Fundamentals of Fiberglassing

The main concern of this chapter is the chemical part of fiberglassing. No prior experience in fiberglassing is assumed. Actual practice fiberglassing exercises are detailed. These exercises are designed for learning the characteristics and applications of both polyester and epoxy resin to reinforcing materials. You will get the experience in fiberglassing necessary for doing fiberglassing repair work and molding, as detailed in later chapters.

You should be familiar with and follow the safety rules and precautions given in Chapter 4. In addition, read the manufacturer's directions and safety precautions for each product and follow them carefully.

To gain a better understanding of fiberglassing materials and techniques, both polyester and epoxy resins will be used with many reinforcing materials. These will be used for practicing, learning, and experimenting rather than actually repairing anything. I feel that this is the best approach to learning the skills and techniques necessary for fiberglassing repair work. It is better to use up some materials to gain necessary skill, control, and confidence than to begin a fiberglassing repair job immediately and botch it.

Let's begin with polyester resins. These are less expensive and easier to use than epoxy resins.

CATALYZING POLYESTER RESINS

The curing process for polyester resins is called *polymerization.* It is fully initiated when a catalyst, usually methyl-ethyl-ketone (MEK) peroxide, is added. The amount of catalyst to be added depends mainly on the working temperature, the amount of resin to be catalyzed, and the working life desired. With a typical polyester resin, ½ percent of catalyst by volume will give a working life or gel time (time from when the catalyst is added until it achieves a gelatinous consistency) of about 60 minutes at 75 degrees Fahrenheit. The working life or gel time is also called *pot life.* It's the time you have for applying the resin. After the resin has started to gel, the remainder in the pot or container should be discarded. If applied to reinforcing material, it will result in a lumpy mess. The resin usually becomes hard soon after this, although the complete cure goes on for two weeks or more. Catalyzed polyester resin will actually cure faster in the container in which it is mixed than when spread thin, such as when applied to reinforcing material.

Remember that different brands and types of polyester resins will not all cure at the same rate when the same amount of catalyst is added. Follow the catalyzing directions for the particular polyester resin being used. This can vary somewhat from the amounts given as samples in this chapter.

In the previous example, if the amount of catalyst was doubled to 1 percent of catalyst by volume, the pot life would be reduced to about 30 minutes at the same 75-degree Fahrenheit working temperature. Two percent of catalyst by volume would further reduce the pot life to about 15 minutes.

If the working temperature in these examples is 90 degrees Fahrenheit and the same amounts of catalyst are added, the pot life in each case would be approximately cut in half. It would reduce to about 30 minutes with ½ percent of catalyst by volume added, to about 15 minutes with 1 percent of catalyst by volume, and to about 7½ minutes with 2 percent of catalyst by volume.

If the working temperature in these examples is 60 degrees Fahrenheit and the same amounts of catalyst are added, the pot life in each case would be approximately doubled. It would increase to about 2 hours with ½ percent of catalyst, to about 1 hour with 1 percent, and to about 30 minutes with 2 percent.

For most fiberglassing repair work, small quantities of resin, usually from about 2 to 8 ounces (½ pint), will be catalyzed for use at a time. If larger quantities are used, there is danger of the pot life expiring before all of the resin can be applied. Once the resin starts to gel, it should be discarded. Because high heat buildup can occur with resin in a container, it is best to pour the resin out in a safe place on the ground. Allow it to harden before discarding it in a trash barrel.

As experience is gained, you might be able to catalyze and use larger amounts of resin at a time for some types of fiberglassing work, perhaps a quart or more at a time. For learning purposes, start with small amounts and then gradually work up to larger amounts as your skill and confidence improve.

Adding Catalyst

You must decide how to add such a small quantity of catalyst. For most work, the amount of catalyst added will range from about ½ to 4 percent by volume. Often the catalyst is supplied in dispensers that allow release of the catalyst by drops. In order to catalyze 1 ounce of resin with 1 percent by volume of catalyst, about 4 drops would be required. While most catalysts also have a scale marking on their containers, desired quantities can also be poured out (usually by drops) by the change in levels on the scale. The markings are usually in ounces or cubic centimeters. Two hundred drops, for example, equals about ⅙ ounce or 5 cubic centimeters of catalyst.

I find it most convenient to add the catalyst by counting drops when small amounts of resin are to be catalyzed. Most catalyst dispensers allow adding drops quickly, so 100 or more drops can be added in a short time period. If you intend to do a lot of fiberglassing, you will probably want to invest in a special catalyst dispenser that allows more rapid dispensing of desired amounts of catalyst. These are available from fiberglassing suppliers. When used, the catalyst is usually purchased in large containers and then poured into the special dispenser as needed. If the catalyst that comes with the resin you purchase does not come in a "drop" dispenser, or you purchase catalyst separately that doesn't, you can use a regular eye dropper for adding the catalyst by drops.

For the first practice fiberglassing exercises, only small amounts of resin will be catalyzed at a time. This can be applied quickly, so only a short pot life is required. Usually 2 to 3 percent catalyst by volume is needed to expedite the cure, which in turn will allow more practice fiberglassing in the same amount of time.

One ounce of resin is about 1/16 pint. One-half percent by volume of catalyst is about 2 drops; 1 percent is about 4 drops; 2 percent is about 8 drops; and 3 percent is about 12 drops. At 75 degrees Fahrenheit, the ½ percent would give a pot life of approximately 60 minutes. One percent would give approximately 30 minutes. Two percent would give about 15 minutes. Three percent would reduce the pot life or working time to about 7½ minutes, which would still allow ample time for applying this small amount of resin.

Using the same mixtures, higher working temperatures reduce the pot life and increase the curing rate. Lower working temperatures increase the pot life and decrease the curing rate.

General Principle

The general principle is the more catalyst, the faster the curing time; the less catalyst, the slower the curing time. Also, the higher the temperature, the faster the curing time; the lower the temperature, the slower the curing time. The same pot life and curing time can be maintained in a range of temperatures, usually from about 60 to 90 degrees Fahrenheit, with most regular polyester resins by varying the amount of catalyst used.

If at all possible, try to do your first practice fiberglassing exercises with a working temperature of about 75 degrees Fahrenheit, or at least at a temperature as close to this as possible. The idea is to keep the temperature variable constant at first so that you can better concentrate on other factors. After you have a little practice, you can learn to fiberglass in various temperatures.

Practice Exercise

The first exercise in catalyzing polyester resin demonstrates the effects of adding different amounts of catalyst to equal amounts of resin on gel and curing time. It gives an opportunity to study the characteristics of cured polyester resin without reinforcing material. You need either finishing or general-purpose polyester resin, catalyst for the resin, four mixing cups (the kind sold at drug stores with ounce markings on the sides are recommended), four small mixing sticks, and one longer mixing stick that can be used to stir the resin in the container in which it comes. You also need a piece of wax paper and paper to protect the area where you will be working, which can be on a bench, floor, or concrete surface outside. You should also have proper protective clothing and safety equipment (see Chapter 3). Follow the safety rules detailed in Chapter 4. This applies to all fiberglassing exercises and repair work covered in this book.

You also need a clock positioned so that it can be seen from the work area. You also need a pencil and notebook for recording the results of the practice exercises for future reference. Place a thermometer in the work area so that you can note the working temperature. You can start by writing the temperature down in your notebook.

When you have everything ready, begin by opening the container that the resin came in. Carefully stir it with a clean stirring stick. When removing the stick from the container, allow as much of the resin to drain off the stick back into the container as possible. Use a clean rag to clean off the remaining resin from the stick. Put the stick aside for later use. Keep this one stick for use only for stirring uncatalyzed resin in the containers in which it is sold.

Pour 1 ounce of resin into each of the four cups. The markings on the sides of the cups can be used as a guide, or you can use a 1-ounce measuring scoop such as the kind used in the kitchen (but don't use it for kitchen duty again after you have used it for measuring out resin). Replace the lid on the resin container and set it aside.

To one of the cups containing 1 ounce of resin, add 2 drops of catalyst. Stir with one of the small sticks. Wait about 30 seconds. Observe the time on the clock and write this down in your notebook. Pour the catalyzed resin out on the piece of wax paper and spread it into a thin layer with the mixing stick. Use the small stirring stick to poke at the resin as the curing takes place. Because 2 drops of catalyst added to 1 ounce of resin is only about ½ percent by volume, it should take about an hour for the resin to gel. It should reach a cheeselike consistency and become hard. By using the stick as a probe, follow the process of the liquid changing to a solid. Write down how long it took from the time the catalyst was added until the gel state was reached, and then how much longer it took for the resin to become hard. The results depend on many factors, such as the particular resin and catalyst used, the working temperature, and the humidity. Almost certainly the gel time and curing time were much longer than really necessary.

With a second cup containing 1 ounce of resin, add 4 drops of catalyst or twice as much as was added to the first batch. This is about 1 percent by volume of catalyst. Again, mark down the starting time, noting the percentage of catalyst added. Again, observe the time to gel state and until the resin becomes hard. These times should be about half as long as previously. The resin should be poured from the cup to an area of the wax paper separate from the first (now hard) resin, which should be saved for later experimenting. Also, keep track of the percentage of catalyst that was added to each one.

Use the stirring stick to spread the resin out on the wax paper into a thin layer. This should be done so that the resin will still be in one piece when it hardens. Use the stick as a probe to determine when the gel state is reached and when the resin becomes hard.

With the third cup of 1 ounce of resin, repeat the same practice exercise, except this time add 8 drops of catalyst. This is approximately 2 percent by volume. Mark down the starting time. Stir. Wait about 30 seconds, then pour the resin out on the wax paper in an area away from the first two batches of resin, which should now be hard. Observe and record the time to gel and to when the resin becomes hard. For a typical polyester resin, the time to gel should be about 15 minutes, but your results might vary. It should become hard very soon—faster than was the case when less catalyst was used.

Data from the Exercise

With the last cup containing 1 ounce of resin, repeat the same steps, except this time add 12 drops of catalyst. This is about 3 percent by volume of catalyst. It should take only about 7½ minutes for the resin to reach the gel state. The resin should become hard very quickly. Record the times in your notebook. Your results should be similar to those shown in Table 7-1.

This will probably be enough fiberglassing for one practice session. Save the four pieces of cured resin. Mark them so that you can remember how much catalyst was added to each one. These pieces of cured resin will be used in the next practice session. Finish the first practice session by cleaning up the work area and putting everything away in an organized manner. Remember to store resin in a cool, dry place.

The data kept in your notebook will be useful as a reference for future fiberglassing. For example, if you later want to catalyze 4 ounces of the same resin, check your notebook. I made Table 7-1 when I carried out this practice exercise. From this table I can determine the amount of catalyst to be added for various working times. For instance, 16 drops of catalyst are used (4 × 4) for 30 minutes to gel or working time. Remember that the data is for a specific working temperature (my working temperature in this exercise was 75 degrees Fahrenheit). If you do future work at a different working temperature, the temperature will have to be taken into consideration and new test data gathered, as detailed previously in this chapter.

CURED POLYESTER RESIN WITHOUT REINFORCING MATERIAL

Polyester resin alone, without reinforcing material, is quite brittle when cured. Take the piece of resin that was formed by ½ percent by volume of catalyst and place it on a hard surface. Tap it with a hammer. It will probably shatter rather easily. Repeat with the other three pieces of cured resin. Could you observe any differences between the ease (or difficulty) of shattering them? In most cases you probably would not be able to detect any differences. The variations in amounts of resin used in this practice work probably would not have much affect on the strength of the cured resin. Things might be different if you went to greater extremes, such as less than ½ percent catalyst by volume or more than about 5 percent catalyst by volume. Too little catalyst would also give an unreasonably long working time, and too much catalyst would not give you enough time to apply the resin to anything.

The hammer test is a form of destructive testing. You found that the resin without reinforcing material shatters rather easily, but you also

Table 7-1. Data from the Exercise in Catalyzing Polyester Resin.

Amount of Resin (Oz.)	Percent of Volume of Catalyst	Drops of Catalyst	Min. to Gel	Min. until Hard
1	½	2	50	70
1	1	4	30	35
1	2	8	15	17
1	3	12	7-½	8

ruined the material in the process. This is an advantage of doing practice work before attempting actual fiberglassing repairs. On actual repair work, you will have little opportunity to do destructive testing. Destructive testing can tell you plenty about the strength and integrity of your fiberglass laminates that nondestructive testing can't, at least not so convincingly.

ADDING REINFORCING MATERIAL TO POLYESTER RESIN

Most of the same materials and supplies used for the first practice exercise will also be required for this one, except that you will only need one (clean) small mixing cup and one small stirring stick. For the following practice exercises, you should have an ample supply of mixing cups and stirring sticks on hand. For this exercise you also need some chopped strands of glass fibers. Because you will only need a small amount, and fiberglass mat will be required for future practice exercises, just purchase fiberglass mat and pull chopped strands of glass fibers from it. Save the rest of the mat for later. Store it inside a plastic bag.

Measure out an ounce of the general-purpose or finishing polyester resin into a mixing cup and then replace the lid on the resin container. Don't forget to stir the resin in the container before pouring or dipping out in a measuring cup the 1 ounce for use in this practice exercise. If this is not done, you will have thinner resin at the top of the container than at the bottom. The stirring assures an even consistency.

Before adding catalyst, add ⅓ ounce of chopped strands (either purchased chopped strands or those pulled from fiberglass mat) to the ounce of resin. With a small mixing stick, stir the resin and the chopped strands together. Make sure that all the chopped strands are saturated with resin.

Add 8 drops of catalyst to the resin. This should be about 2 percent by volume; you only count the resin, not the reinforcing material. You should have approximately 15 minutes of working time. Stir the catalyst into the resin. Then wait about 30 seconds. Pour the mixture out onto wax paper, using the stirring stick to get as much of it from the cup to the wax paper as possible. Use the stick to spread the resin and reinforcing material into a layer about ⅛ inch thick.

Keep track of the time from when the catalyst was added until the gel state is reached and then the time until the mixture becomes hard. This should be approximately the same as when 8 drops of catalyst were added to 1 ounce of resin without reinforcing material.

After the mixture is hard and no longer tacky on the surface, pick it up from the wax paper. Note several things. First, you have more mass than when the resin alone was used previously. Second, the reinforced resin looks different than resin alone. You can probably see some of the strands of chopped glass fiber on the surface of the mixture. The side that was against the wax paper is probably quite smooth; the wax paper acted like a flat molding or forming surface.

Place the material on a hard surface and give it a tap with a hammer. Try to do this in the same manner as was done with the hard resin alone. Did the reinforced material shatter as easily? Unless something drastic happened, it should be much more difficult to shatter the reinforced resin. Even when it does break up, the reinforcing fibers tend to keep the material from shattering.

ADDING POLYESTER RESIN TO MAT

For this practice exercise you need, in addition to the general-purpose or finishing polyester resin, catalyst, and other basic items required for the earlier practice exercises, a ½-inch brush, a piece of cardboard, and a 6-inch square piece of 1½-ounce mat. Because you will need more mat later, purchase a larger piece and cut off a 3-inch square from one corner for use in this exercise. Put the remainder of the mat in a plastic bag, so it will stay clean and dry for later use.

Because 1 square foot of 1½-ounce mat weighs approximately 1½ ounces, the 6-inch square should weigh one-fourth as much, or about 0.38 ounce. Mat laminates are typically 25 to 35 percent fiberglass reinforcing material and 65 to 75 percent resin by weight. For the 25 percent mat ratio, about triple the weight of the mat in resin is required to fully wet out the mat. For the 6-inch square of 1½-ounce mat, three times 0.38 ounce, or 1.14 ounce of resin, will be required.

For this practice exercise, pour about 1¼ ounces of resin into a mixing cup. You will need about 7½ minutes of working time. Look in your notebook and see how much catalyst you should add. For a working temperature of 75 degrees Fahrenheit, this should be about 12 drops for 1 ounce of resin or 15 drops for 1¼ ounces.

Before adding the catalyst, place the piece of mat on the cardboard (Fig. 7-1). Have wax paper ready to place the mat on once one side of the mat has been saturated with resin. Use the cardboard to turn the mat over, so the wet side of the mat will be face down on the wax paper. Have the brush ready.

Add the catalyst to the resin and stir. Wait about 30 seconds. Using the brush, apply resin to one side of the mat, which should be on the cardboard (Fig. 7-2). Use a dabbing action rather than a brushing motion so you do not lump up the mat. This applies mainly to mat; you won't have the lumping problem with cloth and woven roving.

When the one side of the mat is fully saturated with resin, hold the cardboard, turn the mat over, and place it with the wet side down on the wax paper (Fig. 7-3). Using the brush, work any resin that remains on the cardboard onto the mat. Put the cardboard aside. Using the brush, dab the remaining resin on the other side of the mat, saturating the mat and getting the resin spread as evenly as possible (Fig. 7-4). When everything looks okay, clean the resin from the brush with acetone. This must be done before the resin hardens if the brush is to be used again.

Use a stirring stick to probe one corner of the mat to determine approximate gel time and curing time. After the laminate has cured (wait at least a few minutes after the laminate is hard), pick it up from the wax paper and examine it. If everything was done correctly, you should have a mat laminate made up of approximately 25 percent mat by weight and 75 percent resin by weight (Fig. 7-5).

