slight bevel shown at the top of each is merely to make the fitting of the outside casing easier. This casing will be fitted when the engine is nearly complete, and the "trimmings" are being dealt with.

The screwholes are drilled No. 30, at 5/8 in. centres, clean through the block; the steam way is drilled 7/32 in.: and at 3/8 in. from the bottom, a 1/4 in. hole is drilled for the steam pipe. One of these is 2 3/8 ins. long, the other is 1 7/8 ins.; both are screwed 1/4 in. x 40 for 11/16 in. length. The plain ends are inserted in the side holes in the blocks, and silver-soldered.

To make the sockets, chuck a bit of 3/8 in. round or hexagon rod in the three-jaw. I have shown round rod on the drawing, as plumbers always use round sockets, but hexagon stuff is more handy to screw up with a spanner, round sockets needing pliers. Face the end, centre, and drill down about 1 1/8 in. depth with 7/32 in. drill Part off two 1/2 in. full lengths, then chuck each separately, run a 1/4 in. x 40 tap through, and skim off any burr.

The nuts are made same way, and are 3/16 in. wide. Put a nut and socket on each side pipe, running them right back to the end of the thread. Now attach one of the blocks to the flat facing above each outside cylinder steam chest with a couple of 1/8 in. or 5 B.A. screws; any heads will do as they will be covered up later. I guess you all know how to locate, drill and tap the screwholes by this time! Put a 1/64 in. Hallite or similar jointing washer between each block and the facing. The inner ends of the pipes should line up with the screwed stems projecting from the sides of the central fitting. Put a smear of plumber's jointing over the threads; run the sockets off the pipes and on to the stubs, screwing them hard up against the brass cube, then run the locknuts up against the sockets, as shown in the illustration, and the job is complete, as far as the steam pipes are concerned.

All that remains is to couple up the union on the lubricator check valve, with the oil pipe union on the front of the steam pipe fitting; this is done by means of a 1/8 in. copper pipe with a 7/32 in. x 40 union nut at the lubricator end, and a 1/4 in. x 40 ditto at the steam pipe end. The union cones are silver-soldered direct to the pipe; for beginners' benefit I might repeat that these are made by chucking a bit of 1/4 in. copper or bronze rod in three-jaw, and turning the outside to fit the nut. Face, centre, and drill about 1/2 in. depth with 3/32 in. drill.

Turn the end to a cone, either by setting over the top slide, or using a tool ground off at an angle of 30 degrees, then part off 1/16 in. behind the end of the angle. Chuck again, back outwards, open out the backs with No. 32 drill for about 3/32 in. depth, press them on the ends of the pipe, and silver-solder in place. Apply a little wet flux, heat to a medium red, and touch with a bit of silver-solder; I use "Easyflo" wire.

Boiler Feed Pump

When the full-sized "Schools" class engines first appeared, they were provided with a crosshead pump to maintain the vacuum in the train pipe of the vacuum-brake apparatus whilst running. This was a feature of the old London and North Western and Great Western engines, and was the cause of the peculiar "ticking" sound they made when running; the old "Brighton" enginemen often referred to the little L.N.W.R. tanks that ran the through Willesden-Croydon service, as the "clockwork engines."

Although the small injectors I have described are perfectly reliable boiler-feeders, if properly made and kept clean, many builders fight shy of drilling the tiny holes and turning up the little cones, and prefer a pump worked off the motion. Owing to the space between the frames on "Roedean" being full of "works," due to the third cylinder, we cannot use an eccentric-driven pump of the usual type (though some have been advertised !) so I have adopted the same wheeze as on the G.W.R. "1000" class engine, and pressed the erstwhile vacuum pump into service, to pump water instead of air.

In the case of the Southern engine, this is a much easier job than it was on the G.W.R. engine. The vacuum pump on the full-sized job was bolted to a flat seating cast integral with the motion plate. I copied this seating in my simplified motion plate, or rather link-bracket stay, both in the cast and built-up versions; so all we have to do is to go ahead, make the pump, bolt it to the bracket, and connect the ram to the crosshead.

THE pump is single-acting, as usual, the ram being 3/16 in. diameter and 1 5/8 ins. stroke. It has an external easily-packed gland, and a valve-box at the extreme end which clears the sweep of the inside crank webs by 1/8 in. Two unions only are needed, as a short pipe carrying a double-union tee-piece is connected to the delivery end of the valve box, thus providing for feed and bypass connections. The angle fitting connecting the ram to the crosshead provides for automatic alignment, so no difficulty should be encountered when erecting the pump and connecting it up.

Pump Body

Our advertisers will probably supply a casting for the pump body and this should be used, as it saves a bit of labour; if for any reason a casting isn't available, the whole issue can be built up. To machine the casting, first chuck it by the lower end of the valve box, and set the upper end to run truly. Face it off, centre, and drill right through with No. 34 drill. Open out and bottom with first a 7/32 in. drill, then a 7/32 in. D-bit to 3/8 in. depth. Slightly countersink the end, then tap 1/4 in. by 40, and mind you don't spoil the D-bitted seating at the end of the hole. Put a 1/8 in. parallel reamer in the small hole, for enough to true it up.

To mount the casting truly for machining the other end, chuck a bit of brass rod in three-jaw (any size over 3/8 in. diameter will do), turn down 1/4 in. of the end to 1/4 in. diameter, and screw 1/4 in. by 40. Screw the casting on to this by the bit you have just drilled and tapped; if the job was done O.K., the other end of the valve-box will run truly. Repeat the first operation, but don't use the D-bit; leave the hole as finished by the drill. With a little chisel, home-made from a bit of 1/8 in. silver steel, nick all around the little hole, so that the valve ball, when it rises, cannot block up the waterway, and prevent water being sucked into the barrel.

Next, chuck the casting by the chucking-piece opposite the barrel, and set the barrel to run truly. Face, centre, and drill with a 3/16 in. clearing drill (No. 12) until the drill breaks through into the central hole in the valve box, and touches the opposite side of the hole. Turn down 5/16 in. of the end to 5/16 in. diameter, and screw 5/16 in. by 32: whilst turning, it would be advisable to run up the tailstock, with the centrepoint in it, to support the barrel. Tools sometimes dig into unsupported ends of castings, and the result is disaster to tools, work, or more probably both. *Note*, the distance from the centre of valve box to extreme end of barrel should be 2 1/16 ins.

The flat face which butts up against the seating on the link bracket can be milled or filed. If a regular milling machine is available, all you have to do is to grip the barrel in the machine-vice on the table, setting the valve box vertical and the barrel horizontal, and take a cut right across the face with a slabbing cutter, any width over 5/8 in. or if only a narrow cutter is available, take two or more cuts without altering the height adjustment of the table.

The job can be done same way in the lathe, with the casting held in a machine-vice on the lathe saddle at correct height, and the cutter mounted on a spindle between centres. It can also be done by mounting the casting in a machine-vice on a vertical slide, and traversing across an end-mill about 3/8 in. diameter, held in three-jaw, two traverses at different heights of the vertical slide doing the needful. If you clamp it under the slide-rest tool holder, with the face to be machined, at right angles to the bed, a cutter not less than 3/4 in. diameter would be needed, as the whole face would have to be covered by the one cut. However, it isn't a hard job to make a simple two-edged slotting cutter, as I have described in previous notes.

Failing any method of machining, the humble but necessary file will do the job, provided that there is a careful and painstaking person at the handle end of it ! The face must be quite flat, and exactly 1/2 in. from the centre of the barrel, so as to line up with the crosshead pin of the middle cylinder.

Valves

Drop a 5/32 in. rustless steel ball in the D-bitted end of the valve box, put a bit of 3/16 in. brass rod on it, and give the end just one sharp crack with a hammer. That will form a perfect seating, quite water-tight. Take the measurement from top of ball to the top of the valve box with a depth gauge; the depth gauge of my childhood days was one of mother's hat pins stuck through a bus ticket, and it did the job perfectly. A similar gadget enabled me to reset the magneto of a broken-down " Vanguard " motor bus one Sunday night in Charing Cross Road well over 40 years ago, when the coupling shifted and completely stumped the ex-horse-bus driver in charge.

To make the combined cap and union, chuck a bit of 3/8 in. hexagon brass rod in the three-jaw. Face the end, then turn down to 1/4 in. diameter a length equal to the depth taken above: screw 1/4 in. by 40, and part off 3/8 in. from the shoulder. Reverse in chuck, centre deeply with size E centre-drill, and drill right through with No. 34 drill. Turn down 1/4 in. of the outside to 1/4 in. diameter, and screw 1/4 in. x 40. Chamfer the corners of the hexagon. Reverse in chuck, and take a 1/64 in. skim off the other end, then cross-nick with a warding file, to prevent the ball from blocking the waterway when it lifts.

Turn the pump upside down, and drop another ball in the valve box, taking depth as before. Rechuck the 3/8 in. hexagon rod, and face the end; turn down a length equal to indicated depth, to 1/4 in. diameter, and screw 1/4 in. x 40, then repeat process described directly above. Reverse in chuck, run a 1/8 in. parallel reamer through, and take a 1/64 in. skim off the end to true it up. Place a ball on this end, and seat it as described previously, then drop the ball in the hole, and screw both caps home with a touch of plumbers' jointing on the threads. Be mighty careful not to get any on the ball valves or seatings.

Ram and Gland

Rustless steel is the best material to use for the pump ram, but if not available, hard-drawn phosphor bronze would do. Soft brass isn't much use, as it rapidly scores on a long-stroke crosshead-driven pump. Either metal may be used just as it is if the diameter (3/16 in.) is available; there is no need to turn the sliding part. Chuck in three-jaw, face the end, turn down 1/4 in. length to 1/8 in. diameter and screw 1/8 in. or 5 BA. This operation should be one with only about 3/8 in. projecting from chuck jaws; then pull it out a bit farther, and part off at 2 7/16 ins. from the shoulder. Reverse in chuck, and slightly chamfer the end as shown in the illustration.

The gland is made from 7/16 in. hexagon bronze or gunmetal rod. Chuck in three-jaw, face, centre, drill down about 1/2 in. depth with No. 14 drill, open out to 9/32 in. drill, and tap 5/16 in. x 32. Chamfer the corners of the hexagon, and part off at 3/8 in. from the end. Reverse in chuck, put a 3/16 in. reamer through, and chamfer that end as well. Put the ram in the barrel, and pack the gland with a few strands of hydraulic packing unravelled from a piece of the braided stuff used for full-sized pumps; if not available, use ordinary graphited yarn.

How to Erect the Pump

First of all make the angle fitting that connects the ram to the crosshead, sometimes called the pump driver. This is merely a bit of 3/32 in. or 13 gauge blue steel, 7/16 in. wide, bent to a right angle, and filed to the shape shown. The longer side is drilled 3/16 in. clearing (No. 12 drill) to suit the crosshead pin; the other end is drilled No. 22, to allow the pump ram to line itself up automatically. A longer crosshead pin will be needed than that previously specified: the plain part should be a bare 3/32 in. longer.

THE pump driver is clamped tightly against the crosshead by the head of this pin, see plan view of the pump erected; but at the same time, the nut on the pin must not be screwed tight enough to pinch in the crosshead jaw. The pump driver cannot shift, once the nut holding it to the ram is properly tightened up.

To erect the pump, first drill four No. 30 holes in the seating under the link girder, and clear away any burrs around the drill holes on the underside. Turn the driving wheels until the crosshead is at the extreme end of the stroke, then push the pump ram right home, and set it in place under the seating, entering the screwed part of the ram into the hole in the driver, and putting a nut on. Then pull the pump back about 1/32 in. or so, bringing the flange of the pump exactly under the seating. Hold it there temporarily—a toolmakers' cramp at the side, ahead of the link girder, should do it —then turn the wheels very slowly, and watch the pump to see if it moves. If it completes the out-and-home stroke without moving, it is set O.K., but if it moves, slack the nuts on both the end of the ram, and the crosshead pin, very slightly, just enough to allow the pump driver to adjust itself to correct position when the wheels are turned and the pump operates.

Finally run the 30 drill into the holes on the seating, making countersinks on the pump flange; follow with No. 40 drill, tap ⅛ in. or 5 BA, and put screws in. Any heads will do, they don't show. When these are tight, also the nuts on ram and crosshead pin, the pump should work perfectly with the minimum of friction.

The main feed and delivery pipes are not put on until after the boiler has been made and erected, but the little pipe fitting shown, can be made and attached now. This is merely a ¾ in. length of 5/16 in. hexagon brass rod, screwed and countersunk for ¼ in. by 40 union nuts at each end, by the same process described for the valve box unions. Drill right through with No. 40 drill, and drill a No. 23 hole in one of the facets between the screws. Silversolder a 2 ins. length of 5/32 in. copper pipe into this hole, and then put a ¼ in. x 40 union nut on, finally silversoldering a union cone on to the other end.

I usually make these cones from copper rod, as when softened by the silversoldering process, they bed into the countersunk end of the nipple with very little pressure of the union nut, and remain steam-and-watertight. The copper rod is turned to 7/32 in. diameter, an easy fit in the nut, then centred and drilled No. 40. The end is coned to 30 deg. either by slewing the slide-rest around, or using a tool with the end ground off at correct angle. The cone is then parted off, reversed in chuck, and counterbored slightly with No. 23 drill, to take the pipe. The union nut is made from 5/16 in. hexagon brass rod, by the same process as described for the gland nut. The illustrations show how the fitting is attached to the pump.

Cylinder Drain Cocks

Six cylinder drain cocks are required, and are all operated from a cross shaft just behind the rear bogie wheel, the shaft in turn being partly rotated by means of a jointed reach-rod connected to the bottom of a lever pivoting on a screw at the back end of the right-hand frame, close to the drag beam. The cock bodies are made from ¼ in. bronze or gunmetal rod. Chuck a length in three-jaw, face the end, turn down 3/16 in. length to 3/16 in. diameter, screw 3/16 in. x 40, and then take 1/16 in. off the end, to reduce the screwed part to ⅛ in. length.

The object of this is to get full threads the full length of the screwed part; some dies, especially if worn, produce torn or untrue threads at the beginning of the piece being screwed, so that if a little extra length is turned and screwed, any bad portion is removed when the piece is reduced to correct length. This is important when the screwed section is short, as in the present case. Part off at ½ in. from the shoulder, and repeat operation five times.

Chuck a short bit of ⅜ in. or larger rod in three-jaw; face, centre, drive 5/32 in. or No. 22, counterbore the end slightly with 3/16 in. or No. 11 drill, tap 3/16 in. x 40 and skim off any burr. Screw each piece into this, turn the body to the shape shown, centre, drill right through with 1/16 in. or No. 53 drill, and counterbore the end slightly with No. 43 drill, to take a bit of 3/32 in. pipe. Cross-drill the centre part of each cock body with 3/32 in. or No. 42 drill and be sure the hole goes through square with the centre hole, cutting straight across it.

Making taper holes in cock bodies, and turning taper plugs to fit, is supposed to be a highly-skilled and difficult job; well, it is just a simple kiddy's practice job if done as follows. You'll need a taper reamer, so chuck a bit of 5/32 in. round silver-steel, and turn a taper point on it 1 in. long. File away half the diameter of the taper, then heat to medium red and plunge into water. Rub the flat part on a bit of fine emerycloth, taking care not to destroy the sharp edges; then hold it over a gas or spirit flame, resting on a bit of sheet steel held in tongs or pliers. As soon as the bright part turns dark yellow, tip it off the steel into the water again. Rub the flat on an oilstone, and the reamer is ready for use.

Now this is the trick: without altering the angle of the slide, or shifting the cutting tool, or making any other alteration whatever to the setting of the lathe, chuck a bit of 5/32 in. round bronze or gunmetal rod, and turn a blunt-ended taper on the end about ⅝ in. long. Repeat operation according to number of plugs required, plus a couple for "spares." As these plugs must of necessity be the same taper as the reamer, they must also fit exactly any hole reamed by it. Part each off so as to leave about ¼ in. of parallel rod beyond the taper, for chucking purposes when turning and squaring the end for the nut and washer.

Put a tapwrench on the reamer shank, and carefully ream out the holes in the cock bodies until the large end is ⅛ in. diameter. Try a plug in the hole, and mark where it comes through; then file a square on the end, so that when the plug is seated right home in the hole, the end of the squared part will be just inside, as shown in section. This is to allow for grinding in. Chuck the plug, and turn down the squared end to 1/16 in. diameter, leaving enough of the square to project 1/16 in. beyond the cock body. Part off the other end a bare 3/16 in. beyond the body, and file a 3/32 in. square on that end, 3/32 in. long.

To hold the plug for filing this end, chuck a short bit of 3/16 in. round brass rod in three-jaw; face, centre, and drill through with 3/32 in. drill, then ream it with the cock plug reamer, until the plugs will go in to within ⅛ in. of the end. Insert plug to be squared, push the holder back into the chuck jaws until only the amount to be squared projects beyond jaws, and proceed to file the square as I have described many times before.

The washers are made by parting 1/16 in. slices off a piece of 5/32 in. round rod, centred and drilled No. 50; either punch the hole square with a punch made from silver-steel, or else file it with a watchmakers' square file, to fit the square on the plug. Ordinary commercial brass nuts can be used.

Plug Handles

The plug handles are filed up from 3/16 in. x 1/16 in. steel or nickel-bronze strip, to the shape shown; the small end is drilled No. 48, the large end is drilled 3/32 in. and filed square to fit tightly on the plug. A few taps with a hammer will burr over the end sufficiently to prevent the handle coming off. To drill the plugs in the right place in relation to the position of the handles, screw the cocks temporarily into the holes in the cylinders, and mark which is which, so that you can put them back in the proper holes again. I usually mark the handles with a 1/32 in. figure or letter punch. Set all the handles backwards, at 45 degrees (see illustration) then remove cocks, put the tapped bush in the three-jaw (the one used for turning the bodies) screw each cock into it, and put the 1/16 in. drill through the lot. The holes in the plugs will then be exactly in line with the steamways through the cock bodies.

All that remains is grinding in the plugs and for this, smear a little oil, and a bit of flour emery or carborundum, on each. A scrape off your oilstone would also do. Twist the plug back and forth a few times, then carefully wipe all the grinding paste off, cleaning out the holes in plug and body, and reassemble the cocks with a taste of graphite, or cylinder oil, on the plugs. Screw them into the cylinders with a smear of plumbers' jointing on the threads.

The full-sized engines have copper pipes leading from the cocks, to the front of the leading footsteps, blowing the steam and water well forward. This is not absolutely necessary on the little one; but if you wish to fit the pipes, I have shown them in the drawing. They are merely bits of 3/32 in. copper pipe silversoldered into the counterbore at the bottom of each cock, and bent to shape after the cocks are screwed into the cylinders.

THE handles of the two cocks on each cylinder are coupled by a little rod very similar to a wheel coupling-rod, only much smaller. This is filed up from 1/16 in. x 3/16 in. steel strip, and as the dimensions are shown in the drawing, no description is needed. The rod is attached to the cock handles by 9 BA screws, and as these should have a plain part under the head, they can be turned out of 1/8 in. round steel. The threads should be tight, and when they are screwed right home, the rods should be quite free.

The "coupling-rods" are erected on the outer side of the cock handles, the connection from the operating shaft being placed on the inner side, and a countersunk-head screw is needed in each three-thickness joint. I have not shown detailed drawings of the long rods, as they are exactly the same shape as the short ones; but make them of heavier section, viz., 3/32 in. and 1/8 in. wide, with 3/16 in. ends. The lengths are shown in the plan and elevation views.

Cross Shaft

The cross shaft is a piece of 1/8 in. round steel 4 11/16 ins. long. It carries four arms or levers, as shown in the plan drawing, which also contains an inset showing a detail of the levers, with dimensions. The shaft runs in two bearings, which are attached to the main frames just behind the bogie wheels, by two 3/32 in. or 7 BA screws in each, running through clearing holes in the bearing, into tapped holes in the frame.

As on the full-sized engine, the bearings are outside the frame. First cut out and drill the bearings and the levers to the given dimensions, then drive the two inner levers on to the shaft, approximately in the position shown in the plan view. Put two small tight-fitting brass collars, made by parting 5/32 in. slices off a piece of brass rod drilled No. 32, on the shaft at 25/32 in. from each end; then slip the bearings over, and put on the two outer levers. *Note*, all the levers are in line.

Now temporarily erect the shaft, 1 3/4 ins. behind bogie-wheel centre, and 15/32 in. below the bottom edge of frames; a toolmakers' cramp each side will hold the bearings in position. Set the shaft square across the frames, and exactly level; then run the No. 40 drill through the holes in the bearing, making countersinks on the frame, follow with No. 48, tap 3/32 in. or 7 BA and put screws in. Next, line up the left-hand inside lever with the cock handles of the inside cylinder. *Note*, these will be inclined and the connecting-rod between the lever on the shaft, and the back cock handle, will need a slight twist in it, so that the bosses at the ends lie flat against cock handle and lever.

Set the right-hand inside lever 1 1/4 ins. from the end, see plan, and finally make sure all four levers are in line. Then take off the whole issue, carefully braze or silver-solder all four levers and the collars to the shaft (keep the bearings clear of collars and levers during the process) clean up and re-erect. The levers on the shaft are then coupled to their respective cock handles, as shown in plan, by little connecting-rods made from 3/32 in. x 3/16 in. steel strip, 3 3/4 ins. between centres.

Intermediate Hanger and Cab Lever

On both the full-sized and small-sized engine, the span between the cross shaft and the lever in the cab is too great for a single operating rod; it would just buckle up. Consequently, an intermediate hanger is interposed, and the reach rod is split into two sections. Make a bearing from 1/8 in. sheet brass, similar to one of the cross-shaft bearings, but only reaching 3/8 in. below frame, to centre of hanger pivot. Drill the pivot hole No. 41 or 3/32 in., and attach the bearing to the frame, inside this time, and on the right, at 8 ins. behind the cross shaft; see small detail inset.

