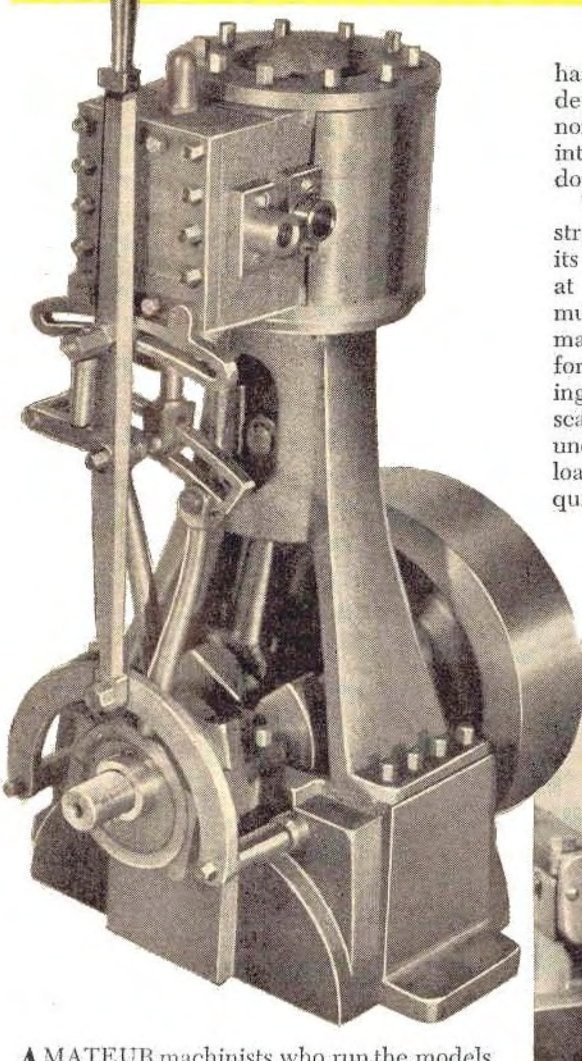
# Vertical STEAM ENGINE

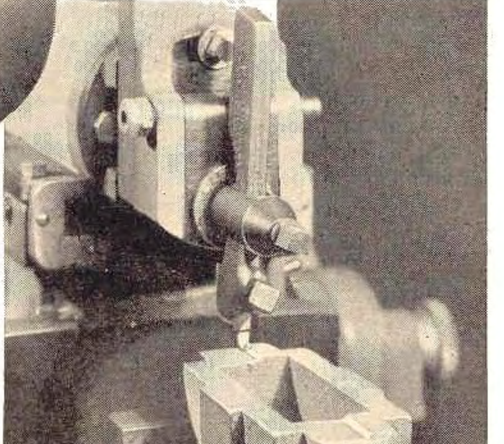


AMATEUR machinists who run the models they build will get double pleasure from this miniature vertical steam engine. Although it is not a scale reproduction of any particular engine, it has the same general appearance and eye-taking appeal of the picturesque old-timers so hard at work about the turn of the century.

The model is equipped with the link-motion reverse gear perfected by George Stephenson for his famous locomotive, *The Rocket*, in the 1830s. This valve action, which also provides a variable steam cutoff, has played a historic role in steam-power development. The engine is a double-acting noncondensing one that exhausts directly into the air with the familiar *puff-puff* of a donkey engine or steam shovel.

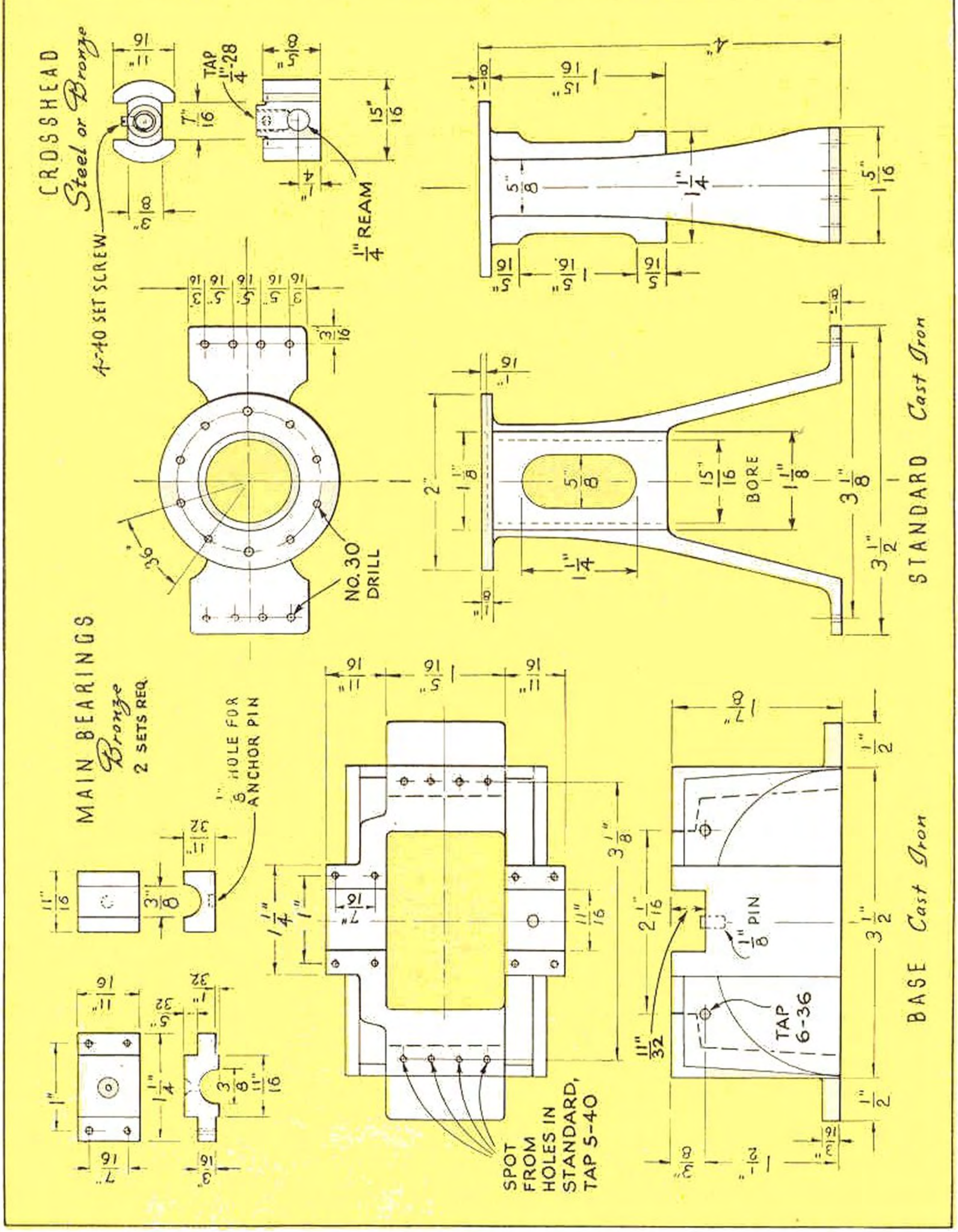
With its 1¼″ cylinder bore and 1″ piston stroke, and with 75 or 80 lb. of steam in its boiler, the little engine will turn over at 1,500 r.p.m. Actual power will depend much on the boiler used and on the workmanship in the engine itself. The design is for heavy duty, however, with main bearings and other working parts larger than scale, and the engine will stand up well under hard, continuous runs at full working load, developing enough power to drive a quite large model boat, a small dynamo, an air fan, or other light equipment of fractional-horsepower rating.

Much exacting work is required in building an engine of this type, espe-



Machining the bottom of the casting for the base. The operation can be done in a lathe as well as a shaper, with the work clamped to the faceplate.

# with Reverse Gear



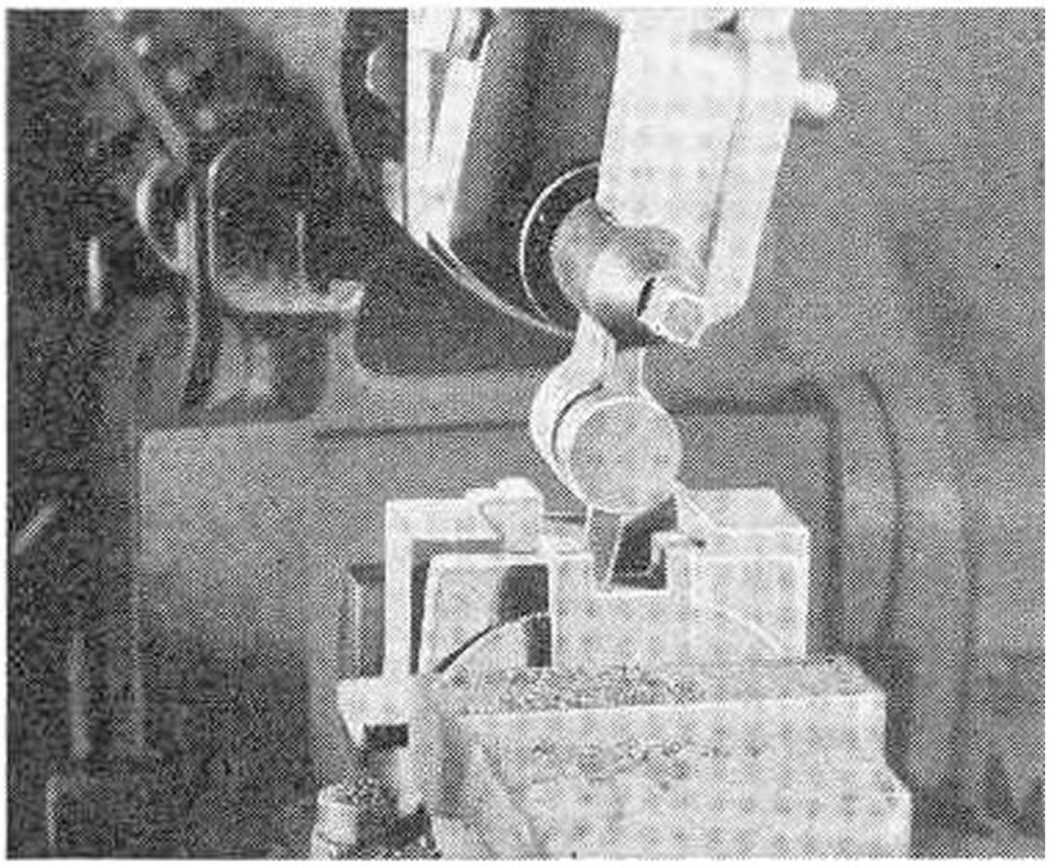
cially since the reverse gear and crankshaft, to be described in a later installment, and other small parts must be machined from steel. However, it is enjoyable work for the modelmaker, and it is of a kind well within the scope of anyone who has become proficient in the use of a screw-cutting lathe.

If you are experienced in woodworking, you can build the necessary patterns and have iron or bronze castings made at your local foundry for the base, standard, cylinder, cylinder head, steam chest, and flywheel. Or you can even make up the sand molds and pour bronze castings yourself. The pattern work, however, is by no means a one-evening project, and castings can be supplied for those who want to get right at the machining. Dimensions shown in the drawings are for the finished parts. If patterns are made, an allowance of 3/32" must be added to surfaces to be machined. Shrinkage allowance need not be considered.

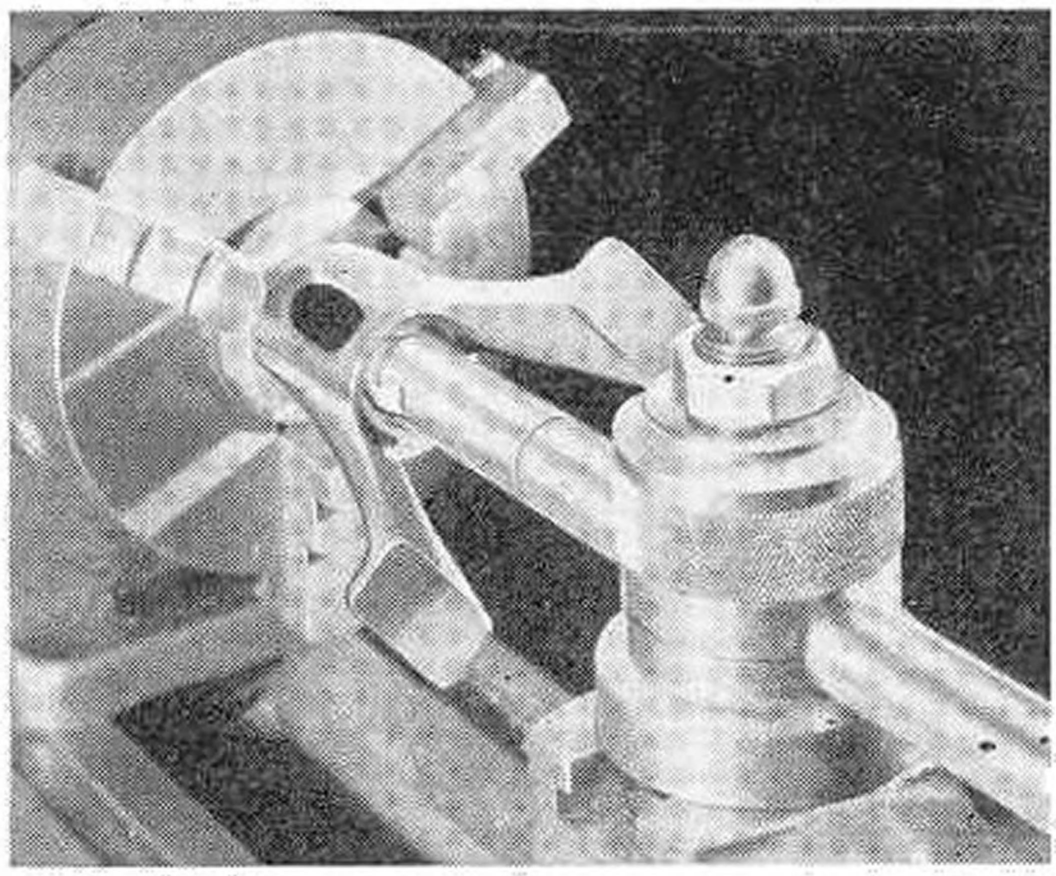
Machining operations are possibly best begun on the base since many of the parts can be fitted on it and temporarily assembled as the work proceeds. The casting is easily handled in a shaper, but if your shop boasts only a lathe, the facing can be done with the work clamped to the faceplate and the milling can be done with the lathe milling attachment. Since the casting is open at the center, only the bottom and top need be faced and slots milled for the bearings, after which the pin holes are drilled and the piece cleaned up with a file. Drilling and tapping the screw holes should wait until the mating parts are fitted, when both can be drilled at the same time.

Two identical main bearings are made up from ⅜" by ¾" brass bar stock cut to length and soldered together in pairs. Mounted in the four-jaw chuck, each bearing is drilled and reamed to size for the crankshaft and the ends faced smooth. The halves are then melted apart and the parts filed to shape and to a good snug fit in the base. Save drilling them and the base for screws until the crankshaft can be set in place.

The standard or main column is held in the three-jaw chuck, and the solid body is bored smoothly and accurately to take the crosshead. With the piece on a mandrel, the head is faced square with the bore and turned to diameter; then the work is reversed on the mandrel and the feet are trued. Screw holes are next drilled in the head to hold the cylinder in place and in the feet for mounting on the base. The tapped holes in the base are spotted from those drilled in the feet.



Slots are machined across the top of the base to take the main bearings, which will be made a snug fit. If a shaper is not available, the work can be done on a lathe with a milling attachment.

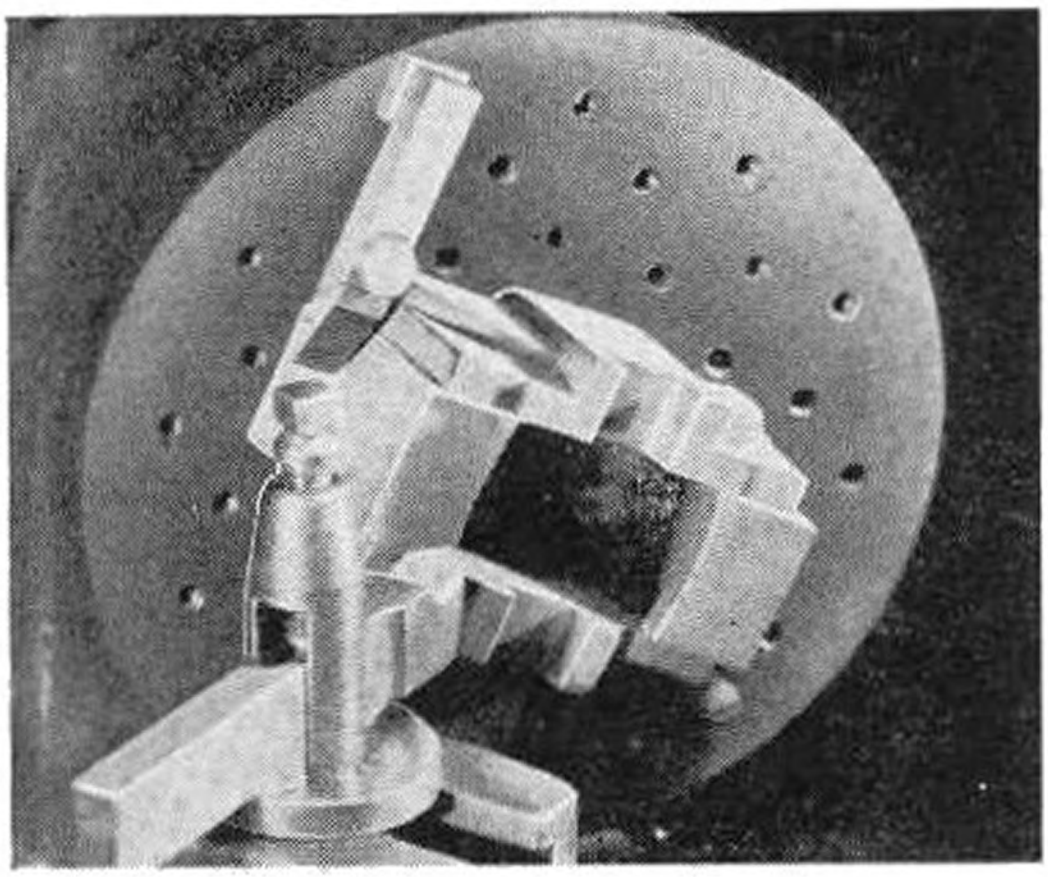


Since the top part of the standard or main column is cast solid, it must be drilled and bored out to take the crosshead. The operation is performed in the lathe with the work in the three-jaw chuck.