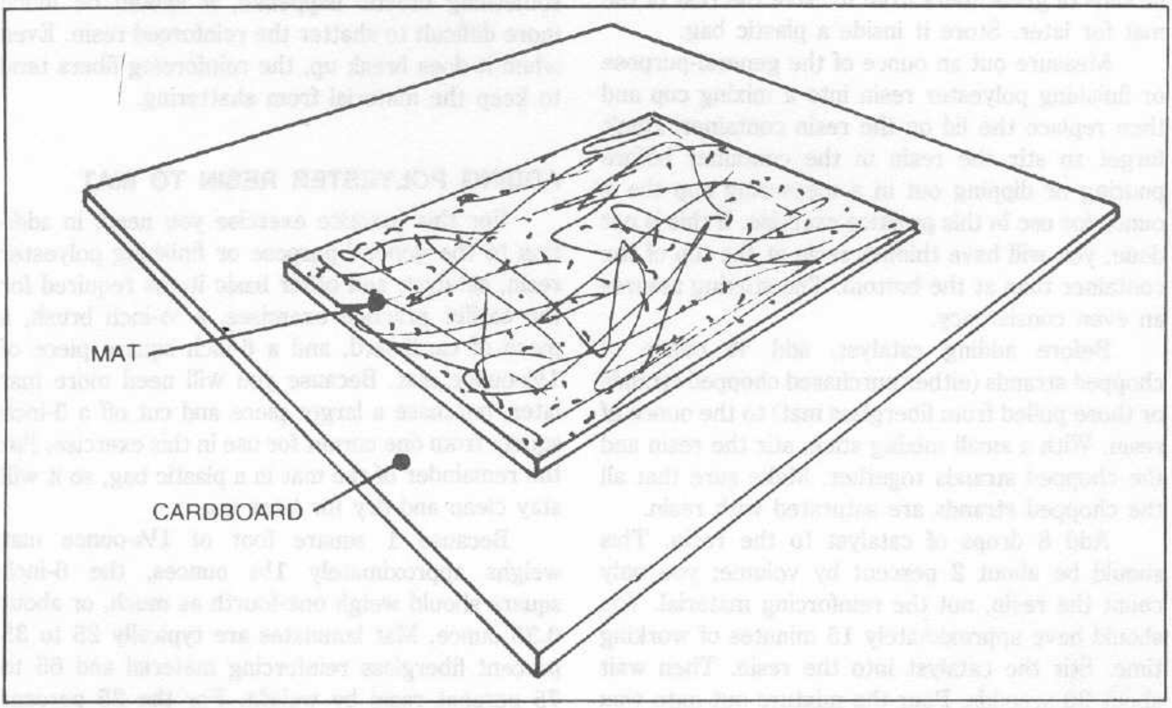

Fig. 7-1. Place the mat on a piece of cardboard.

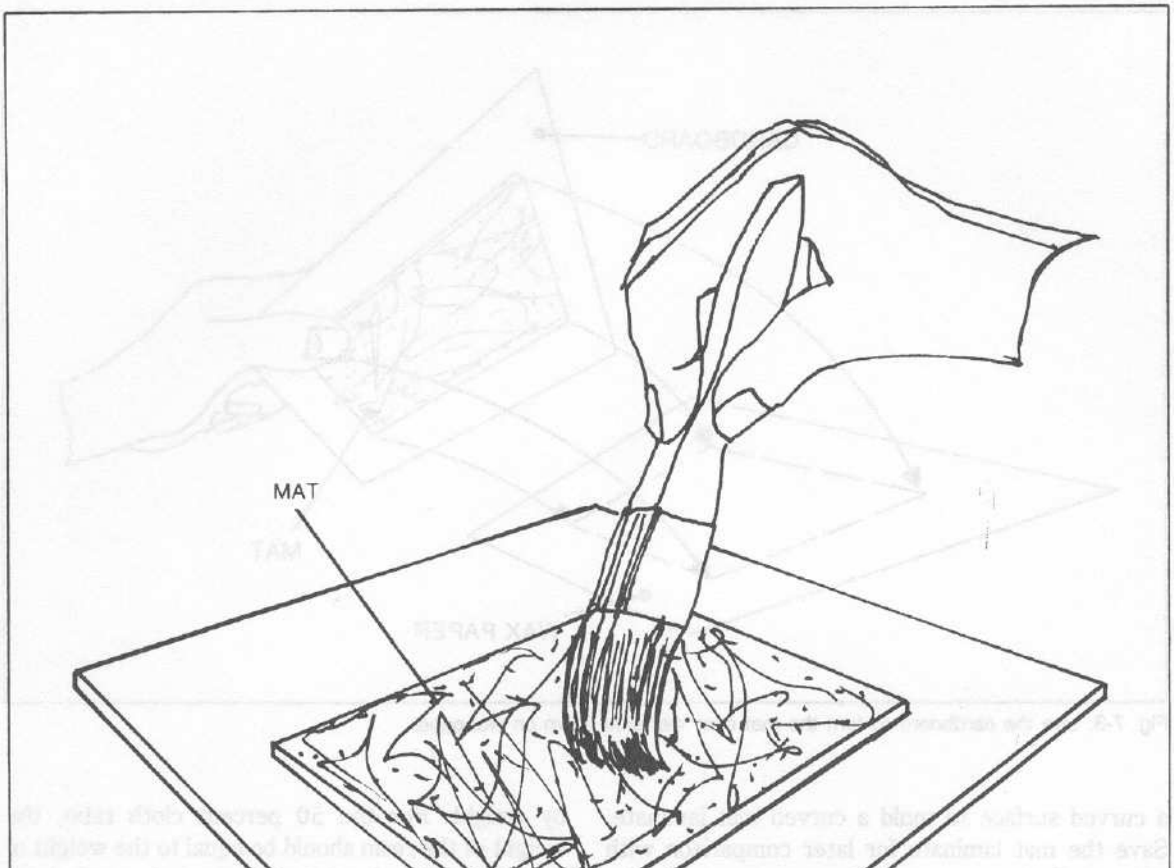

Fig. 7-2. Using a brush, apply resin to one side of the mat.

Slightly more resin was actually used, but some resin probably couldn't be recovered from the cardboard and brush. The finished laminate should weigh approximately 1½ ounces. The laminate should be about 1/20 inch thick. Also, the side of the mat that was placed over the wax paper should be quite smooth as the wax paper acted as a form or flat mold. The wax paper could have been placed on

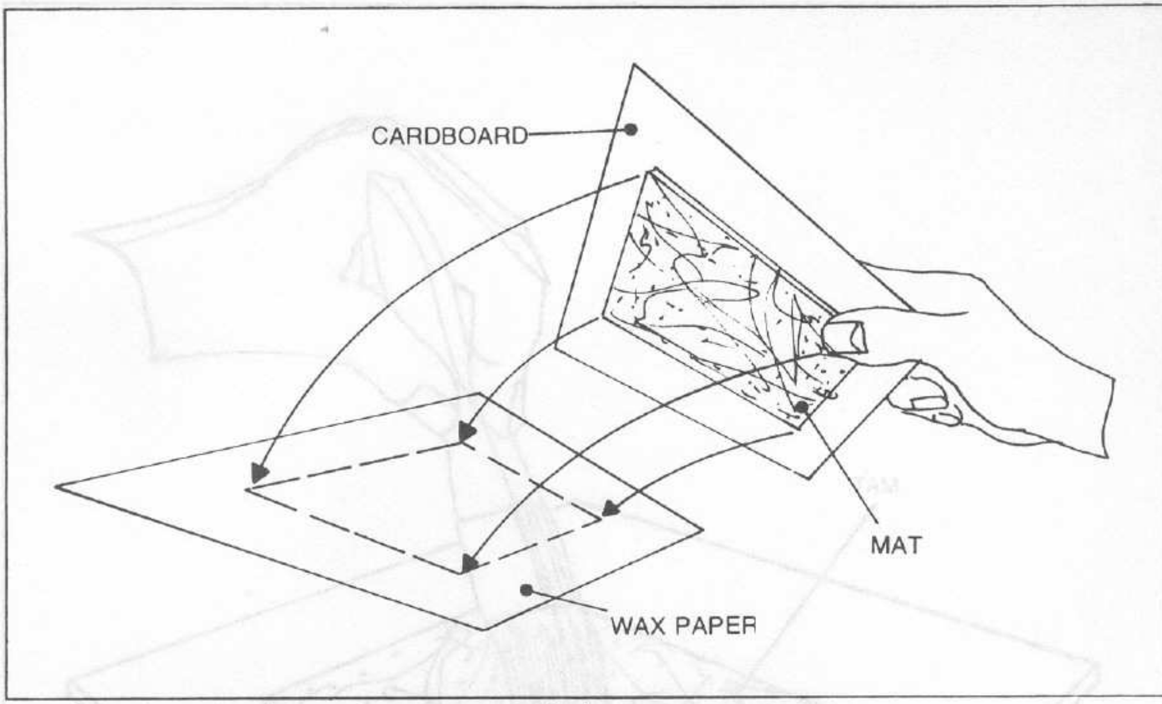

Fig. 7-3. Use the cardboard to turn the mat over wet side down on waxpaper.

a curved surface to mold a curved mat laminate. Save the mat laminate for later comparison with other laminates.

ADDING POLYESTER RESIN TO CLOTH

This is essentially the same as the mat exercise, except this time cloth is used (Fig. 7-6). You will need a 6-inch square piece of 10-ounce-per-square-yard fiberglass cloth. Because you will need more fiberglass cloth later, purchase a larger piece and cut off a 6-inch square from one corner. This will give you one selvaged edge and three that aren't. Be careful when cutting and handling the cloth so as not to unravel the unselvaged edges any more than necessary. Put the remainder of the fiberglass cloth in a plastic bag to keep it clean and dry for later use.

Because 1 square yard of 10-ounce cloth weighs approximately 10 ounces, the 6-inch square should weigh about 0.3 ounce, or 1/36 as much. Cloth laminates are typically 45 to 50 percent fiberglass cloth by weight and 50 to 55 percent resin by weight. For the 50 percent cloth ratio, the weight of the resin should be equal to the weight of the cloth. For the 6-inch square piece of cloth, about 0.3 ounce of resin will be required. Because some resin will be lost on the cardboard and brush, approximately ½ ounce of resin should be used for this practice exercise.

Pour ½ ounce of resin into a mixing cup. For this practice exercise, you will need about 7½ minutes of working time. Look in your notebook and see how much catalyst should be added. For a working temperature of 75 degrees Fahrenheit, this should be about 12 drops for 1 ounce resin or 6 drops for ½ ounce of resin.

Before adding the catalyst, place the piece of cloth on a piece of cardboard. Have wax paper ready as well as a brush for applying the resin.

Add the catalyst to the resin and stir. Wait about 30 seconds. Using the brush, apply resin to one side of the cloth, which should be on the cardboard. A brushing action can be used but take care not to unravel the unselvaged edges of the cloth.

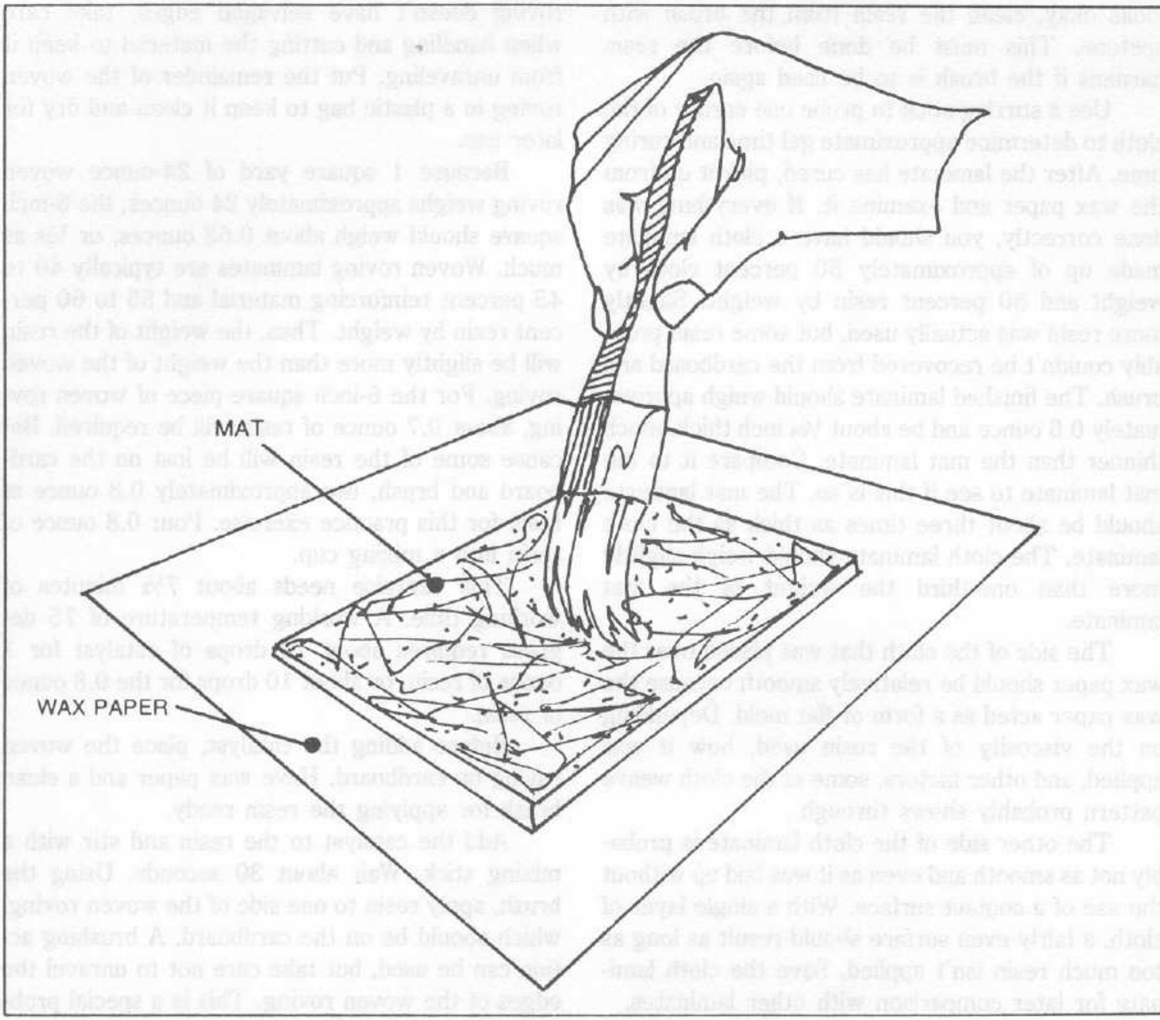

Fig. 7-4. Fully saturate the mat with resin.

Fig. 7-5. Single-layer fiberglass mat laminate.

When one side of the cloth is fully saturated with resin, hold the cardboard, turn the cloth over, and place it with the wet side down on the wax paper. Using the brush, work any resin that remains on the cardboard onto the cloth. Put the cardboard aside. Brush the remaining resin onto the cloth. Saturate the cloth and get the resin spread as evenly as possible. When everything

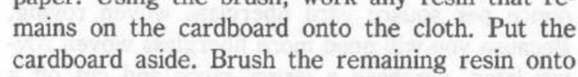
Fig. 7-6. Single-layer fiberglass cloth laminate.

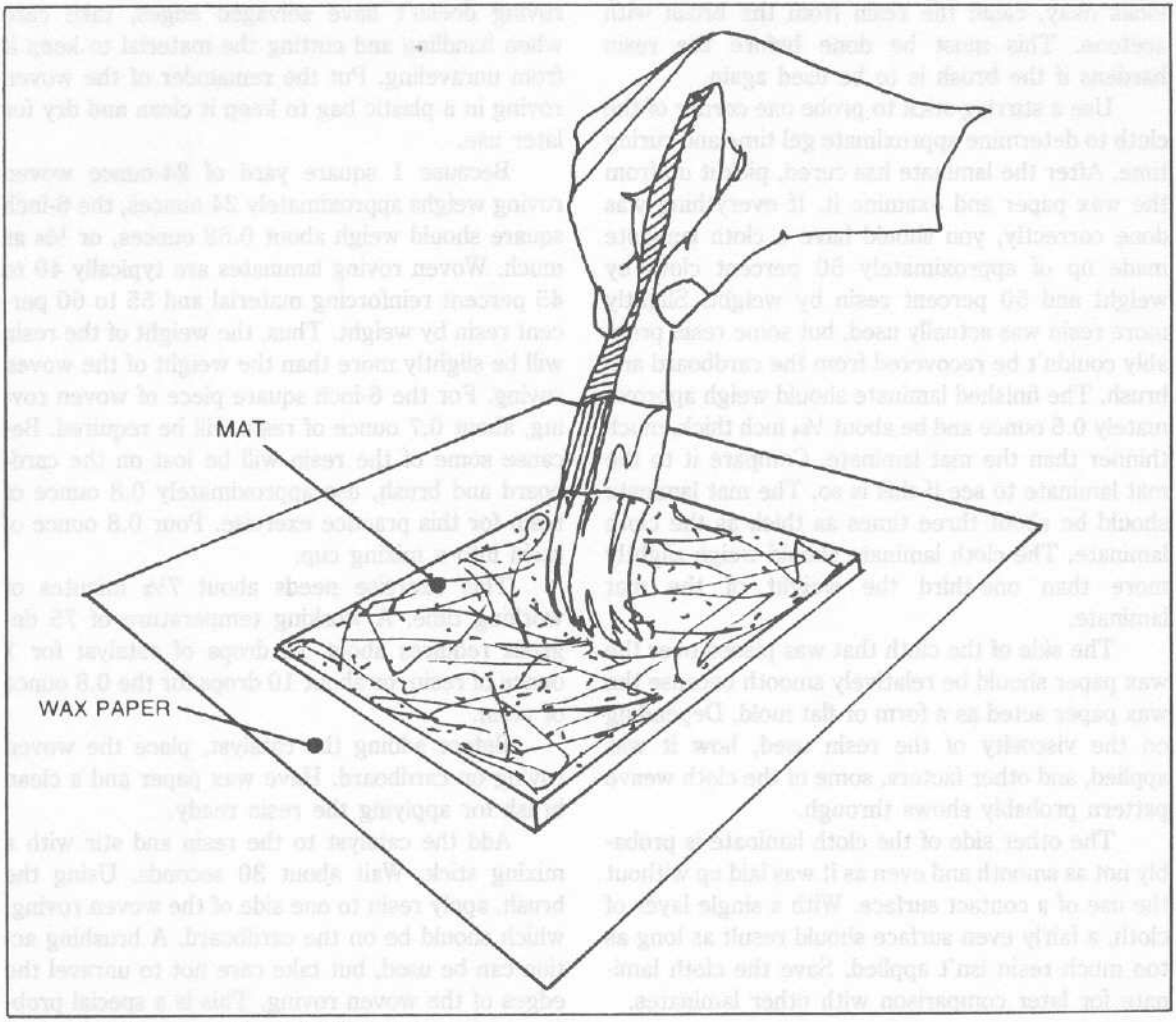

Fig. 7-4. Fully saturate the mat with resin.

