

# **Friendly Aquaponics, Inc.**

## *The Most Advanced Food Production System in the World*

### **FREE VERSION: Construction Manual For Plywood/Epoxy/ Fiberglass Aquaponics Fish and Filter Tanks** **(Use is "free", subject to the following conditions)**

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Friendly Aquaponics, Inc, PO Box 1196, Honokaa, Hawaii 96727

**Notice: Use of this manual for the purpose of constructing or having constructed plywood, epoxy, and fiberglass tanks substantially similar to the ones described herein constitutes acceptance of the following conditions and terms of use of this material:**

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## Introduction

Why would you want to make a plywood and fiberglass tank in the first place? If they're well-built and taken care of, they will easily last thirty years. They can be made with custom partitions, just the size and shape you want, instead of having to make do with whatever tanks you can buy. We made a custom multi-compartment 7,000-gallon integrated tank for our aquaponics farm that had 5 separate compartments in it, multiple fittings, and a shade roof, that would have cost \$22,000 or so from a fiberglass manufacturer, and in Hawaii, would have cost another \$10,000 or so to ship to us. This \$32,000 tank cost us \$1,400 of materials and two weeks of labor by two people.

This FREE construction manual is text-only, and is issued as a free download with the intention of empowering people with no fiberglass experience to be able to build plywood/epoxy/fiberglass tanks. There was an incredible amount of work involved in writing this, and years more in gaining the experience that makes building tanks using this manual much easier than learning the hard way by oneself. But it's still free, because we want to pass this information on. It's sort of the "you're hungry, here's a free bowl of soup" version of the manual.

We also offer a version of this manual which took a LOT more time to put together with complete color pictures of construction techniques, as well as separate downloadable CAD drawings of the tank construction, along with complete materials lists for three different standard tank types and sizes. That's why we charge \$29.95 for it. It's the "you're hungry and paid thirty bucks, here's a delicious five-course hot meal" version of the manual.

The CAD drawings in the purchasable manual are supplied as separate PDF files which you can either view on your computer using Adobe Viewer or email to your nearest Office Max Impress (their printing shop) to have printed on 36" by 24" D-size paper, which is then VERY EASY to use as a paper plan to build your tank(s) from. You can easily use the general principles in this free manual and make your OWN materials list by carefully counting all the sides and pieces and fittings in YOUR tank from a sketch you make yourself.

The FREE version of this construction manual (without the pictures and CAD drawings) is a step-by-step explanation of the process of building these tanks and is probably plenty of information for someone who knows how to build things already. The drawings and pictures that come with the "for sale" manual are a graphic explanation of the same process, and make it much easier if you haven't done anything like this before. Whichever manual you end up using, read the WHOLE thing a COUPLE OF TIMES and make sure you comprehend what's being explained before you start doing or buying anything.

Tim Mann, the writer of this manual, has been building similar structures for nearly 40 years (boats), and some of those structures, notably a 56-foot long one with sails named Tropic Bird, are still working just fine after 32 years in the water. A boat is just a tank designed to keep the water OUT instead of IN. So, if you build your tank (or boat) the way described here, it will likely last for a long time. However, we are counting on you, the users, to share anything new you discover about these types of tanks with us so we can share it with others. If you wish, we will include your name (and contact information if you wish), with your discovery. We don't think we know it all ourselves, as some of the most productive and functional innovations in our systems and techniques came from other people whom we freely acknowledge. This is Hawaii; this is the way of Aloha. We acknowledge our kumu (teachers) freely and are deeply indebted to them for sharing their knowledge with us.

### **Words Appearing in This Manual You Should Pay Extra Attention To:**

**IMPORTANT: When this appears, it means it won't work as well if you don't do it this way, and will work better if you do.**

**WARNING! This means it is dangerous to ignore it; you may injure yourself or others, start a fire or a flood, cut off a piece of your anatomy, or damage or destroy a tool.**

**By the way, a finished tank is heavy and large; it's big enough to kill someone if handled carelessly. Please read the end of Section 5 first, which covers what's involved when turning over a finished tank or moving it to its installation location, to make sure you can handle this part of the job. You have to be able to move your tank safely, or there's no point in building it. It'll just sit in your shop forever.**

## 1. Materials Selection, Tools, and Considerations

**PLYWOOD:** We use exterior grade  $\frac{3}{4}$ " thick ACX **untreated** plywood in our tanks. It is manufactured with the SAME waterproof glue that marine plywood is, but doesn't have the high price tag, because it uses a much lower grade of wood. The "A" in ACX means that one side is good, that is, the "A" side has no knotholes or splits and this is the side we put inside the tanks and cover with fiberglass and epoxy resin to waterproof it. The "C" means that the "C" side HAS knotholes and splits, but this is OK, because it's going to be on the outside of the tank where it won't make any difference. The "X" means exterior, and glued with waterproof glue. If you absolutely need to have your tanks look good on the outside for some reason, you can buy ABX or AAX plywood (which has two good faces), at much higher prices. ACX plywood can be purchased at Lowe's, Home Depot, Fred Meyer's, and many other lumberyard-type places. Plywood is extremely strong for its cost, can be easily cut and shaped into many different configurations easily, and when glued together with epoxy glue is just like steel that has been welded together with welding rod. If you think of epoxy as a "wood welding compound", you'll have an accurate idea of how using plywood and epoxy can create a large structure that is MUCH STRONGER than any of its individual pieces by themselves.

**WARNING!** If you accidentally buy "Interior" plywood, expect it to gradually delaminate and fall apart; although this sometimes takes years. You can tell if you have exterior plywood because all plywood is supposed to have a "grade stamp" somewhere on it that states that is IS exterior plywood. If you're in doubt, cut off a 3" square piece of it, put it in a pot of water on your stove and BOIL IT for about half an hour. Let it cool, then if it's still holding together the next day after it's cooled off, it's exterior plywood.

**LUMBER:** Use "treated" lumber that is treated with a water-based Borate wood preservative. We're going to tell you to paint the tank plywood with this stuff anyway AFTER you've finished the tank, but BEFORE painting it. You can't use treated plywood to build the tanks with because the epoxy/fiberglass combination won't stick well to the Borate-treated wood (which feels kind of greasy when dry, and when wet is, well, WET). This is why we use untreated plywood to build the tanks with, fiberglass the inside of the tank, then treat the outside with a water-based Borate wood preservative before painting it. If you can find it, get DRY treated lumber (that was treated awhile ago, and has had time to dry back out). If you can't get dry lumber, buy it as long before you make the tank as you can, and store it in a dry place with "stickers", little strips of wood, stuck between the lumber in your stack, so it can dry out as much as possible.

**FASTENERS:** For fasteners, we recommend hot-dipped galvanized screws, in the sizes called out in the materials list. IF you have an air-powered nail gun, and you are GOOD with it, you can substitute galvanized gun nails for the screws we suggest you use. You can also hand-nail these tanks. However, a nail can never clamp a glue joint as tightly as a screw can, and although your joints will PROBABLY be OK, they will not be as strong if you use nails.

**EPOXY GLUE/RESIN; THIS IS REALLY IMPORTANT:** every single wood-to-wood joint in these tanks is glued together with the epoxy glue that you later fiberglass the plywood with. You could take all the fasteners OUT of one of these tanks after the glue has hardened, and the tanks would not be any weaker. Conversely, if you only used the screws and NO EPOXY GLUE, the tanks would fall apart. We've had people try to build these tanks this way (without the epoxy glue in the joints) because they "knew better", and they did fall apart. Epoxy glue is one of those things that should cost way more than it does because it solves BIG problems cheaply. Epoxy resin systems that work for these tanks include (but are not limited to): System Three, WEST System Resins, and other two-part epoxy resins that can be purchased at plastics supply houses, boating and marine supply stores, and fiberglass suppliers. Epoxy is the MOST expensive when you purchase it in small quantities; if you can find a place that sells it in five-gallon sizes, with one-gallon sizes of hardener, that will probably be the cheapest.

**IMPORTANT:** You will probably notice that Polyester Resin (sometimes called Surfboard Resin) is less expensive than epoxy. It is also much weaker, and bonds poorly to the wood. To get a polyester/fiberglass coating (layup) the same strength as one layer of fiberglass cloth with epoxy resin, you need to use three layers of fiberglass cloth with three times as much polyester resin. The problem with this is that although the polyester resin costs half as much as the epoxy resin does, you need to use three times as much of the resin, and three times as much fiberglass cloth. It ends up costing twice as much to use polyester for the same strength as epoxy. IT IS NOT GLUE, and cannot be used in place of epoxy glue; it does NOT glue joints together with any strength!! Also, most epoxies are food-grade, while polyester is NOT; it outgasses toxic solvents for quite awhile after you have manufactured it into a tank.

**FIBERGLASS:** Buy 6-ounce fiberglass cloth 50" wide from the same places that have the epoxy, in rolls for the best price. Usually. Shop around for both epoxy and fiberglass prices, because they can vary widely. If someone asks, this is standard "E" glass (for electrical). You don't need to buy the more expensive "S" glass (for structural) unless you're

planning on taking your fish tanks above the stratosphere. The epoxy and fiberglass suppliers will also often have cheap yellow plastic "squeegees" about 6 inches long, get a handful of these to use for squeegeeing resin onto flat horizontal plywood surfaces; they also often have the cheap bristle brushes and roller covers for resin, you will need 2" and 3" brushes and ten or more roller covers.

