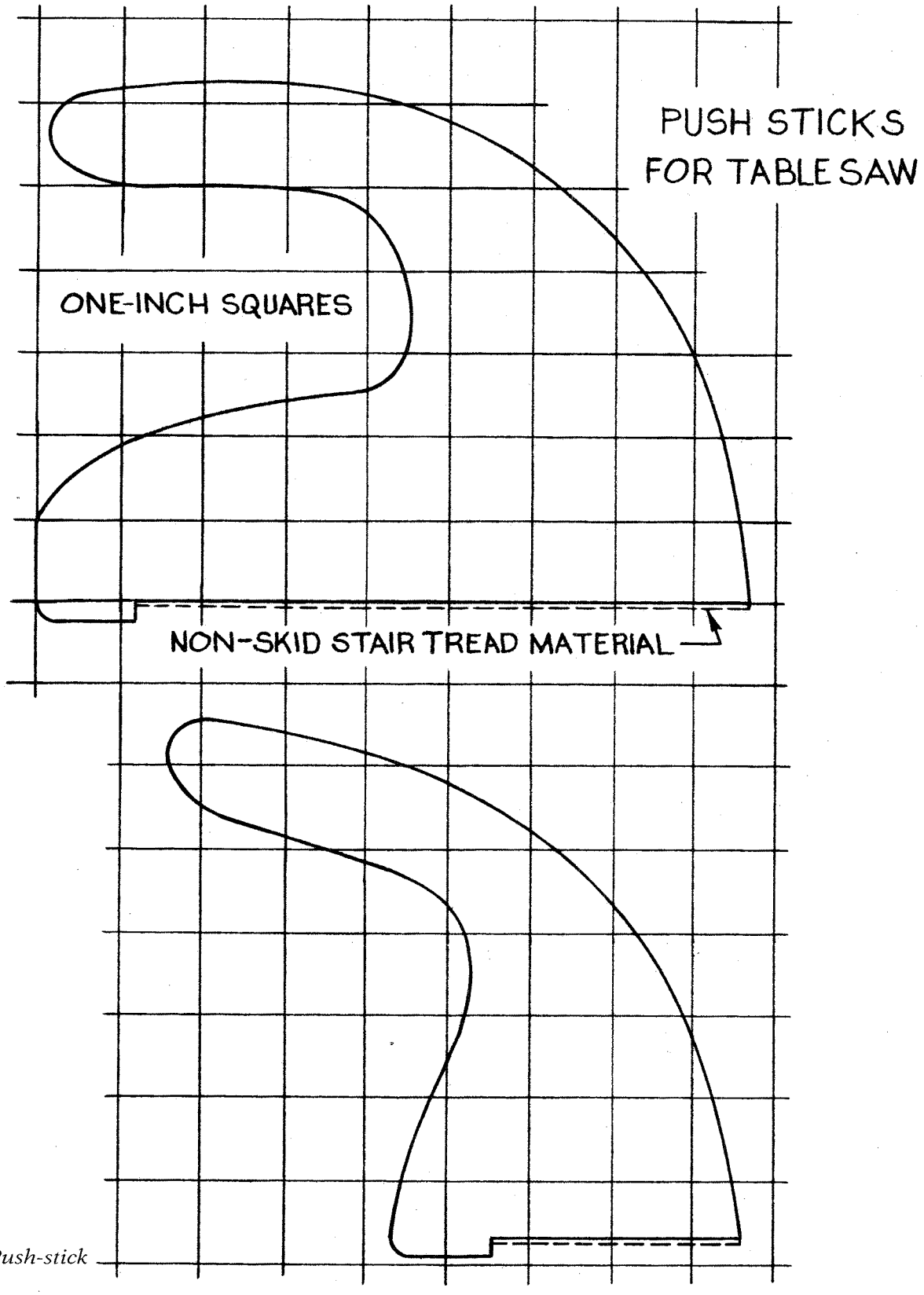


Illus. 1-4. Push-stick patterns.

CHAPTER 2

Basic Mechanisms

The projects in this chapter are mechanical movements that were selected for their interesting actions and because they can be constructed easily in wood. They are fairly easy to build and will give you good experience at fitting and tuning wooden machinery, which will prove extremely helpful when you tackle some of the more complex designs in the book. These five units have a number of similar parts, making it practical to cut parts for all of them at the same time, so why not plan on making the whole set?

Before you begin making any of these projects, or any of the ones that appear later on, study the specific drawings. If you understand the function of each mechanism's part and how it interacts with all of the others, it will help you to prevent problems that can crop up at the final assembly.

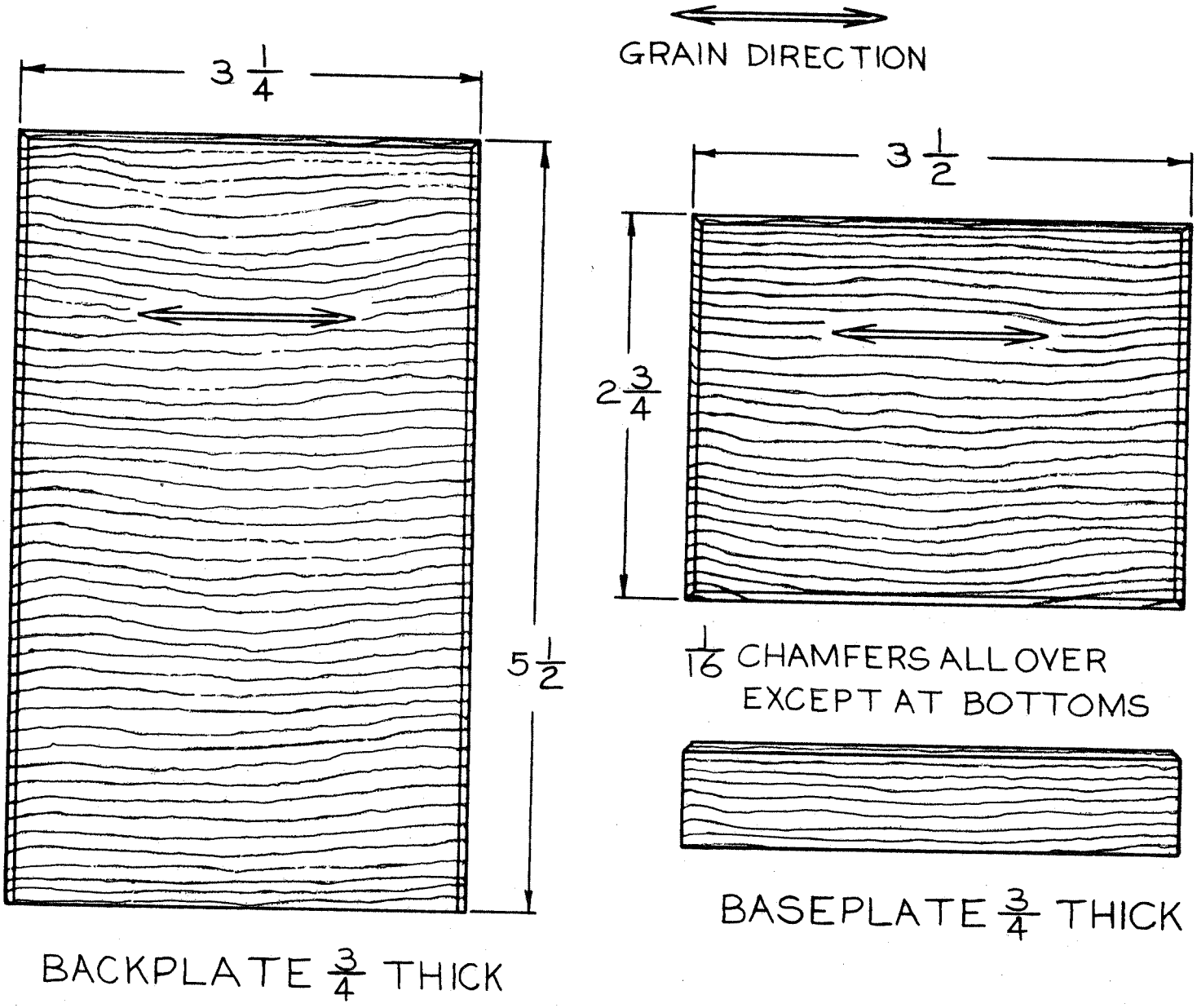
CUTTING THE BACKPLATES AND BASEPLATES

The baseplates are identical for all five units, and the backplates differ only in their hole layouts. (See Illus. 2-1.) To make the backplates, select a piece of hardwood that will have a final width of 5½ inches and thickness of ¾ inch. Joint and plane to these dimensions. Using a clean, sharp blade in the table saw, cut five 3¼-inch pieces from the length of the board. If you clamp a stop block to the saw table, you will be able to cut identical pieces quickly and safely. The purpose in cutting the backs from a wide board, instead of one that matches the 3¼-inch width, is to properly orient the grain for gluing to the base. Throughout this book, on every part drawing where it is needed, the preferred grain direction is indicated by a double arrow on or near the part. Pay attention to these grain directions; they are important.

To make the baseplates, prepare a piece of stock 2¾ inches wide by ¾ inch thick, and cut five 3½-inch lengths from this board. Clean up the saw-cut surfaces on both the backs and bases by sanding them smooth and removing any fuzz.

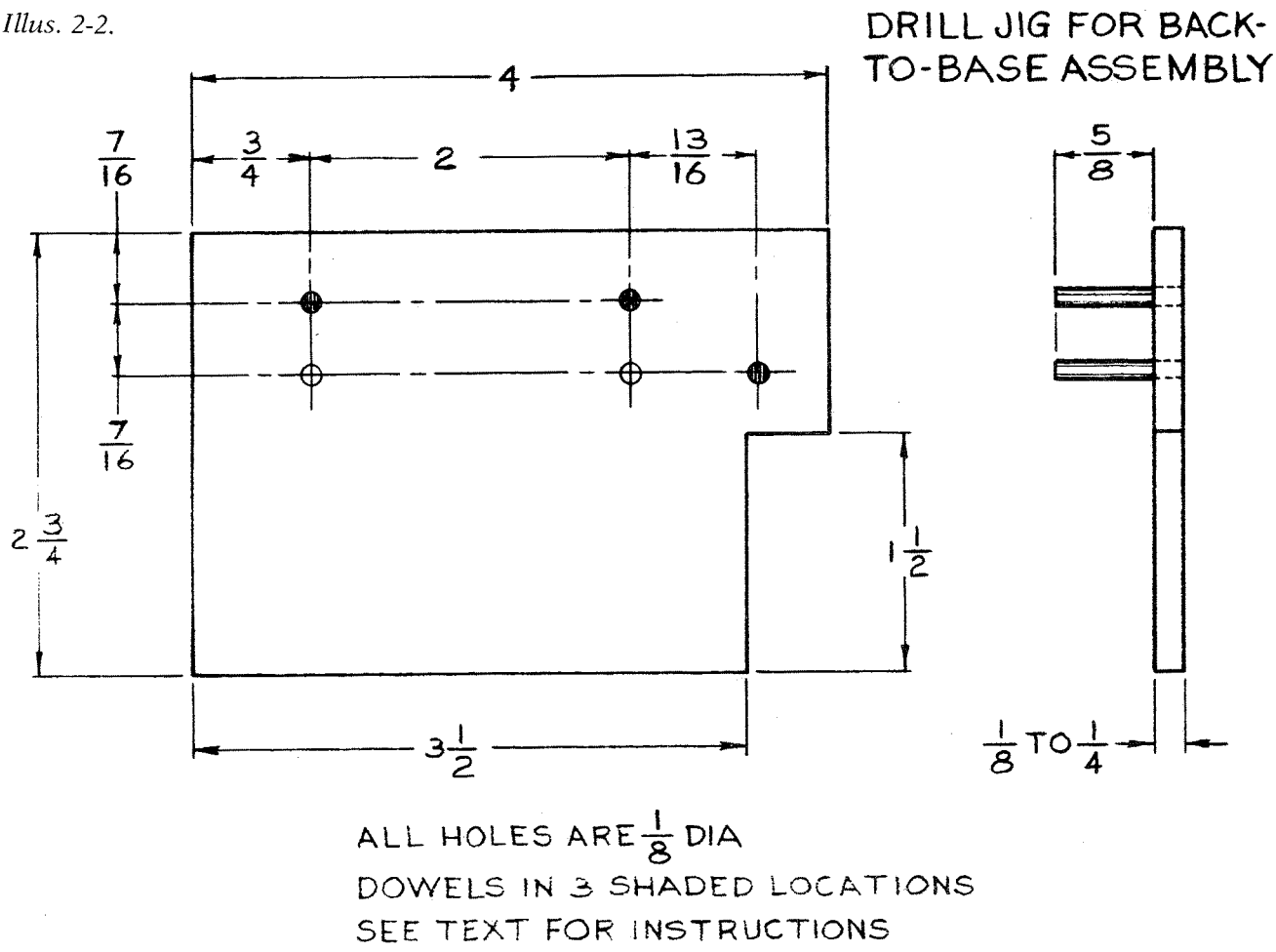
DRILL JIG FOR THE BACK-TO-BASE ASSEMBLY

The time you take now to build this drill jig will be well spent because the jig will save


GRAIN DIRECTION
3 1/4
5 1/2
BACKPLATE 3/4 THICK
3 1/2
2 3/4
1/16 CHAMFERS ALL OVER
EXCEPT AT BOTTOMS
BASEPLATE 3/4 THICK

Illus. 2-1.

Illus. 2-2.



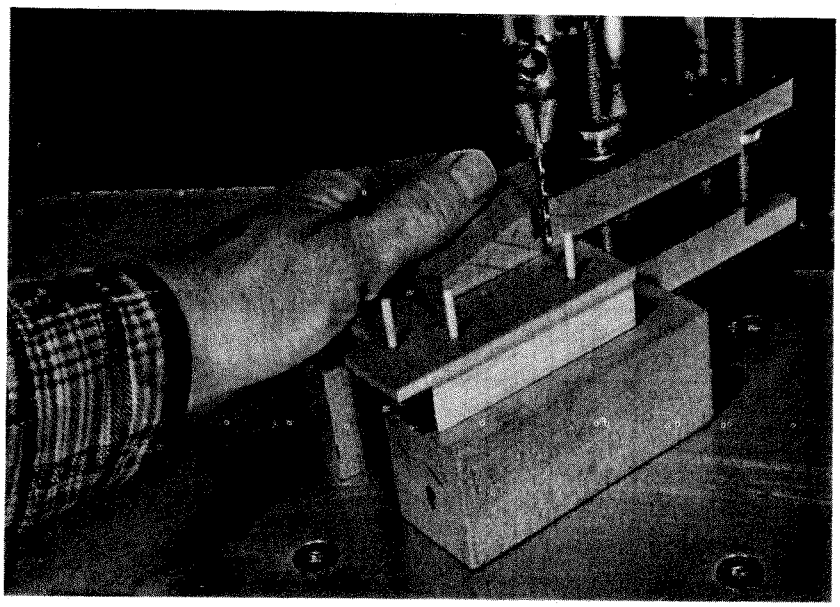
you a considerable amount of time later when you are making the projects. Proper use of this jig will allow you to drill perfectly matched dowel holes in the backplates and baseplates, giving you accurately aligned assemblies.

You can build the jig from Masonite™, hardwood plywood, or good, hard wood that is ⅛ to ¼ inch thick. Cut a piece to 2¾ × 4 inches, and cut the step as shown in Illus. 2-2. Working very accurately, lay out the hole patterns as shown. Drill the five ⅛-inch holes and drive tight-fitting dowels into the three locations indicated; the dowels should be flush with the back of the jig.

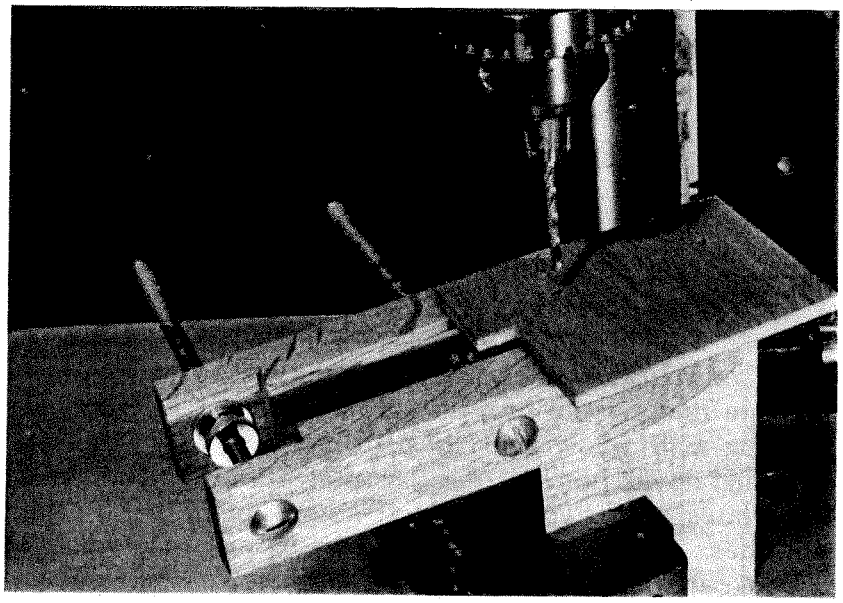
To use the jig, place its back flat against the top surface of a baseplate and flush with its rear edge. Align the left and right edges of the jig with the baseplate, and clamp it in place. (See Illus. 2-3.) If your baseplate is not exactly 3½ inches wide, just center the jig on the part so that the dowel holes will be evenly spaced from both edges. Carefully align the drill with each hole to prevent enlarging the jig, and drill the two holes in the baseplate.

Now, select one edge to be the lower edge of the backplate, and turn it upwards. Set the jig on this bottom surface. The two dowels should touch the back side of the plate, and you should mark the back and front for later reference. The third dowel should touch the edge of the backplate, but, again, if your part is not exactly 3¼ inches wide, just center the holes on the actual width of the plate. Drill the two dowel holes. (See Illus. 2-4.) With holes drilled on all the backs and bases for the dowels, we can now work on the individual mechanisms.

Illus. 2-3. Drilling dowel pin holes in the baseplate, using the drill jig.



Illus. 2-4. Drilling dowel pin holes in the lower edge of the backplate, using the drill jig.

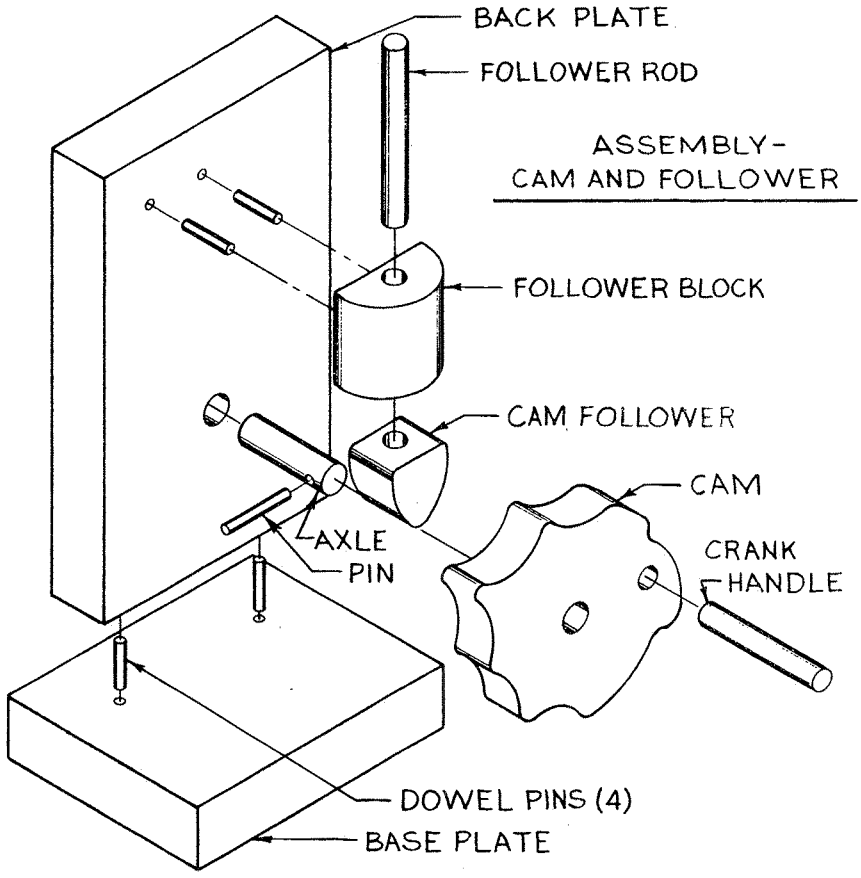


CAM AND FOLLOWER

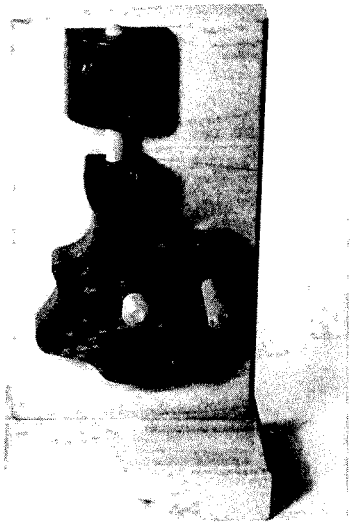
A cam is defined as a machine component with a surface whose profile sets in motion another part called the follower in the desired speed and distance. Cams can be made that rotate, reciprocate, or do a combination of both. This model is a rotary cam which has a number of lobes of different heights and spacings, giving a lively action to the follower.

Making the Parts

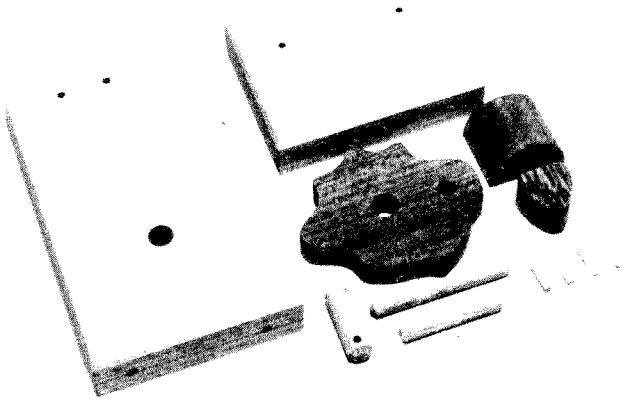
The cam, the most difficult part, should be made first. Prepare a piece of sound, uniform stock ½ inch thick. Photocopy the full-size cam pattern in Illus. 2-9 and stick it onto the wood. (See Illus. 2-10.) I use a quick shot of 3-M spray adhesive on the pattern. When I want to remove the paper, I warm it with a heat gun or over my wood stove; the pattern peels right off.



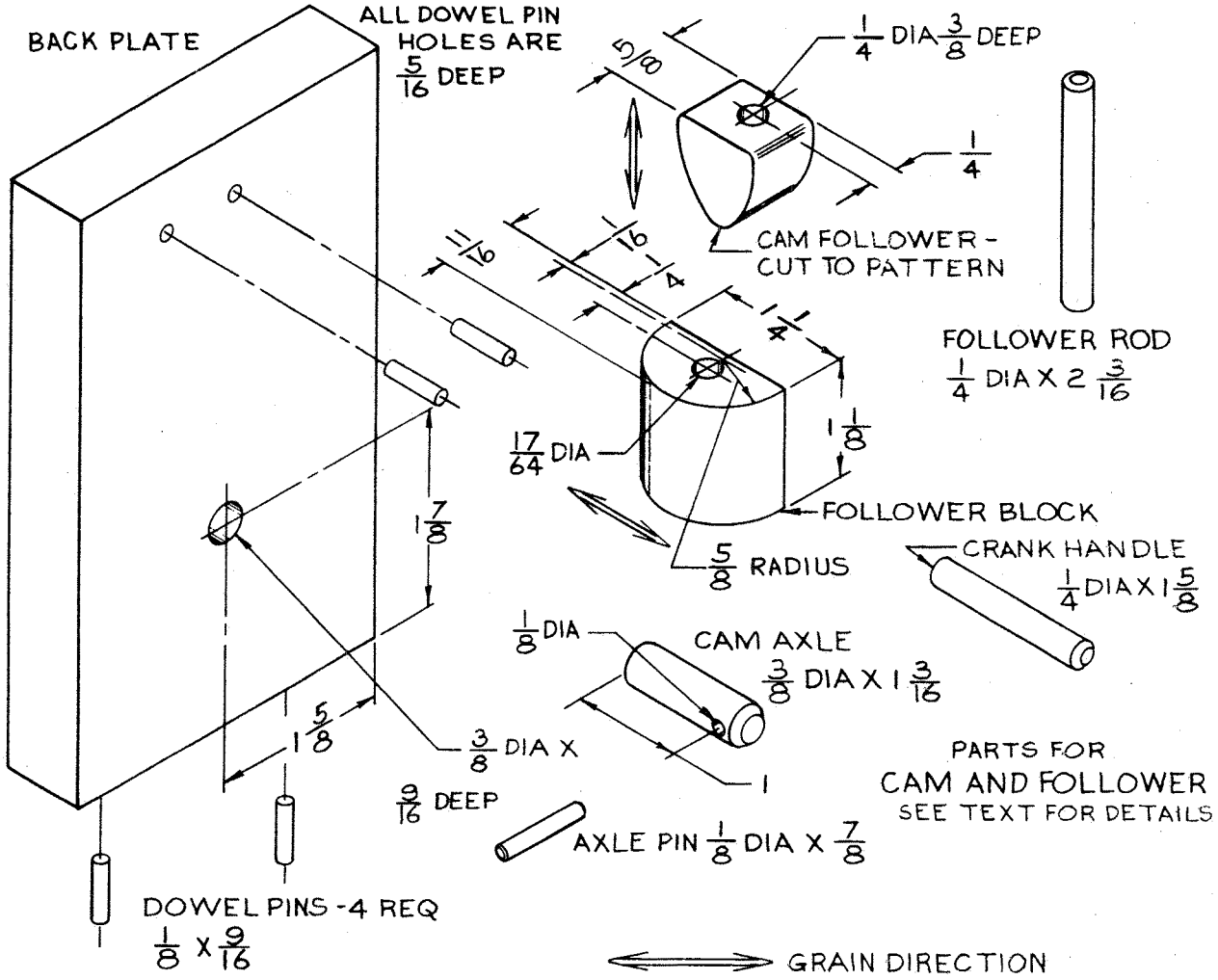
Illus. 2-5.



Illus. 2-6. The Cam and Follower mechanism.



Illus. 2-7. All the parts for the Cam and Follower mechanism.



Illus. 2-8.

Poke an awl into the central point of each hole location, and drill the holes. Check your dowel sizes and refer to the section on drilling in Chapter 1. Note that the hole for the handle does not go all the way through.

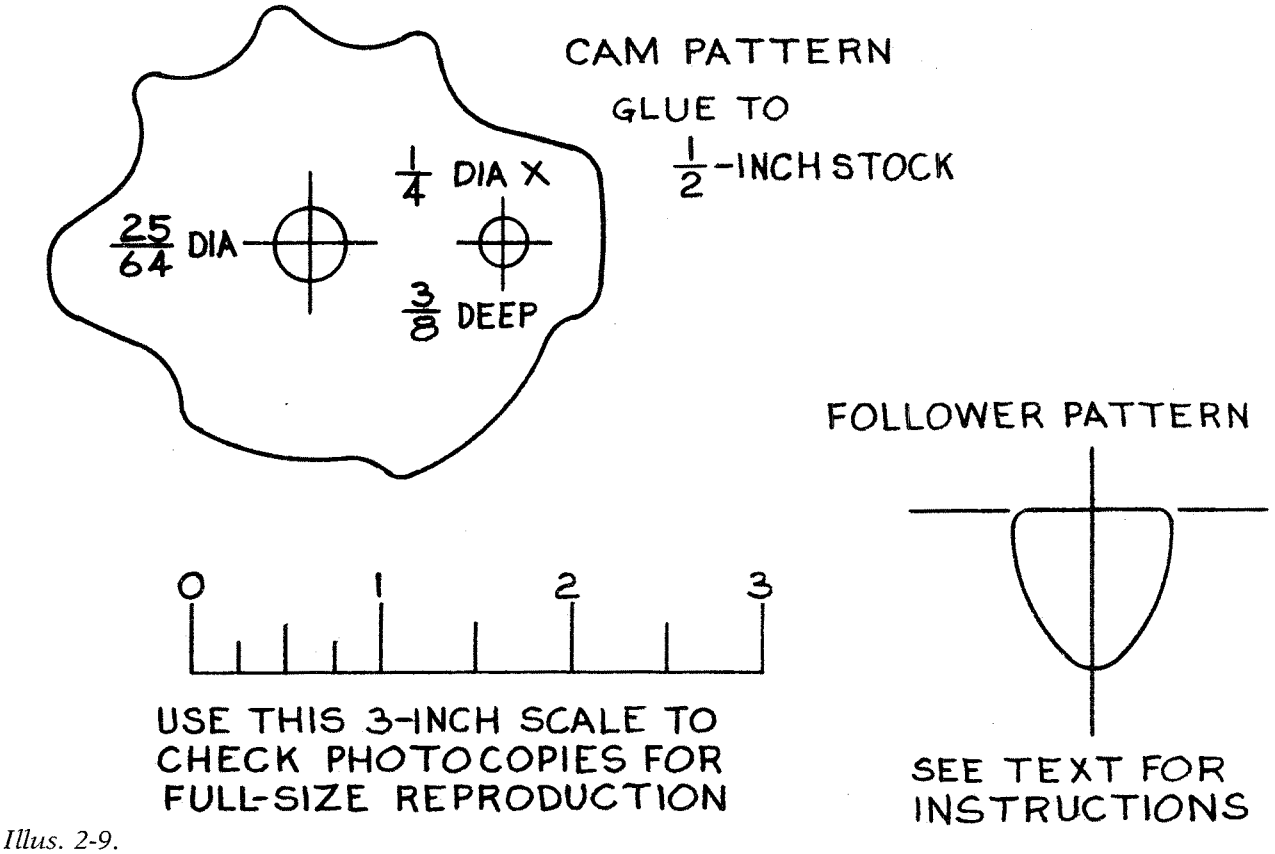
When the holes are drilled, set up the band saw with your narrowest blade, and saw out the cam profile as close to the line as is safe. (See Illus. 2-11.) Now, mount a ½-inch-diameter sanding drum in the drill press and sand the cam profile to the line, using a coarse-abrasive sleeve. (See Illus. 2-12.) Switch to a fine-abrasive sleeve and go around the cam again. If you use a thick block on the drill press table as a work support, you can oscillate the drum up and down while sanding, thereby eliminating all parallel sanding scratches.

For a fine finish, cut a saw slot 3 inches long up one end of a ⅜-inch dowel. Insert one end of a 3-inch-wide strip of 240-grit paper, wrap it around the dowel against the direction of rotation, and anchor it at top and bottom with rubber bands. If you go around the cam with this tool rotating at about 2,000 rpm, the part will acquire a polished surface. Fine-sand the flat faces of the cam and sand a small chamfer all around the profile on each side. Sand off the sharp corners on both sides of the axle hole. Your cam is now completed and should be put somewhere safe to await assembly.

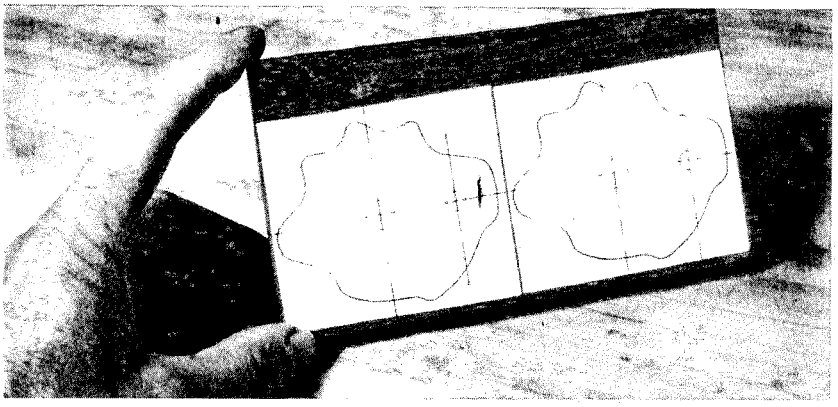
Cam Follower

This small part, shown in Illus. 2-8, must be carefully made. Like most small parts in these designs, it should be left attached to a larger piece of stock as long as is possible. Square up a block that's 5/8-inch thick and of any width greater than the 13/16-inch dimension of the part. Lay out the center of the hole on the end grain and square the center line across the end and down the wide face of the block. Carefully mark the center point of the hole with an awl.

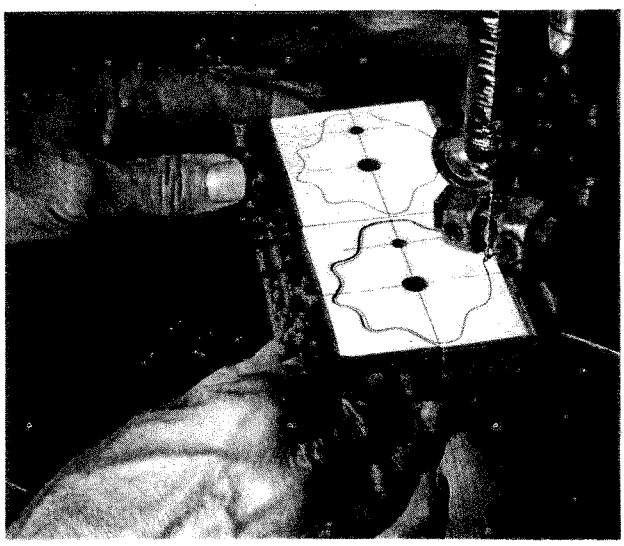
Hold the part in a drill vise or clamp it to a thick block so that it is at right angles in both



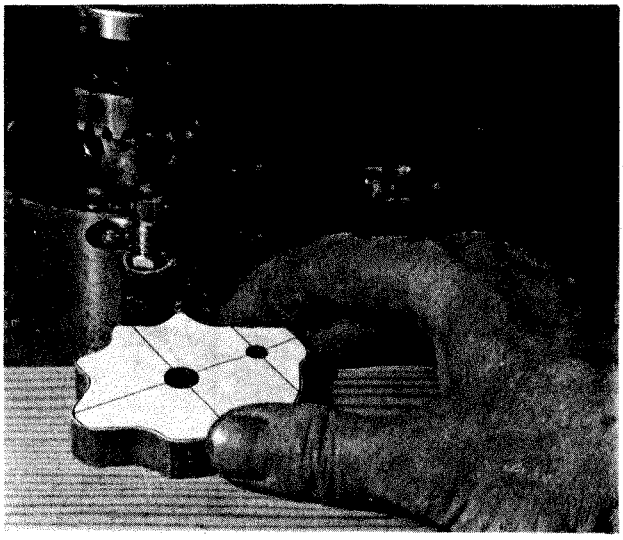
Illus. 2-9.



