

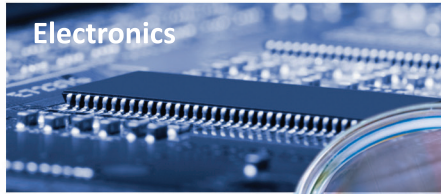
IVES



Cardolite



Construction

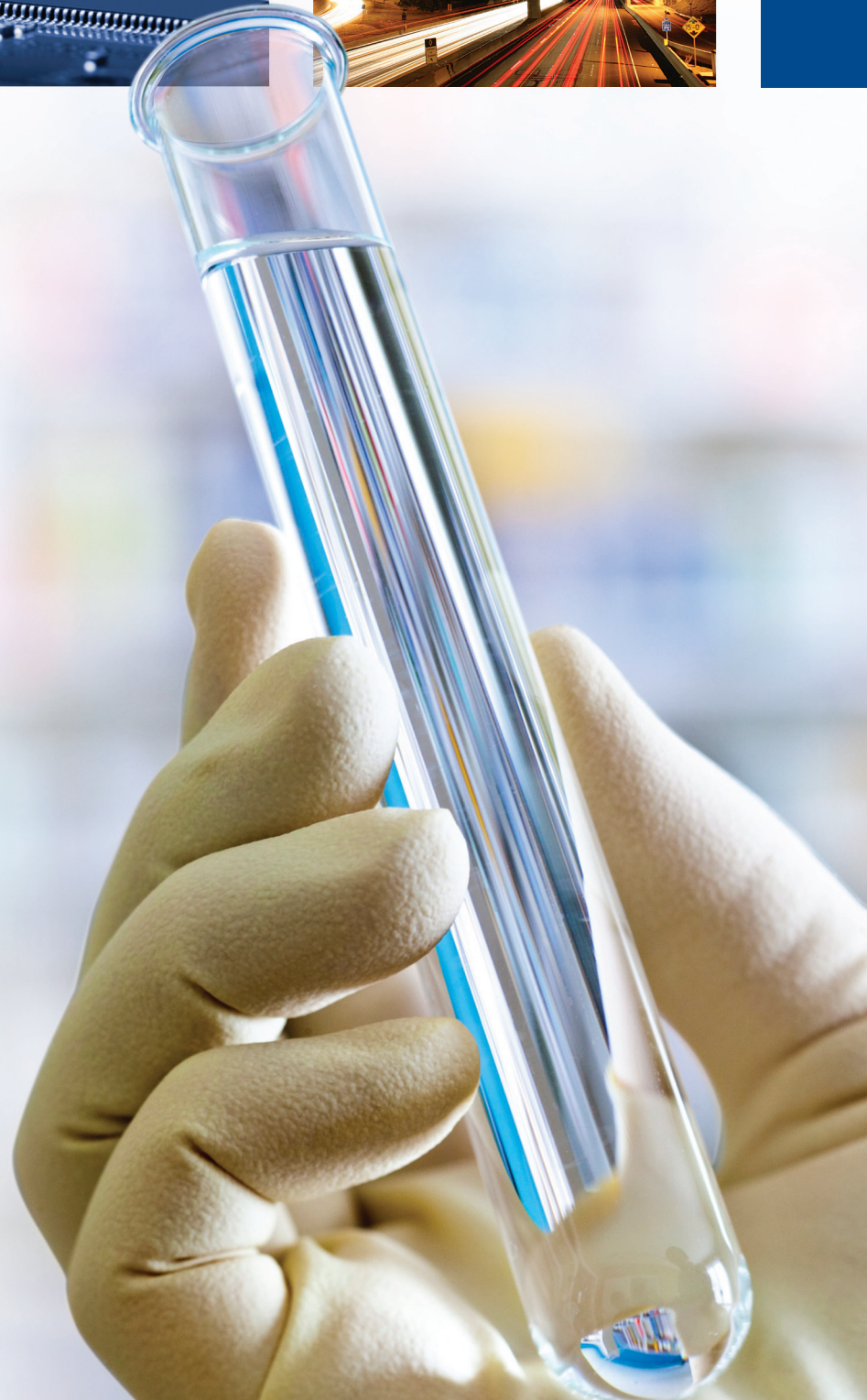


Electronics



Transportation

ADHESIVES



PRODUCT OVERVIEW



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, and friction applications.

