L.B.S.C.'s

3.1/2" G.

1,000 class

('County' 4-6-0)

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(TEXT ONLY)

A.J. REEVES & Co.(Birmingham) Ltd
HOLLY LANE, MARSTON GREEN,
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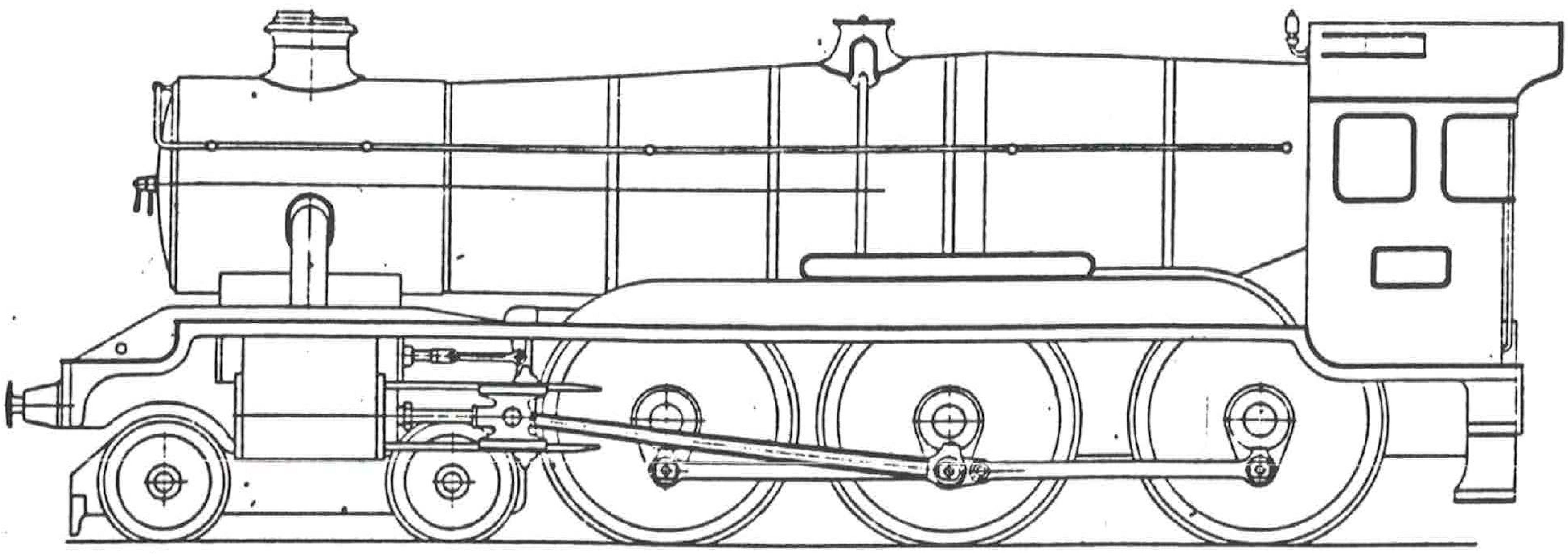
Building a 3½-in. Gauge "1,000" Class G.W.R. Locomotive

By

"L. B. S. C."



BEFORE going into details of construction of the above-mentioned engine, I would like to clear up a point that has been raised by novices and beginners, in practically every instance in which I have started to describe a small locomotive which is virtually a copy of its big sister. They say, "Why not reduce all the dimensions to a suitable scale, and make the little engine exactly the same as the full-sized one, instead of introducing various modifications?"

At first glance, this seems quite feasible; but the querists forget the one great obstacle, viz., that Nature cannot be "scaled." An engine running on a 3½-in. gauge is one-sixteenth the size of a similar engine running on a 4-ft. 8½-in. gauge; and if we made all the parts one-sixteenth of those on the big engine, she would be useless as a worker, and only fit to be exhibited in a glass case.

Engines for Work

I don't suppose one in a thousand of those who build the engines described in these notes, build them for "show" purposes, preferring to operate them under steam, and make them perform in the manner usually observed among their sisters on the full-sized railways, hauling living loads and doing other jobs in the everyday life of a railway engine; and a *working* engine, whether on 4-ft. 8½-in. gauge, or on 3½-in. gauge, *has to be designed and built for its job*. That is the rub!

To cite one or two instances, the frame plates of a full-size G.W.R. "1000" class engine are 1¼-in. in thickness, and are drilled with hundreds of holes for ½-in. and ⅝-in. bolts and rivets, whilst there are no less than eight cross stay plates or frame stiffeners. Now if reproduced in 3½-in. gauge, the frame plates would be only 5/64-in. in thickness, and the bolts and rivets would have shrunk below the size of domestic pins. With the most careful making and erecting, the frame would not stand up for the proverbial five minutes, to the strain of heavy passenger hauling; but the little bolts and rivets would either come loose or break, and the whole issue would bend, twist, and fall to pieces.

Again, if the boiler were made of "scale" thickness metal, and stayed with ditto staybolts, it would not be strong enough to carry a working pressure sufficient to pull anything like a commensurate load. Therefore, in designing and building a little locomotive intended for real work, we do, and yet do not, follow full-side practice, which sounds paradoxical and yet is the absolute truth.

When the Chief Mechanical Engineer of the Great Western Railway, Mr. F. W. Hawksworth, set out to design his fine machine, he knew exactly what loads she would be required to haul, what speeds would be needed, and the curves and gradients of the various routes she would travel over. He therefore produced a specification that would meet the needs. Your humble servant does exactly the same, thereby following full-size practice; but whilst the comparative *dimensions* of the big engine can be adhered to, the *construction* must be comparatively much heavier, because, in proportion to size the little engine has to work much harder than the big one.

Pulling Power

A full-sized passenger engine is seldom loaded to more than four times its own weight, but a small one frequently hauls fifteen or more times its own weight as a matter of course! One of my own locomotives hauls thirteen times its own weight at a speed equivalent to 140 miles per hour, which is an impossibility in full-size practice; can you imagine any big engine doing over two miles per minute with about a hundred coaches behind the tender?

Specificaiton

Now in getting out the specification for the 3½-in. gauge Great Western engine, I carefully studied the blue prints of the big sister, which were kindly supplied by Mr. Hawksworth, and, taking all the leading dimensions, made an outline drawing of the

little engine, which is, as far as measurements and appearances go, an exact copy of the big one. But the "works" are designed for the job! The frame plates are 1/8-in. steel, with buffer and drag beams of heavy steel angle, the whole assembly being stayed by a heavy cast bolster plate, a cross-stay carrying the valve gear rocker bearings, and two more behind the driving axle. The axleboxes are solid, running in cast bronze hornblocks, and spiral springs are used instead of leaf springs. The wheels have to be wider on tread than "scale," with deeper flanges, or the engine would neither stay on the road, nor traverse the curves usually found on small railways; such curves are seldom found in full size, even in colliery sidings, let alone on a main line like that of the G.W.R.!!

Cylinders

The cylinders are "scale" bore and stroke, viz., 1 1/8-in. x 1 7/8-in., but of comparatively heavier construction than full-size, being of bronze instead of iron, on account of corrosion troubles. They have proper piston valves, actuated by the full-size arrangement of valve gear, except for simplified joints and suspension brackets.

Externally, the boiler is "true Swindon" both in size and shape; but the plates of the shell and firebox, backhead, etc., are over three times the comparative thickness of those in the full-size locomotive, whilst the arrangement of tubes and super-heater are in accordance with what I have found most satisfactory in my long experience of locomotive building.

Boiler Feed

The boiler is fed by an injector and a pump; the latter, on the full-sized engine, is the vacuum-brake exhausting pump, but as we are not fitting a working vacuum brake, we might as well make the pump "earn its living" in a manner of speaking. Both gadgets put the water in the boiler via top feeds as in full size. The G.W.R. uses hydrostatic cylinder lubricators; I find mechanical lubricators the most satisfactory in the small size, so am specifying one in this case. The "trimmings" are all true G.W.R., and the little "1000" will, of course, be provided with the latest pattern of straight-sided tender. So much for generalities; now to actual construction.

Frames

For the frames, two pieces of steel plate, 2 3/4-in. wide, 1/8-in. in thickness, and approximately 27 1/2-in. long, will be needed. The best material is soft ductile steel, either blue or bright; don't use hard rolled bright, as it will buckle when the hornblock openings are cut out, and it will be impossible to keep it straight, owing to springing.

Mark off one plate, as shown in the illustration. The position of the holes at the ends, for the screws holding the frames to the beam angles, is not very important; they are the same both ends. The 3/16-in. hole on the sloping part is merely for taking a crane hook when lifting a full-sized engine, so that isn't important either. The holes for the cylinder studs should be about right, though 1/64-in. either way doesn't matter a bean; neither do the little holes in the bottom row. They are for the screws holding the bogie bolster, which is firmly secured by the lower cylinder studs passing through the flanges.

The little holes to the right of the cut-away at the top, are for screws holding the valve rocker brackets. The two holes between the leading and driving hornblock slots *are* important, as they locate parts of the valve gear. The countersunk holes just past the driving hornblock slot, are for the screws holding the frame stays in front of the firebox.

Frame Drilling

Drill a couple of the screwholes at the ends of one frame, then use it as a jig to drill similar holes in the other plate; temporarily rivet the two together, saw and file to outline given, and drill all the holes through both plates, after which they can be parted, and any burrs filed off. You won't mistake which is right and which is left-hand frames, as the countersinks are all on the outside. See that both plates are perfectly flat, and the ends square with top and bottom. Use a piece of 1-in. by 1/4-in. flat steel bar, as a gauge, when cutting out the hornblock slots and filing to size given.

Buffer and Drag Beams

Both beams are made from 1 1/4-in. by 1-in. by 1/8-in. steel angle. If this size is not available, use 1 1/4-in. by 1/8-in., and saw side. Square the ends to a dead length of 6 1/2-in.; if you cannot face off in the lathe, use a file, and check with try-square. The lower ends of the 1 1/4-in. side are rounded off as shown. Slots 1/8-in. wide and 7/8-in. deep are cut in the 1-in. side.

If you have a 1/8-in. slotting cutter, of a diameter large enough to cut a slot 7/8-in. deep, mount it on an arbor or spindle between lathe centres, clamp the beam under the slide-rest tool holder, parallel to lathe bed, and feed into the cutter, using a slow speed, and plenty of cutting oil. If only a thinner cutter is available, it may be used by taking two or more cuts for each slot; the frame plates should fit tightly in the slots. After milling them out, run the cutter in again 5/8-in. from each end of each beam; then, after removing the beams from the lathe, saw out the piece from each end, and smooth out the saw marks with a file, leaving the tops of the beams as shown in the drawing.

Buffer Beam Drilling

Drill the buffer beam for the buffer sockets, and cut the drawbar holes in both beams. To form the long one in the drag beam, drill a few 5/32-in. holes down the middle of the marked-out location, and run them into a slot with a rat-tail file, finishing off to given size and shape with a key-cutter's warding file. The hole in the buffer beam is drilled 1/8-in., and finished to given size with a small square file. Note that the holes in the buffer beam are below centre line.

For attaching the frames to the beams, four pieces of 3/4-in. by 1/8-in. angle, each 7/8-in. long, are riveted to the beams on the inner side of each slot, as shown in the plan view of the front end of frame assembly. Jam any odd bit of 1/8-in. steel plate into the slot, and place the bit of angle against it, holding in position with a toolmaker's cramp. Then drill four No. 30 holes clean through beam and angle, as shown in the illustration of the drag beam, which shows the angle by dotted lines. Countersink the holes on the outside of the beams, put in 1/8-in. iron rivets, and hammer them well down into the countersinks, filing flush on the outside of the beam. The bit of steel used as a gauge, can then be removed.

Hornblocks

The hornblocks are of the same type as specified for "Bantam Cock," and can be machined up the same way; an illustration of how to set them up and endmill them, using a vertical slide, was given in the serial about the engine mentioned. However, the castings I received were very clean; and all the "machining" they needed to fit them to the frame slots, were a few rubs with a file on the contact faces, to enable the flange around the jaws to fit in the openings in frame, and the hornblock to fit snugly against the frame. The feet or lugs of the hornblocks should project slightly below the bottom of the frame when first fitted.

Fit each hornblock carefully to its opening in the frame, hold in position with a toolmaker's cramp, and then drill seven No. 40 holes clean through hornblock and frame, countersinking on the outside. Put in 3/32-in. iron rivets, hammer well down into the countersinks, and file off flush outside frame, at the same time smoothing off any of the flange that projects.

Now temporarily bolt the frames together "inside out," with the hornblocks outside; then, with a big, flat, smooth file, clean out the jaws of each pair until a piece of steel bar 7/8-in. wide, used as a gauge, slides easily between the jaws without any side shake. File off all the bottoms of the lugs flush with frame, and that stage of the proceedings is complete.

The hornstays are fitted next; they are simply 1 1/2-in. lengths of 3/8-in. by 3/32-in. steel strip, drilled as shown in the illustration. Place each in position across the hornblock lugs, run a No. 30 drill through the end holes, making countersinks in the lugs, follow up with No. 40 drill, tap 1/8-in. or 5 B.A., and put the screws in. Hexagon heads look best, but any other kind will do.

How to Erect Frames

Be mighty careful about this job, as everything depends on the correctness of the frame erection; if untrue, the position of cylinders, valve gear, etc., will be all out, and will seriously affect the working of the engine. Jam the frames into the slots in the beams, and set the whole as true as you can "by eye"; then stand the assembly upside-down on the lathe bed, or anything else that is absolutely flat. Both plates should be in contact with the flat surface for the full length, without any rock whatever; the beams should be square with the frames, and each end of each beam should stand exactly 1-in. from the flat surface. When all these ambitions are fulfilled, put a toolmaker's cramp over each angle, holding it tightly to the frame; run a No. 30 drill through the screwholes in frame, making countersinks on the angle; follow through with No. 40, tap 1/8-in. or 5 B.A., and put the screws in. The frame should now be rigid, true and square. If preferred, the angles can be dispensed with, and the frames brazed or Sifbronzed direct into the slots.

Frame Stays

There are two of these, fitted just behind the driving axle, as on the full-sized engine. Most of my designs incorporate an eccentric-driven pump, the support for which forms the frame stay; but as this engine has no eccentric-driven pump, we fit a couple of the full-sized engine's type of stay in lieu. They may either be castings, or pieces of 1-in. by 1/8-in. steel, squared off to a dead length of 2 7/8-in., with a 1-in. length of 5/16-in. by 3/32-in. angle (any metal will do) riveted to each end. The small detail illustration showing the frame assembly at the driving axle, shows how they are fitted; the lower one is set with its angles touching the hornblock. The upper one is set "on the skew," the top being 11/16-in. behind the centre of the hornblock. Both are secured by 1/8-in. or 5 B.A. countersunk screws put through the holes already drilled in the frame, into tapped holes in the end angles of the stays.

Bogie Bolster

The bogie bolster will be available as a casting; or it may be built up. If cast, a chucking piece will be provided in line with the bogie pivot pin; and if this is held in the three-jaw, the pin may be turned to the given size, and the underside of the bolster faced off truly at the same setting. Note, there is no circular boss; a separate rubbing plate will be provided. The extreme end of the pin is reduced to 3/16-in. diameter and screwed 3/16-in. by 40 for the retaining nut. The chucking piece may then be sawn off and the stump filed flush with the casting.

The side flanges, which fit between the frames, must be milled or filed to 2 7/8-in. overall width. They can be endmilled with a 1/2-in. endmill or slot drill held in the three-jaw, if the casting is clamped under the slide-rest tool-holder, or bolted to a vertical slide.

Alternatively, the casting could be held in a machine-vice on the lathe saddle, and the flanges cleaned off by a circular end-and-side cutter mounted on a spindle between lathe centres. These processes have been fully described, with illustrations, when dealing with previous engines in this series.

If a regular milling machine is available, the job is as easy as eating pie, all that is needed being to catch the casting in the machine-vice on the miller table, and traverse it under an end-and-side cutter on the arbor, which is how I do it myself. If no machining facilities are available, a flat file judiciously applied to each flange, will do the trick with a little patience and perseverance. The file was my only method of doing jobs like these, in the days before I acquired the workshop you recently saw illustrated in these pages!

Built-up Bolster

It is easy enough to build up a bolster, and no milling is required. The bolster plate is a piece of 1/8-in. steel, 3 1/8-in. long and 2 1/4-in. wide; it must have right-angled corners. At 1/8-in. from each short side, rivet a 2 1/4-in. length of 1/2-in. by 1/8-in. angle, using 3/32-in. iron rivets, as shown in the sectional illustration; file these off flush underneath. Drill a 5/16-in. hole in the middle. For the bogie pin, chuck a piece of 3/8-in. round steel rod in the three-jaw; turn down 1/4-in. of it to 3/16-in. diameter, screw 3/16-in. by 40, and part off 7/8-in. from the end. Reverse in chuck, turn 3/8-in. of the other end down to 5/16-in. diameter, screw 5/16-in. by 32, poke it through the hole in the bolster plate, and secure it with a home-made nut.

The complete bolster goes up between the frames below the position of the cylinders, the flanges covering the lower row of cylinder stud holes. Fix it in place with three 3/32-in. or 7 B.A. countersunk screws at each side, put through the little holes between the cylinder stud holes; then put the 3/16-in. drill through the four cylinder stud holes, and drill corresponding holes through the bolster flanges. Note, the distance from the end of the frame (back of buffer beam) to centre of bogie pin, is 4 7/16-in.

Axleboxes

The axleboxes are made from 1-in. by ½-in. bronze bar, either cast or drawn. If that isn't available, steel or brass can be used, but it will need bushing.

Failing the use of a milling machine for the side grooves, the lathe can be used, with a ⅜-in. endmill or slot drill in the three-jaw, and the piece of metal clamped on its side under the slide-rest tool-holder, at right angles to the bed. If your cross-slide hasn't sufficient movement to do the whole bar at one fell swoop, use two pieces of bar, each about 3¼-in. long, sufficient for three axleboxes The grooves can also be machined on a planer or shaper.

Set your slide gauge to ⅞-in., the width of the hornblock jaws, and machine the grooves so that this fits tightly; each axlebox should be fitted to its own hornblock, and marked, so that when taken out, all the boxes can be replaced correctly. After grooving, if a cast bar is used, it will need smoothing off on the faces. Each piece of bar can then be chucked in the four-jaw, and the 1-in. lengths parted off it.

Alternatively, the lengths may be sawn off, to a shade over correct length, and then squared off to dead length in the four-jaw. Mark the horns on the right-hand frame, 1, 2 and 3, and those on the left, 4, 5 and 6; fit the boxes, filing the grooves, if necessary, to an easy sliding fit, and mark them to correspond. A set of little figure punches are cheap and very handy; I have four sets of different sizes. Don't forget the boxes should slide easily up and down the slots, and should have no end movement, but should be able to tilt, or move slightly from side to side, to allow for bad places in the track, low joints, crossing frogs and so on.

Drilling Axleboxes

Now mark the centres of boxes, 1, 2 and 3, and drill a ⅛-in. hole through each, either on a drilling machine or lathe, as the holes must go through true and square. Clamp boxes 1 and 4, 2 and 5, and 3 and 6 together, exactly in line all ways; and, using the hole already drilled as guide, drill the second box. Put the whole lot back in the frame, and poke a piece of ⅛-in. silver steel wire through each pair of boxes. The wires should be exactly parallel, and at right angles to the frames. If they aren't, correct the offenders with a rat-tail file, open out the holes with a little larger drill, and try again with a thicker wire to suit. When all are O.K., open out all the holes with a 31/64-in. drill, but don't ream yet. Drill a little countersunk hole in the top of each box for oil, replace in frames, and put the hornstays on.

Wedge each box against the hornstay with a bit of wood or metal between it and the top of the hornblock. Run the No. 30 drill through the centre holes in the hornstay, make countersinks on the bottom of the axlebox, follow with No. 40, and tap ⅛-in. or 5 B.A. The spring pins are 1 7/16-in. lengths of ⅛-in. round silver steel, screwed for 3/16-in. length at one end, and ¼-in. the other, same thread as you tapped the axleboxes. Screw them home through the holes in the hornstays, and see the boxes work freely up and down, when the pins are right home. The springs are wound up from 20 or 19 gauge tinned steel wire; the retaining plates are merely strips of ¼-in. by 3/32-in. steel, drilled No. 30 at ½-in. centres and rounded off at the ends; they are secured by ordinary commercial steel nuts.

Reaming

When all are complete, poke a ½-in. parallel reamer through each pair of boxes; and whilst turning it, work the boxes up and down the hornblocks, thus ensuring that the axles will be perfectly free to revolve, when the engine is running fast over an uneven road, or through a maze of junction points and crossings.

Coupled Wheels

The coupled wheels are slightly different to those we have hitherto used, having a projecting boss on the "pear," as in full-size G.W.R. practice. The machining is, however, carried out in exactly the same way. Chuck the casting by the tread, back outwards, in three-jaw, and set to run truly.

If your three-jaw isn't big enough, you'll have to mount the wheel on the faceplate. Put three bits of parallel wood packing between faceplate and wheel, and hold it by three bolts between the spokes. Face off the back boss; centre, and drill about 3/16-in., then open out with a 27/64-in. drill, finishing with a 7/16-in. reamer. Face off the back of the flange; note that this and the boss have to be finished level. Take a truing-up cut off the flange itself.

Reverse the wheel in the chuck, turn up the boss, and face the front of the rim. Note when turning the boss, that the circular part is 1 1/16-in. diameter, with a rounded edge, and projects 3/32-in. beyond the rim. The "pear" is cut back to within 1/16-in. of the rim.

If you are using the faceplate, locate the wheel truly by turning a piece of steel to fit the centre hole in the mandrel; then insert it, and turn down the bit projecting through the faceplate, until the hole in the wheel boss will just slip on nicely without any shake. Put the wheel over it, and clamp it to the faceplate by bolts and wood packing, as mentioned above. The same set-up will do for finish-turning the treads and flanges.

If you are using a chuck, rig up a special faceplate for the job, by chucking an old wheel, or anything circular, a little less i diameter than the finished wheel. Face truly, recess the centre slightly for about 1½-in. diameter, then centre, drill 9/16-in. and tap any fine thread to suit. Screw in a piece of steel rod, leaving about 1-in. projecting. Turn this down until the hole in the wheel boss will just slip on; screw the end, and fit a nut. Each wheel is then placed on this stub, and the nut tightened, which holds the wheel tightly against the truly-faced plate. Using slow speed and a round-nose tool, rather pointed, with a good tap rake, turn each tread and flange to about 1/64-in. over size. When the last one is on the stub and has been rough-turned, regrind the tool, and finish the tread to size. Then, *without shifting the cross-slide*, put all the rest of the wheels on, and take a cut over each tread. They will then be all exactly the same size, and the coupling-rods will not bind or drag when they are fitted.

The flanges can be turned the same way, and rounded off with a file whilst the lathe is running; the slight chamfer at the edge of the tread can be either tooled or filed, as you prefer. Note.—I have shown the treads parallel or cylindrical, not coned, as

I find this kind runs much easier around the curves found on the usual small railway, which is in accordance with the results obtained in Sir W. Stanier's experiments on the L.M.S.

Drilling Crank-pin Holes

The holes for the crank-pins are drilled by means of a simple jig. Get a piece of bar about 3/4-in. by 1/4-in. section, any length over 2-in., and make two centrepops on it 15/16-in. apart; drill one 13/64-in. and the other 27/64-in. Chuck a stub of 7/16-in. round rod, and take a weeny skim off it, so that it just slides into the 7/16-in. holes in the wheel bosses without shake. Reverse in chuck, and skim the other end to a squeeze fit in the 27/64-in. hole in the jig; then squeeze it in. To use, put the peg into the hole in the wheel boss; adjust until the 13/64-in. hole is in the centre of the "pear," and clamp it there. Put the 13/64-in. drill through the lot; remove jig, and ream the hole in the wheel boss 7/32-in.

Leading Bogie

It is strange, yet true, that certain methods of construction described and illustrated in your humble servant's notes, have been later incorporated in full-sized locomotives.

To quote but two examples: when I described how to build a 2½-in. gauge "Princess Royal" in this journal, I specified a boiler with combustion chamber, and two sets of gear only, operating the inside valves by a simple rocker gear. Over a year afterwards, the L.M.S. started to fit combustion chambers and valve rockers to the full-sized engines. When I described how to build a G.W.R. "Grange" class engine in a contemporary journal, the Swindon product had a bar-framed bogie, and the main frames only extended to the rear of the cylinders, which were cast in one with the smokebox saddle. Instead of that, I specified full-length frames, a plate-framed bogie, and separate cylinders and saddle. About three years afterwards, the G.W.R. switched over to the very things I had specified for the little "Grange," and the design is perpetuated in the "1000" class; so we will now proceed with the construction of the plate-framed bogie.

This is a simple and sturdy component, and can be made in three different ways, using either cast centre, or plate centre angled and riveted, or all brazed. The two frame plates are the same in each case; and to make them you need two pieces of 1/8-in. steel plate, each 8½-ins. long and 1⅜-ins. wide.

Proceed exactly as in the case of the engine frames, marking one out, drilling the screwholes, then temporarily riveting or bolting it to the second plate, so that the two can be sawn and filed to outline, and the holes drilled in the second plate, using the first as a jig or guide. The axlebox openings on the full-sized engine are cut right to the bottom of the frame plates, and separate hornstays are bolted on; but there is no need for this on the little one, as the wheels can be erected after the axleboxes have been fitted, saving labour and simplifying the job. Note when drilling: make up your mind which form of construction you will use, because if the bogie is built with a cast centrepiece, same is attached by nine 6 B.A. screws through each bogie frame. If you use a plate centre, fixed by angles, screws and rivets, five holes only will be needed in each frame, instead of the nine shown in the illustration, and they are drilled No. 30 instead of No. 34. If you are going to braze or Sifbronze the bogie frame assembly, you won't need any screw or rivet holes at all, for the centrepiece or the two end stays; they will only be needed for the hornchecks and spring brackets.

Cutting Axlebox Openings

About the easiest way to cut out the openings for the axleboxes, is to drill a 3/16-in. hole near one corner of the marked-out space, and put an "Abrafile" through it. The way these magic bits of wire walk through steel plate is an eye-opener to the uninitiated; I've no shares in the company, but use them myself, and pass on the tip as useful. The "Abrafile" naturally leaves the corners rounded; but the application of an ordinary square file will soon alter that. Use a piece of 3/4-in. square bar as a gauge; it should fit between the sides of the openings easily, but without shake.

Riveting

When all is O.K., part the two frames, and file off any burrs; then rivet a 7/8-in. length of 3/8-in. x 3/32-in. angle, at each side of each opening, on what will be the inside of the frame. Use 3/32-in. charcoal-iron rivets if you can get them; failing that, use brass rivets. Copper rivets should only be used for framework jobs, when nothing else is available, as they have a tendency to work loose. My pet way of riveting the hornchecks on, is first to drill all the rivet holes in them, and clean off any burring left by the drill. Then I put my bit of gauge-steel in the axlebox hole, jam the piece of angle forming the horncheek against it, hold it temporarily in place with a toolmaker's cramp, drill the rivet holes in the frame, using them in the angle as guide or jig, countersink them on the outside of the frame, and put the rivets in. By putting the piece of bar used as a gauge, in the axlebox openings, and setting the brass hornchecks to it, you automatically get the space between the hornchecks right, and no filing or any other machinery is needed.

The guard irons might as well be got all ready at this stage; they are merely bits of 3/32-in. steel filed to the shape shown in the illustrations, and riveted to the outside of the frame at the lower front corner, when the end stays are fitted. They are bent so as to come exactly over the running rails when the bogie is erected; see plan view.

Axleboxes and Spring Brackets

The axleboxes are easier to make and fit than those in the engine frames, having only one flange and no spring pins. The same remarks apply as to choice of material; our advertisers will be able to supply suitable sticks of metal of the proper quality and section. Drawn gunmetal or bronze rod, or good quality hard brass, can also be used, the section required being 9/16-in. x 7/8-in., or nearest size larger that may be available. A piece about 3-ins. long, will make the four boxes. Whether cast or drawn, the *modus operandi* is the same as described for the main frame boxes; the rebate at each side is formed by milling, planing, or filing, so that the reduced part fits nicely between the hornchecks, sliding easily but without shake.

