

SECTION III - UNDERSTANDING THE CHEMISTRY

Thoroughly knowing epoxy resin chemistry is not necessary before using a System Three product, but having a rudimentary chemical knowledge will help you complete any project more effectively, avoiding pitfalls or surprises which may arise when using epoxy containing materials.

The resin that is the basis for all epoxy is the diglycidyl ether of bisphenol A (DGEBA). Bisphenol A is produced by reacting phenol with acetone under suitable conditions. The "A" stands for acetone, "phenyl" means phenol groups and "bis" means two. Thus, bisphenol A is the product made from chemically combining two phenols with one acetone. Unreacted acetone and phenol are stripped from the bisphenol A, which is then reacted with a material called epichlorohydrin. This reaction sticks the two ("di") glycidyl groups on ends of the bisphenol A molecule. The resultant product is the diglycidyl ether of bisphenol A, or the basic epoxy resin. It is these glycidyl groups that react with the amine hydrogen atoms on hardeners to produce the cured epoxy resin. Unmodified liquid epoxy resin is very viscous and unsuitable for most uses except as thick glue. At System Three Resins we purchase the material in this basic form, then modify it using formulae developed by us. The results are the "Part A's" of the various epoxy resin products we manufacture.

Chemical raw materials used to manufacture curing agents, or hardeners, for room-temperature cured epoxy resins are most commonly polyamines. They are organic molecules containing two or more amine groups. Amine groups are not unlike ammonia in structure except that they are attached to organic molecules. Like ammonia, amines are strongly alkaline. Because of this similarity, epoxy resin hardeners often have an ammonia-like odor, most notable in the air space in containers right after they are opened. Once in the open this odor is difficult to detect because of the low vapor pressure of the polyamines. Epoxy hardeners are commonly referred to as "Part B".

Reactive amine groups are nitrogen atoms with one or two hydrogen atoms attached to the nitrogen. These hydrogen atoms react with oxygen atoms from glycidyl groups on the epoxy to form the cured resin - a highly crosslinked thermoset plastic. Heat will soften, but not melt, a cured epoxy. The three dimensional structure gives the cured resin excellent physical properties.

The ratio of the glycidyl oxygens to the amine hydrogens, taking into account the various molecular weights and densities involved, determines the final resin to hardener ratio. The proper ratio produces a "fully-crosslinked" thermoset plastic. Varying the recommended ratio will leave either unreacted oxygen or hydrogen atoms depending upon which side is in excess. The resultant cured resin will have lower strength, as it is not as completely crosslinked. Excess Part B results in an increase in moisture sensitivity in the cured epoxy and should be avoided.

Amine hardeners are not "catalysts". Catalysts promote reactions but do not chemically become a part of the finished product. Amine hardeners mate with the epoxy resin, greatly contributing to the ultimate properties of the cured system.

Cure time of an epoxy system is dependent upon the reactivity of the amine hydrogen atoms. While the attached organic molecule takes no direct part in the chemical reaction, it does influence how readily the amine hydrogen atoms leave the nitrogen and react with the glycidyl oxygen atom. Thus, cure time is set by the kinetics of the particular amine used in the hardener. Cure time for any given epoxy system can be altered only by adding an accelerator in systems that can accommodate one, or by changing the temperature and mass of the resin/hardener mix. Adding more hardener will not "speed things up" and adding less will not "slow things down".

The epoxy curing reaction is exothermic. This means that it gives off heat as it cures. The rate at which an epoxy resin cures is dependent upon the curing temperature. The warmer it is the faster it goes. The cure rate will vary by about half or double with each 18°F (10°C) change in temperature. For example, if an epoxy system takes 3 hours to become tack free at 70°F, it will be tack free in 1.5 hours at 88°F or tack free in 6 hours at 52°F. Everything to do with the speed of the reaction follows this general rule. Pot life and working time are greatly influenced by the initial tem-



perature of the mixed resin and hardener. On a hot day cool the two materials before mixing to increase the working time.

The gel time of the resin is the time it takes for a given mass held in a compact volume to solidify. Gel time depends on the initial temperature of the mass and follows the above rule. One hundred grams (about three fluid ounces) of SilverTip Laminating Epoxy with Fast Hardener will solidify in 25 minutes starting at 77°F. At 60°F the gel time is about 50 minutes. If the same mass were spread over 4 square feet at 77°F the gel time would be a little over three hours. Cure time is surface area/mass sensitive in addition to being temperature sensitive.

What's happening is this: As the reaction proceeds it gives off heat. If the heat generated is immediately dissipated to the environment (as occurs in thin films) the temperature of the curing resin does not rise and the reaction speed proceeds at a uniform pace. If the resin is confined (as in a mixing pot) the exothermic reaction raises the temperature of the mixture, accelerating the reaction.