With over 30 years of experience, Cardolite is the leader in the production and development of high quality CNSL based materials across the globe. Cardolite manufactures all products at production plants in Newark, New Jersey (USA), Zhuhai, Guangdong (China), and Mangalore, Karnataka (India). With well over 40,000 T/yr of total capacity for the epoxy product line, these facilities are the largest and most advanced CNSL technology manufacturing facilities in the world. They are designed to support the most demanding customers and provide reliable supply of high quality products. Cardolite facilities are ISO 9000 registered and adhere strictly to local and best practice health, safety, environmental, and security standards.

To further advance CNSL technology, Cardolite also operates two advanced research 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. In addition, Cardolite runs a full application laboratory in Beijing, China to help customers accelerate time to market and assure product quality and performance.

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.

From the beginning, Cardolite products have been based on cashew nutshell liquid, a natural, and annually renewable biomaterial. CNSL can be found in the honeycomb structure of the cashew nutshell and is considered a by-product of the cashew nut industry. Therefore, CNSL is a non-food chain material that would be disposed otherwise. This cashew 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.

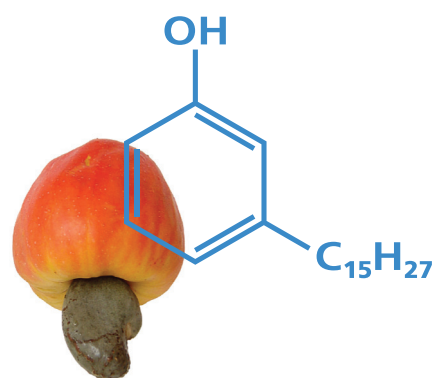
Cardolite Products

Cardolite offers a variety of epoxy amine curing agents, epoxy modifiers, and epoxy and polyol resins based on CNSL technology for use in the formulation of a wide range of high performance ambient and heat cured adhesives.

Cardolite epoxy curing agents called phenalkamines and phenalkamides offer unique benefits to adhesive formulators such as fast and low temperature cure, low viscosity solvent free systems, great overall chemical and mechanical properties, excellent water resistance, and very good bond strength under unfavorable conditions. Cardolite phenalkamines and phenalkamides are ideal for two component, ambient cured adhesives.

Cardolite resin and modifier portfolio is comprised of reactive and non-reactive epoxy diluents and multi-purpose modifiers that not only lower viscosity, but also improve flexibility, surface tolerance and early water resistance, and can accelerate cure without compromising other properties. Moreover, tests have shown that Cardolite modifiers can be formulated to increase bond strength and improve adhesion on oily or damp surfaces. These products are an excellent alternative to substances of high concern such as nonyl phenol and can be used in one component heat cured adhesives or in two component field applied applications.

With three decades of research, Cardolite has pioneered new developments in CNSL technology such as innovative low viscosity, light colored, and faster curing products. In addition, Cardolite has broad expertise and experience supporting, developing, and manufacturing curing agent solutions to fit specific customer needs. If a standard Cardolite product does not function as desired for a specific application, Cardolite can provide formulation technical support and custom modifications.



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 CURE IN EXTREME WEATHER

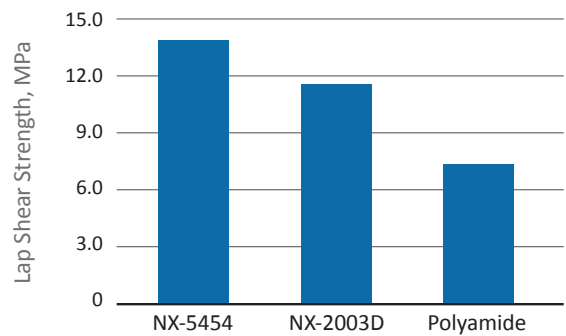
Cardolite phenalkamines and phenalkamides exhibit fast cure even at low temperatures, enable non-critical mix ratios, and show nice film appearance due to good compatibility with epoxy resins. However, due to the long aliphatic side chain of cardanol, CNSL curing agents also have extended pot life and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

