TASK SHEET

# Metering and Mixing Epoxy

Text and photographs by Russell Brown

## MATERIALS:

- two-part epoxy
- 12-oz to 32-oz paper cups
- empty screw-capped metal bottles
- graduated cups
- flat-tipped stir sticks

## TOOLS:

- digital scale
- calculator
- mini-pumps
- positive-displacement (or lever) pumps
- rotary-gear pump (for high volumes)
- hair dryer or heat gun

## INTRODUCTION:

As boatbuilders, the things we make with epoxy are often critical, meaning someone's life could depend on epoxy working the way it should. Yet in many shops the potentially serious consequences of mixing a bad batch (or lots of bad batches) are not well understood.

Two-part epoxy can be incredibly strong, but its full strength is not realized unless the resin and hardener are metered at the correct ratios and then mixed thoroughly. Doing it wrong—using an inaccurate ratio or inadequately mixing it—is a leading cause of epoxy problems and failures. Doing it right will produce light and strong structures and yield the most value from the material.

There are several ways to go about it. Pumps are the most common method, but digital scales and graduated cups are popular, too. All methods have complexities and drawbacks, which is why people like me use multiple approaches.

Epoxy systems typically have two different mix ratios: one by volume, the other by weight. They are different, because the densities of resin and hardener are usually not the same. Apply the correct ratio by volume for pumps and graduated cups, and by weight for metering with a scale.

***Note:*** *This task sheet will not address measuring and mixing epoxy thickeners and additives.*

## METERING WITH PUMPS:

Pumps that deliver an epoxy manufacturer's specified mixing ratios are by far the most reliable method for metering resin and hardener. While a wide variety of dispensing equipment is available, the following is a brief review of pumps for small to midsized shops, and methods for testing them. For technical information about specific pumps and maintenance, consult manufacturers' data sheets, which usually are available online.

• **Mini-pumps** are elegant in their simplicity and are cost-effective. Once primed, it's one full stroke from each pump to get the correct ratio. When more than one pump of epoxy is needed, always start with a pump of resin, then a pump of hardener and repeat, instead of trying to count pumps. ***Note:*** *Some epoxies use mini-pumps that require two or three pump strokes of resin to one pump of hardener, which can be confusing. In my view, mini-pumps aren't ideal for dispensing large volumes quickly, and they don't last forever, but a set costs less than $15, so it's hard to complain.*


*Mini-pumps for pumping small volumes of epoxy are practical and affordable.*

• **Positive-displacement pumps** (sometimes called lever pumps) are well conceived and rather complex tools. They can dispense moderate volumes but are also able to meter small amounts, because when taking less than full strokes, they are still accurate. These are used extensively in small to medium-sized shops and in the aerospace industry. Better and larger positive-displacement pumps are expensive, but the cost can be justified by reliable metering performance and the amount of epoxy saved.


*A positive-displacement pump draws from separate reservoirs of resin and hardener with the stroke of a single lever.*

• **Rotary-gear pumps** are common in shops where higher volumes are needed. They are very efficient at dispensing large volumes of epoxy, but temperature swings can cause viscosity differences that can drive them off ratio, and many are being replaced with the newer positive-displacement pumps.

**Downsides of pumps:** Pumps require maintenance to keep them clean and working well. Positive-displacement pumps often need to be primed daily, meaning a tiny amount is wasted (into a drip cup placed under the spouts), to ensure that liquid is coming from both spouts before taking the first pump stroke, although this issue seems less common if the pumps are kept at room temperature.

Because the viscosity of epoxy is affected by temperature, pumps work much better, can dispense much higher volumes, and require less maintenance if kept at a consistent room temperature. There are multiple methods for this if shop temperatures are cooler, including simply aiming a low-wattage incandescent light bulb in a safe fixture at the pump.

**Testing pumps:** All pumps should be tested every so often and especially before critical jobs to be sure the dispensed ratio is correct. This can be done either with three clean, small, transparent cups of equal size or with a digital scale.