Working time is about 75% of the gel time for the geometry of the pot. It can be lengthened by increasing the surface area, working with a smaller mass, or cooling the resin and hardener prior to mixing. Material left in the pot will increase in absolute viscosity (measured at 75°F, for example) due to polymerization but initially decrease in apparent viscosity due to heating. Material left in the pot to 75% of gel time may appear quite thin (due to heating) but will actually be quite thick when cooled to room temperature. Experienced users either mix batches that will be applied almost immediately or increase the surface area to slow the reaction.

Although the cure rate of an epoxy is dependent upon temperature, the curing mechanism is independent of temperature. The reaction proceeds most quickly in the liquid state. As the cure proceeds the system changes from a liquid to a sticky, viscous, soft gel. After gelation the reaction speed slows down as hardness increases. Chemical reactions proceed more slowly in the solid state. From the soft sticky gel the system gets harder, slowly losing its stickiness. It becomes tack free and continues to become harder and stronger as time passes.

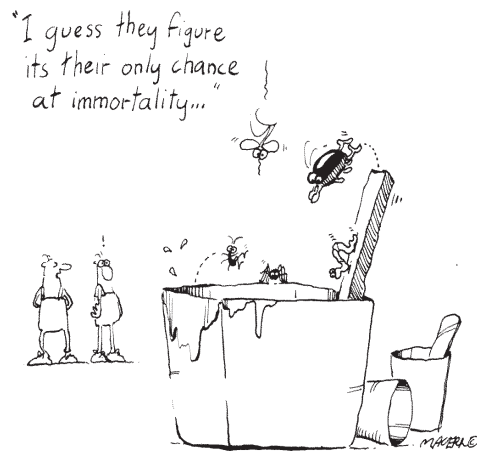
At normal temperatures the system will reach about 60 to 80% of ultimate strength after 24 hours. Curing then proceeds slowly over the next several weeks, finally reaching a point where no further curing will occur without a significant increase in temperature. However, for most purposes room temperature cured systems can be considered fully cured after 72 hours at 77°F. High modulus systems like Phase Two epoxy must be post-cured at elevated temperatures to reach full cure.

It is usually more efficient to work with as fast a cure time as practical for the application at hand if the particular system being used offers this choice. This allows the builder to get along to the next phase without wasting time waiting for epoxy to cure. Faster curing films with shorter tack times will have less chance to pick up fly tracks, bugs, and other airborne contaminants.

A surface film may form on some epoxy systems during the curing process. Technically, this surface film is an amine carbonate that can form in the presence of carbon dioxide and water vapor. More appears on cool damp days than on warm sunny days. This film, often called blush, is water-soluble and should be removed with a sponge and warm water before sanding or painting. Surface blush does not affect the clarity of the cured epoxy film. SilverTip Laminating Epoxy does not form a blush.

Unprotected epoxy resins are not ultimately sunlight resistant. After about six months of exposure to intense sunlight they begin to decay. Additional exposure will induce chalking, yellowing, and eventually the epoxy will disintegrate, losing its mechanical properties. The solution to this problem is to protect the epoxy with paint or with a varnish, which contains an ultraviolet light shield.

Caution must be observed when using epoxy resins along with polyester resins. Observe the general rule that epoxy resins may be applied over cured polyesters that have been dewaxed and well sanded but polyesters should never be used over cured epoxy resins. Unreacted amine in the epoxy inhibits the peroxide catalyst in the polyester causing an incomplete cure at the interface. Sanding does not get rid of unreacted amine. The result is a poor bond even though the surface appears cured. Debonding will be the inevitable result. Our SB-112 epoxy system was designed to get around the "polyester over epoxy" problem. Consult the SB-112 Technical Data Sheet for additional information.



SECTION IV - MEASURING AND MIXING

Measuring and mixing is really easy with most of our epoxy systems because they mix at a 2:1 or 1:1 volume ratio, but this doesn't mean you don't have to pay attention to what you're doing. First, read the label or Technical Data Sheet to see what the correct ratio is for the product you are using. Customers will call our Technical Support line suggesting that something is wrong with the epoxy because it didn't cure properly. We know of no situation where properly-mixed resin/hardener has gone bad or has been contaminated and wouldn't cure. It always resolves that the batch was either improperly measured or insufficiently mixed in the user's shop. Epoxy chemistry just will not allow it to work any other way.

If you're working on a project that requires you mix many small resin batches, develop a measuring technique that is sufficiently

accurate and stay with it. Doing it the same way each time will minimize the chance for error. Measuring errors are insidious and can pop up when least expected. The reasons that errors occur are always because the technique changed, too little time was taken, someone else mixed a batch, or just not enough care was taken.

If using a graduated cup or a straight-sided can, get in the habit of measuring the same way each time. If you pour the resin first, then always pour the resin first. Before adding the hardener, notice how much resin is already in the container, divide this by two (for a 2:1 system) and then add hardener to bring the total to the correct mark. Measuring in the same order each time will avoid the common error of two parts of hardener to one part of resin.