The hanger is made the same size as the levers on the cross shaft, but the hole at the larger end is tapped 3/32 in. or 7 BA, and a pivot screw put through the hole in the bearing, into the hanger. A similar screw, with 3/16 in. of "plain" under the head, screws into the free end of the hanger, and carries the ends of the two reach rods, as shown in the plan. The forward section of the rod is made the same as the rods connecting the cross-shaft levers to the cock handles, and is 8 ins. long between centres; it is connected to the right-hand inside lever on the cross shaft, by a 3/32 in. or 7 BA screw.

The operating lever in the cab is made from a piece of 3/8 in. x 3/32 in. flat steel approximately 3 3/4 ins. long, filed to shape shown. **Drill a No. 48 hole at each end, tap the bottom one 3/32 in. or 7 BA, and fit** a little hand grip, turned up from 1/8 in. steel, similar to the handle of the reversing wheel, in the top one. At 1 1/2 ins. above the bottom hole, drill a 5/32 in. hole, and turn up a shouldered screw to fit it, from 1/4 in. hexagon steel, as shown in the section.

At 1 1/4 ins. from back end of right-hand frame, and level with the top of the drag beam, drill a No. 40 hole and tap it 1/8 in. or 5 BA to suit the screw. Attach the lever to the inside of the frame; when the screw is right home, the lever should move easily, but with a slight stiffness, so that it "stays put" whether the cocks are open or shut. The bottom of the lever is connected to the intermediate hanger by the rear section of reach rod, filed up from 3/16 in. x 3/32 in. steel as before. The distance between centres is approximately 6 5/8 ins., but you can check this from the actual job. See that when all the screws are tight home at the ends of the threads, the joints are quite free on the plain parts of the screws; with a spot of oil on each joint, all six cocks should operate easily when the handle at the footplate end is pushed back and forth.

Buffers

Brake gear is optional, so we can leave that until we come to the "trimmings" near the end of the job, but the buffers might be fitted at this stage. The sockets are turned either from castings, or ⅞ in. round rod, either brass or steel. Chuck the rod or casting in three-jaw, face the end, turn down ½ in. length to ⅜ in. diameter and screw ⅜ in. x 26 or 32. If rod is used, part off at 1¼ ins. from the end. Reverse and rechuck in a tapped bush held in three-jaw. Turn the outside to profile shown; centre, drill right through with No. 30 drill, and open to 11/16 in. depth with 5/16 in. drill. Make a nut from ½ in. hexagon rod, to fit the screwed shank.

For the head, chuck a bit of ⅞ in. round steel in three-jaw; face the end, centre, drill down about 3/16 in. with No. 40 drill, and tap ⅛ in. or 5 BA. Turn down 7/16 in. of the outside to a bare 5/16 in. diameter, a sliding fit in the socket. Part off at 9/16 in. from the end, reverse in chuck, and turn up the head to convex shape as shown. Put a few threads on the ends of a 1½ ins. length of ⅛ in. round steel, and screw it into the tapped hole in the stem. Assemble as shown, with a 19 gauge steel spring in the socket, and a commercial nut on the spindle. Poke the shank through the hole in buffer beam, and secure with the big nut.

WHEN getting out the dimensions and details of a "scale size" boiler for "Roedean," I must plead guilty to indulging in a few chuckles at the expense of certain locomotive designers of not - so - very - long-ago. They insisted that unless a little engine was provided with the biggest possible boiler that the frames would accommodate, the engine would be a failure through shortage of steam. I have here at the present time a 1934 issue of a monthly journal illustrating a locomotive built to this idea. The diameter of the boiler is roughly equal to twice the rail gauge, and it extends from the buffer beam to the drag beam, the mountings looking like warts on a hog's back. In conjunction with ridiculously small cylinders, and small driving wheels, the engine looks a top-heavy freak.

How needless this is can be judged by the fact that one of my own 3½ in. gauge locomotives, an old-fashioned single-wheeler (2-2-2 type) has a boiler only 2⅞ ins. diameter, yet if started off with 35 lbs. on the gauge, hauling my twelve stone, she will be blowing off sky-high before the completion of the second lap of the line. A boiler three times the size would not be of the slightest advantage, as it could do no more than the little one does, viz., maintain a full head of steam under all conditions of service.

For beginners' benefit, may I once more state that it is not the actual *size* of the boiler, but the *temperature* at which it works, that determines the amount of steam produced. Draining off the steam from the boiler lowers the temperature; therefore, to keep the boiler "on top of the job" the firebox and tubes have to be arranged so that they will replace as many, or preferably more, "therms" than are being taken out by the requirements of the cylinders and the cold water going in as boiler feed. The latter must be instantaneously heated to the working temperature of the boiler as it passes the clack, otherwise back would go the needle of the steam gauge. "Roedean's" firebox and tubes will easily fulfil the conditions, so now to construction.

Barrel and Wrapper

As the boiler is of the usual round-backed variety, the barrel and firebox wrapper may either be made in two pieces, using a tube for the barrel, and sheet for the wrapper, or it may be made entirely from a single sheet. In the former case you will need a piece of 3/32 in. or 13 gauge seamless copper tube 4⅜ ins. diameter, and long enough to finish to 9¼ ins. length after squaring off in the lathe.

The easiest way of doing the latter job is to drive a piece of wood into each end; grip one end in the outside jaws of the three jaw, if you have one big enough, and support the outer end with the tailstock centre. If you haven't a big three-jaw, drive a screw into one of the discs of wood; then put on the faceplate, and mount the tube between centres, with the screw going through one of the slots in the faceplate. This allows the faceplate to afford a positive drive. Use a knife tool with plenty of cutting oil. For the second end, simply reverse the job between centres, and put the driving screw in the opposite end. One end should be faced off at right angles, and the other bevelled.

A strip of 16 gauge copper, ½ in. wide and 10¼ ins. long, should be bent to the radius of the inside of the barrel, inserted into it for ¼ in. depth, and fixed by a few 3/32 in. rivets, just enough to hold it whilst the brazing operation is in progress. This is attached to the bevelled end.

The wrapper, or outer sheet of the firebox, is made from a piece of 13 gauge or 3/32 in. sheet copper, cut to the shape shown in the rear section of the illustration of the one-piece barrel and wrapper. The measurements are 15½ ins. long on the longer side, 13⅜ ins. on the shorter side, and 7 ins. wide. This is bent to the shape shown in the cross section of boiler; the curved part of the longer end is bevelled off and placed over the projecting part of the strip riveted to the barrel, the bevelled edges butting together. Secure with a few rivets, as before. The space below the barrel is filled up with a piece of ⅛ in. or 10 gauge sheet copper, flanged over at each side, so that when the straight sides of the wrapper are riveted to it, the overall width is 2¾ ins.

The copper sheet is easy enough to flange, if made redhot and plunged into cold water; you can either grip the piece in the vice, and beat down the edges over the vice jaws, or better still, make the iron backhead former, or forming plate, and beat down the sides of the throatplate over the lower part of it. Three 3/32 in. copper rivets each side will be sufficient to hold the bits together whilst brazing. The latter operation gives the boiler its strength to resist pressure; not the rivets. The upper edge of the throatplate butts up against the edge of the barrel (see sectional illustration) and is cut to the same radius as the inside.

One-Piece Boiler Shell

If preferred, the whole of the shell may be made from a single sheet of 3/32 in. or 13 gauge copper, cut to the shape shown in the drawing. In this case, the 9¼ ins. portion is bent to a complete circle, the edges overlapping for about ¼ in., a few copper rivets being put in to keep the lap joint closed up. The 7 ins. portion is bent to the shape shown in the cross-section of the boiler, and a ⅛ in. or 10 gauge throatplate fitted at the front end exactly as described above.

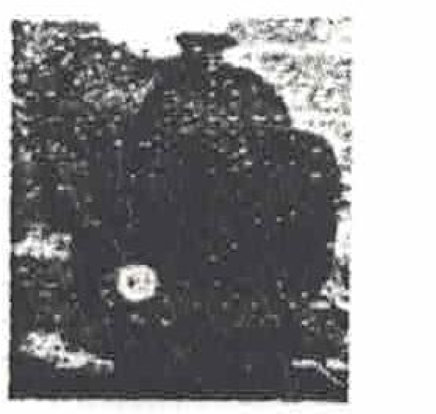
No difficulty should be experienced in bending the copper. I often recollect with a smile the tricks I got up to in childhood days, to bend up my primitive boilers out of tin, or anything else I could obtain. If I could get a coffee or cocoa tin, I could make a swell boiler out of it; but these didn't always happen to be the size required, and then a stone ginger-beer bottle, or something else that was of the size needed, was pressed into service as a former. Once I used mother's hardwood rolling-pin, but it is hardly necessary to add that I cleaned it very carefully afterwards !

How to Braze Up the Shell

For beginners' benefit I might repeat that brazing up a boiler is not a difficult job, though it requires perseverance and usually a lot of perspiration, if a blowlamp or air-gas blowpipe is used. If oxy-acetylene apparatus is available, the whole job is a piece of cake, easier than soft-soldering. I have used an oxy-acetylene blowpipe for my boilersmithing since the beginning of 1932, and would not go back to the old way for all the tea in China.

However, not many folk possess this "putting-on tool," and the great majority still use blowlamps and blowpipes, so I will describe how the job is done with these. *Here a warning !* Certain advertisements of small blowpipes are apt to mislead beginners. They are not intended to do so; but when a beginner reads that a small blowpipe will melt copper, he is apt to jump to the conclusion that it will certainly provide enough heat for brazing.

It is quite possible to melt a bit of thin copper wire with a mouth blowpipe and a little spirit flame, of the kind used by jewellers for repairing brooch pins, bracelets, watchchain links and so forth; but if the flame is applied to a copper sheet, the heat is conducted away as fast as the blowpipe delivers it, and it is impossible to get the metal even uncomfortably warm, let alone at bright red brazing temperature. "Roedean's" boiler requires at least a five-pint-size blowlamp, or an air-gas blowpipe of an equivalent power, having a 1¼ ins. nozzle.



THE other requirements are, a big pair of tongs, a small ditto, some easy-running brazing strip (sometimes called spelter) some silver-solder, both coarse and best grades, some flux such as "Boron Compo," a piece of $\frac{3}{16}$ in. iron wire about 2 ft. long with a point at one end and a ring at the other, a forge, and a pickle-bath. A discarded iron tea-tray makes a nobby forge, with a piece of 16 gauge sheet steel about 8 or 9 ins. high, bent channel-shape and stood up at the back, to prevent the coke or breeze falling overboard.

For a pickle-bath, anything that will not be attacked by the acid will serve. I know of one loco builder who uses a two-gallon glass accumulator jar; another uses a piece of stoneware drainpipe, with a bottom piece of similar material cemented in. My own pickle container was once a wooden box lined with $\frac{1}{16}$ in. sheet lead, but the wood has long since rotted away, leaving the lead lining intact. This is still doing yeoman service, as the lead is able to retain its shape without any assistance; it stands on two wooden battens propped up by a couple of bricks, placed edgewise, which makes it easier to "duck" the brazed parts.

The pickle is diluted sulphuric acid; add one part of commercial acid to about 16 parts of water, *and don't on any account add the water to the acid*, because you'll either have to go to hospital, or buy a new suit of clothes, or both. There is not the slightest danger if you put the water in the container first, and then pour the acid in steadily. Old accumulator acid does fine, too, and as this is already partly diluted, it only needs about four times its bulk of water added to it. Doesn't matter which way you mix the already diluted stuff.

Now for the job. Put a layer of small coke or breeze in the pan. Cover all the joints to be brazed with a paste made up by adding water to some of the flux, and stirring to a creamy consistency. Slap plenty on, and well cover the joints. Stand the boiler shell in the pan, on the coke, with the barrel pointing skywards. Pile up coke all around it, almost to the level of the throatplate, and put some inside as well, piling up to within about an inch of the throatplate.

Have all the requirements right handy—very important that ! Get your blowlamp or blowpipe going good and strong, and heat up the shell at the throatplate and the barrel joint, until the coke begins to glow. Then concentrate on one bottom corner of the throatplate. When the metal glows bright red, dip a stick of easy-running brazing strip into some dry flux, and apply it to the hot spot. If you warm the strip in the blowlamp flame for a few seconds, the flux will stick to it.

If the metal is hot enough, the brazing strip will immediately melt and flow into the joint, as easily as soft solder. Now shift the flame just a little farther along, and repeat the process; but don't go far enough to allow the first dose to set whilst the second is being applied. The action should be more or less continuous.

Beginners note, the actual amount to move the flame is governed by the size of the flame itself; when the centre of it (the hottest part) is blowing directly on the point where you are going to apply the brazing strip, the outer edge of the flame should still be licking the last lot and keeping it melted, so that the fresh dose will amalgamate with it and thus form a continuous joint. Sounds a terrible lot to read about but in reality, you get the knack of it in a very few minutes, and wonder why brazing is regarded as difficult !

Work your way up to the point where the throatplate joins the barrel; then commence the trip around under the barrel, using the same technique, only in this case let enough of the brazing strip melt on to the copper to form a fillet between the throatplate and the barrel, shown by a little black triangle in the sectional illustration of the boiler. When arriving at the opposite side, you can either work downwards to the other bottom corner of the throatplate, or start again from that point and work upwards to the barrel again. If the latter, give the meeting-place a jolly good warming-up, and make certain that the brazing strip at the actual junction melts and flows well, so that it becomes as one, and prevents any possibility of leakage.

If you have made the barrel and wrapper in two pieces, with the butt strip joining them, this joint is now brazed; as the edges are bevelled, all you have to do is to fill up the vee with brazing strip. Lay the boiler shell on its side, put a little more flux over the vee, and, starting from the place where throatplate and barrel meet, blow direct on the vee until that part of it is bright red, then apply the strip. Carry on inch by inch, turning the boiler over to do the other side and finally standing it right way up to do the final bit on top, if the melted strip hasn't already run in and done the job whilst the shell is lying down. It usually did in the days when I used a blowlamp.

Don't stint the strip, any excess can be filed off flush afterwards so that the barrel and wrapper appears to be continuous. Should the strip be shy of starting to run when first applied, use a little bit of the coarse-grade silver-solder; this melts at a much lower temperature, and when the strip is added, the two form a kind of alloy which melts and runs like water. Once the brazing strip has started to run, it will continue to the end of the joint, as long as you keep the heat up.

If your boiler shell is made in one piece, you won't have a circumferential seam to braze, but instead, a longitudinal lap seam under the barrel. The modus operandi is just the same. Cover it with flux, give the lot a preliminary warm up, then start at the smokebox end, melt in some strip and proceed inch by inch until you reach the throatplate. Give this point an extra blow up, so that the joint is rendered continuous and perfectly sound. Should the melted strip bubble at any part of the operation, scratch where the bubbles arise with pointed wire; this will break them up, and prevent "pinholes" or porous places formed by minute "borax bubbles," caused by the boiling-up of the borax in the flux.

When the brazing is finished, let the job cool to black, then carefully lower it into the pickle bath. Mind the splashes! Spots of the pickle will make holes in your clothes or irritate your skin. If any splashes get on your hands, wash off immediately and apply a little boric ointment or vaseline; that will prevent any ill effect. A spot on your clothes, or overall, can be neutralised, if caught in time, by an application of ammonia. These tips are useful! Leave the shell in the pickle from 15 to 20 minutes, then get it out, well wash in running water, and clean up with a handful of steel wool, or a nail-brush and some domestic scouring powder. Clean copper is much nicer to handle, and doesn't poison cuts or scratches.

All the brazed joints in the boiler are carried out in the same way, so there won't be any need to detail the process again. Users of oxy-coal or oxy-acetylene blowpipes need not use coke packing, though it is an advantage, and saves gas, to preheat with a blowlamp. I find that Sifbronze, and the special flux sold with it, gives the best results.

The job is simplicity itself. Cover the joints with wet flux; blow up at the starting point to bright red, then hold a Sifbronze rod, say 1/8 in. diameter, in the flame, and let a drop melt off and fall into the hot place. Then move the flame slightly, and drop another spot, overlapping the first.

Ditto repeato until you have done the complete joint, which should present an evenly rippled appearance. If properly done, the joint is stronger than the metal of the boiler; I find it so, anyway. Pickle, wash off and clean as above.

Firebox

The firebox of the 3½ ins. gauge engine is in proportion to that of the full-sized one, and does not need a thick fire to make all the steam required. The upper part forms a combustion chamber in which are burnt up all smoke and combustible gases rising from the fire bed. Thus the full value of the heat in the coal is obtained and no smoke comes from the chimney, with the exception of a little haze for a few seconds after each firing.

Make the tube plate and door plate first; to flange these, an iron former is needed. This is a piece of 1/4 in. plate, cut to the size and shape indicated by dotted lines in the illustration (*next week*). As tubeplate is longer than doorplate, the former must be made long enough to allow the tubeplate to be flanged over it. If a good hacksaw blade is used, and a drop of cutting oil applied, the saw will walk through the steel with very little effort. The 14 teeth-to-the-inch grade does the job quickest. Saw as near as possible to the marked lines, finish with a file, and round off the sharp corners on one side of the plate.

Lay the former on a piece of 13 gauge (3/32 in.) sheet copper, and scribe a line around, about 3/8 in. from the edge of the former, the length of the piece being according to the length shown in the illustrations for doorplate and firebox tubeplate. Anybody can do the flanging. Anneal the copper plate by heating to red and plunging into cold water; then place the former in the middle of the plate, grip them in the bench vice, and beat down the projecting 3/8 in. of copper over the edge of the former. Note that the rounded-off edge of the former must be placed next the copper.

If the copper tends to go hard, and buckles, re-anneal immediately, otherwise the flange will crack; not that it matters much, as the brazing material will stop up any cracks, but you get a better job without any. When through, file off any raggedness from the edges, and clean the flange with the file.

Instead of setting out the tube holes on the firebox tubeplate, I always set mine out on the iron former, and drill a No. 40 hole at each point. Then not only can the tube holes in the smokebox tubeplate be jigged off from it, but in the event of making another boiler with a similar firebox, the tube arrangement is already available, and no further setting-out is needed.

IN all my boilers you will find the tubes symmetrically arranged, so that setting-out is rendered as easy as possible; in the present instance, the 3/8 in. tubes are set at 1/2 in. horizontal centres, the vertical measurement between rows is 7/16 in., and the tubes are evenly staggered. The 11/16 in. flues are at 13/16 in. centres, and the row 5/8 in. above the top row of small tubes.

After flanging the firebox tubeplate, whilst it is still on the former, poke the No. 40 drill through all the holes, carrying on right through the copper. After removing, drill all the holes out with 23/64 in. drill, and ream 3/8 in. except the top row, which are further opened out with 43/64 in. drill, and reamed 11/16 in. Countersink the whole lot on the opposite side to the flange.

The doorplate is flanged up in the same manner as the tubeplate, but carries the fire-hole ring. To make this, chuck a piece of 1⅜ ins. x 10 gauge copper tube, face the end, and turn down 3/16 in. length to 1¼ ins. diameter. Part off at 21/32 in. from the end. Reverse in chuck, and turn down 5/32 in. of the other end to 1¼ ins. diameter, leaving 5/16 in. of the tube full size. Slow speed, a keen tool, and plenty of cutting oil will make the job easy. Anneal the ring, then squeeze it oval in the bench vice until the "north to south" measurement inside, is 7/8 in.

Lay the oval ring on the doorplate with its centre line 1⅜ ins. from the top; scribe a line all round it, and cut out the piece by drilling holes inside the line, breaking it out, and filing to outline. Clean the edges of the copper, and also the ring; then insert the ring in the hole (narrow side) on the side opposite the flange, and beat the projecting lip outwards and down until the doorplate is tightly gripped between the beaten-down flange and the shoulder, as shown in the longitudinal section of the boiler.

Avoid Copper Sheet Waste

To avoid waste of copper sheet, get the exact size of the piece needed for the firebox sides and crown from the tubeplate and doorplate themselves. Run a piece of soft copper wire, or thick lead fuse wire, around the flange; straighten it out, and you have the exact length of the copper sheet required, at each end. The piece of copper should be 6⅜ ins. wide, the shape being similar to that shown for the wrapper section of the one-piece boiler shell.

Some precise folk go to the trouble of making a hardwood block, the exact shape of the firebox, and bending the copper over it. Very nice if you have the time; but all I do is to put a piece of round bar in the bench vice, with enough projecting beyond the jaws to equal the length of firebox. The plate is then annealed, and the bends marked; it is placed over the piece of bar, and although I am in the "sere and yellow leaf" period of life, I can still exert enough force to bend the copper plate over the bar with my hands, so younger readers shouldn't have the slightest difficulty in thus forming the plate to the shape of the firebox. Clean the edges, and then rivet in the end plates with a few 3/32 in. rivets, just enough to keep the plate in close contact with the flanges whilst brazing.

Crown Stays

The crown stays are of my pet girder type, which are not only easier to fit than rods, but immensely stronger, as they convert the back part of the boiler into a "box" girder, and any millwright will tell you that this is one of the strongest forms of construction. The Menai Bridge to Anglesey is a glorified box girder, and the L.M.S. "Duchesses" haven't managed to break it yet, although locomotives of that size and weight weren't dreamed of at the time it was built !