The boxes can be parted off the stick by holding the latter in the four-jaw and using a parting tool, or they may be sawn off, chucked separately, and truly faced at each end. Mark off two of them for the axle holes, drill these first, and use them as a guide to drill their "opposite mates," as described for the main boxes. A 1/16-in. oil-hole is drilled diagonally from the top of the flanged end, into the bore, the end being countersunk, which enables the journals to be oiled by poking the spout of a small squirt feeder between the spokes of the bogie wheels.

Spring Pockets

Each spring is carried in a pocket drilled in a bracket screwed to the bogie frame exactly above the axlebox. These brackets may also be cast, or made from ⅜-in. square bar, any metal being suitable, as there is no wear. If bar is used, part off four 1¼-in. lengths, and file them up to the shape shown in the underside view; drill the spring pocket with 7/32-in. drill, to a depth of 5/16-in. Each bracket is then placed centrally over the axlebox opening, 1/16-in. above the horncheeks, and temporarily held with a toolmaker's cramp. Make two countersinks on it by putting a No. 30 drill through the holes in the frame; follow with No. 40, and tap ⅛-in. or 5 B.A., securing the bracket with countersunk screws as shown.

How to Erect the Frames

If a casting is used for the centre-piece, it must first be machined on both sides, which can be done by milling, planing or filing. If a regular milling machine is not available, the lathe can be used, by clamping the casting under the slide-rest tool-holder, with the side to be machined, at right angles to the bed, and traversing the job across an endmill, or home-made slot drill, held in the three-jaw chuck.

In the days before I had a milling machine, I did all the necessary drilling on the lathe, using a vertical slide and a small machine-vice as aids to setting up the work, and making my own cutters from silver-steel of suitable size.

Slot Drills

These have been illustrated in notes dealing with other engines; for beginners' and new readers' benefit, I will briefly repeat that a slot drill—which serves the purpose of a commercial endmill—is easily made in a matter of minutes. Merely file the end of the steel like a screwdriver, leaving the tip about 1/16-in. wide; make a nick about 1/16-in. wide and deep in the middle, and back off the cutting edge each side of the nick. Harden and temper to dark yellow, and you are all set. These little home-made cutters leave a good finished surface; they cut more freely than commercial endmills, never choke, and cost next to nothing.

To set up work at right angles to the bed, I put the faceplate on the mandrel nose, ran the slide-rest up to the faceplate, set the work so that it touched the faceplate, and then tightened the clamps. The faceplate was then removed, cutter inserted, and away we went on the job. Simple, but effective!

Facing the Centre Casting

THE top of the centre casting should be raised slightly in the middle, and the raised part should be machined off truly; or the whole of the top surface may be faced off, and a rubbing washer or plate placed between the bogie centre and the bolster.

Either job can be done by chucking the casting in the four-jaw, and using a round-nose tool set crosswise in the rest. The ends of the casting must be filed or milled, so that the overhanging flange at the top, fits exactly into the recess in the upper edge of the bogie frame. The slot for the bogie pin, which will be cored in the casting, may be cleaned out with a file, or endmilled if a vertical slide is available. Simply bolt the casting to the slide, set the slot level with lathe centres, put a ⅜-in. endmill in the three-jaw, feed the work on to it with the top slide, and traverse across with the cross slide. A slight adjustment of the vertical slide, up and down, when taking the final cuts, will give the necessary extra width of slot, to enable it to work freely on the bogie pin. When the machining is finished, place a bogie frame at each side, see both frames are parallel all ways, hold temporarily with a cramp, run No. 34 drill into the holes in frame, making countersinks, follow with No. 44, tap 6 B.A. and fix with roundhead screws.

Erecting with Plate Centre

For this form of construction, a piece of ⅛-in. steel plate, 3¼-ins. long and 2¼-ins. wide, is needed. A round-ended slot 1½-ins. long and ⅜-in. full width, is cut in the middle for the bogie pin to slide in; and the easiest way of doing this, is to drill a ⅜-in. hole at each end, another in the middle, and get the "Abrafile" on the job again, to remove the unwanted pieces of metal in between, afterwards cleaning up with an ordinary file. To erect with angles, rivets, and screws, cut two pieces of ½-in. x ⅛-in. angle, either brass or steel, each 2¼-ins. long, and rivet them to the shorter sides of the plate, ⅛-in. from the edge. Use 3/32-in. rivets, charcoal iron for preference, countersunk at top as shown in the sectional illustration, as the top of the centre plate must be perfectly smooth. Put a bogie frame at each side of the plate, the edges of the plate overhanging the angles, fitting into the recesses in the bogie frame, and the angles themselves going between the frames see cross section, left-hand side. As beforementioned, a single row of No. 30 holes takes the place of the double row of No. 34 shown in the elevation sketch; and countersinks should be made on the angles by a No. 30 drill put through these. Follow with No. 40, tap ⅛-in. or 5 B.A., and secure with roundhead screws.

Stiffening or Tie Plates

The bogie on the full-sized engine has a stiffening plate at each end of the frame, so we fit similar plates in the same way. Each plate is formed of a piece of 3/32-in. steel, 1-in. wide, and 2⅞-ins. long, to fit exactly between the frames at each end. Pieces of ¼-in. x 1/16-in. angle, 1-in. long, are riveted to each end of each plate, flush with the ends, using 1/16-in. iron or brass roundhead rivets; then each plate is placed between the bogie frames, with the angles outwards, and flush with the ends of the frames; see plan view. The holes already drilled in the frames, locate the holes for the rivets in the angles; hold in position with a cramp at each side, put the 51 drill through the lot, and fix with 1/16-in. rivets. The lower rivets in the front plate pass through the guard irons as well, and thus serve a double purpose, keeping the guard irons on, as well as securing the stiffening plates. The above arrangement is used both for the bogie with cast centre, and plate centre fixed with angles.

"Fabricated" Bogie

Many locomotive components, especially on the L.M.S., are now made by welded plate, bar and angle, in preference to riveted joints, and castings; so, if you so desire, you can build up the bogie by bronze-welding or brazing. In that case, the horncheeks and spring brackets should not be attached to the bogie frames until after they are assembled. About the easiest way to hold the frames in position—that is, at the right distance apart, and parallel to each other—is to use a couple of bits of gas barrel as spacers. Square off to a length of $2\frac{7}{8}$-ins. in the lathe, which is the work of a few minutes only; then put them between the frames at the axlebox openings, with a piece of $\frac{1}{4}$-in. rod through the lot, and a nut and washer on each end, clamping the frames tightly to the spacers, and making sure both frames are in line. Make the slotted centre plate as described above, then jam it in the recesses at the top of each frame. The two stiffener plates won't need any angles attached to them; they are cut to the sizes previously given, and jammed between the frames $\frac{1}{4}$-in. from each end. The whole lot can then be brazed up at one heat; if using a blowlamp or air-gas blowpipe, use Boron compo as flux, mixed to a paste with water, and a bit of ordinary soft brass wire as brazing spelter. This will make a nice fillet in each joint. Simply heat to bright red, and then apply the wire when the flux has fused.

If an oxy-acetylene blowpipe is available, the job is actually easier than soft soldering. Mix up some Sifbronze flux to a paste with water, and apply it to the joints. Use a 100 or 150-litre tip in the blowpipe, with the gas pressure adjusted for a silent flame; then apply it to one end of the joint. As soon as the metal glows bright red, drop a spot of Sifbronze, melted off the end of a $\frac{1}{16}$-in. rod, on it; then gradually work along the joint, dropping the little blobs of Sifbronze in. They will run together and form a smooth, even fillet, unlike the rippled fillet they form on copper, which conducts away the heat much quicker than the steel. Always work away from you, so that the tip of the flame is ahead of the actual "scene of operations," so to speak, as the advancing flame kind of pre-heats the work, and the hottest part of the flame has very little to do, to bring the metal to the melting point of the Sifbronze.

Whether the job is done by either of the above methods, let cool until any redness has died away, then quench in water (not acid pickle for steel), clean off all the burnt flux, and should you have left any lumpy places, file them off. The horncheeks and spring brackets can then be attached, as previously described.

Wheels and Axles

The four bogie wheels are $2\frac{1}{4}$-in. diameter on tread, with $\frac{1}{16}$-in. flanges $\frac{1}{8}$-in. deep, and a boss $\frac{1}{16}$-in. proud of the wheel rims. They are turned in exactly the same manner as the coupled wheels, so there is no need to repeat the instructions; and the same applies to the axles, which are turned from $\frac{1}{4}$-in. steel rod, ground for preference, though the ordinary drawn stuff will do if nothing better is available. Press one wheel on each axle; then turn the bogie upside-down on the bench, and drop a little spiral spring in each pocket in the brackets. These springs can be wound up in the lathe—I have described the simple process several times—over a piece of rod held in the chuck, a little over $\frac{5}{32}$-in. diameter, so that the finished spring is an easy fit in the pocket. Use 20 gauge tinned steel wire, and after snipping the spring off to full length, touch each end on a fast-running emery wheel, to square it off. The springs should just be coming into compression when the axlebox is at the bottom of the slot. Insert the axleboxes, taking care the oil hole is at the top when the bogie is right way up; poke the bogie axles through the boxes, and press the other wheel on each axle. The whole issue should run perfectly freely if given a push, and the wheels should run truly without wobble.

If the plate centre is used, or if a cast centre has had its top surface machined all over, a rubbing plate $\frac{1}{32}$-in. in thickness will be needed between the bogie and the bolster on the main frames. This is merely a circle of $\frac{1}{32}$-in. (22 gauge) sheet brass, with a $\frac{3}{8}$-in. clearing hole in the middle. To attach the bogie to the engine, merely slip it over the bogie pin, and secure with a nut and washer. When the washer is tight up against the shoulder on the bogie pin, the bogie should have about $\frac{1}{32}$-in. vertical play, and be free to swing easily from side to side. For the ordinary garden lines, no side control is necessary, as the weight of the engine front end, bearing on the big rubbing plate, sets up enough friction to prevent any side movement, or "hunting" or "nosing," as enginemen call it. The 2-4-0 tank engines on the Isle of Man Railway, which have a long uncontrolled pony truck, rely on friction to prevent side oscillation, and it works very well.

If anybody wished to operate the little "1000" on a very long straight road at high speed, all that would be necessary, would be to drill a $\frac{1}{4}$-in. hole from each side of the bogie, into the centre slot of a cast-centre bogie, and put a light spring each side to bear on the bogie pin, closing the ends of the holes with screwed plugs. A sliding block could, of course, be fitted, but on a little engine intended for work and not show (your humble servant has no use for "models"), it is an unnecessary refinement, as the pin working in a slot direct, is not only simpler, but stronger. The pin would have to be much more fragile, to allow room for the block; and if the engine should happen to hit an obstruction, or derail and bump over the sleepers, a fragile pin would either shear or bend, with consequent damage to the engine.

FOUR eccentrics are required, and these are turned from mild steel bar; a piece of $1\frac{1}{4}$-in. cold-rolled steel shafting is about the best, as it turns easily and resists wear. Chuck in three-jaw and face the end; the tool will indicate the true centre of the piece very plainly, which is a great help when setting out the location of the axle hole. Next, with a parting tool, cut a groove $\frac{1}{16}$-in. deep, $\frac{3}{64}$-in. from the end, after which take two or more overlapping cuts until the groove is $\frac{7}{32}$-in. wide. The bottom is then smoothed off by running the tool along it without advancing it any more into cut.

Tip for beginners: if you use a slow speed and plenty of cutting-oil (I find that one part ordinary paraffin oil to two parts of "Vacmul" or "Houghtolard" gives the best results) and keep the tool sharp, you won't have any trouble through the tool chattering, and the bottom of the groove will be smooth. Part off at a full $\frac{1}{4}$-in. from the end. If the tool is set at centre height, and the speed and feed are right, there will be no chattering, but the cutting will come off the work like a closely-coiled watch spring, with a sound just like bacon frying, and a smell that is nothing at all like it! Parting-off is a job that worries most small lathe users, but there is no reason why it should. Most beginners run their lathes much too fast. If the lathe is undersized or shaky, bring up the tailstock to support the work, making a small centre-hole in the end of the steel bar, in which the tailstock centre can run. This will be cut out when the eccentric is drilled for the axle.

An alternative way of doing the job would be to mount a piece of 1¼-in. steel shafting about 3-ins. long, between centres, and turn the four grooves at the one setting, parting off between each eccentric to a little over half-way through the bar. The four eccentrics could then be cut completely off with a hacksaw, and mounted separately in the three-jaw to face off the sawn portion truly.

It is essential that the axle hole be absolutely true and square, otherwise the eccentric will wobble sideways instead of up and down only, and the valve gear will rapidly wear, besides giving bad steam distribution; and the best way for beginners and inexperienced workers to ensure this is to drill the eccentrics in the lathe, and finish them with a boring tool. As mentioned above, the facing tool will indicate the true centre on each; at 7/32-in. from this, make a heavy centre pop, and then chuck the eccentric in the four-jaw with the pop mark running truly. First, put a ⅛-in. or No. 30 drill through, holding it in the tailstock chuck; follow up with 15/32-in. Then put a small boring tool in the slide-rest, and carefully bore the hole until the driving axle will just push into it by finger pressure. A drive fit is not required, as the eccentrics must be adjustable; but they must on no account be slack on the axle.

The bosses at the side of the groove are turned with the eccentric on a mandrel. Chuck a stub of ⅝-in. rod in the three-jaw, and turn about ⅝-in. length of the end until it will drive into the hole in the eccentric, plain end outward. Rechuck the bit of rod with the eccentric on it, and turn the end to form a boss 13/16-in. diameter and 3/16-in. wide, as shown in the illustration. Knock the eccentric off the mandrel, drill a No. 40 hole in the boss, tap ⅛-in. or 5 B.A. for a setscrew, and the eccentrics are complete.

How to Erect Driving Axle

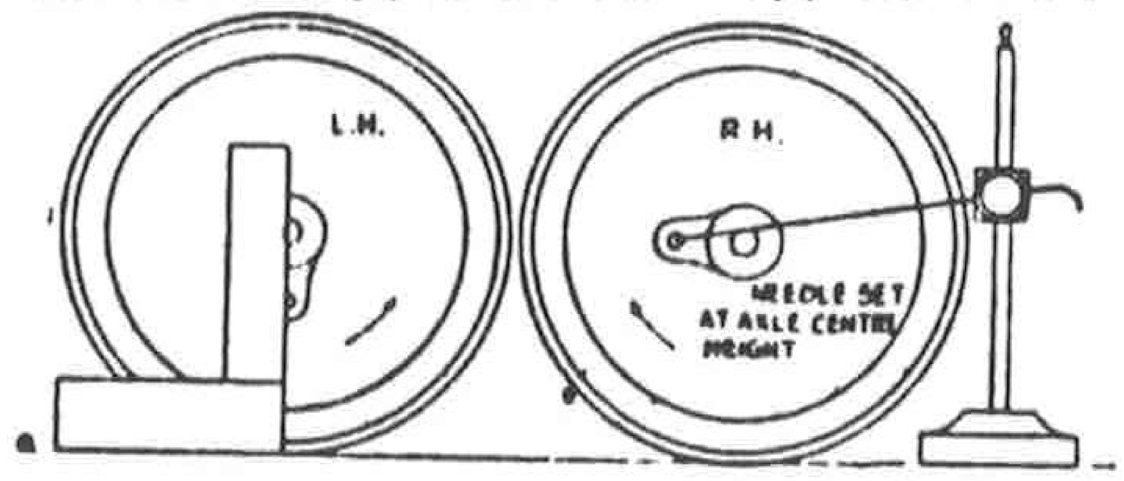
Press one driving wheel on the axle, and put it through one of the axleboxes, then thread on the four eccentrics; the first with the boss next the axlebox, then the next with the boss towards the middle of the axle; then another, boss first, and finally the fourth, boss outwards. Push the end of the axle through the other axlebox, and put the other driving wheel on as far as you can by hand.

This method of assembly completely eliminates any chance of error, either of eccentrics or axleboxes; it is far easier than one might imagine, to get them on wrong way about, and find it out after pressing the other driving wheel right home! Remove the whole assembly from the frame, by taking out the hornstay screws, and set the cranks at right angles; the wheels can then be pressed home. For beginners' benefit, I have included a small illustration showing how the crank setting can easily be checked.

Stand the wheels on something level, such as the lathe bed, with a little block each side of one wheel, so that they will not roll; then set a try-square against the left-hand wheel, the edge of the blade passing across wheel and crankpin centres. Set the needle of a scribing block to the centre of the axle on the other side, and adjust the wheel until the crankpin centre is at the same height, as indicated by the needle in the illustration. When the two wheels are in the positions shown *at the same time*, the cranks are correctly set; the wheel can be pressed right home, and the whole assembly replaced in the frames.

Coupling Rods

For the leading halves of the rods, two pieces of ¾-in. by ¼-in. mild steel bar, a little over 6½-ins. long, will be needed. On one of these, mark the outline of the front section of the rod; centre-pop the bosses, and drill a ⅛-in. hole at each point. Use this rod as a jig to drill its "opposite mate,"



HOW TO QUARTER WHEELS

then temporarily fix the two together by a couple of ⅛-in. rivets through the holes; bits of wire driven in will do quite well. The two front halves can then be milled, or sawn and filed, to the outline.

Anybody who owns, or has the use of a regular milling machine, won't need any detailed instructions on how to do this job; all I do, is simply to grip the pieces in the machine-vice on my miller table, put a 2-in. slabbing cutter on the arbor, feed up the work into the cutter by the table-elevating handle until the cutter has bitten into the steel to the correct depth, and then engage the self-acting table feed; the table then moves along, and the cutter chaws out the surplus metal for the full length and depth, at one fell swoop. Plenty of cutting oil is used, making the cutter do its work easily and leaving a nice "full-size" type of finish.

If a vertical slide is available, the rods can be milled on the lathe. Clamp them horizontally to the slide, by bolts through the boss holes—these may be opened out to ⅜-in. for this purpose—and a distance-piece, or thick washer, say about ¼-in. wide, placed between each boss and the slide. A good hefty endmill, say about ¾-in. diameter, is then held in the three-jaw; the saddle fed towards the headstock until the rod blanks are under the cutter, which should just overlap the two pieces of metal, and the vertical slide is then raised until the cutter begins to bite, say about 1/16-in. deep. The blanks are then traversed across by means of the cross-slide; after cutting the full length, take another 1/16-in. bite, *but don't traverse the work when cutting, in the same direction as the cutter blades move.* With the lathe running in the usual direction, and the rods under the cutter, start cutting at the far end, and draw the work towards you *against* the blades of the revolving cutter. Use plenty of cutting oil, and by aid of a little patience and perseverance, you can get as good work out of the lathe-milling, as on a regular machine. I did all my milling on the lathe, by aid of a vertical slide, in the days when my home workshop contained only a pedal-driven lathe and a hand-operated bench drilling machine.

Coupling Rods

ANOTHER "lathe method" of removing the surplus metal between the bosses, is to bolt the rod-blanks edgewise across the centre of the faceplate, using a clamp and two bolts at each end, and then turn away the centre part to the correct depth, taking a facing cut with a roundnose tool set crosswise in the rest. The drawback to this way of doing it, is flying chips; the blanks hit the tool point twice in each revolution, instead of the usual continuous cut, and the bits fly off in all directions. If one went in your eye, it would be painful!

Rod Profiling by Hand

It is easy enough to saw and file the blanks to shape. Put the blanks in the bench vice with the marked line level with top of jaws; file a slot or gap close to one boss, just wide enough to take a hacksaw blade on its side. Put a blade in your hacksaw frame sideways, lay it in the gap, and saw to the other end, keeping the saw-blade flat on the vice top, and slapping a brushful or two of cutting oil over it. The vice top acts as a guide to the saw, and a little judicious filing afterwards, will true up the bosses and remove the sawmarks.

Part the blanks; now, if you look carefully at the part sectional drawing, you will see that each rod has to be reduced by 5/32-in. on one side, from the larger boss, right to the end. On the other side, they are reduced by 3/32-in. between the bosses, leaving them 1/8-in. in thickness, with both bosses offset. The surplus may be milled or filed away as described above; but as each rod is now separate, and inclined to be rather springy, screw each to a bit of bar, say about 1/2-in. square, to support it whilst the job is being carried out.

To form the tongue where the other section of the rod fits on, a pin-drill is needed, 1/4-in. diameter, with a 3/16-in. pilot pin. This is very easily made. Chuck a piece of 1/2-in. round silver-steel about 2½-in. long; face, centre, and drill a hole about 1-in. deep with No. 14 drill. File the end like a screwdriver; back off each side of the hole, harden and temper to dark yellow, and drive a bit of 3/16-in. silver steel into the hole, cutting it off about 1/4-in. from the edges of the cutter. Open out the hole in the larger end of the rod to 3/16-in.; and, using the pin drill in either lathe or drilling machine, cut away the end of the rod until only a tongue 1/8-in. in thickness is left. The pindrill will cut a recess in the rod; to form the tongue, merely file away the surplus metal around the recess. Note, the pindrilling is done on one side only; the usual pattern of coupling-rod has to be pindrilled both sides, to bring the tongue in the middle. Whilst operating with the file on this end of the rod, finish off the boss completely.

The boss at the leading end should be nicely rounded, and this job can be done in the lathe, after roughing it to shape with a file. Chuck a piece of 1/2-in. square rod in the four-jaw, and turn a pip on the end about 1/4-in. long, and just big enough to fit in the hole in the boss. Put this in the slide-rest tool holder, parallel with lathe bed, and put the boss over the pip. Chuck an endmill about 3/8-in. diameter in the three-jaw; run the slide-rest up so that the boss bears slightly against the teeth on the side of the endmill. Hold the free end of the rod firmly, start the lathe, and as the side teeth of the endmill cut into the surplus metal at the end of the rod, swing it slowly around, the pip forming a kind of fulcrum pin. When the cutter has rounded the end a little, feed into cut a little more, and again swing the free end of the rod around carefully, repeating the process until the boss is rounded to proper shape and size. Warning: don't swing the rod around too far, or the endmill will cut away the oil box on top of the boss.

The other section of the rod is made in pretty much the same way; but as the knuckle joint requires an offset fork, a thicker section of steel will have to be used, 5/16-in. by 1/4-in., two pieces about 6-ins. long being needed. Mark out, and mill, or saw and file to outline as above described, with the two blanks temporarily fixed together. After parting, take 3/32-in. off one side, from the larger boss, right to the forked end; then further reduce by 1/32-in. between the boss and the fork, see sectional illustration. On the other side, take off 1/16-in. right from the fork to the end. Round off both ends as described previously. To slot the fork, clamp the rod under the slide-rest toolholder at right angles to the lathe bed. Mount a 1/8-in slotting cutter on an arbor or spindle—I find an old bolt does fine for this, the cutter being gripped between the nut and the bolt head—and grip the end of it in the three-jaw. If the rod is then fed on to the cutter, with slow speed and plenty of cutting oil, it will form a clean and true slot in the fork.

There is no need to buy a cutter, if you haven't one; a slice off a piece of cast steel rod will do very well, the teeth being filed, and the result hardened and tempered. When tempering, brighten up one side of the cutter with a piece of emerycloth or other abrasive; lay it on a piece of thick sheet iron, bright side up, and hold it with pliers or tongs over the small burner on the domestic gas stove. When the bright part turns dark yellow, tip it into clean cold water. It doesn't matter about the teeth being filed evenly; a cutter with staggered or uneven teeth is less likely to chatter than if the teeth were all even. I have made plenty of these cutters; in the days when I had to consider every farthing three or four times before spending it, I learned by experience how to do a bit of home toolmaking.

Coupling Rod Bushes

All the bearing holes are fitted with bronze bushes turned up from 1/2-in. rod. The driving bush should be an easy fit on the main crankpin without shake; the end bushes, leading and trailing, may be drilled with a clearing-size drill (letter F if you have it) as they need a weeny bit of play, otherwise the rods will bend when the engine runs over a bit of rough road, or through crossing frogs or point switches. The leading bush should project 1/64-in. beyond the rod. The trailing bush has a flange, 3/64-in. in thickness, projecting on the straight or flush side of the rod, whilst the driving bush is flush both sides. All bushes should be turned to a tight squeeze fit in the holes, which are opened out to the sizes given on the drawing. The knuckle joint is connected by a headed pin turned up from 1/4-in. round steel; silver steel for preference. The inner side of the fork has the hole countersunk as shown; the shank of the pin is riveted into the countersink, and filed flush, to clear the wheel boss. The joint should not be riveted up too tightly, so that the knuckle works stiff; it must be quite free.

Put the rods on the crankpins flush side out. The leading bush is prevented from coming off, by the turned and countersunk washer already illustrated along with the crankpins; it is secured by a countersunk screw which should be a fairly tight fit in the tapped hole in the pin. If this merchant should come out and catch the connecting-rod when the engine is running at a high speed, it would be sheared off, and let the end of the rod loose. The centre or driving bush needs no fixing, as the big end of the connecting rod working on the same pin, keeps it in place. The trailing end can either be secured by a washer and ordinary commercial nut, or a special round nut can be made, with a couple of spanner-flats filed on it, as shown in the general arrangement drawing. The coupling rods should be perfectly free at any point of the wheel revolution; if they aren't, there is something wrong with your crankpin-hole drilling, or the quartering, or both. Whatever it is, it should be corrected, and the rods made to run without binding, before proceeding farther. The tips of the oil boxes may need filing slightly to clear the wheel bosses.

Buffers

I usually describe these along with what I call the "trimmings"; but whilst completing the main part of the chassis work, before starting "the works," otherwise the cylinders and motion, it might be as well to fit them. Make four whilst on the job, then you will have the two in hand for the back of the tender. I have shown two alternative patterns, for the reason that the blueprints sent to me from Swindon show the standard G.W.R. taper sockets, and the photograph of No. 1000 herself shows parallel sockets; as details of various engines in the series may differ slightly, you can fit which type you prefer. The construction of both is the same. Castings may be available for both patterns of sockets, in which case there won't be any need for a square washer behind the taper socket, as it will be cast on.

Grip the casting in the four-jaw chuck with the shank running truly; turn it to ⅜-in. diameter, screwing ⅜-in. by 32. Face the end and the back of the flange. Reverse and re-chuck in a ⅜-in. tapped bush held in the three-jaw; turn the outside to shape, face the end, centre, and drill right through with No. 30 drill. Open out to ¼-in. depth with ¼-in. drill for taper socket, or 7/16-in. for parallel socket. Chuck a piece of ⅞-in. round mild steel for the heads; face the end, centre, drill No. 40 and tap ⅛-in. or 5 B.A. for the pin. Turn down ½-in. length to fit the socket, and part off a full ⅝-in. from the end. Reverse in chuck and turn the head slightly convex, round the edge, with a file whilst running, and polish with emery-cloth. The pins are 1½-in. lengths of ⅛-in. round steel screwed both ends; the springs are 18 gauge steel wire. Assemble as shown; put the shanks through the holes in the buffer beam, and secure with nuts made from 7/16-in. or ½-in. hexagon rod (brass or steel) tapped to suit.

THE cylinders I am specifying for the G.W.R. "1000" locomotive are of the correct piston-valve type as fitted to all modern full-sized engines. Many builders of small locomotives shy at making these piston-valve cylinders; why, goodness only knows! An examination of the reproduced drawings will show that actually they are much easier and simpler to machine and assemble, than the usual type with slide valves and separate steam chest. The joints between cylinder block, steam chest, and cover, are abolished at one fell swoop. There are no rectangular ports to cut, and no long passage-ways to drill between bore and ports; no flat facing to be done, no steam-chest bosses to turn, and no spindle gland to make and fit. All that has to be done in place of this work, are simple turning jobs; and if your lathe turns truly enough, and you are sufficiently master of its use to be able to turn and fit the main piston properly, then you are fully qualified to turn and fit the piston valves—so what is there to be afraid of?

Slide valves *could* be used, at a pinch, but it would involve special cylinder castings with an oblique port face, and steam chests designed specially to suit, owing to the maximum distance of 1⅛-ins. permissible between valve spindle and piston rod; and even with the extra work, the cylinders would be less efficient than those shown, so the game isn't worth the candle. Therefore, ye of the faint hearts, pluck up courage and let's get cracking!