Illus. 2-10. The cam patterns glued to the stock.

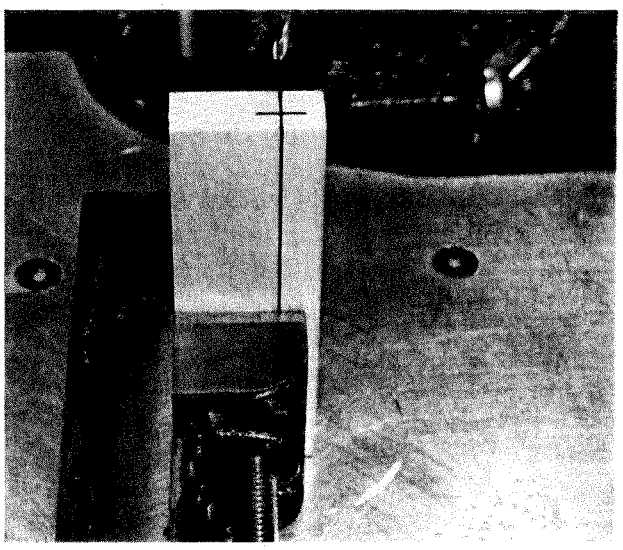


Illus. 2-11. Cutting out the cams with a band saw.



Illus. 2-12. Sanding the contour of the cam.

directions to the drill press table. Drill the hole accurately to a ⅜-inch depth with a ¼-inch brad-point drill. (See Illus. 2-13.) Remove the work from the drill press, but don't disassemble the setup until you have made sure that the hole is parallel to the face and the edge. (Drills sometimes wander in end grain.) To do this, put a close-fitting dowel about 4 inches long into the drilled hole, and hold the block against any flat surface, first



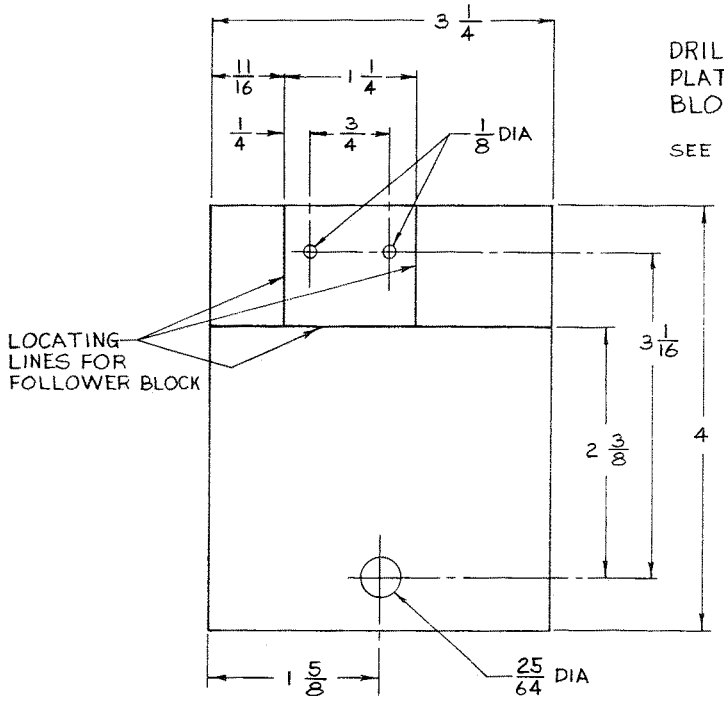
Illus. 2-13. Drilling a hole for the follower rod in the end of the follower blank.

on its edge and then on its face. If the dowel is visibly not parallel with the test surface either way, it is best to saw off the hole and try again.

Cut out the photocopy of the pattern; leave extra paper around the profile, but cut the straight upper edge exactly on the line. Apply adhesive and stick the pattern to the blank with its upper edge flush with the drilled end of the block and its center line accurately aligned with the center line on the face. Now saw the part to the line with a band saw, removing the part from the longer blank. Put a short length of dowel into the hole to serve as a handle, and belt-sand to the line. Fine-sand by hand, using first 150-grit and then 240-grit paper and sanding with the grain until all the scratches are removed. Lightly chamfer all the edges.

Follower Block (Illus. 2-8).

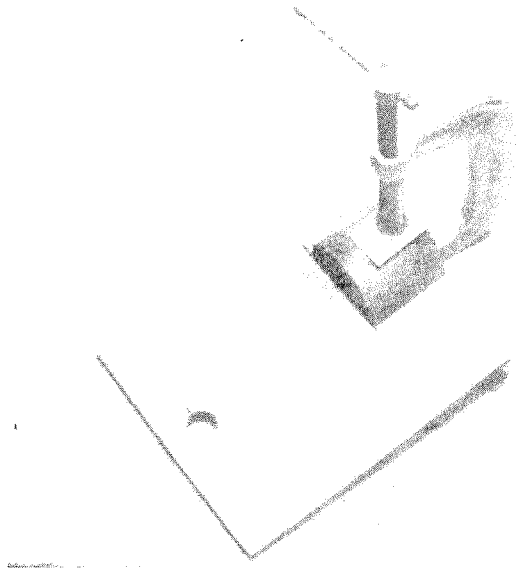
Prepare a piece of stock 1⅛ inches wide, ¾ inch thick and long enough to hold onto. Lay out the hole center and the radius center point on one edge. Set a pencil compass to a ⅝-inch radius and draw the semicircular profile of the part. Drill the hole with a ¼-inch brad-point drill and ream it with a 17/64-inch regular drill. Check the hole to make



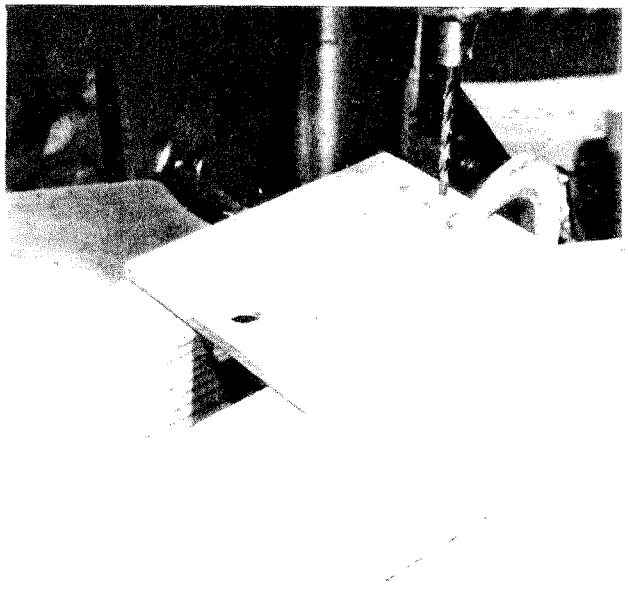
DRILL JIG FOR BACK PLATE AND FOLLOWER BLOCK

SEE TEXT FOR DETAILS

Illus. 2-14.



Illus. 2-15. The follower block clamped to the drill jig.



Illus. 2-16. Drilling the dowel pin holes in the follower block, using the flat jig.

sure that it is parallel to the flat rear face, using the same procedure as with the cam follower. Use a band saw to shape the part, and sand to the line on the belt sander. For all these small parts, the sanding table should be adjusted as close to the belt as possible without actually touching it. Hand-sand with the grain and lightly chamfer the curved surfaces only; don't do any sanding on the flat back surface. Chamfer both ends of the hole.

The dowel pin holes in both the follower block and the backplate are located by a

simple jig. Cut a piece of thin stock to the dimensions shown in Illus. 2-14, and then lay out and drill the holes. Draw the three locating lines heavy enough to be easily visible.

Align the follower block with the three lines and clamp it with a small padded clamp. (See Illus. 2-15.) Support the jig on two parallel strips, as shown in Illus. 2-16, and drill the dowel holes, 5/16 inch deep. This part is now ready to assemble.

Backplate and Baseplate

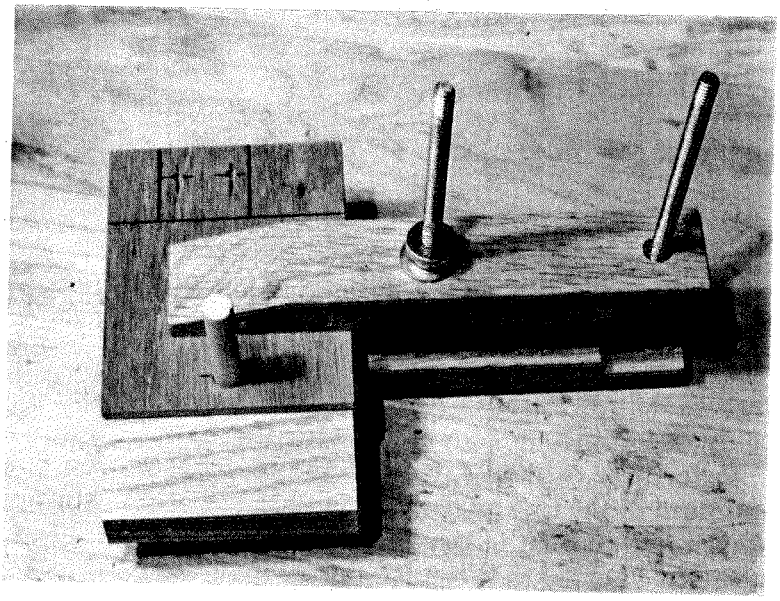
Take one of the backplate blanks and lay out the axle hole center. Drill the hole to the depth shown in Illus. 2-8. Put a short piece of 3/8-inch dowel temporarily into the hole and set the flat drill jig in place. Line up the edges of the jig so that they are parallel with the edges of the plate, and clamp them in place. (See Illus. 2-17.) Drill the two dowel pin holes for the follower block 5/16 inch deep.

Now, sand the backplate to the desired smoothness all over except for the lower edge with the two dowel holes, which should not be sanded. (Also at this time, finish-sand a baseplate.) Finally, plane a uniform chamfer all around, as shown on the drawings. Don't, however, chamfer the lower edge of the backplate or the lower corners of the baseplate. The backplate and baseplate are now ready for assembly.

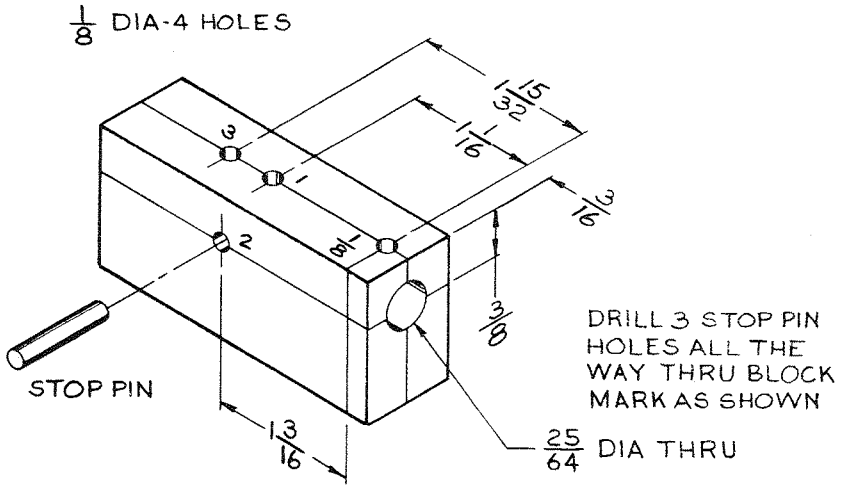
Drill Jig for Axles

Although you can make the parts without this tool, it is very helpful. Drilling accurately centered holes in dowels is never easy. The block jig shown in Illus. 2-18 will drill axles of three different lengths and can be used for four of the mechanisms, so it is worth your time to make one.

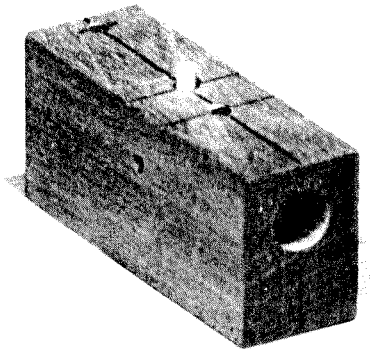
Square up a block of the hardest wood available and scribe the hole centers as shown in Illus. 2-18. Work carefully; the parts you drill in any jig will never be any more accurate than the jig itself. Drill the large central hole from both ends, using first an undersize drill, and then drilling all the way through with the final drill. Put a piece of scrap dowel in the 3/8-inch hole before drilling all the 1/8-inch holes, to prevent splintering. Number the stop-pin holes as shown in Illus. 2-18, as they will be referred to by number from now on. Insert the parts into the jig and hold them against the stop pin by applying thumb pressure on the exposed end. (See Illus. 2-19.)



Illus. 2-17. Drilling dowel holes for the follower block, with the flat jig clamped to the backplate.



Illus. 2-18.



Illus. 2-19. A jig for drilling the pin holes in the axles.

Remaining Parts

The rest of the pieces of this assembly, shown in Illus. 2-8, are all made from dowels. The crank handle is used in four of the five models, and the axle pin in three of them, so you may as well cut all of them at once. Cut them to length with a fine-toothed handsaw and chamfer the ends in the lathe or by sanding. Those parts that will be glued in place should be snugly hand-fitted into their respective holes. These parts will swell the moment they are wetted with glue, so if they are very tight to begin with you may not be able to fully insert them before they lock in place.

Parts intended for running fits should have about 1/64-inch clearance in their holes. This is about the minimum desirable clearance for wooden assemblies if you want the machine to function when the humidity changes. Sand all the parts with fine abrasive, finishing parallel to the grain.

Push-fit the 1/8-inch axle pin into the axle. This is the last piece to be assembled, and you don't want to hammer it in. Use the jig with the stop pin in the number one hole to drill a hole in the axle for the pin.

Dry-Assembling the Mechanism

At this point, with all the parts completed, dry-assemble the mechanism. Put two dowels into their holes in the follower block and mount the block onto the backplate. Place the axle into its hole in the backplate. Now, push the follower rod into the cam follower; it should enter the bottom of its hole without requiring a great deal of force.

Slide the rod into its guide hole in the follower block; the assembly is so designed that the follower will just clear the axle when

everything is correctly made. If there is any interference, check the length of the follower rod; it may be a bit too long. When you have the follower in place, push it all the way up and check its clearance to the backplate. This clearance should be about 1/64 inch. Much less than that, and the follower may hang up. Much more will give a wobbly action. Remember that the follower returns by gravity and must fall of its own weight.

Assemble the cam on the axle and put the handle temporarily in place. With the backplate in an upright position, test the operation of the assembly. When the cam is turned in a clockwise direction, the follower should rise and fall with a smooth positive action; it will work more smoothly when finished and waxed.

If the follower is reluctant to climb any of the lobes on the cam, the chances are that you have undercut the contour and made a steep angle of rise on that lobe. The way to fix this is to slightly reduce the angle of the lobe until the action is acceptable. This should never occur if you work reasonably close to the template outline.

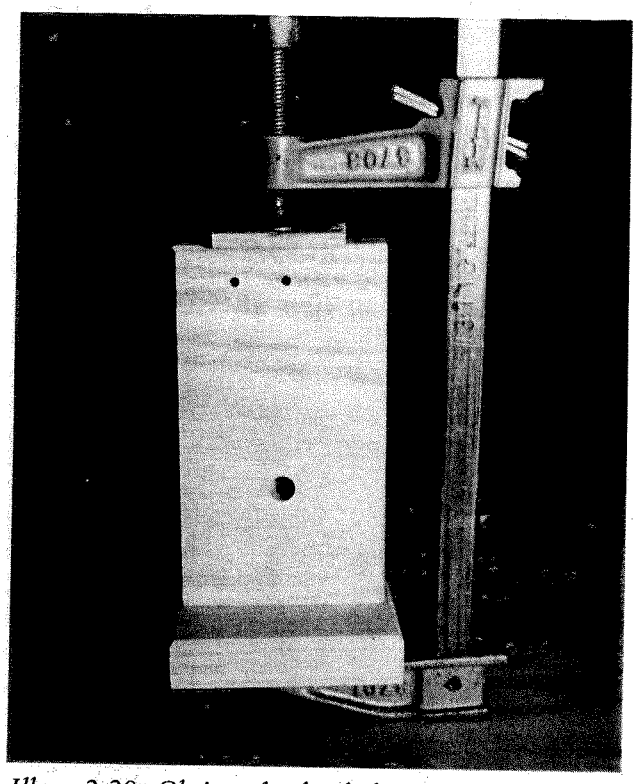
Put two dowels into the holes in the base and set the backplate in position, to see that it can be assembled correctly.

Take everything apart and refer to the section on wet-sanding in Chapter 1. When the parts are smooth enough to suit you, proceed with the assembly.

Final Assembly

Prepare the gluing surfaces of the backplate and baseplate, by lightly scraping them with a sharp scraper. Push two dowels into the holes in the baseplate. You don't have to put glue into these holes, as the dowels only position the parts and don't contribute to the structural strength.

Apply a film of glue to both surfaces and set the backplate in place. Make sure that the axle hole is at the front of the unit (I once glued one backwards). Pull the assembly tight, using one large clamp with a couple of small wood pads to protect the work. With a small square, check the assembly. If the backplate leans to the front or the rear, slightly loosen the clamp and push one of its jaws in the right direction to correct this condition. When you have determined that the assembly is squared up, set it aside to dry. (See Illus. 2-20.)



Illus. 2-20. Gluing the backplate to the baseplate.

Lightly scrape the gluing areas and assemble the follower block onto its dowels. Use a clamp with a piece of cardboard attached to it to prevent the curved surface of the part from being crushed, and glue the block in place. When this assembly is dry, wipe a thin film of glue around the inside of the axle hole in the backplate; use only a little glue so that it doesn't fill the hole. Put a long piece of 1/8-inch dowel or a metal rod in the pin hole of the axle. Put the axle through the cam, and start its end into the hole in the backplate. Keeping the long 1/8-inch dowel reasonably horizontal, tap the axle into its hole until the

pin hole with its long dowel is about 1/32 inch from the face of the cam; more clearance here is better than less. (See Illus. 2-21.) Remove the long dowel and the cam. Glue the crank handle into the cam, and the follower rod into the follower. This completes the gluing.

Clean up the assembly. Before adding a finish, read the section on finishing; the choice of finishes is important. When you have applied a finish to all the subassemblies, work a little wax into the holes in the follower block and the cam. A pipe cleaner is ideal for this purpose. Also wax the follower rod, the axle, and the contours of the cam and follower, and buff off any excess wax. You may wax all other surfaces if you wish. Slide the follower into position, and put the cam on its axle. Push the axle pin into its hole and center it; don't glue this pin. Operate this assembly. There should be a lively clip-clop sound when it is rotated rapidly which will fascinate your family and friends.

Congratulations! You have just built a functioning, all-wooden mechanism.

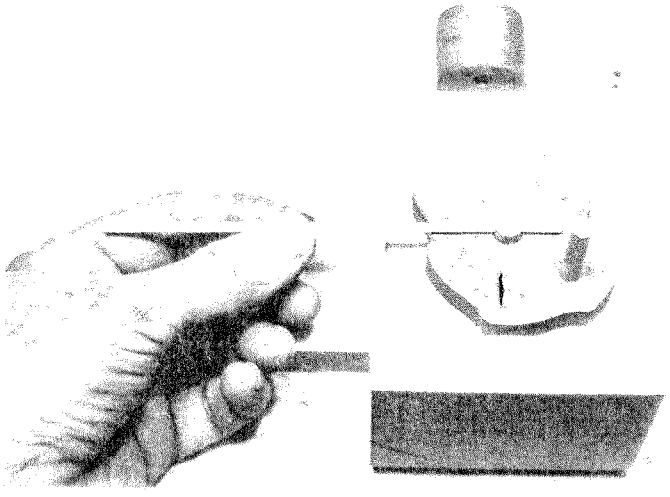
THE ECCENTRIC

If you took a conventional crankshaft and greatly enlarged its crankpin, you would have what is commonly called an eccentric. (See Illus. 2-22–2-24.) An eccentric is preferred wherever the need for a very short stroke makes it impractical to use a regular crankshaft. Its very large bearing area makes the eccentric ideal for high-load applications; heavy presses are usually actuated by large eccentrics. Other such applications include high-pressure piston pumps and steam engine valve gear.

Making the Parts (Illus. 2-25)

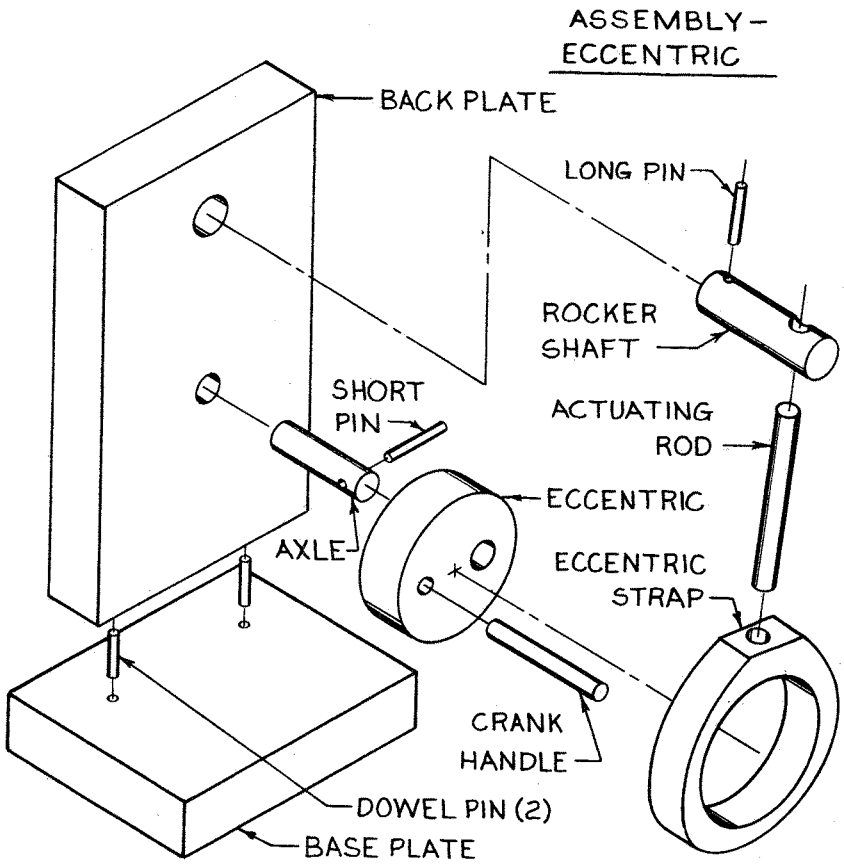
Our model has two main parts that must be fitted together with the proper clearance: the eccentric and the eccentric strap. The order in which you should make these parts depends on the equipment available to you. If you own an adjustable circle cutter, then it doesn't matter which of the two parts you make first. Otherwise, it is best to cut the hole in the eccentric strap, and then fit the eccentric to it.

To make the eccentric strap, plane a sound piece of stock to a ½-inch thickness, and glue on the pattern, which is shown in Illus. 2-27. Using a brad-point drill of the same diameter as the pilot drill in your circle cutter, put a hole in the center of the pattern. (See Illus. 2-26.) This is a surer way to produce an accurately centered hole than attempting to do it with the short, blunt drill in the circle cutter. I substitute a polished piece of steel

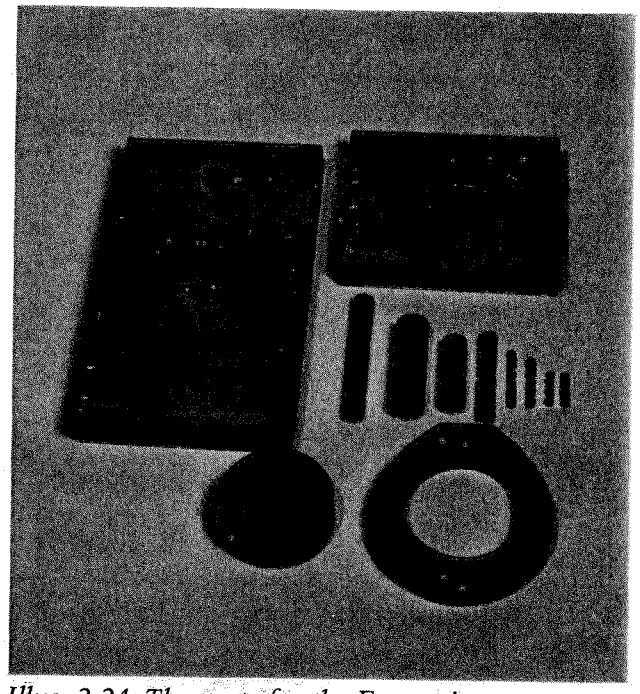


Illus. 2-21. Assembling the axle.

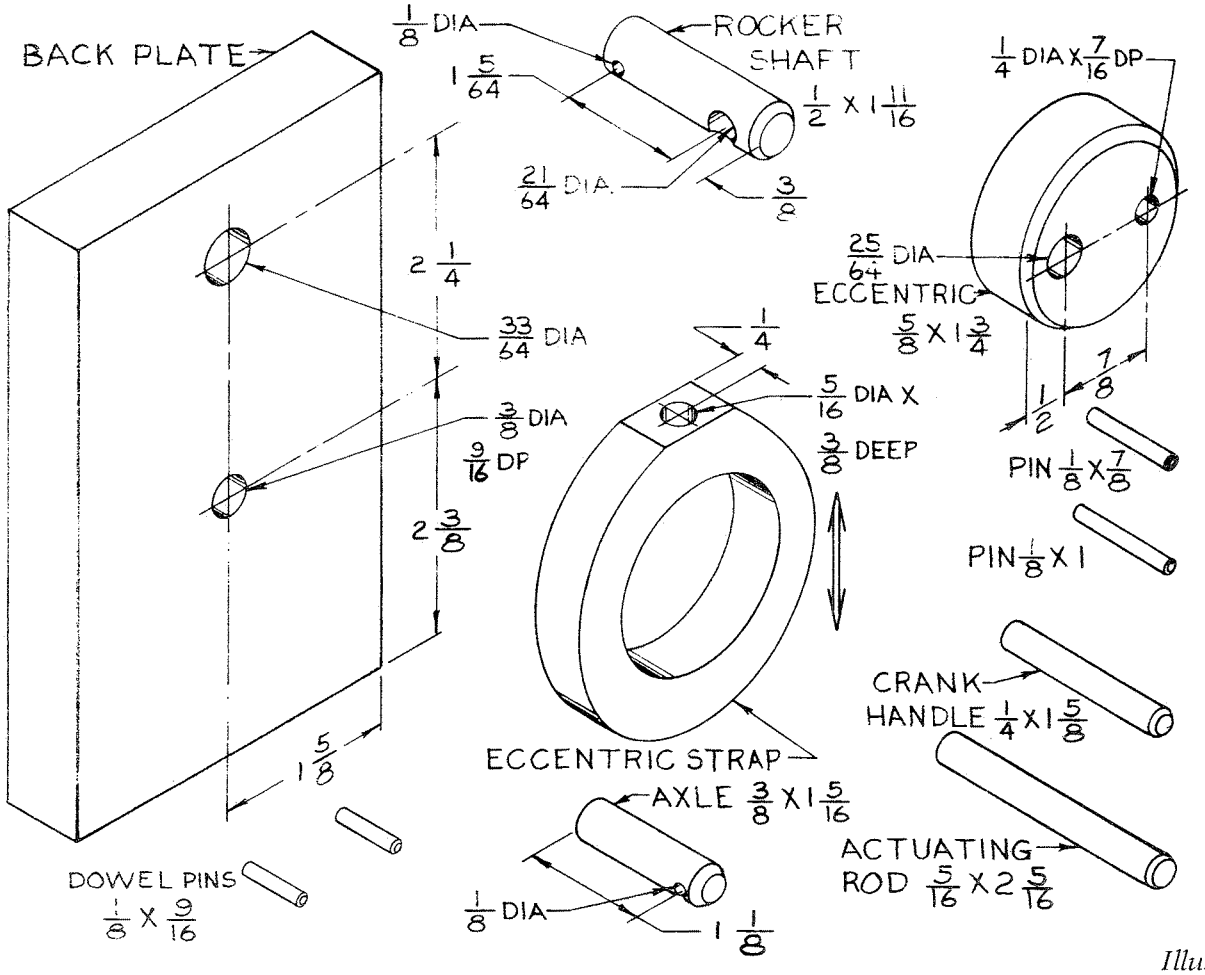
Illus. 2-22.



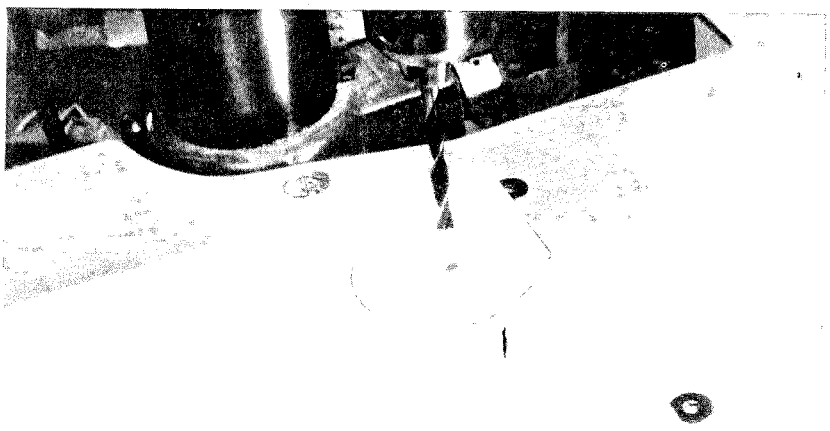
Illus. 2-23. The Eccentric.



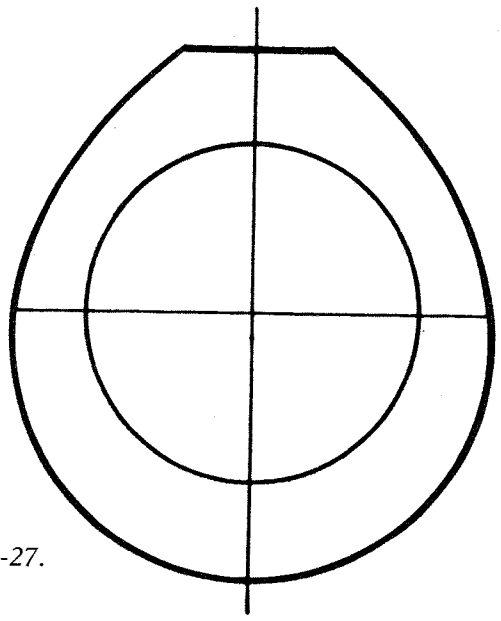
Illus. 2-24. The parts for the Eccentric.



Illus. 2-25.



Illus. 2-26. Drilling the pilot hole in the Eccentric strap. See the following page for the full-size pattern.



Illus. 2-27.

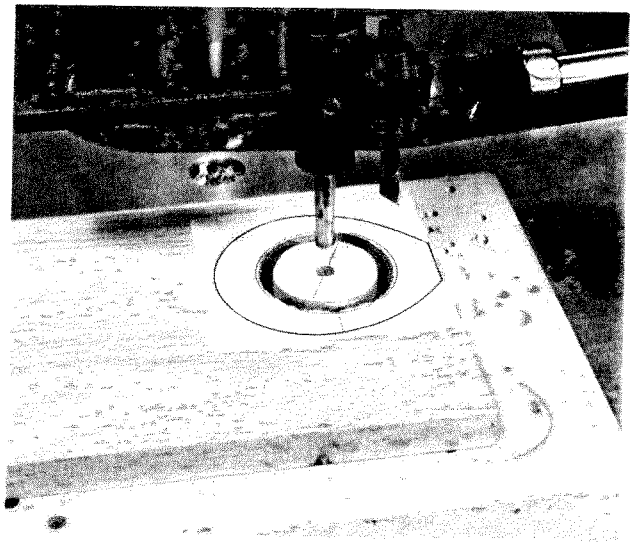
PATTERN FOR

ECCENTRIC STRAP

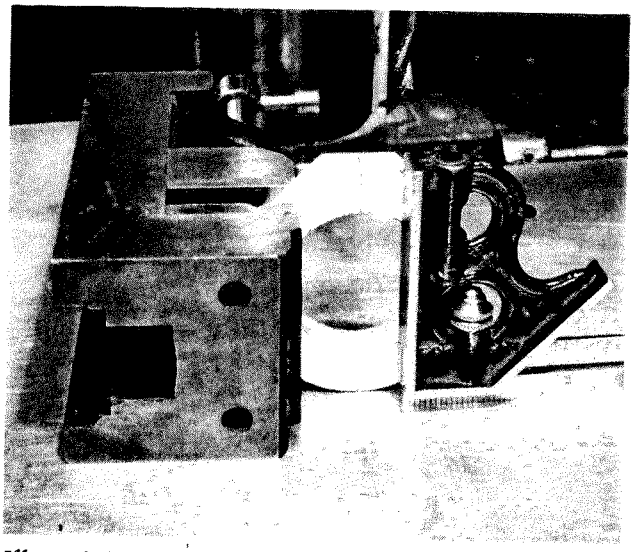
TRACE OR PHOTOCOPY

GLUE TO $\frac{1}{2}$ INCH STOCK

USE THIS INCH SCALE TO CHECK SIZE OF PHOTOCOPY



Illus. 2-28. Cutting the 1¾-inch central hole in the Eccentric.



