LBSC's $3\frac{1}{2}$" GAUGE

BANTAM COCK

(TEXT ONLY)

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Small Locomotive Construction.

"Bantam Cock" 2-6-2, 3½-inch Gauge Engine.

(by "L. B. S. C.")

In response to requests from various readers who follow these notes, and with the kind approval of our worthy Editor, I now propose to describe in detail how to build another 3½-in. locomotive. Many locomotive builders have developed a yearning for something a little more hefty and powerful than the 2½-in. gauge engines hitherto described, but at the same time they don't wish to build a huge 4-6-2 or 2-8-0 that involves a large amount of work, is costly, and so heavy as to spoil its portability; an engine that is easy to build, involving little more work and expense than a big 2½-in. gauge locomotive, seems to be what is needed. It must be fairly portable, and able to run around fairly sharp curves; and castings and parts should be readily obtainable. We have already had a 3½-in. gauge 2-6-0 (L.M.S. "Princess Marina") which was one of the most popular jobs described in this series, so this time I think a 2-6-2 of the L.N.E.R. pattern should fill the bill very nicely.

Everybody knows what excellent engines the L.N.E.R. V2 or "Green Arrow" class proved both for speed and haulage; but they were very heavy engines, and could only work over about one-third of the L.N.E.R. system because of their weight. For this reason Sir H. N. Gresley designed a smaller edition, the V4 class, the first of which was named "Bantam Cock" for obvious reasons; and a real plucky little "bantam cock" she proved. Unfortunately, only two were built, owing to the untimely death of Sir Nigel; his successor did not favour the three cylinders driving on to one axle, nor did he approve of leading two-wheeled pony trucks, so the design was not perpetuated, and a 4-6-0 class of mixed traffic engines took the place of the little "prairies." Recently I spent a few weeks in Staffordshire, to get a little rest and respite from the "doodlebugs," and stayed with a poultry-farmer who has a 2½-in. gauge "scenic" railway, but has succumbed to the wiles of passenger-carrying, and is rebuilding his line to 3½-in. gauge for that purpose. Naturally he needs a new locomotive—and what could be more appropriate for a poultry-farmer than a "Bantam Cock?" Anyway, as he proved a friend in need, and as the old saw says, "One good turn deserves another," I said I would build him a locomotive of that type if my home survived, and I returned in safety. However, there was a stipulation; as his spare time is very limited, he wanted an engine of the simplest possible character consistent with modern appearance, reliability, power, and the minimum of maintenance requirements; so I got out a design for a simplification for the little 2-6-2 which would meet his needs. As she also fulfils the needs of our readers who want a simple, fairly cheap, yet powerful and modern type of 3½-in. gauge locomotive, I suggested to our Editor that I should describe it as well as build it, and he readily approved. Castings and other supplies will be available from the same sources as those supplied for the "Austerity" 2-8-0 and other engines previously described; and blueprints to full size, from our offices as usual.

The 3½-in. gauge "Bantam Cock" differs from her full-size relation chiefly in having only two cylinders, and a parallel boiler. The leading pony truck will have separately-sprung wheels on a simple frame. The cylinders, which will be 1⅛-in. bore by 1⅝-in. stroke—the equivalent of 18-in. by 26-in. in full size—will be very similar to those used for "Princess Marina," having overhead flat slide valves in place of the big engine's piston valves, whilst the conjugated gear will not be needed, two sets of Walschaerts of the simplest possible construction, looking after the steam distribution. Radial axles will not be needed at the trailing end, as either ordinary boxes with plenty of side movement for the axle, or a "camouflaged" pony truck may be used; I will give the alternatives. The boiler will have a wide firebox, and my usual arrangement of tubes and superheater; and will be fed by a single eccentric-driven pump, plus the emergency "stand-by" pump in the tender, the latter being a six-wheeler of standard pattern. In order to make the work of building the engine as easy as possible, I have asked the casting suppliers to do their very utmost to supply cast parts for everything possible, such as the complete pony truck frame, smokebox saddle, valve gear brackets, trailing frame, and complete tender frames with springs, hornblocks and "trimmings" all cast on. If they can manage this, the building of the locomotive will be reduced to what our airmen call a "piece of cake," and a vast amount of time will be saved without reducing power, efficiency, or speed. The simplified "Bantam Cock," with average workmanship, should haul about a dozen adults or a corresponding weight of children, and be easy to handle.

Trailing Frame.

I am hoping, by the time these notes appear in print, or soon after, that complete cast trailing frames, with fixing lugs, horncheeks, dummy leaf springs, and drag beam all complete, will be available. These will save a vast amount of work, and is following big practice in America, where it is now quite common for a complete locomotive frame, with cylinders and smokebox saddle, to be cast in a complete unit. If "Bantam Cock" cast cradles are available, the only work necessary will be to file or mill up the lugs to which the main frames are screwed, and fit the axleboxes, same as I shall describe for the separate type. However, if a cast cradle isn't available, one can be made up from ⅛-in. soft blue steel as follows. A piece of this metal is needed, measuring 16½-in.

by 2½-in. On the two ends of this, mark off the outline of the cradle as shown in the drawing, one right-hand and one left, then saw and file to the marked lines, leaving the centre part 1⅝-in. deep. The piece is then very carefully bent to the shape shown in the plan of the frames; to make certain it is true and square, use a piece of ⅝-in. square bar as a gauge. When placed in the axlebox slots, it should lie exactly at right angles to the cradle. Two 1⅝-in. pieces of ¾-in. by ⅛-in. angle are riveted to the front of the cradle, so that their faces are 2⅞-in. overall measurement; see illustration. Drill the No. 30 screwholes at the back corners, as shown. The drag beam is a 7-in. length of 1-in. by ⅛-in. steel bar, with a slot 1-in. by 3/16-in. cut in it.

The slot may either be milled, or a row of 5/32-in. holes drilled, run into a slot with a rat-tail file, and finished to a rectangular shape with a flat file. Two pieces of ¾-in. by ⅛-in. angle, each 1-in. long, are riveted to one side of the drag beam, so that the measurement over the outside of the angles is 5-in. The drag beam, with angles attached, is now placed at the back of the cradle, and the sides of the cradle clamped to the angles by a toolmaker's cramp on each. See that both sides are perfectly level, and the ends form a right angle with the beam; then run the No. 30 drill through the holes in the cradle, make countersinks on the angles, follow up with No, 40 drill, tap 5 BA. or ⅛-in., and put screws in. I have shown hexagon heads, but any other available can, of course, be used.

Buffer Beam.

The front buffer beam is made from a 7-in. length of 1-in. by ⅛-in. angle; black steel will do quite well. Castings may also be available for this; and if so, all the work needed will be to drill the buffer-shank holes, and the hole for the drawbar; mill the frame slots, and smooth up the whole issue with a file. The beam made from angle, is first drilled as shown in the drawing. Drill the drawbar hole ⅛-in., and file it square with a watchmaker's small square file. Next, cut away ½-in. of the top of the angle at each end; this is to make room for the edging of the running-board on the finished engine. Then cut the two ⅛-in. slots for the frames. Mark out very carefully. The slots can be milled on a regular milling machine, if available, by clamping in a machine vice on the miller table, and running under a 4-in. by ⅛-in. slotting cutter on the arbor; or they can be done in the lathe, if the centres are high enough, by mounting on the saddle with a clamp at each end, and running under a similar cutter on an arbor between centres. They can also be planed out, or machined on a shaper, with a ⅛-in. parting tool in the clapper-box of either, work being either held in a machine vice or bolted down. If done by hand, put the beam vertically in the bench vice, with the marked slot level with the top of the jaws; put two or three hacksaw blades together in the frame, so as to get a good wide slot for a start, and then finish with a keycutter's warding file, making the slots just wide enough to take the frames a tight fit.

Two ⅞-in. lengths of ¾-in. by ⅛-in. angle are riveted to the inside of the beam, so that the outer faces are flush with the inner sides of the slots; see illustration. The frames can then be erected; they are pushed into the slots and held temporarily by toolmaker's cramps. Beginners would be well advised to have a good stock of these clamping gadgets; they can be made in a few minutes from odd bits of square bar, both brass and steel, and well repay the time taken for making. I have a small drawerful, some bought and some home-made, and the saving of time in holding bits together whilst erecting and fixing, is beyond calculation. Next place the two angles on the front of the cradle, between the rear ends of the frame, and fix with two more cramps; then lay the whole issue upside down on the lathe bed, or something equally flat and true. Adjust so that the top edges of the frame are in contact with the bed for their full length; see that the beam and cradle are square across the frames, and that both ends of buffer and drag beams are the same height from the bed at each end. Take great pains over this; the frames *must* be true and square if the motion is to work freely and efficiently. When you are quite satisfied, drill and tap all the screwholes in the angles and lugs, exactly as I described above for the drag beam angles, and put the screws in. The complete frame should now be quite rigid and true.

Pony Bolster.

A bolster is needed to carry the pony truck, and this is made from a piece of the same kind of steel as used for the frames. It is 2½-in. long in the middle, 2-in. at sides, and 3⅛-in. wide. On the centre-line, ¼-in. from the rear end, drill a 9/32-in. hole, and then file the plate to shape as shown in the half plan. At ⅛-in. from each side, attach a 2-in. length of ⅛-in. by ⅜-in. angle (either brass or steel will do) by 3/32-in. iron rivets, as shown in the inserted detail sketch on the half plan. The bolster is fitted under the frame 3½-in. from the front end, the angles passing up between the frames; and it is secured in place by five No. 5 BA. or ⅛-in. countersunk screws passing through the holes already drilled in the frames, into tapped holes in the angles. The pump stay shown in the half plan is not fitted until the pump is made and attached to it. It is quite possible that castings will be available for the pony bolster, and the complete pump with the stay attached; if so, they will merely need filing or milling to fit between the frames, and screwing up.

Hornblocks.

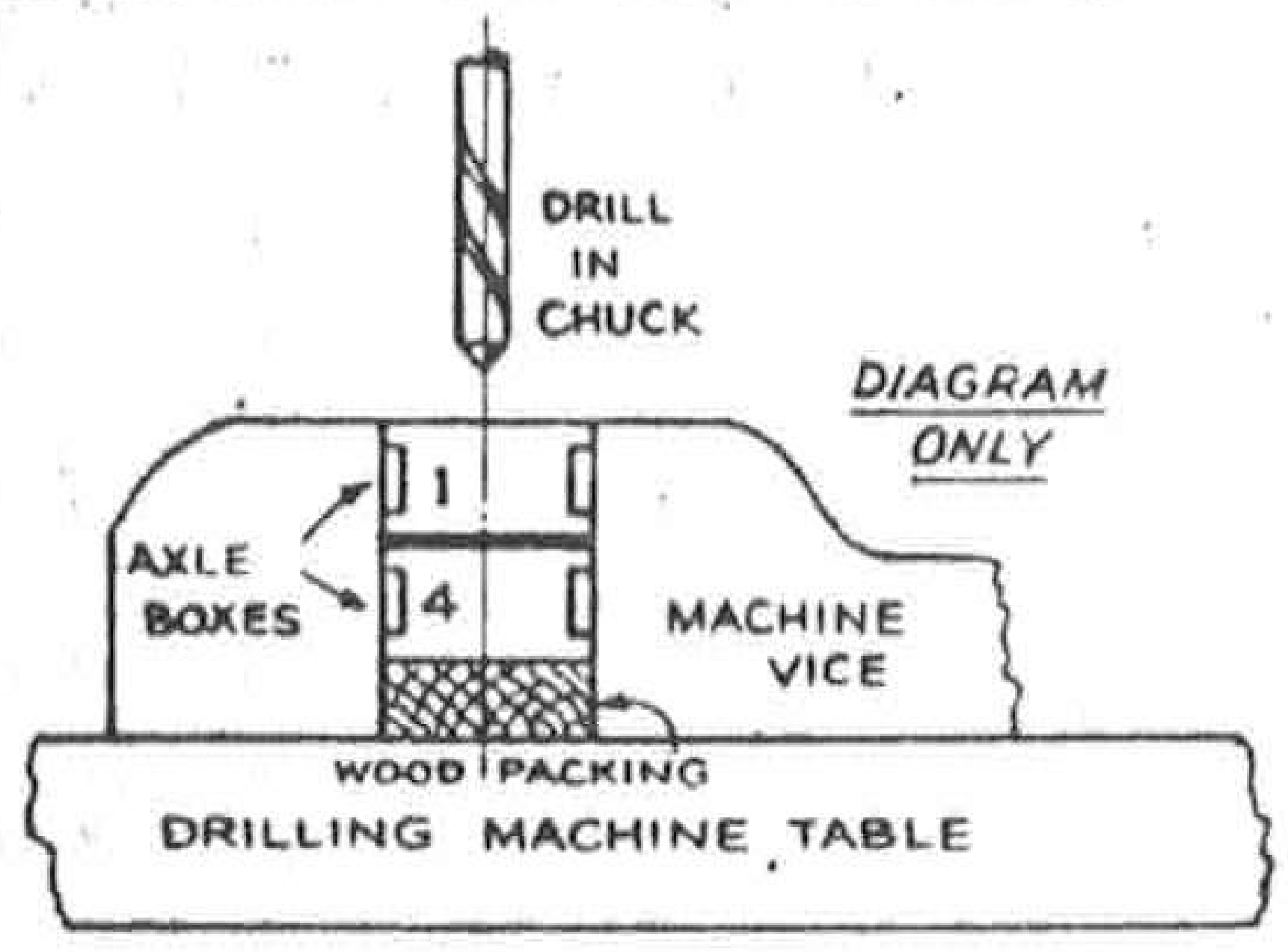
The hornblocks are machined up from gunmetal castings, which can be obtained from the same good folk who supplied castings for the "Austerity" 2-8-0. The plain side of these has to be machined to fit the openings in the main frame; and anyone who owns or has the use of a milling machine, will find this an easy job. They can also be easily machined in the lathe, by use of a vertical slide; see diagram. The castings are attached to the vertical slide by a bolt passing through a clamp plate. The latter is a piece of metal about ⅛-in. in thickness, just a little wider than the space between the jaws, and rests on the flanges at each side of the jaw opening. Set the casting vertically by applying a try square to one of the side flanges, and tighten the clamp bolt so that there is no chance of the casting shifting under cut. Put a ⅜-in. endmill, or a home-made slot drill, in the three-jaw, and feed the work up to it by manipulating the top slide handle. Each side of the flanges can then be machined off truly by moving the vertical slide up and down; the piece above the top flange can be traversed across the endmill by means of the cross-slide. It sounds a long job when detailed out in print, but actually the process is quick. The flanges should stand ⅛-in. above the machined part, and should be an exact fit in the slots in the frame; otherwise the rivets will work loose.

If no facilities for machining are available, the hornblocks can be filed up by hand, gripping in the bench vice, and using a long flat file, which the operator must be careful to hold horizontally. Each hornblock must be carefully fitted to the opening. When all are machined, each must be riveted in place; take off the frames, put a hornblock in one of the openings, and hold it there temporarily with a toolmaker's cramp. Beginners please note—the hornblocks are fitted on the *inside* of the frame. Now drill seven No. 30 holes at the points shown in the drawing, countersink them on the outside of the frame, put in ⅛-in. roundhead rivets, hammer the stems well down in the countersinks, and file off flush, smoothing off any projecting pieces of flange at the same time.

When all are attached, bolt the frames temporarily together " inside out," as the kiddies would say, with the hornblocks outside. The frames must be exactly in line; use any two of the screwholes Then catch the frames in the bench vice, and carefully file out each pair of hornblock jaws until a piece of ⅞-in. wide and ⅜-in. or more in thickness, exactly fits between the jaws, easily but without shake. The frames can then be re-erected. The piece of ⅞-in. bar forms a ready-made gauge, far more satisfactory than a caliper or slide gauge, as it covers the full width of slot.

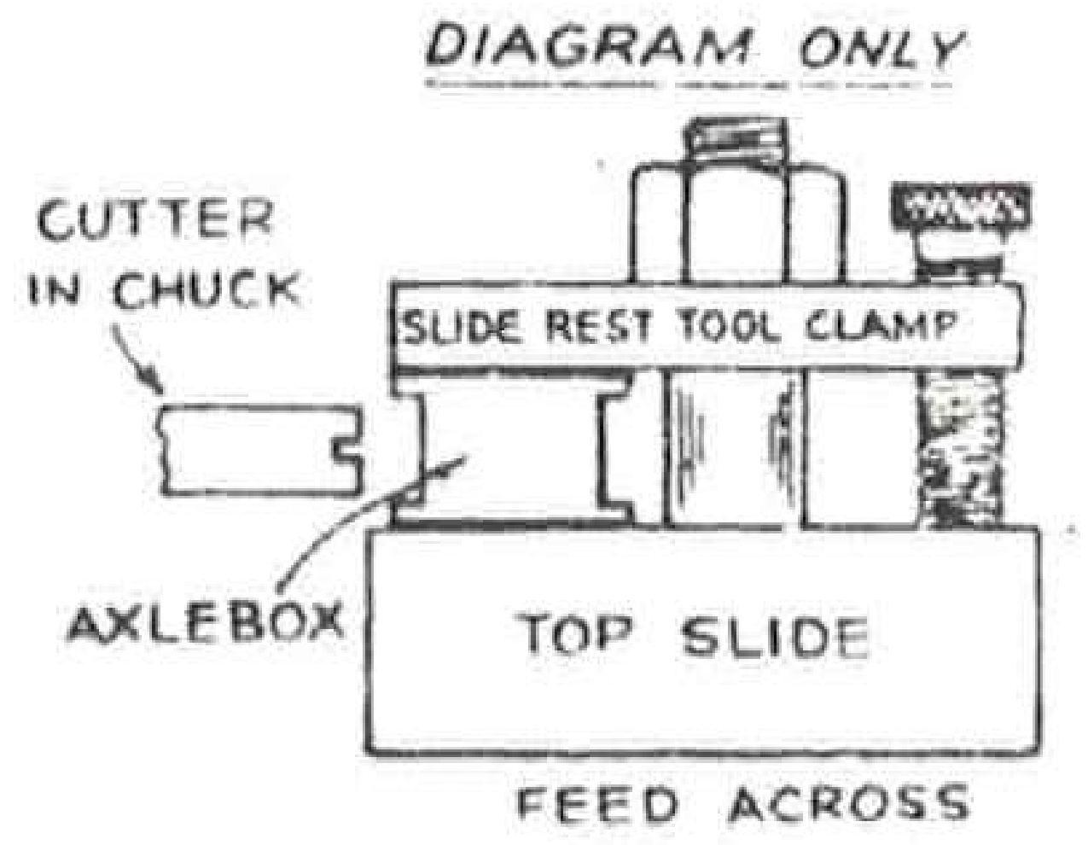
Axleboxes.

The axleboxes may be made either from castings or bar material. If castings are used, they will most likely be in one long length, and are machined up same as bar. A piece of metal about 6½-in. long, 1-in. wide and ½-in. in thickness will make the six. Here again, a horizontal milling machine will clean out the grooves at one cut each side, using a ⅜-in. cutter, and either holding the bar in a machine vice or clipping it to the table; but the lathe may be used, as before. Most amateur lathes have insufficient cross movement on the slide-rest, to machine a groove 6½-in. long at one fell swoop, so the piece of bar should be cut in halves. Put one of the pieces on its side, under the lathe tool-holder, exactly at right angles to the bed; this can be checked by putting the lathe faceplate on the mandrel nose, running the slide-rest up it, and setting the piece of bar parallel to the faceplate. Pack up the bar till the centre of it corresponds to lathe centre height. Then put a ⅜-in. endmill, or a home-made slot drill in the three-jaw, and traverse the work across it with the cross-slide, feeding into cut with the top-slide; which will soon form the groove. For beginners' information a slot drill is made in a matter of minutes by filing the end of a piece of ⅜-in. silver-steel about 3-in. long, like a screwdriver. Make a nick about ⅛-in. wide, in the middle: back off the metal each side of the nick, to form cutting edges, and relieve the sides also slightly, below them. Harden and temper to dark yellow; first make red hot at the cutting edges and quench in water, then brighten up the flat part with a piece of fine emerycloth, taking care not to round the cutting edges. Reheat the *stem*, and watch the colour travel along the bright part; when the dark yellow reaches the cutting edges, pop the cutter pretty quickly into the water again. Give the cutting edges a touch on the oilstone, and the gadget is ready for use.



HOW TO DRILL AXLEBOXES

The axleboxes should fit easily, but without shake, in the hornblocks. Personally, I keep a spare hornblock machined to size, and use it as a gauge when milling the axleboxes; but a slot filed in a piece of ⅛-in. steel plate, to the exact size of the hornblock jaws, does just as well. The slot should be filed out so that the piece of ⅞-in. bar used for gauging the hornblock jaws, fits it exactly. This gauge is applied to the piece of axlebox material under the toolholder, when milling the second groove.



HOW TO MILL AXLEBOXES

When both pieces are machined, saw each into three sections; chuck each one in the four-jaw, and face off the ends squarely, to a dead length of 1-in. In case of any slight variation when filing out the hornblock jaws, fit each axlebox to a hornblock, and mark them, so that each box can be replaced correctly without becoming mixed up. I use a small set of figure punches, but dots or other symbols will do.

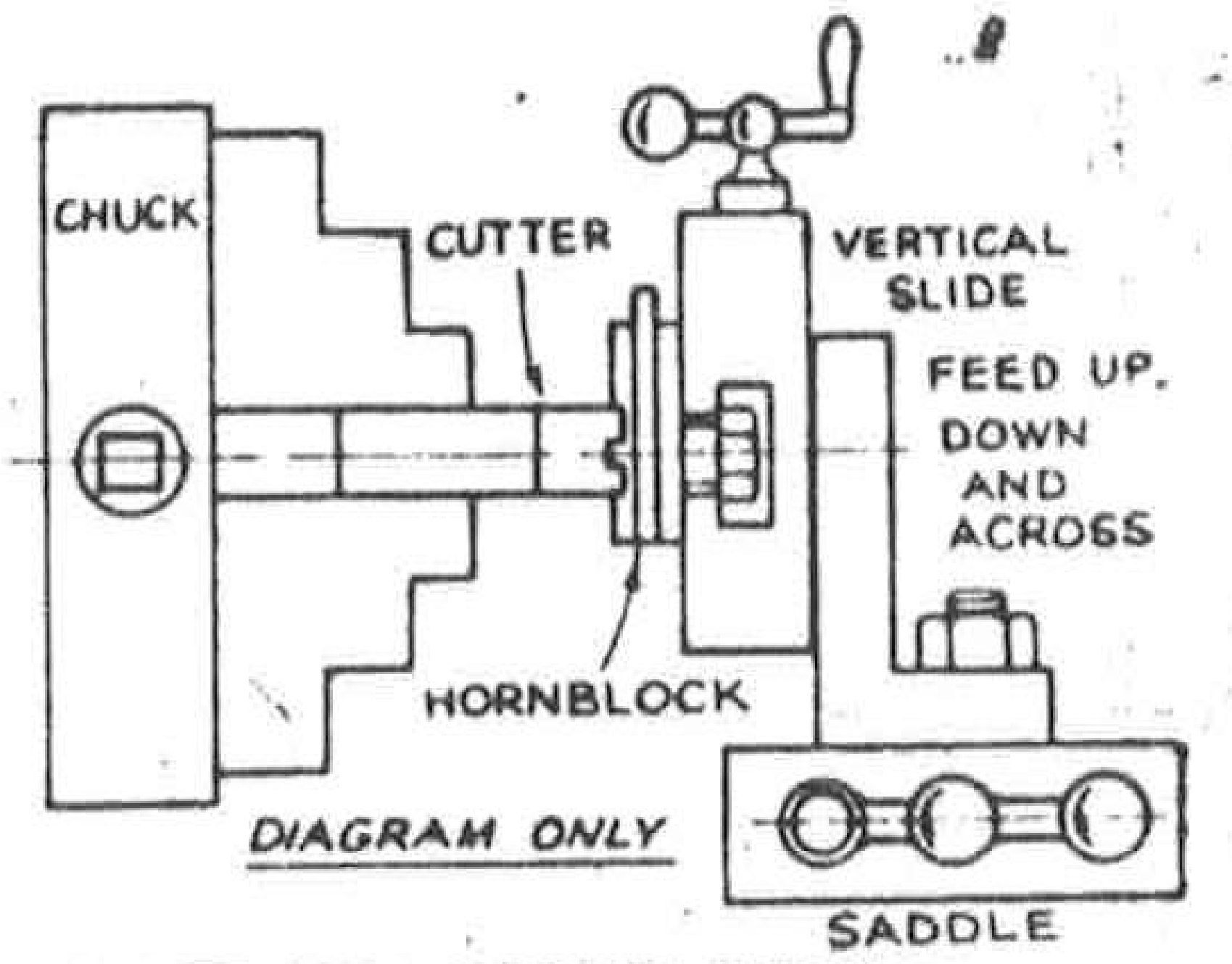
The boxes now have to be drilled for axles and this is done in pairs, otherwise the axles may not stand square across the frames. Centre-pop the three boxes belonging to one side, say 1, 2 and 3, and then clamp No. 1 in the machine-vice alongside its "mate" on the other side of the engine; that will be No. 4. Drill a ⅛-in. hole through both of them, either on a drilling machine, or in the lathe; if the latter, hold the machine-vice against the tailstock, with a drilling pad on the barrel, or a piece of flat wood in front of same, centre being removed. Replace axleboxes in frame, and try a piece of ⅛-in. steel rod through the holes. If it lies square across the frames—check with a try-square—the holes are O.K. and may be opened out with a ½-in. drill. Repeat operation on Nos. 2 and 5, and 3 and 6, trying pieces of ½-in. rod in after completing the lot.

Hornstays.

The hornstays are made from ⅜-in. by 3/32-in. strip steel, and are 1½-in. long. The two inner holes are for the spring pins, and are drilled on the centre line, ½-in. apart. The two outer ones are for the screws attaching the stays to the hornblock lugs, and are drilled 5/32-in. from each end, ⅛-in. from the long edge, so that the screws will clear the vertical part of the hornblock casting. First smooth off the underside of the hornblock lugs flush with the frame; then place one of the hornstays over the lugs of a hornblock, and hold it temporarily in place with a toolmaker's cramp, with the screw-holes nearest to the inside. Put the 30 drill in the screw-holes, and make countersinks on the hornblock lugs; follow up with No. 40, top ⅛-in. or 5 BA., and put screws in. I have shown hexagon heads, but any others available may be used. When all six are attached, the holes for the spring pins in the axleboxes may be drilled and tapped, using the hornstay holes as jigs. Jam each axlebox up tightly against the hornstay, with a wooden wedge between the top of the axlebox and the top of the hornblock jaws. Make countersinks on the bottoms of the axleboxes, through the inner holes in the hornstay, with a No. 30 drill, following up with No. 40 and tapping as above.

Spring Pins and Plates.

The spring pins are 1 5/16-in. lengths of ⅛-in. round silver-steel; twelve are needed. Chuck each in the three-jaw, and using a die in the tailstock holder, put 5/16-in. of either ⅛-in. or 5 BA. thread on one end, and about ¼-in. same pitch on the other. Use plenty of cutting oil when screwing the pins, and work the lathe mandrel back and forth by pulling the belt by hand; otherwise you will probably have torn threads. The shorter screwed end of each pin is then put through the hole in hornstay, and screwed tightly home into the axlebox. I use a home-made steel driver for this job; it is simply a 2-in. length of ¼-in. brass rod with a tapped hole about ⅛-in. deep in one end; the other has a cross handle like a chuck key. This is screwed over one end of the pin, and by its aid, the pin is easily screwed right home; to release the key, simply grip the pin with a pair of pliers, and unscrew the key. With all the pins right home, the axleboxes should have perfectly free movement up and down the hornblocks.



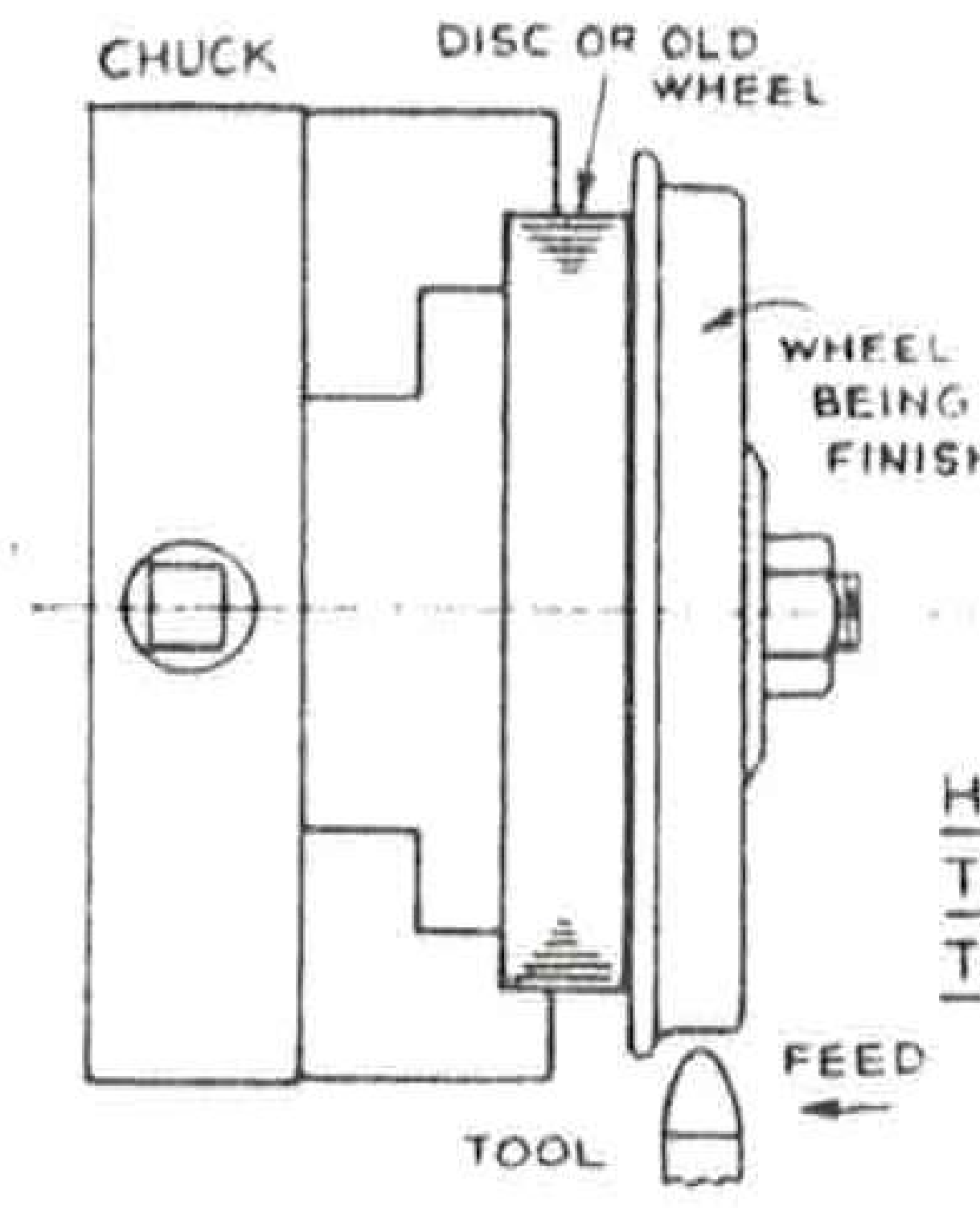
HOW TO MILL HORNBLOCKS

The spring plates are ¾-in. lengths of ¼-in. by 3/32-in. steel strip, each having two No. 30 holes drilled at ½-in. centres. They may be rounded at the ends, or left square; it makes no difference. The springs are made from steel wire, tinned for preference, as the tin coating prevents rusting. Use 20 gauge wire, and wind them in the lathe. Put a piece of ⅛-in. silver-steel in the three-jaw; bend the end of the spring wire at right angles for an inch or so, and poke it between the chuck jaws. Then pull slowly on the belt by hand, guiding the spring wire on to the ⅛-in. mandrel with your thumb and finger. If after winding on about four turns evenly, you press your thumb tightly on the coils and continue to pull the belt steadily, your thumb will act as a kind of feed nut, and the rest of the spring will automatically wind up with even coils. Pieces of the coil, a bare 1-in. long, are cut off, and each end squared by lightly touching against the side of a fast-running emery wheel. Then put a spring on each pin, followed by a plate and two ordinary commercial nuts, as shown in the assembly drawing. As it is an advantage, and a great aid to correct erection of the motion work, to have the axleboxes in correct running position, put a little piece of brass ⅛-in. in thickness between each axlebox and hornstay, between the two spring pins, and tighten up the nuts sufficiently to prevent it accidentally slipping out.

Coupled Wheels.

The six coupled wheels are 4¼-in. in diameter on tread, with flanges ⅛-in. deep and 1/16-in. wide. The treads are not coned, as was usual in big practice until Sir W. A. Stanier carried out the experiments on the L.M.S. which proved that there was no advantage in coning treads. On small engines which traverse sharp curves, coned treads are the cause of excessive slipping of driving wheels, as the centre pair of wheels have their flanges forced over to the inside rail of the curve, and the largest diameter of a coned tread then runs on the shorter rail, the very reverse of what should be the case. It is impossible to prevent one wheel slipping on a curve, when both wheels are rigidly mounted on the axle, because the wheel on the outer rail must travel farther than the inner; but parallel treads minimise the amount of slip.

