L.B.S.C.'s

3.1/2" G.

75,000 class

B.R. Class 4, 4-6-0.

Originally
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MECHANICS – 1952-55

(TEXT ONLY)

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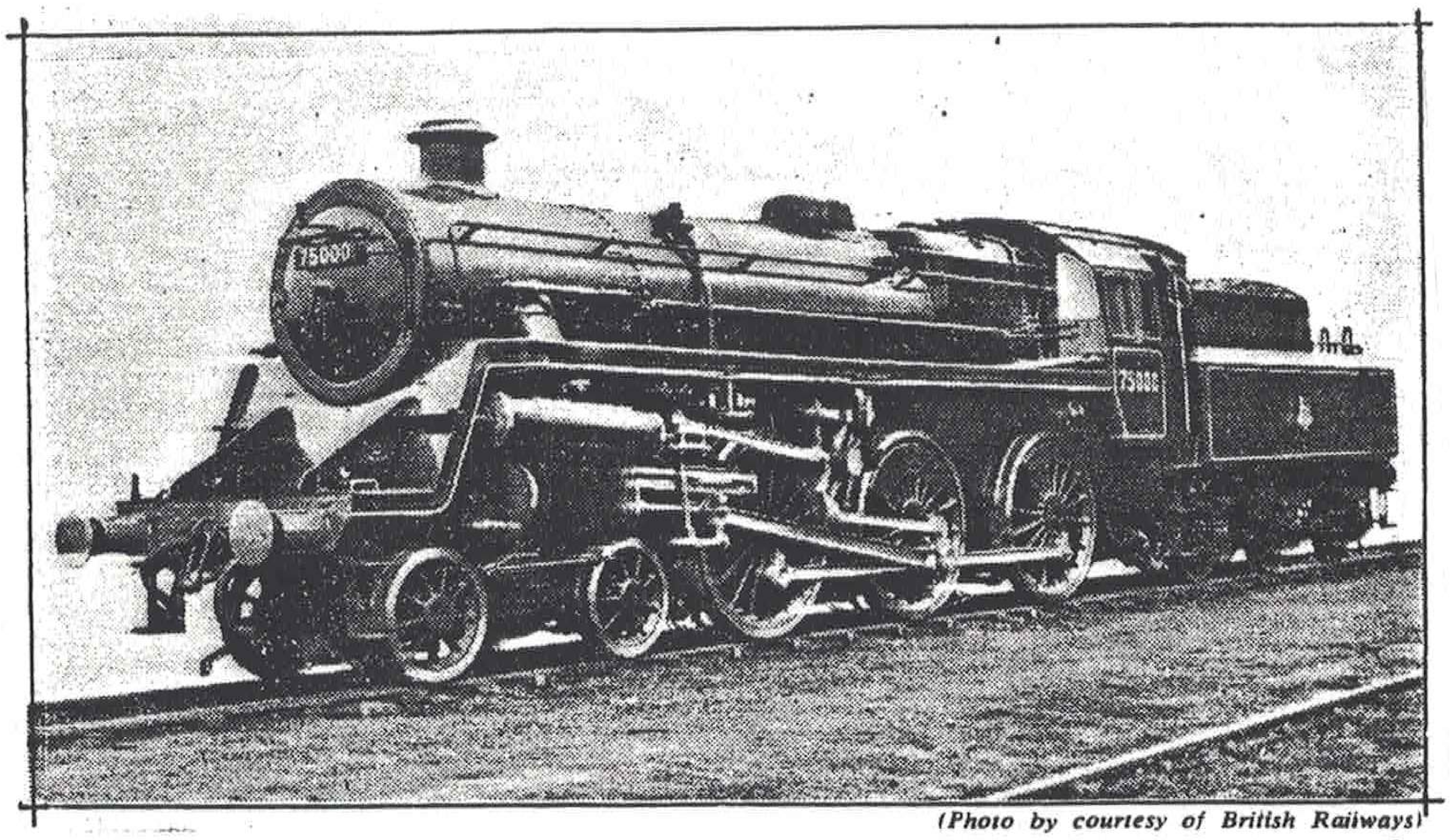

