Building Strip-Planked Boats

With Complete Plans and Instructions for a Dinghy, a Canoe, and a Kayak You Can Build

Nick Schade

author of *The Strip-Built Sea Kayak*

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To my late wife Cathy's mother, Helen.
Without her love and support, I would have a lot less experience
with boatbuilding to put in a book.

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Acknowledgments

In the twenty-five (or so) years since I first laid strips on a set of forms to build a strip-planked boat, I have learned and benefited from many people in a wide variety of ways. My parents let me and my brother mess around with tools and pound nails into wood, so I always felt like I was a boatbuilder—even when what I built didn't really deserve to be called a boat. My brother, Eric, was there at the first strip boat—it was a canoe he was building for which he recruited my assistance, and that got me started down this road. My late wife, Cathy, encouraged me to quit my real job and move forward with building boats. Michael Vermouth of Newfound Woodworks gave me a place to continue when Cathy passed away. Cathy's mother, Helen Stern, treated me as her son and made it possible for me to keep going when, in other circumstances, I would have had to try something else. Paul Smith of the American Craft Museum encouraged me to try harder. The many participants of my kayak-building bulletin board at KayakForum.com provided all kinds of good ideas and innovations and made me put more thought into what I was trying to do. John Harris at Chesapeake Light Craft took a bet on my business and me that made the time spent working on this book easier to justify. Bob Holtzman, formerly of International Marine/Ragged Mountain Press, got me started working on this book, and Jon Eaton deserves a lot of credit for the patience to let me bring it to completion. Finally, Robin's encouragement, faith, and support were a blessing that made the long months spent working on this book much easier to take.

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Part I

The Background

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Chapter 1

Introduction

Let's get this clear from the start: it is a waste of time to build your own wooden boat. These days there are far quicker ways to get yourself on the water than going down to a basement shop, fooling around with a bunch of weird tools, making a big mess, and spending time being careful to do it right. You can go out to the local boating store and buy a boat ready to go that will be perfectly serviceable, getting you where you want to go with a lot less fuss and bother.

Instead of wasting your time building a boat you could be at work earning more money, so you can afford the really high-quality glitter on your fiberglass boat, or maybe a hydraulic elevator to lift a plastic barge onto the roof of your car, or something else useful.

There are few reasons to build a wooden boat that make practical sense on a cost-benefit chart, but for some reason lots of people still want to do it. It may be that they just enjoy the process of converting a raw board into a mode of transportation. I think there is more to it than just an excuse to buff the rust off their tool collection. There is some ineffable quality to wood boats that makes them attractive. The quality goes beyond the strict physical appearance because even rather ordinary-looking boats are attractive when built of wood. Wood grain lends an eye-catching complexity to a surface that simply can't be achieved with synthetic materials.

Building a boat is a big project. It takes time, some physical effort, and a lot of concentration and thought. If all you are looking for is a nice boat, there are plenty of other options out there. If you want an inexpensive craft to go fishing in, there are cheaper options available than building one yourself. If all you really want is a pretty wooden vessel, you may be better off getting someone else to build it for you. Don't take on the task if the idea of the project itself does not appeal to you. On the other hand, building a boat is a break from a world of instant gratification and impending deadlines. You will probably end up bleeding or with a painful splinter at some point during the project. It is very possible that the job will cause you to get angry and swear. But it is also a chance to invest time in making something of value with your own hands.

There is something special about boats. Lots of projects can satisfy the bug to build things, but there are few projects accessible to the average do-it-yourself craftsperson that you can travel in. Unlike a bookshelf, a boat isn't just another inanimate object; it is a partner in exploring new territory. Creating this partner with your own hands, deliberately fitting each piece in place, bleeding on it, dripping sweat as you proceed, and agonizing over each detail fills the vessel with value. It is the challenge and time that you put into it that makes the project worth doing.

The Strip-Building Method

Over the thousands of years that humans have been building small vessels for venturing out on the water, people have created hundreds of different methods for constructing those craft. Traditional boatbuilding typically involves creating a frame and a waterproof shell. The frame usually provides the structural strength of the boat while the outer surface is primarily a means of keeping water out so the boat will float. The frame will often consist of some form of backbone, such as a keel, plus ribs supporting the shell. The backbone provides the basis for strength along the length of the boat. The ribs define the shape of the boat and back up the outer shell. The shell may be in the form of planking, or in the case of traditional kayaks it may just be a layer of sealskin.

A more recent technique fastens multiple small wood strips edge to edge and then encapsulates this shell under layers of fabric and glue. This is the *strip-building* or *strip-planking* method. With strip-built construction, the outer shell provides both the structure and the watertight integrity of the boat. This *monocoque* (French for "single shell") structure includes the strength of the ribs and backbone into the waterproof skin of the boat in one integrated, lightweight, and strong piece. In traditionally built small boats, such as a canoe or Adirondack guide boat, the outer surface was ¼-inch-thick (6 mm) cedar supported by a structure of ribs every 4 or 5 inches (10 to 12 cm) held in place with small tacks or screws. In a strip-built boat the strip thickness may still be ¼ inch or less, but the ribs have been replaced with a woven fabric such as fiberglass, Kevlar, or carbon fiber adhered to the wood with epoxy resin.

You may notice that the title of this book refers to strip-planked boats, yet I often use the term *strip-built*. In traditional boatbuilding methods, planks are fairly heavy boards that you fasten to a structure of internal frames, but in the method described in this book, there are no internal frames; the "planks" are very thin strips of wood that, in themselves, represent much of the boat's structure. That's why I use the term *strip-built* most often, but it means the same thing as strip-planked.

Strip-building is simple in concept: bend a bunch of narrow, flexible strips around a set of forms, and cover them with a waterproof reinforcement. And—unlike many seemingly simple concepts—it is actually relatively simple to do. The strip-built method is well suited for making small boats with minimal tools. It doesn't require extensive training or skill, and it is tolerant of mistakes. While first-time builders may have trouble building a boat that looks exactly how they want, it is very likely that they will build a boat that performs the way they want. It is the nature of the strip-built method that big mistakes are hard to make, and little ones don't hurt.

Because the wood is encapsulated in fiberglass and epoxy, it is quite certain that the finished boat will not leak, even if elsewhere your craftsmanship is not perfect. The epoxy seals all but the largest holes. The fiberglass also reinforces weak joints, making them much stronger. With the wood under a protective coat of epoxy and fiberglass it will not rot. Because the fiberglass and epoxy are perfectly transparent, the full beauty of the wood shines through.

Some builders of larger boats use a technique, also called strip-planking, in which strips of wood that are the same thickness as traditional boat planks, but narrower from top to bottom, are secured together with glue and maybe some nails, but they don't necessarily sheathe the wood in fabric and resin. This technique works well for larger boats that need thicker planking, but for small, lightweight boats, the fiberglass or other reinforcing fabric saturated with epoxy or other resin is a critical part of the building process. Since this book is tailored toward small, cartoppable boats, it assumes all the wood will be encapsulated in resin and fabric.

This "composite" structure comprising wood, glass, and plastic overcomes a lot of problems with wood boat construction while giving many advantages over standard modern fiberglass construction. The epoxy seals the wood from exposure to moisture, virtually eliminating the possibility of rot. The elimination of fasteners like nails and screws does away with localized stress concentrations that can cause failures. And wood is one of the most structurally efficient materials available. This means that for a given weight of material you will be able to make a stiffer panel from wood than any

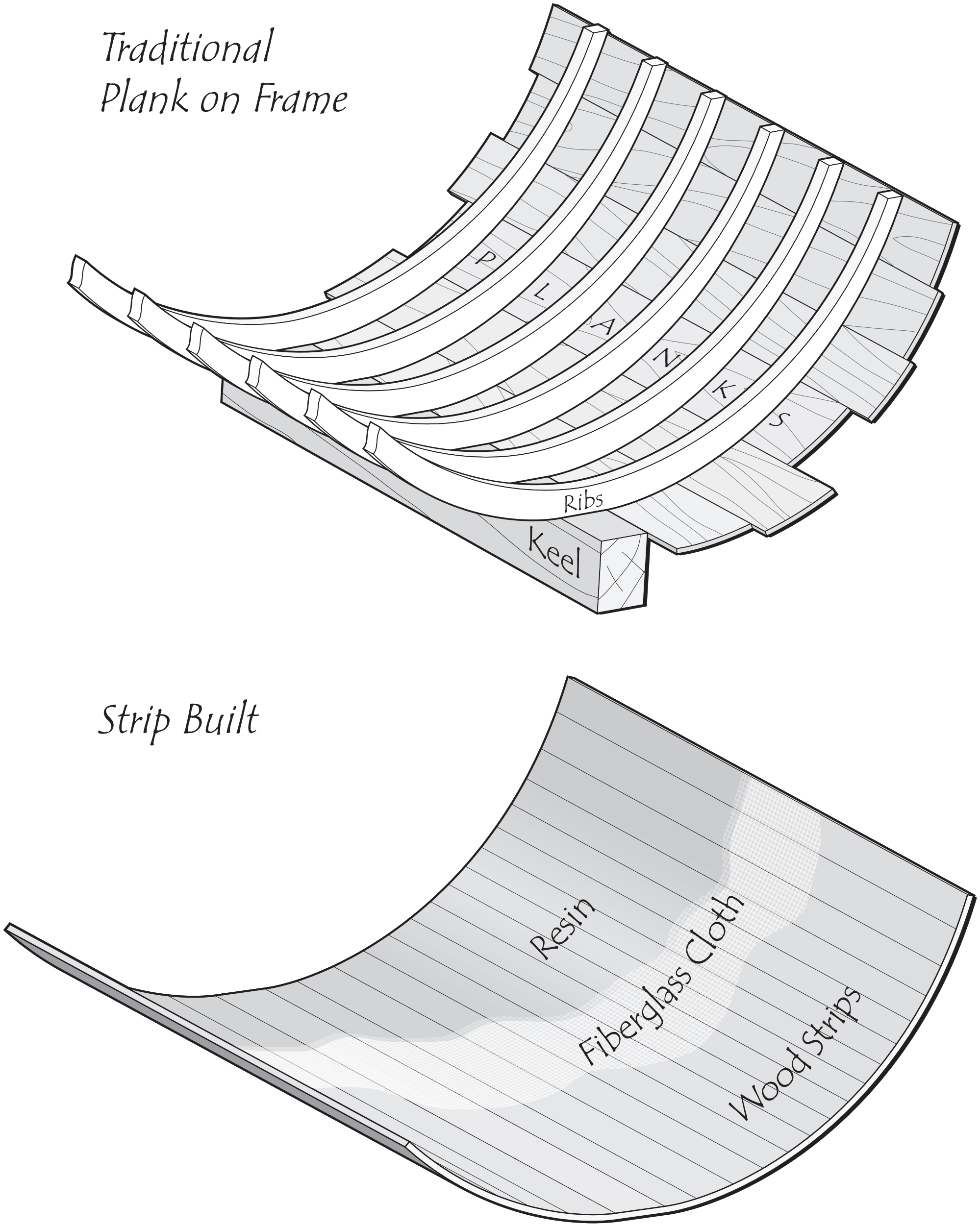

Figure 1-1. *Traditionally, boats were built with a backbone-like keel with ribs defining the shape. This frame of ribs was then covered with planks to make a watertight hull. The frame provided most of the strength. While the planks provided some strength, without the ribs supporting them, they would split. In strip construction a* monocoque *shell provides both the strength and the watertight hull. The thin outer planks are reinforced across the grain with fiberglass fabric secured and sealed in place with epoxy resin.*

other material. Although wood is soft and easily scratched, the layer of fabric and resin protects the surface.

Traditional boatbuilding requires high-quality wood. Since the wood provides all the structural strength, poor grain can create serious weaknesses. Because of the way the wood functions in the structure, strip-building is much more tolerant of lower-quality wood and squirrelly grain. The sandwich of fiberglass-wood-fiberglass acts much like a steel I-beam.

In an I-beam primarily the top and bottom flanges carry the load. The vertical web in between just keeps the two flanges separated. As a result the flange on the outside of the bend is stretched or in tension and the flange on the inside is compressed. The web in between is also in compression. Strip-built construction works the same way, with the fiberglass taking the place of the flanges and the wood acting as the web. Because wood is strongest in compression the result is very strong for its weight.

In brief, the process of strip-building a boat consists of making a building form, covering the form with wood, covering the wood with fiberglass, covering the fiberglass with epoxy, covering the epoxy with varnish, and then finally covering the varnish with scratches as you use the boat. Stated this way it sounds pretty easy. Obviously the details are important, but it helps to think of it in these simple terms.

The forms are a series of sections, like slices of bologna, that define the shape of the boat. These forms are secured to a *strongback*, the supporting structure that holds the forms in their correct location and orientation. Careful setup of the strongback and forms assures the finished boat is the desired shape.

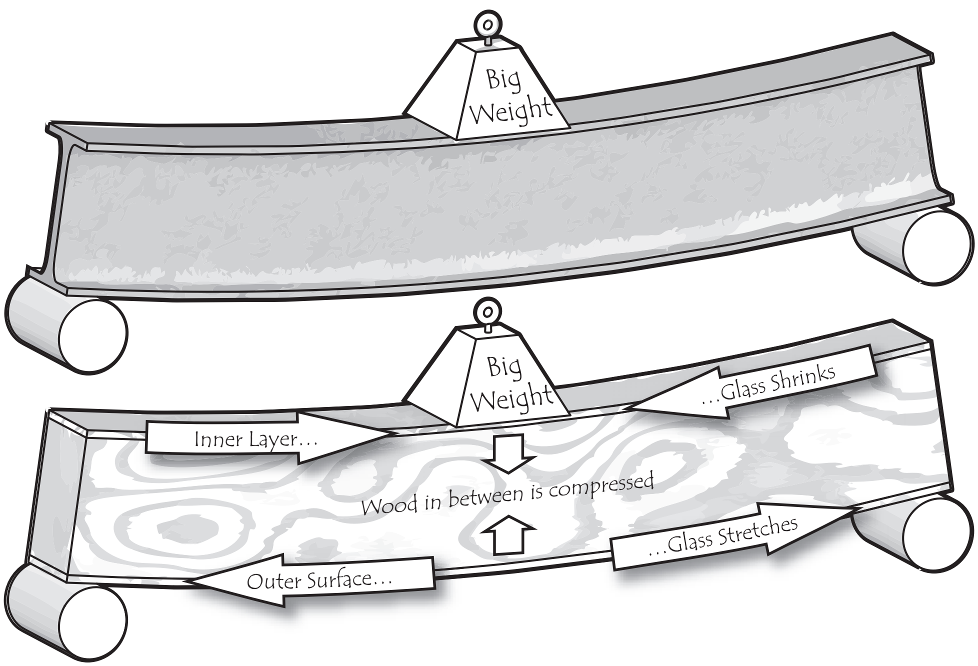

Figure 1-2. *The lightweight strength of the strip-planked shell is achieved in the same way that an I-beam keeps a bridge strong and lightweight. In an I-beam the webs at the top and bottom of the vertical spacer carry most of the force. If these webs were not separated they would bend easily; by spacing them apart, they must either stretch or shrink before the beam bends. On a strip-planked boat, the wood acts as the separator and the fiberglass replaces the web.*

A lightweight softwood such as cedar or pine is generally used. The wood is cut into thin strips about 1 inch (2.5 cm) by ¼ inch (6 mm), or a bit less. This wood is edge-glued together and temporarily secured to the forms with staples. When the forms have been completely covered, the staples are removed and the wood is smoothed with scrapers, planes, and sandpaper.

The lightweight fabric (fiberglass, Kevlar, or carbon) is draped over the prepared wood and trimmed to size. Epoxy resin is then poured and brushed onto the fabric. This bonds the cloth to the wood, and in the case of fiberglass, the fabric becomes completely clear. When the epoxy cures, the shell of the boat is removed from the forms. After smoothing the inside of the boat, the inside is similarly reinforced with fabric and epoxy.

With decked boats like kayaks, the deck and hull are then joined together. More epoxy is added to the outside of the boat to smooth out the fabric texture. This is then sanded smooth. Any outfitting such as seats or gunwales can now be added. Finally, everything receives a protective coat of varnish. Varnish not only enhances the appearance of the boat but also protects the epoxy from sun damage. Every few years you will want to give it a light sanding and reapply the varnish. With a minimum amount of care, you can enjoy your boat for many years.

What You Need to Build a Boat

The tools required to build a strip-built boat are modest. One of my primary tools is an old Swiss Army knife given to me by my grandmother when I was a kid. The only large power tool needed is a table saw to cut the strips. If you don't have one, you will need to borrow a table saw for half a day or so. In addition, you will need some small tools like a block plane, a handsaw, and a sander.

You will need a covered workspace with some control over the temperature. (Remember, the space needs to be a few feet larger than the boat!) You also need a way to get the boat out of the shop. Taking a wrecking bar to the house to extricate a finished boat is more common than people would like to admit, but that doesn't mean it is fun.

Building a boat takes time. You will need some patience. The boat won't be finished tomorrow, but that is part of the beauty of the project. You are putting quality time into making a quality object. You need to be able to resist the urge to take shortcuts. If you want instant gratification, just go out and buy a boat.

Most important, you need a comfy chair in your shop. This is called the "moaning chair." It is there to catch you when you cut your last piece of good wood too short or drill a hole below the waterline. This piece of furniture is a key tool you will use to prevent taking a chainsaw to your project. Remember that almost everything can be fixed if you spend enough time sitting in the moaning chair to come up with a solution. While strip-building is a pretty fault-tolerant means of making a boat, it is inevitable that somewhere along the way you will make use of the moaning chair.

Three Strip-Building Projects

The first ten chapters of this book detail the tasks and methods involved in just about all strip-built boatbuilding projects. The last three chapters describe three boats that you can build using those techniques and demonstrate several design-specific tasks such as installing gunwales and seats.

The Coot, a pram-bowed dinghy, is very easy to build and an excellent first project for anyone the least bit nervous about his or her ability to build a boat. This will make a fine tender for a larger boat.

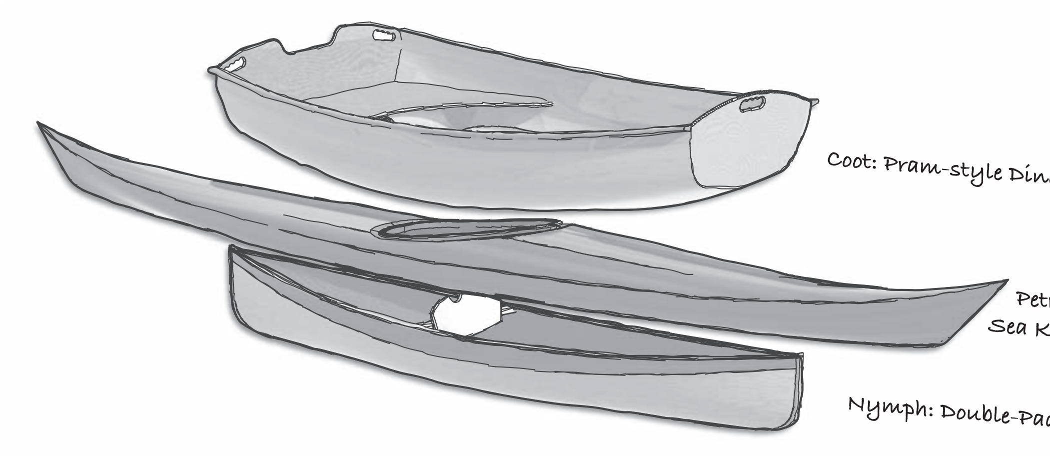

Figure 1-3. *The boats used as examples in this book demonstrate many techniques that are useful for building just about any small boat using the strip-planked method. The Coot is a simple dinghy with transoms at both ends and plywood seats. The Petrel is a sophisticated sea kayak with full deck and coaming. The Nymph is a lightweight double-paddle canoe with a thwart seat.*

The Nymph is a small solo canoe for double paddle with a few features that make it slightly more complicated, and the building as shown involves a few tricks and special materials. Consider it an intermediate-level course in strip-building.

The Petrel is a sea kayak designed for rough waters. As the only fully decked boat of the three, it inherently involves a bit more work, and its cockpit, while highly functional, is also somewhat elaborate. I went all out on the example shown, tricking it out with many optional features—some functional, others cosmetic—to demonstrate how far you can take strip-building if you wish.

Strip-building a boat lets a beginning boatbuilder create a fully functional boat without a lot of skill. It lets a novice builder create a beautiful boat without compromising the performance of the result in any way, and an experienced strip-builder can produce a spectacular work of art that is lightweight, strong, and efficient on the water. There are quicker ways to make your own small boat but few that offer the combination of accessibility for the first-time builder, on-the-water performance potential, and sheer beauty of the finished product.

The goals of this book are to introduce strip-building to beginners, to provide new ideas to novice builders, and to help experienced builders bring their work to the next level. First I describe the general process and then I provide plans and instructions for three different boats. I hope that after reading this book you will have the confidence to tackle building any of the boats I describe, or just about any other small boat using these methods.

Chapter 2

Materials

With all the developments in material science of superstrong substances for aerospace and the military, you would think that wood would be left in the dust. It seems unreasonable that stuff that literally grows in trees could measure up to the performance properties of materials that go into outer space or at Mach speeds. Yet for a lot of purposes wood is actually stronger for its weight than the most exotic modern materials.

Wood

Wood is really what makes this boatbuilding thing all worthwhile. There are a bunch of ways you could go about building a boat that don't involve wood so much, but wood is pretty easy to work with in a home shop, it is lightweight and strong, and it just looks beautiful. What's not to like? It is really hard to go wrong with wood.

People often express surprise when I answer their queries into the weight of my boats. They are under the impression that wood is heavy. I was at a show recently where someone said, "Well, compared to plastic it weighs a lot." I asked him, if he took a chunk of a fiberglass boat and a chunk of wood, which would float? It is true that a big piece of firewood weighs more than a little plastic fork, but if you were to drop both into the water, only the firewood would float. This is because the firewood is less dense than the plastic. If you were to whittle away all the parts of the firewood that didn't look like a fork you would eventually end up with something the same size as the plastic fork. This wooden fork would still float. It would be lighter than the plastic eating implement, and as a bonus it would be stronger than the plastic version.

If you are interested, there are books out there that will do some fancy calculations to demonstrate that, for its weight, wood is just about the strongest material currently available. Of course someone else may come along with a calculation demonstrating how his or her favorite material is somehow stronger. However, for our purposes it really doesn't matter exactly how strong wood is compared to exotic aerospace materials. Suffice it to say, wood is light and strong. It is a naturally occurring composite of fibers and resins that is hard for synthetic materials to beat. As a result, strip-planked boats are typically lighter and often as strong or stronger than commercially made fiberglass boats, and they are much lighter and stiffer than inexpensive plastic boats.

When selecting a wood, we are looking for the attributes just mentioned. We want something light and easy to work with. Knotty wood will make a fine-looking boat, but it is hard to work with. Lignum vitae, or ironwood, is really strong, but it's heavy enough that a board of it would sink. We could even cut a sheet of plywood into strips, but it would be weird looking. But that still leaves a lot of options.

Strips

This book is about strip-building boats, so for that we will need strips. These are typically produced by running a wood plank through the table saw multiple times, cutting off thin pieces of wood. The result is strips that are the width of the original board's thickness, and for most people, this will be the determining factor for strip width.