• **Cup method:** Let's use a 3:1 ratio as an example: Hold two cups under the spouts of the hardener and the resin and make one complete pump stroke. Put the resin cup aside, replace it with the third cup, and do another two full pumps of hardener. The three full pump strokes of hardener should equal the one of resin when the cups are placed side by side. More accurate results can be obtained from doubling the volume of the test: two pump strokes of resin to six pumps of hardener. The test resin and hardener can be poured back into the appropriate container. ***Note:*** *Pouring resin into the hardener container or vice versa is a disaster. If you make this mistake, you will do it only once; it's that bad. The greater the number of different epoxies in use in one shop, the easier it is to screw up. When filling pumps (or metering digitally), always hesitate just before pouring, look at the labels, confirm, and then pour.*

• **Digital scale (plus calculator) method:** Use two cups identical in weight, such as paper coffee cups. Zero the scale with one of the two cups on it, then hold the cups under the pump spouts and pump a few strokes. Weigh the cups separately, writing down the weights. The weight of the hardener should divide into the weight of the resin by the "by weight" mixing ratio of the epoxy you are using. A digital scale should be set on grams and be able to measure tenths of a gram.

The acceptable mix ratio tolerance ranges for most epoxies are listed on the system's technical data sheet. Users can determine discrepancies with a bit of math. ***Note:*** *Some modern laminating epoxies are less tolerant of ratio errors than the standard-use epoxies.*

## METERING WITH DIGITAL SCALES:

This method is simultaneously the best and worst way to meter epoxy. Best, because one can meter very accurately with one relatively inexpensive tool for any mixing ratio. Worst, because it requires good concentration and consistent presence of mind to complete it for every batch of epoxy.

When using a digital scale, errors happen because pouring just the right amount is difficult, and the target numbers must be held in your head while you are looking from the scale to the spout and back again. Some people can do this reliably; others (like me) have to double-check. Scales can pose some challenges, but they are widely used, so a discussion of the methods that I have seen and used seems important.

One method is to place the mixing cup on the scale, zero the scale, pour epoxy resin in the cup, note the weight, zero the scale, divide (with a calculator) the weight of the resin by the mixing ratio, and then add that amount in hardener.


*Metering with a digital scale can be faster by referring to a list of batch sizes for each epoxy and mixing ratio the shop uses.*

This method, though widely used, can be risky. How often have you come up with the wrong sum by pushing the wrong button on a calculator? What if the calculator is covered with sticky plastic wrap, you are tired, and someone is talking to you? Working in a high-level composite shop, I saw this method fail more than once.

Many people, myself included, make a list of batch sizes for each epoxy and mixing ratio they use. These can be written in permanent marker on scrap plywood or cardboard and kept next to the scale, or printed large and taped to the wall.

I start with the by-weight ratio. Say it's 3.5:1. That's 3.5 parts resin to one part hardener, totaling 4.5 parts when combined. When measuring in grams, that's a tiny batch, so you could start with 35:10 = 45. The next size could be double the first, 70:20 = 90. Keep doubling the size to make a range of batch sizes that fit most needs (see **photos**). Intermediate batch sizes can be made by combining a column with the one above, but always write the batch sizes (including the total) legibly, and always check the math by dividing the resin by the hardener. Example: 70 divided by 20 equals 3.5, the correct ratio. ***Note:*** *When using a scale, resin and hardener containers that allow good volume control when pouring are a key to success.*

When mixing larger batches, using the gallon (and smaller) containers that the epoxy comes in can work, but pouring from full containers is difficult and messy. Keeping a set of empty containers with the same labels allows splitting full cans into half-full cans for easier pouring.

When pouring, look at the scale until it nears the target, then look from the spout to the scale and back again to avoid passing the target. If you pass the target with the resin, some can be poured out into another cup, but if you exceed the target when adding the hardener, multiply the excess hardener by the mixing ratio and add that sum in resin to make an accurate (if bigger) batch.