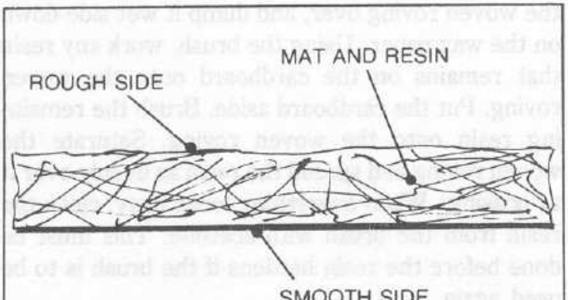

Fig. 7-5. Single-layer fiberglass mat laminate.

When one side of the cloth is fully saturated with resin, hold the cardboard, turn the cloth over, and place it with the wet side down on the wax paper. Using the brush, work any resin that remains on the cardboard onto the cloth. Put the cardboard aside. Brush the remaining resin onto the cloth. Saturate the cloth and get the resin spread as evenly as possible. When everything

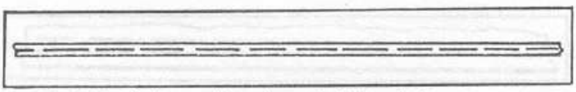

Fig. 7-6. Single-layer fiberglass cloth laminate.

looks okay, clean the resin from the brush with acetone. This must be done before the resin hardens if the brush is to be used again.

Use a stirring stick to probe one corner of the cloth to determine approximate gel time and curing time. After the laminate has cured, pick it up from the wax paper and examine it. If everything was done correctly, you should have a cloth laminate made up of approximately 50 percent cloth by weight and 50 percent resin by weight. Slightly more resin was actually used, but some resin probably couldn't be recovered from the cardboard and brush. The finished laminate should weigh approximately 0.6 ounce and be about 1/64 inch thick, much thinner than the mat laminate. Compare it to the mat laminate to see if this is so. The mat laminate should be about three times as thick as the cloth laminate. The cloth laminate should weigh slightly more than one-third the weight of the mat laminate.

The side of the cloth that was placed over the wax paper should be relatively smooth because the wax paper acted as a form or flat mold. Depending on the viscosity of the resin used, how it was applied, and other factors, some of the cloth weave pattern probably shows through.

The other side of the cloth laminate is probably not as smooth and even as it was laid up without the use of a contact surface. With a single layer of cloth, a fairly even surface should result as long as too much resin isn't applied. Save the cloth laminate for later comparison with other laminates.

ADDING POLYESTER RESIN TO WOVEN ROVING

This is essentially the same as the cloth exercise, except woven roving is used instead of cloth (Fig. 7-7). You need a 6-inch square piece of 24-ounce per square yard fiberglass woven roving. Because you will need more fiberglass woven roving later, purchase a larger piece and cut off a 6-inch square from one corner. Because woven roving doesn't have selvaged edges, take care when handling and cutting the material to keep it from unraveling. Put the remainder of the woven roving in a plastic bag to keep it clean and dry for later use.

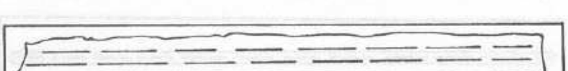

Fig. 7-7. Single-layer fiberglass woven roving laminate.

Because 1 square yard of 24-ounce woven roving weighs approximately 24 ounces, the 6-inch square should weigh about 0.68 ounces, or 1/36 as much. Woven roving laminates are typically 40 to 45 percent reinforcing material and 55 to 60 percent resin by weight. Thus, the weight of the resin will be slightly more than the weight of the woven roving. For the 6-inch square piece of woven roving, about 0.7 ounce of resin will be required. Because some of the resin will be lost on the cardboard and brush, use approximately 0.8 ounce of resin for this practice exercise. Pour 0.8 ounce of resin into a mixing cup.

This exercise needs about 7½ minutes of working time. A working temperature of 75 degrees requires about 12 drops of catalyst for 1 ounce of resin, or about 10 drops for the 0.8 ounce of resin.

Before adding the catalyst, place the woven roving on cardboard. Have wax paper and a clean brush for applying the resin ready.

Add the catalyst to the resin and stir with a mixing stick. Wait about 30 seconds. Using the brush, apply resin to one side of the woven roving, which should be on the cardboard. A brushing action can be used, but take care not to unravel the edges of the woven roving. This is a special problem with such a small piece of woven roving.

When one side of the woven roving is fully saturated with resin, pick up the cardboard, turn the woven roving over, and dump it wet side down on the wax paper. Using the brush, work any resin that remains on the cardboard onto the woven roving. Put the cardboard aside. Brush the remaining resin onto the woven roving. Saturate the woven roving and spread the resin as evenly over it as possible. When everything looks okay, clean the resin from the brush with acetone. This must be done before the resin hardens if the brush is to be used again.

Use a stirring stick to probe one corner of the woven roving to determine approximate gel time and curing time. After the laminate has cured, pick it up from the wax paper and examine it. If everything was done correctly, you should have a woven roving laminate made up of approximately 45 percent woven roving by weight and 55 percent resin by weight. Slightly more resin was actually used, but some probably couldn't be recovered from the cardboard and brush.

The finished laminate should weigh about 1.4 ounces. The laminate should be about 1/25 inch thick, more than twice as thick as the cloth laminate and just slightly thinner than the mat laminate. Compare the woven roving laminate with those of cloth and mat to see if this is true. The woven roving laminate should weigh slightly less than the mat laminate and almost two and a half times as much as the cloth laminate.

The side of the woven roving that was placed over the wax paper should be relatively smooth, as the wax paper acted as a form or flat mold. The heavy weave pattern of the woven roving probably shows clearly. This is why mat is frequently combined with woven roving in laminates to fill in the weave pattern of the woven roving.

The other side of the woven roving laminate is probably not as smooth and even because it was laid up without the use of a contact surface. With a single layer of woven roving laid up over a flat surface, the noncontact surface should come out fairly even. Save the woven roving laminate for later comparison with other laminates.

SUMMARY OF PRACTICE LAMINATES USING MAT, CLOTH, AND WOVEN ROVING

These three practice exercises were intended to show some of the differences among mat, cloth, and woven roving when used with polyester resin in forming laminates. To make the results of the practice exercises more meaningful for future reference, they are multiplied out as though a *square foot* rather than a 6-inch square of each material was used. See Table 7-2.

Remember that the resulting laminates have different thicknesses. To produce laminates that are all approximately 3/32 inch thick, it takes two layers of 1½ ounce mat, six layers of 10-ounce cloth, and 2.3 layers of 24-ounce woven roving.

While the total cost of the resin and reinforcing material for various laminates of the same thickness will vary depending on factors such as where and how you purchase your materials, it generally costs less for a mat laminate. The cost is about 25 percent more for a woven roving laminate, and the cloth laminate costs about twice as much as the woven roving. The cost of the resin is nearly the same for all three laminates. The resin for mat costs the most, followed by the resin for cloth, and then the resin for woven roving. It's mainly the cost of the reinforcing materials that makes the difference. Mat is the least expensive. Cloth is about four times as expensive as mat. Woven roving is about half the cost of the cloth, or about 80 percent higher than mat. Remember that these figures are for the same total thickness of laminate.

Why not just use mat and save money? Whenever mat will serve the purpose, this is the economical way to go. Cloth and woven roving have important strength advantages over mat, so there are many fiberglassing repair jobs where these reinforcing materials should be used.

So far, laminates of only a single layer of one

Table 7-2. Results of Practice Exercises, Assuming a Square Foot of Each Material Was Used.

	1½ Oz. Mat	10 Oz. Cloth	24 Oz. Woven Roving
Weight of Reinforcing Material (Oz.)	1.5	1.2	2.7
Weight of Resin (Oz.)	4.6	1.2	2.8
Weight of Laminate (Oz.)	6.1	2.4	5.5
Thickness of Laminate (inches)	1/20	1/64	1/25

kind of reinforcing material have been used in the practice exercises. Now you will experiment with laminates with two or more layers of the same reinforcing material.

LAMINATING TWO LAYERS OF MAT WITH POLYESTER RESIN

For this practice exercise, essentially the same materials will be required as were used for the single-layer mat laminate (Fig. 7-8). This time, though, you need two 6-inch square pieces of 1½-ounce mat instead of one. You could add another layer to the original mat laminate, except you will need the single-layer one for comparison with the two-layer one. Also, if finishing resin was used, the wax would have to be removed from the surface chemically or by sanding to get a good bond. For this practice exercise you will need either general-purpose polyester resin or both laminating and finishing resin. To better understand the differences between laminating (air-inhibited) and finishing (nonair-inhibited) resins, I highly suggest that these be used for at least some of the practice work.

Begin by making a single-layer mat laminate as was done previously, except this time use either general-purpose or laminating resin. Allow the laminate to cure. If laminating resin is used, the resin should have a tacky surface if the cure takes place in the presence of air. The resin should not contain wax to shield the air from the surface, so the surface can fully cure. General-purpose resin generally contains some wax to allow a reasonable surface cure but not so much as to cause laminating problems. Some fiberglassing experts disagree with this point, believing that general-purpose resins don't do either job very well.

Place the single-layer mat laminate on the wax paper. It would be possible to lay up two layers of mat at once, without allowing the resin from the first layer to cure before adding the second. This can add complications, so wait until later to try it.

Fig. 7-8. Two-layer fiberglass mat laminate.

Because the next layer of mat will be the last layer to be added to this laminate, use laminating, finishing, or general-purpose resin. The wax on the cured surface causes most of the bonding problems, not the wax in the new resin that is being applied. If additional layers are to be added later to the laminate, use laminating resin. If laminating resin is used for this practice exercise, apply a thin layer of finishing resin to both sides of the laminate after the laminating resin has cured, so the surface will cure tack-free.

This might seem confusing at first. After you have worked with the different types of resin for a while, though, everything will become clear.

Place the mat to be used for the second layer on cardboard. Wet out the upper surface with catalyzed resin. Brush on a thin layer of resin on the cured laminate that is on the wax paper. Turn the cardboard over and place the wet resin sides of the two layers together. With the brush, use a dabbing motion to work the two layers together. Wet out the second layer of mat until it is fully saturated with resin. When everything looks okay, clean the brush with acetone before the resin has a chance to harden.

If laminating resin was used, wait until the surface has cured to a tacky state. The resin below the surface will be cured by this time. The surface layer keeps air from the resin underneath and allows it to cure. Catalyze a small quantity of finishing resin and brush on a thin layer to both sides of the laminate. The side that was previously on the wax paper can be placed back on the wax paper on the same side as soon as that side has been coated with finishing resin. Often the wax paper itself will inhibit the air from that side of the laminate and allow the surface to cure tack-free, even when laminating resin is used.

If finishing resin was used throughout, the wax could be removed from the surface of cured resin with acetone. Put the acetone on a clean white cloth and wash the surface with acetone. The wax can also be removed by sanding the surface, but this is more difficult.

Examine the laminate with two layers of mat. It should be approximately twice as thick as the previous mat laminate that had only one layer of mat. With a sharp object, try to separate the laminate at one edge between the two layers of mat. If everything was done correctly and quality materials were used, the laminate should show little or no tendency to delaminate here.

As more and more layers are added to a laminate, the back side of the laminate tends to become more and more uneven, especially when mat is used. Some bunching up and lumping of the mat is almost inevitable.

LAMINATING THREE LAYERS OF MAT WITH POLYESTER RESIN

Repeat the same practice exercise, but make a laminate with three layers of 1½-ounce mat. Do this in three stages. Allow the first layer of the laminate to cure before adding the second layer. Allow this layer to cure before adding the third layer. Allow the laminate to cure.

The three-layer laminate should be approximately ⅛ inch thick. Compare this with the two-layer laminate, which should be about $^{3}/_{32}$ inch thick. The single-layer laminate should be about $^{1}/_{20}$ inch thick.

LAMINATING TWO LAYERS OF CLOTH WITH POLYESTER RESIN

This practice exercise requires essentially the same materials as for the laminate with two layers of mat. The exception is that 10-ounce fiberglass cloth will be used instead of mat.

Make a single-layer cloth laminate, except use either general-purpose or laminating resin. Allow the laminate to cure. If laminating resin is used, the resin should have a tacky surface if the cure takes place in the presence of air. The resin should not contain wax to shield the air from the surface, so the surface can fully cure. Leave the single-layer laminate on the wax paper.

If this is the last layer to be added to this laminate, use laminating, finishing, or general-purpose resin. If additional layers are to be added to the laminate later, use laminating resin. If laminating resin is used for this practice exercise, apply a thin layer of finishing resin to both sides of the laminate after the laminating resin has cured, so the surface will cure tack-free.

Place the cloth for the second layer on cardboard. Wet out the upper surface with catalyzed resin. Brush on a thin bonding layer of resin to the cured laminate that is on the wax paper. Turn the cardboard over and place the wet resin sides of the two layers together. Line them up so that the edges are even. Use the brush to smooth out the upper layer of cloth. Wet out the upper layer of cloth until it is fully saturated with resin. Work out any air bubbles that appear in the cloth by dabbing them down with the brush and working them off to one side of the laminate. When everything looks okay, clean the brush with acetone before the resin has a chance to harden.

If laminating resin was used, wait until the surface has cured to a tacky state. The resin below the surface will be cured by this time. Catalyze a small quantity of finishing resin and brush on a thin layer to both sides of the laminate. The side that was previously on the wax paper can be placed back on the wax paper on the same side as soon as that side has been coated with finishing resin. The wax paper can inhibit the air from that side of the laminate and allow the surface to cure tack-free, even when laminating resin is used.

If you should later decide to add more layers to a laminate with finishing resin on the surface, remove the wax from the surface with acetone. Apply acetone to a clean white cloth and wash the surface. The wax can also be removed by sanding the surface.

Examine the laminate with the two layers of cloth. It should be approximately twice as thick as the one-layer cloth laminate. With a sharp object, try to separate the laminate at one edge between the two layers of cloth. If everything was done correctly and quality materials were used, the laminate should show little or no tendency to delaminate here.

The two-layer cloth laminate is thinner than the single-layer mat laminate. While cloth has many characteristics that make it useful for certain types of fiberglass laminating work, it isn't good for building up laminate thickness. The use of cloth is also an expensive method for building up thickness as cloth is much more expensive than mat or woven roving for achieving the same thickness in a laminate.

The back side of the cloth laminate should be fairly smooth, though not as smooth and even as the side that was against the wax paper. Cloth tends to remain fairly even unlike mat, which tends to bunch up in some areas and form an uneven surface.

LAMINATING THREE LAYERS OF CLOTH WITH POLYESTER RESIN

Repeat the same practice exercise, except this time add an additional third layer of cloth to the laminate. Do this in three stages. Allow the first layer of the laminate to cure before adding the second layer. Allow this layer to cure before adding the third layer.

Allow the laminate to cure. If laminating resin was used, add a thin layer of finishing resin to the surfaces of the laminate, so it will cure with a tack-free surface.

The three-layer cloth laminate should be about 1/20 inch thick, about the same as a single-layer mat laminate made with 1½-ounce mat. The three-layer cloth laminate is stronger (assuming that the laminate was laid up properly and quality materials were used). The materials for the cloth laminate were more expensive. It took approximately three times as long to lay up because three layers of reinforcing material were required instead of one. The cloth laminate contains more fiberglass reinforcing material and less resin.

LAMINATING TWO LAYERS OF WOVEN ROVING WITH POLYESTER RESIN

This practice exercise requires the same materials as for the laminate with two layers of cloth. Instead of 10-ounce cloth, use 24-ounce fiberglass woven roving.

Make a single-layer woven roving laminate using either general-purpose or laminating resin. Allow the laminate to cure. If laminating resin is used, the resin should have a tacky surface if the cure takes place in the presence of air. The resin should not contain wax to shield the air from the surface, so the surface can fully cure. Because this is the last layer of woven roving to be added to this laminate, use laminating, finishing, or general-purpose resin.

Place the woven roving for the second layer on cardboard. Wet out the upper surface with catalyzed resin. Brush on a bonding layer of resin to the cured laminate that is on the wax paper. Turn the cardboard over and place the wet resin sides of the two layers together. Line them up so that the edges are even. Use the brush to smooth out the upper layer of woven roving, taking care not to unravel the weave of the woven roving. Wet out the upper layer of woven roving until it is fully saturated with resin. When everything looks okay, clean the brush with acetone before the resin has a chance to harden.

If laminating resin was used, wait until the surface has cured to a tacky state. The resin below the surface has cured by this time. The surface layer keeps air from the resin underneath and allows it to cure. Catalyze a small quantity of finishing resin and brush on a thin layer to both sides of the laminate. Clean the brush with acetone. Allow the surface of the laminate to cure tack-free.

Examine the laminate. It should be approximately twice as thick as the previous woven roving laminate that had only one layer of woven roving. With a sharp object, try to separate the laminate at one edge between the two layers of woven roving. If everything was done correctly and quality materials were used, the laminate should show little or no tendency to delaminate. Woven roving tends to have a resin-rich area between layers when laminated without a mat layer to fill in the coarse weave pattern of the woven roving. The two-layer woven roving laminate should be only slightly thinner than the two-layer mat laminate.

LAMINATING THREE LAYERS OF WOVEN ROVING WITH POLYESTER RESIN

Repeat the same practice exercise, except this time add an additional third layer of woven roving to the laminate. Do this in three stages. Allow the first layer of the laminate to cure before adding the second layer. Allow this layer to cure before adding the third layer.

Allow the laminate to cure. If laminating resin was used, add a thin layer of finishing resin to the surfaces of the laminate, so it will cure with a tack-free surface.

The three-layer woven roving laminate should be about ⅛ inch thick, slightly thinner than the three-layer mat laminate. The three-layer woven roving laminate is much stronger (assuming that the laminate was laid up properly and quality materials were used). Woven roving also builds up thickness quickly and is only slightly more expensive on a laminate thickness basis than mat. Woven roving is a fairly difficult material to work with, however. For laminating work, a layer of mat is generally sandwiched between layers of woven roving.

OTHER LAMINATING METHODS

In the previous mat, cloth, and woven roving exercises, the reinforcing material was placed on a piece of cardboard and wetted out on one side first, before being placed on the wax paper or added to a laminate. This method works well for small pieces of reinforcing material, but other methods also work. For example, a layer of catalyzed resin could be applied to the wax paper and then dry reinforcing material placed on it. When additional layers are added to a laminate, the same technique can be used. Brush on a layer of resin to the surface of the cured laminate where the next layer of laminate is to be added. Place the dry reinforcing material on the wet resin. Saturate the reinforcing material with catalyzed resin. This method will usually suffice to adequately wet out the reinforcing material.