Typical strip thicknesses are about ⅛ to ⅜ inch. The strip thickness will depend on the size of the boat, type of wood chosen, and how the boat will be used. Large, heavy boats, those that will carry a lot of weight or will be subjected to high forces, will be better off with thick strips. Small, lightweight boats that will be gently used can get away with thinner material. Heavier woods will often allow the choice of a thinner strip while still maintaining good strength.

There are a lot of variables to consider, but they can be grouped into categories to help you make a judgment: how is it to work with, what does it look like, how will it hold up, and how much will it weigh.

Softwoods. The word *softwood* sounds pretty straightforward, but it really refers to wood that comes from conifers. In other words, the wood may be hard or soft, but the tree has needles and cones. There are some hardwoods that are softer than many softwoods, but in general softwoods are on the softer side. It happens that woods that are soft also tend to be lightweight. Maybe it is really the other way around—that light wood tends to be soft, and it also tends to be easier to shape and less strong. While they may be less strong, many types of softwoods still have good strength relative to their weight.

The standard wood for strip-building is cedar. Atlantic white and northern white cedar are not that easy to find, but they are lightweight and easy to work with. The wood is pale blond, with a little bit of visible grain. These woods are most readily available near where they grow. Atlantic white cedar is sometimes called boat cedar and grows along the eastern seaboard from Mississippi to Maine. Northern white cedar is native to the arboreal forest of Canada and ranges down into the northern United States and south along the Appalachian Mountains. Neither of the white cedars are available in long boards. The trees do not grow that big, but the wood is very nice.

More commonly available is western red cedar, which is often used as siding. Although the trees are native to the Pacific Coast in Oregon, Washington, and British Columbia, its long, clear grain and weather resistance creates demand. It is available in many lumberyards catering to high-end builders and is occasionally found in home centers. The wood varies in color from a pale blond similar to white cedar, through various shades of red and brown, to a deep maroon and rich chocolate. It is sometimes available in long lengths if full-length strips are desired for a longer boat.

Both the white cedars and western red cedar are considered the go-to woods for strip-building. They offer a good combination of strength and weight. They are easy to work with—they cut, plane, and sand easily. While they are naturally rot resistant, this is not really necessary. There are a variety of other trees that are related to these cedars that may provide useful strips.

Cypress grows in the swamps of the southern United States and provides a dark-blond wood with distinctive grain. It is harder, stronger, and heavier than the cedars but may be more readily available to builders who live in its natural range. You may be able to find nice long, knot-free boards at locally operated lumber yards and specialty wood suppliers.

Port Orford and Alaskan yellow cedar are both less common light-colored cedars. They are both at the heavier end of the spectrum but are quite tough. Alaskan yellow cedar is particularly well suited for accent stripes. It is very light in color and often has very little visible grain. While most cedars have quite pleasant smells, Alaskan yellow smells somewhat foul to some people.

Related to the cedars is redwood. This is a fairly brittle wood that is a little heavier than western red cedar. It can have a nice red tone that looks really nice; however, I have had trouble with epoxy bonding to it long term.

The rather intimidating table that follows shows the strength properties of some selected woods suitable for the strip-planked method.

The Specific Gravity column indicates the relative weight of each wood (lower numbers are lighter). The other columns indicate various forms of strength, in terms of bending, taking a hit, or being squeezed, stretched, or otherwise abused. For these, higher numbers are stronger. The nerds among us can get all excited by the different numbers; everyone else can notice that lighter woods are generally weaker, and stronger woods weigh more.

A fairly common cedar you may be able to find is eastern red cedar, also known as aromatic cedar. This is the stuff they make cedar chests from. While the wood is nice looking with distinctive color and grain, it grows in fairly small trees with a lot of branches, so it often has a lot of knots. The knots combined with being somewhat brittle make this wood hard to work with. However, the results may be nice if you have the patience.

If you have trouble finding cedar or need some contrasting colors, most other softwoods work well. Pine is pretty easy to find. You should be able to find clear, knot-free boards at most lumber outlets. Pine is heavier than cedar, has a consistent light yellowish color, and is easy to work with.

Although the spruce 2 by 4 studs available at most home centers are generally pretty poor quality, it is often possible to pick through the pile to find some nice clear specimens that can be milled into good strips. The strips will be heavier than cedar, but the price is right and, as long as the wood is dry, they should work well.

The bottom line is that just about any softwood can be used. Check your local lumber source and see what is available. Outside of North America your selection may be quite different from what is available here, but it is likely that there is something suitable.

Hardwoods. Hardwoods have traditionally been used only for trim on strip-built boats. Stems and gunwales are places where some tougher wood will help protect the boat from wear and tear. But there are reasons to choose hardwood for the strips. Although they tend to be heavier, that gain in weight is usually offset with a gain in strength. This may allow you to use thinner strips to keep the weight low.

Unfortunately, many of the desirable softwoods are still being harvested from old-growth forests. This raises the ethical issue of whether we should be turning those trees into boats, even if they are pretty. And there is the practical issue that the old-growth wood is getting harder and more expensive to find. Most hardwood, on the other hand, is being harvested from second- and third-growth areas in a pretty sustainable manner. This makes hardwoods an option worth considering.

Being generally harder than softwoods, hardwoods are also harder to work with. Everything from ripping strips to sanding may take a little more effort and time on the harder of the hardwoods. But there are several hardwoods that aren't so hard.

The late boatbuilder and writer Robb White swore by tulip poplar. It is a fast-growing tree that reaches up to the sky straight and tall, showing off its tulip-like blossoms to whoever gets up high enough to see them. The wood is almost as light as cedar and is quite tough. It machines very easily. Although the color may be a little boring—a pale beige with occasional streaks of green that eventually turn muddy brown—poplar is a fairly common hardwood available at home centers at a good price.

Basswood is well known to wood-carvers and model makers as being lightweight and easy to work with. It ranges from white with almost no visible grain to a darker brown. While it is hard to find in long lengths, it makes a good strip material. Like poplar, you may find the color a little boring, but both poplar and basswood take stain well if you want to spice it up a bit.

Sometimes called white walnut, butternut is a low-density wood with a little bit more interesting grain than poplar or basswood. It is a light tan to pinkish or amber color with occasional dark-brown streaks. It machines easily and can be stained, but like basswood, it can be hard to find in long boards.

Mechanical Properties of Selected Woods Suitable for Strip Planking[1]

Species Common Name	Specific Gravity[2] (Dry)	Static Bending			Impact Bending — Height of Drop Causing Complete Failure	Compression Parallel to Grain— Maximum Crushing Strength	Compression Perpendicular to Grain—Fiber Stress at Proportional Limit	Shear Parallel to Grain— Maximum Shearing Strength	Tension Perpendicular Grain— Maximum Tensile Strength	Side Hardness— Load Perpendicular to Grain
		Modulus of Rupture	Modulus of Elasticity	Work to Maximum Load						
		(kPa)	(MPa)	(kJ/m^3)	(mm)	(kPa)	(kPa)	(kPa)	(kPa)	N
Hardwood:										
Ash	0.6	103,000	12,000	115	1,090	51,100	8,000	13,200	6,500	5,900
Basswood	0.37	60,000	10,100	50	410	32,600	2,600	6,800	2,400	1,800
Butternut	0.38	56,000	8,100	57	610	36,200	3,200	8,100	3,000	2,200
Cherry	0.5	85,000	10,300	79	740	49,000	4,800	11,700	3,900	4,200
Maple, Silver	0.47	61,000	7,900	57	640	36,000	5,100	10,200	3,400	3,100
Maple, Sugar	0.63	109,000	12,600	114	990	54,000	10,100	16,100	—	6,400
Oak, Red	0.63	99,000	12,500	100	1,090	46,600	7,000	12,300	5,500	5,700
Oak, White	0.68	105,000	12,300	102	940	51,300	7,400	13,800	5,500	6,000
Sassafras	0.46	62,000	7,700	60	—	32,800	5,900	8,500	—	—
Yellow Poplar	0.42	70,000	10,900	61	610	38,200	3,400	8,200	3,700	2,400
Softwood:										
Cedar:										
Atlantic White	0.32	47,000	6,400	28	330	32,400	2,800	5,500	1,500	1,600
Northern White	0.31	45,000	5,500	33	300	27,300	2,100	5,900	1,700	1,400
Port Orford	0.43	88,000	11,700	63	710	43,100	5,000	9,400	2,800	2,800
Western Red	0.32	51,700	7,700	40	430	31,400	3,200	6,800	1,500	1,600
Douglas Fir	0.48	90,000	12,300	72	660	47,600	5,300	9,700	2,700	2,700
Pine:										
Long Leaf	0.59	100,000	13,700	81	860	58,400	6,600	10,400	3,200	3,900
Sugar	0.36	57,000	8,200	38	460	30,800	3,400	7,800	2,400	1,700
Eastern White	0.35	59,000	8,500	47	460	33,100	3,000	6,200	2,100	1,700
Western White	0.38	67,000	10,100	61	580	34,700	3,200	7,200	—	1,900
Redwood	0.35	54,000	7,600	36	380	36,000	3,600	7,600	1,700	1,900
Spruce, White	0.4	68,000	9,200	53	510	37,700	3,200	7,400	2,500	2,100
Spruce, Sitka	0.36	65,000	9,900	65	640	35,700	3,000	6,700	2,600	2,300
Imported:										
Balsa	0.16	21600	3,400	14	—	14,900	—	2,100	—	—
Mahogany, African	0.42	73,800	9,700	57	—	44,500	—	10,300	—	3,700
Mahogany, True	0.45	79,300	10,300	52	—	46,700	—	8,500	—	3,600
Spanish Cedar	0.41	79,300	9,900	65	—	42,800	—	7,600	—	2,700

[1]Extracted from Wood Handbook: Wood as an Engineering Material, available online from the USDA Forest Service, Forest Products Laboratory.
[2]Specific gravity is the density relative to water where the specific gravity of water is 1. Lower numbers are lighter.
[3]Specific gravity calculated: volume wet, weight dry.

Figure 2-1. *Use this table to evaluate the strengths and weaknesses of your chosen material for strips.*

Those are some options in lighter-weight, softer hardwoods. They will be the easiest options to work with, but some of the more common harder hardwoods can produce spectacular results. Think of maple with its different figures: curly, tiger, bird's-eye, and so forth. The possibilities for a spectacular-looking boat are exciting. The downside of these figured woods is that they are notoriously hard to work with. However, with patience you should be able to make a strip-built boat out of any wood. Fairly common woods such as walnut, cherry, birch, and oak or less common such as locust, elm, or chestnut are all possible sources of strip material.

These heavier woods will obviously make a heavier boat if you use them at full thickness. At ¼ inch thick most of these woods will be fairly hard to bend. This is fine for a larger boat, but smaller boats have tighter curves that may be hard to conform your strips to. To save weight and to make it easier to fit to the forms, and with more expensive wood to get more strips from a board, you will want to use thinner strips with these woods.

Alternatives. Obviously if we can stray from the standard cedar and other softwoods into the area of domestic hardwoods, we could also go into some of the exotic hardwoods. Many of these woods are harvested from jungles where it may be better they stayed, but they do offer some exciting possibilities. Mahogany is well known for being easy to work with, strong, and beautiful. Spanish cedar is not only used for cigar humidors but also makes nice strips. I even know of a strip-built canoe made of ebony.

Again, due to the weight, strength, and expense of many exotics, thin strips become a good option. Thinner strips do provide less room for error, but presumably, with expensive material you are already being careful not to make mistakes.

You can even avoid wood altogether. All of the techniques described in this book can be adapted to synthetic materials such as foam. At first blush you may think this is the perfect solution for the lightest boat. After all, foam is lighter than wood. It is usually true that foam is lightweight, but it is not as tough as wood. It tends to dent easily. Because of this, you often need to apply more fiberglass to protect the soft core, which will bring the weight back up. Working carefully, you can make a lightweight boat out of foam strips, but you may be able to make something just as light and even stronger with wood strips.

Plywood. Plywood is often a good choice for parts where a relatively flat, stiff panel is needed. You could make a transom by gluing up a panel of strips and then fiberglassing it, or you could just cut it out of a suitable piece of plywood. While I still like to protect my plywood under a layer of fiberglass and epoxy, using it where a large panel is needed can be a time-saver. Plywood is also useful for making some parts such as the recess around a kayak cockpit that have a simple bend in one direction.

While a layer of fabric on both sides will convert a cheap piece of plywood such as luan "door skin" into something much stronger and more waterproof, marine plywood is still worth considering. The primary difference between marine plywood and the other kinds is that the marine stuff does not have any interior voids or holes in the internal veneers. Voids accumulate humidity, which can lead to rot, and they represent weak spots in the structure.

While you could use fir marine plywood, it tends to have checks or cracks on the surface veneers that are hard to deal with, making it not very nice looking. Under a layer of reinforcing fabric and painted, it would probably be fine. For better-looking results, however, hardwood and mahogany plywoods are a good choice. A common material is okoume. This is available in thickness from 3 mm up to 1 inch. Okoume is a tropical wood related to mahogany. Another source of high-quality material is aircraft plywood and related birch plywoods that are available as thin as 1⁄32 inch.

Cove-and-Bead Strips. The strip-plank method is strongly associated with cove-and-bead strips. The cove-and-bead is much like a tongue-and-groove, but it can produce a tight joint even when the adjacent strips are oriented at an angle to each other. By milling a radius on one edge (a bead) and a matching hollow on the other edge (a cove), a ball-and-socket-like joint is created. As you strip around the curves of the boat, this joint will be pretty tight without a lot of fussing. The cove-and-bead is made by running each strip through a router, cutting the bead first and then the hollow, more delicate cove.

Notice that I did not say a "perfectly tight" joint. I'll get into that more in a moment, but first, a little background. It would seem to make sense to have the diameter of the cuts match the thickness of the strip: ¼-inch-thick strips suggest a cove that is ¼ inch in diameter. And indeed you can buy bits designed for this purpose.

Notice that a ¼-inch-diameter cove cut full depth into the edge of the strip will be ⅛ inch deep. If you push a ¼-inch-diameter bead ⅛ inch straight into a ¼-inch-diameter cove, and then try to rotate it down a bit, the "wings" at the edges of the cove immediately start push-

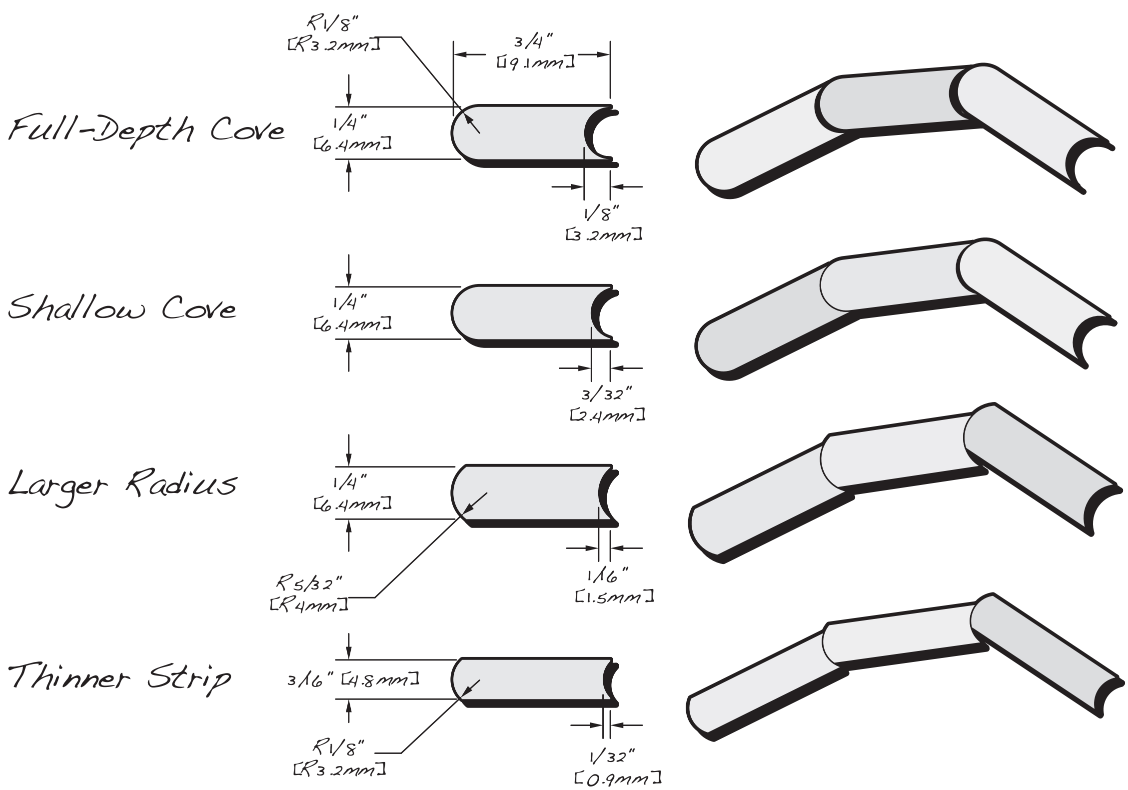

Figure 2-2. *The standard cove-and-bead strip for small boats is about ¼ inch thick and has a ¼-inch-diameter cove or bead on each end. The obvious thought is the cove should be ⅛ inch deep, but this can cause problems. Not only are the feather-edged wings on either side of the cove delicate and weak, but they can also make it hard to seat the bead all the way into the cove when the strips meet at an angle since the wings get in the way. A shallower cove that leaves a tiny square edge on either wing is a little more rugged, and it allows a little more freedom of rotation for easier tight fits on tighter angles. Milling a larger-radius cove-and-bead or using the same bit on a thinner strip also makes tight joints easier but may result in a less smooth surface.*

ing against the side of the strip and don't allow it to rotate without opening up a gap inside the joint. This internal gap will be hard to see as you build, but it may open up during fairing. It also weakens the structure a bit.

The first solution is to leave a little bit of a square edge on each wing. The second is to use a diameter for the cove and bead that is slightly larger than the thickness of the strip. For ¼-inch strips it may be hard to find a 5⁄16-inch-diameter bit, so a ¼-inch bit may have to do, but you can also use that same bit on thinner strips.

Using a larger-diameter bit will help eliminate the internal gaps, but I have found that I can actually produce tighter joints by beveling each strip with a hand plane to fit, one at a time. While this method takes longer and requires more technique and skill, it allows for a very snug joint.

Cove-and-bead strips are not necessary to build a good boat. A tight, hand-planed bevel joint will be every bit as strong, and in some cases stronger than cove-and-bead. For very thin (⅛-inch) strips, hand-planed bevel joints are really the only viable option. It takes a lot of work to do the hand beveling, but with practice it becomes pretty routine. Complicated shapes, in fact, may actually be easier to accomplish because the bevel provides a natural stop for maintaining a difficult angle between two adjacent strips.

While cove-and-bead strips can be a timesaver, it depends on the boat how useful they are. It does take time to mill your own cove-and-bead strips accurately and consistently. If you are unable to do a good job with the initial milling, you may be better off just leaving the edges square and then beveling.

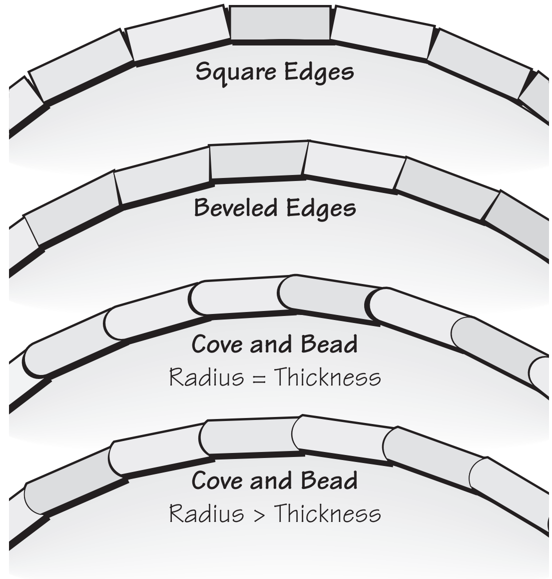

Figure 2-3. *For a quick and dirty boat or a design with lots of flat surfaces, square-edge strips leave some gaps, but epoxy will probably fill them in. However, the surface may be slightly uneven. Carefully hand planing bevels on the edges produces tight joints on the outside of the boat, but it takes a lot of skill to keep the gaps tight on the inside. Again the strips provide no assistance in keeping the surface even, so some additional sanding may be required. Using cove-and-bead strips where the diameter of the cove equals the thickness of the strip produces a smooth surface with initially tight joints, but sanding may open up hidden gaps. Using a larger diameter helps assure tight joints after sanding but may require a little more sanding.*

Details, Details

So, how thick is thick, how heavy is heavy, and how strong is strong? I was afraid you would ask. It is a complicated set of questions without hard-and-fast answers because it really depends on what you are trying to accomplish. A dinghy that needs to be tied to a dock, fighting for space with the working skiff of the local lobsterman, probably needs to be stronger than a little canoe that will be used by the little old lady from Pasadena. The answer for one use is not necessarily the best choice in the next.

The baseline of strip-built canoe construction is ¼-inch-thick cedar covered with 6-ounce fiberglass. These scantlings have been used to build thousands of canoes and kayaks that have been used in a wide variety of conditions. Some have broken and failed, but most have survived years of use. If you are building a boat for one or two people that is going to be paddled in calm to moderately abusive conditions, this building schedule is a good starting point. If you are carrying more weight, or powering the boat with an engine, or venturing into extreme conditions, you may want to adjust the materials to make your boat stronger. A denser wood, thicker strips, and/or more or heavier glass are probably called for. Similarly, you may choose to go with thinner, lighter wood or less or lighter fiberglass if you are a lighter than average paddler, plan to race and are willing to shave a margin of safety to achieve better performance, or will restrict your paddling to mild conditions.

I have built many boats with 3⁄16-inch-thick cedar, covered with 4-ounce glass on the outside and exotic fabrics on the inside, and put them through a lot of abuse. I have successfully broken some, but it took a lot of work. Most boaters are not as willing to put their boat through the abuse I have subjected some of my boats to.

Part of your decision will be based on how you plan to abuse your boat. The forces a boat sees out in deep water in big waves is different from what happens when you run over a submerged stump, and this differs from dragging over rocks. With waves the forces are distributed over large areas; stumps stress small "point" areas; grinding over rocks is more abrasive.

Strength against distributed forces comes through stiffness. This allows the forces to be absorbed over the wide area. Thicker panels are stiffer, suggesting thicker strips. Point loads also benefit from stiffness, so long as the local spot that is subjected to the load is strong enough to survive the concentrated force. A harder wood under the glass can protect against a surface dent, as does a thicker layer of fiberglass. A dent in the surface is the first step toward a failure.

Another way to protect against a structural failure is to make the boat resilient. This is the opposite of stiff and requires thinner strips. A resilient boat will flex gracefully when it hits something. This is a little tricky, because if something is too flexible it won't handle large, distributed loads well. A boat that survives folding in half unharmed is not that useful if it folds in half while you are a mile offshore. But thin strips of a tough wood, with enough glass to hold it all together, could make a resilient boat. As a practical matter it may be pushing the limits of wood to make strip-built boats with thin enough strips to bend resiliently without breaking, but if you are an adventurous builder there are possibilities for building lightweight boats using thin strips.