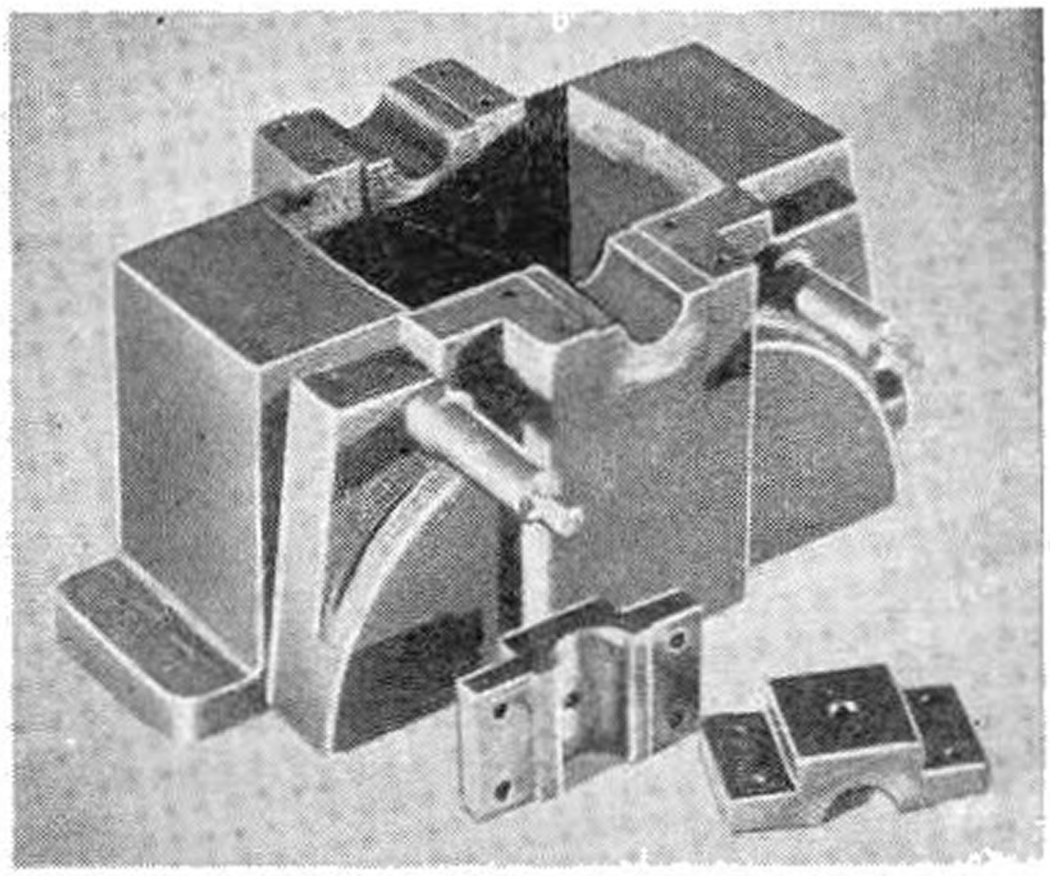
In making the crosshead, a short piece of cold-rolled steel or bronze is held in the three-jaw chuck and turned to a nice sliding fit in the main-column bore. Next, the upper end is recessed and turned to shape, and it is also drilled and tapped for the piston rod while still chucked so the outer diameter and the piston-rod hole will be concentric. The part is then cut off and the opposite end faced smooth.

Grooves are cut on both sides in the shaper or with the milling attachment, leaving a ⅜" thick web to take the forked end of the connecting rod. The hole for the connecting-rod pin is then cross-drilled in the lower end.

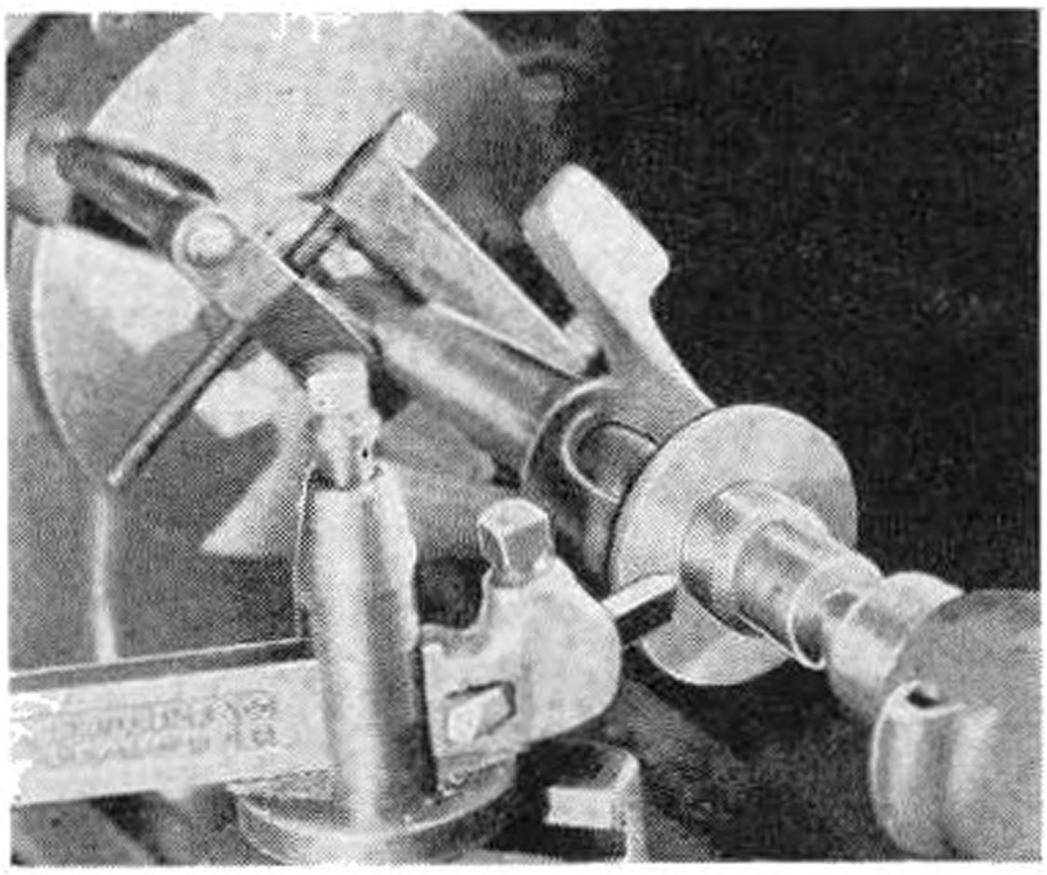
TO BE CONTINUED.



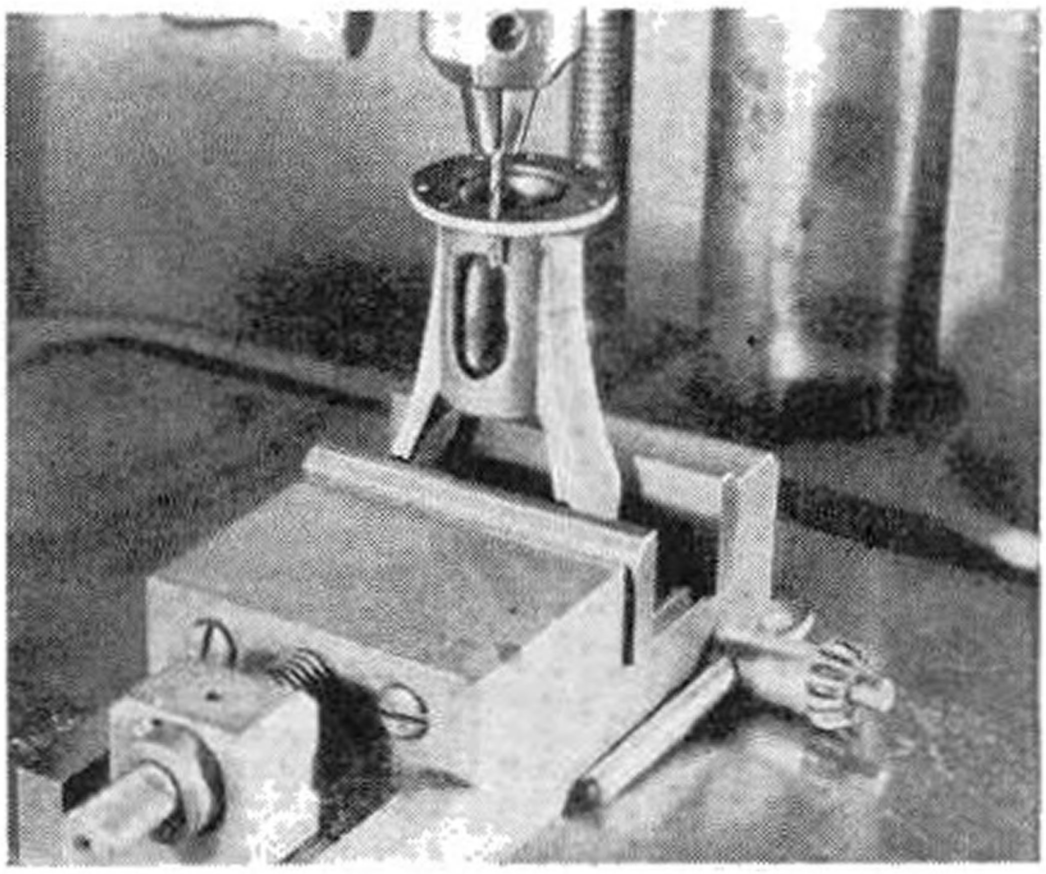
Here the base casting is clamped to the faceplate of the lathe, and the top is machined smooth and to height. A heavy cemented carbide tool is used. Any rough spots are cleaned up with a file.



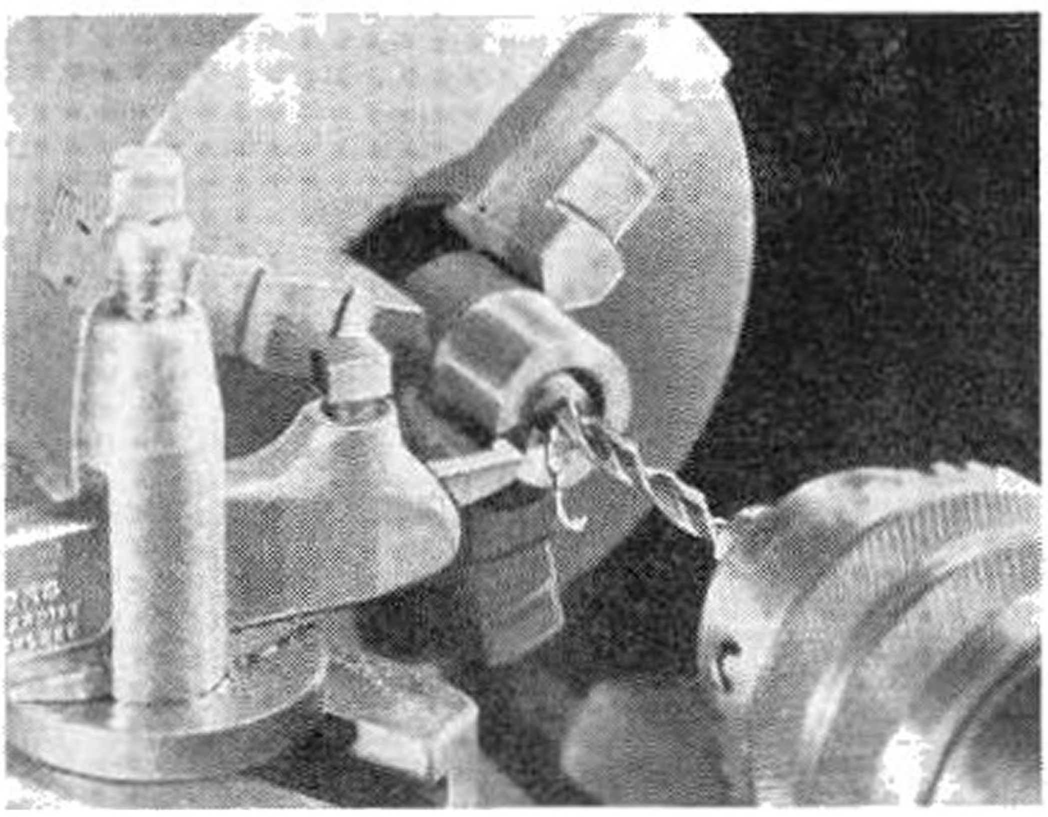
Halves for the main bearings are drilled and reamed while soldered together, then split apart and each half filed to shape. Here the lower halves are in their slots, the upper ones beside the base.



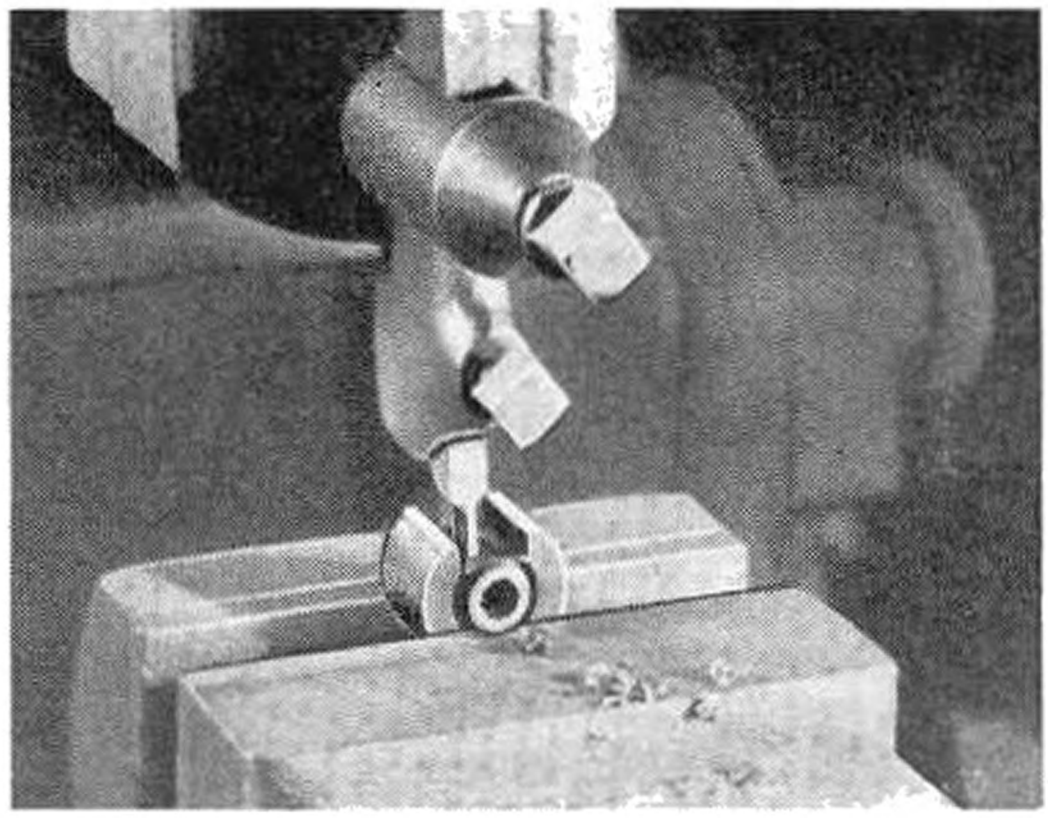
The column is then mounted on a mandrel held between centers for facing the head square with the bore and turning to diameter. It is next reversed on the mandrel and the feet faced smooth and true.



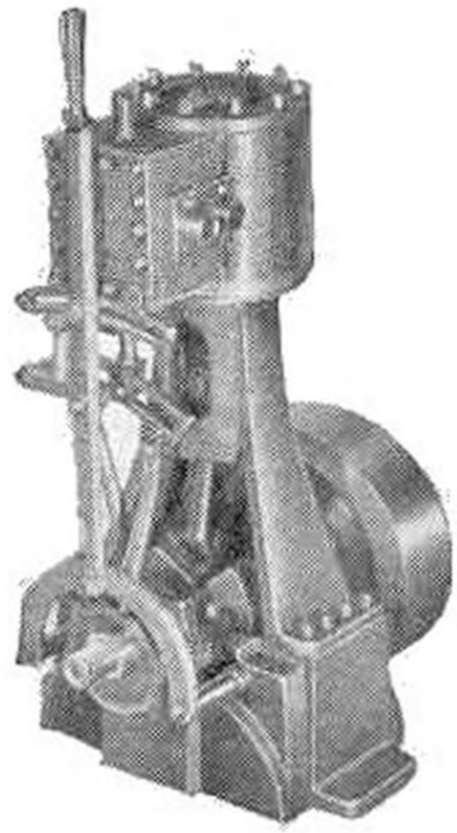
Drilling the head for screws to hold the cylinder in place, and the feet for four mounting screws apiece, completes the standard. Tapped holes in the base are spotted from those drilled in the feet.



Stock for the crosshead is turned to a sliding fit in the main-column bore; then one end is recessed and turned to shape. The piece is also drilled and tapped for the piston rod while chucked.



Grooves milled in opposite sides of the crosshead take the forked end of the connecting rod. This operation may be done in a shaper, as shown here, or with a lathe milling attachment.



# Machining Cylinder

PART TWO

MUCH of the performance of a steam engine depends on the accuracy and smoothness of the cylinder bore. This is as true for the miniature reversing engine here described (see PSM, April '47, p. 190) as for full-size engines.