(Photo by courtesy of British Railways)

British Railways 75000 in 3½" Gauge

THE standard Class 4 tender engine now appearing on British Railways is a logical development of the ubiquitous Class 5 mixed-traffic 4—6—0 tender engine of the former L.M.S.R., and the Class 4 tank engine with 2—6—4 wheel arrangement. It is light, yet powerful, with all the liveliness of the tank engine, combined with the route availability and range of action, of the tender engine. The wheels are small enough for ample power and snappy acceleration, yet at the same time they are large enough for a good turn of speed; the cylinders are of ample capacity, and are backed by a boiler capable of supplying all the steam needed under any conditions of working. They should prove a useful acquisition to the B.R. standard fleet.

This engine is a very suitable type to copy in 3½ in. gauge. It is not too heavy for taking along for a run on a friend's line, as it can easily be carried. Being a small type of 4—6—0, the castings and material can be purchased at a fairly reasonable price; and in this connection, I have incorporated in the design as much existing stuff as is practicable, so that many stock castings may be used. The material for the boiler also will be cheaper than that needed for a Pacific, or larger type of 4—6—0. The components can easily be machined up on the equipment usually found in home workshops; for instance, the driving wheels are within the capacity of a 4 in. chuck, and the cylinders can be machined in the faceplate of an ordinary 3½ in. lathe. While the engine is correct in external appearance, and has all the usual British Railways characteristics, I have been able to simplify the design and construction, in order to make the job of building the locomotive as easy as possible, consistent with efficiency. A well-known Chief Mechanical Engineer, now retired, who was responsible for some of the most efficient locomotives ever put on rails, said in my own workshop, when examining some of my handiwork, that for maximum efficiency, a locomotive must be designed to suit the rail gauge and the work expected from it; and I have tried, as always, to put that precept into practice.

Brief Specification

The 3½ in. gauge engine has ordinary plate frames, with angle-steel buffer and drag beams, and is supported by the bogie bolster and the pump stay. The hornblocks and axleboxes are similar to those I specified for *Bantam Cock*, described in these notes some years ago. The coupled wheels are the same size as specified for *Princess Marina*; and if wheels with B.R. balance weights are not available, those mentioned may be used, as the piston stroke is the same, and the pear-shaped bosses are large enough to allow for the crankpins being fitted at the correct distance from the axle centres. The bogie is a simplified edition of the standard B.R. bogie, using coil springs and cast equalisers; but the sliding-block centre is retained.

The cylinders are proper piston-valve type, and are proportioned to those on the full-sized engine, viz., 1⅛ in. bore, 1¾ in. stroke, with ⅝ in. piston valves; the big ones are 18 in. bore, 28 in. stroke, with 10 in. valves. They are supplied with cylinder oil by a mechanical lubricator behind the buffer beam. The three-bar guides and crossheads are similar to those specified for *Roedean*. The valves are actuated by the standard British Railways type of Walschaerts valve gear; but the details are simplified, inasmuch as no valve-spindle guides are specified — they are not needed on a 3½ in. gauge locomotive—and I have substituted a pair of simplified cast brackets to carry the expansion links and reversing gear. The brackets on the full-sized engines are complicated boxes of tricks, being built up with welded joints. This is all right in full size, where each joint can be separately welded, the joints being sufficiently far apart to allow of this being done. A suitable bracket of similar construction would be impossible to make as small as 1/16th of full size, as it would have to be welded (or brazed) at every point at the one heating; and it would be an exceedingly difficult matter to clamp the parts together for that purpose. A built-up bracket of similar appearance, but simplified construction, can be made without too much trouble, and I will deal with that when we come to it.