Abrasion differs from getting hit by waves or running over a stump in that it is more of a surface issue. Abrasion occurs when a sharp object rubs against the boat. This could be the rough surface of barnacles or the sharp point of a hidden rock. The worst case may be a rock sharp enough to slice into the surface. While this kind of abuse may not result in catastrophic failure, over time it can mess up your boat. The best protection against abrasion is a solid layer of reinforcing fabric and epoxy. The wood under the fabric is less important than the protective shell of the resin and cloth.

Resin

One of the most significant downsides of wood is that it really doesn't play well with water. Traditionally built boats are constantly at battle with water. Water makes the wood swell up and get bigger. It then may dry out and get smaller. This opens up seams and loosens fasteners. At the same time little critters and plants find wood a nice place to set up housekeeping. The wood can provide food and shelter for a variety of organisms. All it takes for them to thrive is the presence of a little water and air. As a result wet wood will rot and deteriorate with time. This deterioration is not inevitable; with a little care to keep the wood dry it will last a long, long time.

The question is, how do you keep a boat dry? You don't actually have to keep the boat dry; you just want keep the wood dry. And the answer is—plastics.

Epoxy is a two-part liquid plastic that, when mixed together, becomes a hard, waterproof plastic. By sealing the wood under a plastic layer it is possible to keep the wood dry and free from rot.

Polyester

When most people who know a little bit about fiberglass think of fiberglass they are thinking about a very sticky, stinky liquid resin used to repair cars and large fiberglass boats. This stinky stuff is polyester resin. Polyester is a liquid plastic mixed with solvents that turn into a solid when exposed to a catalyst. It is relatively inexpensive, and you can control how quickly it hardens by adjusting how much catalyst you add. A small amount makes a slow batch; a lot can make a "hot" batch. As the resin hardens, the solvent is driven off, leaving very small holes in the plastic that will slowly absorb water and let it permeate into the wood.

Polyester resin is not a very good adhesive, so it doesn't bond to wood very well, but it can still be used for strip construction if you are trying to save money. I'm not sure it is worth it, but there are some old strip-built boats out there built with polyester resin, so it can't be too bad.

Vinylester

Vinylester is related to polyester resin, but it creates stronger chemical bonds during its curing reaction. It still contains the solvents used in polyester, but it absorbs less water. It has better physical properties than polyester overall, but it is also more expensive. If you are looking for something better than polyester, you might as well go straight to epoxy.

Epoxy

The standard resin used for strip-building boats is epoxy. It is strong, bonds well to wood, and is very resistant to water absorption. Epoxy uses two liquids mixed in precise proportions that fully react with each other to create a hard solid. The two parts of the mixture are typically called resin and hardener. This can be a little confusing because after the two parts are mixed together, the liquid is called resin. Epoxy does not typically contain any solvents, so everything in the two parts stays incorporated into the final product. If the proportions of the resin and hardener are not correct, the mixed resin will not cure completely and may be weak or may remain liquid even after the chemical reaction is complete.

The curing speed depends on the chemistry of the hardener. Most manufacturers formulate several different hardeners to control the speed, making a "fast" and a "slow" hardener. Because the correct proportions must be present in the mix, you cannot adjust the speed by varying the amount of hardener; however, you can use a mix of the fast and slow resins just so long as the total proportion of hardener to resin remains the same overall.

Epoxy bonds very well to wood and other materials, so it is the ideal material for bonding fiberglass to the wood strips. One of epoxy's biggest limitations is that the ultraviolet light in sunlight will cause it to degrade. If the surface of epoxy is left exposed to sunlight for a long time, it starts to deteriorate, becomes cloudy, and eventually just falls apart. This doesn't happen immediately, but any exposed epoxy should be protected with varnish or paint.

You will often come across the term *amine blush*, usually just called blush, associated with epoxy. Blush is a waxy coating that appears on the surface of some freshly cured resin. It is the result of a reaction between the chemicals in the resin and humidity in the air. While there are several brands of epoxy that are said to be blush-free, you should be aware of the possibility even when using these resins. I have found that even ostensibly blush-free epoxies will sometimes blush in really humid weather.

The problem with amine blush is that it interferes with the bonding of additional coats or layers of epoxy. Whenever it occurs, you should clean the surface thoroughly with water. Use fresh, clean water and a clean sponge or scouring pad to clean the whole boat. Dry the whole surface with a clean rag. Be sure the entire boat is dry before applying more epoxy.

Note that sanding off the blush is not as effective as washing. The sanding will clean some off, but it will just smear the rest of it around. The blush will also cause your sandpaper to gum up quickly.

If you think your epoxy has had enough time to cure, yet it still feels sticky, you may have blush. Try pressing your thumbnail into the epoxy; if you cannot easily scratch the surface the epoxy is probably cured and you just need to remove the blush. Take a wet rag, wipe a small patch of the surface, and then wipe it dry. If the surface no longer feels sticky, the problem was blush.

Safety

Whatever variety of resin you use, it is important to remember that they are reactive petrochemicals that you want to be careful handling. Epoxy can cause an allergic reaction and is a skin irritant. Polyester and vinylester resin can damage the respiratory tract and central nervous system. Use them in a shop with good ventilation, wear an organic vapor respirator, and wear protective gloves while handling them.

Despite all that scary stuff, it is possible to use the materials safely. Read the material safety data sheets (MSDS) for the materials you are using. Most epoxies are considered safe for use at home, but you should investigate any chemicals you bring into the house.

Reinforcing Fabrics

This fabric is really the key to the success of the strip-built method. It provides most of the reinforcement required to hold the boat together, and it creates a thick barrier between the rocks and water and the wood core. It is really pretty amazing stuff, and yes, there actually is fabric there over the wood.

It is often hard for first-time observers to wrap their mind around the idea that the outside surface of a strip-built boat is covered with fabric. They see the wood and just think that there is a lot of varnish on it. When they think of fiberglass they visualize the pink stuff in their attic and don't understand how there can be any form of cloth between their hand and the wood.

Fiberglass is not the only reinforcing fabric that can be used on strip-planked boats. It is just the only one that becomes completely transparent when saturated with resin. There are other synthetic materials that are also suitable for reinforcing the boat. We'll address these in the following sections.

Figure 2-4. *To help keep the fabric clean and undistorted, make a fabric dispensing rack from 2 by 6 lumber and electrical conduit to hold the rolls. Shown on this rack are black carbon fiber cloth, Kevlar (straw colored), and some different kinds of fiberglass. The plastic keeps dust off the material.*

It is the combination of the fabric reinforcement and the plastic resin that makes the system work. Whenever you try to bend something, the outside of the bent material is stretching in tension and the inside is shrinking in compression. Fibers are really good at resisting tension but, as they say, "you can't push a rope," so they need help in compression. The plastic of the resin is good at withstanding this compression. The resin also bonds the fabric to the wood and makes the wood and fabric work together as one integrated composite material.

Fiberglass

Fiberglass comes in several varieties that have different properties. The most common is E-glass, but some people use higher-strength S glass. They are both thin fibers of glass; the difference is in the chemical properties of the glass itself.

Figure 2-5. *Reinforcing fabrics are available in a variety of materials. The white fabrics on the left are fiberglass, which becomes clear when saturated with resin. The black carbon fiber (top right) stays black. Woven tapes of different widths (middle right) are available for reinforcing and joining parts. The spool on the lower right contains carbon fiber "tow," an unwoven roll of fibers that can be used to make reinforcing ribs.*

E-Glass. E-glass is just standard fiberglass. The only time people will use the term *E-glass* is when they want to differentiate it from S glass. If you go to a supplier and ask for fiberglass, you will generally get E-glass. The "E" stands for electrical, but that doesn't really matter for our purposes, since we don't really care if our boats are good electrical insulators. It is pretty much the same glass used in windows, the kind that looks a little greenish when you look at the edge of a pane. This color isn't really noticeable in the raw fabric, but if you have a piece next to some S glass, the S glass will look marginally whiter.

All fiberglass cloth starts out appearing white. This is due to light reflecting and refracting off all the little individual glass fibers. When it is saturated with epoxy resin, the individual strands no longer disrupt the light and demonstrate that they actually are clear. The glass and the resin have similar light-handling properties, so the glass completely disappears in the resin.

S Glass. The "S" in S glass stands for strength. It is a higher-strength material than electrical glass, with about 40% higher tensile strength and up to 20% higher compression strength. Otherwise the fabric handles just about the same as the standard E-glass. It cuts with the same scissors, and it wets out (fully saturates with resin) in the same way. However, it has slightly different optical properties from E-glass. As a result, while it still becomes completely transparent, it tends to bend the light a little bit in the fiberglass-epoxy layup. This means that it is not completely invisible in the finished boat. Close examination of the surface will reveal a faint weave pattern within the layup.

It is a good option if a high-strength layup is required but you don't want to obscure the wood with an exotic fiber like Kevlar or carbon.

Sizings. Reinforcing fabrics are not merely the base fiber woven into cloth. After the cloth has been woven, it is cleaned and treated. The cloth is then finished with a sizing that helps the resin bond with the material. There are a variety of different finishes that are compatible with different resin systems. Double check with your fiberglass supplier to be sure the cloth you order is compatible with the epoxy. This treatment does degrade with time, exposure to heat and humidity, and rough handling. Cloth is usually fine for a couple of years, but if it is several years old, the cloth should be tested if it is to be used in critical applications.

Weaves. The standard weave pattern for fiberglass is the typical over-under-over-under pattern known as plain weave. This pattern works well for just about all the uses we may have, but there are some other patterns, such as twill, where the yarns go over-over-under-under, or satin weaves, where they go over-under-under-under. The twill is better at conforming to complicated shapes than plain weave, while still holding together pretty well. Satin weaves conform even better, but they may get a little loose and distort easily.

Even within a weave style there can be differences. Some cloth has a very tight weave, whereas others are looser. A looser weave generally wets out easily, absorbing resin more readily because resin can get in and air can get out readily. Looser weaves also conform to tight curves better. On the other hand, it is possible to make a lighter boat with tighter weaves because less resin is needed to fill up the spaces between fibers.

Weight. Fabrics such as fiberglass, Kevlar, and carbon fiber are sold by weight per area, typically ounces per square yard. A standard-weight fiberglass for small boats is 6 ounces per square yard, referred to as 6-ounce cloth, and it is available from 24 ounces down to 1 ounce. The practical range for small boats is between 12 ounces and about 4 ounces, but in special situations lighter and heavier weaves may make sense.

Figure 2-6. *Fabrics are produced in many weave patterns. The "over-under-over-under" weave is called plain weave and is most typical. Keeping the yarns over a few extra times, or going under a few yarns before going over, produces fabrics with slightly different properties. The twill weave goes over two and under two. When made with two different yarns such as carbon and Kevlar, the pattern looks a little like houndstooth, with a distinctive repeating pattern. Because the yarns have few bends, there is less stress on the fibers, making them a little stronger. This is also true of satin weave where the yarns are under for several spots and hop over for one. This relatively loose weave is smooth and conforms easily to complicated shapes.*

Exotic Fibers

There are a variety of materials out there beyond fiberglass that are suitable for reinforcing strip-built boats. Essentially, any fabric that can be used in composite layups with epoxy can be applied to wood strips. Unfortunately, none of them are as transparent as fiberglass. Generally those that start out white become somewhat translucent when saturated with resin, but many are essentially opaque. Due to this, they can be somewhat difficult to wet out.

Glass provides obvious feedback when it is completely saturated since it becomes clear. The opaque fabrics usually just become marginally darker when you apply resin, and this does not necessarily indicate they have been fully wet out. The cloth may be saturated, but there may not be enough resin to saturate through to the wood. Cloth that is not adhered to the wood will usually show up as a bubble or ripple in the otherwise smooth surface. Opaque fabrics require careful inspection before you complete the wet-out to assure that it is fully bonded to the wood.

Exotic fabrics are also more expensive. At the time of this writing Kevlar was about two and a half times the price of glass, and carbon fiber cloth was almost eight times the cost. Given the relatively small amounts used in these boats, the cost of the material will still be small compared to the amount of labor you will put into the boat, but you may decide that any benefit is just not worth the expense.

Kevlar. Kevlar is the material famous for being bulletproof. Kevlar is a brand of aramid fiber made by DuPont, but other brands, such as Twaron (from Teijin Aramid), are available. Technically, the bulletproof stuff is a slightly different product (Kevlar 29), but the stuff used on boats (Kevlar 49) is similar.

These fibers are very tough and tenacious. They really don't like to break. The material is also very low density. As a result the fabric suggests the possibility of making a strong, lightweight reinforcement for strip boats.

Unfortunately, it is not as straightforward as it first seems. Kevlar is a low-density material, so for a given volume it weighs less than fiberglass. But if you turn this around, a 6-ounce fabric weighs 6 ounces per square yard regardless of the material, so the low-density Kevlar takes up more volume than the glass. This means it will absorb more epoxy. In the final analysis the exotic cloth may result in a heavier boat unless you use a lighter-weight fabric than you would have used otherwise. While it may seem like an obvious choice to just switch to a lighter-weight fabric, the most commonly available Kevlar is 6-ounce. It is difficult to find lighter-weight versions.

Theoretically it will make the boat stronger. However, as a practical matter, given the resin absorption, you may do as well using a double layer of fiberglass. A hard hit will probably do similar damage to a boat made with one layer of 6-ounce Kevlar as it would to two layers of 6-ounce fiberglass, and the weight will be similar. While Kevlar may have a slight advantage, it has the downside of being hard to work with. It is difficult to cut, requiring special scissors, and is a little more difficult to wet out with epoxy than fiberglass.

Carbon Fiber. Carbon fiber is the miracle fiber of the moment. It is used in everything from hockey sticks to jet fighters. It has a reputation for being lightweight and strong. It also has a striking deep-black color with a distinctive glistening weave texture. The aerospace industry processes it into wings using high-pressure autoclaves to eke the most out of the material.

Because most of us don't have an autoclave kicking around in our basement, we need to lay it up in the same manner as fiberglass. As a result it runs into the same problem as Kevlar; even though carbon fiber itself is light, it absorbs more epoxy than fiberglass, so it is hard to get superlightweight layups by hand. However, it is stronger than fiberglass and results in a stiffer layup, so if you are willing to pay the extra expense to save a couple of pounds you can use a thin carbon fiber cloth to create a lightweight boat.

The downside of carbon fiber is that it is somewhat brittle. It will absorb a lot of energy before breaking, but it tends to fail suddenly when pushed too far. What carbon fiber does effectively is look dramatic. The deep black creates a nice contrast with the wood strips of the rest of the boat.

Carbon fiber is a little hard to work with. While it cuts easily with regular scissors and wets out easily, it is hard to tell when you have completely saturated the fabric.

Like Kevlar, carbon fiber is most commonly available at 6 ounces per square yard. Because of the lower density of the fabric, this can result in a heavier boat than 6-ounce fiberglass used in the same location. Carbon fiber is available in lighter weaves—2-ounce cloth is available—but can be even more expensive than Kevlar.

Hybrids. One way to get the properties of several kinds of fabric is to use a hybrid cloth that combines yarns of different materials. For example, a carbon–S glass cloth may have carbon yarns running the length of the roll, with glass fibers running crosswise. The carbon yarns can be laid across the boat acting as ribs, with the glass running lengthwise for additional reinforcement. Carbon-Kevlar cloth has the stiffness of carbon fiber with the final toughness of Kevlar.

The exotic fabrics have a certain sex appeal and can be used effectively to make a better boat, but the additional performance of these materials is often not proportionate with the added cost and hassle in their use. Use them with the knowledge that they are not going to make a huge difference in the weight, strength, or quality of the finished boat.

Tapes. Just about any type of fabric is available in a narrow tape form. These tapes can be used wherever a narrow piece of cloth is needed to reinforce the boat. Most tapes are woven specifically to be used in tape form and have a selvaged edge where the yarns that cross the tape turn around and head back the other way. This is useful in that it keeps the edges of the tape from becoming frayed. The downside is the edge tends to be a little thicker than the body. Furthermore, fiberglass tape is available in pretty much one 9-ounce weight, which is a good compromise for a lot of uses but may be thick when used in conjunction with other thinner weights of cloth. The prewoven glass tape also does not seem to wet out as clear as the wider cloths.

It is possible to cut your own tape from wider rolls, just by using your scissors and cutting the width you need. This can be useful where you need long strips but don't need the heavy strength of the prewoven tape. There are also some specialty machine-cut tapes, but they are hard to come by.

One useful form of manually cut tape is bias tape. This is just a fancy name for strips of cloth cut on the bias with the cloth, or at 45 degrees to the weave. If you roll out a square of cloth onto a clean cutting surface and start cutting at one corner heading diagonally across the square toward the opposite corner, you are cutting on the bias. Cut a few strips of the width needed and you now have bias-cut tape.

The benefit of bias tape is that it conforms well to difficult shapes. With the fibers running diagonally across the tape, the fibers can move relative to each other like scissors. They can change angle easily. This allows the tape to get wider or narrower and otherwise distort quite easily. It is this ability to distort that we are looking for. On complicated surfaces or sharp angles the fibers need to adjust to conform, and the bias cut allows them to do so. Because the cloth distorts easily, you need to handle bias-cut cloth gently. Tugging on it will cause it to distort prematurely. Handle bias tape carefully.

Glues

Glue is used in two major ways in strip building. First the strips are glued together edge to edge. Second, after the strips are in place, another form of glue is used to adhere the reinforcing fabric to the wood. The first form of glue just needs to be able to glue wood to wood with a bond that is at least as strong as the wood. The other form is more specialized; it needs to be strong and waterproof and bond to wood as well as glass and other unusual substances.

Notice that I did not say the first form of glue had to be waterproof. Gluing the strips together sounds like something where you would want a waterproof adhesive, but it is not required. The fiberglass and epoxy will coat all the wood, completely encapsulating it in an impermeable layer of reinforced plastic. Even if this protective reinforcement is ruptured, very little water actually gets into the wood. As a result, waterproof glue is not needed between the strips.

Carpenter's Glue

The standard yellow wood glue (available under many trade names, including Elmer's ProBond and Titebond) is polyvinyl acetate (PVA). This is a water-based glue that cleans up with soap and water, dries quickly, and is quite affordable. There are actually waterproof versions of this type of glue on the market, but as stated above they are not required. You may feel that even if waterproof is not required, you might as well use a waterproof PVA if it is the same stuff, but adds an extra degree of safety. While this makes sense, I have not found that the waterproof version is really the same. The standard carpenter's glue has a nice "tack." When you press strips together, the standard glue will grab and hold the new strip quickly, and it will tend to stay in place. If you rub the two pieces together as you are assembling the joint, the seam bonds together very quickly. You still need to clamp or otherwise hold the parts in place for a few minutes longer, but by the time you have the next strip ready, the glue is generally strong enough to remove whatever you have holding the seam tight. I have found that the more waterproof PVA glues do not seem to have this property as much. I also find that some of the more waterproof PVA glues do not dry as clear as the old standby. Of course, the formulations may change as time goes on, so you may have different results than I did.

PVA is actually a thermoplastic when it is dry. This means that heat will soften it and reactivate the glue. If you make a mistake, it is possible, if difficult, to heat up the wood and pull the joint apart. The downside of this property is, if you do not have tight joints, a boat left out in the sun may have some softening of the joints. This can result in some print-through of the seams to the outer surface, and in the worst case the stress may create a white line in the fiberglass. Striving for nice tight joints between strips can minimize the chance of this.

Cyanoacrylate

The most famous of this type of glue used an advertisement that featured a guy hanging from a hardhat glued to a steel I-beam. Cyanoacrylate (CA) glues like Super Glue cure very quickly and are quite strong, although they can be brittle. While they are expensive enough that I would not recommend them for gluing together a whole boat, their quick-cure capacity makes them a good clamp substitute for hard-to-hold objects. You can purchase spray accelerants that cause the glue to set up almost immediately. I use them in combination with other glues when I want a quick bond. You do not need to deal with the little tubes of glue typical of Super Glue. Several manufacturers sell larger bottles in a variety of different viscosities under trade names including Hot Stuff and Great Planes. I like a somewhat thick CA glue or a gel for most wood gluing.

Epoxy

The same epoxy resin that is used to wet out fiberglass fabric can also be used as glue. The epoxy used in building strip-planked boats is different from the hardware store consumer grade epoxy and 5-minute stuff. Five-minute epoxy has its uses for quick-tacking jobs, but I've switched to CA glue for most of those tasks. The epoxy used to wet out fiberglass and other fabrics is a liquid with a viscosity similar to heavy cream, usually with a mix of 2:1 (resin to hardener) or higher. Many people refer to this epoxy as the West System after the product developed by the Gougeon brothers. I usually use MAS resin, but the West System is a good choice, as is System Three. There are some other, less expensive brands that many people have used with good success. Ask around to get recommendations.

These low-viscosity resins are usually designed to flow into fiberglass and other fabrics to wet it out easily. Lower-viscosity resins do this faster and as a result are easier to use. They will also soak into the wood slightly to promote a strong bond. The mixed resin is used unmodified to seal wood, wet out fabric, and later, fill the weave texture. It can be used straight to glue wood to wood, but this is not really what it is designed for.

Straight epoxy has a fairly low viscosity and does not have much reinforcing ability. This is good when combined with fiberglass. The low viscosity lets it flow into the fabric, and the fabric provides the reinforcement. But used as a glue all by itself it often drains out of the glue joint, leaving a starved bond where there may be gaps or air pockets between the two pieces you are attempting to glue together. This is obviously not going to be as strong as you may wish.

To make a good glue from epoxy, you can add stuff to already mixed resin. Depending on what you are looking for, there are a variety of fillers that will thicken the resin or make it structurally stronger.

Colloidal Silica. A colloid is a dispersion of fine particles in another substance. Colloidal silica, sometimes called fumed silica, is essentially a really, really fine glass powder. You can add it to mixed resin to make it less viscous and harder. The amount you add will depend on how you are going to use the mixture. A mayonnaise-like consistency works well for gluing wood pieces together, while a peanut-butter-like thickness is good for *fillets*, which are long, coved epoxy structures used to fill in sharp interior angles between two surfaces, such as where a bulkhead meets the inside surface of a hull. The peanut butter consistency is also good for creating wear protection on exposed surfaces such as along a keel line.

Sold under several brand names including Cab-O-Sil and Aerosil, it is a commonly available filler for use with epoxy and other resins. If you need only a little bit, or are looking for a substitute, common baking flour can be used. While the final product is not as hard, wheat flour will thicken resin quite effectively.

Wood Flour. Known to those not in the know as sawdust, wood flour can be used much like colloidal silica. Where the silica makes a whitish mixture, wood flour makes a brown substance that I like to call "dookie schmutz." The color will depend on the wood the dust was made from. A good source is the dust collector of your sander. While the pile under your table saw can be mined for epoxy filler, it will make a coarse, lumpy mix, whereas the sander provides smoother filler. One of the beauties of this filler is if you collect it from your own boat, you will have a filler that closely matches the color of the boat. It will typically be a little darker than the solid wood, but you can adjust the tone by adding some colloidal silica.

I use dookie schmutz where I want a fillet to ease the angle in a sharp inside corner such as the coaming to deck joint of a kayak. Because of the fibers in wood, wood flour adds some structural strength to resin, but the fibers are short enough that it doesn't amount to much.

Chopped Fiberglass. Short strands of chopped fiberglass, sometimes called "kitty hair," will add more strength to resin. This material is commercially available in a variety of lengths. Longer strands create a lumpy mix but are stronger; shorter pieces will mix more smoothly, with some loss of strength. Because mixing forces air into the mix, resin with chopped fiberglass is usually translucent with a milky cast to it. Chopped glass can be added to dookie schmutz where more strength is required or anytime you need a thick structural adhesive.