The side girders are each formed of one angle and one channel, placed back to back and riveted together. At one time I used two channels (still do, for Belpaire fireboxes) but the top angle of the outer channel in a round-backed boiler had to be bent right over at an acute angle to get it in place; and I found—by actual experiment, which is the only satisfactory way—that this angle could be dispensed with, if a fillet of brazing material were run along the upper edge of the stay, as shown by the black triangles in the cross section. The centre girder is formed of two angles placed back to back.

All the lot, angles and channels, are bent up from 16 gauge copper, the feet of all being 5/16 in. wide. The centre angles are ⅜ in. high in the middle, and 5/16 in. at the ends. The outer angles of the side girders are 1 3/16 ins. high, the channel being bent over at same height, and curved on the flange, to the radius of the inside of the wrapper (see cross section of boiler). Incidentally, I strongly advise all builders of "Roedean" to obtain the full-size blueprints of the boiler, as this helps enormously in getting the correct shape of the plates; but be sure you get those issued from *Mechanics'* offices.

RIVET the angles and channels together as shown, the horizontal spacing of the rivets (3/32 in. roundhead copper) being about 1 in., then rivet the whole lot to the firebox crown, as shown in the cross section.

My own method is to drill all the holes in the flanges of the girders first, with No. 41 drill, then put an outside girder in place, marking off the location of two of the holes with a fine scriber, or a small automatic centrepunch with 3/32 in. tip. These two holes are drilled, and the rivets put in; it is then an easy job to drill all the other holes, using those in the girder flanges as a guide.

I use a broken stub of No. 41 drill driven into the end of a piece of 3/16 in. brass rod about 3 ins. long, which is held in the handbrace chuck, and enables the drill to reach all the holes quite easily. The rivets are put through from inside the firebox, the heads rested on a piece of flat bar placed vertically in the vice, and the stems knocked out flat on the girder flange by a rivet punch, made from a bit of ¼ in. silver steel, with a slight countersink in the end. If this is placed over the rivet stem or shank, and the other end hit with a hammer, the trick is done. Fancy heads are not necessary, as once the boiler is assembled, they "sink into the depths of obscurity," so to speak, for the lifetime of the boiler. *Note*—before assembly, clean the flanges and the crown of the firebox; clean joints make sound joints.

Brazing the Firebox

I have already explained the brazing process but here is the sequence of events, and the variations needed when brazing up the firebox. Cover all joints with flux paste, as before, then stand the firebox in the pan, doorplate upwards, and pile the coke or breeze in and around it. Heat the lot up first, then concentrate on one bottom corner as before, and work your way right around, taking the firehole ring "in your stride" when you reach it; the flame of the lamp, playing on the adjacent seam, will also heat the ring so that a fillet can be run around the top of it at the same time.

Do the underside of the ring exactly the same as the joint between the throatplate and the barrel, finally giving the whole ring an extra-special blow up, to allow the brazing strip to form an even fillet with no pinholes. On arriving at the other bottom corner, turn the firebox end for end, tubeplate upwards, and repeat the process; but watch your step very carefully indeed when doing the upper part where the tube holes are, otherwise you might suddenly find one big ragged hole in place of a lot of little round holes. The metal between them is easily melted !

Finally, stand the firebox right way up in the coke. Cut six narrow strips of silver solder (coarse grade) and lay them close to each flange. Blow up the whole crown of the firebox to redness, and the silver solder strips will melt and seat in right underneath the flanges. Then run a fillet of brazing strip along each flange, same process as brazing the seams and joints, taking care to cover all the rivet heads. If the blowlamp flame is directed down between the girders, you will find that it is quite easy to get the strip to melt and flow, whilst attending to the middle flanges; in fact, the melted strip will probably try to fill up the spaces between the side and centre flanges, and if so, let it, as the box will be all the stronger. When you are absolutely certain that no places have been missed, either at the ends or along the crownstay girder flanges, let the whole issue cool to black, put it in the pickle for 15 minutes or so, wash off, and clean up as before.

Smokebox Tubeplate

Make the smokebox tubeplate next, as it will be needed to act as a tube spacer whilst the tubes are being silversoldered in.

A circular former 4 ins. diameter is needed for this; anything available, such as a discarded chuck plate, or even a locomotive wheel casting, may be used. Cut out a circle of $\frac{1}{8}$ in. or 10 gauge sheet copper approximately $4\frac{7}{8}$ ins. diameter, anneal it, and flange it over the former as previously described. It will probably need annealing two or three times before you get the flange right down, at right angles to the plate.

Chuck this in the outside jaws of the three-jaw, flange outward, and face off the ragged edge. Reverse it, and hold it by the outside jaws bearing on the inside of the flange; you can't use the inside jaws, because the lower steps get in the way. Turn down the outside of the flange until it is a tight push fit in the end of the barrel.

Scribe a line right down the middle of the side opposite the flange, and clamp the firebox former to it, so that the bottom middle hole is a bare $\frac{3}{8}$ in. from the edge, and the scribed line visible through that hole and the one directly above it in the third row. Then put the No. 40 drill through the lot; remove former, open out all the holes, ream them same as firebox tubeplate, and countersink slightly both sides. Drill and tap the stay and steam pipe holes, as shown in the drawing.

Tubes

The nest of tubes comprises four $\frac{11}{16}$ in. x 20 gauge flues for housing a four-element superheater—there is nothing to beat "red-hot" steam for efficient and economical working—and eighteen $\frac{3}{8}$ in. x 22 gauge tubes, the combined effect of which will maintain a full head of steam for any condition of service. If your lathe has a hollow mandrel that will take the tubes, square them off in the chuck, to a length of $9\frac{1}{4}$ ins. but if the ends are filed off square, it will do. Well clean all the ends.

Anybody with previous experience may be able to silversolder the whole bunch at one heating, but beginners had better do them in two or three instalments. In the former case, insert the lot in the holes in the firebox tubeplate, letting them project through about $\frac{1}{32}$ in., and then put the smokebox tubeplate on the other end to act as spacer, and hold them whilst the silver-soldering is in progress.

I usually smear wet flux all over the tubeplate first and then put some around each tube before inserting same into the firebox; this ensures that they are all covered. It is a patience-trying job to get the smokebox tubeplate over the ends, like putting the second side on a set of clock works, and getting the pivots into the bearing holes. Anyway, when you have done it, line up the tubes with the sides of the firebox, and see that they are square with the tubeplate. Then up-end the firebox in the pan, tubes pointing skywards, and pile the coke or breeze all round, almost up to the level of the tubes outside, and within an inch or so inside. Cut some silver-solder into little bits about $\frac{3}{16}$ in. square, or less if you like, and drop the pieces all among the tubes.

Heat up very carefully, keeping the flame off the tubes until the tubeplate is well heated: the coke inside should begin to glow, and help matters a lot. When the tubeplate reaches dull red, blow partly on the tubes and partly inside the box, the idea being to get both the tubeplate and all the tubes for about 1 in. up, red at the same time. When this occurs, the silver solder will melt and flow easily, running around all the tubes, and filling up the countersinks. A silvery ring should show around each tube, inside the firebox. When O.K. let cool to black, pickle, wash off and clean up.

Beginners and inexperienced workers can do the four superheater flues first; then the upper two rows of small tubes, finally the lower rows. After each heat, the job is pickled, washed off, and the remaining tubeplate holes cleaned and fluxed. Finally, when the tubes are all in, take off the smokebox tubeplate, heat the whole of the tube ends to bright red, quench in the pickle (mind the splashes once more!) and wash off and clean up. This softens them ready for expanding into the smokebox tubeplate.

First Stage of Assembly

Well clean inside the top of the wrapper, the end of the boiler barrel, and inside the bottom of throatplate. Cut a piece off $\frac{1}{4}$ in. x $\frac{5}{16}$ in. copper rod to fit exactly at the bottom of the throatplate between the side flanges; round off the corners that will go next to throatplate, and bevel off the sides slightly, so that the brazing material can penetrate between the rod and the plate, as shown by the black marks in the illustrations. *Note*, it is the $\frac{1}{4}$ in. side that has to be bevelled. This piece of rod is jammed in between the side flanges at $\frac{1}{16}$ in. from the bottom.

With the boiler upside down on the bench, slide in the firebox and tube assembly, until the firebox tubeplate hits up against the piece of copper rod just put in. Set the firebox so that it is midway between the sides of the wrapper, then put a toolmaker's cramp over the throatplate, piece of rod, and firebox tubeplate to hold the lot together.

See that the top flanges of the crown stays are bearing full length along the top of the wrapper, and that the firebox is absolutely central; then put another cramp over each flange and the wrapper, to hold them tightly together. At $1\frac{1}{8}$ ins. from the end of the wrapper, drill a No. 41 hole clean through wrapper and each flange, and put a $\frac{3}{32}$ in. or 7 BA bolt in each one, to make them "stay put" whilst doing the rest of the drilling and riveting; the clamps can then be removed.

Now put about four $\frac{3}{32}$ in. copper rivets through the throatplate, piece of rod, and firebox tubeplate, drilling the holes No. 41. Rivets $\frac{5}{8}$ in. long will be required; if you haven't any, use bits of copper wire, headed over at each end. That clamp can now be removed as well. Next, drill No. 41 holes through wrapper and crown-stay flanges, at $1\frac{1}{8}$ ins. intervals, both sides. File off any burrs, and rivet with $\frac{3}{32}$ in. copper rivets.

The holes in the wrapper may be slightly countersunk, and the rivets hammered flush. The rivets may easily be inserted from the inside, by aid of a strip of metal about $\frac{1}{4}$ in. wide and 6 ins. long, with a notch cut in the end, like a distant signal. Jam the rivet in the notch, insert it in the hole, then pull away the strip.

PUT a bit of stout bar in the bench vice, say about $\frac{5}{8}$ in. by 1 in. section, letting a little over 6 ins. project from the side.

If the boiler is slipped over this so that it goes between the crown stays, the head of the rivet may be rested on it, whilst you assault the stem projecting up through the hole, with the ball end of the hammer. Aim straight, take it steady, and don't dint the copper; a battered wrapper betrays rank carelessness! Finally, remove the two temporary $\frac{3}{32}$ in. bolts, and substitute rivets; also smear a good dose of wet flux along the flanges, ready for the brazing job.

How to Fit Smokebox Tubeplate

Put the smokebox tubeplate in the end of the boiler barrel, flange first, and tap it down with a hammer and a bit of wood until it almost touches the tubes. Make sure it is vertical; then line up the tubes with their proper holes by aid of a wooden skewer, or a blacklead pencil, and carefully drive the tubeplate home until the tubes stand out about 1/16 in.

They must then be expanded by driving a taper drift into each. If you have an old drill shank, taper socket, or anything else that will fit the tubes, that will do fine; if not, turn a taper on a suitable bit of steel rod, and polish it with fine emerycloth. The exact angle of taper doesn't matter a bean; the best results are given by one approximately the same as the Morse taper. Grease the drift before inserting into the tube end; a couple of sharp cracks with a hammer will make the tube fit the hole perfectly. If by any chance the drift sticks—it shouldn't, by the good rights—give it a tap sideways. We are now ready for another spot of blowlamp artistry.

Brazing Up the Assembly

The first item in this stage of "operation perspiration" is to braze the circumference of the smokebox tubeplate to the barrel and silversolder the tubes; to do this we need a special rig-up. Get an old iron tray, or big tin lid, or something similar (old dust-bin lid would do) and cut a hole in the middle with a hammer and cold chisel, big enough to let the boiler-barrel through. Put it over the barrel about 3 ins. down, then up-end the boiler, and prop up the whole bag of tricks, close to your ordinary brazing pan, about 3 ft. from the ground, using bricks or something else that won't burn, for supporting the tray.

Pile some coke all round the end of the barrel, almost to the level of the tubeplate; then smear wet flux all round the edge of the tubeplate, and around the tubes. It is advisable for inexperienced workers to plug the end of each tube with a wad of asbestos string or flock, to prevent inadvertent burning.

The circumferential joint is done by the usual method; heat up until the coke glows, then concentrate at one point until the copper is hot enough to melt the brazing strip. Proceed by small stages, as previously described, until the circle is complete. For silversoldering the tubes, you can either cut little squares of silver-solder and drop them among the tube ends, blowing direct on the lot until the silver-solder melts and runs around; or you can blow on the tubes until the ends, and the tubeplate, are dull red, then touch each with a strip of silver-solder, held in the small tongs. The final result is the same.

Now you need to "get a move on." Grab the boiler with the big tongs, tip off the tray and coke, and lay the boiler on its back in the brazing pan, with the firebox wrapper overhanging the edge. Put a brick, or something else weighty and fireproof, on the barrel to prevent the whole issue from tipping up. Cut four strips of coarse-grade silver-solder about 5 ins. long, and lay them alongside the crownstay flanges where they join the barrel. If the flux has dried, add some more.

Now heat up the flanges and wrapper evenly by blowing alternately inside and out. When they attain dull red, the silver-solder will begin to melt; then blow hard on the outside of the wrapper, opposite the flanges. The wrapper and flanges should then glow medium red, and the silver-solder should sweat through completely. If you have another blowlamp, even a small one, get it going for this job, and either prop it up so that it blows along the flanges, or better still, get somebody to hold it for you. The easy-running brazing strip, dipped in dry flux, is then applied to the outer side of the crownstays, and a fillet run in right along, as indicated by black triangles in the cross section of the boiler. Be sure all the rivet heads are covered with the silver-solder. If you only have the one blowlamp, and cannot get enough heat single-handed to run a fillet of brazing strip the full length, run in more silver-solder. It will be practically as effective, but a jolly sight more expensive!

Users of oxy-coal or oxy-acetylene apparatus won't have the slightest trouble here, as their more powerful and concentrated flames will heat the wrapper and flange easily to the melting-point of the strip. Run the flame very slowly along the outside of the wrapper, and apply the strip, or Sifbronze rod, on the inside, direct to the centre of the hot spot (you'll see it all right!) which will melt it immediately it touches.

The piece of rod between throatplate and firebox tubeplate is not brazed-in at this stage, but later on, when doing the foundation ring; so let the job cool to black once more, put it in the pickle, wash off and clean up. As the boiler is now getting heavy, be careful how you lower it into the pickle; don't on any account let it slip, or the splashes might get into your eyes and cause serious injury. Remember the motto "safety first"!

BUILDERS who have not yet made the back-head former (which, as I mentioned previously, could also be used for forming the throat-plate) should do it now, cutting it from a piece of ¼ in. iron or steel plate, and rounding off one edge. The size and shape is shown in the dotted line in the illustration of the backhead. Anybody who made the throatplate without its aid need not bother about the 1 in. extension at the bottom; just make it the length required for the backhead. Lay it on a piece of 1/8 in. or 10 gauge sheet copper, and scribe a line around it ⅜ in. away, except at bottom.

Cut out the piece of copper, well anneal it, then flange it over the former as previously described. Novices may be surprised to find that the thicker metal is easier to flange than the thinner, as it has less tendency to buckle; but as it needs more "walloping," it gets harder, so re-anneal if the edges show any signs of cracking. File off any raggedness, and clean up the flange with the file; the more scratches there are in it, the better the brazing material will hold.

Measure from the top of the wrapper (inside) to the lip of the firehole ring; transfer this measurement to the backhead, and from that location, mark the outline of the firehole ring on the backhead. Cut the hole in the same way as you did the one in the firebox doorplate, but leave it well undersize at first.

Try the backhead in position, and note if your firehole opening needs any correcting; if it does, the correction can be made easily. When the hole is right size and in the right place, the backhead can be drilled for the longitudinal stays and the regulator gland, as shown in the illustration; it should then slip nicely into place in the end of the boiler shell, with the outer lip of the fire-hole ring projecting through the oval hole in the middle. Beat the lip outwards, until it beds down on the backhead, and clamps same tightly against the shoulder on the ring.

Let me once more remind beginners that these places where metal joins metal should always be well cleaned before assembling "for keeps." The edge of the wrapper should be in close contact with the back-head flange all the way around; if it isn't, teach it good manners with a few taps with a light hammer, and if it still remains obstinate, drill a few No. 48 holes through wrapper and flange, whilst same are in close contact. Hold either in the bench vice, or by aid of a big cramp.

Tap the holes 3/32 in. or 7 BA, screw in some stubs of threaded copper wire, and cut off flush with wrapper sheet. Don't bother about forming heads, as any projections may be filed off flush after the final brazing job.

The next job is to fill in the space around the bottom of the firebox with the other sections forming the foundation ring. The piece at the back is made from ¼ in. x 5/16 in. section copper rod, and is fitted exactly the same as the piece at the bottom of the throatplate, between the flanges of the back-head. Well clean it, bevel the sides slightly, and round off the ends a little, where they come up against the backhead flange; then fit it about 1/16 in. clear of the bottom edge of the backhead.

Put a toolmaker's cramp over the lot—firebox plates, piece of rod, and backhead—to prevent movement; then drill No. 41 and put three or four rivets through, same as the throatplate joint. *Note*, when riveting up, don't hit the plates and close them in on the bit of rod where same is bevelled off, or else the brazing material won't be able to run in the groove, and the joint will not be as strong as it should be.

The side pieces can next be fitted the same way; but as the waterspace at the sides of the firebox is only ¼ in., use ¼ in. square copper rod. Clean, bevel off, and rivet in, as already described; if the rivets are spaced 1 in. apart, it will be plenty. Should there be any gaps at the ends, where the side pieces join the cross pieces, just plug them with little splinters of copper driven in. There is no need to be fastidious over this job, as the brazing material does all the necessary sealing; the splinters merely prevent molten brazing material either dropping inside the boiler, or forming stalactites which are dabsters at gathering fur and scale, and preventing the boiler being thoroughly clean after washing out.

Bushes

No bushes are needed in the backhead at all; the ⅛ in. plate of which it is formed allows of all fittings being directly attached, the backhead being drilled and tapped either for screwing in the shanks of the water gauge and valves, or for the screws securing the regulator flange. The only bushes required are for the dome, safety valves, and the clacks or check valves for the boiler feeds. All bushes should be either of copper, or a hard metal which has a high melting temperature, such as the material known as plumber's weldable metal, used in modern copper-pipe plumbing installations with bronze-welded joints. Maybe our advertisers will be able to supply a casting in this or an equivalent metal for the dome bush, in which case the turning and fitting of it is a simple "kiddy's practice job."

Cut a 1½ ins. hole in the top of the boiler barrel, with its centre 6 ins. from the front end; drill a ring of holes around the marked circle, break the piece out, and file up the ragged edge, or else use a plumber's trepanning tool, same as they use for cutting big holes in galvanised water tanks and so on. This is similar to a carpenter's centre-bit, but the cutter is adjustable; I made one very quickly by bending the end of a small lathe parting-tool at right angles, and fitting it in a cross hole at the end of a piece of round rod.

The illustration explains itself; to use, drill a hole in the boiler barrel, big enough to take the pilot pin of the tool; hold the shank of the tool in a carpenter's brace, insert the pin in the hole, turn the handle, and the cutting edge of the tool will very quickly carve out a clean circle. Use plenty of cutting oil, to make the job easy and the cut clean.

Chuck the cast ring in the three-jaw and bore out the inside to 1¼ ins. diameter; then rechuck on the inside jaws, and turn the outside to the given dimensions, the spigot being turned to fit tight into the hole in the boiler. It must not be slack enough to fall out whilst the boiler is being moved on the final brazing job; same applies to all the rest of the bushes. If no casting is available, the bush can easily be made from a piece of copper plate about ⅜ in. thick, and a little over 1¾ ins. square.

Chuck truly in four-jaw, centre, drill with the biggest drill you have available below 1¼ ins., then bore out the surplus until the hole is that size. Chuck by the hole, on the bottom step of the inside jaws of the three-jaw, and turn the outside, same as described for a cast bush. It will make the job easier, on a small lathe, if the corners are roughly sawn off before turning the outside; otherwise, should the tool be fed into cut too quickly, the point may be knocked off, with possible damage to some part of the turner's anatomy!

The first safety-valve bush is located 5⅜ ins. behind the middle of the dome bush, and the other ¾ in. behind that. Drill ⅝ in. holes at these points, and turn the bushes either from ⅝ in. copper rod, or from thick-walled copper tube. I got hold of a short length, designed for hydraulic press piping and intended to stand a pressure of several tons per square inch, and it makes nobby bushes. The safety-valve bushes are drilled with letter Q or 21/64 in. drill, and tapped ⅜ in. x 26.

Two smaller bushes are needed for the feed clacks; these are turned from ⅜ in. rod, with 5/16 in. spigots, and are tapped ¼ in. x 40. They are fitted into 5/16 in. holes drilled in the boiler barrel, on the centre line, 1½ ins. from the smokebox; if you take a look at the general arrangement drawing, you will see the position of the feed clack close to the smokebox.

Final Brazing Job

May I impress on all beginners, and novices at coppersmithing, that on this job you want to have all your impedimenta handy, and if using a blowlamp, see there is plenty of paraffin in it; for if it decides to die out just as the brazing material is nicely running, the job will be spoilt. Also, don't forget that the secret of success is *heat*, and plenty of it. You can't burn the boiler, when assembled, with a five-pint blowlamp, so just "let her rip for all she's worth." In fact, if you have, or can borrow another blowlamp, even only a one-pint, and can get somebody to act as "mate," it renders the job very much easier.

Cover all the joints with wet flux as previously described; it should be mixed with just enough water to allow it to stick to the joints, and not run off when the boiler is turned upside down, or up-ended. Use "Easyflo" flux, or jeweller's borax, for the firehole ring flange and the bushes; Boron compo or Tenacity No. 3 for the backhead and foundation ring, if you are using easy-running brazing strip.

Lay the boiler on its back in the coke in the brazing pan, and pile up coke or breeze all around the firebox end to the level of the foundation ring.