To turn the wheels, first file off any superfluous knobs and excrescences which might have been left by the foundrymen; some of them are very fond of leaving a piece of the "gate" attached to the flange, and if left on when starting to turn the wheel, it would probably break the tip off the turning tool. Then chuck in three-jaw, gripping by the tread, and setting to run as truly as possible. With a roundnose tool set crosswise in the rest, at centre height, face off the back of the wheel, and true up the flange, using slow speed and back gear for the back of the rim and flange, and cutting out back gear for the boss. Then centre, drill right through the boss with 27/64-in. drill, and ream 7/16-in., using the reamer held in the tailstock chuck. Next, turn the wheel around in the chuck, and grip it, face outwards, by the flange.



HOW TO TURN WHEEL TREADS AND FLANGES

Turn the face of the rim, and face off the boss, with a roundnose tool as above; back gear for rim, and direct drive for the boss. Then put a parting tool, or a knife tool, in the rest, and cut a little step about 1/16-in. wide and deep, at the point where the spokes join the rim, representing the joint between wheel centre and tyre on a full-sized locomotive. Note that the thickness of the boss should be ½-in. exactly, from back to front of wheel. Some castings are excessively thick—goodness knows why!—and any excess should be turned off the *back* of the wheel. If the front is reduced, the spokes may come flush with the boss, and completely spoil the appearance.

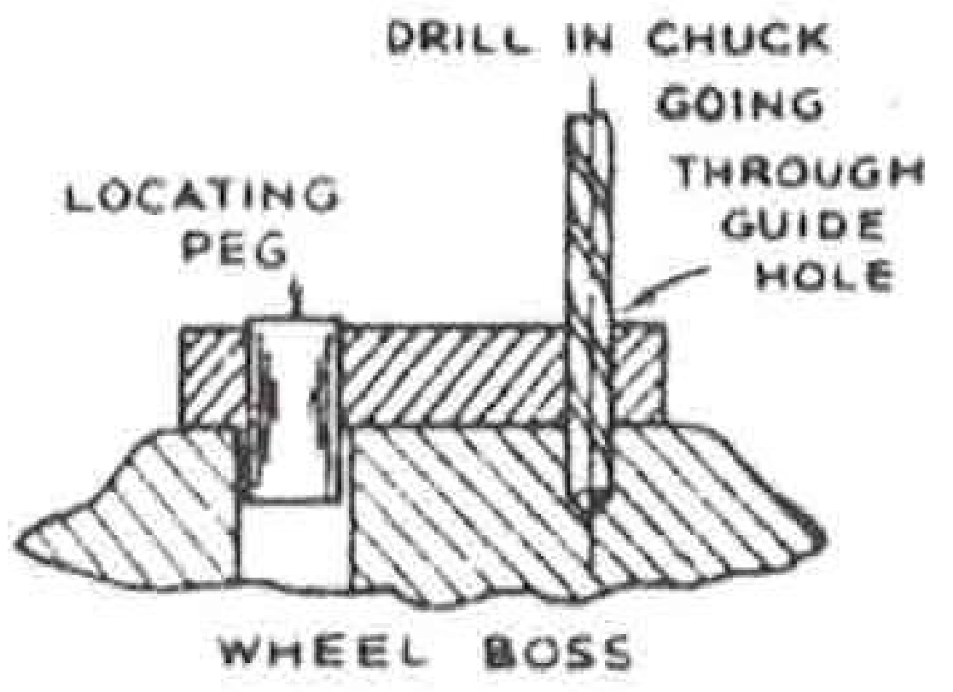
Beginners sometimes have difficulty in getting all coupled wheels exactly the same diameter; they won't, if they carefully observe the following simple instructions. Chuck a spare wheel casting, or an old chuck back, or something of similar dimensions, in the three-jaw; this should be slightly less than 4¼-in. diameter. Face it truly, and recess the centre about 2-in. diameter and 1/32-in. or so deep. Centre and drill 13/32-in. hole in the middle, and tap it 7/16-in. by 26 or any other fine pitch. Screw into this a stub mandrel, made from a piece of ½-in. steel rod 1½-in. long, previously turned down to 7/16-in. diameter for ½-in. length, and screwed same as hole in disc or wheel just mentioned. It must fit very tightly. Carefully turn this down until a coupled wheel can be slid on to it without any shake; then screw it 7/16-in. by any fine thread for about half its length, and fit a nut. Take a final slight cut over the face, to make certain it is quite true. Put a coupled wheel on the stud, face outwards, and tighten the nut. With an ordinary roundnose tool, using slow speed and back gear, the tread and flange can now be rough-turned to within about 1/64-in. of finished size. When the last of the six has been roughed, regrind the tool, and carefully take off the last sixty-fourth, keeping the speed very slow when the tool cuts the root of the flange, otherwise you will get chatter-marks all around the radius. Now, *without altering the setting of the cross-slide,* mount each of the rough-turned wheels and take the finishing cut; they will all be exactly the same diameter when finished. The tips of the flanges can be rounded off with a file, whilst revolving, before removing the wheel from the improvised "faceplate." Some folk advocate turning the wheels on their own axles, but I never use any other method than that described in full above, for beginners' and new readers' especial benefit. If the wheel is not adequately supported *at the rim,* where the turning tool is operating, you are bound to get chatter-marks. The treads and flanges of turned wheels should never be polished with emery-cloth, or by any other means; they smooth off pretty soon enough on the railheads in service.

Crank and Coupling Pins.

First drill the wheel bosses for the crank and coupling-rod pins. This is easily done by a jig, as it is absolutely essential that all the throws should be exactly the same length. The jig is made from a piece of steel about ¾-in. wide, ¼-in. in thickness and 1½-in. long. Scribe a line down the middle, and set off two points 13/16-in. apart, making heavy centre-pops. Drill two 7/32-in. holes through the pops, either on a drilling machine, or in the lathe, with the drill in three-jaw, and the work held against the tailstock barrel, the centre being removed. Open out one of the holes to 27/64-in., and slightly reduce the end of a ½-in. length of 7/16-in. round rod, until it can be driven halfway in. The jig is then complete. To use it, scribe a line down the centre of each wheel boss; insert the projecting bit of rod into the hole in centre of wheel boss, and adjust the jig until you can see the line crossing the centre of the 7/32-in. hole. Then clamp in position with a toolmaker's cramp; put a 7/32-in. drill through the hole in the jig, and drill right through the wheel boss, the hole in the jig guiding the drill truly. Repeat process on each wheel, and each throw cannot help being identical.

The leading and trailing crankpins can be turned from 1/4-in. round rod, silver steel for preference, and the driving crankpin from 3/8-in. ditto. For the leading pins, chuck the rod truly in three-jaw, and turn down 7/16-in. of the end to a drive fit in the crankpin holes in the wheel bosses; the *modus operandi* is exactly the same as when turning the wheel seats on the axles, as described below. Part off to leave 5/16-in. of full diameter beyond the shoulder. Reverse in chuck, centre, and drill a No. 40 hole about 7/16-in. deep; tap this 1/8-in. or 5 BA, and repeat process for second pin. The retaining washers are turned from 7/16-in. rod, or 1/2-in. rod turned down to 7/16-in. in the three-jaw. Centre, and drill a No. 40 hole about 3/8-in. deep; countersink it, and part off a washer 1/16-in. in thickness. Countersink again and part off the second washer. Ordinary commercial countersunk screws are used to fix the washers in place after erecting the coupling rods later on.

For the driving pins, chuck a length of 3/8-in. round silver steel truly in the three-jaw. Turn down the spigot as described above, and part off at 7/8-in. from the shoulder. Reverse in chuck, and turn down 3/16-in. of the outer end to 3/16-in. diameter, to form the spigot on which the return crank is fitted.

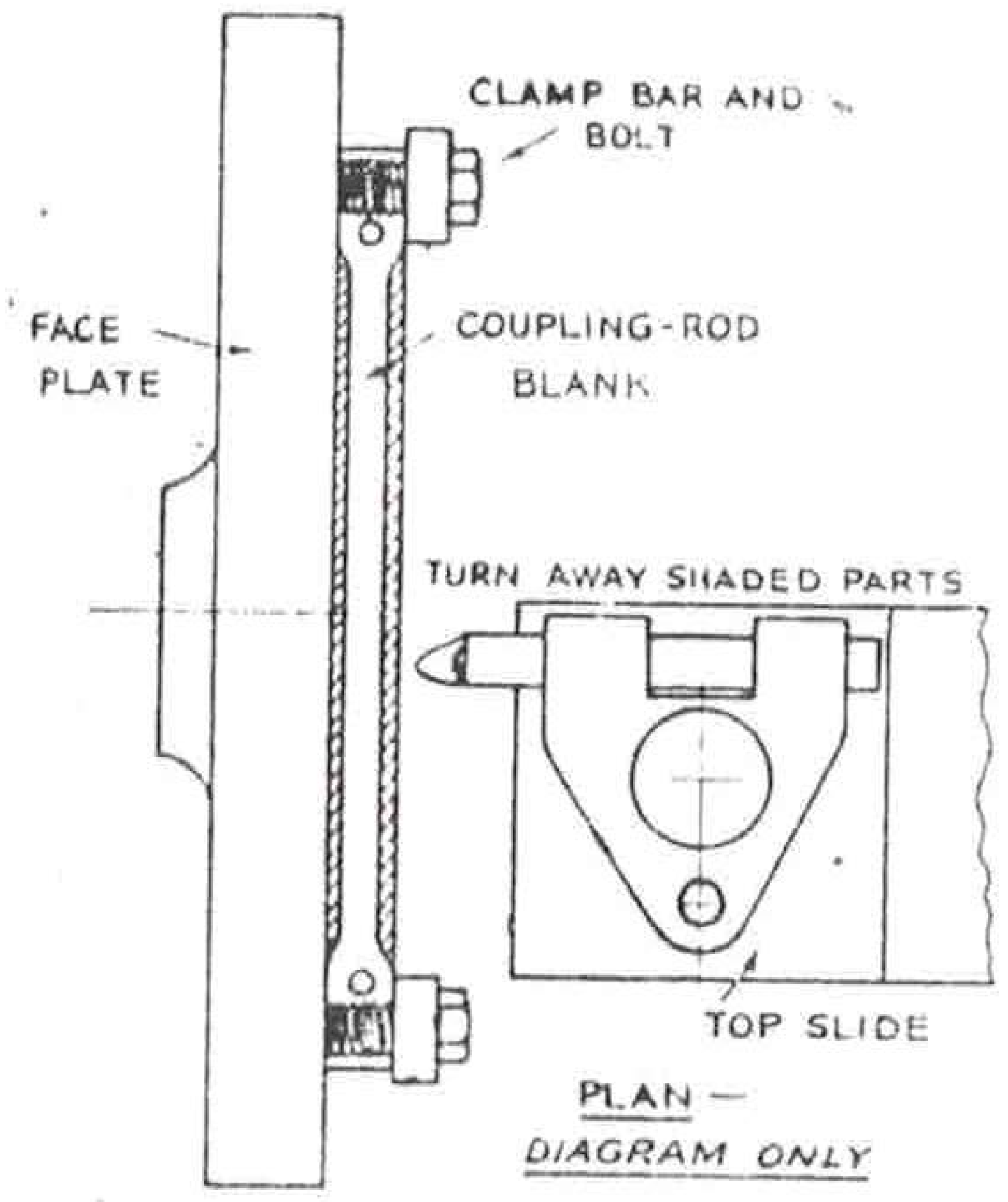


HOW TO DRILL CRANKPIN HOLES

The trailing pins are made from 1/4-in. rod; chuck truly and turn down the spigot for the wheel boss, as described above. Part off at a bare 1/2-in. from the shoulder. Reverse in chuck, and turn down about 3/16-in. of the outer end to 5/32-in. diameter, leaving 9/32-in. of full diameter for the coupling rod to run on. Screw the end either 5/32-in. by 40, or else reduce it a shade more and screw 4 BA. The crankpins can now be carefully pressed into the wheels between the vice jaws; if they go hard, reduce slightly with a file, and don't over-force them, or the cast-iron bosses of the wheels will soon split.

The Coupling Rods.

The three coupled axles are turned from 1/2-in. round mild steel, each piece being 4 3/8-in. long. Chuck truly in the three-jaw; if the chuck is a little out, and the rod wobbles, put a piece of thin foil, or even paper, between the offending jaw and the rod. Then face off the end, using a knife tool in the slide-rest, and turn down 1/2-in. length to a full 7/16-in. diameter. This wheel seat wants to be a force fit in the wheel, and a turner of average skill can get it to size with the turning tool; but beginners and inexperienced workers should turn the seat until it just won't enter the hole in the wheel boss, and then ease it with a file until it goes in rather tightly a little over halfway by hand. It must *not* be slack, and at the same time the remaining portion must not be so tight, that pressing it right home will split the wheel boss. Reverse in chuck, and turn a similar wheel seat on the other end, making the distance between the shoulders 3 9/32-in., and the wheel seats 1/2-in. long. One wheel can be pressed on to each axle, by using the bench vice as a press. If the jaws of your bench vice won't open wide enough, a little extra room can usually be wangled by removing the two steel insets usually fitted to all bench vice jaws. If the wheel goes very hard on the axle, remove it and file a shade more off the wheel seat. Be careful to set the wheel and axle true and square in the vice, otherwise there is a risk of bending the wheel seat and causing the wheel to wobble; an untrue wheel will not keep to the track, the flange climbing the rail-head. Before the second wheel is pressed on to each axle, the eccentrics must be made and fitted, for driving the feed pump and the mechanical lubricator.



HOW TO MACHINE COUPLING-RODS IN LATHE

Eccentrics.

The two eccentrics are identical except that one is drilled 1/4-in. out of centre, and the other only 3/16-in. They are made from 1 1/4-in. round steel rod; a scrap end of steel shafting is just the right material. Chuck it in the three-jaw, and face the end with a knife tool; this will indicate the true centre of the piece of metal, from which the eccentric centre is measured. Now with a parting tool, carefully cut a groove 1/4-in. wide and 1/16-in. deep. You don't have to use a tool 1/4-in. wide to cut the groove; if you

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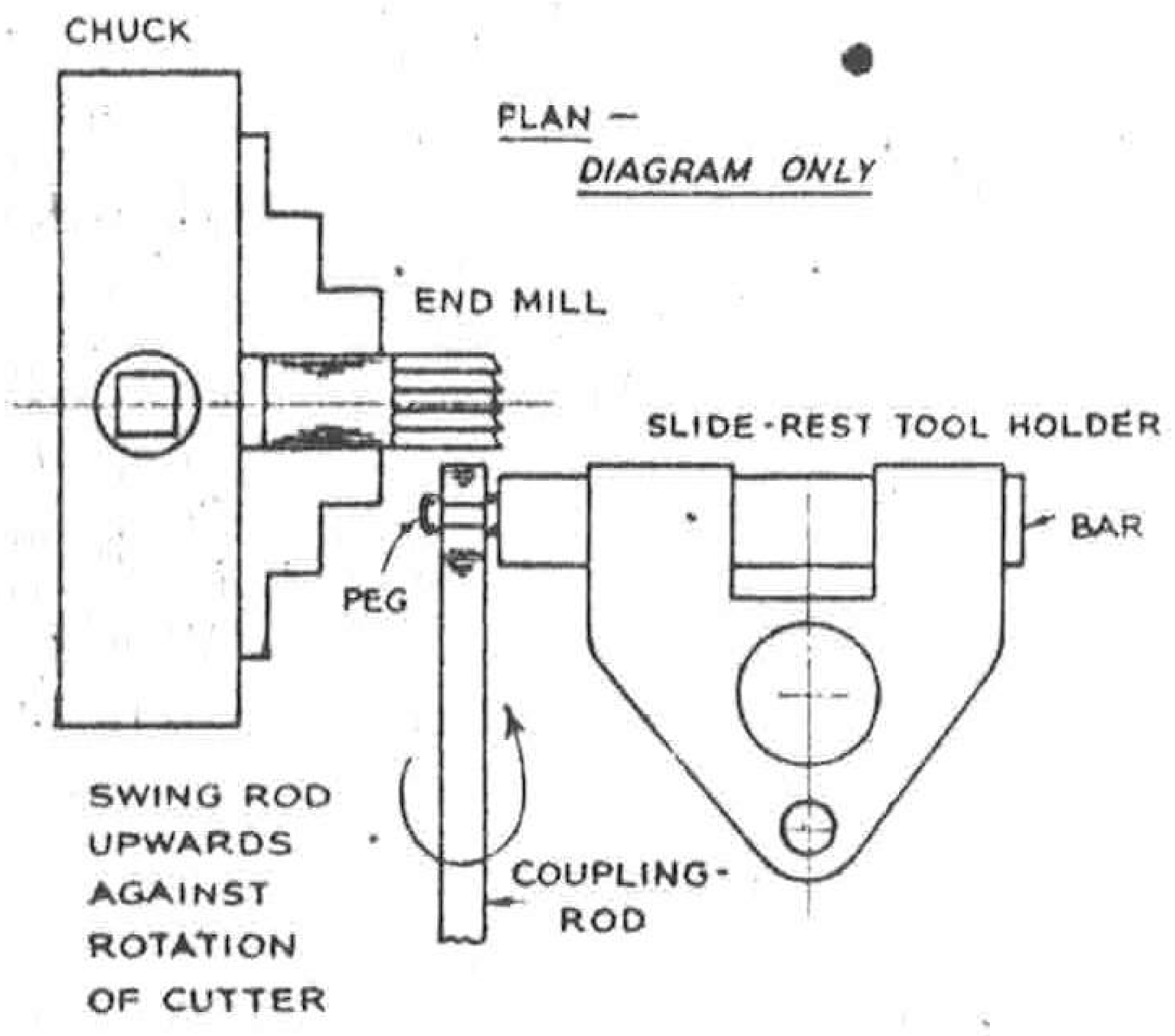
* Continued from page 205.

did, it would chatter abominably in the average amateur's small lathe—in fact it would do that on many big regular engineering lathes! An ordinary narrow parting tool about 3/32-in. wide at the cutting edge, will do the job very well indeed, if a slow speed is used, and plenty of cutting oil applied. Cut the first groove with the parting tool at 1/16-in. from the end of the piece of rod; then take another cut slightly overlapping the first, until the groove is widened to the required ¼-in., finally traversing the tool along the full width of the groove by means of the top slide. This should give a smooth finish to the bottom of the groove; then part off ⅝-in. from the end, and repeat operation for the second eccentric.



HOW TO ROUND OFF THE COUPLING-ROD BOSSES

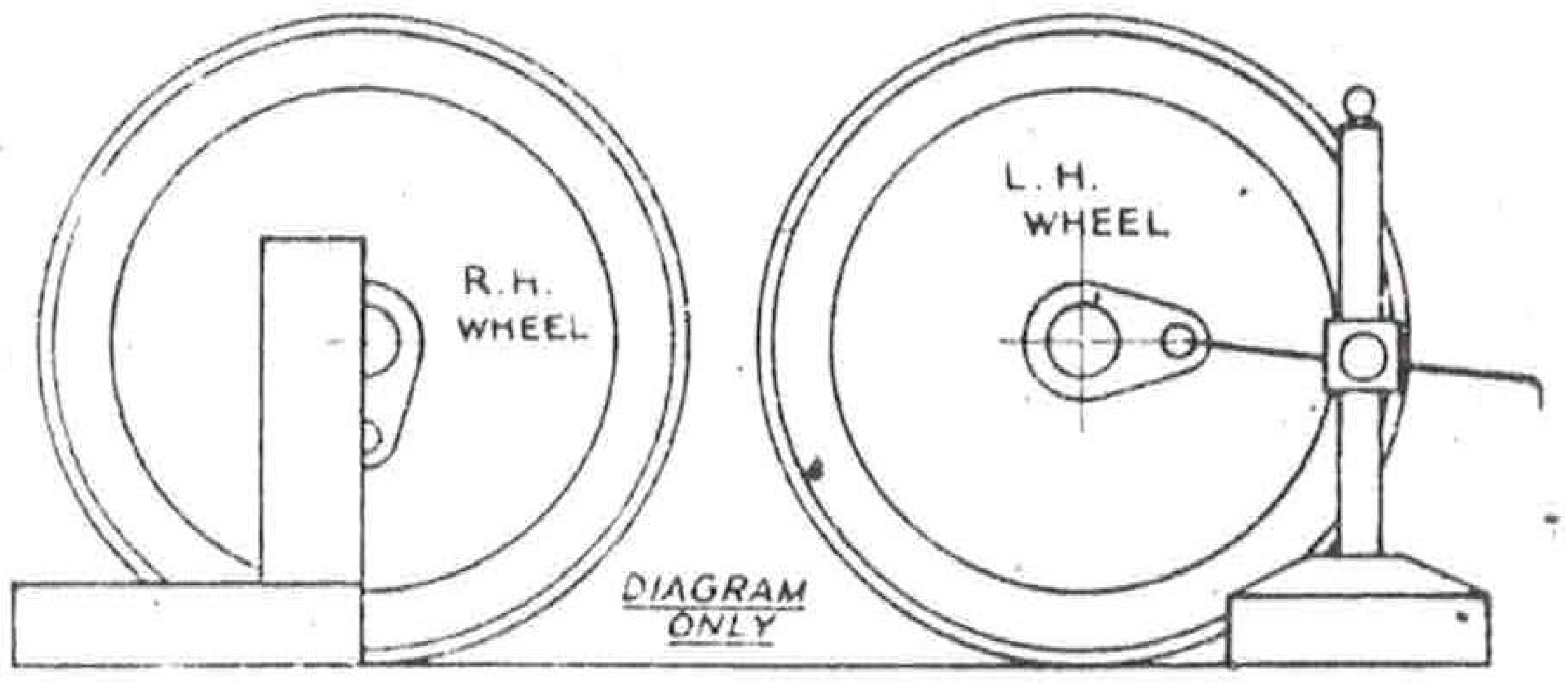
As noted above, the facing tool will indicate the true centres on each of the pieces. On one of them, make a heavy centre-pop ¼-in. from true centre, and on the other at 3/16-in. Drill a ⅛-in. pilot hole right through each. The way I get them true, is to lay the piece of metal, pop mark down, on the drilling machine table, first smoothing off any burr around the pop mark. The jaws of a self-centring chuck are then opened sufficiently to allow the chuck to be dropped over the piece of metal; and with the three jaws resting on the table, the chuck is tightened, the piece being automatically located in it quite truly. The chuck is then turned right over, and the hole drilled in the usual way, the chuck acting as a machine vice. I keep an old chuck especially for this purpose, and it has no backplate: but the chuck off the lathe can be used just as easily. Anybody who hasn't a drilling machine, should chuck the piece of metal in the four-jaw, and adjust same until the pop mark runs truly; then centre and drill from the tailstock chuck in the usual way, afterwards opening out the holes with a ½-in. drill, to fit closely on the axles.

To turn the bosses, the blanks must be mounted on a mandrel, which in this case is simply a short piece of steel driven tightly into the hole, from the grooved side. This should be chucked in the three-jaw, the grooved side bearing up hard against the chuck jaws; the boss can be turned with a knife tool. Don't take too heavy a cut until the eccentric part of the metal has been turned away, and use plenty of cutting oil. Turn the boss to ¾-in. diameter and ¼-in. width; this will leave a 1/16-in. flange between the boss and the eccentric groove. Drill a No. 40 hole in the boss, and top it ⅛-in. or 5 BA. for a setscrew.

The eccentric with the hole 3/16-in. out of centre, goes on the leading coupled axle, the one with the wheel having the shortest coupling-rod pin, and the other one on the driving axle, the wheels of which carry the largest pins. Put on one of the axleboxes, then the eccentric, then the other axlebox, and finally the corresponding wheel, pushing the latter on as far as it will go by hand; the next job will be to "quarter" the wheels and press them right home, preparatory to erecting in frame.

How to Quarter the Wheels.

The next job is to press the coupled wheels right home on the axles; but before doing this, each pair has to be "quartered"; that is, the cranks must be set at 90° or right angles. First of all, put the axleboxes on the axles, and make certain they are on in the right order, and the right way around. My own usual plan, for quickness and certainty, is simply to push the axles through the holes in the axleboxes while the latter are still in place in the frames, not forgetting the eccentrics which go between the axleboxes, and then put the wheels on as far as they will go by hand, setting the cranks at right angles as near as possible, "by eye." The right-hand crank should lead; that is, when the crank on the right side of the engine, looking from the back towards the front end, is right down, the one on the left should point forward. However, on a two-cylinder engine with independent valve gears, it doesn't really matter which side leads, so long as the cranks are at right angles.



HOW TO "QUARTER" THE WHEELS

Now take each pair of wheels, complete with axles and boxes, out of the frames, which is merely a matter of taking out the hornstay screws. Stand one pair on something dead flat, such as the lathe bed or saddle, or a surface plate if you have one. A piece of plate glass makes an excellent-surface plate; I have been using one for years past. It originally formed part of the windshield of a friend's automobile, but one afternoon he got into a bit of an argument with an electric tramway car at the top of Brixton Hill, and the tram came out "top-dog." Nobody was even scratched, but the bump cracked the windshield right across the middle; so my friend had the two pieces cut square, and gave me one. It surely *is* an ill wind that blows nobody good!

Put a little block under each side of oue wheel, so that the assembly won't roll away, and then apply a try-square to one side, stock on the flat surface, and blade alongside the wheel. Adjust wheel until the edge of the blade passes across the centres of the axle and crankpin. Then set up your scribing-block on the other side, and adjust the needle point to the centre of the axle. Apply it to the crankpin; if the centre of the crankpin doesn't come "spot on" to the needle, adjust the wheel on the axle until it does. When both sides are in the positions shown in the sketches, *at one and the same time,* the wheels are correctly quartered. They can then be pressed right home. I use an 11-in. bush press for my squeezing jobs, but the bench vice is just as good; the only drawback is that the jaws of the smaller ones won't open wide enough. A little extra can usually be "scrounged" by removing the steel inserts from the vice jaws; but if that doesn't prove sufficient, and you have no other means of pressing, the wheels may be carefully driven home. A block of metal must be placed on the bench (or whatever you are going to do the job on; it needs something pretty solid!) and the boss of the lower wheel rested on it; then a stub of brass rod, or another metal block, should be placed on the boss of the upper wheel, to receive the hammer blows. Go carefully with the hammer, and the job is "in the bag." Leading and driving wheels can then be replaced in the frames; leave the trailing pair off until the pump is fitted. Although the screws can be inserted between the wheel spokes, it is handier when the wheels are out of the frame. Experience taught me that it is more convenient to erect the parts between frames, before fitting coupling rods and other outside components, so the next item is to make and erect the feed pump.

Pump Stay.

The pump is supported by a substantial stay, or brace, which passes across the frames just ahead of the trailing coupled axle. This may either be a casting, or built up, or simply bent from a piece of plate. It is 1¼-in. deep, 2⅞-in. wide over flanges, and 3/16-in. in thickness. All the machining a casting will need, is cleaning up the flanges, and drilling and tapping the hole for the pump barrel. A file will do the former job, if handled carefully. Anybody who has a milling machine, or the use of one, has only to catch the casting in the machine vice and run it under an ordinary cutter, preferably wide enough to do the lot at one bite. The job can also be done in the lathe by the same process illustrated for milling axleboxes, the stay being clamped under the lathe tool-holder and traversed across an endmill or slot drill held in the three-jaw. Make certain that the measurement over flanges is dead 2⅞-in., or when the stay is erected and the screws tightened, the frames will be distorted. Put a ½-in. hole through the middle of the stay, same as you did for the axleboxes, so that it goes through perfectly true and square, and tap it 9/16-in. by 26.

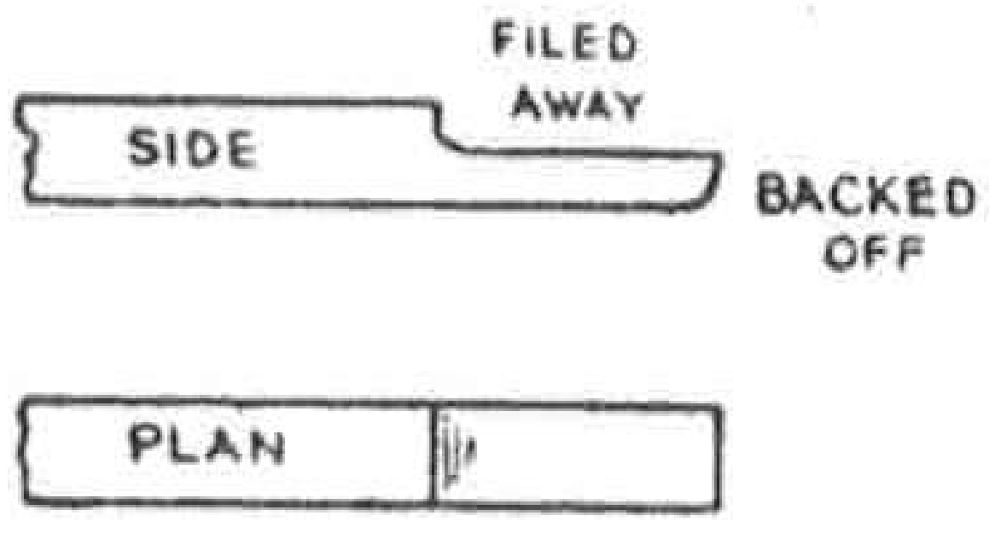
To make a built-up stay, take a piece of brass plate 3/16-in. thick, and saw and file it to a rectangle measuring 2⅞-in. by 1¼-in. Rivet a length of ⅜-in. by ⅛-in. brass angle at each side, to form flanges, and file off flush; or else make two flanges from 3/16-in. by ⅜-in. brass bar, and silver-solder them on. The simplest way of all, if you are good at flanging, is to use a piece of plate 3¾-in. long, and bend the flanges over by catching the plate in the bench vice and using a hammer judiciously. The centre hole is drilled and tapped as above.

How to Make the Pump.

The pump body and valve box may either be a casting, or built-up; castings should be available by the time these notes are in print. First, chuck, in three-jaw by one end of the valve box, and set the other end to run truly. Face off, centre, and drill an 11/64-in. hole right through. Open out with letter R or 11/32-in. drill for a bare ⅜-in. depth, and bottom the hole with a D-bit of same diameter, to a total depth of 7/16-in. Countersink the end slightly, and tap ⅜-in. by 32 or 40; don't run the tap in far enough to spoil the ball seat at the bottom. Enter a taper broach into the hole at the bottom of the ball chamber, and feed it very slightly in, whilst you pull the lathe belt by hand a few turns; this is a precaution to true up the end of the hole, in case the drill doesn't cut exactly round. They *should* do, naturally, but often they don't, like many other things in this benighted world. Skim off any burring around the end of the valve box.

Readers frequently write in to ask where they can buy these small D-bits. You don't have to buy them, they can be made in a few minutes. Get a couple of inches of silver-steel the requisite diameter, file away half the diameter for a length of ½-in. or so, file the end square, and back it off. Heat to red, and plunge into cold water. Brighten the flat part on a piece of fine emerycloth; reheat the round end, and watch the bright part. You'll see it change colour; and as soon as the light brown arrives at the end, pop the lot in the water again very quickly.

To turn the other end of the valve box, the casting should be mounted on a stub mandrel, made in a couple of minutes. Chuck any odd bit of ½-in. round rod, turn down ¼-in. length to ⅜-in. diameter with a knife tool, leaving a sharp true shoulder. Screw ⅜-in. by 32 or 40, to match thread in valve box. Don't remove from chuck, but screw the valve box on to it. The other end of the valve box is then treated same as the first end, except that it is drilled 7/16-in. depth, and there is no need to use the D-bit. As the rising ball valve must not block the hole above it, make four little nicks with a tiny chisel around the hole, as shown in the section. The chisel can be filed from a bit of 1/8-in. round silver-steel, and hardened and tempered.