There are actually a wide variety of chopped fibers that may be added to epoxy resin. Kevlar and carbon fiber are both available in short chopped form. These fillers provide some of the properties of the materials in long fiber form, but with the ability to make a putty or glue.

Graphite Powder. While it sounds like it may be related to graphite cloth or carbon fiber, graphite powder does not have much strength. It is more like a lubricant. This fine black dust may be added to resin to make a coating or paint. The addition of the graphite makes the resin-coated surface quite slippery. If you coat the bottom of your boat with it, the boat will slide easily over rocks with less tendency to scratch. Perhaps obviously, the coating is black, which is usually fine for the bottom of the boat.

Microballoons and Microspheres. There are times when you want a lightweight filler. For example, you might need to fill in an area without adding much weight. What you want to do is add a lot of air to the resin and have it stay in while it cures. Maybe some tiny plastic balloons or itty-bitty glass bubbles? Phenolic microballoons and quartz microspheres are just the thing. You can mix these in the resin to create a low-density putty or filler. The phenolic balloons are reddish brown and the quartz are bright white. They can also be combined with the other fillers noted earlier to create a combination of properties. These lightweight fillers also help make the hardened epoxy easier to sand.

Polyurethane

A recently popular glue on the market is polyurethane based. The most famous of these is Gorilla Glue, but Elmer's and Titebond sell similar products. The glue reacts in the presence of water or humidity, becoming a strong, waterproof adhesive. With a good tight joint this glue works very well. In loose joints, the same chemical reaction turns the glue into a sticky foam that oozes out, sticking to everything. The foam is easy enough to remove, but it can make a mess of your tools and workbench. I have used this on stem laminations, and some people have substituted it for carpenter's glue between strips, but it makes a big mess and is hard to clean up, and I just don't find it worth the cost or effort.

Spray Adhesive

The best way to transfer full-size patterns onto form material is to glue them on. I often use 3M Super 77 that you can obtain from the hardware store, but woodworking suppliers sell a variety of spray adhesives for temporarily attaching patterns to wood. This is a task ideally suited to spray adhesive. Temporary versions are good if you want to be able to peel off the pattern, but I tend to leave the patterns in place. If I don't want the pattern to come off, I will spray both the material and the pattern and press them together.

You can also use some more aggressive spray adhesives such as 3M Hi-Strength 90 to glue foam padding onto seats or backrests.

Hot-Melt Glue

Every crafts shop and scrapbook supply store sells hot-melt glue, which is applied with a heat gun that melts the hard stick of glue. It is not exactly considered a good boatbuilding adhesive, with good reason. It is weak and softens up with heat. But it is fast acting. If you want a quick, temporary clamp, a drop of hot glue often does the trick. I use it instead of staples when I don't want to put holes in the strips. And there are places that will be reinforced with

Figure 2-7. *The strip planks need to be temporarily secured to the forms. The widely available T-50 utility staple on the lower left is the standard. I like the Bostich heavy-duty staple remover. It does a good job of pulling the staples without damaging the strips. If you prefer, hot-melt glue can be used instead of staples. The glue sticks are strong enough to hold the plank in place but weak enough to break when you are done. Masking tape or strapping tape also provides a good, quick, temporary clamp to hold together adjacent strips.*

fiberglass and epoxy where the low strength is not a problem, but the quick set is a benefit.

A variety of formulations of hot glue are on the market, and they seem to change without much notice. I guess the scrapbookers aren't that particular about how their glue works. You should do some testing to make sure that it works the way you expect. Get a high-wattage glue gun that will quickly heat the glue. Some come with a temperature switch that can be useful when you don't need full power.

Tape

Another nontraditional boatbuilding material is tape. Masking tape and packing tape have a variety of uses from acting as temporary clamps to removing excess material when trimming fiberglass. It is not a material that generally gets left in the boat, but more of a tool that helps in manufacturing.

Masking Tape

Masking tape is useful wherever you want to protect something from getting paint or other glop on it, but it has a lot of other uses as well. It can be used to help create a clean edge on fiberglass, clamp strips in place while glue dries, or protect the boat from sticking to the forms.

I use a lot of the blue painter's tape because it tends to peel off cleanly and can be left in place for a few days without drying out or becoming brittle.

Packing Tape

The fiberglass-reinforced packing tape makes a wonderful clamp when you need to apply more tension or pressure than the masking tape can handle. It can be hard to peel off, but if you fold over the end before sticking it down, it usually pulls up cleanly.

Waxed Paper

Waxed paper comes in amazingly useful in a variety of ways. If you need a slippery surface on the outfeed table of your table saw, a strip of waxed paper works great. If you are making a mess with glue and don't want to gum up your worktable, a strip of waxed paper makes cleanup easy.

Paint and Varnish

While it may not be obvious, the reason for paint and varnish is not to make your boat pretty; that's just a side effect of the real use. Epoxy and wood don't like sunlight. Ultraviolet light is hard on more things than just your skin. It breaks down chemical bonds and causes stuff to fall apart and fade.

Varnish and paint provide a protective layer over the materials that really matter. While the finish may fade, crack, and peel in time, it is better to have it happen to this outer layer than the important structure of the boat.

If you do a good job preparing the surface before applying the first coat of finish, a strip-built boat will not require much work when it comes time to refinish. Unlike traditional wooden boats where you need to sand down to raw wood, you usually only need to scratch up the existing finish a bit before applying more.

Spar Varnish

Spar varnish is the traditional finish for wooden boat parts that are left "bright." It is a clear mix of resins and UV protective additives that bonds to the wood and epoxy to create a protective barrier. This traditional finish is generally fairly straightforward to apply straight out of the can. You usually do not need to mix in any thinners, catalysts, or hardeners; just open the can, pour it through a filter, and brush it on. It can be sprayed if you have the right equipment, but it may need to be thinned down. I use Z-Spar Captain's Varnish from Pettit. I find it easy to use straight from the can, but even varnish from a home center should produce good results. Uncured epoxy can slow down the cure time of the varnish, so if you find your first coat takes a while to dry, don't panic; give it some time.

While not as durable as some of the modern finishes, good old varnish has proved reliable and long-lasting enough for most common uses. A matte or satin varnish looks very nice in some situations, but it is important to note that part of the UV protection of varnish comes from the gloss finish reflecting the harmful radiation away from the boat. The nonglossy varnishes are made dull by the addition of material that also makes it a little softer and less durable.

Polyurethane

Many modern varnishes are partially made of polyurethane, which is harder than traditional oils and resins and increases the longevity of the finish. Some can be used straight out of the can, but others must be mixed with a hardener or catalyst immediately before application. Some of these are quite noxious and should only be applied with professional protective equipment. Regardless of the noxious qualities, you will want to look for formulations with UV protective additives.

Harder finishes are less prone to scratching, but nothing is proof against dragging a boat over rocks. Even the hardest finish available is likely to get scratched up after a year of hard use and may require refinishing even if elsewhere on the boat is still in fine shape. Because harder finishes are more difficult to scratch, they are also more difficult to sand prior to applying the new finish.

Automotive finishes are a good option if you have access to the equipment to apply them. UV protection is a common property of car clear coats. If you know what you are doing, these finishes are a viable option for a boat.

Paint

While you may think it is a shame to cover the beautiful wood with paint, it is actually much better UV protection than any clear finish will ever be. A nice coat of paint on parts of the boat can accent the wood and make the whole boat look better. The primary difference between a marine paint and a good-quality household paint is the level of gloss. Marine paints tend to be shinier, and for that the manufacturers like to charge a lot more. Good-quality exterior household oil-based paint will work very well on a boat and will not be adversely affected by salt water.

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Chapter 3
Tools

The tools required for strip-building small boats are modest. A beginner with a limited budget can do a good job with a few basic tools. These tools are common and useful additions to any toolbox if you don't have them already.

Hand Tools

Most of the work of building a strip boat can be done with hand tools, which is nice because they are quiet and generally pleasant to use. Many beginning woodworkers are intimidated by hand tools because they think they are fussy to work with. If there is one trick to making hand tools easier to use it is keeping them sharp. This applies particularly to edge tools like chisels and planes, but any device that is intended to cut even if it is not thought of as an edge tool, such as sandpaper or a rasp, will produce better results when new and sharp.

Students in my boatbuilding classes often have problems making their tools work when the tools are dull. For example, with a plane that isn't cutting, students will fiddle with the adjustments to try to make it work better, but instead they end up with a tool that is all jammed up and now really doesn't work. The solution is to keep your tools sharp.

Sharpening Tools

I cannot emphasize enough the benefits of sharp tools. Many people may have a plane or a jackknife they bought years ago and have never sharpened. Let me tell you right now that it is dull. Even if you've only ever used it to spread peanut butter, it's dull. It was probably dull the day you bought it, and since then it has gotten duller just sitting in your sock drawer. If you've only used your plane once, that's probably because it was dull. If it had been sharp, you likely would have used it more often.

Counterintuitively, sharp tools are less likely to cause mistakes than dull ones. Sharp tools can be adjusted to remove less material, they are easier to control, and they are less likely to be overpushed, which causes unwanted cuts. This means that for reasons of safety as well as ease, you are better off with a sharp tool than a dull one. Sharp tools are a pleasure to use. Dull tools are endlessly frustrating.

Whole books have been written on sharpening hand tools. It is beyond the scope of this book to try to teach you everything you need to know to get your tools sharp. If you don't know how to sharpen your tools, please do some research to learn how to do it. An Internet search for "sharpening tools" will yield a wealth of information. See also the Bibliography section of this book for books on keeping your tools sharp.

If you are working with softwoods most of the time, your edge tools should stay sharp a long time, but a "long time" is measured in hours of work, not months or years. It is possible (but doubtful) the brand-new plane you bought was sharp when you got it, but after a day of consistent use, resharpen it whether you think it needs it or not.

A well-sharpened edge tool can be used to shave the hair off your arm; however, I don't want to see a bunch of boatbuilders with scarred arms, so I don't recommend you use your body as a calibrated sharpness testing device. Instead, try sliding the sharpened blade along the plastic barrel of a pen. If the blade immediately grabs into the pen it is sharp; if it slides it is not quite as sharp as it could be.

I could get all philosophical with you about how sharpening your tools is the essence of understanding your tools, but what matters is that edge tools cut by being sharp. It is possible today to purchase some very expensive hand tools. They aren't worth a thing if they are dull. The cheapest plane available will work quite well if you learn how to sharpen it. Better tools will not make you a better woodworker, but sharper tools will.

Figure 3-1. *Sharp tools make just about everything quicker, easier, and more precise. You can do a good job sharpening your tools with sandpaper stuck to a piece of glass, or use waterstones as shown. The little jig that holds the plane blade on the right will shorten the time spent sharpening, or you can use the more sophisticated jigs shown below the stones.*

Stones. Try not to get too caught up in the specifics of what kind of stone to use. In the end the principles are the same; you use some sort of abrasive surface to grind away at the steel of the cutting edge until the edge has no radius on it. Then you proceed to finer abrasives until the cutting edge is polished. People use waterstones, oilstones, diamond stones, sandpaper, abrasive powders, files, and grinding wheels (wet and dry). They all work, each has its own benefit, but in the end they are all doing the same thing: grinding away at the steel.

Precision woodwork requires flat grinding surfaces. Softer sharpening stones will tend to "dish" as you use them and will require flattening. The work we are doing building these boats does not require the greatest precision, but a flatter grinding surface will reduce the amount of time spent sharpening.

Honing Guides. Don't be afraid to cheat. Some people may feel that clamping your blade into some fixture to hold it while you are sharpening is a sign of moral turpitude. The goal of sharpening is a good edge on your tool. It is not a path to enlightenment. A honing guide is designed to hold your blade at a consistent angle throughout the sharpening process. It helps assure you only do as much grinding as necessary. This makes sharpening faster and easier. Since the goal is to build a boat, not spend your time with your nose literally to the grindstone, anything that speeds up sharpening is a good thing.

There are a wide variety of honing guides available. The most sophisticated help you lock in an angle and create microbevels and all sorts of fun stuff. The cheapest ones just clamp on the blade and roll back and forth and are still very much up to the job.

Knives

When it comes to trimming things, nothing can beat a sharp blade on the end of a handle, commonly known as a knife. Knives can be used to trim strips, sharpen pencils, and remove squeezed-out glue.

Jackknife. My jackknife is probably one of my most used tools. I rough out strip shapes with it, peel up tape, and use the screwdriver blade to pull staples. I like a knife that takes a good sharp edge, has a thin blade, and is comfortable in my hand. I find a modest Swiss Army knife (not one of those with a gazillion blades) works well

Figure 3-2. *The tool I use the most fits in my pocket. The little Swiss Army knife shapes most of my strips. The pocketknife below it works almost as well. A replaceable-blade utility knife has a variety of trimming uses but is not as good at shaping strips. A couple of chisels are useful for shaving down high spots.*

for me. The thin blade cuts cedar strips without trouble, and the whole thing drops into my pocket easily. Having some other tool blades such as a screwdriver and awl on the knife has often proved handy. While these other blades are not as good as a full-size, dedicated screwdriver or awl, it is often convenient to have something close at hand.

I've tried some bigger folding knives with hefty blades, but I find the small blades work better. Thick blades tend to split strips instead of cutting them. You could probably do well with a fixed-blade whittling knife or some chip-carving knife, but you will want to find a convenient way to protect yourself from the blade while you wander around the boat.

Utility Knife. A retractable-blade utility or box knife is not a replacement for a jackknife or whittling knife, but it does have its uses. It doesn't work well for trimming strips because it is harder to control. Instead I use mine for trimming fiberglass. It does a fine job trimming the edge off fiberglass cloth that has been wet out with epoxy.

I find the retractable-blade utility knives with the reversible, replaceable, trapezoidal blades work better than the snap-off blade box knives, but both will work. Again, sharp is the key to these knives working well. Reverse, replace, or break off the blade when it gets dull. Don't spend time wrestling with a dull blade. By the way, the "safety"-style utility blades with the rounded tips are pretty worthless for most boatbuilding uses.

Planes

Planes are just fancy knives held in a convenient handle and jig. Various parts of this handle help limit the depth of cut, maintain an optimum cutting angle, and get the removed wood out of the way. The best ones have an easy way to adjust the depth of the cut.

Block Plane. A block plane differs from other types by having the blade bevel on the top, but this is not why they are useful for strip-building boats. They are also small, and much of the work you will do with them is likewise small. A block plane fits in the palm of your hand and can easily be used one-handed with the piece you are working on held in your other hand. You can also hold the plane so it cuts pushing away from you or turn it around so you pull it toward you. It is a handy little tool that can do precision work or remove material quickly.

There is a wide range in the quality of block planes available. Big-box stores will have some real abortions but may have one or two that are decent by Stanley or Record. You can find some very nice used planes at tag sales and through used tool dealers; typically these will be by Stanley. Specialty woodworking outlets have some really excellent modern planes by Lie-Nielsen, Veritas, and others.

Look for a plane that has some threaded adjustment for blade depth. There are good planes that require you to tap the blade in and out, but life is easier with a good depth adjustment. On larger block planes, look for

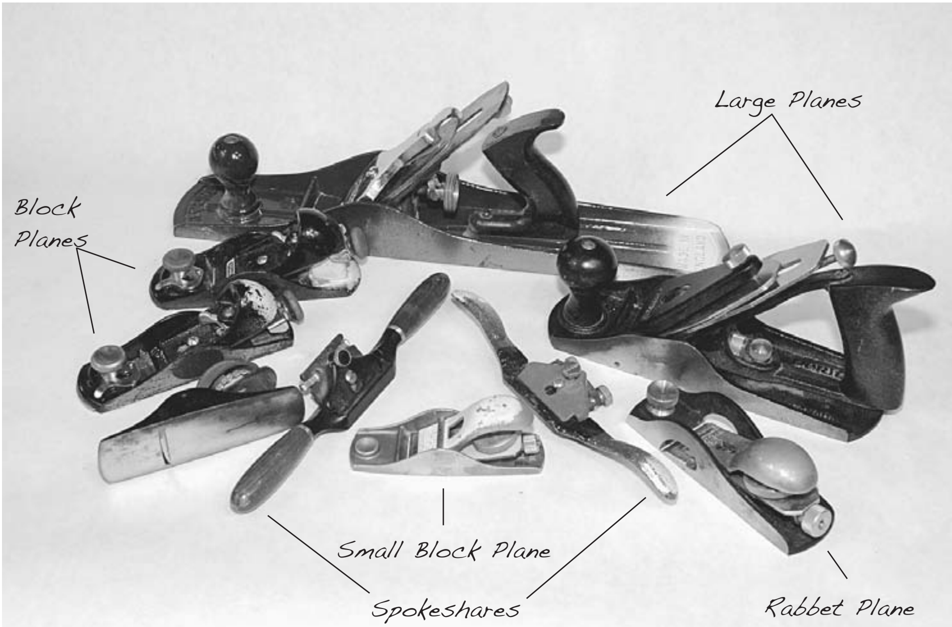

Figure 3-3. *Planes and spokeshaves provide great control for removing small amounts of wood. The little block plane front and center is my favorite. I use it for fitting all my strips, both in tapering strip ends and beveling their edges. It fits easily in one hand and can be pushed or pulled. The two similar block planes shown are also very serviceable; however, new versions of these may need a lot of tuning to get them working well. The larger planes at right don't get used as much, but they are good for creating long, tapered strips or fairly large, flatter surfaces. Also shown is a rabbet plane, with its blade extending all the way to the side of the foot. This allows you to adjust a bevel on a strip already on the forms. The spokeshaves can help fair rounded and concave areas.*

an adjustable throat, which lets you vary the width of the gap that shavings come through. A narrow opening helps control tear-out when working on funky grain. A wider opening allows big hunks of wood to come up easily so you can remove wood quickly. An adjustable throat is less common on the smaller planes.

Hold the plane in the palm of your hand before buying. You want it to fit comfortably without sharp edges cutting into your hand. As would be expected, you will get what you pay for. More expensive planes will generally use thicker, harder steel for the blade and will be machined with more precision.

Unlike furniture making where precision flat surfaces are required, strip-built boatbuilding should not require the intensive tuning-up of a plane recommended by some woodworking magazines. However, you do want to make sure the plane doesn't have places where the shavings will jam up. If the leading edge of the sole has a sharp edge you might want to ease it with a file so it doesn't catch.

Rabbet Plane. A rabbet plane is much like a block plane except the blade comes all the way out to the edge so you can plane right up against a face. This is useful in certain operations, but it is not all that common a need. A shoulder plane or any plane where the blade extends all the way to the edge of the tool would do much the same work as a rabbet plane for our purposes.

Spokeshave. Take a small plane, stick handles out the sides, and you will get something like a spokeshave. They are designed for shaping wagon wheel spokes and offer a lot of control for rounding over long surfaces. They have a short foot, so they also work well getting into concave or hollow areas. They are made with a flat or rounded foot. I find the flat foot to be easier to use. Like block planes, spokeshaves may also be used on a push or pull stroke.

Figure 3-4. *A paint scraper has a variety of uses, from removing glue drips to shaping concave surfaces. My favorite is the one at the top left with the thick handle. This started out with a square blade, but I have ground a variety of different curves at the corners and sides to conform to a variety shapes. I was hoping the wood-handled unit to its right would prove useful since it is preshaped to some good contours, but it was too light. The cheap hardware store version on the top right is much better. The three little ones to the right are useful despite being light. They reach into small spaces well. At the bottom is a cabinet scraper. This does not get much use on softwoods, but it can quickly level off a sag in epoxy. The putty knife to the left can be used as a scraper, as a lever for aligning kayak decks, or even for applying putty.*

Scraper

A scraper is an edge tool like a knife or chisel, but instead of slicing in along the blade, the blade is dragged perpendicular to the surface. This is an easily controlled way to shave away at hard materials such as glue, epoxy, and wood. They are particularly good at removing drips and high spots without damaging the surrounding surface.

Paint Scraper. Most paint scrapers have a long handle with a blade mounted perpendicularly at the end. You press the blade down on the surface and pull the handle. The blades are typically sharpened at a fairly steep angle of 30 to 45 degrees. I keep a fine file handy to touch up the blade when it needs sharpening. Paint scrapers are commonly available at just about any hardware store or home center, although a woodworking supply store may have higher-quality options.

Cabinet Scraper. Take a small rectangular sheet of thin, high-quality steel, make the edges square and smooth, and then burnish the edge with a hard rod so a tiny little burr is rolled over and you have a cabinet scraper. While it seems like you hold the blade perpendicular to the surface, the actual blade is that itty-bitty little burr on the bottom edge. This slices into the surface and can cut smoothly through the most difficult materials.

If you choose to take on the task of building a boat from tiger maple, a cabinet scraper can be used to prepare a beautiful surface. They also work very well for shaving down an uneven coat of epoxy.

Sanding Tools

Most people really don't much like sanding. There are some who claim it is a Zen thing and that they quite enjoy the process, but few have risen to that level of enlightenment. Those of us still seeking the deeper significance of sanding would rather just find a way to get it done in as efficient and timely a manner as possible. Good sandpaper and the appropriate tools can make the whole experience of sanding much more fulfilling. The choice of using power sand-

Figure 3-5. Hand sanding is always a part of strip-planking boats. A good sanding block is essential to fast, efficient work. I use the round unit on the right with "used" disks off my random orbit power sander. The round pad on the left is a soft foam conforming adapter for use with the power sander or hand sanding pad. The standard rubber sanding block at the lower center works very well with sheet sandpaper. I also wrap sheet paper around the chunk of foam to get at inside surfaces. Sandpaper can be glued or stapled to different-shaped blocks of wood to fit curved shapes. Under all the other blocks is a shop-made "long-board" fairing sander. This quickly levels out uneven surfaces.

ers versus hand sanding is going to depend on your experience and your patience. Power tools are usually faster, but this is a mixed blessing. Fast may mean you're messing things up more quickly. I will discuss power sanders later, but sanding by hand is almost always better when it comes to fine detail work. Use power tools when you have large expanses to work on, and hand sand when it is important you don't make a mistake.

Sandpaper. Sandpaper is just a bunch of little edge tools bonded to a piece of paper or cloth. The same need for a sharp edge that applies to knives, planes, and scrapers also applies to sandpaper. If your sandpaper is dull you will be working harder and accomplishing less satisfactory results than when you are using new, sharp sandpaper. We all have the desire to save money and resources by using sandpaper until it is so worn out that it doesn't do anything at all. We don't want to toss out a sheet until all the sand has been rubbed off.

One key to getting the quick and effective results with sandpaper is to replace it early. Cedar does not wear down sandpaper very fast, but some woods will gum up the paper, and hardwoods can wear it out pretty quickly. Epoxy and fiberglass can be quite hard on the grit, wearing it down quickly. Whatever you are sanding, pay attention to your sanding progress; when it starts to take a while to do what used to take moments, it is time to switch off your sandpaper for a fresh sheet. This may take as little as 5 minutes and rarely more than 10 when using a power sander.

A good-quality stearate-coated aluminum oxide sandpaper will usually work well for wood, epoxy, and varnish. The stearate coating helps prevent gumming up while the aluminum oxide lasts reasonably long.

Sanding Block. It is no good having the best, sharpest, most excellent sandpaper the world has to offer without having something to hold it with. There are times when you just want to hold a bit of folded-up sandpaper in your hand, but for serious material removal, you need a sanding block. Even if you think you are going to do all your sanding with a power sander, you will still want the ability to efficiently sand areas that are hard to reach with power tools.