How to Set up the Cylinder Castings

The cylinder castings supplied by our advertisers will probably be cored truly for cylinder and steam-chest bores; check them off, and ascertain if the coreholes are at the correct centre spacing. If not, smooth off one end of the casting with a file, and coat it with a brushful of marking-out fluid, made by dissolving some shellac in methylated spirits, and adding a little blue or violet colouring dye. This dries almost instantly, can be used for any metal including aluminium, and scriber scratches made in it show up like the railway tracks at Clapham Junction on a sunny day. Plug the core holes with little discs of wood; mark out the correct centres on same, and scribe circles with dividers in the marking-out fluid, showing the exact position of main and steam-chest bores.

More About Cylinder Boring

I DON'T suppose a 1⅛-in. parallel reamer forms part of the equipment of the average amateur workshop; but if it does, continue boring, opening out by successive cuts until the "lead" of the reamer will just enter. If no reamer is available, set your slide-gauge or inside callipers to 1⅛-ins., and bore carefully until they will just enter. Tip to beginners: to get the bore as true as the lathe will possibly do it, take two more traverses through the bore, in and out, *without shifting the cross slide*, after the hole is opened to size. Use fine feed and slightly higher speed. This will leave a finish practically equal to a reamed hole.

Now — *very* important, this — slack the bolts holding the angleplate to the face-plate, and readjust the angleplate until the corehole, or marked circle, as the case may be, of the steam-chest bore runs truly. Then tighten bolts again, and bore that out to 1-in. diameter, by the same process as mentioned above. The two bores will then be exactly parallel. Unless the centre hole in the lathe mandrel is big enough to admit the end of a 1⅛-in. reamer, it is useless trying to ream either main or steam-chest bores in the lathe; so take a final skim off the flange to remove any burrs, and take the cylinder casting off the angleplate. After doing the second cylinder, put a bit of 1¼-in. brass rod in the three-jaw, and turn down about 1-in. of it to a tight push fit for the main cylinder bore; mount the cylinder on it, unturned flange outwards, and face off the flange with a roundnose tool set crosswise in the rest, bringing the length of the casting to 2½-ins. If the cylinder slips on the improvised mandrel, one turn of paper around it will teach it manners. The mandrel should not be driven into the bore, otherwise the cylinder may be distorted.

Machining Bolting Face

To machine the bolting face, simply up-end the cylinder on the angleplate, securing it by a bolt through the bore, with a big washer under the nut, large enough to span the bore, plus a bit over. It should be the same size as the cylinder cover. Lower the angleplate a bit, so that the cylinder is central on the faceplate, and set the face at right angles to the lathe centreline by aid of your scribing block, resting on the saddle or bed, adjusting the casting until the needle touches the bolting face, about 7/8-in. from centre, during the complete revolution. Face off until the bolting face is exactly 7/16-in. from the edge of the main bore, the centre of which should then be correct distance from frame, viz., 1-in.

Reaming Bores

If possible, it is advisable to let the castings stand a week or so between boring and reaming, as sometimes they alter their shape a bit after the hard skin has been cut away and released the cooling stresses. I have known cylinder castings to go several thousandths oval in a week, and always let mine "season" thus. Also, test your reamer by running your thumbnail along the blades: and if any roughness is apparent, rub them with an oilstone. Catch the casting in the bench vice, between a couple of lead clams, and very carefully work the reamer through by aid of a good hefty tap-wrench. Caution: be extremely careful to let the reamer kind of "float"; don't press it down, or force it to either side, or the bore will be taper instead of parallel. A drop of cutting oil on the blades helps matters very considerably. When you have pushed the reamer to the full depth of the flutes, take off the wrench and push the reamer clean through. Many inexperienced workers have ruined a good reamed bore by taking out more scrapings from one end in an involuntary "draw-back" cut.

Builders who have no reamer, and bore to size, will have to take a chance on the casting altering shape. The bore of the steam-chest is, of course, done in the same way as the main bore, using a reamer 1-in. diameter.

How to Drill Passageways

As the exhaust on an internal-admission piston-valve cylinder comes out at each end of the liner instead of via a central port, we have to drill a big exit hole the full length of the cylinder, and make connections with the steam chest and exhaust pipe outlet. For the steam chest connections, make a centre-pop in the casting, 7/32-in. from each end and about 3/16-in. from the edge of the bolting face; see port cross-section. As shown in that, drill a 7/32-in. hole between the bolting face and the main bore, breaking into the steam-chest bore. Tap the ends of each hole 1/4-in. by 40, but don't plug the holes yet. Now—note this very carefully—make a pop mark on one end of the cylinder, 1/4-in. from the bolting face, and [illegible]-in. above centre of main bore; that is, [illegible]-in. from the bottom of the bolting face. From this point drill a 1/4-in. hole the full length of the casting, either on drilling machine or lathe, crossing the first vertical hole and breaking into the second. Tap the end [illegible]-in. by 40, but don't plug it. Lastly, in the middle of the bolting face, and [illegible]-in. from the bottom, drill a 9/32-in. hole, breaking into the longitudinal hole: tap that one 5/16-in. by 40 for the exhaust pipe. Scrape off any burrs; if the steam-chest has been reamed, put the reamer through again.

Shake out all chippings.

On top of the casting you will find a flat seating, for the steampipe flange. Smooth it off with a file, and drill a 7/32-in. hole in the middle. A slot 1/8-in. wide and about 1/4-in. long, is needed, close to each end of the bore, as shown in the perspective sketch. These slots can be formed by carefully centre-popping, drilling, and finishing with a rat-tail file; they can be drilled easily enough as they go in at an angle (exact degree doesn't matter a bean), but take care not to let the drill slip and make a scratch in the bore. When done, scrape off all burrs, or put the reamers through both main and steam-chest bores again: and that completes the actual work on the castings. You'll be finding it much easier than cutting rectangular ports and drilling long weeny holes, and truing up huge flat faces!

Steam-chest Liners

The best material for the steam-chest liners is a piece of hard cored bearing metal, as used for automobile gudgeon pin bushes and other jobs where a combination of resistance to both heat and wear, is required. Advertisers who are marketing castings will doubtless include the proper stuff in their sets. On a lathe that is not flimsy, the liner can be bored, and the outside turned, at the one setting. If cast cored stick is used, put a plug in the end; a small push-fit metal plug, with a flange, similar to the front cover, is most suitable. Face the end before fitting it. Chuck in three-jaw with about 3½-in. or so projecting from the jaws; then make a centre in the plug, with a centre-drill in the tailstock chuck. Put the back centre in the tailstock, and run it up to support the piece of rod whilst the outside is turned to suit the reamed hole in the cylinder. Warning: *don't use a "mike" for getting the correct size*; use the cylinder itself as a gauge. I knew somebody who reamed a pair of cylinders with the correct size of reamer, 7/8-in. in his case, then turned his liners to a dead 7/8-in. by "mike measurement." Instead of a squeeze fit, they were a beautiful sliding fit. In the present instance, it doesn't matter if the reamer cuts a whole sackful of thousandths large, both in main and steam-chest bores, *as long as pistons and liners are fitted to the bores*, and not made to "mike measurements."

Now, here is a simple way of ensuring that your liners are a press fit in the cylinders. With a small scraper, or even a pocket-knife, take a weeny scrape off the edge of one of the cylinder steam-chest bores. About twice around, and not more than 1/32-in. into the bore, is plenty. Next, either using the self-act, or the top slide set truly as for boring, turn the outside of the liner until it will just go very tightly into the scraped enlargement at the end of the steam-chest bore. Only just! And take the sharp edge off the end of the liner at that, whilst gauging it with the cylinder, otherwise you may be misled by a slight burr on the sharp edge.

How to Cut the Ports

Instead of the "fag" of setting up and endmilling ports in a flat face, all we have to do, is to put a parting tool in the slide rest, and cut two grooves 3/32-in. deep and 1/8-in. wide, in the outside of the liner. The first is cut at 15/16-in. from the faced end of the liner, and the second 1⅛-in. beyond that; see illustration of liner. A small cut can also be made, about the same depth, 15/16-in. beyond the second port (3¼-ins. from the faced end) to indicate exactly where to part off after boring. The latter job is done precisely the same as the cylinder boring; remove the plug, and bore until the "lead" of a 5/8-in. parallel reamer will just enter. The liner can then be parted off.

The next job is to establish communication between the port grooves and the bore of the liner. This is done by either filing or milling away the bottom of each groove at opposite sides, the file or mill cutting right into the bore; but leave a bridge 3/8-in. wide between the top and bottom openings, so that the liner will remain all in one piece, and strong enough to stand squeezing into the cylinder casting. One of the detail illustrations shows a section through the port, and you can see where the bridges are left at each side. To connect the port with the slots at each end of the cylinder bore, file or mill a flat 1/4-in. wide and 9/16-in. long, in the wall of the liner, as shown in the drawing. Now chuck the liner truly in the three-jaw, and put a 5/8-in. parallel reamer right through it. Put a carrier on the reamer shank and hold it against the tailstock centre with your left hand; grab the tailstock bodily with your right, and slide it along the bed, pushing the blades of the reamer clean through the liner, only stopping to reverse and pull the reamer out again. Important—keep the reamer against the tailstock centre all the time, to prevent any bell-mouthing or tapering of the liner.

This should be a Tight Squeeze!

Enter the end of the liner into the little scraped part at the end of the steam-chest, making quite certain that the liner is dead parallel with the cylinder bore, square with the flange, and the flats lining up with the slots connecting the ends of the bores. The liner can then be very carefully squeezed or driven right through the steam-chest bore, so that it projects 3/8-in. each side of the cylinder casting. How this is done, depends on what appliances you have. I use a bush press, the ram of which has a movement of 11½-ins., so am O.K. for the job.

A big, hefty vice is the next best thing, but the jaws would have to open 5¾-ins. to admit cylinder and liner. Somebody I know, who has a 5-in. lathe with a massive head and tailstock, put the cylinder block against the faceplate, removed the tailstock centre, brought the barrel up against the liner, and pushed it through the cylinder by the simple expedient of turning the hand-wheel; but that would be too much of a good thing for the constitution of the average amateur lathe!

About the best way out of the difficulty would be to get a ½-in. bolt about 6-ins. long, and a couple of big washers. Line up the cylinder casting and liner, put the bolt through the lot, cylinder end first, with a washer at each end, and put on the nut. Hold the bolt vertically in the bench vice by the head, and turn the nut with a good stout spanner. As the nut goes down the bolt, it will force the liner into the cylinder ahead of it. Carry on until the liner is in far enough for the whole issue to go between the jaws of the bench vice and finish in the vice. To get the projection at the side opposite to the squeezing-in side, put a block of metal at least ½-in. thick, with a ¾-in. hole in it, between the cylinder and the vice-jaw; this can be done just before the liner is squeezed in flush with the end of the cylinder, and when pressure is again applied to the outer end of the liner, the other end will come out through the cylinder end, into the hole in the block.

Drilling the steam and exhaust ways in the liner, is simplicity itself; merely poke the 7/32-in. drill down the hole in the seating for the steampipe flange, into the liner. Then turn the cylinder over, and put the drill down the two long holes at each end, into the liner. Finally, put the 5/8-in. reamer through the liner again, to remove all burring, and correct any distortion due to pressing; be sure there are no chippings left in the passageways, and fit the plugs as shown.

Right at the bottom of the cylinder, make two centre-pops 3/16-in. from the edge of the flanges; drill them 5/32-in. for 3/16-in. depth, and tap 3/16-in. by 40. From these, drill a 1/16-in. hole at an angle, so that it emerges in the cylinder bore close to the flange; scrape off any burrs. These holes are for the cylinder drain cocks, which are needed with piston-valve cylinders, to release any condensate or priming water that may get into the cylinders.

Make the piston rods first; they are merely 3⅜-in. lengths of 7/32-in. rustless steel or nickle-bronze rod, with ¼-in. of 7/32-in. by 40 thread on one end. Chuck the rods in three-jaw, and put the thread on by aid of a die in the tailstock holder.

Drawn bronze rod is best for pistons used in cast bronze cylinders; if cast metal is used, it should be of a different grade to the metal of the cylinders. Chuck in three-jaw, face the end, centre, and drill down ½-in. depth with 3/16-in. drill. Turn the outside for about 1-in. length, to a diameter 1/64-in. larger than cylinder bore. At ⅛-in. from the end, form a groove with a parting tool, 3/16-in. wide and a full 3/16-in. deep. Part off at 7/16-in. from the end, repeating operation for second piston. Chuck one of the pistons in three-jaw; open out centre hole with 7/32-in. or No. 3 drill for 3/16-in. depth, and tap the remainder 7/32-in. by 40. Put a piston-rod in the tailstock chuck, run tailstock up and enter the screwed end of the rod in the piston; pull the lathe belt by hand until the rod is screwed right home, flush with piston head. This "precision-chuck" method of fitting pistons to rods, is the best I know for ensuring perfect truth, and at the same time eliminating any laborious and finicky taper turning and boring; also no nut is required.

If a collet chuck is available, use that to hold the piston-rod when finish-turning pistons; if not, use a split bush in the three-jaw. Truth is absolutely essential for free working. Chuck any odd bit of brass rod about ½-in. diameter and about ½-in. long, in three-jaw; centre, and drill 13/64-in. right through. Remove from chuck, and split lengthwise at one side with a hacksaw; replace, with the sawcut between two jaws. With a little boring tool made from the tang end of a file, bore out the hole until the piston-rod will just slide in; then enter it, and tighten the chuck jaws. The rod will be held as truly as in a precision collet. Now, with very fine cuts, turn down the piston until it will slide into the cylinder without the slightest sign of shake.

Covers

THE front covers of both cylinder and steam-chest are what I call "kiddies' practice turning jobs." Chucking pieces will be provided on them, to grip in the three-jaw. Face off, turn the rims to given diameters (see drawing), then turn the registers that fit the bores, with a knife tool. They should fit the bores without shake; the large one only goes in 1/32-in., but the small one enters 3/16-in. A true contact face on the flange, can be obtained by drawing the tool straight back, after turning the register or spigot. Saw off the chucking pieces; reverse in chuck, either gripping by the rims, or in a stepped ring, with a sawcut in the side, like the stepped bush; face off the other side.

The back covers are nearly as simple; chuck by the tenon provided, face, centre and drill a No. 2 hole in the large one, and a 22 in the small one; turn the registers as given, then saw off the chucking pieces and reverse in chuck as above. The smaller cover merely has a 3/8-in. boss, 3/16-in. wide, formed on the outside; there is no gland. The big one should have the oval boss faced off; then open out the hole with an 11/32-in. pin drill to a depth of 5/16-in., and tap it 3/8-in. by 32 or 40, using the tailstock chuck to guide the tap truly. The gland is turned from 1/2-in. bronze rod, round or hexagon, just as you please. Chuck in three-jaw; face, centre, and drill 1/2-in. depth with No. 40 drill. Turn down 1/4-in. of the outside to 3/8-in. diameter, and screw to match the tapped stuffing-box, with die in tailstock holder. Part off at 3/8-in. from the end; screw into the stuffing box, and run a 7/32-in. reamer through the lot. If the gland is made from round rod, file four C-spanner nicks in the rim, as shown in the illustrations.

Guide Bars

The seatings for the guide bars should be planed, milled or carefully filed; the cover could be held in a machine-vice fixed to the slide-rest, or the saddle, as convenient, and set at the right height to run under a cutter mounted on an arbor either held in chuck or between centres. A fine machine-vice can easily be improvised from two bits of angle steel held together by two bolts in the vertical members, holes being drilled in the horizontal members for holding-down screws. When I was an enthusiastic but impecunious kiddy, my first machine-vice consisted of two short lengths laboriously sawn off a cast-iron bedstead rail, held together by two stove-bolts from a broken kitchen fender.

The large covers are drilled No. 34 and the small ones No. 43 (don't accidentally reverse those figures!) for fixing screws as shown. To get the large covers in place, a moon-shaped "bite" must be filed out of the edge of each. The guide-bar seatings must be set at right angles to the bolting face; and to set these truly, lay the cylinder, bolting face down, on the lathe bed. Set a trysquare alongside the cover, the stock of the square resting on the lathe bed, and set the guide-bar seating to the blade. To locate the screwholes in the cylinder and liner ends, put the covers in place, and hold temporarily with a cramp. Run the No. 34 or 43 drill through the holes in the cover, making countersinks in the contact faces of cylinder and liner. Drill these No. 44 (large) and 51 (small), tapping 6 and 8 B.A. respectively. Hexagon-head screws are usually preferred, but personally I think round or countersunk screws look just as well. Don't fix them "for keeps" yet; leave them off until the piston-valves have been fitted.

Piston Valves

Finally we come to what those who haven't done the job before, regard as the pons asinorum of the whole bag of tricks; but when they have safely crossed it, look back and laugh at the simplicity of it.

Rustless steel or hard drawn bronze rod are about the best materials for the piston-valves. If you can possibly get hold of a piece of precision-ground rustless steel 5/8-in. diameter, it should be an exact sliding fit in the reamed liner, and you don't even have to turn the bobbins! If not, chuck a piece the nearest size larger, in three-jaw, and turn down about 1 1/2-ins. of it to 1/64-in. over 5/8-in. diameter. Face the end, centre, and drill to 1 1/2-ins. depth with 3/16-in. drill; the spindle just "floats" in the valve. At 1 3/8-ins. from the end, make a groove with a parting tool, so you'll know where to part off after sizing the bobbins. With a roundnose tool, turn away 15/16-in. of the middle to 3/8-in. diameter, leaving a bobbin exactly 7/32-in. wide on either side of the gap. Then, with the same tool, carefully reduce the bobbins to an exact sliding fit in the liner, same as you did the piston, and part off. If there should be any burr left around the centre hole, reverse in chuck, and skim it off flush. If that isn't easier than sawing, filing, or milling out a flat valve, gouging out the cavity, and facing it truly, I don't know what could be!

The spindle is merely a 3 3/8-in. length of 5/32-in. rustless steel or bronze rod, with 2-ins. of 5/32-in. by 40 thread on one end, and 3/16-in. of same pitch on the other. The locknuts are made from 1/4-in. hexagon brass rod; chuck in three-jaw, face, centre, and drill down 3/4-in. or so with No. 30 drill. Tap 5/32-in. by 40, and part off four 1/8-in. slices. Chamfer by screwing each on a stub of screwed rod held in chuck, close to the jaws, and touching with a tool ground off to a slight angle. Screw two of the nuts on the long thread, put the valve on, and secure by the other two nuts. Any place will do; adjustment isn't made until the valve gear is erected. Put a smear of cylinder oil on the bobbins, insert with liner, and put the covers on. No joint is required, as there is only exhaust pressure to withstand, and that is precious little with your humble servant's valve setting.

The large piston is packed with a ring of 3/16-in. square braided graphited yarn, laid in the groove, the ends being scraped off at an angle, like the cut in a piston ring. It should just be tight enough in the groove to allow it to be easily prodded into place with the blade of a pocket-knife, or a screwdriver, when the piston is inserted in the cylinder. Beginners should bear in mind that pistons should be steam-tight, but not mechanically tight; the easier they move, the more power is delivered at the drawbar. If a piston is properly fitted, as described in these notes, the packing acts merely as a seal, and a film of oil between cylinder bore and piston, prevents any steam leakage. Any of my own engines run freely when given a push, which is a sign that there is nothing mechanically tight about the pistons, yet the sharp exhaust beats equally demonstrate the absence of "blow-by."

The gland is packed with a few turns of graphited yarn; an oiled paper gasket is placed between cylinder flange and covers, the screws inserted, and the job is complete. Proper piston-valve cylinders are really terribly difficult to make, don't you think? I can imagine your answer!

Guide Bars

Four pieces of rectangular section steel, 3/16-in. by 3/8-in., each 4-ins. long, are needed for the guide bars. If you can, get hold of a length of bright silver steel, or rustless steel, use it in preference to drawn mild steel bar, which, however, will serve if nothing better is available. File carefully to the shape shown, and drill two No. 41 holes at 1/8-in. from the squared end. Note, at the widest part of the bar, 2 5/8-ins. from the squared end, the bar should be left full thickness, for a full 1/4-in. each way, to allow for fitting closely between the jaws of the guide yokes or brackets. The rubbing surface of each bar should be smoothed off on a sheet of emery-cloth laid on the lathe bed, or something equally flat and true, so that the crosshead works on it with the minimum of friction.

Crossheads

The crossheads are very similar to those on the full-sized engine, having a separate centre-piece with the shoes or slippers brazed or silversoldered to it. On the big engines, the slippers are bolted to the centre-piece, but in the small size we could not fit bolts strong enough to stand the stress of heavy passenger hauling.

A piece of mild steel bar approximately 2½-ins. long, of ⅜-in. by ⅞-in. section, will make both centre-pieces. Clamp it under the slide-rest tool holder, parallel to the lathe bed, and at centre height; put a ¼-in. endmill or slot drill in the three-jaw, and cut a slot across the end, a good ⅝-in. in depth. Reverse the piece, cut another in the other end, then saw the piece in half.

Chuck truly in the four-jaw, with the unslotted end outwards, and turn it to the shape shown in the illustrations; the exact diameter of the neck doesn't matter, but it should not be less than 5⁄16-in., leaving the head full size. Face off, centre, and drill No. 3, breaking into the slot. The other end of the piece can then be carefully filed to the shape and dimensions shown. At ¾-in. from the turned end, drill a cross hole through both sides with letter C or 15⁄64-in. drill, and ream ¼-in. for the cross-head pin.

Slippers

The shoes or slippers can be made from bronze, or steel, just as you prefer. Steel shoes with bronze or whitemetal liners are commonly used in full-size practice; a good subterfuge, for those who prefer the bronze shoes on account of sweeter working, but object to the colour, is to use bronze, and tin over the outside to represent steel.

A piece of rod, of ½-in. by ¼-in. section and about 6-ins. long, will make all four. If you own, or can have the use of, a milling, planing, or shaping machine, the ⅜-in. by 1⁄16-in. groove for the guide bars can be machined out of the full length of the bar at one fell swoop. If not, cut the piece of bar in halves, and clamp each on its side under the slide-rest tool holder, or in a machine-vice attached to a vertical slide, and traverse across a ⅜-in. endmill or slot drill held in the three-jaw, in exactly the same way as described for milling out the grooves in the main axleboxes. Then reverse it, and mill a ⅛-in. rebate at each side, leaving a tongue or tenon ¼-in. wide and ⅛-in. high, in the middle.

The process is the same as described for bogie axleboxes, only you don't have to take off so much metal. Cut the planed or milled metal into four lengths that will measure 1¼-ins. after the ends have been nicely squared off; then file away the tongue at an angle each side, as shown in the detail sketch, leaving it full-length in the middle for a length of ½-in.

Assembling Slippers

Next, place a shoe at the top and bottom of each centre-piece, as shown in the assembly sketch; the tongue under the slipper should fit tightly in the slot in the centre-piece, if the machining has been correctly done. See that they line up perfectly; then, if the shoes are steel, braze them, and if bronze, silver-solder them in position. In either case, merely put a smear of flux at each side, heat to redness, and touch the point of contact between shoe and centre-piece, at each side, with a bit of soft brass wire for steel shoes, or best grade silver-solder for bronze shoes.

I use "Chemico" brazing flux mixed to a paste with water, for brazing with brass wire or any kind of spelter, strip or granules; for best-grade silver-solder, powdered borax similarly mixed. When obtainable, I recommend "Easyflo" silver-solder and the special flux sold for use with it, for all small jobs calling for a neat finish. I have no shares in the company; merely speak as I find, and pass on a useful tip. Don't quench in acid pickle, on account of the steel centre; use clean water, and if any burnt flux sticks to the crossheads, scrape it off, then polish them up with fine emery-cloth or other abrasive.

Crosshead Pins

The crosshead pins are just a kiddy's practice job in metal turning. Turn them from 5⁄16-in. hexagon steel rod held in three-jaw, to dimensions given, taking care that the turned part has a smooth finish, and exactly fits the reamed hole in the crosshead. Use a tailstock dieholder for threading the ends.

Note: one pin is longer than the other; the reason for this is that the right-hand crosshead carries the arm for operating the pump, which is located under the running board on the right-hand side of the engine, and the pin passes through this arm as well as the crosshead. Ordinary commercial nuts are used on the pins.

Guide Yokes or Brackets

These are the same pattern as used on the full-sized engine, and our advertisers will be supplying castings for them. Very little machining is needed; in fact, they can be finished with a file quite well.

However, any builder who possesses, or has the use of, a milling or planing machine, can first of all grip the casting, back upwards, in the machine vice, and take a cut over the back flange which makes contact with the frames. Drill the holes, and temporarily attach the casting to a bit of square bar, ½-in. or larger, by a couple of screws through the holes. If this bar is then held in the machine-vice, level with the top of the jaws, the seatings for attachment for the guide bars can be milled or planed at the one setting. For milling, use a side-and-face cutter; for planing or shaping, use a bent tool in the clapper box, feeding downward with the vertical slide. The guide bar seatings will then be found to be square with the back flange, and parallel to each other. Two No. 41 holes are drilled in each seating, as shown in plan view; when the yokes are erected, 3⁄32-in. screws are run through these, into tapped holes in the bars.

Connecting Rods

The connecting rods are machined up in pretty much the same way as the coupling rods, so no fully-detailed repetition will be necessary. Each needs a piece of ⅜-in. by ⅞-in. mild steel bar approximately 9-ins. long. Mark the outline on one of the bars, drill a ⅛-in. hole at the location of the big and little-end bushes, use the drilled rod-blank as a jig to drill the other, then rivet temporarily together, and mill, or saw and file to outline, as given for coupling-rods.

Part the two pieces; then mill, plane or file 1⁄16-in. off each side, leaving the big end full width for a distance of 13⁄16-in. Next, take another 1⁄32-in. off each side, this time leaving the little-end ¼-in. wide for a distance of ⅝-in. Put a flute 3⁄16-in. wide and 1⁄32-in. deep, on the outer side of each rod, if you are using milling, shaping, or planing machine: if only hand filed, the flute can be omitted, or else milled on the lathe.

For the latter job, use a 3/16-in. slotting drill or endmill in the three-jaw: clamp the rod on its side under the slide-rest tool-holder, at centre height. Feed into cut with the top slide, and traverse across the cutter with the cross-slide. Use medium speed, a sharp cutter, and plenty of cutting oil for a cleanly-cut flute. The lathe will probably have insufficient traverse on the cross-slide, to do the full length of flute at one go; so when shifting the rod to get another bite, be careful not to interfere with the height adjustment, or the flute will have a step in it, and look hideous. Round off the ends of the rods, as described for the coupling-rod bosses.

Bushes

Open out the holes in the little ends of the rods to 11/32-in., and those in the big ends to ½-in.; fit bronze bushes in both, by the same process as you fitted them to the coupling-rods. The bushes in the little ends are filed flush with the sides of the rod, and are reamed ¼-in. to fit on the crosshead pins without shake. The big-end bushes project a bare 1/32-in. each side, the projections acting as spacers to keep the big ends from rubbing against the coupling-rod bosses.

The big end should have a bare 1/64-in. side movement, and be an easy running fit on the main crankpin, but without any "sloppiness." A 1/16-in. oil hole can be drilled down the oil-box boss on the big end, clean through the bush, and the upper part enlarged with a 3/16-in. drill, to hold a couple of drops of oil. Run the reamer through the bush after drilling, to remove any burr left by the drill.

THE cylinders are erected with the piston-rods dead on the line of motion, the bolting faces being 1-in. from the top of the frame, and the front end of the cylinder block exactly 3 3/16-ins. from the front end of the frame, behind the vertical part of the buffer beam. Put one of the cylinders in this position, and temporarily hold it thus by means of a big toolmaker's cramp, as shown in the detail illustration.

Piston Rod Aligning

For checking the alignment of the piston rod, your humble servant uses nothing more formidable than a piece of ordinary sewing cotton. Pull the piston-rod out of the cylinder as far as it will come; take a piece of cotton about a foot long, stretch it tight, and hold one end over the piston rod, exactly parallel with it for its full length. The other end of the cotton should lie exactly across the centre of the driving axle, when in its correct running position, viz., 1/8-in. from the bottom edge of the frame. Shift the cylinder until the desired result is obtained, then tighten the clamp sufficiently to prevent the cylinder accidentally shifting.