D - BIT

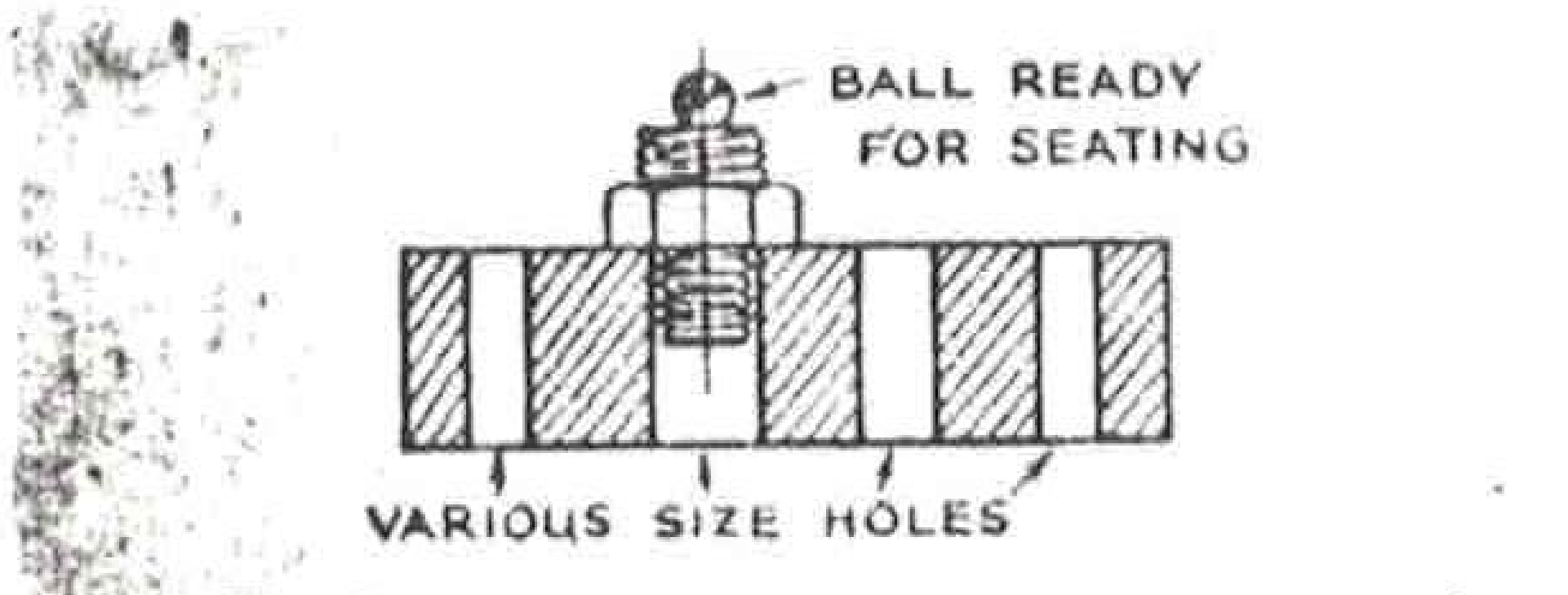
On the end of the casting opposite the barrel, you will find a chucking piece. Grip this in the three-jaw, and set the barrel to run truly; a gentle tap or two with a light hammer is usually sufficient for this. Face off the end, centre, and drill a 3/16-in. hole right through the barrel, into the central passage in the valve box. Open out this hole to 1-in depth with a 3/8-in. drill. The length of the barrel, from the end to the valve box, is also 1-in., and any burring left by the drill must be skimmed off. Turn down the outside of the barrel with a round-nose tool, to 9/16-in. diameter for a length of 7/8-in. and screw it 9/16-in. by 26 with a die in the tailstock holder. The chucking piece may then be sawn off, and the back of the valve box rounded off with a file. Make a distinguishing mark with a letter punch, or put a couple of popmarks on the D-bitted end of the valve box, to indicate which is the top, so that there is no chance of the pump being inadvertently erected upside down. Such things *can* happen!

To build up the barrel and valve box, if no castings are available, part off a piece of 1/2-in. round brass rod 1 3/8-in. long, chuck in three-jaw, and machine up exactly as described for the cast valve box, except that there is no need to mount it on a stub mandrel for machining the second end; merely reverse in chuck. For the barrel, chuck a length of 5/8-in. round rod; gunmetal or bronze if possible, as this resists wear better than brass. Face the end, then drill and open out as described for the cast barrel; let the 3/16-in. drill go in about 1 1/4-in., and the 3/8-in. drill about 7/8-in. Turn down 7/8-in. of the outside to 9/16-in. diameter, and screw as above; then part off 1 1/4-in. from the end. With a round file 1/2-in. diameter, file a half-round recess in the parted-off end, so that the valve box will fit in it closely. Tie in place with a bit of iron binding-wire (thin stuff like that used for tying the stalks of a bunch of flowers) and silver-solder it. Beginners fight shy of silver-soldering and brazing, but both processes are simple and easy —when you know how; and here is the "how" for this job. Use either best grade silver-solder, with powdered borax as flux, or Johnson-Matthey's "Easyflo" and the special flux if available. The process is the same with either. Mix a little flux to a creamy paste with water, smear around the joint, heat to medium red with a blowlamp or gas blowpipe, and touch the joint with a strip of the silver-solder or Easyflo, which will immediately melt and "flash" around the joint. Let it cool to black, and then quench in acid pickle, made by adding one part of commercial sulphuric acid to about twenty of water. Old accumulator acid diluted with water to four times its bulk, also does fine. Wash in running water and polish up. Beginners might like to know that the acid pickle is for the purpose of removing all the burnt flux, and cleaning the job. It can be polished very well, merely by applying a clean rag, though a calico bob on the end of a grinder spindle makes a really posh finish, and in double-quick time at that! Finally put the 3/16-in. drill down the barrel, and drill through into the valve box, scraping any burrs out of the latter.

Two 7/32-in. valve balls are needed; rustless steel if available; if not, use bronze. If steel, drop one in the D-bitted end of the valve box, hold a piece of brass rod on it, and hit the end of the rod one gentle crack with a light hammer. This will seat the ball watertight. Now with a depth gauge, take the distance from top of ball to top of chamber. Chuck a piece of 1/2-in. hexagon brass rod in the three-jaw; face the end, then turn down the outside to a diameter of 3/8-in. and a length 1/32-in. less than indicated by the depth gauge. Screw 3/8-in. by 32 or 40 to match the valve box, and part off 11/16-in. from the end. Reverse in chuck, turn down 1/4-in. of the other end to 5/16-in. diameter, and screw 5/16-in. by 32. Centre deeply with size D centre-drill, and put a 5/32-in. or No. 22 drill right through. Cross-nick the lower end with a watchmaker's flat file, and screw into the top of valve box.

Turn the valve box upside down and drop a ball in the other end. Take the distance, as before, from ball to end of box. Chuck the 1/2-in. hexagon brass rod again, turn down the end to 5/16-in. diameter for 1/4-in. length, and screw 5/16-in. by 32. Centre deeply, and drill down about 7/8-in. depth with 11/64-in. drill. Part off at 3/4-in. from end. Reverse in chuck, and turn down the other end to a diameter of 3/8-in. for the same length as indicated by the depth gauge; then carefully face 1/32-in. off the end. This will give the proper lift to the ball, and true the seating same time. To ensure the hole being perfectly round, enter a taper broach in it, press slightly and pull the lathe belt by hand for a few turns of the mandrel.

Remove from chuck, and stand it on end, valve seat up. To avoid damage to the union cone seating or the threads, the best way is to have a disc of iron about 1/2-in. in thickness, with a few holes of various sizes drilled through it. If the union end of the fitting is dropped into a suitable hole, the hexagon part rests on the disc and will take the recoil from the slight blow when the valve ball is seated. If you are using steel balls, place the ball on the seat and serve it exactly the same as the one in the valve box. If you are using bronze balls, get an ordinary steel cycle ball same size, and form the seatings with that. If you try to seat a bronze ball direct, it will go out of truth; they won't stand knocking about! Screw the fitting into the bottom of the valve box, as shown in the illustration, and that end of the pump is complete. A little jointing compound as used by plumbers, gasfitters, etc., such as "Boso White," may be smeared over the threads to ensure that they are perfectly watertight against pressure.



HAMMERING AND PRESSING BLOCK

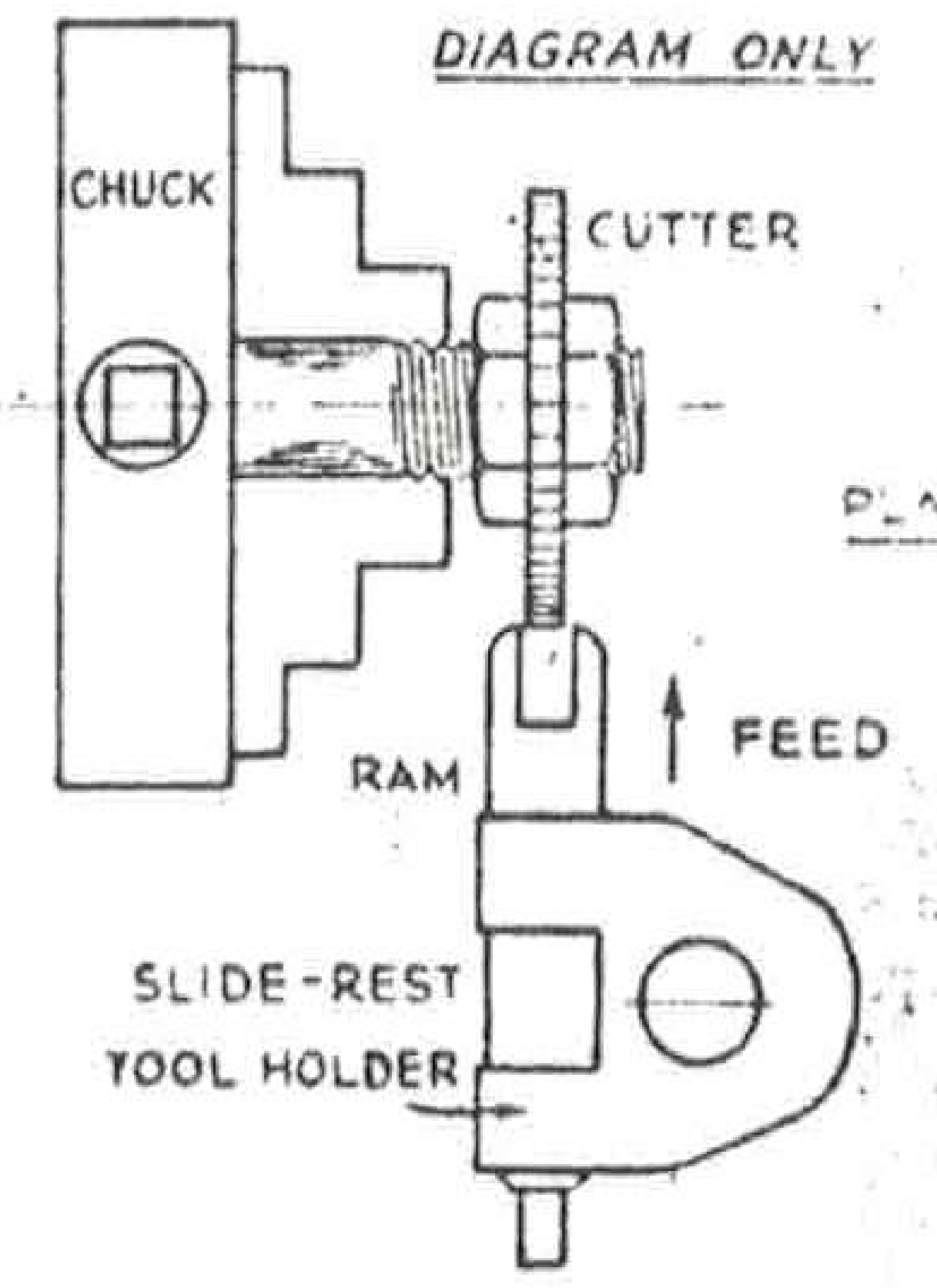
The pump body is now screwed into the stay as far as it will go; make certain the valve box is perfectly vertical, with the marked end (the delivery valve) at the top. A locknut is run on to the barrel, as shown in the drawings; this is merely a 3/16-in. slice of ⅞-in. hexagon rod, drilled and tapped same as the pump stay. Alternatively you can use an ordinary 7/16-in. Whitworth nut—brass for preference, but steel will do—which is chucked in the three-jaw and thinned down to 3/16-in. thickness. The thread is drilled out with a ½-in. drill in the tailstock chuck, and a new thread, 9/16-in. by 26, tapped in the hole.

The gland nut is made from ¾-in. round bronze or brass rod. Chuck in three-jaw, face, centre, drill down ¾-in. depth with ⅜-in. drill, open out with ½-in. drill to ½-in. depth, and tap 9/16-in. by 26. Slightly chamfer the end, part off at ⅝-in. length, reverse in chuck, and chamfer the other end. Four or six 1/16-in. grooves are made lengthwise in the outside, to take a C-spanner for adjusting; these can be planed, milled, or hand-filed according to the means available. Alternatively, if builders prefer, the nut may be made from hexagon stock, and adjusted with an ordinary spanner.

The pump ram is made from a piece of ⅜-in. round metal 2 1/16-in. overall length. Ground rustless steel is best; failing that, use drawn phosphor or nickel bronze, or any hard non-ferrous alloy, but not brass unless there is nothing else available, as this wears rapidly. Chuck truly in three-jaw, and turn down one end to a full 5/32-in. diameter for 5/16-in. length, to form the anti-airlock pin (see sectional illustration). Pumps have been condemned by other writers as unsatisfactory and unreliable, due to air or steam locks. The provision of this simple "tail" entirely prevents any possibility of air becoming trapped in the pump, and none of my engines have ever suffered from pump failure. At 1½-in. from the shoulder, drill a cross-hole with No. 31 drill, and put a ⅛-in. reamer through; then round off the end, and slot the ram at right angles to the hole, to take the end of the eccentric rod. The easiest way to do this, is to clamp the ram under the slide-rest tool-holder, at right angles to the bed, and packed up to centre height. A ⅛-in. milling cutter is mounted on a stub mandrel—old bolt will do—and the bolt held in the three-jaw. The ram is then fed on to the cutter by moving the cross-slide across the lathe bed (see illustration). If you have no suitable milling cutter, make one; it will come in handy for various other jobs. I made all my own when I couldn't afford to buy them; in the old days, an engineman's weekly wage didn't cover luxuries! A ⅛-in. slice parted off a piece of 1½-in. round cast steel, or any equivalent, makes a nobby cutter, the teeth being filed in with an ordinary three-cornered file. It doesn't matter if the teeth are slightly uneven or badly spaced; the cutter is not so liable to chatter. Drill the hole before you file the teeth, by chucking in three-jaw, centring, and using a drill in tailstock chuck or barrel in the usual way. Make the cutter bright red, and plunge edgewise into cold water; rub up on a piece of fine emery cloth, place the cutter on a piece of sheet iron, and hold it over the domestic gas stove with the flames turned low. When the cutter turns dark brown, pop it in the cold water again. It is then ready for use. I don't say for one moment that these home-made cutters will cut as easily and cleanly as an expensive professionally or commercially-made tool; but they are good and cheap substitutes, and save a lot of hand filing. If the cutter leaves any burrs, smooth them off with a fine file. The ram should slide easily in the pump barrel. Pack the gland with either a few strands of graphited yarn, or the special packing used for full-sized pumps, which is sold braided, but can easily be unravelled. In the old days, pumps were usually packed with tallowed hemp; but the acid in the tallow played Old Harry with the brass and gunmetal, covering them with a green poisonous coating which was dangerous to scratched hands.

The complete pump may now be erected in the frames; the position is shown in the plan drawing. The back of the stay should be exactly 1-in. from the centre of the rear coupled axle; the bottom level with the bottom of frame, and the valve box exactly vertical. The centre of the barrel will then be level with the centre of the driving axle, when the axleboxes are in correct running position. Run a No. 30 drill through the holes in the frame at each side of the stay, and make countersinks on the flanges; follow up with No. 40, drilling right through flanges, tap ⅛-in. or 5 BA., and put in countersunk screws as shown in the plan drawing.

(see next page)



HOW TO SLOT THE PUMP RAM

The Main Frames.

Although illustrations were given in the issue of January 5 last of the main frames, detailed instructions for their marking out and construction have not hitherto been given. In the present instalment these particulars are set out in full.

For the main frames, illustrations of which are given on the next page, two pieces of ⅛-in. steel plate 20¼-in. long and 3-in. wide, will be needed; the kind recommended in the soft blue variety, which does not distort and buckle when the axlebox openings are cut out. See that both pieces are perfectly flat, and square at the ends; then mark off one of them to the outline shown in the drawing, which gives all the necessary dimensions. Great care should be taken in marking out the holes for steam and exhaust pipes, and cylinder fixing screws; no trouble should arise if the following procedure is carried out. After marking the outline of the frame, set off a point 3 13/16-in. from the front edge of frame, and 7/16-in. below the top edge, as shown in the drawing. Make a good deep centre-pop. At a point ¾-in. below this, and ⅝-in. farther back, make another deep centre-pop. The former gives the location of the hole for the cross steam pipe, and the latter for the exhaust pipe. Now set out the location of the cylinders, as shown by the dotted lines in the drawing. In the centre of the opening marked out for the driving axlebox, and ⅝-in. from the bottom, make a centre-pop. Mark off a point 13/32-in. from the bottom edge of the front end of frame, just ahead of the piece to be cut out to clear the pony wheels. Draw a line from this point, to cut clean through the centre-pop showing running position of driving axle; this is the centre-line of motion, and passes through the cylinder bores. On this line, at 3¼-in. from the front of the frame, draw another line *cutting it at right angles*—very important, that—extending just to top the frame, and 9/16-in. below the centre-line. Draw another similar line 2⅜-in. farther back. This also extends 9/16-in. below centre line, but only reaches to within 1/16-in. of the top line of frame. Connect tops and bottoms of both lines by lines 2⅜-in. long, parallel to centre-line of motion, and you have the outline and correct position of the cylinders. It is then only a minute's work to set out the bolt or stud holes; the middle one at the bottom should be marked off first, 7/32-in. below centre line of motion, and exactly underneath the exhaust hole. Mark off two more, ⅞-in. each side of the previous one; and then two more still, ⅞-in. above the previous two. Centre-pop them all, and the trick is done.

The small row of countersunk holes below the cylinder location, are for the screws holding the pony-truck bolster in place; they are located 3/16-in. from the bottom edge of the frame, and ⅜-in. apart, the end one coming just below the bottom right-hand cylinder stud hole. Centre-pop them all; then mark out and centre-pop the holes for the screws fixing the frames to the buffer beam and trailing truck. The location of these is clearly shown on the drawing. Next, at 1⅜-in. from the centre of the trailing coupled axlebox slot, mark out the three holes for the screws holding the pump. Finally we have a very important hole—last, but decidedly not least!—between the leading and driving axlebox openings. This is for the bush which carries the reversing shaft. It is located 2½-in. behind the centre of the leading axlebox slot, and 1 9/32-in. from top of frame. Centre-pop deeply.

Now put your No. 30 drill through *every* centre-pop, and then file off the burrs on the other side of the frame. Place the two frame plates together, and clamp them with a couple of toolmaker's cramps, which may be home-made as I have described in previous notes. Drill two holes in plate No. 2, using any of the holes at the extreme ends of the frames as guide or jig holes; put a couple of rivets through, and temporarily rivet the two plates together. Now put the No. 30 drill through all the holes in the second plate, using those in the first as guides; then open out the larger holes—cylinder stud holes, pipe holes and reversing-shaft bush holes—with the appropriate size drills. This will be found far easier and more accurate, than direct drilling; I have detailed out the full procedure for the benefit of beginners, as I get many requests to do so in direct correspondence, and a pair of accurately-drilled frame plates are the first essentials to a well-made and efficient engine. Nothing like building on a good foundation!

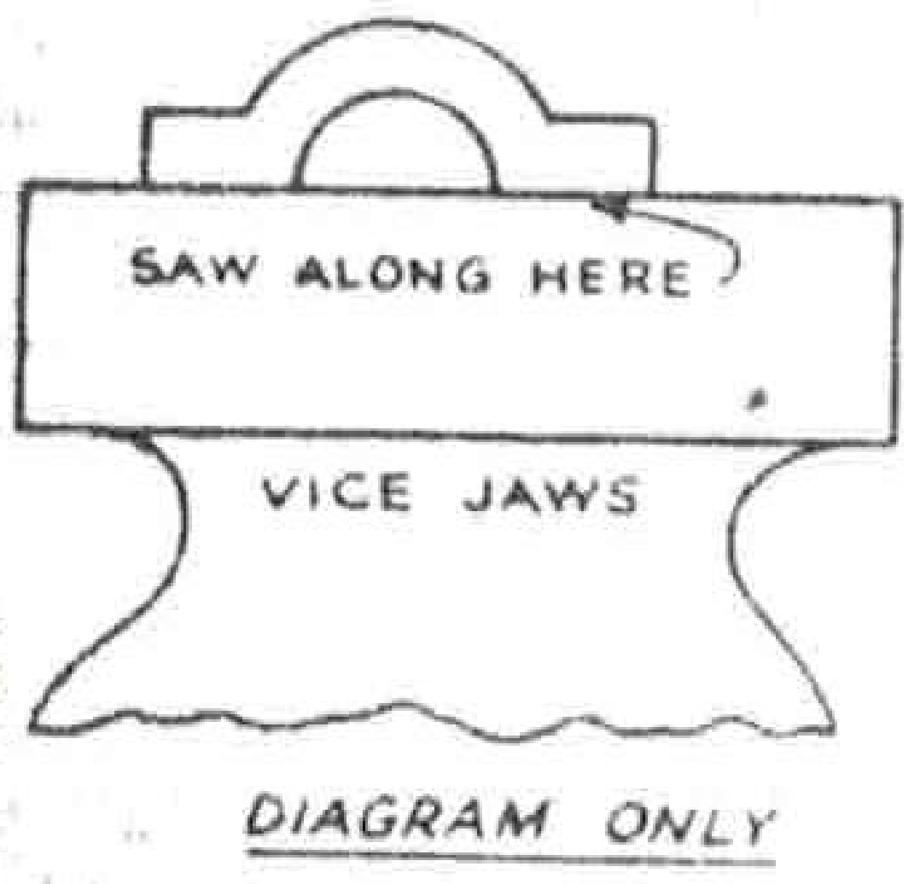
The next stage of the proceedings, is to saw and file the frames to outline, which is a simple "rule-of-thumb" job. I would again remind beginners that the rawest recruit can saw a straight line by using the top of his bench vice as a guide. If the frames are placed in the vice with a marked line showing just above the jaws, the hacksaw blade can be put on its side in the frame, and the frame plates sawn along with the sawblade lying flat on top of the vice jaws, so that they guide it perfectly straight. A little cutting oil, same as you use for turning steel, applied to the sawblade with a brush, doubles both the speed of cutting, and the life of the blade. Soapy water with a little washing soda in it, is less expensive and nearly as good.

To cut the axlebox openings, drill a line of 3/32-in. holes almost touching, just below the horizontal line at top; then saw down each side, keeping just inside the marked line, with the frames gripped upside down in the vice, and the row of holes just above the jaws. Grab the tongue of metal between the cuts, with a pair of flat-nosed pliers, give it one or two waggles back and forth, and out it comes. File away the ragged edges until a piece of 1-in. flat bar, used as a gauge, will slip nicely into each slot without any shake or sloppiness. Knock out the rivets, and there are your frames. Carefully smooth off any burring around drilled holes and along the edges.

Eccentric Strap and Rod.

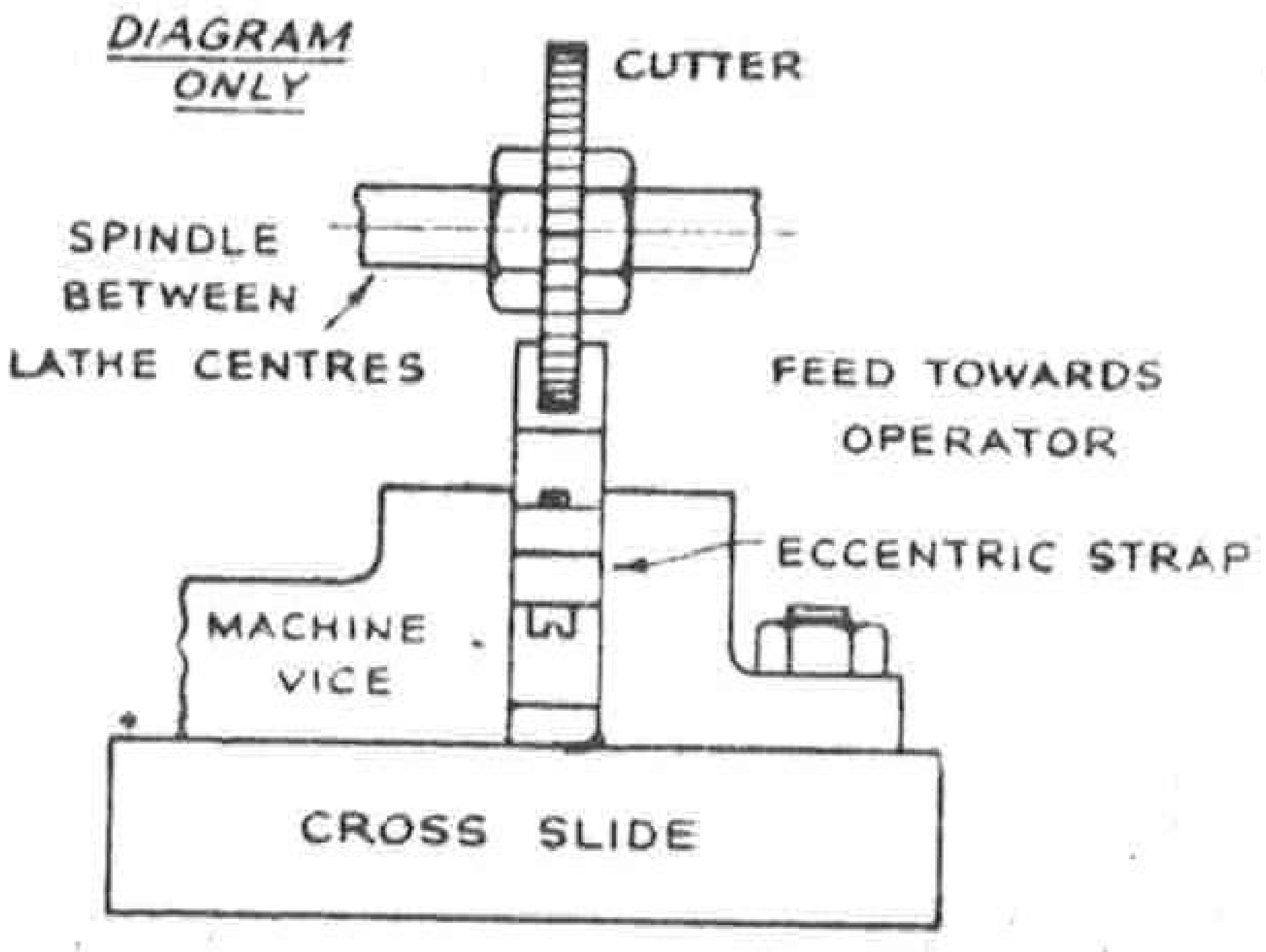
The eccentric strap is made from a casting which is first cleaned up with a file. Centre-pop the ears or lugs, and drill a No. 40 hole through each. Scribe a line across the middle of the lugs, catch the casting in the bench vice with the line just showing, and saw right across with a fine-tooth hacksaw blade, keeping same pressed down in contact with the top of vice jaws; this ensures beginners making a clean square cut. Open out the holes in the plain half, to No. 30 size, and tap those in the half with the lug for the rod, either ⅛-in. or 5 BA. Rub the sawn faces on a fine file laid on the bench, to remove the saw marks, then screw the halves together. Mark both lugs on one side, so that the two halves can always be replaced correctly after taking apart for any purpose.

The core hole will now be oval, but chuck the strap in the four-jaw, adjusting jaws so that the hole runs as truly as possible. Face off one side of the strap, and bore out the corehole until it is an exact fit on the eccentric. I usually turn up a piece of steel to the same size as the eccentric, and bore the hole until the steel fits nicely, but without any shake. To face the other side, put the bit of steel in the three-jaw, wind a couple of turns of paper around it, and clamp the eccentric strap on it by its own screws, rough side just overhanging. This can then be easily faced off until the casting is a bare ¼-in. wide, and a nice fit between the flanges of the eccentric tumbler. A slot ⅛-in. wide and 5/16-in. deep, is cut in the back lug, for the rod; this can be planed or milled, or put in with a key-cutter's warding file. If a ⅛-in. milling cutter is mounted on an arbor and run between lathe centres, the strap could be clamped in a machine vice on the saddle, adjusted to correct height, and run under the cutter, which would clean out a neat groove at one fell swoop.



HOW TO PART ECCENTRIC STRAP CASTING

The rod is filed up to the shape, previously illustrated, from ⅛-in. flat mild steel. The wide end is pushed into the groove in the lug on the strap, and secured with a couple of 1/16-in. steel or brass rivets; it may be soldered as well, if you wish. Leave the rod a shade longer than shown, and set the actual working length from the job itself, as follows. Put the eccentric strap on the tumbler, and set it on back dead centre, exactly as shown in the sectional illustration. Push the pump ram into the barrel as far is it will go; then put the end of the eccentric rod in the slot in the ram. With a bent scriber, mark off on the eccentric rod, the position of the gudgeon-pin hole in the ram, putting the point of the scriber through the hole itself. Now remove the eccentric strap and rod; find the centre of the little circle marked by the scriber, *and at 1/32-in. nearer to the strap,* drill a No. 30 hole for the pin. This allows for 1/32-in. clearance between the ends of the ram and the barrel of the pump, on back centre, and ensures that the pump always delivers the maximum quantity of water at each stroke. Round off the end of the eccentric rod, and caseharden the eye. Heat it to bright red, and dip into any good casehardening powder (Kasenit, Pearlite, Ecosite, etc.) or into powdered yellow prussiate of potash. Reheat until the yellow flame dies away, and then quench in clean cold water; clean up and polish. Be sure and get all the burnt powder out of the eye.



HOW TO SLOT THE ECCENTRIC STRAP

The gudgeon pin, or wrist pin, can be turned from ¼-in. silver-steel rod to the shape shown in the drawing, cross-drilled No. 51 and secured by a 1/16-in. commercial split pin; or it may be a piece of ⅛-in. silver-steel shouldered down to 3/32-in. at each end, screwed, and furnished with ordinary commercial nuts.

Coupling Rods.

The coupling rods are made from ¼-in. by ¾-in. flat mild steel bar, four pieces being needed; two 4¾-in. long, and two 6¼-in. Mark off one long section and one short section; drill ⅛-in. holes at the crankpin centres, use the two marked pieces as jigs to drill the two unmarked, and rivet each pair together temporarily with bits of ⅛-in. wire driven into the holes. To make the marking show up plainly, I coat the parts with a fluid made from shellac dissolved in methylated spirit, with a little colouring dye added; violet in my case. This dries in a few seconds, leaving a dark violet surface on which scriber marks stand out as silvery lines.

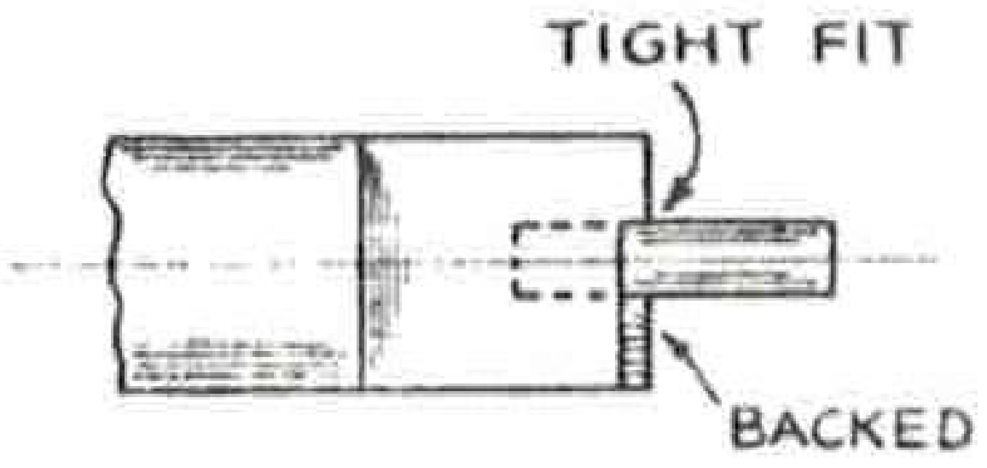
If you have the use of a milling machine, it will make easy work of the rods; each pair is clamped horizontally in a machine vice bolted to the milling table, and a small slabbing cutter used to remove the surplus metal. I am still using an old high-speed cutter bought for a shilling as "Government surplus" after the last war; it is 1¼-in. diameter and ⅝-in. wide, and has seen service on three different machines, milled hundreds of jobs, and still emulating the famous "Charley's Aunt." Failing a regular milling machine, the lathe can be used to get the rods to shape, and the diagram, on page 245, March 9, shows how this is done. Bolt the rod blanks to the faceplate, across the centre, with a bar across each end, secured by two small bolts. Use a roundnose tool set crosswise in the slide-rest, plenty of cutting oil, and don't take too "greedy" a cut; a fairly slow speed must also be used if the lathe is a small one. For cutting oil I use a mixture of "Vacmul," two parts, and paraffin one part, but any good cutting oil will serve. I prefer paraffin dilution, as it keeps the machines silvery bright; whereas water mixtures, as commonly used in production factories, will rust up the lathe if you don't wipe off every drop of surplus after finishing a job. This method of making the rods, will leave the radii of the bosses slightly rounded, but a judicious application of a file will soon settle that little item.

The recessing of the faces, is done same way, and if no miller is available to cut the flutes, they can be endmilled by exactly the same process as illustrated for milling the grooves in the axle-boxes; or they may be left out altogether. None of the Stroudley engines on my old road had fluted rods, and the Great Western and many L.M.S. engines dispense with flutes likewise.