**PAINT:** The paint we recommend is Benjamin Moore Soft Gloss exterior Moorglo latex enamel. We paint the exterior non-fiberglassed surfaces of the tank with HiBor or other brand of borate water-base wood preservative and let it dry well before putting the paint on. We use three coats of paint, without using a primer. If you do use a primer, use a Benjamin Moore primer. Yes, I know you can get cheaper paint. Cheap paint is a fool's game, and we have heard so many horror stories from people who used cheap paint then spent days fixing the problems later. Benjamin Moore paint paints so easily, and covers and weathers so well, that it IS cheap paint and is worthwhile finding a dealer near you and putting in the time to get the RIGHT paint. It's what professional painters use, because their time is worth more than anything to them, and this paint takes less time to paint right and look good than any other. If you want to do a Cadillac job on your tanks, use three coats of a good oil-base polyurethane floor enamel in any color you like. This paint is hard as nails after it's dried for a couple of weeks, and is reasonably priced.

**BRUSHES:** For brushing the epoxy, use those throw-away cheap bristle brushes. Get ten or twenty of the 2" or 2-1/2" for painting glue joints, and ten or twenty of the 3" (4" is better if you can get them) for fiberglassing. Get a gallon of acetone and a gallon of lacquer thinner and a plastic or glass gallon jar with a screw-on lid (Why? Covered later in "Gluing Tricks"). Get a bucket of water, an old towel, and some "Simple Orange" or equivalent mechanic's hand cleaner for cleaning epoxy off your hands.

**FILLER:** For mixing with the epoxy resin to fill cracks and make fillets (explained later), use microballoons, which are tiny spheres of phenolic resin. They can be purchased the same places epoxy resin can. You can substitute a filler called microspheres for microballoons. Microspheres are tiny quartz spheres, but they are more work to work with, make a harder filler that is MUCH more difficult to sand if you need to sand it, AND use more resin, which actually makes them a MORE expensive filler to use. Don't be tempted to use cheaper fillers such as sawdust, chopped fiberglass, silica, or asbestos. They will make your job HELL IN CAPITAL LETTERS if you need to sand fillets or holes filled with them.

**TOOLS:** It's easy to build plywood tanks (or boats) if you have the following tools: measuring tape, hammer, carpenter's square, hand saw, battery-powered drill, drill bits, screwdriver bits, jigsaw (for cutting large round holes), 6-1/2" or 7-1/4" SkilSaw with good 42-tooth carbide blade, 4" or 4-1/2" minigrinder with some 50-grit and 36-grit disks, 5" or 6" orbital or random-motion sander with 80-grit and 60-grit sandpaper, 1-1/4" and 3" putty knives, a knife, scissors, regular sandpaper, a rasp, and a couple of plastic clipboards (yes, clipboards, cheap plastic ones. I'll explain in a bit); also, 2-oz plastic daisy cups, 4-oz plastic daisy cups, 8-oz plastic cups, and clean cans of all sizes up to a gallon, with no sharp edges on the top, all used to mix epoxy in. If you can afford it and know how to use one, a router with a 3/4" radius round-over bit makes rounding the outside corners REALLY EASY. If you have fewer tools than this, it's more work. Get a friend with tools and building skills involved if this sounds like Greek to you, or just bite the bullet, buy this stuff, and teach yourself how to use it all. There are some great Sunset books on "How To.....", that you can buy at most Home Depots and Lowes. It's how I got my first sailboat 40 years ago when I was 17 and had no money and fewer skills.

## 2. Gluing and Fastening (This should be called "Epoxy and Epoxy")

This is really simple: everytime you put two pieces of wood, or wood and plywood, together, you paint the contact surfaces on both sides with epoxy glue, then fasten them together with something that will hold them just long enough for the glue to harden. Epoxy glue is stronger than the wood itself; a properly glued epoxy joint will break the wood on one side or the other of the joint but NEVER at the glue line; so gluing pieces of wood together with epoxy glue is the same as WELDING them together; when you're done, you have one BIG piece of very strong wood. We use cheap galvanized 2-1/2" long #8 flathead screws or nails to clamp the joints together while the glue hardens, and although we COULD take them out afterwards without making the joint any weaker, that's a lot of WORK, which I'm personally allergic to, so we just leave them in.

Paint enough glue on both sides of your joint so that some squeezes out both sides of the joint when you put the joint together with screws or nails. Seeing this glue squeeze-out is the only way to know that you have enough glue in the joint. If you DON'T SEE the glue squeeze out, you may have a dry joint, which can be weak, and which there is NO way to fix after the fact so it is strong again. It's a one-shot deal. If you are gluing the plywood end-grain to another piece of plywood or wood, paint the end-grain piece first, then paint some glue on your other mating piece, then come back and paint a second coat of glue on the plywood end-grain because it will have soaked all the first coat into the grain. It is a

good idea to let the epoxy-painted areas on ANY wood-to-wood joint have what's called "open-joint time", which means you paint the glue onto them, then let the glue soak into the two pieces of wood for five minutes or so before you slap them together. If you just throw the joint together as soon as you finish paint the glue on, without letting it have open-joint time, the excess glue will squeeze out of the joint, THEN the wood on either side of the joint will absorb glue AWAY from the glued surface, making the glued surface dry and weak. Giving your glue joints five minutes of open-joint time makes them STRONG!

Epoxy is a two-part resin glue that can also be used for fiberglassing (covered next). When you mix the two parts (called hardener and resin) together in the correct amounts, the glue will remain liquid for a certain time (called the working time), then start to get hard, then become completely rock-hard. Epoxies are formulated to match temperature conditions in the work environment; there is a cold-weather epoxy for 60 degrees or below, epoxy for 75 to 85 degrees, and epoxies for above 85 degrees. These are often available as different hardeners that are sold with a single resin system, and are often called FAST hardener (for cold-weather conditions), REGULAR hardener (for room-temp weather conditions), and SLOW hardener (for hot weather conditions). Epoxies DO NOT WORK the same way as polyester (surfboard) resin does; you CANNOT mix more hardener in to get them to set faster, and less hardener in to get them to set more slowly. If you do this, you will simply have a slimy mess that does not set up AT ALL, and that you have to scrape off and wash with acetone before you can try again! Epoxies are designed to work ONLY with preset mixing ratios (that are different, and that are specified for whichever particular brand you purchase). In other words, you need to mix the epoxy EXACTLY as the directions specify, and not change the mix ratio. Especially do not mix hardener from one brand of epoxy with resin from another, it may also give you a slimy mess to clean up.

Slow, regular, and fast refer to the relative time that the mixtures of different hardeners and resin take to gel in your mixing container, and then to get hard on the surface you apply them to. Generally speaking, warmth makes ANY epoxy set up faster, cold makes ANY epoxy set up more slowly. You would get a slow hardener if you are working in hot conditions, OR if you need a long working time and need the glue to stay liquid a long time before setting-up. You would get a fast hardener if you were working in cold conditions, OR if you needed the glue to set up really fast. You would be smart to buy small amounts of the different hardeners of the epoxy system you are thinking of working with, and try them out in your working temperatures to see how long a working time they give you, and how fast they gel and harden, BEFORE you purchase any large amounts. Using your small sample amounts of epoxy, glue up some small pieces of plywood and wood, then fiberglass one side of the plywood for practice. After these have hardened, you can have fun trying to break the glue joints or trying to make dings in the epoxy fiberglass surface. You will be surprised how much force it takes, and what a super material this stuff is.

**IMPORTANT:** Epoxy comes in a variety of "systems". An epoxy system will usually consist of one or more different types of resin, and two or more different "speeds" of hardener (usually slow, medium, and fast). Each system uses the same mixing ratio for its resin and hardeners; BUT this can vary from system to system. You can generally purchase what are called "mixing pumps" for these systems that screw onto the resin cans and give you the right ratios of resin to hardener for your mix automatically. Each system will have different ratio mixing pumps, and you also can't use the pumps from one system for another. You CAN'T mix epoxy from one system with another, and you CAN'T mix two epoxies from the same system that have DIFFERENT mixing ratios. Well, you can, but you get epoxy soup, jello, or coagulated blobs as a result, not glue. So settle on a good epoxy system and stick with it.

**WARNING! Be VERY AWARE that epoxy does something called "exotherming". This means that if you mix up a lot of epoxy in a big can (say gallon size), and don't get it out of the can onto your surfaces fairly fast, the epoxy in the can will start getting HOTTER. As epoxy gets hotter, the chemical transformation that turns it hard moves FASTER, and it gets HOTTER because it is getting HOTTER. If you're concerned about the \$60 per gallon or so you paid for the epoxy, this is what's called a "negative feedback loop". It gets worse FAST, and it is only a matter of seconds sometimes if you haven't noticed it until the can starts to smoke. If you have enough epoxy in a large enough can and turn your back on it for too long, it will actually start to burn, not to mention burning your hand if you touch the can. This is also the reason that you DON'T throw an exotherming can of epoxy into the trash: the trash can may go up in flames a couple of minutes later! And REALLY, REALLY, DON'T EVER LET EXOTHERMING EPOXY NEAR ACETONE OR LACQUER THINNER!!! We told you so. And that wing of the house really was laid out wrong, and you were thinking of redoing it anyway, right?**

You deal with epoxy's tendency to exotherm by mixing small batches of epoxy at first, until you get used to working with it. IF a batch of epoxy starts to exotherm, you'll notice this first because the epoxy in the center of the can will get GUMMY and viscous (before it starts to smoke). DON'T put any more epoxy on your work when you see this happening; STOP, put the can DOWN on a dirt or concrete floor away from flammables, clean the piece you were working on so it

has a clean edge for the next batch, clean your brush, squeegee, and hands, take a five-minute break and a few deep breaths, and start again, this time mixing a little less and learning how to work a little faster and cleaner. Throw away the exothermed can after it has cooled down completely; it is useless for mixing resin now.