PUT some asbestos cubes, bits of millboard, or anything else that is fireproof, inside the firebox to protect the tubes; I've done several with broken gas-fire elements, and a bit of asbestos millboard over them.

Now get your blowlamp or blowpipe going good and strong, and warm up the whole of the firebox end of the boiler. If you have obtained assistance, the mate can operate on the other side to the coppersmith-in-chief. The actual process is pretty much the same as for the joints previously described, except that as you have not only the two plates to heat, but the foundation ring as well, the job takes longer to reach the melting point of the brazing strip; and progress is naturally slower all round, as the extra metal has to be heated up "step by step."

Start by concentrating the flame on one back corner of the foundation ring; if you have an assistant, one flame should play on the outside, and the other towards the inside, the two flames converging on the point to be heated. As soon as it becomes bright red, apply the brazing strip dipped in flux, which should immediately melt at the tip and start flowing in, filling up the vee-groove between the foundation ring and the plate at either side of it. Shift the flame along a little as before, and repeat operation, working your way right round until back at the starting point, where extra heat will be needed to melt the first application again, as well as the last, to combine them and form an unbroken ring of spelter right round the firebox bottom.

As before, if the strip doesn't seem to want to start, a little coarse-grade silver-solder melted in first will do the needful. Where two lamps are used, or two gas blowpipes, the flames should work in unison; so all the mate has to do, is to follow the movement of the operator-in-chief's flame, keeping the second flame playing on the same spot as the first.

The tray or lid with the hole in it should be close handy and propped up on a couple of bricks, or something else that won't burn. Now this is where quick action is needed. As soon as the foundation ring is finished, grab the boiler with the big tongs, pop the barrel through the hole in the tray or lid, letting the throatplate rest on the tray; with the domestic coal shovel, quickly transfer some of the hot coke from the brazing pan to the tray, piling it up almost to the backhead. Then away you go with the blowlamp again, starting at one bottom corner of the backhead, and working your way right around.

The firebox flange can be done with silver-solder, either coarse grade, or "Easyflo." If the flame is directed straight on to the flange, it will become hot enough to make either grade of silver-solder run well, though probably it would not reach the temperature required for the brazing strip.

Finally, stand the boiler, right way up, in the brazing pan, and give the dome bush and safety-valve bushes a dose of silver-solder, blowing on them direct, same as firehole ring. Then tip the boiler first one side and then the other, to fix the bushes for the feed clacks. Let the boiler cool until it is black, then pick it up with the tongs, and carefully lower it into the pickle.

Be extra careful to avoid getting splashed, because the first time the acid runs into the interior of the boiler, the heat of the tubes and firebox will promptly blow it out again with a terrific commotion. The second time it will stay in. Leave the boiler in the pickle from 20 to 30 minutes; then fish it out, and wash well in running water, finally scrubbing it with an old nailbrush, or similar article, and rubbing it up with a handful of steel wool.

Those who doubt their ability to finish the job with brazing strip, because of lack of blowlamp power or any other cause, can, if they so desire, use coarse-grade silver-solder for the foundation ring, and best grade, or "Easyflo," for the backhead. But don't rely on any of the "'tectics," or any material with a phosphorus content, for strength. They are very brittle (what foundrymen call "short") and should only be used as a seal for close-riveted joints, for which purpose they are perfectly satisfactory.

Builders who have oxy-acetylene apparatus at their disposal should use Sifbronze and the special flux sold with it. No coke-packing is needed, but it saves the gases if the job is preheated with a blowlamp. For a boiler this size, I should use my 750 litre tip, with slightly reduced gas pressures, so that the flame does not hiss so loudly as when welding steel. The *modus operandi* is the same as before; start at one corner and work right round, heating the metal to the melting point of the Sifbronze rod, and dropping it on, spot by spot, each one overlapping the previous one. The metal must be very bright red, as otherwise the Sifbronze will not fill the vee-grooves. For the bushes, the flame must be diffused, and not hiss at all, otherwise the silver-solder will be overheated, will crystallise, and the joint will be as porous as a sponge.

Test for Pinholes

Before proceeding further, it would be advisable to give the boiler a rough test for pinholes in the brazing. A liberal use of the scratching wire in the melted brazing material, wherever bubbles appear whilst the job is in progress, will break them up, but it often happens that a novice or inexperienced worker gets a bubble or two and doesn't notice it.

The boiler can be tested just like you would test a cycle or motor inner tube for a puncture. Plug up all the holes except one; bits of wood screwed in will usually do, as they "cut their own thread" if slightly tapered. The dome hole can be plugged with a big cork or bung, with a few turns of string around the barrel to prevent it blowing out. Make a brass adapter to fit the unplugged hole, and solder the screwed end of a discarded tyre valve into it, so that an ordinary tyre pump may be attached.

Put the boiler in a bath with enough water to cover it, and pump about 20 lbs. air pressure in. If there are any pinholes, these will be indicated by a stream of bubbles. Drill a No. 55 hole at the spot, tap it 10 BA and screw in a stub of copper wire, with a smear of plumbers' jointing on the threads. This will effect a permanent repair.

Longitudinal Stays

There are four longitudinal stays, three solid and one hollow, the latter carrying steam for the blower from the footplate end to the smokebox. The former are made from 3/16 in. round copper rod, and the latter from 3/16 in. tube about 18 gauge. The rods are fixed by " blind " nipples screwed into the smokebox tubeplate and the backhead; the tube carries the blower valve at the backhead end, and a " thoroughfare " nipple, with union, at the smokebox end.

To make the nipples, chuck a bit of 3/8 in. hexagon brass rod in three-jaw. Face, centre, and drill to 3/8 in. depth with 5/32 in. or No. 22 drill; tap 3/16 in. x 40. Turn down 5/16 in. of the outside to 5/16 in. diameter and screw 5/16 in. x 40. Part off a full 1/8 in. from the shoulder; reverse in chuck, and chamfer the corners of the hexagon. Six are required.

The rods are the same length as the distance from the outside surface of the smokebox tubeplate to the backhead and it would be best to get this from the actual boiler, in case of any discrepancy between the given measurements and the actual job. Screw the rods 3/16 in. x 40 for about 3/8 in. each end; then screw a nipple on one end of each, for about three threads, and insert the rod in the boiler.

To get the stay easily through the hole in the other end, I usually insert a long piece of tube (1/4 in. in this case) which is easy to guide through both holes. The end of the stay rod is then inserted into the end of the tube which is then pulled back through the boiler, taking the stay rod with it, and guiding it to the hole at the other end. Screw the nipple right home, then put another nipple on the projecting bit of threaded rod at the other end, and screw that one home too. The outer threads engage with those in the tapped hole, and the lot is locked solid. A smear of plumbers' jointing on the threads ensures steam-tightness.

Machining Blower Valve

The hollow stay is the same length as the solid stays, but is only screwed at one end, the other being silver-soldered to the stem of the blower valve as shown. To make the valve, chuck a bit of 3/8 in. hexagon brass rod in three-jaw, face the end, centre, and drill to 1 in. depth with 3/32 in. or No. 43 drill. Open out to 1/2 in. depth with No. 30 drill, bottom with a D-bit (same size) to a further 1/16 in. depth, making the total 9/16 in., and further open out 1/8 in. of the end, with No. 21 drill, to clear the plain part of the screwdown pin.

Tap the middle part 5/32 in. x 32 to get a quick action, but be careful not to let the tap damage the seating at the bottom of the enlarged hole. Turn down 1/4 in. of the outside to 1/4 in. diameter, and screw 1/4 in. x 40. Part off at 15/16 in. from the end. Reverse in chuck, turn down 5/16 in. of the other end to 5/16 in. diameter, and screw 5/16 in. x 40. Open out the hole for 1/4 in. depth with No. 13 drill. Drill a 5/32 in. hole in the middle of one of the facets, and in it fit a 1/4 in. x 40 union nipple; this is made in a minute or so.

Chuck a piece of 1/4 in. round brass rod in three-jaw, face the end, centre deeply with a size E centre-drill, and drill down about 1/2 in. with a 3/32 in. or No. 43 drill. Screw 1/4 in. length of the outside, with 1/4 in. x 40 die in tailstock holder; part off at 3/8 in. from the end. Reverse in chuck (you can hold it by the threads without damaging them, if you don't screw up the chuck too tightly) and turn down about 1/16 in. of the outside to a squeeze fit in the hole in the side of the valve. Squeeze it in; also fit the plain end of the hollow stay into the plain end of the valve, and silver-solder both joints. If any silver-solder runs on to the threaded stem of the valve, run the die over it again.

Pin and Gland Nut

Although the pin and gland nut are not needed yet, I have shown them, to save space and future reference. The pin is merely a 1 in. length of 5/32 in. silver steel or phosphor-bronze rod, turned to a point at one end, and threaded as shown, to suit the tapped hole in the valve. The wheel is turned from 7/16 in. round rod (dural makes nice wheels) the square hole being formed by first drilling a No. 41 hole through it, and then, driving through the hole, a punch made from a bit of 3/32 in. square silver-steel, filed off square at one end, hardened, and tempered to dark yellow.

The end of the pin is filed square to fit—I have described how to file true squares, dozens of times—pushed through the wheel, and the end riveted over slightly. The wheel looks better if four holes are drilled in the web, as shown. The gland nut is made exactly the same as the union nuts on the crosshead pump, and is packed with a few strands of graphited yarn.

To guide the hollow stay home, put a bit of stiff wire through both holes in the boiler; put the end of the hollow stay over the wire, and pull the latter back. It will guide the hollow stay to the exit hole; then screw the valve right home in the backhead.

The stay end of the " thoroughfare " nipple is made the same way as the " blind " one; but part off at a full 3/8 in. from the shoulder. Reverse in chuck, centre deeply with centre drill, drill 3/32 in. in till you break into the tapped hole at the other end, turn down 1/4 in. of the outside to 1/4 in. diameter, and screw 1/4 in. x 40. Smear the threads with plumbers' jointing, and screw home on the hollow stay in the same manner as the blind nipples. Note that when the blower valve is screwed in tightly, the union nipple on it should stand vertical, so that it may easily be connected by a short pipe with the union on the whistle turret, to be described later.

Firebox Stays

Some recent experiments I have carried out in firebox staying have definitely proved that a larger number of small stays are preferable to a smaller number of large stays. On a boiler made experimentally of much thinner copper than I usually specify, not only was there no sign of " buttoned-cushion " effect at high test pressure, but the finer thread of the smaller stays was easier to screw and tap, and far less likely to start leakage, under expansion and contraction stresses.

For that reason I am specifying firebox stays of the same diameter as hitherto used on 2½ ins. gauge engines; but there are 5[illegible] of them in each side of the firebox, six in the throatplate, and another six in the backhead. They are made from 1/8 in. copper rod, screwed either 1/8 in. or 5 BA (latter for preference, as the thread is finer) headed over outside, and nutted inside the firebox.

How to Make a Staybolt Tap

A special staybolt tap will be needed and as this is not a commercial article at present it will have to be home-made. It is easy enough to make, anyway. It differs from the ordinary tap in having a long pilot pin to guide the tap through the two holes in firebox and wrapper, so that the thread is " continuous," despite the gap formed by the water space between the plates.

A piece of ⅛ in. round silver-steel is needed, about 3 ins. long. Chuck this in the three-jaw with about ¾ in. projecting, and carefully turn down ⅝ in. length to a full 3/32 in. diameter. Use a gauge to get the right size; this is a piece of sheet metal with a No. 40 hole drilled in it. When the turned part just slides nicely in the hole, it is O.K. for size. Use a roundnose tool and plenty of cutting oil. The next 1 in. of the steel is screwed ⅛ in. or 5 BA with a die in the tailstock holder. Again, use plenty of cutting oil, and work the embryo tap back and forth in the die, pulling the lathe belt by hand, to get clean threads, which are essential. File a square on the extreme end to take a tapwrench.

Forming Grooves

The threaded part must have three grooves milled in it if possible; if no cutter is available, file four flats. A small saw-type cutter with rounded teeth would be needed; if you have one, mount it on a spindle between lathe centres, hold the embryo tap in a machine-vice bolted to the lathe saddle, and set it at such a height that the cutter will make a cut a shade deeper than the threads. Three cuts will be needed, but they need not be spaced to " mike measurements "; approximate spacing will do.

The first three or four threads next to the pilot pin are then carefully backed off with a fine file. If you look at the flutes and the backing-off of one of your ordinary taps, you will get a better idea of how to do the job. If the four-flat version is used, file the flats slightly sloping, so that the section is nearly a perfect square at the pilot pin, but the threads are barely touched at the other end.

Hardening and Tempering

The tap will need hardening and tempering; make it bright red, and plunge vertically into cold water. To temper, first brighten a flute, or flat, as the case may be, with fine emerycloth and mind you don't spoil the cutting edges. Then place it on a bit of sheet iron or steel, and hold it over a gas or spirit flame; the small burner of the domestic gas stove will do. As soon as the brightened part turns dark yellow, tip the tap into the cold water.

The cutting part of the tap will now be O.K. but the pilot pin will be too hard, and liable to snap off; so make the kitchen poker redhot, and hold it against the pilot pin until same goes dark blue. This will draw the temper of the pin without hurting the business part of the tap.

FOR making and fitting the stays, first of all, mark out the position of the staybolt holes on the outside of the firebox wrapper, centre-pop the marks, and drill No. 40. Don't hit the punch hard enough to distort the plates, and drill the holes with the drill at right angles to the wrapper sheet; see the cross lines on the cross section of boiler. If a drilling machine is available, prop up the boiler at the correct angle on the table, so that the drill goes through square with the plates.

I shouldn't advise drilling stay holes on the lathe, as the boiler is rather awkward to hold up at the correct angle, and you would probably break the drill. If no machine is available, a hand brace is the best substitute. If the drill is kept sharp, and lubricated with a drop of cutting oil (I use Vaughan's " Cutmax " diluted with one-third its bulk of ordinary paraffin) the job isn't nearly so tedious as it would seem.

Three holes are drilled in the backhead above the firehole, and three below. There are six in the throatplate, and three of these are too close to the barrel to allow of being drilled in the ordinary way, as the drill chuck would foul. However, that trouble is soon overcome ! I have a piece of 3/16 in. round rod 12 ins. long with a broken stub of a No. 40 drill stuck in the end of it that can be used, either on the drilling machine, or in a hand brace, to get at places where the chuck won't go.

It is best to put one row of stays in at a time. If you tap the lot, and the plates distort slightly, the threads won't line up, and the stay will not enter the firebox plate. Start with the two rows nearest the top of firebox. Tap them first of all with the home-made pilot tap, working it back and forth, and lubricating with cutting oil. Then run an ordinary second or plug tap through; the thread cut by the pilot tap will guide the ordinary tap to the hole in the firebox plate, and the staybolts can then be fitted.

To make them, cut about a dozen 6 ins. lengths of ⅛ in. round soft copper rod or wire; chuck each in the three-jaw, and put a full ⅝ in. of thread on each end, with a die in the tailstock holder, using plenty of cutting oil, and keeping the clearance holes in the die clear of chippings. Clean, true threads are essential, if leakage is to be prevented.

Put a tapwrench on the bit of rod, anywhere between the threads, and screw the wire into the tapped holes in wrapper and firebox, right to the end of the thread. As the rod emerges into the firebox, hold an ordinary commercial brass locknut against it, and let the end of the staybolt enter the nut as you screw the former home. A small pair of blacksmith's tongs can be made in a few minutes from a couple of 7 ins. lengths of ⅛ in. x ¼ in. flat steel rod, and a 3/32 in. rivet; these will be found far handier for holding the nuts than a pair of pliers, as the jaws can be bent to come parallel at the width of the nut flats, and the nut won't slip out.

After screwing home, snip off the rod or wire about ⅛ in. from the surface of the wrapper; when all the screwed ends have been inserted, rescrew the remains in the lathe, repeating operations until they are all used up.

To tighten up the nuts inside the firebox, I use a little articulated box spanner, another home-made gadget which takes but little time to make, and saves a vast amount of that priceless commodity. A bit of ⅜ in. round steel rod about ¾ in. long is squared off at both ends in the lathe. Centre one end and drill a shallow hole, say about twice the thickness of the stay nut, and the diameter of same over the corners. Put a nut in the hole, and hammer the sides, so that the hole becomes hexagon-shaped, and fits the nut.

Braze a little bit of flat rod about ¼ in. long to the other end and at the end of that, pivot another bit of same section flat rod, with a 3/32 in. iron rivet, leaving the joint loose enough to allow movement. If you put the hexagon end over the stay nut, you can tighten it up much quicker than I can write these words; the long jointed handle renders the tightening of the upper and seemingly inaccessible rows, extremely simple.

Tapping Holes

When tapping the holes close to the boiler barrel, which prevents the tapwrench being turned, use an extension tapwrench made from a bit of 3/16 in. copper tube about 12 ins. long. One end is knocked into a square, to fit the square on the tap shank and the tapwrench is clamped on the other end, clear of the boiler barrel.

The stays must be supported inside the firebox whilst the outsides are headed over. On the straight parts of the firebox, a piece of square or flat iron bar held in the vice jaws, with part of its length projecting from the side, will do all right; the firebox is simply slipped over the bar, the end of the stay rested on it, and the bit outside the wrapper beaten down into a cup head with the ball end of the hammer. There is no need to worry about making pretty heads, as the lagging sheet covers them.

To support the stays at the upper part of the box, either screw or braze on a slightly curved thickening piece. I use one bar, with a blob brazed on at one end, and use either end of the bar as required by the shape of the firebox. When all the stays are headed over, give all the nuts a final tighten up, but be careful not to strip the threads.

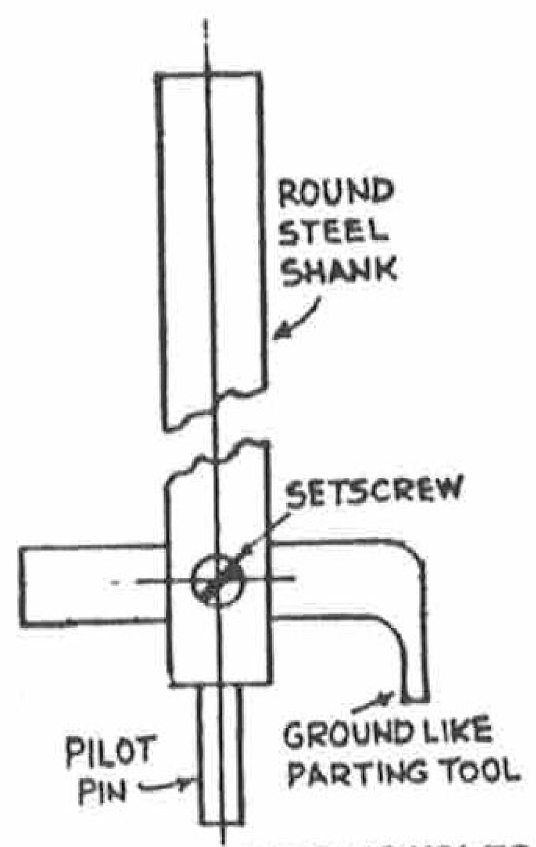
How to Sweat the Stayheads

If the staybolt threads are a perfect fit in the tapped holes and the locknuts really lock against the plates in the firebox, the whole bag of tricks should be steam- and watertight without further treatment. However, novices and beginners usually manage to get a torn thread or two, and oversize tapped holes, and other potential sources of leakage, so it is advisable to sweat over the stayheads and nuts with solder. Plumbers' solder is best, but ordinary tinman's solder will do perfectly well. For this you need some liquid soldering flux, and a small wire brush. *Don't on any account use a paste flux.* Baker's fluid, chloride of zinc, or killed spirits of salts (muriatic acid) are all suitable.

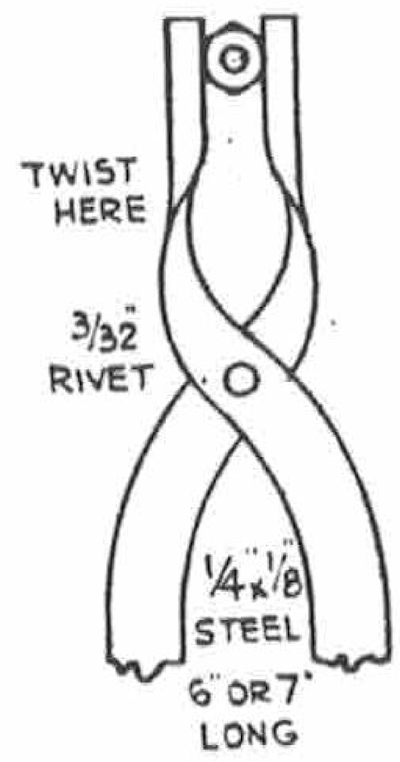
The latter is prepared by putting the acid in an earthenware jar or dish, and dropping pieces of zinc into it until no more will dissolve. Don't inhale the fumes, and do the job outdoors. A little powdered sal ammoniac added, is an advantage. The brush can be made by jamming a bundle or tuft of thin iron wires into the end of a bit of copper tube (odd end of boiler tube will do) and flattening it, to hold the wires. Fit a wooden handle to the other end, as it gets very hot in use.

Lay the boiler on its side in the brazing pan, and smear some soldering flux all over the heads and nuts, with the wire brush. Then, with the blowlamp, or gas blowpipe, heat the boiler evenly all over until it reaches the melting point of the solder, easily ascertained by touching the stayheads with the stick of solder. Then melt a little between the heads and, still keeping up the heat, spread the melted solder all over the whole of the stayheads. Keep dipping the brush in the flux.

