Technical
Information

Cold Temperature Bonding

Catalog number 000-915

Strategies for successful application and curing of WEST SYSTEM® epoxy at low temperatures

We have been formulating and using epoxy resins since 1969–in warm weather and cold, under ideal shop conditions and in miserable, field repair situations. In that time we have conducted an extensive amount of research to better understand epoxy's handling characteristics and performance under a wide variety of conditions.

Although epoxies can be formulated to cure in a wide range of working conditions, no one resin/hardener combination is ideal for all conditions. Several resin/hardener combinations are required, each one formulated to perform best in a different range of application temperature *(see Figure 2, page 3)*. They rely on a complex chemical reaction to achieve their strength and longevity. Ignoring their limitations can drastically affect the outcome of the chemical reaction and compromise the performance of cured epoxy.

We know that most epoxies perform well or, at least reach a higher percentage of their potential physical properties, at temperatures of 60°F and above. Some resin/hardener combinations are formulated to cure in temperatures as low as 35°F. However, simply using a hardener that cures in colder temperatures does not guarantee dependable bonds. A number of other factors can significantly affect your epoxy's bonding ability in cold weather.

Epoxy can be used at cold temperatures, but must be handled and applied with techniques adapted to cold temperatures. This paper will discuss how epoxies work, why they perform differently under cold conditions, and what steps you can take to assure dependable bonds in cold weather. If you still have specific questions, our technical advisors will be happy to answer them. Call 866-937-8797 (toll free), Mon.–Fri., 8–5 ET.

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Chemical characteristics

Mixing an epoxy resin and hardener together starts a chemical reaction which produces heat. This is called an exothermic reaction. The surrounding or ambient temperature affects the mixture's temperature and its rate of reaction and degree of cure. Warmer temperatures accelerate the reaction, while cooler temperatures retard the reaction and reduce the crosslinking activity of the epoxy molecules *(Figure 1)*.

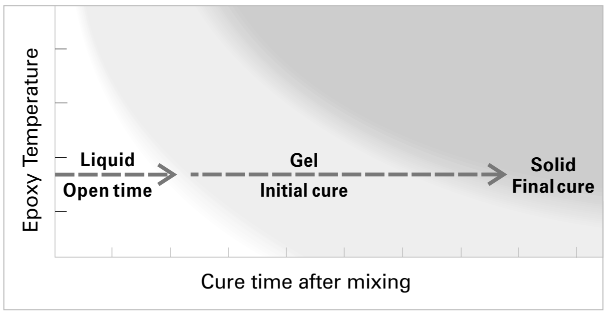

Figure 1—All resin/hardener combination goes through the same phases of cure. All combinations cure faster at warmer temperatures and cure slower at cooler temperatures.

In cool temperatures, more time is required to achieve the same degree of cure, or crosslinking, as occurs in a shorter period at higher temperatures. If the temperature is too low, the epoxy may eventually harden, but may not reach a complete cure or achieve its designed physical properties. Although the partially cured epoxy may have enough strength to hold the structure together, it could fail prematurely.

Epoxy joints in various structures are subject to different types of load during their working life. Many of the joints in a boat for example may be subject to millions of small repeated (fatigue) loads. Others must resist slow stretching and deforming under steady loads (creep-rupture).

One of the dangers in using epoxy in cold weather, is that epoxy that has not cured completely will be more flexible. Testing clearly demonstrates that increased flexibility seriously reduces an adhesive's ability to resist fatigue and creep-rupture. Information about fatigue, fatigue testing, and the how flexibility affects the fatigue life of epoxy, can be found in *000-545 Fatigue Aspects of Epoxy and Epoxy/wood Composite Materials*, published by West System Inc. The notched beam test is a relatively simple test that demonstrates a flexible epoxy's inability to resist creep-rupture. Information about how you can perform this test yourself can be found in the paper *000-815 Notched Beam Test for Creep-Rupture*, published by West System Inc.

Working properties

Ambient temperature has a profound affect on the working or handling properties of uncured epoxy as well as its rate and degree of cure. A change in temperature will drastically change epoxy resin's viscosity, or thickness. The viscosity of water varies little with temperature changes until it either boils or freezes. However, temperature's affect on the viscosity of epoxy is much more obvious. As the temperature drops, epoxy becomes proportionally thicker, reducing its ability to flow out. This change has three important consequences when working with epoxies in cold conditions.