Illus. 2-29. Setting the centerline on the pattern square with the drill press table.

rod for the pilot drill whenever I do this kind of operation.

Bore a trial hole in a test piece if you already have made the eccentric. Otherwise, just cut the hole to the drawing dimension and make the eccentric to fit. If you have the eccentric, then bore a hole to give it a clearance of at least 1/64 inch, but not more than 1/32 inch. (See Illus. 2-28.)

Remove the work from the drill press, cut out the outer profile with a band saw, and sand it, but don't remove the paper pattern just yet. Square the center line of the pattern across the flat upper end of the part, and lay out the center of the hole for the actuating rod. Secure the part in a drill vise or clamp it to a block, setting the center line on the face of the pattern square with the drill press

table. (See Illus. 2-29.) Next, drill the rod hole. Now, remove the paper pattern, round the corners of the curved contour, and sand the part.

If you don't own a circle cutter, there are several other ways that you can make this part. A hole saw can be used; you will probably have to use a sanding drum to smooth the hole's surface. You can also saw out the circle with a jigsaw or even a coping saw, and drum-sand to the line. These loosely fitted parts do not need precise circles.

The eccentric is best made as a slice off a round rod. This produces a part with the end grain on its flat faces, and one that has the best chance for remaining circular when the humidity changes. If you don't own a lathe and can't get 1¾-inch rod, just cut a ⅝-inch-thick slab off the end of a piece of 1¾-inch-thick stock, lay out the circle, and saw and sand the slab to size. The least desirable alternative is to cut the disk from flat stock, preferably quarter-sawn.

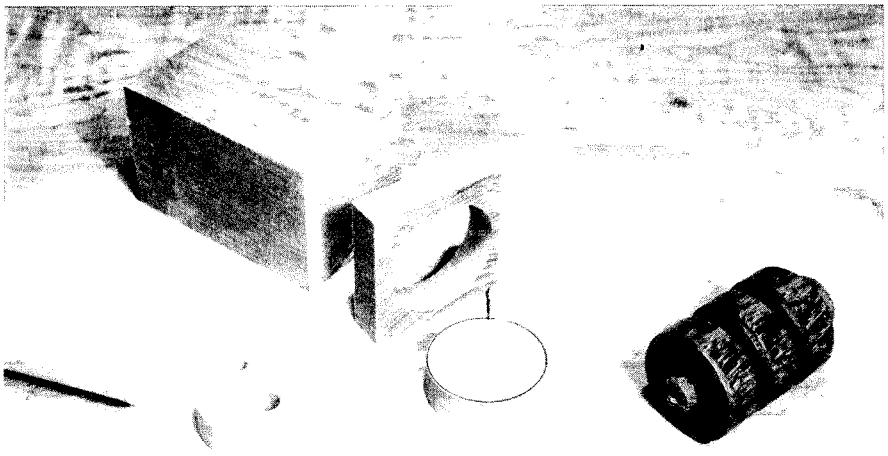
Fit the eccentric into the hole in the eccentric strap, allowing a 1/64-inch-minimum clearance. Illus. 2-30 shows parts cut from a rod and sawn from a slab, and a stack of three parts turned in a lathe.

Lay out and drill the axle and crank handle holes; remember that the handle hole goes only part of the way through. Hand-sand the outside diameter in the direction of rotation, sanding through 240-grit or finer paper. If you make the part on a lathe, a large chamfer on the outer face will enhance its appearance. Otherwise, hand-sand or file a small chamfer.

The rocker shaft is used on two of the five mechanisms, so you might consider making the simple block jig for drilling the holes. (See Illus. 2-32.) Illus. 2-31 shows all its dimensions. This jig is made like the axle jig. Hold the part against the stop pin in the jig, and drill the 21/64-inch hole. Put a short piece of 5/16-inch dowel through the jig and the part, and drill the ⅛-inch hole. This way both holes will be aligned, which does not make the part work any better, but certainly makes it look better. Chamfer both ends of the shaft to the drawing dimensions, using a lathe or by belt- or disk-sanding.

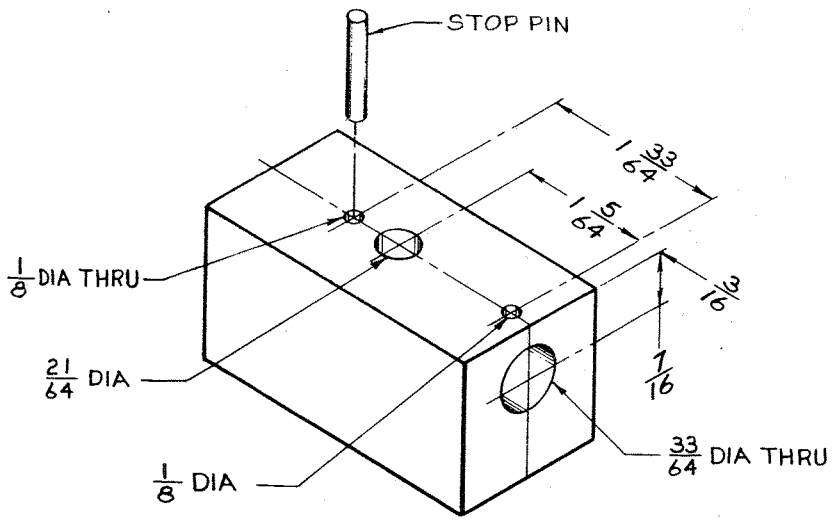
Make the actuating rod, the crank handle, and the axle. Drill the axle using the jig with its stop pin in hole number 2. (See Illus. 2-18.) Cut the long and short axle pins, and sand each so that you can use your thumb to push-fit it into its hole. Then make two small dowel pins for the back-to-base assembly.

Take one of the backplate blanks and, checking that the two dowel pin holes are on the bottom edge, lay out the two hole centers on the front face. Drill the axle hole to depth, and the rocker shaft hole all the way through. You probably don't own a 33/64-inch drill and won't want to buy one, so cut a 3-inch-long

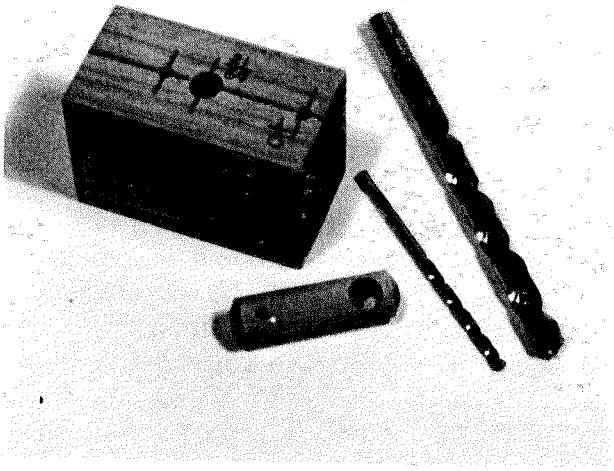


Illus. 2-30. Three methods of making an Eccentric. The piece on the left was cut from a rod. The piece in the middle was sawn from an end-grain slab. The three pieces on the right were turned on a lathe.

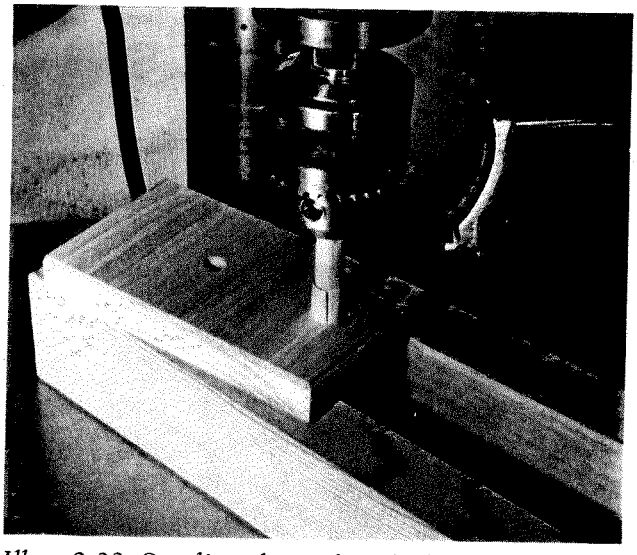
Illus. 2-31.



DRILL JIG FOR ROCKER SHAFT



Illus. 2-32. This drill jig is used to make the rocker shaft for the Eccentric and the Self-Conjugate Cam.



Illus. 2-33. Sanding the rocker-shaft hole to size.

slot on a ⅜-inch dowel, anchor a piece of 100-grit paper into the slot, and, turning the rod in the direction of rotation, wind on enough sandpaper to just fill the drilled hole. Run this tool at a fairly low speed, below 1,000 rpm, while oscillating it up and down. You will have the desired fit for your rocker shaft in a short time. (See Illus. 2-33.) This hole sander is a handy tool that I make in various sizes to smooth or enlarge holes where needed.

Lightly chamfer the large hole, front and back, and fine-sand the part; chamfer the corners last. Also, sand and chamfer one of the baseplates. Now, make a dry assembly of all the parts to check fits and clearances.

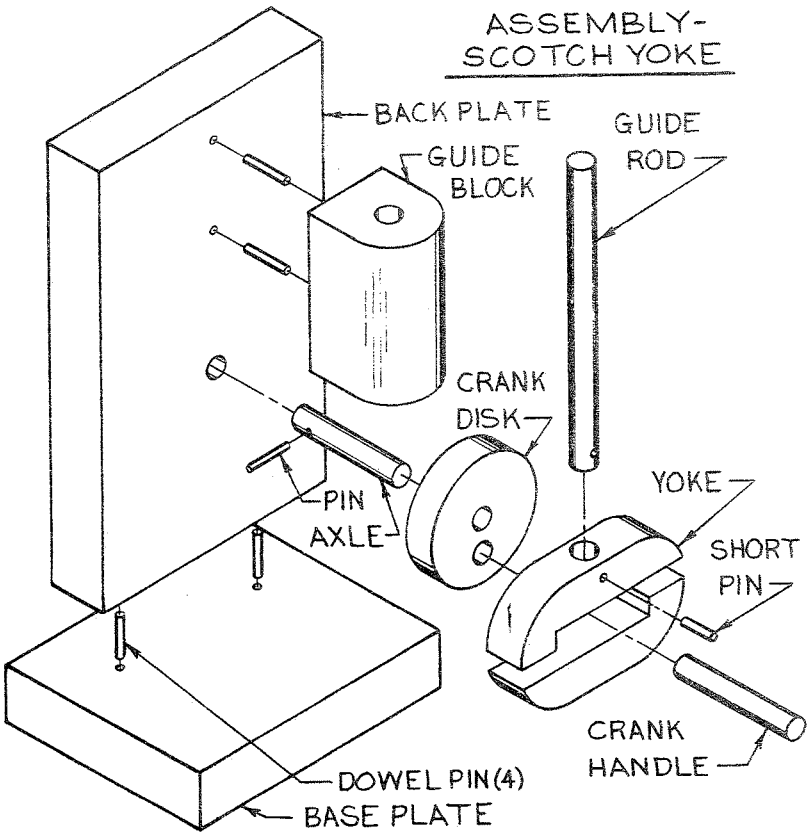
Assembling the Mechanism

Fine-sand all the parts, raising the grain if necessary. Glue the backplate to the baseplate, checking for squareness as outlined in the cam and follower instructions. Glue the actuating rod into the eccentric strap, checking against a flat surface to be sure that the rod is parallel to the face of the part. Put a long dowel into the axle pin hole to assist in keeping the hole level, and put the axle through the eccentric. Wipe a little glue around the inside of the axle hole, put the axle into the hole, and tap it in until the long rod is 1/32 inch from the face of the eccentric. Glue the crank handle into the eccentric. (See Illus. 2-24.)

Apply a finish to all the parts, and when they are dry, wax all the sliding surfaces. Place the eccentric on its axle and push in the shorter of the two axle pins, centering it neatly. Put the slide rod through its hole in the rocker shaft, and simultaneously slide the shaft into its hole and the eccentric strap onto the eccentric. Push in the long axle pin behind the plate. You can now try your mechanism and show it to the neighbors.

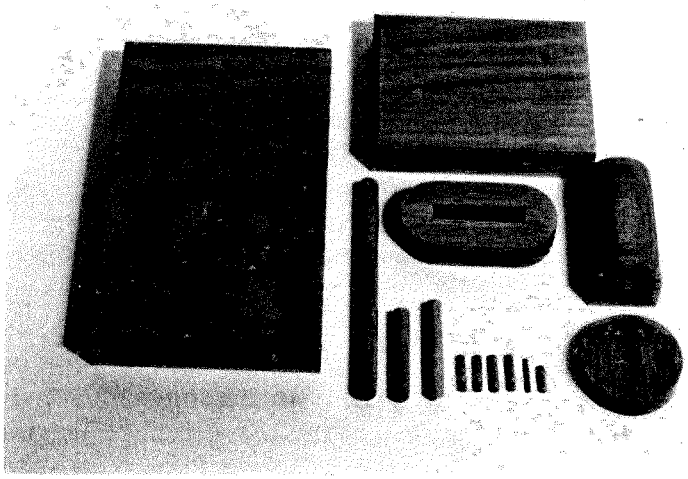
SCOTCH YOKE (ILLUS. 2-34–2-36)

The third unit in this group is an example of the pin-and-slot mechanism known to steam-engine enthusiasts as the Scotch Yoke. The use of this design eliminates the need for the conventional connecting rod found in most engines, and results in a very compact mechanism. Its somewhat greater mass limits the Scotch Yoke to slow-running applications, but it was used a great deal on small marine steam engines and on reciprocating pump drives. Various versions of this mechanism are often used in industrial equipment designs.

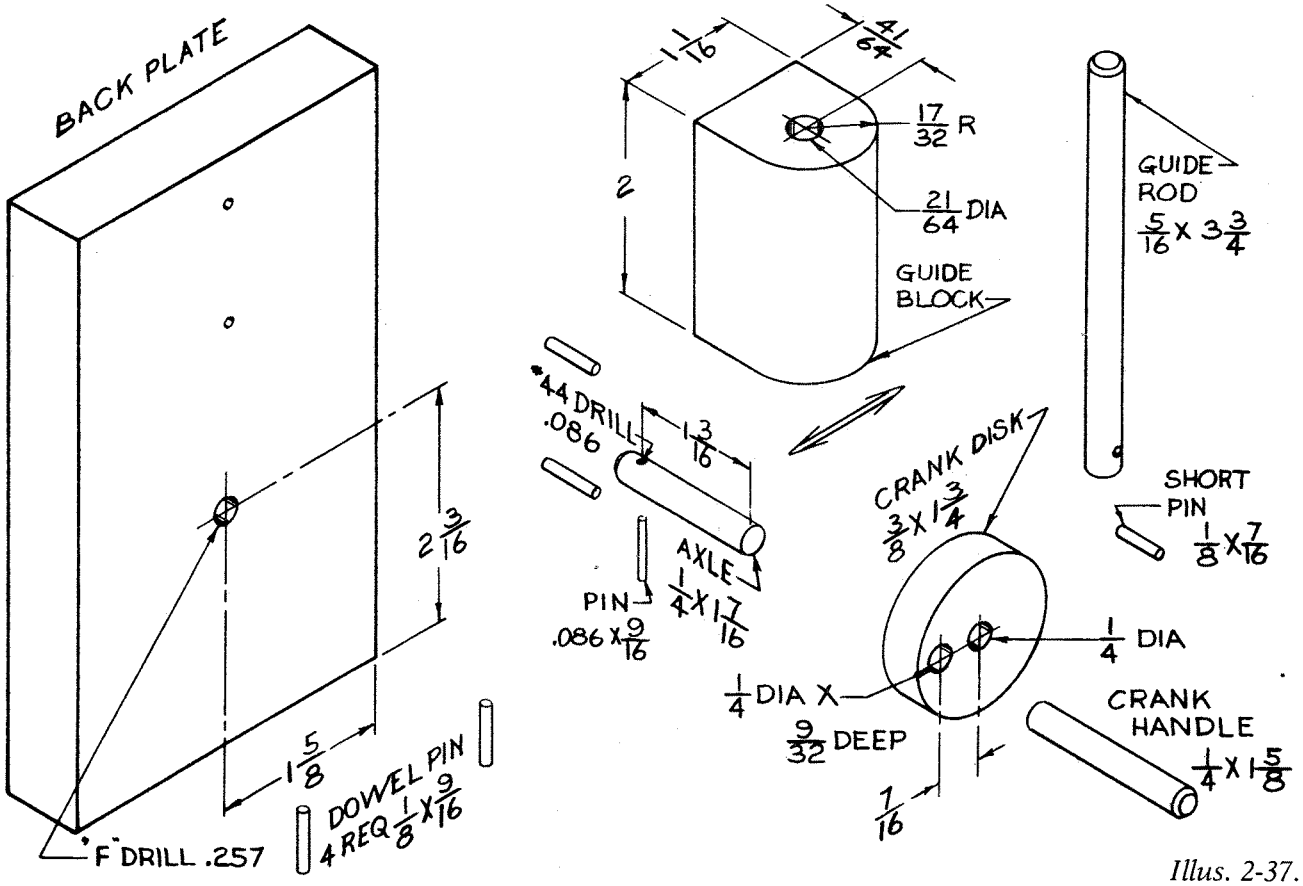


Illus. 2-34.

Illus. 2-35. The Scotch Yoke.



Illus. 2-36. All the parts for the Scotch Yoke.



Illus. 2-37.

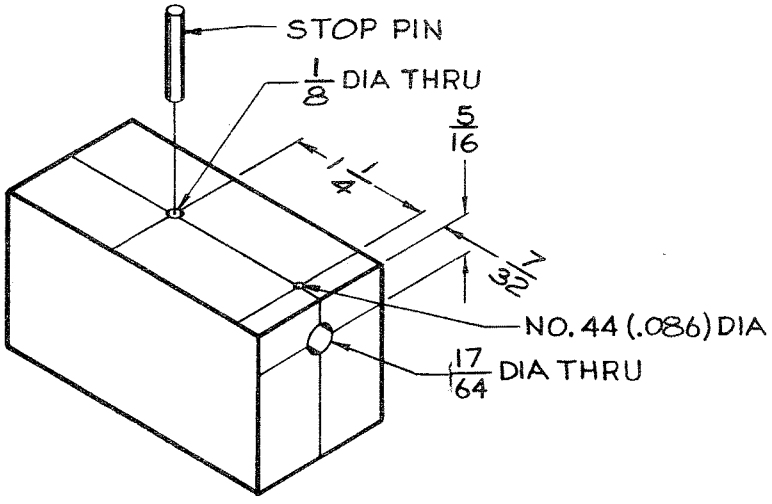
Making the Parts (Illus. 2-37)

The backplate has only a single axle hole and two small dowel pin holes in its front surface. It is important in this design that the axle fits properly into its bearing hole, so test your dowel stock to be sure that you have selected the best available size drill. A letter F drill drills a diameter of .257 inch, which is exactly halfway between ¼- and 17/64-inch, and usually makes a nice running fit for a ¼-inch-diameter rod. Holes for the two small dowel pins are located in both the backplate and the guide block by means of the flat drill jig shown in Illus. 2-40, which ensures proper placement of the block.

The guide block is made from a thick piece of stock whose grain must run across the part, as shown in Illus. 2-37. If you can't get thick material, glue two thinner pieces to make the block, but make certain that the joint does not run through the guide rod hole. Lay out the center and radius of the hole on each end of the block, drill halfway through from both ends using a ¼-inch brad-point drill, and finish by drilling with a 21/64-inch drill all the way through from one side. (See Illus. 2-41.) Check that this hole is parallel to the back face of the block. Saw and sand the radius to the line, fine-sanding by hand parallel to the direction of the grain. Center the block in the lines on the drill jig, clamp it in place, and drill the two dowel pin holes 5/16 inch deep.

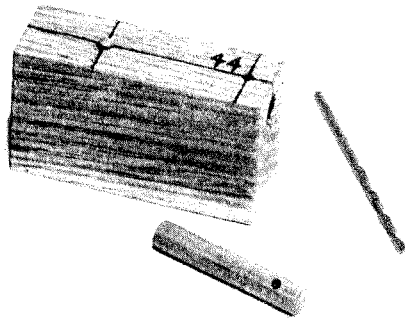
Machine the two halves of the yoke across the end of a wide board and cut them off after the work is completed. I use a wide enough piece of stock to get several sets of parts from it. Saw out the step and smooth its surface, if necessary, using a fine file. (See Illus. 2-43.) Do all necessary smoothing of this surface before slicing the block into individual parts, as these will be small pieces and difficult to work on. The depth of the step should be about 1/64 inch greater than the diameter of the dowel you will be using for the crank handle; more clearance won't matter, but too little may cause the device to bind at the top and bottom of the stroke, especially if your crankshaft is a little loose in its bearing.

When you are satisfied with the quality of this step, cut the end off the board (Illus. 2-44), set the rip fence the correct distance from the blade, and cut the piece into individual yoke parts (Illus. 2-45). Make sure that you use a push stick, as described in the equipment section. Don't get your fingers anywhere near the blade.

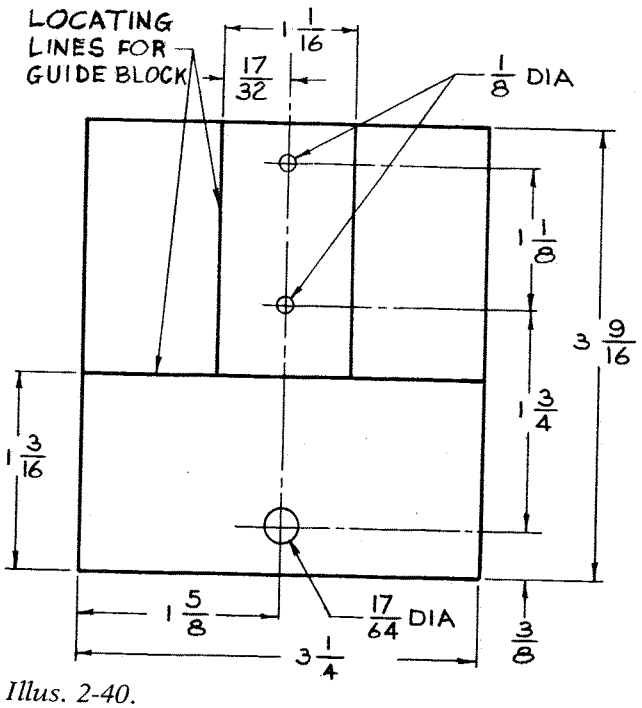


DRILL JIG FOR 1/4 INCH AXLE

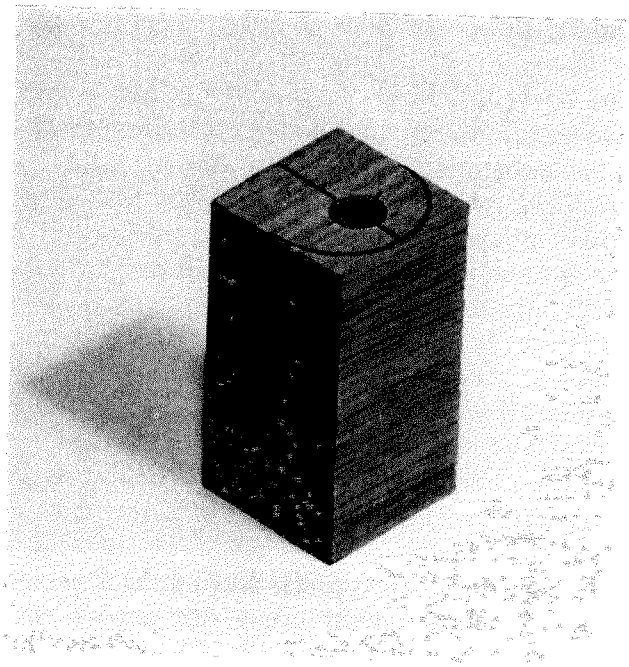
Illus. 2-38.



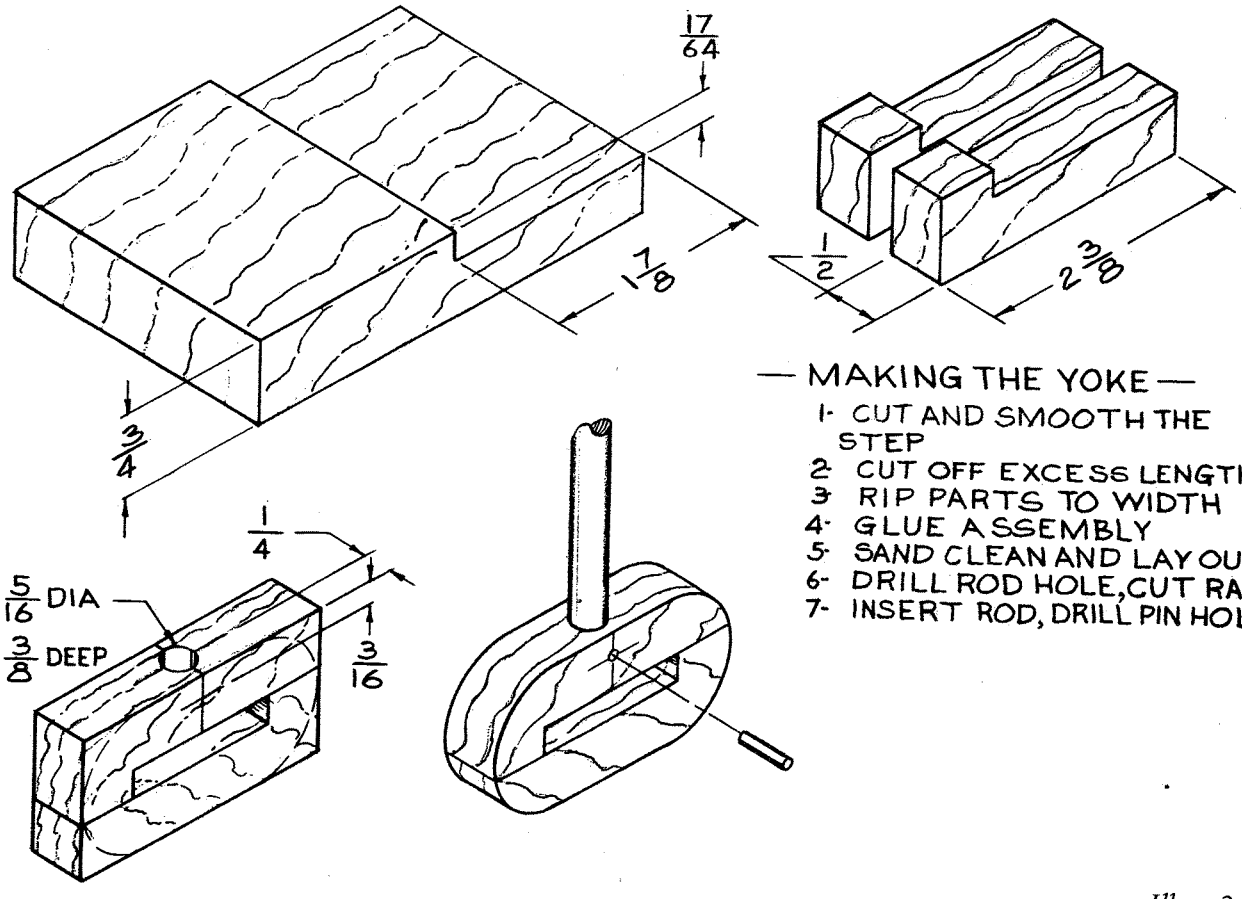
Illus. 2-39. This drill jig is used to drill a pin hole for a ¼-inch-diameter axle.



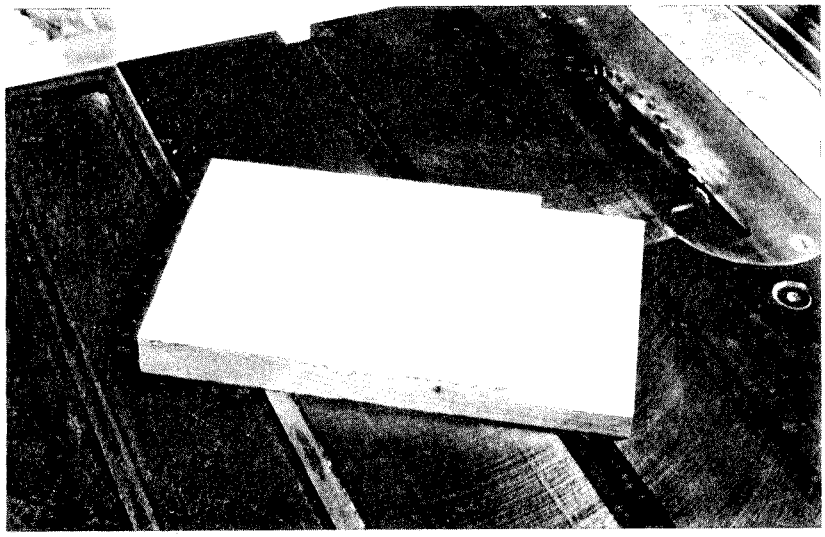
Illus. 2-40.



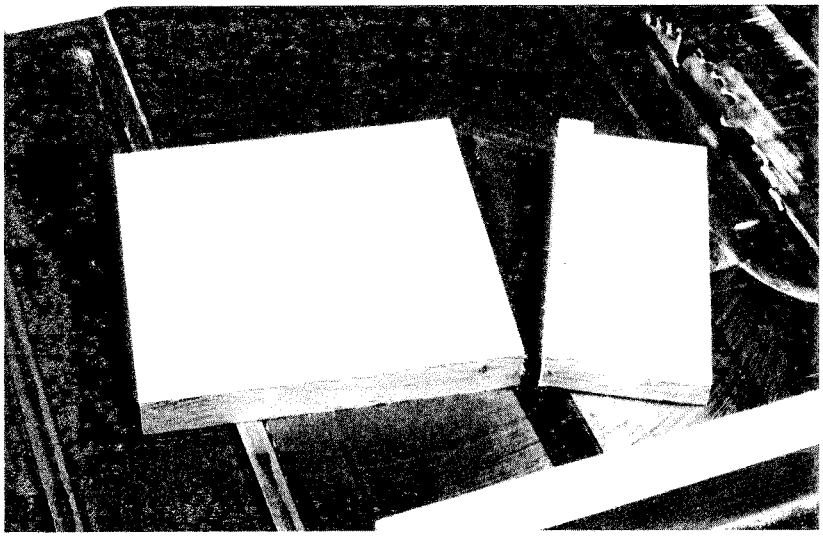
Illus. 2-41. The guide block with the hole drilled.



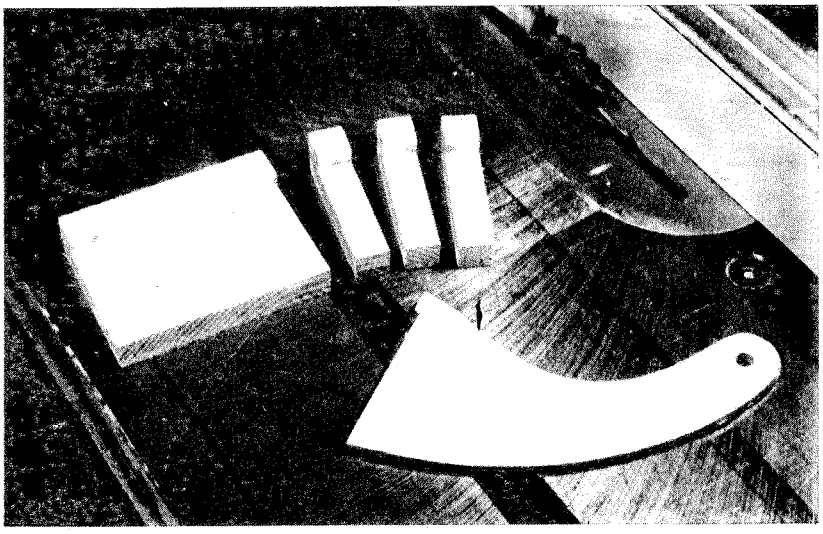
Illus. 2-42.



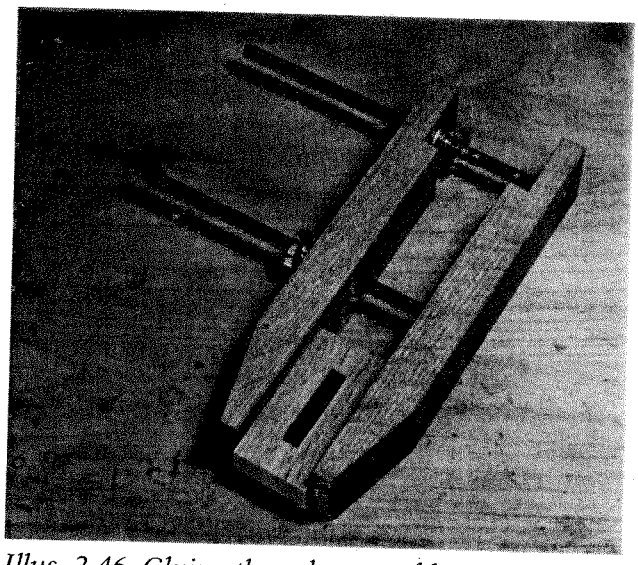
Illus. 2-43. The first step in making the yoke.