Locating Cylinder Screw Holes

To locate the position of the stud or screw-holes on the bolting face of the cylinder, you need a 3/16-in. twist drill at least 3½-ins. long. If such a drill is not available, you can make a substitute out of a piece of 3/16-in. silver steel, say 4-ins. long. File one end to an arrow point, and back off the two edges; harden and temper to dark yellow. Whether using twist drill or centreing drill, put it in your handbrace, and poke it through the screw-holes in both frames, as shown in the illustration, making countersinks on the bolting face of the cylinder.

When all are countersunk, remove cylinder, drill the countersinks 5/32-in. and tap 3/16-in. by 40. Repeat with the second cylinder.

Making Bolts and Nuts

The cylinders may be attached either with hexagon-headed set-screws, or studs; both can be home-made, as fine-thread screws or studs are not sold commercially in this size. For the screws, chuck a piece of 5/16-in. hexagon steel rod in the three-jaw; face the end, turn down 3/8-in. length to 3/16-in. diameter, screw 3/16-in. by 40 with a die in the tailstock holder, and part off to leave a head 1/8-in. in thickness. Reverse in chuck, and chamfer the corners of the hexagon.

Studs are merely pieces of 3/16-in. mild steel, 5/8-in. long, screwed 3/16-in. by 40 at both ends.

For nuts, chuck a piece of 5/16-in. hexagon mild steel or brass rod in three-jaw (brass may be used if desired, as the nuts are inside the frame and out of sight): face, centre, drill down 5/32-in. for about 1-in. depth, tap 3/16-in. by 40, using tap in tailstock chuck to keep true threads, and part off 1/8-in. slices, which may afterwards be re-chucked, and the corners of the hexagon chamfered off on one side of the nut.

Don't drill deeper than 1-in. at each shot, or the hole will run out of centre; drills are prone to "wander" in a deep hole, as the accumulation of chippings cannot get away, and tend to push the point of the drill aside from the "straight and narrow path."

The cylinders should not be permanently attached to the frames yet, as they have to come off several times during the erection of the rest of the bits and gadgets, so just temporarily attach them with a couple of screws in each.

How to Erect Guide Bars and Yokes

Put a guide bar on top of gland boss, and another at the bottom, holding them on with a toolmaker's cramp, but leaving one of the screw-holes exposed. See that both bars are butting up tightly against the cylinder cover; then measure the distance between the inside of the bar and the frame. This should be 1/32-in., *all the way along*, right from the cylinder to the extreme end of the bar, both top and bottom. Adjust bars if necessary, to get this result; then run a No. 41 drill in the exposed hole at the cylinder end of the bar, making a countersink in the gland boss. Follow with No. 48, tap 3/32-in. or 7 B.A., and put a screw in tightly. Repeat operation on bottom bar, then remove clamp. Check distance from bars to frame, to make certain they haven't shifted; then put the other two screws in by the same easy proces of locating, drilling and tapping.

Locating Guide Yokes

Next place the guide yoke in position, temporarily removing the cylinder for the purpose if you can't wangle it on without. The correct location is close to the leading coupled wheel, with the centre-line of it 2⅝-ins. from the cylinder cover, so that the top and bottom seatings are opposite the thickest parts of the guide bars. When correctly located, put a crosshead between the guide bars, to hold them in close contact with the seatings on the yoke, and put a toolmaker's cramp over the back flange of the yoke, and the engine frame.

The No. 30 drill can then be run through the frame, using the holes in the yoke flange as guides, and the yoke secured to the frames by three 1/8-in. or 5 B.A. bolts in each. Ordinary cheese-head screws can be pushed through from inside the frame, and nuts put on them outside the yoke flange; this is easy, and the outside appearance is O.K.

Run a No. 41 drill through the holes in top and bottom seatings, and make countersinks on the guide bars; then shift the crosshead clear of the yoke, and drill the bars No. 48 at the marked places. Tap 3/32-in. or 7 B.A., and put screws in, hexagon head for preference, filing off flush on the inner side of the bars, so that the crosshead slides freely past the yoke.

This arrangement is a simple adaptation of the way the guide bars are fixed on the full-sized locomotives, and provides a rigid fixing which will stand up to the pull and thrust of the pistons when the little "1000" is starting off with a dozen or more passengers, in true Great Western fashion.

FIRST of all, run the crosshead back to the piston rod, and see if the latter will enter the hole in the crosshead boss. If not, ease out the hole with the "lead" end of a 7/32-in. parallel reamer until the piston rod fits tightly. Then put the connecting rods in position; an ordinary commercial nut and washer can be used to hold the big end in place on the crank-pin, or you can, if you so desire, make round nuts with a couple of flats filed on each, similar to those on the full-sized engine.

Put the little ends in the recesses in the crossheads, and poke the pins through from the inner side, securing with commercial nuts and washers. Note—the right-hand pin will apparently be too long, as we haven't yet made the arm to drive the pump, and shall not until all the working parts are done; so a temporary washer can be put on the pin outside the crosshead, for the time being, to make up for the missing arm.

Push the piston rod into the cylinder as far as it will go; then turn the wheels until the crank is on front dead centre. As the crosshead approaches the cylinder, the boss will go over the end of the piston rod. When the crank is actually on dead centre, and the crosshead is as near to the cylinder as it will ever be, the piston rod must be advanced into the crosshead boss another 1/32-in., giving that much clearance between the piston head and the front cover.

If you cannot do this by holding the piston-rod with a pair of pliers, and applying a little gentle persuasion—don't damage the rod in the process!—the only alternative will be to take off the front cover, and carefully drive the piston back 1/32-in. by aid of a hammer and a piece of hard wood. Don't apply a metal "drift" to the piston.

When the rod has been pushed into the crosshead boss the correct amount, drill two No. 43 holes side by side, as close together as possible, clean through the boss and the piston rod. Squeeze into these, two little pins made from 3/32-in. silver steel, slightly tapered at one end, taking the place of the tapered flat cotter usually fitted to full-sized engines.

Turning Over

The coupled wheels should now be turned by hand, and if the fitting and erecting has been properly carried out, there should be no tight places anywhere, the crossheads sliding easily between the guide bars without any shake. Should there be a tight place anywhere, search for it carefully, and correct it before proceeding any further with the job.

For beginners' benefit I might add that the usual place on a "first attempt" where tight places might be found, is in the alignment of the guide bars; if they are ever so slightly out of parallel, they will bind in the grooves at top and bottom of the crosshead, at one point in the stroke.

Guide bars should always be tried in the crosshead grooves before erection, to make quite certain that they are a proper fit, sliding freely without shake. It is essential that everything thus far erected, should work sweetly before the valve gear is made and installed; and that will be our next job.

Valve Gear

As far as general design, measurements, distances between pin centres, and other details are concerned, the valve gear now to be described for the 3½-in. gauge G.W.R. "1000" class locomotive, is a one-sixteenth reproduction of the valve gear on the full-sized engine; so no builder need have any qualms about the correctness of the steam distribution. The C.M.E. of the G.W.R., Mr. F. W. Hawksworth, very kindly provided me with a quarter-size blue print of the valve gear of the big engine—it is seldom indeed that such intimate and correct details are allowed outside any locomotive works!—and this not only saved a great deal of scheming out the sizes of the small rods, links and other impedimenta, but ensured that the little engine would faithfully reproduce all the well-known characteristics of the beautiful and efficient machines now doing their share in upholding the traditions of the Great Western in the speed and power line.

The only alterations I have made are constructional details which are more suitable for a 3½-in. gauge engine than if made exactly to the specifications for a 4-ft. 8½-in. gauge. For example, the bearing for the rock shaft is a single sleeve between the pendulum levers, instead of two separate bearings outside them; and the link hanger works on a substantial overhung pin instead of being supported by a special bracket. In both cases, the construction is much easier, and the bearing surface—consequently the resistance to wear and inaccuuracy—greatly increased.

Beginners who are making the little "1000" as their first attempt at locomotive building, should bear in mind that on the accuracy of the valve gear, and the way the various parts are made and erected, the success or failure of the engine depends. Follow the instructions carefully, especially in the fitting of the various pin joints, and you will be rewarded by snappy beats, lively acceleration, and tremendous hauling power. Now to construction.

Eccentric Straps and Rods

The eccentric straps are made up from castings, which should be cleaned up with a file if necessary. First centrepop both ears or lugs, and drill right through, using No. 44 drill. Hold the strap in a small machine-vice, which may be used either on the table of a drilling machine or held against a drilling pad in the lathe tailstock; it is necessary for the holes to go through fair and true. Next make a couple of marks on one lug of each strap, as shown in the illustration; either with a centre punch or figure punch, so that when the lugs are parted, they may be put together again the right way; then scribe a line across each pair of lugs, level with the middle of the middle of the strap. Hold the strap in the bench vice, with this line just showing above the jaws, then saw across with a fine hacksaw, keeping the blade in contact with the vice-jaws, thus getting a true and level cut. Give the sawn faces a rub on a smooth file laid on the bench—the easiest way for beginners to get a true surface—and then open out the holes in the semi-circular half with a No. 34 drill, tapping the holes in the other half (the one with the projection on it) with 6 B.A. tap. Screw the halves temporarily together with 6 B.A. screws.

Chuck the strap in the four-jaw with the hole running as truly as possible; face the side, and carefully bore the hole with a boring tool as used for the cylinders, until it is an exact fit for the eccentric tumbler. The best way of ensuring this is to turn a bit of round steel rod to the exact diameter of the eccentrics at the bottom of the groove, viz., 1⅛-ins., checking by "mike" or callipers, and use it as a gauge. After boring all four straps, chuck the gauge itself in the three-jaw, with a turn of paper around it, and 7/32-in. projecting from the chuck jaws. Clamp each strap in turn on this, by its own screws, and face off the unturned side with a roundnose tool set crosswise in the slide rest, until the strap is level with the end of the gauge. The strap should then be an exact fit in the groove in the eccentric.

Carefully file or mill away 3/32-in. of the solid lug on each strap, forming a rebate for a length of 3/16-in., for attachment of the eccentric rods, as shown in the illustrations. Don't forget that two are right-hand and two left-hand. Finally drill an oil hole as shown in the "step," with No. 60 drill, and counterbore it slightly with a 3/32-in. or No. 40 drill.

Forked Rods

To save needless repetition, I might here mention that all forked rods in the valve gear may either be milled or sawn and filed, out of the solid, or else built up. Owners or users of milling machines will know how to do the former simple job without instruction. In the latter case, the rod is made from a piece of the same thickness as the main part of the rod, to whatever dimensions are shown, and the fork formed by brazing a little block of steel on to the end. Tie the block in place with a bit of iron wire, put a smear of wet "Boron" compo or any similar brazing flux (ordinary borax will do at a pinch) on the joint, heat to bright red, and touch with a piece of thin, soft brass wire, which will melt and flow in. Quench in water only. All forks are formed by clamping the rod under the slide-rest tool holder, at lathe centre height, and running up to a slotting cutter, like a small circular saw (all tool stores sell them) on an arbor between centres, or held the chuck. In the days when a lathe was my only workshop machine-tool, I just put the cutter on a bolt, and clamped it with the nut, holding the shank of the bolt in the three-jaw when using. Simple, but effective!

Rounding the Eyes

The eyes are rounded off by using a Wilmot filing jig or button. Simply get a bit of round silver-steel, same size as the outside of the eye, turn a little pip on the end to fit the hole, and part off about ¼-in. length. Harden right out by heating to red and dropping into cold water. Put the pip in the hole in the end of the rod to be rounded off, grip in bench vice, and file away the projecting rod until the file touches the jig; you won't hurt the jig, as the file won't cut the hard metal. Two jigs may be used if desired, and the rod clamped between them.

Rod Drilling Jig

Make four eccentric rods by the methods described above, to the shape and dimensions shown in the drawings. These have to be attached to the straps by pinning and soldering; but it is absolutely essential that all four must be exactly the same length, and when I say *exactly*, I mean just that! Therefore, make up a jig for assembling them.

Get a bit of flat steel bar about 4½-ins. long and 1-in. wide; it need not be thicker than 3/16-in. or so. Scribe a line down the centre, and on it set out two points 2 15/16-ins. apart. Drill these with No. 32 drill. Drive a short piece of ⅛-in. silver-steel into one of the holes; this should be filed slightly, in the lathe, to a sliding fit in the No. 32 holes in the eccentric-rod forks. Drop a washer ⅛-in. in thickness over it. Chuck the piece of 1⅛-in. round rod which you used as a jig when boring the straps, in the three-jaw, and turn a pip on the end about 3/16-in. long, to a tight fit in the other hole in the jig bar; part off about ¼-in. length, and drive the pip into the bar, so that the ¼-in. slice of 1⅛-in. rod lies flat on it. The jig is then complete.

To use it, place an eccentric strap over the large boss, with the rebate in the lug upwards. Put the rod in position with the holes in the fork over the peg, and the flat side of the rod downwards; this will be correct for all four rods, as although two are right-handed and two left-handed, the rebates are formed the proper side in the straps, as already indicated. The fork in the eccentric-rod should rest on the spacer washer, and the wide-end should rest in the rebate in the strap. The eccentric rods should be left full length when making them, and filed so as to fit the rebate exactly when assembled on the jig.

A spot of Baker's or other liquid soldering fluid should then be applied to the joint; and a bead of solder applied by a hot soldering-iron, held on long enough to allow the solder to sweat through, will attach the rod to the strap. Remove from jig; and when all four have been thus temporarily assembled at the right centres, drill a couple of No. 42 holes through strap and rod, on each joint. Slightly countersink both sides, then drive a short bit of 3/32-in. steel rod into each hole, hammer down into the countersinks, and file flush. Clean away any trace of the soldering fluid, and polish up the rods with a bit of fine emery-cloth glued to a thin stick. By following the above simple directions, the veriest "Billy Muggins" shouldn't have the slightest difficulty in turning out four identical assemblies.

Expansion Links

The best material for the expansion links is a bit of 3/16-in. ground flat stock, the trade term for the fine grade cast steel used for making gauges and other precision tools. Most tool stores sell it. Alternatively, you can use ordinary mild steel and case-harden it.

With a pair of dividers, strike an arc on the steel, to a radius of 3 11/32-in., and set out your link around this line, to the dimensions given in the drawing. Note: in addition to the two lugs for attachment of the eccentric rods, there are two more (one front and one back) to which the lifting block is fixed. Useful tip: *form the slot first*, and when you have that O.K., the outline of the link can be cut out around it. If the slot should be spoiled, you can easily cut another, and very little time is wasted; but if you cut the full outline first, and then spoil the slot so that the whole issue has to be scrapped, well, it's just too bad!

Slot Cutting

The slot *could* be machined out; but where it is only a case of two links required for one engine, it is far easier and quicker to do the job by hand, saving a lot of setting up. Just drill a few 5/32-in. holes along the radius line in the middle of the slot; run them into one, by aid of a rat-tail file, then finish with an ordinary thin flat file such as key-cutters use, until a piece of 3/16-in. silver steel rod can be run from top to bottom of the slot easily, but without shake. It's an easy job, really! Now, ease the slot top and bottom, for about 1/16-in., so that the dieblocks won't wear "steps" in the slots at the extremities of their movement; the big engines have quite large gaps at each end. Drill the holes for the eccentric rod pins on a drilling machine, or in the lathe; *not* by hand, as they *must* go through dead at right angles to the link.

The lifting block is a piece of 1/8-in. by 5/16-in. mild steel, a full 3/4-in. long, filed oval as shown. On one side of it, file a gap 1/16-in. deep and 3/8-in. long, to clear the head of the die bolt. On the other side, 1/16-in. off centre (note that very carefully) drill a 1/8-in. hole, for the stud. To make this, chuck a bit of 5/16-in. silver steel rod in the three-jaw, and turn down 1/16-in. of it to a tight drive fit in the hole in the lifting block; part off about 11/32-in. from the shoulder. Reverse in chuck, and turn down to 7/64-in. diameter, enough of the other end to leave 3/16-in. full length of full diameter; see illustration. Screw the end 6 B.A., and put a 6 B.A. nut on it to prevent damage to the thread whilst you squeeze the pip into the hole in the lifting block. Now clamp the lifting block to the link by aid of a toolmaker's cramp; drill a No. 52 hole clean through the lot at each end, countersink both ends of the holes, drive in little pieces of 1/16-in. steel wire, hammer down into countersinks, and file flush.

If the bits of wire, and the pip on the stud, are *real* drive fits, the links should be O.K. as they are; but to make doubly sure give them a taste of silver-solder or brazing wire. The former is easier; apply a little wet flux to each point to be silver-soldered, that is, both ends of the lifting block, and around the stud. Heat to medium red, and apply the weeniest bit of silver-solder to each spot. Whatever you do, *don't* blot up the stud, or let any get in the link slot. Whilst still red-hot, drop into clean cold water to harden the link and stud, then clean and polish.

If the link has been made from mild steel roll it in some case-hardening powder (Kasenit, Ecosite, Pearlite, or any other good brand) whilst still red hot. Warm up again until the yellow flame dies away, then quench out in cold water, clean and polish.

Final tip on expansion-link making: don't by any mischance forget that right and left-hand links are needed. The construction and measurements of links, blocks and studs are exactly the same, the difference being obtained by attaching the blocks at the opposite sides of the links; or, as they have no tail, merely turning one upside down.

Die Blocks

The die blocks are merely two little blocks of steel, same thickness as the links, 1/4-in. long, and the sides filed to the same radius as the link slots; see illustration. They should slide easily from top to bottom without shake. Drill a No. 32 hole through the middle of each, and put a 1/8-in. reamer through. If silver (or cast) steel, harden right out. If mild steel, caseharden as above.

There is no need to turn the die bolts out of the solid; if 1/8-in. round silver steel is used, the "natural" finish will be found greatly resistant to wear. Chuck a bit in the three-jaw, and turn down 3/16-in. of one end to 7/64-in. diameter; screw 6 B.A. Part off a full 5/8-in. from the end; reverse in chuck, and turn down a full 1/16-in. of the other end to 5/32-in. diameter, leaving 9/16-in. of full-diameter plain, between screw and shoulder. Chuck a bit of 5/16-in. round steel rod in the three-jaw, turn down 1/8-in. or so to 9/32-in. diameter; face, centre and drill 5/32-in. for about 1/8-in. depth, letting the centre-drill form a slight countersink. Part off a 1/16-in. slice; place this over the end of the bolt, and rivet the slight projection into the countersink. The only duty of the bolt-head is to prevent the die block slipping out of the link, so there is no need to braze on the head.

Link Hanger

On the full-sized locomotive, the link hanger bracket has a projecting arm carrying a support for the outer end of the hanger spindle; but on the small engine there is no need for this, as the spindle can be made stout enough to support a far greater weight than the few ounces of motion work, without any suspension of the outer end. To add a touch of "realism" I have, however, shown the bracket flange the same shape as in full size. It can either be turned from the solid, or built up; the latter is far easier.

For the solid job, a piece of 7/8-in. round mild steel is chucked in the three-jaw; face the end, centre, drill down about 3/8-in. with No. 48 drill, and tap 7 B.A. Turn down 5/16-in. length to 3/8-in. diameter, and further reduce 3/16-in. length to 5/16-in. diameter; part off at 9/16-in. from the end. Reverse in chuck, gripping by the 3/8-in. portion, and turn down 1/8-in. length to 5/16-in. diameter, to fit the hole in frame. The large flange left, may be filed to the shape shown in the drawing, as on the big engine, or left circular, just as you prefer.

Built-up Bracket

To build up the bracket, chuck a piece of 3/8-in. round steel, face the end, and drill and tap as above. Turn down 5/16-in. length to 5/16-in. diameter, and part off 9/16-in. from the end. Reverse in chuck, and turn down 1/4-in. length to 5/16-in. diameter, to fit hole in frame. File up the flange to the shape shown, from a piece of 1/8-in. steel plate 5/8-in. square; brass would do just as well. Drill a 5/16-in. hole in the middle, drive it on to the plain end of the turned spindle, so that 1/8-in. projects, and the flange is hard up against the 3/8-in. shoulder; then silver-solder it, leaving a fillet on the 3/8-in. side of the flange, but a sharp corner on the 5/16-in. side.

Suspension Lever

The hanger, or suspension lever, is filed up from a bit of 1/8-in. by 3/8-in. steel strip, and has a 3/8-in. boss on it, 5/16-in. long. All bossed levers are made in the following manner. In the present instance, drill a No. 32 hole at each end of the hanger, at 3/4-in. centres as shown. Chuck a piece of 3/8-in. round mild steel in the three-jaw, and turn a pip on the end 1/8-in. long, to fit tightly in the hole in the end of the hanger;

part off at 3/16-in. from the shoulder. Drive it into the hanger, and braze it, using a bit of brass wire as brazing material: simply apply a little wet flux, heat to bright red, and touch with the brass wire, which will melt, run around the boss, and form a fillet. Chuck the boss in the three-jaw, face off anything projecting through the lever, centre, drill through with No. 14 drill, following with 3/16-in. reamer. The drill will remove the pip. Counterbore 3/32-in. deep with a 5/16-in. pin drill, and turn up a washer to fit the recess easily; this should have a No. 41 countersunk hole in it. Poke a 1/8-in. parallel reamer through the bottom hole, then put the hanger on the bracket, drop the washer in the pin-drilled recess, and secure it with a countersunk screw. The assembly is shown in the end view of the valve gear.

Rockshaft Bearing

The bearing for the shaft carrying the pendulum levers, again differs from full size, inasmuch as the latter has two plummer-block bearings bolted to a vertical plate at right angles to the frames. These support the shaft on the outside of the levers. On the small engine we can go one better by using a bearing sleeve or bush the full length between the levers, giving far more comparative bearing surface, and needing only one support parallel to the frames. This may either be a casting, or built up; the former will only need cleaning up with a file, chucking in three-jaw, and drilling and reaming.

To build up, chuck a piece of 3/8-in. bronze or gunmetal rod in the three-jaw; face the end, and part off 1-in. length. Re-chuck, centre, and drill right through with No. 5 drill. At 5/16-in. from one end, make a slot 1/8-in. wide, halfway through the sleeve; this can be done best by milling or planing, but it may also be carefully filed. The slot *must* be at right angles to the sleeve. Into the slot, drive a piece of 1/8-in. by 3/8-in. rod (either brass or steel will do) 1¼-ins. long, and silver-solder it. Chuck the sleeve in the three-jaw, put the No. 5 drill through again to remove the obstruction now in the bore, and follow with 7/32-in. parallel reamer. Drill a 1/16-in. oil hole in the top, and remove any burr with another application of the reamer.

Pendulum Levers

The outside pendulum lever is virtually a simple crank, made from a bit of 1/8-in. by 3/8-in. steel, filed to shape shown. Drill both ends No. 32, and then open out the upper hole with No. 3 drill. Make a little crank-pin from 1/8-in. round silver steel, 1/4-in. long, with a reduced end 1/8-in. long, 3/32-in. dia meter, and screwed 7 B.A. or 3/32-in.; put on a nut to protect the thread, and squeeze into the hole in the narrower end of the lever. Squeeze a piece of 7/32-in. round silver steel 1 7/16-in. long, into the hole in the wide end of the lever, which should be slightly countersunk; then braze it as described for the hanger. The pin shouldn't actually need brazing if it is a really good squeeze fit; if at all "suspicious," however braze it. Countersink the hole on the inner side of the lever, and fill up the counter sink with melted brass wire, filing off flush.

The inside lever is filed up from 1/8-in. by 3/8-in. steel, and has a boss on it 1/8-in. wide, fitted and brazed exactly as described for the boss on the hanger. Chuck the boss in three-jaw, centre, drill No. 3, but don't ream. The hole in the narrower end is drilled No. 32 and reamed 1/8-in. Put the spindle with the outside pendulum lever on it, through the sleeve, in which it should fit easily *but without shake*; very important that! Put the inside lever on the spind in step with the outside one, and sque home, leaving the weeniest bit of endpl just sufficient to ensure free movement. No the outside lever goes at the longer end the sleeve. The complete assembly is placed in the recess in the top of frame shown in the illustration, and held in po tion by a toolmaker's cramp. The bra goes inside. Put the No. 30 drill thro holes in frame, making countersinks on bracket; follow with No. 40, tap 5 B.A., put countersunk screws in, with locknut the inside of the bracket.

Valve Rod

The two long valve rods which the diagonal connections between link hangers and the inside pendulum levers, can be made either from 1/4-in. square steel, and milled, or sawn and filed to shape, or from 1/8-in. by 1/4-in. flat steel rod, with little blocks brazed on at either end as previously described; so there is no need to repeat the process in detail. Note that the hanger end is offset 3/16-in., and the rod should measure 4 13/16-ins. between the centres of pinholes in the forks, *after* setting over.

The set can easily be made by catching the short end in the bench vice, using clams of sheet copper to prevent the jaws disfiguring the surface of the rod, and pulling the longer end carefully by hand. Note also that the lower end fork is drilled No. 32. The die bolt should be a tight fit in this end; on the full-sized engine it fits into a taper. We can reproduce this by slightly broaching the holes in the fork with an ordinary 1/8-in. taper pin broach, and very slightly tapering the end of the die bolt to suit. It only needs the tiniest bit of both broaching and tapering, to get a satisfactory fit, merely enough to prevent any rocking of the die bolt in either the hanger or the valve fork rod. Any slackness here will affect the valve setting.

Reversing Shaft and Bearing

The bearings for the reverse shaft can be made either from castings, or turned from the solid. In the latter case, chuck a piece of 3/8-in. by 3/4-in. brass bar truly in the four-jaw. Face the end, centre, and drill down 5/8-in. depth with 15/64-in. or letter C drill. Turn 1/4-in. of the outside to 3/8-in. diameter, slightly rounding off as shown; then, 3/8-in. from the shoulder, run the parting tool in until the core diameter of the piece is just above 3/8-in. If the groove formed by the tool is less than 1/8-in. wide, take another bite alongside of, and overlapping, the first; then part off ½-in. from the end. Reverse and re-chuck in the three-jaw; skim down the projecting 1/8-in. until it will just enter the 3/8-in. hole in frames, then run a 1/4-in. parallel reamer through. Round off the corners with a file. Castings can be machined up in similar manner, as a chucking piece will be provided.

The reverse shaft, or weighbar shaft, as enginemen call it, is made from a piece of 1/4-in. silver steel, squared off at the ends in the lathe, the finished length being 3 5/8-ins. This carries two lifting arms, which are filed up from 1/4-in. by 3/8-in. mild steel rod, and slotted as shown in the illustration. Tip: it is a good wheeze to take a piece of rod about 2-ins. long, and slot both ends of it, by clamping under the slide-rest tool holder, and running up to a cutter as previously described, reversing the piece for the second slot and then cutting it in half; or else use a longer bit of rod, slot the end, saw off enough for one arm, and repeat process. Never try to grip a small piece for slotting, as it will probably fly out of the tool-holder, and might cause damage or injury. Beginners may also care to learn that the necessary exact alignment of the holes in each side of a forked rod or lever, can be obtained easily by either drilling the hole before slotting, or else jamming a scrap of metal in the slot and drilling through the lot. Otherwise, if one side is drilled, and the drill left to find its own starting point on the other side, the chances are a hundred to one that the drill will wander, and go through "cock-eyed."

The larger ends of the lifting arms are drilled a drive fit for the shaft; if you have a set of letter-size drills, use C first, and follow up with D, which will be correct. If not, use 15/64-in., and then ream or broach out the hole until it will drive tightly on to the rod. The two lifting arms are then driven on to the shaft, to the positions shown in the drawing. They must be exactly in line, and this can be checked by putting a piece of 1/8-in. round steel rod, or a 1/8-in. drill shank, through all four holes in the forked ends. It should slide easily through the lot at once; if not, adjust arms until it does. Both arms can then be brazed or silver-soldered to the shaft; or alternatively, they can be drilled No. 43 through arm and shaft, and pinned with bits of 3/32-in. silver-steel wire. Make two brass or steel collars as shown, from 3/8-in. round rod; these are "kiddy's practice jobs," needing no detailed instructions.