The ends are rounded off in the lathe by a simple process. After milling or turning the rods to shape, part each pair, and open out the crankpin holes to 7/32-in. Now take a piece of square steel bar of the same size as your turning-tool shanks, so that it will go in the lathe tool-holder. Turn down one end to a diameter that will just enter the 7/32-in. holes in the ends of the rods, for a length of about 5/16-in.

Put this in the tool-holder, parallel to the lathe bed, and pack it up to centre height if necessary, with the peg overhanging the side. Put a ½-in. endmill which has side as well as end teeth, in the three-jaw. Slip one of the coupling-rods over the peg, and grip the end very firmly. Feed up with the cross-slide, as shown in the illustration, and when the boss of the rod meets the cutter, swing the rod slowly around the peg. When the end takes shape, feed in a shade more, and repeat operations until the end is rounded off to correct size. Warning to beginners: don't swing the rod too far around, and cut away the oil-box! Any slight irregularity can be corrected afterwards with a file.

The knuckle joint is of the usual fork-and-tongue pattern, as used on full-sized locomotives. Clamp the short section of rod under the lathe tool-holder, and follow exactly the same procedure as you did when slotting the pump ram. To form the tongue, a 7/16-in. pin drill is required, with a 7/16-in. pilot pin; this may be home-made. Chuck a piece of 7/16-in. silver steel in the three-jaw; face the end, centre, and drill 3/16-in. diameter for about ¼-in. depth. File the end like a screwdriver, and back off as shown in the illustration; then harden and temper to dark straw-colour, as described for D-bits. Touch up the cutting edges on an oilstone. For the pilot pin, turn down the end of a half-inch of 7/32-in. silver steel, until it is a tight push-fit in the hole. If this is used in the drilling machine, or lathe, and the end of the coupling rod rested on, or against, a piece of wood with a ¼-in. hole in it to accommodate the projecting end of the pin passing through the hole in the rod, it will speedily reduce the thickness of the end of the rod. The tongue is formed by pindrilling each side until a piece is left in the middle, exactly fitting the jaws of the boss on the short rod. The hole on the plain side of the rod is countersunk, and a shouldered pin from 5/16-in. silver steel, turned to fit, the outer end being shouldered and screwed ⅛-in. or 5 BA. The pin is secured by an ordinary commercial nut and washer.



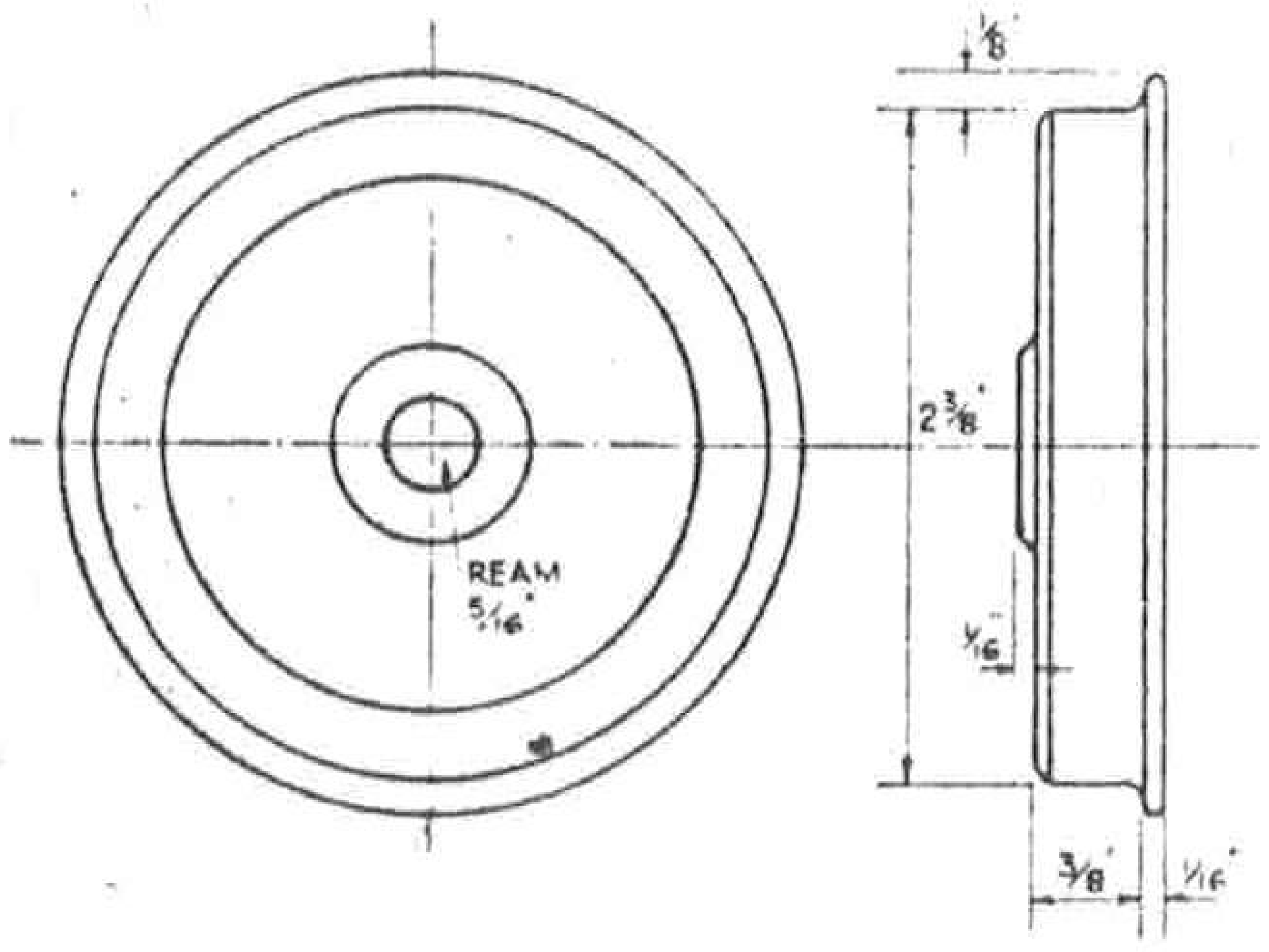
PIN DF

With the same pin-drill, form a recess 1/16-in. deep in the front bosses of the two longer rods; after which, all the bosses may be bushed. Open out the holes in the leading and trailing bosses with an 11/32-in. drill, and the driving bosses with 15/32-in. drill. Chuck a piece of ⅜-in. bronze or gunmetal rod, face the end, and drill down about ½-in. depth with ¼-in. drill. Turn down the outside to a tight drive fit in the holes in leading bosses, part off two 3/16-in. lengths, and press them into the holes. Each bush for the trailing bosses must be turned separately from 7/16-in. rod, as these bushes have a flange (see illustration). The driving bushes are turned from ½-in.

rod, and reamed 3/8-in.; they have no flanges. Finally, drill a No. 55 hole in each oil box, and counterbore it about 5/32-in. as shown by the dotted lines. The rods are then put on the crankpins, the leading bosses being prevented from coming off by a 7/16-in. washer in the recess, held in place by a countersunk screw; the trailing bosses have a nut and washer. No fixing is needed for the driving bosses, as they are covered by the big-ends of the connecting rods. The wheels should turn perfectly freely when the rods are on; the driving boss should be a good fit on the pin, without slackness, but the leading and trailing bosses should have a slight amount of play, to allow for axlebox movement. On full-size locomotives, the allowance is usually 1/16-in., and this is what causes the ringing rattle or clank of a coupled engine drifting with steam off.

Trailing Wheels and Axle.

In order to keep the construction of he locomotive as simple as possible, a pair of ordinary axleboxes, similar to those used on a tender, are fitted to the trailing frames in place of a pair with radial motion; but to allow the locomotive to traverse fairly sharp curves with ease, the axles are arranged for 3/16-in side movement at each side of the centre. Alternatively, a pony truck could be fitted, similar to the one which will be described for the leading end. This has one advantage, inasmuch that it could be pivoted to the ashpan; and when the " dumping-pin ' is pulled out, the ashpan, complete with pony truck, and the firebars, would all come away and leave the firebox open and unobstructed at the bottom. The outside appearance of the engine would not be altered in any way whatever, as a pair of cast dummy springs with axleboxes complete, would be fitted to the frames as shown in the general arrangement drawing; but the pony truck would entail some additional work, so I recommend the arrangement of plain axle with side-play, as described below.



PONY AND TRAILING WHEELS

The wheels are 2 3/8-in. diameter on tread, width, flanges and bosses being similar to those on the coupled wheels; and the method of machining is exactly the same, so I need not repeat all the details. Turn up four wheels of the same diameter whilst you are on the job, as the wheels for the leading pony truck are exactly similar to the trailing wheels; this saves much time. The trailing axle is turned up in much the same way as described for the coupled axles; but it differs by projecting through the wheels, and the journals are outside. A piece of 3/8-in. round mild steel 5 3/4-in. long will be needed. Chuck truly in three-jaw, turn down 11/16-in length to 1/4-in. diameter, and slightly round off the end; then turn down a further 1/2-in. length to a squeeze fit in the holes in the trailing wheel bosses, as described for the coupled axles. Reverse in chuck, and repeat process, taking care that the distance between the shoulders is 3 9/32-in. Both wheels may then be pressed on.

Trailing Horns and Axleboxes.

At the time of writing, I understand that one of our advertisers will be offering cast trailing frames complete in one piece, with drag beam integral, and lugs for attaching to main frame; but due to the difficulties of moulding, the hornblocks and cast dummy springs must be separately attached. Another advertiser will be supplying the trailing frame in four separate castings, viz., two sides, front cross brace, and rear beam, only needing to be screwed together; but in this case the sides will have the horns and dummy springs cast on, so—as the Cockney costermonger would say—" you pays your money and tikes your choice." The built-up trailing frame made from plate, already described, will of course need separate horns and springs. These will be of the usual pattern, as supplied for plate-framed tenders.

Trailing Horns and Axleboxes.

No machining is required, the backs simply being smoothed off with a file, so that they bed properly against the frame. The jaws are also smoothed out with a file until a piece of 5/8-in. square bar, used as a gauge, will slide easily between them without shake. They *could* be milled, if a regular milling machine is available; but it is hardly worth while rigging up for milling in the lathe, when a few judicious strokes of a file will produce equally satisfactory results. It is sometimes much quicker to do a job by hand, than by machining!

The buckle or hoop of the dummy spring is drilled 1/4-in. for reception of the coiled spring (see section) and a No. 30 hole is drilled at each end of the top plate. The complete assembly is then placed over one of the slotted openings in the trailing frame; to get the exact location, slide the piece of 5/8-in. square bar into the frame slot, and put the hornblock casting over it, which will line them up correctly. Next, temporarily clamp the casting to the frame by means of a toolmaker's cramp, drill four No. 41 holes each side, above, below, and between the ribs, and rivet with 3/32-in. roundhead charcoal iron rivets. For the sake of appearance, the heads should be outside, and not distorted; for a riveting dolly in an instance like the present, I use a piece of steel, tapered at one end, which has also a cup-shaped depression in it. This is made by countersinking the end slightly with a drill, putting an ordinary steel cycle ball in the countersink, and giving it several hearty biffs with a hammer. The dolly is placed vertically in the vice, and the head of the rivet reposes in the cup whilst the stem is attacked with the riveting hammer (see sketch below).

The spring pins are 13/16-in. long and 1/8-in. diameter, and the easiest way to make them is to use pieces of 1/8-in. round steel or iron wire, screwed at both ends and furnished with ordinary commercial nuts. The lower ends of the spring pins pass through small brackets, bent up from 5/16-in. by 1/16-in. strip steel, or cut out of 1/16-in. sheet, and riveted to the frame. As they are only for "ornament" and carry no weight, a single 3/32-in. rivet is plenty good enough for attachment.

If separate cast side frames are used for the trailing cradle, and they have the horns and springs cast on, the only work needed will be to clean out the jaws until the 5/8-in. square bar slides in, and drill the spring pockets in the hoops or buckles.

The axleboxes can be made from castings or from bar material. In the former case, the two boxes will probably be cast in one unit, end to end, so that they may be machined together, to fit the horn cheeks. The method adopted, is exactly the same as described for the coupled axleboxes, so there is no need to repeat the instructions. The boxes are then sawn apart, and each chucked separately in the four-jaw, so that top and bottom may be faced off square.

If the boxes are made from bar material, a piece of 7/8-in. square brass bar will be required, approximately 2-in. long. A channel, 5/8-in. wide and 1/8-in. deep, is milled in each side by the same process as described for the coupled axleboxes; note that this channel is not central, but has a flange 3/32-in. wide at one side of it, and 5/32-in. at the other. The piece of bar should slide easily without shake, between the horncheeks, after being milled. It is then sawn, or parted in the lathe, into two portions, the ends being faced off truly in the four-jaw, so that the boxes measure 7/8-in. from top to bottom.

The lids may be either dummies, or real working lids, as desired. In both cases they are cut from 1/16-in. sheet brass, to the shape shown in the illustration, the lugs being drilled No. 51. If dummies, they are simply attached to the axlebox fronts by a couple of 1/16-in. screws, either round or hexagon-headed. If real, the holes for the axle journals should be drilled right through the boxes, the lids covering the ends of the holes. The screwholes should be tapped just deep enough to allow the screws to seat home tightly, but not grip the lugs of the lids; and one of the lugs should be slotted, as shown in the detail sketch. If this lug is lifted, the lid can be pulled out sufficiently to clear the screwhead, and then swings upwards on the opposite screw, exposing the bearing hole all ready for the application of the driver's oil feeder. The holes for the journals must be an easy fit, so use a clearing drill, G. or 17/64-in., so that the axles run perfectly free when the boxes are out of line on an uneven road, or passing through crossings. Centre-pop the boxes, and chuck in four-jaw with the pop mark running truly; start the hole with a centre-drill in the tailstock chuck, finishing off with a drill of the proper size.

The spiral springs are made from 20 gauge wire, tinned steel for preference, as it does not rust; if unobtainable, use ordinary steel wire. Wind as described for coupled wheel springs, over a piece of 5/32-in. round steel in the chuck. Grind off the ends nice and square.

The hornstays are merely strips of 1/16-in. steel, 1/8-in. wide, attached to the bottom of the hornblock slots by 1/16-in. screws, which may be hexagon-headed.

If anyone wishes to fit real working leaf springs, they should be made on the system devised by Mr. T. H. Glazebrook, which gives the necessary flexibility plus "real" appearance. Instead of the plates being 1/16-in. in thickness, each one is made of four thin laminations; the top plates, for example, should be composed of four pieces, each of 3-in. overall length, 3/8-in. wide, and 1/64-in. in thickness, six groups of four plates each, completing the spring. The buckle, or hoop, should be made from 1/2-in. square bar, and the plates clamped in it by a 1/8-in. screw at the bottom, the head resting on the axlebox and transmitting the load.

The spring pins are exactly the same as used for the cast dummies; but as the brackets in this case carry the load, they should be made triangle-shaped where they are attached to the frames, and fixed by three rivets in each. The horncheeks need not be castings, but made from 1/2-in. by 3/8-in. brass angle, 1/8-in. thick, the ribs or webs being cut from 1/8-in. sheet brass and silver-soldered in; or alternatively, the webs might be left out altogether, as the angle itself is plenty strong enough to stand the stresses unaided, on a locomotive of 3½-in. gauge.

Pony Truck.

The leading pony truck is of a similar pattern to that which I specified for the 2½-in. gauge "Green Arrow," and differs from the pony truck on "Princess Marina" by having the wheels separately sprung, instead of the whole truck being given free movement. Whilst the latter is more flexible, and especially suited to tracks which are out of level in a lateral direction, it has one disadvantage; if an extra-wide rail gap or badly laid crossing frog is encountered on a curve when the engine is running at high speed, the jar lifts the whole frame and tends to derail the engine. With a rigid frame and separately sprung axleboxes, the jar only takes effect on the axlebox receiving it, and the action of the spring is, of course, far quicker. Incidentally, leading pony trucks are looked upon with suspicion by many full-sized locomotive engineers. The late Sir H. N. Gresley made extensive use of them in his numerous 2-6-0 and 2-8-0 classes, as well as the "Green Arrows," "Bantam Cocks," and "Cock-o'-the-North" types, all of which appeared to give complete satisfaction; however, it is significant to note that his successor, Mr. E. Thompson, is reverting to the use of a leading bogie.

Pony Frames.

These may be made either from ⅛-in. steel, or from castings. The good folk whose addresses were recently published, should be able, by the time these notes are in print, to supply cast frames with the horns and spring brackets integral. If the frames are to be built up, two pieces of ⅛-in. steel will be needed, each 6-in. by 1¾-in.; these are marked out as shown in the published drawings, sawn and filed to the given outline, and then bent to the shape shown in the plan sketch. The openings for the axleboxes are ⅝-in. wide and 15/16-in. deep. The horncheeks are pieces of ¼-in. by 1/16-in. brass angle 11/16-in. long, riveted to the sides of each opening, by 1/16-in. rivets; put a piece of ⅝-in. bar in the slot, to act as a gauge, set the piece of angle close against it, clamp temporarily with a toolmaker's cramp, drill No. 51 holes through angle and frame, countersink them outside, and put in 1/16-in. roundhead rivets, heads inside the frame, and hammer the stems flush into the countersinks. The bright soft steel rivets supplied by Mr. Linstead are ideal for this job; copper rivets should not be used for frame parts unless no other kind are available, as they are liable to come loose under the stresses to which they are often subjected on a small locomotive intended for real work. I might here call attention to the fact that engines such as "Bantam Cock" are NOT "models," but *real* little locomotives, the only fundamental difference from those operating on 4-ft. 8½-in. gauge being the size; they are fired and driven in exactly the same manner, and in many cases can exert a tractive effort actually greater, in proportion, than their big sisters.

The pony frames are attached at the rear ends, to the block which works on the king pin. This as a ¾-in. length of ½-in. by ⅜-in. brass bar, with a 5/16-in. hole drilled through it, as shown in the illustrations. The frames are placed on either side of it, and temporarily held in position by a toolmaker's cramp, care being taken to have the frames exactly parallel. Drill a No. 30 hole clean through frames and block, put a bolt in, screw up tightly, remove cramp, drill the second hole, and fit the other bolt. The bolts are made from pieces of ⅛-in. round steel, and full 1-in. long, screwed at both ends and furnished with nuts.

The front ends of the pony frames are connected by a stout tie bar. This may be drilled and tapped each end for a ⅛-in. or 5 BA. screw, in which case the rod should be sawn a little over length. Chuck in three-jaw, face, centre, drill down about ½-in. with No. 40 drill, and tap as above; reverse in chuck and repeat operations, keeping the overall length to 2⅞-in. The holes in the frame are drilled No. 30 (this should be done when the frames are temporarily riveted together for cutting out) and countersunk on the outside, the tie bar being placed between, and secured by two countersunk screws. Alternatively, the tie bar may be made from a piece of round steel rod, 3¼-in. long. Chuck in three-jaw as before, but turn down 5/16-in. of each end to ⅛-in. diameter. Countersink the holes in frames, as for the screw fixing, but put the pips on the ends of the tie bar through the holes, and hammer them down into the countersinks, filing off flush. As it is unnecessary to take the frames apart again, this fixing is quite in order, and makes an exceedingly strong job.

Rubbing Plate.

The weight of the front end of the locomotive is transferred to the pony frame, by the bolster under the cylinders bearing on a rubbing plate fixed across the pony frame, flush with the top of same. This is a piece of 1-in. by ⅛-in. mild steel cut at each side on an angle to suit the pony frame; see plan drawing; the back edge should be 13/16-in. from the centre of the king pin hole. A piece of ¼-in. by 1/16-in. angle is riveted to each side, the holes in the plate being countersunk, and the rivets hammered down and filed off flush; the rubbing surface must naturally be left perfectly smooth. The rubbing plate is then placed in position, and the angles attached to the side frames either by rivets or screws. If the former, drill No. 41 holes through frame and angle, and use 3/32-in. steel or iron rivets; if the latter, a pleasing finish can be made by putting screws through from the inside—ordinary cheesehead screws do quite well—and nutting them outside. Beginners especially, should note that the top of frame, and the rubbing plate, must be exactly level, so that the pony truck can move easily from side to side under the bolster.

Wheels and Axle.

The wheels are exactly the same size as those described for the trailing axle, so we need not go over that part again. The axle is turned from ⅜-in. round mild steel in the same manner as the coupled axles, particular attention being paid to the wheel seats, so that the wheels can be pressed on without splitting the bosses, or coming loose. Press one wheel on, but leave the other until the axleboxes have been made and fitted in the frames.

The axleboxes are made from ½-in. ⅞-in. bar; bronze if you can get it; good hard brass if not. Should ordinary commercial "screw-rod" be the only material of the right section available, it can be used, if the axle holes are drilled ½-in., and bushes made from round bronze rod forced in. The wear between horncheeks and axleboxes is negligible on a carrying axle in 3½-in. gauge. A piece of bar about 1½-in. long is needed, and this has a ⅛-in. rebate milled each side, exactly as described for the coupled axleboxes; but there is only one flange, on the outside, otherwise the boxes could not be inserted between the horncheeks. The boxes should be an easy sliding fit in the horns; and top and bottom should be squared off in the four-jaw chuck, after sawing the milled bar in half.

The axle holes are drilled on the centre line, ⅜-in. from the top of the box; drill one, and use it as a jig to drill its opposite mate, as explained for the coupled axleboxes. A small oil hole is drilled with a 1/16-in. drill, near the flange, so as to be clear of the place where the spring takes a bearing; see plan drawing. Use letter W drill for the axle holes, if you have it, as the axles must be perfectly free to turn when the boxes are out of line on a bad road, or running through a crossing or junction.

The springs are carried in drilled pockets in overhead brackets, one of the simplest and most efficient contrivances I know of. The brackets are filed up from 5/16-in. by ⅜-in., or ⅜-in. square bar (any metal will do) to the shape and dimensions shown in the detail drawing; the hole for the spring is drilled 7/32-in., and is " blind." Drill two No. 30 holes 5/32-in. above the top of the axlebox opening, and ⅜-in. each side of its centre line. Countersink them on the outside of the frame. Clamp the bracket temporarily in position with a toolmaker's cramp, hole underneath, in the position shown in the drawing; run the 30 drill in the frame holes, making countersinks on the bracket, follow up with No. 40; tap either ⅛-in. or 5 BA., and put countersunk screws in. The springs are wound up over a 5/32-in. mandrel from 19 gauge tinned steel wire; square off the ends by touching them on the side of a fast-revolving emery wheel. If they are just starting to compress when the axlebox is right at the bottom of the opening, the strength should be about right in running position. Drop the springs in the pockets, turning the pony truck upside down for this purpose; insert the axleboxes, making sure the oil hole will be at the top when the pony is on the engine, push the axle, with one wheel attached, through the holes in the boxes, press on the other wheel, and the pony truck is complete.

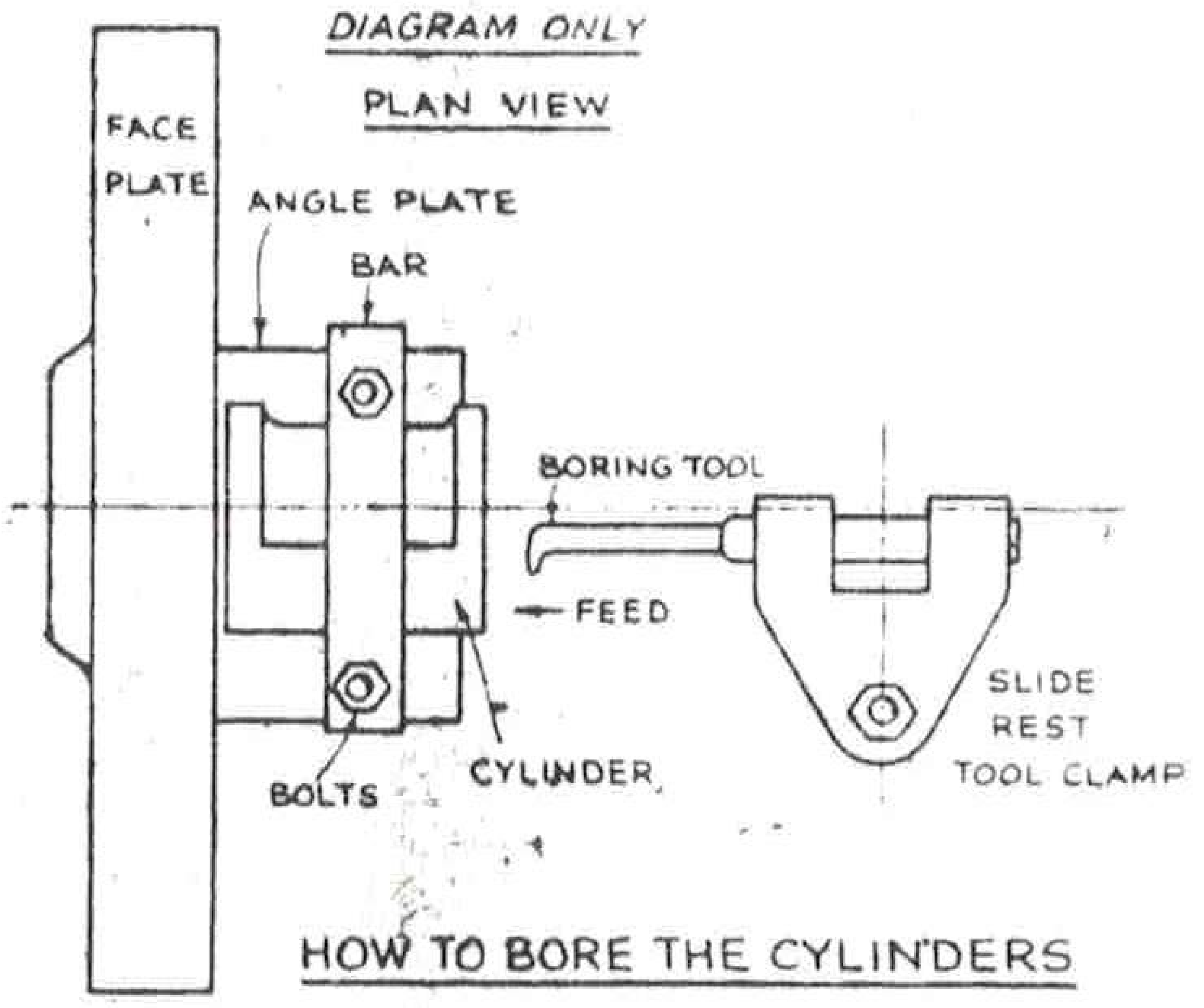
If Castings Are Used.

If cast components are used, the whole issue should be done in an evening, or at most two. The only work needed on the side frames, will be to smooth out the horncheek jaws with a fine file, and drill the spring pockets in the cast-on brackets. King pin block, and front tie-bar, are fitted in the same manner as described above; but the rubbing plate will have side lugs cast on, which only need smoothing with a file, and screwing to the side frames. Axleboxes and wheels are fitted exactly as described above.

The completed pony truck is attached to the bolster on the locomotive frames by the king pin. To make this, chuck a piece of 5/16-in. round mild steel in the three-jaw; face the end, and turn down 5/16-in. of it to ¼-in. diameter, screwing ¼-in. by 40. Turn down a further ⅛-in. bare length, to 9/32-in. diameter, a tight fit in the hole in the bolster plate. Part off at 1⅛-in. from the end. Drill a No. 41 cross hole close to the end of the plain part. Fit this pin to the bolster, and secure it with a nut, which can be made from ⅜-in. hexagon rod; brass will do quite well. Put the pony truck in position, the hole in the block passing over the king pin, and secure it from falling off, with a washer and an ordinary 3/32-in. split pin, as shown in the illustration. the bolster bears on the rubbing plate, When the engine is standing on the track, and transfers the weight of the front end to the axleboxes via the pony frames and the springs. No side control is necessary, as the friction between the rubbing plate and the bolster will prevent any " hunting," the same as it does on the full-size 2-4-0 tank engines on the Isle of Man railways.

The Cylinders.

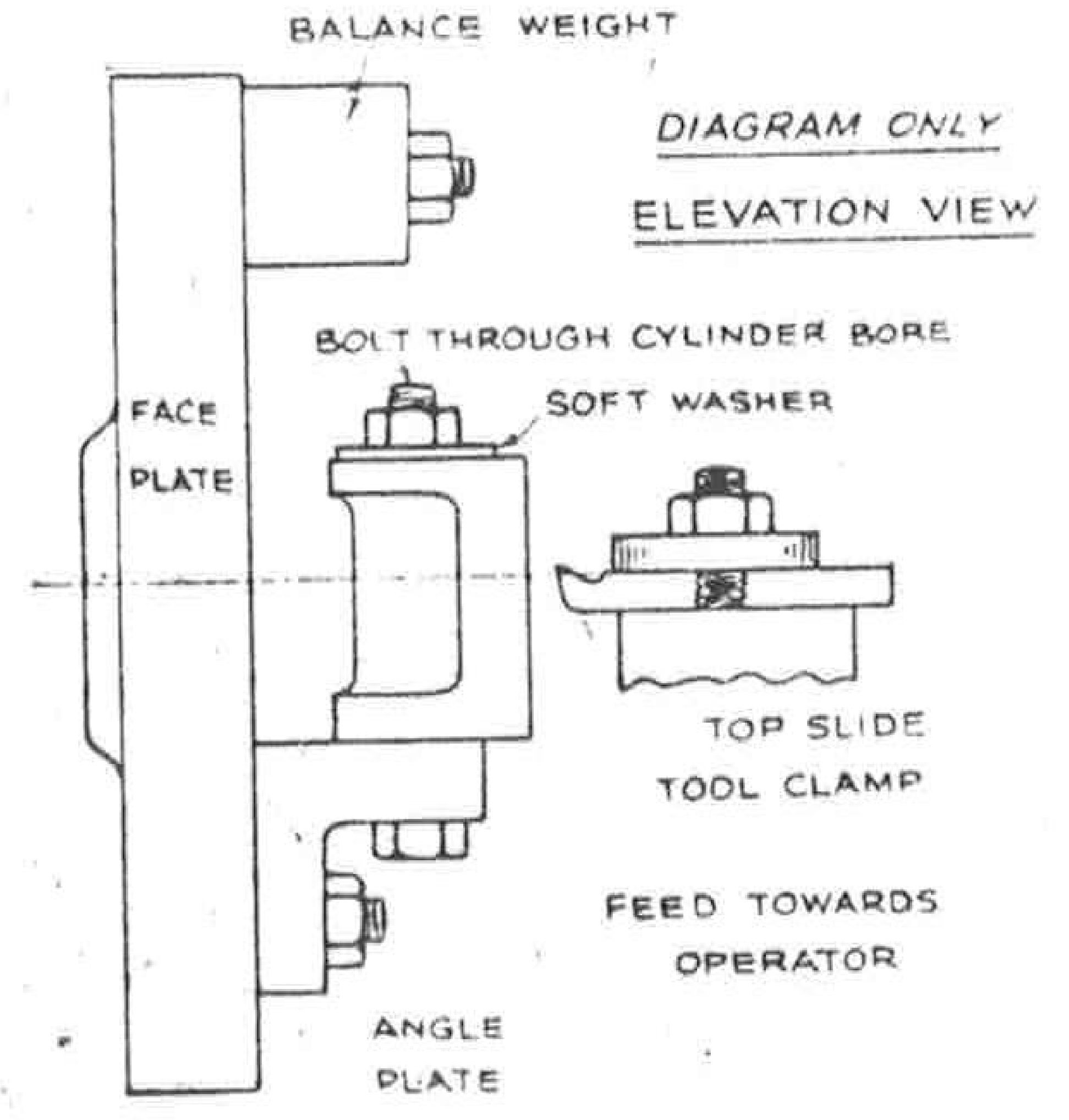
As we are only using two cylinders instead of copying the three of the full-sized engine, they will have to be larger than " scale " to obtain the equivalent power, those specified in the accompanying drawings being equal to a full-size pair 18-in. by 26-in. By the time these notes appear in print, castings should be available with ports cast in, but not passageways. It is much easier to drill passageways than to cut ports; and with small cast-in passageways, there is a risk of internal leakages which do not show up until the engine is either steamed or tested under air pressure. Also, it is a mistake to have long passages too large, as they have to be filled with steam twice in each revolution of the driving wheels, and the steam serves no useful purpose, being merely blown to waste *via* the exhaust, when the valve opens the exhaust port. The correct size is the " happy medium," which offers no hindrance to entry and exit of the steam when the locomotive is travelling at a good speed with normal load.