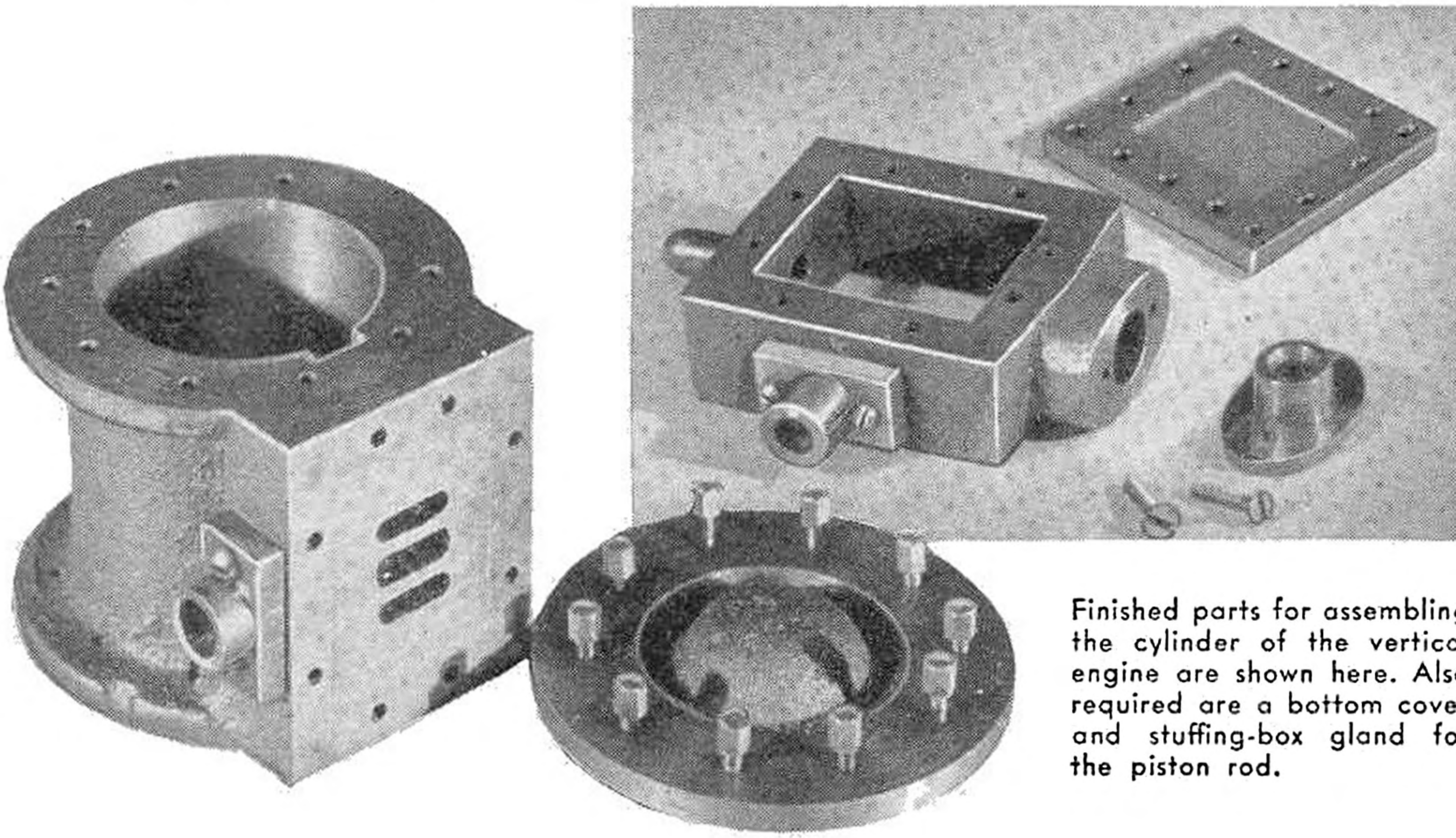
The casting for the cylinder is first mounted in the the three-jaw chuck and a roughing cut taken across the bottom so it can be reversed and held squarely for facing the top. If you have available an expanding mandrel, the cylinder is best bored after the rough facing and then mounted on the mandrel, where its ends can be faced smooth and squared accurately with the bore.

Lacking such a mandrel, face the top smooth first, and then reverse the piece and face the bottom smooth and square before attempting to bore. Although the cylinder may be held in the three- or four-jaw chuck for these operations, there is less likelihood of slipping if it is clamped to the lathe faceplate with lugs over its flange.

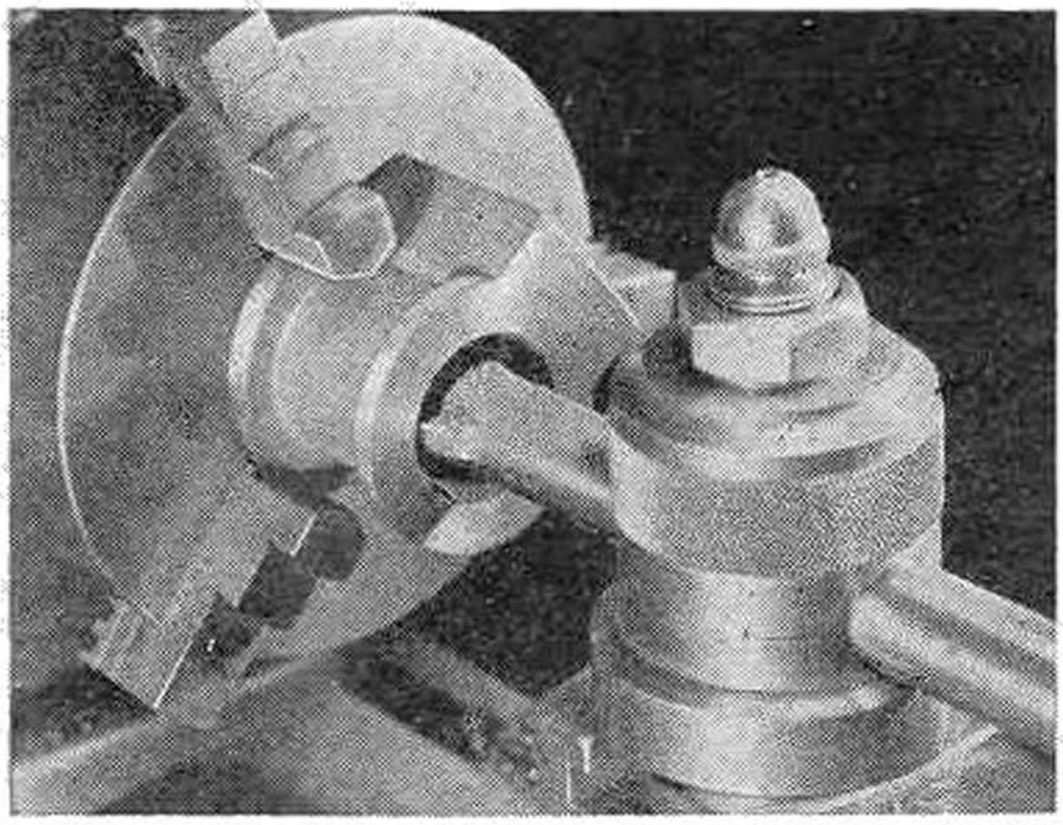
Bore the cylinder first with a heavy roughing cut to get the bit under the hard surface scale and bring the hole nearly to size. Then, with a freshly ground bit inserted in the boring bar, take light finishing cuts while using a very fine power feed. If care is taken in sharpening the bit and setting it to eliminate chatter, an almost mirrorlike finish can be obtained.

The steam-port face can be machined in the shaper or, as shown in one of the photographs, while mounted on an angle plate in the lathe. Again take a heavy roughing cut first to get under the scale, and then, with the bit freshly ground and honed to a keen edge, finish with light cuts and a fine feed.

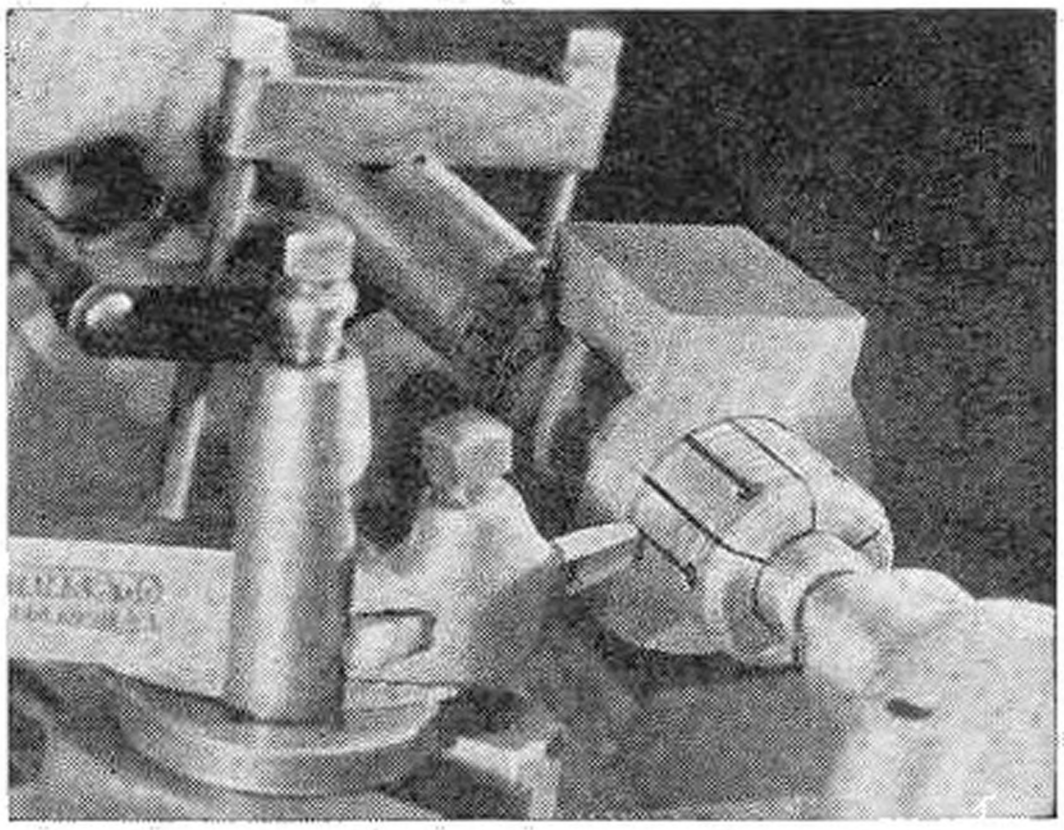
Remove the work to the drill press, clamp in the vise, lay out the steam and exhaust ports carefully, and drill a series of holes for each. Chip out the intervening metal and file the resulting slot to shape. Then mount the work in the angle vise and drill four holes for each of the two angle ports to meet those in the face. Chip and file out as before. A chisel made from 3/32" drill rod and hardened may be used for chipping. The cylinder is next remounted in the vise and



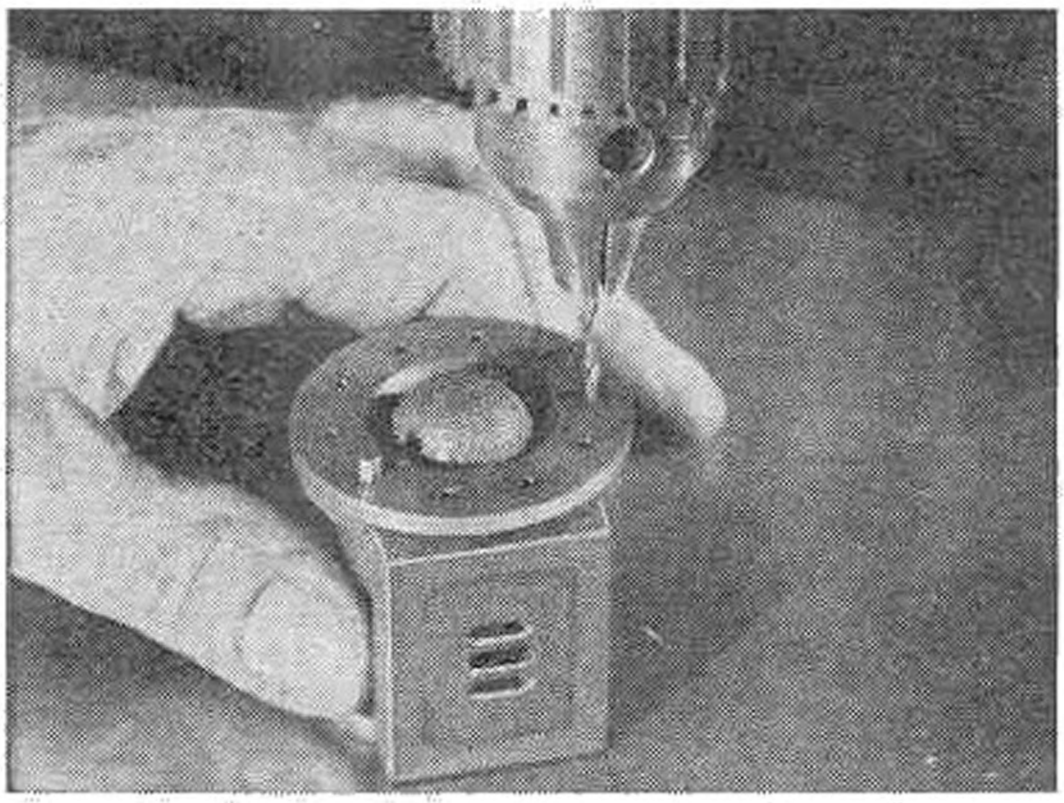
Finished parts for assembling the cylinder of the vertical engine are shown here. Also required are a bottom cover and stuffing-box gland for the piston rod.



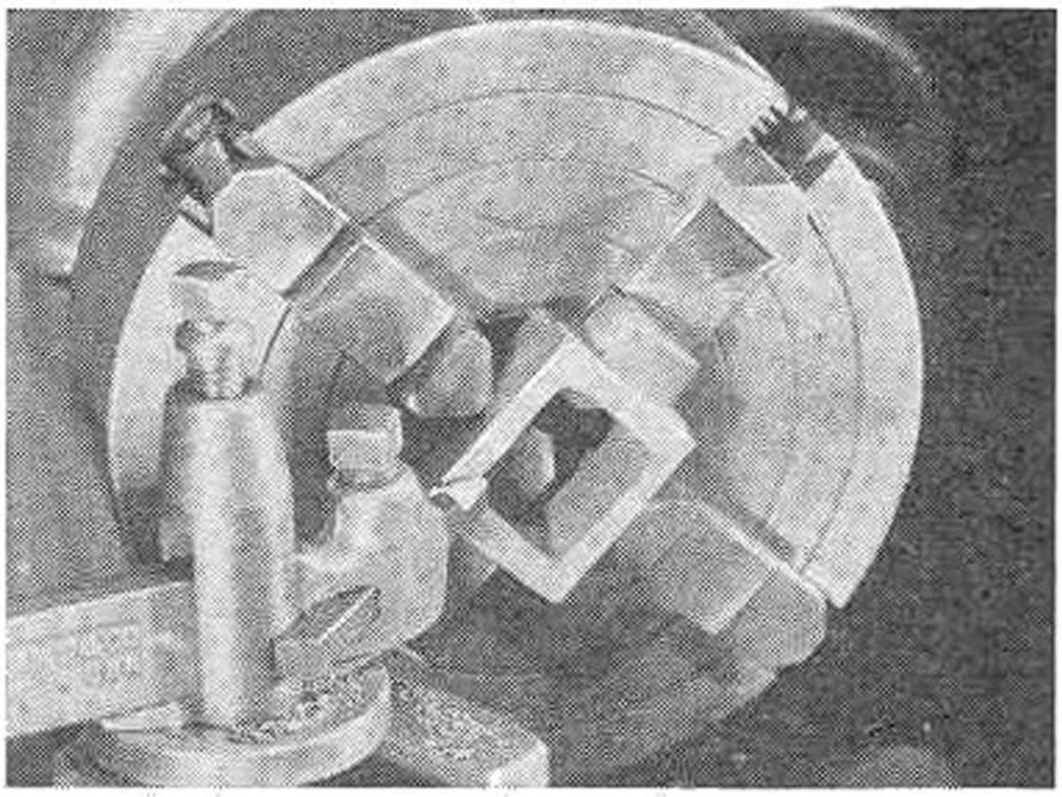
**1** In boring the cylinder, take a heavy roughing cut to get under the surface scale. Finish the bore with light cuts and a freshly ground bit.



**2** If an expanding mandrel is available, bore the cylinder before finish-facing the flanges; if not, machine the flanges first and then bore.



**5** Drill and tap one hole in the flange, and then bolt the cylinder head on before spotting the others. Use a clamp at the opposite side.



**6** Face the steam chest on both sides, taking a heavy roughing cut on each first and finishing with light cuts to assure a steamtight joint.

the exhaust port drilled in from the side to meet that in the face. Don't drill the 4-48 holes until the covers have been made.

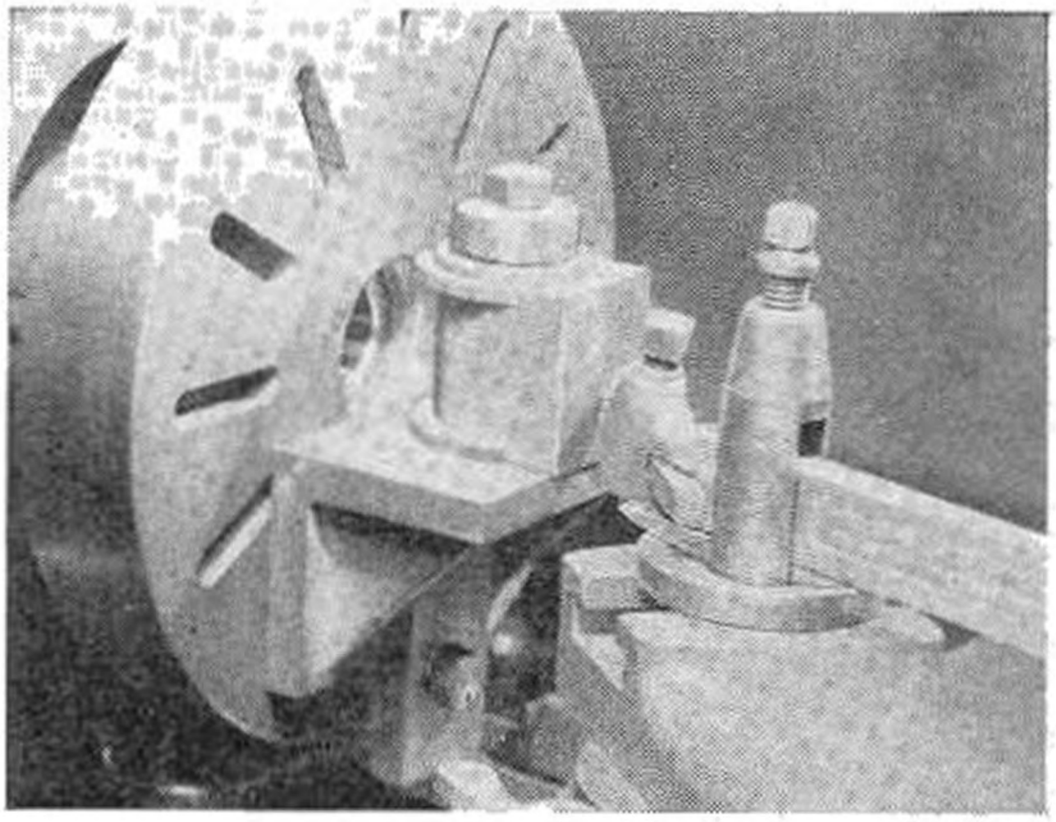
Mount the cylinder-head casting in the three-jaw chuck and turn the chucking lug straight so the casting will run true when reversed. Machine the top and outer edge to shape, and then score a light 1⅜" circle on the face for locating the bolt holes. Again reverse the piece in the chuck, take off the chucking lug, face smooth, turn the step to a good snap fit in the cylinder bore, and drill a 7/16" hole ¼" deep to clear the nut on top of the piston.