**IMPORTANT: Don't EVER work in direct sun if you can avoid it!** Epoxy in the sun heats up and hardens up REALLY fast, and can cut your working time by a factor of ten or more. Also, if you're trying to fiberglass something so that it is waterproof, epoxy setting up in the sun tends to get little bubbles that are indicative of AIR passing through the fiberglass cloth, which means it is NOT the waterproof barrier you're intending to create. If you're working on something big that can't be moved inside, then you should take the time to rig some kind of a tent or shade to keep the sun off the part you're working on. Or at the very least, do your fiberglassing early in the evening or in the morning under lights. You also need to keep moisture off anything you're working on that is outside, so you may need some kind of tarp anyway to do this.

**WARNING! Be AWARE that epoxy, if not measured accurately and mixed thoroughly, will sometimes never get hard! The only thing worse than epoxy that goes off too fast is epoxy that DOESN'T GO OFF AT ALL! Now you have a REAL mess to clean up that makes exotherming look like a party. You have to scrape the epoxy off, then wash the wood surface with a couple changes of acetone and rags, wearing gloves and using a breather mask so you don't inhale acetone vapors. This is dangerous to say the least, and there's no other way to get unhardened epoxy off. The best way to measure epoxy accurately is buy a set of mixing pumps; they make these for every epoxy resin system and ratio available, and they are a good investment and guarantee of good mixes if you use them properly. Read the directions!**

Getting wet is a concern if you're working outside; I've had epoxy layups set up for an hour or so and still be sticky when a torrential rain came down. The next day, after the epoxy had gotten dried-off and baked in the sun for a couple of hours, it was all hard, just a little milky where the water had puddled. I never was able to test this milky epoxy quantitatively to see if it had lost strength or adhesion, but it seemed quite hard, and worked all right on the boat for the next 17 years. However, IF your epoxy is still LIQUID when it starts raining, you need to write it off. Scrape as much off as you can with rubber gloves on, in the rain, while it is still wet (doesn't this sound like FUN?). After the rain is gone, let what's left get hard, then grind it off until it's smooth and ready to do the job again. Because epoxy underwater doesn't set up exactly the same way, or as hard, as epoxy that is dry, this will likely gum up fifty to a hundred bucks worth of grinding disks before you are back to the bare wood surface you need to have in order to be able to start all over. Oh, and you need to wait until the wood is dry to grind it off, which may take a couple of days, or weeks, depending on how much it rains or dews at night in your location. Is it starting to sound like building tanks inside a shelter or buying and rigging some tarps to keep them dry might be a good idea? It is!

**IMPORTANT: Before you EVER mix any epoxy for glue, putty, or fiberglassing, make absolutely CERTAIN:**

- ✓ Your work is completely ready to go; that every part is cut, sanded, rounded, pre-drilled with holes, (or whatever else needs to happen), fitted to the other parts it needs to match up to, and placed close to where it gets installed. If you have a complex item to make, name and/or number all your parts, and write on the end of a part "this end connects to the so-and-so", then assembly will be a breeze. If you have trouble visualizing this, make yourself a sketch of this that MAKES SENSE TO YOU, then consult that sketch while you are assembling the item. Remember, you can often stop halfway through an item and finish tomorrow, just remember to put temporary braces on with screws (and NO glue) to hold parts at the correct angles and locations; the epoxy will set up overnight and you WON'T BE ABLE TO ADJUST ANYTHING the next day!
- ✓ Make sure all sawdust and chips are brushed or blown off your parts with compressed air so you don't get this stuff incorporated into your glue joints and fiberglass job.
- ✓ Make sure that all brushes, squeegees, putty and fiberglass tools are clean and ready to work with and set out near at hand. Make sure they are not sticky from the batch of putty or epoxy from ten minutes ago that no one bothered to clean off them, or even worse, covered with sharp little snags and lumps that will grab your fiberglass cloth because the epoxy was allowed to harden overnight into bumps and knots all over the tools.
- ✓ Make sure that any fiberglass pieces you're going to use are cut, neatly folded, and weighted down on a clean sawhorse or other shop surface so they can't blow off onto the ground.
- ✓ Make sure screwdriver drill batteries are charged, you have the correct driver bit in them, and that you have a can or box of the correct screws right next to your work or in your toolbelt nailbags.
- ✓ If you're clamping something, have the clamps ready and open to the right distance.
- ✓ Have something to drink that's easy to grab sitting somewhere it can't accidentally get knocked onto your work and get it wet, in a glass or bottle that doesn't care if it gets epoxy boogers all over the outside.

- ✓ Have all these ready and available: mechanic's hand cleaner dispenser, a bucket of rinse water for after you clean off with the hand cleaner, and clean rags to dry your hands on. I've gotten epoxy in my eyes before, and simply gone into the house and rinsed WELL with warm water out of the sink, with no apparent ill effect afterwards. This doesn't work with polyester resin, you can burn your corneas with that stuff.
- ✓ DON'T have your best iPod out and playing music to work to, because you are going to need to turn it down, or skip a song, or something, and forget and get epoxy all over the touchpad. This makes an iPod last a VERY short time (ask me how I know!). What DOES work is to put the iPod into a baggie with its cord coming out the end, and just get the epoxy on the baggie. This trick works for phones and cellphones also.

**Gluing Tricks:** Here are some gluing tricks to make the best possible joints, and to make your job easy:

Trick #0: Work cleanly! IF you put a piece of colored masking tape on the side of the epoxy mixing can that you will grab with your fingers, use it to "cue on" when you're going for the can, and ALWAYS grab it by that colored tape side, then ALWAYS wipe your brush off on the other side, then you have a CHANCE of coming out of an epoxy job with clean fingers. Treat your squeegee the same way: don't lay it down in the resin, and if it gets resin on the area you hold it by, grab a rag and wipe it clean right away. Have small 12" by 12" (or so) scraps of plywood available to use as "coasters" to set your epoxy can, squeegees, and brush down on, otherwise you will leave all kinds of epoxy "boogers" around your shop that will harden and have to be scraped or ground off whatever you boogered on later. If you follow these guidelines, your squeegee, brush, and can grab surfaces will stay free of sticky epoxy, and your job will be a breeze. Conversely, if you get your hands sticky, everything tends to go downhill from there, starting with your inability to handle things without sticking to them. STOP, clean off with rags (and hand cleaner/rinse/dry if you got that badly fouled) and try it again, cleanly this time!

Trick #1: Paint the glue on both of your joint surfaces, then put your brush back in the brush garage (see trick #3) and come back 1 to 5 minutes later and assemble the joint. This is called "open-joint time", and will allow glue to soak into both your pieces of wood, ensuring a much stronger joint. If you paint the glue on then jam the joint together quickly before the glue has had time to soak into the wood, all the excess glue will squeeze out of the joint, and THEN the wood soaks up the glue that is left in the joint, making the joint DRY and relatively WEAK. This is why we do open-joint time. If you notice that your wood has REALLY soaked up the glue, put a second coat on and let it sit awhile so that it looks "glossy" before assembling the joint. You know you did a good job if glue squeezes out all along the joint. It is NOT a waste of glue, it is a valuable indication that you have a joint you can depend on!

Trick #2: To make a clean joint after the two pieces have been fastened together and the excess epoxy has squeezed out of the joint, clean the squeezed-out glue off both sides of the joint with a flexible putty knife and/or rags, then clean the putty knife off with a rag. Have plenty of rags, put them in the trash when they get too gluey, and DON'T pick up a glue-covered rag by accident. If you do, see #4 and clean your hands right away! If you are the type who doesn't mind the feel of rubber or thin plastic gloves (I HATE THEM!), you can try using them. Work clean!

Trick #3: Make a brush "garage". This is a glass or plastic gallon jar with a screw-on lid. You put about an inch of acetone and another inch of lacquer thinner, in the bottom of this jar. When you finish painting epoxy in a glue joint or a fiberglass job, wipe the excess epoxy off the brush into your epoxy can, then put the brush into the brush garage. Mosh it around down there in the solvent until all the epoxy is washed out of the bristles, then just leave it there (with the lid on) until your next epoxy job. You just take it out the next time you need it, whack it a couple of times against the leg of a sawhorse to get it dry, then use it. You can keep these "throwaway" brushes going for months this way, and save yourself a ton of money over actually throwing them away. Note: every so often you will see your acetone/lacquer thinner mixture in the brush garage getting really THICK; this means it's time to throw it away and refill the garage with new solvent. If you ignore this, you will notice because the stuff sets up inside the brush garage, and you have to throw the whole thing away. Dispose of this stuff in a conscious and safe manner, it's flammable AND somewhat toxic.