The reversing arm is filed up to the shape shown, from 3/32-in. by 3/8-in. flat mild steel, and bent to 1/4-in. offset as shown in the end view of the valve gear. Both ends are furnished with bosses, made and fitted as previously described, the dimensions being given in the illustrations. The smaller boss is drilled No. 32 and reamed 1/8-in.; the larger boss is served in the same manner as the lifting arms, as it should be a tight fit on the end of the shaft. Don't fit it to the shaft yet, however, otherwise you won't be able to erect the shaft in the bearings.

The two lifting links are filed up from 1/8-in. by 3/8-in. strip mild steel, to the shape shown. The upper ends are drilled No. 32 and reamed 1/8-in.; the lower holes are drilled 1/4-in., and furnished with pressed-in bronze bushes turned from 3/8-in. drawn bronze rod. Chuck the rod in the three-jaw, face the end, centre, and drill down about 1/4-in. depth with No. 14 drill. Turn down 1/8-in. of the outside to a tight drive fit in the hole in the lifting link, and part off to leave a flange 1/16-in. in thickness. After squeezing in the bushes, poke a 3/16-in. parallel reamer through.

THAT completes the components for the valve gear. Before assembling and erecting, every hole in which a pin works should be casehardened. The holes needing this are those which have been reamed. Simply heat the eyed end to bright red, dip in casehardening powder as mentioned when describing links, and see that the eye is well filled up with it. Reheat until the powder fuses and the yellow flame dies away, then quench in clean cold water. Clean up, and polish with fine emerycloth. Don't leave any grit in the eyes. Casehardened eyes, with "natural" silver-steel pins working in them, give first-class results in any valve gear, resisting wear to the utmost, and permitting the gear to retain its accuracy, with consequent correct valve events, and the maximum power with minimum steam consumption.

How to Assemble and Erect the Valve Gear

The whole of the link motion can be assembled in two units, right and left hand, which are then erected in the frames, and the weighbar shaft erected and coupled up. Being able to assemble the motion whilst out of the frames, makes the job very easy. First drill the screwholes in the main frames for the brackets; the coupled wheels will have to be dropped to allow for this, but that only means taking out the hornstay screws. Note carefully; at 9/32-in. each side of the centre of the upper holes (3/8-in.) and 3/16-in. above and below, drill holes through frame with No. 34 drill, and countersink them. At 7/32-in. each side of centre of 3/16-in. lower holes, and also 7/32-in. above and below, drill and countersink similar holes. Leave the wheels down until the screws are all in.

First stage in assembly is to couple the eccentric rods to the links. The fore-gear eccentrics (nearest to frames) are coupled to the top of the links, and the back gear ditto (nearest to centre of engine) go at the bottom. Look closely at the plan view of the valve gear, and you'll see how the forks line up, one above the other. Squeeze pieces of 1/8-in. silver steel clean through forks and link, and file flush each side; the 1/8-in. steel is a drive fit in No. 32 holes, and a running fit in the reamed holes, so no further fixing is needed.

Now put the link hanger over its pin on the bracket, drop the washer into the recess, and secure it with a 7 B.A. countersunk steel screw, which should be a fairly tight fit in the tapped hole, so that it doesn't stand a chance of coming out on the road. Next, put a die block on the die bolt, and insert same in link, from the side carrying the lifting block. On the other side of the link, put a bronze or steel washer, 9/32-in. diameter and 1/16-in. in thickness over the bolt, to act as spacer and prevent the die block slipping out that side.

Put the bent end of the valve rod, bend pointing downwards, over the end of the link hanger, and line up the holes; then squeeze the projecting end of the die bolt through the lot, and put the nut on tightly. Study closely the end view of the valve gear and you'll see how the whole issue goes together. Note, the die, and the end of the link hanger, should move freely, but without shake, on the die bolt, but the latter should be a tight fit in the sides of the fork at the end of the valve rod. There should be no appreciable side play at all, the parts should just touch, but with freedom to move against each other.

The complete assembly can now be dropped into place, and the spigot on the link hanger bracket entered into the 3/16-in. hole in the frame, the eccentric straps placed over their respective sheaves, and secured by 6 B.A. bolts, with a locknut at the end for safety sake. This locomotive will be able to trot along at a considerable speed, and the "works" will be well shaken up, so it behoves all builders to take precautions! Put a toolmaker's cramp over the link hanger bracket and the frame, to hold them in close contact whilst drilling and tapping. Run the No. 34 drill through the holes in the frame, making countersinks on the flange of the bracket; follow up with No. 44 drill, tap 6 B.A., and screw four 6 B.A. countersunk screws in tightly.

Place the lower end of the inside pendulum lever between the jaws of the fork at the upper end of the valve rod; line up the holes, and secure with a little bolt made from a piece of 1/8-in. round silver steel, shouldered down to 3/32-in. at both ends, screwed, and furnished with ordinary commercial nuts. The plain part of the bolt should be a full 1/4-in. long, so that the jaws of the fork are not pinched in on the pendulum lever when the nuts are tightened.

How to Erect the Reverse Shaft

Put the two collars on the reverse shaft, also the two bearings or brackets, spigots outwards, and insert into holes in frame. This is easily done if you poke the longer end through the right-hand hole first, from the inside; then hold shaft level with centres of holes, and run the brackets along until the spigots enter them. The two brackets are now attached to the frame in exactly the same manner as described for the link hanger brackets. Next, attach the two lifting links to the studs on the lifting blocks, by slipping the bushed ends over them, with the flange next to the block (see end view of motion) and secure with a nut.

The upper ends of the lifting links are put between the jaws of the lifting arms on the weighshaft, and secured by two little bolts made exactly as described for the one in the pendulum lever. See that the shaft is set in its brackets or bearings, so that the lifting links are exactly vertical; then run the collars up against the bearings, drill No. 53 holes through collars and shaft, and squeeze in little pins made from 1/16-in. silver steel. The collars prevent any end movement of the shaft, and consequent straining of the gear.

All that remains is to put the reverse arm on the right-hand end of the shaft, setting it slightly forward, the hole being 5/16-in. from the vertical line, when the motion is in midgear, with the lifting arms horizontal, and the die blocks in the middle of the links. Pin it by drilling a No. 43 hole clean through boss and shaft, and squeezing in a pin made from 3/32-in. silver steel. The wheels may now be replaced, and all the pin joints and bearings treated to a spot of good machine oil.

If the valve gear has been properly made and erected, the wheels should turn without anything binding, jerking, or running hard; the reverse arm should move easily back and forth, with the wheels in any position, the links running freely up and down the die blocks; and there should be no appreciable play at the outside pendulum lever, if you try to move same with your fingers whilst the wheels are stationary. Beginners may get a slight shake, but if not more than 1/64-in., let it go; it can be compensated in the valve setting, as I shall show later on. If more than 1/64-in., find out where the slackness is, and correct before proceeding farther.

Valve Crosshead

THE next job will be to connect up the outside pendulum levers with the valve spindles, and set the valves. Get a piece of 1/4-in. square steel rod long enough to clamp in your slide-rest tool holder; set it at lathe centre height and at right angles to the lathe bed, and cut a slot 1/8-in. wide and 5/16-in. deep in the end, by running up to a 1/8-in. slotting cutter on a spindle either between centres or held in chuck, as described for valve gear. Reverse the piece, and repeat operations on the other end.

A crosshole is drilled with No. 32 drill across each fork; this may either be done before slotting, or by jamming a scrap bit of 1/8-in. metal into the slot after it is cut, and drilling through the lot. This will ensure both holes being in alignment, and square across the jaws. If you drill one side first, and leave the drill to make its own start on the inside of the other jaw, the chances are that it will wander.

Round off each end, same as the forks of the eccentric rods, then put a 1/8-in. parallel reamer through both sides, or else use a 1/8-in. home-made "sausage-ended" reamer as previously described.

Saw off the two slotted ends, or chuck in four-jaw and part off, to a length of 1/4-in. full. Then chuck each truly in the four-jaw, plain end outwards. Face off to 1/4-in. exact length, centre, drill No. 30 and tap 5/32-in. by 40; don't let the drill and tap go in far enough to open out the slotted portion. Turn down about 3/32-in. length of the outside to 7/32-in. diameter for appearance sake; then screw the crossheads or forks tightly on the ends of the valve spindles.

Connecting Links

The connecting links are made from two pieces of 1/8-in. by 1/4-in. mild steel rod, each 1 5/8-in. long. Scribe a line down the middle of one piece, make two centrepops on it 1 5/16-ins. apart, and drill them No. 32; use the drilled rod as a jig to drill the other. Round off the ends and reduce the middle part by filing or milling, to the shape shown in the illustration; then ream both ends 1/8-in.

The holes should be casehardened, as previously described; briefly, for new readers' benefit, heat each eye to bright red, roll in any good casehardening powder ("Kasenit," "Pearlite," etc.), filling up the hole, reheat until the powder all fuses and the yellow flame dies away, quench in cold water, and clean and polish. One end of the connecting link is placed over the pin in the outside pendulum lever, and secured with an ordinary commercial nut and washer; it must be free to move, without any slackness whatever.

The other end is placed between the jaws of the valve crosshead, and secured by a little bolt made from a piece of 1/8-in. silver steel, turned down at each end to 3/32-in., screwed either 3/32-in. Whitworth or 7 B.A., and furnished with nuts. The length of the plain part should be a weeny shade more than the overall width of the valve crosshead, so that when both nuts are tight against their shoulders, the crosshead jaws are not pinched in. You should be able to turn the bolt with your fingers.

How to Set the Valves

As the ports and valves cannot be seen, the valves must be set under air pressure. As a matter of fact, I always set the valves of my own engines under pressure, whether they can be seen or not, because the valve gear takes up the position it will occupy on the road, when there is pressure on the valve, and a more accurate setting is obtained. Run a 1/4-in. by 40 tap into the steam inlet on top of the cylinder *for two or three threads only*, and screw a short bit of copper tube into each; an inch or so will do.

The other requirements are, a cycle pump and a tin can. Solder up the seams of the can to make them airtight, also solder in a piece of 1/4-in. tube, and a cycle valve. Connect the tube to the one on the cylinder with a piece of rubber tube, and screw the cycle pump connector to the valve. By pumping air into the can, you have plenty available to do the valve-setting job, one side at a time.

Item No. 1 is to adjust the valve on its spindle until you have equal port opening both ends. Push the reverse arm right forward, so that the links are in their lowest positions, with the dieblocks at the top of the slots. Tighten up the setscrews in the fore-gear eccentrics; any position on the axle will do.

Pump some air into the can, and turn the wheels forward by hand. If you get a long hiss out of one cylinder-cock hole, and a short one, or none at all, at the other, the valve is off centre, and must be adjusted. Unscrew the valve spindle from its cross-head, take off the front steamchest cover, pull out the valve, and make the adjustment with the locknuts. It requires a little patience, but it is seldom three shots at most, fail to do the trick. Sometimes it comes right first time.

After making one adjustment, replace valve and try again; you need not replace the steamchest cover until the job is finished, as it is on the exhaust side of the valve. When the hisses sound equal at each end, the exact period of opening can easily be checked by noting how many wheel spokes pass the end of the guide bar whilst the hissing continues; they should be equal at each end of the movement.

Alternatively, you can make a mark on the wheel rim opposite the end of the bar as the hissing starts, and another when it stops. If the markings on the wheel rim are the same distance apart for each end of the valve movement, the port openings are equal.

The rest is plain sailing. Set the crank on front dead centre, that is, with the piston rod right home in the cylinder as far as it will go. Slack the setscrew holding the fore-gear eccentric on the same side, and with the links right down, slowly turn the eccentric in a forward direction until you hear a faint hiss from the hole for the front cylinder cock; then tighten the setscrew. Turn the wheels by hand in a forward direction. If the valve has been correctly adjusted for equal openings, you will hear the same faint hiss exactly as the crank arrives at the back dead centre.

Repeat operation on the other side of the engine; then put one crank on front dead centre again, reverse the valve gear by pulling the arm back so that the links are in their highest position, and turn the corresponding eccentric backward until the faint hiss is heard from the front hole. Tighten the setscrew, and repeat the operation on the other side of the engine. When air blows faintly from each of the four holes in turn, as the crank arrives exactly on the dead centres, in each direction, the valves are set correctly, and the engine will, literally, "go Great Western."

Reversing Gear

The reversing gear at the footplate end is a simplified copy of that used on the full-sized G.W.R. engines, and is different to any type hitherto described in this series of notes.

The screw is inclined, the reach rod, or reverse rod, going straight down from its connection on the nut, to the reverse arm on the weightshaft, without any bend. The bearings for the screw, and the guide for the nut, are mounted on a box base attached to the frame on the right-hand side near the back end. Castings will be provided, having the base, bearings and guide all in one unit; but they can be built up if desired.

The casting should be first cleaned up with a file, if there are any rough places on it, and the top of the guide for the nut filed very smooth and straight. Both front and back of each bearing lug should also be smoothed off. Centrepop the bearing lugs at 3/16-in. above the surface of the guide at each end, and drill them with a No. 30 drill, taking care that the drill is exactly parallel to the top of the inclined guide. Open out the higher bearing with 7/32-in. or No. 2 drill, and tap it 1/4-in. by 40.

Make a little nipple to suit, from a piece of 5/16-in. hexagon brass rod held in the three-jaw. Face, centre, and drill down about 5/16-in. with No. 30 drill. Turn down 3/16-in. of the outside to 1/4-in. diameter, and screw 1/4-in. by 40. Part off to leave a 3/32-in. head; reverse in chuck, and chamfer the corners of the hexagon.

Reversing Screw

To make the screw, chuck a piece of 7/8-in. round steel rod in the three-jaw with about 3/8-in. projecting. Face the end, and turn down 9/16-in. length to 9/32-in. diameter. Turn down 5/32-in. of that, to a shade under 3/32-in. diameter, and screw it 8 B.A. Push the rod back in the chuck until there is only 3/32-in. of plain part showing, and file it 1/8-in. square.

For beginners' and new readers' benefit, here is a simple way of doing this. Use a flat file with a plain or "safe" edge, which is placed next the chuck jaws, so that they are not damaged. Put one of the chuck jaws vertical, and hold it there whilst you file a small flat on the projecting piece of rod. Turn the chuck for a quarter turn, till the jaw is in the position of the hour hand of a clock at three o'clock, and file another flat. Turn another quarter, to six o'clock, and file flat No. 3; the last one is filed with the chuck jaw at nine o'clock, and there is your square, all present and correct. If you keep the safe edge of the file hard up against the chuck jaws whilst filing, the square will be perfectly even.

Pull the rod out of the chuck until there is about 1¾-ins. showing behind the 9/32-in. shoulder; screw this 9/32-in. Whitworth, with a die in the tailstock holder.

As the Great Western locomotives, like most other engines on other lines, have left-handed reversing screws, use a left-handed die if you have one; otherwise a right-handed one of the ordinary pattern will have to do. Anybody who has a screwcutting lathe, and likes to take the trouble, can make a two-start screw, and thus get quicker action, as the nut would travel twice the distance with one turn of the reversing handle.

Two-start Screw

To do this, set up your wheels to cut 12 threads per inch, and instead of using a single-point tool in the slide rest, set up a 24-thread chaser. As this will be advanced at twice the speed of the ordinary 24-pitch thread, it will cut two complete threads of 12 pitch, side by side, the result being a perfect two-start thread.

The quicker action is handy when the engine is used on a short up-and-down line; but for continuous running I prefer the single thread. It allows a very fine adjustment of the cut-off point, and "stays put" without the need for a catch. A stwo-start or other multiple thread often "creeps" into full gear unless a catch and toothed plate is fitted behind the handle; and this is not only a "watchmaker's job" on a 3½-in. gauge reversing gear, but very flimsy, and liable to be easily damaged.

Really, the best form of reversing gear for an engine running on a short, straight line, is a "pole" lever with the usual trigger, latch and sector plate. There is little chance of notching up on a run of 50-ft. or less, each way.

Part off the screw at 1 11/16-ins. from the shoulder; reverse in chuck, and turn down the end for 5/16-in. length, to 1/8-in. diameter. It doesn't hurt the screw to hold it in the chuck jaws, as long as you don't over-tighten the chuck.

Reversing Nut

The nut is a little block of bronze, gun-metal, or hard brass, 7/16-in. long, 5/16-in.

wide, and 3/8-in. high. On the wide side, at 3/16-in. from one end, and midway between top and bottom, make a centrepop, and drill and tap the nut to suit whatever thread you have put on the reversing screw. Round off the top as shown. Centrepop the middle of the short side, drill No. 40, and tap 1/8-in. or 5 B.A. Make a pin to suit, from a 7/16-in. length of 1/8-in. round silver steel. Turn down one end slightly and screw it 8 B.A. Put a few threads on the other end to match the tapped hole in the side of the nut, and screw it home as shown in the illustration. The amount of plain part projecting, should be a shade over 1/8-in., so that the nut, when screwed home, doesn't grip the end of the reach rod. An ordinary commercial 8 B.A. nut is used.

Reversing Handle

The handle is filed up from a piece of 3/32-in. by 5/16-in. strip steel, or an odd scrap of 3/32-in. steel plate will do. Drill a 1/8-in. hole in the middle, and file it square, with a watchmaker's square file or a Swiss needle file, to fit nicely on the square formed on the screw. Drill two 1/16-in. holes at 7/16-in. from the centre of the handle; turn up two little handle grips from 3/16-in. round steel, to the shape shown, leaving a 1/16-in. pip on the end of each. Drive these pips into the holes in the handle, and slightly rivet over at the back.

To assemble the gear, place the nut on the guide, near the higher end, insert the screw through the tapped hole in the rear bearing, and screw it through the nut, pushing the screw forward until the pip on the end enters the lower front bearing. Then put the nipple on the screw, as shown in the drawing, and screw it home in the back bearing. When the nipple is tightened up, the screw should be quite free to turn, but without any end movement. The handle is then fitted on to the square, and secured by an 8 B.A. nut and washer.

Reverse Gear Erection

To erect the complete assembly on the engine frames, drill four No. 30 holes in the lower part of the cast base, in the position indicated in the drawing. Set the complete reverser 1/4-in. from the back of the frame, the bottom of the cast base being level with the top of the drag beam.

Clamp in position temporarily, with a toolmaker's cramp; then, using the four holes drilled in the base as guides to locate the drill, drill four corresponding holes in frame, and secure the lot with four 1/8-in. bolts, or screws and nuts, as shown in the port section. If preferred, the holes in the cast base can be drilled No. 40 and tapped 1/8-in. or 5 B.A.; the holes in the frame drilled No. 30, and setscrews put in, instead of bolts.

Built Up Reverse Stand

If anybody prefers to build up the reversing gear stand instead of using a casting, the box part can be bent up from 3/32-in. sheet brass, leaving the bottom and right-hand side open, as indicated on the sketch of the casting. The bearing lugs can be made from 3/16-in. by 3/8-in. brass bar, silversoldered to the base, whilst the guide for the nut can be a strip of the same material, silversoldered between the two bearings. The corners of the box base should also be silversoldered. Nut, screw and handle are made the same as for a cast stand, and the whole issue is erected the same way.

Reach Rod

A piece of 1/8-in. by 1/4-in. flat steel rod about 12¾-ins. long is needed for the reach rod, or reverse rod, connecting the reversing nut to the arm on the weighbar shaft. The approximate length of this rod between centres of pinholes is 12-ins., but the exact length should be obtained from the engine itself, in the following manner. Put the link motion in midgear; that is, with the dieblocks in the middle of the links. The reverse arm on the end of the weighbar shaft will then incline slightly forward.

Owing to the offset connection of the lifting links to the expansion links, the movement of the reverse arm is slightly more from midgear to full forward, than from midgear to full backward; therefore, set the nut on the reversing screw so that it is 9/16-in. from the back bearing instead of being exactly in the middle. Take the distance between the centre of the hole in the arm on the end of the weighbar shaft, and the centre of the pin in the reversing nut, and that will give you the exact dimension of the reach rod between pinhole centres.

A small block of steel, 1/4-in. wide, 3/16-in. thick, and about 5/8-in. long, is brazed on to one end of the reach rod, and machined up into a fork or clevis, exactly as described for the eccentric rods.

After setting out, drilling the pinholes with No. 32 drill, and putting a 1/8-in. reamer through them, the ends of the rod and the fork can be rounded off, and the rod reduced in width from 1/4-in. to 3/16-in. between the eyes, for appearance sake, either by milling or filing.

Built-up Reach Rod

ANYONE who does not care for the job of reducing nearly a foot of steel from 1/4-in. to 3/16-in., could, if they so desire, build up the rod from a piece of 3/16-in. by 1/8-in. steel, brazing on a little boss at one end, to form the eye for attachment to the reversing nut, and brazing on a piece of 1/4-in. by 3/16-in. steel about 5/8-in. long, at the opposite end, to machine up into the fork shown in the illustration (last week).

When erecting, the eye at the rear end of the rod is merely slipped over the pin on the reversing nut, and secured by an ordinary commercial 8 B.A. nut and washer; at the forked end, a 1/8-in. pin, shouldered down at each end and nutted, as described for the valve crosshead pin, is put through fork and reverse arm. When the nut on the reversing screw is at each end of its travel, the dieblocks should be at the ends of the links, but not actually touching them. That completes the motion work.

Testing

If a temporary pipe connection is now made to the two cylinders, and a motor tyre pump attached, the wheels should turn easily when the pump is operated, working equally well in either direction, the exhaust beats coming from the holes in the cylinder bolting faces with exceedingly sharp snaps.

If the pump has a fairly long hose, put the chassis on the workshop floor, and you will find that one vigorous stroke of the pump will send the chassis careering halfway to the opposite wall. For air pressure test, the holes for the drain cocks in the cylinder flanges must, of course, be temporarily plugged.

Exhaust Pipes

Two pieces of 5/16-in. copper tube, each 1¾-ins. long, will be needed, also a 1/4-in. tee-piece and two locknuts. One end of each pipe has 1/8-in. of 5/16-in. by 40 thread cut on it, and the other end 3/4-in. length of same pitch.

Hold the pipes in the three-jaw, and use a die in the tailstock holder; don't forget a drop of cutting oil helps in producing perfect threads on copper pipes.

The tee-piece can be either cast or built up. If cast, it will have a chucking piece on it, to hold in the chuck whilst drilling and tapping the boss for the blast pipe. Chuck by one side of the tee, and set the other to run truly. Face the end, centre, drill right through with 9/32-in. drill, and tap 5/16-in. by 40.

To face the opposite end, screw the tee on a stub of 5/16-in. brass rod held in three-jaw and threaded to suit. Then chuck by the spigot, face the end of the blastpipe socket, centre, drill 11/32-in. until the drill breaks into the central passage, and tap 3/8-in. by 40.

Built-up Tee

To build up the tee, chuck a piece of 1/2-in. brass rod in the three-jaw and part off a piece 1 1/8-ins. long. Re-chuck it, centre, drill right through with 9/32-in. drill, and tap 5/16-in. by 40. Part off another piece of 1/2-in. rod a full 3/4-in. long; chuck it, centre, drill 11/32-in. and tap 3/8-in. by 40. File a half-round hollow in one end, tie it to the middle of the first piece with a bit of thin iron wire, and silversolder it.

Poke the 11/32-in. drill down the end, drill into the hole through the cross piece, and there is your tee. Put the 5/16-in. by 40 tap through again, to remove any burrs.

Tee Nuts

To make the nuts, simply chuck a piece of 7/16-in. hexagon rod; face, centre, drill about 1/2-in. deep with 9/32-in. drill, tap 5/16-in. by 40, and part off two 3/16-in. slices. They can be re-chucked separately, and the corners of the hexagons chamfered, for the sake of appearance.

Exhaust Assembly

To assemble and erect, put a locknut on each of the pipes, screwing it down to the end of the thread; then screw the pipes into the tee until they meet in the middle. Hold the assembly between the exhaust holes in the cylinders, screw each pipe out of the tee, into the cylinder, until right home, as shown in the illustration; then screw the locknuts back against the tee, and you are all set. Keep the stem of the tee upright. No jointing paste is needed on the threads, as there is only the exhaust pressure to contend with.

The blastpipe is a 2 1/4-in. length of 3/8-in. copper tube screwed at both ends, one end being screwed into the stem of the tee, as shown.

Blast Nozzle

The upper end carries a combined blast nozzle and blower ring. To make this, chuck a piece of 7/8-in. round brass rod in the three-jaw; face, centre, and drill down about 3/4-in. depth with 7/32-in. or No. 3 drill. Turn down 9/16-in. length to 1/2-in. diameter, and taper off 1/4-in. of the end, as shown in the section. Part off at 5/8-in. from the end, leaving a 1/16-in. flange of full diameter.

Reverse in chuck, open out the centre hole for 3/8-in. depth with 11/32-in. drill, and tap 3/8-in. by 40. The nozzle can either be left as drilled, or if a refinement is desired, can be "streamlined" as shown in the section, by means of a half-round reamer, home-made from a bit of 5/16-in. silver steel.

Chuck the 7/8-in. rod again, centre, and drill about 3/8-in. deep with 1/4-in. drill. With a square-ended boring tool in the slide-rest, or a 3/4-in. D-bit in the tailstock chuck (I use the latter; D-bits are easily home-made, any size, and always mighty useful) open out the hole to form a flat-bottomed recess 1/4-in. deep and 3/4-in. diameter. Part off at 5/16-in. from the end. Drill four No. 70 holes in the top of it, as shown in the plan view, and a 3/16-in. hole in the side. In the latter fit a 1/4-in. by 40 union nipple.

Chuck a bit of 1/4-in. brass rod in three-jaw, face the end, and centre deeply with a size E Slocomb drill, or any equivalent centre-drill. Drill with a No. 40 or 3/32-in. for about 1/2-in. depth. Screw the outside 1/4-in. by 40 for about 1/4-in. length, and part off at 7/16-in. from the end. Reverse in chuck, and turn down the plain end to a tight push fit in the 3/16-in. hole in the side of the blower cap.

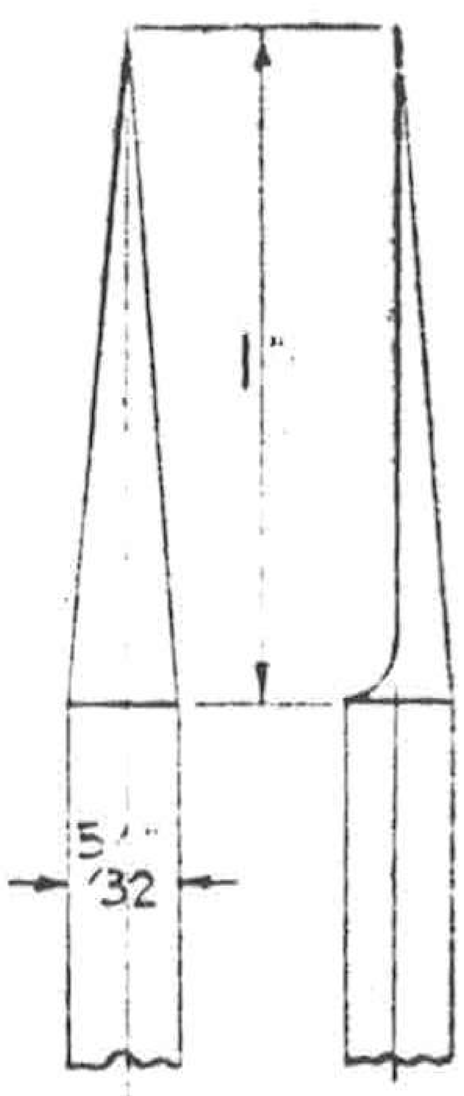
Insert it, put the cap over the central part of the nozzle, as shown in the illustrations, and silversolder the joint around the base of the cone, the joint between cap and flange, and the nipple into the blower cap, at one heating. Merely smear some wet flux around the joints, heat to medium red, and touch the joints with a strip of silversolder. Johnson-Matthey's "Easyflo," and the special flux sold with it, is the best stuff I ever used for jobs like these, and I haven't any shares in the company, at that! Quench out in acid pickle, wash off and clean up.