I suggest that you try this method of laminating by first using mat, then cloth. Compare the resulting laminates with the ones laid up by using the cardboard wet-out method to see which method works best for you.

Still another method is to apply two or more layers of reinforcing material in one operation, without allowing the first to cure before adding additional layers. This can result in a faster lay-up, but it can result in problems, especially when laying up large pieces of reinforcing material. Also, there is a limit to the number of layers that can be added in one operation, usually two or three, while still maintaining a quality lay-up.

As a practice exercise, try laying up two layers of mat in one operation. Begin by placing the first layer of mat on a wet layer of resin on the wax paper. Saturate the mat with resin. Use a dabbing action of the brush to keep the mat from lumping up. Place the second layer of mat on the wet resin of the first layer. Finish wetting out the second layer of mat. When this laminate has cured, compare it with a laminate with two layers of mat that was laid up with the first layer allowed to cure before the second was added.

Repeat this same practice exercise using two layers of cloth. Place the first layer of cloth on a wet layer of resin on the wax paper. Saturate the cloth with resin. Place the second layer of cloth on the wet resin of the first layer. Finish wetting out the second layer of cloth. When this laminate has cured, compare it with a laminate with two layers of cloth that were laid up with the first layer allowed to cure before the second was added.

From these practice exercises, it should be apparent that there is no method that is best for laying up a laminate. Experiment to find out what method works best for you. Some methods are faster than others, but it's important that you don't lose control. Also, it is fairly easy to lay up two layers of reinforcing material in one operation when small pieces of material are used, but this can be much more difficult to do without losing control when large pieces of reinforcing material are used.

For these practice exercises, the lay-up work was done with a brush. You might now want to use squeegees and laminating rollers. These will be especially useful when working with fairly large pieces of reinforcing material.

LAMINATES WITH MORE THAN ONE KIND OF REINFORCING MATERIAL

For many types of fiberglassing repair work, it is desirable to use more than one type of reinforcing material in the same laminate. The importance of using a mat layer between layers of woven roving has always been explained. Mat can also be effectively combined with cloth. In some laminates mat, cloth, and woven roving will be used. Composite laminates are used to take advantage of the characteristics of the different reinforcing materials. For example, mat gives thickness and fills in small spaces such as the weave pattern of cloth and woven roving. Mat also gives a smooth surface against a mold. Cloth adds strength to a laminate but doesn't give much thickness, and it is also expensive.

After doing the practice exercises, you have probably found a laminating method that works best for you. This can be used for the following practice exercises using more than one kind of reinforcing material in the same laminate.

Mat and Cloth

Using 6-inch squares of reinforcing material, make a laminate of one layer of 1½-ounce mat and one layer of 10-ounce cloth (Fig. 7-9). Allow the laminate to cure. With a sharp object, try to separate the two layers of the laminate at one edge. If everything was done properly and quality materials were used, there is a strong bond between the layers of reinforcing material. The thickness of the laminate should be equal to approximately the combined thickness of a one-layer mat laminate and a one-layer cloth laminate with the same weights of reinforcing materials. The laminate should appear different on the two surfaces. Short strands of reinforcing material should show on the mat side. The weave pattern of the cloth should show on the cloth side.

Make a cloth-mat-cloth laminate. The mat is sandwiched between two layers of cloth. This type of laminate tends to smooth out the surfaces of the mat on the side of the laminate away from the mold or form, but it leaves the weave of the cloth showing on the surface.

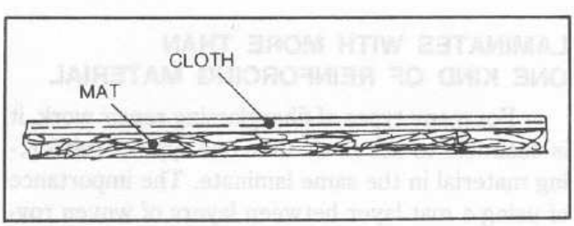

Fig. 7-9. Laminate with one layer of mat and one layer of cloth.

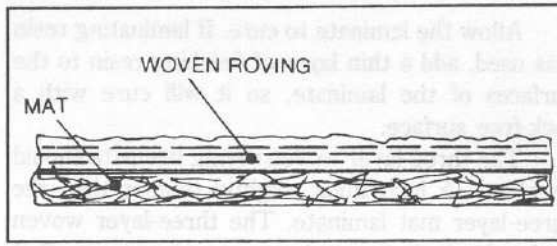

Fig. 7-10. Laminate with one layer of mat and one layer of woven roving.

Make a mat-cloth-mat-laminate. The cloth will be sandwiched between two layers of mat. This adds considerable strength to a two-layer mat laminate without adding much thickness. The cloth is expensive, however, so this must be taken into consideration. Many fiberglassing repair jobs call for even thicker laminates of mat and cloth in various combinations.

Mat and Woven Roving

Using 6-inch squares of reinforcing material, make a laminate of one layer of 1½-ounce mat and one layer of 24-ounce woven roving (Fig. 7-10). While various laminating techniques can be used, it is best to place the woven roving on wet mat or to place the mat on wet woven roving so that the mat can fill in the coarse weave of the woven roving. If one layer is allowed to cure first, added reinforcing material will not penetrate the surface. The reinforcing materials must be thoroughly saturated with resin. Allow the laminate to cure.

The woven roving adds considerable thickness to the laminate, almost as much as the mat, and greatly increases the strength as compared to a laminate of mat only. For the same thickness, the woven roving layer of the laminate (woven roving and resin) is only slightly more costly than the materials for the mat layer.

With a sharp pointed metal object, try to separate the two layers of the laminate at one edge. If everything was done properly and quality materials were used, there is a strong bond between the layers of reinforcing material. The thickness of the laminate equals approximately the combined thickness of a one-layer mat laminate and a one-layer woven roving laminate with the same weights of reinforcing materials. The laminate again appears different on the two surfaces. Short strands of reinforcing material show on the mat side. The heavy weave pattern of the woven roving shows on the woven roving side.

Make a woven roving-mat-woven roving laminate. The mat is sandwiched between two layers of woven roving. This lay-up should fill in the coarse weave pattern of the woven roving layers inside the laminate but leave the coarse weave pattern showing on the outside surfaces.

Make a mat-woven roving-mat laminate. The woven roving will be sandwiched between two layers of mat. This adds considerable strength to a two-layer mat laminate and increases the thickness by almost one third.

When woven roving is used in laminates, it is frequently alternated with layers of mat. If this is not done, pockets of resin without reinforcing material tend to form in the coarse weave pattern of the woven roving. This results in resin-rich areas that are brittle and tend to crack under stress.

Mat, Cloth, and Woven Roving

Using 6-inch squares of reinforcing material, make a laminate of one layer of 1½-ounce mat, one layer of 10-ounce cloth, another layer of 1½-ounce mat, and a layer of 24-ounce woven roving (Fig. 7-11). Use wax paper as a flat form or mold for the first layer of mat. While various laminating methods can be used, I suggest that the first layer of mat be laid up and allowed to cure. Then add the cloth layer. Allow this to cure. Next, add both the mat and woven roving layers all in one operation, so the mat will fill in the coarse weave pattern of the woven roving.

Allow the laminate to cure. The laminate should be smooth on the side that was against the wax paper. The other side should show the coarse weave pattern of the woven roving. The laminate gives a good combination of thickness and strength, assuming that the lay-up was done properly and quality materials were used. Laminates

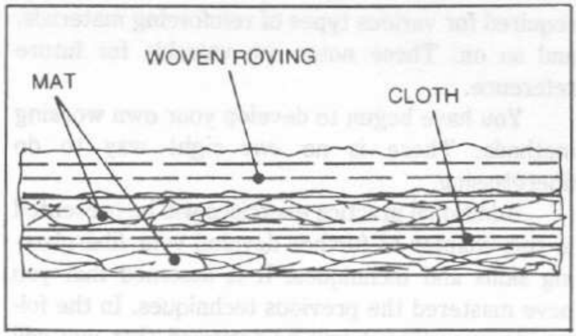

Fig. 7-11. Mat, cloth, and woven roving laminate.

with combinations of reinforcing materials are frequently used for fiberglassing repairs.

SUMMARY OF TECHNIQUES OF LAMINATING WITH POLYESTER RESIN

The practice exercises were designed for learning the basic techniques of forming laminates with various reinforcing materials and polyester resin. If you have conscientiously performed the practice exercises, you learned the basics of catalyzing polyester resins and applying the resin to mat, cloth, and woven roving to form laminates.

You now routinely follow the safety rules and precautions given in Chapter 4 and on the labels of the materials used. You know the importance of careful working habits and clean working conditions. Because you are doing a chemical form of construction, you keep the work areas clean to avoid contaminating the chemicals being used.

You now realize that the polyester resin must not only be applied to the reinforcing material but in the proper amount depending on the reinforcing material used. Mat laminates generally contain about 25 to 30 percent mat reinforcing material by weight, with the remaining 70 to 75 percent resin by weight. Cloth laminates contain about 45 to 50 percent cloth reinforcing material by weight, with the remaining 50 to 55 percent resin by weight. Woven roving laminates contain about 40 to 45 percent woven roving reinforcing material by weight, with the remaining 55 to 60 percent resin by weight.

Keep notes relating to fiberglassing on the amount of catalyst added, working time, the resin required for various types of reinforcing materials, and so on. These notes are valuable for future reference.

You have begun to develop your own working methods. There is no *one* right way to do fiberglassing.

Additional practice exercises will be presented in this chapter to further develop your fiberglassing skills and techniques. It is assumed that you have mastered the previous techniques. In the following exercises it will be assumed that you will catalyze the polyester resin before adding it to reinforcing material, that you will add an amount of catalyst that will give you sufficient working time for the particular job, and that you will know the proper amount of resin to use for each type of reinforcing material.

ADDING A MAT AND POLYESTER RESIN LAMINATE TO WOOD

In addition to the basic materials required for the previous practice exercises, you need a 6-inch square piece of plywood (Fig. 7-12). This can be cut from 1/4, 3/8, or 1/2-inch plywood. Exterior plywood of any grade can be used. Avoid interior grade plywood for fiberglassing work. You also need sandpaper in an assortment of grits from coarse to fine and a sanding block (see Chapter 3).

In this and following exercises, a layer of fiberglass (resin and reinforcing material) will be laid up on and bonded to plywood. This can be thought of in many ways, such as wood covered on one side with a layer of fiberglass or as a composite laminate of plywood and fiberglass. The fiberglass laminate will be chemically laid up and bonded to the plywood. This is different from, say, gluing or other-

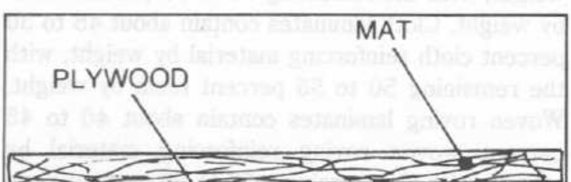

Fig. 7-12. Mat layer laminated to plywood.

wise bonding a cured sheet of fiberglass laminate to plywood, which is also a possibility similar to adding plastic laminates to plywood for tabletops.

It is sometimes difficult to get a good bond between the laminate and plywood using polyester resin. The more expensive epoxy resin gives a better bond. This should become apparent later when practice exercises are done using epoxy resin.

For this exercise, take one of the 6-inch squares of plywood and, using coarse sandpaper, rough sand one side of the plywood. This will help give the resin a better bond. After the surface of the wood has been rough sanded, wipe the area down with an acetone-soaked rag. While opinions vary on how the wood should be sanded for fiberglassing, I have found it best to use cross-grain sanding and to scratch up the surface of the wood considerably while at the same time keeping the surface of the wood fairly even.

Using scissors or snips, cut a 6-inch square of 1½-ounce mat. Remember to wear polyethylene gloves to protect the skin and to help keep the mat clean.

Place the plywood on heavy paper arranged to protect the work area. Pour enough resin for wetting out the mat into a mixing cup. This will be approximately the same amount of resin that was required for a one-layer mat laminate, about 1¼ ounces. Finishing, general-purpose, or laminating resin can be used. If laminating resin is used, a small amount of finishing resin must be added to the surface of the laminate to help it cure tack-free.

Add catalyst to the resin in the mixing cup. Approximately 7½ minutes of working time will be about right. Stir catalyst into the resin. Wait about 30 seconds.

Using a brush, apply a layer of resin to the plywood surface where the laminate is to be added. Place the dry mat in position on the plywood in the wet resin. An alternate method is to place the mat on cardboard and wet out one side of the mat. This is then turned over onto the wet resin on the plywood.

Apply resin to the mat with the brush. Use a dabbing, rather than brushing, action to avoid bunching the mat up. Once the mat is thoroughly saturated with resin, do not apply additional resin. For best results, no more than 75 percent of the laminate by weight should be resin.

Allow the resin to cure tack-free. If laminating resin was used, a thin layer of finishing resin should be added to the surface of the cured laminating resin, so the surface will cure tack-free.

Examine the laminate. Using a sharp-pointed metal object, try to separate the fiberglass laminate from the plywood at one edge. The effectiveness of the bond depends on many factors. If proper techniques and quality materials were used, a reasonably strong bond should have resulted.

Save the laminate for comparison with other laminates. These laminates will also be useful later for practice sanding—an important skill for fiberglassing repair work.

ADDING A CLOTH AND POLYESTER RESIN LAMINATE TO WOOD

This practice exercise is essentially the same as the previous exercise, except that cloth will be used instead of mat (Fig. 7-13). Using scissors or snips, cut a 6-inch square of 10-ounce fiberglass cloth. Remember to wear polyethylene gloves to protect your skin and to help keep the cloth clean.

Place a 6-inch square piece of plywood on heavy paper arranged to protect the work area. Pour enough resin for wetting out the cloth into a mixing cup. Add catalyst.

Using a brush, apply a layer of resin to the plywood surface where the laminate is to be added. Place the dry cloth in position on the plywood in the wet resin. An alternate method is to place the cloth on cardboard and wet out one side of the cloth. This is then turned over onto the wet resin on the plywood.

Apply resin to the cloth with the brush. Once the cloth is thoroughly saturated with resin, do not apply additional resin. For best results, no more than 55 percent of the laminate by weight should be resin. Smooth out the cloth and remove any air bubbles that form. This can be done with the brush, or a squeegee can be used.

Allow the resin to cure tack-free. If laminating resin was used, a thin layer of finishing resin should be added to the surface of the cured laminating resin to help the surface cure tack-free.

Examine the laminate. Using a sharp-pointed metal object, try to separate the fiberglass laminate from the plywood at one edge. The effectiveness of the bond depends on many factors. If proper techniques and quality materials were used, a reasonably strong bond should have been made. Save the laminate for comparison with other laminates and for practice sanding.

ADDING A WOVEN ROVING AND POLYESTER RESIN LAMINATE TO WOOD

This practice exercise is essentially the same as the previous one, except that woven roving will be used instead of cloth (Fig. 7-14). Using scissors or snips, cut a 6-inch square of 24-ounce fiberglass woven roving.

Place a 6-inch square piece of plywood on heavy paper arranged to protect the work area. Pour enough resin for wetting out the woven roving into a mixing cup. Add catalyst.

Using a brush, apply a layer of resin to the plywood surface where the laminate is to be added. Place the dry woven roving in position on the plywood in the wet resin. An alternate method is to place the woven roving on cardboard and wet out one side of the woven roving. Then turn it over

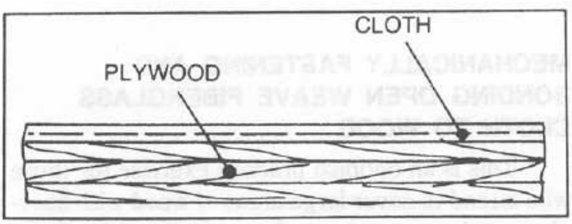

Fig. 7-13. Cloth layer laminated to plywood.

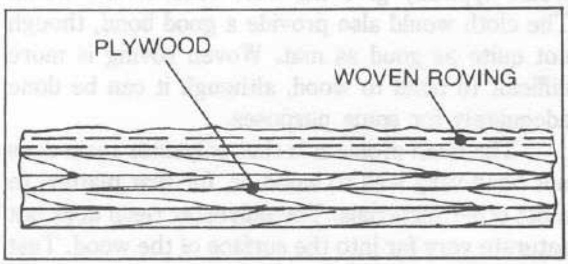

Fig. 7-14. Woven roving layer laminated to plywood.

onto the wet resin on the plywood. Remember, however, that the latter method is generally only suitable for use with fairly small pieces of reinforcing material.

Apply resin to the woven roving with the brush. Once the woven roving is thoroughly saturated with resin, do not apply additional resin. For best results, no more than 60 percent of the laminate by weight should be resin. Smooth out the woven roving and remove any air bubbles that form. This can be done with the brush or a squeegee. When the correct amount of resin is used, the heavy weave pattern will still clearly show. The tendency might be to fill in the low areas with resin. This will result in areas of resin without reinforcing material that will be brittle and subject to cracking.

Allow the resin to cure tack-free. If laminating resin was used, add a thin layer of finishing resin to the surface of the cured laminating resin.

Examine the laminate. Using a sharp-pointed metal object, try to separate the fiberglass laminate from the plywood at one edge. If proper techniques and quality materials were used, a reasonably strong bond will result.

COMPARISON OF MAT, CLOTH, AND WOVEN ROVING LAMINATES BONDED TO WOOD

Compare the mat, cloth, and woven roving laminates bonded to wood. The mat should have given the thickest laminate, with the woven roving just slightly thinner. The cloth provided a very thin laminate.

Assuming that the pieces of plywood were equally rough sanded for each laminate, the mat would typically give the best bond to the wood. The cloth would also provide a good bond, though not quite as good as mat. Woven roving is more difficult to bond to wood, although it can be done adequately for some purposes.

The main problem is that polyester resin does not bond very well to wood or, for that matter, to most other materials. The polyester resin does not saturate very far into the surface of the wood. Test this out on one of the practice laminates by using a sharp-pointed metal object to chip away some resin from the wood.