Trick #4: Cleaning your hands and tools: Get some "Simple Orange" or similar brand automotive mechanic's hand cleaner, and a bucket of water. After getting epoxy on your hands, put a couple of squirts of the hand cleaner on, scrub your hands well with it to get all the epoxy loose, then rinse in the water to get the loosened epoxy and hand cleaner off your hands, and dry with a shop rag. It will completely take the "sticky" from the glue off your hands. DO NOT EVER, EVER, wash your hands or skin with acetone or any other solvents; you will simply dilute the resin, then the solvent will take it directly through your skin into your blood stream. This is how they give medications to hemophiliacs (people who bleed abnormally; they can't give them a shot because the little hole from the needle will bleed for hours afterwards), they mix the medication with medically pure acetone and PAINT IT on the patient's skin. You're warned! Work clean and clean up clean!

Trick #5: Get the right tools and teach yourself how to use them. Make some simple stuff first before you tackle your first tank. Try making a box out of some scrap plywood. Put wheels on it and make a kid's wagon out of it. Make a box with straight sides and 90-degree corners, then try and break it to see how good your glue joints were. Learn how to use the sanders. Have someone who knows saw safety teach you how to use the SkilSaw, because you can really take a piece of yourself off with one! Get used to using all this stuff FIRST, before you have sticky glue on everything as well making it ten times as difficult. And when you notice you have sticky glue all over you, you should start thinking about what it would take to Work Clean! Working clean simply means only having a touch or two of sticky spots on your hands and clothing after a couple hours of working with epoxy. Not always attainable, but as they say "Worth the trouble!".

### 3. Filleting and Sanding (and NOT Sanding!)

We talk about fillets next because they're usually the next thing you do after gluing the pieces together, but often before the final fiberglassing is done. A fillet is a rounded bead of epoxy/microballoon putty you put into a corner between two pieces of plywood with a wooden tongue depressor. The rounded end of the tongue depressor makes exactly the right radius. When you put this into an inside corner, it not only helps glue the corner together more strongly, but ALSO gives you a very easy corner to fiberglass later. There are two ways to do this:

#1. Put the fillet in, doing the cleanest, most careful job you can do. To do this, you mix up your microballoon/epoxy putty with a putty knife on a clean piece of plywood about the size of a clipboard (a cheap plastic clipboard actually works VERY WELL for this putty mixing board). Mix the microballoons into the epoxy with a 3" putty knife in a place that is NOT windy (microballoons are not only expensive, they are very light, and will blow away off your clipboard to be lost in the dirt if you try to mix them in the wind) to a consistency like stiff whipped cream, so they will hold a "stiff peak", then use a standard 3/4" wide tongue depressor (TD) to apply the putty into the corner between your two pieces of plywood or boards. Tuck gobs of putty into the corner with the tip of the TD and wipe them back and forth, until you have a wad of putty in the corner for about 18" or so of the corner's length. Then, putting the TD flat against one of the sides that make the corner, AND 90 degrees from the corner, scrape off the excess putty on this side and wipe it back off on the putty board. Next, put the TD flat against the OTHER side, and scrape off the excess putty on that side. If you do this right, the fillet that's left will be smooth, round, and require a minimum of sanding. If your fillet has holes in it, apply more putty next time before you wipe the excess off. If it has bumps, you didn't wipe carefully, and this will cost you later with more sanding than if you'd left a neat, smooth fillet. Once you get good at this, you will be very fast, and can apply tens of feet of fillets in a matter of ten or twenty minutes.

Mix small batches of putty at first until you get the hang of it, because it will harden up faster if it's left in a big lump on the putty board while you are messing around with a few inches of fillet, trying to get it perfect. DON'T BOTHER! You will get good at this quickly, and you'll be able to just rip when you're laying down a fillet. After you're done you let it harden overnight or so until it's completely dry and hard, then sand the bumps off before you put any fiberglass over this corner. You will probably be wise to start out doing it this way until you get some fiberglassing experience under your belt and are ready to try #2 which follows:

#2. Put the fillet in with your fiberglass pieces all measured, cut, weighted down and ready to go on, and put the fiberglass right on over the wet epoxy fillet BEFORE the fillet hardens and needs to be sanded. I'll talk about this in much more detail in the section "Putting Together The Pieces", where I explain why you do NOT want to assemble a tank before fiberglassing if you can help it. This avoids needing to sand and blow off the fillets before fiberglassing them, and saves A TON of time, but it is not for the fainthearted or those with little experience with fiberglass and epoxy resin.

### 4. Fiberglassing

The most important thing to know about fiberglassing is: you WANT to fiberglass pieces of plywood when they are HORIZONTAL, THEN assemble them into structures if you can. You do NOT want to assemble a tank BEFORE fiberglassing if you can help it. This is unless you have a ten-ton crane the way we do, and can ROTATE the 2,000 pound tank so each surface you're working on is horizontal when you fiberglass it. I work on boats this way, and while it's worth the extra trouble it takes to turn the boat so my fiberglass surface is horizontal, I also fiberglass everything that it's possible to fiberglass flat on a bench in the shop, BEFORE ever assembling it onto the boat. When you understand how fiberglass works, you'll also understand why you want to do it this way. NEVER get yourself into a situation where you need to fiberglass vertical surfaces; this is like those disclaimers in car commercials: "Professional driver, closed course". Fiberglassing upside-down on ceilings is kind of like Evil Knievel jumping the Grand Canyon on a motorcycle, don't try it unless you're him.

The easy way to accomplish this is to put the pieces of one tank side together with buttblocks, then install all your 2X stiffeners onto the tank sides while they're laying flat on a couple of sawhorses, then fill and sand the fastener holes, then fiberglass the entire tank side while it's still laying horizontally on the horses, then assemble the tank sides into a tank. It is SO easy this way, and the tank side (the biggest and heaviest single thing you have to deal with) is only about a sixth of the weight of the finished tank!

When someone says they're "fiberglassing" something, they're talking about two components: fiberglass cloth that goes onto a surface, and some kind of resin that you use to saturate it with. The resin hardens and gets strong, both bonding the fiberglass cloth to the surface under it, and making the surface very hard, waterproof, and puncture-resistant at the same time. Fiberglass cloth is actually made from GLASS, the same stuff they make windows from. Although brittle and easily broken when in the form of a window, glass becomes very flexible when formed into a thin thread, then spun into yarn and woven into fiberglass cloth.

There are other special-purpose forms of fiberglass: matt, roving, biaxial, triaxial, and many special types of fiberglass fabrics for use in boats, airplanes, and space shuttles. We will be using the most common and affordable forms of fiberglass: 6-ounce cloth and some 24-ounce roving. 6-ounce fiberglass cloth has a texture like fairly fine burlap; you can see the individual thread it's made from quite easily. It feels silky to the touch, but don't let this fool you into rubbing it onto your cheek; it IS glass, and you will embed many fine GLASS slivers into your sensitive skin when you do this.

When you work with fiberglass, long pants, shoes with socks, and long-sleeve shirts are advisable. This is because the little fibers (little GLASS needles!) that come off the fiberglass will get on your skin if the skin isn't covered completely. This doesn't bother some people, but makes others itch like crazy. When you take these clothes off, store and wash them separately from any other clothes, because small bits of glass fibers get stuck in the clothes and migrate to other non-work clothes in the washing machine and dryer, making them itchy too! You MUST use a breathing mask or respirator of some kind, even when working in the open air, because small bits of glass fibers shed off the cloth and float around in the air for you to suck in. These fibers will stick in your lung surfaces and will NOT come out; breathing fiberglass dust can create what's called silicosis, which is a destructive lung disease. Wearing long pants, long-sleeved shirts, and a good breathing mask, you are ready to work safely with fiberglass.

Several layers and/or types of fiberglass are often combined, laid down dry, and then "wet out", or saturated with resin, to make what's called a "layup", a finished fiberglass covering for a wood structure like a boat or tank, or a fiberglass part for a boat or car. When someone says something is "fiberglassed", they are referring to the fact that the DRY fiberglass cloth needs to be wet out with a resin to make the complete "fiberglass" job or item.

There are many kinds of resin; the two most common are epoxy and polyester. Polyester resin is the stuff they make surfboards and fiberglass boats with, it is the resin in Bondo and other car body fillers; and it has a distinctive sharp odor from the methyl ethyl ketone and esters in the resin. This resin will burn your skin if you get it on you, and the hardener (methyl ethyl ketone peroxide in dimethyl pthalate, or MEKP) is a strong oxidizer that is like battery acid on your skin. Polyester resin is only one-third the strength of epoxy resin, and has about one-tenth the adhesion to a wood surface that epoxy resin does.