The bolt holes are then stepped off accurately with dividers, centerpunched, and drilled clearance size. Snap the head in place, spot one of the holes in the flange with a clearance-size drill, drill tapping size, and tap. Next, insert the bolt and spot the remaining holes. Make a file mark on meeting edges so that the head can be replaced in the same position; then finish drilling and tapping the flange.

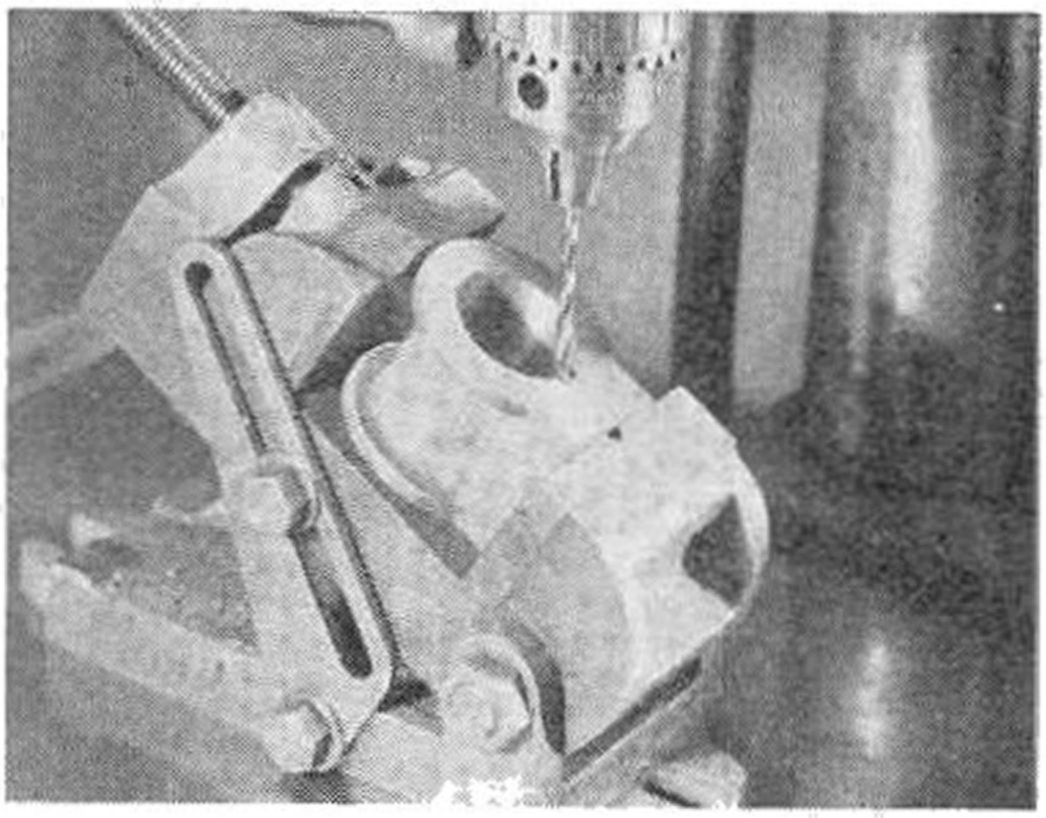
In machining the lower cover, it is important that the step fitting in the cylinder bore be concentric with the piston-rod hole so there will be no binding at that point. Equally important it is to turn the step on the outer face, or bottom, concentric for fitting the shouldered bore in the standard.

One way is to turn the gland stem and shoulder on the outer face first, bore and counterbore the ¼" hole, and then mount the piece on a stub arbor or in a step chuck to face and step the inner side for a snap fit in the cylinder bore. In counterboring for the gland, be sure to start carefully in the piston-rod hole to assure concentricity.

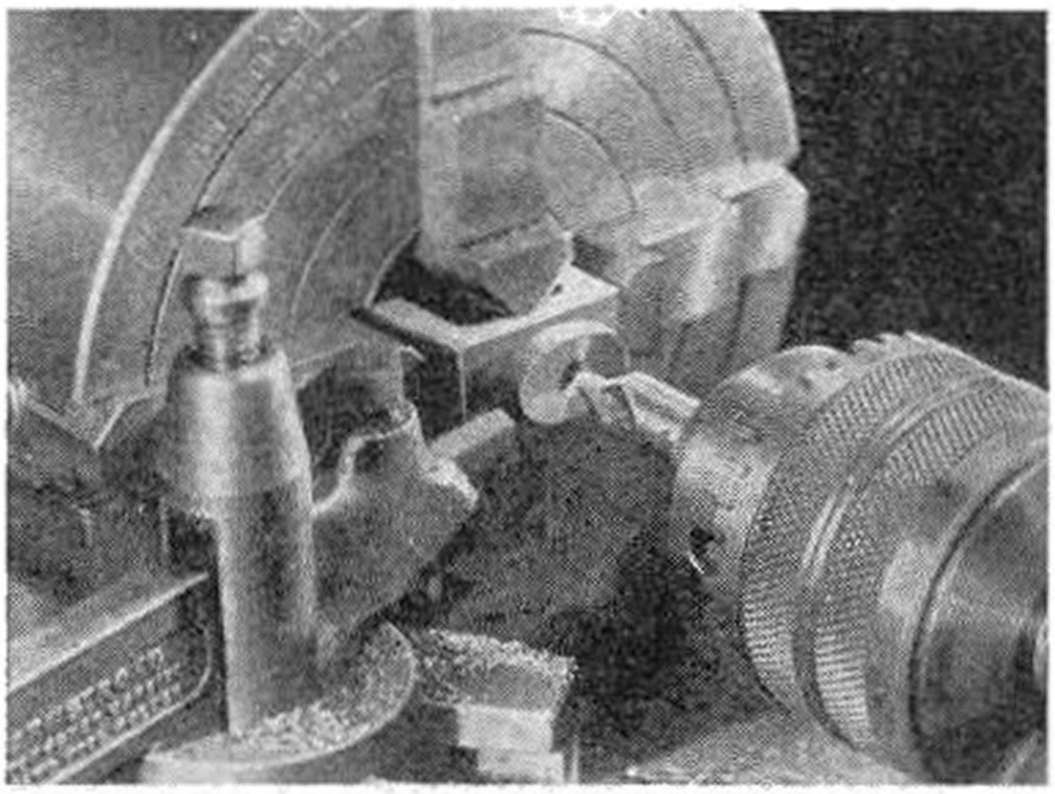
Snap the lower cover on the column, clamp, and spot the bolt holes through the column flange. Then snap the cover on the



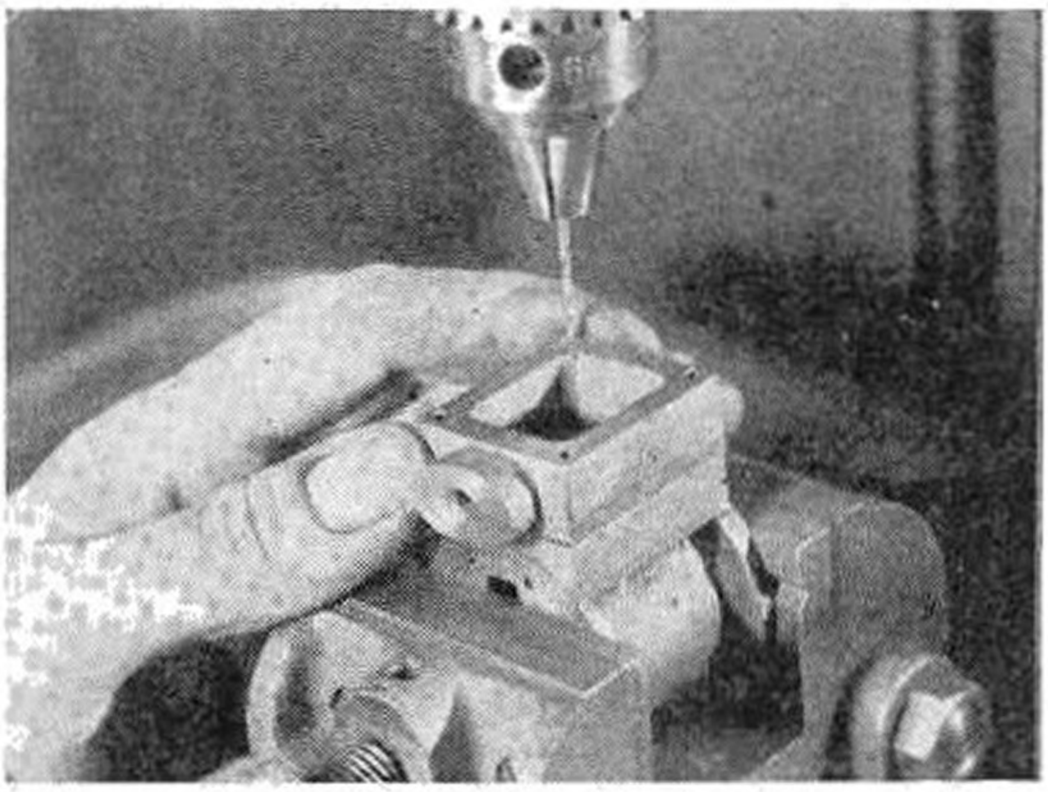
**3** Machine the steam-port face with the cylinder mounted on an angle plate, finishing with very light cuts. A shaper will also do the job.



**4** Ports are bored at an angle from both ends of the cylinder to connect with the steam ports in the face. Chip and file them to shape.



**7** Chucked gland end out, the steam chest can be drilled and reamed for the valve stem and the hole then opened out to take the gland.



**8** Corner holes are completed first in the steam chest and cylinder steam-port face; then the parts are bolted and the remaining holes drilled.

cylinder and repeat as for the head. Put witness marks on the column, cover, and cylinder flange, making certain that the valve face is at 90 deg. to the crankshaft centerline of the base.

Face the steam-chest casting on both sides, holding it in the four-jaw chuck, and bring it to proper thickness. A heavy roughing cut followed by several light finishing cuts will assure a steamtight joint.

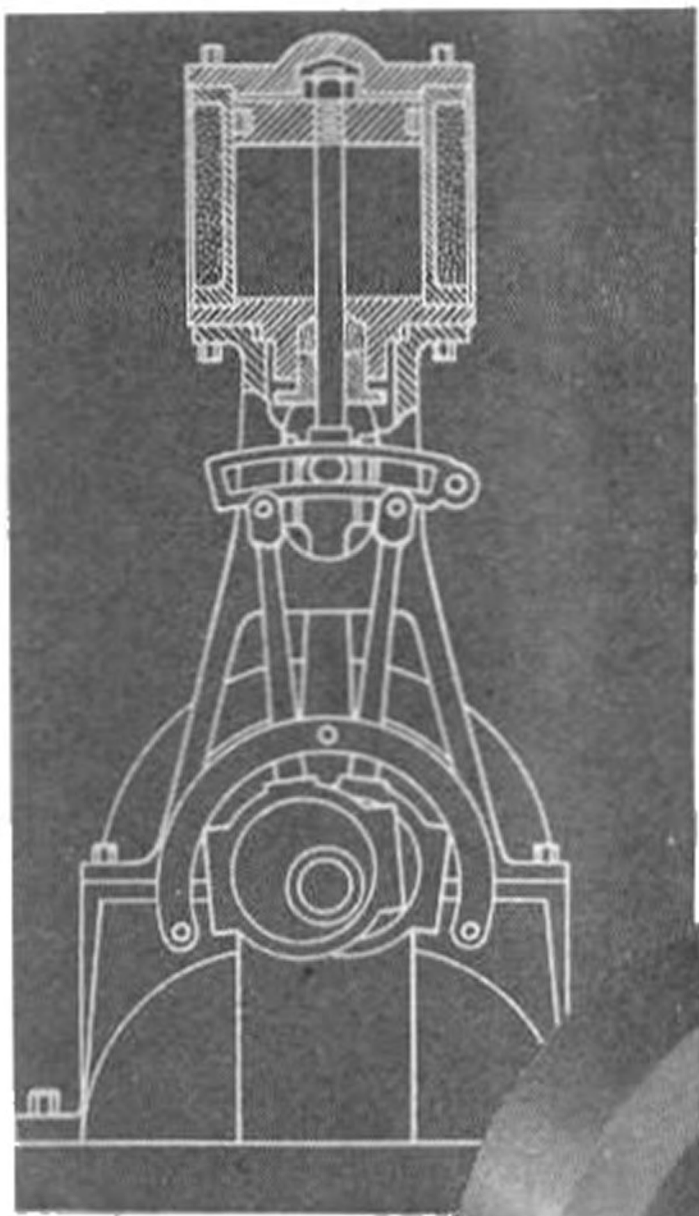
Some difficulty may be encountered in drilling for the valve stem, since the inner surfaces of the steam-chest casting will have a slope. If you have a hand grinder, a small flat can be ground inside the stem-guide end for a drilling surface, after which the steam chest can be chucked and the hole drilled all the way through from the gland end. Otherwise it may be best to lay out the holes as accurately as possible on the outer surfaces, drill each from the outside with an undersize drill, and then ream from the gland end. In this case, drill the gland end first, counterbore, and support it with the tailstock center when drilling from the stem-guide end. Finish by enlarging the upper hole with a No. 3 drill and tapping ¼"-28.

Lay out the 14 bolt holes, drill the four in the corners clearance size, and spot, drill, and tap the corner holes in the cylinder steam-port face. Bolt through the four holes, and drill the remaining 10 tapping size through the steam chest into the cylinder. Separate the parts, tap the cylinder holes, and open up those in the steam chest.

Face the steam-chest cover in the lathe, mill the recess, clamp the steam chest to it in the drill press, and drill the bolt holes.

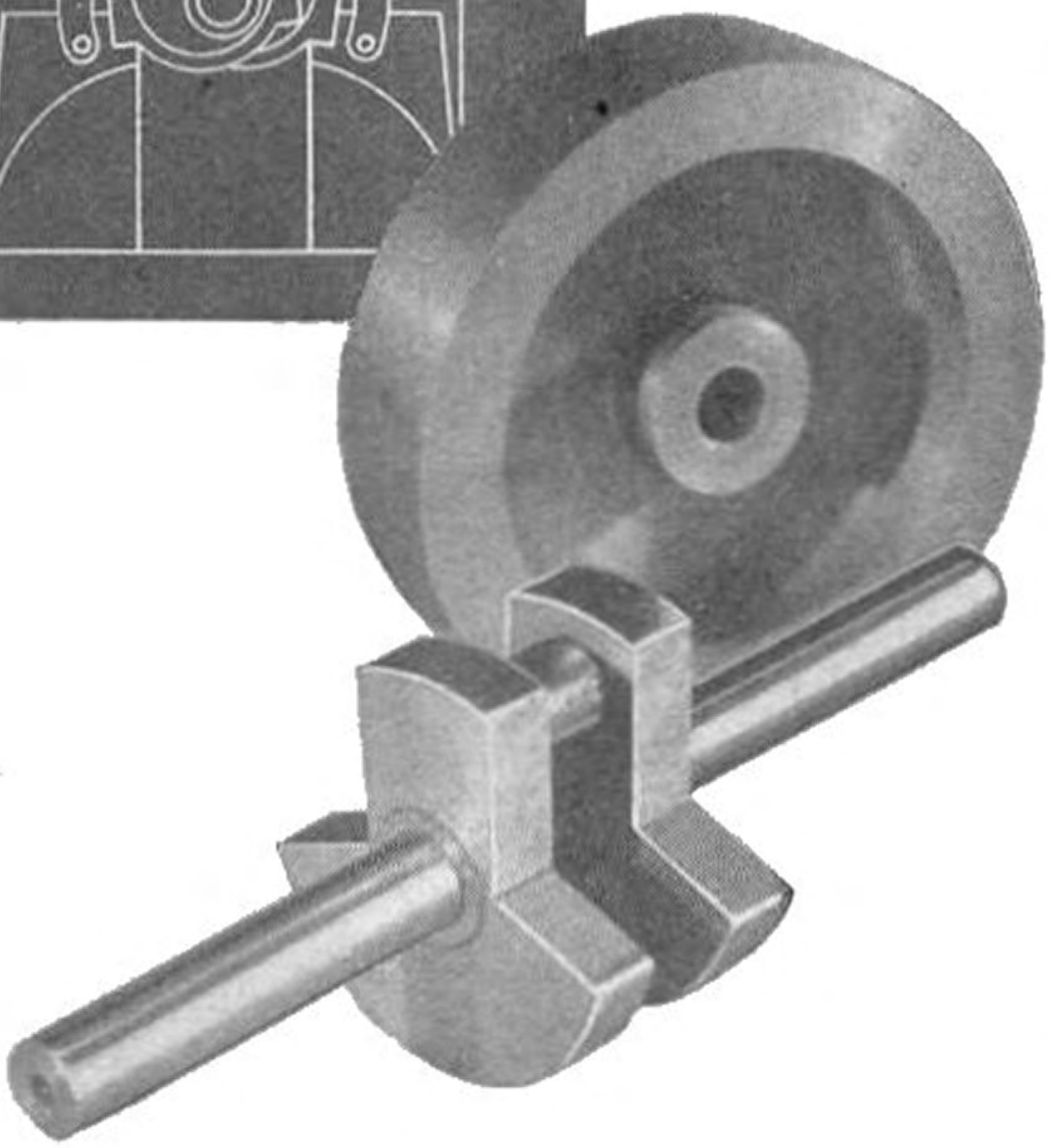
The valve-rod and piston-rod glands, valve-stem guide, and steam-pipe flange are turned from bronze bar stock to dimensions on page 193.