I wear out a lot of sanding disks in my random orbit sander. But even when they don't cut that efficiently anymore with the power tool, they have some life left for hand sanding. I have a round sanding pad with hook-and-loop material on the bottom that makes good use of those partially spent disks.

I find I do most of my hand sanding with this sanding pad, but for wet sanding a finish, I use a hard rubber block that holds cut sheets. This provides good support behind the sandpaper and doesn't mind getting wet.

Fairing Board. Take a long piece of flexible material, stick some sandpaper to it, and you have a fairing, or long, board. A piece of 3 mm to ¼-inch-thick plywood with handles mounted at each end will do the job. You can use spray adhesive to stick the paper on. I was able to find some hook-and-loop material and long hook-and-loop paper. The long-board quickly knocks off high spots, bridges over low spots, and automatically smoothes the surface to make it more even. It will make a lot of sanding dust pretty quickly.

Vacuum. Clean up that sanding dust with a vacuum cleaner or shop vac. You will be creating a lot of dust in the course of the project and having some way to keep it under control will keep the shop clean and may keep other residents of the house a little happier. You will want to be able to hook the hose directly to your random orbit sander and may also adapt it to collect dust on your table saw and other large tools. Some vacuums intended for wood shops allow you to plug the tool cord directly into the vacuum, and the dust collection will automatically turn on whenever you power up the tool.

Polishing. A fine, dust-free finish on the boat is hard to achieve without a dedicated paint room. If this really matters to you, the best way to remove any dust spots is to buff out the varnished surface.

Most polishing starts with very fine sandpaper, but it is hard to bring the surface to a high gloss the way a polishing compound does. A look at the shelves of an automotive supply store will give you lots of alternatives. You don't want a compound that contains silicone as it can make later refinishing difficult, but most rubbing and polishing compounds will work on boat finishes. Rubbing compounds are slightly coarser than polishing compounds. After sanding you will start with a rubbing compound, then move to a polish. The compounds can be applied and worked by hand, using a bonnet on a random orbit sander, or with a dedicated power buffer.

There are some extremely fine grit sanding products available. These are made with grits of abrasives that are carefully graded to be very uniform. The grits are then adhered to soft foam pads. A complete set of these pads can be used to bring a surface all the way from dust laden to a deep, uniform gloss. They are more expensive than the compounds, but they produce spectacular results.

Finishing Tools

I've heard stories of people so consumed by the process of achieving the perfect varnish coat that they would strip naked before entering the paint room to defend against the introduction of any dust into the sacred space. If you do everything else perfectly, a little bit of dust in the air before your varnish dries will introduce slight imperfections into the glossy finish. It took me years of practice applying varnish before dust made a lick of difference in my finish, and even now a perfect finish rarely stays that way beyond the first time the boat is used.

It is not that hard to get a very nice finish, but getting a perfect finish takes practice and patience. Before getting too caught up in the effort, take stock of what you are going to do with the boat. If you are going to end up dragging it across a beach to put it in the water, it doesn't seem worthwhile to strip naked when applying the finish.

Varnish Brushes. The quality of your finish is dependent on the prep work you do before dipping a brush. The next most important factor is the paint or varnish itself. After that, a good finish requires a good brush. For some people, this means a badger must give up its coat. I've never used a really fine brush. I suspect they are a beautiful thing and do a wonderful job of applying finish to a surface, but I use disposable foam brushes instead.

I have found that I can apply a smooth, even coat with a good-quality foam brush. It may

Figure 3-6. *You need brushes and mixing pots to work with epoxy. Yogurt or deli containers work very well, but be sure you clean them out thoroughly before use to avoid contaminating your resin. Plastic party cups or large unwaxed paper cups are a good alternative if you need to buy something. I always keep a variety of small cups around for small batches of resin and for use as "grunge" cups. Disposable roller trays can be used with short paint rollers for applying coats of resin. The cheap bristle "chip" brushes spread epoxy well, and lost bristles disappear in the resin. Cotton swabs are good as small brushes for touch-up work. Foam brushes work very well for applying varnish. Waxed paper comes in handy for protecting your workbench when you need to glue small parts or wet out a piece of fiberglass.*

not be as good as an expert can do with a fine natural-bristle brush, but it is still good. It may not seem economically sound to throw away a brush when you could just clean out a bristle brush, but cleaning a brush uses a lot of paint thinner and a fair amount of time, so I figure it is a wash.

The foam brushes I use have fine, open-cell foam. I usually find these at specialty woodworking or marine stores. I have not had good luck with those from big-box stores.

Spraying

If you know how to do it, spraying is an excellent way to get a beautiful finish. If you have the equipment and know how to use it, spraying is probably the quickest and cleanest way to apply a finish. If you don't have the equipment, I don't feel it is worth buying it specifically for a single boatbuilding project. It takes practice to get spraying right and good equipment is expensive, so it may be quite an expense and take a long time before you get the desired finish.

One option that some builders have used successfully is aerosol spray cans. However, you will pay a premium for the same amount of finish, and you may have trouble finding cans of good-quality stuff.

Varnishing Accessories

Beyond brushes there are other tools that will help with successful finishing. You will want rags and need some stirring sticks and containers. Building a strip-planked boat, you will have an almost endless supply of stirring sticks in the form of scrap strips.

Tack Cloth. Dust is a perennial bugaboo of achieving a fine finish. A tack cloth is a useful tool in controlling the dust. The cloth is typically cheesecloth soaked in some sticky stuff. After vacuuming the boat and rinsing it off with water and mineral spirits, wiping the surface with a tack cloth will pick up most of the residual dust.

Tack cloths are used exclusively for oil-based finishes such as varnish. They are not to be used between coats of epoxy. The sticky stuff on the cloth can interfere with proper bonding and curing of subsequent layers of epoxy. Use the tack cloth only before applying varnish or oil-based paint.

Lights. While a brush is an obvious varnishing tool, lights are less expected. The only way to be sure you apply an even coat of varnish without any drips or "holidays," where you missed a spot, is to carefully watch what you are doing. If you cannot see drips and holidays, you will not have much success preventing them. A set of bright lights arranged around your boat as you apply the varnish will make mistakes clear so you can deal with them while the varnish is still wet.

I use a set of halogen shop lights on stands placed at either end of the boat to light my work. Set the lights down at the level of the boat to highlight any mistakes.

Files and Rasps

There are lots of times when a file or rasp comes in handy. They cut well against the grain of wood and can concentrate cutting on a specific spot of epoxy or fiberglass.

Traditional-Cut Files and Rasps. You can spend a lot of money on really fine woodworking files, but I find the most handy to be a 4-in-Hand (or 4-in-1) shoemaker's rasp. This has a flat, coarse rasp and medium file on one side, and rounded versions of the same on the other side. They fit well in a tool apron and come in handy in a wide variety of situations where you need to remove a little material quickly. They tend to work best on hardwoods and epoxy.

Figure 3-7. *Files, rasps, and microplanes can deal with tricky wood that may aggravate a plane. Shinto wood rasps will quickly remove wood or delicately remove epoxy sags. The 4-in-Hand on the left will do the same or soften a sharp edge of fiberglass. The microplane at the bottom has many tiny blades that shape wood easily.*

A fine mill-cut metal file is very useful for putting a quick new edge on a paint scraper. Either hold the scraper in your hand or clamp it in a vise and use firm, steady strokes to get your scraper cutting better.

Shinto Wood Rasp. These things are essentially a bunch of bent, two-sided hacksaw blades that are riveted together with a handle attached, and they are wonders of brute force carpentry. They cut in almost every direction and are very resistant to clogging up. I find them particularly useful for removing that big drool of epoxy and fiberglass that somehow ended up in the middle of my deck. A couple quick strokes of this rasp will knock it down to size in an awful hurry. They are also good for removing a lot of wood quickly and surprisingly cleanly.

Microplanes. These are woodworking tools that have migrated into the kitchen to make fine lemon zest for your apple crisp. Time to steal them back out of the chef's drawer and put them to the use they were designed for. They are stainless steel with acid-etched teeth. While they look a lot like a Stanley Surform tool that you may have collecting dust in the back of your woodworking drawer, they work a lot better. These are great tools for fine shaping of wood, and they cut quickly and efficiently. If you have a stem that needs a little sculpting, microplanes do a fine job.

Saws

When you have to cut wood, you are going to need a saw. Like just about everyone else, I have become quite enamored of the Japanese-style saws that cut on the pull stroke. They are laser sharp and cut through cedar like nobody's business.

For basic cutting strips to length, I don't even bother with a saw (see the next section), but for major trimming at the stem or transom, a Japanese pull saw is hard to beat.

Figure 3-8. *Cutting strips to length can be done with a saw or shrubbery pruners. Shown here are Japanese-style pull saws, which cut on the pull stroke, allowing a very thin blade that cuts very quickly and easily. The top saw has both a ripping blade and a cross-cut blade.*

Figure 3-9. *Fiberglass is usually cut with scissors. They will likely get coated with epoxy, and cutting glass dulls them, so don't go to the sewing kit thinking no one will notice. Second from the right is a battery-powered fabric cutter that may be worth the investment if you do a lot of fiberglass work. If you have a smooth surface to cut on, the rolling cutter on the right works well for cutting strips of cloth.*

Pruners

Here's another reason to raid the spouse's tool kit. A pair of garden pruners makes an excellent tool for lopping strips to approximate length before fine-fitting them in place. I use the kind that has one sharp blade cutting against an anvil instead of two sharp blades that cut past each other like scissors.

Scissors

You will need a pair of scissors to cut fiberglass. A good stout pair will hold up better, but you don't need to buy an expensive pair specifically for fiberglass. They are going to get covered with epoxy, so you most likely won't be able to get away with using the kitchen shears for long, although they would probably work great.

The same scissors that cut fiberglass will work fine for cutting most other fabrics, such as carbon fiber, but they may not be worth a darn for cutting Kevlar. A brand-new pair of high-quality scissors may cut Kevlar for a while, but as soon as they get dull they will become almost useless for Kevlar. If you get a pair that works, do not cut anything else with them. There are some inexpensive scissors sold for cutting Kevlar that seem to work quite well. Get a pair and paint them gold or something so you know not to use them for cutting apart chickens. Glass can be cut with dull scissors, which is good since it dulls them pretty quick.

Rolling Cutters

If you have the tabletop for them, the rolling cutters sold in fabric stores work quite well for fiberglass. They are especially nice when you need to cut a bunch of bias-cut strips. The downside is you need a smooth tabletop without any scratches or deep gouges. The fibers of glass will get pushed down into the scratch and the roller will fail to cut them. It is most annoying to pull away a length of bias-cut cloth and find that it is attached by one fine strand.

Epoxy Tools

Since epoxy is a glue, it loves to stick to stuff. This means that it has a wonderful way of ruining good tools. While with woodworking tools you can sometimes get away with borrowing something from the kitchen and returning it with the chef being none the wiser; it is much harder to get away with when using epoxy and fiberglass. Your tools will likely get coated with a thin crust of goo, and the glop will not be casually mistaken for a persistent spot of tomato sauce.

Mixing Pots. Despite the obvious convenience, don't use nice Pyrex measuring cups you think are collecting dust in the kitchen. They will be missed. One word: yogurt. If you eat a lot of yogurt you will live to 1,000 and will never be at a loss for containers to mix epoxy. The quart size is perfect. They hold a good amount of epoxy and are deep enough that you won't generally spill much. I also like them for holding varnish. They can often be used multiple times because hardened epoxy pops right out. The smaller, single-serving-size containers are good for small batches. Sour cream containers work as well, but sadly they do not come with fruit at the bottom.

Paper cups also work well, although wax-covered cups may lose a little wax into the epoxy, which can cause issues. I have also used cutoff milk jugs, soda bottles, paint thinner cans, and laundry detergent containers. Whatever you use, make sure it is clean. Leftover detergent or dairy products are not a beneficial addition to epoxy.

Brushes. Most hardware stores carry inexpensive, natural bristle, "chip" brushes. These have wooden handles, metal ferrules, and boar bristles. I buy a box of 2-inch-wide brushes. Chip brushes have a severe tendency to lose bristles. There are a couple of things you can do about it. One, you can glue the bristles into the ferrule with a bead of epoxy or CA glue at the top of the ferrule. This usually restrains most of the bristles. Two, you can wrap your hand with tape, sticky side out, and jam the bristles against the tape to pull all the loose hairs.

For initial glassing it is OK to lose a few bristles; the whitish hairs become almost clear and against the wood they virtually disappear. For the final coats of epoxy, on the other hand, a stray bristle will impede the flow of epoxy, causing a thicker or thinner spot or a drip. This is not the end of the world, but it makes more work in your effort to get a smooth finish.

When I'm doing glassing I usually yank the end of the bristles to remove the loosest and then just live with them pulling out. In the finish coats I spend more effort to minimize the stray hairs.

Rollers. There are two kinds of roller covers that work well with epoxy: foam and short nap. The suitable foam covers have about a ⅛-inch layer of open-cell foam. These are specialized rollers, not like the ones you may find at a home center. I generally buy them from my epoxy supplier. The short-nap roller covers also have about ⅛-inch-long upright bristles. You may be able to find these at a home center. The thinness of the foam or nap is important in that it does not soak up a lot of resin but will hold the resin briefly and release it easily without a lot of pressure. I personally prefer the short-nap rollers as they don't seem to pump air into the epoxy the way the cells of the foam rollers can.

Most roller covers come in 7- or 9-inch lengths. I find this is longer than I need, so I cut them in half and slide them onto a short or adjustable-length roller frame. To cut them in half I roll them carefully through a band saw, being sure to clean off all the sawdust debris afterward.

Squeegees. There are various schools of thought on squeegees. Some people like a thick piece of rubber like those used for doing silk screening; other people cut rectangles out of gallon milk jugs. Each person will swear his or her tool is

Figure 3-10. *I use plastic applicators or squeegees to spread epoxy and remove excess resin from the cloth. Larger ones get the most use, but small ones are good for small areas. I use the little plastic mixing sticks on the left like a putty knife to smooth small spots or fillets.*

Figure 3-11. *To temporarily hold the strips in place, you can clamp little U-shaped jigs that fit over the strips to the forms.*

the ideal tool for pushing around epoxy. I use the typically yellow plastic squeegees sold at auto parts stores. They are pretty good. They have a nice flex and a good edge. If you leave any residual epoxy on pretty thick it will peel off easily; otherwise, wipe the squeegees clean with a rag for reuse. Eventually their edge gets a little fuzzy from dragging across the fiberglass. A couple swipes with a sharp block plane will renew the edge.

Stirring Sticks. You are building a strip-built boat, so it is very unlikely you will be hard up for stirring sticks. All those strips that came out of the table saw backward at 150 miles per hour because you neglected to use feather boards are probably already sized about right. Any scrap strips are good for stirring epoxy.

Other Tools

Clamps. A boatbuilder can never have too many clamps. Big clamps, little clamps, C-clamps, quick clamps—any kind of clamp you may come across will probably come in handy at some point during the building process. The clamp I reach for the most is a spring clamp, basically a clothespin on steroids. Spring clamps are quick and powerful, they don't get ruined when handled with hands dripping with epoxy, and they are just plain handy.

Stapler. In strip-planking, a staple can act as another kind of clamp. A 9⁄16-inch staple shot through a strip into the form will usually stay put until the glue dries. You could use a pneumatic stapler, but they generally shoot the staple in too deep. You want the staple to stand a little proud of the surface. I use a standard T-50 utility stapler. They are affordable, easy to use, and don't require an umbilical to a compressor. There are newer, "easier" varieties of staplers, but I have found that the old-style, heavy-duty one made by Arrow is the most reliable.

If the stapler gets gummed up with glue, you can soak it in hot water for a while to clean off all the glue—assuming you use a water-soluble glue.

Staple Pullers. You can use the screwdriver on your Swiss Army knife to remove staples if it is the closest tool at hand, but it is better to use a tool designed to remove staples. Don't reach for one of those things that look like the jaws of an extinct predator. They will just make scars on the boat. I got a heavy-duty staple remover from the local big-box office supply store. It has a tooth, which slides under the staple, connected to a lever that pries it up. The wide bottom of the tool protects the wood while keeping the strip pressed into place. I modified the tool from the store slightly by sharpening the tooth. The tooth is replaceable if it ever wears out.

Sometimes you will break a staple, in which case it is handy to have a pair of pliers around so that you can grab the end of a broken leg and pull it up.

Measuring and Marking. You won't have to do a lot of measuring, but a tape measure and a combination square with a removable steel ruler will find use. Setting up the spacing of the forms is best done with a tape measure. A combination square helps assure all the forms on the strongback are straight. A simple compass that holds a pencil (like the one you used in school) can be used for transferring shapes and marks.

I never seem to have a pencil when I need one; they all seem to end up on the other side of the boat. Get a big box of pencils and spread them around the shop.

Et cetera. There are going to be other tools you need to complete the boat, but most of them are not really specialized for boatbuilding and are standard to just about any tool kit. For example, you'll need a hammer, screwdrivers (Phillips, flathead, and maybe square-drive), a drill (I recommend a cordless electric drill), and twist drill bits. Also get screwdriver bits for the electric drill, which will save you a lot of time and muscle driving and removing screws. A box of sheetrock screws, although not really a tool, will come in handy for quickly securing forms, holding down a recalcitrant strip, and many other uses.

Power Tools

A dedicated builder who buys precut strips and forms could build the rest of the boat exclusively with human-powered hand tools. A knife, a block plane, a handsaw, a sanding block, and a pile of sandpaper are about all that is needed. But we don't need to be that pure. The right selection of small power tools will make the project go quicker.

Handheld Power Tools

Random Orbit Sanders. A random orbit sander (ROS) has a round head that spins and shakes in an effort to eliminate sanding swirls associated with disk sanders. These sanders have become quite easy to find since I bought my first, with big-box home centers carrying several different brands and European manufacturers offering Pentagon-worthy versions in stylish stacking boxes. I've switched back and forth between

Figure 3-12. *Power sanding saves a lot of time. The go-to tool is a random orbit sander, such as the middle unit, the larger one to its left, and the smaller detail sander at lower right. These remove material quickly with a minimum of sanding marks. The largest unit is the most powerful and the fastest, but it's hard to control; the small unit is good for small narrow pieces; and the middle unit is a good compromise. Above the smaller detail sander is a right-angle grinder. With very coarse sanding disks, this tool can remove a lot of material in a hurry. A detail sander is shown lower left, which occasionally is good for getting in tight spots. At top is an automotive polisher for buffing a finish.*

a palm-size version and a larger, more powerful right-angle version. The latter is great for doing a lot of damage quickly, if that is what you want to do, but it is heavy and takes two hands to control well. The palm-size unit is easier to control, but it's slower. If you are working on a large, nearly flat surface, the more powerful unit is nice, if dangerous. Most people will do very well with the small, less expensive palm unit.

A good random orbit sander will make quite quick work of turning a roughly stripped boat into a beautiful smooth surface. It will also even out bumpy fiberglass and epoxy. All of this means turning wood or fiberglass into fine dust, so a dust-collection system you can hook up to a shop vacuum cleaner (noted earlier) will make your lungs happy and help keep the fine powder out of the heating system.

The sander also wears out sandpaper very quickly. I find that even the best sandpaper seems to lose its effectiveness after a few minutes rubbing around on the face of an ROS, but it is still pretty good for hand sanding. I use hook-and-loop disks on the ROS and have a little hook-and-loop hand sanding block. Pressure-sensitive adhesive sanding disks are cheaper than the hook-and-loop versions, but they tend to rip when you peel them off the sander and therefore are hard to reuse.

Detail Sander. Most of the fine work of a detail sander can be done by hand. There are few places where there is enough sanding required in a small spot that it is worth the effort of breaking out a small power sander, but then again, part of the fun is collecting tools, and a nice detail sander has a combination of power and precision that is enticing. I'm sure you can find enough work for it to justify the cost. I know I have. You cheapskates who don't want to spend the money are forgiven.

Jigsaw. You could use a handsaw for cutting hatches and cockpits on a kayak or a band saw to cut forms and seats, but a variable-speed jigsaw comes in handy for a variety of uses. I usually have some large coarse blades for cutting forms and some very fine blades for cutting kayak hatches.

Figure 3-13. *Some other useful power tools include routers and jigsaws. The large router in the middle is mounted in a plunge frame that can be used to make some specialty parts. Mounted to a table it can be used to mill cove-and-bead strips with the cutter bits shown below. The trim router on the left is useful for rounding over gunwales. The jigsaw on the right does a good job cutting hatches.*

Heat Gun. An industrial-strength heat gun is like a hair dryer that can melt solder. You don't need it that hot for anything on a boat, but getting epoxy on the bathroom hair dryer may lead to divorce. A concentrated blast of heat can be used to soften and bend some of the more stubborn strips. You don't need to steam wood to soften it; a little heat can do the job just fine.

Epoxy also becomes less viscous when heated, so a heat gun can be used to help epoxy flow. Heating a spot where you want epoxy to run or soak in well will lower the viscosity of the epoxy, and as the area cools it will draw the epoxy into its pores. If you have an area of epoxy that is full of bubbles, lightly blowing on it with hot air can expand and pop them for a clearer finish.

Router. If you are milling your own strips and want cove-and-bead joints, you will need something to make those coves and beads. As explained in Chapter 2, cove-and-bead is like tongue-and-groove and can help the strips fit together tightly. I can't think of anything in the kitchen that will do the job, so for most people this will be a router. A router is just a motor that spins a cutter really fast. It can be handheld to round over the edge of a piece of plywood or mounted upside down on a router table to mill a cove or bead on a strip.

For milling strips you will want a router table. This will let you safely run strips through the cutters with feather boards in place. See later in the chapter for further discussion of both of these items.

The router requires special bits to be useful. Cove-and-bead strips need a specialized cutter. At this point most major router bit manufacturers make canoe bits, often in matched sets. One bit cuts the cove and the other the bead. These bits cut a round profile with a ¼-inch diameter intended for ¼-inch-thick strips. This diameter may also be used for thinner strips such as 3/16 inch. The bits come under a variety of names such as cove and bead, flute and bead, or canoe bits. Lee Valley Tools (leevalley.com) sells both a matched set and a single bit that can be positioned to cut both the cove and the bead.

There are many situations where a router is a good tool. A round-over bit makes quick work of adding a consistent radius to an edge. Straight bits are good for following patterns to make accurate copies of a shape. You can get straight bits with a bearing at one end that will exactly follow a template. This is a great way to make repeatable shapes such as the strongback hole in forms for boats using internal strongbacks.

Stationary Power Tools

With the large power tools you can probably get by with going over to your brother-in-law's for a weekend to get all the work done and bring your production back to your own shop. But what's the fun of that? If you don't have a table saw yet, now is your excuse.

Table Saw. Cutting cedar strips does not take a very powerful saw. It is pretty soft stuff, but if you need to cut 1,000 linear feet of strips, it will mean the saw is running continuously for several hours, so you probably won't be happy with the cheapest out there. Cutting hardwoods takes a little more power, but strip building is not a table saw intensive project, so if you need to justify a really nice saw, take up making cabinets.

The best saw blades I have found for cutting strips are 7¼-inch-diameter blades intended for handheld circular saws. They will work fine in a 10-inch saw. The benefit of these is that they are very thin so they don't waste a lot of wood. They are available with carbide-tipped blades and are very affordable.

You will want a zero-clearance insert for your table saw. This can just be a piece of wood cut to fit your saw that you carefully raise your saw blade up through.