This means that not only will your polyester fiberglass job peel off the wood subsurface relatively easily, but also that you need to use THREE TIMES AS MUCH of both resin and fiberglass cloth to get the same strength as if you are using epoxy and fiberglass cloth. This is why, although epoxy resin costs from 50-100% MORE per gallon than polyester, it is actually CHEAPER. To get the same strength as a polyester "layup" using three layers of fiberglass cloth and three gallons of polyester resin, you only need to use ONE layer of fiberglass cloth with ONE gallon of epoxy resin. Although your epoxy resin costs twice as much, you only use one-third as much resin AND one-third as much cloth. Your resulting epoxy/fiberglass job, FOR THE SAME STRENGTH, costs HALF as much as if you'd done the same thing with three times as much polyester resin and fiberglass cloth. So, unless you are in a situation where fiberglass cloth is nearly free and epoxy resin costs five times as much as polyester, we don't need to talk about polyester resin again. If you are forced to use polyester, use breather masks, rubber gloves, good ventilation, protective eyewear, and don't get it on your skin, in addition to all the protective measures mentioned before.

These are the steps involved in a successful fiberglass job with epoxy:

**Build it right:** Whatever you're fiberglassing needs to be soundly and strongly built first. We are not saying you have to build it first and then fiberglass it, because we just spoke about the advantages of fiberglassing parts first while flat and then assembling them. We are referring to the need for the joints in your structure to be properly glued and

fastened together. The thin layers of fiberglass we use impart minimal structural strength and will NOT make a weak structure strong. You need to glue your structure together correctly, or the fiberglass will just be a waste of time and money. We use thin fiberglass because it adequately waterproofs the plywood and give it a hard skin that is difficult to puncture. Doing it this way doesn't use a lot of expensive resin and fiberglass, but gives you the good result of a durable and waterproof tank.

**Prepare it right:** Before you can fiberglass it, whatever you build needs:

- ✓ To be dry. All wood surfaces need to be dry before you can fiberglass them. If it's wet the fiberglass won't stick, and the resin may not completely get hard.
- ✓ To have all the holes, cracks and crevices filled with epoxy/microballoon putty. Fiberglassing a surface DOES NOT fill gaps, cracks, or holes. Gaps from holes or crevices underneath the fiberglass may mean leaks into the plywood later, which cause rot and premature failure of tanks.
- ✓ To be sanded smooth then dusted or vacuumed or blown off with compressed air to get it clean. If there's a bunch of junk on the surface, and you put fiberglass cloth over it, it will result in bumps and voids that make a poor glass job and will promote leaks in the future (if not right away).
- ✓ To be in the shade. If you work in the sun, you not only have made it almost impossible for yourself with resin that is setting up within minutes of application, but have also made a poor glass job.
- ✓ To be reachable (Q: How do you fiberglass the middle of an 8-foot wide tank? A: with four-foot long arms!). All preparation for accessibility (ie, scaffolds, stepladders, painter's planks, etc) needs to happen before you can get the fiberglass cut and ready to go on, and REALLY needs to happen before you EVER mix any resin.
- ✓ Your fiberglass cloth needs to have been stored so that it can't get wet, or even damp. Fiberglass cloth that has gotten wet once CANNOT EVER be completely dried out so that it is as strong as new, dry cloth, and this may weaken your glass job or the bond of the fiberglass to the wood.

**Cut and apply the fiberglass dry first:**

- ✓ Roll out the dry fiberglass cloth on your clean horizontal surface, cut it, and weight it down with CLEAN weights that won't shed junk onto it; dirty weights such as rocks can make a mess when you come by with the resin.
- ✓ If your surface is wider than the width of the fiberglass cloth, roll out a second piece, making a 2" overlap with the first one. More overlap than this is unnecessary, less is OK, but don't get less than an inch or so of overlap.
- ✓ If you're fiberglassing 48" wide tank sides, buying 50" wide 6 ounce fiberglass cloth is perfect: you won't have to use two pieces and then throwaway the cutoff strip.
- ✓ Take your DRY (not sticky!) plastic or rubber squeegee and lightly squeegee the dry fiberglass cloth down, starting from the middle of your piece and going long ways out to the ends to eliminate bubbles and wrinkles.
- ✓ After squeegeeing out the dry cloth with your dry squeegee, you will sometimes have a "bubble" of cloth at the ends. You put clean weights on the edges and ends of the fiberglass cloth when you first laid it out, just lift these weights and squeegee the cloth underneath them, then put them back down in the same place. You end up with a piece of cloth that is squeegeed flat and weighted down. Now your cloth stays in place while you are applying the resin to it.
- ✓ Also, if it is windy, trim the edges of the fiberglass cloth closely to the edge of the plywood surface you're fiberglassing so it doesn't blow up and wrap onto the top of itself when wet with resin; this makes a real mess!

**Wetting-out the fiberglass:**

- ✓ After making sure that you have all your tools ready (squeegees, scissors, rags, hand cleaner, etc), and your fiberglass cloth is squeegeed down dry on your plywood and weighted so it won't blow away, you can mix resin and begin fiberglassing. This is what's known as the laminating coat; you are laminating the fiberglass to the wood surface underneath.
- ✓ Start by mixing small amounts of resin, until you know how much you can comfortably work with in the time you have before it starts to gel and get hard (what's known as "pot life"). If you have a fast hardener and/or a relatively fast setting epoxy system, you will want to mix smaller batches. Also, until you are experienced with how much resin a job requires, if you mix larger batches, you may find that you just mixed a gallon of resin when you only needed a quart, and have to throw away the other three quarts.
- ✓ Don't mix until you are completely ready to commit the time necessary to do the job. If you have a two-hour job, don't mix resin half an hour before the cook calls lunch. DON'T EVER WALK AWAY IN THE MIDDLE OF MIXING A BATCH OF RESIN, to answer the phone, get a drink of water, etc. You run the chance of not remembering how much of what you have already put into your mixing can, and either adding more, not enough, or going ahead and mixing what you think is both parts of your epoxy when you haven't even added the hardener yet (my trick!).
- ✓ WET IT OUT: With your plywood surface horizontal, start in the MIDDLE of the workpiece, and pour about half your first mixed batch of resin out onto the surface. Take your yellow plastic squeegee (or rubber, or other cheap plastic

squeegee), and spread the resin left and right, left and right, with repetitive movements of your hand and arm, holding the squeegee at a slight angle towards your direction of hand movement, and only using a slight pressure downwards on the cloth (1/2 to 1 pound or so). If you have a 4-foot wide piece of plywood as often happens, work from both sides. Move pools of resin around on the work surface with the squeegee until it has contacted all the fiberglass cloth. You will see the fiberglass cloth start becoming transparent as the resin saturates it. When the cloth has turned from the white it is when dry so it is completely transparent with no white strands showing so that you can clearly see the plywood underneath, you have completely saturated the cloth. Check for any little places it still shows white, and squeegee the resin back over that place until it turns clear. Now it's time for the next part of this process.

- ✓ Note: If you've moved the pools of resin around and around, and there STILL is an area of the cloth that is white, or ghostly white, and you've moved the pool of resin over that area repeatedly, and the area is still not completely clear so you can see the plywood underneath, then you probably are fiberglassing with cloth that is, or was at some time, WET in the white area. There is no way to fix this but to keep your cloth dry next time until you use it.
- ✓ SQUEEGEE IT OUT: If you've kept your fiberglass dry and followed instructions so far, you have a saturated piece of fiberglass cloth that looks quite clear, and you can see the wood grain underneath easily. You'll notice that the resin is pooled up and very thick in some places and not as thick in other places. To fix this, and to leave only the amount of resin in the cloth that is necessary for best strength and waterproofness, take your squeegee and squeegee from the center of your workpiece out towards one end with slightly more downwards pressure on the cloth (about 3-4 lbs or so). This slight extra pressure will squeeze all the excess resin out of the cloth and towards the dry end of your workpiece. After finishing an area with this technique, you will be able to clearly see the cloth "grain" and although the cloth is still transparent and wet out with the resin, you have removed all the excess resin and moved it towards the dry end of your work where you will now use it to wet out that area. Squeegeeing the resin out like this uses the minimum amount of expensive resin, and makes your job stronger than leaving those fat pools of resin on the surface. It also makes it look nice and professional!
- ✓ Repeat this process of putting resin on, wetting out the fiberglass cloth and squeegeeing the excess resin out until you reach the end of your work piece. Some anticipation is needed here, because if you dump a bunch more resin than you need onto the work near the end, you will just have to squeegee it off again into your mixing can. So, in addition to only mixing small batches as you near either end of your work piece, just put a little resin on at a time so you don't have to scrape a bunch back off.
- ✓ If you have small areas of work that you can't use a squeegee on, or parts of the work that are vertical surfaces, you can apply resin with a 3" or 4" brush, then wipe the extra epoxy off the brush into the mixing can and use the now-dry brush as a squeegee to flatten bubbles and spread epoxy from thick spots to dry spots. This is how we squeegee down the fiberglass in any corners over the tops of fillets, whether the fillets are wet or dry.
- ✓ You're DONE (!! ) when you can see the cloth grain on the whole work piece, and there are no puddles of resin (which show up as big glossy spots on the cloth where you can't see the cloth grain), and no white spots indicating that the cloth hasn't been saturated there yet. Now you clean up.