HOW TO BORE THE CYLINDERS

Any lathe of 3-in. centres or over, that is worthy of the name, should be able to carry the cylinder castings on a small angleplate attached to the faceplate, for facing one end, boring, and machining the port and bolting faces. For the benefit of beginners who are building "Bantam Cock" as a first attempt, I have included a couple of diagrammatic sketches showing the set-up at a glance. First of all, check the casting and see if the corehole is reasonably true; it was O.K. on the sample castings submitted for my inspection. Some folk prefer to make their own patterns and get castings done locally; and all foundrymen are not so particular, so if the corehole is out, smooth the end of the cylinder with a file, put a wooden plug in the corehole, set out the proper centre of the bore on it, and scribe a circle on the end, giving correct location of the bore. If the end of the cylinder is coated with marking-out fluid, the scriber marks will show up very plainly. I use a fluid consisting of shellac dissolved in methylated spirit, with a little colouring dye added; it dries instantly, and can be rubbed off when the job is done.

Should there is any irregularities in the portface, smooth them off with a file. Attach a small angleplate to your faceplate, lay the cylinder casting on it, portface down, and secure in position with a bar across the casting, held down by a bolt at each end. The casting should be set parallel with the lathe bed, and this is easily done by applying a small try square, with its stock to the faceplate and its blade to the bolting face of the cylinder. Now adjust the angleplate on the faceplate until the corehole—or marked circle, as the case may be—runs truly; if you stand your scribing block (or surface gauge) on the lathe bed, and apply the point of the needle to the corehole or circle, you can soon see in which direction the angleplate requires shifting, to correct any wobble. Tighten the bolts well, but not sufficiently to spring the angleplate or distort anything. Put a roundnose tool crosswise in the slide-rest, and take a facing cut clean across the end of the cylinder.



HOW TO MACHINE PORT AND BOLTING FACES

The best results when cylinder-boring, are obtained by the use of a self-acting feed; so if your lathe has screw-cutting gear, put a train of wheels on, to get the slowest feed obtainable with those available. Some of the larger and more elaborate machines have an independent self-act operated from a separate shaft; this, of course, may also be used, providing the feed is not too coarse. If the lathe is a plain one, with neither screw-cutting gear nor self-act, the top slide will have to be used for the boring operation, and must be set true for this purpose, before attempting to bore. The easiest way of doing it, is to chuck a piece of rod in the three-jaw, with a length of metal projecting from the chuck, equal to the length of the cylinder. With an ordinary roundnose tool in the slide-rest, take a fine cut the full length of the rod, and measure the diameter at start and finish, with a micrometer. If the measurements do not tally, adjust the top slide and take another cut, repeating until the piece is turned parallel full length. If you have no "mike," use ordinary calipers, and judge by the feel.

Put a boring tool in the slide-rest, as shown in the plan diagram, and take a cut through the cylinder, deep enough to clean out all the sandy skin from the inside of the corehole. Then open out with successive cuts until just a weeny shade under size. If you have a 1⅛-in. parallel reamer, bore until the "lead" of this will just enter. If not, set a pair of inside calipers to a fraction under 1⅛-in., and bore until they will enter. Then regrind the tool, and finish the edge on an oilstone, before taking the final cuts; and when the bore is correct size, take a couple of traverses through the bore *without shifting the cross-slide.* This will make up for any springing in the tool.

I usually advocate, for those who possess the necessary reamers, that these should be used by holding them against the tailstock centre by hand, with a carrier on the shank to prevent turning, and pushed through the cylinder bore by sliding the tailstock bodily along the bed. In the present case, this procedure is ruled out of court by the fact that very few, if any, amateur home-workshop lathes have a centre hole in the mandrel, big enough to allow the reamer to enter, as it would have to do in order to pass through the bore. Therefore, the reaming can be done by hand; simply catch the casting in the bench vice, and work the reamer through very carefully by means of a tapwrench on the shank. But before you do this, face off the other end of the casting; chuck a bit of brass rod about 1¼-in. diameter in the three-jaw, turn it down until the cylinder will go on a tight fit. Put it on, unturned end outwards, and face off with a roundnose tool set crosswise in the rest. The overall length is 2⅜-in., and an equal amount should be turned off each end so as to keep the flanges the same thickness.

Beginners frequently get toolmarks in the bores. These can easily be removed by wrapping a piece of fine emerycloth around a stick, so that it fits the bore loosely. Chuck this improvised lap in the three-jaw; put the cylinder on it, run the lathe as fast as possible without causing a miniature earthquake, and move the cylinder up and down the lap, letting it "float" when in your hand, so as not to make the bore bell-mouthed. About two minutes of this treatment will give a glassy finish to a badly-scratched bore, without interfering with its accuracy.

How to Machine the Flat Faces.

Put the faceplate and angleplate on again, and stand the cylinder end-up on the latter; fix with a bolt through the bore, having a washer under the nut, to prevent damage to the faced end of the casting. Set the bolting face parallel with faceplate, by applying your try square with the stock against the faceplate, and the blade against the portface. Tighten the central bolt, and go ahead as shown in the diagram. There is no need to mark out; face off until you have exactly 7/16-in. of metal between bolting face and bore.

Slacken the bolt, and slew the casting around a quarter-turn, to bring the portface right for facing off; check with try-square as before. Then get busy with the facing tool, continuing until there is ⅜-in. of metal between portface and bore. Given average workmanship, the casting should now be truly machined; faces parallel with each other, and with the bore, and square with the ends, with port and bolting faces exactly at right angles.

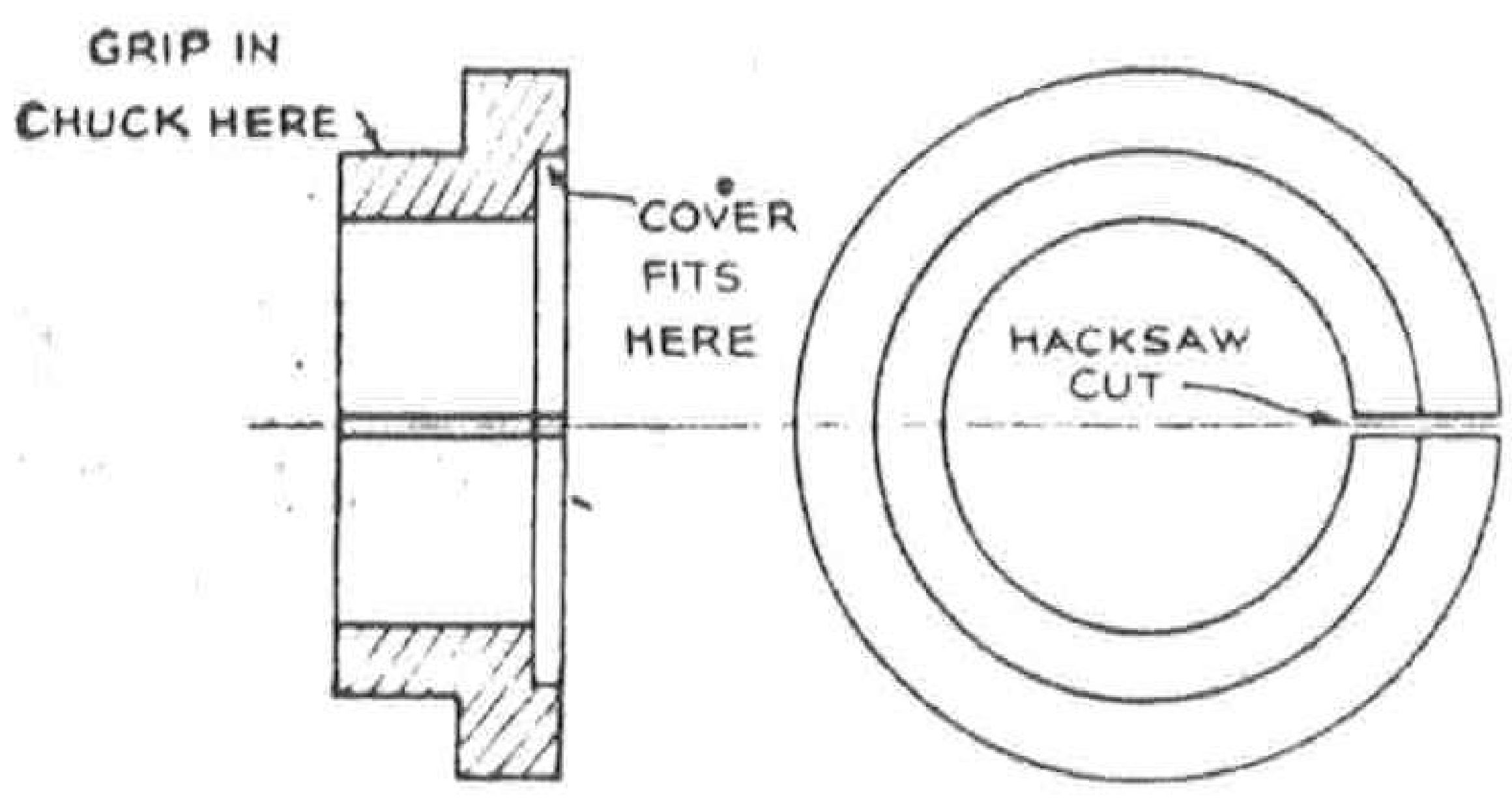
Ports and Passageways.

If the ports are cast in the cylinders, all they will need is truing up the edges with a small chisel. If not, mark them out on the portface, as shown in the illustration. If a vertical slide is available, bolt the cylinder to an angleplate, end-up as shown in the facing-off diagram, but attach the angleplate to the vertical slide. Put a ⅛-in. endmill, or home-made slot drill (as used for axlebox milling, only smaller) in the three-jaw; adjust casting by means of the vertical slide screw, until a marked-out port is level with it, and cut the port for feeding the casting on to the cutter with the top slide screw, and traversing across it with the cross-slide. If no stops are provided on your cross-slide—very few amateur lathes have this simple and useful refinement—note how many turns of the cross-slide handle are needed for ¾-in. movement, and don't "over-shoot the platform" as the enginemen would say.

To cut the exhaust port, either use a ¼-in. endmill or slot drill, or take two or more cuts with the ⅛-in. at different levels. If you haven't a vertical slide, bolt the casting end-up on the lathe saddle, or the top slide, whichever is most convenient; and put sufficient packing under it, to bring the port you are going to cut, level with the endmill. Users of the handy 4-in. roundbed Drummond lathe can get height adjustment either by swinging the saddle around the bed, or adjusting the cross-slide pillar. Note: although the ports are shown with squared ends on the drawing, it doesn't matter at all if they are left rounded, so long as the sides are straight. Ports may also be cut by hand, by drilling small holes in a row, close together, and chipping into a slot with a small chisel.

A bench drilling machine, or a power drill, makes easy work of the passageways. Three No. 30 holes are needed between the bore and the port, at each end of the cylinder. Make three centre-pops a shade over ⅛-in. apart, at the lip of the bore; then put the casting, end-up and slightly on the slant, in the machine vice, the angle being just sufficient to allow the drill to go straight from the centre-pop to the bottom of the port. I always set mine by eye, simply pulling the drill down *outside* the cylinder; you can see at a glance, where the drill is going to break into the port. Tips for drilling: Use a drill ground slightly "off-centre," so that it cuts a bigger hole than its own diameter. If you are unlucky, and it breaks, the bits can easily be shaken out, and the casting saved; but it won't break if you keep withdrawing it and letting the chips clear. Drills usually break through the flutes becoming clogged with chips, and seizing in the hole; another frequent cause of breakage is when the drill breaks through into another hole, and it tries to run forward, the edge catches in a "jag," and is torn off. Therefore, "watch you step" as the drill breaks into the port.

The passageways can also be drilled by hand; to do this, catch the casting in the bench vice at such an angle, that a drill in a small handbrace, held horizontally, will go straight from the centre-pop to the bottom of the port. Then all you have to do, is to keep the brace level, turn the handle, and push, observing the same strict caution as before, about grinding the drill off centre, keeping it clear of chips, and care when breaking through. When all the holes are drilled, file a small bevel at each end of the bore, so that steam can pass into same from the passages, when the cylinder covers are bolted on (see sectional illustration).



SPLIT BUSH FOR HOLDING CYLINDER COVERS

For the exhaust passage, make a centre-pop on the bolting face, midway between the ends and ⅜-in. from the top, and drill a 9/32-in. hole ¼-in. deep. Then, with a 15/64-in. drill, make a hole from the bottom of the exhaust port, to the one just previously drilled; doesn't matter which end you start from. Finally, tap the "entrance to the way out" in the bolting face, 5/16-in. by 32 or 40, as shown in the drawing of the section through exhaust port. The portface can then be trued up by rubbing it on a sheet of fine emery or other abrasive cloth, laid business-side-up on something absolutely flat, such as a surface plate, piece of plate glass, or the lathe bed. The finished surface should NOT be polished, but have a matt appearance, formed by innumerable fine scratches, which hold a film of oil and form a perfect steam-tight seal between valve and face, at the same time allowing the valve to slide as though on roller bearings.

Cylinder Covers.

The covers should have chucking pieces cast on. If the front cover is gripped by the chucking piece in the three-jaw, the register, which fits the cylinder bore, the contact part of the flange, and the rim, can all be turned at the same setting; a simple straightforward job needing no detailing out. The chucking piece is then sawn off, the cover gripped in a stepped bush held in three-jaw, and the outside faced off. The cover could be held by the rim direct, in the three-jaw, and set to run truly; but the rim might be marked by the jaws, so I recommend the stepped bush for holding. This is merely an ordinary shallow bush, with a recess in one end to take the cover, and a hacksaw cut through it, so that when gripped in the three-jaw, it closes on the edge of the cover, holding it firmly, but without any risk of damage.

The back cover entails a little more work. Grip by chucking piece in three-jaw; face off, turn the register (which must fit the bore *exactly*, without shake) true up the contact flange, and turn the edge. Then centre, and drill 3/16-in. clearing, using No. 11 drill, and letting it penetrate the chucking piece. Saw off the latter, and re-chuck in the stepped bush, gland boss outwards. Face this off, open out the centre hole with a pin drill to 11/32-in. diameter and ½-in. depth; tap ⅜-in. by 32 with tap guided by tailstock chuck. The threads must be true, otherwise the gland will bind on the piston rod, and cause trouble. Face as much as you can, without cutting into the boss; then remove from chuck, and finish with a file. Be careful to have the seating for the guide bar, flat, square, and at the proper distance from the piston rod hole, as shown in the illustrations.

The piston rod gland is made from ½-in. round bronze rod. Chuck in three-jaw, face, centre, and drill down ¾-in. depth with 3/16-in. drill. Turn down ½-in. of the outside to ⅜-in. diameter, screw ⅜-in. by 32 with die in tailstock holder, and part off at ⅝-in. from the end, leaving a head ⅛-in. in thickness, which has four C-spanner slots cut in it with a watchmaker's flat file, or a hacksaw. Hexagon rod may be used, if you prefer a hex-headed gland. Reverse in chuck, and skim off any burr. *Warning*: the threads *must not be slack*, or the gland may work out when the engine is travelling at a "scale" 100 m.p.h. or more (she will, easily, with half-a-dozen adults) with disastrous results to the motion.

Eight holes are drilled in each cover, 5/32-in. from the edge, spaced as shown in the end view of the cylinder. Use No. 34 drill, and space the two top holes just wide enough apart, to miss the steam passages. *Note*: the flat top of the gland boss must be at right angles to the bolting face when the back cover is screwed home. To ensure this, lay the cylinder on the lathe bed, or something equally flat and true, with the bolting face down. Put the cover on, and adjust as near as you can by eye; then apply a try-square with its stock on the lathe bed, and the blade against the top of the gland boss. When it touches the flat top for its full width, the cover is set correctly, and may be fixed temporarily in position with a toolmaker's big cramp, or any other convenient means. Run the 34 drill through all the holes, making countersinks in the cylinder flange; remove cover, drill out the countersinks with No. 44 drill, and tap 6 BA. The cover is attached with 6 BA. steel screws, hexagon head for preference; 6 BA. is about the most available size at the time of writing, which is lucky for "Bantam Cock" builders! The front cover screws are located, and the holes drilled and tapped in like manner.

Piston and Rod.

The piston rod is a piece of 3/16-in. round metal 3 9/16-in. long; if you can get rustless steel, either ground or drawn, use it, but if not, either nickel or phosphor bronze will do. Don't use brass, or any of its kindred alloys, as they will not stand up to the wear. Chuck in three-jaw, and put ¼-in. of 3/16-in. diam. by 40 T.P.I. on the end, with a die in the tailstock holder.

To make the piston, chuck a piece of 1¼-in. rod in the three-jaw. Drawn bronze or gunmetal is the stuff I recommend; but cast stick bronze is suitable, or even specially cast pistons made of the same alloy as used for automobile engine pistons, may be available. Face the end, centre, and drill down a full ½-in. with 5/32-in. drill. Turn down the outside to 1/64-in. larger than the cylinder bore, for a length of about 1¼-in. With a parting tool, make two cuts, one ½-in. from the end, and the other ½-in. beyond that, going in about 3/16-in. In the middle of each of the piston blanks, form a groove ¼-in. wide and deep, with the parting tool; then part off the first blank. Re-centre and drill as above, then part off blank No. 2; it is best to drill the second, from a fresh centre, after the first is parted off, as drills sometimes "wander" in hard metal, and No. 2 might be more like an eccentric than a piston, when parted off.

Chuck a blank in the three-jaw, and open out the centre hole for ¼-in. depth, with 3/16-in. drill, or No. 13; tap the rest of the hole 3/16-in. by 40, using the tailstock chuck to guide the tap. Now put a piston rod in the tailstock chuck, gripping it tightly; run it up to the piston blank, enter into the hole, and pull the lathe belt by hand until the rod seats home. The screwed part holds the piston to the rod, and the plain part ensures truth; this is the way the chucks of precision lathes are fitted to their mandrels, and I always fit my own pistons by this method, as I have found no better means.

To finish-turn the piston, the rod should be held in a collet, or in a split bush in the three-jaw. Not many amateurs' lathes are fitted with collets; I have a 3-in. Boley lathe, which has a set taking up to 5/16-in., and very useful they are, at that. To make the split bush, chuck a piece of ⅜-in. round rod about ½-in. long, in the three-jaw; face, centre, drill No. 14, and poke a 3/16-in. parallel reamer through. Make a dot opposite No. 1 jaw. Remove from chuck, and split longitudinally with a hacksaw; one cut will be sufficient. Replace with dot in correct position; and holding lightly, run the reamer through again to remove any burring from the sawcut. Put in the piston rod, tighten chuck hard, and the rod will be gripped firmly and will run dead true. Now, with a freshly-ground tool, take off a few tiny skims from the piston, until it will slide in the cylinder bore freely, but with no sign of a shake. It must not be tight, or it will seize when hot, nor must it be loose, or the packing will blow off. Aim for the happy medium! A piston should be steam-tight, but not mechanically tight. My 2½-in. gauge pacific "Fernanda" will coast a full lap of my railway, 250-ft., with steam shut off, yet there is not the faintest sign of a blow either on the piston valves or the pistons themselves, which is a sign that both are steam-tight but not mechanically tight.

Steam Chests.

The steam chests have cast-on bosses, but separate covers. Chuck in three-jaw by one boss, and set the other to run truly; a gentle tap will do the trick if it is inclined to wobble. Centre the outer boss with a centre-drill in the tailstock chuck; put the point centre in the tailstock barrel, and use it to support the boss whilst turning it to size. Then turn the steam chest end-for-end, and repeat operations on the other boss; the sides of the steam chest can be faced off at the same time as the bosses are turned. Remove the point from tailstock barrel, replace chuck, put a No. 21 drill in it, and drill through the boss. Open out to ½-in. depth with a 9/32-in. pin drill, tap 5/16-in. by 32, and carefully face off the end. Although unsupported, it will stand a light cut.

Reverse in chuck, and drill the other boss No. 30, tapping the end about ⅛-in. down, with a 5/32-in. by 40 tap. Turn up a little plug to fit, from 3/16-in. hexagon brass rod. The gland has no head, owing to limited movement allowable for the valve crosshead or fork. Chuck a piece of 5/16-in. bronze or gunmetal rod in three-jaw; face, centre, drill down ½-in. with No. 21 drill, screw ½-in. of the outside with 5/16-in. by 32 die in tailstock holder, part off 7/16-in. from the end, and cross-nick one end with a thin flat file or a hacksaw.

The inside of the steam chest, and the two outside walls that were not turned, may be finished with a file. The lower contact face may be machined in the lathe, as the bosses do not project beyond it; and the easiest way of doing this, is to chuck it in the four-jaw, with the side to be machined outwards, and taking a facing cut clean across the whole issue with a roundnose tool set crosswise in the rest.

The other face, on which the top cover fits, cannot be done in this way, as it would cut into the bosses, so it may be carefully finished with a file. It *could* be machined by mounting on a vertical slide, and traversing across a big endmill in the chuck; or if a milling machine is available, it may simply be clamped in the machine-vice, and traversed under a small slabbing cutter, or an ordinary cutter about ½-in. wide would do, if several traverses are taken, and each one allowed to overlap the previous cut.

Set out the location of the screw-holes, as shown in the illustration, and drill them No. 30; then fit the cover. This is merely a piece of ⅛-in. brass plate measuring 2⅜-in. by 1⅞-in., and sits on the steam chest between the bosses. Clamp in place with a toolmaker's cramp, and poke the 30 drill through the screw-holes in the steam chest walls, carrying on right through the cover. Mark which is the top, and file off any burring around the holes. The steam inlet is drilled in the wall farthest from the bosses, on the centre line, 9/16-in. from the front end of cover; and don't forget that the two steam chests are right- and left-handed when you drill the holes! Use 7/32-in. drill, and tap ¼-in. by 40.

Put the steam chest in place on the cylinder, and clamp temporarily; run the 30 drill through the screw-holes, making countersinks on the portface. Remove, drill the countersinks No. 40, and tap either ⅛-in. or 5BA. Steam chest and cover may be attached by hexagon-headed setscrews, countersunk setscrews, or studs made by screwing 1⅛-in. lengths of ⅛-in. round steel at each end, and fitting nuts to one end. I prefer countersunk setscrews, as they come flush with the cover, and the whole lot are completely below the running-board, which makes a neat job.

Slide Valve and Spindle.

The slide valves may be either castings, or made from ½-in. by 1-in. bronze or gunmetal drawn or rolled bar. If the former, the composition of the metal should be different to that of the cylinder castings; metal of the same grade on two rubbing faces, is likely to result in scoring, and uneven wear. If bar material is used, either chuck a piece in the four-jaw and part off two 15/16-in. lengths, or else saw them off to full length, and chuck each separately, facing off to dead length with a roundnose tool set crosswise in the rest. If a regular milling machine is not available to mill the grooves in the back, they can be milled in the lathe by alternative methods; one, is to hold the valve blank in a small machine-vice attached to the lathe saddle, and traverse it under a suitable milling cutter mounted on a spindle between centres. The valve must, of course, be set at correct height to get the proper depth of the groove. The second method is to clamp the valve on its side under the slide-rest tool-holder, and traverse it across an endmill or slot drill of suitable diameter, held in the three-jaw chuck, in a manner similar to the process described for milling axle-boxes. The valve could also be held in a machine-vice attached to a vertical slide. I might here mention that a vertical slide is an invaluable accessory to any lathe, and should strongly advise everybody who does not possess one, to remedy that deficiency at the earliest possible moment. For instance, with the valve held, face outwards, in a machine-vice on a vertical slide, it is a simple job to mill out the cavity in the valve, using a ⅛-in. or 3/16-in. endmill or slot drill in the chuck, feeding into cut with the top slide, and traversing the valve over the cutter by operating the handles of the vertical slide for up-and-down cuts, and the cross-slide for the back-and-forth cuts. It does not matter if the cavity has rounded corners. Failing that, the cavity can be formed by drilling a countersink, say, 15/32-in. diameter and ⅛-in. deep, and chipping it to dimensions shown, with a small chisel made from ¼-in. silver steel. Another way of making the valves would be to use for each, a piece of hard brass plate, 15/16-in. by 1-in., and ⅛-in. in thickness. Mark off the cavity on this, and cut it out by drilling and filing, the result looking like a window frame for a doll's house. Then silver-solder it to a block of brass, same length and width, but ⅜-in. in thickness, and cut the grooves in the back, as described above. This valve would not last as long as one made from solid bronze, as the heating for the silver-soldering, renders it soft, and susceptible to wear; but it is easy to get the cavity the right size, as the "window frame" can be tried over the ports. Face the valves by the method given for portface.

Finally, we have the valve spindle and nut to make. The spindle is a piece of 5/32-in. rustless steel, nickel or phosphor bronze, 3 9/16-in. long. One end has 3/16-in. of 5/32-in. by 40 thread cut on it, for attachment of the valve crosshead. Use die in tailstock holder, gripping the rod in the three-jaw chuck. Reverse in chuck; turn down ¾-in. of the other end to ⅛-in. diameter, and at the end of that, cut ⅞-in. of 5/32-in. by 60 thread, to accommodate the valve nut. If no 60 die and tap are available, use 40 pitch, but the finer one gives better adjustment. The nut is simply a ⅞-in. length of ¼-in. by 5/16-in. brass, with a hole drilled and tapped in it at 3/16-in. from one end, as shown in the small detail sketch, to suit the spindle thread.

The cylinder is assembled as shown in the sectional illustration; pack the glands with a few strands of graphited yarn. For the piston, a piece of ¼-in. square braided graphited packing, cut like a piston-ring and laid in the groove, gives excellent results; whilst the joints between steam chest, cylinder, and all covers, can be made from 1/64-in. Hallite or any other good jointing, or failing that, brown paper soaked in cylinder oil.

Guide Bars.

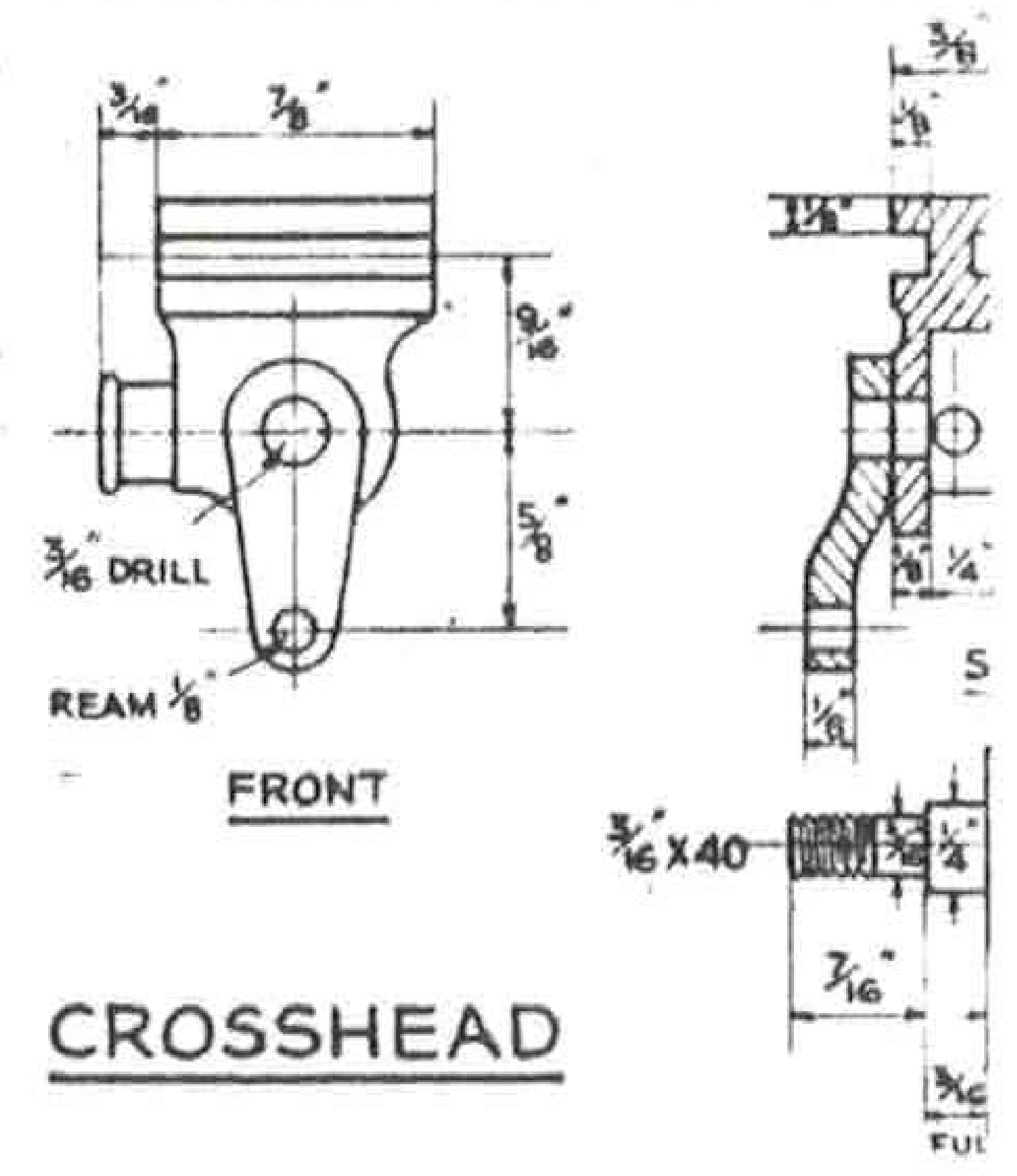
In 2½-in. gauge size I usually specify a single overhead guide bar in place of the double one on the full-size engines, for considerations of strength; as light and flimsy parts may look very pretty, but would not last the proverbial five minutes. However, on 3½-in. gauge we can make a fairly accurate copy of the double bar, and obtain sufficient strength without any appearance of clumsiness, by making the bars of silver-steel of ordinary commercial sections, and providing adequate support at both ends. The top bar is a 3¾-in. length of ⅛-in. by ⅜-in. flat silver-steel; this material has a polished surface and offers the minimum of frictional resistance to the movement of the crosshead. Both ends should be squared off in the lathe, using the four-jaw chuck to hold the bar. On the centre-line, at 7/32-in. from one end, drill a No. 21 hole for the 5/32-in. screw which holds the bar to the boss on the back cylinder cover. Two pieces of ⅛-in. square silver-steel, each 3 5/16-in. long, are needed for the lower bars; one end is squared off, and the other end bevelled for a distance of ¼-in. or so, to clear the connecting rod on its upper movement. At 3/32-in. from the squared end of each, drill a No. 48 hole, and another one 5/16-in. farther along.

Two distance pieces are needed; one is ⅜-in. square, and the other ⅜-in. by ¼-in., both ⅛-in. in thickness. Any metal will do; mild steel is about the best. The larger piece is secured by four screws, and the smaller piece is bronzed in position; the removable piece allows the one-piece crosshead to be easily inserted between the bars before bolting up to the cylinder. To assemble, lay the top bar on the bench, with a little piece of packing underneath each end, then place the narrow distance piece across it at the end away from the screwhole. Put the square distance piece 7/16-in. from the other end, then the two lower bars on top of the distance pieces, the edges of same being flush with the outer bar, leaving a ⅛-in. space between. Now put a toolmaker's cramp over the lot; the wide bar being clear of the bench, will allow this to be done. Make certain that nothing has shifted, then put the No. 48 drill through the holes in the narrow bars and carry on right through distance-pieces and tap bar. Take off clamp; open out the holes in distance pieces and wide bar with No. 41 drill, and countersink the holes in the top of the wide bar. Tap the holes in the narrow bar 3/32-in. or 7 BA., then reassemble the whole lot, using countersunk screws as shown in the section. Replace the narrow distance piece very carefully, and tie a piece of thin iron wire around the bars, to prevent it moving. It can then be brazed or silver-soldered in position; put on a smear of flux, heat to dull red for silver-solder, or bright red for brass. Touch the joint with a piece of thin strip silver-solder, or brass wire as preferred, which will melt and penetrate the joint. Let cool to black, then quench in water, clean off, and re-polish the bars with a piece of fine emerycloth wound around a flat stick, or anything flat and thin; a steel rule does the trick fine.

Place the guide bar assembly on the flat top of the gland boss, as shown in the general arrangement drawing, and hold it in position with a clamp, or by putting the whole lot in the vice, if the jaws will open wide enough. Run the 21 drill through the hole in the end, and make a countersink on the boss; remove, drill No. 30 and tap 5/32-in. by 40. Don't fix the bars to the cylinders "for keeps" yet, as the crossheads must be made and fitted before this is done.

Crossheads.

The crosshead is a simplified version of the full-size job, the body and slippers being made in one piece. A piece of ⅜-in. by ⅞-in. mild steel bar is needed for each; this should measure 1⅛-in. overall length, after one end has been squared off truly in the four-jaw chuck. At ⅛-in. from the squared end, a groove, a full ⅛-in. wide and deep, must be milled on each side. If a regular milling machine is available, this presents no trouble at all; but in its absence, the job can be done in the lathe by clamping the piece of metal end-up in the lathe tool-holder, or attaching to a vertical slide, and traversing it across an endmill in the chuck, as described for axleboxes. Alternatively it could be done by holding the metal in a machine-vice bolted to the lathe saddle, and traversing under a ⅛-in. circular slotting cutter on a spindle between lathe centres. If adjusted to the correct height, with machine running slowly and the cutter well supplied with cutting oil, the full depth and width can easily be machined out at one traverse, either on lathe or miller. I have cut a groove ½-in. wide and same depth, on all four sides of a lathe turret, with one cut only for each groove.