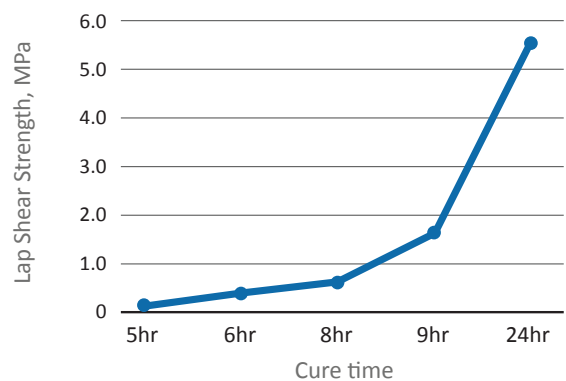
BONDING UNDER WATER

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. Phenalkamines and phenalkamides absorb much less water than competitive technologies which becomes more noticeable at higher temperatures exposure. 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.

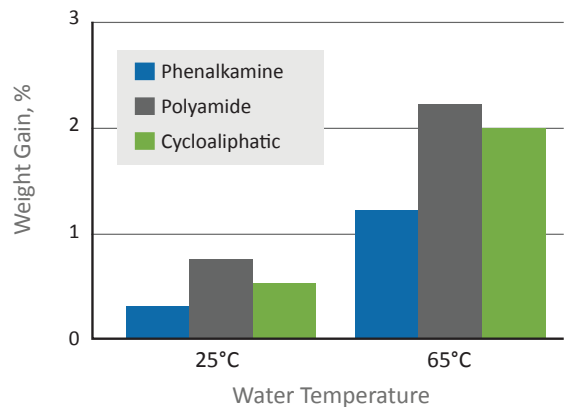
Bond Strength with Liquid Epoxy (EEW 190) on Sand Blasted Carbon Steel at 0°C for 7 Days Cure



NX-5454 Bond Strength Development with Liquid Epoxy (EEW 190) on Non-abraded Carbon Steel at 5°C



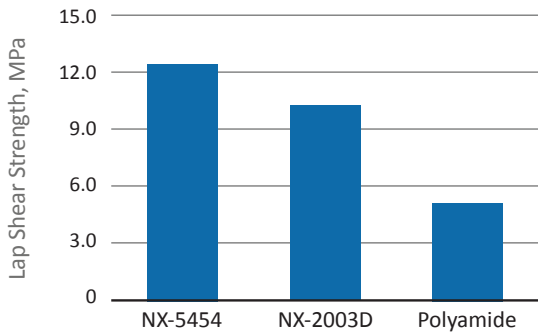
Comparative Water Resistance of CNSL Curing Agents



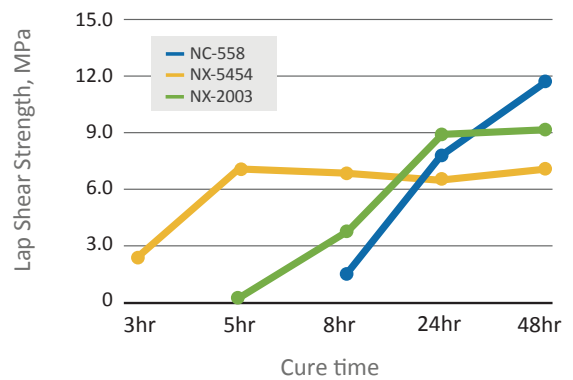
Bonding Under Adverse Conditions



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



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



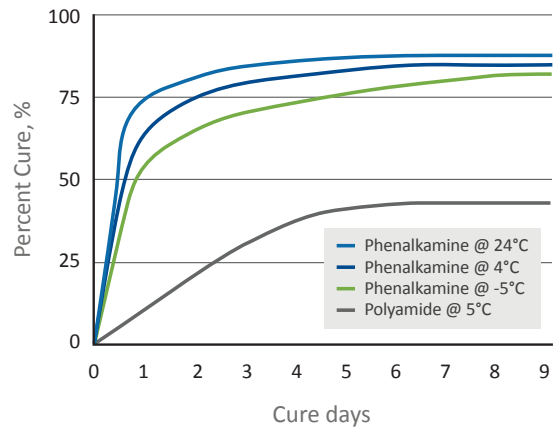
Phenalkamine based Epoxy Adhesion to Concrete

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.