### **Glass job cleanup:**

- ✓ After you're DONE, wipe all the epoxy off any brushes into the mixing can(s) and put the brushes back into the brush garage, mashing them around to get the epoxy off them.
- ✓ Wipe ALL the epoxy off the squeegees with a rag until they're dry and clean. If you leave a little epoxy on the squeegee each time, it will build up to the point the squeegee is unusable, or will give you a poor glass job. Even cheap squeegees are a couple of bucks each, and throwing them away each time adds up. Check the squeegee's edge with your finger before you use it the next time. If you can feel a little "snag" with your finger, just run a piece of 120-grit sandpaper over it to smooth it down before using it again.
- ✓ Clean off your hands (Gluing Tricks #4).
- ✓ Clean off the cat, who walked under the tank side you were working on at just the wrong moment. Don't use acetone, this will result in a flammable and grumpy cat, use the mechanic's hand cleaner and water.
- ✓ The first time you fiberglass, you're thinking so hard about doing the job right you may get resin into your slippers, shoes, on your pants, shirt, etc. Get these things off before the resin hardens up because they will get glued to you when the resin hardens, and will remove skin when you try to remove them. Use the mechanic's hand cleaner on the parts of your body they were starting to get glued to. Try to work more cleanly next time.

### **Fill-coating the fiberglass:**

- ✓ After the laminating coat is completely dry to the touch, you can put on the fill coat. The fill coat fills in the grainy-appearing surface of the fiberglass that is left after the laminating coat and gives you a smooth glossy surface that's ready to sand and paint, or just to use. Depending on how thickly you roll on the fill coat, you may need two fill coats to completely fill in the cloth weave.

- ✓ Use a good 9" roller handle with a short-nap cheap 9" roller, and a cheap DEEP metal or plastic roller pan. Stay away from foam rollers unless you're absolutely SURE they won't disintegrate when they get soaked with epoxy (most do!).
- ✓ Mix small batches until you're sure how much resin you can handle at a time. Mix the resin in a can, then pour into your deep roller pan. Roll the resin thickly onto your work surface, then roll back over it several times with strokes in different directions to even it out. This is NOT painting, where you are trying to put on a relatively thin coat and prevent runs or drips. This is a horizontal surface (hopefully!), and you can roll on a thick coat that can fill the grain of the fiberglass cloth completely. If you do, you won't have to put on a second coat.
- ✓ Even if you are going to assemble this flat piece with several other pieces into a tank, you should fill-coat it now while it's horizontal, as it may be vertical later, and will require two or three fill coats to completely fill then. This is because you can't put a fill coat on a vertical surface as thickly as you can now when it's horizontal.

## 5. Putting Together The Pieces

You do NOT want to assemble a tank BEFORE fiberglassing if you can help it, unless you have a ten-ton crane and can ROTATE the heavy tank so each surface you're working on is horizontal when you fiberglass it. So, most of us (without crane) will follow the following assembly procedure after we've built our tank pieces, fiberglassed them while flat on sawhorses, and put the fill coat on them while flat on sawhorses.

### **Assembly:**

- ✓ After the fill coat(s) is completely dry to the touch, you can assemble the pieces of your tank. We start with the bottom of the tank set flat on strong sawhorses, with the sawhorses set so you can reach all the screw locations around the edges and inside the tank from the bottom with the battery screwgun. Pre-drill clearance holes for the screws at 8" or so apart on all parts of the tank. You need to have planned out how the pieces overlap, in other words, which piece goes on top and which on the bottom, and so on. Install one side of the tank first onto the bottom, and put temporary braces of 1x2's with screws or something similar to hold it upright at each end. You will probably need at least two people to maneuver a 4-foot by 16-foot long tank side up onto the tank bottom into its correct location. Having more people makes it easier and safer.
- ✓ Oh, I almost forgot to remind you to put glue on both mating surfaces: tank bottom and tank side, before lifting the tank side up into place. This of course makes it extremely slippery once you place the two glue surfaces together, and also makes picking up the tank side without getting epoxy all over your hands somewhat problematical. Don't worry, it is possible. After you have two or three of these under your belt, it will seem like a breeze, and the nightmare of the first tank side going onto the first tank bottom will be a hazy memory.
- ✓ Move the tank side so that one end of it matches up EXACTLY with the end of the tank bottom, and, while a couple of strong people (or temporary 1X2 braces) hold the tank side up and keep it from falling off the tank bottom onto the ground, where the glued surfaces will get covered with dirt and gravel, meaning you need to start all over, put in one 2-1/2" #8 flathead screw (the "standard" fastener for this type of tank construction) there. Next, put in one screw midway between the first screw and the other end of the tank, aligning the side of the tank flush with the edge of the tank bottom plywood at the same time. You may have to shove the tank side in or out to get it to line up. Put a third screw into this joint at the far end from the first screw you installed, again lining up the edges of tank bottom and side before screwing. Now your tank side is nominally connected to the tank bottom by these three screws, and you need to put in the rest of the screws.
- ✓ To put in the rest of the screws, you first put in a screw that is located halfway between one end screw and the middle screw you already put in, pushing the tank side in or out to align it with the edge of the tank bottom first. There are two of these: a screw halfway between your middle screw and each end screw. This now has your tank side aligned with the tank bottom in five locations where the five screws are. Usually this is enough to make the tank side reasonably straight and aligned with the tank bottom. If it's not, just put in additional screws in locations where the side and bottom are not yet aligned, pushing the side into alignment first. When the side of the tank reasonably follows the bottom of the tank, put in all the rest of the screws.
- ✓ **IMPORTANT:** When you install a side of the tank, you either need to install the ends and inside bulkheads of the tank at the same time to keep it at a 90-degree angle to the bottom, or you need to install temporary braces that you can remove later when you do install the ends and inside bulkheads. Why is this? Well, imagine just leaving the tank side where it is, and then the epoxy glue setting up. It will be solidly fastened there, and when you try to install a tank end that has a 90-degree angle corner onto the tank side, which may have had its glue set up at an 85-degree angle, you will find that you can't move the tank side, and have to trim a chunk off the tank end. Now, your tank will have an 85-degree angle corner in it, which will not only make it look wonky, but will throw off everything else you glue onto the tank. Just get everything 90 degrees and you'll have a much easier time.

### **Final Inside Seam Filleting And Fiberglassing After Assembly:**

- ✓ After all the tank pieces have been assembled together, and the glue on all the joints is completely dry to the touch, you can start filleting seams and fiberglassing them. This completes the final waterproofing of the tank. Pick any joint you want to start on, and sand it lightly for about 3" onto the plywood on both sides with a piece of 36-grit hand sandpaper to take off any snags or bumps that could catch your fiberglass cloth and make leaks. Sweep up sanding dust, then blow joints clean with compressed air, or vacuum out after all joints are sanded.
- ✓ Mix epoxy/microballoon putty according to instructions previously given, and fillet all joints. If you are confident enough by this time to try fiberglassing over wet putty, have 3" or 4" wide 6 oz fiberglass tapes cut to fit all joints, with about 1" overlap at each end. You can get this tape from the same place as you bought the fiberglass cloth from (this is easiest and the least amount of work), or you can cut pieces of tape from your roll of fiberglass cloth (this is the most work).
- ✓ The first time you try this "wet fillet taping", plan on only doing a single joint from end to end. Fillet the joint, then roll out your 3" or 4" fiberglass tape dry onto the joint and centered on the joint (remember, you cut it to length and had it all ready before you mixed the fillet putty?). When the tape is laid out onto the joint, with a 2" or 3" brush apply epoxy to your tape to wet it out. When it is wet, wipe the brush clean on the edge of your mixing can, then use the dry brush to squeegee the bubbles out of the fiberglass tape and flatten it. It should look neat after you're done, with no white dry areas or big glossy puddles of resin. If you don't get this perfect the first time, don't worry, you'll get better with each seam you do.
- ✓ If you're still energetic after your first seam, mix some more putty and keep going on the next seam, and the next, and so on. If you're really a maniac about this, and are GOOD at it, you can fillet AND tape the inside of a multi-compartment large tank in six hours or so from one end to the other.
- ✓ If you had trouble taping over the wet epoxy fillet and don't want to try doing more until you have more experience, you CAN do it in two steps: fillet the joints, let them dry overnight, and sand the bumps off, blow or vacuum the dust off again, THEN tape the seam. Although this may be easier if you had a hard time taping the wet joint, it requires MUCH more of your labor, and you have to wait for the fillets to harden at least a day before you can sand them. This makes the tank construction process take longer.
- ✓ If you don't finish taping the whole tank in one operation and have to resume again the next day, REMEMBER to sand off the sharp and bumpy edges at the ends of the tape you put on the day before. If you just fiberglass over these without sanding them smooth first, you will end up with big bubbles under the next piece of tape that goes over the top of these sharp edges (equals leaks!).
- ✓ If you have noticed any bubbles (these look white, and are obviously an area where the fiberglass came up off the surface and air got in underneath, despite your attention and best efforts) in any of your fiberglass tapes or the areas you fiberglassed while horizontal in the shop, you need to do the following to MAKE SURE the bubble does not become a leak through your fiberglass into your plywood (which will rot the plywood from the inside and make the entire thing a waste of your time): cut the bubble out with a razor knife. Sand the edges of the bubble so they are smooth, then cut 2 pieces of fiberglass cloth that are 2" bigger than the bubble on all edges, wet them out and let it harden. Do this with all the bubbles you can find in the tank. Guess what? If you just do a careful, methodical job of fiberglassing the tank to begin with, you won't have to repair any of these bubbles!
- ✓ After finishing filleting and taping all the seams inside the tank (and this includes tape OVER filled screw heads if you have drilled holes THROUGH fiberglass to screw plywood onto the other side of it), let the epoxy on the tape harden overnight, then sand the bumps off it the next day, either with hand 36-grit sandpaper or 50 or 80 grit on the orbital sander. Sweep and vacuum everything out, then put your fill coats on the tape inside the tank with a 3" or 4" brush (remember, you already have fill coats on all your plywood surfaces that you put on them when they were horizontal in the shop). You may need to put two fill coats on to completely coat any vertical tape surfaces; horizontal tape surfaces usually only need one coat. Don't be a maniac about this looking good, it's going to be inside a FISH TANK. The fish DON'T care.