If something happens that makes you question the batch (the phone rings and you forgot which numbers were which), *don't think twice. Get rid of it.* Stir it together so it will cure, and then, if it's a big batch, dump it out into an old paint tray or something flat so it doesn't exotherm (a chemical reaction that causes heat and toxic fumes when a large batch of epoxy is left to cure in a mass).

Smaller batches need smaller jugs with spouts that are easy to keep clean and offer good volume control. You can use plastic bottles, but the hardener can react with or even

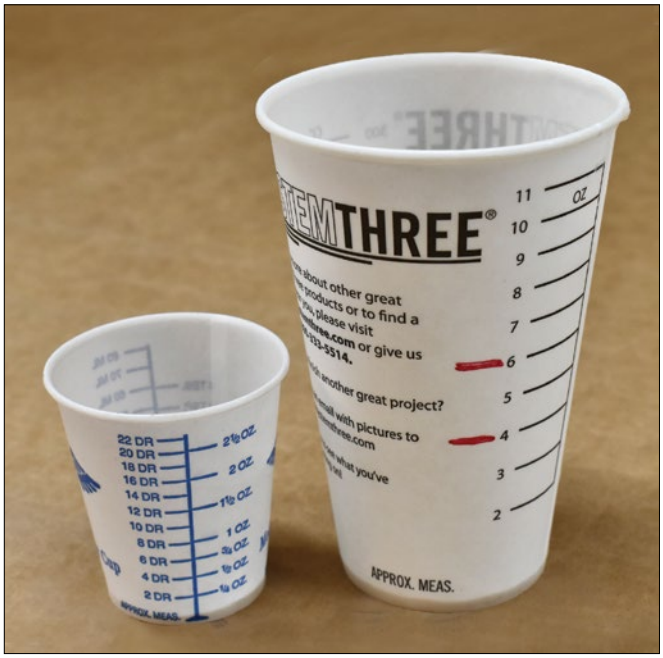
*A versatile method to meter small batches employs easy-to-pour and -clean metal containers and a list of batch sizes by weight ratio.*


degrade some plastics. Empty metal cans are better but hard to find. The ones in the photo, found at McMaster-Carr, work well. Thousands of small shops worldwide mix small, accurate batches of epoxy with small bottles and a scale, and it's an ideal, clean method to keep an epoxy kit on board or for metering and mixing when traveling.

## METERING WITH GRADUATED CUPS:

This method can work well for metering epoxy that's mixed at a 1:1 or 2:1 ratio, but accuracy is lost when the hardener becomes a smaller part of the total. Some plastic cups can be surprisingly inaccurate. Testing with water using a small medicine cup (on the left in the image below) or the scale can be illuminating. Using a tall, narrow cup offers a better chance of an accurate batch than a shorter wide cup. To avoid mistakes, mark with a permanent marker the ratio and batch you want to mix (2:1 batch shown). To pour more accurately, turn the cup until you can see the marks from the inside of the cup when pouring.

These cups, along with screw-capped bottles, are a good way to mix epoxy on board without having to carry pumps or a scale, and they are also great for mixing two-part paints.




*Metering with graduated cups works well for a 1:1 or 2:1 ratio, but accuracy is lost when the hardener constitutes a smaller part of the total.*

## MIXING:

**Mixing tools:** Mixing is usually done in a cup with a stir stick, both simple tools, but as we all know, some tools work better than others. In this case, using the right tools will allow more thorough mixing. I prefer paper mixing cups, because, unlike plastic cups, they have straight sides and a flat bottom. Using a stir stick with straight edges and a flat tip, you can scrape the sides and bottom of the cup when mixing, so unmixed epoxy is not left there to contaminate an otherwise well-mixed batch.

• **Good stir sticks** can be cut from scrap wood on the table-saw. They should be wide enough to stir well, yet light enough so they don't tip the cup over when it's empty. They can have their edges straightened on a sanding block, and if they are cleaned after use, either by dry-wiping or with a bit of alcohol, they can last forever. Having a quiver of different sizes for different batch sizes is great.