CROSSHEAD

Draw a line down the centre of one side of the crosshead blank, and at ¾-in. from the top, make a centre-pop. Drill it out 3/16-in., and be quite sure the drill goes through squarely. Now with a ⅝-in. pin drill having a 3/16-in. pilot pin, recess one side of the crosshead blank to the depth of ¼-in. The surplus metal at the bottom is then filed away to the edge of the hole, as shown in the detail sketches, and a small groove put in with a rat-tail file, just below the slipper grooves. Don't forget to make one crosshead as shown, and the other opposite hand.

To make the job neat and easy, the crosshead boss may be screwed in and brazed. In the centre of the back, and ¾-in. from the top—that is, dead level with the crosshead pinhole already drilled—make a centre-pop and drill it out 7/32-in.; tap ¼-in. by 40. Chuck a piece of 7/16-in. or ½-in. round mild steel rod in the three-jaw; face the end, and turn down about 3/16-in. to ¼-in. diameter. Screw ¼-in. by 40, then take 1/16-in. or so off the end, to ensure that the spigot starts with a full thread. Turn down another ⅜-in. or so, to 7/16-in. diameter, if ½-in. rod was used; then reduce the end for 3/16-in. length to 5/16-in. diameter, and part off a full ¼-in. from the shoulder. Reverse in chuck, and round off the little bead for appearance sake; centre, and drill right through with No. 13 drill. Note: unless the builder of this locomotive is either experienced, or a fairly skilled workman, the boss should not be drilled before being fitted to the crosshead; but the drilling should be left until after the crosshead has been tried up in place, and the hole can then be correctly located from the cylinder gland. This will make absolutely certain that the hole in the boss is dead in line with the piston rod, and eliminate any binding of the crosshead in the guides. Screw the boss into the hole in the back of the crosshead tightly, but leave the brazing until the crosshead arm is attached.

The crosshead arm, which drives the bottom of the combination lever *via* a union link, is made from a piece of mild steel ⅛-in. in thickness, 7/16-in. wide and a full 1-in. long. This is filed up to the shape shown in the detail illustration, and is offset ⅛-in., the bend being in the middle. The holes should be drilled *after* bending, so as to keep them the correct distance apart. To hold the arm to the crosshead for brazing purposes, I use a steel bush, which is afterwards drilled out. Chuck a bit of soft steel rod, any size over 3/16-in., and turn down about ⅜-in. of it to a tight drive fit in the upper hole in the arm. Centre and drill ⅛-in., then part off ¼-in. from the end. Drive it into the hole in the arm; then drive the projecting end into the hole in the crosshead, adjusting the arm until exactly vertical. Apply a little flux to both the joint between crosshead and arm, and the crosshead boss; then proceed as given for the end of the guide bars. Either brass wire, or silver solder may be used. After cleaning and polishing up, put a 3/16-in. drill through the bush which held crosshead and arm together; this will completely eliminate the bush, and leave the arm firmly attached to the crosshead, with a correct-sized hole through both, ready for the crosshead pin.

The latter is turned up from a piece of ⅝-in. round mild steel. Chuck in three-jaw, face the end, and turn down ⅝-in. length to ¼-in. diameter; then further reduce ⁷⁄₁₆-in. length to ³⁄₁₆-in. diameter, and screw about half of it ³⁄₁₆-in. by 40, using die in tailstock holder. Part off to leave a head fully ¹⁄₁₆-in. in thickness; then reverse in chuck, and face off the head to a shade under ¹⁄₁₆-in., as it must not project beyond the crosshead when in place. If it does, the leading boss of the coupling-rod will catch it when trying to pass behind the crosshead. As a commercial ³⁄₁₆-in. nut would be outsize and look clumsy, make a nut to suit, from ¼-in. hexagon steel rod, or tap out a ⁵⁄₃₂-in. nut to suit.

Connecting Rods.

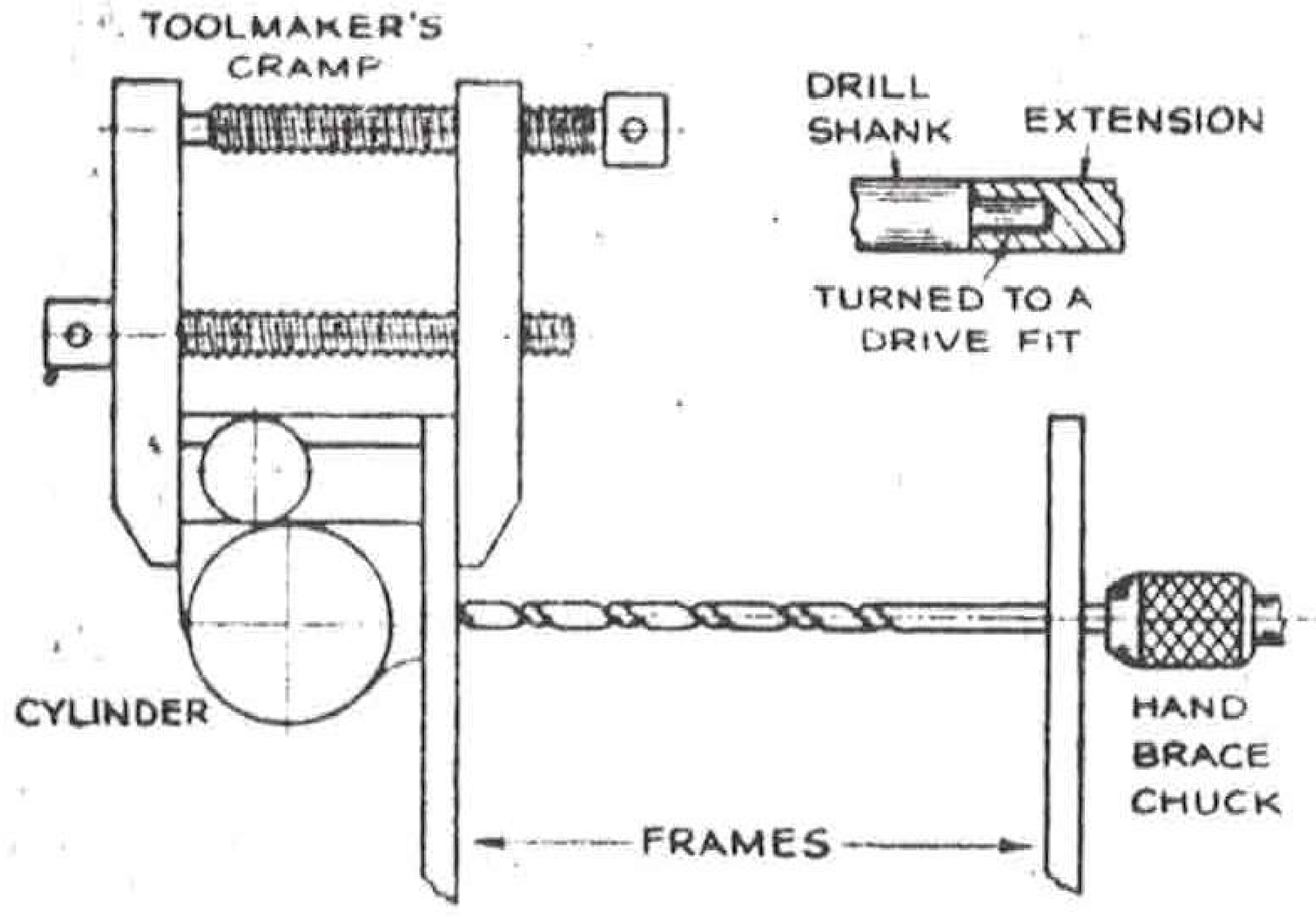
The connecting rods are very similar to the coupling rods, and have the plain circular solid-bushed big ends first introduced by Mr. G. Churchward on the Great Western locomotives; an easily-made and efficient pattern which has since found great favour. Two pieces of mild steel bar are needed, each ⅞-in. by ¼-in. section, and 6-in. long. Mark one out, as shown in the illustration, and drill ⅛-in. holes at the big and little end centres; use this as a jig to drill the other, then temporarily rivet the pieces together, and proceed to machine up the rods exactly as given for the coupling rods; there is no need to waste space by detailing out all the same work again. When finished, part the rods, and drill the little ends ⅜-in.; turn up a couple of bronze bushes, same way as the centre bush of the coupling rod, and squeeze them in. Ream to size after squeezing, as the bushes usually contract a little during the latter process. File flush both sides of the rod.

The big end has a wide flanged bush which gives ample bearing surface to withstand the stress of the drive, and at the same time resist the wearing action of the big crankpin revolving in it. Drill out the big end with ½-in. drill. The bush is made from good quality drawn prosphor-bronze rod; chuck a piece ⅝-in. diameter in the three-jaw, face the end, centre, and drill ²³⁄₆₄-in. for about ½-in. depth. For easy drilling in the material, the drill should be ground slightly off-centre, so that the hole it makes, is slightly larger than the drill itself; if the hole is same size, the bronze heats up, and seizes on the drill. The oversize hole made by the given size of drill, will be just right for cleaning out to ⅜-in. with a reamer, after the bush has been pressed in. Turn down ⁹⁄₃₂-in. of the outside, to a tight squeeze fit in the ½-in. hole, and part off a full ⅜-in. from the end; reverse in chuck, skim off any burring, and very slightly chamfer the edge of the flange. The bush can then be pressed in; drill and countersink the oil hole right through the boss on the rod, and the bush, then put the ⅜-in. reamer through the latter. Don't forget, beginners, to make one rod left-hand, and one right-hand.

How To Erect Cylinders.

First of all, put the crossheads on the guide bars, by taking out the screwed-in distance piece and sliding the crosshead in place, the grooved part fitting between the two narrow bars; then screw the bars to the cylinder covers, with a single ⁵⁄₃₂-in. screw in each. Put the crosshead pins through the little ends of the connecting rods, and the screwed part of the pin through the hole in crosshead, securing same with a nut outside the arm. Then put the complete assembly in place on the frame, and hold it temporarily by a big toolmaker's cramp placed over frame and cylinder. Note the exact position; it is shown on the frame drawing, and those who have purchased the full-size blueprint, will be able to see it at a glance. The top of the steam chest cover is level with the top of the frames, at the front end; the distance between the front edge of the steam chest cover, and the front edge of the frames, is 3¼-in. The cylinders are slightly inclined, the back edge of the steam chest cover being approximately ³⁄₃₂-in. below the top of the frame. The axleboxes should be placed in the running position, as mentioned earlier in these notes; then, when the piston-rod is fully extended, and the connecting rod in a straight line with it, the connecting rod should pass exactly over the centre of the driving axle.

My own pet way of locating the position of the screwholes in the bolting face of the cylinder, is to put a drill through the holes in *both* frames, and make countersinks on the bolting face; the holes are then drilled at the countersinks, and tapped for the screws. The frames are 3⅛-in. over the outsides; a new ³⁄₁₆-in. drill is 3½-in. long, so if you have a new one, or one that has not been shortened by grinding, put it in your hand brace with only ¼-in. in the chuck. You can then poke it through the holes in the frame, and it will reach the bolting face and enable the countersinks to be made; the grip afforded by the ¼-in. held by the chuck, being plenty for such a light operation. If, however, your drill won't reach, lengthen it; this is a very simple operation. Chuck a short piece of ³⁄₁₆-in. round rod (any metal) in the three-jaw; face the end, centre, and drill down about ¼-in. or so with ⅛-in. drill. Chuck the short ³⁄₁₆-in. drill in the three-jaw, shank outwards, and turn down ¼-in. of the shank to a tight drive fit in the hole in the bit of drilled rod. Drive it on whilst the drill is still in the chuck, and you now have a drill with an extended shank, which will do the trick easily. Incidentally, these extended-shank drills are useful for all sorts of purposes, and I have a number of them of varying sizes. I often recollect with a smile, how astonished the telephone fitter was, when he came to install our telephone after we first came to our present address. It was



HOW TO LOCATE SCREW HOLES
IN CYLINDER BOLTING FACE

a brand new house, and naturally I didn't want it unduly knocked about, so I drilled the holes through the walls myself, to accommodate the telephone wires. You should have seen the look on his face when he found a 5/16-in. hole clean through 9-in. of brickwork, and hardly a burr on each side of the plaster facing! When he had put his wires in, he asked rather timorously if I would mind telling him how it was done, as he had never seen such a clean-cut hole through a wall in all his experience; so I gave him the drill that did it—a "Novo" high-speed drill with a foot of 5/16-in. mild steel rod brazed on to form an extended shank.

After making the countersinks, remove the cylinder, drill 5/32-in, and tap 3/16-in. by 40. There are no commercial hexagon-head screws this size, so you must make them, but that is easy enough. Chuck a piece of 5/16-in. hexagon steel rod in the three-jaw, and turn down 3/8-in. length to 3/16-in. diameter; screw 3/16-in. by 40, and part off to leave a head about 3/16-in. in thickness. Reverse in chuck, and chamfer the corners; make a dozen screws whilst you are at it, enough for both cylinders, and a couple to spare—in case you drop one on the floor and can't find it! Don't, however, attach the cylinder at once; before doing that, set up the other cylinder in exactly the same way, and drill and tap the screw-holes. Both of the cylinders may then be fixed in place, and the crossheads pinned to the piston rods.

The clearance between cylinder cover and piston, must be equal at both ends of the stroke; to ensure this, have the big ends of the connecting rods on the crankpins, but the crosshead clear of the piston rod. First push the piston rod in as far as it will go; that is, until the piston hits up against the front cover. Then put the main crank on front dead centre; that is, when it is nearest to the cylinder. While putting it in this position, the crosshead boss will go over the end of the piston rod again. When the crank is on the dead centre, hold it there, and push the piston rod, very carefully, 1/16-in. farther into the crosshead boss; this will give the required clearance. Drill a No. 43 hole clean through boss and rod, and squeeze in a little piece of 3/32-in. silver steel, to act as a cotter. If the wheels are now turned by hand, everything should work freely; if there are any tight places, seek them out and correct before going any farther.

Valve Gear.

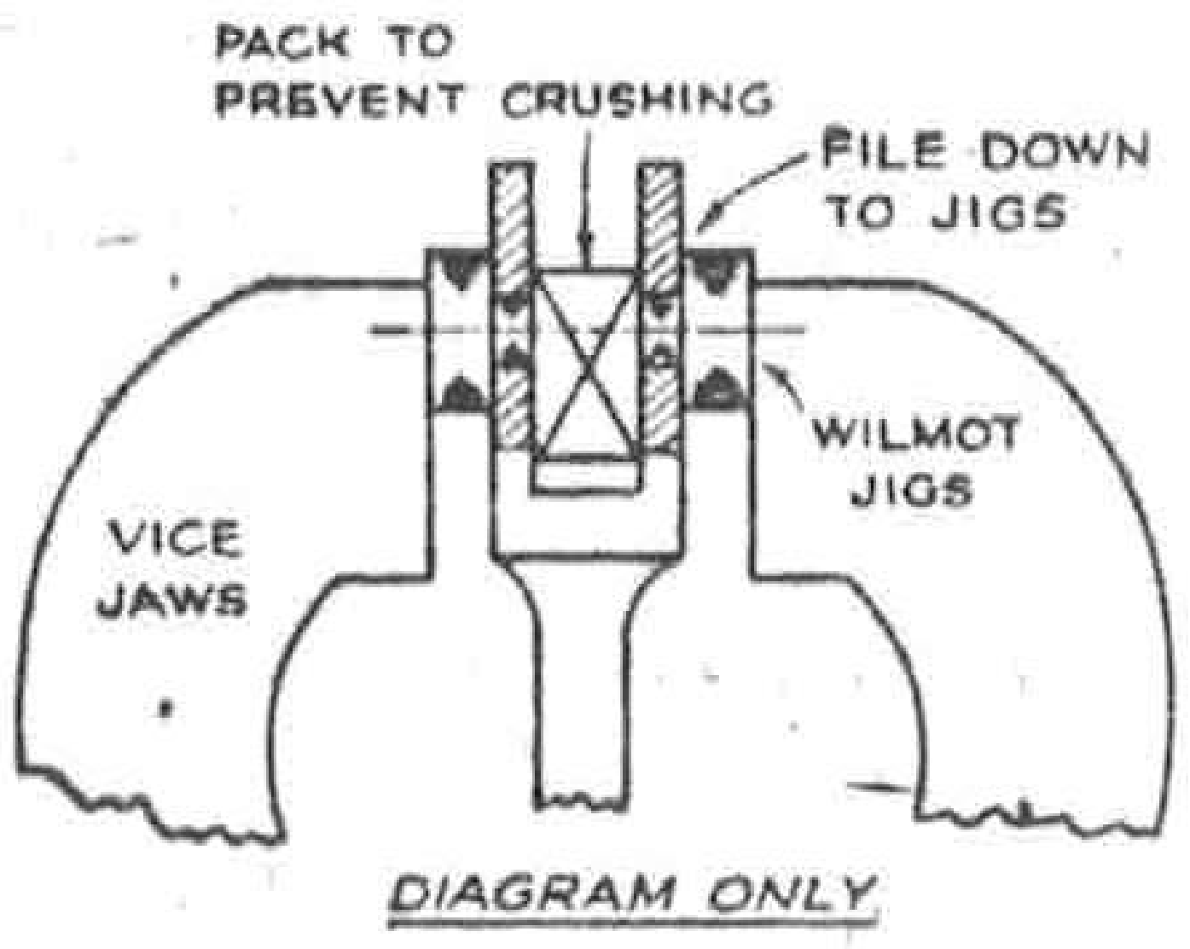
Now we come to that part of the engine which used to be the *pons asinorum* of all builders of little locomotives, but which is now, as our airmen would say, a piece of cake. The trouble arose through so-called "model" designers getting the idea fixed in their heads, that steam had to be admitted to the cylinders for the full stroke, or very near it; they would have known different if they had put engines on the track instead of on paper! For new readers' benefit I might mention here, that the success of my locomotives is due to the wholesale scrapping of "model" ideas, and the substitution of the principles of the full-sized engine, "lock, stock, and barrel" as the old saw has it; and engines like "Bantam Cock" are *not* "models" but small editions of their big sisters, being *real* engines intended for a *real* job of work. The only fundamental difference is in the size, and the rail gauge.

"Bantam Cock's" valve gear is practically the same as that of the full-sized engine, except that the layout is simplified to make the construction and erection as easy as possible, and the arrangement of parts adapted to work slide-valves instead of piston valves. Examination of the plan drawing shows it to be a "straight-line" gear, and "single-sided," the expansion link being supported by a single trunnion of ample dimensions, instead of two small pivots. This link is kept in place by the radius rod, which is in turn retained by the lifting arm on the reverse shaft. This arm operates the radius rod *via* a dieblock working in a slot, the slot being placed ahead of the link instead of behind it; the reason being that the reverse shaft has to cross the frame between the coupled wheels, and is therefore too close to the link to permit of the usual arrangement. The expansion link is supported by a cast bracket, which has a central web for attaching to the ends of the guide bars, the bracket itself being bolted to the frame. The reverse shaft is moved by a vertical lever close to the left-hand arm, which is connected to a wheel-and-screw in the cab, by a long reach rod which is located under the running-board for over half its length. The valve gear is arranged for giving the maximum cylinder power with the minimum steam consumption; and the engine is notched up when running, the steam being used expansively, exactly as in full-size practice. Now to construction; we will start from the cylinders, and "work our way back."

Valve Crosshead.

This is attached to the valve spindle, and supports the upper end of the combination lever. Chuck a short length of 7/16-in. by 5/16-in. steel rod in the four-jaw, and set it so that the long side is 3/32-in. off centre; if rod of this size is not available, use the nearest larger that you have. Face off the end, and turn down 3/16-in. length to ¼-in. diameter; centre, drill down about ¼-in. depth with No. 30 drill, and tap 5/32-in. by 40. Part off at 11/16-in. from the end, and repeat process. At ½-in. from the end of the boss, on the narrow side, and on centre line of same, drill a hole with No. 23 drill, making certain it goes through square. All the holes in forked ends of valve gear rods and links, should be drilled before slotting, and held in a machine vice either on the table of a bench or pillar drill, or against a drill pad on the lathe tailstock, if a drilling machine is not available. They should never be drilled by hand. The crosshead is then slotted to the dimensions shown in the illustration, by the method given for coupling-rod fork, and similar parts. As the crosshead cannot be clamped under the lathe tool holder direct, on account of its short length, it should be fixed in the end of a bit of ½-in. square bar. Face the end of the bar, drill a shallow hole in it, ¼-in. diameter, and push the boss of the crosshead into the hole, securing either with a setscrew, or a touch of soft solder. Clamp the bar under the slide-rest tool-holder, feed up to the cutter as previously illustrated, and form the slot; if the crosshead was soldered in, heat the end of the bar to the melting-point of the solder, pull out the crosshead with a pair of pliers, and wipe off any surplus solder that may adhere to it.

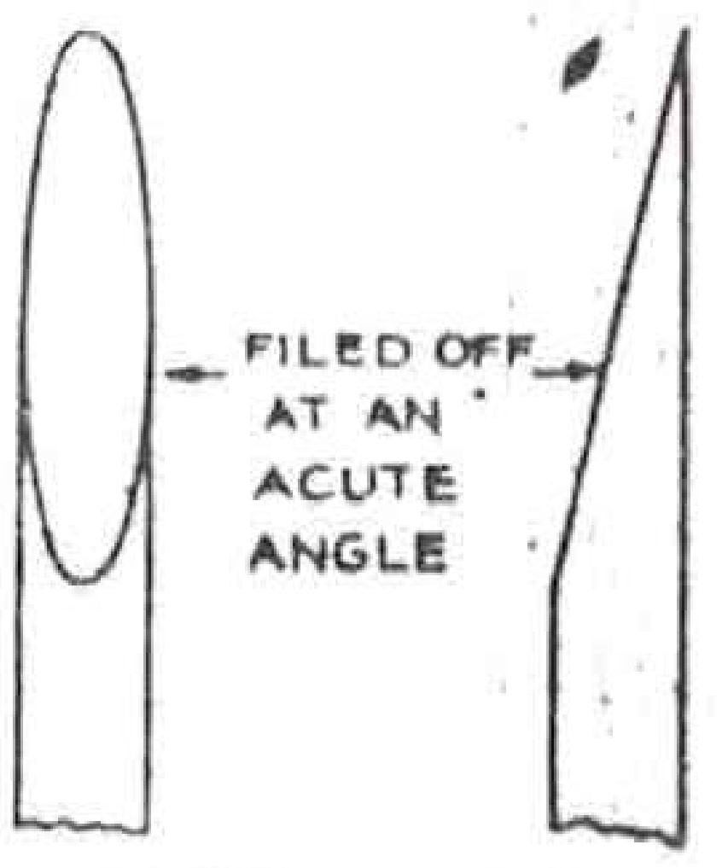
The ends of all valve components may be rounded off truly, in a minimum of time, by using a pair of Wilmot jigs. These are merely stubs of hard steel, with a pip fitting the hole in the component. In the present instance, chuck a piece of 5/16-in. round silver-steel in the three-jaw; face the end, and turn down 1/16-in. length to a push-fit in the holes in the crosshead. Part off at ¼-in. from the end, and repeat process. Make the two pieces red-hot, drop into cold water, and they are ready for use. No tempering is needed. Put one in each side of the crosshead; place a bit of ¼-in. metal between the jaws, so that they will not be crushed, and put the lot in the vice, as per illustration. File the projecting rough ends until level with the buttons. You cannot file below them, as they are too hard for the file to touch. On removing the buttons, it will be found that the ends of the crossheads are rounded off evenly. Polish up with fine emery-cloth, and screw the crossheads tightly on to the valve spindles, as shown in the plan of the complete gear. Adjustment of the valves can be made simply by turning the spindle, which alters their position by moving the long nut on the back of the valve. Finally put a 5/32-in. parallel reamer through the two pinholes, truing them to size and ensuring they are in alignment.



HOW TO USE FILING JIGS

Combination Levers.

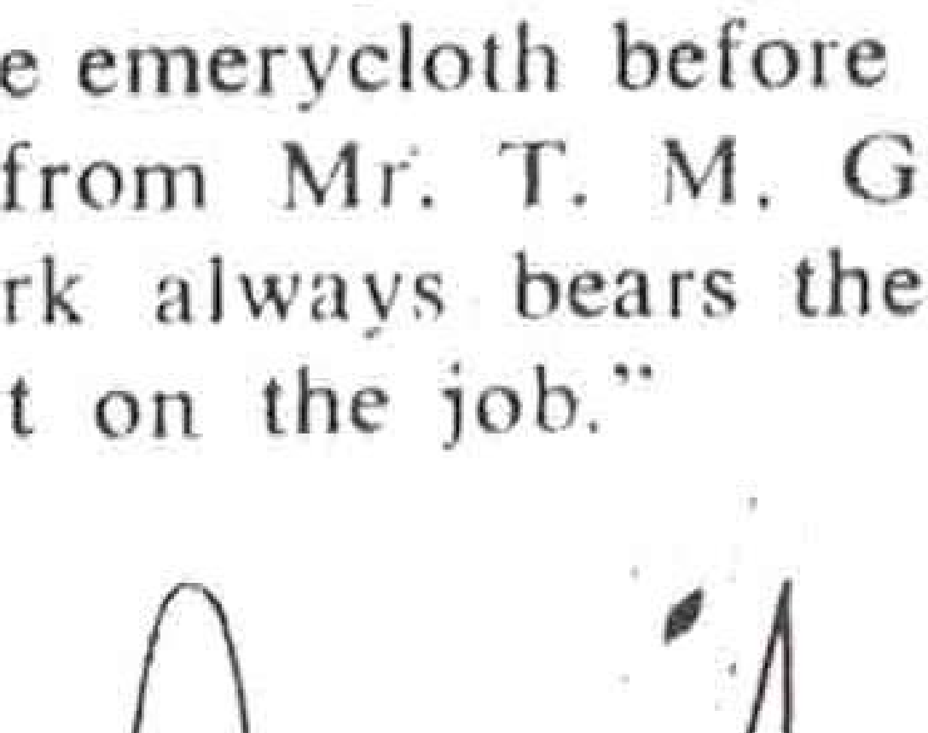
These are made from ¼-in. by 5/16-in. mild steel, or 5/16-in. square would do. On a piece about 5½-in. long, mark the outline of the two levers, the eyes near the centre, the forks at the ends. Centre-pop and drill all the holes with No. 23 drill. Clamp the piece under the slide-rest tool-holder, and slot each end ⅛-in. wide and ⅝-in. deep, as described for coupling-rod; then saw the piece in half, and file or mill to shape shown, rounding off the ends with the Wilmot jigs mentioned above. Finally put a 5/32-in. parallel reamer through the top and bottom holes, leaving the middle hole as drilled. Polish up with fine emerycloth; a very fine finish, as used by instrument-makers, can be obtained by rubbing a little beeswax on the emerycloth before using; this tip came from Mr. T. M. Glazebrook, whose work always bears the finish of an "expert on the job."



HOME-MADE HALF-ROUND REAMER

Union Links.

No detailed description of these is necessary, as they are made by practically the same process as described above; but they must be made separately, as both ends are slotted. When finished, pin the link to the bottom of the combination lever, as follows. First see if a piece of 5/32-in. round silver-steel fits perfectly in the reamed hole in the combination lever. The material which I have been using personally, is an absolutely accurate working fit in the hole finished by my 5/32-in. reamer, hence the given dimensions on the drawings.



UNION LINK

I find, however, that both silver-steel and reamers may vary a little, according to their source; so if your steel doesn't fit the hole made by your reamer, make a special reamer from a bit of the steel itself. This is easy enough; all you need do is to file the end of a 3-in. length of the steel to a long oval, harden and temper to dark brown, and rub the oval face on an oil-stone. Used with a tapwrench on the shank, it will ream a 23 drilled hole to an exact working fit for steel of its own diameter. Slightly taper the end of a short bit of 5/32-in. silver steel; put the end of the combination lever between the jaws of the fork at the end of the union link which has been drilled No. 23, drive the steel through the eyes, cut off and file flush. The eye should work on the pin without any shake, and the pin should be quite tight in the union link.

Motion Bracket.

By the time these notes appear, castings should be available; the brackets *could* be built up in emergency, but the use of a casting saves an immense amount of that priceless commodity, "time," as very ilttle work is needed. The side that fits against the frames, and the support for the guide bar, only need smoothing off with a file. Holes are drilled in both, for fixing screws, as shown in the drawings. The circular lug which forms the bearing for the link trunnion, must be drilled 15/64-in. and reamed 1/4-in., and must be exactly square with the bracket; it should be drilled from the inside, with the outer face of the boss resting on a true piece of hardwood, either on the drilling-machine table, or against a drill pad on the lathe tailstock barrel. After drilling, ream the hole carefully by hand.

A built-up bracket could be made by cutting out the outer member of the bracket from 9/16-in. steel plate; a piece of 1/8-in. by 3/8-in. flat steel, bent at right angles, could be used for the guide bar support, and a piece of 1/2-in. by 1/8-in. for the top bar and the part which bolts to the frame. The whole unit could be temporarily assembled with a few 1/16-in. screws, and the joints brazed. For the link trunnion bearing, drill a 3/8-in. hole in the outer member, where a boss is shown on the casting, and squeeze into it a bronze bush 1/4-in. wide with a 1/16-in. head; this is reamed 1/4-in., after pressing in. Don't forget that one bracket is R.H., and one L.H., as illustrated.

To erect the brackets, put them temporarily in place, and hold with a toolmaker's cramp against the frame. Note carefully: the position of the trunnion hole must be exactly 2 7/8-in. ahead of the centre of the driving axle, as shown in the plan drawing, and 1 1/8-in. above it—that is, 1 1/4-in. from top of frame. The foot to which the guide bar is attached, should rest on the end of the bar, and be in contact with same full length, which will settle the slight inclination of the bracket. Run the 30 drill through all the holes in the lug which fits against the frames, and either make countersinks on the frame, or carry on and drill clean through, as desired. In the former case, drill out the countersinks No. 40, tap 1/8-in. or 5 BA., and use setscrews to hold the bracket; in the latter case, use bolts. Short setscrews must be used to hold the guide bar to the support, on account of the crosshead shoe passing beneath.

Expansion Links.

The expansion links are cut from 3/16-in. steel plate. The best material to use, is the fine quality cast steel used for gauge-making, and known as "ground flat stock," as the links can be hardened and tempered, and there will be no appreciable wear during the lifetime of the locomotive. Failing that, ordinary mild steel, casehardened, will do. Mark the outline of the links on a piece of steel, and cut the slots first; then, if you spoil one, it won't be such a tragedy as if you had cut a complete link to shape, and spoilt it with a bad slot. It is possible to machine the slots; but for a matter of two only, it is far quicker to do the job by hand. I never bother about setting up a machine for forming only two link slots. Drill a few 7/32-in. holes on the centre-line of the marked slot; run them into a sausage-shaped opening with a small round file, and then with a watchmaker's flat file, or a small Swiss "fish-back," file the slot to 1/4-in. width and 1 1/4-in. long. Test with a piece of 1/4-in. round silver steel; when same slides up and down easily, with no appreciable shake anywhere, the slot is O.K. and the ends may be finished off square.

The links are then sawn and filed to outline, the tail being reduced to 1/8-in. in thickness. It is a good wheeze to drill the tail hole No. 23 before reducing the thickness and filing to shape. Use the Wilmot jig to guide the file when rounding off, then put a 5/32-in. reamer through the hole.

There are two ways of making the trunnion; take your choice. The first is to chuck a piece of 3/8-in. square steel in the four-jaw, face the end, turn down 1/4-in. length to 1/4-in. diameter, and part off to leave a square flange 1/16-in. in thickness. Either mild or silver steel may be used; aim for a perfectly smooth finish on the round part, which must be absolutely parallel. File the opposite sides of the flange to the slight angle shown in the drawing. The second way is to chuck a piece of 1/4-in. round silver steel in the three-jaw, face the end, and turn a pip, a little over 1/16-in. width, and 3/16-in. diameter. Part off at 3/16-in. from the shoulder. Cut a 3/16-in. square from a piece of 1/16-in. mild steel sheet or strip, drill a 3/16-in. hole in the middle, countersink it, drive in the pip, rivet over and file flush. This construction is illustrated in the end view of the link. Put the flange exactly in the middle of the link, tie in position with iron binding wire, and braze. Apply a slight smear of wet flux each side—Boron compo. is about the best for this job—heat to bright red, and touch each side with a bit of thin soft brass wire, which will melt and flow in.

Warning—don't get any brass on the inside of the slot! Now, if the links are made of cast steel, plunge into clean cold water as soon as the brass has set, which will harden them. If of mild steel, roll them in some casehardening powder (Kasenit, Ecosite, Pearlite, or any good commercial preparation) and reheat to dull red before quenching out; but don't make them hot enough to melt the brazing.

First Stage of Erection.