### **Tank Bottoms And Final Outside Seam Fiberglassing:**

- ✓ After you have finished filleting and taping, then fill-coating all the seams inside the tank, it's time to turn the tank over and fiberglass the bottom of the tank. Why do this? Well, the bottom of the tank is going down on the ground. Even if you put wood preservative on the bottom and paint it, it will sooner or later get moisture in the plywood, and the moisture will be the beginning of dry rot, which will eventually ruin the tank, possibly within a year or two. If you completely encapsulate the bottom of the tank to about three inches up the sides with epoxy and fiberglass, then the bottom of the tank will not be able to absorb any moisture from either the inside or the outside of the plywood making up the tank bottom. You will paint the sides of the tank above the fiberglass on the outside with wood preservative before painting with oil-base enamel, so they will also be proof against dry rot. The only difficult part of

this is turning the tank over so the bottom is horizontal and you can work on it. Depending on the size of your tank and how much it weighs, you may be able to do this with a few friends, or you may need a backhoe or a really big tree nearby and a chain hoist or wire come-alongs.

- ✓ **WARNING!** You need to have thought out turning over the tank long before you get it assembled. While you may have been able to easily move the bottom, sides, and ends of the tank around in the shop while you were working on them, you now have a completed tank that weighs five to six times as much as any one of these single pieces that you could easily move before. BE REALLY CAREFUL!!! A tank that weighs a couple hundred pounds can hurt someone if you're careless while turning it over; a tank that weighs a thousand pounds can easily KILL someone! If you don't feel confident with this, hire a professional of some sort who has insurance and a good reputation (a crane operator, a contractor with a backhoe), and have them do this with a trained crew. Although I've moved large objects weighing up to six tons (boat hulls) with just a couple of hand-cranked wire come-alongs, I had LOTS of experience moving small objects before I tried moving these large ones. We have a six-ton crane and are trained and certified in its use, and that makes it easy for us to do even very large tanks this way.
- ✓ **You need to do this twice!** You also need to turn the tank BACK OVER after fiberglassing the bottom is finished, AND you need to be able to transport the finished tank to where it will be installed, all without dropping the tank on any hard objects such as rocks or pieces of rebar, which could make a dent through the fiberglass on the bottom, which will turn into a LEAK, which will eventually rot your tank out and require repair or replacement of part or all of the tank. BE CAREFUL NOT TO DING THE BOTTOM OF THE TANK WHEN MOVING IT!!!!. We use PVC pipe rollers over 2x8 boards to roll tanks short distances, a trailer with a ramp we can roll the tank down, but we never DROP a tank on the ground or drag a tank across the ground! We also prepare the ground where the tank will sit first with a 3-4" layer of sand covered with a layer of 6-mil black construction plastic plus a layer of ground cloth so that weeds don't grow out from under the tank and make a mess later.

## 6. Fitting Types and Installation

- ✓ There are two types of fittings we use in these plywood/fiberglass/epoxy tanks; the easiest and cheapest one is the piece of PVC pipe filleted-in to the side of the tank. If you put this type in you can easily glue on any type of fitting you want on both sides after the tank is installed; and you can get all these fittings at any construction supply store such as Lowes or Home Depot. The other type of fitting is a standard bulkhead fitting (called a through-hull fitting in the boating world), that we purchase through a company called Aquatic EcoSystems in Florida (their toll-free phone number is 877-347-4788, call and ask for a printed catalog first, as their online store is difficult to use at best, even when you know what's in it).

Both types of fittings are installed in the tank AFTER it's fiberglassed and topcoated inside. You can install these fittings before or after painting the outside. We'll describe the PVC pipe fitting first:

- ✓ **What is PVC pipe? Can I use that black or gray stuff?** There are many different kinds of PVC pipe, but the only one that is important is schedule 40 (white PVC pipe and fittings), because it's the only one that's food-grade. We assume you're going to put fish or hydroponic vegetables or abalone or some such in your plywood tanks, right? Well, if you eat it later, the water it grows in needs to ONLY travel and be held by food-grade surfaces such as epoxy/fiberglass, and food grade plumbing such as schedule 40 PVC. There are many other colors and types of PVC pipe: SDR 25 and 35, gray electrical conduit. There is the black ABS pipe, which is used for sewers and drains. NONE of them are food-grade; you shouldn't use them even if you get them for FREE!
- ✓ **What size pipe to use?** First, determine what size of pipe you're going to use for which fittings in your tank. A good general rule of thumb is to use a pipe that is the next size larger than whatever size fitting your water pump has on it for any pressure water lines. What does this mean? Well, let's say you're pumping water from your sump tank or last aquaponics trough back up to your fish tank and you have a water pump with a 3/4" fitting on it; you would put an adaptor on that to get it up to 1" PVC pipe size right after the pump, and run that 1" line all the way back to your fish tank. That 1" line from the pump to your fish tank is your pressure water line because it has pressure in it produced by the water pump.

For return lines, or the gravity-flow pipes coming out of the fish tank that take your water to the aquaponics troughs or to another lower fish tank, you need to use a pipe at least TWICE the size of the pressure water line. A gravity-flow pipe is one where the water just falls into the pipe from the force of gravity, and has very little pressure in it as a result. Because of this lower pressure, you need a larger pipe to permit the same amount of water to flow. If you use the SAME size pipe for both pressure inflow and gravity outflow, you will simply pump your tank full until

it overflows onto the ground, because not as much water will go down a 1" gravity flow water line as will flow in a 1" pressure water line. So, in the example we just used where you have a 1" PVC pressure water line coming into the fish tank, you need a 2" PVC gravity flow water line coming OUT of the fish tank. Now we'll show you how to install the fittings into the tank that these lines attach to.

- ✓ **PVC pipe filleted into the side of the tank** Purchase or borrow holesaws that EXACTLY fit (as close as possible but slightly smaller, we'll explain why in a moment) the sizes of pipe you're going to use for your tank fittings. You will need a BIG drill to power a holesaw any larger than 2" or so. A Milwaukee "Hole Hawg" is what we use for up to 6" holesaws. BE CAREFUL WITH BIG DRILLS! They have so much horsepower and torque that they can injure you badly if the holesaw binds and you don't let off on the drill trigger within about 0.12 seconds! Locate your holes carefully: measure twice, drill once as the saying goes.

You CAN put the "plug" from a mistake back into the same hole with microballoon putty and some fiberglass and epoxy, but it won't be hard and ready to work on for another day. So spend the time necessary to get it right. Drill ALL the holes for all the different sizes of fittings FIRST (slightly SMALLER than the pipe, or exactly the right size for a tap-in fit). Cut pieces of PVC pipe to this formula: make the pipe 3 times longer than the "nominal size" of the pipe. Example: for 3/4" pipe, make the piece 2-1/4" long; for 2" pipe, make the piece 6" long. This is assuming you're going through a normal 3/4-inch thick tank wall. If the wall is much thicker, make the pipe accordingly longer.

We put the inflow fitting for our tilapia tanks about 3" down from the top of the tank. The water level inside the tank is about 8" down from the top so the fish can't easily jump out. The reason for having the water inflow above the water surface in the tank like this is that we can easily SEE if there's anything wrong with the water flow into the tank. If it seems much less than normal, we notice it when we feed the fish, and that alerts us to the possibility that some junk has gotten into the pump intake filter. A water inflow fitting installed under the water surface of the tank won't give you this important feedback. You can also just lead the water inflow over the top of the tank edge and avoid the fitting entirely. Water outflow fittings are installed high up on the sides of the tank, where, if there's an earthquake that busts underground lines or a "human stupidity event" involving a valve or something similar, you only lose water down to the level of the outflow fitting and don't end up draining your tank and killing your fish.

When you have all the fitting holes cut the correct size, sand the outside surface of all the pieces of pipe with some 60-grit sandpaper until they're well scratched-up. This gives them some "tooth" and allows the epoxy to bond to them really well. Take your piece of pipe and tap it into the hole you've drilled (which fits it perfectly and holds it firmly for the next operation). Wait! You mean your pipe is LOOSE in the hole? Go back to "A", buy another holesaw slightly smaller than, OR exactly the same size as the pipe and try it again. Now, if the hole is slightly smaller, you may need a 3/4" round file or rasp to enlarge it a little (careful, not TOO large, check fit frequently while filing!). Ideally, your piece of pipe will need to be tapped into the hole with a rubber mallet or short piece of 2X4 so that it is firmly held. This is important because you are going to put a microballoon fillet around it on both sides next, and if it moves at all you are likely to end up with a mess. Make sure it's solidly held in the hole before mixing any epoxy, then mix and apply as noted in "3. Filleting and Sanding".