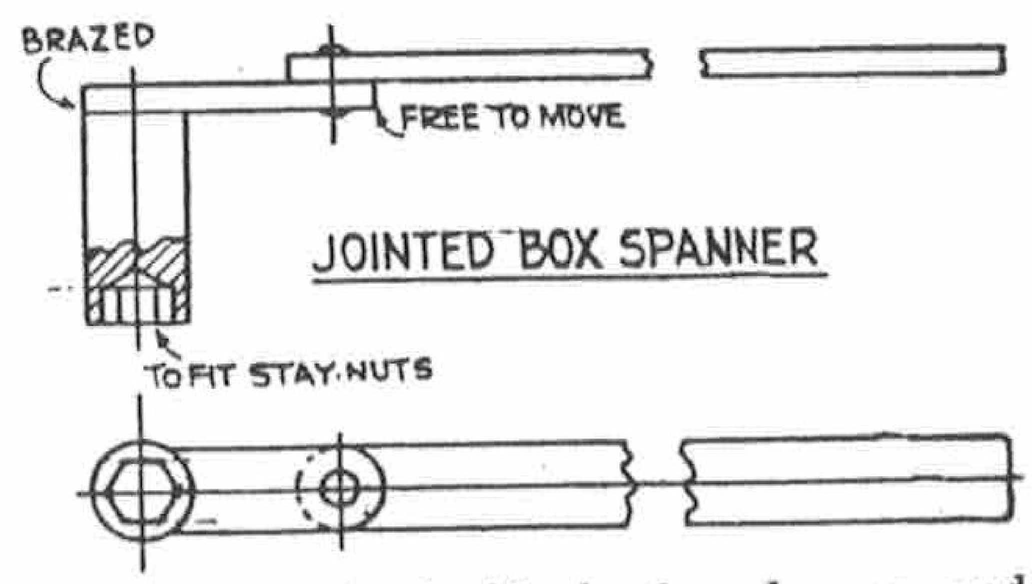
When both sides, and throatplate and backhead have been done, apply same process to the inside of the firebox, seeing that



TOOL FOR CUTTING HOLES IN SHEET METAL



SMALL TONGS FOR HOLDING STAY-NUTS



JOINTED BOX SPANNER

the whole of the inside is tinned over, and every staynut, and any portions of the stays projecting through the nuts, are well and truly covered by the melted solder. When you are quite satisfied that no places have been missed, drain off any surplus solder, let the boiler cool slightly until the solder sets, and then wash the whole lot well in running water to remove all traces of flux.

A good scrub with an old nailbrush, or something similar, will make quite certain that no flux remains; if any is left on, it will form a poisonous green deposit, which is good neither for the copper nor the builder of the engine.

VERY little equipment is required for testing the boiler by hydraulic pressure, the requirements being merely a hand-operated pump, a pressure gauge reading to 200 lbs. or over, and a few plugs and adapters. The emergency hand pump which will be fitted in "Roedean's" tender will be very suitable, so we might as well make this right away. It can be put aside after the testing job, until the tender is built, and there will then be one job less to do !

Although the pump is easily made without castings, some builders would rather use a casting; our advertisers will probably be able to oblige, so I will give the necessary variation in construction in the description of how to make the pump. Personally, however, I much prefer the built-up one, as fitted to all my own engines; I can make one complete in about two hours, doing the job as follows.

Stand and Barrel

The stand is made from a strip of copper or brass, 1/8 in. thick, 5½ ins. long, and 1 in. wide, bent to the shape of an old Great Western broad gauge bridge rail. The quickest way I know of making accurate bends without a bending machine is to mark off the strip at the places where the bends come and bend in the bench vice by aid of a bit of bar the correct width. I usually keep a few short bits of various widths in a box on my bench, within easy reach of the vice. In the present instance, a piece 1¼ ins. wide would be needed.

First grip the strip in the vice, with the line showing the location of one of the top corners, just visible above the jaws. Bend at right angles, then put the bit of bar in the angle, and bend the second angle over it. Next, put the bit of bar between the sides, at the correct distance from the end; grip in bench vice as shown in the illustration, and knock the projecting bits outward and downward, until they are at right angles to the sides. Trim off to correct length. You can do the whole job far quicker than I can write the instructions!

Drill two No. 30 holes in each bottom lug, for the fixing screws; another in the middle of the top, for the shank of the anchor lug, and two more on the centre-line of each side, 1 in. from the bottom. To get these the same height, I mark them off with a scriber, with the stand resting on the drilling-machine table. Open out these two holes with a 35/64 in. drill.

The barrel is a piece of 9/16 in. brass treblet tube, squared off at each end in the lathe, to a length of 2¼ ins. If treblet tube (which is thin hard-drawn brass tube very smooth and true in the bore) is not available, use whatever grade you can get, but smooth out the inside on an improvised lap.

Get a bit of round wood a little smaller than the bore; wrap a few turns of emery-cloth or other abrasive of fine grade, around the wood until it just fits the tube loosely. Grip in three-jaw, put the tube on it, run the lathe as fast as possible, and move the tube up and down the revolving lap a few times. The inside should then be absolutely true and smooth. Ream or carefully file the big holes in the stand, until the barrel will fit tightly in them, as shown in the illustration.

If a casting is used, the stand and barrel will be in one piece. Grip the barrel in three-jaw, set to run truly, face off the end, centre, drill right through with 3/16 in. drill, follow up with 31/64 in. drill, and finally poke a ½ in. parallel reamer through. To face the other end, mount the casting on a bit of ½ in. round rod held in three-jaw. If you wind a turn of thin paper around the rod, the barrel will go on it tightly enough to allow the end to be faced off. The base of the stand is filed or milled flat and the screwholes drilled in each corner with No. 30 drill. The anchor lug will be cast on the barrel; file it smooth both sides, and drill No. 30.

Valve Box

The valve box for the built-up pump is made from a 1½ ins. length of 7/16 in. round brass rod, truly faced at each end. Chuck in three-jaw, centre, and drill right through with No. 24 drill. Open out with 9/32 in. drill to about ⅜ in. depth, and bottom to 7/16 in. depth with a 9/32 in. D-bit. Tap 5/16 in. x 32 or 40, but don't let the tap go in far enough to hit and spoil the D-bitted seating. Slightly countersink the end of the hole.

Reverse in chuck, and repeat operations, except that the D-bit need not be used. Instead, nick the bottom of the hole with a little chisel made from a bit of ⅛ in. round silver steel, as shown in the sectional illustration. Drill a 7/32 in. hole halfway along the side, cutting into the central hole, and tap it ¼ in. x 40. Finally poke a 5/32 in. parallel reamer through the remains of the No. 24 hole.

Chuck a bit of brass rod any size over ½ in., and turn down ⅛ in. of it to a tight fit in the end of the barrel. Part off at 7/16 in. from the shoulder. Reverse in chuck, turn down 5/32 in. length to ¼ in. diameter, and screw ¼ in. x 40; centre, and drill through with ⅛ in. drill. Screw this into the hole in the side of valve box, then press the projecting part into the end of the barrel, taking care to have the valve box vertical, and the D-bitted seating uppermost. Then solder around the joint between valve box and barrel, and the places where the barrel goes through the stand.

Use ordinary "soft tommy," not silver-solder: the heat necessary for silversoldering would distort the barrel and completely spoil the whole bag of tricks. As long as the spigot on the valve box is a very tight fit in the end of the pump barrel, soft solder will be perfectly satisfactory, as the pump spends all its working life in cold water.

If a cast valve box is used, machine it in exactly the same way as described above; then chuck it in three-jaw, holding by the chucking piece provided. Turn the boss on the opposite side to a very tight fit in the reamed barrel; then centre it, and drill a ⅛ in. hole right into the central passage-way. Cut off the chucking piece, filing away all traces of the stub; then erect the pump exactly as described above, pressing the boss into the barrel, and soldering the joint.

Valves and Unions

The rest of the pump is made and erected exactly the same, whether built-up or cast. Drop a 3/16 in. rustless steel ball in the D-bitted end of the valve box, and seat it as described for the crosshead pump valves, taking the depth with a gauge. Chuck a bit of 7/16 in. hexagon brass rod in the three-jaw; face the end, and turn down to 5/16 in. diameter, a length 1/32 in. less than that indicated by the depth gauge. Screw 5/16 in. x 32 or 40, to suit the thread in the valve box, and part off ½ in. from the shoulder. Reverse in chuck, face the other end, centre deeply, and put a ⅛ in. or No. 30 drill right through. Turn down about 5/16 in. length to 5/16 in. diameter, and screw 5/16 in. x 32 or 40. Cross-nick the other end with a thin flat file, and screw home.

DROP another ball in the other end, and take depth as before. Chuck the 7/16 in. hexagon rod again, face the end, centre, and drill with No. 24 drill to about ⅝ in. depth. Turn down to 5/16 in. diameter a length equal to the distance shown by the depth gauge, and screw 5/16 in. x 32 or 40, to match the valve box tapping; then face off 1/32 in., to ensure a truly flat seating for the ball. Part off at 5/16 in. from the shoulder. Reverse in chuck, and put a 5/32 in. parallel reamer through the hole. Cross-nick the bottom as mentioned above, then seat the ball on the hole at the screwed end, assembling as shown in the illustration.

Beginners please note that the balls should only lift about 1/32 in., otherwise they don't seat as the ram reverses its direction of movement, and water is forced back past them, reducing the efficiency of the pump. Excessive lift of the valves is one reason why commercially-made pumps, both hand and eccentric driven, are what we call "sometimers": sometimes they feed, and sometimes (more often than not!) they don't.

Ram and Operating Gear

A piece of rustless steel or bronze rod 2¼ ins. long, is needed for the ram or plunger. If treblet tube has been used for the pump barrel, or if a cast one has been reamed ½ in., then ½ in. round rod should be an exact sliding fit in it, and should need no turning. If the barrel is of an odd diameter in the bore, then you'll have to turn a ram to fit it from the next larger size of metal available. A packing groove about ¼ in. wide and ⅛ in. deep is turned ⅛ in. from one end. The other end is rounded off and a ⅛ in. full wide slot cut in it for the end of the pump lever, by the same method described for the forked joints in the valve gear. Cross-drill it No. 32.

The lever is a piece of ¼ in. x ⅛ in. brass or nickel-bronze rod a bare 2½ ins. long. Slightly bevel one end, and round off the other. At the latter end drill a No. 30 hole, and another 1 in. above it. The links are two pieces of 1/16 in. x ¼ in. brass or nickel-bronze rod, a full 2¼ ins. long, rounded off at the ends, and drilled No. 32 at 2 ins. centres. The anchor lug is made from the same material as the handle. Chuck a bit truly in four-jaw, turn down about 5/16 in. length to ⅛ in. diameter, and screw ⅛ in. or 5 BA. Drill a No. 30 hole ⅜ in. from the shoulder; cut off just above it, and round off the end.

To assemble, put the bottom of the lever through the slot in the end of the ram, and drive a bit of ⅛ in. rustless steel or phosphor-bronze through the lot, cutting same off flush at each side. Don't use brass wire, as it wears away too quickly. Put a connecting link each side of the lever, at the upper hole, and pin in the same way. Fix the anchor lug between the links at the opposite end, and ditto-repeato the pinning.

Pack the groove with a few strands of unravelled hydraulic pump packing—or failing that, graphited yarn—insert the ram into the pump barrel, and the stem of the anchor lug in the hole in the top of the stand. If you hold the nut below the hole, and turn it as the stem comes through, it will go on easily enough; tighten with a spanner, but be careful not to strip the threads.

If the pump is placed in a pan of water, and the lever waggled back and forth, it should squirt like nobody's business; but be careful where you test it! One of our readers made up a pump for one of the 2½ ins. gauge engines described in these notes; it was night-time when he was ready for testing, so he brought the washbowl from the scullery sink and put it on the kitchen table, right underneath the gas globe. He gave the handle a wag, up went the water, and out went the gas, the shattered splinters of the globe cutting his hand. He thought he had made a pump, not an imitation of one of the fountains in Trafalgar Square! Joking apart, if you put your thumb over the outlet, the pressure should push it up easily when the lever is operated, otherwise the pump won't be any use for testing the boiler.

Extension Handle Required

An extension handle will be needed, both to obtain the necessary leverage, and to operate the pump through the filling hole in the tender, when it is finally installed. The socket which fits over the pump lever is a 1½ ins. length of rectangular brass tube (commercial article); if unobtainable, bend a bit of 18 gauge sheet around a length of ¼ in. x ⅛ in. rod, and silversolder the joint. The handle is a 5 ins. length of the same section rod, pushed for about ½ in. into one end of the socket, and secured with a couple of 1/16 in. brass rivets.

Inner Dome

Before making the test, the inner dome must be turned up and fitted to the dome bush. A casting will be provided for this, and in appearance it resembles a dished cylinder cover. Chuck it by the spigot provided, face off the contact flange, and turn the edge to 1¾ ins. diameter. Reverse in chuck, gripping by the edge, and part off or turn away the chucking piece, leaving a tiny boss, as shown in the section. Centre this, drill No. 30 and tap 5/32 in. x 40, for a small screwed plug. This allows for oiling the regulator valve.

Drill eight No. 34 holes equidistant around the flange; then fit the cover to the dome bush in exactly the same way as described for fitting the covers to the cylinders. Put a 1/64 in. Hallite or similar jointing gasket between the cover and the bush; and for the pressure test it would be advisable to use 6 BA steel screws. These may be replaced by brass ones when the cover is attached "for keeps"; after fitting the regulator.

How to Test the Boiler

The 7/16 in. tapped hole in the smokebox tubeplate, and the little one in the dome, must be plugged by temporary plugs which can be turned up from any odd scraps of brass rod of suitable size, and need no description. Screw them home tightly, with a jointing washer under the heads. The regulator hole in the backhead may be closed by its own gland fitting partly machined. Chuck a piece of ⅞ in. brass or bronze rod in three-jaw; turn down ⅜ in. of the outside to ⅜ in. diameter, to fit the hole in backhead. Part off a full ⅛ in. from the shoulder.

Reverse in chuck, turn the outside to 13/16 in. diameter, drill four No. 40 holes as shown in the illustration, and attach the flange to the backhead with four 3/32 in. or 7 BA screws, like fitting a cylinder cover. The turned part goes inside the boiler with a jointing gasket as above, between flange and backhead. Steel screws may be used for the pressure test.

Make up two adapters to fit the safety-valve bushes. The lower part of these are screwed to fit the bushes, and the upper part screwed ¼ in. x 40, and countersunk. The finished gadget should look exactly like the top fitting on the valve-box of the pump just described. One of the adapters is connected to the pressure-gauge by a piece of ⅛ in. pipe, with a union nut on one end to suit the nipple on the gauge. The other end has a ¼ in. x 40 union nut to fit the adapter. A similar piece of pipe, furnished with union nuts and cones, connects the other adapter to the upper union of the pump, which should be placed in a pan of water close to the boiler, as shown in the diagram.

Before screwing the adapters home, fill the boiler full of water; then screw them in tightly and connect up. As the boiler must be *full* of water for the test, with no air pockets, take a little screw out of the dome, give the handle of the pump a waggle or two, and when the water runs out of the hole, replace the screw. All is then ready for the "grand slam."

A VERY few strokes of the pump will run the pressure up to 50 lbs. and at that stage, stop and take a look at the way things are shaping. If all O.K., go up to about 75 lbs. and then take another look. Should there be any leakage, stop the test and make good before proceeding further. If still all right, go by about 20 or 30 lbs. stages until you reach 160 lbs. which is twice the working pressure, and more than sufficient to "prove the boiler sound," as they said in the days of the "Rocket."

Should there be a slight movement of the crown sheet, don't worry at all; it will only be the soft copper settling itself into the best position to resist pressure. If there is a faulty place in the boiler, it will give out under the pressure without any bang, in fact you probably won't hear it; the pressure will simply fall to zero, and a few drops of water will be released. If the boiler stands up all right, leave the pressure on a little while; if nothing further should happen, release the pressure by undoing one of the unions, then remove fittings, and empty the water all out. You'll have the satisfaction of knowing that the boiler is perfectly safe for 100 lbs. pressure if necessary, though she will do all you need with 80 lbs.

I might mention here, for beginners' benefit, that the gospel of an abnormally high boiler pressure combined with small cylinders, giving greater thermal efficiency, is theoretical moonshine. In the first place a small boiler working at, say, 200 to 250 lbs. per square inch, is a potential steam bomb; and if I had any kiddies, I should think more than twice before letting them go near such a contraption. Secondly, the construction of a boiler to stand such a pressure is a far more ticklish job than the one I have just described; and thirdly, even when the boiler is made, there is no guarantee that it will *maintain* the pressure.

Many full-sized engines on British Railways fail lamentably to maintain working pressure on the kind of stuff doled out to them by the National Coal Board! On a little engine with small-bore cylinders, depending on high pressure for power, such pressure must be maintained, otherwise "you've had it." My personal experience is, that around 80 lbs. is the best working pressure for all locomotives between 1¾ ins. and 5 ins. gauge; the boilers do not call for "super" workmanship, the power is there if the cylinders are arranged to suit, and the pressure is easily maintained. But there is one essential—the steam must be *hot;* and I mean just that. You will have noticed that "Roedean's" boiler carries four superheater flues!

Smokebox

It is quite possible that the advertisers who sell castings for this locomotive may provide a casting for the smokebox, if so, it saves considerable work. The casting can be machined easily by aid of a 4 ins. four-jaw independent chuck. It should first be chucked truly, with the door end outward; the front faced off, and the door hole trued with a boring tool. The casting should then be reversed, and held with the inside jaws of the chuck taking a bearing inside the door hole. The open end can then be carefully turned to fit the end of the boiler barrel.

On the average home-workshop lathe, it would be a good policy to fit a thick wooden disc in the open end and let the back centre support the job; otherwise, if the tool digs in or catches up in any way, the casting will probably fly out of the chuck and become badly distorted, apart from the risk of damaging the operator's anatomy. The outside should be smoothed all over with file and emerycloth; the chimney, liner, and door are fitted exactly as described below for the built-up version.

Most full-sized smokeboxes having the wrapper sheet shaped to go between the frames and dispensing with a saddle, either have a flat bottom plate riveted in, or else have no bottom plate at all; in the case of an inside-cylinder engine, the top of the cylinder casting forms the bottom of the smokebox. On my old line, the L. B. & S.C.R., the top of the casting was protected from the corrosive action of the ashes and cinders by a layer of firebricks set in fireclay, which also made certain that the bottom was airtight. If air can leak in, the engine won't steam and the same applies to a little engine, more so than a big one.

On a little engine, also, the conventional construction presents difficulties in attaching the smokebox to the boiler; whereas the full-sized article never has to come off, it is desirable to make the small one easily detachable, and at the same time an airtight joint is essential.

TO get over all the difficulties at one fell swoop, I usually make a smokebox of the wrapper-sheet type in the manner described below. The actual smokebox is a tube, either fitting over the end of the boiler barrel, or attached to it by a "piston-ring" joint.

The external wrapper-sheet is simply wrapped around it and projected downward between the frames. The front of the smokebox is made the same shape as the wrapper, and carries the door in the usual way, but it has a turned ring riveted to the back of it which is pressed into the end of the tube forming the smokebox barrel. Holes for the steam and blast pipes are cut in the bottom of the tube.

How to Build Up the Smokebox

In the present instance, the smokebox is flush with the boiler barrel, and that means that the tube forming the shell must be of smaller diameter than the boiler barrel, the difference amounting to the thickness of the wrapper sheet. Therefore, you need a piece of 16 gauge brass or copper tube (it need not be seamless or solid-drawn, the common variety does just as well) 4¼ ins. outside diameter. Square off each end in the lathe, as described for boiler barrel, to a length of 3⅝ ins.

To attach this to the boiler barrel a stepped ring is needed, ¼ in. wide; this may either be a casting, or a strip of brass or copper ¼ in. wide and about 5/32 in. thick, bent into a ring and brazed at the joint. The internal diameter should be a shade under 4 ins. diameter. Either casting or bent-up ring should be chucked in three-jaw, half its length turned to a tight fit in the boiler barrel and the other half to fit the smokebox shell. *Tip*—put a disc of wood, an old wheel, or anything else handy, of suitable diameter, inside the ring before gripping in chuck; it is hardly necessary to add the reason!

The wrapper sheet is a piece of 16 gauge soft brass, or soft mild steel, 3⅝ ins. wide and approximately 13¼ ins. long, bent to the shape shown in the front view of the smokebox. It should fit closely and may be held to the shell by a couple of screws or rivets each side, just above the point where it turns down to go between the frames. Either screws or rivets should be countersunk, and filed off flush on the outside.

The front is cut from a piece of ⅛ in. brass plate, to the shape shown in the front view, the circular part being the same diameter as the outside of the wrapper sheet, and the straight part projecting 9/16 in. below the smokebox shell. The hole for the doorway is 3 ins. diameter, and the easiest way to cut it is to chuck the plate in the four-jaw with the circular part running truly. The three-jaw might hold it, if the jaws are not too wide, and allow the straight part to go up between two of them. A parting tool set crosswise in the slide-rest will cut out a true and clean hole in a very short time; run at a slow speed, and use plenty of cutting oil. If the hole doesn't come out right size, finish with a boring tool. Take off the sharp edges of the hole; if you don't, you'll wish you had, when you put your fingers inside the smokebox and catch your knuckles on the sharp edge !

Attaching Ring

The attaching ring can be turned up from a casting, of angle section as shown in the drawing, or from a piece of ¼ in. square brass rod bent into a ring, the joint being silversoldered. Either type should be riveted to the front plate ⅛ in. from the edge of the circular part, using 1/16 in. brass rivets, countersunk on the outside. The ring should be a tight push fit in the smokebox shell. After riveting, chuck the front plate complete in the three-jaw, gripping by the ring, and take a 1/32 in. skim clean over the lot. This ensures a true seating for the door, which must close airtight.