The boiler is a straightforward job, with taper barrel, Belpaire firebox, and has a neat and pleasing chimney and other adornments. The regulator in the dome is operated by an external rod connected to a push-and-pull "pendulum" handle in the cab. The feed clacks are mounted near the top of the boiler barrel at the smokebox end; and water is supplied by an eccentric-driven pump, and an injector. The cab is the standard B.R. type supported by the boiler, and has an angular front and rear "balcony." There are no splashers over the wheels; splashers are evidently clean out of fashion, after a very long reign on British locomotives. Instead, the American type of running-board is fitted, but it has a deep valance, and a drop front. Strangely enough, a pair of running-boards of exactly identical type, were fitted to a Gauge 1 Pacific-type engine some 25 years ago, by a Warsop friend named Tom Lucas, now, alas! passed to the Great Beyond. The tender runs on six wheels, and is of the standard B.R. pattern; it carries the usual emergency hand pump in the tank. So much for generalities; now to construction.

Main Frames

For the frame plates, two pieces of ⅛ in. mild steel will be needed, each 26½ in. long and 3¼ in. wide. Either bright or blue steel will do, but it should be soft and ductile, so that it won't spring out of the flat when the hornblock openings are cut. Mark out one plate, and drill any two of the end holes; put the two plates together, drill corresponding holes in plate No. 2, using those in plate No. 1 as a guide; rivet the plates temporarily together, and saw and file to outline. Note the following points when marking out. The four holes at each end of the frame are only needed if it is intended to erect the frame with angles, rivets and screws; if the frame is to be brazed up (I make my frame joints with Sif-bronze, by aid of an oxy-acetylene blowpipe), no holes are needed. The exact position of the hoisting hole doesn't matter, as these small locomotives don't usually require a powerful crane to lift them!

The bottom row of holes between the bogie-wheel clearances are for the screws securing the bogie bolster. The two slanting rows above them are for the screws or studs holding the cylinders, and their position is important; but it is easily obtained as follows. Mark out the frame outline, first of all. On the vertical centre-line of the middle (driving) axlebox opening, and ⅝ in. from the bottom edge of the frame outline, make a centre-dot. At the front end of the frame, 1⅛ in. from the bottom, make another; then draw a diagonal line connecting the two, as shown on the frame drawing (the first drawings will be published in a later instalment). This is the centre-line of motion, and rises at an angle of 4 degrees from the horizontal. On this line, at 4 13/16 in. from the front end of frame, make another dot. That gives you the centre of cylinders; and the location of the bolting face of cylinders can then be set out by drawing another line, at right angles to the centre-line of motion, cutting through the centre-dot. At ½ in. below the centre-line of motion, and parallel to it, draw a line extending 1 7/32 in. each side of the line previously mentioned; this is shown dotted in the illustration. At each end, draw a line at right angles to the bottom line, and 1⅝ in. high; connect the top ends, and the resulting rectangle is the exact location of the bolting face of the cylinder. Set out the holes as shown, locating from the centre-line of motion, and the intersecting line; also the 7/16 in. hole for the exhaust, and drill the lot through both plates. The centre-line of motion, and the position of the cylinder, should be set out on the second frame plate while they are still riveted together.

The two holes at the top are for the smokebox saddle screws; and the three behind the leading hornblock opening, are for the screws holding the pump stay. The latter are countersunk, and will serve to indicate which is the outside of the frame when the plates are separated. File off all burrs around the drill-holes. Should the frame plates spring after parting, they must be carefully flattened before attaching the buffer and drag beams. If the frames are to be erected by brazing to the beams, clean the ends with emery-cloth.