Silver Solder Hints

The pickle I use for jobs like the above, or any other small fittings, is old accumulator acid diluted with three times its bulk of ordinary tap water, and a glass jam jar does fine for a pickle bath.

A self-blowing gas-blowpipe can be made from 6-ins. of 3/8-in. boiler tube, with two 5/16-in. holes near one end of it. A nipple is turned up from a bit of brass rod as shown in the illustration, and the whole doings connected up to the nearest gas point, by a bit of rubber tube. This gadget will silversolder all the boiler fittings easily. Screw the combined blast and blower nozzle on to the blast pipe, no jointing material being required, and the exhaust arrangements are complete. The steam pipes cannot be attached until the boiler is made and erected.

"L.B.S.C." describes cylinder drain cocks



REAMER FOR COCK BODIES

PLUG cocks are an abomination in boiler fittings: regular readers of these notes will have noticed that I never specify them for that purpose, as in my experience I find they either leak badly, or stick, and if any force is attempted to free them, the handles promptly break off.

However, in the case of cylinder drains, it is what is popularly known as "a horse of another colour." Sufficient oil finds its way to the plugs, from the cylinder and valve lubrication, to eliminate all chances of a "stick-up"; and that same film of oil around the plug is usually sufficient to prevent any leakage. Even if a slight wisp of steam does get by, it is of no moment, and does not affect the running of the engine; but it is easy enough to make correct-fitting plugs that will not leak, as the following instructions will show.

Reamer

First of all we need a reamer for the taper holes in the plug bodies. As the cocks are only very weeny fittings, I always use one of my injector-cone reamers, but it is only a few minutes' work to make a special one. Get a piece of 5/32-in. round silver steel about 3-ins. long, chuck in three-jaw, and turn a cone point on it 1-in. long, as shown in the illustration. If your slide-rest has a graduated base, set it over to about 4 degs. and you'll find the taper will come about right. File away half the diameter of the tapered part, and harden and temper.

For beginners' benefit, I will repeat briefly, heat the tapered part to medium red (cherry) and plunge into cold water. Rub the flat face on a piece of fine emery-cloth, taking care to keep it quite flat, and not destroy the sharp edges; this will brighten it up.

Now lay the reamer on a piece of sheet iron, and hold it over the small ring on the domestic gas stove, if you haven't a proper Bunsen. Have a cup of cold water handy; watch the brightened part of the taper like a cat watching a mousehole, and as soon as it turns dark yellow, tip the reamer into the water. Rub the flat face again on an oilstone until it is once more bright, and the edges are keen, and it is ready for service. Same instructions apply to injector-cone reamers, to be described later.

Cock-plug Fitting Made Easy

Not only beginners, but many experienced workers, have difficulty in turning small cock plugs to an exact fit in the taper holes in the bodies; that explains why "leakers" are so numerous! There is no need for this at all; after you have turned the cone point on the reamer as described above, *don't alter the setting of the slide-rest in any way whatever*, but get a few bits of 5/32-in. bronze or brass rod, and turn a taper on the end of each. These tapers need not go right to a point; leave the end 1/16-in. wide. This will, of course, have no effect on the angle of taper, and the turned pieces will *exactly* fit any hole tapered by the reamer. There is no trial-and-error business at all; if plugs and reamer are turned with the same setting of the top slide, they just can't do anything else but fit exactly!

Cock Bodies

The cock bodies are made from 1/4-in. round rod, bronze, gun-metal, or a good quality brass are all suitable, but don't use the brittle alloy known in the trade as "screw-rod," or the nozzles will break off when you try to bend them. Chuck a piece in the three-jaw with about 3/4-in. projecting; face the end, turn down 1/4-in. length to [illegible]-in. diameter, using a knife tool, and screw 5/16-in. by 40. Then, with a round-nose tool, form the shape of the cock body as shown in the illustration; pull the rod a little farther from the chuck, and part off at 1-in. from the end. Four of these will be needed; it wouldn't be a bad wheeze to make six, in case you spoil any on subsequent operations!

Form Tools

If you like to take the trouble to make a form tool for getting the cock bodies all the same size and shape, instead of using the roundnose, get an old flat file, and soften it by heating to bright red and letting it cool slowly. In my young days I used to leave them in the kitchen fire at night, and they cool off with the contents of the grate.

Grind the teeth off the end, and file it to the contour of the cock body "in reverse," in a manner of speaking, so that the outline of the end of the ex-file corresponds to the illustration, if laid on it. Harden and temper, oilstone the cutting edge, put it in your slide-rest tool-holder, and feed straight in. To get a nice finish, free from chatter, the tool should have its cutting edge exactly at centre height, and be used as close to the chuck as possible.

Deep Hole Drilling

Re-chuck the blanks in a tapped bush held in the three-jaw; the bush is just an odd bit of metal about 3/8-in. diameter and 1/2-in. long. Chuck, face, centre, drill right through with 5/32-in. drill, slightly countersink the end with 3/16-in. or No. 11 drill, tap 5/16-in. by 40, and skim off any burr. Don't remove from chuck, but screw the blank into it, and it will run dead true. Face the end carefully, centre, and drill right through with 1/16-in. or No. 52 drill.

The secret of drilling deep holes in metal without breaking the drill, is to keep withdrawing it to get rid of chippings, these cause breakage by jamming the drill through the flutes becoming choked up solid. I use a lever-operated tailstock when drilling small holes in my Boley lathe, and work the lever back and forth like a pump handle; by this means a No. 80 hole can be made full length of the drill. Turn down about 3/8-in. of the end to [illegible]-in. diameter, to form the nozzle, as shown in the illustrations.

Carefully file a small flat on each side of the round part of the cock body; centre-pop one side, and drill a 3/32-in. hole right through. If you haven't a drilling-machine, use the lathe, as it is important this hole goes through quite square, and cuts exactly across the longitudinal hole through the cock body.

Next, ream the hole to a taper, with the reamer previously made. It can be used with a tapwrench; but I find the most satisfactory way is to hold the reamer in the three-jaw, pull the lathe belt by hand if the lathe is power-driven, or work the foot pedal very slowly, if foot-driven. Put the hole in the cock body, over the reamer, and gently press it with your fingers toward the chuck, until the cross hole is tapered full depth. The small end will then be a shade over 3/32-in. diameter, and the larger end approximately 1/8-in. If the edges of the holes are sharp, slightly flatten them with a fine file; not much, merely remove the sharp edge.

How to Fit the Plugs

CHUCK each of your ready-tapered plug blanks in the three-jaw, put a cock body over them, and see how much projects through the small end of the tapered hole. Turn that amount, plus about 1/64-in. on each plug, to 5/32-in. diameter; then further reduce to 1/16-in., leaving the last 1/16-in. or so next to the plug, the full diameter. File this little bit square, and screw the rest either 1/16-in. Whitworth, or 10 B.A. I have a set of American machine-thread taps and dies, the 1/16-in. being 72 threads per inch, and always use that pitch on weeny cock plugs. Part off a full 3/8-in. from the shoulder next the square, and file another square on that end, to take the handle.

Beginners will probably wonder how on earth they are going to hold the tapered plug, without damaging it; well, everything is easy *when you know how*.

Chuck a short bit of 1/4-in. brass rod in three-jaw; face, centre, and drill it 3/32-in. Put the taper reamer in the tailstock chuck, and ream the hole with it until the entrance is 1/8-in. diameter. Pull out the reamer, and there is a nice little taper socket in the chuck, running dead true; all you have to do, is to push each of your taper plugs tightly into it, and file the square just as I described for the squared part of the reversing screw. Quite simple!

Square-hole Washers

Each plug needs a square-holed washer and a nut. To make the washers, chuck a bit of 5/32-in. brass rod in three-jaw; face, centre, drill down 1/2-in. or so with No 48 drill, and part off four slices a bare 1/16-in. in thickness. File each hole square with a watchmaker's square file, so that it fits nicely on the square on the small end of the plug. Before fitting, rub each side on a piece of very fine emerycloth, to remove any burring.

Ordinary commercial nuts may be used, but I prefer longer ones; they are less likely to come off on the road. Chuck a bit of 1/8-in. rod in three-jaw; face, centre, drill down 1/2-in. or so with No. 55 drill, and tap 1/16-in. or 10 B.A. to suit the thread on the end of the plug. Part off about 3/32-in. from the end. The nuts can either be used as they are, or a flat can be filed each side. If you happen to have a bit of 1/8-in. hexagon brass rod, the nuts may be made from that, and slightly chamfered before parting off.

Handles

The handles are filed up from 1/2-in. lengths of 3/16-in. by 1/16-in. strip, or from any odd bits of 1/16-in. steel sheet that may happen to be kicking around. One end has a square hole in it, made in the same way as those in the square-holed washers; the other end is drilled with a No. 48 drill. The handles should be a tight fit on the squares on the cock plugs; if they are at all loose, secure them with a touch of solder. If riveted over, you will probably damage the plug in the process; it isn't worth chancing.

Now put the plugs in, and put on the nuts and washers temporarily; don't screw them up too tightly. Set two of the cock handles at an angle of about 45 degs. pointing to your left, and the other two pointing to the right, looking at the handle side of the cock; then put a drill down the central passageway, and drill right through each plug. This makes two cocks right for each cylinder; the cocks should be open when the handles incline to the front of the engine. In the drawing, they are shown in the "shut" position.

Grinding In Plugs

The plugs must be ground in, before screwing into the holes in the cylinder flanges. Remove nut and washer, take each plug out, and scrape a few shreds off your oilstone, or if you have been sharpening tools, and a drop of dirty oil is left on the stone, this will do quite well. Smear it over the plug, and grind it into the socket lightly for a couple of dozen turns, or thereabouts; then carefully wash off every trace of the oilstone grit with a brushful of paraffin, taking care nothing is left in the passageway.

Rub the point of a soft blacklead pencil over the plug before assembling the cock "for keeps"; the nut shouldn't be tightened up sufficiently to prevent easy movement. The cocks can then be screwed into the cylinders with a touch of plumbers' jointing on the threads; handles on the inside, and the nozzles bent forward as shown. As they are only 1/64-in. in thickness, you should be able to do this by finger pressure alone; if not, use a bit of wood. A piece of 16 gauge lead fuse wire poked down each nozzle will prevent any closing up, and it can be pulled out afterwards.

Should you be unlucky enough to break off a nozzle, don't worry; merely file the end of the cock off square, counterbore the hole very slightly with a No. 43 drill, fit a bend made from 3/32-in. tube in the counterbore, and solder it. Only the merest touch of solder will be sufficient.

Cock Connecting Link

The two cock handles on each cylinder are connected by a sort of 0000-gauge coupling-rod filed up from a bit of 3/16-in by 1/16-in. steel strip, to dimensions given in the illustration. They are placed between the handles and the cock bodies, and secured by a 9 B.A. screw at each end, passing through the 48 hole in the plug, into the tapped hole in the rod. The screws should fit the tapped holes tightly; if slack, slightly burr the ends on the inside, to prevent losing them on the road.

No provision is made for operating the cocks from the footplate, as they are only needed when starting up from all cold, and it would be a fairly difficult matter to arrange a rod connection, as several levers and bell cranks would be needed to get around the various obstructions.

The only alternative, for footplate operation, would be a Bowden wire of microscopic diameter inside a bit of 3/32-in. tube, as on the L.N.E.R. Pacifics. Drivers of these small locomotives always give them a run without load, to warm up when first starting from cold; and when walking beside the engine, it is easy enough to close the cocks direct by a finger-touch on one of the little cock handles, the coupling-rod doing the needful on the other. As several readers have, from time to time, asked for instructions on plug-cock making, I have given the above in full detail, to "kill two birds with one shot."

"L.B.S.C." describes the mechanical lubricator

THE mechanical lubricator is of the simple oscillating-cylinder type; and though small, is easy enough to make. If you can get hold of a piece of 1 1/4-in. square brass tube (commercial article before the war) for the oil tank, use it; if not, build it up from 18 gauge brass sheet. Cut a strip 6-ins. long and 1 1/4-ins. wide; bend it into a square with 1 1/4-in. sides. Stand it on a piece of the same kind of metal, a little over 1 1/4-ins. square, in your brazing pan or tray, and silver-solder all around the bottom, and the corner forming the joint. Pickle, wash off, clean up, and file the bottom flush with sides. On the centre line of one of the sides, 5/16-in. from the top, drill a 3/16-in. hole; and a similar one exactly in the middle of the bottom of the container.

Pump Stand

Chuck a bit of 5/16-in. square brass rod truly in your four-jaw; face the end, centre drill to about 3/16-in. depth with 5/32-in. or No. 22 drill, tap 3/16-in. by 40, and part off at 1 1/4-ins. from the end. Set out the position of all the holes as shown in the detail illustration, making centre-pops at each point; note, the location of the ports is obtained by striking an arc from the centre of the trunnion hole, with divider points set 1/4-in. apart, the holes being dotted off 1/16-in. each side of the centre line.

Trunnion and bearing holes must go through absolutely square with the face; so if you haven't a drilling machine, use the lathe, with the drill in the three-jaw, and the stand supported by a tailstock drilling pad, a bit of truly-faced hard wood being placed between stand and pad.

Tap the bearing hole 3/16-in. by 40, and open out the trunnion hole at the back of the stand, to 1/8-in. depth, with 1/4-in. pin drill if you have one. If not, an ordinary drill will have to do. The recess at the trunnion hole, and the rebate at the top of the stand, can be formed either by milling or filing. I cut six pump stands to length at once, clamp them side by side in a machine-vice on the table of my milling machine, and form recesses and rebates at one fell swoop.

The right-hand port is drilled right through into the tapped hole at the bottom of the stand; the left-hand port is only drilled to about 1/16-in. depth, and a small groove is chipped from it to the bottom of the stand, across the port face as shown, to allow oil to enter the port. True up the rubbing faces by rubbing on a sheet of fine emerycloth laid on the lathe bed, or other truly-faced surface.

Pump Cylinder

Chuck the 5/16-in. square rod again, and part off a piece 5/8-in. long. On one end of this, on the centre-line, and 5/16-in. away from one edge, make a centre-pop. Re-chuck in four-jaw with this centre-pop running truly; drill right through with No. 33 drill, open out to 3/16-in. depth with 3/16-in. drill, and tap 7/32-in. by 40. Poke a 1/8-in. parallel reamer through the remains of the hole. Set out the port and trunnion holes on the side farthest from the bore, as shown in the illustration, the port being 3/32-in. from the bottom, and the trunnion hole 1/4-in. above it, both on the centre line. Drill the port with No. 54 drill, letting it pierce the bore; drill the trunnion hole No. 48, and don't pierce the bore. Tap it 3/32-in. by 60, if you have a tap and die of that pitch; if not, 7 B.A. Run the 1/8-in. reamer through the bore again, to remove any burring, and then turn a little plug to a tight drive fit in the end of the bore, as shown. Solder over it, for safety sake, so that oil pressure can't force it out.

Pump Ram

The pump ram is a piece of 1/8-in. round rustless steel or bronze rod, a bare 7/8-in. long, with a No. 48 cross hole drilled in it at 3/4-in. from the lower end. The little gland is turned from 1/4-in. hexagon brass rod, same process as used for the piston glands. The trunnion is a 7/8-in. length of 3/32-in. round steel or bronze; one end is screwed to fit the tapped hole in the pump cylinder, and the other either 3/32-in. Whitworth or 7 B.A. Screw tightly into the pump cylinder, but not tight enough to make an indentation in the bore.

Make certain the rubbing face of the cylinder is properly trued up, same as that of the pump stand, before screwing in the trunnion; and see that same is exactly at right angles to the port face. Pack the gland with a few strands of graphited yarn, and assemble pump as shown in the sectional illustration, using a spring wound up from 22 gauge tinned steel wire, secured by an ordinary commercial nut and washer.

Bearing, Spindle and Crank

To make the bearing, chuck a piece of 5/16-in. hexagon brass rod in the three-jaw; face the end, centre, and drill down 1-in. depth with No. 41 drill. Turn down 27/32-in. of the outside to 3/16-in. diameter, and screw 3/16-in. by 40 with die in the tailstock holder. Part off at 15/16-in. from the end, reverse in chuck, and slightly chamfer the corners of the hexagon.

For the locknut, re-chuck the rod, centre, and drill down about 3/16-in. depth with 5/32-in. or No. 22 drill. Tap the hole 3/16-in. by 40, chamfer the corners of the hexagon, and part off a 1/8-in. slice. If a burr is left on the nut, rub it on a file and run the tap through again. Tip to beginners: if you grind your parting tools at an angle sloping back from right to left, they will seldom leave a burr.

The spindle is a piece of 3/32-in. silver-steel wire, 1 7/16-ins. long, with 1/8-in. of 3/32-in. or 7 B.A. thread on one end. The screwing of the other end had better be left until the ratchet lever is fitted, as the nut must be tight at the end of the thread when the lever has just enough freedom to swing backwards and forwards easily, without any side movement.

Crank

For the crank, chuck a bit of 3/8-in. round brass rod; face, centre, drill down about 3/16-in. depth with No. 48 drill, and tap same thread as the end of the spindle. Part off a 1/8-in. slice, and on it drill a No. 53 hole, 1/8-in. from the centre. Tap this 9 B.A., and screw in a piece of 15 gauge spoke wire, to form the crankpin.

Beginners' tip, once more: any cycle dealer sells spokes of all usual gauges, either singly or for a few pence per dozen, and they are just "the cat's whiskers" for jobs like the above, or for making valve gear pins, and various other locomotive jobs. When I built my old 4-4-2 "Ayesha," a quarter-of-a-century ago, I used two bits of spoke wire for the valve crosshead pins. They are still doing duty.

Outlet Valve

Chuck a piece of 5/16-in. round brass rod in the three-jaw; face the end, centre, and drill down about 5/8-in. with No. 44 drill. Turn down 5/32-in. of the end to 3/16-in. diameter, and screw 3/16-in. by 40; part off 9/16-in. from the end. Reverse in chuck, open out to about 1/4-in. depth with 3/16-in. drill, bottom the hole to 5/16-in. depth with a 3/16-in. D-bit, slightly countersink the end, and tap 7/32-in. by 40, taking care not to let the tap run in far enough to spoil the ball seat. Run a 3/32-in. reamer through the remains of the small hole; you can make one by filing one end of a couple of inches of 3/32-in. silver-steel to a long oval, like a sliced sausage, hardening and tempering to dark yellow, and rubbing the oval face on an oilstone. Drill a 3/16-in. hole in the side, about half-way along, and fit a union nipple in it.

Chuck a bit of 1/4-in. brass rod, turn about 3/8-in. of it to 7/32-in. diameter, and screw it 7/32-in. by 40 for about 1/4-in. down. Face the end, centre deeply with size E centre-drill, drill down about 3/8-in. depth with 5/32-in. drill, and part off 5/16-in. from the end. Reverse in chuck, and turn the plain end for about 3/16-in. length, to a tight fit in the hole in the side of the valve body; press it in, and silver-solder it. Pickle, wash off, and clean up.

Cap

For the cap, chuck a piece of 5/16-in. hexagon brass rod in three-jaw; face, centre, and drill down about 5/16-in. depth with No. 30 drill. Turn down 5/32-in. of the outside, to 7/32-in. diameter, and screw 7/32-in. by 40. Part off at 3/8-in. from the end; reverse in chuck, and chamfer the corners of the hexagon. Drop a 1/8-in. rustless steel ball on to the seating; seat it by resting a bit of brass rod on it, and giving the end of the rod a sharp crack with a hammer. Wind up a spring from a piece of tinned steel wire about 26 gauge, and insert it into the hole in the cap; then screw the cap home. Note, the ends of the spring should be squared off by touching them against a fast-running emery wheel; and no great pressure is needed on the ball, the compression of the spring should be sufficient to hold the ball firmly on its seating, and no more.

How to Assemble the Lubricator

This is a simple job. Put the stand, with pump cylinder attached, into the tank, and screw the outlet valve into the hole in the bottom of the stand, through the hole in the tank bottom. Line up the hole in the top of stand, with the hole in side of tank. Insert bearing, put the locknut on inside tank, then screw bearing into stand, until the head just touches the tank side. Run back the locknut and tighten it, thus gripping the tank side between it and the head. Tighten up the outlet valve underneath, and the job is done.

Ratchet Gear

The ratchet wheel should be 7/16-in. diameter, 5/32-in. in thickness, and have about 35 teeth. If you can't make one, get a suitable one from your local watch and clock repairer.

Put a No. 43 drill through the hole in the wheel, and drive the plain end of the spindle through it, until the screwed end is 1 1/16-ins. clear of the wheel. Caution! — very important, this — mind you don't drive the wheel on the spindle the wrong way around, or the gadget won't pump! The vertical part of the teeth should face left, looking at the short end of spindle; see illustration.

Now push the crankpin through the cross-hole in the end of the pump ram, and hold the crank disc opposite the end of the bearing. Push the screwed end of the spindle through the bearing, and screw it into the crank disc. When right home, the spindle should have about 1/64-in. end play; if more or less, adjust the position of the ratchet wheel on the spindle, until the correct clearance is obtained.

Pump Testing

The pump can now be tested. Put some fairly thick oil into the tank (the grade used for automobile engines will do) and turn the ratchet wheel slowly in a clockwise direction. You will feel a slight resistance as the pump ram forces the oil through the delivery valve against the pressure of the spring. When oil appears at the union nipple, press your thumb on it with all the strength you can muster, and continue turning the ratchet wheel slowly. No matter how hard you press, the pump, if O.K., will force the oil past your thumb. These weeny gadgets think nothing of pumping against 400 lbs. pressure.

To settle an argument among some of our fraternity in a full-sized locomotive works, one was put on the full-sized gauge-testing apparatus, and it promptly sent the master gauge over the 400 lbs. mark, at which point the operator called it off, for fear of damaging the master gauge!

Ratchet Pawls

All that remains are the ratchet lever and pawls. The lever is filed up from a bit of 1/4-in. by 5/32-in. steel, 1 1/4-ins. long; one end is drilled No. 41, and the other has three No. 48 holes in it, as shown. Put it temporarily on the spindle, close to the ratchet wheel, with a 3/32-in. washer outside it, and run a 3/32-in. or 7 B.A. die right up to the washer. This will give the correct length of thread required. Drill a No. 53 hole 5/16-in. below the bearing hole, and tap it 9 B.A.; drill a 1/16-in. hole at the side, lower down (see illustration) for the end of the spring actuating the moving pawl. The latter is filed up from any odd scrap of 3/32-in. steel, drilled No. 48, and needs no detailing; ditto the stationary pawl, which is drilled No. 43. The former is attached to the ratchet lever by a 9 B.A. screw with 3/32-in. of "plain" under the head; slightly rivet over where it projects through the lever. The pawl must be quite free. The spring is wound up from a bit of 30 gauge steel wire.

The stationary pawl is mounted on a small spindle turned up from 3/16-in. steel held in the three-jaw. Turn down the end for about 3/16-in. length, until the pawl will just slip on, then run the 8 B.A. die on until it touches the pawl. Part off at 7/16-in. from the end. Reverse in chuck, gripping by the reduced part, and turn down the other end to the same diameter, leaving a piece 3/32-in. wide in the middle, as shown in the detail sketch; screw 8 B.A. Drill a No. 43 hole in the tank about 3/8-in. from the edge, near the top, poke the fully-screwed end of the spindle through it, and secure by a commercial brass nut inside the tank. The whole lot is then assembled as shown.

Note, both pawls should be case-hardened, as described for valve gear parts. If the stationary pawl does not click freely into the teeth of the ratchet wheel, falling by its own weight, a piece of thin flat steel, such as used for gramophone governor springs, or even a piece of steel wire, can be attached to the tank by a 9 B.A. screw just behind the pawl, and arranged to press lightly on its back. A snap-on lid can be made from 18 gauge metal, a simple job needing no detailed instructions.

How to Erect and Drive the Lubricator

The composite drawing shows how the lubricator is erected and operated. A 1 1/2-in. length of 1/2-in. by 3/32-in. angle brass, is attached to the front of the tank by two or three 3/32-in. or 7 B.A. screws, with nuts inside the tank; or it may be riveted on, just as you fancy. This is attached to the underside of the top part of the buffer beam by three 3/32-in. or 7 B.A. screws at about 5/8-in. centres, passing through clearing holes in the beam (No. 40 drill) into tapped holes in the angle. The distance from beam to tank should be approximately 1/4-in. The ratchet gear should be on the right-hand side of the engine, looking towards the front end.

The drive is taken direct from the inside pendulum lever on the right-hand side. Make a little fork from 7/32-in. or 1/4-in. round steel, as described for valve crossheads and other valve gear parts. Tap the stem 3/32-in. or 7 B.A., and screw it on the end of a 6 1/8-in. length of 3/32-in. silver steel.

The other end of the rod carries a small boss, filed up to the shape shown, from a bit of 3/16-in. by 1/4-in. brass or gun-metal, or from any bit of scrap bronze of suitable size, that may be handy. This is drilled No. 32 and reamed 1/8-in., and is attached to the pendulum lever by a bolt passing through lever, valve rod fork, and boss as shown. The fork is attached to the ratchet lever by a 9 B.A. screw with 1/8-in. of plain part below the head, which may be screwed into one side of the fork, or pass right through and have a nut on the outside; just as you fancy. There are three holes in the ratchet lever.

Put the reversing gear of the engine very nearly in the middle, and turn the wheels by hand; then connect the fork to the hole in the ratchet lever, which gives it sufficient movement to click the pawl over one tooth per revolution of the driving wheels.

Delivery Check Valve

Lastly, a double-outlet delivery check valve is needed, to distribute the oil to both cylinders. Chuck a piece of 5/16-in. round brass rod in the three-jaw, turn down the end for 1/4-in. length to 7/32-in. diameter, screw 7/32-in. by 40, centre deeply with size E centre-drill, and drill down for about 7/8-in. with No. 44 drill. Part off at 1 1/16-in. from the end. Reverse in chuck, and form a valve chamber 3/8-in. deep, exactly as described for the valve below the lubricator, fitting two nipples on opposite sides as shown, and silver soldering them.

The cap, ball valve, and spring are also as previously described. Connect this check to the union under the lubricator, by a short bend made from 1/8-in. copper pipe with a union nut and coned nipple on each end, as shown in the composite drawing. The nipples should be level with the tops of the cylinders, and will be connected to the two steam pipes when same are fitted after the boiler is made.

The boiler described

As will be seen from the accompanying illustrations, the boiler for the little "1000" class locomotive is a regular "Swindon Kettle," having the unmistakable outline and general appearance of the full-sized products of the Swindon locomotive factory. It is also pretty correct in external dimensions, being approximately one-sixteenth full size, the correct "scale" of the engine. No beginner need fear any shortage of steam, as long as he "keeps the home fires burning," and plenty of water in the gauge glass.

Everybody conversant with full-size locomotive practice, knows what wonderful steamers the Great Western boilers are: and it is a curious but very significant fact that a small locomotive boiler built on the same lines, does its job in the same efficient manner.

Formers for Flanged Plates

As three shaped formers are needed, we might as well make them first, so that they will be all ready when the coppersmithing is in hand: and here is a useful tip which experienced hands may find of service, as well as beginners. Full-size illustrations of the iron formers required for the backhead, throatplate, and firebox tube and door-plates or sheets, will be found on the blueprint of the boiler. All marking-out and measuring, and transferring dimensions to the iron plates, can be completely eliminated in the following simple manner. Get some tracing paper, trace the outlines of the formers on it, cut out the tracings, and stick them on the pieces of iron you are going to use for the formers. It only remains to saw and file to outline.

Alternatively, put a sheet of white paper on the bench, with a "carbon" on it, and put the blueprint over the lot. Run around the outline of the former on the blueprint, with any tool having a hard, blunt and smooth point, and the carbon will transfer the outline to the white paper underneath. Cut out and use as mentioned.

Don't forget that a hacksaw with anything between 14 and 22 teeth per inch, will walk through 1/4-in. iron very easily indeed, if a brushful of cutting oil (same as used for turning) is applied to the blade. Soapy water is a very good substitute. Put all your pressure on the down or outward strokes, and make about one stroke per second. Saw as close to the pattern as possible, and finish off with a file. Round off one edge of each former, as shown in the detail sketch.