• **Paper coffee cups** (12 oz or so) are perfect for smaller batches and can be affordably purchased in bulk. Quart-sized (32 oz) or larger paper cups can be found at hardware and paint stores. I always snip off the rolled upper edge of the cup with scissors, because it makes it easier to scrape the walls of the cup when mixing and because epoxy can be scraped off the stir stick without drips running down the outside of the cup. This is also helpful with thickened batches of epoxy.

TASK SHEET

# METERING AND MIXING EPOXY



I mix metered resin and hardener in three steps repeated two or three times:

**1.** Stir vigorously to get the batch moving inside the cup.

**2.** Scrape the walls of the cup. With the cup flat on the table, this can be done by rotating the cup past the stick with your palm.

**3.** Draw the stick backward over the edge of the cup to remove unmixed epoxy from the stick. Now again stir hard, scrape, and clean the stick.

I recommend two full minutes of stirring, but fully mixing the epoxy is much more than just swishing it around. Following these steps, you get a more thoroughly mixed batch, or a batch mixed in less time.

***Notes:*** *If the hardener is much thinner than the resin, slowly fold the hardener into the resin to avoid having hardener slop over the edge of the cup. Use a cup at least double the size of the planned batch. Cold epoxy is difficult to mix thoroughly. A small temperature increase will make it thinner and easier to mix. A hair dryer or heat gun set on low and laid on the bench can provide a warm blast in front of which to rotate the cup while mixing.*



## CRYSTALLIZATION:

Epoxy resin can crystallize in temperatures as high as 60°F (15.5°C). Crystallization appears as opaque resin that's thicker and often chunky, starting in the bottom of the can or pump. It is relatively easy to make it dissolve and disappear with heat, using one of multiple methods: Putting jugs in a tub filled with hot water is easy and safe. Avoid using crystallized resin. Warm it until *all* signs of crystallization disappear.

Crystallization in pumps is a common cause of pump clogging and failure, but you can't put a pump in hot water. It takes only about five minutes to turn a large upside-down cardboard box into a temporary oven for pumps, *but it must be carefully monitored and never left alone.* Here's how to make one: Cut a port in the side of the box that a very small electric fan heater can fit through, but don't put the heater inside the box; just put the face of the heater in the port (so that it's drawing cold air from

outside the box). Cut a similar-sized port on the other side of the box for air to escape. Place a thermometer in the box with the pump, and monitor the temperature—120°F (49°C) is optimal. Remember, there are plastic and rubber parts in pumps, so don't overdo it, and don't risk a fire.

## CONCLUSION:

Choosing a method and practices for metering epoxy to control the escape of resin and hardener before they are mixed is very important. Wet epoxy can be hazardous to work with, but it cures and becomes inert if it is metered and mixed right, so the hazard goes away once it cures. However, if either of the two parts gets loose in your shop without a chance of curing, you have created a potential health risk through skin contact. Say you spill a dab of hardener on the floor and drag a power cord through it, and then every time that cord gets coiled, skin contact with a corrosive irritant can occur. The same thing happens when containers with drips of unmixed epoxy running down the sides get spread everywhere.

Cleanliness makes working with epoxy safer and much more fun. To recap: If in doubt, dump it out. Just because it gets hard doesn't mean it's good. Hesitate and double-check before pouring. Pumps are great and so are scales, but the latter require concentration to avoid mistakes. Heat makes epoxy flow and helps resin and hardener mix, while unmixed epoxy should never be allowed to roam your shop. Study the manufacturer's data and instructions for the epoxy and the metering kit you use. With these methods and common-sense precaution, you should get your money's worth from this wonderful stuff. PBB

***About the Author:*** *Russell Brown wrote the definitive book* Epoxy Basics *and designs and builds unconventional craft. He has made custom composite parts for at least 40 years. Because he could not afford to have others do it, he made his own on the boats he built for himself and later those he built for others. He runs Port Townsend Watercraft, a kit-boat company, with his wife, Ashlyn, while also working on boats that "make sense" to him.* Epoxy Basics *and other how-to books can be found at The WoodenBoat Store or www.ptwatercraft.com.*