TO BE CONTINUED



**Vertical Steam Engine with Reverse Gear PART THREE**

# Making the

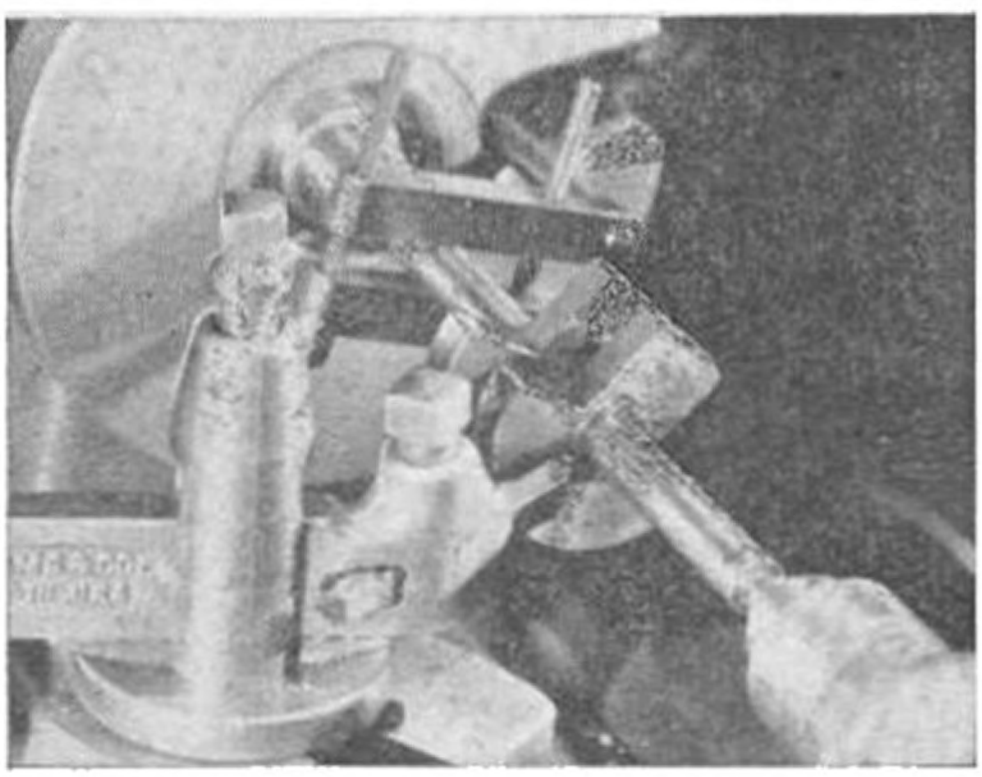


Alignment of the two ends of the shaft is assured if it is made as one piece and cut when pinned in place. The flywheel is turned from a casting.

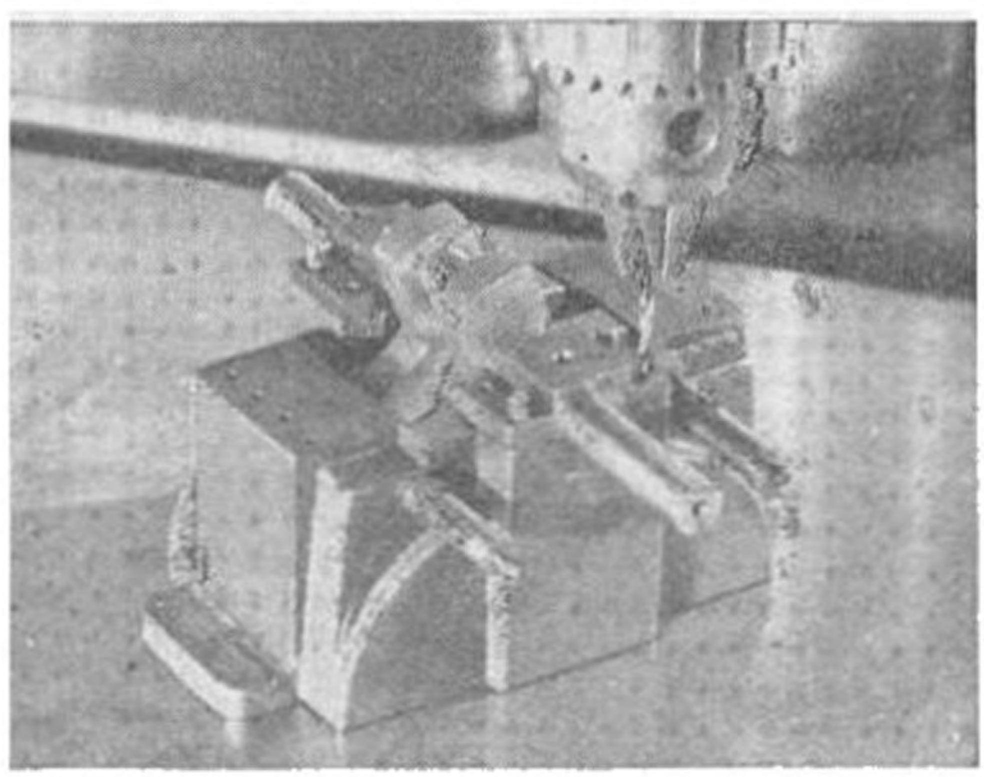
AN ACCURATE, true-running crankshaft is necessary if the model steam engine is to work freely and use steam with maximum efficiency. This part is assembled from a shaft, two webs, each with an integral counterbalance, and a crankpin. All are made up from solid steel stock, the webs cut with a hacksaw and filed to shape from two 5/16″ disks and the shaft and pin cut from drill rod.

Clamp the webs together and drill them at the same time for a drive fit on the shaft and pin. Because the shaft is cut as one piece 4⅜″ long and must be driven a considerable distance, it may be necessary to ream the ⅜″ holes for it slightly. Press both webs on the crankpin first. Next, with a block between the webs to prevent bending the pin, drive the crankshaft through. Then drill and pin all parts. Pieces of bicycle spoke make good pins.

The assembled crankshaft is next mounted between centers in the lathe and with the block still between the webs. Face the outer web sides smooth, form the 1/32″ collars, and turn the outer rim of the balance weights and the ends of the webs smooth and to exact diameter. Finally cut out the part of the crankshaft between the webs and file the inner faces smooth. Key-

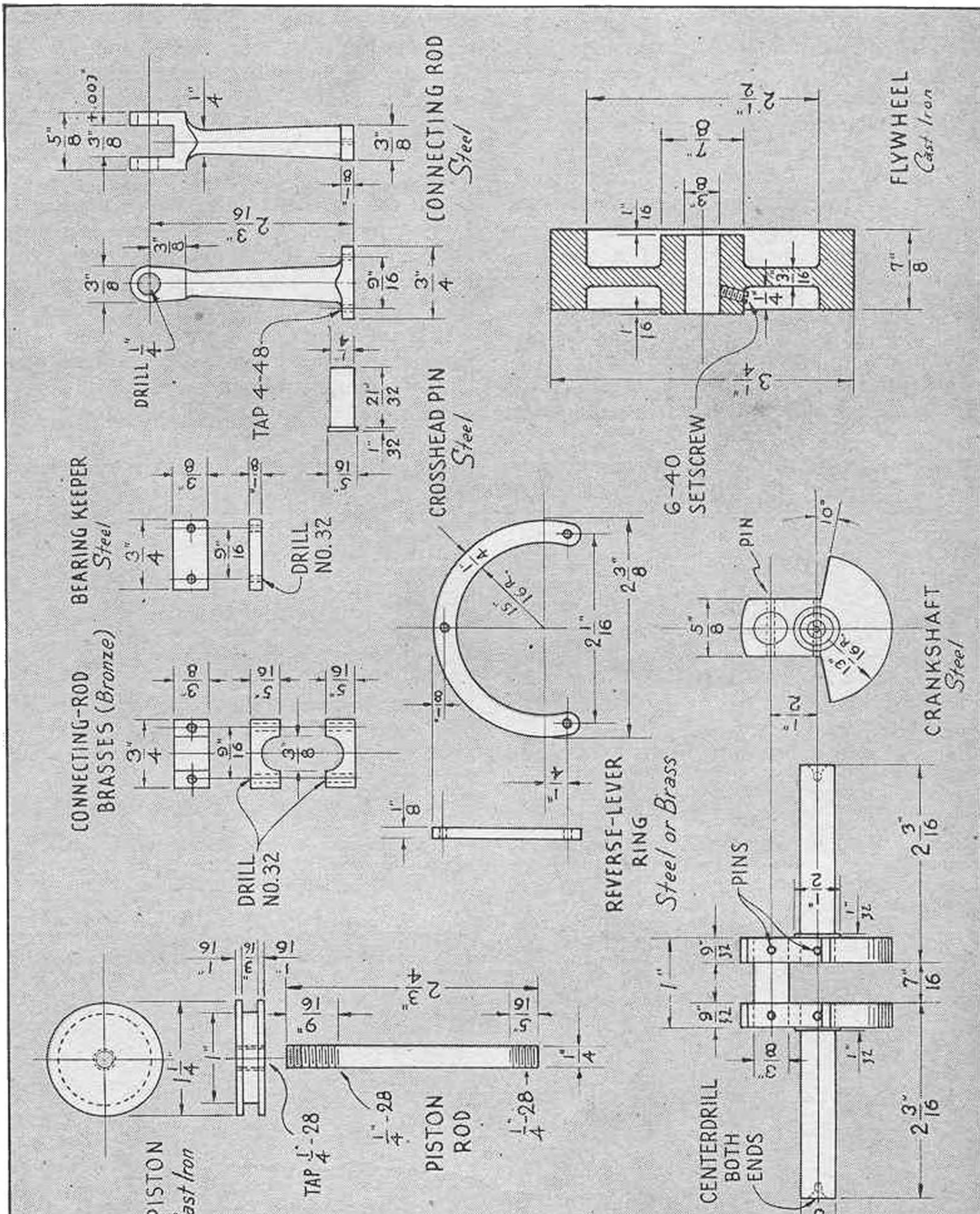


Mounted between centers, the crankshaft is faced smooth on the webs and the collar turned. A block between the webs prevents distortion.



Holes for the bearing bolts are drilled through the bearing caps while the crankshaft is in place to assure alignment of the bearing halves.

# Crankshaft and Running Gear




All dimensions for the crankshaft, flywheel, connecting rod, piston, and piston rod are shown in the drawing. The reverse-lever ring is also shown and may well be made at this time.

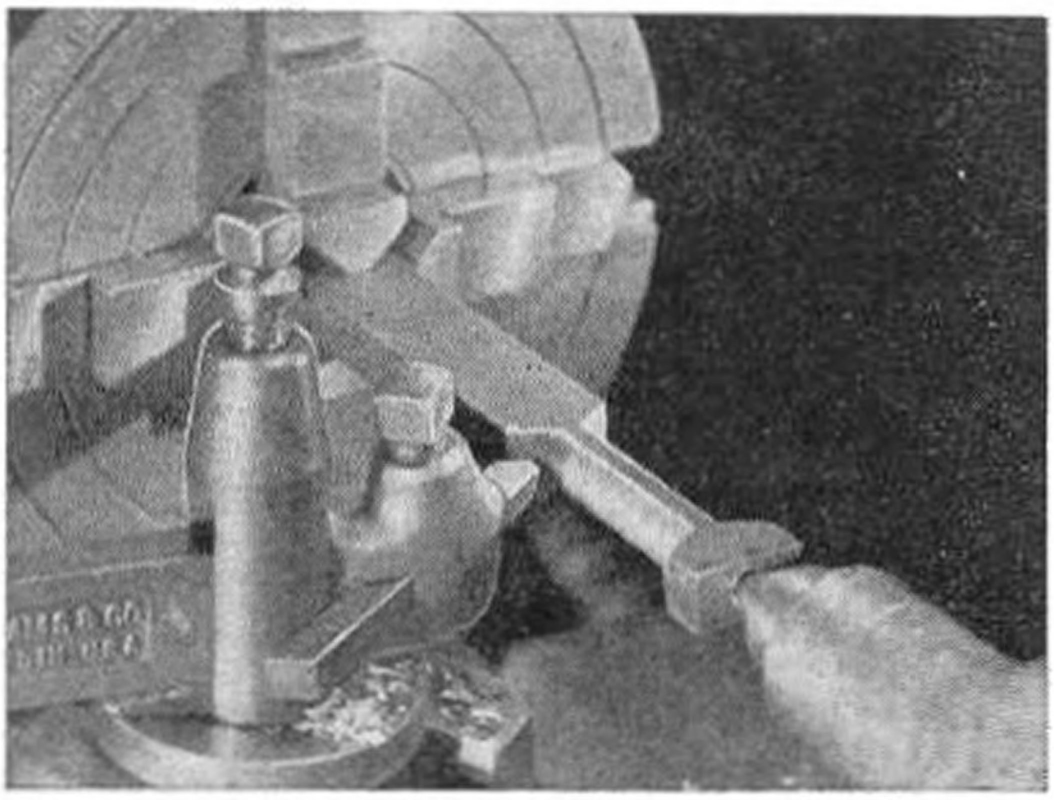
ways or setscrew flats are optional, depending on the use the engine is meant for.

Fit the finished crankshaft into the bearings next, clamp on the bearing caps, and rotate the shaft to make sure it turns freely. There should be no binding, since shaft alignment is insured when the webs are pinned before cutting out the center portion. With the shaft in place, drill and tap the bearing holes and bolt both caps down.

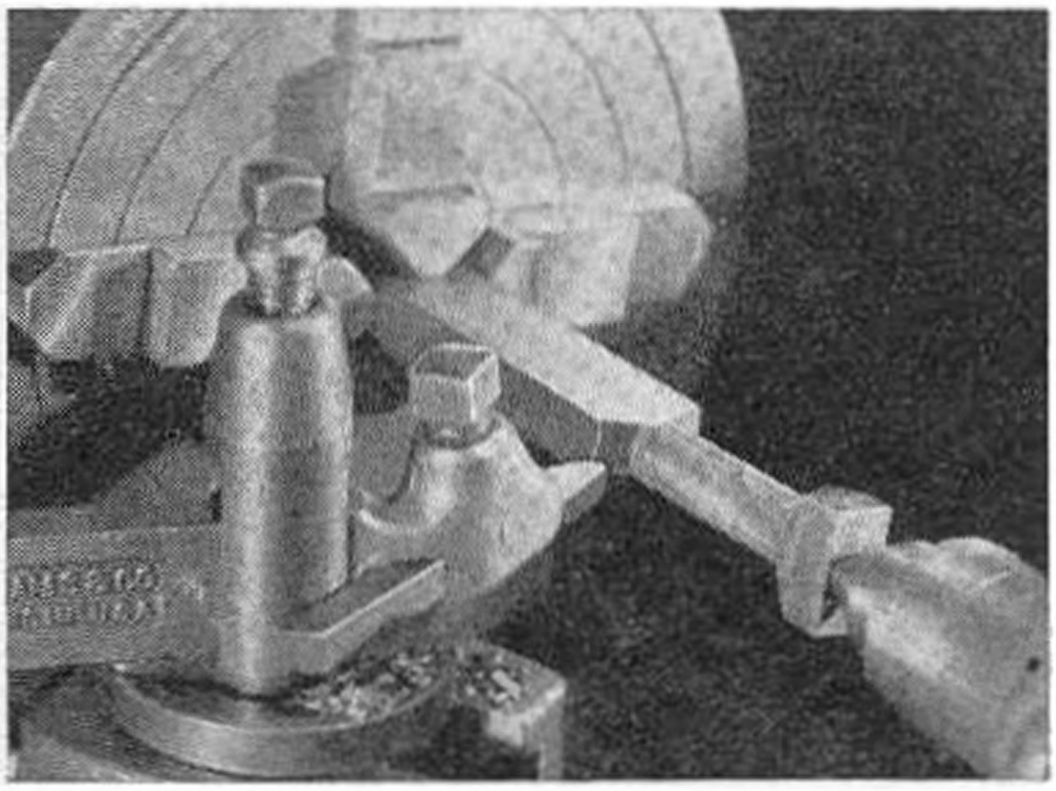
The connecting rod is rough-turned to shape from ⅜" by ¾" steel bar in the four-jaw chuck. It is removed and heated to a bright red, and the small end is twisted 90 deg. This can be done with a heavy wrench while the work is held in the vise. Then the piece is rechucked, its tapered section turned to shape and polished bright, and the work cut off. Drill, saw, and file the forked end to shape, and drill for the connecting-rod pin. Turn the pin to a force fit in the fork or thread it for a retaining nut.

Make up the connecting-rod brasses from flat bar bronze stock and the connecting-rod keeper from steel. Cut to length and drill for the screws that hold them to the connecting rod. Drill and tap the end of the rod and with two 4-48 steel screws assemble brasses and keeper on the rod. The crankpin hole is then drilled and reamed through the bearing brasses, and the end assembly is filed accurately to size.