With a more powerful saw you can gang up several blades on the arbor to cut more than one strip at a time, but only do this if you have a power stock feeder.

So now I'm talking about how to feed cattle? Actually, the "stock" in this refers to wood. A stock feeder is a motor with rubber wheels and a gantry system to position the motor over your saw. This is a real luxury and not worth the cost for the casual boatbuilder, but if you are going to cut a lot of strips, it will push your material smoothly and consistently through the saw blades without getting your fingers anywhere near the teeth of the spinning blade.

Instead of a stock feeder, most people use feather boards. These are merely pieces of wood with one end cut at an angle. The angled end is then partially ripped to produce flexible fingers that can be used to press the wood you are milling against the table and fence. They serve to hold the material in its proper place and also prevent the stock from kicking back and getting shot across the room and turned into stirring sticks.

You can make your own feather boards with a band saw. Use either straight-grained

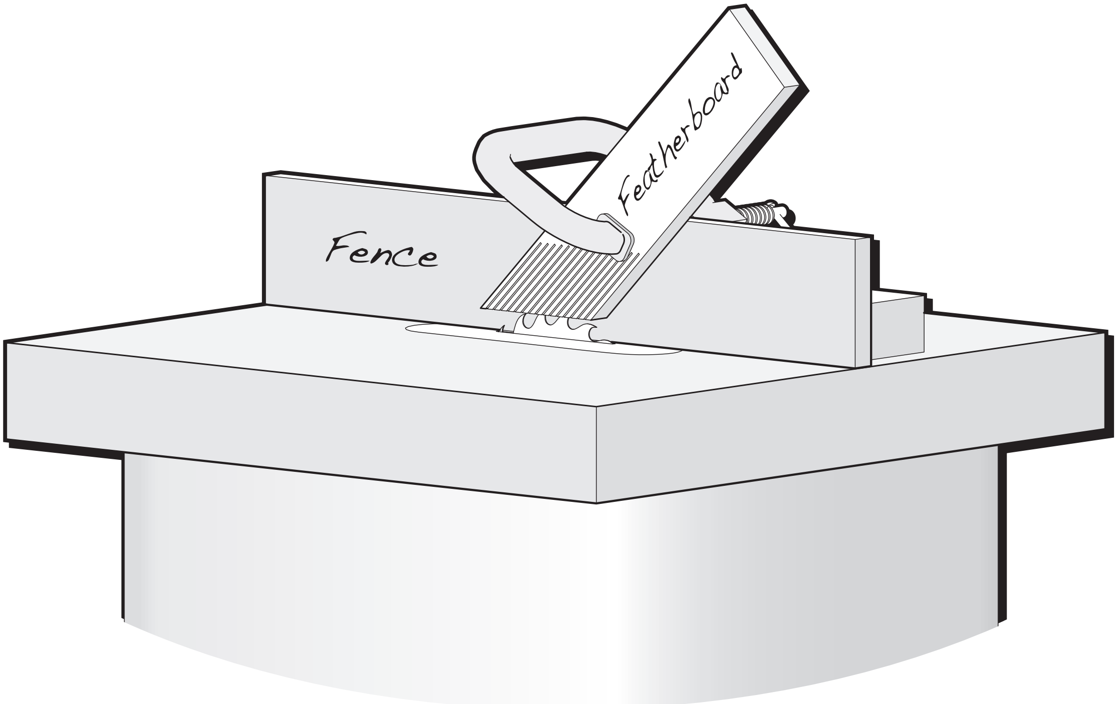

Figure 3-14. *A* feather board *is just a piece of scrap wood with a comb-like end created by slotting it with a saw. It is used to hold raw material down on the table as you cut strips. Lower the blade below the table, put your board up against the fence, and place the feather board on top so the feathers are slightly bent. Clamp it securely in place. Now remove the board you are about to mill. After turning on the saw, slowly raise the blade up so it cuts into the bottom of the feather board.*

pine or plywood. Cut the end of the pine board at an angle, then cut a series of slices lengthwise into the end of the angle to create a comb-like appearance. This piece can be clamped to the fence or table of your table saw or router table. Adjust the placement so the fingers bend slightly, applying pressure to hold wood you are cutting tight against the table or fence.

A plywood feather board usually is made with a little longer edge and wider fingers. Because the fingers are not as flexible, they need to be placed more precisely.

Band Saw. I am often asked whether it wouldn't be more efficient with wood to use a band saw to cut the strips. Given the thin kerf of a band saw blade, it would seem to make sense that a band saw would waste less wood than a table saw. I think with careful cutting band saws may work well for this purpose, but the 7¼-inch circular saw blades are very thin and leave a very smooth surface, whereas band saws generally leave a fairly rough surface. But more important, they are not as well suited as a table saw for producing cuts of consistent thickness. The blade has a tendency to wander, and as a result you will probably have to remove more wood to get consistent thickness.

Where the band saw really comes into its own is cutting curves. Band saws make quick and accurate work of cutting out forms and things like inner stems and transoms. You can do all this work with a jigsaw, but a band saw is easier and quicker.

Thickness Planer. One of the keys to a smooth surface on your finished boat is getting all the strips even with one another. The first step toward that end is getting all your strips a consistent thickness. A well-tuned table saw will do an excellent job of this, but a thickness planer will ensure accuracy. The need for consistency is most obvious when you are milling a cove and bead. You want the radius cut exactly in the middle of the strip. If the thickness varies even a little bit the cove will fall out one side. This isn't the end of the world, but you are going to be dealing with the discrepancy later in the building process.

Router Table. A router table isn't a tool all by itself. It is a means of holding a normally hand-held router on an even surface. It allows you to safely mill cove-and-bead strips and follow a template, such as when cutting the strongback hole on the forms of a decked boat such as a kayak.

Safety Equipment

A boatbuilding shop has a wide variety of hazards, from sharp tools and flying debris to loud noises and toxic dust. There are the obviously dangerous things like the spinning blade of a saw, as well as seemingly innocuous dangers like sawdust. Follow the manufacturer's recommended safety instructions for any tools you use. Wear safety glasses whenever you use power tools. If you are sanding or doing something else that makes a lot of noise, wear hearing protection. Most woods have evolved to be at least somewhat distasteful to bugs. What "distasteful" really means is "poisonous." If it is poisonous to bugs, it probably is not so good for humans. In fact, wood dust is considered a potential carcinogen. Wear a dust mask whenever you are doing a task that may put dust into the air. The little "comfort" masks available at home centers aren't sufficient. Get quality dust filters that go on a professional respirator mask.

Figure 3-15. *Although many of the materials used in strip building may seem benign, there are risks. You should strongly consider wearing hearing and eye protection whenever you run power tools. Wood sawdust is considered carcinogenic; a good dust mask (upper left) will keep it out of your lungs. Even though epoxy does not smell much, an organic vapor respirator (upper right) is highly recommended. You also don't want to get epoxy on your skin, so wear gloves.*

Epoxy is a concoction of petrochemicals—while not as full of volatile organic compounds as some other resins, you don't want to mess with it. Wear organic filters on the same respirator mask as you use with the dust filters whenever you are in the room with uncured resin. Wear latex, vinyl, or nitrile exam gloves whenever you are handling wet epoxy, and avoid getting the resin on your skin. Do not handle the epoxy with your bare hands. Even after the epoxy has dried to the touch you should consider wearing gloves when sanding, and always wear a good dust mask when sanding epoxy. Buy a full box of 100 gloves and replace your gloves frequently. The gloves are somewhat delicate and will rip and need to be replaced. There will also be lots of times you need gloves to handle epoxy, then you will need clean hands to handle your roll of cloth, and then need gloves immediately after. If your first pair of gloves are gloppy with epoxy, you don't want to mess up your roll. Take your gloves off and put on a new pair after handling the roll of glass.

It may seem like an inconvenience to pull on an uncomfortable respirator and sweaty gloves every time you handle any little bit of resin, but remember, we build boats because it is fun; there is no compelling reason to take unnecessary risks. No matter how much you would like the boat done by a certain day, it really doesn't need to be. The amount of time expended to be careful and safe is just more time spent enjoying the process of building the boat. And how much time does it really take to put on a pair of gloves anyway?

Chapter 4

Making the Building Form

Strip-planked boats are made on a form based on the cross-sectional lines of the boat. A *table of offsets* is the traditional method of documenting the *lines* of a boat. *Lofting* is the art of converting the table of offsets (which are merely measurements from an arbitrary baseline) back to lines (or, simply put, curved outlines) from which you can then make forms to build a boat. For some people tackling a boatbuilding project, lofting the boat can be one of the most intimidating hurdles. The lofting skills required for a kayak are minimal. The reason for lofting is to get a full-size drawing of the boat. Obviously, for a large sailboat this is quite a stunt. But for most small boats the task does not require clearing out the loft of your workshop. Often you can produce these drawings on large sheets of graph paper or an easel pad from an office supply store.

Offset Tables

The offset tables in this book comprise two or three major sections as shown in the illustration. The upper contains waterline measurements, and the lower one or two contain buttocks measurements for the deck (if any) and hull. There are also small additional sections showing the locations of the gunwale, feature line, and *sheerline* (on a decked boat).

Across the top of the table is a list of form locations (the forms are usually called *sections*, but for our purposes "forms" makes more sense since they will be traced on plywood and cut out, becoming the cross-sectional shapes over which you will form the boat). So what does all this mean?

The Form Offsets

The forms are like slices of bologna cut at intervals from the sausage that is the boat. The slicing typically starts from the front, with the long position being the distance of the form away from the bow of the finished boat. In the Coot table of offsets shown on page 178, for example, the first form is 6 inches from the bow. The second is 1 foot 6 inches from the bow, and each consecutive form is spaced 12 inches apart until the stern of the boat is reached. The forms are created in the shape produced by the intersection of these form planes and the surface of the boat. The buttocks and waterlines are lengthwise slices through the boat; the buttocks are vertical slices and the waterlines are horizontal slices. The intersection of these planes produce contour lines on a map. The 7-inch waterline is a line drawn on the surface of the boat at an elevation of 7 inches above the *datum waterline* or *design waterline* (DWL), and a 3-inch buttocks line is a line drawn 3 inches out from the centerline (CL) of the boat. Looking in three dimensions, the zero point is the extreme bow of the boat on the centerline at the DWL.

The offset tables are created by taking measurements wherever the planes of the waterlines or buttocks slices intersect the contour of the form plane on the boat surface. Every time either a waterline or a buttocks line intersects the surface of the boat at a form location, the position of that intersection is noted. Since the locations of the two intersecting planes are known, the only measurement needed is the third dimension.

It is a little confusing, but in the buttocks sections of the table the numbers are elevations,

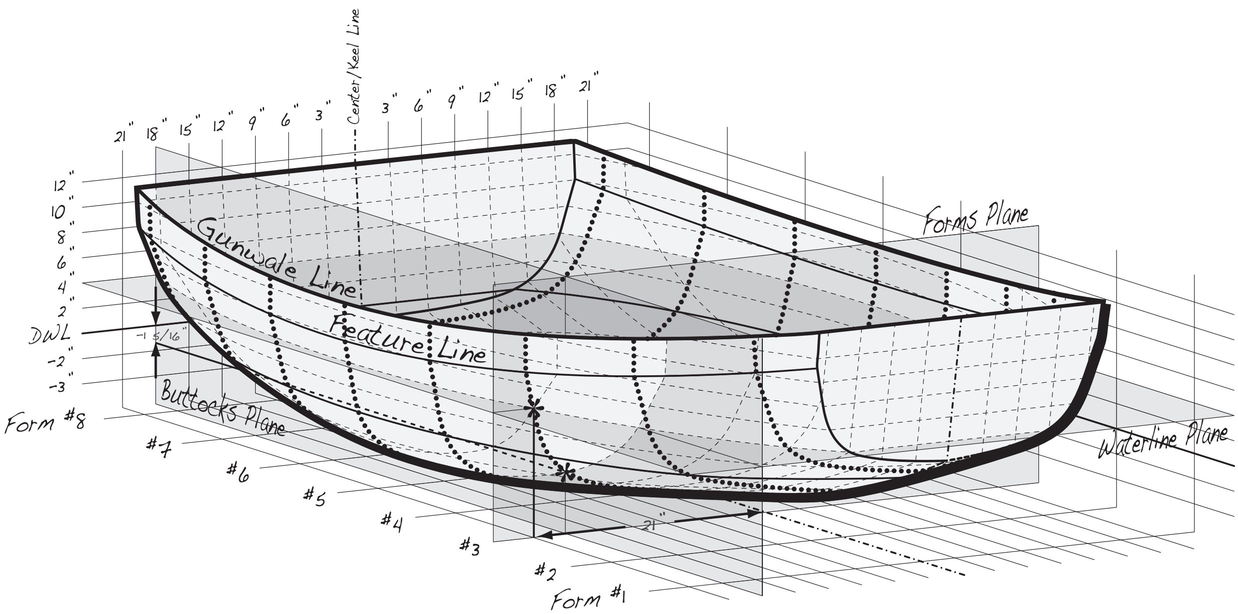

Figure 4-1. Offsets *are a means of defining a boat's shape in a table of numbers. The numbers are derived by slicing up the boat along different planes. The horizontal planes are called* waterlines *because they are parallel to the water. The vertical, lengthwise planes are called* buttocks lines *for some unknown reason that we probably shouldn't investigate too closely. Finally there is the vertical slice across the boat. These are the numbers we really want because they correspond to the forms used to build the boat. These forms are described by the measurements of where the other two planes intersect the form and the outer surface of the boat. The vertical buttock plane 18 inches from the center of the boat intersects form 3 at 1⁵⁄₁₆ inches below the datum waterline (DWL), and the waterline plane 4 inches above the DWL intersects the outer surface of the boat exactly 21 inches out from the centerline. Put enough of these points on a piece of paper and you can draw the whole form.*

even though a buttocks line is an offset from the centerline. This offset is called a *half-width*, for the simple reason that it is the measurement from the centerline to one side instead of a measurement all the way from one side to the other. The first column of numbers says what the half-width offset is, and all the following columns give the height at which the form intersects the buttocks line. Looking at the buttocks section of the offset table for the Coot, following the 18-inch row out to form 3, you are confronted with the number −1⁵⁄₁₆. Looking at the figure here you can see that if you measure down 1⁵⁄₁₆ inches along the 18-inch line starting at the DWL you will get a point on the edge of the form. Similarly, the 4-inch waterline row of the table yields an offset of 21 at form 3. Measuring 21 inches from the centerline gives another point on the form. Repeating this process for every buttocks and waterline while placing marks on graph paper will eventually produce a series of dots that define the form.

There are two other points that define the shape of form 3; the gunwale and the feature line. The gunwale data puts a mark 9¹⁵⁄₁₆ inches above the DWL and 21¹¹⁄₁₆ inches over from the centerline; this marks the top edge of the boat. The feature line describes a corner in the curve defining the form. This corner is located by a height and a half-width. You can now con-

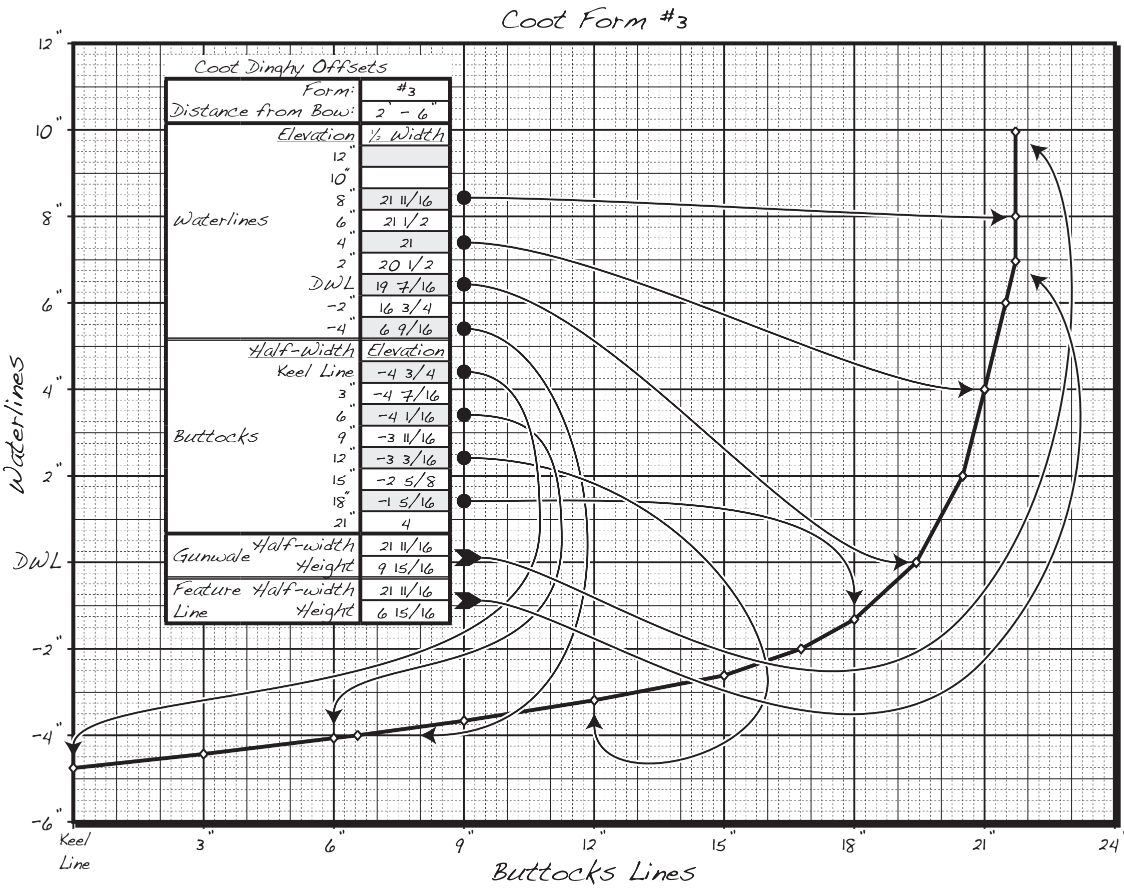

Figure 4-2. *Form 3 shows how the numbers in the offset table correspond to the shape of the form. The numbers in the waterline section indicate the distance out from the center of the boat along the corresponding waterline, so following the horizontal 8-inch line out 21 11⁄16 inches places a point on the curve. The buttocks section includes distances above the DWL along the corresponding vertical line, with negative numbers indicating points below the DWL. Following the 12-inch vertical line down 3 3⁄16 inches produces another point on the edge of the form. The feature line indicates a corner on the edge 21 11⁄16 inches horizontally and 6 15⁄16 inches vertically. The end of the line is defined by the gunwale, which is also 21 11⁄16 inches over but 9 15⁄16 inches up. Once you have plotted all the points, connect them together with a smooth curve, except for the feature line point, which should be an angle.*

nect the dots to produce a drawing of the form located at 2 feet 6 inches from the bow of the boat. You can use a French curve or flexible spline to draw a smooth curve from the keel up to the feature line, allow a corner at the feature line, then continue the line up to the gunwale. On a decked boat like a kayak, you will have data for both the deck and the hull, with a sheerline separating the two, and possibly a feature line or chine, but the process is the same. Symmetrical boats like most canoes are nice because you only need to draw out forms for the front half; the back half are just repeats of the front forms.

The easiest way to do this is on a sheet of graph paper with ¼-inch grids. You don't need to draw both sides right away, so the sheet does not need to be bigger than half the boat width. Near one edge draw a centerline, and several inches up from the bottom mark the datum waterline. You will be less confused if you keep each form on a separate sheet.

A ruler marked in sixteenths of an inch will help you get the data points accurately transferred to the paper. Proceed to mark all the offsets for the form. Mark the sheerline clearly on the drawing. This will come in handy when you start laying strips.

After you have plotted all the points for one form, you must connect them. A naval architect would probably use a French curve or a spline to make sure the connecting lines are smooth. The French curve can be tedious to use; a spline or flexible ruler is easier. A spline can be anything that bends in a nice smooth manner, like a wood batten. Drafting stores sell several different flexible rulers. In the end, all the effort to draw a precision line is probably not worth it. You may actually get away with just connecting the points with straight lines. The offsets are pretty close together. When you are building the boat, the natural tendency of the strips to bend smoothly will hide small problems in your drawing. You can reach a happy medium between straight lines and splined lines by freehanding a curve through each point.

Other Parts

Most boats will have other parts or forms for which the standard offset table is not the best format for documentation, but tables of numbers are still often the most expedient means of presenting the data. Again, you will be plotting the data on graph paper and then connecting the dots.

Drawing the Patterns

Whether you used a pencil and ruler or a computer and printer to plot the data, you will eventually have drawings of all the forms. Include the CL, DWL, diagonal line, and sheerline on the final drawings. They serve as the reference lines when you start building. With open boats, you will need to include some extra material on the forms to elevate them all to the same height off the strongback. With closed boats you will want a hole cut in most of the forms through which the strongback will be strung. Usually this hole is 2 inches wide by 4 inches tall. If you only drew one half of the form, transfer this half-pattern to larger paper so you have both sides. Brown packing paper is a good source of large paper. You will glue the drawings to medium-density fiberboard (MDF) or plywood and cut them into pieces, so if you want a copy of your work, make a duplicate before proceeding.

If this lofting is too much for you, full-size drawings of all the forms and patterns are available from the author. See the Sources section at the end of the book for sources of plans for these boats and others.

Cutting Forms

The forms define the shape of the finished boat. Care and attention to getting the forms right from the start will pay off in faster work in stripping, less time spent sanding, and a better-looking and better-performing finished product. Cutting out the forms is pretty easy. It amounts to nothing more than cutting along a line, but it is worth taking the time to be accurate.

If you have lofted out the forms from the tables in this book, you should end up with a full-size drawing of each form drawn out individually. With a boat like the Coot where each form is quite large, it may not be practical to draw both sides of the boat on one really big sheet of paper. Plans supplied by designers may come full size, drawn with both sides of the boat showing and with each form separate from

Figure 4-3. *Instead of transferring lines from the drawing to your form material, cut out full-size drawings, glue them to the form material with spray adhesive, and cut out around the lines. This way all the reference lines are included on the forms.*

the others, or you may get plans with only half of each form, and possibly drawn all together in one drawing. The most accurate way to transfer the lines to your form material is to glue a full-size copy showing both halves of the boat directly to the material and cut out around the lines.

If you do not have every form drawn individually, you can take the drawings to a copy center to make suitable prints. With designs that are symmetrical bow to stern, you only need to have one pattern for each of the two matching forms in front and back. Look for copy centers that provide services for the architecture and building trades. They will have large-format copiers for dealing with blueprints. These copies may cost a bit, so if you are low on cash you could make careful tracings on newsprint, but some accuracy may be lost. You could also take whatever drawings you have and use a pin to poke holes through them into your form material and connect the dots with a pencil.

If you are working from a stacked drawing, these plans usually include the front of the boat on one half of the drawing and the back on the other, so you are only seeing half the form. Fold each drawing in half along the centerline of the drawing so that when you carefully cut out along the line on one side, you get an exact copy on the other side. Watch that the fold stays tight so that both sides are symmetrical.