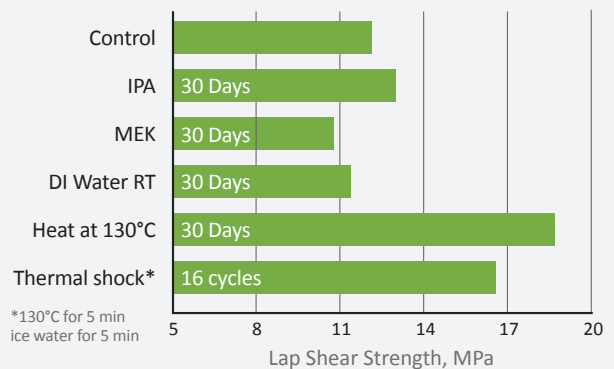
Phenalkamine Low Temperature Cure Data and Comparison



DURABLE BONDS

CNSL curing agents exhibit excellent chemical resistance due to its aromatic ring. In combination with their other properties such as high bond strength, adhesion to non-treated and wet concrete and metal surfaces, wide mix ratio, good pot life, and excellent water resistance, the result is an epoxy adhesive with very good aging properties under different strenuous conditions as illustrated here.

Different Aging Conditions



Curing Agent Property Selection Chart

Product	Viscosity ¹ @ 25°C (cPs)	Technology	Type	Color ² (Gardner)	Amine Value ³ (mgKOH/g)	AHEW ⁴	Gel Time ⁵ (min)	Thin Film ⁶ 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 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

¹ASTM D2196 ²ASTM D1544 ³ASTM D2074 ⁴Theoretical based on total product weight ⁵50g at 25°C ⁶ASTM D5895 @ 200 micron

Adhesive Applications

Cardolite products find use in structural adhesive applications such as automotive, electronics/electrical, and building and construction. Various industries can take advantage of unique properties of CNSL based curing agents, epoxy products, and polyols for enhancing performance.



TRANSPORTATION

- Adhesion to various substrates: metals, composites, glass, plastics
- Durability: water resistance, thermal shock, corrosion resistance
- Flexibility and impact resistance
- Good mechanical properties
- Surface tolerant (oil contaminated surface)

CONSTRUCTION

- Durability: excellent aging resistance
- Adhesion to construction materials: metals, concrete
- Fast cure at low temperature: rapid strength development
- Surface tolerant (moisture, oil, water, etc.)
- Non-critical mix ratio

ELECTRONICS

- Thermal shock and mechanical resistance
- Moisture resistance
- Low Hydrolyzable Chlorine and Halogen free
- Flexibility

Curing Agent Mechanical Properties Selection Chart

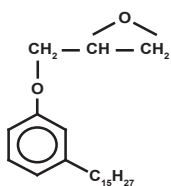
Curing Agent	T _g ⁷ (°C)	Tensile Strength (MPa)	Flexural Strength (MPa)	Compressive Strength (MPa)	Elastic Modulus (MPa)	Lap Shear ⁸ (MPa)
NC-540	105	54	98	81	2,457	16
NC-558	61	41	105	56	1,985	21
NX-2003	74	55	94	76	2,384	20
NX-2003D	79	51	108	75	2,309	20
NX-5454	60	47	88	72	2,019	12
NX-5198	38	13	27	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 3040	75	52	97	77	2,173	23
LITE 3060	76	66	110	89	2,696	18

⁷DSC ⁸Sand blasted substrate Test specimen cured at 40°C for 16 hours with liquid epoxy (EEW 190)

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.