Buffer Ends and Drag Beams

The beams may be made from 1 in. × ⅛ in. steel angle; or, alternatively, castings may be used, but they should not be of iron, as a collision or a severe bump, would break a cast iron beam. I prefer the angle. Each beam makes a piece of angle 6½ in. long, after the ends have been squared off. The front beam is drilled for buffers, as shown, and the hole for the drawbar shank drilled ⅛ in. and filed square. The front bottom corners are cut away in a curve at each side. The back beam merely has a drawbar slot cut in it, 1 in. long and 3/16 in. wide. The top of each beam has two slots cut in it, at a distance of 2⅞ in. between the inner edges; these may be milled with a ⅛ in. saw-type cutter, if a milling machine is available. They may be cut in the lathe, with a similar cutter on an arbor between centres, the beam being clamped under the slide-rest tool holder, and set parallel to the lathe centre-line. The slots may also be sawn and filed, if the beams are held vertically in the bench vice with the marked lines just showing above the jaws, which then act as guides for saw and file. In my early locomotive building days, I had no trouble in cutting accurate slots by aid of the tops of the vice jaws; it only needs care and patience.

The ends of the upper part of the buffer and drag beams are cut away on an angle, to form gussets; this is a simple sawing and filing job needing no detailed description. If the beams are to be brazed to the frames, no further work on them is necessary; but for angle fixing, two pieces of ¾ in. × ⅛ in. angle, brass or steel, must be riveted to the beams, flush with the inner edges of the slots. Jam any odd piece of ⅛ in. steel plate in the slot; set the angle up against this, and temporarily secure it with a toolmaker's cramp. Drill four holes with No. 30 drill, through angle and beam, in the form of a square; countersink them outside beam, rivet up with ⅛ in. iron rivets, and file smooth on outside of beam.

Hornblocks

It is advisable to fit the hornblocks before erecting the frames. One or two of our advertisers supply hot pressed hornblocks of the size and type specified for this engine, and I strongly recommend their use, on account of the work they save. All that is needed is to drill the seven No. 41 screw-holes in each, filing off any burrs. Fit each to an opening, temporarily clamp in position with a toolmaker's cramp, drill the holes in the frame, using those in the hornblock as guide, countersink on the outside of frame, rivet up with 3/32 in. iron rivets, and file flush outside frame. Clamp the two frames together with the hornblocks outside; smooth the rubbing faces with a file, and test with a bit of ⅞ in. square bar. When this slides between the jaws without shake, the hornblocks are O.K.

If castings are used, the contact faces will probably need machining off, and this may be done in the lathe, if a vertical slide is available. Clamp the hornblock, contact side outwards, to the vertical slide, setting the casting either horizontally or vertically as preferred, and traverse it across a ⅜ in. endmill or slot drill held in the three-jaw chuck. Judicious use of a file will do the job, where machining facilities are not available. When the contact faces are O.K., drill the screwholes, and proceed to fit the hornblocks to the frames as described above. If any of the flange projects outside the frame, file off flush, and also file the inner flanges so that the overall thickness of the fitted hornblocks is ⅜ in. as shown in the side view. (Drawings will be published in the next instalment.) The bottoms of the feet, or legs, are filed flush with the bottom of the frame.

How to Erect Frames

If the slots in the buffer and drag beams have been accurately cut, the frames should line up correctly, whether for brazing or screwing. In either case, jam the ends of the frames into the slots, and lay the frame on the lathe bed, adjusting until the straight part of the lower edges is in full contact with the lathe bed at both sides, so that the frames don't rock in the slightest. Try the frames and beams for squareness, with a try-square; they should be at exactly right angles. Measure from lathe bed to top edge of beams; all four ends should tally exactly. When the above conditions are fulfilled, the frames are ready for fixing. If screws are used, poke a No. 30 drill through the holes in the ends of frames, and make countersinks on the bits of angle riveted to beams. Follow with No. 40 drill, running it clean through the angles; tap ⅛ in. or 5 B.A., and put steel screws in. Round or hexagon heads look best, but cheeseheads can be used if the former are not available.

To braze the beams, true up as above; then put a couple of distance-pieces between the frames, with big clamps on the outside, to hold the frames securely whilst under heat. I use bits of 2 in. iron pipe, squared off in the lathe to the exact distance between frames, and use regular G-cramps; but hardwood blocks, or anything else available, may be pressed into service, and clamped by putting pieces of steel bar at each side of frame, holding these together with long coachbolts, or any other kind available, above and below. The frames must be held quite rigid, or they will shift, and spoil the job. See that the buffer and drag beams are jammed tightly in place.