There are some ways to overcome this problem. The reinforcing material can be mechanically fastened to the wood with staples or by other means. The more expensive epoxy resin, which gives a superior bond, can be used instead of polyester resin.

Another problem is that fiberglass and wood have different physical properties, which in some cases can cause the fiberglass to delaminate from the wood. For this reason, nonfiberglass reinforcing materials such as polyester, which has greater elasticity, are sometimes used instead of fiberglass reinforcing material for covering wood.

To staple reinforcing material to wood, both the reinforcing material and the wood must be dry. Resin will quickly clog up most staple guns, and most staples cannot be driven through cured resin. When the reinforcing material is stapled dry to the wood, resin applied to the outside of the reinforcing material will not provide a good bond with the wood for most reinforcing material. A large open weave cloth seems to work best. Polypropylene and some other nonfiberglass reinforcing materials can be stapled on dry, adequately wetted out, and bonded by applying polyester resin from the outside of the material.

The three laminates each gave different exterior surfaces. The mat has a tendency to bunch up in some areas, giving a somewhat uneven surface. The cloth usually gives a smooth surface, but the weave pattern of the material tends to show through. This can be minimized by using lightweight cloth with a close weave pattern. The coarse weave pattern really shows through on woven roving and makes it very difficult to sand smooth, unless additional reinforcing material and resin are applied to fill in the weave pattern.

MECHANICALLY FASTENING AND BONDING OPEN WEAVE FIBERGLASS CLOTH TO WOOD

This is an optional practice exercise for those who intend to cover large areas of wood with fiberglass, such as covering a plywood boat with a fiberglass skin. In addition to the materials for the previous practice exercises, you will need fiberglass cloth with a large open weave pattern (7.5 ounces per square yard is about right), a heavy-duty staple gun, and staples. While regular steel staples can be used, rustproof *monel staples* are recommended, especially for boats and other marine applications.

Rough sand one surface of a 6-inch square piece of plywood for bonding. Wash with acetone.

Using scissors or snips, cut out a 6-inch square of cloth with a large open weave pattern. Place the cloth dry on the wood and staple it to the wood. Space the staples a couple of inches apart, either in a pattern or at random. Make sure that the cloth is stretched tight and smooth.

Place the plywood with the fiberglass cloth stapled to it on heavy paper arranged to protect the work area. Pour enough resin for wetting out the cloth into a mixing cup. Add catalyst.

Using a brush, saturate the cloth with resin. Once the cloth is thoroughly saturated with resin, do not apply additional resin. A common mistake is to apply too much resin.

When everything looks okay, clean the brush with acetone before the resin has a chance to harden. Allow the laminate to cure.

The laminate should be both bonded and mechanically fastened to the plywood. Set the staples below the surface of the laminate. Additional layers of reinforcing material can be added to this by using regular laminating methods.

MECHANICALLY FASTENING AND BONDING POLYESTER CLOTH TO WOOD

This is another optional practice exercise for those who intend to cover large areas of wood with fiberglass (I'm using the term fiberglass even though no glass fiber reinforcing materials are used), such as a plywood boat. For this practice exercise, you will need a 6-inch square of 4.2-ounce-per-square-yard polyester reinforcing material. Purchase a larger piece of the material and cut off a 6-inch square. Place the remainder of the material in a plastic bag for storage.

Rough sand one surface of a 6-inch square piece of plywood. Wash the surface with acetone. Allow the surface of the wood to dry.

Place the dry polyester cloth on the wood and staple it in place. Space the staples a couple of inches apart, either in a pattern or at random. Make sure that the cloth is stretched tight and smooth.

Place the plywood with the polyester cloth stapled to it on heavy paper arranged to protect the work area. The 4.2-ounce polyester cloth requires about the same amount of resin as 10-ounce fiberglass cloth. Pour the resin into a mixing cup. Add catalyst. Using a brush, saturate the cloth with resin. This will give a soak-through bond to the wood. Once the cloth is thoroughly saturated with resin, do not apply additional resin. A common mistake is to use too much resin. It is far better to apply too little resin, as more can always be added later. It is very difficult to remove excess resin.

When everything looks okay, clean the brush with acetone before the resin has a chance to harden. Allow the laminate to cure.

Examine the laminate. Even without the staples, polyester cloth bonds well with polyester resin to wood. The staples supplement the bond and allow the polyester cloth to be held in position dry. This is a big advantage when covering large areas of wood.

Using a sharp-pointed metal object, test the bond to the wood at one edge. Part of the wood will usually break away before the bond will separate.

Additional layers of polyester cloth can be added to the laminate. This is done without the use of staples, as it is almost impossible to drive them through the first cured layer of the laminate.

While opinions vary, I prefer to use polyester cloth rather than fiberglass cloth for covering plywood. The material is only slightly more expensive than fiberglass and, in my opinion, well worth the small additional cost. Polyester cloth is an extremely easy material to wet out with polyester resin. The resulting laminate has greater adhesion, toughness, and abrasion resistance than a similar laminate using fiberglass cloth. Unlike fiberglass reinforcing material, the polyester cloth is nonirritating to the skin, an important advantage especially for those who have dermatological sensitivity to working with fiberglass reinforcing materials.

MAT AND POLYESTER RESIN LAMINATE WITH A CORE

Some fiberglassing repair work calls for laminates with core materials, such as end-grain balsa or rigid plastic foams. For this practice exercise, you will need a 6-inch square of ¼-inch thick polyurethane rigid foam or closed-cell polyvinyl chloride foam. Polystyrene foam cannot be used with polyster resin.

A two-layer mat laminate will be added to each side of the core material to form a sandwich core laminate (Fig. 7-15). Cut out four 6-inch squares of 1½-ounce mat.

Place the core material on heavy paper arranged to protect the work area. Pour enough resin for wetting out one layer of mat into a mixing cup. Add catalyst.

Using a brush, apply an even coat of resin to one side of the core material. Place a layer of dry mat on the resin and press it into the wet resin. Apply additional resin to the mat by using a dabbing action with the brush so you do not bunch up the mat. Thoroughly saturate the layer of mat with resin. When everything looks okay, clean the brush with acetone before the resin has a chance to harden.

Allow the first layer of mat laminate to cure. Then add a second layer over it. Allow this to cure.

Turn the laminate over. Using a brush, apply an even coat of resin to the bare side of the core material. Place a layer of dry mat on the resin and press it into the wet resin. Apply additional resin to the mat by again using a dabbing action with the brush. Thoroughly saturate the layer of mat with

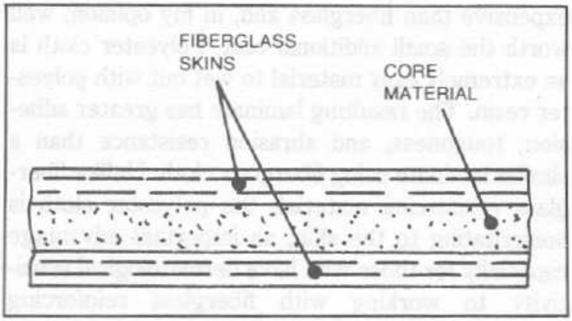

Fig. 7-15. Sandwich core laminate.

resin. When everything looks fine, clean the brush with acetone.

Allow this layer of mat to cure. Then add a second layer over it. Allow this to cure.

Examine the sandwich core laminate. The ¼-inch core material should have fiberglass skins approximately 3/32 inch thick on each side. The total thickness of the core and fiberglass skins should be about 7/16 inch thick. Although the two skins have a tendency to shear off the core material when certain types of stresses are applied to the laminate, the core laminate has greater structural strength for many applications than a similar four-layer mat laminate without a core. The advantages and disadvantages of core construction will be examined more fully in Chapter 8.

CLOTH AND POLYESTER RESIN LAMINATE WITH A CORE

This is similar to the previous practice exercise, except two-layer cloth laminates will be added to each side of the core material instead of mat laminates to form a sandwich core molding. Cut out four 6-inch squares of 10-ounce fiberglass cloth.

Place the core material on heavy paper arranged to protect the work area. Pour enough resin for wetting out one layer of cloth into a mixing cup. Add catalyst.

Using a brush, apply an even coat of resin to one side of the core material. Place a layer of dry cloth on the resin, press it down, and smooth it out. Apply additional resin to the cloth with the brush. Thoroughly saturate the cloth with resin. When everything looks good, clean the brush with acetone.

Allow the first layer of cloth laminate to cure. Add a second layer over it. Allow this to cure.

Turn the laminate over. Brush on an even coat of resin to the bare side of the core material. Place a layer of dry cloth on the wet resin, press it down, and smooth it out. Apply additional resin to the cloth until it is thoroughly saturated. When everything looks fine, clean the brush with acetone.

Allow this layer of cloth laminate to cure. Add a second layer over it. Allow this to cure.

Examine the sandwich core laminate. The ¼-

inch core material should have fiberglass skins approximately 1/32 inch thick on each side. The total thickness of the core and fiberglass skins should be about 5/16 inch thick.

MAT, CLOTH, AND POLYESTER RESIN LAMINATE WITH A CORE

This is similar to the previous practice exercise, except each skin will have one layer of mat and one layer of cloth. Cut out two 6-inch squares of 1½-ounce mat and two 6-inch squares of 10-ounce fiberglass cloth.

Place the core material on heavy paper arranged to protect the work area. Pour enough resin for wetting out one layer of mat into a mixing cup. Allow this to cure. Then turn the laminate over. Repeat the laminating procedure on this side, adding first a mat layer and allowing it to cure, then finally a cloth layer. Allow time for the laminate to cure.

Add a cloth layer of laminate to the mat layer. Allow this to cure.

Turn the laminate over. Repeat the laminating procedure on this side, adding first a mat layer and allowing it to cure, then finally a cloth layer. Allow time for the laminate to cure.

Examine the sandwich core laminate. The ¼-inch core material should have fiberglass skins approximately 1/16 inch thick on each side. The total thickness of the core and fiberglass skins should be about 3/8 inch.

COMPARISON OF CORE LAMINATES

Compare the three core laminates. The mat lay-up should have the thickest skin. The mat and cloth laminate should be next thickest. The cloth laminate should be the thinnest.

The difficulty of laying up the laminates depends on many factors. All of them should have been fairly easy, though.

While these rigid foam cores add some structural strength to the laminate, the main purpose here is to position the two fiberglass skins apart. Other materials, such as plywood, could also be used as a core material. Depending on the particular lay-up, the plywood core could form a significant part of the structural strength of the finished core laminate.

BONDING LAMINATES TO VARIOUS MATERIALS WITH POLYESTER RESIN

Polyester resin gives a poor bond to metals, hardwoods, and other nonporous surfaces. Polyester resin acts as a solvent to some plastic materials such as polystyrene. It cannot be used for bonding a laminate to these plastics. The ability of polyester resin to provide a bond varies from good to poor with other plastics.

Try to gather up scrap pieces of aluminum, steel, a hardwood such as oak, glass, and a variety of plastics. Sand a 1-inch square area on the surface of each material and wash off with acetone. Place these pieces on heavy paper positioned to protect the work area. For each different material, cut a 1-inch square piece of 1½-ounce mat.

Pour enough polyester resin into a mixing cup to wet out all of the mat pieces. The resin can be general purpose, laminating, or finishing.

Catalyze the resin for about 15 minutes of working time, then bond and wet out one piece of mat to each different material. For example, brush on a layer of resin to the bonding area of aluminum. Place a 1-inch square of mat in the wet resin. Press the mat down and smooth it out. Using a brush, saturate the mat with resin. Then repeat on each different material. If the polyester resin happens to soften or dissolve one of the plastics, discontinue the exercise with that material and go on to the next material. When you are finished with the bonding and wetting out, allow the polyester resin laminates to cure.

With a sharp-pointed metal object, test the bond of each laminate. While the results might vary, the bonds were probably poor in most cases. With some of the materials, you might be able to easily peel the laminate off; on other materials the bond might be better. This practice exercise should show that polyester resin bonds poorly to most nonporous surfaces. This same practice exercise will be repeated later with epoxy resin, which generally gives a much better bond to nonporous materials.

POLYESTER PUTTY AND FILLERS

Many polyester resin putty and filling compounds are on the market. These are often formulated for special purposes, such as for marine use or auto body repair. You can also mix up your own polyester putty by adding chopped glass fiber strands and/or milled fibers to polyester resin, either by themselves or with a thixotropic (thickening) powder. For good results, the mixture should contain at least 25 percent by weight of reinforcing material.

As far as fiberglassing repair work is concerned, putty and fillers should be used to supplement laminating work, not as a substitute for it. Use polyester putty and fillers sparingly. Manufactured polyester putty can be used with or without glass fiber reinforcing material.

Several fibrous and powdered additives are used to give polyester resin a putty consistency in manufactured polyester putty and filler compounds. Some of these additives reinforce the resin; others actually weaken it. When using manufactured polyester putty and filler compounds, purchase a small amount and try it out before buying large quantities.

For this practice exercise, you will need a small container of manufactured polyester putty and the necessary catalyst, which is usually sold with the resin putty mixture. The catalyst can be in liquid or paste form, depending on the particular type and brand. Use only the catalyst specifically recommended by the manufacturer. You will also need polyester resin, chopped glass fiber reinforcing material, and thixotropic powder for mixing up your own polyester putty.

First, catalyze a small amount of the manufactured putty. Spread it out in a thin layer on wax paper. Combine chopped glass fibers (these can be pulled from fiberglass mat) and thixotropic powder with polyester finishing resin. Try to get at least 25 percent of the mixture by weight in chopped fibers. Mix well. Then add catalyst. The amount of catalyst to be used depends only on the amount of resin, not on how much chopped glass fiber or thixotropic powder was added. Mix the catalyst using a stirring stick. Spread the putty out in a thin layer on wax paper.

Allow both samples of putty to harden. Compare them first by trying to crack the putty in two using a sharp-pointed metal object. You probably won't be able to do this, at least not easily, with the putty that you mixed. Manufactured polyester putty that I'm familiar with varies from almost as good as the putty you mix yourself to putty that cracks easily. Also note that the putty you mix usually has a hard surface. The manufactured putty might or might not.

Place the two samples on hard surfaces. Tap first one, then the other, with a hammer. The putty that you mixed should hold together by reinforcing material even when the resin is shattered. The manufactured putty might or might not.

For the next practice exercise, you will need one of the mat laminates from a previous practice exercise. Rough sand two areas on the surface for attaching small areas of putty, then wash these areas with a clean cloth soaked with acetone.

Catalyze a small amount of the manufactured putty and apply a thin layer to one of the areas on the mat laminate. Mix up a small amount of your own putty and add catalyst. Apply a thin layer to one of the areas on the mat laminate.

Allow the two areas of putty to cure. Compare them first by trying to pry them loose from the mat laminate with a sharp-pointed metal object. The putty that you mixed probably was bonded well. The manufactured putty might or might not be bonded well.

Tap each sample of putty with a hammer. The putty that you mixed should have held firm. The manufactured putty might have survived the hammer tap, or it might have shattered.

When I require polyester putty for fiberglassing work, I mix up my own as detailed earlier. I have a putty that contains glass fiber reinforcing material. The cured mixture is similar to a mat laminate, though not quite as strong.

When I want the convenience of a manufactured putty, I use epoxy compounds. While epoxy resins are generally much more difficult to apply than polyester resins, this does not apply to some of the newer epoxy putty compounds. Some have fast curing times and are about as easy to apply as most polyester putty compounds. Practice exercises using epoxy putty are given later in this chapter.

SANDING POLYESTER LAMINATES

Practice sanding some of the laminates to see if you can achieve a flat smooth surface. Use a sanding block and aluminum oxide or silicon carbide sandpaper. If there are high spots to be removed, start with a coarse grit sandpaper, but no coarser than necessary to remove the high spots in a reasonable amount of time. Coarse paper also leaves scratches. Gradually work down to finer grits of sandpaper. Use the sanding block.

There might be low areas that require filling with putty. Fill these areas with polyester putty as detailed earlier. A putty knife can be used. Because most polyester putty has some shrinkage during curing, the area should be slightly higher than the desired finished surface. Allow the putty to cure, then resume sanding with a sanding block. Use a fairly coarse grit of sandpaper to remove excess putty, but make certain that the scratches do not extend below the desired finished surface. Some manufactured polyester putty sands easily; others are more difficult to sand. The polyester putty that you mix yourself is generally quite difficult to sand, about the same as sanding a mat and polyester resin laminate.

Finish the sanding with fine grits of sandpaper. Use a sanding block. Do the fine sanding wet or dry.

SUMMARY OF FUNDAMENTAL TECHNIQUES OF FIBERGLASSING WITH POLYESTER RESIN

Most manufactured fiberglass moldings are made with polyester resin. Repair of damage to these fiberglass moldings is usually done with polyester resin.

The techniques covered in the practice exercises using polyester resin form the fundamentals for most fiberglass repair work. If you have mastered these basic skills, you should have little difficulty with the fiberglassing repair work detailed in later chapters. Conversely, if these fundamental skills have not been learned, much difficulty will probably be encountered in attempting fiberglassing repairs.

I consider the polyester resin portion of this chapter to be the most important part of this book. From this point on, I will assume that you know these fundamental skills and techniques.

FACTS ON EPOXY RESINS

The practice exercises presented in this chapter for *epoxy resins* can be considered optional. They are intended for those people who want to do repair work requiring the use of epoxy resin and for those who want a more complete understanding of fiberglassing.

While polyester resins can be used for most fiberglassing repair work, there are certain applications where it will not work. For these jobs, epoxy resin is often the answer. It has greater bonding strength, better physical characteristics, and less shrinkage than polyester resin. The epoxy resin is usually two or three times more expensive than polyester resin. Epoxy resin has a slower curing time, making it much more difficult to use. Epoxy resins are generally more dangerous to use from a health and safety standpoint than polyester resins.

When using epoxy resins, follow the manufacturer's directions and observe all health and safety precautions. Follow the safety rules and precautions given in Chapter 4. Always wear protective clothing and use proper safety equipment. If any unusual reactions develop from working with epoxy resins, consult a physician.

TYPES OF EPOXY RESINS

Many manufactured epoxy resins are available. Select epoxy resin that is formulated for the particular use which you have in mind. This is usually stated on the container's label.