Cut out each form from the surrounding paper, leaving about ½ inch around the outside of each pattern. Distribute these patterns around your form material. The form material may be any sheet stock you have available. I prefer MDF because it is cheap and dimensionally stable, but plywood and particleboard work fine. Half-inch-thick material is thick enough to be stiff and strong but thin enough to be

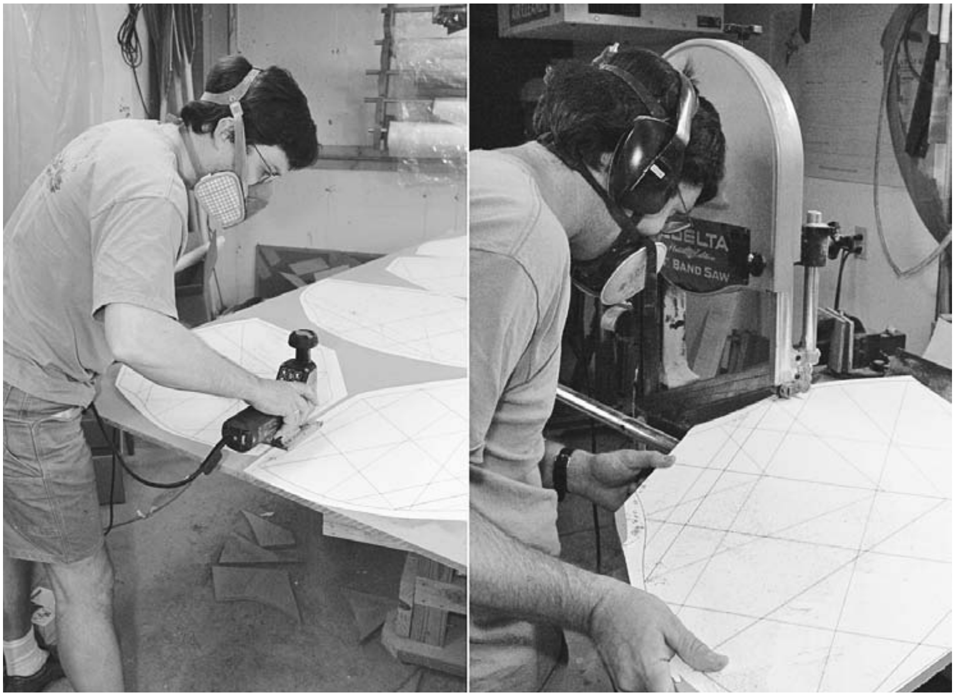

Figure 4-4. *The easiest way to cut out forms is to roughly cut the parts from the panel and then bring them to a band saw. If you don't have a band saw, you may still want to roughly cut before making your close cut with the jigsaw.*

fairly lightweight. The plans in this book assume ½-inch-thick forms. For the sectional forms, the thickness is not that relevant, but the end form shape may assume the strips touch the form at a certain width.

I try to lay out the patterns to use the MDF as efficiently as I can. A typical kayak will use less than one 4-foot-by-8-foot sheet. Adhere the patterns to the MDF by flipping the paper over and spraying the back side with spray adhesive. Then lift the pattern and spray under it directly on the MDF. Align the pattern carefully and lay it down into the adhesive. Use the palm of your hand to press down the pattern, working from the center out, to avoid wrinkles. Let the adhesive dry for a while.

I will usually start by roughly cutting out each form from the MDF with a handheld power jigsaw and an aggressive blade. Cut halfway between the forms, staying well away from the edges initially. This makes the individual forms easier to handle.

If you are building a symmetrical design, cut out another rough area of wood larger than the pattern and tack this together with the chunk containing the pattern so you can cut two copies of the form simultaneously. I will usually nail the two pieces together with finishing nails placed along the centerline at the intersection of any useful reference lines. You will want to remove the nails later, so don't drive them all the way through both pieces, just far enough to hold the pieces securely together. Don't put nails too close to the edge where they might interfere with sawing around the outline.

A band saw is probably one of the best tools for cutting out the forms, but your handheld power jigsaw will do well also. A ¼-inch wide,

Figure 4-5. *If you don't trust your hands to cut out forms exactly on your first try, cut them oversize and then sand down to the line. Here I'm also beveling the edge of the form.*

6-tooth-per-inch (TPI) band saw blade will do just fine. On your jigsaw a 10 TPI blade with ground (as opposed to stamped) teeth should work. If you have not changed your blade in a while, now is the time to do it. It is much easier to cut close to a line with a very sharp blade than one where you need to push hard. Don't try to save money on your saw blades by continuing to use the same blade after it gets dull. MDF is quite hard on blades, dulling them quickly, so you may need to replace your jigsaw blade several times.

It is much easier to saw along a line if you can see the line clearly. Have good light on your band saw and try to not cast a shadow on your line. In the end you want the edge of the form right on the line. If you are good, you can probably cut right to the line the first time, but it takes practice. You may want to start by cutting a little *proud* of the line—that is, leaving a small amount outside of the line. Anything you leave, you will eventually need to sand away, so aim to leave about 1/16 inch. Uneven edges will make it harder to remove the excess, so try to keep the border consistent. As you get used to cutting you will be able to come closer to the line.

With large forms on the band saw you need to think about whether the form will fit between the cutting blade and side support. I generally cut with the form on the outside of the blade to eliminate any concern, but large pieces of scrap that might interfere should be cut off ahead of time. A band saw will cut off your finger without slowing down. Butchers use band saws to cut through bones when cutting up meat. Set the blade guard down close to the form and control the form as you guide it through the blade while keeping your hands well away from the blade. Push the material through the blade at a smooth, constant rate.

Jigsaws are generally safer. They don't cut as fast and it is hard to get your hand in where you can hurt yourself; however, the blade does poke out the bottom of the material. You don't want to put your hand under the part you are cutting, and you don't want to cut into your worktable. I often put a couple of sticks across the top of a large trash barrel to support my part. The scrap falls right in the trash for my kind of cleanup.

If you want to save some weight on your forms, you can cut holes out where there is excess material. The jigsaw will make quick work; just drill a starter hole and start cutting. Leave at least an inch around the edges and don't allow long, unsupported edges. Leave enough material so that the form is still strong.

The best tool for zeroing in on the final edge of the forms is a table-mounted power sander. I use an oscillating belt sander, but a large disk sander also works. While using a disk sander, make sure you use the half of the disk that pushes your work down on to the table. Coarse, 50- to 80-grit sandpaper is appropriate. With light pressure bring your form up against the moving sandpaper, and rotate the form against the sander. Don't just push and hold it there—you want to keep the piece moving to avoid making a flat spot. Rotate the piece against the direction the sander is moving. If you don't, the sander will be happy to make it move the other way and send a small form spinning across the room.

Work smoothly down to the line. Press the piece against the sander, rotate it, and then pull back. Either hit the same spot again or reset your hands and work down along the edge. Come right to the line. It is more important to be consistent about how you leave the line than to hit the edge or the middle. It is probably easiest to leave the line than to split it in half. I try to draw my patterns with fine lines so there is little doubt of how I am doing. The sander may lift the paper a little bit, obscuring the line. Just press the tattered edge down so you can see the line. Work carefully all the way around the form.

I will sometimes draw up my forms with a bevel indication. This is essentially another form pattern indicating the shape of the face on the smaller side of the form. If the form material is ½-inch thick, this means I determine two form lines ½ inch apart along the length of the boat. I cut the form to the larger line and then hold the form at an angle as I sand it to hit the inner line. This takes some practice and, as I discuss in Chapter 5, is not necessary, but it is an option for those who feel so inclined.

Forms that will be mounted on an internal strongback need an accurately located and shaped hole cut in the middle. The form will be strung on the strongback through this hole, and the hole will serve as the primary reference point for aligning the form. Accurate placement will make accurate alignment easier.

The hole must be placed in the same relative position on each form. I usually use the centerline and waterline as location references, with the hole centered on the centerline and at some constant height relative to the waterline. This height should be based on where you can locate the strongback so that it is as long as possible without interfering with the strips on the outside of the boat.

With the location determined and marked on the form, drill a starter hole near two opposite corners. Use your jigsaw to cut the two edges associated with each starter hole. Again, working over a trash can works well here. You can either cut right to the line if you are confident in your ability, or you can cut a little inside the line and clean it up later.

To clean up the hole after cutting, you will need an accurate jig and a router with a template bit. A template bit is a straight-cutting bit with a bearing at one end of the cutter that is the same diameter as the cutter. This lets you cut a shape the same size as a template. Then you need a template the size of your mounting hole (I use 2 inches by 4 inches). This template needs to be accurate because all your holes are going to match it exactly.

I start making the template by making an accurate rectangle the size of my desired hole. This is easy enough on a table saw. MDF is a good choice for material, but good plywood would work as well. Place this rectangle on top of your template material and trace it. Cut out

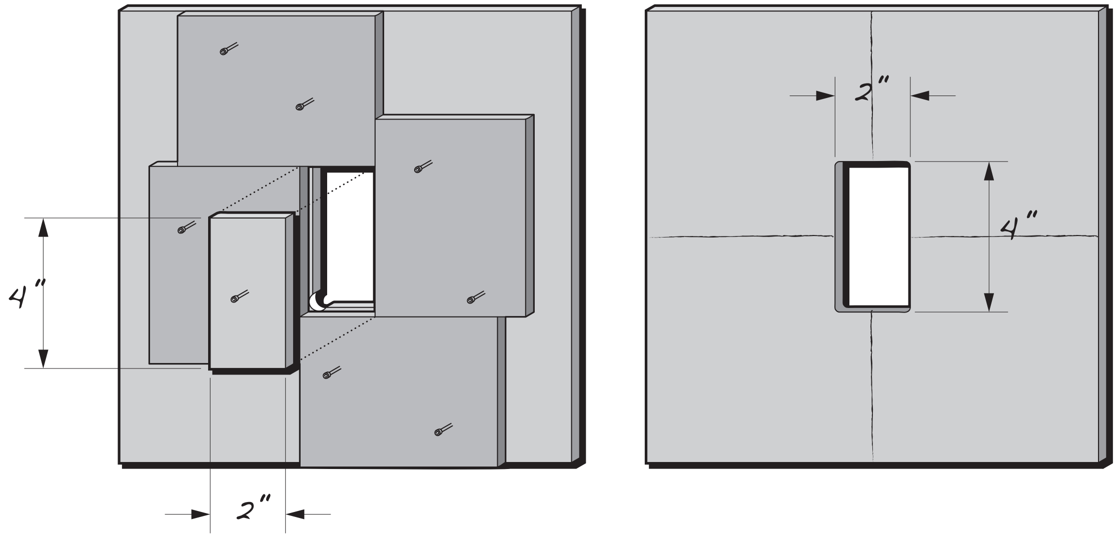

Figure 4-6. *You can cut accurate holes for an internal strongback with a router and a template. The trick is to get your template accurate. I start with an accurately cut 2-inch-by-4-inch rectangle. This is easy to cut with a table saw. Then rough-cut a slightly undersized hole in your template material. Lay the rectangle over the hole, then surround the rectangle with pieces of scrap wood, nailed temporarily in place. Remove the rectangle and use your router to cut the full-sized hole.*

the hole slightly small with a jigsaw. Place the 2-by-4-inch rectangle back on top of the hole and surround it with scraps of material with good straight edges. Nail these down. Pull the rectangle out, revealing the hole. Make sure the hole is fully contained by the scraps and is no bigger. Mount your router in a router table and a ¼-inch-diameter straight template bit with the bearing at the top. Extend the bit so it reaches up through the rough hole, bearing on the scrap bits.

Use the router to remove the excess around the edges of the hole. You should now have a hole exactly the same size as your original rectangle. Remove the scrap bits. The hole will have slightly rounded corners. Mark the centerlines of the hole. Pound a couple of large-head nails such as roofing nails through the template, cut off the ends on the underside about ⅛ inch from the surface, and push them back up flush on the underside so the heads stick up a little on top.

To use the template, line it up on your forms above the pre-roughed-out strongback holes. Use the centerlines to help with the alignment. You can make other marks that correspond to reference lines on your particular forms. Pound the nails flush so they secure the template to the form. Use the template bit on the router table to clean up the holes. Pop the template off and do the next form.

Because of the radius of the bit, this system will leave a rounded corner. Instead of trying to square up all the corners, I generally round over the corners of my strongback with a router. Even the aluminum strongback can be rounded over with a bit intended for wood; it just makes really sharp shavings of aluminum. If you would rather square up the corners of the holes, you can use a rasp or a corner chisel intended for squaring up routed hinge mortises.

I like to make a stack of the forms in the order they will be placed on the strongback, with everything lined up appropriately. This is

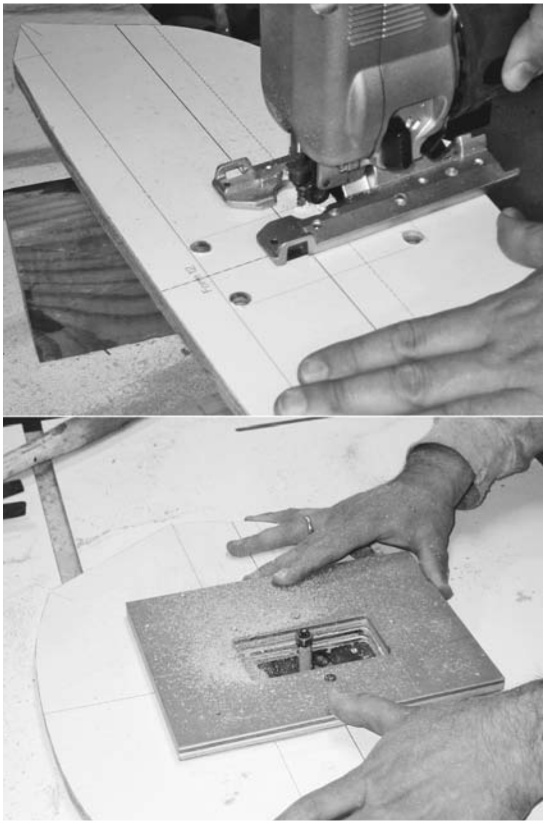

Figure 4-7. *An accurate internal strongback hole can be made with a router jig. Rough out the hole by drilling holes in the corners, then sawing out the scrap. Tack an accurate jig in place over the hole, and use a straight router bit with a bearing at the end to follow the inside of the jig.*

a great way to catch errors before going too far. If the forms are misnumbered it should become quite obvious that the stack of forms doesn't change in a gradual and even manner. If the forms do not have any numbers, you should easily be able to determine the right order by making the stack look good. The forms should get progressively bigger and smaller, without a smaller form between two bigger forms or the other way around.

If everything checks out, your forms should now be done. In Chapter 5 we will discuss converting your cool little stacks of forms into a full-size building jig that is ready to build a boat upon.

Part II

The Building Process

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Chapter 5

Getting Started

I'm sure some builders want to just jump in and start building, without getting too caught up in organizing themselves, but some effort put into preparation now can save time later. There are others who will become so intent on getting everything perfect before they start that they will never actually get around to building a boat. Good preparation will make the project go faster, but there is no substitute for actually getting started for finding out what you really need.

Obviously there are a number of things you have to do before you start assembling the boat, such as cutting strips and forms and setting up the strongback. Other things such as how you organize the strips for easy access are more a matter of convenience but will make a difference as you proceed.

Setting Up Shop

First, you absolutely must have a shop that is about 20 feet by 40 feet, with 10-foot ceilings and radiant floor heating, fully equipped with every power tool imaginable, a dust-collection system, and a great sound system. Internet access is required as well. We can all dream. I build my boats in a small basement with a bulkhead door at one end to get the boat out. I don't really have room to build boats and cut strips at the same time, but I still manage to get a few boats out into daylight every year.

At a minimum, you are going to need a space a few feet bigger than the boat in each direction. For longer boats, you may need to build diagonally across the space to maximize your length. You need room to walk on either side, and unless you like stooping down to get under the boat, you should have enough room to slip around at least one end.

Lots of people have built strippers outside, but it can introduce problems unless you have very consistent weather with moderate temperatures and little rain. The woodworking can be done in a very cold or warm shop, but epoxy and fiberglass work is best done in a climate-controlled space where it is warm enough for the epoxy to cure, but not so warm that it cures before you can get it out of your mixing bucket. It is OK if the shop cools off or warms up when you are not working on the boat, but the ability to have some control over the temperature when you are not around can make many processes more predictable.

You don't want it to rain on the strips before you get a solid coat of epoxy and fiberglass on them, and high humidity will increase the likelihood of the epoxy blushing. In some regions, this may just mean a tarp strung over the work area; in others a fully enclosed shop may prove worthwhile. In an unheated garage, a kerosene or propane heater can usually get the space up to a good working temperature. Liquid epoxy resin is flammable, but the fumes are not a fire hazard. As long as you keep the heater away from drips of wet epoxy, they should be safe. Please read the recommendations of your particular epoxy manufacturer.

For those of us who can't afford the dream shop, a basement or garage will be the best option, although I know of people who have built boats in living rooms and apartment hallways. Making a boat does involve making a bit of a mess. There is dust from sanding and drips of epoxy. While a lot can be done to keep the mess to a minimum, some residual crud will find its way onto the floor and the surrounding environment. If you are building in a cramped apartment it may be wise to factor in your security deposit as part of the cost of building your own boat. Personally, I think it's worth it.

If you are working in a space where you need to protect the floor, a couple of sheets of plywood laid down under your work area should catch most of the mess and survive the whole building process. A little duct tape on the seams will keep epoxy from leaking onto the hardwood floor or carpet.

A good vacuum system and a system for hooking it up to your sander will go a long way to keep the dust from finding its way behind the furnace—or under the sofa—as the case may be.

The easiest system for holding your strongback and boat while you are working on it is a set of sawhorses. If you plan to make a lot of boats, some sort of rolling system may make sense, but a sturdy set of horses is hard to beat.

Milling Strips

Cutting strips is fairly straightforward use of a table saw. I will not attempt to teach you how to use a table saw in this book. There are whole books devoted to that subject. Let me just tell you that there are a lot of experienced woodworkers out there who are missing a few fingers after picking a fight with the spinning blade. A blade that can cut through oak without bogging down will not even burp after chewing off your finger.

Milling strips means turning a beautiful, wide board into a few thin pieces of wood and a lot of sawdust. You want to be as efficient and safe as you can as you do this procedure. For safety you want feather boards or a power stock feeder, and for efficiency you want a thin kerf blade.

Feather boards are pieces of wood cut at an angle at the end and then sliced into a comb. They are used to apply pressure to stock being moved through power tools and keeping them from moving backward. This allows you to push your boards through the saw while keeping your hands well away from the blade and not worrying about kickback. (See page 44 in Chapter 3.) If you don't know what kickback is, it is related to how the saw may bite off your finger.

At the very least you want a feather board to hold the board down against the table. This usually requires some sort of fence extension to allow a secure mounting point. Set your saw to the thickness of the strips you are cutting. If you are going to plane the strips down to thickness, set the width a little more than the final thickness.

If you are using roughly sawn wood, you will first want to run your material through a thickness planer. Check that all your boards are the same thickness and plane them to consistent thickness as necessary.

With the saw blade lowered all the way down, place your board on the saw, up against the fence. Adjust the feather board so it is slightly flexed and secure it in place. Try sliding the board to be sure it will move. It should move forward easily, but not slide backward at all. Remove the board. Start the saw and slowly raise the blade until it cuts into the bottom of the feather board. With the feather board in place, it should be impossible to get your hands near

Figure 5-1. *Applying some wax to the table of the saw will help material slide, making it easier to cut.*

the blade while cutting a board because the blade is contained below the feather board.

You will want good support before and after the table. This could be sawhorses or a worktable. I am not a big fan of standard support rollers as they have a tendency to steer the board, making it hard to create a straight cut. I put some waxed paper down on the top of my sawhorses and table to make it easier for the board to slide around.

A straight cut requires constant pressure pushing the board against the fence, while feeding it forward through the saw. This can be hard to maintain with just two hands. Some people use a magnetic feather-board system that can be moved in toward the fence as strips are cut off, making the board narrower. As you get to the end of the board you will need a push stick to guide the board forward on the last bit of the cut. Be careful to keep the board moving straight through the saw.

Note that most saws come with throat inserts with a fairly wide gap where the blade comes through. Thin strips may get caught in this gap. You may want to make or buy a zero-clearance insert. Also, the board will slide much more easily over the table if you wax and buff the tabletop.

Uniform-thickness strips produce the best results, and the best way to get uniform thickness is to apply uniform pressure with a uniform feed rate. This is hard to do by hand, so I purchased an automatic stock feeder. This is like a little motorized car that is anchored to the table so that when you try to make it drive down a board, it pulls the board under it. The

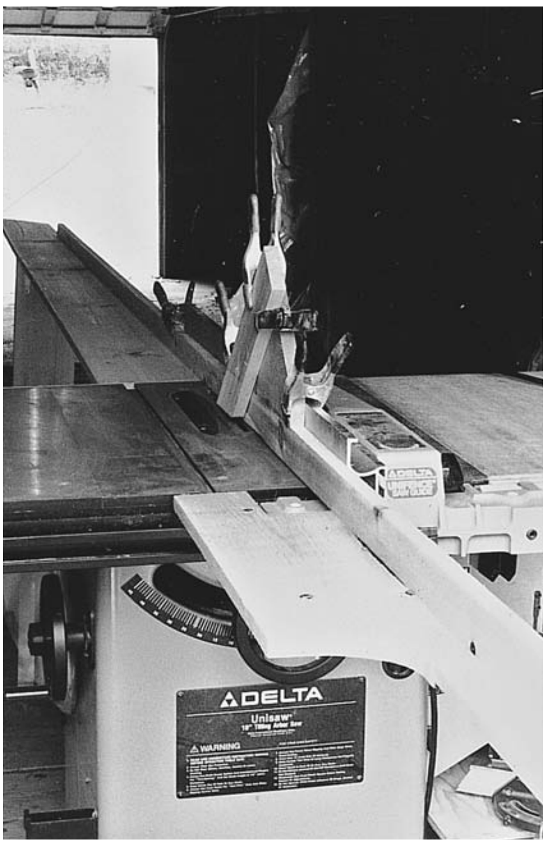


Figure 5-2. *Extra-long infeed and outfeed tables on the table saw help control long boards so the resulting strips are more uniform. Extend the fence on the infeed end to assure alignment of long boards. Notice the cutaway on the infeed table so you can grasp the board as it gets narrower.*

Figure 5-3. *If you are cutting a lot of strips, a power stock feeder is a nice luxury. It feeds the board at a constant rate while holding it down on the table and firmly against the fence all while keeping fingers away from the spinning blade. Notice I am wearing ear, eye, and breathing protection while making all that noise and dust.*

Figure 5-4. *You can save some time at the table saw by ganging together several blades on the saw arbor. I use a blade stabilizer as a spacer between the blades. Note that ganging up blades can be very dangerous if you are hand feeding the boards through the saw. I don't recommend this without using a stock feeder.*

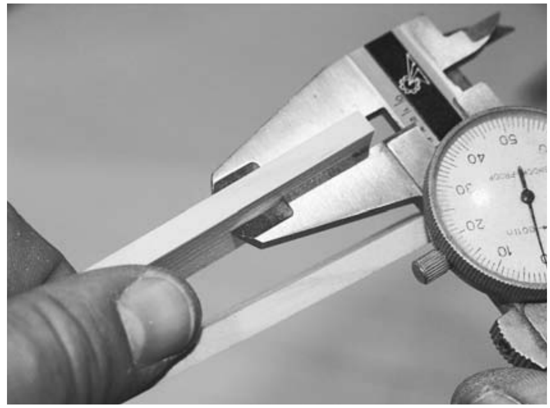


Figure 5-5. *A smooth, fair surface on the boat starts with uniform-thickness strips. Check the strips as they come out of the saw to make sure they are at least as thick as you need after thickness planing. Check a few scraps through your thickness planer before running your strips, and spot-check as you go to make sure nothing moved.*

stock feeder pushes your material at a constant rate while holding it against the fence. This is a luxury item if you are only building one boat, but if you are going to cut a lot of strips, it is a nice addition to your shop. It allows you to cut consistent strips without ever having to get your hands anywhere near the blade.

