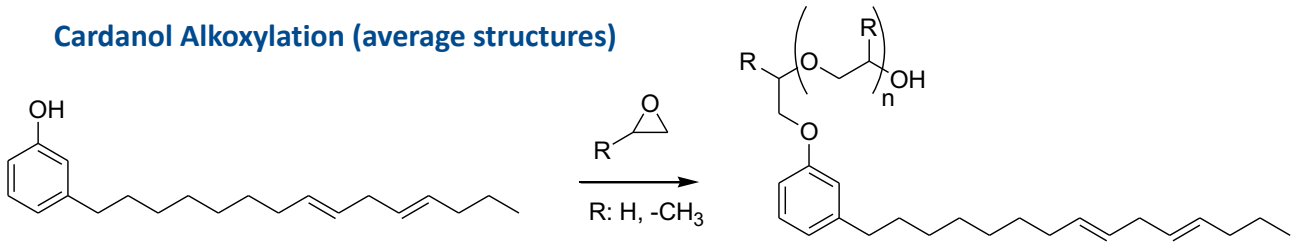
*Properties on page 13

SELECTOR GUIDE

Technology	Industry	End Use	Recommended Product Lines
Epoxy	Construction and infrastructure	Tile adhesives, Grouts, Potting, Concrete bonding, Construction joints	Fast cure Phenalkamines (NX-5607, NX-2003, NC-558, LITE 2002) Diluents (NX-2026, LITE 2020) Waterborne (NX-8101)
	Transportation	Automotive assembly, EV battery adhesives, Honeycomb adhesives, Composite/plastic adhesives, Marine adhesives, Automotive sealants (acoustics)	CNSL epoxy diluents and resins (NC-513/NC-514/NC-547 family, LITE 513DF, NX-2026, LITE 2020) Fast cure Phenalkamines (NX-5607, NC-558, NX-5454) Phenalkamides (LITE 3040, LITE 3060, LITE 3025) Polyamides (NT-1544, NT-1542)
	Industrial	Potable water, Honeycomb panel bonding, Polishing wheel, Sand paper	Fast cure Phenalkamines (NC-558, GX-6004, LITE 2002, NX-5608) Phenalkamides (LITE 3040, LITE 3060) Polyamides (NT-1544, NT-1542)
	Electronics and Electrical	Chip adhesives, PCB, Potting/ Encapsulants	CNSL Epoxy diluents and resins (NC-513/NC-514/NC-547 family, LITE 513DF, NX-2026, LITE 2020)
Polyurethane	Building and construction	Glass sealant, Water proofing, Construction Joint adhesives and sealants	Polyols (NX-9001 family, NX-9005, NX-9007) Diols (NX-9201, NX-9203) Diluents (NX-2026, LITE 2020), NCO blocking agent (NX-2026)
	Transportation	Automotive assembly, EV battery adhesives, Plastic adhesives, Automotive sealants (acoustics)	Polyols (NX-9008, NX-9014, NX-9005, NX-9001 family) Diols (NX-9203/LP, NX-9212) NCO blocking agent (NX-2026)
	Industrial	Honeycomb panel boning, Wind blades adhesives, Wood adhesives	Polyols (NX-9005, NX-9007, NX-9011, NX-9014) Diols (NX-9212)
	Electrical	Potting and encapsulants	Polyols (NX-9001 family, NX-9005, NX-9008)
	Packaging	Food Packaging adhesives	Polyols (NX-9005, NX-9006, LITE 9006, NX-9016)

CNSL SURFACTANTS

Cardanol Alkoxylation (average structures)



R = H, n=0: Ultra or LITE 2020, 1 EO cardanol (diluent)

R = H, n=6: NX-7507, 7 EO cardanol; R = H, n=8: NX-7509, 9 EO cardanol; R = H, n=11: NX-7512, 12 EO cardanol

- High renewable content from non-food chain source
- Replacement for nonyl phenol ethoxylates and natural oil-based surfactants
- Non-toxic, better labeling

SURFACTANTS TYPICAL PROPERTIES

Properties	NX-7507 (7EO)	NX-7509 (9 EO)	NX-7512 (12 EO)
Color (Gardner)	10	10	10
Viscosity at 25°C (cPs)	180	150 - 300	100 - 500
pH (5% Aq. Soln.)	9	8.5	7.8
HLB values (calculated)	10.1	11.4	12.8
OH value (mg KOH/g)	100	89	81
Cloud point (2% in BDG 10%)	66	74.5	80
Pour point (°C)	9	3	18
Surface tension (mN/m)	53	50.1	43.7
Foaming efficiency (ml at 0,1 wt.% actives, 25°C, initial/5 minutes)	24/23	28/27	47/42

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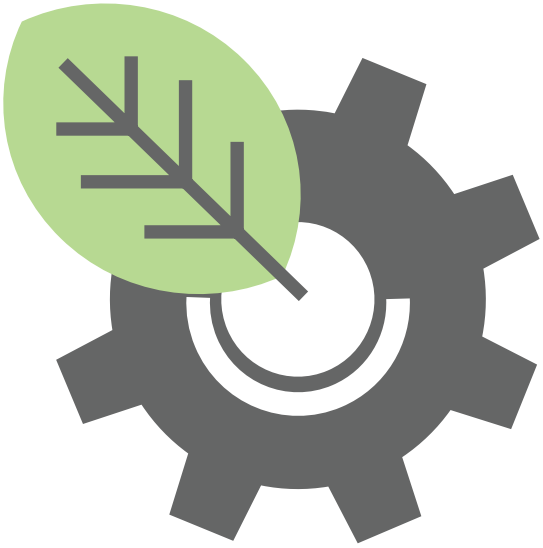

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