Epoxy resin requires a matching curing agent or hardener. Depending on the particular formulation, various ratios of resin to curing agent or hardener are used to give the same curing time at a certain working temperature. For example, one type uses half epoxy resin and half curing agent or hardener by volume. The amount of curing agent or hardener used, though, can be reduced by up to 50 percent. Another type is 4 to 1, with 4 parts of epoxy resin being used with 1 part curing agent or hardener by volume. Proportions of from 15 to 25 parts can be used with 100 parts of epoxy resin. Still another type is 6 to 1.

ADDING CURING AGENT OR HARDENER

There are wide variations on the amount of curing agent or hardener to be used. Follow the manufacturer's directions carefully. The measurement can be by volume or by weight, which often differ. For example, one type has a weight of 9 pounds per gallon of resin and 7 pounds per gallon of curing agent or hardener.

After the curing agent or hardener has been added, the time required to harden is generally much shorter when the liquid is in a container or pot than when it is applied in a thin layer to a surface, where the atmosphere cools the surface. To reduce the curing time, heat lamps or other flameless heating devices are often used.

With most types of epoxy resin, there is a range of amounts of curing agent or hardener that can be used. More hardener will reduce the curing time; less hardener will increase it. Unfortunately, changing the proportions often also changes the properties of the cured product.

If you add a pint of curing agent or hardener to a pint of epoxy resin, you get a quart mixture. Remember this when purchasing epoxy resins and hardeners.

The same resin can be used for both laminating the finishing work, so you will only need one type. Achieving a tack-free surface does not depend on inhibiting the air, as is the case with polyester resin.

The slow curing time creates many problems in laminating work. The work is slow because you have to wait so long for the curing to take place. This also makes lay-up work difficult. It is usually impractical to press a piece of reinforcing material into position and hold it there while you wait, say, eight hours for the cure to take place. Use of external heat can greatly speed up the cure, but it's still much slower than when polyester resins are used. Also, remember that some epoxy resins have faster curing times than others.

Ideally, all the polyester practice exercises would be repeated with epoxy resin. The amount of time that this would take makes it impractical, unless you plan to do a large amount of fiberglassing work using epoxy resins. Also, epoxy resin is expensive, so I have reduced the number of practice exercises. The attempt is to cover the main skills and techniques while keeping the amount of epoxy resin required to a minimum.

Because so many types of epoxy resins are in use, no specific mixing instructions will be given. Follow the manufacturer's directions. The amounts by weight required to wet out a certain piece of reinforcing material will be approximately the same as for polyester resin, as both weigh about 9 pounds per gallon. Because the hardener for epoxy resin might weigh less, often about 7 pounds per gallon, this will throw the weight measurements off a little. Everything should still work out about right when small quantities are being used. Again, remember that when you used polyester resin, consider only the weight of the resin and not that of the catalyst. In the case of epoxy resin, the weight of both the resin and the curing agent or hardener should be added together.

The first practice exercise is to add curing agent or hardener to a small amount of epoxy resin. Using a stirring stick, mix them together. Then pour the mixture out onto wax paper and, using the stick, spread it out into a thin, even layer. Epoxy resins have various viscosities, so some will not pour easily. Use the stirring stick to help get the mixture to the wax paper.

A heat lamp or other heating device can be used to speed up the cure. Follow the manufacture of the epoxy resin's directions in this regard.

Even with external heat of, say, 150 degrees Fahrenheit, it still might require two hours or more for the resin to cure. This is better than the 12 hours or more that it would usually take the same resin to cure at room temperature, especially if you are doing a job that cannot proceed until the resin has cured.

When the epoxy resin has cured, remove it from the wax paper. With a sharp-pointed metal object, try to crack off a piece of the resin. While this can probably be done fairly easily, it is usually more difficult to do than was the case with a similar piece of cured polyester resin.

Place the epoxy resin on a hard surface and tap it with a hammer. It will probably shatter rather easily, but not as easily as a similar piece of cured polyester resin.

ADDING REINFORCING MATERIAL TO EPOXY RESIN

Add chopped strands of fiberglass reinforcing material to the epoxy resin. This can be done before or after the curing agent or hardener has been added. The chopped strands should form about 25 percent of the mixture's weight.

Mix well. Then pour or work the mixture out of the mixing cup to wax paper. Using the stick, spread the mixture out into a thin even layer. Allow the mixture to cure with or without the use of a heat lamp.

After the mixture is hard and no longer tacky on the surface, pick it up from the wax paper. Several things should be noted. The reinforcing fibers add to the mass of the resin. The reinforced resin looks different than resin alone. You can probably see strands of chopped glass fiber on the surface of the mixture. The side that was against the wax paper is probably quite smooth because the wax paper acted like a flat molding or forming surface.

Place the material on a hard surface and give it a tap with a hammer. Try to do this in a similar manner as was done with the hard epoxy resin. Did the reinforced material shatter as easily? Unless something drastic was done wrong, it should be much more difficult to shatter the reinforced resin. Even when it does break up, the reinforcing fibers tend to keep the material from shattering. Although it will probably be difficult to tell the difference from a hammer tap test, it should have been more difficult to shatter the epoxy reinforced material than the polyester reinforced material that was used in an earlier practice exercise.

ADDING EPOXY RESIN TO MAT

Epoxy resin will be added to a 6-inch square piece of 1½-ounce fiberglass mat. The mat should weigh about 0.38 ounce. Mat laminates are typically 25 to 35 percent fiberglass reinforcing material and 65 to 75 percent resin and curing agent by weight. For the 25 percent ratio, about triple the weight of the mat in resin and curing agent is required to fully wet out the mat. For the 6-inch square of 1½-ounce mat, three times 0.38 ounce, or 1.14 ounces of resin and curing agent (combined weight) will be required.

Because some of the resin will probably end up in the brush or otherwise not become part of the finished laminate, I suggest that you mix about 1¼ ounces. This is the combined weight of both the epoxy and the curing agent. Before adding the curing agent to the resin, place the piece of fiberglass mat on a piece of cardboard. Have wax paper ready for transfer of the laminate once one side has been wetted out with resin.

Add the curing agent to the measured out amount of resin. Stir the mixture together. Using a brush, apply resin to one side of the mat, which should be on the piece of cardboard. Use a dabbing action rather than a brushing motion so you do not lump or bunch up the mat.

When one side of the mat is fully saturated with resin, hold the cardboard, turn the mat over, and transfer it to the wax paper so that the wet side of the mat is face down on the wax paper. Put the cardboard aside. Using the brush, dab the remaining resin on the other side of the mat. Saturate the mat and get the resin spread as evenly as possible. When everything looks fine, clean the resin from the brush with epoxy solvent. This must be done before the resin hardens on the brush if the brush is to be used again, but most epoxy resins allow plenty of time for this cleaning.

Allow the laminate to cure with or without the use of a heat lamp. After the laminate has cured to the point where it has a tack-free surface, pick it up from the wax paper and examine it. If everything was done correctly, you should have a mat laminate made up of approximately 25 percent mat by weight and 75 percent resin and hardener by weight. The finished laminate should weigh approximately 1½ ounces. The laminate should be about ¹⁄₂₀ inch thick. The side of the laminate that was placed against the wax paper should be quite smooth, as the wax paper acted as a form or flat mold. The wax paper could have been placed on a curved surface to mold a curved laminate. If everything was done properly and quality materials were used, the laminate should be stronger than a similar laminate laid up with polyester resin.

ADDING EPOXY RESIN TO CLOTH

This is essentially the same as the previous mat exercise, except this time cloth reinforcing material is used. You need a 6-inch square piece of 10-ounce-per-square-yard fiberglass cloth.

Because 1 square yard of 10-ounce cloth weighs approximately 10 ounces, the 6-inch square should weigh about 0.3 ounce, or ¹⁄₃₆ as much. Cloth laminates are typically 45 to 50 percent fiberglass cloth by weight and 50 to 55 percent cloth ratio, the weight of the resin and hardener should be equal to the weight of the cloth. For the 6-inch square piece of cloth, about 0.3 ounce of resin will be required. Because some resin will be lost to the brush and elsewhere during application, mix approximately ½ ounce of epoxy resin and hardener (total weight).

Pour the required amount of epoxy resin into a mixing cup. Before adding the curing agent, place the piece of cloth on a piece of cardboard. After resin is applied to one side, it will be turned onto the wax paper, as was done previously with the mat.

Add the required amount of curing agent or hardener to the epoxy resin. Using a brush, apply resin to one side of the cloth, which should be on the cardboard. Use a brushing action, but take care you do not unravel the unselvaged edges of the cloth.

When one side of the cloth is fully saturated with resin, pick up the cardboard and turn the cloth over onto the wax paper wet side down. Using the brush, work any resin that remains on the cardboard onto the cloth. Put the cardboard aside. Brush the remaining resin onto the cloth. Saturate the cloth with resin and spread the resin as evenly as possible. When everything looks fine, clean the brush in epoxy solvent.

Allow the laminate to cure with or without the use of a heat lamp or other flameless heating device. After the laminate has cured, pick it up from the wax paper and examine it. If everything was done properly, you should have a cloth laminate made up of approximately 50 percent cloth by weight and 50 percent epoxy resin and hardener by weight. The laminate should be about ¹⁄₆₄ inch thick, much thinner than the previous mat laminate. Compare this to the mat laminate to see if it is so. The mat laminate should be approximately three times as thick as the cloth laminate. The cloth laminate should weigh only slightly more than one-third the weight of the mat laminate.

The side of the cloth that was placed over the wax paper should be relatively smooth, as the wax paper acted as a form or flat mold. Some of the cloth weave pattern probably shows.

LAMINATING TWO LAYERS OF MAT WITH EPOXY RESIN

An additional layer of mat will be laminated to the previous epoxy mat laminate in this practice exercise. You will need a 6-inch square piece of 1½-ounce mat. Place the mat on the cardboard.

Approximately the same amount of resin and hardener will be required as was used for the first layer of the mat laminate—about 1¼ ounces. Pour the required amount of epoxy resin into a mixing cup. Add the required amount of curing agent or hardener and mix together with a stirring stick. Using a brush, apply resin to one side of the mat, which should be on a piece of cardboard.

Brush on an even layer of resin to the bonding surface of the cured mat laminate. Pick up the cardboard and turn the mat to be added to the laminate over so that the two wet resin areas are face to face. Position the new layer of mat, then smooth it out. Using the brush, dab the remaining resin onto the mat. Saturate the mat and spread the resin as evenly as possible. When everything looks good, clean the resin from the brush with epoxy solvent.

Allow the laminate to cure with or without the use of a heat lamp or other flameless heating device. After the laminate has cured, pick it up and examine it. The second layer of mat should have approximately doubled the thickness of the laminate. With a sharp-pointed metal object, try to separate the two layers at one edge of the laminate. If everything was done properly and quality materials were used, the layers should be bonded together well.

LAMINATING TWO LAYERS OF CLOTH WITH EPOXY RESIN

An additional layer of cloth will be laminated to the previous epoxy cloth laminate in this practice exercise. You will need a 6-inch square piece of 10-ounce cloth. Place the cloth on cardboard.

Approximately the same amount of resin and hardener will be required as was used for the first layer of the cloth laminate — about ½ ounce. Pour the required amount of epoxy into a mixing cup. Add the required amount of curing agent or hardener and mix together with a stirring stick. Using a brush, apply resin to one side of the mat, which should be on a piece of cardboard.

Brush on an even layer of resin to the bonding surface of the cured cloth laminate. Pick up the cardboard and turn the cloth to be added over so that the two wet resin areas are face to face. Position the new layer of cloth and then smooth it out. Using the brush, apply the remaining resin to the cloth. Saturate the cloth and spread the resin as evenly as possible. When everything looks okay, clean the resin from the brush with epoxy solvent.

Allow the laminate to cure with or without the use of a heat lamp or other flameless heating device. After the laminate has cured, pick it up and examine it. The second layer of cloth should have approximately doubled the thickness of the laminate. With a sharp-pointed metal object, try to separate the two layers of cloth at one edge of the laminate. If everything was done properly and quality materials were used, the layers should be bonded together well.

OTHER METHODS OF LAMINATING WITH EPOXY RESIN

When adding a second layer to a laminate, an alternate method is to apply resin to the bonding surface of the cured laminate. Place the dry reinforcing material on this, press it down, and smooth it out. Finish by saturating the reinforcing material with resin.

Two or more layers can also be added to a laminate in one operation without waiting for the first layer to cure before adding the second, and so on. This can present problems, as the reinforcing materials might not stay in position until the resin has cured. One possible solution is to place cellophane over the top layer after the laminate has been saturated with resin. Then place a board over this and place a brick or other weight on the board. This works well on flat laminates and can sometimes be adapted to curved ones.

USING EPOXY AND POLYESTER RESINS IN THE SAME LAMINATE

You can start a laminate with epoxy resin and then finish with polyester resin, or vice versa, provided that the first resin is allowed to thoroughly cure before the second resin is applied. You can use epoxy resin for making crucial bonds and then finish off a laminate with less expensive polyester resin.

As a practice exercise to demonstrate this, add a mat layer using polyester resin to the two-layer cloth laminate that was laid up with epoxy resin. To do this, you will need a 6-inch square of 1½-ounce mat. Pour out approximately 1¼ ounces of polyester resin into a mixing cup and add catalyst. You will need about 7½ minutes of working time. Stir with a mixing stick. Wait about 30 seconds. Brush on an even layer of resin to the bonding surface of the cured epoxy laminate. Place the dry mat on the wet resin. Position it and smooth it out. An alternate method is to wet out one side of the mat placed on a piece of cardboard and then turn it over onto the wet resin on the cured laminate. Using the brush, apply additional resin to the mat. Use a dabbing motion of the brush to avoid bunching up the mat. Thoroughly saturate the mat and spread the resin evenly. When everything looks okay, clean the brush with acetone.

Allow the laminate to cure. Then examine it. Using a sharp-pointed metal object, try to separate the mat layer from the rest of the laminate. If everything was done properly and quality materials were used, the polyester resin should have formed a strong bond with the epoxy resin.

As a practice exercise to demonstrate that this also works in reverse, bond a layer of mat using epoxy resin to one of the polyester cloth laminates from a previous practice exercise. Wash the bonding surface of the polyester laminate with acetone to remove any surface wax that might be present. You will need a 6-inch square of 1½-ounce mat. Approximately 1¼ ounces of epoxy resin and curing agent or hardener (combined weight) will be required to bond and saturate the mat. Pour the required amount of epoxy resin into a mixing cup. Add the required amount of curing agent or hardener and mix together with a stirring stick. Using a brush, apply an even layer of epoxy resin to the bonding surface of the cured polyester laminate. Place the dry mat on the wet resin. Position it and smooth it out. An alternate method is to also wet out one side of the mat with resin before turning it over onto the wet layer of resin on the cured laminate. Apply additional resin to the mat with the brush by using a dabbing action. Thoroughly saturate the mat and spread the resin evenly. When everything looks okay, clean the brush with epoxy solvent.

Allow the laminate to cure. Then examine it. Using a sharp-pointed metal object, try to separate the mat layer from the rest of the laminate. If everything was done properly and quality materials were used, the polyester and epoxy resins should have bonded together well.

OTHER EPOXY RESIN LAMINATES

Many other laminates can also be formed with epoxy resin and fiberglass mat, cloth, and woven roving. Practice exercises for these are not included here because they are not required for most fiberglassing repair work. If you do need to use epoxy resin for a lay-up not included in the previous practice exercises, you might want to try it first as a practice exercise before using the lay-up on an actual repair job.

ADDING A MAT AND EPOXY RESIN LAMINATE TO WOOD

For this practice exercise, you need a 6-inch square piece of ¼, ⅜, or ½-inch plywood. Rough sand one side of the plywood with coarse sandpaper. This will help give the epoxy resin a better bonding surface. Use cross-grain sanding and scratch up the surface of the wood considerably, while at the same time keeping the surface of the wood fairly even.

You also need a 6-inch square piece of 1½-ounce fiberglass mat. Place the plywood on heavy paper arranged to protect the work area.

Approximately 1½ ounces of epoxy resin and curing agent or hardener (combined weight) will be required to saturate the mat. Because some of the resin will go into the surface of the wood, add an additional ¼ ounce for a total of 1½ ounces.

Pour the required amount of epoxy resin into a mixing cup. Add the required amount of curing agent or hardener to this and mix together with a stirring stick.

Using a brush, apply a layer of resin to the rough sanded surface of the plywood. Place the dry mat in position on the plywood in the wet resin. An alternate method is to place the mat on cardboard and wet out one side of the mat. This is then turned over onto the wet resin on the plywood.

Apply epoxy resin to the mat with the brush. Use a dabbing, rather than brushing, action to avoid bunching the mat up. Once the mat is thoroughly saturated with an even layer of resin and everything looks okay, clean the brush with epoxy solvent.

Allow the resin to cure with or without the use of a heat lamp or other flameless heating device. After the laminate has cured, examine it. Using a sharp-pointed metal object, try to separate the fiberglass laminate from the plywood at one edge. If everything was done properly and quality materials were used, there should be a strong bond — considerably stronger than when polyester resin is used.

ADDING A CLOTH AND EPOXY RESIN LAMINATE TO WOOD

This practice exercise is essentially the same as the previous exercise, except that cloth will be used instead of mat. You will need a 6-inch square piece of 10-ounce fiberglass cloth.

Rough sand one surface of a 6-inch square piece of plywood. Place the plywood on heavy paper arranged to protect the work area.

Approximately ½ ounce of epoxy resin and curing agent or hardener (combined weight) will be required to bond the cloth to the wood and saturate the cloth. Pour the required amount of epoxy resin into a mixing cup. Add the required amount of curing agent or hardener to this and mix with a stirring stick.

Using a brush, apply a layer of resin to the bonding surface of the plywood. Place the dry cloth in position on the plywood in the wet resin. An alternate method is to place the cloth on cardboard and wet out one side of the cloth. This is then turned over onto the wet resin on the plywood.

Apply resin to the cloth with the brush. Once the cloth is thoroughly saturated with an even layer of resin and everything looks okay, clean the brush with epoxy solvent.

Allow the resin to cure, then examine it. Using a sharp-pointed metal object, try to separate the fiberglass laminate from the plywood at one edge. If everything was done properly, there should be a strong bond — considerably stronger than when polyester resin is used.