Up-end the assembly in the brazing pan —courtesy title, that, because an old discarded iron tea-tray, or similar piece of hardware, will do fine, if some coke or breeze is put in it. Rest the beam on the coke, and prop up the frame assembly so that it stands vertically. Anoint the joints with some wet flux; Boron compo mixed to a paste with water is as good as anything. Carefully heat the beam, and the frame ends, until they glow bright red, and the flux has fused; then apply some thin soft brass wire to each joint. This will melt, flow in, and form a nice fillet. Let cool to black, reverse frame, and ditto repeato operation on the other end. Quench in water, knock off all burnt flux with an old file (if you break the end off, the file will make easy work of the job), then clean up, removing all trace of scaling from the steel.

If any builder of this engine is the lucky owner of an oxy-acetylene blowpipe, he can follow my example, and the job will be just a piece of cake. All I do is to give the joints a dose of Sifbronze flux, heat them by blowing on them direct, using a 150-litre tip in the blowpipe, and applying the end of a No. 1 Sifbronze rod to the joint, as soon as it glows bright red. The intense heat of the oxy-acetylene flame brings the steel to the melting temperature of the Sifbronze so quickly that the centre part of the beam isn't even discoloured. The very small amount of burnt flux nearly all flies off when the job is quenched out in water, and any residue is easily knocked off, leaving a perfect joint.

Bogie Bolster

The bogie bolster may be a casting in iron or gunmetal, or it may be built up from steel plate and angle. If anybody owns, or has the use of a bending brake, the bolster may be merely a piece of ⅛ in. steel plate, with the ends bent up to form flanges, similar to the alternative pump stay. The bending could also be done by gripping the metal in the bench vice, and making the bends by aid of a hammer used judiciously; but unless the metal is very soft, or is heated, there is a risk of the bend cracking, so I don't advise that method.

If a casting is used, chuck it in the four-jaw, and face off the underside. Then clamp it under the slide-rest toolholder, set at the correct height for a ½ in. endmill or home-made slot drill (I prefer the latter) to clear out the "step" at each side. The endmill or slot drill is held in the three-jaw chuck, and the casting traversed across it by operating the cross-slide handle, in the way described for milling out the grooves in axle-boxes. Lucky milling machine owners can merely grip the casting in a machine-vice on the miller table, and run it under a side-and-face cutter on the arbor; I do mine like that, using a cutter 3 in. diameter and ½ in. wide. The steps, or rebates, could also be cleaned out on a planer or shaper, with the casting held in the machine-vice, and operated on by a square-ended tool in the clapper-box.

To build up the bolster, simply cut a piece of ⅛ in. mild steel plate, 3⅛ in. long and 1¾ in. wide, and make sure the corners are square. Rivet a length of ¼ in. × ⅛ in. angle, either steel or brass, along each shorter side, at a distance of ⅛ in. from the edge. Use 3/32 in. iron rivets; countersink the holes underneath the plate, and file flush after riveting. File the ends of the angle, flush with the plate. Alternatively, a piece of ½ in. × ⅛ in. steel bar could be clamped to the plate at each side, and the joints brazed as shown in the illustration of the pump stay (to be published in a later instalment). Whether the bolster is cast, or built up, the bogie pin is the same. Turn it up from 5/16 in. round mild steel, to the dimensions given in the illustration. Drill a 9/32 in. hole in the middle of the bolster, push the end of the pin through, and secure with a nut, as shown. The nut should be made from ⅜ in hexagon rod, either brass or steel. Turning pins and making nuts are just kiddy's practice jobs, needing no detailed instructions.

The completed bolster is placed at the front end of the frames, between the bogie wheel clearances, and is secured by five ⅛ in. or 5 B.A. screws at each side. Either round or hexagon heads may be used as desired. The exact location is shown on the half-plan of assembled frames.