With the stock feeder and a powerful saw, you can also gang up several blades. Most saws have the ability to place a spacer between two blades so each pass through the saw cuts two strips. This could be quite dangerous to try while hand feeding the stock because it is hard to push the last bit through the two blades. The downside of cutting two strips at a time is you can mess up your wood twice as fast.

As you are cutting your strips, keep an eye on the results. You may find you start getting narrow spots in the strips at one particular part of the board. If you sight down the length of the board along the edge that you are cutting, you will usually find that the edge is no longer straight and this area is cut a little deeper. With careful cutting you may be able to straighten out the edge a bit, but it is often easier to just flip the board over so you are starting again from the factory-cut edge. If you mess up both edges, you may need to use a hand plane or jointer to true up the edge again.

This can really mess up your life if you wish to do some sort of book-matched pattern. Book matching is a technique that emphasizes wood grain where consecutive slices of wood are opened up adjacent to each other so the grain on either side is a mirror image across the seam. (See the sidebar on page 106 in Chapter 6 for more information.) For a book-matched pattern to work, each strip must come from directly adjacent to the previous strip on the board. Any failure to do this will get into a different grain pattern and disrupt the gradual change expected.

Before cutting a board for book matching you want to make some marks to help you reassemble the order of the board after cutting. You will try to keep the strips in order as you cut, but some diagonal marks drawn across the end of the board will provide a reference if the strips

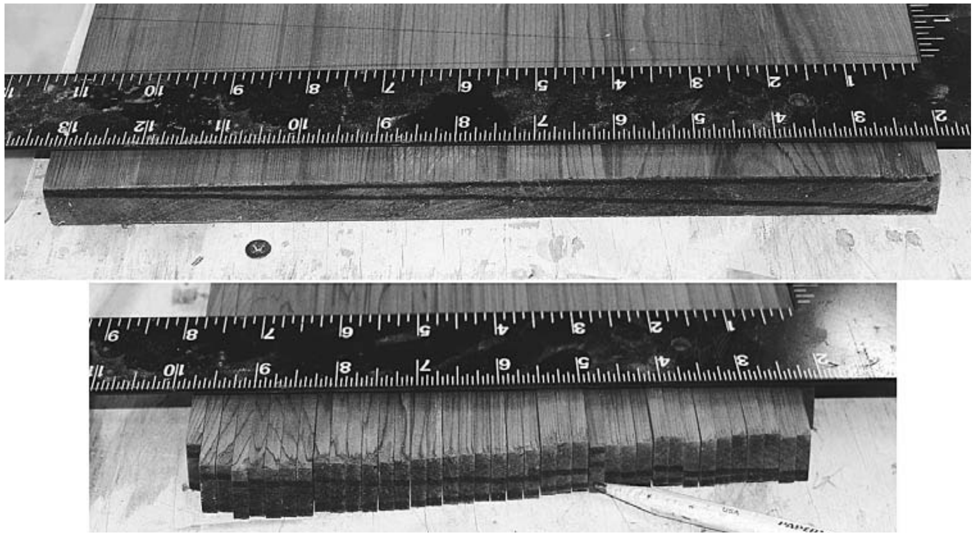


Figure 5-6. *A lot of wood is turned into dust when cutting strips. Here an 11-inch-wide board (top) is turned into eighty $\frac{3}{16}$-inch-wide strips (bottom), and 30% of the wood has been converted to sawdust. These strips are destined to be book-matched. The end of the board was marked with a diagonal line. In the cut strips the pencil points to one strip that is upside down.*

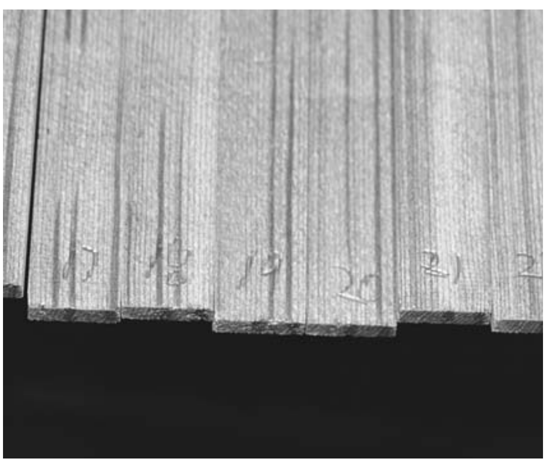


Figure 5-7. *Book matching strips requires you to keep the strips in order. Here I've numbered the strips for easy reference. Write the numbers at several locations along the length and on both sides so you can find numbers even when the strips are cut short. I circle the numbers on the back side so I can quickly identify which side should show.*

Figure 5-8. *Every once in a while mistakes happen. This strip broke along the grain. Throwing the strip out would have messed up the book matching pattern. Instead, I used some CA glue to put it back together. Under fiberglass no strength will be lost, and the repair will disappear.*

get shuffled. I use a permanent marker on the end grain and also make some light pencil marks on the face of the board. Using a marker on the face would leave marks on the finished boat.

As you cut the strips for book matching, arrange them on a nearby table in the order they are coming off the board. If you are gang sawing more than one strip at a time, pay attention to the placement of each strip in the arrangement.

After cutting all the strips, it is a good idea to run them all through a thickness planer to assure they are all the same thickness. You only need to finish one side. With careful table saw work, this step is not strictly necessary, but it is one more step that may pay off with less work later on. Most planers will be able to handle several strips at a time, but you don't want to try to feed too many because they can get tangled and make a mess.

Cove-and-Bead

If you are going to make cove-and-bead strips it is particularly important that the strips are of consistent thickness. Because the cove-and-beads need to be centered on the strip, the center needs to be in the same place on all the strips. Set up your router in a router table to cut the bead first. The cove is more delicate, so the less you handle it after milling, the better. You will need some scrap strips to help you set up. These should be just like the strips you will be milling. Start with the fence set so the bit just barely hits the strips. Adjust the bit height so both the top and bottom of the strip are hit equally. Run a few strips through to be sure that they are being milled consistently. When the height is right, adjust the fence so the depth is just sufficient to round over the edge. You don't want to make the strip narrower; if you scribble on the edge with a pencil, the router should just remove the color from the center of the edge.

Set up a feather board to hold the strip down at the router bit and another to hold the strip against the fence. Run another test strip to be sure everything is still running right.

When you're milling the coves and beads you don't want your fingers to come anywhere near the cutter. Feather boards serve to keep your fingers away while holding the strips tight against the cutter. The upper feather board is cut from a piece of plywood and has a board in front of it to help hold it in place with some spring clamps.

Run all the strips through the same way. For example, if you have planed the strips, run all the strips with the planed side down against the table for both the bead and the cove. In this way, any misalignment while centering the bit will be off in a consistent and predictable way. If you are planning on book matching strips you will want to be particularly cognizant of the cove-and-bead location. And depending on your intended stripping pattern you may actually want to have every other strip milled on the opposite side. Think about what you intend to do. Frankly, if I'm going to do complicated stripping patterns, I don't bother with cove and bead at all. My brain cramps up trying to figure it out.

Set up to mill the cove in a similar manner. Replace the bit with the cove-cutting bit. Start with the fence set to make a very light cut centered as close as possible on the thickness of the strip. Flip the strip over and check the height. Adjust the height so it splits any difference. When you think you have it set, adjust the fence until one or both of the top or bottom edges becomes a feather thickness. If one edge becomes finer sooner, the bit is too close to that edge; adjust the height slightly so both edges are the same thickness. When it is right, adjust the fence so the cut is not as deep. You want a slightly square edge on either side of the cove.

Set up your feather boards again, and make sure nothing has shifted. When it all looks good, run your strips again. Again, keep the planed side down or follow whatever rule you chose, but be consistent.

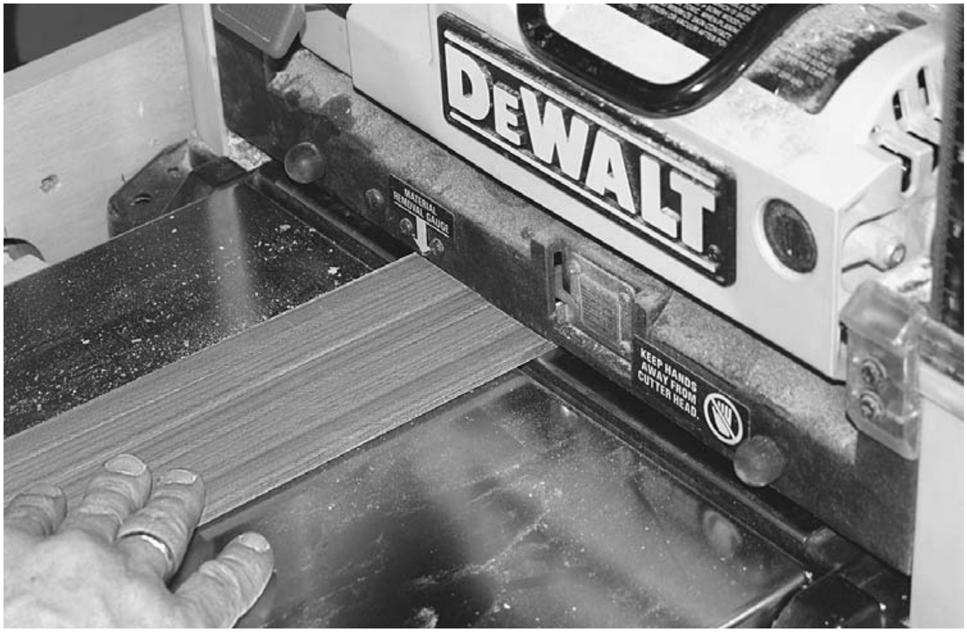


Figure 5-9. *Using a consistent thickness of strips helps produce a smooth surface, but this is particularly important with cove-and-bead strips. It is almost impossible to keep the cove-and-bead centered on the strip if the thickness varies. Running the strips through a thickness planer after they come off the saw solves the problem. Here I'm running five strips through simultaneously.*

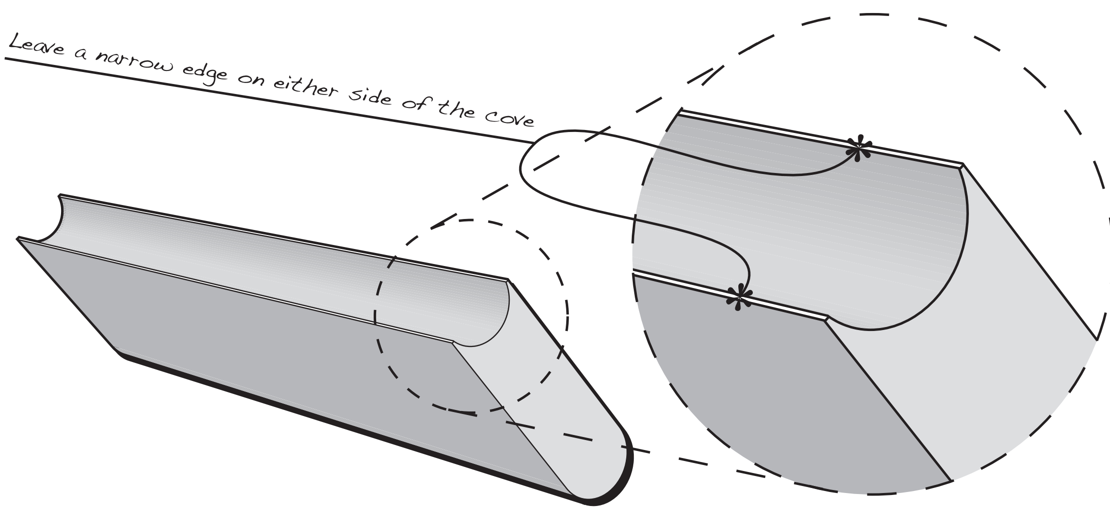
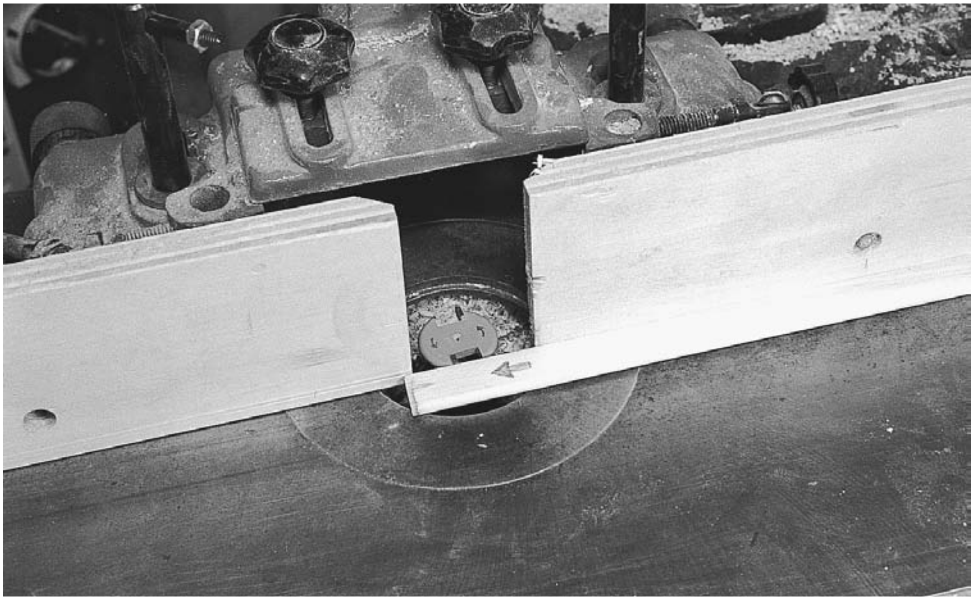
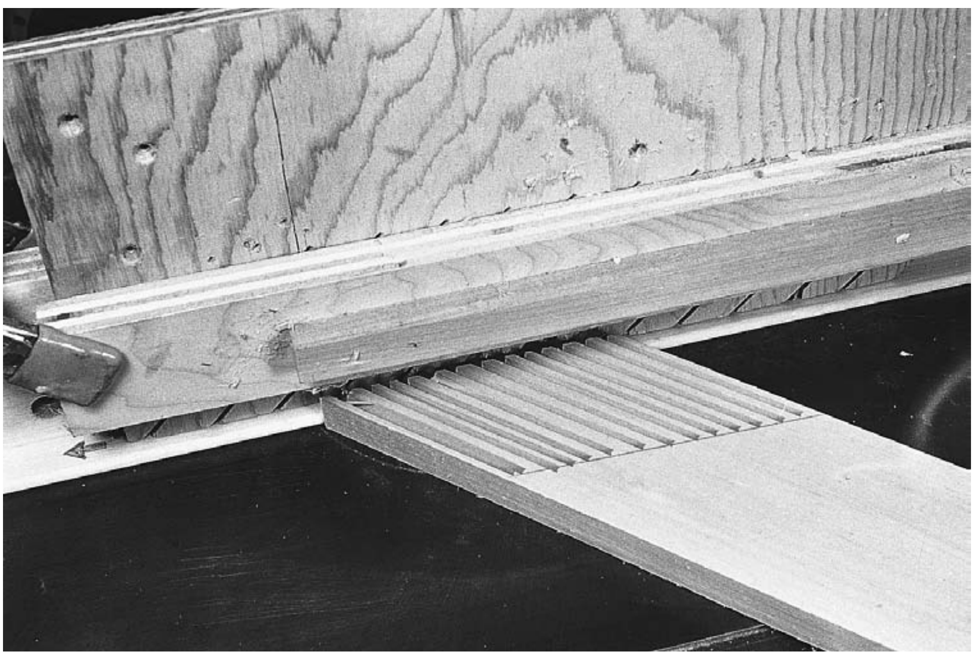


Figure 5-10. *The cove side of a cove-and-bead strip can be delicate. If you leave a slightly square edge it will be stronger than a fine feather edge. The strips need to be uniform in thickness to get a uniform edge on both sides.*





Figures 5-11 and 5-12. *The coves and beads are milled on the strips on a router table. Set the router up so the bit is turning opposite of the feed direction of the strip. When the bit height has been adjusted so it cuts down the middle of the strip and the fence has been adjusted so the depth is just deep enough, install feather boards. One board should hold the strip down on the table, with another pressing it against the fence.*

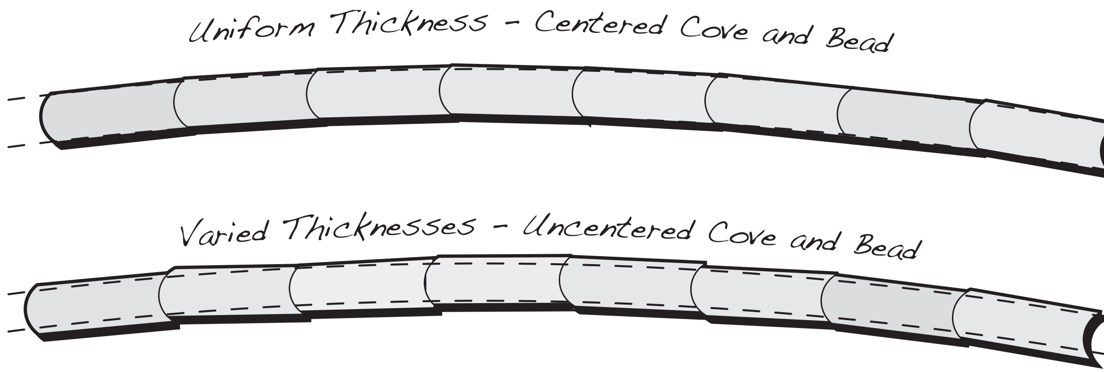


Figure 5-13. *Carefully milled strips create a smoother finished surface. Sloppy milling requires more sanding, planing, and just plain elbow grease. After all of that work, the remaining wood will be thinner.*

Obviously, the power stock feeder can be used here as well. The consistent feed rate will help produce more uniform strips. Another option if you have the tools is to set up two consecutive routers so the bead and cove are cut in one pass.

Setting Up Forms

The building form is the key to the boat shape. Once the building form is set up, all you really need to do is cover it with strips of wood. While the stripping will even out small errors, an accurate building form is a pretty good guarantee of an accurate boat shape.

The building form consists of two parts: the form or rib shapes, and the spine or strongback that holds them all together. An accurate building form starts out with a straight strongback. A strongback can be just about any reasonably stiff, reasonably straight object that allows you to mount the forms in their appropriate location.

With open boats, the forms are oriented so the boat is built upside down. With deck boats, the forms need to be flipped over during the stripping process. Usually people start with the boat upside down so they work on the hull first. There is no hard-and-fast rule on this, and if you are using an internal strongback you can start either way. Plans for decked boats that use an external strongback typically assume the builder will start with the boat upside down.

Strongbacks

A strongback can be an old wooden ladder, a plywood box, or an aluminum extrusion. The primary goal is to have a reliable reference so the forms will stay in their proper orientation relative to one another. While I said it should be straight, that is not really a requirement so long as you can establish some straight and true reference lines, mount the forms securely relative to those reference lines, and have confidence that they will stay there throughout the boatbuilding process. When boiled down to its essence, this is not a very high standard. The strongback need not be very sophisticated; it just needs to be reliable.

Strongback Selection. Exactly what you use for a strongback will depend on the style of boat you are building, the material you have on hand, how many boats you are going to build, and what you are comfortable with. There are two basic styles: internal strongbacks, which

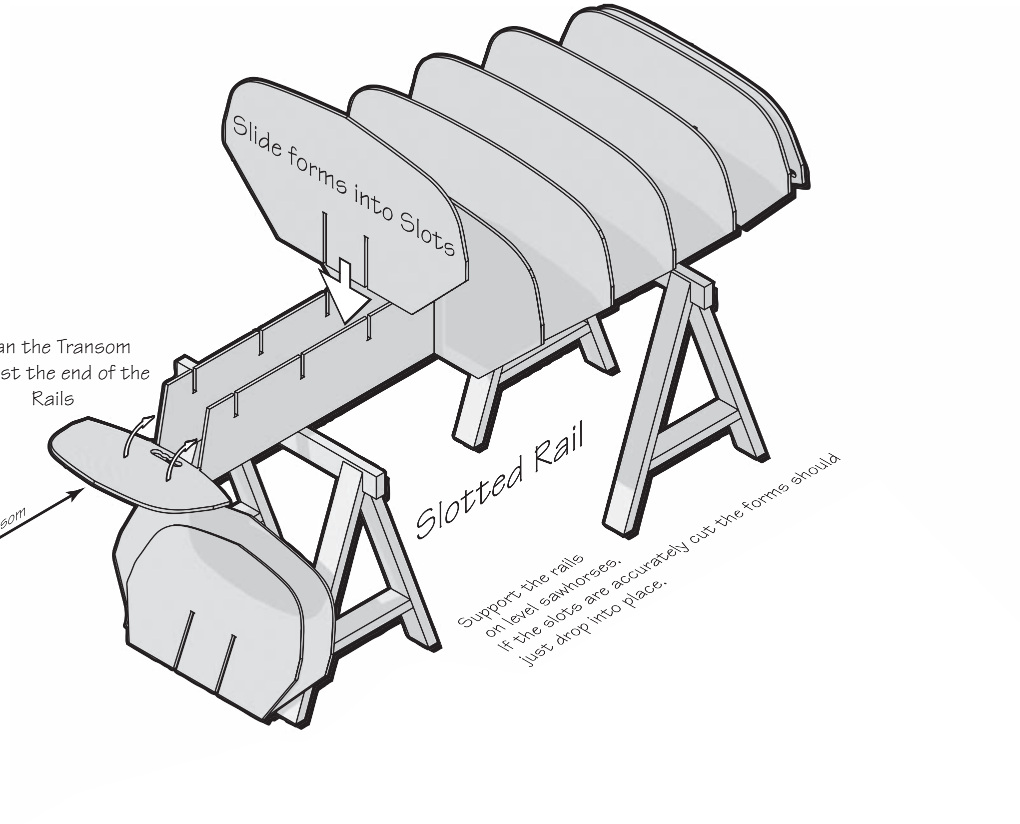


Figure 5-14. *The forms are secured in their appropriate location on a strongback. There are many kinds of strongback, but keeping it simple is always a benefit. The slotted rail is as simple as they come, but may be hard for a first-time builder to produce accurately. Boat kit manufacturers sometimes provide this system. The external strongback is probably the most common. In this example a plywood box beam provides a firm, steady, straight, and stiff base for supporting the forms. The forms are screwed to the box beam via simple wooden cleats. For decked boats like kayaks, an internal strongback is a good option. It can be made of a straight and true 2 by 4 (if you can find one), a small box beam, or if you are building enough boats to justify the cost, an aluminum extrusion. In this case the end forms are screwed in place on the ends of the beam and 11½-inch-long L spacers assure a 12-inch distance between forms. The middle spacer is cut to accept a couple of wedges that tighten up all the spacers along the length of the boat. On a straight strongback this allows the forms to be released and realigned quickly and easily.*