The door may either be a casting, or knocked up from a brass blank about 3¾ ins. diameter, and ⅛ in. thick. If a casting, there will be a chucking piece on the outside; all you have to do is grip this in the three-jaw, face the edge, and turn the door to correct diameter. The hinge straps will be cast on, so mind the tool doesn't catch them. The outside of the door can be smoothed with a file and emerycloth. Either saw off the chucking piece and file the stub flush, or chuck the door in the three-jaw and part or turn it off.

If a brass blank is used, first dish it. Heat to red and plunge into water, to soften it. Then lay it on a block of lead and hit it with the ball end of the hammer, starting from the middle and working outwards. Chuck the result in three-jaw, concave side outwards, gripping by the edge, but leaving just enough projecting to face off and form a contact surface to butt against the smokebox front. Sounds ticklish, almost like hair's-breadth chucking, but really it is quite easy, as you'll see when you do it. Whilst in the chuck, face off about ¾ in. of the centre, and solder a stub of ⅝ in. round rod to the faced spot. Reverse in chuck, and grip by the stub. If the embryo door wobbles, rechuck it by the edge again, setting it to run truly; then take a cut off the brass stub until that runs truly too.

Finishing

When reversed, and the stub held in three-jaw, the door should now run truly, and the outside can be turned all over. I usually remove the hammer-marks with a roundnose tool set crosswise in the rest, operating both slide-rest handles together; then I finish with a hand engraver, or pointed tool, resting same on the shank end of a tool projecting from the side of the slide-rest tool holder, in lieu of a regular hand-rest. A bit of fine emerycloth held to the door will give it a good finish. Then heat the door until the stub melts off.

The above door will require separate hinge straps riveted on. I use strips of 18 gauge steel, bent around to form the eye through which the pin goes. The joint is silversoldered; if you stop up the eye through being too lavish with the silver-solder (I avoid this by using silversolder in wire form, very convenient for small work) don't worry, but put a No. 51 drill through. The hinges are riveted to the door, using bits of blanket pins for rivets; those I have need No. 57 drill. Countersink on the outside, and file flush. The jaw part that fits over the lug is filed out last of all.

The lugs themselves are made from ⅛ in. square rod. Chuck in four-jaw, set to run truly, and turn down a full ⅛ in. length to 3/32 in. diameter, screwing 3/32 in. or 7 BA. Part off a bare ¼ in. from the shoulder. Place the door in position on the smokebox front, and mark off the position of the lugs, right in the middle of the jaw of each hinge strap. Centrepop the places marked drill, No. 48, and tap 3/32 in. or 7 BA; then screw the lugs in.

REPLACE door, and drill the holes in the lugs by putting the drill down the holes in the ends of the hinge straps. For this purpose I use a special extension drill; merely the broken end of an ordinary drill fitted into the end of a piece of ⅛ in. silver-steel, long enough to reach well above the smokebox, so that when held in the drill chuck, the latter is quite clear of the smokebox.

The hinge pin is a piece of 1/16 in. round silver steel, or 16 gauge spoke wire, slightly beaded over at the top, so that it won't fall through. The hinge lugs described above may be fitted to a cast smokebox; hinge straps cast on to a cast door are cleaned up with a file, drilled, and then the door is put in place, and the holes in lugs drilled exactly as described above.

No dart or crossbar is used on the full-sized "Schools" class engines, the door being secured by six dogs at equidistant spacing, as shown in the front view. On the little engine, they are filed up from ⅛ in. square rod, to shape shown in the detail drawing; the studs are made from bits of 15 gauge spoke wire, and ordinary commercial nuts are used.

Liner and Chimney

On the top line of the smokebox, at 1 13/16 ins. from the open end, cut a hole 1⅛ ins. diameter, by same process as holes cut in the boiler shell. This is to accommodate the chimney liner, which is a 2¼ ins. length of brass or copper tube about 18 gauge, and 1⅛ ins. outside diameter. Soften it, and bell it out at one end to 1⅝ ins. diameter; this is easily done with the gadget a plumber uses to perform similar operations on lead pipes, or a tapered piece of metal. The way I usually do it, is to grip the piece of tube in the three-jaw, put a bit of grease in the end, then insert a stout bit of smooth steel rod a little way; the lathe is then started, and the bit of rod pulled towards me, the action being what you might call "spinning in reverse."

The bell-mouth is soon formed, but as the metal hardens under the process, re-anneal it if it tries to buckle, or it may crack. The bell can be formed easily in another way, viz., by holding the tube against the edge of a block of lead, and flanging it outwards with the ball end of the hammer.

Cut a piece of 16 gauge sheet copper or brass 2¼ ins. square and make a hole in the middle in which the liner will fit tightly. Bend this to the same radius as the inside of the smokebox shell; push the tube through from the concave side until it projects ⅞ in. from the convex side, then silver-solder it, from the concave side. Don't get any blobs of silver-solder on the other side—if any seeps through, file it off, otherwise the liner plate won't fit snugly against the shell. Put a smear of plumbers' jointing around the liner where it comes through the the plate, insert into position from inside the smokebox, and secure the plate with four 3/32 in. or 7 BA countersunk brass screws, nutted inside the smokebox, as shown in the broken-away part of front view.

The chimney is a plain turning job. Chuck the casting in three-jaw and bore the inside, same as you would bore a cylinder, until it is a tight push fit on the liner; use a piece of same sized tube as a gauge. The chimney can then be mounted on a mandrel between centres—piece of hardwood will do—and turned to the profile and dimensions shown. The base is finished with a file and smoothed off with emerycloth, or similar abrasive. Be careful to have the chimney right size and shape, as nothing mars the appearance of a locomotive as much as a badly-shaped chimney.

Regulator

The full-sized "Schools" engines have the standard type of Maunsell regulator, the working parts consisting of a rectangular-faced head with ports, and two valves—main and pilot—superimposed on the port face, and held in position by two flat springs. Whilst this could of course be reproduced in the small size, it entails a lot of fiddling work, which I usually call "watchmaking," and the complete assembly would hardly be robust enough to stand up to the work usually expected from 'L.B.S.C.' jobs. I have therefore substituted the type of regulator which we had on the old "Brighton" engines, and which not only gives satisfactory service, but is strong, simple, and easy to make.

For beginners' information, it is just a plain stand or column with a vertical circular valve face at the top, with round ports, over which works a circular valve centrally pivoted, with ports corresponding to those in the valve face; this valve is partly rotated, to open and close the ports, by a double-armed lever on the regulator rod, connected to the valve by a link at either side.

Stand and Valve

Castings will be provided for the main part of the regulator, the stand, valve face and bosses being all in one piece; but if anybody prefers to build up, it is a simple job. Use a piece of ⅜ in. square brass rod for the column, a disc 11/16 in. diameter and ⅛ in. full thick for the valve face, and a piece of ⅛ in. by ⅜ in. flat bar for the bracket. The steam pipe boss can be made from a ⅜ in. length of ½ in. round rod, and the little boss for the bearing supporting the end of the regulator rod, from a bit of ¼ in. round rod. The whole lot can then be silversoldered together at one heating, and the built-up component machined in the same way as a casting.

Smooth off the top of the column with a file, centrepop it, and drill down with ¼ in. drill to within ⅛ in. of the bottom; tap the end of the hole 9/32 in. by 40, for a plug. There should be a little boss on the casting, right opposite the steam-pipe boss, long enough to serve as a chucking-piece; grip this in the three-jaw, and set the steam-pipe boss to run truly. Centre it, drill 9/32 in. until the drill breaks through into the vertical hole, and tap about ⅜ in. of the end with a 5/16 in. by 40 tap.

Chuck a bit of ⅜ in. rod in the three-jaw, turn down about ⅜ in. of it to 5/16 in. diameter, screw 5/16 in. by 40, screw the steam-pipe boss on to it, and turn the little boss truly. Face off to a full ⅛ in. length, centre, and drill a full ⅛ in. depth with No. 30 drill, but mind you don't pierce the central passage. If you happen to be unlucky, however, don't worry. Face the boss clean away, level with the column, and open out the hole to 3/16 in.; then make a little "blind" bush from a bit of ¼ in. brass rod as shown by dotted lines; press it in, and sweat it like a stayhead.

Chuck the casting in the four-jaw with the valve face running truly; face off, centre, and drill ⅛ in. depth with No. 48 drill. Countersink the end of the hole, and tap the rest 3/32 in. or 7 BA. On the same centreline as this hole, at a full ⅛ in. above and below it, drill two No. 30 holes for the steam ports. The upper one has a triangular nick made at the side, as shown, which acts as a pilot port, and allows steam to build up gradually on the pistons when starting a heavy load on wet and slippery rails, and prevents slipping. The separate pilot port does the same job on the full-sized engines. Plug the top of the column with a bit of round brass rod screwed to suit, and be careful that the plug doesn't enter far enough to obstruct the port; file the clearance as shown. I usually screw the end of a piece of rod two or three inches long, enter same into top of column, and screw home, sawing off the rod flush with the top of the stand, and sweating over the plug, same as a stayhead.

File a nick in the casting, as shown, to clear the edge of the dome bush when the regulator is in place. On the top centre line of the boiler, 3/16 in. ahead of the dome bush, drill a No. 30 hole, and another ⅜ in. farther ahead, countersinking them both. Now try the casting in position; if the bracket end is entered first, and then the casting tipped up, in a manner of speaking, it will pass through the bush all right. Hold in position, and mark off the position of the hole nearest the dome bush, with a scriber. Remove casting, centrepop the middle of the little ring, drill No. 40 and tap ⅛ in. or 5 BA. Replace casting, and put a screw in to hold it in position; see that it is square and level, then locate the other screwhole by putting the No. 30 drill down it, and making a countersink on the casting. Remove and drill and tap as before.

THE valve can be a casting, or filed to shape from a bit of good quality brass plate ⅛ in. thick. Drill a No. 41 hole in the middle, and countersink it; then above and below, drill two No. 30 holes to match those in the portface, but slightly off-centre as shown. The ears or lugs are drilled No. 48 and tapped 3/32 in. or 7 BA. Both valve and portface are then truly faced, first on a smooth file, then on fine emery-cloth laid on some flat true surface, just as described in previous notes for slide valves. To make an extra-special job, both faces may be rubbed on a piece of plate glass, with a little pumice powder and water, or very fine carborundum powder and thin oil. Both leave a matt surface which holds lubricating oil, ensures free working, and prevents leakage; but care must be taken to wash off all trace of the grit before final assembly.

Screw a 5/8 in. length of 3/32 in. bronze or hard brass rod, with a few threads of 3/32 in. or 7 BA pitch at each end. Screw this into the tapped hole in the valve face, and make absolutely certain it is at right angles to same. The spring is wound up from 23 or 24 gauge bronze or hard brass wire, and secured with a brass nut.

Operating Gear

The double-armed lever for operating the valve is filed up from a bit of 1/8 in. brass plate, to the dimensions given in the illustration. The holes in the ends are drilled and tapped, same as the lugs on the valve. The 1/8 in. square hole may be drilled 1/8 in., and either filed square with a watchmaker's square file, or drifted out. To make a suitable drift, all you need is a couple of inches of 1/8 in. square silver-steel. Square off one end, and slightly bevel the other. Heat the squared end to red, plunge into water, then clean with fine emery-cloth (don't blunt the sharp edges) and temper it to yellow on a bit of sheet iron, as described for the staybolt tap. Drive it clean through the hole in the lever; the bevelled end allows it to pass, even after being slightly burred by the hammering.

The two connecting links are merely bits of 1/16 in. x 3/16 in. strip metal, nickel-bronze for preference, though brass will do; they are drilled No. 41. Bronze screws will be needed for attaching the links both to lever and valve; these are not made commercially (at time of writing, anyway, though two or three of our advertisers may take the hint!) so chuck a bit of 3/16 in. bronze rod in three-jaw. Face the end, and turn down a full 3/16 in. length to 3/32 in. diameter. Slip one of the connecting links over it, and screw with a die in the tailstock holder until the die just touches the link. This will allow the screw to be driven to the end of the thread, leaving the link free to work on the plain part. Part off at 3/32 in. from the shoulder, and slot the head with a fine hacksaw. The midget saw frames sold by the "Eclipse" and other makers, with little blades to match, are just right for jobs like these.

The regulator rod is a piece of 5/32 in. rustless steel, nickel-bronze or phosphor-bronze rod 11 1/8 ins. long. Chuck in three-jaw, and turn 1/8 in. of the end to 1/8 in. diameter, to fit the hole in the little boss at back of column; then file the next 1/8 in. square, to fit the square hole in the double-armed lever. Beginners had better file 1/4 in. of the rod square first, then turn 1/8 in. of the square away, in case they damage the turned bit when filing the square, which should fit the lever easily without shake. Turn the rod end for end, and repeat process, except that instead of leaving a plain spigot on the end, turn it 3/32 in. bare, and screw 8 BA.

Gland and Handle

The footplate end of the regulator rod passes through a gland fitting which may be made from either a casting, or a piece of 13/16 in. round brass or gunmetal rod. If this size isn't available, use the next larger, and turn it down to size required. Chuck in three-jaw and face off the end; then turn down 3/8 in. length to 3/8 in. diameter, so that it will just enter the hole in backhead. Part off a full 1/8 in. from the shoulder. Reverse in chuck; centre, drill right through with No. 21 drill, open out to 3/8 in. depth with 1/4 in. drill, and tap 9/32 in. x 32. Make a gland to suit, from 7/16 in. round rod; chuck in three-jaw, face, centre, and drill No. 21 for about 1/2 in. depth. Turn down a full 1/4 in. of the outside to 9/32 in. diameter; screw 9/32 in. x 32, and part off at 3/8 in. from the end. Reverse in chuck, and take a skim off the end, to true it up; then, with a hack-saw or a thin warding file, form four C-spanner slots in the flange as shown. Drill four No. 43 holes in the big flange for the fixing screws, scraping off any burring.

The end of the fitting projecting into the boiler is filed to form part of a regulator stop, eliminating any need for an ugly excrescence on the backhead. File away 1/8 in. of the end, to a little over half the diameter; say to the bottom of the spindle hole. Chuck a bit of 3/8 in. brass rod in three-jaw, and take a skim off it so that it just passes easily through the hole in the backhead. Centre, and drill about 3/8 in. deep with No. 24 drill; file away a little more than half the diameter for about 1/8 in. length, and part off at 5/16 in. from the end.

How to Erect the Regulator

Disconnect the actuating links from the disc, then insert the regulator in the boiler through the dome bush. If you put the bracket end in first, then push it forward, at the same time bringing the stand up straight, you'll find that the bottom of the column will pass the dome bush all right. Insert the two countersunk screws (which must be gunmetal, bronze, or good quality brass) through the holes in the boiler shell into the bracket; see that the regulator lines up "fore and aft" are all right, then tighten the screws. Put the double-armed lever down the dome hole very carefully—don't drop it!—holding the two actuating links vertical; then recouple these to the valve disc. If you rotate the disc so that the lug into which the screw fits, is as high as possible, it will be easy enough to get the screw in. When both are fitted, and well tightened so that they cannot work loose, the square hole in the double-armed lever should be exactly in line with the round one in the little boss at the base of the column.

Press the little stepped collar on the handle end of the regulator rod, setting it about 1 1/4 ins. from the end; then insert the rod into the boiler, carefully manoeuvring it so that the turned spigot on the end passes through the hole in the double-armed lever, and enters the blind bush or bearing at the bottom of the column. The square on the rod will then engage the square hole in the lever, and the regulator valve can be operated by turning the rod. Now set the regulator valve in the "shut" position; that is, as shown in the end view of the regulator completely assembled. The holes in the portface should be completely covered, with a little overlap.

Next, push the gland fitting over the end of the rod, and enter it into the hole in the backhead. *Note*, the step on the fitting, and its "mate" on the collar, must be opposite, so that they engage properly, as shown in the sectional view of the gland assembly. When the flange of the gland fitting is held tightly against the backhead, the rod should have just 1/64 in. end play. If more, or if it has none at all, the collar must be shifted forward or back on the rod, as the case may be, until the required movement is obtained; just the 1/64 in., no more or less.

Now be careful over the next bit. With the regulator valve still in the "shut" position, move the gland fitting in an anti-clockwise direction until the shoulder of the stop on it, comes in contact with the shoulder of the stop on the collar. Keep it in that position, then locate the screwholes on the backhead by putting the No. 43 drill through the holes in the flange of the fitting, and making countersinks on the backhead. Follow up with No. 51, drilling through the backhead, and tap 8 BA; then put two of the screws in to hold the fitting temporarily in place. Put a tapwrench or small carrier on the projecting end of the regulator rod, and turn it anti-clockwise, same as when opening the regulator on a finished engine, and watch the valve. The ports in same should line up exactly with those in the portface, when the other shoulders of the stops come into contact; if they don't, remove the gland fitting, and file a little off the offending shoulder.

When all O.K., drill a No. 53 hole through collar and rod, and squeeze in a pin made from a bit of 16 gauge bronze or hard brass wire; then replace the gland fitting, putting a 1/64 in. gasket or washer, made of Hallite or similar jointing material, between the flange and the backhead. Use roundhead brass screws, and put a little taste of plumbers' jointing on the threads. If you poke the point of your scriber down each hole, and pierce the gasket before putting the screws in, they will go home quite steam- and water-tight.

Regulator Handle

Any type of handle may, of course, be fitted to suit the builder's pet fancy. The handle I have shown, is similar to that fitted to the full-sized engines, and resembles a pair of horns when bent outwards to clear the fittings.

THE easiest way to make the handle, is, first to chuck a piece of 1/4 in. round rod, nickel-bronze for preference, centre and drill a 1/8 in. hole in it for about 3/16 in. down, and part off a 1/8 in. slice. The handles themselves can be made from 3/16 in. round rod, the grips being turned to the outline shown, with the rod held in the three-jaw. The flat part can be filed, or milled. The handles are silversoldered to the boss, with the whole lot laid out on a piece of sheet asbestos laid in your brazing pan; the two handles should be set approximately 20 degrees apart, as in full size.

Set the regulator with the ports half open; then note the position of the square on the end of the rod projecting from the gland. With the little punch made for the hole in the double-arm lever, or with a watchmaker's square file, square the hole in the boss, so that when same is placed on the end of the regulator rod, the right hand handle is horizontal, as shown in the illustration. Pack the gland with a few strands of graphited yarn; put on the handle, secure with an 8 BA commercial steel nut, and the regulator is complete.

Steam Pipe and Flange

The main steam pipe, or dry pipe as it is sometimes called, is a piece of 5/16 in. copper tube 5 ins. long; this should be not thinner than 20 gauge, as it has to be screwed both ends. Put about 1/4 in. of 5/16 in. x 40 thread on the regulator end, and about 3/8 in. of either 32 or 40 pitch on the smokebox end, according to the pitch in the tapped hole in the smokebox tubeplate. Beginners note, that the finer pitches should always be used wherever possible for pipe work, as the deeper cut of a coarse-pitch thread unduly weakens the pipe, and breakage is liable to occur at the end of the thread. This is especially so in boiler work, where the pipes are stressed by expansion and contraction. Put a smear of plumbers' jointing on the threads at the regulator end, and screw the tube into the regulator stand through the hole in the smokebox tubeplate. If the end of a round file is poked into the outer end of the tube, it forms an excellent "screwdriver," and is released by turning backwards.

The flange may be either a casting, or made from a 5/8 in. length of 7/8 in. hexagon brass rod; both are machined same way. Chuck in three-jaw, face, centre, and drill right through with letter J or 9/32 in. drill; tap 5/16 in. x 32 or 40, to match steam pipe, for about half the depth. Turn down 3/8 in. of the outside to 5/8 in. diameter; further reduce 1/4 in. length to 7/16 in. diameter, and screw 7/16 in. x 32 or 40, to match the tapped hole in the smokebox tubeplate. Reverse in chuck, take a truing-up skim off the face, and slightly chamfer the corners of the hexagon. Put a little plumbers' jointing on the threads, and screw the flange on to the end of the steam pipe which should just project clear of the tubeplate. The outer threads will engage with the thread in the tapped hole; and when right home, the whole lot will be locked solid.

Superheater Elements

The superheater is made on the same principle as the full-sized one, though simplified to suit the small engine, and it really will superheat the steam; the hotter the steam, within reason, the more efficient the engine will be. It consists of four elements housed in the four large boiler flues, and these are connected by headers made from copper tube. Each header carries a circular flange, for attachment to the steam flange on the tubeplate and the flange on top of the vertical pipe feeding the cross pipe connecting all three cylinders.

Each element requires two pieces of 3/16 in. by 22 gauge copper tube 8 7/8 ins. long. The firebox ends are joined by block bends. If anybody cares to make the spearheads I used to specify, by bending the tubes at a slight angle, filing off, and joining direct by brazing, that will be quite all right; the principal reason why I now specify block bends is because beginners either blocked up the spearheads by applying too much brazing material, or burnt them through overheating on the brazing job. Regular brazing is necessary here; when the engine is pulling hard, the intense heat from the fire is too much for silversolder.

The block bends are not easily burnt, though very easy to braze. Each one is made from a little block of copper 5/8 in. long, 1/2 in. wide and 1/4 in. thick. On one end, make two centrepops a bare 1/4 in. apart; and these are drilled out to 1/2 in. depth with No. 14 drill, same being inclined in towards the centre, so that the holes break into each other just inside the block, as shown in the section. Fit one of the elements into each hole, and braze it, using soft brass wire, or Sifbronze rod; *not* silversolder. The process is exactly the same; just apply a little flux, same kind as used for boiler brazing, heat to bright red, and touch the joints with the wire or rod. A little fillet will form instantly around each pipe.