Setting Out Tube Holes

The firebox former is also used as a jig for drilling the tube locating holes in firebox and smokebox tube plates, and for this purpose has a 3/32-in. or No. 40 hole drilled at the location of each tube.

Find the centre of the former with a rule, and scribe a line down it: then at 3/8-in. from the top, scribe a line right across. Make a centre-pop on this line, 7/16-in. each side of centre, and another 7/8-in. farther along each side: that gives you the correct location of the four superheater flues.

Scribe a parallel line 5/8-in. below the horizontal line mentioned above; another 3/8-in. below it, and yet another 3/8-in. below the last. Scribe a series of vertical lines 15/64-in. apart, each side of the vertical centre-line: where these vertical lines intersect the horizontal lines, make your centre-pops as shown in the illustration—four on the bottom line, five on the middle, and six on the upper, the holes being evenly staggered.

Run either a No. 40 or 3/32-in. drill through the plate at each centre-pop: if you have no drilling machine, use the lathe, with the drill in the three-jaw, and the plate supported by a drilling pad on the tailstock barrel. Put a piece of wood between plate and pad, to prevent the drill damaging the pad. File off all burrs.

Smokebox Former

The former for the smokebox tubeplate is merely a plain disc 3 5/8-ins. diameter: anything that size will do, such as an old chuck plate, or even a wheel, so long as one edge is rounded off. No holes are needed in it, as the tube holes in the smokebox tubeplate are located by clamping the firebox former to it, and putting the drill through the holes in that.

To save potential correspondents from wasting their time and my own, may I call attention to what appears at first glance to be an error in the measurements given for the width of the throatplate and backhead formers.

There is *no* error! The overall width of the firebox wrapper at the bottom, is

2¾-ins. The thickness of the wrapper is 3/32-in., and of the backhead and throatplate, 1/8-in. The sum total of the four thicknesses of metal—both sides of wrapper, and both sides of backhead flange, would appear on paper to be 7/16-in., but actually it isn't. The reason is, that the process of flanging the backhead, and cleaning up the flange, reduces the thickness of the metal forming the flange, to 3/32-in.; consequently the sum total of the four thicknesses of metal (two flanges and two wrapper sheets) is actually ⅜-in. only. This, subtracted **from the overall width of 2¾-ins., leaves 2⅜-ins. as the correct width for the bottom of the former, as shown in the drawings. I hope I have made that quite clear.**

THERE are two ways of making the taper barrel; from a tube, or a piece of sheet copper. A professional coppersmith, or anybody who could get the use of a set of tube bending roles, could make a seamless taper barrel from a piece of tube about 12 or 11 gauge.

The tube is annealed, and well rolled at one end only; this stretches the metal and causes the tube to become taper. I have made taper barrels by hand; but it is a long job hammering out the tube over an iron mandrel, and a barrel made from sheet and Sifbronzed, gives just as much satisfaction, so I don't knock any up from tube any more.

Barrel from Tube

The easiest way for a home worker to make a taper boiler barrel from tube, is to get a piece of 4½-ins. by 13 gauge tube roughly 10¾-ins. long, and anneal it by heating until red, then plunging into clean cold water. Slit it lengthwise with a fine-toothed hacksaw, using some cutting oil on the blade. The piece taken out should be V-shaped, about 1½-ins. wide at one end, tapering to about ⅛-in. at the other. It doesn't matter about filing out the saw marks; leave them as they are.

Just close up the cut until the tube assumes a taper form, 4 7/16-ins. diameter at the larger end, and 4-ins. at the smaller **end. Cut a strip of 16 gauge copper, ½-in. wide; clean it well, also the inside of the tube along the joint, and rivet the strip inside the tube, over the joint, with a few 3/32-in. copper rivets, at about ½-in. centres, to form a butt seam.**

Sheet Metal Barrel

For a sheet metal barrel, you need a piece of 3/32-in. (13 gauge) sheet copper, approximately 10¾-ins. wide, one side 14⅜-ins. long, and the other side 12⅞-ins. long. A geometrical expert would no doubt project the exact shape of the barrel "in the flat," on to his sheet of copper; but there is no need to go to all that trouble! Just "roll up the barrel" over any round object which happens to be suitable and handy, so that the edges overlap about ⅜-in. Make certain that the edges are clean and put a few 3/32-in. copper rivets at about ½-in. centres, through the overlap.

If you have anything of suitable diameter to drive into the ends, and make them perfectly round, well and good; if not, put a piece of round iron bar, such as an old sash-weight, horizontally in the vice-jaws, place the barrel over the projecting end of it, and use your hammer with judgment and discretion. It isn't such a difficult job to get a truly circular barrel, as many beginners might imagine. Hammer the lap joint well down, so that the plates are in close contact.

Beginners take particular notice: when the boiler is erected on the chassis, the bottom of the barrel is horizontal, and the top only is taper; so the ends must be sawn and filed square with the bottom of the barrel, where the joint is located. By applying a try-square to the ends of the barrel, with the stock as close to the joint as possible, you can easily see, by comparing the ends of the barrel with the blade of the square, how much has to come off, and where to cut it. After trimming off both ends square with the bottom of the barrel, the length of same should be exactly 10¼-ins.

Throatplate and Backhead

Before bending up the wrapper sheet, as the outside of the firebox is called, both the throatplate and backhead must be made. Lay each former on a piece of ⅛-in. sheet copper, and scribe a line all around, except at the bottom, at a distance of 5/16-in. from the edge of the former.

Unless you have a good hefty bench shearing machine, the pieces must be sawn out; and an ordinary hacksaw will not go around the curves, so the best thing for the job is a metal-piercing saw, like a fret-saw with a good stout blade. Personally, I use a "Driver" jig-saw for jobs like these; but an ordinary pedal-driven fretsaw machine, such as used for making wooden ornaments, toys and such like, does very well if a metal-cutting blade is used with it.

Don't forget that a drop of cutting oil, as used for turning steel, is a wonderful help when sawing soft copper, which makes the saw tend to "cling."

Put the former against the metal, **with its rounded edge next the copper; grip the lot in the bench vice, and beat down the projecting strip of copper on to the former.** If the copper goes hard, or tends to wrinkle or buckle whilst this job is in process, re-anneal at once, or you will crack the flanges. When the flange has been hammered down all around, clean it up with a coarse file, and also trim off any ragged edges.

Hole Cutting

The next job is to cut a hole 4⅛-ins. diameter in the throatplate. This will touch the flanges at each side, and come just below the flange at the top. Scribe the circle on the copper with a pair of dividers.

The hole may be cut by drilling a series of ⅛-in. holes all around just inside the ring, breaking out the piece, and finishing with a file; or a single hole may be drilled close to the ring, a metal-piercing sawblade put through it, and the disc "fretsawed" out.

A plumber's "washer-cutter" could also be used; I once saw a plumber cut a 4½-in. hole in a galvanised iron tank with an adjustable washer-cutter in a hand brace, so I guess he wouldn't have had much trouble in doing the above job!

Bending Throatplate

The bottom of the throatplate has to be set back ¾-in., in two bends; one is just below the hole, and the other ¾-in. from the bottom; see longitudinal section of boiler. At each point, file a V-nick in the flange at each side; it will then be found quite easy to grip the bottom of the throatplate in the bench vice, and put the bends in by pulling on the plate with your hands. If too stiff, use a carpenter's mallet as a gentle persuader; it won't damage the copper.

The backhead also has to be bent slightly outwards, the bend being 2-ins. from the top. As the bend is only 5/16-in. off the original line at the bottom, there is no need to nick the flanges; hold the backhead upside-down in the bench vice, with the line of the bend level with tops of jaws, and a gentle application of the before-mentioned mallet will soon do the needful.

A ¾-in. hole for the regulator bush can be drilled in the middle, right up close to the flange; but the hole for the firehole ring should be left awhile, as it has to be located from the actual ring after the firebox and tubes are erected in the boiler.

THE wrapper sheet needs a piece of 3/32-in. sheet copper, 7½-ins. wide, 17¾-ins. in length on the longer side, and 15-ins. on the shorter side. If the metal is hard, soften it by heating to red, and quenching in clean cold water. Clean up all edges, and bend to the shape of the throatplate and backhead.

Anybody who is handy at carpentering, could shape up a block of wood to the size of the firebox end of the boiler, taking dimensions from the longitudinal and cross-sectional illustrations, and bending the copper sheet around it. This should give the exact outline to the wrapper very easily.

The way I do them, is to put a stout round bar of iron in the bench vice, with enough projecting from the side of the jaws to equal the length of the wrapper. The line of the bend is laid on this, and a good hearty press-down on the sheet of copper, each side of the bar, licks the sheet of metal into shape.

The process is repeated for each bend, and then the backhead and throatplate, with the formers temporarily placed inside them to prevent damage to the flanges, are inserted into the rough-shaped ends, and the copper carefully hammered into close contact with them.

You can't put the formers inside the flanged plates in the present instance, on account of the bends in the plates; but the ⅛-in. copper is stiff enough to stand being mildly "assaulted" without coming to any harm.

Next set the throatplate in the larger end of the wrapper, so that when it stands vertical, the top of the wrapper slopes downward ¼-in. towards the back; see longitudinal section. Run a scriber around the inside, close to the throatplate, marking the outline of same on the copper; remove the throatplate, and cut away the copper to the line. Replace the throatplate, which should now come flush with the trimmed edge of the copper, and secure the wrapper to the throatplate flanges by a few 3/32-in. copper rivets all around.

Intervals of about 1-in. will be plenty, as the rivets are only for the purpose of holding the parts together whilst being brazed or Sifbronzed. The latter processes supply the strength needed to enable the boiler to stand its working pressure.

Brazing the Boiler Shell

The requirements are, a pan or tray to serve as a forge; a five-pint blow-lamp or equivalent-sized air-gas blow-pipe; easy-running brazing strip (commonly known among coppersmiths as "spelter"), coarse and fine grade silver-solder, flux for all three, large and small tongs, and a thin rod or stout wire with a point at the end.

A pan can be bent up from 16 gauge sheet iron; the back should be about 8-ins. or 10-ins. high, and the front about 3-ins.; length being sufficient to take the boiler. I have used a discarded tea-tray with a bit of sheet iron bent channel-shape and stood up in the back of it. Small coke or blacksmith's breeze does for packing the work.

"Boron" compo is the best flux I have ever used for general brazing; Johnson-Matthey's B6 alloy and "Easyflo" fill the silver-solder bill, and the makers supply the special fluxes for them; any good easy-running brazing strip will serve. My favourite, "Lafitte," is a French production now off the market.

Pickle Bath

A pickle-bath is needed for cleaning the work after brazing; a wooden box with a lining bent up from 1/16-in. sheet lead, is about the best I know. A big glass or earthenware accumulator jar does very well; so does a piece of stoneware drainpipe of large diameter, plugged at one end. The "pickle" is made by adding one part commercial sulphuric acid to about 16 parts its bulk of water. Old acid out of accumulators, diluted with three times its bulk of water, also does well.

Brazing Technique

For beginners' and new readers' benefit I will run through the first brazing job in detail; the rest are done much the same.

Stand the firebox shell, throatplate upward, in the pan, and pile coke or breeze all around it to about 1-in. below the hole. Mix up some flux to a paste with water, and smear thickly all around the joint between wrapper and throatplate. Smear some more along the barrel seam, then stand the barrel in position on the throatplate, covering the hole, being mighty careful that the bottom is at right angles to the upper part of the throatplate. Lay another fillet of flux all around the barrel where it rests on the throatplate. Start up your blow-lamp or gas blow-pipe, and if the former, make certain there is enough paraffin in it to see the job through, for you risk failure if the heat dies out in the middle of the operation. Have all your impedimenta to hand where you can easily reach it without leaving the job.

Heating

First blow on the coke piled around the work, and heat it until it glows and begins to burn; then heat up the throatplate, and the lower part of the barrel. As soon as they reach dull red, and the flux begins to fuse, concentrate on one of the lower corners of the throatplate; and when that reaches bright red, hold your strip of easy-running brazing material in the flame of the lamp for a few seconds, dip it in some dry flux (keep a little in a tin close handy), then apply it to the red-hot metal. It will immediately melt at the end, and flow into the joint, just like solder does.

Shift the flame of the lamp along an inch or so, but not clear of the melted spelter; and as soon as this new section glows bright red, dip the strip in the flux again, and once more apply it to the work. The new deposit of melted strip should flow back and join the first lot, making a continuous "stream" the same as two streams of water would, if they met in a groove.

Shift the flame again a little ahead, repeating the above operations of dipping the strip in the flux and applying it to the red-hot metal, and keep on until you reach the middle of the top of the throatplate.

Make a fresh start from the other bottom corner, and work your way up the other side until you meet the "first instalment" at the top. Play the flame on the junction until both streams of spelter, from the right and left sides, unite perfectly into a single stream.

Whilst doing this, the barrel will probably reach bright red, too, at the point where it is resting on the throatplate in the blow-lamp flame. Give the lamp an extra pump up, and concentrate on that point, dipping the strip into the dry flux again, and applying it to the junction of the barrel and throatplate. It will run under the edge, and also pile up in a fillet.

Now work your way, inch by inch, completely around the barrel, feeding in enough spelter as you go, to form quite a substantial fillet; and when you arrive at the starting point, give an extra "blow up" to make quite certain that the starting and finishing points of the spelter fillet melt and unite as one, so that there will be no chance of leakage. This is very important; beginners sometimes neglect it, and the consequence is, that the finishing end merely "sticks" to the starting end, and when the boiler expands and contracts under working conditions, leakage starts.

Brazing Barrel Seam

When you are quite sure that you have done the job O.K. so far, grab the boiler with the big tongs and lay it on its back in the pan, piling up some coke around each side of the barrel as quickly as you can. Then start blowing on the end of the longitudinal seam at the open end of the barrel. When this reaches bright red, first apply just a little coarse grade silver-solder; this will melt and entirely disappear into the joint. Then follow up with the strip of spelter, as above.

If you have made a butt joint, be sure the spelter fills the crack right up; the marks left by the saw teeth make an excellent "key" for holding the brazing material. If you made the barrel from sheet, with a lap joint, run enough spelter along the lap to form a fillet. Don't forget to cover the rivet heads.

Work your way right along the joint, inch by inch, until you reach the throatplate; and on arrival, take exactly the same precautions as when arriving at the top of the throatplate, to ensure proper amalgamation of the two lots of spelter.

The whole secret of the job is to have sufficient heat to make the spelter run freely, take it steady so that each application of the strip melts and forms a continuous deposit in the seam, and keep dipping the strip into the flux, so that there is no chance of oxide forming, and making the joint unsound. Should there be any bubbling when applying the strip, scratch in the molten metal with the pointed wire; this will break up the bubbles, and remove any oxide on the heated metal.

Pickling

On completion, carefully lift the boiler shell clear of the coke with the big tongs, knocking off any bits which may be sticking to it. Let it cool to black, then carefully lower it into the pickle bath. Mind the splashes; if any should land on your clothes or overall, holes will soon appear. If any land on your skin, wash them away at once, or you will get severe irritation, although the acid is too diluted to cause actual burns. When pickling a boiler-brazing job, I always take precautions by holding a shield (discarded rubber lavatory mat) between myself and the pickle bath. A sheet of stout brown paper would do.

Leave the job in the pickle for 15 to 20 minutes, then fish it out with the big tongs, wash in running water under the kitchen tap, knock off any bits of burnt flux that may be sticking to it, and clean up with a handful of steel wool, or a brush and some domestic scouring powder. A clean job is not only nicer to handle, but it eliminates any chance of poisoning a cut or scratch.

If you haven't already made the firebox former plate, which was shown superimposed on the drawing of the throat plate former, do it now, cutting it out with hacksaw and file from a piece of ¼-in. iron or steel plate. The location of the tube holes are clearly shown and fully dimensioned, and be very careful indeed to set them out exactly to the given measurements. Make a good heavy centrepop at each location, and drill the holes with No. 40 drill. Don't forget to round off one edge of the former. The same one does for the door plate as well as the tube plate.

Firebox Tube Plate

Lay the former on a piece of $\frac{3}{32}$-in. or 13 gauge sheet copper, and scribe a line all around except at bottom, at a distance of ⅜-in. away. Cut out the piece by the same method that you used for the throat plate; and if the copper is at all hard, make it red-hot and plunge into water to anneal it.

Clamp in the bench vice alongside the former, and beat down the copper over the edge of the former, same as for throat plate. Don't forget that if the copper shows any signs of going hard under the hammer or mallet, it should immediately be re-annealed, or the flange will crack.

Before removing the copper plate from the former, poke your No. 40 drill through all the holes in the former, carrying on right through the copper. File off any raggedness around the flange, and clean it up with a coarse-cut file.

Remove the copper plate from the former, open out all the tube holes with a $\frac{23}{64}$-in. drill, and ream them ⅜-in. Open out the flue holes with a $\frac{47}{64}$-in. drill, and ream them ¾-in. If you haven't reamers of the size named, use drills of correct size to finish, after drilling to the sizes mentioned.

If you try to put a ¾-in. drill straight through the copper plate, with only the No. 40 hole to guide it, the resulting hole won't be round at all, but polysided. As an alternative, especially for beginners, the larger holes may be drilled under size, and finished with a small half-round file, a piece of ¾-in. tube being used as a gauge. This should fit tightly in the hole. All holes should be slightly countersunk on the opposite side to the flange.

This is cut out of $\frac{3}{32}$-in. or 13 gauge copper, and flanged, exactly as described above for the tube plate; but it is 1-in. shorter, as the back of the firebox is not so deep as the front. Also, the copper on the top of the door plate should not be beaten down right into close contact with the former, as the flange is not exactly at right angles, owing to the forward slope of the door plate. If you take a look at the longitudinal section of the boiler, you will see exactly what I mean.

Trim up the flanges, and clean with a coarse-cut file as mentioned above, but don't drill any holes in it yet. One large oval hole will be needed for the firehole ring, and this is marked off direct from that component, which is next made.

Firehole Ring

In the earlier types of full-sized boilers, the firehole ring was a solid and heavy iron ring placed between the firebox door sheet and the backhead, a row of rivets being put through the lot. Epansion and contraction caused leakage, and the solid ring was superseded by flanging out the inside firebox door plate to meet a similar flange formed around a corresponding hole in the backhead, the joint being riveted.

In the small boiler we effect a compromise by making use of a flanged ring devised by my old friend and "fellow-conspirator" of the L.B. and S.C. Ry., Mr. W. E. Briggs: no rivets are needed, the job is simplicity itself, and the ring forms a substantial stay between firebox and backhead.

To make a Briggs ring for the present boiler, a piece of $1\frac{3}{8}$-in. by $\frac{3}{8}$-in. copper tube is needed, $1\frac{1}{16}$-in. long. Chuck this in the three-jaw, with half of it projecting: and with a good sharp knife tool, aided by a little cutting oil, turn down $\frac{1}{4}$-in. of it to a diameter of $1\frac{1}{4}$-ins. Reverse in chuck, and turn down $\frac{5}{16}$-in. of the other end to a similar diameter. Heat to redness, and quench in your acid pickle; this will clean as well as soften it. Wash the acid off, and give it a finishing rub with steel wool or emerycloth.

Now carefully squeeze it in the bench vice until it assumes an oval, the internal diameters measuring $\frac{7}{8}$-in. and $1\frac{3}{8}$-ins.

Lay the oval ring on the firebox door plate, $\frac{3}{4}$-in. from the top, and midway between the sides; run a scriber all around, marking the exact outline of the reduced part of the ring on the copper. Cut out the piece, either by drilling a ring of holes inside the marked line, breaking out the piece, and filing to outline, or by drilling one hole, putting the blade of a metal-piercing or coping-saw through it, and fretsawing out the piece of copper.

Put the shorter flange of the firehole ring through the hole, on the side opposite to the flange of the door plate, and beat down the projection outwards, all around the hole. The metal of the door plate will then be firmly gripped between the flanged-over lip and shoulder of the ring; see longitudinal section of boiler.

Don't forget to clean the metal all around the hole, before inserting the ring, otherwise you are in for a spot of trouble when the brazing job comes along.

Firebox Sides and Crown

The sides and crown sheet of the firebox are made from one piece of 13 gauge or $\frac{3}{32}$-in. sheet copper, approximately $13\frac{1}{4}$-ins. long and 6-ins. wide. Cut this roughly to the shape shown in the illustration, and then bend it to the shape of the firebox, taking the two end plates as guides, same as you did for the firebox wrapper. Either a hardwood former can be used on which to bend the copper, or it may be bent over a bar placed in the bench vice as previously described. I never have any trouble bending fireboxes by hand pressure, neither should any person of average strength.

The firebox tube plate and door plate can now be riveted into the longer and shorter ends of the firebox respectively; only sufficient $\frac{3}{32}$-in. copper rivets need be put in, to hold the sides and crown in close contact with the flanges whilst the whole lot is being brazed. About 1-in. centres would do. See that the surfaces in contact are thoroughly clean, to ensure a sound brazed joint.

THE system of staying both firebox and wrapper by girders instead of direct rods, was another result of experience. Small rods of any length above $\frac{3}{8}$-in. or so, waste away in the middle; I have dissected several boilers with direct-rod-stayed crown sheets, and found the wastage very pronounced. In one case, where brass alloy was used for the stay rods, the centre of several of them, originally $\frac{5}{16}$-in. diameter, were no thicker than a blanket pin, due to wastage.

When I started experimenting many years ago, with the girder stays, several different forms were tried, and tested to destruction with a hydraulic pump to determine the "survival of the fittest." The outcome was that I adopted two girders with single flanges for smaller boilers, such as those on the average-sized $2\frac{1}{2}$-in. gauge engine, and double girders plus a central bowed girder, for larger boilers, such as the one specified for the G.W.R. "1,000" class engine.

Any millwright will tell you that a box girder is one of the strongest forms of construction known.

To make the crown stays for the firebox of the "1,000" class engine, cut out four pieces of 16 gauge sheet copper to the dimensions given, and bend on the dotted lines.

Beginners note: the distances between the dotted lines, are the actual measurements of the crown stay over flanges; therefore, grip the narrow part in the bench vice with the line just showing above the jaws, and bend over the wide part. If you grip the wide part, and beat the narrow flange over the vice jaw with hammer or mallet, you'll find the height of the girder exceeds the given dimensions by twice the thickness of the metal.

When cutting out and bending, don't forget that you need two right-hand and two left-hand girders, and one of each has a wider top flange. Rivet the two sheets forming each complete girder, back to back; then mark out and drill the $\frac{1}{2}$-in. holes to allow the wrapper stays to pass through; see longitudinal section of boiler.

Fish-Backed Girder

The fish-backed girder in the middle requires two pieces of 16 gauge copper, cut out and bent as shown in the smaller detail illustration. These are riveted together to form an inverted tee, and a clearance filed at $2\frac{7}{8}$-ins. from one end, to clear the central wrapper stay.

All three completed girders are then riveted to the firebox crown sheet in the positions shown in the cross-section of the firebox and wrapper, with $\frac{3}{32}$-in. copper rivets at about $\frac{1}{2}$-in. spacing. Don't forget that the highest part of the side girders should be at the tube plate end of the firebox, and the nich in the centre one nearest the back.

The Next Brazing Job

The assembled firebox and crown stays can now be brazed, the method used being the same as described for barrel and wrapper. Coat all the joints with wet flux; stand the firebox in the brazing pan, firehole ring uppermost, and pile coke or breeze all around and inside.

Heat the lot to dull red, then start at one bottom corner and work your way right around, as described previously in detail. When arriving at the upper part of the firebox, run a fillet of spelter all around the firehole ring.

When through with that end of the firebox, turn it the other way up, and repeat the process of starting at the bottom corner and working all around the joint between flange and plate, but here, a word of warning.

The metal between the tube holes is very easily melted, as they are small, and the flame of the blow-lamp or blow-pipe is able to lick all around and through the holes; therefore, when brazing around the upper part of the tube plate, keep the flame away from the tube holes as much as possible, otherwise you'll suddenly find you have one big ragged hole instead of a lot of little round ones, and the ceremony of building up a firebox thus far, will have to be repeated.

Finally, stand the firebox in the pan, right way up. First of all, run in a little coarse-grade silver-solder between the crown sheet and the flanges of the girders. As previously mentioned, melted silver-solder has a much greater fluidity and penetrating power than melted brazing strip, and it will "sweat" clean through the joints, making an extra sound job. Then apply the brazing strip, and run in a fillet alongside the edges of the crownstay flanges, to give additional strength. Be sure to cover all the rivet heads.

Let the job cool to black, quench in pickle, leave it in from 15 to 20 minutes, then fish out with the big tongs, well wash in running water, and clean up. A handful of steel wool, of medium grade, is best for the cleaning-up job. Never handle any dirty copper if you can possibly avoid it.

One-Pint Lamp Brazing

Several readers have asked for instructions on how to braze the boiler with a one-pint blow-lamp, saying they have nothing larger. You just can't do it; a one-pint lamp does not deliver sufficient "therms."

The only alternative would be to put the boiler shell on a good pile of coke, light same, and blow up the whole pile with a pair of bellows until the fire and the shell were bright red, and sufficient heat had been obtained to melt the brazing material. The one-pint lamp could then be used as a sort of auxiliary, to apply a little extra heat in any spot where required.

The firebox and crown stays could be brazed in the same way. There is one slight advantage in using a fire, inasmuch as the whole of the job is heated at once to a uniform temperature, and it is easy to apply the spelter and silver-solder, which will flow right round the whole joint and form a continuous seal, just like soft solder does.

The disadvantage is the size of the fire, and the heat it radiates; by the time you have finished the job, you will feel like that almost forgotten delicacy, a roast turkey!

Smokebox Tubeplate

The next item is the smokebox tubeplate, as this is needed to act as a spacer to hold the tubes in position whilst they are silver-soldered into the firebox. A circular former is needed, 3⅝-ins diameter and ¼-in in thickness; anything circular of the right diameter will do; I frequently use an old chuck plate, or a wheel of suitable size.

Cut out a circle of ⅛-in sheet copper 4½-ins. diameter, clamp it alongside the former in the bench vice, and flange it over as already described. Being fairly thick, it will probably need annealing two or three times during the process.

When the flanging is completed, chuck the plate in the three-jaw, flange outwards, and skim off any raggedness with a round-nose tool set crosswise in the rest. Then rechuck the plate the other way about; you probably won't be able to get it on the steps of the inside jaws of the chuck, as the steps nearest the centre of the chuck won't open out sufficiently, and will get in the way if you try to use the outer steps.

Use the outside jaws of the chuck, and put the flange of the tube plate over them, gripping by the inside of the flange. Turn down the flange to approximately 3 27/32-ins. diameter; then file the upper part of the inside of the taper boiler barrel parallel at the end, so that the smokebox tube-plate is a tight fit in same. See longitudinal section of boiler.

The position of the holes for the longitudinal stay nipples, and the steam-pipe flange, is clearly shown in the illustration; set them out, drill a No. 30 pilot hole at each point, then open out and tap as indicated.

Use 9/32-in. drill for the 5/16-in. by 40 tapped holes, and 29/64-in. for the ½-in. by 32 tapped hole.

The position of the tube holes is obtained by using the firebox former as a jig. Lay it on the convex side of the tube-plate, with the bottom row of No. 40 holes approximately 7/16-in. from the edge, and the rows of holes parallel with the row of stayholes in the upper part of the tube-plate. Fix temporarily in position with a toolmaker's cramp, and poke the No. 40 drill through the lot. Remove the former; open out the smaller holes with 23/64-in. drill, and the larger with 47/64-in., reaming them ⅜-in. and ¾-in. respectively, or serving them the same as described for the firebox tube-plate; then slightly countersink them on both sides.

THE boiler barrel contains four ¾-in. superheater flues and fifteen ⅜-in. fire tubes. The overall length of them all is 11-ins., after the ends have been squared off in the lathe.

Most small lathes have a hollow mandrel that will allow the ⅜-in. tubes to be held in the three-jaw, with only an inch or so projecting from the chuck; but the larger ones require steadying.