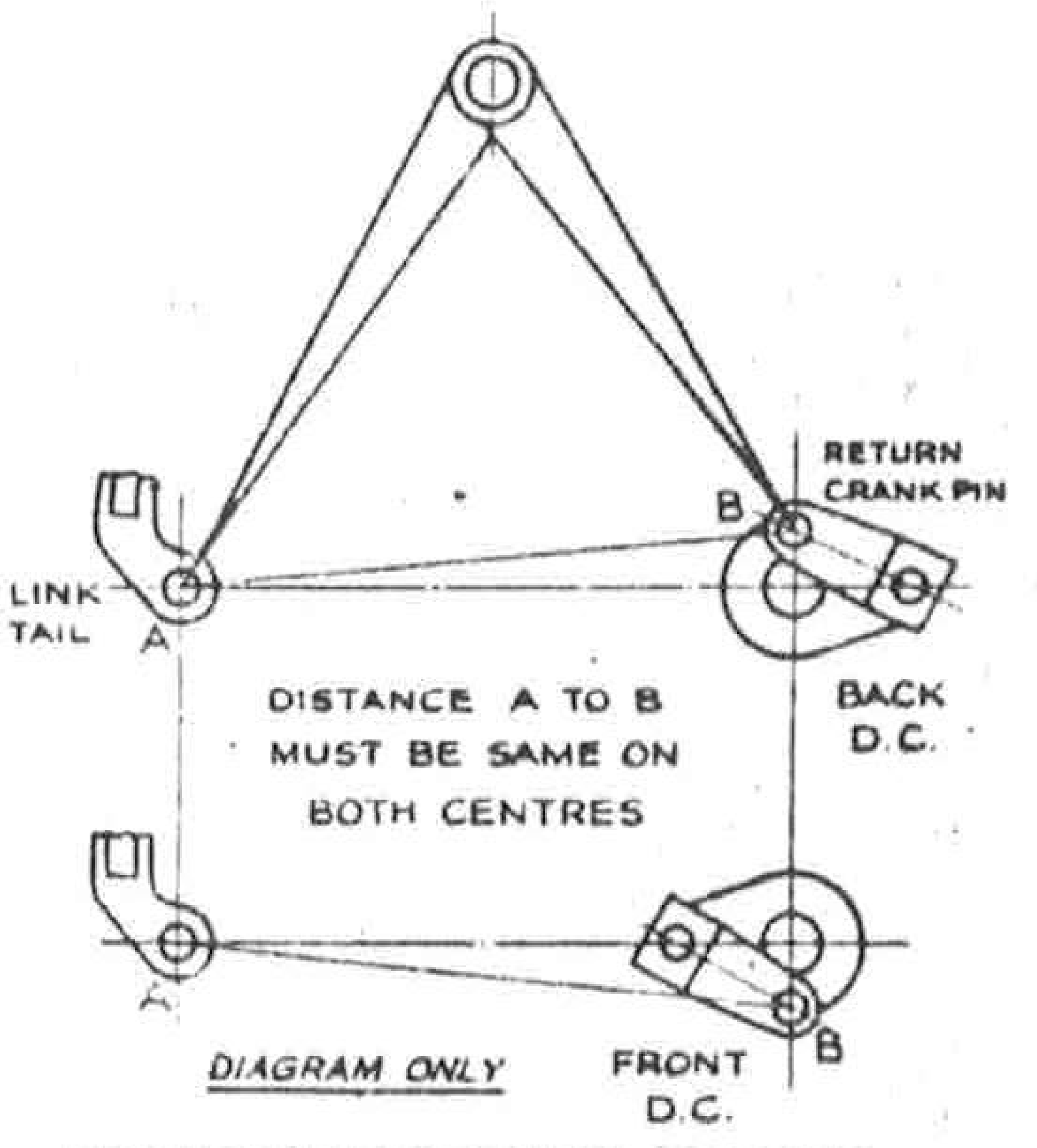
The valve gear components so far made, may now be erected. Put the expansion links in place first, the trunnions entering the holes in the brackets from the inside, and make sure they oscillate freely. Now take the radius-rod-combination-lever-union-link assembly, and put in position with the die-block in the slot in the expansion link, the top of combination lever between the wide jaws of the valve crosshead, and the face end of the union-link over the drop arm on the main crosshead. The two last-mentioned joints are secured by little bolts made from 5/32-in. silver steel, short pieces of which are chucked in the three-jaw and turned down for about ⅛-in. length to 3/32-in. diameter at each end. Screw 3/32-in. or 7 BA., and use ordinary commercial nuts. The bolts should be a shade longer between shoulders, than the outside width of the forks, so that when the nuts are screwed up tightly, the bolt is still free to revolve, but has no appreciable end play. The nut at one end can be made a fixture by slightly riveting over the projecting scrap of screw thread. These shouldered bolts are ever so much neater, and more "engine-like," than if the rod were screwed full diameter and furnished with 5/32-in. nuts; I always make use of this method of fixing valve gear joints where convenient, on my own engines.

Return Cranks.

The return cranks, or eccentric cranks as they are known amongst American railroad men, are made from ½-in. by 3/16-in. mild steel bar, being simply filed to shape, and the small end rounded by aid of a filing jig. The front is slightly relieved, as shown. After drilling the 3/16-in. hole in the square end, drill a No. 41 hole through the thickness of the crank butt, and make a hacksaw slot cutting across this hole into the 3/16-in. hole; (see illustration). The crankpin is made from a 9/16-in. length of 5/32-in. silver steel; chuck in three-jaw, and turn down a bare 3/16-in. of one end to 7/64-in. diameter; screw 6 BA. Slightly taper the opposite end; put a nut on the threads to protect them, and squeeze the pin into the No. 23 hole in the crank.—Put each crank on the main crankpin, with the return crankpin set at approximately ½-in. from the main crankpin, and leading it, as shown in the general arrangement drawing. Make two little bolts from bits of 3/32-in. silver-steel screwed at each end and fitted with nuts; don't turn these down, as strength is required here. Put these in the cross-holes in the butts of the cranks, and tighten up just enough to prevent the crank slipping on the main pin.

How to Set the Return Cranks.

The correct sequence of valve movements, and consequently the efficiency of the locomotive, depends on the return cranks being set correctly; and this job, though vital, is simplicity itself. First of all, put the main crank on front dead centre; then set the expansion link in such a position that you can run the die-block up and down it without any movement of the valve spindle taking place, and temporarily fix it thus. Now, with a pair of dividers, take the distance from the centre of the return crankpin, to the centre of the hole in the tail of the link. Next, shift the main crank around to back dead centre, and apply the dividers to link tail hole and crankpin again; the distances should tally exactly. If they don't, shift the return crank on the main crank so that the return crankpin moves half the difference. Tighten up again, and repeat the check-up. When the distances tally exactly with the main crank on either front or back dead centre, the return crank is correctly set, and—note this particularly!—*the distance between the divider points is the exact between-centre length of your eccentric rod,* so keep them set whilst you make the rods, as below. Well-tighten the return crank bolts.



HOW TO SET RETURN CRANKS

Eccentric Rods.

To make these, follow the same procedure as for the combination levers, using ¼-in. by 7/16-in. section steel, or the nearest you can get to it. Alternatively, the rod could be made from ⅛-in. by ½-in. steel, and after filing or milling the main part to shape, a little block could be brazed to one side, to be filed, or milled, and slotted to form the little fork or clevis which engages with the link tail. The distance between centres, of the hole in the fork and the bush hole, should correspond exactly with the setting of the dividers mentioned above; I always mark off my own rods with the ready-set dividers right away. Drill the hole in the plain end 7/32-in., and turn up a little bush from 5/16-in. phosphor bronze rod; chuck in three-jaw, face, centre, drill No. 23 for a full ¼-in. depth, turn down 9/64-in. of outside to a squeeze-fit in the hole in the rod, and part off to leave a flange 1/32-in. in thickness. Squeeze into the rod, then put a 5/32-in. reamer through the bush, which may then be placed over the return crankpin and secured by a nut and washer. The forked end fits over the tail of the link, and a bolt made as described for the top of combination lever and union-link, is put through the lot. There should be no appreciable play in any of the joints, but they should all work perfectly freely.

Reversing Shaft.

The reversing shaft works in the two 3/8-in. holes already drilled near the tops of the frames between the leading coupled and driving wheels; but they first have to be bushed. Chuck a piece of 1/2-in. round bronze or gunmetal rod in the three-jaw; face the end, centre, and drill down about 7/8-in. depth with 1/4-in. drill. Turn down 1/4-in. of the outside to a full 3/8-in. diameter, a squeeze-fit in the 3/8-in. holes in the frames; part off at 5/16-in. from the end, leaving a flange 1/16-in. in thickness. Repeat operation for bush No. 2; skim off any burring, and then squeeze them into the holes in the frame, having the flanges on the outside, as shown in the plan of the assembly.

The shaft itself is a piece of 1/4-in. round steel; either mild or silver will do, overall length being 5 13/16-in. It carries two lifting arms and a reversing arm. The latter, and one lifting arm, are brazed on, but the second lifting arm is made detachable, otherwise you couldn't get the shaft erected. The two lifting arms are filed up from 3/32-in. by 3/8-in. mild steel, to the size and shape shown in the end view of the shaft; the larger end of one is drilled a tight fit for the shaft, and the smaller is tapped 1/8-in. by 60, if taps and dies are available for that size, otherwise use 5 BA. First drill both ends with No. 40 drill, at 1 1/4-in. centres; then do the tapping, and slightly countersink one side of each. The larger end of the fixed arm should be opened out with a letter D drill, if you have it; if not, use 15/64-in. drill, and then ream the hole with a taper broach until just large enough to drive on the end of the shaft.

To make the dieblocks, chuck a piece of 5/16-in. square silver-steel in the four-jaw; face, centre, and drill 5/32-in. for about 1/2-in. depth. Part off two 3/16-in. slices. Each of these should be filed, slightly convex one side and slightly concave the other, until they can be slid from end to end of the slots in the links, quite easily but without appreciable shake. Then countersink one side of the centre hole; heat the blocks to cherry-red, plunge into water, clean and polish up. The blocks may be left quite hard, as they stand no risk of breakage.

Warning to beginners: So-called "model" designers who have had no actual practical experience in locomotive building, usually specify a plain round pin working in a narrow slot, instead of proper dieblocks. The effect is, that after a short period of running, the line contact between pin and slot is worn away, flats appear on the pin, and little depressions are formed in each side of the slot; consequently the pin becomes "sloppy" and the valve setting is affected, causing the engine to lose any power it may have had, and becoming wasteful of steam. You cannot do better than follow full-size practice, and use proper links and dieblocks. Some of those I have made and fitted, have not developed any appreciable slackness after over 20 years of service. The proof of the pudding is in the eating—I have seen many of the other kind!

Radius Rods.

These should be cut from the same kind of material as the links, but 1/8-in. in thickness. The small ends are drilled No. 23 and reamed 5/32-in., using the filing jig for rounding off. The slot in the large end should be made exactly as described for the link slots, except that a piece of 1/4-in. square silver steel can be used as a gauge, and it should slide freely for the full length. Keep it by, as the dieblocks for attaching to the lifting links can be made from it later on. At the large end, exactly 3 1/8-in. from the centre of the eye at the other end, drill a No. 40 hole and tap it 1/8-in. or 5 BA., slightly countersinking one side. Chuck a piece of 5/32-in. silver steel in the three-jaw chuck; turn down 3/16-in. length to 1/8-in. diameter, and screw to suit the tapped hole. Part off at 1/4-in. from end. Screw this tightly into the end of the radius rod; rivet over at back, into the countersink, and file flush. Put a dieblock over the pin, countersink side outward, and rivet over the pin into the countersink, leaving it free to oscillate, but with no end play; file off flush. Before fixing the dieblocks to the radius rods, the latter should be hardened and tempered, if cast steel, or casehardened, if mild steel, in the same way as described for the expansion links. The small end of each radius rod can then be placed in the jaws of the fork at the top of the combination lever, opposite the lower holes, and pinned in exactly the same way as described for the union links. Don't forget to make one right-hand and one left.

The detachable lifting arm has a steel boss brazed to the larger end. The easiest way to get this concentric, and make it "stay put" whilst being brazed, is as follows: Chuck a piece of 3/8-in. round mild steel rod in the three-jaw; face the end, then turn a pip on it a full 3/32-in. long, and a tight fit for the No. 40 hole in the end of the arm. Part off at 1/4-in. from the shoulder; drive the pip into the arm, so that the shoulder butts close up, and braze the joint. Smear a little flux all around the boss, heat to bright red, and touch the joint with a bit of thin soft brass wire, which will melt and form a fillet. Let it cool to black, quench in water (not acid pickle for steel) and clean up. Chuck the boss in the three-jaw, centre the end of the pip projecting slightly from the arm, then put a letter D or 15/64-in. drill through the lot, following up with a ¼-in. parallel reamer; but note that the reamer should only be entered a little way, barely to the end of the tapered "lead," as the boss must be a tight fit on the reversing shaft.

To make the dieblocks, chuck a piece of ¼-in. square silver-steel truly in the four-jaw; face the end, centre, and drill down about ⅜-in. or so with No. 31 drill. Countersink slightly, part off a ⅛-in. slice, and repeat operation for second die. For the pins, chuck a piece of ¼-in. round steel rod in the three-jaw; turn down about ¾-in. of it to 7/32-in. diameter, and further reduce another 3/16-in. of the end to ⅛-in. diameter. Screw this for a bare 3/32-in. of its length ⅛-in. by 60, if taps and dies are available, otherwise use 5 BA. The fine threads are a great advantage in places where the threaded portion is very short, or where fine adjustments have to be made. Bevel off the shoulder to match the countersinks in the dieblocks, and part off ¼-in. from the end; then repeat operations. Put the dieblocks on the pins, and screw home as shown in the detail sketch, but don't screw the pins in so tightly that the dieblocks cannot move; they should be free to turn, but without endplay. When properly adjusted, burr over the projecting end of the screw into the countersink, and file off flush, both front and back.

The reverse arm is made from a piece of ⅛-in. by ⅜-in. flat steel, filed up to shape and dimensions shown; the hole at the small end is drilled No. 21, and the large end is treated exactly as described for the large end of the fixed lifting arm. Now drive this arm on the end of the shaft, letting same project through 3/32-in.; then drive the lifting arm on to the projection. Set the two arms at right angles; braze them both, as described above for the detachable arm boss, and clean up. Two collars should then be made, as a precaution for side-slip of the reversing shaft; they are not absolutely essential, as the radius rods would not permit the shaft coming out, but they save undue friction between the lifting arms and the radius rods. Chuck a piece of ½-in. round steel rod in three-jaw; face the end, centre, drill down about ⅝-in. or so with ¼-in. drill, and part off two ¼-in. slices. Remove any burr, and drill and tap them for ⅛-in. or 5 BA. setscrews as shown.

To erect the shaft, put one of the collars on it, and push it through the two bearings, holding the arms clear of the rest of the "works"; then turn it down so that the arms are in correct position, and enter the dieblock into the slot in the radius rod. Next put on the other collar, and the other arm; this must be pushed far enough on to the shaft to allow it to be turned into the correct position, and the dieblock entered into the slot in the radius rod, after which it is pulled back again to the end of the shaft, when both arms should just clear the radius rods, and the slots in the latter should slide easily over the dies. All that remains, is to adjust and pin the detachable arm. To do this, first of all put the fixed arm in such a position that the dieblock in the expansion link is exactly in the middle, and the radius rod does not move when the wheels are turned by hand. Clamp the shaft temporarily in this position, then adjust the detachable arm so that the same effect obtains on the other side. When both main dieblocks are in the centre at the same time, and neither radius rod moves when the wheels are turned, the adjustment is correct; drill a No. 53 hole clean through the boss of the detachable arm and the reversing shaft, and squeeze in a pin made from a bit of 1/16-in. silver-steel wire. Run the collars up to the bushes, tighten the setscrews, and you are "all set."

Wheel-and-Screw Reverser.

Reversing and notching-up is effected by a simple wheel and screw in the cab. By the time these notes appear in print, castings should be available for the stand and wheel; but they may be built up if desired, and I will give that method first. The stand is made from a piece of ⅛-in. steel plate 2 5/16-in. long and 1⅜-in. wide; file to the shape shown, reducing the lower part to a width of ⅞-in. Another piece of ⅛-in. steel, 1⅝-in. long and ⅞-in. wide, is riveted to the bottom of this by four 3/32-in. charcoal iron rivets, or it may be brazed if preferred, in which case 5/16-in. overlap would be plenty, instead of the ⅝-in. shown; the bottom should project 1-in. below the main part of the stand. The two bearings for the screw are made from 7/16-in. round steel rod; chuck in three-jaw, face, centre, and drill down about ½-in. with No. 11 drill. Part off two 3/16-in. slices: rechuck one of them, open out the hole with 9/32-in. drill, and tap 5/16-in. by 40.

Mill, plane, or file a shallow groove ⅛-in. wide and about 1/32-in. deep, in the edge of each; this should be a tight fit for the top edge of the stand. Put one at each end, and braze or silver-solder them in place. After cleaning, run the top through the front one again to clear the threads, and make a screwed bush to suit, from ⅜-in. hexagon brass rod; chuck in three-jaw, face, centre, drill down about ⅜-in. with No. 21 drill, turn down 5/16-in. of the outside to 5/16-in. diameter, screw 5/16-in. by 40, and part off ¼-in. from the end.

If a casting is used for the stand, it will only need cleaning up with a file, and the "step" at the bottom trued up. The bearings will be cast on; one is drilled No. 11, and the other drilled and tapped as above, a bush being made and fitted exactly as described.

To make the screw, chuck a piece of ¼-in. round mild steel rod in the three-jaw, face the end, and then turn down 9/16-in. of it to 3/16-in. diameter; further reduce 5/32-in. of the end to 3/32-in. diameter, and screw it 3/32-in. or 7 BA. A length of 3/16-in. of the plain part must then be squared; for the benefit of beginners and new readers I will repeat the easiest way of performing this operation. Push the piece back in the chuck jaws until only 3/16-in. of the plain part is projecting. Put one of the chuck jaws in vertical position, like the hands of the clock at 12 noon; then, with a flat file having a "safe" or plain edge, which is allowed to rub against the chuck jaws, file a flat on the projecting metal. Now turn the chuck jaw around to the 3 o'clock position, and file another flat; repeat operation in 6 and 9 o'clock positions, and there is your square, "all-present-and-correct-sergeant." Now pull the piece of metal out of the chuck until about 1½-in. of the full diameter is exposed, and screw a little over 1-in. length of this with ¼-in. Whitworth die in the tailstock holder. The coarse thread is used to ensure quick action of the reverser; it only needs 12 turns to reverse the engine. For the correct thing the thread should be left-handed, so that the wheel turns clockwise for forward gear, as on most full-sized engines; but this is merely a matter of taste. On the old "Brighton" we had right-handed screws, and to notch up or reverse, we just turned "mangle-wise." Aim for a perfect thread when screwing; if plenty of cutting oil is applied to the die, and the mandrel worked back and forth by pulling the lathe belt by hand, the thread should be O.K. Part off at 1¼-in. from the shoulder; then reverse in chuck, but don't grip tight enough to spoil the thread. Turn down the end for ¼-in. length to 5/32-in. diameter, leaving the screwed part a bare 1-in. long. It should just go between the bearings.

For the nut, chuck a piece of ½-in. square rod in the four-jaw, and set to run truly. Bronze or gunmetal is best for the nut, but brass may be used if the harder metal is not available. Face the end, centre, drill down about ½-in. with No. 11 drill, and part off ⅜-in. from the end. Rechuck, and run a ¼-in. Whitworth tap through. In the middle of one of the facets, mill, plane or file a groove almost down to the centre hole, and a full ⅛-in. wide, an easy sliding fit on the top edge of the stand. In the middle of the adjacent facet, drill a No. 30 hole and tap it 5/32-in. by 40. Round off the corners for appearance sake. For the pin, chuck a piece of 5/32-in. round steel rod in the three-jaw, and put three or four threads on the end with a 5/32-in. by 40 die. Part off at 7/16-in. from the end; reverse in chuck, turn down 3/16-in. of the end to ⅛-in. diameter, and screw ⅛-in. or 5 BA. Screw this into the side of the nut, so that a full ⅛-in. of plain projects; then run the ¼-in. tap through the centre hole again, to clear off any burring. Put the nut on the stand between the two bearings; poke the three-step end of the screw through the tapped bearing, enter it into the nut, and wind it through until the shoulder of the screwed part comes up against the back bearing. Screw the small hexagon-headed bush into the front bearing, the hole in same going over the 5/32-in. tail of the screw.

When right home, the screw should be free to turn, but should have no end play; and when turned, the nut should run up and down full length between bearings, with no tight places anywhere.

If a casting is used for the wheel, it will have a chucking boss on it, and this merely has to be gripped in the three-jaw whilst the wheel is turned and drilled at the one setting. Alternatively, the wheel can be made from 1⅛-in. round rod; any metal you fancy. Dural. makes fiue wheels; I was presented with a few odd scrap ends some time ago, and several of my own locomotives now sport very fine reversing wheels! Chuck in the three-jaw, turn the wheel to shape, leaving a little boss projecting in centre, and recessing the part forming the spokes; this can be done with a tool having a rounded point, set crosswise in the rest. Centre, drill ⅛-in. and part off, leaving the rim of the wheel about 3/16-in. wide. Drill four 3/16-in. holes equidistant in the spoke recess, then file away the surplus so as to leave four spokes. About the handiest gadget to use for this purpose is an "Abrafile," which cuts in any direction in which you push it, never slips, and removes metal at an astounding speed. I never came across anything like it for filing out irregular-shaped holes, or sawing around corners—and I've no shares in the firm at that; merely speak as I find. Drill a No. 48 hole in the rim of the wheel, opposite one of the spokes, and in this fit a little handle, turned to the shape shown, from a bit of ⅛-in. steel or nickel-bronze rod; the stem of the handle should be a drive fit in the 48 hole. There is no need to file the hole in the boss to a square shape; punch it, using a couple of inches of ⅛-in. square silver steel for the job. Simply file the end of the steel flat, harden and temper to dark yellow, and drive it through the boss; this will form a square hole that should be an exact fit on the squared portion of the screw shaft projecting beyond the back bearing. Put the wheel on the shaft and secure it with an ordinary commercial nut.

The complete assembly is erected exactly above the side of the trailing frame or cradle on the left-hand side of the engine, at 9/16-in. from the edge of the drag beam. Take the two outer screws out of the angle, and temporarily clamp the stand in the position shown in the illustration; then with a bent scriber put through the screwholes from the inside of the frame, mark off the location of the holes on the lower extension of the stand. Remove, centre-pop, and drill No. 30, and at the same time drill two more holes in the extension, to correspond, as shown. Replace the stand, and secure it either with two longer screws running into the already tapped holes in the frame fixing angle, or else drill out all four holes clean through frame and angle, and put small bolts in. This makes the strongest job; and the bolts may be made from bits of ⅛-in. round steel nutted at both ends. However, if screws are used in the already tapped holes, they might as well be used for the other two; if so, run the 30 drill in and make countersinks in the frame; follow with No. 40, drilling right through, tap ⅛-in. or 5 BA., and use the two original screws taken from the angle, which will be right length for the job.

Reversing or Reach Rod.

Connection between the nut on the reversing screw and the reversing arm on the shaft is by means of a long curved rod made from ⅛-in. by 3/16-in. mild steel, with a fork at one end to embrace the top of the reversing arm, and an eye at the other, to go over the pin in the nut. To make this out of the solid would entail an abnormal amount of milling or filing, and the easiest way to avoid this is to use the ⅛-in. by 3/16-in. section for the rod itself, brazing little blocks on each for the fork and eye. Take a piece of rod about 18-in. long and bend as shown in the illustration; make a fairly sharp bend at one end (exact radius is of no matter) the flat side being the wider, then at about 4½-in. from this bend, put the downward set in the rod that takes it below the running-board on the finished engine (see the general arrangement drawing) and brings it level with the top of the reversing arm. The forked end is made by brazing on a block of steel ⅜-in. wide, ¼-in. thickness, and approximately ¾-in. long; simply butt the ends together on a flat bit of asbestos millboard laid in the brazing pan, apply some flux, blow to bright red, and touch with a bit of brass wire as before. When cooled to black, quench in water and clean up. The fork can then be formed exactly as described for the valve gear parts.

The eye is made by chucking a piece of ⅜-in. round steel rod in the three-jaw; face, centre, drill down about 9/16-in. with No. 21 drill, and part off a ⅛-in. slice. File off any burr; then cut the bent-up part of the reach rod to right length as given in the drawing, slightly radius out the end to suit the curvature of the eye, butt together, and braze as above. Beginners and inexperienced workers please note: the *exact* length of the reach rod between centres of holes in fork and eye, should be obtained from the actual job, as follows. Put the nut exactly in the middle of the space between the two bearings on the reverser stand; then put the reversing arm on the shaft in such a position that the main dieblocks are in the middle of the expansion links. The distance between the centre of the hole in the reversing arm, and the centre of the pin, is the length of the reach rod between centres. Polish it up, slip the eye over the pin in the nut, and secure with an ordinary commercial nut; the fork is attached to the reversing arm by a little bolt made from 5/32-in. silver steel, nutted each end, as described for other parts of the valve gear.

Exhaust Pipes.

A great deal has been said and written on the avoidance of right-angle bends and other discrepancies in exhaust pipes. I made a number of experiments with various pipe arrangements; and found that what really mattered, as far as little locomotives are concerned, was that the exhaust pipes should have ample area, and take the most convenient route to the blast nozzle. The arrangement shown in the illustration, with straight pipes and a full-bored centre piece or tee, cuts back pressure to the minimum, and affords the spent steam an easy route to the atmosphere. I might add, for the special information of beginners, that the "pull" of the blast on the fire depends on the speed with which the steam leaves the blast nozzle; and this speed can be obtained, without a ridiculously small nozzle.

The body of the tee on the exhaust arrangement for "Bantam Cock" is a piece of ½-in. square brass rod. Saw off a piece a little over 1-in. long, chuck it truly in the four-jaw, face the end, centre, drill right through with either 7 mm. letter J or 9/32-in. drill, and tap 5/16-in. by 32. Reverse in chuck, and face off the other end to 1-in. length; it doesn't matter if the piece doesn't run dead true for the second facing job, the end will be square with the sides, all the same. In the middle of one of the sides, drill a ⅜-in. hole for the blastpipe. This is a 2¾-in. length of ⅜-in. by 20 gauge copper tube; chuck in three-jaw, and put a few threads on one end, either ⅜-in. by 32 or 40. Fit the plain end into the hole in the body part, and silver-solder it; just put a smear of flux around, heat to medium red, and touch it with a bit of best-grade silver-solder. I always use "Easyflo" for jobs like these, and the special flux supplied with it, all comes away on quenching out, and leaves the work clean and neat. After washing off and cleaning up, run the tap through again, to clean out any burring left by the drilling and blastpipe fitting.

Cut two pieces of 5/16-in. by 20 gauge copper tube, to a length of 1½-in., and put 5/16-in. of thread on one end of each; on the other end, put about ¾-in. of thread, all being 5/16-in. by 32. Make two locknuts from 7/16-in. hexagon brass rod; merely chuck the rod, face, centre, drill down about ½-in. or so with either of drills mentioned above, tap 5/16-in. by 32, and part off two 3/16-in. slices. They can be chamfered, if you wish; but they are out of sight, and it doesn't make any difference to the working of the engine if they are left as parted off. Rub them on a file if there are any burrs left around the tapped holes, and screw one right to the end of each long thread on the pieces of cross pipe. These are then screwed into the tee until they touch in the middle.

To erect, hold the assembly midway between frames, in line with the exhaust holes on the cylinders; screw the pipes out of the tee, into the holes in the cylinders, until right home; then run the locknuts back until they are right against the tee, as shown, and tighten with a small spanner. You can, if you wish, silver-solder a plain nut on each tee, near the short-screwed end, for the purpose of turning the pipe when screwing home into the cylinder; but I usually do the job with a pair of pliers. If the threads are a good fit, there is no need to use any plumber's jointing compound on them, as there is only exhaust pressure to withstand; but put some on if the threads are at all slack, or you will have the steam coming out of the joint instead of the blast nozzle, and the steam of the boiler may be affected.

Combined Blast Nozzle and Blowing Ring.

The chimney being fairly wide, a single jet as used on most 2½-in. gauge engines, is not suitable for a good draught with no waste of steam, and a ring blower is desirable. This can be combined with the blast nozzle in the manner shown in the illustration; I have found this type very effective. The nozzle itself is made from a piece of ⅞-in. brass rod. Chuck in three-jaw, face, centre, and drill down about ⅝-in. with 3/16-in. drill. Turn down 7/16-in. of the outside, to ½-in. diameter; chamfer off as shown, leaving ¼-in. next the shoulder, the full ½-in. diameter; then part off at ½-in. from the end, leaving a ⅞-in. flange 1/16-in. in thickness. Reverse in chuck; open out the centre hole for about ¼-in. depth with letter R or 11/32-in. drill, and tap ⅜-in. to match the top of the blast pipe.

Chuck the ⅞-in. rod again; centre, drill down about ⅜-in. with ¼-in. drill, and open out with ½-in. drill to same depth. This will ensure that the hole is a good fit over the turned section of the nozzle. Now, with a square-ended boring tool set crosswise in the rest, counterbore the end of the rod to a diameter of ¾-in. and a depth of 3/16-in.; then part off ¼-in. from the end. This will leave an angle ring 1/16-in. in thickness. In one side of it, drill a 5/32-in. hole, and in this, fit a ¼-in. by 40 union nipple. Chuck a bit of ¼-in. brass rod, face the end, centre deeply with a size E centre-drill, drill down about ⅜-in. with 3/32-in. drill, screw ¼-in. of the outside with ¼-in. by 40 die in tailstock holder, and part off about 5/16-in. from the end. Reverse in chuck; you can hold by the threads for the slight job of turning a little pip on the end, to fit tightly in the drilled hole in the side of the angle ring. In the top of the ring, drill three No. 70 holes at equidistant spacing; see plan sketch. The whole issue is then placed over the nozzle, as shown in the sectional drawing, and the top and bottom joints, also the nipple, silver-soldered at one heat. Don't put on too much silver-solder, to block the annular passage, or stop up the little jet holes. After quenching out in the pickle, let some water run into the nipple and out at the jets, to ensure there is no trace of the acid pickle left in the passage. The combination blast and blower nozzle is not fitted permanently until the boiler is erected, so just screw it on lightly *pro-tem* so that it won't get lost or mislaid.

Steam Pipe Assembly.

This is pretty much the same as the above, except for being a little smaller. The tee is made in exactly the same way, only from ⅜-in. square brass rod, drilled 7/32-in. and tapped ¼-in. The steam pipe is 5/16-in. diameter, and 1¼-in. long, fitted tightly into a hole in the centre of the tee. Another similar hole is drilled in the front of the tee, and a tapped bush is fitted in this, to take the stem of the oil delivery clack. Chuck a piece of 5/16-in. round brass rod in three-jaw, face the end, centre, and drill down about 5/16-in. with No. 22 or 5/32-in. drill. Tap 3/16-in. by 40, and part off 1¼-in. from the end. Squeeze this into the hole in the front of the tee, faced side outwards; silver-solder the lot, and run the tap through again to remove burrs. Lock-nuts and cross pipes are made and fitted exactly as described for exhaust pipes, only they are ¼-in. diameter only. The assembly is erected in the same manner; but this time, as the joints have to stand boiler pressure, they must be "doped" with plumber's jointing. Beginners seem a bit hazy about what this stuff is; well, it is just a compound, usually with a white-lead base, which is smeared on the threads, and sets hard and quite steam-tight. There are several good makes, sold in pound tins. My favourite is "Boss White." If the ready-mixed jointing cannot be readily obtained, a good substitute can be made by mixing up red lead and goldsize to a stiff paste. There are also good jointings made in powder form, such as "Vulcan" jointing powder, which is mixed to a stiff paste with ordinary boiled linseed oil.

A fairly hefty union screw will be needed on top of the steam pipe, to take the superheater connection; it *could* be made by a socket and back nut, as the pipe will be same size, but a union is much handier. Chuck a piece of ⅝-in. hexagon rod in the three-jaw, and turn down about 5/16-in. of the end to ½-in. diameter; screw ½-in. by 26. Face the end, centre deeply with a big centre-drill, drill down about ⅝-in. depth with ¼-in. drill, and part off ½-in. from the end. Reverse in chuck, open out about 3/16-in. depth with letter J or 9/32-in. drill, and tap to match the top of steam pipe. This is also fitted temporarily only, until the boiler is made and erected.

Mechanical Lubricator.

A regular supply of proper-grade oil is an absolute necessity for any little engine using very hot steam in cylinders made from non-ferrous metal; and the only way to ensure it, is to fit a mechanical lubricator. The simplest and most reliable type is that which employs an oscillating cylinder for the pump, as it requires no valves in the pump itself, the inlet and outlet ports being opened and closed by the movement of the cylinder. Pumps of this type have operated in my own locomotives for years without needing attention nor adjustment of any kind, and have never failed. Another advantage of a mechanical lubricator is that there is neither waste nor "gulping"; when the engine stops, the oil feed automatically stops also, and resumes operations at the first turn of the wheels.