First, it is more difficult to meter and mix the resin and hardener. The cold resin and hardener do not flow through the dispensing pumps easily and the thicker material clings to the surfaces of the pumps, containers and mixing tools. Colder and thicker resin and hardener take much more time and effort to blend thoroughly. The potential for inaccurate metering and incomplete mixing, compounded by a less efficient chemical reaction, greatly increases the possibility of a deficient bond.

Second, the epoxy is much harder to apply. In coating applications the epoxy mixture will not flow out as easily resulting in thicker, uneven coats that require more sanding to achieve a smooth finish. In bonding applications, the thicker epoxy will not wet out or penetrate porous surfaces as well and may result in an unreliable bond.

Third, air bubbles may be introduced during mixing or application and held in suspension due to the chilled epoxy's increased viscosity. Air bubbles reduce epoxy's strength in a bond and a coating's effectiveness as a moisture barrier. In addition, air bubbles show through clear coating applications.

Cold weather techniques

We've told you all of the reasons why using epoxy in cold weather is difficult and risky. However, this doesn't mean that you can never use epoxy in cold weather. With a little advanced planning and by observing the following eight precautions, most of these problems can be overcome and their consequences avoided. We've used these techniques for over 30 years, because they help assure dependable epoxy bonds in cold weather.

1. Use WEST SYSTEM 205 Fast Hardener. 205 Hardener has been designed with a polyamine system that cures well at temperatures as low as

HARDENER	USES Resin/Hardener	HARDENER TEMPERATURE RANGE (°F)	CURE SPEEDS at room temperature		
		Room Temp. 40° 50° 60° 70° 80° 90° 100°	POT LIFE 100g cupful	WORKING TIME thin film	CURE TO SOLID thin film
205 Fast	General bonding, fabric application and barrier coating		9–12 minutes	60–70 minutes	6–8 hours
206 Slow	General bonding, fabric application and barrier coating		20–25 minutes	90–110 minutes	10–15 hours
207 Special Coating	Extra clear fabric application and clear coating		22–27 minutes	110–130 minutes	12–18 hours
209 Extra Slow	General bonding, fabric application and barrier coating		40–50 minutes	3–4 hours	20–24 hours

Figure 2—The Hardener Selection Guide shows the ideal temperature range for each hardener. 205 Hardener cures at much lower temperatures, but has a very short working time at higher temperatures. 209 Hardener will not cure properly at low temperatures, but provides more working time at higher temperatures.

35°F *(Figure 2)*. Keep in mind the extended cure time required before removing clamps or sanding. 206 Slow Hardener and 207 Special Coating Hardener should not be used below 60°F without elevated temperature post-curing, and 209 Tropical Hardener should not be used below 65°F without post-curing. For best results, some applications such as clear coating, for which 207 Hardener is designed, should be postponed until the temperature approaches normal room temperature (72°F).

2. Warm resin and hardener before using. As mentioned, the warmer the resin and hardener, the lower the viscosity. Thinner resin and hardener will flow through pumps better, cling less to containers and mixing equipment, and mix more thoroughly. The initial chemical reaction will get off to a better start and result in more crosslinking even if the mixture cools after it is applied to a cooler surface. The thinner mixture will initially flow out smoother and wet-out porous surfaces better.

Warm the resin and hardener with heat lamps or keep it in a warm area until you are ready to use it. You can build a small portable hot box out of rigid sheets of foil-backed insulation, with a regular light bulb or an electric heating pad inside to maintain a temperature of 70°F–90°F. This method allows you to keep the warm resin and hardener close to your work and allows less time to cool off between dispensing and application.

3. Dispense resin and hardener in the proper mixing ratio only. Altering the amount of hardener will seriously compromise the epoxy's ultimate strength. WEST SYSTEM Mini Pumps are designed and calibrated to dispense the correct ratio—one full pump stroke of hardener for every one full pump stroke of resin. If you are not able to warm the resin and hardener, do not use excessive force when dispensing. Keep steady pressure on each pump and allow each pump head to make a full stroke down and a full stroke up. Remember, the resin and hardener become thicker and more difficult to pump when they are cold.