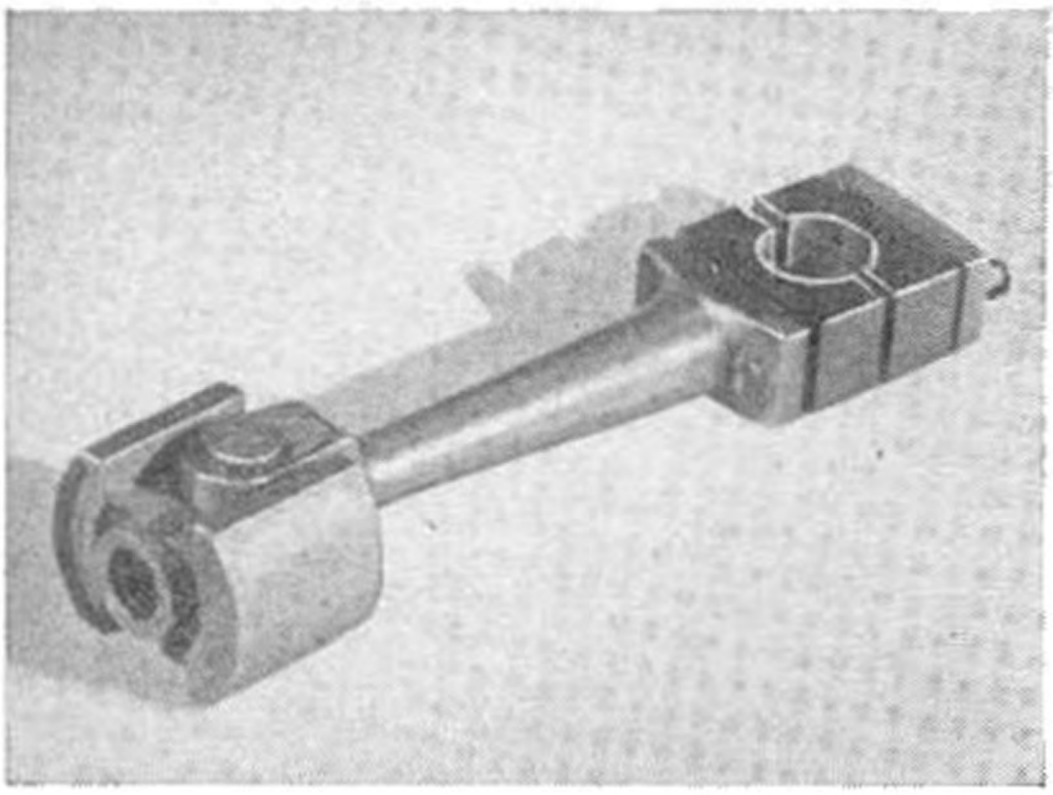
Centerdrill a 2¾" length of drill rod for the piston rod, thread both ends, and screw it into a hole drilled and tapped in a rough piston blank made from a ⅞" steel disk. Mount the work between centers and face both sides of the piston so it will run dead true. Then turn it to a nice sliding fit in the cylinder bore and cut the groove to width and depth for the piston ring. This ring, being a standard size, can be purchased, though one can be made up in the lathe from a short bar of cast iron if the



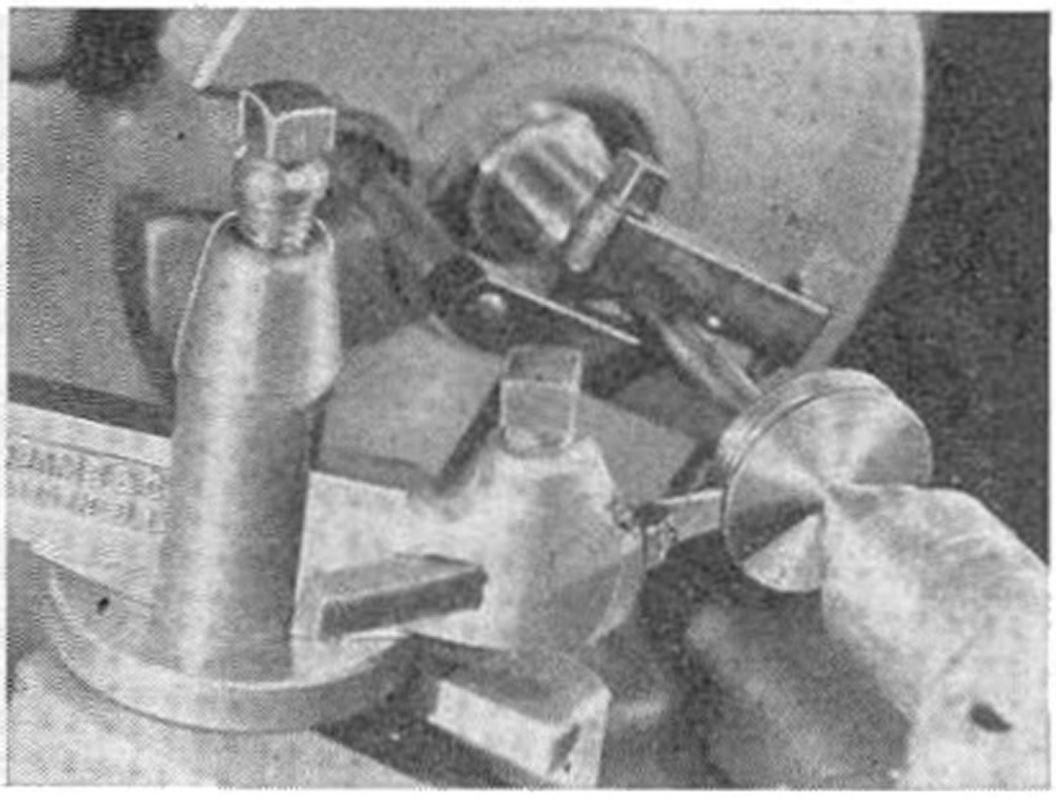
Steel bar stock is rough-turned to shape for the connecting rod, removed from the lathe, heated a bright red, and the small end twisted 90 deg.



Back in the four-jaw chuck, the connecting rod is turned for the taper, which is polished bright, and the piece is then cut off to length.



This is the connecting-rod assembly. The brasses are drilled and reamed while screwed together to give a nice running fit on the ⅜" crankpin.



The piston is turned from a blank that has been drilled, tapped, and screwed to the piston rod. It is faced true, turned to size, and grooved.

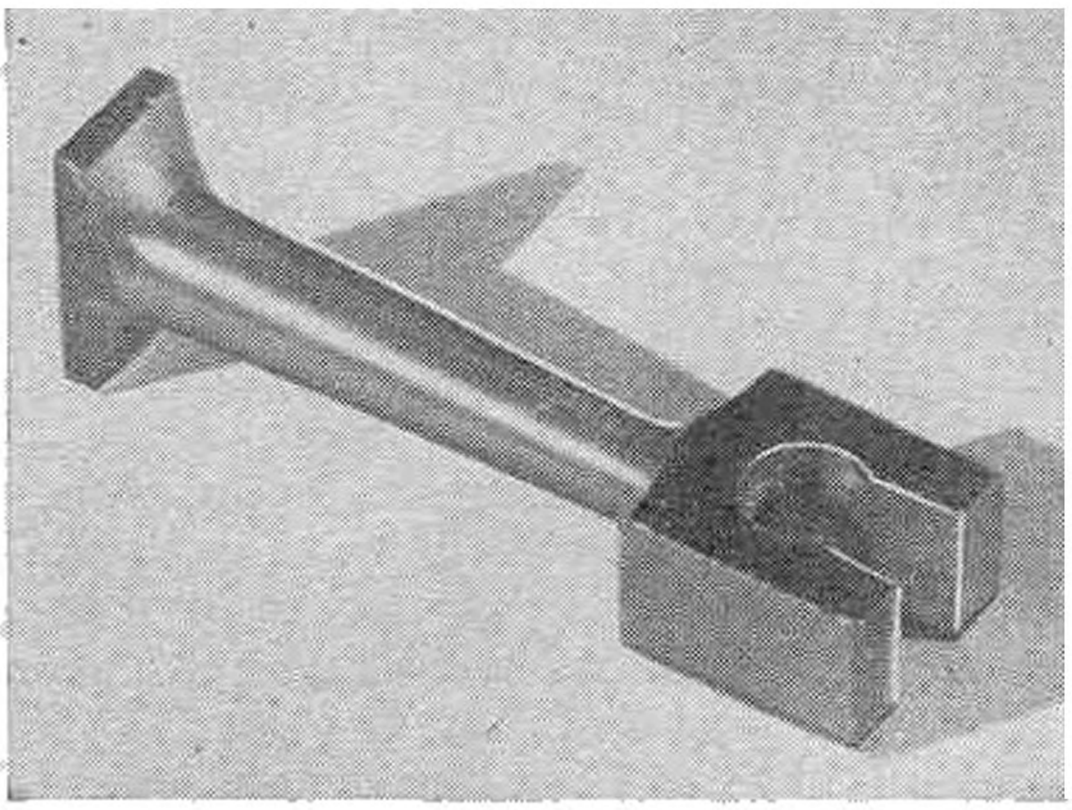
modelmaker is experienced in ring turning.

Enough of the parts will now have been completed so that you can make a trial assembly and test the piston travel. Assemble the base, the column or standard, the bottom cylinder cover, the cylinder itself, the piston and piston rod, and the connecting rod. Leave off the top cylinder cover so the movement of the piston can be checked. Likewise it will be unnecessary to put in the glands for the test.

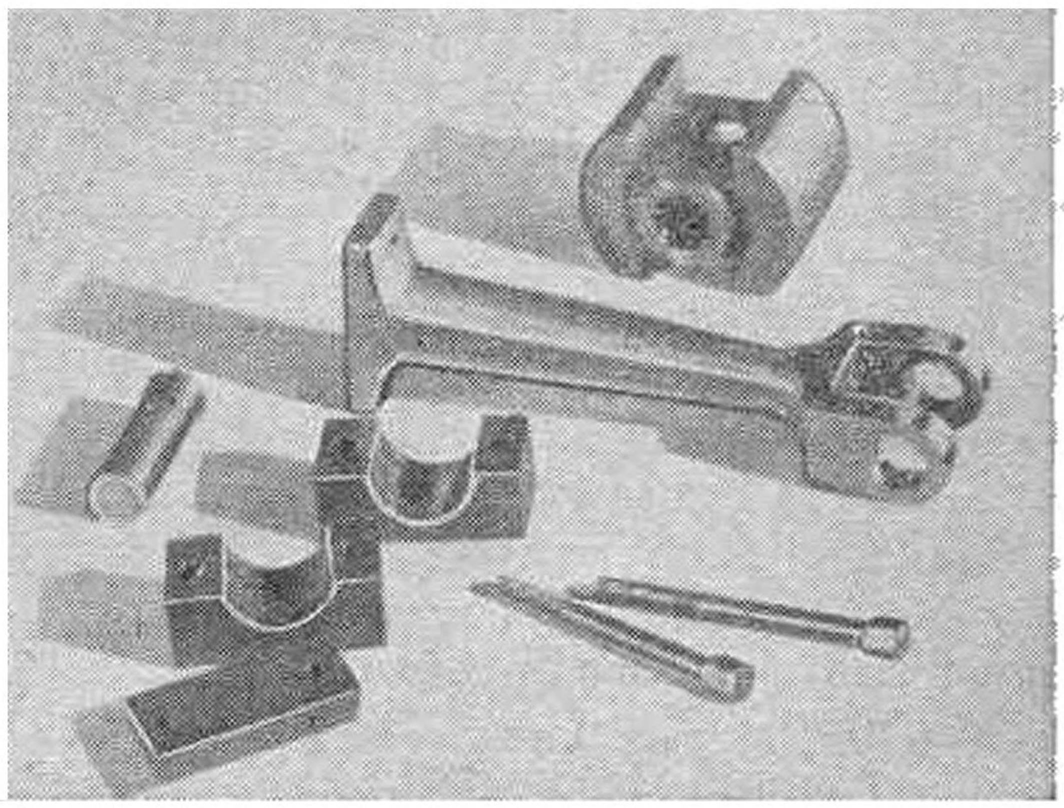
If the machining has been accurately done, the assembled engine should work freely when the crankshaft is turned. Note carefully the travel of the piston, which should be the same distance from the top and bottom of the cylinder, clearing at both points by 1/32". If it should hit at the bottom, the piston rod can be turned a little further out of the crosshead. Place the top cover on the cylinder and again move the piston through its travel. Any binding at the top will indicate that the piston is striking there, and a shortening of the piston rod will be necessary.

The reverse-lever ring is a section of a circle turned from a square piece of ⅛" steel plate. It is first chucked in the four-jaw chuck, where the center is bored to size. Rechucked in the three-jaw with the expanding jaws gripping inside the hole, it is brought to proper outside diameter. A section of the ring is next cut out, and the holes are drilled for mounting the part on the engine base.

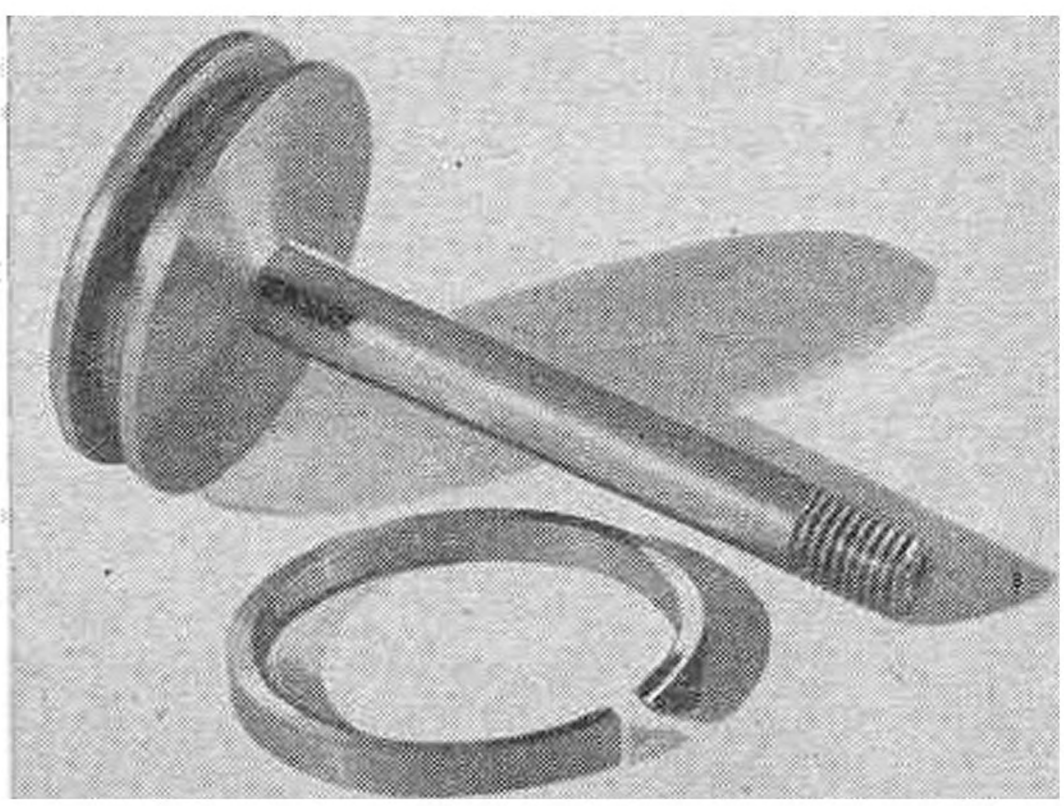
After so much work on bar stock, machining the flywheel will be a pleasant relief. This is made from a fine gray-iron casting. It is rough-turned to size in the three-jaw chuck, and the shaft hole is then drilled and reamed. The work is next mounted on a mandrel held between centers, and the hub, edges, and inside of the rim are faced to run dead true. TO BE CONTINUED



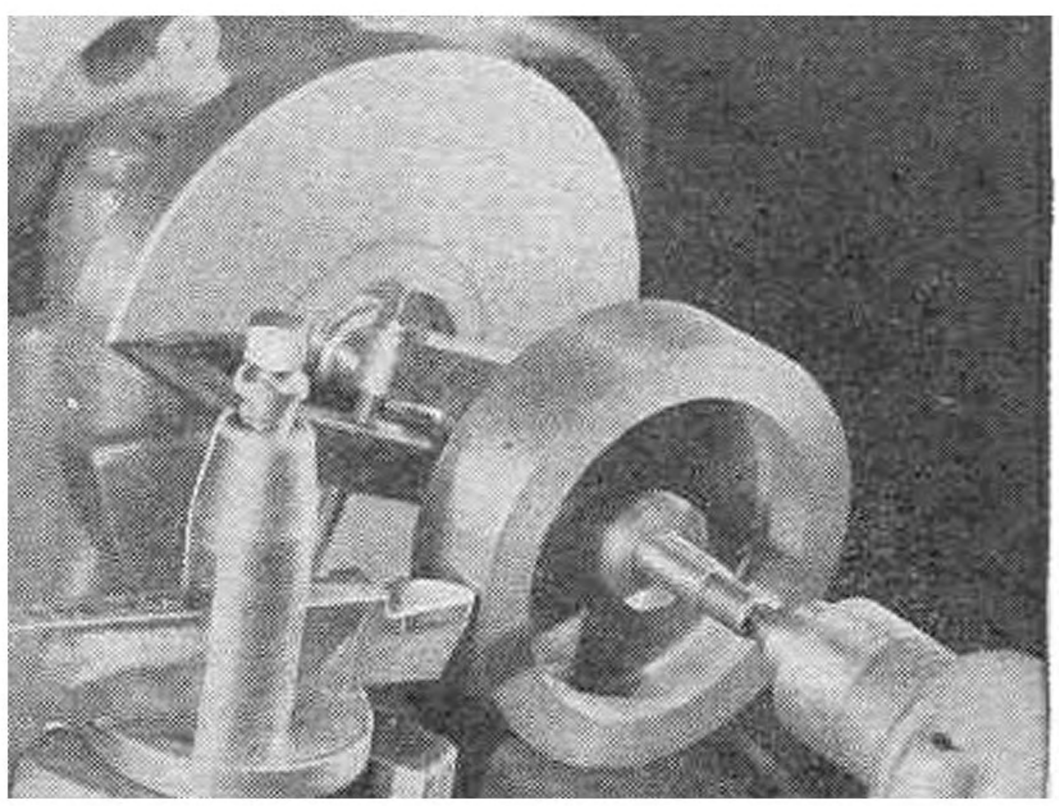
Shaping of the forked end is begun with a drilled hole and rough sawing, and the fork is brought to final dimensions by hand filing or milling.



Here the connecting rod is shown with its keeper, brasses, pin, and screws, together with the crosshead, which was described in Part I.

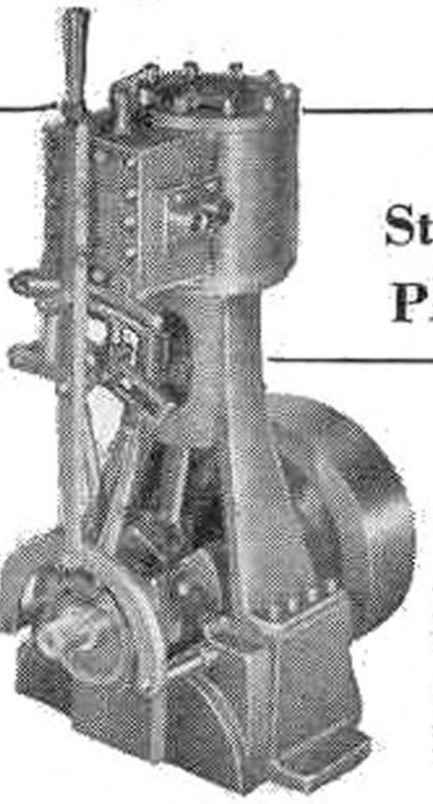


It will hardly pay to make your own piston ring, which is a standard size readily available. It is shown here with the completed piston and rod.