The container for "Bantam Cock's" lubricator is made from 18 gauge sheet brass or copper. Cut a strip 1 3/16-in. wide, and 5-in. long; bend this into a rectangle measuring 1½-in. by 1-in. If the joint springs open, wind a bit of iron binding wire around it, to keep the edges in contact; then stand it on a piece of the same kind of metal, about 1¾-in. by 1¼-in., on the coke in your brazing pan, and silver-solder all around the bottom, and the joint at the corner. After pulling and washing off, file the bottom flush with the sides. In the centre of the bottom plate, drill a 5/32-in. clearing hole (No. 2 drill) and at 3/16-in. from the top of one of the shorter sides, drill a 3/16-in. clearing hole (No. 11 or 5-mm.), on the centre line.

The pump stand is a piece of 5/16-in. square brass rod, squared off at both ends in the four-jaw chuck, to a dead length of 1 3/16-in. Set it to run truly before facing the bottom end; then centre, and drill to 5/32-in. depth with No. 30 drill. Tap the hole 5/32-in. by 40, using a plug tap to get the thread full depth. At 3/16-in. from the top, drill a 5/32-in. hole clean through, and tap it 3/16-in. by 40; this hole, also the trunnion-pin hole, must go through absolutely square with the face; so if you haven't a drilling machine, use the lathe, putting the drill in the three-jaw chuck, and holding the work against a drilling pad on the tailstock barrel, with a bit of truly-faced hardwood in between. The trunnion-pin hole is drilled No. 41, and both holes must be exactly on the centre-line. Next, with a ¼-in. pin-drill, make a recess in the back of the stand about 5/32-in. deep, as shown by dotted lines in the side view of stand. At the top, mill or file away a clearance for the crank; this is 7/16-in. long and 3/32-in. deep. Another clearance is milled or filed 3/16-in. below that, about 1/16-in. deep, and extending to within 7/32-in. of the bottom; this ensures the cylinder working oil-tight against the stand, and reduces the rubbing area. Finally, at ⅛-in. from the bottom, drill two No. 55 holes, each of them 1/16-in. away from the centre-line. The right-hand one is drilled through into the blind hole at the bottom of the stand; see section of complete lubricator. The left-hand one is drilled in for 1/16-in. only, and a little groove is chipped or milled from this, to the bottom of the stand; see face view. The face is then rubbed, first on a dead smooth file laid on the bench, and then on a piece of finest grade emerycloth, or similar abrasive, laid "business-side-up" on the lathe bed or some other true surface, the same as for facing slide valves and other surfaces needing to be true.

The pump cylinder is made from a piece of 5/16-in. by ⅜-in. brass rod, squared off at both ends, in the four-jaw chuck, to a length of ⅝-in. Make a centre pop in the middle of one end, and chuck in four-jaw, so that the pop mark runs truly; drill a hole clean through with a No. 33 drill. Open out to about 3/16-in. depth with 3/16-in. drill, and tap 7/32-in. by 40; run a ⅛-in parallel reamer through the rest of the hole. One side of the cylinder can then be rounded off, as shown in the plan view; on the opposite side scribe a line down the centre. In the middle of this, drill a No. 48 hole and tap it 3/32-in. by 60, if you have the fine thread tap and die available; if not, use the nearest you have. At 1/16-in. from the bottom, drill a No. 55 hole breaking into the central bore. Put the reamer through again, to remove any burr, and turn up a little plug for the bottom; this must be a tight driving fit, and may be soldered over, for safety precaution. Make a little gland from ¼-in. hexagon brass rod, to suit the cylinder, using same process as described for the larger cylinder glands; and for the ram, use a piece of ⅛-in. rustless steel or bronze rod, 11/16-in. long, with a No. 48 hole drilled across it at a bare 3/32-in. from the upper end, to take the crank-pin. The gland is packed with a few strands of graphited yarn. True up the the trunnion pin, which is merely a ¾-in. rubbing face as described above; then fit length of 3/32-in. round silver steel with a few threads at each end. It is of vital importance that this shall be screwed in *exactly at right angles to the portface;* otherwise oil will leak out between, and the lubricator will fail to deliver against pressure. Poke the trunnion through the hole in the stand, see that the faces make proper contact, and secure with a little spring of 24 gauge tinned steel wire, and a nut, as shown in the sectional illustration.

For the spindle bearing or sleeve, chuck a piece of 5/16-in. hexagon brass rod in three-jaw; face the end, centre, and drill a full 1-in. depth with No. 41 drill. Turn down a bare ⅞-in. length to 3/16-in diameter, and screw it 3/16-in. by 40; part off at 15/16-in. from the end, reverse in chuck, skim off any burr, and chamfer the corners slightly. Make a nut to suit, about ⅛-in. in thickness, from same size rod; use same process as for locknuts on the steam and exhaust pipes. This sleeve, and the check valve, hold the pump in place in the container.

The check valve is made from 5/16-in. round brass rod; chuck a piece in three-jaw, face the end, centre, and drill down about ⅝-in. with No. 44 drill. Turn down 3/16-in. of the end to 5/32-in. diameter, and screw 5/32-in. by 40; then turn off about 1/32-in. or so, leaving 5/32-in. length of thread of full diameter. When screwing a very short piece, it is always a good plan, especially for beginners, to make the piece a little longer to start with, and turn to length after screwing; the reason being that small dies, especially when worn a little, often tear the first thread or two before getting a proper "bite," and naturally a torn thread does not hold securely. Making the piece longer, and then turning to length after screwing, effectually gets over this trouble, and ensures that the piece shall have good threads for the full effective length needed.

Part off at 3/8-in. from the shoulder; reverse in chuck, open out with 3/16-in. drill and bottom to 5/16-in. depth with a 3/16-in. D-bit. Tap the hole about 3/16-in. down, with 7/32-in. by 40 tap, and run a 3/32-in. reamer through the remnants of the 44 hole. If you haven't a reamer this size, either make one by filing off the end of a piece of 3/32-in. silver steel diagonally, and hardening and tempering it, or else broach the hole very carefully with an ordinary hand taper broach. Drill a 5/32-in. hole in the side of the body and fit a 7/32-in. by 40 nipple in it, using same process as described for the nipple on the blastpipe nozzle; silver-solder it in. The cap is turned from 5/16-in hexagon brass rod, made same as described for glands, except that the hole drilled 5/32-in., doesn't go right through; see illustration. Seat a 1/8-in. rustless steel ball on the hole, and between the ball and cap, put a little spring made from brass or bronze wire, about 26 gauge, to keep the ball on the seat, as the check valve works upside down.

To erect the whole bag of tricks, stand the pump in the container, with the hole in the base of the stand, lining up with the one in the bottom of the tank; then screw the check valve into the stand, through the hole. The valve should be right home when the nipple points to the rear (see assembly view). Now poke the sleeve through the hole in side of tank; put the nut on, screw the sleeve home into the top of the stand, so that the head just comes up against the outside of tank without bending it, and tighten up the locknut.

For the crank, chuck a piece of 3/8-in. brass rod in three-jaw; face, centre, drill down about 3/16-in. with No. 48 drill, tap 3/32-in. or 7 BA, and part off a 1/8-in. slice. At 1/8-in. from the centre, drill a No. 50 hole, and drive in a piece of 15 gauge spoke wire, leaving 1/4-in. projecting; round off the end. The spindle is a piece of 3/32-in. steel 1 7/16-in. long, with 1/8-in. of thread on one end, to match that in the crank. The other end carries the ratchet gear. The wheel is 7/16-in. diameter, 3/32-in. in thickness, and has 35 teeth. If anybody has difficulty in procuring a suitable wheel from a local clockmaker, they can get one by sending 1s. 9d. to Mr. T. H. Glazebrook, 36 Haslemere Road, Thornton Heath, Surrey, who will forward one carriage paid. Please note, Mr. Glazebrook is not connected with the trade in any way whatever, and this service is purely friendly. Having the necessary appliances, he made a few for my own use, to save me some of that precious commodity, "time"; and when I mentioned that several builders of other locomotives had been held up for lack of suitable ratchet wheels, he volunteered to come to the rescue. The price barely covers the cost of labour.

Open out the hole in the wheel with a No. 43 drill, and carefully drive the blank end of the spindle through it until it projects about 7/32-in; if the vice is used to squeeze it through, take care not to bend the spindle. Next put 1/8-in. of thread on the outer end. *Warning*: when putting the wheel on the spindle, take care the teeth are as shown in the drawing, and not the other way around. Mistakes are easier made than corrected! The ratchet lever is filed up from a piece of 3/32-in. steel strip about 1/4-in. wide, to dimensions given in the drawing; the upper hole is drilled No. 41. The moving pawl is filed up from a piece of the same steel, to shape shown; it is drilled No. 48, and pivoted on a 9 B.A. screw in a tapped hole in the lever, 5/16-in. below the spindle hole. Alternatively, it could be mounted on a plain pin turned up from 3/16-in. steel, driven into a No. 48 hole in the lever, and slightly riveted over. Whichever way is adopted, it must work very easily. A light spring is attached to a No. 55 hole drilled a similar hole lower down the lever, as shown.

The stationary pawl is also filed up from 3/32-in. steel strip, to shape shown in the drawing, and is pivoted on either a 9 B.A. screw or a turned pin, as mentioned above. In either case, the stem of the screw or pin passes through a No. 48 hole drilled in the tank, and is nutted on both sides, the nut on the outer side acting as a spacer, to keep the pawl in line with the ratchet wheel. This pawl should be free enough to fall on the teeth by its own weight, and no spring is required. Both the pawls should be hardened, by heating and dipping in any good case-hardening powder, as described for valve gear parts and other items. The ratchet lever is retained on the spindle by a washer and an ordinary commercial nut: and when this is screwed right home tight, the lever should just be free to swing easily without side shake. To put the spindle in place, push the crankpin through the hole in the ram, then hold the crank level with the end of the sleeve; push the spindle through, and screw it into the chank until right home, when the end play should be a bare 1/64-in. If the lever is now waggled back and forth, the pump should operate; a movement of 5/16-in. or so on the bottom of the lever should click one tooth.

To test the pump, put a little thick oil in the tank, and turn the spindle by hand, until oil appears at the union nipple underneath. Then put your thumb over the nipple, squeeze as hard as you can, and work the ratchet lever. No matter how hard you squeeze, it should be impossible to prevent the oil coming out. It might be of interest to beginners, and others who are doubtful as to the power of these little oil pumps, to learn that in a full-size locomotive works, one was tested on the apparatus used for testing full-sized pressure gauges; and the little pump promptly pushed the master gauge around to over 500 lbs. per sq. in., at which pressure the tester stopped it, for fear of damaging the gauge! A lid for the container can easily be made by cutting out a piece of metal or hardwood to the exact size of the top of the tank, and flanging over it, a piece of thin sheet brass or copper, in exactly the same way as a boiler plate is flanged (see coming notes on the boiler). A small section has to be filed out of the flange on one of the smaller sides, to clear the head of the spindle sleeve.

How to Erect the Lubricator.

A drawing is appended, showing exactly how the lubricator is erected, connected up, and driven. First of all we need an oil delivery clackbox, to screw into the tee on the cross steam pipe. To make this, chuck a piece of 5/16-in. round brass rod in the three-jaw; face the end, centre deeply with a size E centre-drill, and drill down about ¾-in. with No. 44 drill. Turn down ¼-in. of the end to 7/32-in. diameter, and screw 7/32-in. by 40. Part off at ⅝-in. from the end, reverse in chuck, and proceed exactly as described for the check valve under the oil container, except that instead of making the nipple 7/32-in. and countersinking it, turn it up from 5/16-in. round rod, turn ¼-in. length to 3/16-in. diameter and screw it 3/16-in. by 40, leaving a flange at the end of the thread, as shown. When completed, screw the clack into the tee on the steam pipe, as shown in the assembly drawing, with the stem pointing downwards. Use a little plumbers' pointing on the threads of the nipple.

The lubricator is erected over the pony axle, and is supported by an angle bracket. This should be 1½-in. long, and could be made from ¾-in. by 3/32-in. brass angle, one side being reduced as shown, or a piece of 3/32-in. sheet brass or copper bent to shape. It is attached to the container, ⅜-in. from the bottom, by three 3/32-in. screws, with nuts inside the tank; and to the top of the buffer beam by three similar screws running through clearing holes in the angle, into tapped holes in the top of the beam. The union on the check valve under the tank is connected to the clackbox by a piece of 3/32-in. copper tube, bent as shown, to allow for expansion; this has a union nut and cone on each end. To make the nuts, chuck a piece of ¼-in. hexagon brass rod; face the end, centre, and drill down about ¾-in. with No. 40 or 7/64-in. drill. Open out to 3/16-in. depth with 3/16-in. drill, tap 7/32-in. by 40, part off at ¼-in. from the end, and chamfer the corners of the hexagon both ends for neatness sake. To make the cones, chuck a piece of 3/16-in. copper rod; and if the nuts won't pass over it, take off a slight skim until they will. Centre and drill down about ½-in. with No. 43 drill, then chamfer the end, either by setting over the top slide to 30 deg., and using a roundnose tool, or leaving the rest set parallel, and forming the chamfer with a tool ground off to 30 deg. angle. Part off at ⅛-in. from the end; put the nuts on the pipe, press on the cones, silver-solder them—take care not to let any silver-solder get in the coned part!—quench in acid pickle, wash off, clean up, and attach the pipe as shown in the illustration.

Finally we have to fix a drive for the ratchet lever. This is operated from the eccentric already placed on the leading axle for that purpose. Machine up a strap for it, exactly as described for the feed pump eccentric strap, except that instead of having a flat rod, the boss is drilled No. 40 and tapped 5BA or ⅛-in. A fork or clevis is made from ¼-in. square steel, similar to the valve crosshead, only smaller, but by the same process; the slot should fit nicely over the end of the ratchet lever, and the pin made from a bit of 15 gauge spoke wire, screwed 9 BA at both ends and furnished with nuts. The stem or boss of the fork is tapped the same as the boss on the eccentric strap, and the two connected by a piece of ⅛-in. silver steel, screwed at both ends to suit. The fork should be adjusted on the rod, so that the ratchet clicks—one tooth at each revolution of the coupled wheels. This rate of feed is ample for the cylinders, yet not sufficient to blow the oil to waste up the chimney, and sprinkle the driver and passengers; a tankful of oil will last the engine for about three miles' running.

Boiler.

The "kettle," as it is facetiously known among certain enginemen, is of a type I schemed out nearly 20 years ago, after some experimenting, and is an exceedingly fast steamer. For beginners' benefit I might mention here, that it isn't "square inches of heating surface" in themselves, that makes a boiler steam; the vital thing is how much of the heat of the fire can be transferred to the water, and how quickly it can be done. A boiler with a long barrel, small firebox, and long tubes, even with a big grate and a large amount of "paper" heating surface, may prove an utter failure at maintaining pressure on the road; whilst a boiler similar in external dimensions, but with a smaller grate area and much less "paper" heating surface, might blow off all the time. Now there are two kinds of heat; radiant and conduction. Switch on a motor car headlamp and hold your hand in the ray. You feel heat instantly, though the lens through which the ray passes, is stone cold. That is radiant heat. Switch off the light, and take out the lamp bulb—mind you don't drop it, for it will be jolly hot! Well, that is conduction heat. One kind is radiated, so to speak, and the other is transmitted; something like radio and telephone.

The fire burning in a locomotive firebox gives off both kinds of heat. It is quite obvious that the firebox plates themselves, get the full benefit of both kinds, making the firebox the most valuable of the total heating surface of the boiler; but the tubes only get the heat conveyed by the hot gases, or products of combustion, coming off the fire. It is also plain to see that if the tubes are of considerable length, the farther ends of them are of little use for water heating, as the gases are cool by the time they reach that point. Enlarging the tubes, introduces another undesirable factor, as if the tubes are of large bore, each will contain a "core" of hot gases surrounded by cooler ones, all of which will be sucked into the smokebox and blown to waste up the chimney.

Ordinary common-sense reasoning will make it clear that in order to obtain maximum efficiency, a large firebox volume or capacity (which is a different thing altogether to an outsize in grates) combined with moderate tube length, is what is needed; and by adding a combustion chamber to an ordinary firebox in a long-barrelled boiler, you get both. Combustion chambers are a feature of most modern full-sized locomotive boilers with short wide fireboxes, which are usually shallow as well. They are not so essential with a narrow and deep firebox, as the upper part of this kind forms a combustion chamber in itself. An old locomotive superintendent of the London and North Western Railway, J. E. McConnell, fitted combustion chambers to some of his narrow-firebox engines way back in the eighteen-fifties; but he overdid it and made the tubes too short, in consequence of which, a great deal of heat was wasted up the chimney.

The combustion-chambers specified for my boilers, are longer in proportion than those on full-size locomotives; but you cannot "scale" Nature, for many reasons, and in my experiments I found that the best results were obtained with boilers in which the combined length of firebox and combustion chamber was about equal to the length of the tubes. As the irregular oval shape of the chamber was not self-supporting under pressure, like a round tube would have been, I adopted the "strut" system of staying; and instead of using rod struts inside the chamber, used tubes, and let the water get inside them. This added heating surface is the most valuable part of the boiler, and at the same time kept the water "on the move," as heated water always rises. The first boiler I made on this principle, had the water tubes sloping diagonally in alternate directions, but I found that placing them almost vertical, gave better steaming and also more support to the flattened crown of the chamber. I have built many boilers to this design; in fact seven of my own present fleet of locomotives have them, and all are absolutely O.K. in every respect. In the "Bantam Cock's" boiler, the sides and crown of the firebox, the upper part of the combustion chamber, and the back pair of water tubes, are all directly exposed to the radiant heat of the fire, whilst the conducted heat is absorbed by the rest of the chamber, the other water tubes, and the fire tubes and flues, leaving precious little to be blown out of the chimney. The superheater elements also get a share. The above should put all beginners, novices and tyros "wise" to the reason for the design.

Barrel and Wrapper.*

Unfortunately the firebox is just a weeny bit too deep for the barrel and wrapper to be made from a single piece of tube by the split-and-open-out method, so we shall have to use tube for the barrel, and sheet for the wrapper, or outer shell of the firebox. A piece of 16 gauge seamless copper tube 4¼-in. diameter and 12¾-in. long will be needed, and one end of this must be squared off in the lathe, or filed off square by hand. At 11½-in. from that end, make a sawcut halfway through the tube, using a fine-toothed saw, and keeping the cut at right angles to the tube at the starting-point of the cut. Then, from the opposite side of the diameter, make a slanting sawcut across the tube, to meet the one already made, on the "halfway line." The length of the tube at the bottom should be 12⅝-in., and its personal appearance as shown in the small detail illustration. The roughness left by the saw, can be smoothed off with a file.

A piece of 16 gauge sheet copper measuring 13¾-in. by 6⅜-in., will be required for the wrapper sheet. This is cut to the shape shown in the small detail sketch, and then bent to an arch shape, the curve at the top corresponding to the radius of the boiler barrel, and the "legs" straddling out to 5¼-in. wide at the bottom. Cut a strip of 16 gauge sheet copper ½-in. wide and about 6½-in. long; bend this into a half-circle, to fit inside the boiler barrel, and rivet it into the back end of same, the ends just coming to the sloping part, and leaving ¼-in. projecting. Now place the wrapper sheet over the "step" formed by barrel and strip, and rivet the lot in position; use 3/32-in. by 3/16-in. roundhead rivets at about ½-in. centres, the heads being inside, and the stems hammered down flush into countersunk holes on the outside. The holes should be a fairly tight fit for the rivets, which vary in diameter, according to the source of supply; those I use are just right in holes drilled with a No. 40 drill.

Throatplate.

The space below the barrel, at the front of the wrapper, is filled in by a piece of 3/32-in. or 13 gauge copper sheet, cut to shape and flanged at each side. These flanges should be wide, as shown, for the purpose of affording additional support to the side sheets of the wrapper, at a point where ordinary round stays would be difficult to fit, on account of the joints of the inside firebox. Cut a piece of 13 gauge sheet copper to the dimensions given in the detail illustration, and bend it over each side at right angles, as indicated by the dotted lines. On the full-sized engine, the sides of the wrapper are curved, but on the small one I have specified them straight, for ease of construction; there is nothing detrimental to the working or appearance of the engine, by using straight sides. As all the joints of the boiler are brazed, there is no need to form a flange around the curved part under the barrel; simply cut out the half-moon-shaped segment, and then fit the plate between the sides of the wrapper, making certain that the upper part of it butts up closely against the end of the barrel.

The flanges are then riveted to the sides of the wrapper by ¼-in. by 3/32-in. roundhead rivets at ½-in. centres, heads inside, and stems hammered down into countersunk holes in the wrapper sheet. The way I usually do this job, is to insert the plate, and hold it temporarily in place by a small toolmaker's cramp at the bottom of each flange, the cramp pinching the flange and wrapper sheet close together. Holes are drilled directly above the clamps, and rivets put in; two more holes are then drilled right at the top of the flanges, and rivets put in there. The clamps can then be removed, and the rest of the rivets put in. It is hardly necessary to add, that before any of the boiler joints are assembled, the metal should be thoroughly cleaned with rough emery-cloth or other abrasive, so as to ensure that the brazing material will run in and make a sound and perfectly steamtight joint.

The First Brazing Job.

It was amusing to read in some of the older books on so-called "model engineering"—a term I heartily detest—that boiler-brazing was "a very difficult job, which should only be undertaken by an experienced coppersmith," and that it was "impossible to do it at home, because of the equipment needed"; a blacksmith's forge being one of the requirements!! Well, we have learned a jolly lot since those days; and I say right here, without hesitation, that the rawest tyro or beginner can make an excellent job of brazing up a boiler, providing he follows a few simple instructions, and no elaborate outfit is needed. Heat you certainly want, and plenty of it; for "Bantam Cock's" boiler it requires either a five-pint paraffin blowlamp, or an equivalent air-gas blowpipe, unless the builder is one of those lucky folk who own, or have the use of oxy-coal or oxy-acetylene apparatus. About fourteen years ago I invested in an oxy-acetylene set (No. 2 "Alda") and it was one of the best labour—and perspiration!—saving devices I ever purchased; by its aid, all the joints of a copper locomotive boiler can be made easier than soldering up a tin toy boiler, and stronger than the material of the boiler itself. I will refer to the actual process later on; meanwhile, as at present most amateur locomotive-builders are restricted to the use of an ordinary blowpipe or blowlamp, I will describe how the boiler can be successfully made by that method.

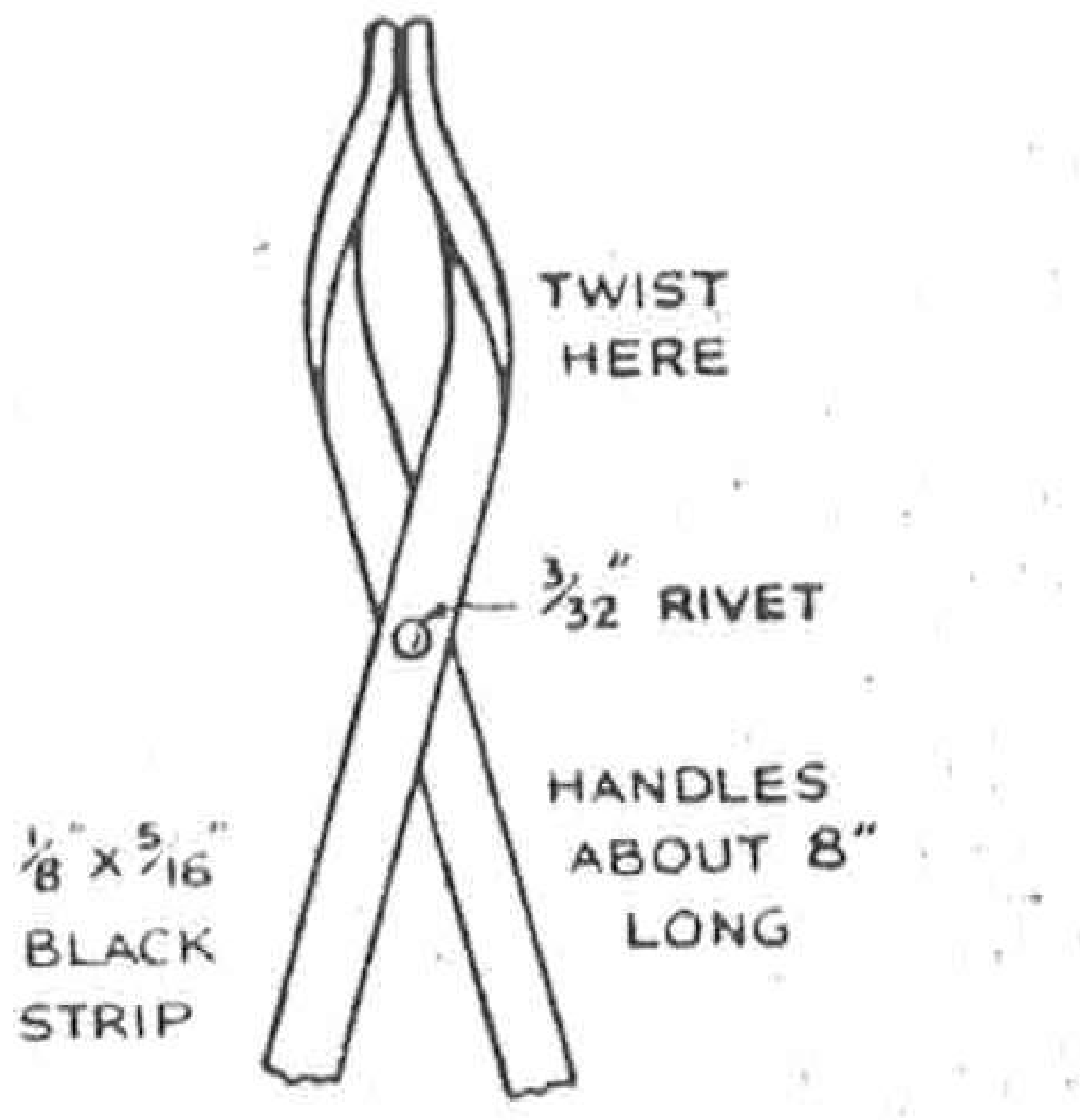
A simple iron tray will serve for a forge; it should be long enough to take the boiler, and the back edge should be higher than the front, say about 8-in. or so. My first "brazing forge" was a discarded iron teatray, donated by a sympathetic mother who encouraged my childhood efforts; and a piece of sheet iron, bent channel-shape, and stood up in the tray so that it enclosed three sides, retained the coke. Previous to that, I used a biscuit tin with one side cut away, and a one-pint blowlamp provided all the heat needed for my modest efforts at boilersmithing. The following "accessories" are also wanted, viz., some easy-running brazing strip, silver solder, flux, a scratching wire, large and small tongs, and a pickle bath. The easiest-running brazing strip that I know of is Johnson-Matthey's B6 alloy, which is really a coarse-grade silver solder, but runs very freely; whilst the best silver solder (used for the thin boiler tubes) is "Easyflo," made by the same people, who also supply suitable flux. Ordinary zinc-alloy brazing strip is also suitable, and much cheaper, though it requires more heat to make it run; and the best flux to use with this, is "Boron compo," which is sold in tins by most ironmongery stores.

Brazing the Boiler.

Ordinary best grade silver solder may be used for tubes, with powdered borax as flux. The scratching wire is simply a 2-ft. length of iron wire about 3/16-in.

The scratching wire is simply a two-foot length of iron wire about 3/16-in. diameter with a point at one end, the other being bent into a ring. The large tongs are similar to those used by a blacksmith, and are used for handling the hot boiler; whilst the small tongs can be made in five minutes from a couple of bits of 1/8-in. by 5/16-in. black steel strip, joined by a 3/32-in. rivet. They are used for holding short lengths of brazing strip, silver solder, and any small objects. The pickle-bath is a receptacle made of earthenware, or lead, big enough to hold the boiler, and contains a mixture of commercial sulphuric acid and water in the proportion of from 1 acid to 16 or 20 water. Old accumulator acid mixed with four times its bulk of water, serves the purpose equally well. Anything handy can be used for the bath or container; I know of a builder's foreman who used a piece of drain-pipe with a plug cemented into one end. My own pickle-bath was made by lining a wooden box of suitable size with sheet lead 1/16-in. thickness; there were no joins in the lead lining, the corners of which were simply folded in the same way as we used to make paper boxes when we were kiddies at school. In course of time, the wooden box rotted away by action of weather and acid, leaving the lead lining still doing its job, and it is still going strong at the time of writing, although it has been in use for 15 years; the 16 gauge metal has retained its shape and held the acid pickle although minus the physical support of the wooden box. When mixing, pour the water in first, and add the acid; don't on any account put the acid in first.

Now for the job. Stand the boiler shell in the pan or tray with the barrel pointing skywards, and pile small coke or breeze all around and inside the wrapper; outside almost to a level with the throatplate, inside about an inch below it. Mix up some of the flux to a creamy paste with water, and spread it along each flange, and around the junction between throatplate and barrel; also around the butt joint on the outside of the barrel, and along the butt strip inside. Get your blowlamp or blowpipe going good and strong; if a lamp is used, see that there is enough paraffin in it, because if it dies out on you when the brazing material is just running nicely, it will be just too bad, both for the boiler, and your peace of mind! Blow all around the joints, letting the flame play on the coke, so that it ignites, becomes incandescent, and helps the heating. When the throatplate and the lower part of the barrel reaches a red heat, concentrate the flame on one corner, and as soon as that reaches a very bright red for zinc-alloy brazing strip, or medium red for B6, apply the strip in the flame. A little will melt off the end and run into the joint. Now move the flame along a little way, and repeat operation; each application of brazing material should be made so that it slightly overlaps the previous one, and makes a continuous flow of metal into the joint. It takes a long time to write this, and a little time to read it; but with a good powerful blowlamp and properly-heated coke, it should take less to do it, the action being practically continuous. Once the boiler shell has been properly heated in the first place, it takes but little concentration of the lamp flame to bring it to the required temperature for melting the strip. Beginners should take special heed *that the strip must not be applied to the copper until same is hot enough to melt it;* otherwise the strip will melt off into little balls that will lie on the insufficiently-heated metal and become oxydised, so that when the metal eventually becomes hot enough to allow the molten balls of brazing material to flow into the joint, oxide, dirt and impurities go with it, so that the joint is not only porous but lacks mechanical strength, and has an "almond rock" appearance.



HOME-MADE SMALL TONGS

Using the above "technique," as they say in the classics, work your way right around the joint between barrel and throatplate, allowing sufficient brazing material to run in and form a fillet, and then go down the other flange. After that, grab the boiler shell with the brass tongs, and turn it over on its side. Blow on the outside of the barrel, over the butt strip, and run some brazing material into the joint between barrel and wrapper, turning the boiler shell over to do the other side. When you are satisfied that the brazing material has penetrated between the flanges and in the circumferential joint, let it cool to black; then pick it up with the big tongs and lower it carefully into the pickle-bath. Mind the splashes! Everywhere a drop lands on your overall or clothing, a hole will appear in a short time, so use a shield of some sort between yourself and the bath whenever you are pickling a brazing job. I use a discarded rubber lavatory mat; but stout paper will do at a pinch.

Should the boiler shell take a long time to heat up, the lamp flame is not powerful enough: the metal will blacken, and the flux paste will dry out and be partly blown away. To counteract this, pump the lamp a little harder, and when applying the strip, dip it into the flux before each application. When it melts, rub the pointed end of the scratching wire in the molten metal, which will nullify any oxidation of the surfaces and help the metal to flow. The scratching wire can also be used to break up any borax bubbles that may appear in the molten metal. When through, and the boiler has been put in the pickle, let it stay for about 15 minutes or so; then fish it out with the big tongs, wash well under the domestic tap to remove all traces of the pickle, and rub it up with a handful of steel wool, which will make it pleasant to handle. Dirty copper is not only unpleasant, but it is liable to cause skin trouble if allowed to come in contact with a freshly-made scratch or other small wound; and you can't be too careful!

I have fully detailed out the above process in response to requests from beginners; and as every brazing job on the boiler is done by the same method, there will be no need for repetition, and I will only call attention to special jobs such as the ends of the tubes.

Formers for Plate Flanging.

The two ends of the firebox, the backhead, and the tube plates for the end of the combustion chamber and the boiler barrel, all have to be flanged; and the flanges are knocked up over iron plates called "formers." I make mine from ¼-in. metal, and saw them out if small, but use an oxygen cutting blowpipe if large. Some folk use hardwood formers, but iron ones give better results, and they stand a lot more of what the railway shopmen in my time called "hammer-and-plonk." Those for the firebox and backhead can be made right away, as the firebox plates are the next job. The dimensions of the formers are given in the illustration, and plates flanged over them will fit the boiler. Mark out the dimensions on a suitable bit of ¼-in. steel or iron plate, scratch the outline, and dot it in with a centre-punch; when sawing, it is difficult to see the line, but the dots show up all right. When sawing, I use a high-speed sawblade with 18 teeth to the inch, and keep it well supplied with cutting oil, as used for turning steel. With slow strokes, about 60 per minute, and plenty of pressure, the blade will simply walk through the steel, without losing any teeth or becoming blunt. As an ordinary hacksaw blade won't cut around corners or sharp curves, you have to cut straight lines as near the curves as possible, and finish to outline by filing; but that wonderful and simple little gadget, the "Abrafile," will cut the