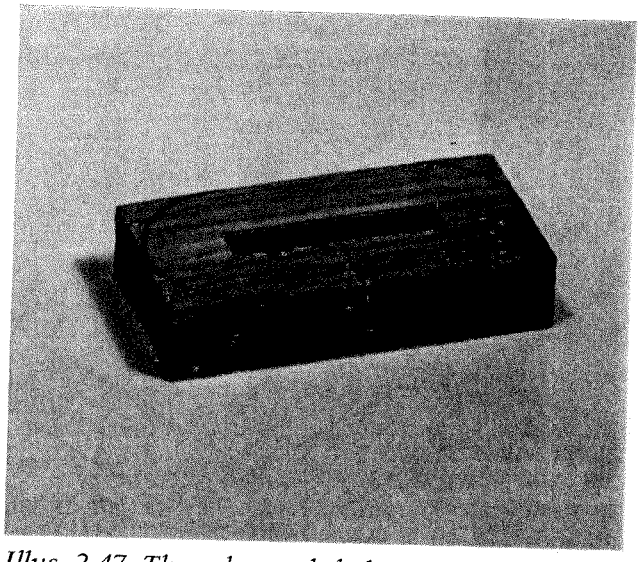
Illus. 2-44. The end of the blank cut off to the length of the finished parts.



Illus. 2-45. On the left is the blank. In the middle are the three parts cut off a blank. On the right is the push stick used to make this cut.



Illus. 2-46. Gluing the yoke assembly.

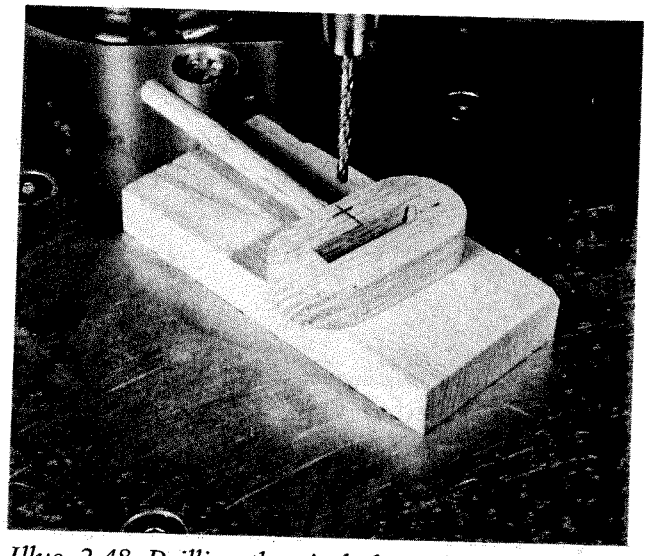


Illus. 2-47. The yoke sanded clean and laid out.

Check that the two yoke halves fit well together, and glue them as shown in Illus. 2-46, clamping lightly. Remove any squeezed-out glue from inside the yoke before it has a chance to harden. Let the glue get quite gummy, and use a narrow knife blade to remove it from the slot.

When the joints have dried, sand the two flat faces, lay out the two large radii, and saw and sand to shape. Lay out the center of the guide rod hole, and square its center line down the front face of the yoke. Mark the center of the pin hole. (See Illus. 2-47.) Check the actual size of your 5/16-inch dowel stock, and select a drill that will drill a hole into which it will fit snugly. Drill the guide rod hole in the yoke to the depth shown, taking care that the drill point doesn't break through into the slot. Sand the guide rod if necessary to achieve a snug fit, keeping in mind the fact that this part must be inserted last of all at assembly, and should not be hammered in.

Push the rod into the yoke, and drill the 1/8-inch pin hole through both parts. (See Illus. 2-48.) Remove the rod, without allowing it to turn, and make a pencil dot just below the pin hole. Now, make a pencil mark inside the 5/16-inch hole, and you will be able to assemble the parts in the same orientation as when they were drilled.



Illus. 2-48. Drilling the pin hole in the yoke and the rod.

Next, make the crank disk from 3/8-inch-thick stock. I use a circle cutter with its disk-cutting tool bit; the parts require only light finish-sanding. You can also saw out the part or turn it on the lathe. Lay out the crank handle hole and drill to depth, keeping the hole as square as possible with the face.

Make the remaining dowel parts: the crank handle, the axle, the two small pins, and the

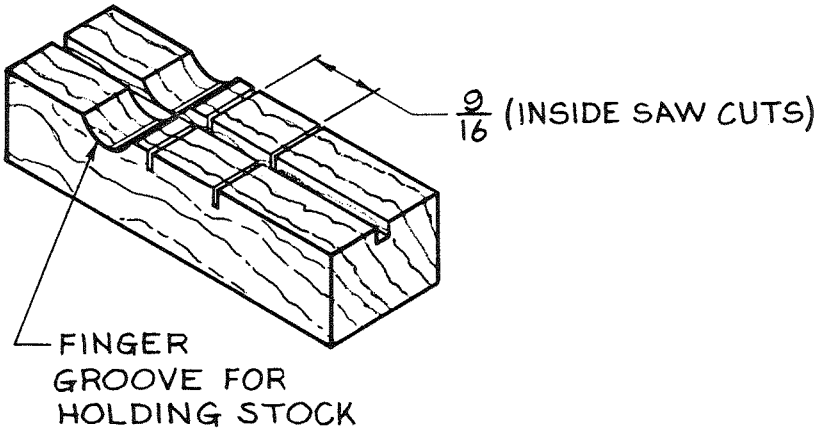
four 1/8 × 9/16-inch dowel pins. The axle should be a close fit in its bearing hole in the backplate. It must also fit snugly into the center hole of the crank disk, but not too tightly, because you have to adjust it while gluing the parts.

A hole must be drilled into the axle for its little pin. I use round toothpicks that are very close to .086 inch in diameter. This corresponds to the size of a number 44 drill, which is what I use to drill the axle. I shave the pins to size by pushing the toothpicks through a sharp-cornered hole drilled in a piece of steel with a number 44 drill. To make one or two pins, you can just sand them so that they can be push-fitted into their axles.

The drill jig for the axle hole, shown in Illus. 2-38 and 2-39, and the cutting jig for the small pins, shown in Illus. 2-49 and 2-50, can be used on several of the mechanisms if you want to make them. If you build these jigs now, they will make it easier to build the mechanisms later on.

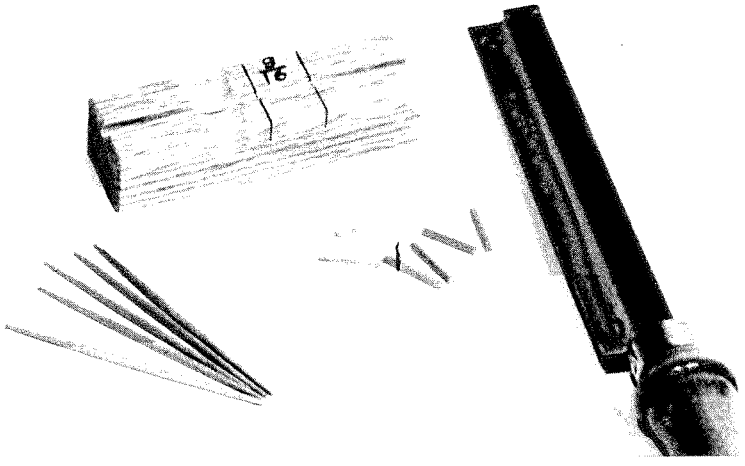
The retaining pin for the guide rod should be exactly 7/16 inch long or slightly shorter. If the pin is even a little too long, you may not be able to disassemble the mechanism. To disassemble the mechanism, position the crank handle at top center and drive in the short pin until the guide rod can be wiggled out of its hole. The yoke is now free, and the pin can be removed for reassembly. If you

Illus. 2-49.



JIG FOR CUTTING AXLE PINS
(FROM TOOTHPICKS)

Illus. 2-50. Axle-pin cutting jig.



make the pin too long, it will hit the backplate before it clears the guide rod, and you will have to resort to surgery to remove it.

When all parts are completed, assemble the components. Start with the axle-to-disk assembly. Working quickly, put a film of glue inside the axle hole in the disk and place the axle into the hole. Insert the axle through the backplate and immediately tap it into the disk until the small pin hole is about 1/64 inch from the backplate. (Now you see why these parts should not be fitted together too tightly before gluing.)

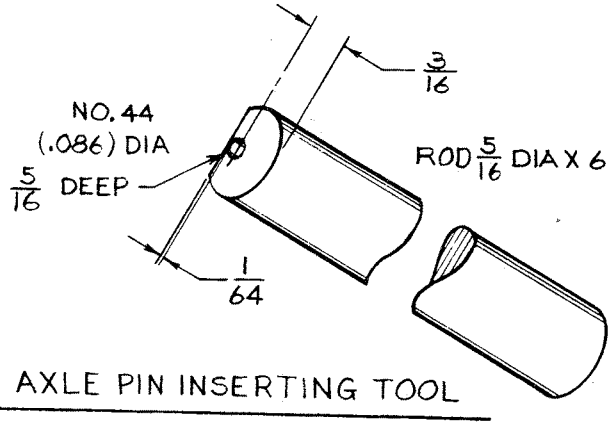
Let this joint dry. Then sand the end of the axle flush with the front of the disk and finish-sand the disk. If you pad the axle with thin cardboard and hold it in a drill chuck, you can sand the diameter and corners of the disk while it is rotating, which is a quick way to get a smooth, finish-sanded part. Glue the crank handle into its hole in the disk, and check carefully to be sure it is square to the surface in all directions.

Put two dowel pins into the holes in the backplate and set the guide block in place. Make a trial assembly of all parts, and test their operation. Make sure that there is clearance between the flat face of the yoke and the crank disk. There should be just enough clearance for the unit to move freely, but not enough for the yoke to swivel noticeably while operating. Try the yoke in both possible positions; sometimes the rod hole is not exactly centered in the thickness of the part.

You can remove excessive clearance by taking a little material off the flat face of the guide block. If any binding is detected, increase the clearance of the crank handle in the yoke. When everything suits you, glue the guide block to the backplate, and the back to the baseplate. When the glue has dried, finish and wax all the components. (See Illus. 2-36.)

Assembling the Mechanism

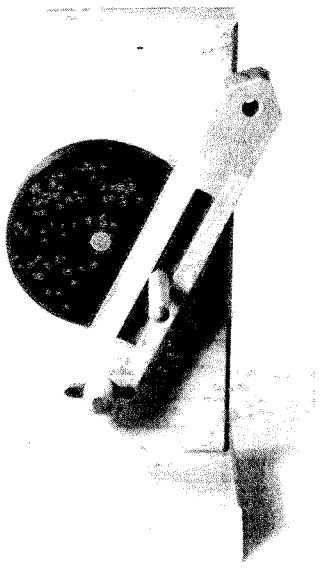
To assemble the mechanism, insert the crank assembly into the backplate and push in the axle pin. Illus. 2-51 and 2-52 show a tool you can make to do this more easily. Set the yoke on the crank handle and slide the guide rod down through its block and into the hole in the yoke, keeping the two pencil dots aligned. Line up the holes and push in the short pin. You have now completed another mechanism to add to your collection.



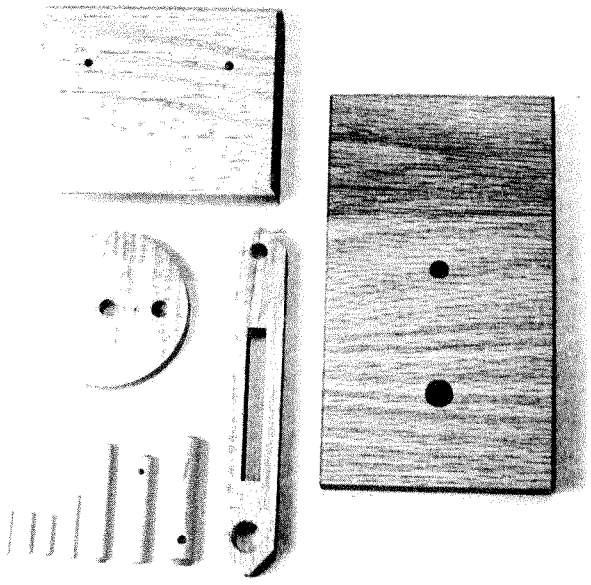
Illus. 2-51.

Illus. 2-52. Using the assembly tool to insert the small pin in the Scotch Yoke axle.

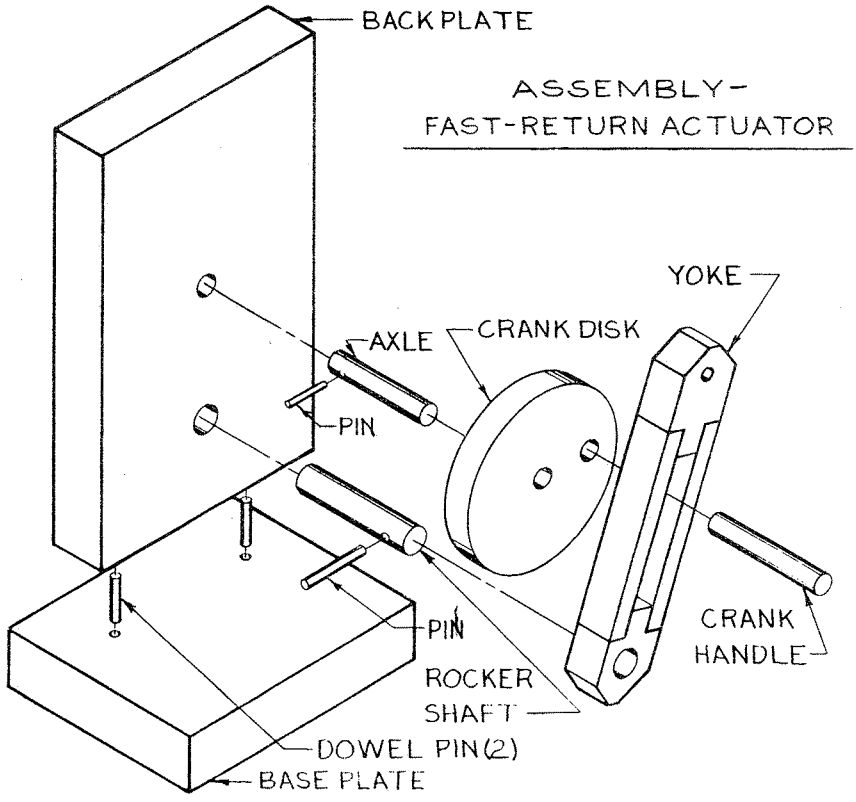
FAST-RETURN ACTUATOR



Illus. 2-53. The Fast-Return Actuator.



Illus. 2-54. The parts for the Fast-Return Actuator.



Illus. 2-55.

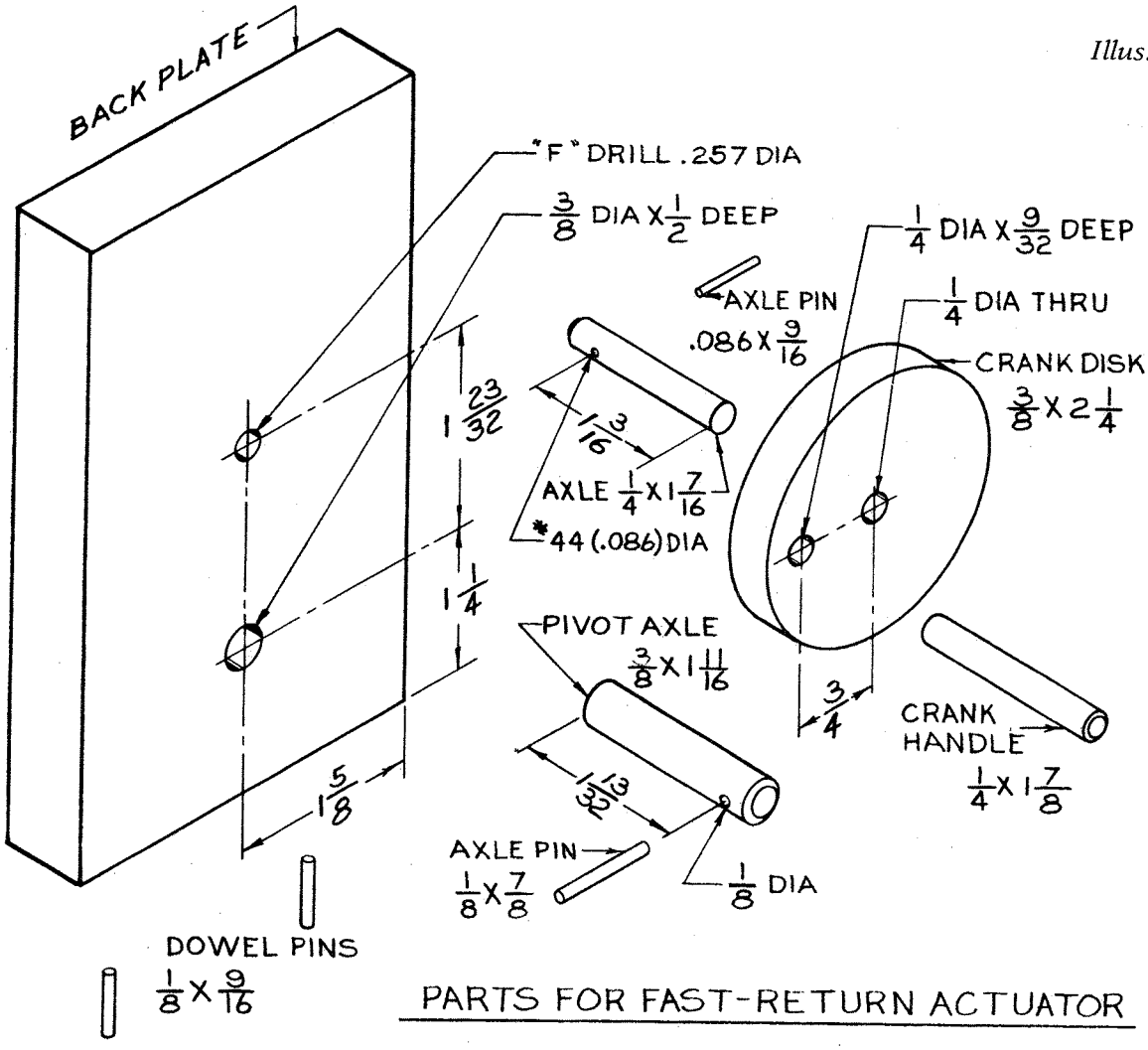
The fourth model in the series is another version of a pin-and-slot mechanism. It is used in applications where a slow, powerful working stroke is desired in combination with a rapid return stroke. This action can be found in metal shapers and slotters, reciprocating power saws, and other machinery having similar requirements.

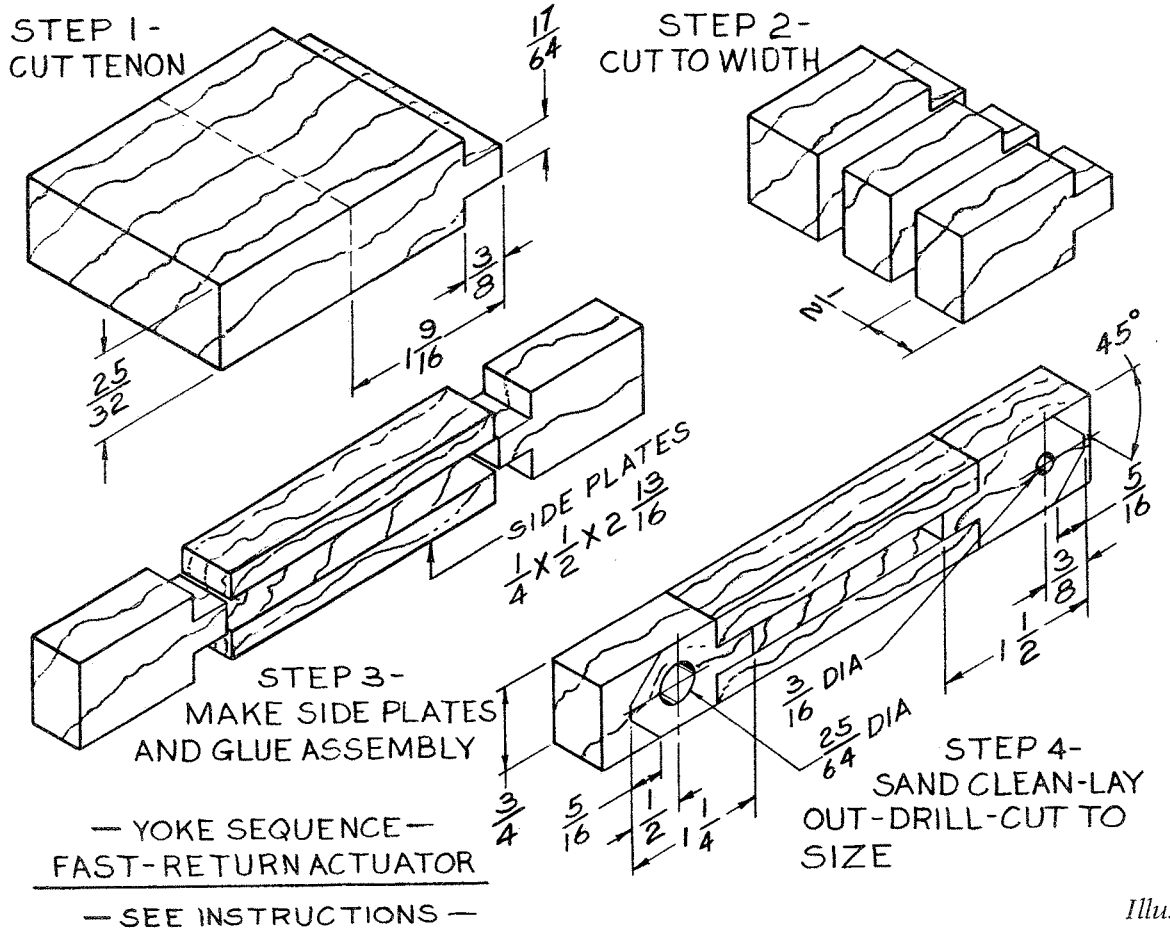
Making the Parts (Illus. 2-56)

The backplate of this device has an axle-bearing hole identical to the one in the Scotch yoke previously described, only the locations differ. The same instructions apply for fitting the axle, for making the crank disk, and for assembling these components, so I won't repeat them here, but will refer you to the preceding sections. The only new instructions for this unit will give details of the yoke and its pivot axle. (See Illus. 2-57.)

As the two end pieces of the yoke are very small, leave them attached to the larger block from which they are cut for as long as is possible. Plane a piece of material 25/32 inch thick, at least 1½ inches wide, and long enough to hold comfortably. Square one end of this piece and cut the central tenon across its width. If you flip the block to cut both sides at the same settings, the tenon should

Illus. 2-56.





Illus. 2-57.

be accurately centered. Make several cuts to get to the 17/64-inch dimension, as this dimension must not be cut undersize. If you have a problem at this stage, just saw off the tenon and try again.

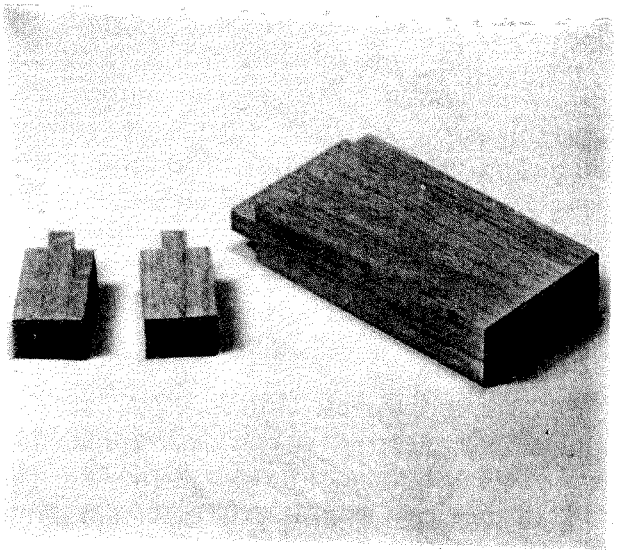
When the dimensions are satisfactory, saw off the end so that it's a little over 1½ inches long. Rip this end into two ½-inch-wide pieces. (See Illus. 2-58.) As it is a lot easier to work on a large part, don't do the remaining work on these pieces until the yoke assembly has been glued.

Plane a couple of pieces to ¼ × ½ inch for the yoke side plates, and cut each to a length of exactly 2 13/16 inches. Make a pencil mark to identify the outer face of each piece, and finish the other, inner face of each to a smooth surface.

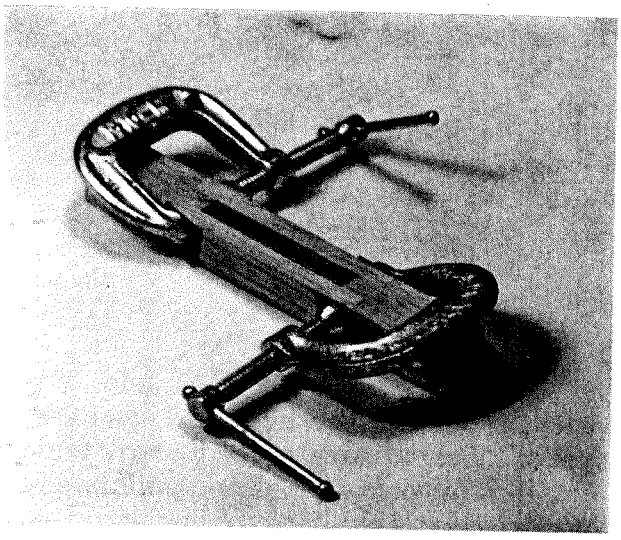
Make a trial assembly of the four parts to check for any unsightly gaps, and, if none exist, apply glue sparingly and assemble the yoke. Place squares of cardboard under a small clamp on each end, and pull the assembly up snug by applying a large clamp on the long axis of the part. Then tighten the small clamps and loosen the large one. (See Illus. 2-59.)

Remove any squeezed-out glue from inside the slot as explained in the section on the Scotch yoke. When the glue has dried, sand the part clean, lay out the holes and the corner angles, and drill and shape these details to complete the part. (See Illus. 2-60.)

In all but its length, the pivot axle is identical to the axles in the first two mechanisms. If you made the drill jig, place the stop pin in hole number 3 to drill this part. Sand the diameter of the pin so that it can be push-



Illus. 2-58. The blank and two yoke end pieces.

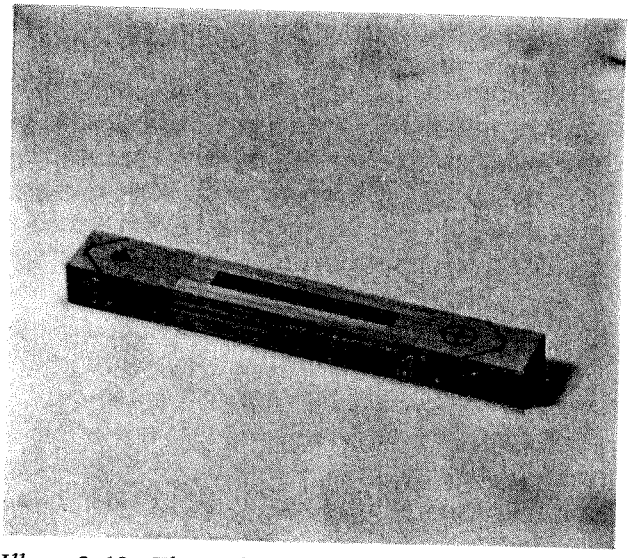


Illus. 2-59. Gluing together the yoke assembly.

fitted snugly into its hole in the backplate. Make the two axle pins and the two dowels for the back-to-base assembly.

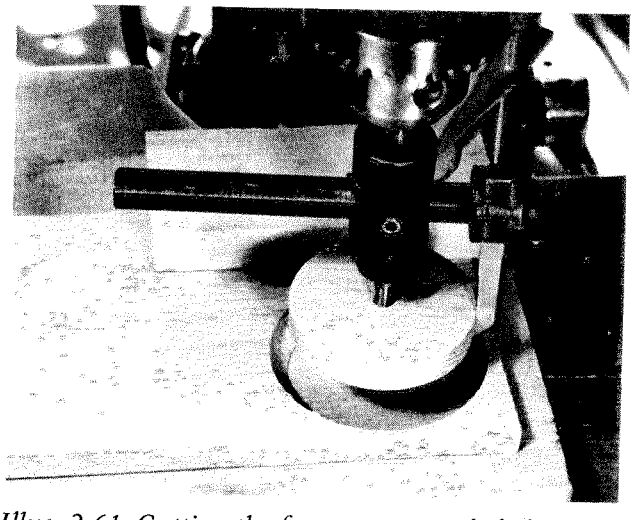
Assembling the Mechanism

You should by now have completed the crank disk assembly, which, as previously stated, is identical in all but a few dimensions to the one for the Scotch yoke. (See Illus. 2-61.) Proceeding with the assembly, insert the crank axle into its bearing hole in the back-

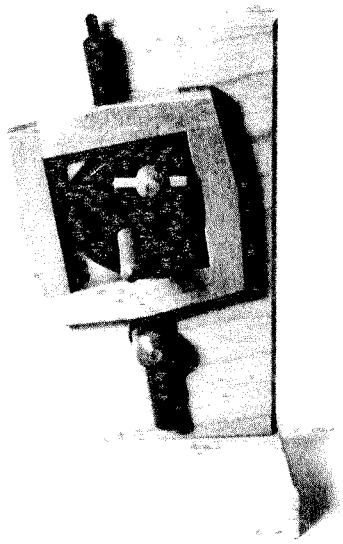


Illus. 2-60. The yoke laid out so that it can be trimmed to its final shape.

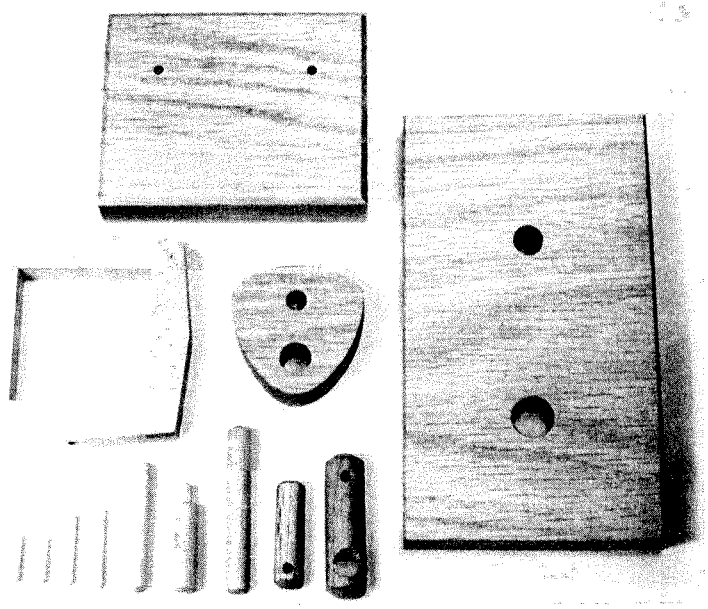
plate. Wipe a little glue around the inside of the pivot axle hole, and place the axle into the hole. Put the yoke in place, insert a long rod in the axle pin hole to help keep it level, and tap in the axle until the pin hole is about 1/32 inch from the yoke. Remove all loose parts and glue the back to the base. When it is dry, clean up the parts, apply a finish, and wax the moving surfaces. Assemble all the parts and push in the two axle pins. Try the mechanism. It is now complete and ready to display. (See Illus. 2-54.)



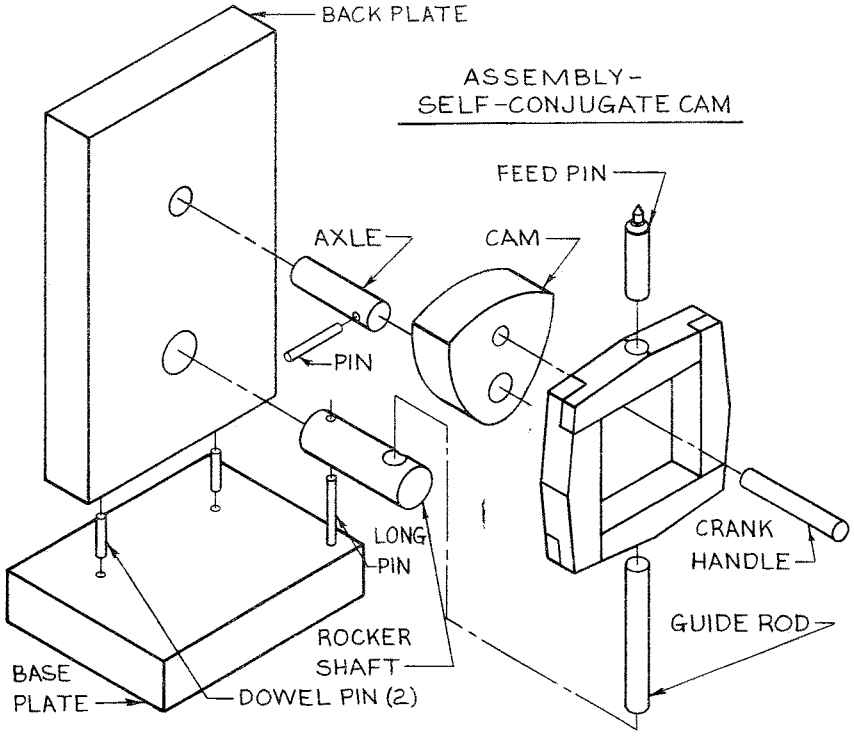
Illus. 2-61. Cutting the fast-return crank disk, using the circle cutter with disk-cutting bit.



Illus. 2-62. The Self-Conjugate Cam.



Illus. 2-63. The parts for the Self-Conjugate Cam.