Rough-turned to size from a casting, drilled, and reamed, the flywheel is next mounted on a mandrel and its rim and hub are faced to run dead true.

Vertical
Steam Engine
PART FOUR

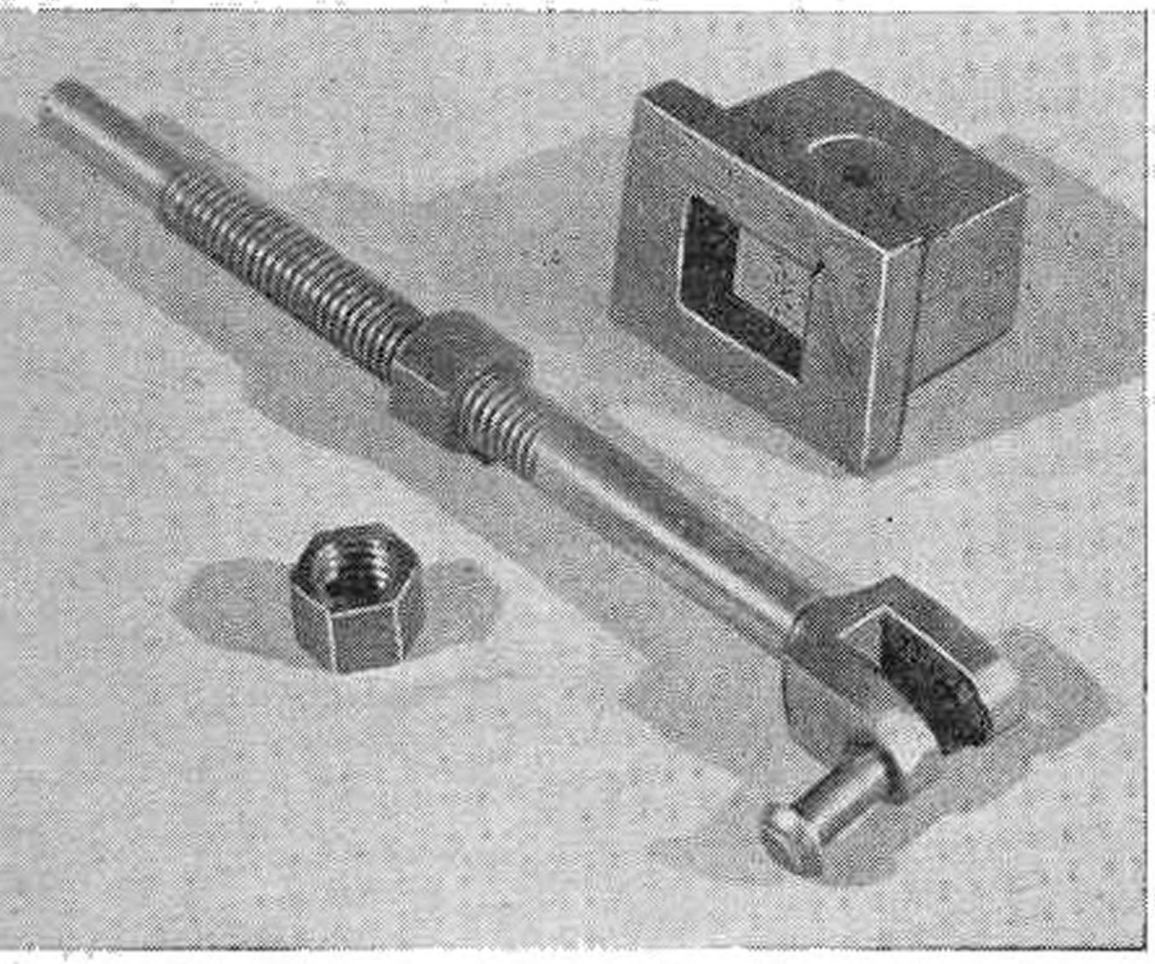


Here's the finished job as she'll look when you make the parts described in this last installment

# Building the

AT ONCE the most fascinating and the most difficult part of this engine to build, the reverse gear is derived from Stephenson's famous link motion. The valve rod, which moves the slide valve over the ports, is not connected directly to an eccentric at all, but to a small block that slides in a slotted quadrant or link. Two eccentrics, oppositely offset to give the correct advance for both forward and reverse running, are connected to the two ends of this link. A control lever connected through a drag link can shift the slotted quadrant and its connecting eccentric rods one way or the other, bringing the link block and consequently the valve into line with either the forward or the backward eccentric, and so determining which way the engine will run.

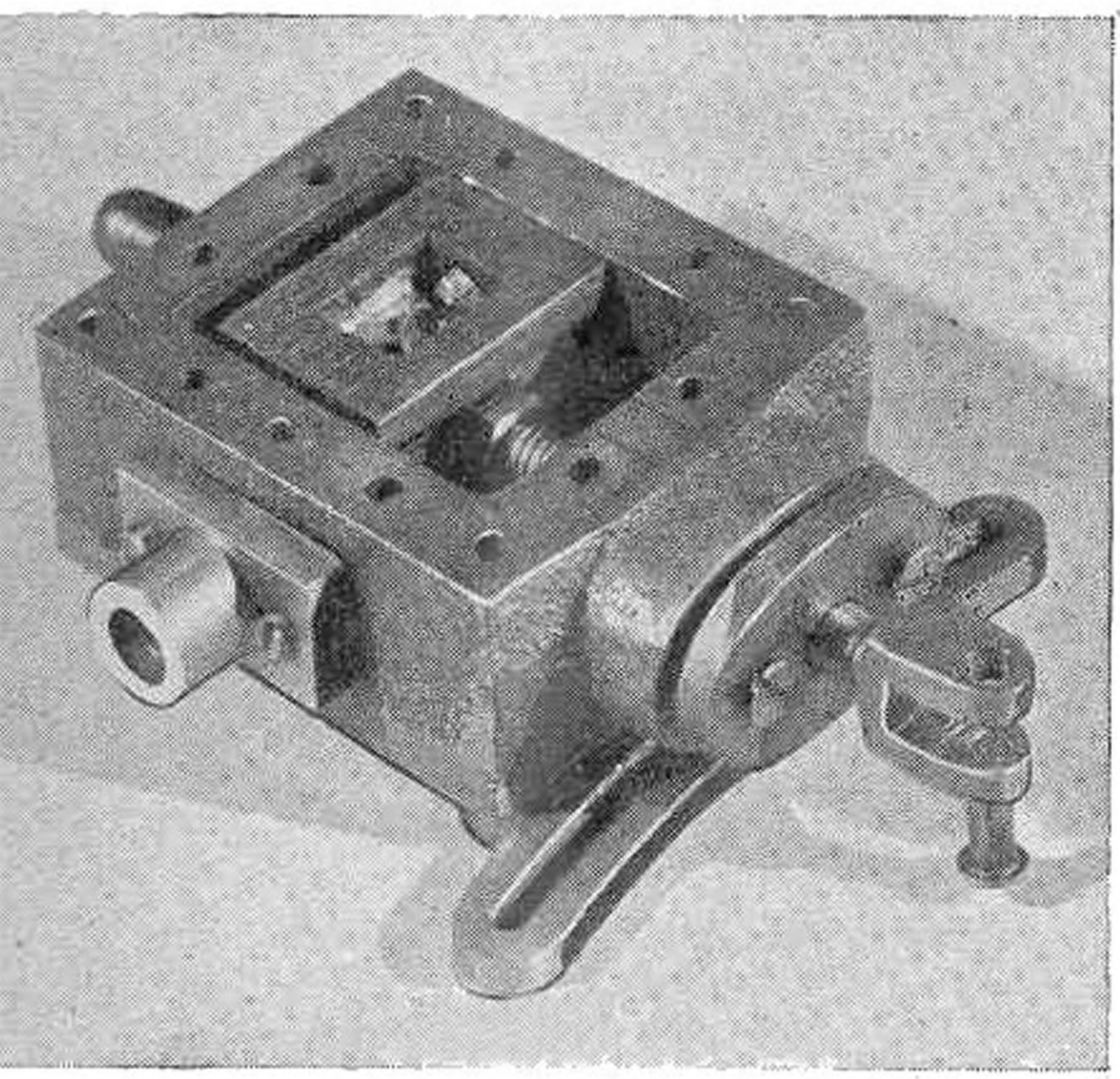
When the link block is midway in the slot, no motion is imparted to the valve even if the crankshaft is turning, and the engine will soon stop. Either side of this position, though, the valve will operate with reduced travel. Steam will be cut off during a greater part of the stroke, saving on fuel, a condition analogous to high gear in an automobile transmission and precisely that which obtains in a steam locomotive running at high speed with a moderate load.



The slide valve is located on the valve rod by a pair of locking nuts that provide travel adjustment. The nuts must be a tight fit on the thread.

The slide valve consists of two pieces of bronze, the face a piece of ⅛" plate in which a rectangle is cut by drilling and filing to form the steam cavity or recess. To this is silver-soldered a bronze block. The hole for the valve rod is filed slightly oval with a needle file so that the valve has some slight play against the port face and may be held on it firmly by steam pressure.

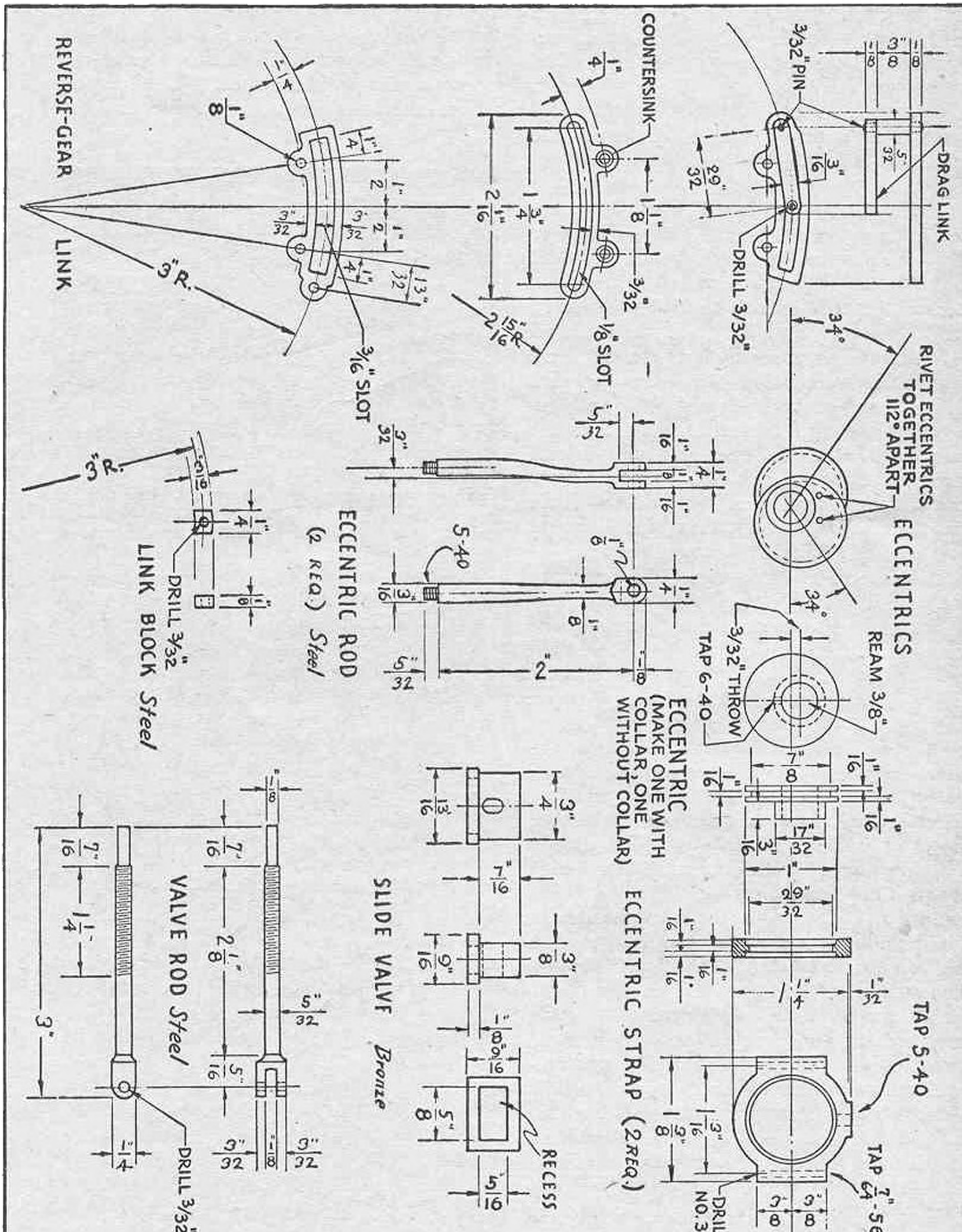
Turn the valve rod from 5/16" square steel rod, shouldering the end to a sliding fit in the guide atop the steam chest and threading the stem with some fine thread such as 8-36 or 6-40. Drill the square end for the 3/32" pin that will connect it to the link block, cut the slot, and file to shape.



Steam chest and valve assembly. The valve is not clamped snugly but floats between the nuts so that steam pressure can hold it against the port face.

Eccentrics can be turned from short ends of stock. Chuck a piece 3/32" off center, turn the hub, and drill and ream the ⅜" shaft hole. Then chuck the piece truly in the three jaw to turn the 1" outside diameter and the ⅞" groove, and cut off. Make a second eccentric with no hub. *[Turn the page.]*

# Reverse Gear




Precise work in laying out, machining, and hand fitting will be particularly rewarding with these parts.

Face both smooth, slip them on a short piece of ⅜" rod, and rivet together at exactly the angle shown in the drawings.

To make the eccentric straps, cut two pieces 1⅜" long from 3/16" by ⅝" cold-rolled steel for each strap. Lay out, drill, and tap the bolt holes for fastening the two halves together. Those in the lower half are drilled out to clear the 7/64" bolts. With the halves bolted together, each blank is chucked and bored to a running fit on its eccentric. The outside is then roughly sawed and brought to final shape by hand filing.

Eccentric rods are turned from ¼" square steel. They should be cut slightly long to allow for shortening in the bend. Lay out the hole in the fork end after bending, measuring from the shoulder at the threaded end. Drill, slot, and file the fork to shape.

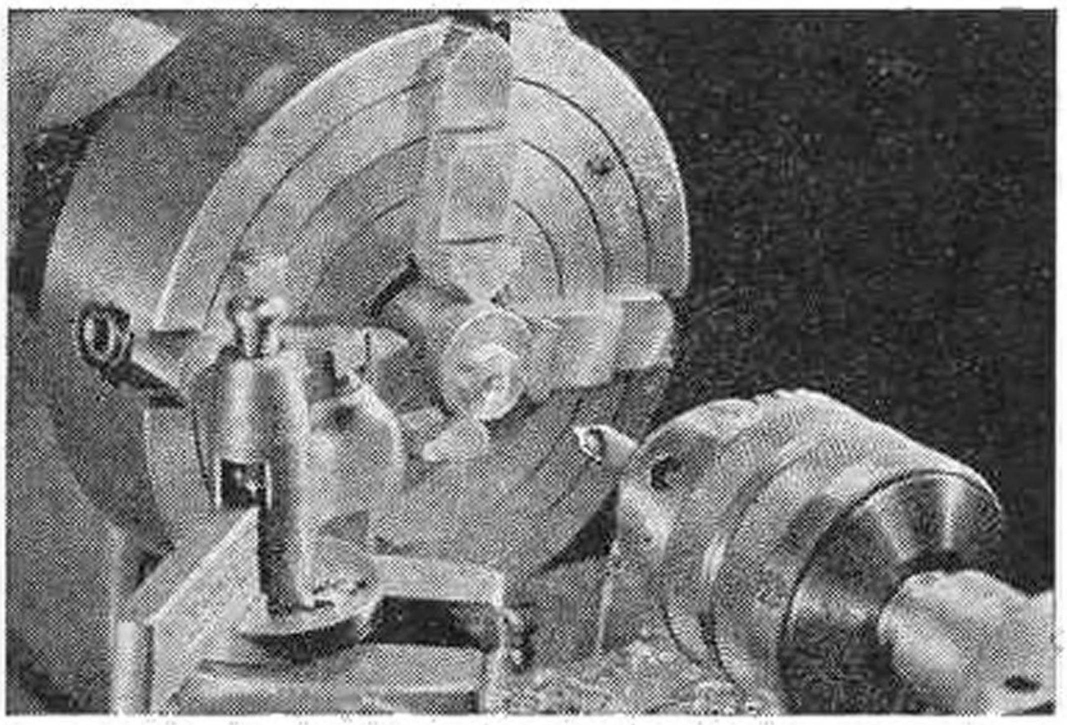
With dividers, carefully lay out the reverse link on ⅛" steel plate. To make the slot, drill a series of undersized holes, drill between to overlap them, and finally file to the radiuses. Drill for the eccentric-rod pins and finish the outside by filing to shape. Note that the link block has sides of the same curvature as the link slot, in which it should be a perfect sliding fit, without play.

The reverse lever and its quadrant, drag link, and clamping nut offer no special difficulties. With the various short pins and the valve-rod nuts, you are ready to assemble the valve gear. One of the photos shows it in a trial assembly, less the reverse lever.