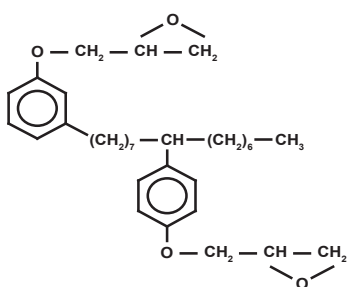
CARDOLITE NC-513/ULTRA LITE 513



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

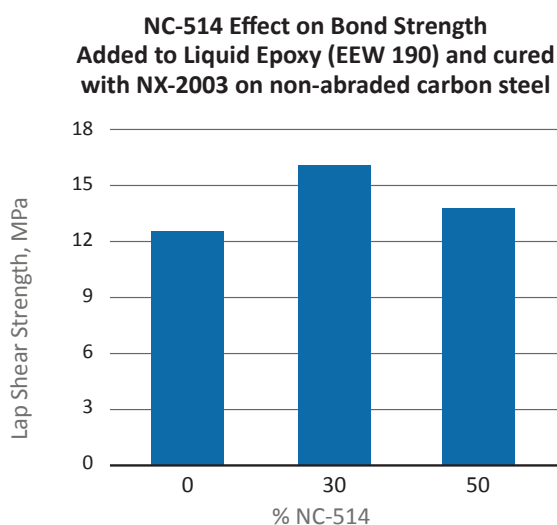
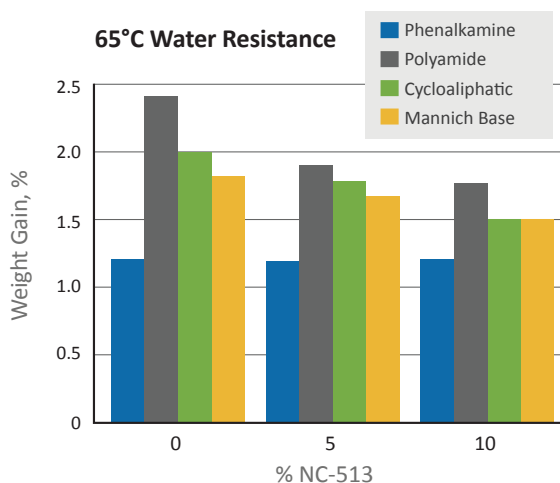
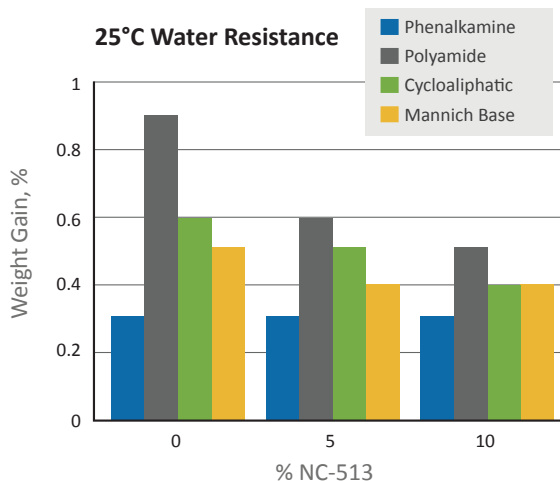
flexural strength. These reactive diluents have very low viscosities and low volatilities, which make them ideal for helping formulate solvent-free adhesives. As for other cardanol based products, these diluents are hydrophobic and exhibit very good water resistance. Good reactivity means these diluents 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

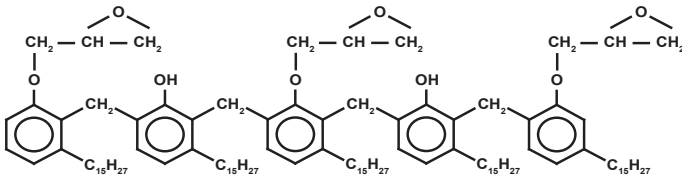


Cardolite NC-514 is a flexible difunctional glycidyl ether epoxy resin exhibiting the reactivity and chemical characteristics of a traditional bisphenol A type resin. The chain of

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 strength.

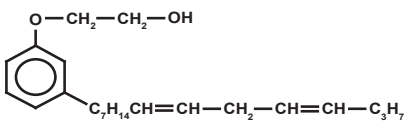


CARDOLITE NC-547



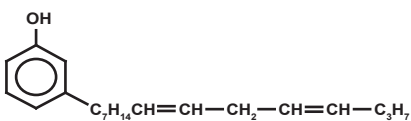
Cardolite NC-547 is a polyglycidyl ether epoxy novolac resin derived from cardanol. This resin can be used in conjunction with standard epoxy resins to bring additional flexibility and longer pot life to adhesives without adversely affecting chemical and water resistance.

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.