The long curing time of epoxy resin can cause problems with air bubbles. It is usually impractical to keep pressing them down and working them out until the resin cures, as is often done when polyester resin is used. One possible solution is to place cellophane over the top layer after the laminate has been saturated with resin. A flat board is then placed over this, with a brick or other weight placed on the board. This often works well on flat laminates and can sometimes be adapted for use on curved laminates.

ADDING POLYESTER LAYERS TO EPOXY LAMINATES

When covering wood with fiberglass, the first layer can be applied with epoxy resin to give a good bond to the wood. After the epoxy resin has cured, additional layers can be added to the laminate with polyester resin, which is less expensive and easier to work with.

As a practice exercise, add a cloth layer using polyester resin to the plywood and mat and epoxy resin laminate laid up in the previous practice exercise. To do this you need a 6-inch square piece of 10-ounce fiberglass cloth and approximately ½ ounce of polyester resin for bonding and wetting out the cloth. Pour ½ ounce of resin into a mixing cup. Add catalyst and stir. Wait about 30 seconds, then brush on an even layer of resin to the bonding surface of cured epoxy laminate. Place the dry cloth on the wet resin and position it. Smooth out the cloth. An alternate method is to wet out one side of the cloth with the cloth placed on a piece of cardboard. Turn the cloth over onto the wet resin on the cured epoxy laminate.

Using the brush, apply additional resin to the cloth. Thoroughly saturate the cloth with resin and spread the resin evenly. When everything looks okay, clean the brush with acetone.

Allow the laminate to cure. Examine the laminate. Using a sharp-pointed metal object, try to separate the cloth layer from the mat layer of the laminate. If everything was done properly, the polyester resin should have formed a strong bond with the epoxy resin.

Another practice exercise is to add a mat layer using polyester resin to the plywood and cloth and epoxy resin laminate laid up in the previous practice exercise. You need a 6-inch square piece of 1½-ounce fiberglass mat and approximately 1¼ ounces of polyester resin for bonding and wetting out the mat. Pour 1¼ ounces of resin into a mixing cup. Add catalyst and stir. Wait about 30 seconds. Brush on an even layer of resin to the bonding surface of the cured epoxy laminate. Place the dry mat on the wet resin and position it. Smooth out the mat. An alternate method is to wet out one side of the mat and place this wet side down on the wet resin on the cured laminate.

Using the brush, apply additional resin to the mat. Thoroughly saturate the mat with resin and spread the resin evenly. When everything looks okay, clean the brush with acetone.

Allow the laminate to cure. Examine the laminate. Using a sharp-pointed metal object, try to separate the mat layer from the cloth layer. If everything was done properly and quality materials were used, the polyester resin should have formed a strong bond with the epoxy resin.

OTHER METHODS FOR ADDING EPOXY RESIN LAMINATES TO WOOD

Most methods detailed earlier in this chapter for bonding laminates to wood using polyester resin can also be used with epoxy resin. For example, an open weave fiberglass cloth can be applied to the wood dry and fastened in place with staples. The epoxy resin can then be applied to the cloth. This will usually give a good bond to the wood and allow the cloth to be wetted out all in one operation.

Most nonfiberglass reinforcing materials can be applied with epoxy or polyester resin. For example, polyester cloth reinforcing material can be applied to the wood dry and fastened in place with staples. Epoxy resin can then be applied to the cloth. This will usually give a good bond to the wood and allow the cloth to be wetted out all in one operation, as was done in a practice exercise using polyester resin.

While all of the polyester resin practice exercises for laying up core laminates can also be done with epoxy resin, only one practice exercise will be given here. Others from the polyester section of this chapter can be done with epoxy resin for additional practice.

For this practice exercise, you will need a 6-inch square of ¼-inch thick polyurethane, polystyrene or polyvinyl chloride rigid foam. A one-layer mat laminate will be added to each side of core material to form a sandwich core laminate.

Cut out two 6-inch square pieces of 1½-ounce fiberglass mat. Place the core material on heavy paper arranged to protect the work area. The mat laminates will be added one at a time. For the first one you need about 1¼ ounces of epoxy resin and curing agent or hardener (combine weight).

Pour the required amount of epoxy resin into a mixing cup. Add the required amount of curing agent or hardener and mix together with a stirring stick.

Using a brush, apply an even coat of resin to one side of the core material. Place a piece of dry mat over the resin, press it down, and smooth it out. Apply additional resin to the mat. Use a dabbing action with the brush to avoid bunching up the mat. Thoroughly saturate the layer of mat with resin. When everything looks okay, clean the brush with epoxy solvent.

Allow the resin to cure with or without the use of a heat lamp or other flameless heating device. After the first laminate has cured, turn the laminate over. Apply a mat laminate to this side of the core material in the same manner as was done on the other side. Again, allow the resin to cure.

The ¼-inch core material should have fiberglass skins approximately 1/20 inch thick on each side, forming a sandwich laminate. Although the two skins have a tendency to shear off the core material when certain types of stresses are applied to the laminate, the core laminate generally has greater structural strength for many applications than a similar two-layer mat laminate without a core. The advantages and disadvantages of core construction will be examined in more detail in the next chapter.

The possibility of shaping core materials and then laying up a fiberglass laminate over them also exists. Surfboards are often constructed in this manner. Methods and uses in fiberglassing repair work are detailed in later chapters.

BONDING LAMINATES TO VARIOUS MATERIALS WITH EPOXY RESIN

Unlike polyester resin, epoxy resin usually gives a good bond to metals, hardwoods, and other nonporous surfaces. Epoxy resin will also bond to many types of plastic.

For a practice exercise, gather up scrap pieces of aluminum, steel, a hardwood such as oak, and a variety of plastics. To give good bonding surfaces, rough sand a 1-inch square area or larger section on each different material. Place these on heavy paper positioned to protect the work area. Cut a 1-inch square piece of 1½-ounce fiberglass mat for each material.

Mix enough epoxy resin and curing agent or hardener to bond and wet out all of the pieces of mat. Then bond and wet out one piece of mat to each material. For example, brush on a layer of resin to the bonding area of the aluminum. Position a piece of mat in the resin. Press the mat down and smooth it out. Using a brush, saturate the piece of mat with resin. Repeat on each material. When finished with the bonding and wetting out, allow the epoxy resin to cure.

With a sharp-pointed metal object, test the bond of each laminate. While the results might vary, the bonds to most of all of the materials should be quite good, much better than those achieved in the similar practice exercise with polyester resin. When making fiberglassing repairs on these materials, epoxy resin should be used rather than polyester resin.

EPOXY PUTTY AND FILLER COMPOUNDS

Several epoxy putty and filler compounds are on the market. Many materials, including glass fibers, ground-up steel, stainless steel, aluminum, bronze, lead, and carbide granules, can be added to epoxy resin to form putty and filler compounds. Epoxy putty will bond well to many materials, including steel, iron, aluminum, bronze, brass, wood, ceramic, concrete, plastics, fiberglass, nylon, and glass. Special purpose epoxy putty and filler compounds are available for repairing rubber and making gaskets and other flexible items. While most epoxy putty compounds will not bond to wet surfaces, there is a special epoxy compound that will bond and cure when applied to wet surfaces or even underwater.

You can also mix up your own epoxy putty by adding chopped glass fiber strands to epoxy resin. You can also add thixotropic powder to epoxy resin, with or without adding chopped glass fiber strands, to form a filler compound. Milled glass fibers can be used with or in place of chopped glass fibers.

When purchasing manufactured epoxy putty and filler compounds, select a type that has been formulated for the particular type of job you have in mind. For example, you want a type for marine use that contains no metals that will rust or corrode. For repairing auto bodies, you need a type that has the necessary flexibility and adhesion qualities. Epoxy fillers are available that match the appearance of various metals such as steel, stainless steel, brass, bronze, and aluminum. General-purpose epoxy fillers are available in clear, gray, black, white, and other colors.

For this practice exercise, you need about ½ pint of manufactured general-purpose epoxy putty and the matching curing agent or hardener, which is usually sold along with the epoxy putty. Sometimes the epoxy putty is sold in a kit with the necessary curing agent or hardener, mixing containers, measuring devices, and stirring sticks.

You also need epoxy resin, chopped glass fiber reinforcing material, and thixotropic powder for mixing up your own epoxy putty. First, measure out a small amount of the manufactured epoxy putty. It is important that you don't get any of the epoxy putty left in the container mixed with even a small amount of curing agent or hardener. If you do, the curing will start even if you seal the container back up. Any stick used in the epoxy putty container should not be used in the curing agent or hardener container, or vice versa.

Add the required amount of curing agent or hardener to the epoxy putty. Follow the manufacturer's directions carefully. Some epoxy putty and filler compounds have fast curing cycles even at room temperature.

Mix the epoxy putty and curing agent or hardener together. Use a stirring stick to work it out of the mixing container (which can be a cup, plate, or even a clean piece of wood) and spread it out in a thin layer on a piece of wax paper.

Combine chopped glass fibers (these can be pulled from fiberglass mat) and thixotropic powder to epoxy resin until a thick paste consistency is achieved. Mix these into the epoxy resin with a stirring stick. Add the required amount of curing agent or hardener to a small amount of the paste mixture. Save the rest of the paste mixture for later use.

Mix the curing agent or hardener with the small amount of epoxy putty mixture. Spread the putty out into a thin layer on wax paper.

Allow both putty samples to cure. Compare them first by trying to crack the samples in two using a sharp-pointed metal object. Your ability to crack one or both of them in two depends on many factors, but in most cases, this should not be easy to do.

Place the two samples (or the largest remaining piece of each one) on a hard surface and tap them with a hammer. The manufactured putty might or might not shatter, depending on what type of reinforcing it contained and other factors. The putty that you mixed might have shattered, but it was probably held together to some extent by the glass fiber reinforcing material.

I've found several brands of manufactured epoxy putty compounds that work well for me, so I use these rather than mixing up my own. I also appreciate the fast curing times of some of the manufactured compounds.

For the next practice exercise, you need one polyester laminate from a previous practice exercise and one epoxy laminate. Wash the surface of the polyester laminate to remove any wax that might be present.

Add curing agent or hardener to a small amount of manufactured putty and putty that you mixed up yourself. Apply these in thin layers to small areas of the two laminates. Keep track of which putty is in each location. You should have a sample of each putty on both the polyester laminate and the epoxy laminate.

Allow these to cure. Compare them by first trying to pry the samples loose with a sharp pointed metal object. If everything was done properly and quality materials were used, either the samples could not be pried loose, or it was fairly difficult to pry them off.

Tap each sample of putty with a hammer. The results will vary depending on many factors, but this should give you a general idea of the strength of each sample and allow you to make a rough comparison of the putty compounds.

Try bonding samples of the two types of epoxy putty (the manufactured one and the one you mixed up) to scraps of various materials, such as aluminum, hardwood, steel, concrete, glass, and many plastics. Allow the samples to cure, then try to pry them loose using a sharp pointed metal object. Write the results down in your notebook for future reference. Note which type of putty worked best with each material and which materials allowed satisfactory bonding.

SANDING EPOXY LAMINATES

Practice sanding some of the epoxy laminates from the practice exercises. Use the same techniques as were used for sanding polyester laminates, as detailed previously in this chapter.

SUMMARY OF EPOXY PRACTICE EXERCISES

While many types of fiberglassing repair work can be done with the less expensive polyester resin, there are certain jobs that call for epoxy resin. The epoxy practice exercises were designed not only to give practice in handling and applying epoxy resin but to show some of the advantages of using epoxy resin instead of polyester resin for certain types of work.

BASIC CONTACT MOLDING WITH POLYESTER RESIN

Contact molding techniques can be applied to both repair and construction projects, as detailed in later chapters. The purpose here is to introduce the basic techniques for contact molding.

In contact molding, one side of the molding is formed against the mold surface. Shallow rectangular shapes are introduced here; more complex shapes and deeper molds are detailed in later chapters.

Shallow-Depth Rectangular Contact Molds

Shallow-depth rectangular contact molds can be formed from a variety of materials, such as from fine-grained wood using ordinary woodworking techniques. Because contact molding gives a smooth surface on one side only, it is important to note that there are two basic forms a shallow-depth rectangular contact mold can take. If you want to mold a shallow rectangular tray with a smooth upper surface, the contact mold surface will look like the bottom surface of a tray (Fig. 7-16). If you want to mold a shallow rectangular tray with a smooth under surface, the contact mold surface will look like the upper surface of a tray (Fig. 7-17). To mold a shallow rectangular tray with a smooth upper surface, the mold is placed with the contact surface upward (see Fig. 7-16). The molding is then laid up over this (Fig. 7-18) and removed from the mold after it has cured (Fig. 7-19). If it is to be used as a tray, it is then turned over so that the smooth molded surface faces upward.

Contrast this to a mold for a shallow rectangular tray form with a smooth under surface (see Fig. 7-17). The mold is positioned like an upright tray, and the molding is laid up inside (Fig. 7-20) and removed from the mold after it has been cured (Fig. 7-21). Depending how the molding is to be used, it can be positioned like a tray with a smooth underside or a cap or lid with a smooth top. In each case, remember that the molding is not a duplicate of the mold but a reverse image.

Shallow rectangular molds can be shaped from a single piece of wood, or two or more pieces can be glued together. Ordinary woodworking techniques are used for shaping shallow and medium-depth rectangular molds from wood. Figure 7-22 shows a wood mold suitable for molding a shallow tray form with a smooth upper surface (when the tray is turned upright). Figure 7-23 shows a wood mold suitable for molding a shallow tray form with a smooth lower surface (when the tray is turned upright).

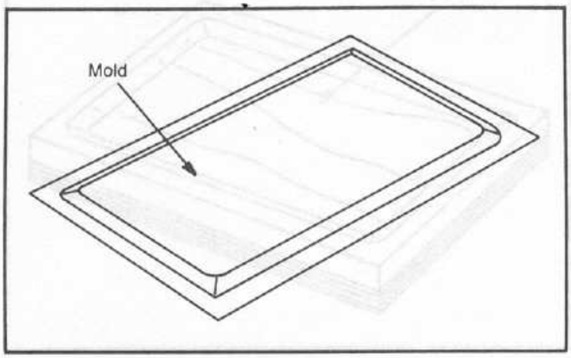

Fig. 7-16. Convex contact mold for tray form gives molding with smooth concave side.

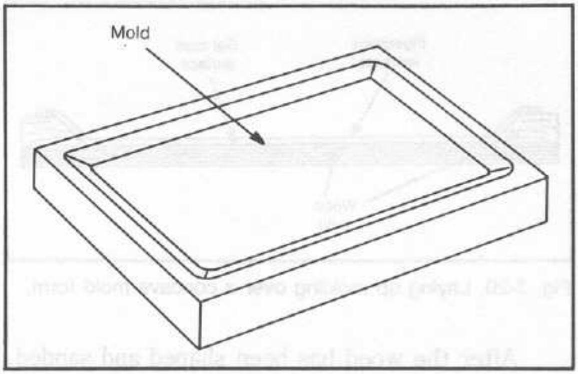

Fig. 7-17. Concave contact mold gives molding with smooth convex side.

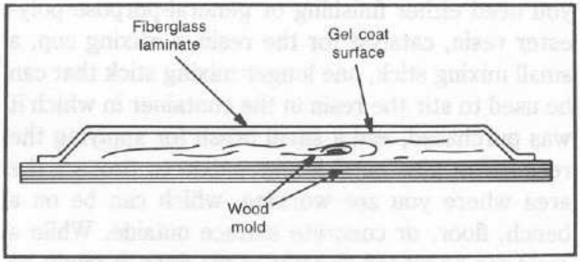

Fig. 7-18. Laying up molding over a convex mold form.

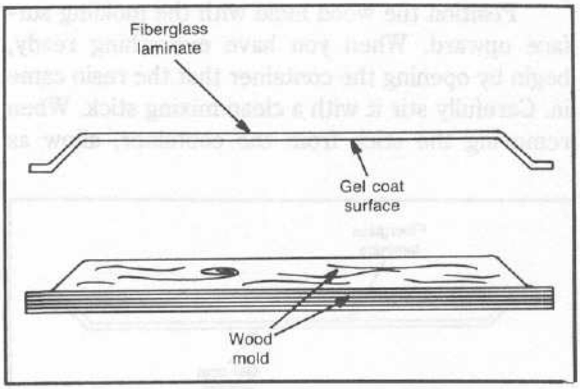

Fig. 7-19. Molding is removed from the mold.

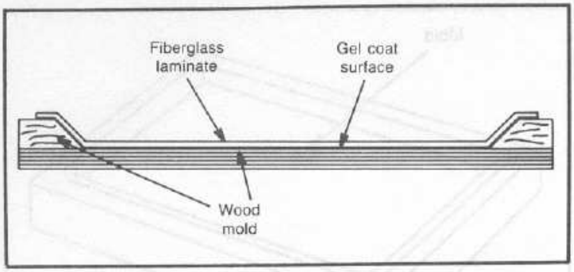

Fig. 7-20. Laying up molding over a concave mold form.

After the wood has been shaped and sanded, the next step is to prepare the wood surface so that it is suitable for molding. One method is to coat the molding surface with a thin layer of polyester resin. In addition to the shaped and sanded wood mold, you need either finishing or general-purpose polyester resin, catalyst for the resin, a mixing cup, a small mixing stick, one longer mixing stick that can be used to stir the resin in the container in which it was purchased, and a small brush for applying the resin. You also need heavy paper to protect the area where you are working, which can be on a bench, floor, or concrete surface outside. While a mold can be placed directly on the floor, it might be more convenient to place it on a raised surface. You should also wear proper protective clothing and safety equipment.

Position the wood mold with the molding surface upward. When you have everything ready, begin by opening the container that the resin came in. Carefully stir it with a clean mixing stick. When removing the stick from the container, allow as

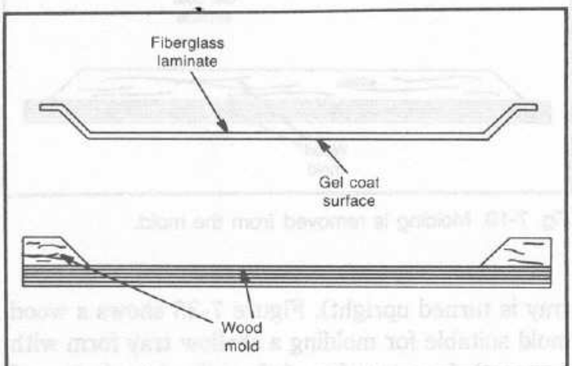

Fig. 7-21. Molding is removed from the mold.