Illus. 2-64.

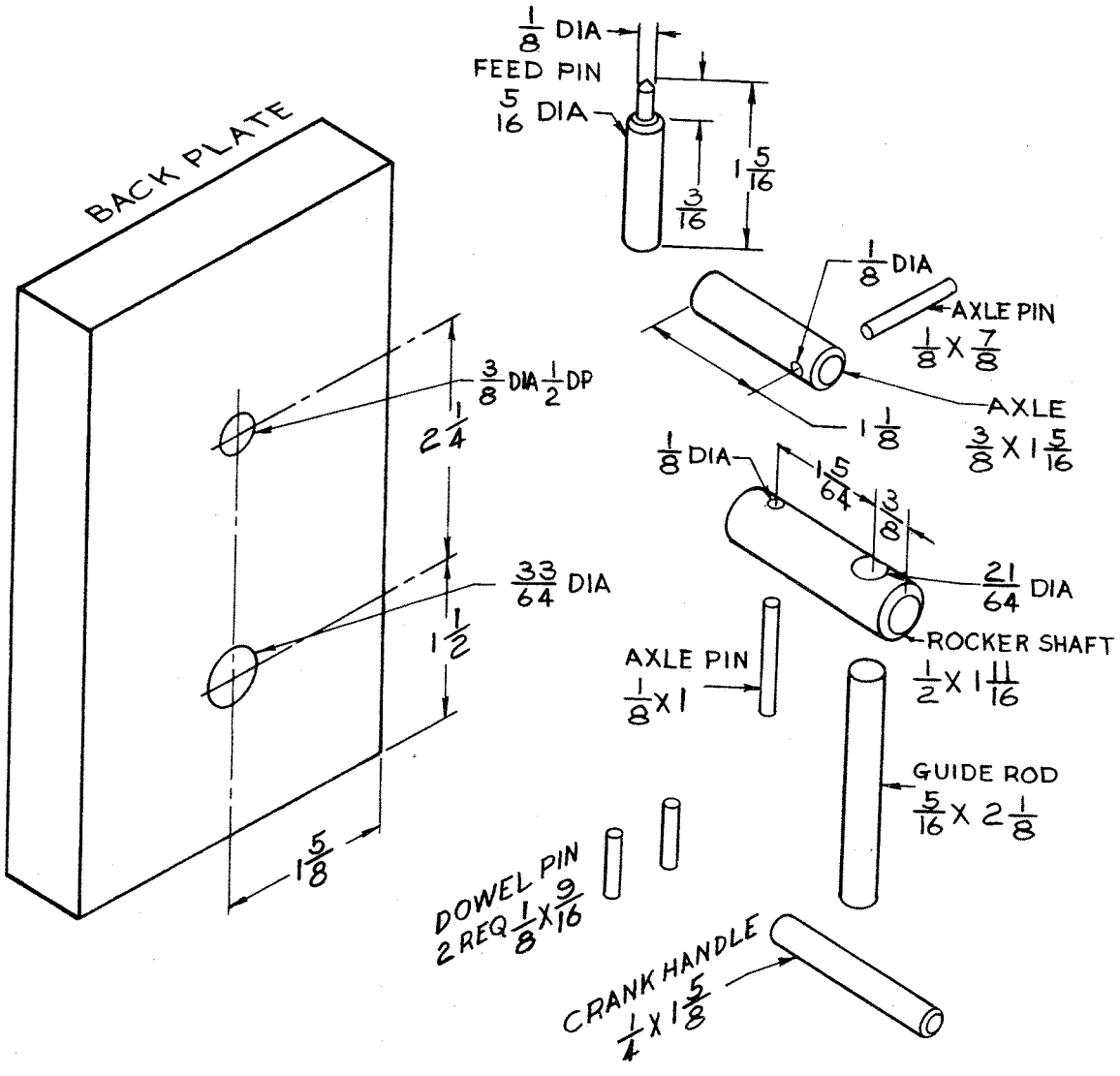
While the more common form of rotary cam requires an external force, such as a spring or gravity, to keep its follower in contact, the self-conjugate cam positively controls its follower, eliminating this dependence. A cam of this type can be operated in any desired position, and can rotate at high speed, with no possibility of "floating" of the follower that limits the speed of conventional designs.

This particular device is known as the Mitchell Motion, named for its inventor, and has been in use for many years for stepping film through motion-picture equipment. Its unusual action makes this an interesting display model.

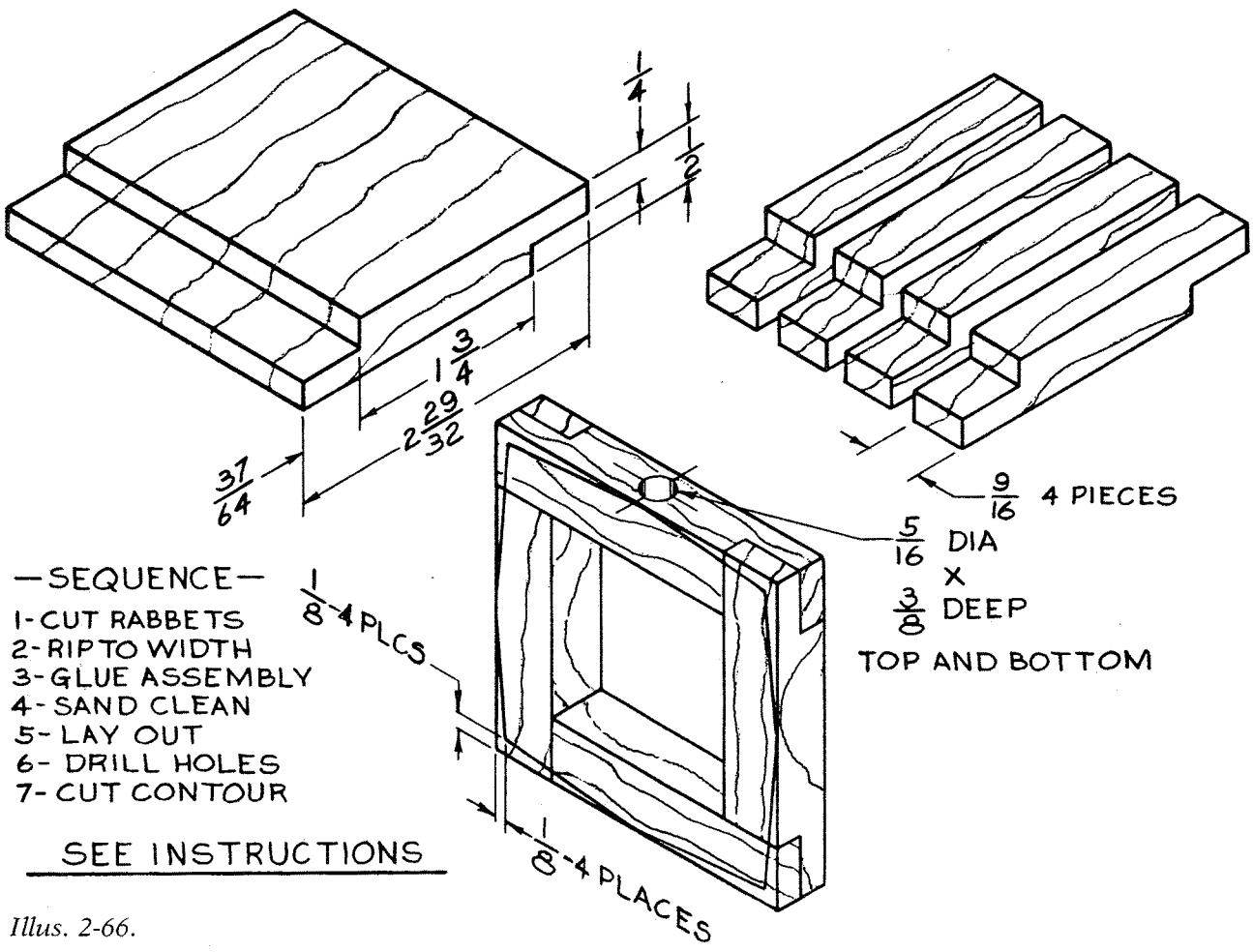
Making the Parts (Illus. 2-65)

In all but the hole layout, the backplate for this model is identical to the one for the eccentric, so review the instructions for that model. The cam axle and the rocker shaft are also exact duplicates of those on the eccentric. The only parts that are unique to this model are the cam and its follower yoke.

Make the yoke first, as it is much easier to fit the cam to it than the other way around. Plane a piece of straight-grained stock that's at least 3 inches wide to a thickness of ½ inch. Square one end, and cut off a piece 2 29/32 inches long.



Illus. 2-65.



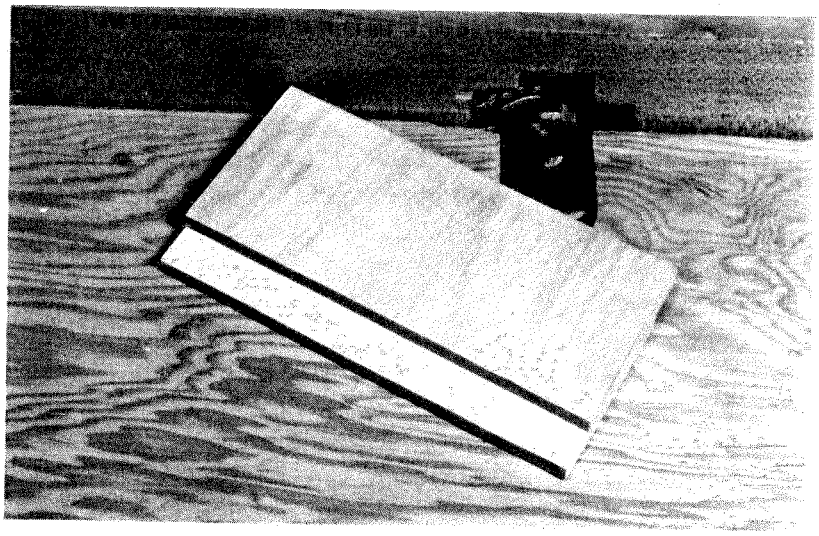
Illus. 2-66.

Now, cut the corner half-lap joints across both ends of the piece as shown in Illus. 2-66 and 2-67, making the cuts as close as possible to one-half the thickness of the stock. A table-mounted router is a good tool for cutting the half-lap joints, if you have one. Note that the joints are cut 1/64 inch too long, which gives some extra material to trim after gluing. When the half-lap joints are cut, rip the piece into four widths, as shown in Illus. 2-68.

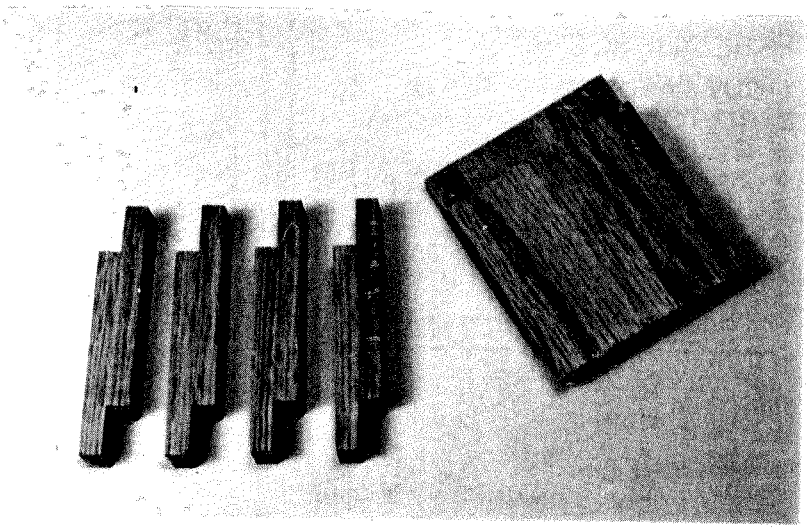
Temporarily assemble the yoke, and mark the outer face of each piece with a pencil. Don't omit this step, as it's very easy to assemble these parts backwards. Now, sand the inner face of each piece, and remove any fuzz or splintering from the joints. Apply glue sparingly and assemble the yoke, using one small clamp at each corner. (See Illus. 2-69.) Gently tighten these four clamps, apply a larger clamp alternately across the width and height to draw the joints snug, tighten the corner clamps, and allow the glue to dry, removing any excess from inside the yoke. When the glue is dry, flat-sand the two faces and trim the excess stock at the four corners.

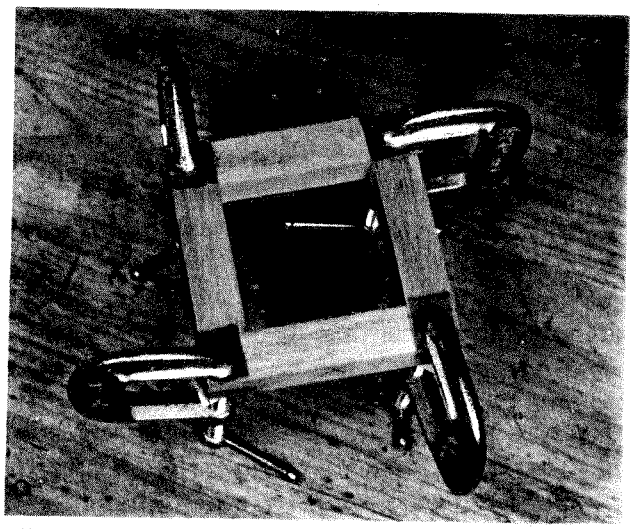
Lay out and drill the two holes for the guide rod and the feed pin, taking care that the drill point doesn't break through to the inside of the yoke. All that remains is to lay out the angled contours on the four sides and

Illus. 2-67. The yoke blank with half-lap joints cut on each end, on the router table.



Illus. 2-68. The four yoke sides cut from a blank.



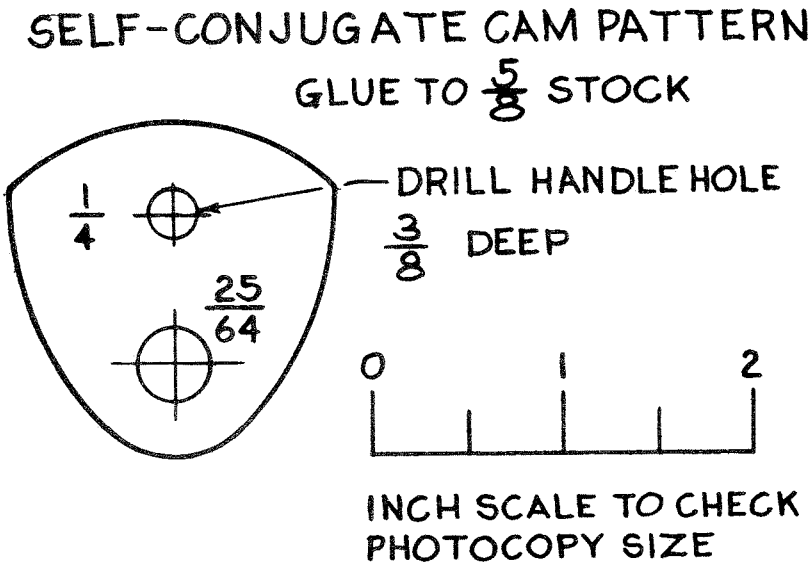


Illus. 2-69. Gluing together the yoke assembly.

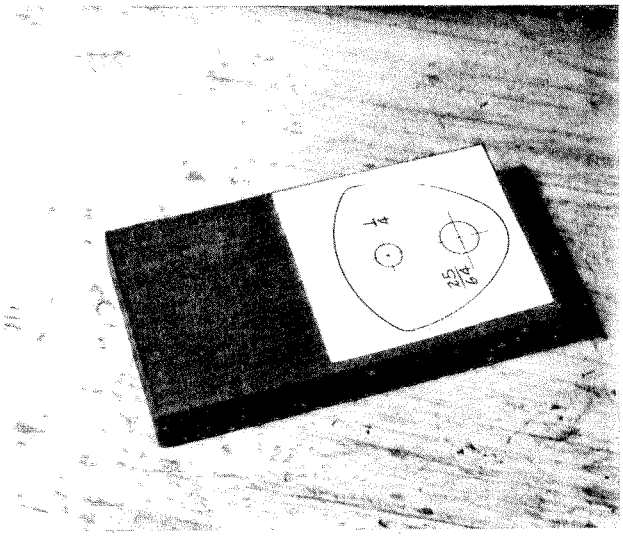
cut and sand to the lines. Finish-sand the part, lightly rounding all corners.

Having completed the follower yoke, now make the cam. Glue a photocopy of the cam pattern shown in Illus. 2-70 onto a piece of 5/8-inch-thick stock. (See Illus. 2-71.) Be sure to lay a steel ruler across the graduations on the photocopy to check the reproduction's size. Many photocopiers make oversized prints, and that won't do for this application.

Drill the axle and handle holes, and saw the part to its outline with a band saw. Sand carefully to the line, and test the fit in the yoke. Allow at least 1/64-inch clearance at all points of rotation, and more if you are working in a very dry environment. I once made a



Illus. 2-70.



Illus. 2-71. The cam pattern glued to a blank.

motor-driven display model that locked solid when the West-Coast-winter humidity took effect. The cam should measure exactly the same at any two diametrically opposed points around its contour when checked with a caliper. Hand-sand the contour in the direction of rotation, finishing with 240-grit or finer abrasive.

Cut the guide rod from a piece of 5/16-inch dowel, and sand and fit it into one of the holes in the yoke. Glue the rod in place, checking its parallelism as explained in the instructions for the preceding designs.

Make the feed pin, and glue it into the remaining hole in the yoke. The small, turned end section is nonfunctional in this model, so you can leave it at its full diameter if you don't have a lathe.

The remaining parts are the handle, the two axle pins, and the two small dowel pins, all of which are identical to those in earlier designs. (See Illus. 2-63.) Glue the handle into the cam, and then glue the axle into the backplate, tapping it in until its pin hole is just clear of the cam. Review this procedure in the cam and follower instructions, if necessary.

Assemble the back to the baseplate, clean up the parts, and apply a finish. When the finish is dry, wax the bearing surfaces and assemble the model. The action of this mechanism will intrigue almost everyone.

If you made all five models, you now have an interesting and unique set of wooden mechanisms. Have fun with them.

CHAPTER 3

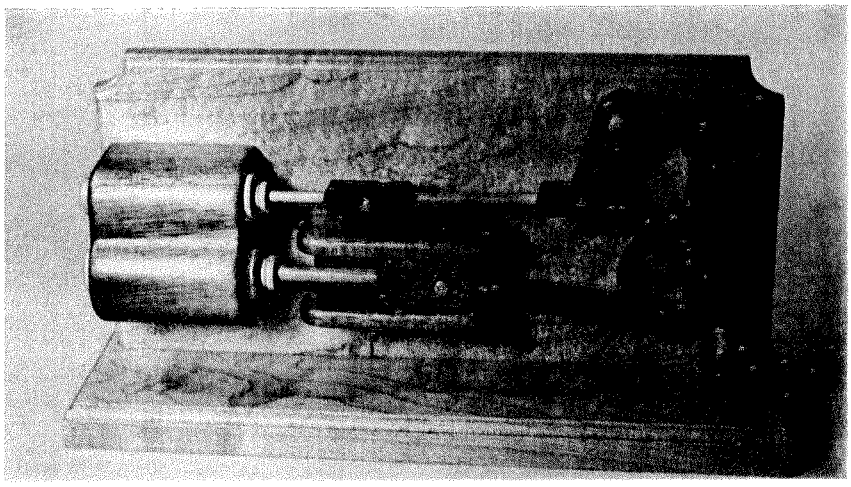
Stationary Steam Engine

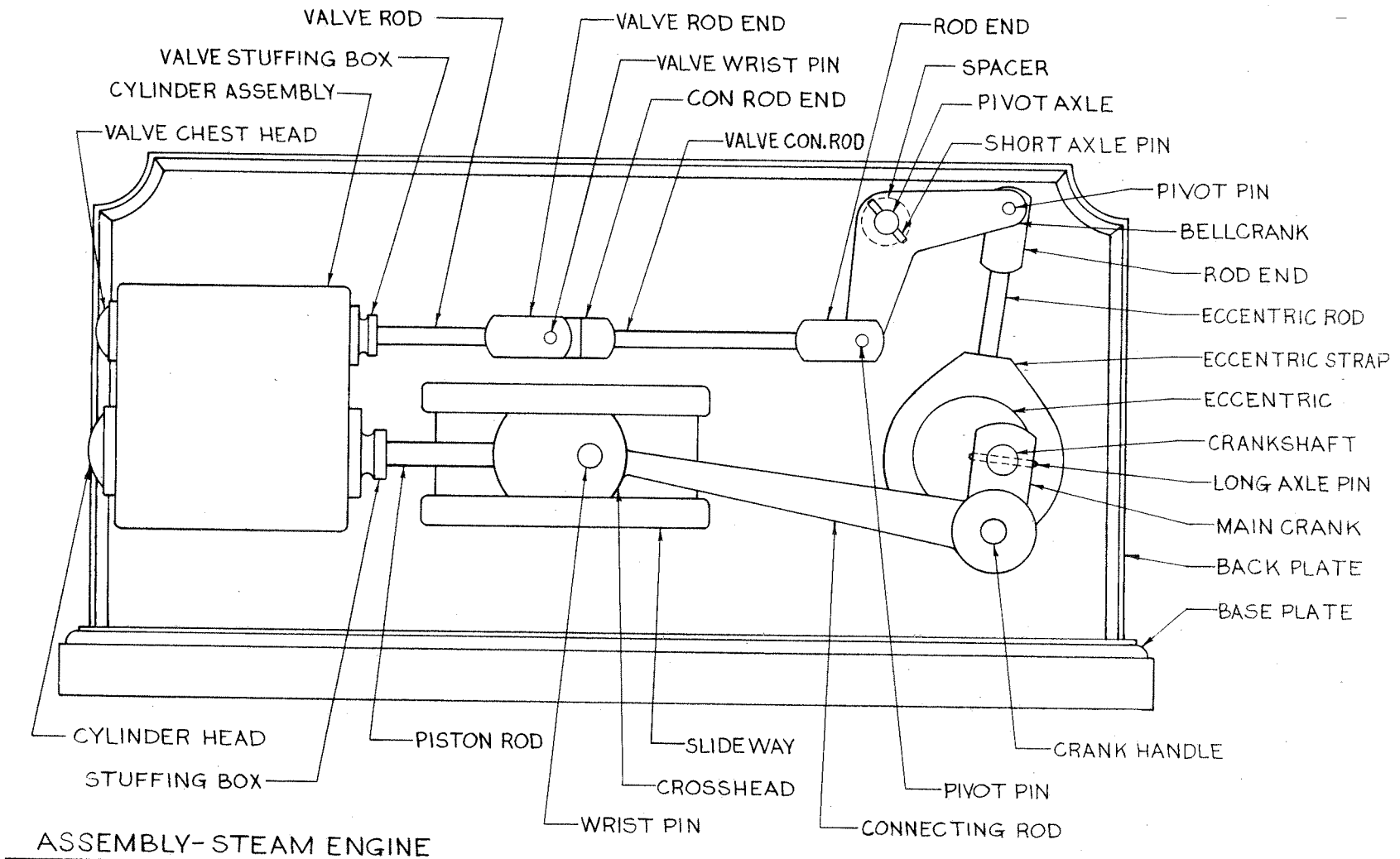
This is a model of a type of engine that was in common use until the middle of the twentieth century. I saw large versions of this engine operating in 1946, and a few are still in daily service in the United States. Since a steam boiler can be designed to be heated by any locally available fuel, such engines are ideal for use in remote areas, where they can still be found. Because of its many visible moving parts, the steam engine remains a perpetual favorite, making this model a desirable project.

HOW THE MECHANISM WORKS

A sliding valve above the steam cylinder is actuated by an eccentric on the crankshaft. This valve admits steam pressure at the end of each stroke, to the side of the cylinder that the piston is approaching, while simultaneously admitting the steam from the other side of the cylinder to the exhaust port. As both "in" and "out" strokes of the piston deliver power to the crankshaft, this is known as a "double-acting" engine.

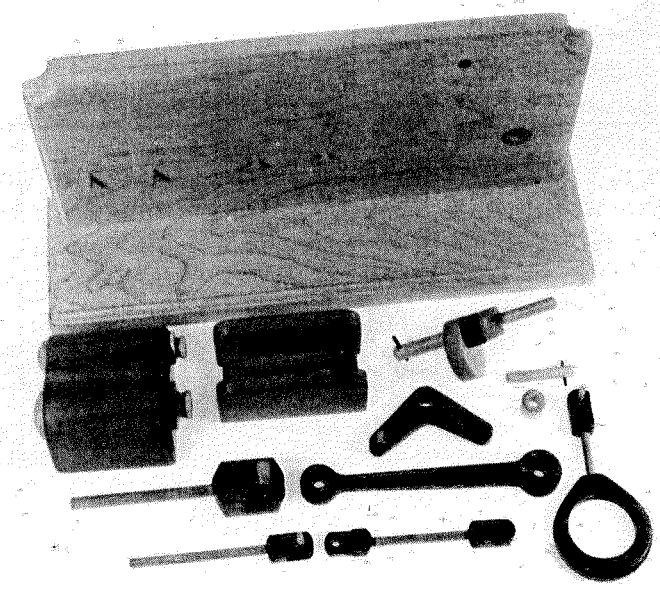
Illus. 3-1. The Stationary Steam Engine.





ASSEMBLY- STEAM ENGINE

Illus. 3-2.



Illus. 3-3. All the parts for the Stationary Steam Engine.

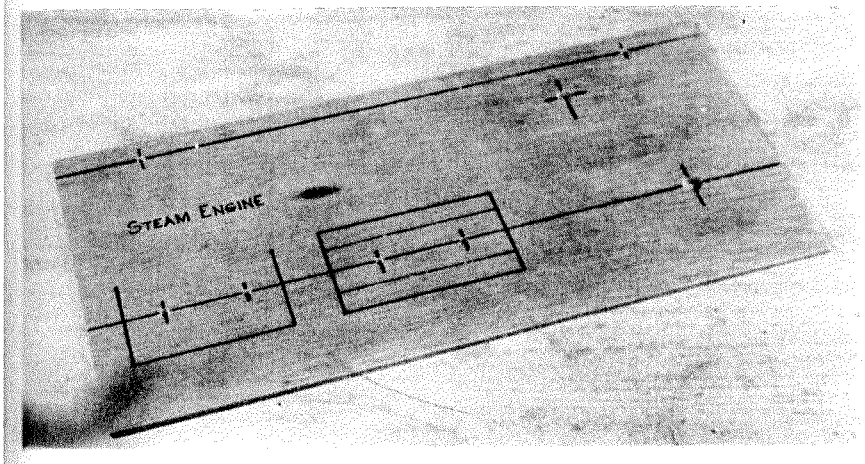
BUILDING THE MECHANISM

You should have built some of the models in the preceding chapter before attempting this project. This model is not recommended for beginners. There are many small parts that must be properly made and fitted, so follow the instructions closely unless you are experienced with small work.

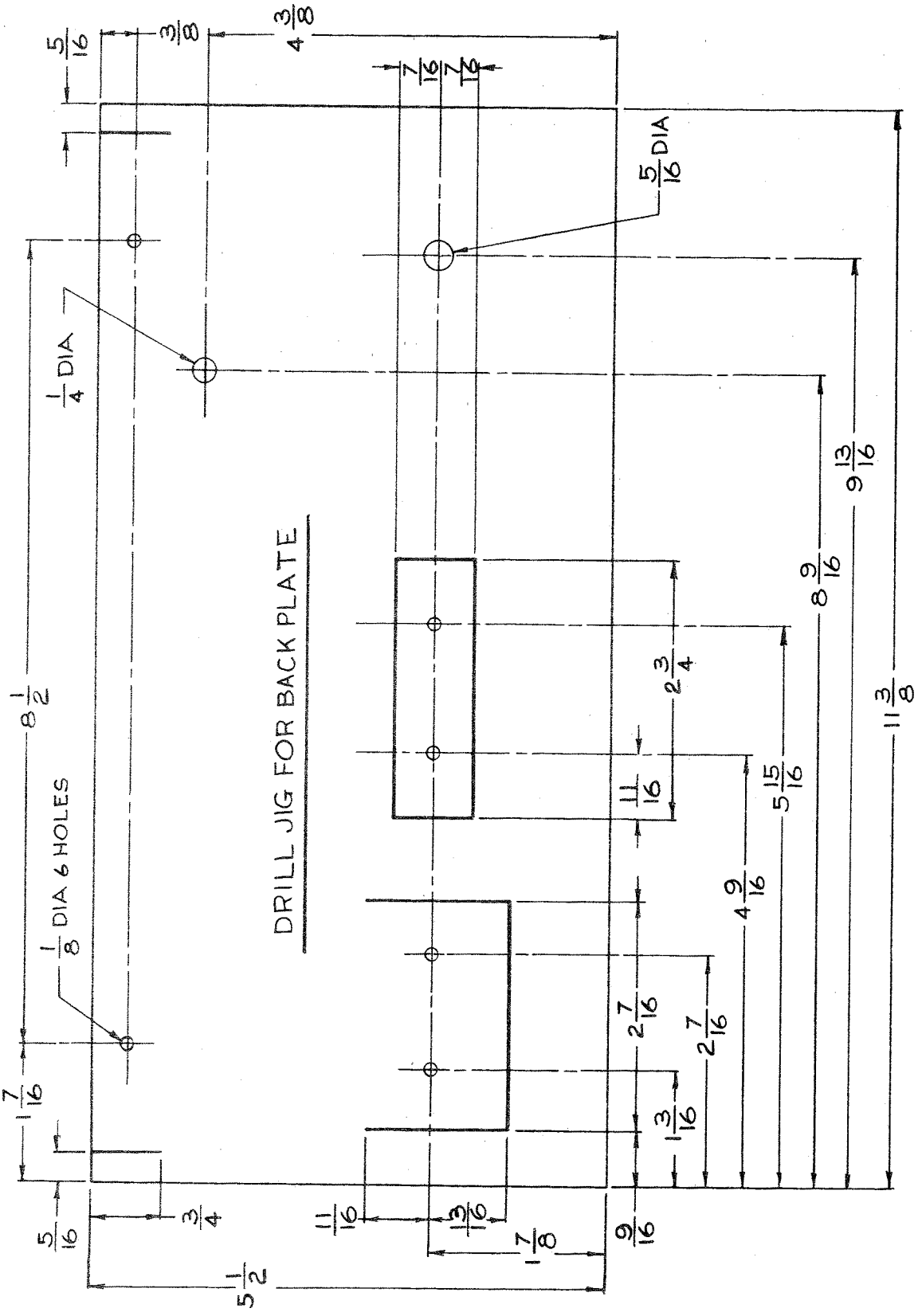
DRILL JIG

As good alignment of the many components is essential for a smoothly operating engine, you should first make the drill jig shown in Illus. 3-4 and 3-5. This tool locates all holes in the backplate and its mating parts, including dowel holes for the back-to-base assembly.

Square up a piece of hardboard or plywood that is ⅛ to ¼ inch thick to the dimensions indicated in Illus. 3-5. Make a very careful layout; then check the dimensions again. If the dimensions are correct, drill the holes as shown. When you have made the jig, start on the actual components of the model.



Illus. 3-4. The drill jig.


DRILL JIG FOR BACK PLATE
5/16
3/8
4 3/8
7/16
7/16
5/16 DIA
1/4 DIA
1/8 DIA 6 HOLES
8 1/2
9 13/16
8 9/16
11 3/8
2 3/4
11/16
5 15/16
4 9/16
2 7/16
2 7/16
1 3/16
1 7/16
5/16
3/4
11/16
3/16
1 7/8
9/16
5 1/2

Illus. 3-5.

MAKING THE PARTS

Backplate and Baseplate (Illus. 3-6 and 3-7)

Select for these parts a neutral-colored wood that does not have a prominent grain pattern, to best show off the moving parts. Joint and plane the material to its proper thickness. Cut the baseplate to its finished size. Before doing the same thing to the backplate, decide if you want to make the coves on the upper corners and the quarter-round bead. These decorative cuts are not essential, so you can omit them if you do not have the equipment for this work. If you decide to omit them, cut the backplate to its finished size. If, however, you want to include them, do the following:

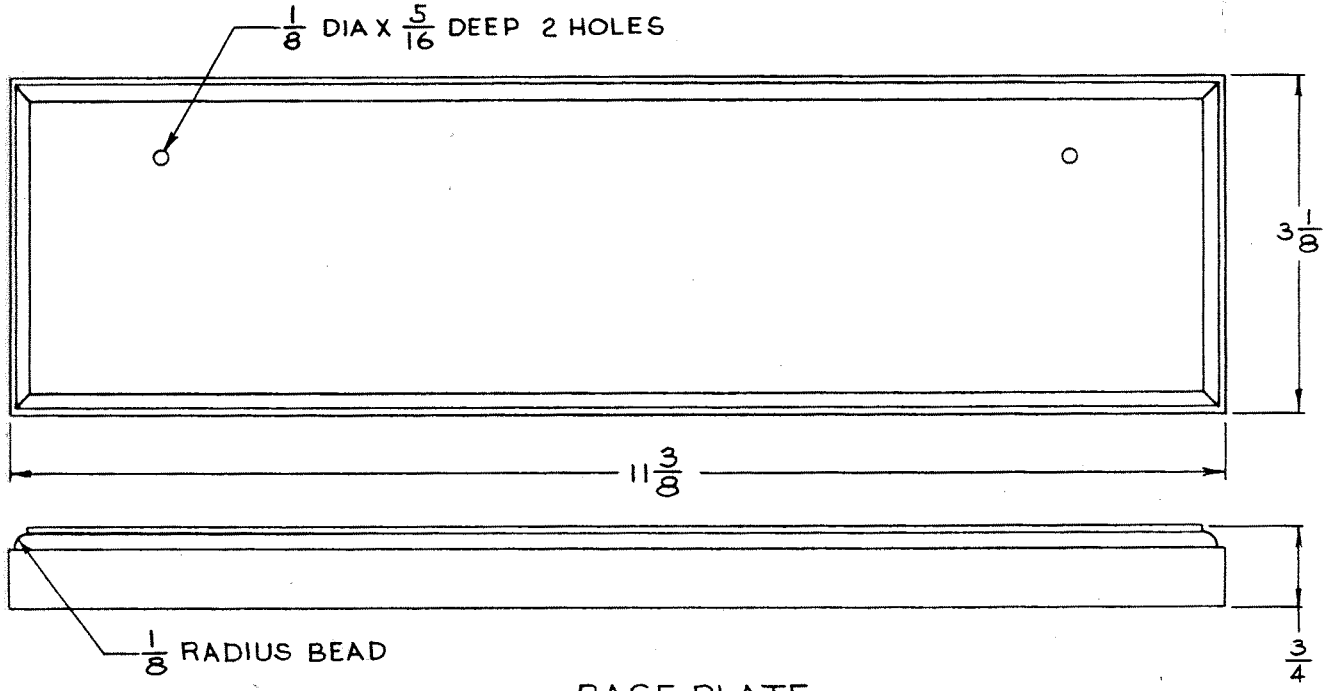
1. Cut the blank about ⅜ inch longer and ¼ inch wider than its final dimensions. Lay out the length, width, and the cove radii, dividing the extra material equally all around. (See Illus. 3-8.)