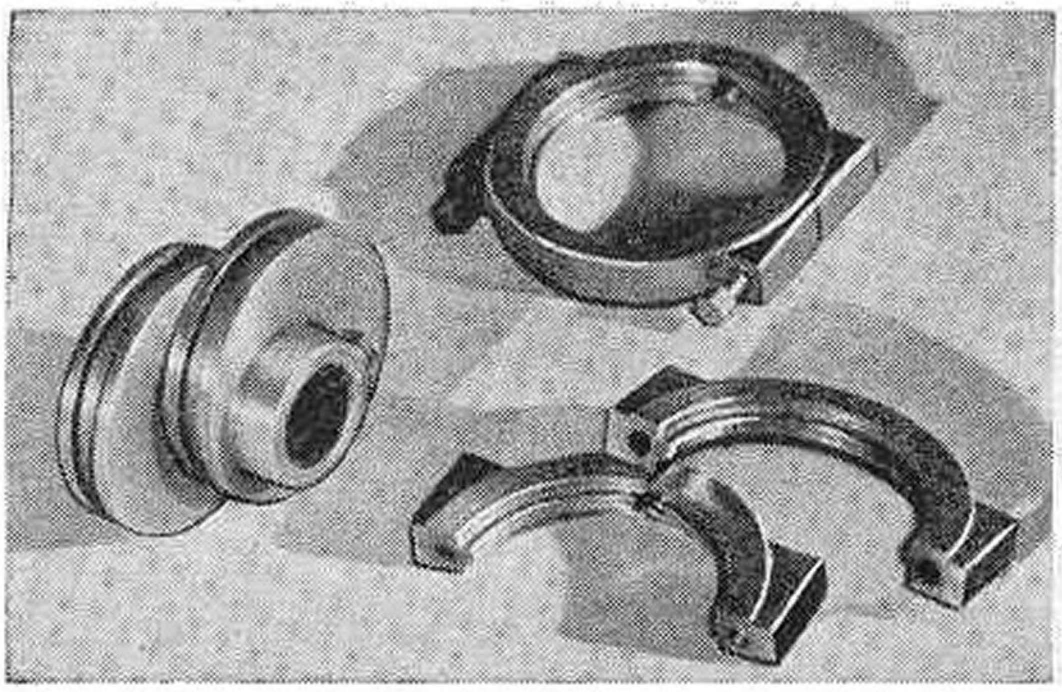
Assemble the steam chest, valve, valve rod and adjusting nuts, and gland as in the photo on page 174. Be sure the valve rides freely on the rod so that its face may be lifted a trifle above the bolting surface of the chest in the position shown—enough to allow for more than the thickness of a gasket between chest and port face. To allow full contact with the port face, the adjustment nuts should be drawn up only to position the valve, not to clamp it. Either tap the nuts somewhat less than full thread depth for a tight fit on the rod, or make two thin nuts out of each one to provide locking.

With the cylinder and running gear assembled, mount the steam chest temporarily without the cover and connect the eccentric rods to the link. Set the two eccentrics on the shaft so that the crankpin throw bisects the angle between the eccentrics. You can then observe the valve travel by turning the crankshaft.

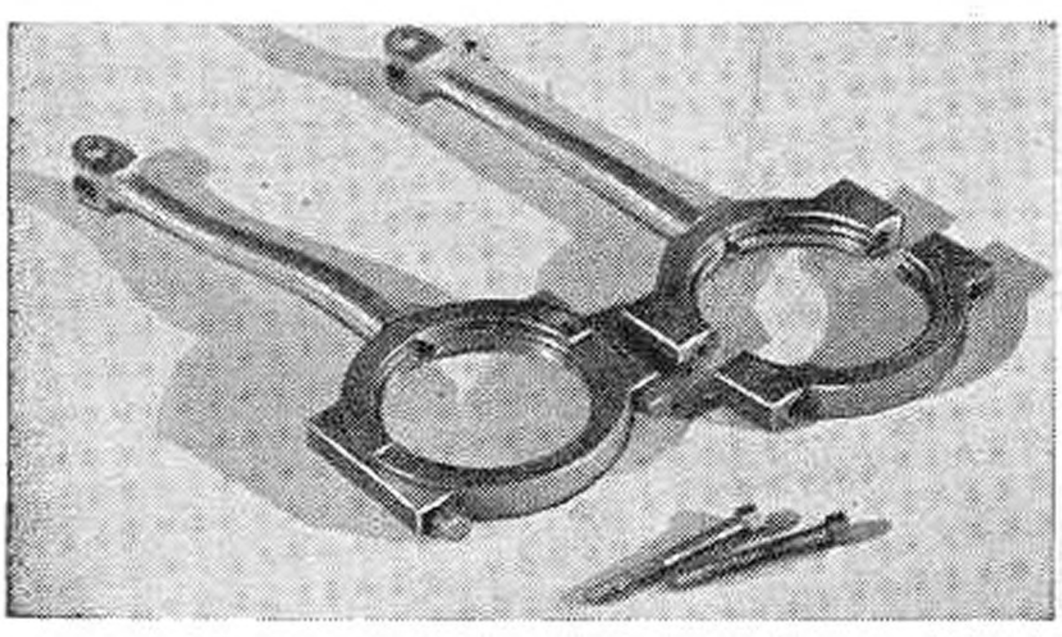
Steam ports should just begin to open as the piston reaches top or bottom dead center. The valve should uncover both ports to an equal degree, and at no point expose the exhaust port. These conditions will best be observed at full forward and full reverse setting, with the link block at the two ends of the slot. At intermediate positions valve travel will be shortened, and cutoff—the closing of the port last admitting steam—will occur earlier in the stroke. If setting the valve nuts does not correct valve travel, it



Each eccentric is turned separately. Round stock is chucked 3/32" off center and the shaft hole is drilled. It is then centered and the outside turned.



The eccentrics, one without a hub, are then riveted or pinned together. After each pair of strap halves is bolted together, the inside diameters are bored.

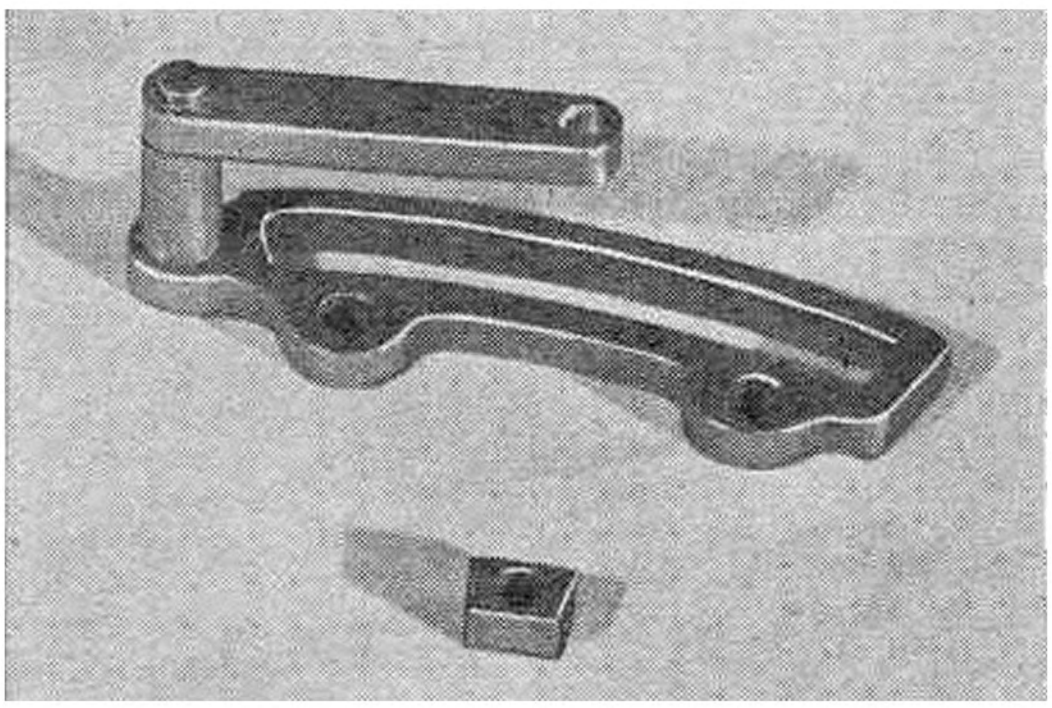


One or both eccentric rods are offset slightly so as to bring the centerlines of their forks directly over the centerline of the assembled eccentric.

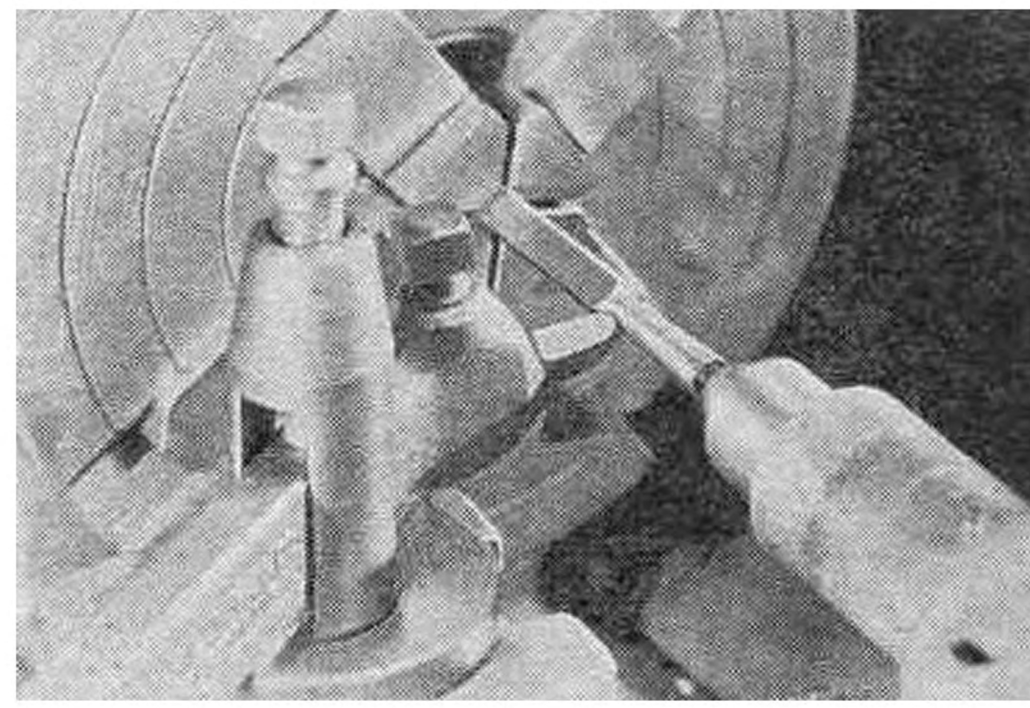
may be necessary to reset the eccentrics, or even shorten or lengthen their rods.

Assemble the engine, using oil freely on all moving parts, with gaskets and graphited gland packing. Run it in at low speed on steam or air, or by outside power, until the parts have worn to a good fit and lost any initial tightness. The steam line should have a lubricator to oil the cylinder.

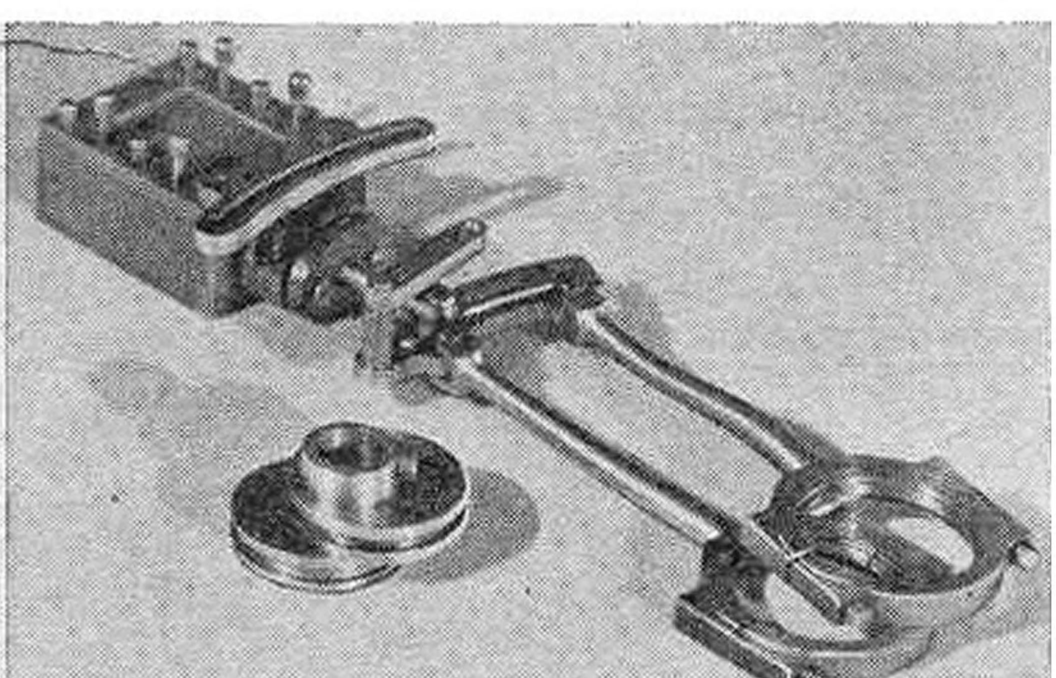
Beware the temptation to throw over the reverse lever at high speed. While the engine should stop at mid-quadrant setting, you'll want a throttle valve for fuller control. It's well to add asbestos lagging and a sheet-metal jacket to the cylinder to minimize condensation, and to start up slowly until the cylinder is hot and any condensate has escaped via the exhaust. Being of cast iron, the engine will safely stand pressures up to 100 lb. END



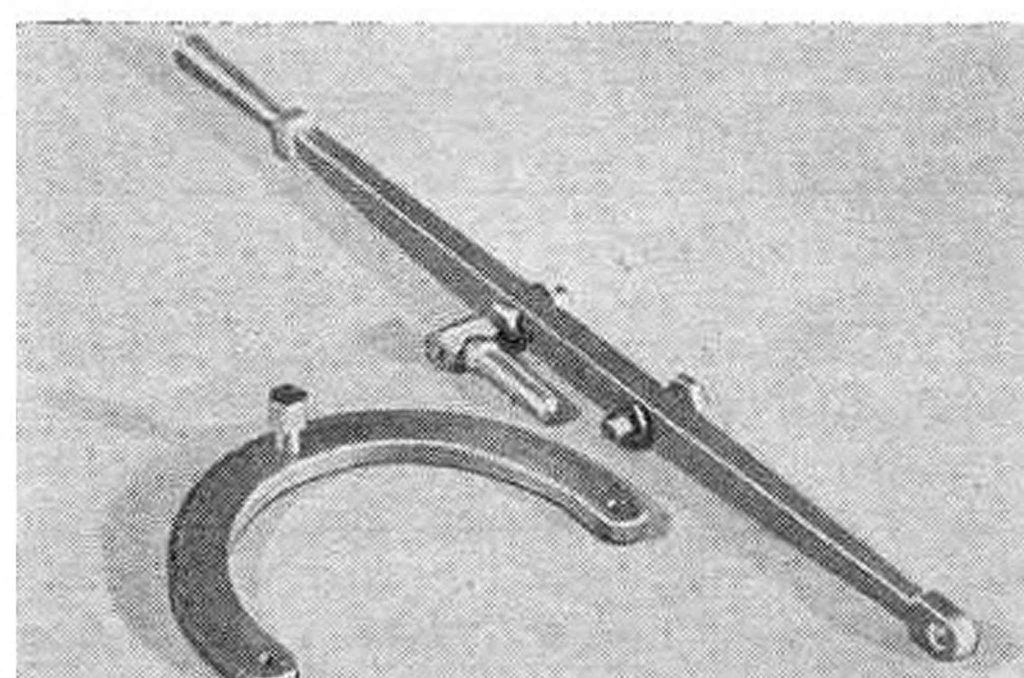
A short pivot stud connects the drag link to the reverse link. Also above is the link block, shaped to match the slot, which fits the valve-rod fork.



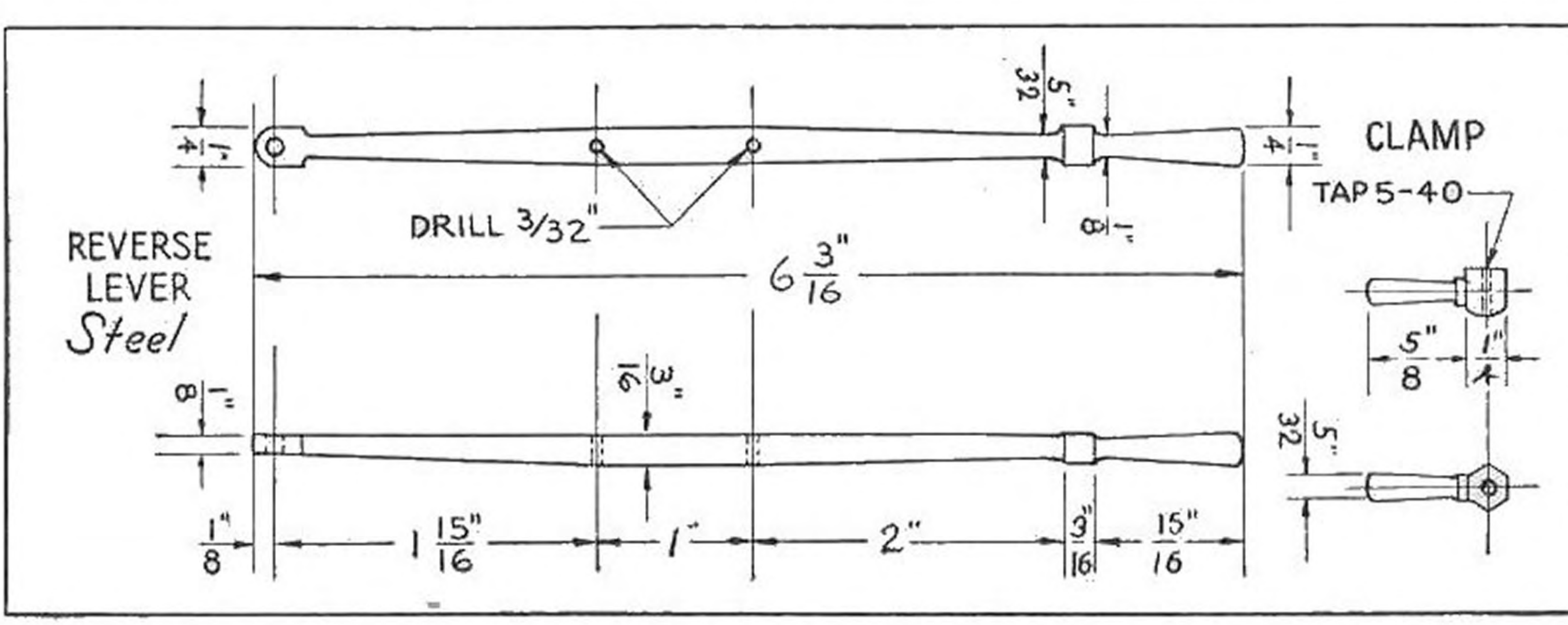
Chucked in the four-jaw, a piece of 1/4" square steel is turned down to form the handle of the reverse lever. Holes must be located as in the drawing.



How the reverse gear will be assembled on the engine. The quadrant on the steam chest receives the clamp screw that locks the reverse-lever setting.



At its lower end, the lever pivots on a stud that screws into the ring, which will itself be bolted to the base. The clamp nut is fitted with a handle.



# Assembly for Steam Engine