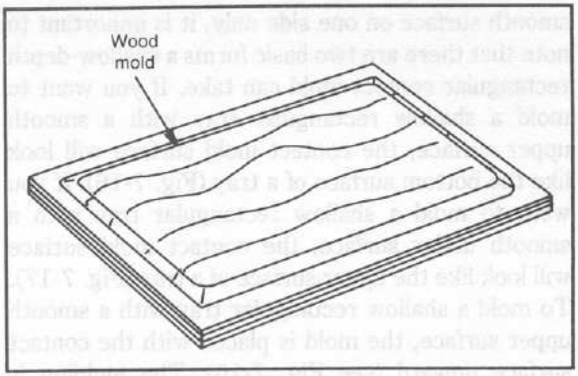

Fig. 7-22. Wood mold for laminating tray shape with smooth concave side.

much of the resin to drain off the stick back into the container as possible. Use a clean rag to clean off the remaining resin from the stick and put the stick aside for later use. Use this one stick only for stirring uncatalyzed resin in the containers in which it is sold.

You need about 1 ounce of resin for each square foot of wood surface to be covered. Pour the required amount of resin into the mixing cup. Replace the lid on the resin container and set it aside.

If available, add about ⅛ ounce of styrene monomer to the resin and mix thoroughly. While the resin can be applied to the wood surface without this, the thinning action of the styrene thins the

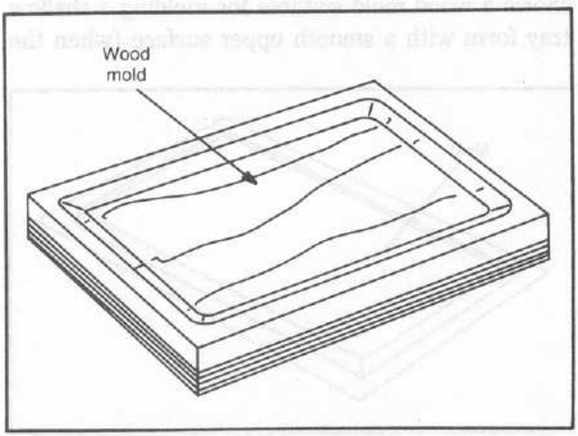

Fig. 7-23. Wood mold for contact molding tray form with smooth convex side.

resin and allows it to better penetrate the surface of the wood.

Next, add 8 drops of catalyst for each ounce of resin to the resin. This is approximately 2 percent by volume, which should give about 15 minutes of working time. Wait about 30 seconds, then brush a smooth thin layer of the catalyzed resin onto the molding surface (Fig. 7-24). When you have finished applying the coat of resin to the molding surface of the wood and everything looks okay, clean the brush with acetone before the resin hardens on the brush. Allow the resin to harden on the wood surface. Even though this should happen about 15 minutes after the resin is applied, it is best to wait at least an hour before attempting to sand the surface.

Next, lightly sand the surface with fine-grit paper to remove the surfacing agent. This is not necessary if laminating resin is used. An alternate method is to remove the surfacing agent by wiping the surface with acetone on a clean cloth.

Then apply a second coat of polyester resin in the same manner as detailed above. When this has cured, apply a third coat in the same manner. When the third coat has cured, sand with fine-grit wet/dry sandpaper and water.

The next step is to polish the surface using a buffing compound. This can be done by hand with a clean cloth or with a power buffer.

It is important to take the necessary time to make a good mold. Any defects in the mold surface will be copied on the moldings made with the mold.

A variety of existing shallow-depth rectangular forms can be used as molds. Shallow depth trays and pans made of stainless steel and aluminum are ideal. Many plastic trays and pans also work, though the plastic must be a type that polyester resin will not dissolve. Keep in mind that you are not making a duplicate of the tray or pan but are using it as a mold to obtain a reverse image. For contact molding, you will use one side of the tray or pan when laying up a molding, although many trays

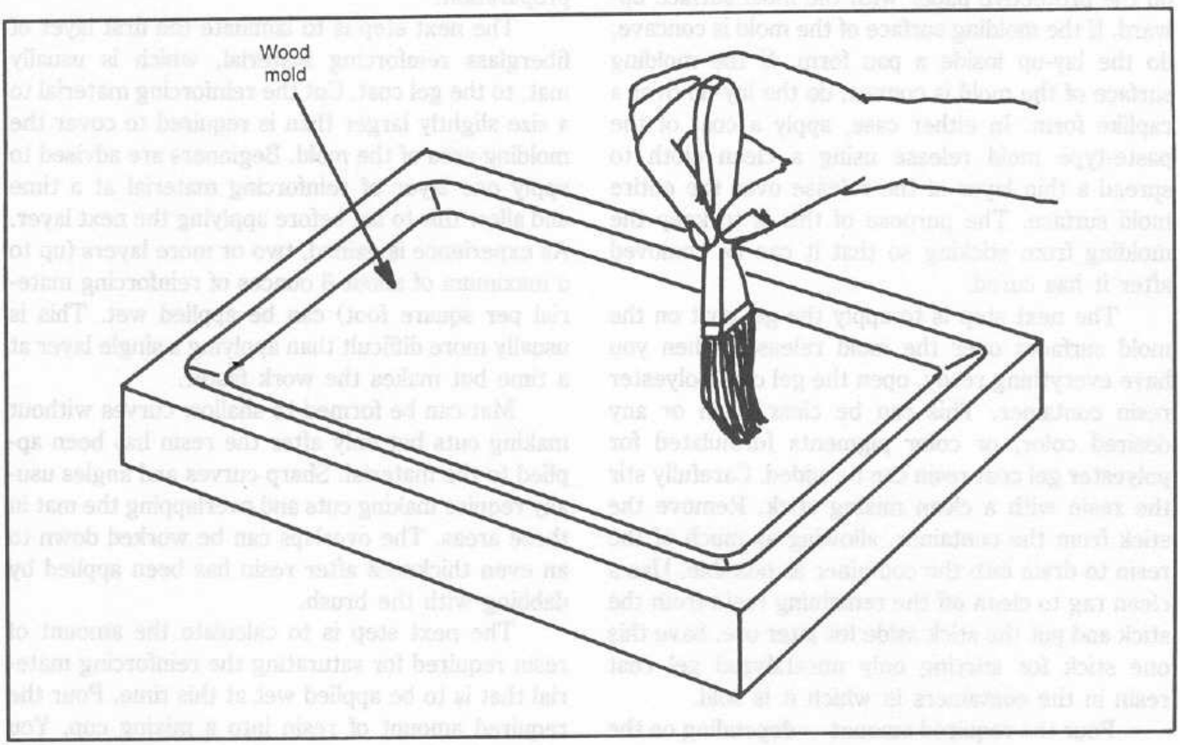

Fig. 7-24. Brush a smooth thin layer of catalyzed polyester resin on the wood molding surface.

and pans will allow molding on either side. Make certain that the mold form does not have vertical sides or overhangs that will make removing a finished molding difficult or impossible.

Shallow and medium-depth rectangular contact molds can also be made from a variety of other materials. For contact molding, you will use only one side of the mold, either for a concave or convex molding form.

Contact Molding Shallow and Medium-Depth Rectangular Forms

To contact mold a shallow-depth rectangular form, you need a suitable mold, a paste-type mold release, polyester gel coat resin, laminating and/or finishing or general-purpose polyester resin, catalyst for the resin, mixing cups, short and long mixing sticks, a small brush for applying the resin, and fiberglass reinforcing material (mat is recommended for first attempts at molding).

The shallow-depth rectangular mold is placed on the protective paper with the mold surface upward. If the molding surface of the mold is concave, do the lay-up inside a pan form. If the molding surface of the mold is convex, do the lay-up over a caplike form. In either case, apply a coat of the paste-type mold release using a clean cloth to spread a thin layer of the release over the entire mold surface. The purpose of this is to keep the molding from sticking so that it can be removed after it has cured.

The next step is to apply the gel coat on the mold surfaces over the mold release. When you have everything ready, open the gel coat polyester resin container. This can be clear resin or any desired color, or color pigments formulated for polyester gel coat resin can be added. Carefully stir the resin with a clean mixing stick. Remove the stick from the container, allowing as much of the resin to drain into the container as possible. Use a clean rag to clean off the remaining resin from the stick and put the stick aside for later use. Save this one stick for stirring only uncatalyzed gel coat resin in the containers in which it is sold.

Pour the required amount—depending on the area to be covered, about 1 ounce per square foot—of the gel coat resin into a mixing cup. Replace the lid on the gel coat resin container and set it aside.

Next, add the catalyst to the resin. This is approximately 2 percent by volume, which is usually used for polyester gel coat resin at 75 degrees Fahrenheit. This can vary for the particular brand of gel coat resin being used, however. Follow the manufacturer's directions. Wait about 30 seconds, then brush a smooth thin layer of the catalyzed gel coat resin onto the mold surface over the mold release agent. Use a continuous motion with the brush (Fig. 7-25) rather than painting back and forth. The gel coat should have a thickness of only .02 to .03 inch. A thicker layer will be brittle and subject to cracking and crazing. When you have finished applying the coat of resin and everything looks okay, clean the brush with acetone. Allow the resin to harden.

Gel coat resin usually doesn't contain a wax additive. The laminate can therefore be laid up directly over this with no additional surface preparation.

The next step is to laminate the first layer of fiberglass reinforcing material, which is usually mat, to the gel coat. Cut the reinforcing material to a size slightly larger than is required to cover the molding area of the mold. Beginners are advised to apply one layer of reinforcing material at a time and allow this to set before applying the next layer. As experience is gained, two or more layers (up to a maximum of about 6 ounces of reinforcing material per square foot) can be applied wet. This is usually more difficult than applying a single layer at a time but makes the work faster.

Mat can be formed to shallow curves without making cuts but only after the resin has been applied to the material. Sharp curves and angles usually require making cuts and overlapping the mat in these areas. The overlaps can be worked down to an even thickness after resin has been applied by dabbing with the brush.

The next step is to calculate the amount of resin required for saturating the reinforcing material that is to be applied wet at this time. Pour the required amount of resin into a mixing cup. You will probably need about 7½ minutes of working

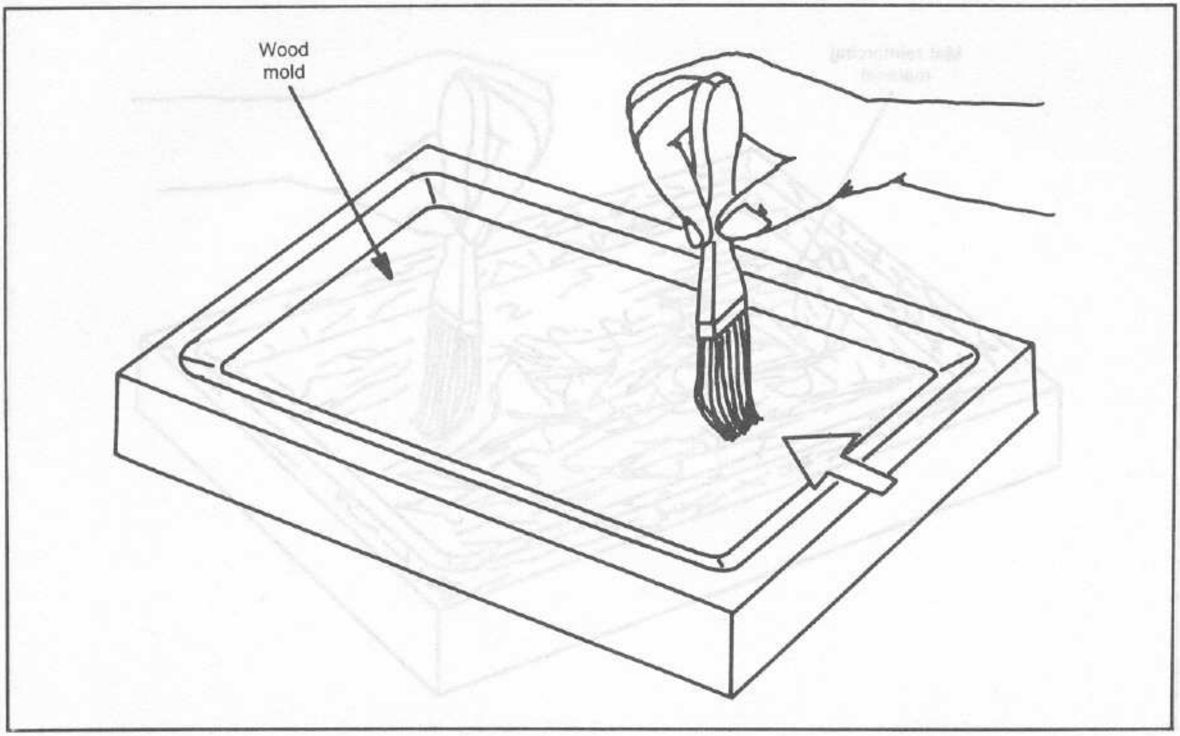

Fig. 7-25. Apply gel coat to the mold surface with long continuous strokes of brush.

time to apply the resin to a single layer of reinforcing material; more time might be required for multiple layers.

Add the required amount of catalyst to the resin and stir. Wait about 30 seconds. Then, using the brush, apply a coat of resin over the gel coat layer that was applied to the mold surface and allowed to set previously.

Position the first layer of fiberglass reinforcing material (usually a mat layer) over the wet resin so it is centered, press it down, and smooth it out. For mat, use a dabbing action rather than a brushing action to avoid lumping up the mat.

Saturate the reinforcing material with resin (Fig. 7-26). Spread the resin to saturate as evenly as possible, including areas of the reinforcing material that extend slightly beyond the desired size of the finished shallow-depth rectangular form. These can be trimmed off later after the laminate has cured.

If a second layer of reinforcing material is to be applied, wet over the first layer, position it in the wet resin, press it down, and smooth it out using the brush. If the second layer is cloth rather than mat, use a brushing action but be careful not to unravel the cut edges of the cloth.

Saturate the second layer of reinforcing material with resin. Spread the resin as evenly as possible. Saturate all areas of the reinforcing material.

Apply all layers of reinforcing material that are to be applied wet at this time. When everything looks okay, clean the resin from the brush with acetone.

It generally works best if laminating resin is used for all but the final layer of resin on the backside of the laminate. The final layer should be sanding or finishing resin to give a surface that is not sticky so that it can be sanded.

Allow the laminate to cure. If additional layer or layers of reinforcing material are to be added to the laminate, measure out and catalyze the required amount of polyester resin. Brush on a layer of wet resin over the cured laminate. Position the first additional layer of fiberglass reinforcing

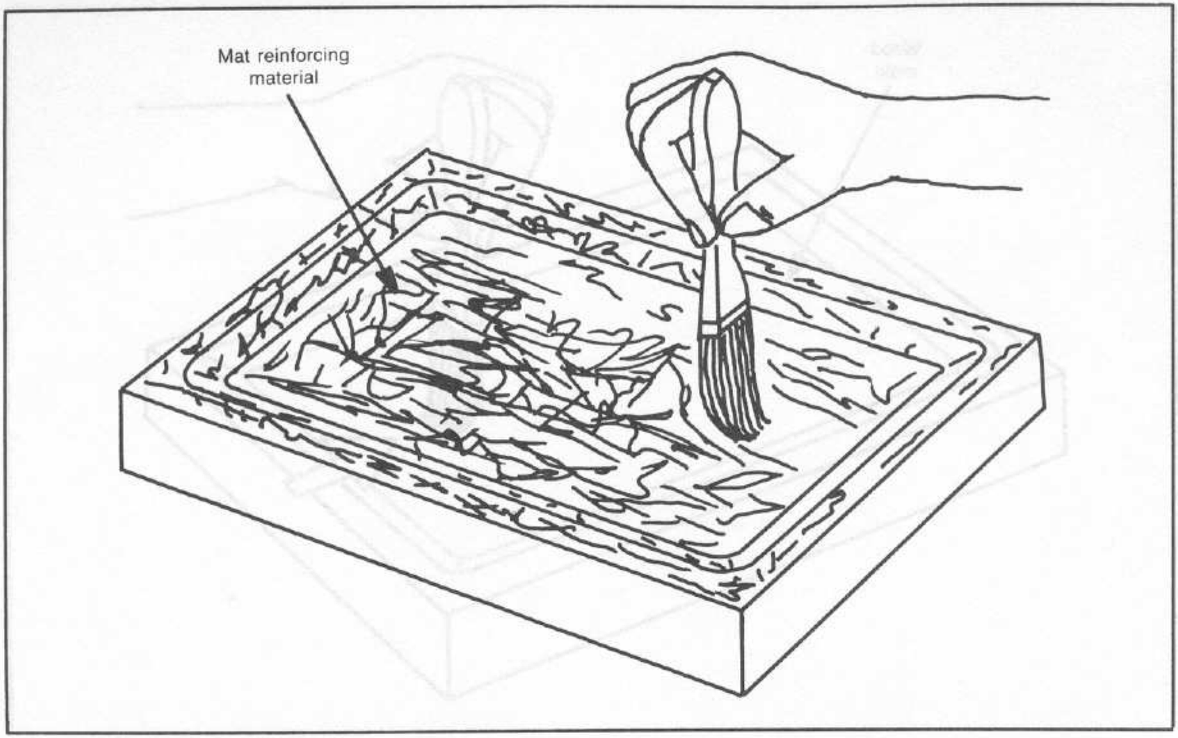

Fig. 7-26. Saturate the reinforcing material with resin.

material over the wet resin. Center it, press it down, and smooth it out. The brush can be used for this.

Saturate the reinforcing material with resin. Spread the resin as evenly as possible. If additional layers are to be applied wet, these should be added at this time in a similar manner.

Allow the laminate to thoroughly cure, then remove it from the mold. Even though the mold release was used, it still might be necessary to pry the laminate loose with a putty knife or other similar tool.

This completes the chemical part of the construction. For most projects, the fiberglass molding requires trimming. First mark the pattern and saw off the excess fiberglass at the lip of the tray or pan form. Sawing methods are detailed in Chapter 6. Next, file and sand the edges smooth. Polish and buff the gel coat surfaces and, for some projects, the edges of the laminate.