2. Make the cove cuts with a band saw, and sand the coves to the lines, using a small drum sander. You can finish-sand the cuts by using 240-grit garnet paper on a split dowel, running in the drill press.

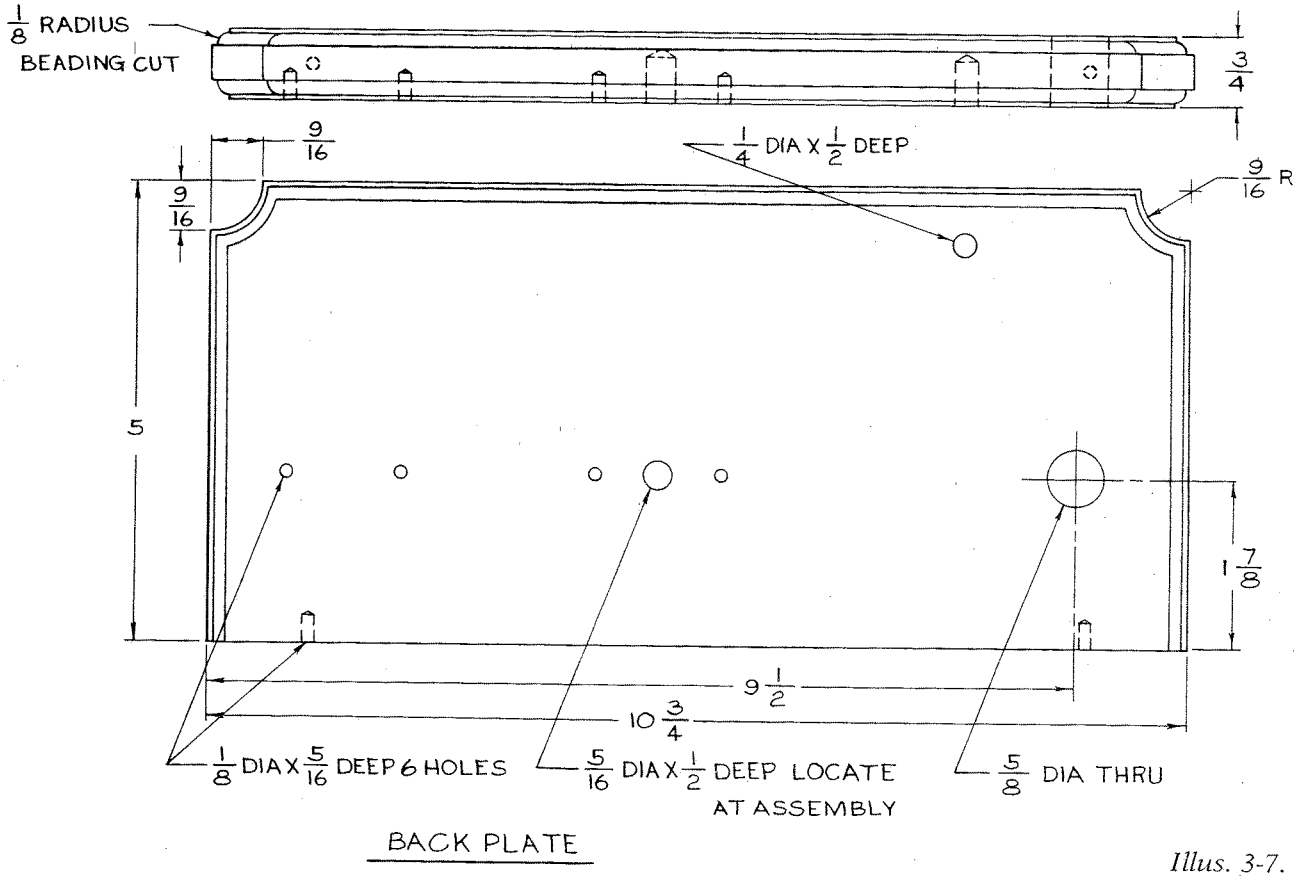
3. With a steel square and a marking knife or other blade, score the cross-grained end lines deeply all around the block. This will help prevent splintering when you trim the block to its finished length. (See Illus. 3-9.)

4. Flat-sand the two faces of the part with 240-grit paper. It is generally considered good practice to do all cutting before any sanding, but as sanding after small mouldings are cut will often destroy the sharpness of detail, I make this compromise, and accept the possible wear on the cutter from embedded abrasive grains.

5. Set up a table-mounted router with a ⅛-inch-radius beading bit. Adjust the height of the cutter above the table so that the two shoulders of the bead are cut exactly equal. Make test cuts on scrap material, until you

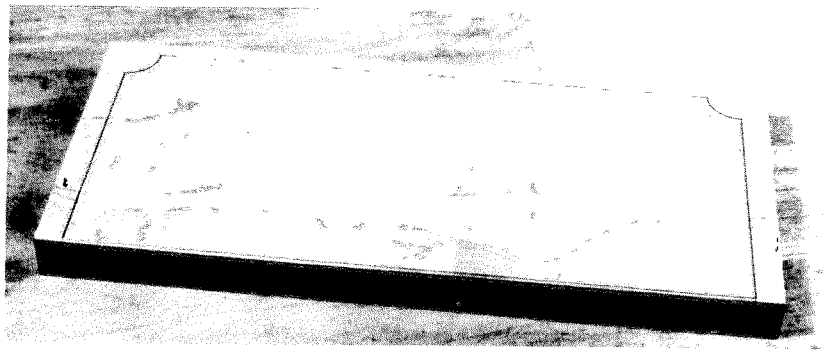


Illus. 3-6.



Illus. 3-7.

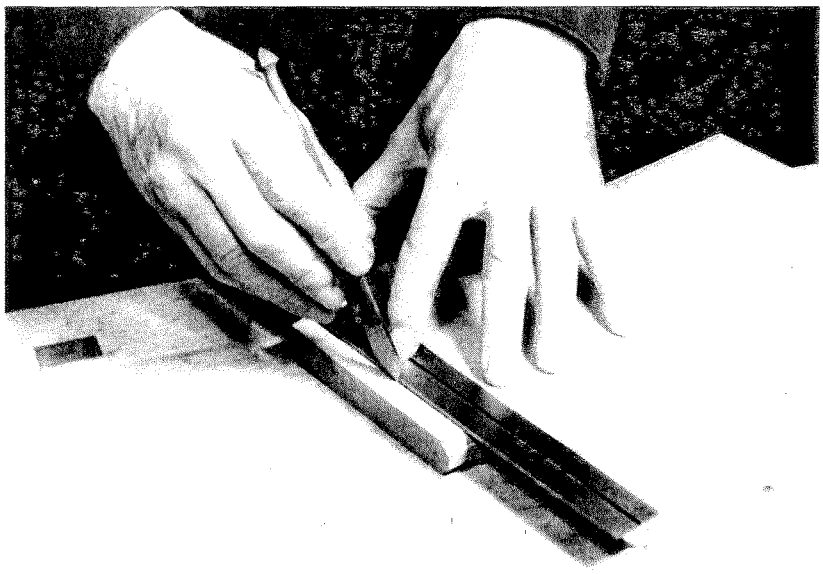
Illus. 3-8. The backplate laid out.



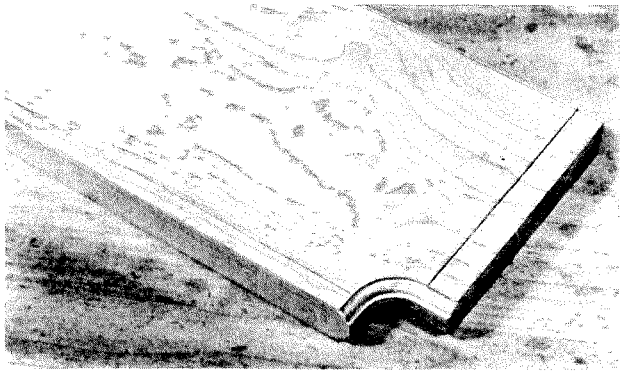
have this just right. I like to slow down the router by 30 to 40 percent; this allows me to feed the work slowly and maintain good control over it; this way, there is no chance that the wood will be scorched.

6. Cut the beads around both faces of each cove. As one of the cuts at each end of the part is fed into the grain, you will undoubtedly see some chipping at the entrances or exits of these cuts. This is the reason for the extra material on the blank. Sand the beads very lightly if necessary, using only fine-grit sandpaper to remove fuzz. (See Illus. 3-10.)

7. Set up a sharp, clean-cutting blade, and saw the extra material off each end, cutting just outside of the knife lines. Sand the end surfaces clean and smooth with 240-grit abrasive.



Illus. 3-9. Scoring lines on the backplate with a knife.



Illus. 3-10. A cove with beading.

8. Saw the excess height off the top edge only, planing it smooth, and fine-sanding lightly if needed.

9. Cut the beads on the ends of the part. To avoid chipping at the cove cuts, start all the end cuts in the coves and feed out to the bottom edge. If you make one cut at each end with the part flat on its face, and one cut with the part vertical against a fence, proper direction of feed can be maintained. This is why the shoulders of the beading cut should be exactly equal. Illus. 3-11 shows this operation.

10. Cut the beads on the upper edge, and, last of all, trim the extra material from the lower edge. You should now have a finished part with crisp, uniform decorative beading all around.

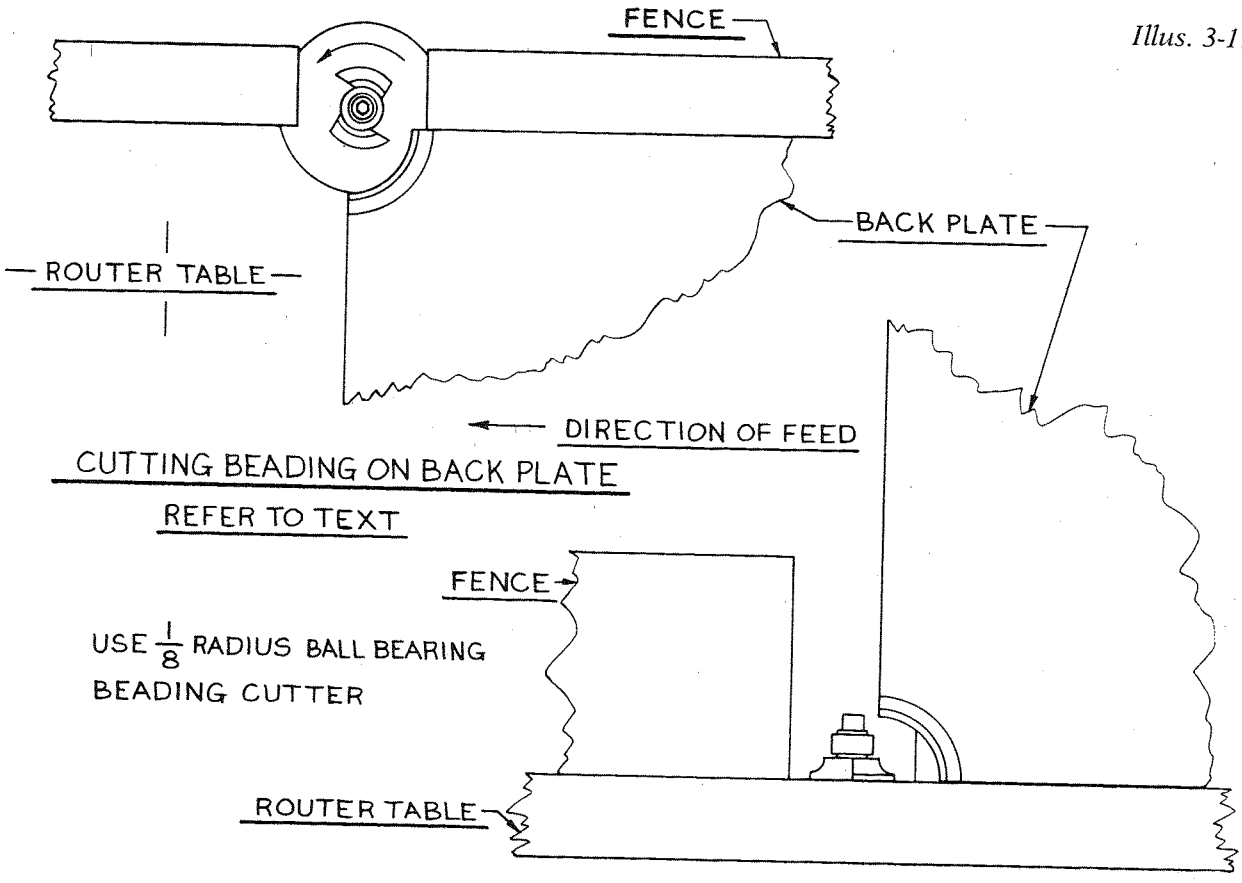
Now, cut the beading all around the upper surface of the baseplate; use a small, square scrap block as a pusher to minimize chipping on the cross-grain cuts, which should be made first.

Lay out the center of the crankshaft bearing hole on the backplate. Drill a 5/8-inch hole at this location; clamp the part to a backup block to avoid chipping when you drill through. (See Illus. 3-12.) Select a piece of 5/8-inch hardwood dowel for the bearing and sand it to a close fit in the backplate hole. Cut the bearing to length, and chamfer its back end, leaving the front square.

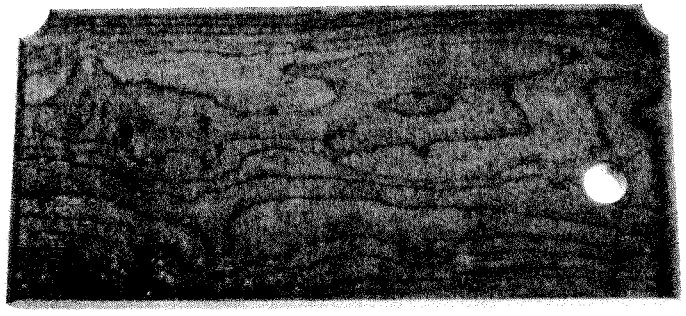
Finish-sand the back face of the plate, raising the grain if necessary; it will be difficult to do this later. Glue the bearing in place, with its front end flush with the surface of the plate. Let it dry, and sand it clean. Carefully mark the center of the dowel, and draw a short vertical line through this point.

Place the drill jig on the plate, its lower edge flush with that of the part, and, looking into the hole in the jig, center the line drawn on the bearing face. Clamp the jig in place, drill all the holes to the depths shown, and remove the jig. (See Illus. 3-13.) Small errors may cause your crankshaft bearing hole to be something less than perfectly centered in the 5/8-inch dowel, but this will not affect

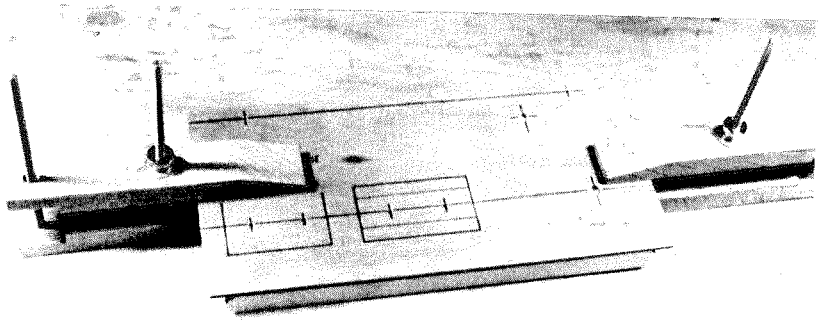
Illus. 3-11.



Illus. 3-12. The backplate with the large hole for the bearing.

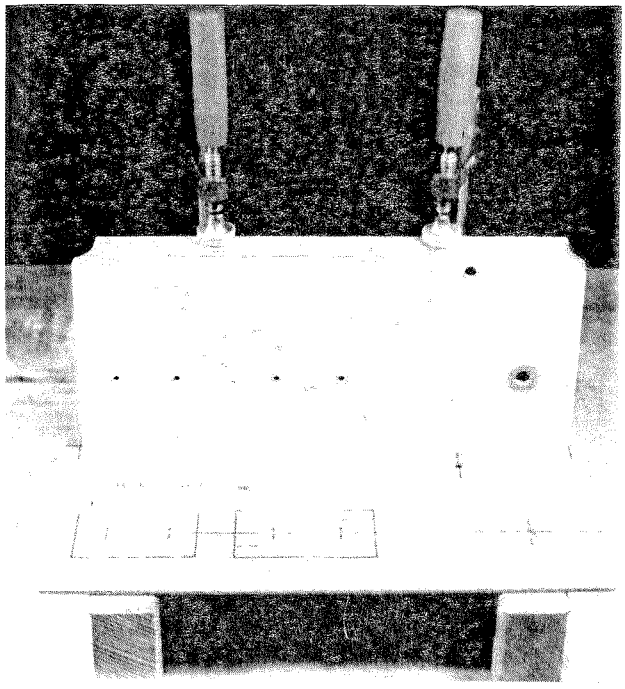


Illus. 3-13. The drill jig clamped to the backplate.



operation, and won't be noticeable after assembly.

Set the drill jig on two blocks to provide clamping clearance, and place the backplate upright on the jig. The rear face of the plate should be flush with the top edge of the jig, and the length of the backplate accurately centered over the two locating lines. (See Illus. 3-14.) Clamp the backplate securely, invert it, and drill the two dowel holes.



Illus. 3-14. The backplate clamped to the jig for drilling dowel holes.

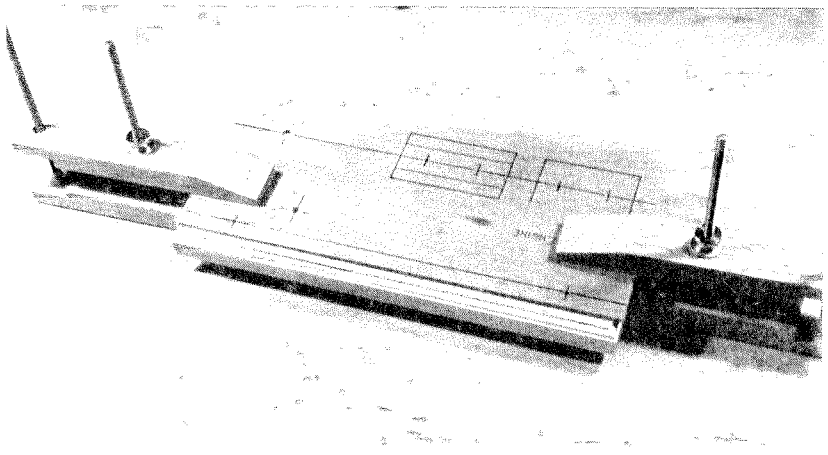
The only work that needs to be done on the baseplate is drilling the dowel holes. Lay the jig on the plate with its edges ¼ inch in from the rear edge of the part. It does not have to be exactly ¼ inch in, as long as you keep the jig and the plate parallel to each other. Both ends of the jig should be flush with those of the part. If there is any difference in length, center the jig and the plate with each other. (See Illus. 3-15.) Clamp the jig and drill the two holes.

Clean up the parts and dry-assemble them with two dowels. Check for any large gaps at the joint, and correct these using a scraper or a small plane. When the fit is acceptable, assemble the parts; apply glue very sparingly, to minimize squeeze-out. Clamp the joint securely; check for squareness, and remove any excess glue after it has gummed up enough not to smear. Put the assembly aside to dry. You are ready for the next step.

Cylinder and Valve Chest

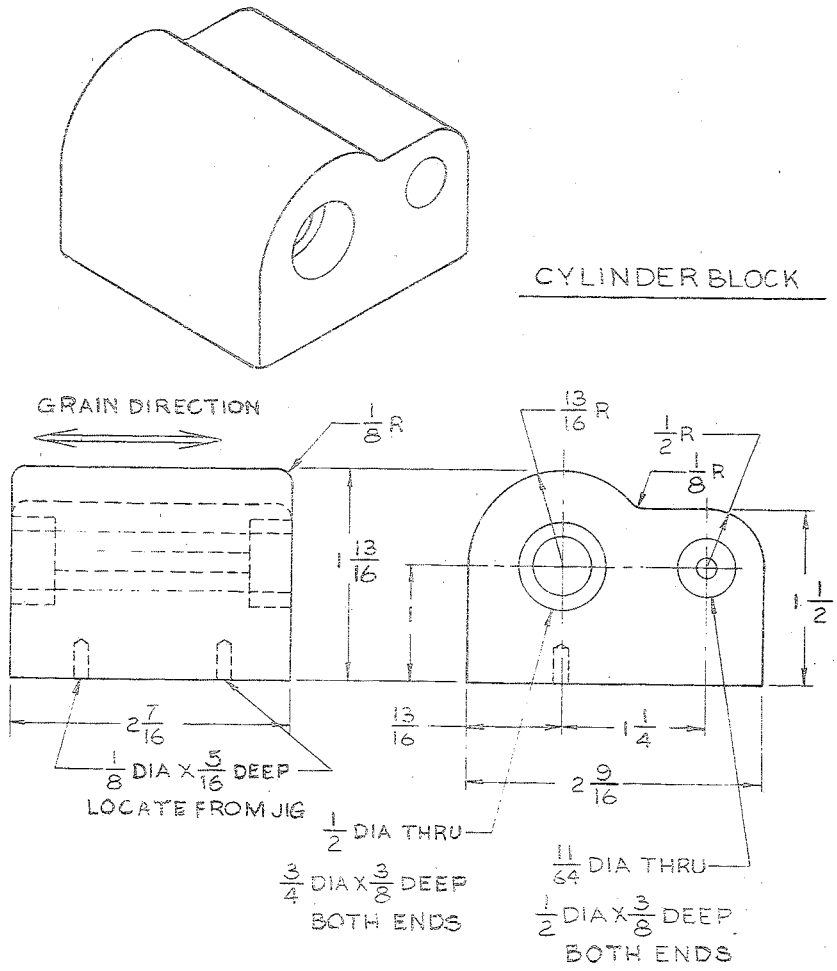
This is a thick part that you may have to build from two or more pieces of wood. Keep any glue joints well away from the hole locations, and orient the grain direction as shown in Illus. 3-16. Glue the assembly and let it dry thoroughly before proceeding further. (See Illus. 3-17.)

Square-up the block and sand the end grain smooth enough to show the layout lines

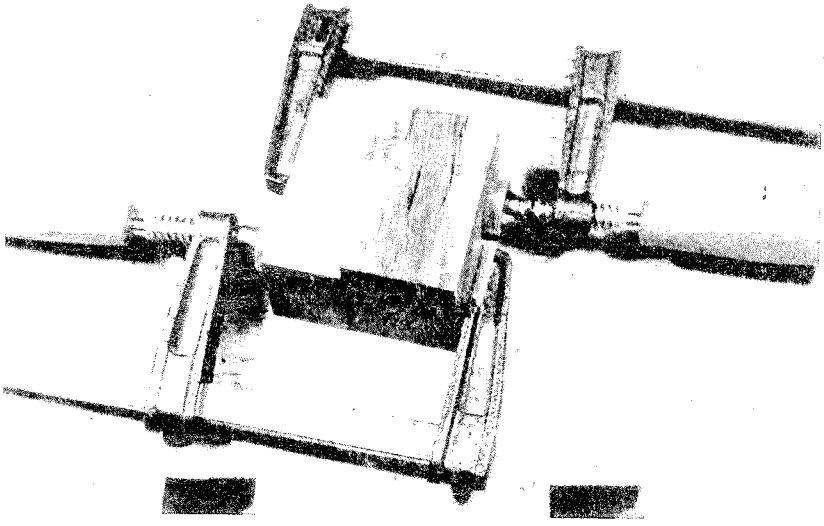


Illus. 3-15. The drill jig clamped to the baseplate.

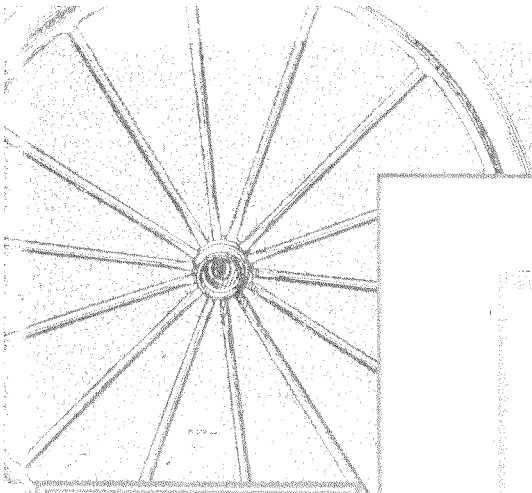
Illus. 3-16.

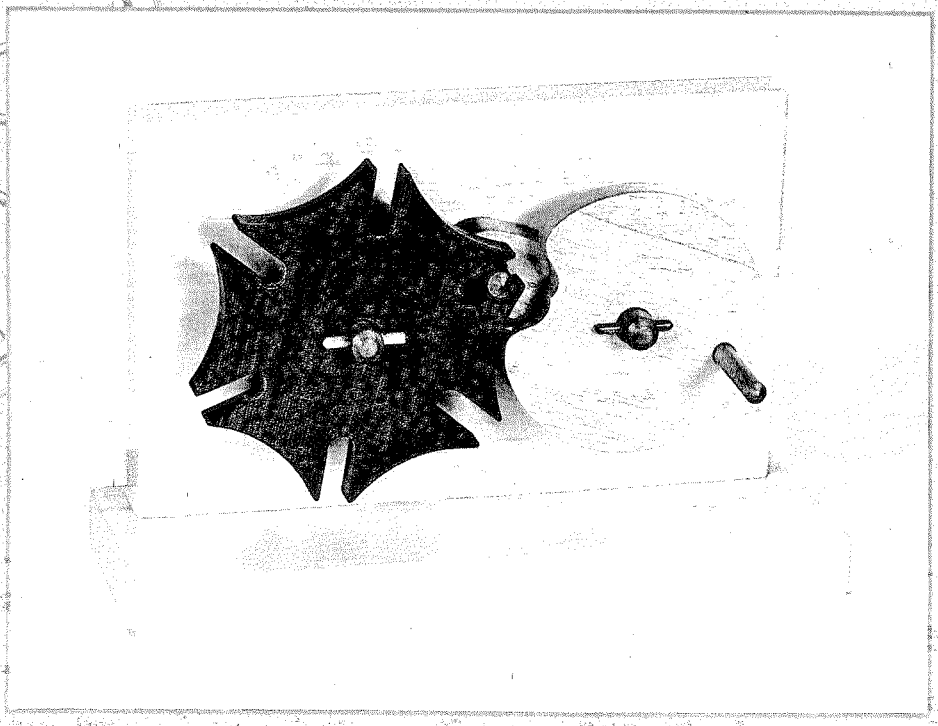


Illus. 3-17.

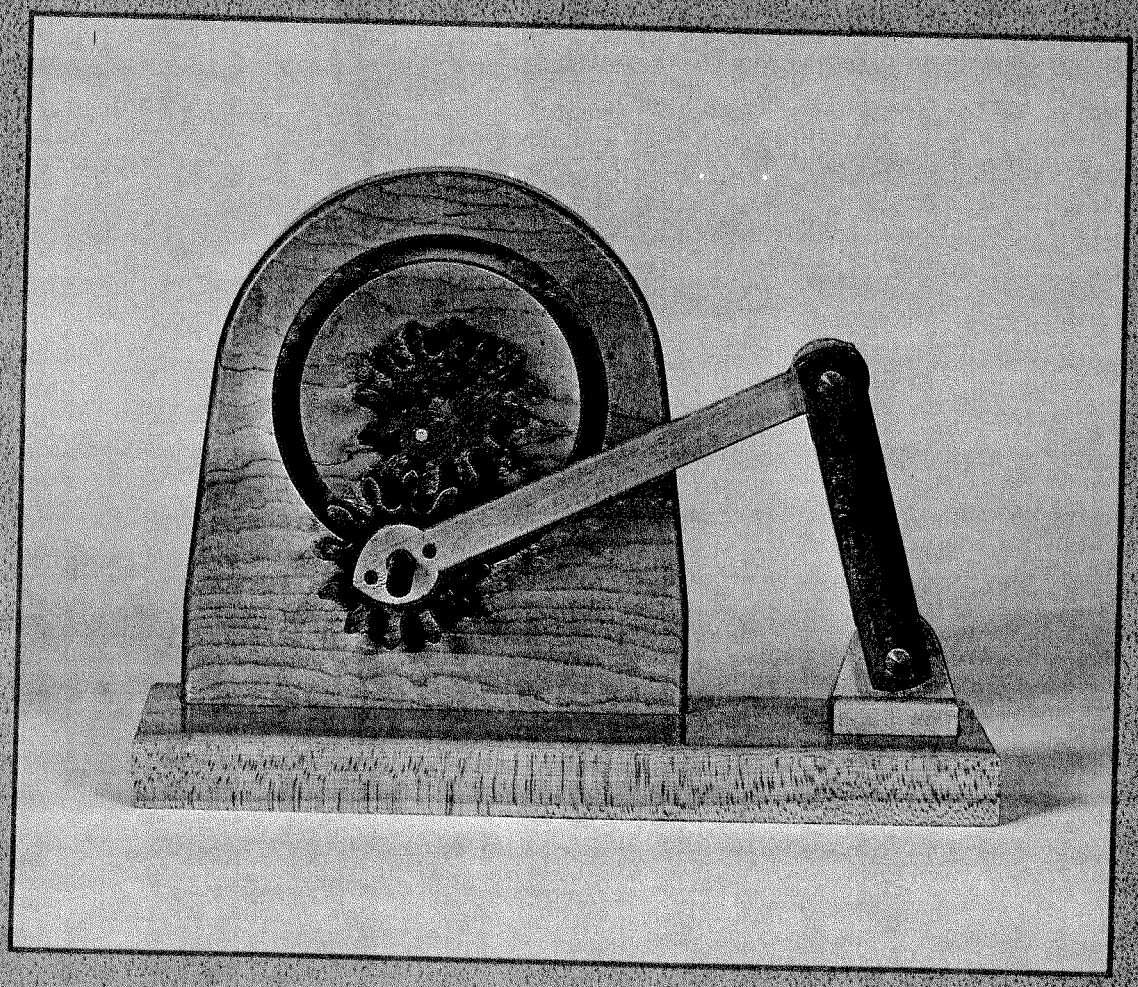


clearly. Lay out the hole centers on both ends, and draw the contours of the part, using a pencil compass. (See Illus. 3-18.) Using brad-point or spade drills, bore the shallow counterbores in both ends of the cylinder and valve chest; then drill the central holes all the way through. (See Illus. 3-19.) The hole for the valve rod is shown undersized; it will be

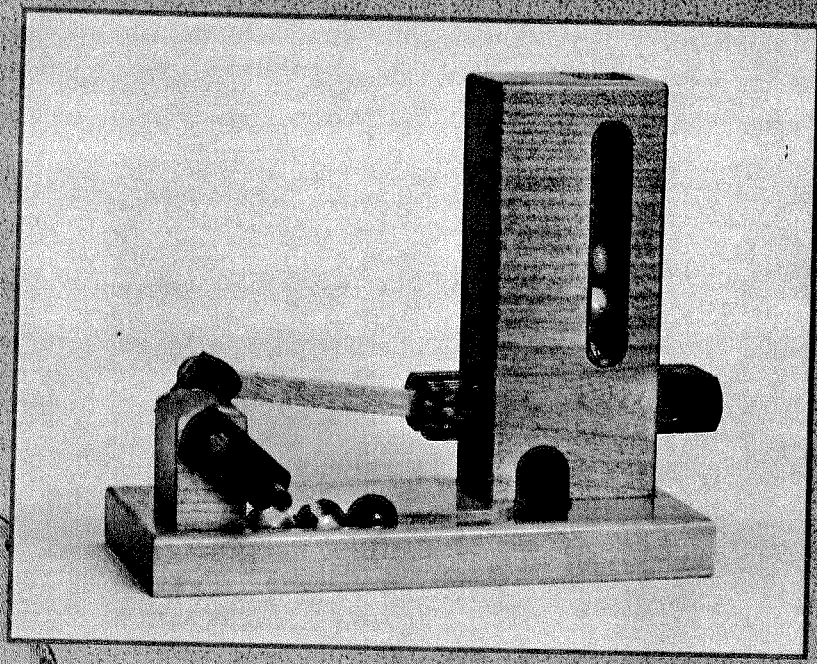


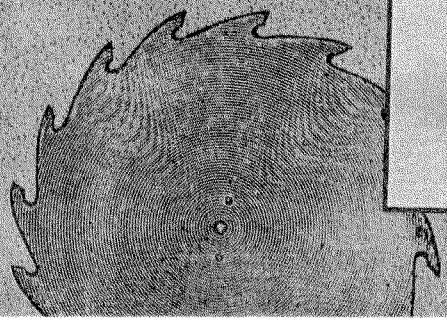


(Right) The Geneva Wheel has an intermittent output motion—the driven member is prevented from moving except when actually driven. (Below) The Loose-Link coupler is based on a very old design used in farm equipment. It is loosely fitted and can operate in very dirty conditions.