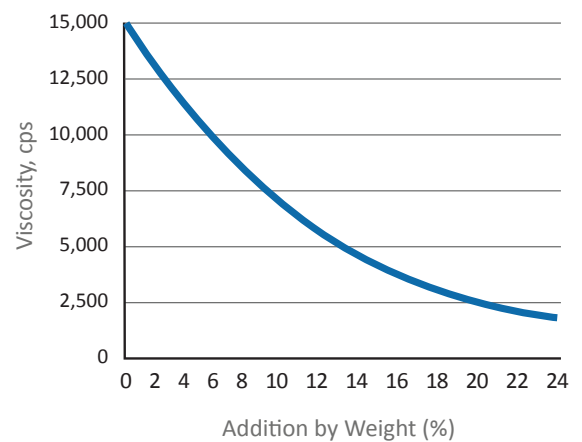
CARDOLITE NX-202X SERIES



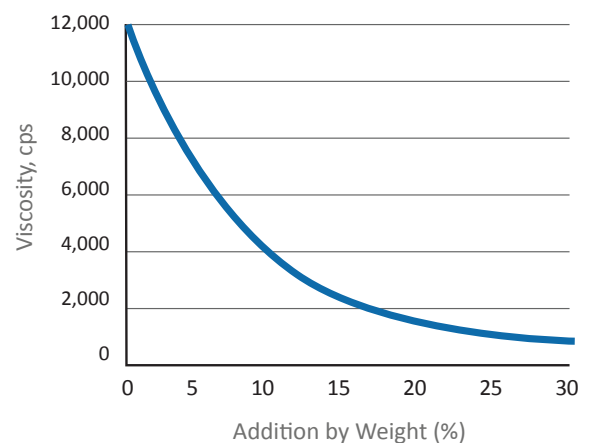
Cardolite NX-202x products are low viscosity multipurpose resin modifiers. The long hydrophobic aliphatic side chain of the cardanol molecule gives these products a very low viscosity and provides excellent early water resistance and corrosion protection. By using NX-202x products as epoxy diluents and 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 ¹ (Gardner)	Viscosity ² (cPs)	Volatile Loss or Solids ³ (%)	EEW	Hydrolyzable Chlorine (%)
NC-513	Reactive diluent	11	50	≤ 0.5	425 - 575	≤ 2
Ultra LITE 513	Reactive diluent	1	24	≤ 0.5	≤ 450	≤ 1
NC-514	Epoxy resin	17	25,000	≤ 3	350 - 500	≤ 2
NC-547	Epoxy novolac resin	18	28,000	≤ 2	550 - 850	≤ 2.5
LITE 2020	Nonreactive resin modifier	12	90	≥ 97 (solids)	-	-
LITE 2100	Hydrocarbon resin modifier	4	450-750	≤ 1	-	-
LITE 2100R	Hydrocarbon resin modifier	4	500-1,000	≤ 1	-	-
NX-2023D	Nonreactive resin modifier	10	100	≥ 99.5 (solids)	-	-
NX-2023	Nonreactive resin modifier	5	60	≥ 99.5 (solids)	-	-
Ultra LITE 2023	Nonreactive resin modifier	1	50	≥ 99.5 (solids)	-	-
NX-2024	Nonreactive resin modifier	4 - 9	50	≤ 0.5	-	-
NX-2025	Nonreactive resin modifier	≤ 5	50	≤ 0.5	-	-
NX-2026	Nonreactive resin modifier	≤ 2	45	≤ 0.5	-	-

¹ ASTM D1544 ² ASTM D2196 at 25°C ³ ASTM D2369-98 * LITE 2020 and LITE 2100 are not approved for sale in Europe

CNSL POLYOLS

In addition to epoxy curing agents, resins and modifiers, Cardolite offers a line of renewable, CNSL based polyols that have unique qualities compared to other polyester or polyether polyols.

CNSL polyols have improved water resistance because of their long aliphatic chain, the absence of ester bonds (hydrolyzable), and fewer ether oxygen atoms compared to typical polyether polyols (less hydrophilic). Cardolite polyols designed for polyurethane adhesive applications have shown excellent resistance to salt water, acid, and alkali solutions. This allows polyurethanes to withstand unfavorable conditions such as those encountered in construction and industrial sites around the world. In addition, CNSL polyols provide very fast cure for quick return to service.

CNSL Polyols Property Selection Chart

Product	Type	Color ¹ (Gardner)	Viscosity ² (cPs)	Hydroxyl Value ³ (mg KOH/g)	Hydroxyl Eq. Weight ³ (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

¹ ASTM D1544 ² ASTM D2196 at 25°C ³ GPC



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