4. Stir the resin and hardener *thoroughly*. Mix the resin and hardener longer than normal (two minutes minimum) and scrape the sides and bottom of the mixing container. Use a mixing stick shaped to reach the corners of the pot. For a given volume of resin and hardener, a smaller diameter mixing pot will improve the chemical activity because the limited surface area will not dissipate heat produced by the reaction.

If you are unable to warm the resin and hardener, allow the allow the mixture to stand in the pot for several minutes before using. This induction period will help get the chemical reaction started.

5. Warm the bonding surface as much as possible. The epoxy will thin out as it is applied to a warm surface. It will flow out much smoother and penetrate better, resulting in a stronger bond. Warming can be done by constructing tents around small areas and heating with portable heaters, warming the area with hot air guns, hair dryers or heat lamps. Small components or materials (such as fiberglass cloth) can be warmed before use in a hot box as described in above. Avoid unvented open-flame heaters that burn kerosene or fuel oil. Unburned hydrocarbons have been known to contaminate bonding surfaces, and elevated moisture and CO_2 levels may inhibit epoxy's cure. Catalytic heaters do not appear to pose a problem unless they're used in a confined space such as a curing tent or box.
Another temperature related problem occurs throughout the year, even in warm climates, when

overnight temperatures drop well below daytime temperatures. The daily variation in temperature may cause moisture contamination problems if epoxy is applied to an exposed structure or surface too early in the day. A hull, for example, that has cooled overnight may remain colder than the surrounding air until the afternoon. Water vapor can condense on the cooler surface and affect the adhesion and cure of epoxy applied over it. If the bonding area cannot be heated, allow the surface and the surrounding area to come up to air temperature before applying epoxy.

6. Prepare surfaces carefully between applications. When coating at cold temperatures, the slower cure can result in the formation of an amine blush on the surface. The blush feels like a waxy film on the surface of the cured epoxy. Just before applying subsequent coatings, wash the surface with warm water using a 3-M Scotchbrite™ pad. Before the water evaporates, dry the surface with plain white paper towels and sand any remaining glossy areas with medium grit sandpaper.

7. Allow additional cure time before removing clamps or stressing joints. As a general rule, double the cure time for every 18°F drop in temperature. Allow extra time for pre-stressed joints and joints that will be subject to high loads.

8. Post-cure the epoxy if possible. Post-curing can help to complete the epoxy mixture's crosslinking and boost the epoxy's physical properties even after a week or two of cold temperature. Post-curing simply is the process of applying heat to complete or speed the cure after the epoxy has reached a partial cure at ambient temperature. Elevate the temperature of the epoxy and substrate gradually to avoid thermal shock. Although any temperature elevation will improve crosslinking, try to boost the temperature to room temperature (72°F) or warmer. The time required depends on the hardener used, the post-cure temperature and how much further the cure has to go. Generally, higher post-cure temperatures require shorter post-cure times. Do not exceed 140°F and do not remove clamps or load the joint until after the final cure. CAUTION! —Heating a porous material may cause air within the material to expand and "out-gas". If an epoxy coating applied over the material has not gelled enough before starting the post-cure, bubbles from the out-gassing material may show up in the cured coating. Allow the epoxy to reach a partial cure before post-curing.

   A variety of post-cure techniques can be used. In some cases your shop will naturally warm itself enough to complete the cure during the day, following a cold night. Outdoors, building a plastic tent to trap solar heat can easily boost the temperature enough for post-cure even during cool weather. Turning up the thermostat, using radiant heaters, electric heaters or electric blankets are the most common way to control the post-cure temperature in a shop. It is not necessary to heat the entire structure if you are working on only a small area. Tents of plastic or insulated board are very helpful for confining heat to specific areas and provide greater mobility with a limited heat source, both indoors and outdoors.

Cold weather storage

It is best to store WEST SYSTEM materials above 35°F with the container caps screwed down tightly to avoid moisture contamination. Resin that is subject to freeze/thaw cycles may crystallize. However, the formation of crystals does not permanently harm the epoxy, and they can be removed easily. Place the open containers in a pan of hot water and stir the epoxy with a clean stick until all crystals have melted and the liquid becomes clear. Remove from the water, replace the lids tightly and invert the container to melt any crystals which may be clinging to the top of the container. If the resin in the pump has crystallized, pumping warm resin through it should dissolve the crystals. ■