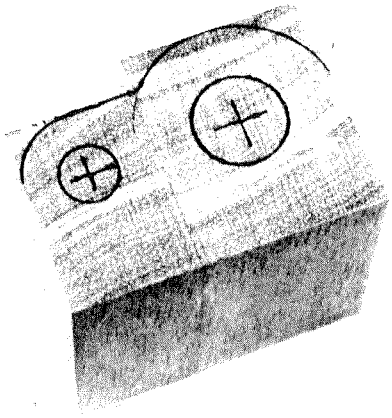
The Sun-and-Planet mechanism (above) was invented in 1775 by James Watt as a substitute for the more common crankshaft. (Right) The Single-Part Feed mechanism is a wooden version of a very common feeding system.



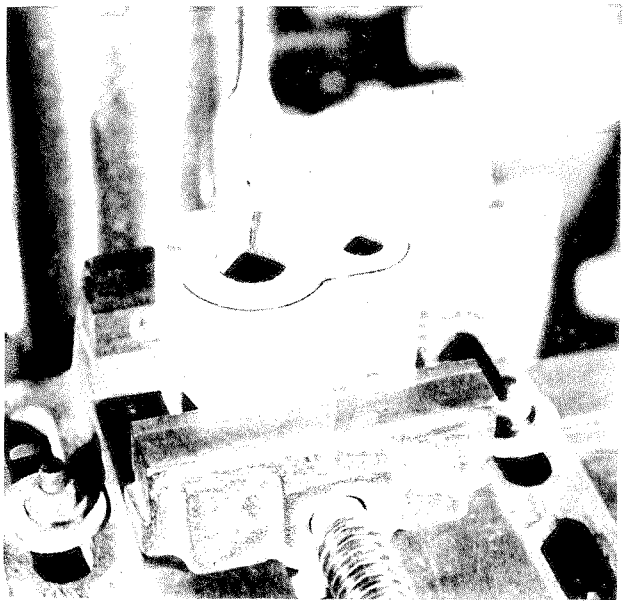


line-drilled to size through its stuffing box at assembly.

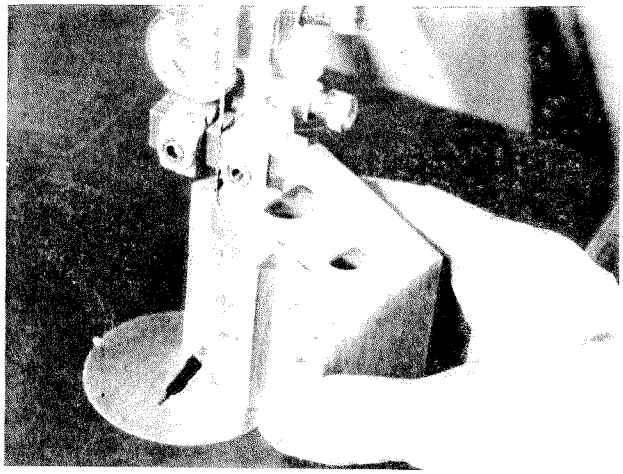
Cut the contour with a band saw and sand it; then round the corners as shown in Illus. 3-20. Now, set the cylinder block, with the valve chest towards the top, on the drill jig, and center it over its locating lines. (See Illus. 3-21.) Clamp it in place, invert it, and drill the two dowel holes 5/16 inch deep. (See Illus. 3-22.) Sand the block smooth and clean, and put it aside to await assembly.



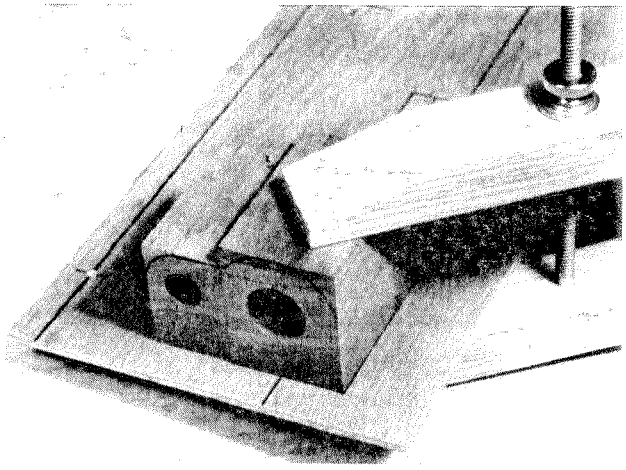
Illus. 3-18. The cylinder block laid out.



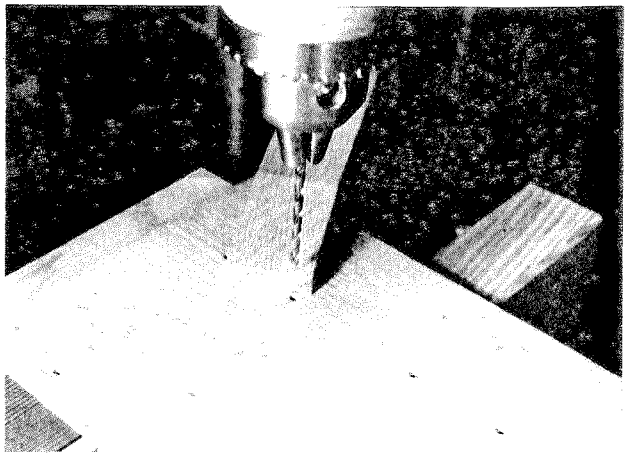
Illus. 3-19. Drilling the cylinder block.



Illus. 3-20. Cutting out the cylinder contour on the band saw.



Illus. 3-21. The cylinder block clamped to the drill jig.



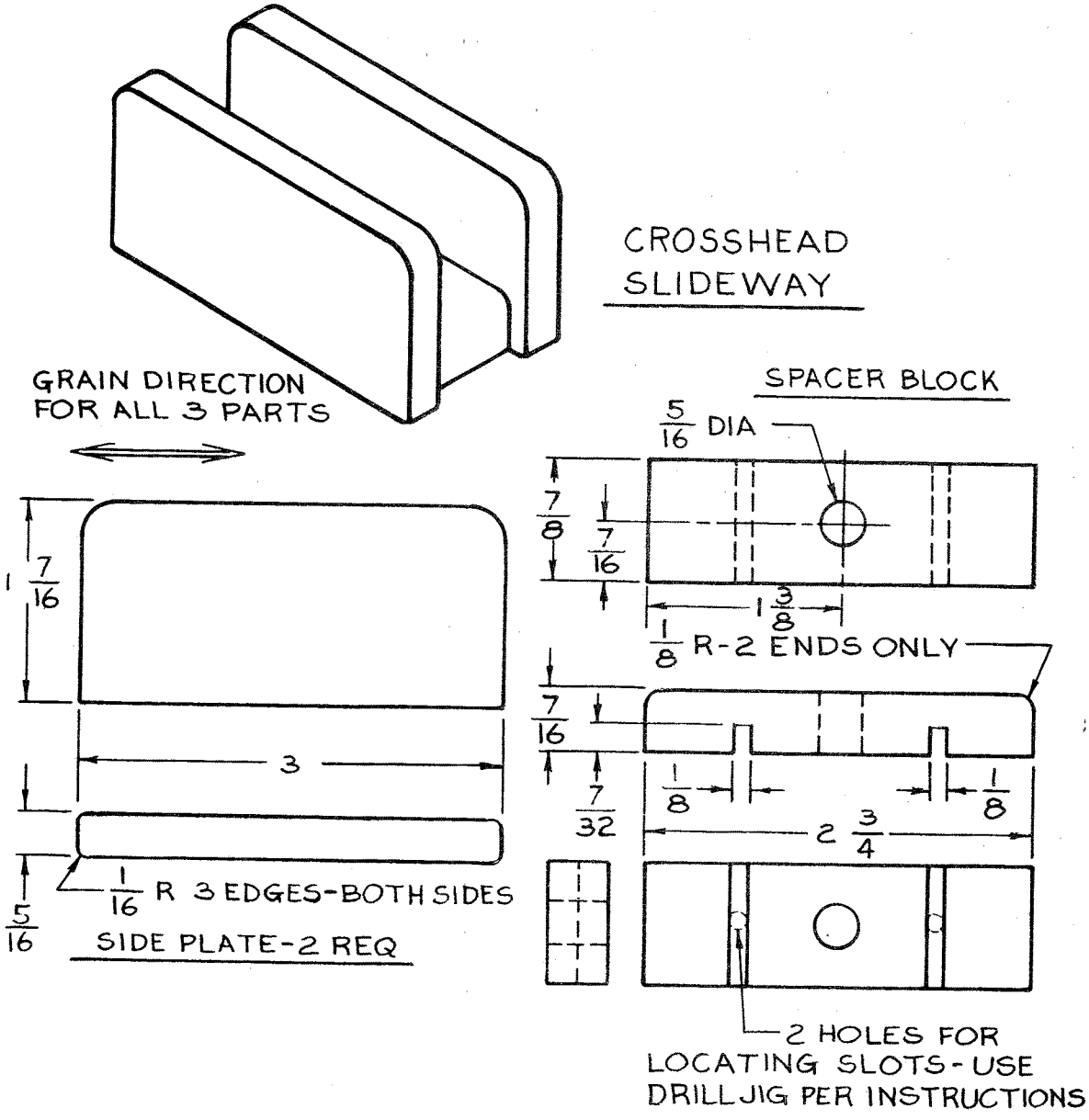
Illus. 3-22. Drilling dowel holes in the cylinder block.

Crosshead Slideway

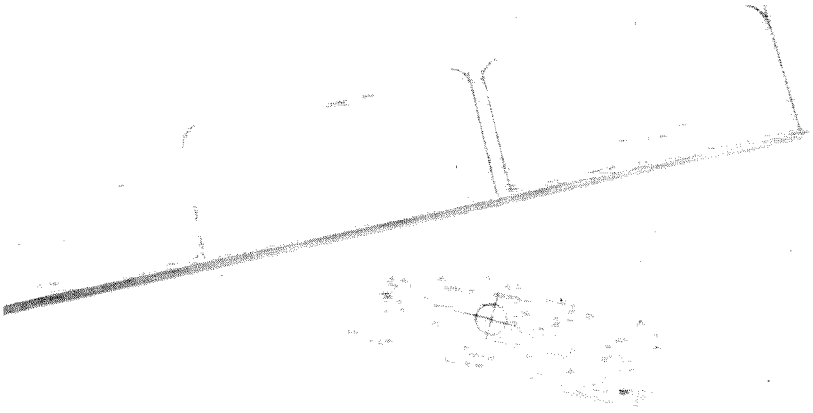
The three parts of this subassembly can be cut to size on a table saw and sanded clean. (See Illus. 3-24.) Round the corners of the two outer members as shown in Illus. 3-23; also round the upper corners on the ends of the spacer block. Clamp the spacer block, accurately centered in its locating lines on the jig, and drill the two dowel holes ⅛ inch deep. (See Illus. 3-25.)

Using a marking knife and a steel square, scribe lines across the block at both edges of each dowel hole. Scribe these lines around the corner on one edge of the part; this will give you a set of marks on which to align your table-saw blade. Cut slots ¼ inch deep at each dowel hole location. (See Illus. 3-26.)

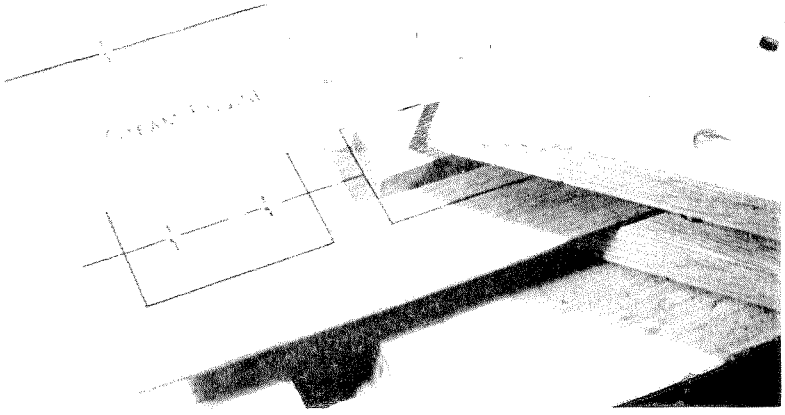
Leaving the saw setting undisturbed, put two short dowels into the crosshead slide location on the backplate and test the fit. The slots in the block should fit on the dowels



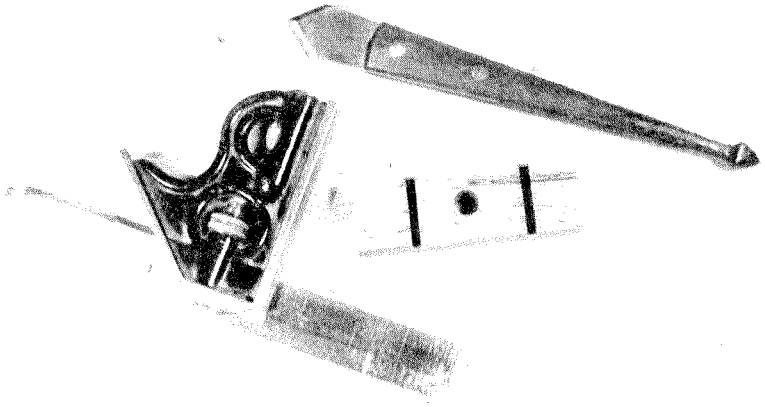
Illus. 3-23.



Illus. 3-24. The parts for the slideway laid out.



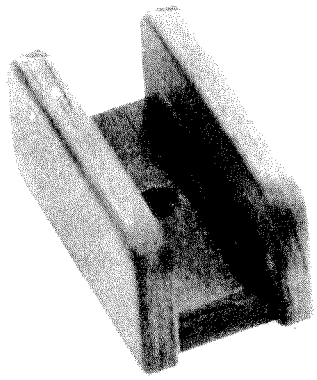
Illus. 3-25. The slideway spacer block clamped to the drill jig.



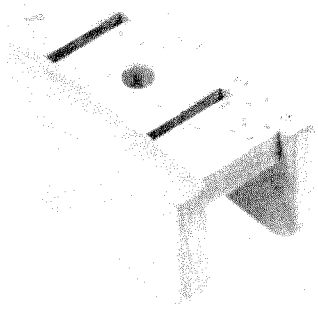
Illus. 3-26. The slideway spacer block and the tools used to scribe and cut the slots in it.

tightly, but still permit vertical adjustment. If the fit seems *too* tight, determine where stock needs to be removed, and trim a little in the appropriate slot. When this has been done, fine-sand all three parts and glue them together. Check that the sides of the clamped assembly are parallel to each other, to ensure that they don't lean in or out.

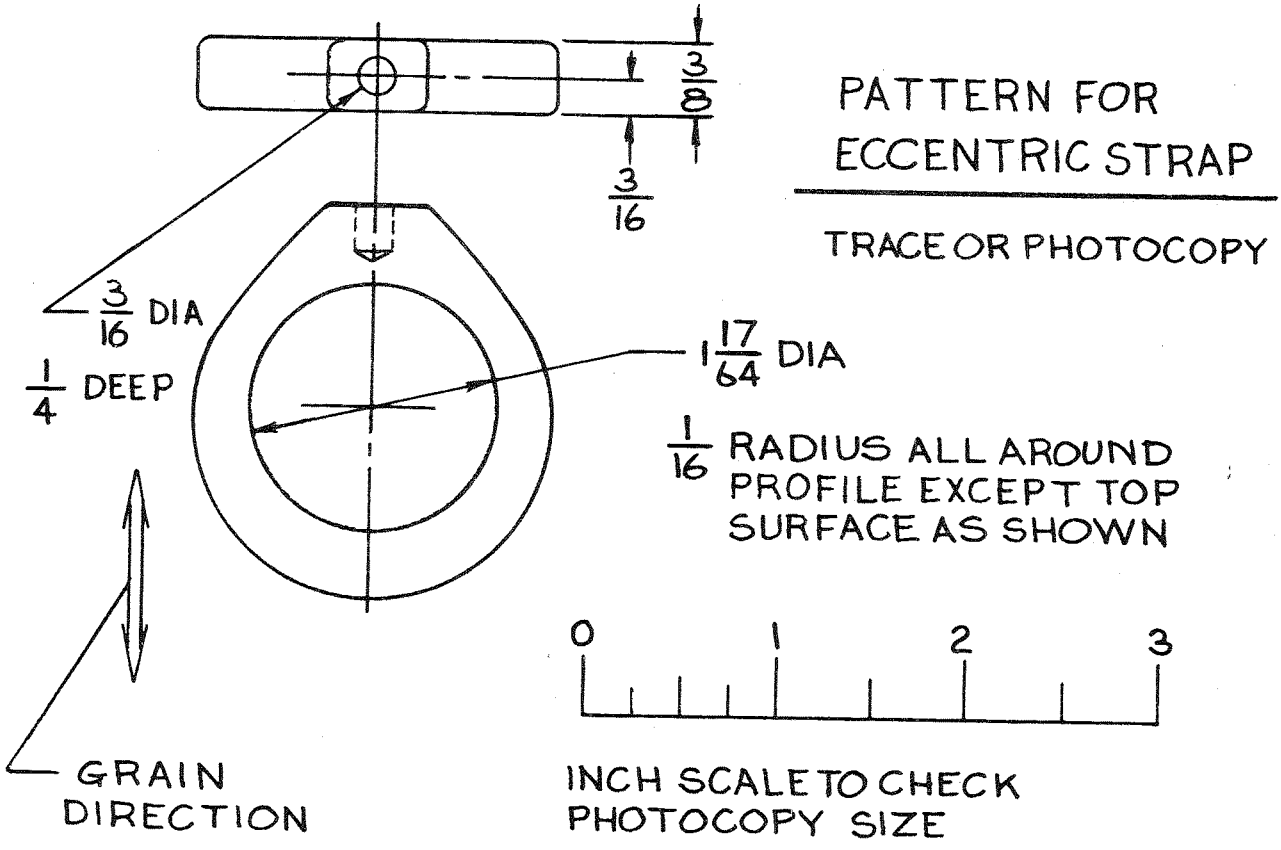
Once again, remove any excess glue from inside the assembly after it has become quite gummy, at which time it can be cleanly removed. When it is dry, flatten the base of the subassembly using a scraper or a small plane. This completes the crosshead slideway. (See Illus. 3-27 and 3-28.)



Illus. 3-27. The completed slideway.



Illus. 3-28. The bottom of the completed slideway.



Illus. 3-29.

Eccentric Strap

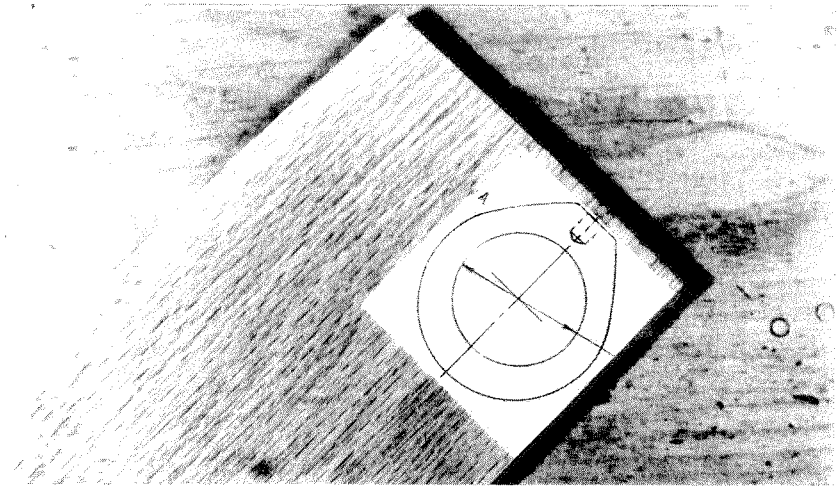
Plane a piece of stock to slightly more than 3/8 inch to allow for sanding, and glue on a photocopy or a tracing of the eccentric strap. (See Illus. 3-29 and 3-30.) Using a small circle cutter, or whatever else you have, cut the center hole. (See Illus. 3-31.) If sanding is required to smooth the hole surface, do it now while you are working with a large piece of wood.

Cut the part with a band saw and sand it to size. Square the centerline across the end and mark and drill the rod hole. Grip the part in a drill vise with its centerline aligned with the jaws; this automatically puts the part square with the drill press table. (See Illus. 3-32.)

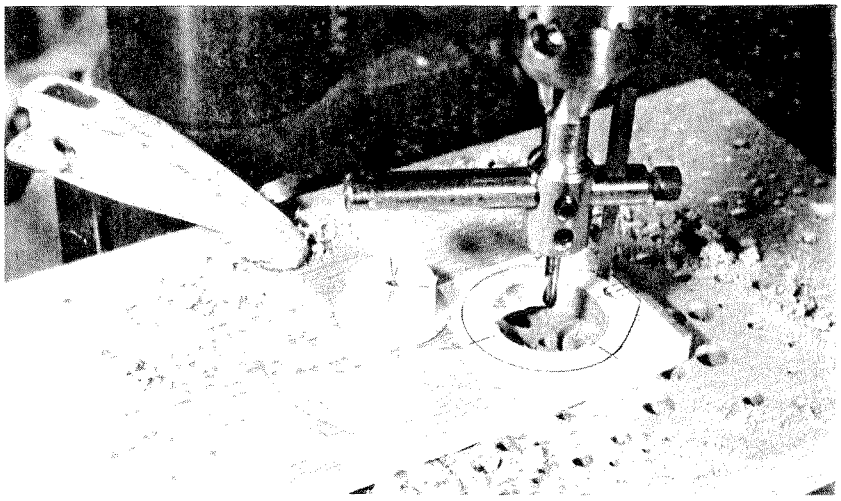
Round the corners, except for the flat upper edge, raise the grain, and finish-sand the part.

Eccentric

Draw a circle for the eccentric and lay out and drill the 5/16-inch-crankshaft hole. (See Illus. 3-33) Cut out the circle with a band saw and sand it to size. Hand-sand in the direction of rotation. The part should have a minimum clearance in the eccentric strap of 1/64 inch, and up to 1/32 inch on the diameter if local humidity varies greatly. A vernier or dial caliper is a useful tool for getting similar parts round and accurately sized. (See Illus. 3-34.)

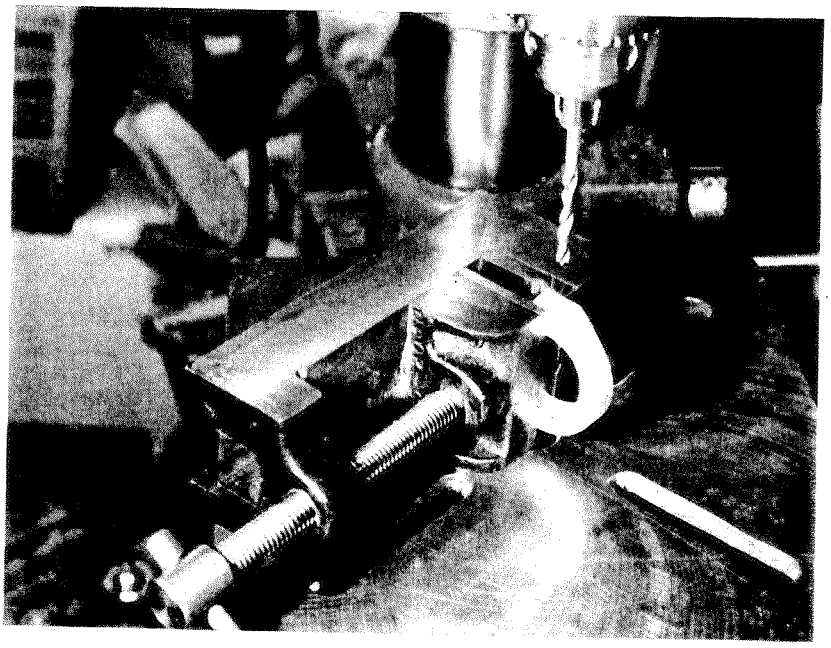


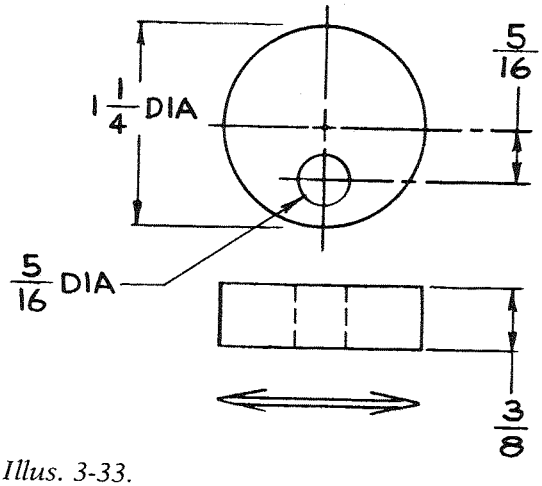
Illus. 3-30. The eccentric strap pattern glued to the stock.



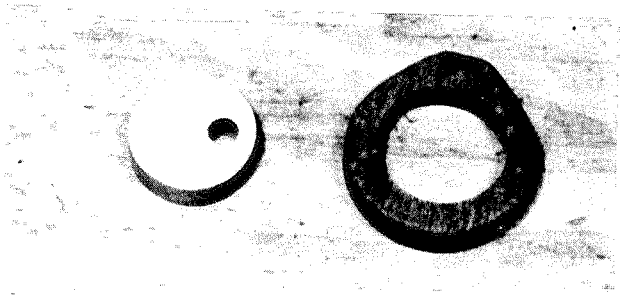
Illus. 3-31. Cutting the center hole in the eccentric strap.

Illus. 3-32. Drilling the rod hole in the eccentric strap.





Illus. 3-33.



Illus. 3-34. The eccentric and the eccentric strap.

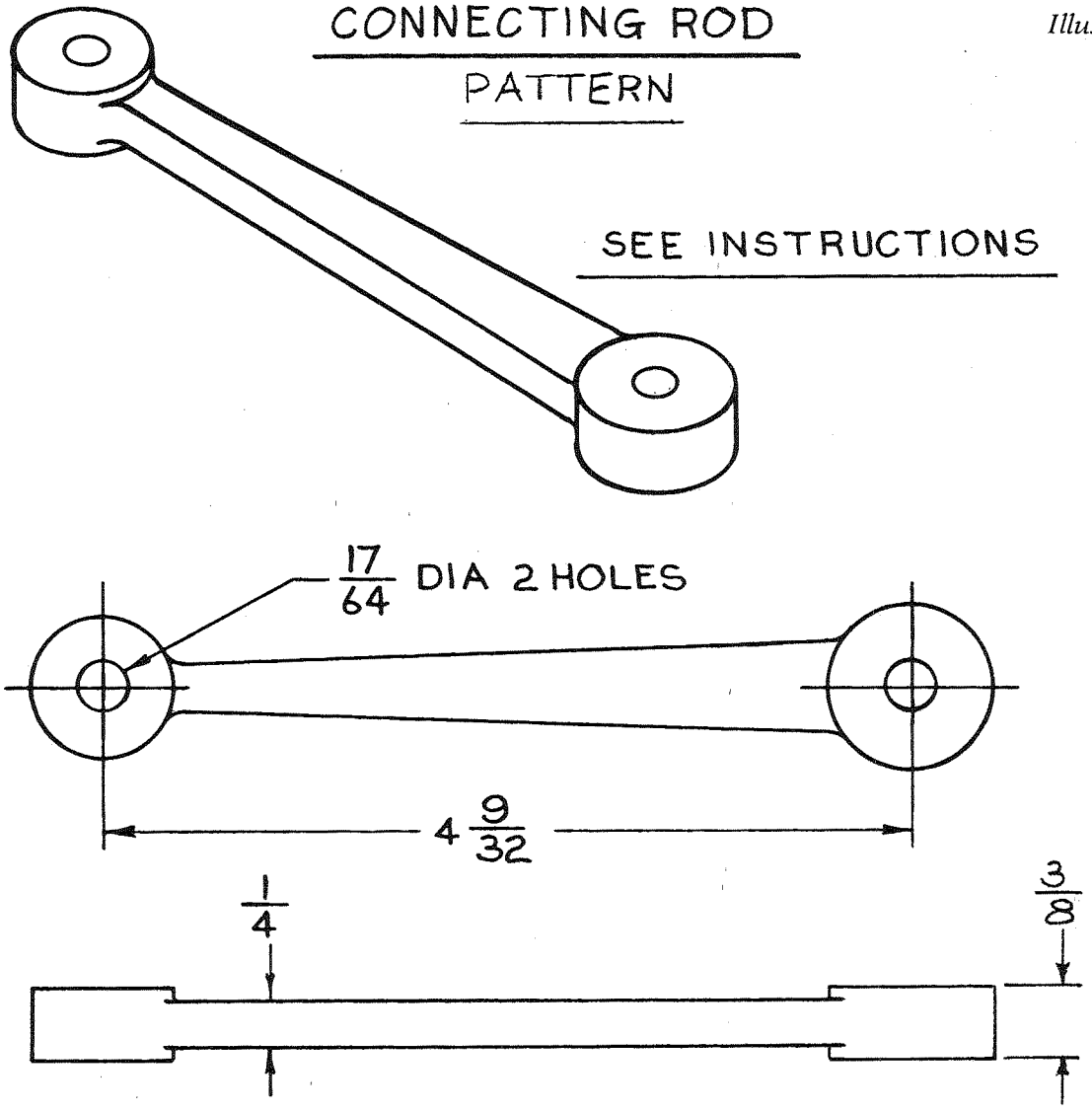
Connecting Rod

First, measure the photocopy of the pattern shown in Illus. 3-35 to make sure it is at its proper size; then glue it onto the stock. (See Illus. 3-36.) If the distance between the centers of the holes is noticeably longer than shown in Illus. 3-35, the piston rod may hit bottom at the end of its stroke. Drill the holes accurately, and saw out the contour. File and sand to the line; work carefully, as this is a highly visible part.

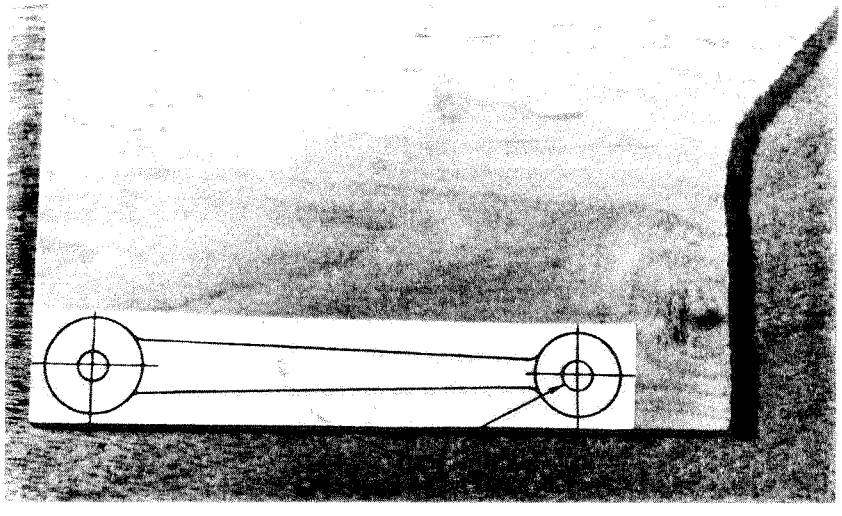
The undercut central web is not essential to the functioning of the model, but it does enhance its appearance. I cut away most of the excess material with a rotary planer, and complete the job with small chisels and files. (See Illus. 3-37 and 3-38.) Take your time and do a nice job on this. Round the corners on the central web only and fine-sand the entire part, just removing the sharp corners all around the two end bosses. (See Illus. 3-39.)

Crosshead

Prepare a piece of material ¾ inch thick, and at least 2 inches wide by 5 inches long. (See Illus. 3-40.) Joint one edge smooth and square, lay out the part, and drill the wrist pin hole. (See Illus. 3-41.)

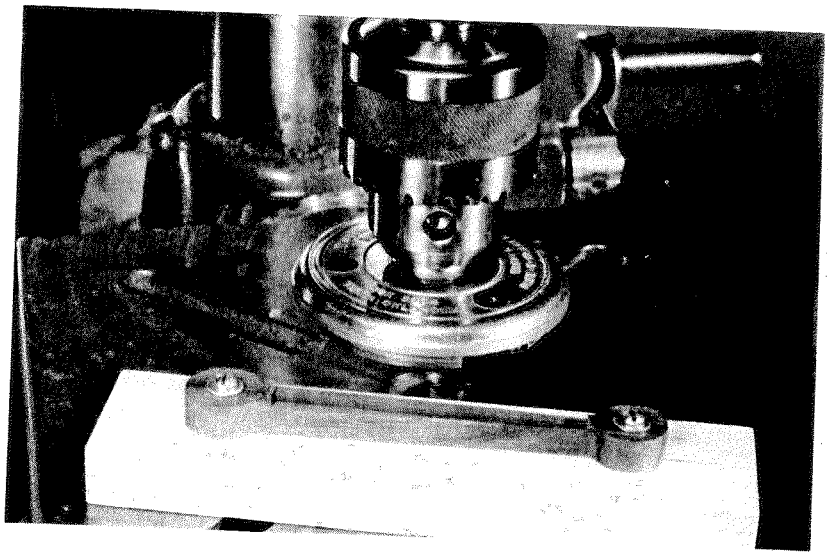


Illus. 3-35.