Pickle and wash off. Let water run through elements and bends, to remove all internal scaling. The ends of the blocks are rounded off with a file, as shown. Soften the other ends of the elements by heating to red and plunging into the acid pickle, which cleans them as well, ready for attaching to the headers; but rinse in water afterwards. Bend slightly as shown in the illustration.

Headers and Flanges

The upper or "wet" header is made from a 2¼ ins. length of ⅜ in. copper tube about 22 gauge, and the lower or "hot" header from a 2¾ ins. length of the same material. The ends of both are plugged with little discs of 16 gauge sheet copper, cut out and driven tightly in the ends; or you could turn a bit of ⅜ in. rod to a tight fit in the ends of the tubes, and part four 1/16 in. slices off it. The holes for the ends of the elements are drilled with No. 14 drill at 13/16 in. spacing, except the last one in the wet header, where it is cut short to clear the blower valve union; the end one is 7/16 in. from its next-door neighbour.

At 1 1/16 ins. from the same end, opposite to the row of holes for the elements, drill a ¼ in. hole; also at 1 1/16 ins. from the end of the hot header, opposite the element holes, drill a similar hole. At ⅝ in. from the longer end of the wet header, drill a No. 32 hole for the pipe which will go to the snifting valve. See that the ends of the elements are quite clean, and assemble them in the headers as shown in the illustrations. The No. 14 drill usually makes a hole into which a 3/16 in. pipe will fit tightly; mine does, anyway! The ends can be eased with a file if necessary.

The flange for the wet header is made either from a casting, or a slice 7/16 in. thick, parted off a ⅞ in. brass rod. Chuck in three-jaw, centre, and drill ⅜ in. depth with ¼ in. drill. Skim the face up truly. Next, drill a ¼ in. hole in the thickness of the flange, meeting the other one at right angles, as shown. With a ⅜ in. round file, form a groove across this hole into which the header tube will bed nicely. Drill three No. 40 screwholes as shown in end view; then mount the flange on top of the wet header in the position shown in front view—don't put the hole the wrong side!—and tie it in position with a bit of thin iron binding-wire.

THE other flange is a ¼ in. slice off the same rod; but this time the ¼ in. hole is drilled right through, and the half-round groove filed right across the back. Don't drill any screwholes; these are located from the flange on the vertical steam pipe after the boiler is erected on the frames. Tie the flange in position on the front of the hot header pipe, in the position shown in the illustrations. Put a piece of ⅛ in. pipe about 6 ins. long, in the No. 32 hole drilled in top header. Cover all the joints with wet flux, and silversolder every joint in the whole bag of tricks, at the one heating. For jobs like this, I use "Easyflo," with the special flux sold with it; it does the job in the way I like it done. Ordinary best-grade silver-solder, and good clean borax, powdered and mixed to a paste with water, are the next best. When you are certain no place has been missed, let cool to black, quench out in acid pickle, and wash off. Let the water run through the superheater, in at one flange and out at the other, to remove all traces of internal scaling. Grit and scale would play Old Harry with the piston-valves if it got down to them, so take precautions.

Erection is simple; merely insert the elements into the flues, line up the flange on the wet header with its mate on the end of the steam pipe, run the No. 40 drill through the holes, making countersinks on the steam-pipe flange, follow with No. 48 drill, and tap 3/32 in. or 7 BA. Use slotted-head screws, and put a gasket of 1/64 in. Hallite between the faces, same as regulator gland fitting.

Blower Pipe and Ring

The blower ring is made from a piece of copper tube ⅛ in. diameter and about 5 ins. long. Soften it by heating to red and plunging into cold water; then bend one end into a ring about 11/16 in. diameter, letting the open end butt up against the side of the pipe, as shown in the plan view. Silver-solder the joint, and drill three No. 70 holes in the ring. Stand the boiler temporarily on the frames, in the position it will occupy when finally erected; leave the smokebox off, just propping up the barrel with a bit of strip metal across the frames. Put the ring over the blastpipe nozzle, then bend the pipe so that it meets the blower union on the end of the hollow stay. Remove the pipe, and fit a union nut and cone to the end.

For beginners' information, I never use the separate "lining" (trade term for the cone part of the union) but silversolder a copper cone direct on the pipe, and am never troubled with leaky unions. I just chuck a bit of copper rod in three-jaw, turn it until it will enter the union nut easily, then centre and drill it for the pipe. The edge is bevelled off at an angle to match the countersink in the union screw; and this being made with a centre-drill, the top slide is slewed around to 30 degrees, which turns the cone to suit. The cone is then parted off about 1/16 in. behind the tapered part. I make two dozen or so at a time, so always have a few in hand when doing any "plumbing."

For union nuts, merely chuck a bit of hexagon rod in three-jaw; face, centre, and drill clearing size for pipe, then open out, drill and tap to suit the union screw. Part off, reverse in chuck, and chamfer the corners of the hexagon. Average time, one minute each! While the boiler is temporarily in position on the frame, line up the flange on the hot header with the one on the vertical steam pipe, and locate, drill, and tap the screwholes, same as described for the wet header and steam pipe flanges.

Snifting Valves

For the information of our readers who are beginners maybe it would be as well if I explain briefly the function of a snifting valve. Its proper name is vacuum relief valve, but you can trust enginemen to apply their own terms! Anyway, if steam is suddenly shut off when the engine is running, she will, of course, continue to coast by virtue of the momentum of the weight of engine and train. The pistons will continue to move back and forth in the cylinders; but as the steam is off, the cylinders now act as pumps, sucking away all the steam which remains between regulator and steam chests, and creating a vacuum in the main steam pipe, superheater elements, steam chests, and in the cylinders themselves.

As every schoolboy knows, Nature abhors a vacuum, and air will fly in to destroy it at any available spot; in the instance mentioned, if there is no other way in, it will go down the blastpipe of the engine, as the valves uncover the exhaust edges of the ports. It stands to reason that air sucked from inside the smokebox is going to take grit and ashes along with it; and grit and ashes are certainly going to play Old Harry with the pistons, valves, cylinder bores and steam-chest liners!

If an aperture is made anywhere in the steam line, between regulator valve and cylinders, air will be sucked in there, and blown out of the blastpipe in the same way as exhaust steam; so most full-sized locomotives are provided with an automatic valve which admits air to the "wet" side of the superheater header. It is really a clack or check valve, which works works "upside down." When the regulator is open, the pressure in the steam pipe keeps it up against its inverted seating; when steam is shut off, it falls off the seating, and admits air to the superheater header. This air is sucked through the elements by the pumping action of the pistons, and prevents the elements from becoming overheated, as they might do when there was no steam in them. Thus the snifting valve "kills two birds with one stone."

When the "Schools" class engines were new, they had two little snifting valves on the smokebox behind the chimney, sticking out on either side like a pair of snail's "horns." The present C.M.E. does not think they are necessary, and is removing them, substituting another device which admits steam to the pipe, instead of air. Be that as it may, the snifting valves are decidedly an advantage on a little engine; I found that out over 20 years ago! Therefore I am specifying a pair which are similar to those originally fitted to the "Schools" engines by the late Mr. Maunsell. They are correct in appearance, only a little larger than "scale" size, but the working parts are simplified without sacrificing any efficiency.

How to Make the Valves

Chuck a piece of 5/16 in. round rod in three-jaw; bronze or gunmetal will be best, but good quality brass will do if nothing better is available. Face the end, and centre deeply with size E centre-drill. Turn down 5/16 in. of the end to 1/4 in. diameter, using a roundnose tool, so as to leave a radius. Screw 1/4 in. by 40, and part off at 15/16 in. from the end. Reverse in chuck; centre, drill right through with No. 40 drill, open out to 7/16 in. depth with 3/16 in. drill, tap 7/32 by 40 for about 5/16 in. depth, slightly countersink the end, and skim off any burr. With a little chisel made from a bit of 1/8 in. silver-steel, cross-nick the bottom of the enlarged hole, so that when the ball is at the bottom of the chamber, air can pass it into the drilled passage.

Chuck a piece of 3/8 in. rod; face, centre, and drill to a depth of 7/16 in. with No. 40 drill. Open out with No. 34 to 1/4 in. full depth, and poke the end of a 1/8 in. parallel reamer in as far as it will go, to get a true seating for the ball. Turn down a full 7/32 in. of the outside, to 7/32 in. diameter, and screw 7/32 in. by 40; take a skim off the end, to ensure its being absolutely flat and true. Part off at 9/16 in. from the end.

REVERSE the component, holding in a tapped bush held in three-jaw; I have explained how to make a tapped bush in a couple of minutes, in previous instalments.

At 5/32 in. from the end, or 1/16 in. from the shoulder, form a groove 3/32 in. deep, and 3/32 in. wide, which can easily be done with a parting tool. Next, reduce the 1/16 in. collar between groove and bush, to 5/16 in. diameter—the parting tool will do this in a jiffy—then turn the part beyond the groove, to the shape of an open umbrella, or a mushroom with a pimple on the top. The easiest way to do this, is with a hand tool, ground off like the letter V inverted, but with the point rounded off. For a hand-tool rest, I usually put a tool in the slide-rest the wrong way round, with the shank end projecting from the side; run it up to the work, and rest the business end of the hand-tool on it. A little careful manipulation of the hand tool will soon grow a "mushroom."

Next, with a 5/64 in. or, No. 48 drill, drill two holes right across the bottom of the groove, at right angles; these will cut across the central passageway near the blind end. Cut two oval flanges from 18-gauge sheet brass or copper; these should measure approximately 5/8 in. by 3/4 in. At 9/16 in. from the back of the smokebox, and 1 3/16 ins. from the top centre line, drill a 5/16 in. hole at each side; then put a 5/16 in. parallel reamer in, and whilst turning it, gradually bring it up to the vertical position, as the snifting valves stand vertically.

The next item requires a little care; drill and ream the two oval flanges in the same way, but leave them so that they fit tightly on the bodies of the snifting valves. Try both valves in place; whilst doing this, the mushroom heads can be screwed in finger-tight, but there is no need for the valve balls to be in. Adjust flanges so that they bed down to the curve of the smokebox, and allow the snifting valves to stand about 1/16 in. above them at the highest point (see cross section of valves erected, page 381).

When correctly set, carefully remove the valves, with flanges attached, and be careful not to upset the adjustment of same. Remove the heads, then carefully silver-solder the flanges to the valve bodies; only use the smallest bit of silversolder on each, so as to avoid leaving a fillet on the underside. If you should be unlucky, and get a fillet, don't attempt to file it away, but countersink the hole in the smokebox sufficiently to let the flange bed down truly.

Pickle, wash off, and clean up; then drill four No. 51 holes at equal spacing around the flange, and countersink them. Seat a 5/32 in. rustless steel ball on the screwed head, same way as seating a ball on the cap at the bottom of the hand pump; drop the ball in the valve body, and screw in the cap with a smear of plumber's jointing on the threads. Take care not to get any on the valve seat. Bronze balls may, of course, be used, but if so, then use a 5/32 in. cycle ball to form the seating; if you start biffing a bronze ball, like a steel one, it will have a pattern on it like a golf ball very quickly.

Fit the completed valves to the holes in the smokebox, and secure them by four 1/16 in. or 16 B.A. brass countersunk screws in each. If a smear of plumber's jointing is put around the underside of each flange, it will prevent any air leaking in and destroying the smokebox vacuum.

How to Connect Up

The connections are shown in the illustration, which is practically self-explanatory. Each valve is connected by a union nut, cone, and bit of bent pipe, to a central T-piece which in turn is connected to the wet header by the pipe already silver-soldered into it for this purpose. The drawing shows regular bends, but as long as the pipes start and finish as shown., it doesn't matter what shape they are.

For beginners' benefit, union nuts are made as follows, and with a little practice, take about one minute apiece. Chuck the hexagon rod (5/16 in. in this case) in three-jaw; face, centre, drill about 5/16 in. deep with No. 30 drill, open out to 3/16 in. depth with 7/32 in. drill, tap 1/4 in. by 40, and part off at 1/4 in. from the end. Rechuck, and chamfer off the corners of the hexagon (both ends) for appearance sake. The cones should be made from copper rod, as it seats in the coned hole much better. Chuck a piece in three-jaw, the nearest size larger than 7/32 in., and turn it until a union nut will slide over it easily. Centre the end, and drill No. 40 for about 3/16 in. depth.

To form the cone, if your slide-rest has a graduated marking on the top slide, slew it around until just over the 30 degrees, then take a cut across the edge of the copper rod with a roundnose tool. If the rest is unmarked, use a squarenose tool in the slide-rest, with the corner of it ground off to the required angle. Incidentally, a tool thus ground is used for chamfering union nuts. Part off the core about 1/16 in. from where the taper starts; reverse in chuck, and open out the end for about 1/16 in. depth with No. 32 drill, so that it will just go on the end of the 1/8 in. pipe tightly. Bronze or gunmetal rod can be used for cones if copper rod is not available.

The tee can be filed up from a bit of brass of convenient size; and the two 1/8 in. pipes are cut to a length of 1½ ins., softened and bent by finger pressure to avoid kinking. Drill the tee with No. 32 drill, put it on the free end of the 1/8 in. pipe already silversoldered into the header (this may be shortened to about 3 ins.) put a bend in each end of the tee; then the nuts, and last of all the cones. The whole lot can be silversoldered at one heat, after which the smokebox can be temporarily put in position on the boiler end, and the pipes adjusted so that the union nuts will screw on to the lower ends of the snifting valves when the boiler is permanently erected.

Safety Valve

The full-sized engines have two Ross pop safety valves. Pop safety valves can be fitted to the little engine if desired, but I don't recommend them. As there is so little distance between the water level and the bottom of the safety valves in a little engine, and Nature refuses to be "scaled," small pop safety valves are addicted to causing the boiler to prime badly. The sudden release of steam when they pop off, causes an immediate reduction of pressure on the surface of the water just below the valve; result, up jumps a miniature waterspout, which, if the water level is well up the glass (where it should be) reaches the bottom of the valve, and a shower of water is blown out with the steam. The action will continue, once it is started, until the valve closes again.

I fitted pop safety valves to several of my own engines, when I first made successful valves which lifted and shut down as in full-size practice, with only between 3 and 5 lb. pressure drop; but after a few doses of wet spray in my face and down my neck when driving, I thought it rather too much of a good thing, and reverted to the ordinary plain valve on all my engines except "Annabel," the 2-6-6-4 American Mallet, which has a very large boiler, and does not prime. However, for those who wish to fit pop safety valves, I have included a drawing of one, which can be made without the use of a "double-seated" pin drill.

How to Make the Plain Valve

The body of the valve can be made either from a casting, or from a piece of ½ in. hexagon bronze or gunmetal rod. Chuck in three-jaw, face the end, turn down 5/16 in. length to 3/8 in. diameter, and screw 3/8 in. by 26 to match the boiler bush. Part off at 7/8 in. from the end; repeat process for second valve. Chuck the blank in a tapped bush held in three-jaw; centre the end, and drill right through with No. 24 drill. Open out to about 3/8 in. depth with 9/32 in. drill, and bottom the hole with a D-bit of similar size, to a full ½ in. depth. Tap the upper end of the hole 5/16 in. by 40, and poke a 5/32 in. reamer through the remains of the No. 24 hole. Turn the outside to the outline and dimensions shown.

The spindle and cup can be turned from [illegible] in. round rod held in three-jaw. Turn a bare ½ in. length down to 3/32 in. diameter, using a knife tool with the point rounded off a little, so that it leaves a radius. Part off about 3/32 in. from the shoulder. Reverse in chuck, and turn down the blob at the end, to a bare 7/32 in. diameter. Centre, it, and countersink it a little with 3/16 in. drill, but don't go in far enough to weaken the spindle where it joins the cup: see section.

The nipple is made from 5/16 in. round rod. Chuck in three-jaw, face, centre, drill No. 40 for a bare 3/16 in. depth, screw the outside 5/16 in. by 40 for same distance, then part off a 1/8 in. slice. File a nick at each side, to let the steam escape from the column.

The spring is wound up from 22-gauge tinned steel wire, and the ball which should be 3/16 in. rustless steel, seated on the hole as previously described. The whole lot is assembled as shown; the spring should just be starting to compress, as the nipple enters the thread tapped in the column. *Note*—the thread should not be too easy, otherwise the nipple will work out when the engine starts to blow off.

How to Make the Pop Type

Although externally the pop and plain valves are identical in appearance, and both contain a ball valve held down by a cup and spring, the interior arrangements are a little different, as can be seen if the sectional illustrations are compared: Chuck a piece of round rod in the three-jaw, the nearest size larger than 3/8 in. Turn down 1/4 in. of it to 3/8 in. diameter, and screw 3/8 in. by 26; further reduce 1/8 in. full from the end to 5/16 in. diameter, and screw 5/16 in. by 40. Centre, and drill down a full ½ in. depth with No. 33 drill.

Put a 7/32 in. drill in the tailstock chuck, and feed it in until the full diameter of the point just enters; no more. Replace the drill with a 7/32 in. D-bit, and feed carefully in until it has cut a recess 1/8 in. deep. Take a very light skim over the end, to remove any burr, and part off at 7/16 in. from the end. Rechuck—you won't hurt the threads if you use discretion when operating the chuck key—and put a 1/8 in. parallel reamer through the hole.

THE body of the valve is turned from ½ in. hexagon rod. Chuck in three-jaw, face the end, centre, and drill to 5/8 in. depth with 9/32 in. drill. Tap the end 5/16 in. by 40 for about 3/16 in. down. Turn the outside to the same profile as given for the plain valve, and part off a full 9/16 in. from the end. Reverse in chuck, and tap the other end same as the top.

The cup and pin are made also in similar manner, but the cup is turned so that it easily fits the top of the D-bitted recess in the base of the valve, and is chamfered at the bottom. The nipple is also made same way as the one for the plain valve, and the whole bag of tricks is assembled as shown in the illustration. A 1/16 in. or 10 B.A. setscrew may be put into one of the facets of the hexagon, as indicated, to prevent the two halves of the valve parting company when the valve is removed from the boiler for any purpose.

For beginners' benefit, the action is as follows. When the steam reaches blowing-off pressure, it overcomes the resistance of the spring and lifts the ball, escaping into the recess, and pressing on the underside of the cup; but as this is of greater diameter than the small surface of the ball on the ⅛ in. reamed hole, and the pressure of the spring is still the same, the edge of the cup is promptly blown up clear of the edge of the recess, and the steam escapes with a sudden rush. After the pressure has fallen three or four pounds, which it soon does, owing to the free release, the spring " takes command " again, aided by the back pressure in the column pressing on top of the cup; and the ball is " flopped " on to its seat again.

Some of the valves I have made have been so sensitive that the action was almost as rapid as the beating of a kettledrum, with no variation of pressure shown on the gauge. One in particular imitated perfectly the " brrrr—brrrr " of the telephone ringing tone, whilst the one originally fitted to old "Ayesha " caused much hilarity by continually blowing " raspberries."

How to Test the Valves

For testing my safety valves and setting them to blow off at a predetermined pressure, I use a small brass air tank with a bush for the valve, and two unions, to which are connected a tyre pump and a pressure gauge; the latter is the full-sized gauge which I use for testing boilers. All that is necessary, it to screw down the nipple of the safety valve fairly tight, then pump up to 80 lbs. pressure. The nipple is then slacked back until the valve starts to blow off. If the pop safety-valve does not shut down until the pressure has dropped considerably, the cup is too close a fit in the recess. Remove it, chuck by the spindle in three-jaw, and take a small skim off it, not more than one thousandth of an inch. Try again, and repeat operation, if necessary, until the valve pops off at 80 lbs. and shuts down after a drop of between 3 and 5 lbs.

There is no need to use a special air tank for testing " Roedean's " valves; use her own boiler, with the adapter and pressure gauge you used for boiler testing, and an ordinary automobile tyre pump in place of the water pump. If you have already purchased a small steam gauge for the engine, it wouldn't be a bad wheeze to kill two birds with one shot, and test the little gauge against the big one at the same time. I always test my small gauges against the big one I use for boiler testing, which is very accurate. The small gauges vary from 10 to 15 lbs., some fast, some slow. I reset the needles so that the gauge registers correctly at the working pressure, which is the one that matters!

Arrangement of Footplate Fittings

Before erecting the boiler on the chassis, the rest of the fittings can be mounted on the backhead, and an illustration is shown, indicating how the whole bag of tricks can be set out in a neat and tidy manner. As Nature refuses to be " scaled," workable fittings on a 3½ ins. gauge locomotive have to be considerably bigger than the proportionate size of those on a full-sized engine.

For example, we have to use a 3/16 in. water gauge, to obtain reliable readings, and this is equivalent to a glass 2¼ ins. diameter on " Roedean's " big sisters! Therefore, to get these comparatively gigantic fittings in, it is necessary to rearrange the whole issue; in many locomotives I have seen, on club and exhibition tracks, the footplate has been an unsightly and inaccessible jumble, for which there isn't the slightest excuse. It is a good thing to be neat and tidy.

To save time and separate drawings, I have included the outline showing shape and dimensions of the cab front, also the connections for the tender pipes below the drag beam. The cab has what is known on the railway as " tumble-home," that is, it inclines inward " above the waist-line," same as many Continental engines' cabs, to clear the small-bore tunnels on the bit of line between Tonbridge and Hastings. This was necessary in the full-sized article. It isn't, of course, essential on the small one; a straight-sided cab can be fitted, and would look very well, but as the big engine's cab has the tumble-home, I have included it.