- ✓ **Standard Bulkhead Fitting** This comes in three types of plastic: food-grade PVC (usually the most expensive); food-grade polypropylene (middle-range in cost); and non-food-grade ABS (the cheapest kinds). It is the simplest fitting in terms of labor involved, but is more expensive to buy, and is VERY EXPENSIVE in the larger sizes; 3" and 4" are \$26 and \$54 respectively for ABS plastic fittings, and you're not done yet; you still need a male threaded adaptor on each side to attach PVC fittings to such as a filter on the inside of the tank and your plumbing on the outside. Installation is simple: just holesaw the right size hole (you also need to get the right size holesaw for each bulkhead fitting, and they are NOT the same size as the holesaws for a piece of PVC pipe the same "nominal" size). You can purchase these at Aquatic EcoSystems in Florida (their toll-free phone number is 877-347-4788) as we mentioned earlier. You can also get them at boat or marine stores, but they're likely to be a LOT more expensive because they have the "boat" designation. We use PVC pipe filleted-in to the tank walls because it's a LOT less expensive, and they're easy to install.

## 7. Airstone Installation

- ✓ You will need to install airstones if this is a fish tank or abalone tank. If you're growing something else exotic, you may need aeration for it. Run PVC airstone lines under the upper tank reinforcing 2x, clipping them to it with galvanized pipe straps and screws. Use Aquatic EcoSystem adaptors catalog number 62006 1/4" NPT X 1/4" barb to attach AES number BTV40 black vinyl airstone tubing from adaptor to the airstone. A good general rule of thumb for sizing your PVC airline is that if you have 8 0.5 cubic-feet-per-minute (cfm) stones or less, you can use 1" pipe; 24 stones or less, 1-1/2" pipe; 40 or less, 2" pipe, or use the AES airline sizing chart in their catalog.
- ✓ You drill holes for these adaptors in the PVC or Driscopipe airline that are the correct size for a 1/4" NPT (National Pipe Thread) tap, then tap threads into the holes with the tap and a 1/2" 12-point socket wrench, then install the adaptors with not too much torque. Use regular Schedule 40 PVC pipe for airlines; DO NOT use thin wall schedule 40 pipe for airlines because there's no "meat" to tap and thread the adaptor into. After the 62006 adaptor is installed into the PVC pipe, the airstone tubing just pushes onto the airstone and the adaptor. We point the adaptors straight down when installing them, then the airstone tubing goes on and up around the upper tank reinforcing 2X, over the rim, and down into the tank.
- ✓ **IMPORTANT:** You need to install (2) diffuser bumpers (AES #DB10) or equivalent on each airstone. These are heavy o-rings that roll onto the airstone, one on each end. These synthetic airstones are made of a gritty material like sand that is glued together, and need these bumpers installed to hold them off of your tank sides or bottom. Otherwise, the constant jiggling and bumping they do while putting out air WILL GRIND A HOLE THROUGH YOUR FIBERGLASS, causing a leak and time and money wasted in a repair. Install the airstones with just enough tubing so they hang down the sides of the tank about 2 inches off the bottom. Don't cut the tubing too long so they actually sit on the bottom, because then they will grind a hole through your fiberglass.
- ✓ Aeration can be done in all kinds of ways using all kinds of equipment and methods. There are many ways to create aeration: airlift pumps, water sprays, paddlewheels, rotors, blowers, compressors, etc. They all use MORE electricity to create the same level of DO (dissolved oxygen) in the water than medium pore airstones connected to regenerative blowers do. So you can experiment with them if you want and have the time and money. We never had extra time or money, so we just use the airstones and regenerative blowers. They work wonderfully!
- ✓ The reason we use the equipment and methods detailed in the following paragraphs is that they are the MOST ENERGY-EFFICIENT for the depth of water we have. You will have your air generation devices on 24/7 for years once you start up and they need to not only be dependable, but as energy-efficient as possible. Any inefficiency will multiply many times over and show up in your bottom line at the end of each year.
- ✓ Aeration in these systems is created by a regenerative blower connected by Schedule 40 white PVC pipe and food-grade vinyl tubing to medium pore airstones which are near the bottom of the tanks and troughs.
- ✓ Here's the reason why the airstones are at or near the bottom: It is easier to push air out of an airstone that is in shallow water than out of one that is in deep water. But even though it is easier and makes lots of bubbles, you don't get as much oxygen into the water as you do if the airstone is deeper. When the airstone is deeper the bubbles come out of the airstone smaller (with more surface area), and travel further to the surface, with the surrounding water absorbing oxygen from the bubble all the way to the top of the tank where it bursts at the surface. Less fuss, but much more DO into the tank water.
- ✓ So we have our airstones 2" off the bottom of the tank, which gives us a high DO with minimum electrical usage. The airstones tend to get clogged with aquaponics system crud over a period of time (usually six months to a year in our 70-78 degree F water), costing you more electricity for a given amount of aeration, so they need to be scrubbed or powerwashed then dunked in a Chlorox or hydrogen peroxide solution to clean them off, then dried off in hot sun for a couple of days, every six to twelve months or so. To do this, you need to either take just a few off at a time, plug the tubing they were attached to, and clean them; or you need a spare set of airstones so you can rotate them in while the others are cleaned.
- ✓ **WARNING! DON'T** put airstones back in your system without making absolutely sure they are free of Chlorox. If they still have bleach down in their pores, the bleach will just transfer into the system water when you hook them back up and may stress and/or kill your fish and plants.

## 8. Fill and Test Tank

- ✓ It's probably a good idea to fill your tank to the top and test it while it's still in the shop. Did you do a good job? Are all your glue joints actually glue joints? Did you read and follow the plans, or did you invent something new? Are you willing to bet you did a good job? If you have a low confidence level in your first tank, you might want to move it out onto the driveway before filling it with a couple thousand gallons/eight tons of water. If it does go poof you haven't dumped that eight tons of water in your shop or garage, but down your driveway into the gutter. We have had so many people try out "new" things and get "different" and more "exciting" results than we got when we did it the old tried-and-true way that's in this manual, that it's difficult to catalog them all. What we DO know is that if you follow the manual, it works. If you have purchased the

## 9. Moving Tanks: Ways and Considerations

- ✓ A small finished tank is heavy. An 8-foot long, 4-foot wide by 4-foot high tank probably weighs around 400 pounds; You can wrestle it around with a friend, some PVC pipe rollers, and some 2X4's on the ground. This is a small, easy-to-move tank. You can make a ramp out of 2x8's and slide it up into the back of a pickup truck. If you have five or six strong friends, you can simply pick it up and put it in the back of the pickup truck, then follow the reverse procedure when you are at the tank installation site.
- ✓ A BIG finished tank is REALLY heavy! A 12-foot by 12-foot by 4-foot deep tank probably weighs around 1,200 pounds, and you can wrestle it around, CAREFULLY, with a single friend, a couple of 2,000-lb capacity wire comealongs (that you can buy at a hardware store for around \$49.95 each), some 1" PVC pipe in 16-foot lengths for rollers, a minimum of four 2x8's about 16 feet long, and "strong points" located in the direction you want the tank to go that you can attach the comealongs to to pull the tank along on top of the PVC pipe rollers. You need a couple of things to make this work: one, the ground needs to be level. If your ground slopes, the tank will simply take off downhill on the PVC rollers, and you'd better get out of the way FAST!
- ✓ The second thing you need is "strong points" on the tank. You need to be able to latch onto the tank to pull it, and putting a rope or chain around the entire thing creates problems of its own. It's much easier to be able to just shackle a comealong to a nice fitting bolted onto the tank where the tank is strong enough to take the strain. Proper fittings and methods of attaching them are included in the "for sale" tank plans; if you decide to design some yourself, make sure they're STRONG and STRONGLY ATTACHED with BIG THROUGH-BOLTS, NOT screws, lagbolts, or other wimpy fasteners.
- ✓ If you're going to lift your HEAVY tank, the "strong points" on the tank need to be strong enough to support their share of the weight. You need four points on the tank to attach chains or lifting straps to; these four chains or straps will come to a single point above the tank, and that is the point you attach your backhoe or crane hook to. What do you mean "backhoe or crane?". Well, unless you have strong points about ten to twelve feet off the ground (minimum) at your shop, AND strong points about ten to twelve feet off the ground at your tank installation site that you can use to lift the tank with wire comealongs or chain falls, you're going to need some help. You have to be able to lift this thing UP to get it onto a trailer or truck for transportation to your installation site. The easiest way to do this, unless you've had a LOT of experience lifting and moving things with wire comealongs, is to hire someone with a backhoe or boom truck (small crane) to help you with it, or to move it for you.
- ✓ A "radical" idea: It might just be easier and cheaper to just build a huge heavy tank right where you plan to use it than it is to move it. The easy way to accomplish this is by constructing a cheap "hoop house" using PVC pipe and clear plastic, or build one from 2x4's and plastic (kind of like a temporary greenhouse using very cheap materials). Just remember, if your wood does get wet from your structure failing or wind blowing rain sideways into the structure, you need to fix the structure, then dry the wood out before you can do any more gluing or fiberglassing on the tank.
- ✓ Happy tanking!