A steady is made in a few minutes by nailing together a couple of pieces of wood at right angles. Put a drill, the size of the tube, in the three-jaw, and run the wood against it whilst the lathe mandrel is revolving; if one angle of the wood is kept pressed on the lathe bed, the drill will make a hole right size for the tube, exactly at centre height. All you then have to do, is to put the tube in the chuck, put the wooden steady on the other end about ½-in. along, and temporarily fix the steady to the lathe bed by a coach bolt through the base. The end of the tube can then be squared off in a matter of seconds. Clean the ends with emerycloth.

Tube Gauges

The best thickness for the flues, is 20 gauge, but 18 gauge may be used if the former is not available; slightly thinner will also do, but don't go below 22 gauge. The small tubes should be not more than 20 gauge, and I do not recommend any thinner gauge than the 22 mentioned, as they may easily be burned when being silver-soldered in by an inexperienced amateur coppersmith. However, an experienced one could use 24 gauge if he so desired, though that is the limit.

Anybody who has had a little experience can silver-solder the whole nest of tubes in at one heat; inexperienced workers may possibly do better by "taking two bites," in a manner of speaking. In the former case, fit all the tubes into the holes in the firebox tube-plate; they should be tight, and project through about $\frac{1}{32}$-in.

Now put the smokebox tube-plate temporarily on the other end, adjust the nest of tubes until they are parallel with top and sides of the firebox, and stand the assembly in the pan, with the tubes vertical. Cover the whole of the upper part of the tube-plate with wet flux—this may be done, if you like, before fitting the tubes, and some wet flux smeared around each tube before inserting into the tube-plate. Cut some little squares of best-grade silver-solder and drop them in between the tubes. Pile coke or breeze all around the firebox, and fill the inside until about 1-in. below the tube ends; then get busy with your blow-lamp.

Heat the tube-plate to redness, aiming mostly at the inside, and keeping the flame away from the small tubes as long as possible. When the tube-plate glows red, direct the flame first on the superheater flues, adding a little more silver-solder to them, and then among the small tubes. The silver-solder will melt and run around each tube of its own free will and accord, providing they are clean, properly fluxed, and the heat is right. The lot should be a medium red; not too bright, to avoid any chance of burning.

To make certain of good joints, take a good final blow on the tube-plate inside the firebox, when the reflected heat from the coke will cause the silver-solder to "sweat" through the joints, leaving a silvery ring around each tube.

Using "Easyflo" Wire

One of my friends, Mr. T. Hearn, of Watford, uses "Easyflo" in wire form (commercially obtainable) in the following simple manner. He fluxes all the tubes and tube-plate before assembly, then winds up a "spring" of "Easyflo" wire, the inside diameter of which is the same as the tubes. This is cut longitudinally, the "spring" falling into single coils. One of these is sprung around each tube, and pressed down into the flux. The job is heated up as described above, and as soon as correct temperature is reached, the rings of "Easyflo" wire melt and disappear into the joints, forming a perfect seal around each tube.

For the two-stage job, first put in the superheater flues, and the top row of small tubes; then proceed as above. As there are only two rows, you can see if the silver-solder is running properly; if not, assist it with the scratching wire. Pickle, wash off, and clean around the rest of the tube holes; then insert the rest of the tubes and repeat process.

In case any beginners think they can insert the second batch of tubes before the first lot cools, and so do the job at one heating, I would remind them that the rest of the holes would be badly oxydised, and even if they fitted the remaining tubes to the hot firebox, the silver-solder wouldn't stick to the dirty surfaces.

Whether "two-stage" or "one-shot" method is employed, finally pickle the whole issue, and wash off; remove the smokebox tube-plate, and heat the whole bunch of tubes at that end, to a red heat. Quench out in the pickle, and wash off. This softens the tubes for expanding into the smokebox tube-plate.

First Stage of Boiler Assembly

The next step in construction is to assemble the firebox and tubes into the boiler shell, which is easy. Lay the shell on its back on the bench, and slide the firebox and tubes into it, until the firebox tube-plate comes up against the vertical part of the throat-plate. Adjust carefully so that there is the same distance between firebox and wrapper at either side, and then put a good strong toolmaker's cramp over the tube-plate and throat-plate, to prevent them shifting.

Now take a look at the top flanges of the crownstay girders; these should be in contact with the top of the wrapper for the whole of their length. If not, adjust the whole issue until they are; then put another cramp on, to hold one of the flanges tightly to the wrapper, and prevent any movement at that end. Drill a couple of No. 40 holes through wrapper and the outer flanges, and put in a couple of $\frac{3}{32}$-in or 7 B.A. screws and nuts, to hold the lot in place whilst riveting.

Do the same at both ends of the bottom of the throatplate. The clamps can then be removed. Drill about three more holes along the bottom of throat-plate, and put in $\frac{3}{32}$-in. roundhead copper rivets; then take out the screws and replace them with two more rivets.

Riveting

Drill a series of No. 40 holes through wrapper and top crownstay flanges, at about 1-in. centres; countersink them on the outside of wrapper, and put in $\frac{3}{32}$-in. copper rivets, heads inside. These can easily be inserted with a strip of metal about $\frac{1}{4}$-in. wide, with a notch cut in the end, like a distant signal. Jam the rivet in the notch, insert in hole, and then pull away the strip.

To hold up the rivets whilst hammering the stems into the countersinks, put a piece of iron bar in the bench vice, long enough to reach to the end of the crownstay flanges, and slip the boiler over it after inserting each rivet.

When hammering down, beginners should be very careful to hit the rivet shank and not the wrapper. It looks like careless workmanship, when the wrapper looks as if it had been out in a severe hailstorm! A few light blows with the ball head, and then a couple of hearty and judiciously-aimed smacks with the flat end, should lay the rivet stem neatly level with the wrapper. It only needs a little practice. Finally, replace the two screws with rivets, put in same as above.

How to Fit the Smokebox Tube-plate

The tube-plate should be clean all over, to ensure perfect brazed and silver-soldered joints. Insert it flange first, and be sure that it is perfectly vertical. Tap it down very gently until it almost touches the tubes; then, with a wooden meat skewer (if you can find one outside a museum!) or a black-lead pencil, very carefully line up each tube with its respective hole in the tube-plate.

They will move very easily, as the process of silver-soldering them into the tube-plate will have softened the firebox ends. Don't distort the smokebox ends on any account—one reason for using a wooden "persuader." When they are all lined up, drive the tube-plate home until the whole bunch are standing $\frac{1}{32}$-in. or so clear of the tube-plate, and same is square with the end of the boiler barrel; see longitudinal section of boiler.

Brazing the Tube-plate

THE tubes should be expanded into the holes, as the closer they fit, the easier will the silver-solder run around them.

All you need for this job is a taper drift to fit each side of tube; anything taper and smooth will do, such as the shank of a broken drill, old lathe centre, or similar. If nothing is readily available, turn a piece of mild steel to a slight taper, to fit into the tube, and well polish it with emery-cloth whilst running in the lathe.

Grease the drift, insert into the tube end, and two or three sharp cracks with the hammer will cause it to force out the tube into close contact with the hole. If it is reluctant to come out, give it a crack sideways, which will promptly teach it good manners.

For the brazing job you need a tray, lid, or anything that will hold some coke, about 9-ins. diameter or more. Cut a hole in it big enough to let it go over the smokebox end of the barrel about 3-ins. Stand the boiler in the brazing pan with the barrel pointing skywards, and put the "holey" tray over it, piling up coke in same, all around the barrel, to the level of the smokebox tube-plate.

Put some wet flux all around the joint between barrel and tube-plate, and around the tube ends. To prevent the flame going inside the tubes and burning the thin metal, it is advisable to plug the end of each tube with a wad of asbestos wool, flock, or string, pushing it down just below the level of the tube-plate.

Now heat up the whole issue, coke, boiler end, and tube-plate, to a dull red, and then concentrate on any point in the circumference of the end of the barrel, letting the flame blow partly outside and partly on the tube-plate. When the metal reaches bright red, apply the stick of easy-running strip (previously dipped in dry flux) and when it melts and starts to flow, work your way right around the circumference, as described for the throat-plate operation. If the stick shows any reluctance to start and flow easily, use a little coarse-grade silver-solder first, as previously mentioned.

To do the tube ends, you can either cut the silver-solder into small squares and drop them among the tubes, or apply the silver-solder in the strip. In the former case, blow the flame direct on the nest of tube ends, concentrating first on the four superheater flues, and guiding the silver-solder when melted, if it needs it, with the pointed scratching wire, so that it forms a fillet around each tube, clean and free from bubbles.

Repeat the operation on each row of small tubes. If the strip application method is desired, blow on the ends of the four large flues until they glow bright red, along with the surrounding metal of the tube-plate; then dip the strip of silver-solder in the dry flux, and apply it to the end of each tube, letting enough melt off to form a fillet. Serve the small tubes with a dose of the same medicine, and don't forget to use the scratch wire to break up any bubbles that may form.

Brazing Crown Stays to Wrapper

Take off the little tray, and whilst the boiler is still hot, grab it with the big tongs and lay it on its back in the brazing pan, with the firebox end overhanging the edge.

Put a brick, or anything else heavy enough that may be handy, on the barrel, to prevent it tipping up. Put some wet flux along each side of each girder flange—use a brush for this job—and lay a strip of coarse grade silver-solder, the full length of the flange, in the flux.

Blow the flame of the blow-lamp or air gas blow-pipe, partly inside and partly outside, until the firebox wrapper becomes dull red; then apply it full force to the underside, that is, what is really the top of the wrapper. When this becomes bright red, the silver-solder will melt and sweat in under the flanges of the girders.

This job will be greatly assisted if you have a small blow-lamp or blow-pipe which will enable another flame to be played inside the boiler, to keep the girder flanges red-hot while the one underneath obliges in the same way on the wrapper.

The great thing is, to make certain the melted silver-solder sweats clean through the full area of contact. The joints will then be stronger than the actual metal, and the boiler will be perfectly safe and sound, at even twice the specified working pressure.

When you are absolutely certain that the desired result is obtained, let the boiler cool to black, then carefully lower it into the pickle, avoiding all splashes (be careful, it is getting pretty heavy now, and if you accidentally let go, there will be a tremendous splash!), letting it remain in the solution for about 20 minutes. Then wash in running water, and clean up as before.

It will be noticed that no directions have been given for brazing the joint between throat plate and firebox; this is quite in order, as that joint is brazed along with the foundation ring.

Backhead

The actual job of making the backhead is pretty much the same as described for the throat plate, but it is a little smaller, owing to the back slope of the firebox wrapper. The material used is the same, viz., ⅛-in. or 10 gauge sheet copper; and there is an advantage in this thickness of metal, inasmuch as the fittings, such as water gauge columns, steam valves and so on, can be screwed direct into the plate without any need of separate bushes.

The only bush needed, is for the regulator, and that is only necessary because the barrel of the fitting is too high up for the flange to make contact with the backhead all around; the upper part of it would come opposite the curved part of the backhead flange, as you can see by a glance at the longitudinal section of the boiler.

An illustration of the former needed for the backhead, with measurements, has already been given, so if you have not made it, do so now, cutting it out of ¼-in. steel or iron plate, same as the others. One edge should be well rounded off.

Lay the former on a piece of ⅛-in. or 10 gauge sheet copper, draw a line all around it, except at bottom, about $\frac{5}{16}$-in. from the edge, and saw out the piece to outline. Anneal it by heating to red and plunging into clean cold water; or if you like, quench it in the acid pickle first, and wash it afterwards, which will clean as well as soften it.

Clamp it in the bench vice alongside the former, the side with the rounded edge next the copper, and beat down the flange as previously described. The ragged edge of the flange can be cleaned up a little with a coarse-cut file (I use the "Dreadnought" milling files for jobs like these, as the wide curved teeth take off the surplus metal in two wags of a happy dog's tail, and they never choke with soft metal filings) but there is no need to worry about a posh job, as the flange is hidden from sight for evermore, when the boiler is finished. Use the same file to clean up the surface of the flange itself, where it comes in contact with the wrapper.

The backhead on the "1,000" class engines is not vertical, but slopes part of its length; so beginners note carefully — at 2⅛-ins. from the top of the backhead, make a sawcut in the flange at each side, and slightly bend the plate, so that when the upper part is vertical the bottom edge stands out 5/16-in. farther back. See longitudinal section of boiler. If the edge of the wrapper does not correspond, cut it to suit.

The sawcuts will, of course, open slightly, but that doesn't matter, as the flange is brazed to the wrapper. On the centre line of the backhead, at 17/32-in. from the top, make a centre-pop, drill it first ¼-in., then about 7/16-in., and finally open it out with 47/64-in. drill and ¾-in. reamer, same as for the ¾-in. tubes; this hole will touch the flange.

Regulator Bush

Copper is the best material to use for the regulator bush, as it stands up to brazing. Don't use brass on any account, or the bush stands a very good chance of completely disappearing, as there is little difference in melting temperature between brass and the brazing material. More than one beginner has found that out to his sorrow, when using brass screws instead of copper rivets to hold parts together for brazing, and suddenly finding lots of nothing in the holes where he put screws!

I make all bushes in boilers, wherever possible, from thick-walled tube, and in the present instance should use a piece of 1-in. diameter tube with a wall 3/16-in. in thickness. Chuck in three-jaw, face the end, turn down ¼-in. length to ¾-in. diameter, a tight fit in the hole in the backhead, and part off ⅜-in. full from the end. Reverse in chuck, gripping by the step; face off the flange, and just take the sharp edge off around the hole; then drive the bush into the hole in the backhead.

If no tube is available, a piece of copper rod can be used, and turned up same way; after reversing in chuck, centre, drill a pilot hole about 3/16-in. diameter, then open out with a ⅝-in. drill, and very slightly countersink the hole before the final facing skim.

Good drawn bronze rod is the next best to copper, the hard cored stick used to make bearing bushes doing very well; but maybe our advertisers may be able to supply castings of suitable metal. Pipe flanges and other fittings used in regular plumbing work, are now made as castings in a grade of metal called plumber's welding metal, which will stand up to oxy-acetylene blowpipe operation without any fear of melting.

Fitting Backhead

To fit the backhead is an easy job. Measure the distance from the top of the wrapper to the top of the firehole ring, transfer this measurement to the backhead, and from it, mark out an oval hole corresponding to the projecting lip of the ring.

Cut out the hole in the same way as the similar hole was cut in the firebox door plate, but leave it on the small side, and "offer up" the backhead to its correct position. You can then see if the hole will be in the right place when enlarged to proper size; if not, mark which side needs enlarging the most, to bring the hole right, and file accordingly.

When finished to size, all you have to do is to put the backhead in place, with the lip of the firehole ring sticking out through the hole, and beat same outwards and down, resting the inner side of the ring on a piece of iron bar gripped in the bench vice and projecting from the side. The backhead will then be held firmly between the shoulder of the ring and the beaten-down flange, and all that remains, is to hammer the sides of the wrapper into close contact with the backhead flange all around.

They usually "stay put" all right for me, but if yours proves a recalcitrant sort of merchant, and refuses to keep in touch with the backhead flange all the way around, fix it with a few copper studs. Put a clamp on temporarily, or hold it in the vice, to squeeze the wrapper to the flange; drill No. 48, tap 3/32-in. or 7 B.A., and screw in a stub of copper wire threaded to suit, cutting off flush with the plate. Three each side, and two in the top, should be ample.

Foundation Ring

The foundation ring isn't a ring at all. It is in three pieces, made from ¼-in. square copper rod. Fit the end piece first; cut a length of rod to fit tightly between the ends of the flanges at the bottom of the backhead, rounding off one corner at each end, to fit snugly against the backhead. Clean it well, and put in place about 1/16-in. away from the edge of the backhead, so as to allow room for a small fillet of brazing material. Put a toolmakers' cramp at each end, over backhead and firebox door plate, to prevent the piece of rod slipping, then drill three or four holes through the lot—firebox plate, rod and backhead—with No. 41 drill, and rivet together with 3/32-in. roundhead copper rivets, heads inside the firebox. This will prevent any movement whilst the brazing job is in progress.

The side pieces are fitted in the same way, to fill up the space between firebox and wrapper, but they have to be bent to the same angle as the bottom of firebox and wrapper, at approximately 2¼-ins. from the back end. A few 3/32-in. copper rivets through firebox, rod and wrapper, at about 1-in. centres, will hold the whole lot together, and prevent any parting of the plates whilst the job is being heated up for brazing in the sections of the foundation ring.

If there should be any interstices showing at the ends, where the sections butt against each other, plug them with small splinters of copper driven in tightly, otherwise the molten brazing material will run in and form stalactites inside the water space, making lovely mud and scale traps.

This precaution need not be taken by builders using an oxy-acetylene blow-pipe and Sifbronze, as this material fills up all nooks and crannies of its own free will and accord. I will give you a few hints on Sifbronzing, after dealing with the *modus operandi* of the blow-lamp artists; see following notes.

Safety Valve Bush

The safety-valve bush might also be brazed in, or silver-soldered, at the one heating, when doing the final brazing job, so make a centre-pop on the centre line of the top of the barrel, 2¼-ins. ahead of the throat plate, drill it about 5/16-in., and open out to 11/16-in. Turn up a bush to fit, same as described for the regulator bush, but tap it ⅜-in. by 26, and slightly countersink it. Note—when fitting this bush, the flange must not lie on the barrel all around, otherwise when the safety-valve is screwed in, it will imitate the Leaning Tower of Pisa. The safety-valve must be vertical, so set the bush in the hole so that the flange is horizontal, parallel to the bottom of the barrel: see sectional elevation of boiler.

The Final Brazing Job

The last brazing operation is not as formidable as some beginners might imagine; but it needs plenty of heat, and careful handling. Evening or a dull day is the best time for a job like this, as the melted brazing material can be seen flowing much more readily than in bright daylight. I might add that it would be a very congenial job at time of writing, as it is snowing, and the temperature is well below freezing-point. As a matter of fact, I have been working on two boiler jobs myself, to get some extra warmth. No electric power nor light is needed when using an oxy-acetylene blow-pipe!

Have all your apparatus handy, plenty of coke or breeze in the pan, and plenty of paraffin in the blow-lamp, also get the lid or tray used when brazing in the smokebox tube plate, and open out the hole so that it will pass over the taper boiler barrel right up to the throat plate. A couple of bricks, or fire tiles, will also be needed to prop up the lid or tray when brazing in the backhead.

Brazing Foundation Ring

First of all, smear some wet flux all around the foundation ring, joint between backhead and wrapper, around firehole flange, regulator and safety valve bushes, and over all the rivet heads, then lay the boiler on its back in the pan, and pile the coke or breeze up to the level of the foundation ring at each side.

To protect the tube ends, put a bit of asbestos millboard over them, and fill the firebox to the level of the foundation ring with asbestos cubes, or broken bits of any sort, such as scrap bits of gas fire elements.

Then get the blow-lamp going good and strong, and start the hotting up process. If you have a small blow-lamp as well, get that going, too. The more evenly you can heat the boiler, the better it will be. When all the coke begins to glow red, and the flux starts to fuse, give the big lamp an extra pump up, and concentrate on the back corner of the foundation ring nearest you. When this glows red, dip the brazing strip in some dry flux, and apply it to the joint; if it doesn't melt and run in at once, the job is not hot enough.

To make a really successful brazed joint, the metal must be hotter than the melting point of the brazing material. However, sometimes, as mentioned before, the strip is a little bit shy of starting (all depends on whose make of strip you are using) and a taste of coarse grade silver-solder first applied to the joint, will teach it better manners.

Once the material has started to run, it will keep on running, providing you keep up the heat; and the procedure is now the same as described for the first brazing job. When the strip has melted and covered the corner of the firebox, shift the flame along slightly, and as soon as the metal becomes bright red in the flame, apply more strip.

Proceed in the direction the flame is blowing, and work your way right around. Whether you make a continuous run, and return to the starting point, or go halfway, and then do the other half in the same direction so as to meet the "first instalment" at the opposite corner, is a matter for your own decision. I usually start at the nearest corner, go along the nearest side, turn the front corner, and do the joint between tube plate and throat plate, then come back to the starting point, do the piece between backhead and firebox door plate, turn that corner, and work along the opposite side until the far corner of the tube plate-throat plate joint is reached. Whether you complete the circuit at the near or far corner, give the junction point an extra dose of blow-lamp, so that there isn't the least doubt that the two ends have thoroughly melted and run together, otherwise you will get leakage, as a crack will start under the alternate heating and cooling of the boiler under working conditions.

Beginners should not forget that any oxide in the brazing material will cause unsound joints, so keep on dipping the strip into the flux every time before applying it to the joint, as an antidote to oxidisation. Also, allow enough melted strip to flow into the joint, to form a fillet along each side of the foundation ring, between it and the plates; and don't forget to cover the rivet heads.

Quick Action Needed!

As soon as the foundation ring is done, and before the boiler has any chance to cool off, stand the "holey" lid or tray on the bricks or other support, grab the boiler with the big tongs, and put the barrel through the hole in the tray, so that the throat plate rests on it. Pile some coke or breeze around the wrapper as quickly as you can, and then repeat the operation described for brazing in the throat plate, starting at the bottom corner, and working right around.

See that the melted metal sweats in thoroughly between backhead flange and wrapper. As silver-solder, even coarse grade, flows easier and penetrates better than the easiest of easy-running brazing strips, beginners and inexperienced workers are well advised to use it for both the firehole ring and regulator bush. The flame of the blow-lamp can be played directly on the bush, and the silver-solder will run around it like water, making a perfect and neat seal.

Go around the firehole, same as an ordinary brazed joint, as the ring is rather too large to heat up all at once, the surrounding metal absorbing the heat too quickly. Keep a sharp look-out for any missed places, and if there is any bubbling, apply the scratching wire, dipped in flux, keeping the flame of the lamp playing on the job.

When you are quite satisfied that no places have been missed, pull the boiler out of the hole in the lid or tray, and stand it right way up in the brazing pan. Play the flame full force direct on the safety-valve bush; and when that and the surrounding metal glows red, apply enough silver-solder to run around and form a fillet.

Pickling

That completes the brazing; let the boiler cool to black, then carefully lower it into the pickle. Take great care to keep clear of splashes, holding something such as a big sheet of paper between you and the boiler, because when the acid pickle runs inside and meets the hot firebox and tubes first time, it usually blows out again, and splashes everything for a considerable distance around. The second time in, is usually quiet.

Leave the boiler in the pickle for 20 minutes or so, then fish it out, well wash inside and out with running water, and give the outside a good rub up with a handful of steel wool, or some domestic scouring powder.

"Sifbronzing" Boiler Joints

If any reader building the G.W.R. "1,000" owns, or can get the use of, an oxy-acetylene blow-pipe. I strongly recommend its use in preference to either a blow-lamp or an ordinary air-gas bellows-operated blow-pipe. This recommendation is, as usual, the result of actual personal experience: it is about 16 years now, since I purchased my No. 2 "Alda" equipment from the British Oxygen Company, and it has served me faithfully and well, not only in locomotive boiler construction, but in making many other parts of an engine. Dozens of components which either have to be riveted, or else made as castings, can be "fabricated" by the aid of the blow-pipe, some Sifbronze, and what is usually known as a "little common savvy." One great advantage of the "oxy-acet." is that it puts the heat exactly where you want it: the perspiration attendant upon getting close to a five-pint blow-lamp in full blast, is entirely done away with.

The job is simplicity itself; easier than soldering up a leak in a domestic kettle. When fitting the sections of the foundation ring, for example, bevel off the outer edges, as shown in the detail sketch. It isn't necessary to pack the job in coke or breeze, although this saves a little gas; it is an advantage to preheat the boiler with a small blow-lamp, a one-pint being quite sufficient to "take the chill off" and prevent unequal expansion under the concentrated heat of the oxy-acetylene flame.

"Sifbronze" Procedure

Mix up some Sifbronze flux to a paste with water, and apply it in a fairly thick coating all around the foundation ring and the backhead joint; if the regulator bush is copper, put some around that, too. Ordinary borax, or "Easyflo" flux, mixed in the same manner, can be used for the firehole ring.

Connect up your blow-pipe to the gas cylinders, and put a 500-litre tip in the blow-pipe. This is larger than recommended by the makers of the blow-pipe for a similar thickness of metal; but I find that it makes a more satisfactory job, and easier to carry out, if a large tip is used with a little less gas pressure. If the flame hisses loudly, as it does with the usual pressure, inexperienced workers will find the melted Sifbronze being blown along the joint, instead of sinking into it. Now preheat the job; if you are not using a small blow-lamp for this, set the blow-pipe for a big diffused flame, and go all around the ring several times, to get it well warmed up.

Then adjust the flame to a gentle hiss, not too violent, and concentrate on one corner of the firebox. Have your stick of No. 1 Sifbronze ready, dipped in the flux, and as soon as the corner of the firebox glows bright red, put the Sifbronze rod in the flame just above the joint, and let a blob melt off and drop on the heated metal. It will immediately spread, run in the bevel or groove between the copper rod forming the foundation ring, and the copper plates at either side, also fill up any cracks or interstices.

Now shift the flame along a weeny bit, and repeat the process, dropping the second blob so that it overlaps the first; then continue same way all around the whole doings until you get back to the starting point. Alternatively, do one side and the throat plate end, then come back and "start from scratch" again, doing the backhead end and the other side.

The joint between backhead and wrapper is done same way, drop by drop, each overlapping. Start from each bottom corner, working up to the regulator bush; on arriving there on the second journey up, go around the bush, and let the Sifbronze form a fillet. The finished joints should have a rippled appearance, with never a sign of a bubble or pinhole. Every Sifbronzed joint—inside firebox, crown stays, smokebox tube plate and so on—are all done by the same "technique."

Tubes can be silver-soldered, using a diffused flame without any hissing, and the firehole ring silver-soldered with the flame hissing gently. Pickle and clean as above.

Test for "Pinholes"

The boiler can now be given a rough test under air pressure, to find out if there are any "pinholes" in the brazing. These are usually caused by borax bubbles; and there shouldn't be any, if the scratching wire has been freely used. However, it is advisable to make the test, especially in the case of beginners or other inexperienced coppersmiths.

Make a simple adaptor to screw into the safety-valve bush; I use a brass plug made from hexagon rod, turned down for about 1/4-in. and screwed to fit the bush. The head is about 5/16-in. wide, and carries a tyre valve. You can use either a car or cycle tyre valve, and it may be either screwed or just soldered in, as preferred. There is not the slightest need to make a posh job of it, so long as it answers its purpose.

Screw this adaptor into the safety-valve bush, and couple a tyre pump to it. The small holes in the smokebox tube plate can be plugged with round, slightly tapered pieces of wood, which will make their own thread if screwed into the holes; and a rough metal plug may be turned to fit the steam pipe hole. This plug will come in handy for the final pressure test. The regulator bush can be plugged with a cork; this will do quite well, if pushed tightly in and tied with a strand or two of wire, or even with string, as a great pressure is not needed.

Put the boiler in a large pan of water, or even the family bath, with enough water to cover it, and pump about 20 lbs. air pressure into it. If there are any pinholes, they will immediately show up by emitting a stream of bubbles, just like a puncture does in a car or cycle tube. Should any show up, mark the places, and after removing the boiler from the water and drying it, drill a No. 55 hole at each spot, tap it 1/16-in. or 10 B.A., and screw in a stub of copper wire smeared with plumbers' jointing. Screw in the wire until it breaks off in the hole, and file flush. This treatment cures a pinhole for good and all time. The boiler is then ready for staying.

Longitudinal Stays

There are four longitudinal stays, three being solid rods, and one of thick tube, which carries steam to the blower in the smokebox. The three solid stays are secured by "blind" nipples; and the hollow stay, by the blower valve and a "thoroughfare" nipple. Eighteen of these blind nipples will be needed altogether, as the cross stays through the firebox wrapper are also secured by them; so make the lot at one go. Chuck a length of 3/8-in. hexagon rod in the three-jaw; brass will do quite well if nothing better is available, as they never have to come out when once fixed, and do not have to withstand brazing heat. Face the end, centre, and drill down to a depth of 3/8-in. with either 5/32-in. or No. 22 drill, and tap 3/16-in. by 40. Turn down 5/16-in. of the outside to 5/16-in. diameter, and screw 5/16-in. by 40, using a tailstock die holder to ensure true threads. Part off to leave a head a full 1/8-in. in thickness; reverse in chuck, and chamfer the corners of the hexagon, for appearance sake.