THE cab windows are of an irregular shape also, in full size, so I have shown them thus. After they are cut out, file out two little brass frames; 1/32 in. thick (22-gauge) is plenty, about ⅛ in. wide. Cut out two pieces of thin mica or cellophane, same size as the frames, sandwich them between the cab front and frame, and rivet the lot together with bits of domestic pins. Alternatively, use 12 (or smaller) B.A. screws. An old friend of mine, who loves watchmaking, uses 16 B.A. screws for his cab windows, and a jolly fine job it makes, too—but they are a bit *too* small for my liking!

The opening for the boiler cannot be cut out until the latter is erected on the chassis; for a good fit between boiler and cab front, measurements must be taken from the actual job. You'll hear all about it from the driver and fireman, if they get nearly blown off the footplate by draughts through the cracks, when the engine is doing a bit of record-breaking!

Regarding the fittings, the combined whistle-valve and turret goes on top of the backhead, with the whistle-valve handle pointing left. The left-hand front union carries the syphon pipe for the steam gauge, which is ¾ in. diameter and reads to 120 lbs.; it is set above the reversing wheel, low enough to be seen easily below the cab roof, when you are sitting on a flat car behind the tender. The right-hand union is coupled to the blower valve already fitted on the hollow stay, by a ⅛ in. pipe with union nuts and cones on each end.

The valve between steam gauge and regulator gland, is the injector steam valve, connected to a drop pipe leading direct to the steam end of the injector (to be described in the immediate future) which is located under the left step. I have shown an alternative type of Southern regulator handle, for those builders who do not fancy the Maunsell " ram's horns." This is a very neat handle, designed by Mr. Urie for the 4-6-0 and other engines built at Eastleigh during his time as C.M.E. The self-explanatory detail drawing (last week) gives the size needed.

It was at one time considered that the water around the firebox had too much " boil and bubble " about it, to render a gauge glass in the position shown, capable of giving correct indication. Well, I tried it—nothing like seeing for one's self!—and the gauge worked as well there, as in any other place. As full-sized engines have the water gauges either side of the regulator, we might as well follow suit, to the nearest we can, but there is one more point where we differ from full-size, on account of Nature. Due to capillary attraction, the little glass will show a higher level than that of the water in the boiler, so we have to raise the glass a bit, and this entails, on the present boiler, the provision of an elbow in which to screw the top fitting.

The feeds from injector and crosshead pump, go in at the front end of the barrel, near the smokebox; but for the emergency feed from the hand pump in the tender (fitted really as "insurance" only, and seldom or never used) a clack is screwed into the backhead, just below the blower valve. Just below this is the handle of the bypass valve, which is located under the footplate: this valve allows the surplus water from the pump to be returned to the tender tank, as the pump is always working to full capacity.

Provision should always be made for cleaning "fur" and scale out of the boiler, especially in districts where the water contains chalk and lime: so we fit a big washout plug in one bottom corner of the backhead, and a screwdown blow-off valve in the other. The firehole doors on the big engines are double, and work in slides: but similar doors on a little one, would get choked with dust, and the doors do not close properly. Only recently an engine belonging to a friend failed to steam on my own road, because of cold air going through the door. I have shown my favourite "tried, tested, and proved" swing door, which has no faults—except for its resemblance to the door of the domestic oven! Anyway, the L.N.E.R. engines, and the Great Northern of Ireland, use similar doors, so there cannot be any objection on the score of appearance: and personally, I prefer efficiency. All my own engines have swing doors.

On the full size "Schools" engines, the feed pipes between engine and tender are carried by brackets made from plate, and bolted to the outside of the drag beam; a similar arrangement is shown in the illustration, the pipe spacing given being my "standard" for all normal 3½ in. gauge engines, so that any engine fits any tender.

Details of Fittings

Two or three of our advertisers are supplying castings for the boiler fittings, and most of the machining on these is carried out in much the same way as on those made up from rod material. The principal difference is in the way the castings are chucked. Most of the built-up components are turned from round rod held in the three-jaw; but a four-jaw independent chuck would be needed for turning, say, the union bosses on a cast turret, and cast bottom water gauge fitting. Screw-down valves, clacks and so on, usually have a chucking-piece cast on, opposite the union boss or other turned part, and this is held in the three-jaw whilst machining is carried out; it is cut off when the job is completed.

If rod material is used, it should be good quality bronze or gunmetal; or brass can be used if nothing better is available. It should, however, be best quality; the grade known as "screw-rod," because of its ability to take a clean thread and therefore used for screw making, is not much good for fittings. It becomes brittle, and rapidly corrodes if the water has, like most "town main" water, been "treated." Silver-solder in wire form, such as "Easyflo," makes clean and neat joints if used with care and discretion. After silversoldering my own fittings, I pickle them for a few minutes, wash off, dry them, and hold them against a fine wire scratch brush stuck in the end of the grinder spindle. This revolves at 2,900 revs. per min., and in a few seconds they shine like a bride's wedding ring.

Combined Whistle Valve and Turret

Part or saw off a piece of 5/16 in. round rod a full 1 in. long. Chuck in three-jaw; face, centre, and drill right through with No. 43 drill. Open out to about 3/8 in. depth with No. 14 or 3/16 in. drill, and bottom to ½ in. depth with 3/16 in. D-bit. Slightly countersink the end of the hole, and tap 3/16 in. deep with 7/32 in. by 40 tap. Skim off any burr. Reverse in chuck; open out to 3/8 in. depth with 3/16 in. drill, countersink and tap as above, skim off burr, and poke a 3/32 in. parallel reamer through the remains of the small hole.

At ¼ in. from the D-bitted end, drill a 5/32 in. hole right across, and another in between. At ¼ in. from the other end, drill a similar hole, for the whistle-pipe union screw. The illustration will show you which side to drill it. In the two side holes, fit union screws. To make them, chuck a piece of ¼ in. round rod in three-jaw; face the end, centre deeply with size E centre drill, drill down about 3/8 in. depth with No. 40 drill, screw the outside ¼ in, by 40 for ¼ in length, using the die in a tailstock holder.

Part off at 5/16 in. from the end, reverse in chuck, and turn the blank end to a squeeze fit in the hole in the side of the turret body. All union screws being made by same process, I need not repeat it for other fittings. A similar screw, but threaded 7/32 in. by 40, goes in the other hole. In the bottom hole, between the two side unions, is fitted the piece that screws into the boiler. Chuck the 5/16 in. rod again, turn down ¼ in. length to 7/32 in. diameter, and screw 7/32 in. by 40. Part off at 3/16 in. from the shoulder. Reverse in chuck, holding in a tapped bush. Centre, and drill through with No. 40 drill. Turn the outside to shape shown, then reduce 1/16 in. length to a squeeze fit in the hole under the turret body.

Silversolder all four joints at the one heat; pickle, wash, and clean up. Seat a 1/8 in. rustless steel ball on the seating, same process as pump valves; turn a little cap for the end, from 5/16 in. hexagon rod, drilling same with No. 30 drill, as shown in the section, to take the end of the spring. This should be of bronze wire, about 24-gauge, with both ends filed off square so that it takes a fair bearing at the ends, on both ball and cap. Anoint threads of cap with a little smear of plumbers' jointing before screwing home.

Make a similar turned and screwed cap for the other end, but use 3/8 in. hexagon rod; and instead of drilling a blind hole in it, drill a No. 48 hole clean through, centring and drilling before parting the piece off the rod. Screw this in the end, and note which corners of the hexagon come at top and bottom when the cap is right home; then remove it, and file them away to leave the end rectangular, as shown in the view of the complete footplate. Cut a 1/16 in. slot across, either by milling or planing, or by sawing and filing, if no other method is available. In this, fit a little lever as shown in the plan view. This can be made the shape shown, or it may simply be a piece of 16-gauge strip metal filed slightly taper, as it out of sight under the cab roof.

In the 48 hole in the cap, fit a pin made from a piece of 15-gauge rustless steel or bronze wire, of such a length that when the lever is pressed in, the ball is pushed about 1/64 in. off the seating. This will pass plenty enough steam to blow the whistle. If the end of the lever is shaped and pivoted as shown, it will not fly right right back when released, but only sufficiently to allow the ball to seat, and leave a little play for the push-pin. For pivoting these little levers, I always use a bit of domestic blanket pin, for which a 57 drill makes a squeeze-fit hole, and 56 drill a clearing hole.

DRILL a 3/16 in. hole on the top of the wrapper, as close to the backhead as possible, so as to pierce the backhead flange; tap it 7/32 in. by 40, and screw the stem of the turret in it, not forgetting the plumber's jointing. Connect the right-hand union to the union on the blower valve, by a 1/8 in. pipe furnished with union nuts made from 7/16 in. hexagon rod, and cones made as described for the snifting valve unions.

Injector Steam Valve

Chuck a piece of 5/8 in. round rod in three-jaw; turn down 1/4 in length to 1/4 in. diameter, centre, and drill 3/16 in. depth with No. 23 drill; part off at 15/16 in. from the end. Reverse in chuck, gripping by the turned part; centre and drill right through with No. 43 drill. Open out with No. 30 drill for about 5/16 in. and bottom with a 1/8 in. D-bit to a bare 1/2 in. Further open out about 1/8 in. depth with No. 21 drill, and tap the rest of the No. 30 hole with 5/32 in. by 32 tap. Take care not to cut into the seating. Turn down 1/4 in. of the outside to 1/4 in. diameter, and screw 1/4 in. by 40. At 5/16 in. from the shoulder of the flange, drill a 5/32 in. hole into the central hole, and in it fit a 1/4 in. by 40 union screw, as described for whistle turret. Fit a 9 in. length of 5/32 in. copper pipe into the plain boss, and silversolder that and the union screw at the same time.

The valve pin is made from a 7/8 in. length of 5/32 in. round rustless steel or hard-drawn bronze. Chuck in three-jaw, turn down 3/16 in. of the end to a shade under 1/8 in. diameter, and form a point on the end; I usually rough it with the ground-off corner of the tool in my four-way turret, used for chamfering nuts and such-like jobs; then I just take a sweep across the taper with a dead-smooth flat file, which leaves it a true cone with a polished surface. Screw the next 1/4 in. of the pin with 5/32 in. by 32 die in tailstock holder.

File a square on the other end—I've described how to do this scores of times—and fit a little handwheel turned down from 7/16 in. rod; the wheel is just a kiddy's practice job needing no detailing. To get the square hole in it, file or face the end of a short bit of 3/32 in. square silver steel about 1½ ins. long, so that it is true, then harden, and temper to dark yellow. Bevel off the other end slightly.

Drill a 3/32 in. hole in the wheel before parting it off the rod; after parting lay the wheel on the bench vice jaws, open about 1/8 in., and drive the punch clean through. File the end of the pin to fit, and slightly rivet over after putting on the wheel. The gland nut is made exactly the same as union nuts, and packed with a few strands of graphited yarn, the whole lot being assembled as shown. Drill four No. 48 holes in the flange.

At 7/8 in. to the left of the regulator spindle, and a shade higher, drill a 1/4 in. clearing hole in the backhead. Bend up the end of the pipe attached to the injector steam valve, so that it will touch the top of the boiler when the valve is in place, insert in the boiler, push the valve home, and secure it to the backhead by four 9 B.A. brass screws, roundheads for preference. *Note*—before fitting "for keeps," file off any burr on the backhead, caused by the drilling and tapping, and put a gasket of 1/64 in. "Hallite" or similar jointing, between flange and backhead. Don't punch the screwholes in it; merely prick through the flange with a scriber before inserting screws; smear plumber's jointing on threads.

Water Gauge

Chuck a bit of 5/16 in. rod in three-jaw; face, centre, and drill about 5/8 in. depth with 3/16 in. clearing drill, say No. 11, as the gauge glasses are seldom truly circular. Put about 5/32 in. of 5/16 in. by 32 thread on the end; part off at 1/2 in. from the end, reverse in chuck, and tap the other end 7/32 in. by 40. At 3/16 in. from the tapped end, drill a 3/16 in. hole, and in it put a fitting made the same way as the one at the bottom of the whistle turret, but a shade larger. Make it from 3/8 in. round rod, screw it 1/4 in. by 40, and drill No. 30. When pressed home, the shoulder should be 3/8 in. from the centre of fitting, as shown in the section. Make a cap to fit, same as the end of the whistle turret, but don't drill it up.

For the bottom fitting, chuck the 3/8 in. rod again; face the end, centre, and drill down about 5/8 in. with No. 48 drill. Open out with No. 30 drill to 1/4 in. depth, and bottom with 1/8 in. D-bit to a full 3/8 in. depth. Tap about 5/16 in. of the hole 5/32 in. by 32. Turn down 7/8 in. of the outside to 5/16 in. diameter, chamfering off the end as shown, for appearance sake. Part off at 1 3/16 ins. from the end. Reverse in chuck; turn down 3/16 in. length to 1/4 in. diameter, and screw 1/4 in. by 40. Centre, and drill No. 30 for 11/16 in. depth. Be careful not to go deeper, or you'll cut out the part that forms the seating of the blowdown valve.

AT 3/8 in. from the shoulder, drill a 3/16 in. hole, breaking into the central passage. At 5/16 in. further along, and diametrically opposite, drill a 5/32 in. hole. In the former, fit a nipple made like a union screw, but to size, as shown, and instead of being countersunk, it is drilled No. 11 for about 3/32 in. depth, to accommodate the bottom end of the gauge glass. Below this, the hole is drilled No. 30. A 7/32 in. by 40 union screw is fitted in the other hole, same as the whistle valve. Both top and bottom fittings can then be silversoldered up at one heating.

The valve pin is made by the same process as the injector steam valve pin, but fitted with a cross handle made from 1/16 in. steel wire (rustless for preference) instead of a wheel. The gland nuts are made same way as union nuts, using 3/8 in. hexagon rod, drilling the "through" hole No. 11, and tapping 5/16 in. by 32. The elbow to carry the top fitting is made from a 5/8 in. length of 3/8 in. rod. This is chucked in three-jaw, centred, and drilled 7/32 in. for a full 1/2 in. depth, the end being tapped 1/4 in. by 40 and countersunk very slightly. At 5/32 in. from the blind end, drill a 3/16 in. hole, and put a 1/4 in. by 40 nipple in it, made like a union screw but not countersunk. Drill it No. 30, and silversolder it in.

To erect the gauge, drill a 7/32 in. hole in the top of the wrapper, 3/4 in. to the right of the top centre line of the boiler, and as near the edge as possible, so that the hole pierces the backhead flange, and gives a good hold for the screw threads. Tap 1/4 in. by 40, and screw in the elbow fitting, lining it up "fore-and-aft." This is easily done by screwing in a piece of straight 1/4 in. rod with a few 1/4 in. by 40 threads on one end; the long rod can be set parallel with the boiler centre line, easier than the short socket. As it is important that the socket should "stay put" and not twist, sweat it with solder, like a stay, when you have set it O.K.; or, if you haven't made your boiler yet, fit it before the final braze-up, and give it a dose of silver-solder at the same time the backhead is brazed in, which is what I usually do myself.

At $1\frac{7}{8}$ ins. below the centre of the socket, on the same vertical line, drill a $\frac{7}{32}$ in. hole in the backhead, and tap it $\frac{1}{4}$ in. by 40. The bottom fitting of the gauge is screwed into this, and the top fitting in the socket. Take out the top plug, and line up the two fittings with the same drill that was used to drill the holes for the glass. When the shank end of the drill is put down the top fitting, and falls plumb into the recess in the bottom one, the fittings are properly lined up; and when the glands are tightened, there will be no pressure on the glass.

Beginner's note—Don't use joint gaskets between the gauge glass flanges and the backhead. If the fittings don't line up when screwed in tightly, either take a light scrape around the tapped hole with a pin-drill, or use one or more copper washers made from foil, between flange and backhead. Give the threads the usual dose of plumber's jointing.

The packing rings are made from rubber. Put a piece of $\frac{3}{16}$ in. bore rubber tube over a bit of $\frac{3}{16}$ in. rod and try the gland nuts on it. If they won't go on, chuck the rod in three-jaw, run the lathe pretty fast, and hold a bit of fine glass-paper to the rubber, which will reduce it to the required diameter in a few seconds. Wet a discarded safety-razor blade, and apply it to the revolving rubber tube every $\frac{3}{32}$ in. or so. When you push the rubber off the rod, it will fall into rings. Cut a piece of $\frac{3}{16}$ in. glass tube to a length of $1\frac{1}{2}$ ins.—nick it with a three-cornered file, and it will snap easily—put it down the top fitting, put a wet ring on it, then the two nuts back to back, and another wet ring. Let the glass drop into place, run the nuts up to the screws (they will take the rings with them) screw up fingertight, and then give about another quarter-turn with a spanner. The nuts should just be tightened sufficiently to prevent leakage—no more, as the glass must be perfectly free to expand.

Clacks

Three clacks or check valves are needed. Chuck a piece of $\frac{3}{8}$ in. rod in three-jaw, and turn down about $\frac{7}{8}$ in. to $\frac{11}{32}$ in. diameter. Face the end, and centre deeply. Turn down $\frac{5}{16}$ in. length to $\frac{1}{4}$ in. diameter with a roundnose tool, so as to leave a small radius, and screw $\frac{1}{4}$ in. by 40. Part off at $\frac{3}{4}$ in. from the end. Reverse in chuck, centre, drill right through with No. 34 drill, open out to about $\frac{1}{4}$ in. depth with $\frac{7}{32}$ in. drill, and bottom to $\frac{3}{8}$ in. depth with $\frac{7}{32}$ in. D-bit. Put a $\frac{1}{8}$ in. parallel reamer through the remains of the 34 hole.

Slightly countersink the top, tap $\frac{1}{4}$ in. by 40, and skim off any burr. At $\frac{7}{32}$ in. from the top, drill a $\frac{3}{16}$ in. hole in the side, and silversolder in it a fittting made like the one in the upper part of the water gauge. Seat a $\frac{5}{32}$ in. rustless steel ball on the hole, and make a little screwed cap from $\frac{5}{16}$ in. hexagon rod, with a projection as shown, to prevent the ball lifting more than $\frac{1}{32}$ in. off the seating.

At $1\frac{1}{2}$ ins. from the front end of the boiler barrel, on the horizontal centre line, drill a $\frac{7}{32}$ in. hole and tap it $\frac{1}{4}$ in. by 40. The location of these holes should be set with the boiler temporarily in place on the frames, using a scribing block, or failing that, a steel rule, measuring from rail level. It looks rather careless on the builder's part if one check valve is higher than the other! Screw them in, making sure that the bodies are vertical; remove caps [illegible] balls, and sweat them like a stay. [illegible] brushful of liquid flux is applied, a[illegible] bead of solder placed alongside the fi[illegible] a few seconds' application of a blow[illegible] flame will melt the solder, same pene[illegible]ing the joint and making a perfect tho[illegible] practically invisible seal. This is no[illegible] than bushing, though of course there [illegible] objection to anybody putting bushes [illegible] when brazing up the boiler shell, if [illegible] so desire.

THE third clack is screwed into the backhead, on the right-hand side, at the same level as the two side clacks; see illustration.

Washout Plug and Blowdown Valve

The washout plug is a simple turning and screwing job needing no detailing out, and is made from $\frac{1}{2}$ in. rod. It is screwed into a tapped hole in the backhead, on the left-hand side, as close to the foundation ring as possible. The blowdown valve is located in a similar position on the right-hand side, and this also needs no detailing, as it is simply a glorified edition of the blowdown valve of the water gauge, except that the end is squared for a key or box-spanner, instead of having a cross handle. It is made from $\frac{1}{2}$ in. round rod to the sizes given, or the body can be machined from a small casting.

Bypass Valve

Chuck a piece of $\frac{5}{16}$ in. round rod in three-jaw. Face the end, centre, and drill No. 44 to $\frac{7}{8}$ in. depth. Open out and bottom to $\frac{9}{16}$ in. depth with No. 30 drill and $\frac{1}{8}$ in. D-bit; further open out to $\frac{1}{8}$ in. depth with No. 21 drill, and tap the 30 section with $\frac{5}{32}$ in. by 32 tap. Turn down $\frac{1}{4}$ in. of the outside to $\frac{1}{4}$ in. diameter, and screw $\frac{1}{4}$ in. by 40. Part off at $\frac{15}{16}$ in. from the end. At $\frac{7}{16}$ in. from the screwed end, drill a No. 23 hole in the side; $\frac{5}{16}$ in. below, and diametrically opposite, drill a similar hole, and in it fit a $\frac{1}{4}$ in. by 40 union screw. Fit a short bit of $\frac{5}{32}$ in. pipe in the other hole, and silversolder both at the same heat. The gland nut and valve pin are made same as those in the injector steam valve, except that the valve pin is made 4 ins. long, so that it may project up through the footplate when the valve is erected.

Firehole Door

The firehole door can be made from a casting, or 18-gauge steel. In the former case, the hinges will be cast on, and only need drilling, for the hinge pin, whilst there will be a boss for the air baffle. This is merely a piece of 18-gauge steel filed to an oval shape, $\frac{1}{8}$ in. less all around than the size of the actual firehole; it can be attached to the boss on the door, by either a rivet or a screw. If a plate door is made, the dimensions will be the same as the cast door, an oval $1\frac{1}{2}$ ins. long by 1 in. wide; the same kind of baffle is used, the boss being superseded by a distance-piece made from a $\frac{1}{4}$ in. slice off a $\frac{3}{8}$ in. rod, with a hole in the middle for the screw or rivet.

The hinge straps are small editions of those on the smokebox door, riveted on with pieces of domestic pins for rivets, or they can be brazed, just as you like. The shape of the handle, and the spring catch, is shown in the plan view; the part of the hinge which is screwed to the backhead, is