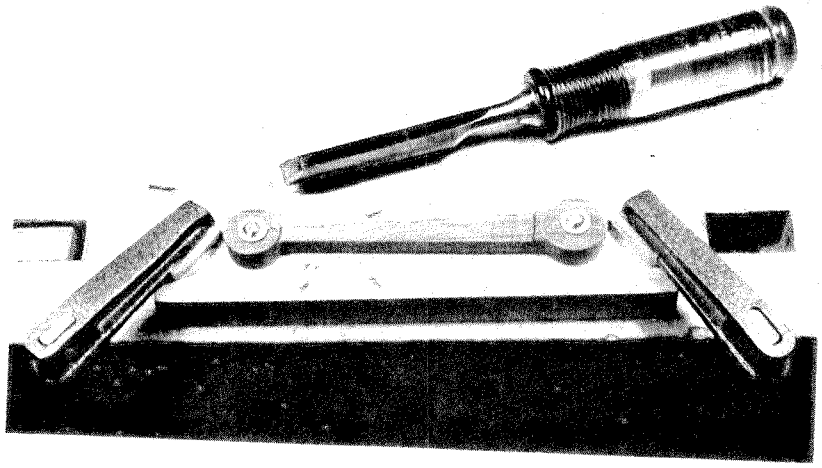


Illus. 3-36. The connecting-rod pattern glued onto the stock.

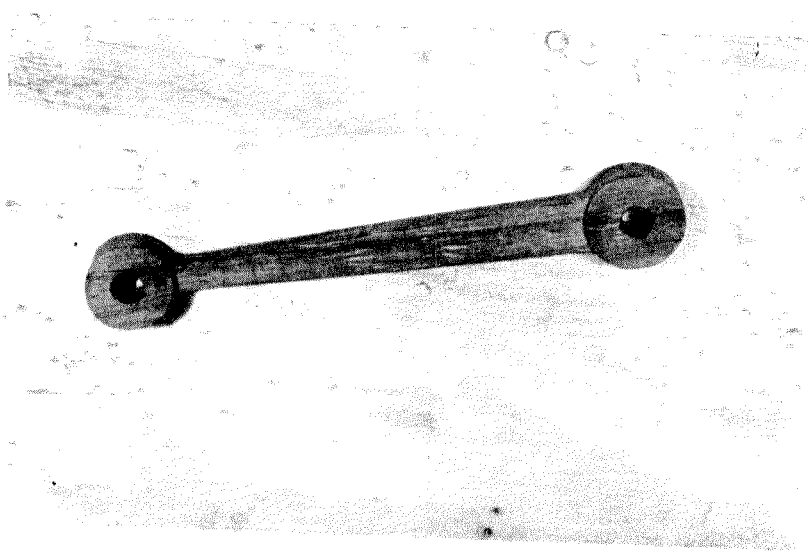
Illus. 3-37. Cutting the web on the connecting rod.

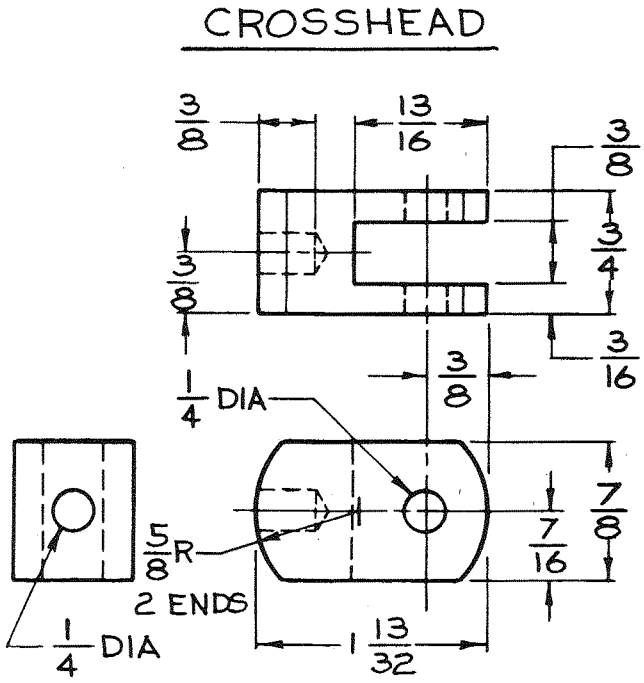


Illus. 3-38. Rounding the end bosses.

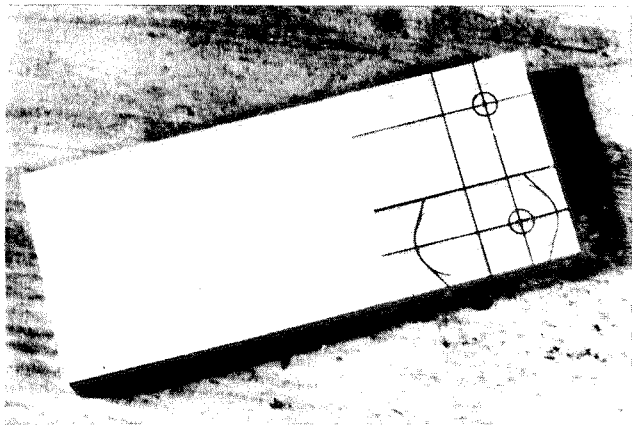


Illus. 3-39. The completed connecting rod.





Illus. 3-40.



Illus. 3-41. The crosshead laid out.

Set up a router table with a fence and insert a long ¼- or 5/16-inch cutter. If your router table has a large center hole, clamp a thin wooden auxiliary table over it to support the small parts while cutting. Adjust the fence so that the cutter is centered reasonably well over the thickness of the part.

Use a square-edge pusher block to prevent chipping, and rout the slot to depth, taking cuts not more than 3/32 inch deep. When the depth is correct, move the fence a little at a time, flipping the part over to make a cut on both sides of the slot at each setting. (See Illus. 3-42.) The finished width of the slot should be a little over ⅜ inch. Cut the part to its finished outline, square the centerline across the solid end, and drill the rod hole parallel to all the faces of the part. Fine-sand all over, and lightly round all the sharp corners. (See Illus. 3-43.)

Rod Ends

The procedures outlined below and shown in Illus. 3-46 keep these small parts attached to a large blank for as long as possible:

1. Plane a piece of stock so that it's ⅜ inch thick and about 2 inches wide by five inches long. The edges and ends should be square and parallel.

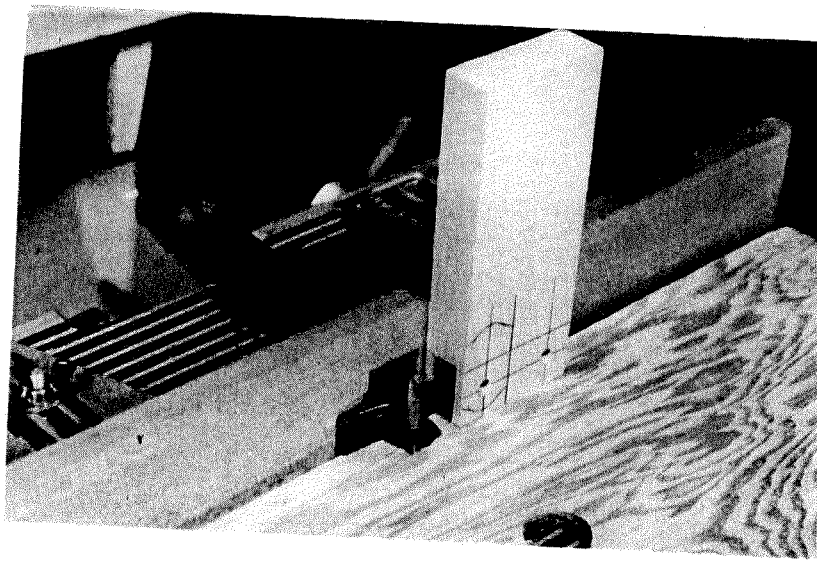
2. Mark two lines so that they are parallel to each edge; these lines represent the widths and centerlines of the parts. At one end of the blank lay out the valve-connecting rod end; its 3/16-inch-thick tongue should extend outward. On both faces of the blank, cut with a knife the lines at the inboard end of the tongue. This will prevent splintering when you are cutting this detail.

At the other end of the blank, lay out the valve-rod end, with its slot facing outward. Lay out the remaining two rod ends in the middle of the block. A draftsman's circle template is a useful tool for drawing the end radii on these parts. (See Illus. 3-44.)

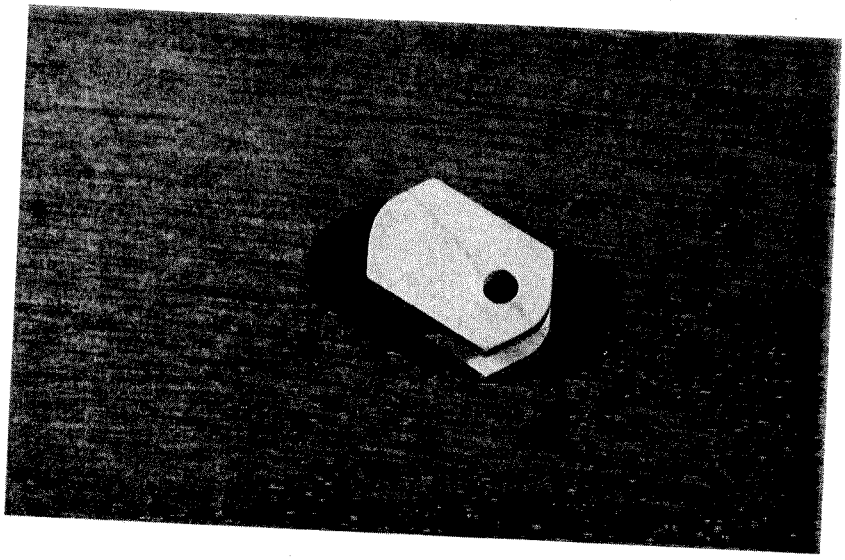
3. Using a sharp-pointed awl, accurately mark each hole location and drill the holes, paying careful attention to the diameters shown in Illus. 3-45.

4. The outer radius of the valve connecting-rod end should now be bandsawed and sanded to the line. The reason for doing this now is that the layout will be lost when the tongue is cut. (See Illus. 3-47.) To cut the tongue, you must have a table insert that comes right up to the saw blade. If you don't have one, cut one from wood, screw it in

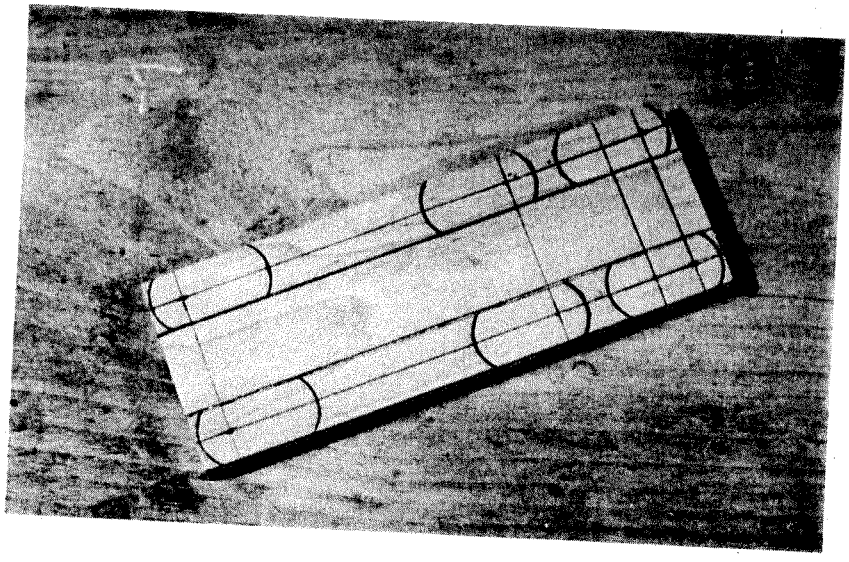
Illus. 3-42. Cutting the slot in the crosshead.

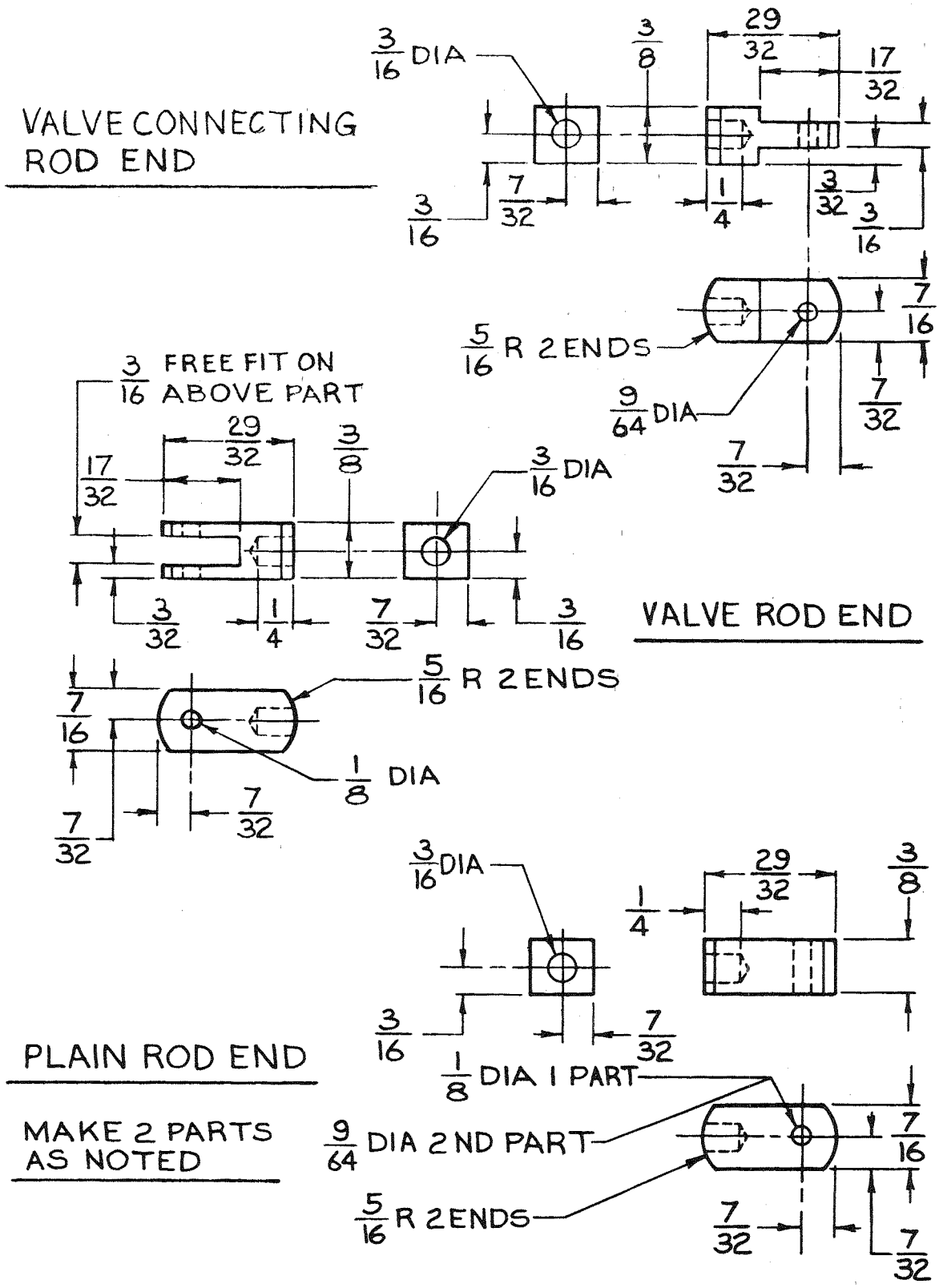


Illus. 3-43. The completed crosshead.

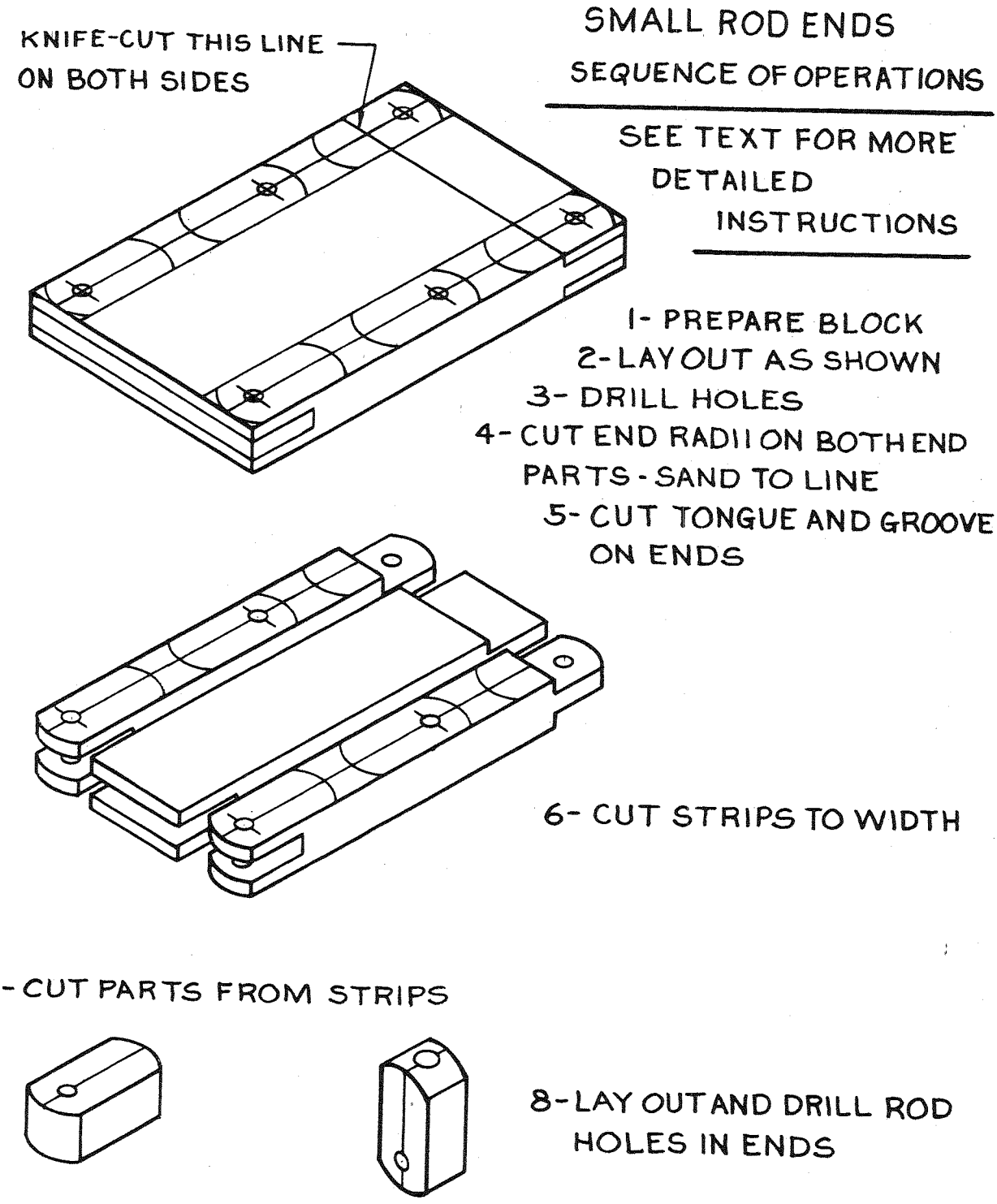


Illus. 3-44. The layout for the rod ends.

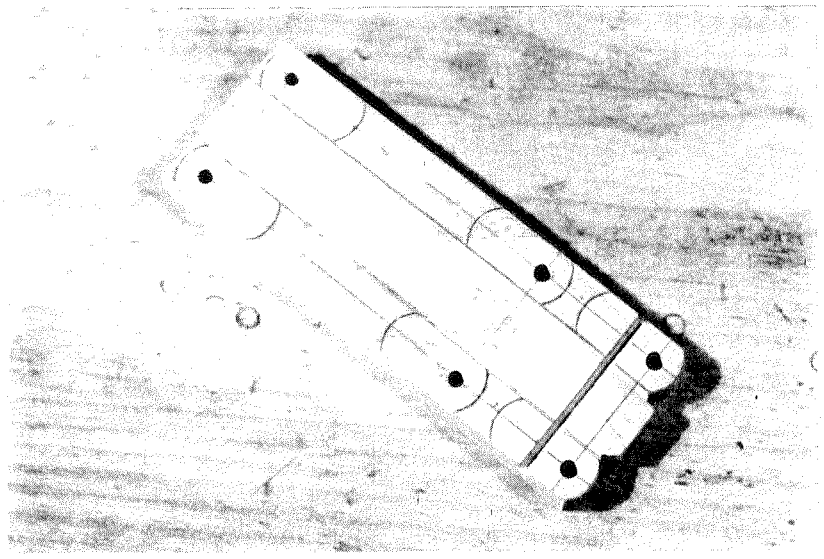



VALVE CONNECTING ROD END
3/16 DIA
3/8
29/32
17/32
3/16
7/32
1/4
3/32
3/16
5/16 R 2 ENDS
9/64 DIA
7/16
7/32
7/32
3 FREE FIT ON 16 ABOVE PART
29/32
3/8
17/32
3/16 DIA
3/32
1/4
7/32
3/16
VALVE ROD END
5/16 R 2 ENDS
7/16
1/8 DIA
7/32
7/32
3/16 DIA
29/32
3/8
1/4
3/16
7/32
PLAIN ROD END
1/8 DIA 1 PART
MAKE 2 PARTS AS NOTED
9/64 DIA 2 ND PART
5/16 R 2 ENDS
7/16
7/32
7/32

Illus. 3-45.


KNIFE-CUT THIS LINE
ON BOTH SIDES
SMALL ROD ENDS
SEQUENCE OF OPERATIONS
SEE TEXT FOR MORE
DETAILED
INSTRUCTIONS
1- PREPARE BLOCK
2- LAY OUT AS SHOWN
3- DRILL HOLES
4- CUT END RADII ON BOTH END
PARTS - SAND TO LINE
5- CUT TONGUE AND GROOVE
ON ENDS
6- CUT STRIPS TO WIDTH
7- CUT PARTS FROM STRIPS
8- LAY OUT AND DRILL ROD
HOLES IN ENDS

Illus. 3-46.



Illus. 3-47. The radii cut on the rod ends.

place, and feed the rotating blade up through it to saw its own slot. A close-fitting insert is an absolute requirement for safely working on small parts.

Set the blade to a height of 3/32 inch above the table, and make the shoulder cut for the tongue on each face of the block. If you cut just short of the knifed lines, there should be no splintering. (See Illus. 3-48.)

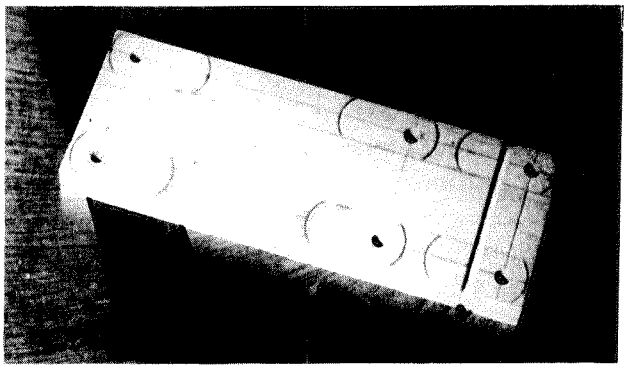
Now, move the blade up to the full height of the tongue, and set the rip fence a little more than 9/32 inch from the blade. Using a square piece of scrap for a pusher block, make a cut on each face of the part. Measure the thickness of the tongue and make very small adjustments to the fence until you get a thickness of 3/16 inch. (See Illus. 3-49.)

Leaving the saw set at the same height, move the fence so that the saw blade is approximately centered over the thickness of the part. Invert the blank and cut the slot in the fork, using the same method as before to cut both sides equally. The slot should measure 3/16 inch or slightly more. (See Illus. 3-50.)

5. Now rip the two pieces from the block, leaving just enough extra material for a plane shaving to remove saw marks. (See Illus. 3-51.) Saw all the parts to their outlines and sand the end radii.

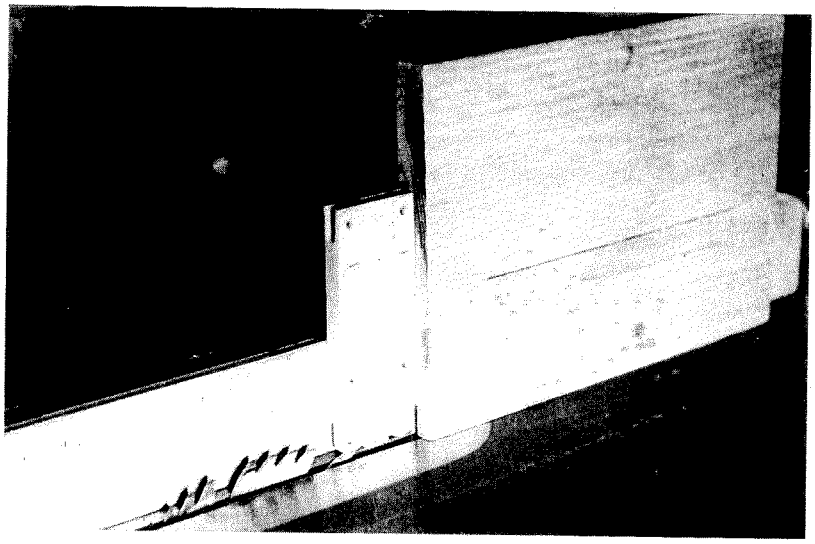
6. Lay out the centers of the rod holes in the ends of the parts. A small drill vise is a valuable accessory for drilling these holes. You can clamp the vise to your drill press table, using a stop piece to locate the work. When the position of these holes has been accurately centered under the spindle, all the rod holes can be accurately drilled. It's worth the trouble to make this setup. (See Illus. 3-52 and 3-53.)

7. Fine-sand the parts, and gently round the corners. (See Illus. 3-54.) Store these and other small pieces in closed jars or cans. If your shop is anything like mine, small parts that fall may never be seen again. I have occasionally seen parts that I thought were lost being crunched in the jaws of my Dalmatian.

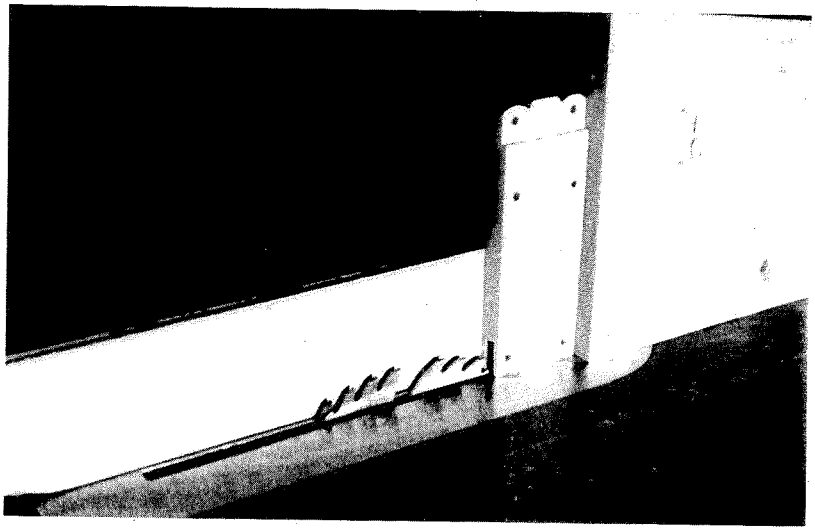


Illus. 3-48. The first saw cut for the tongue.

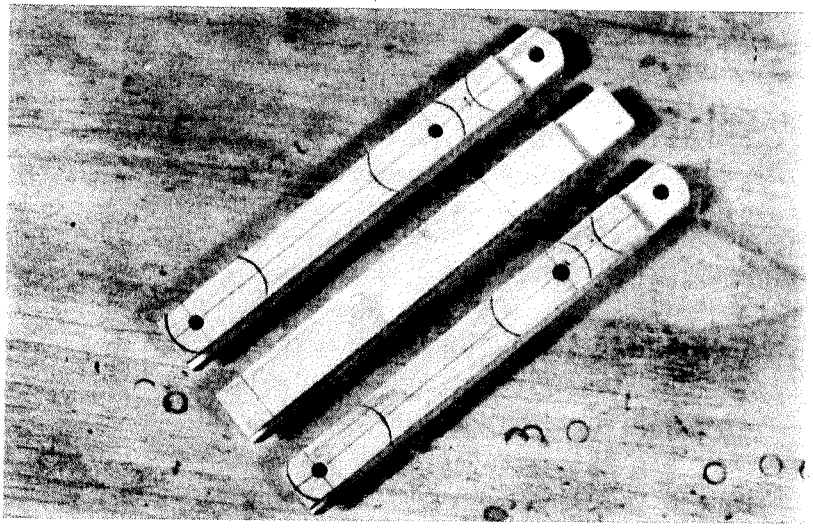
Illus. 3-49. Cutting the tongue to its final thickness.

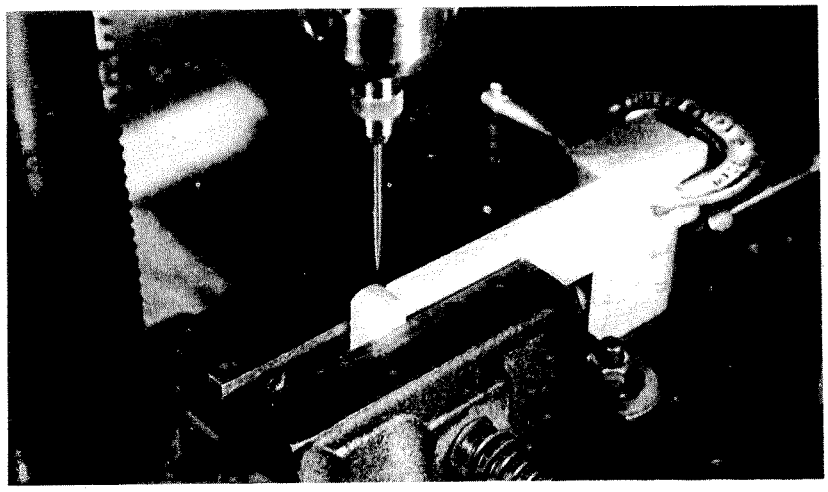


Illus. 3-50. Cutting the slot in the fork.

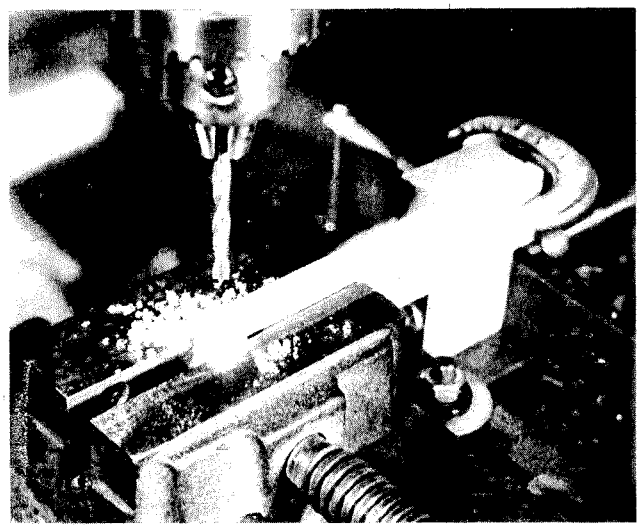


Illus. 3-51. The rod ends cut to their final width.

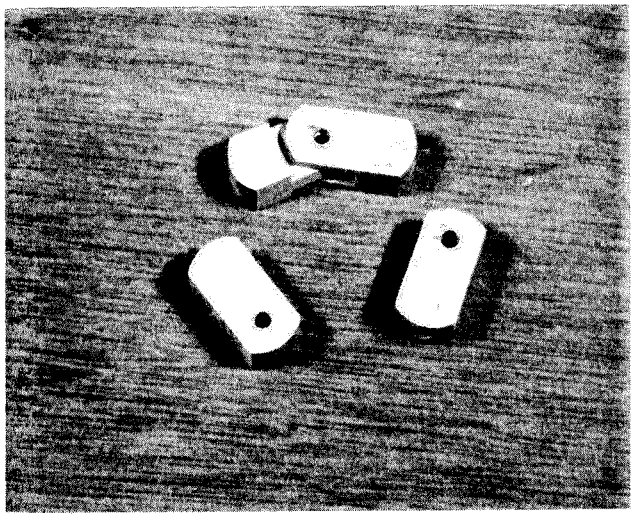




Illus. 3-52. Aligning the center of the rod hole on the end of the part.



Illus. 3-53. Drilling the rod holes.



Illus. 3-54. The completed rod ends.

Bellcrank

This part, shown in Illus. 3-55, and the main crank are cut from 7/16-inch-thick stock, so it is advisable to plane material for both at the same time. Glue the bellcrank pattern to the wood, drill the holes, and cut out the outline with a band saw. (See Illus. 3-57.) Sand to the line, and round all corners. I use a 1/16-inch-radius cutter on the router table, and just run the part around on both faces. Fine-sand to the desired smoothness. (See Illus. 3-58.)

Main Crank

Joint one edge of the stock and lay out the part as shown in Illus. 3-56. Drill the holes, cut out the part, and sand it to size. (See Illus. 3-59 and 3-60.)

Remaining Parts

The remaining pieces, shown in Illus. 3-61 and 3-62, are made from dowel stock. A lathe is a definite asset for this work, but you can get by without one. Check the fits of the various parts in their respective holes, first determining which ones are running fits and which should be snug. Most of these pieces should be assembled by thumb-pressing them together. You definitely don't want any sledge-hammer fits on this small work. Note that it is a lot easier to sand a length of dowel to size before cutting it into little pieces.