Pump Stay

The instructions for machining and erecting the bogie bolster can also be applied to the pump stay; the only difference being, that as it fits between the frames, the sides are machined off flush, as shown in the illustrations. It may be a casting, or built up, either as a plate with bent flanges, or flanges made from angle, or just brazed-on strips. A 9/16 in. plain hole is drilled in the middle, as the pump will be arranged with a square flange which is bolted to the stay. The stay is erected with the flanges pointing forward; the bottom edge of stay is set level with the bottom edge of frame, and the flanged side of the stay is set at 1⅝ in. from the centre of the leading hornblock opening. It is secured by ⅛ in. or 5 B.A. countersunk screws put through the clearing holes in the frames, into tapped holes in the flanges of the stay.

Axleboxes

The axleboxes are of my usual specified type, and can be made from castings, or from 1 in. x ½ in. drawn bronze rod, a piece nearly 7 in. long being required. I prefer the drawn material, as it saves machining the axleboxes all over. If cast axleboxes are used, they will probably be cast in a stick; this should be cleaned up, so that it is quite smooth. If the lathe cross-slide has sufficient traverse to mill the grooves for the full length, simply clamp the piece of bar under the tool clamp, at right angles to lathe centre line, and packed up to centre height. In the days when I only had a lathe and a hand-drilling machine, I used to put the faceplate on the mandrel, and run up the slide-rest close to it, which enabled the bar to be set parallel to the faceplate, simply by holding a steel rule against the faceplate, and letting the bar touch the other side of the rule. If the cross traverse isn't sufficient to mill the bar at one fell swoop, do it "in twice," by cutting the bar in half. The groove is formed by traversing the piece of bar, by aid of the cross slide, across a ⅜ in. endmill, or home-made slot drill, held in three-jaw. Run the lathe at a good speed. When through, either part off the boxes in the lathe, or saw up the bar, and face the ends of each axlebox truly, holding them in the four-jaw, and using a roundnose tool set crosswise in the rest.

Mark the hornblocks 1 to 6; fit each axlebox to its hornblock separately, and mark it to correspond; then they won't get mixed up. Centrepop Nos. 1, 2 and 3 in the centre, and drill a No. 3 hole in each, dead square with the sides of the box. If you haven't a drilling machine, use the lathe, with the drill in the three-jaw, and the box held against a drilling pad in the tailstock barrel. Drill the other three, by clamping each to its opposite mate on the other side of the engine, viz., 1 to 4, 2 to 5, and 3 to 6. Put the axleboxes in place and run a bit of ⅛ in. silver steel through the holes in each pair. If it lies dead square across the frames, O.K. If it doesn't, correct with a file, use a bigger drill to "round" the hole, and try with a thicker rod. When all are O.K., open out the holes with 31/64 in. drill, and put a ½ in. parallel reamer through, with the boxes in place.

THE hornstays are just 1½ in. lengths of ⅜ in. × 3/32 in. mild steel strip, drilled as shown in the illustration, and attached to the hornblock feet by ⅛ in. or 5 B.A. screws; any available heads will do. To locate the spring-pin holes in the axleboxes, so that the boxes will work easily, jam each up tightly against the hornstay, using wood wedges. Poke the No. 30 drill through the holes in the hornstay, and make countersinks in the axleboxes; follow with No. 40 drill, tap ⅛ in. or 5 B.A., and screw in spring pins made from 1 5/16 in. lengths of ⅛ in. round silver steel, screwed at both ends, as shown in the illustrations. If these are screwed into the axleboxes through the holes in the hornstays, they should fit so that the boxes move easily up and down, without any binding.

The springs are wound up from 19 gauge tinned steel wire, around a bit of ⅛ in. rod held in the three-jaw. The spring plates are made from ¼ in. × 3/32 in. steel strip, to the dimensions shown, and are secured by ordinary commercial nuts. The whole assembly is shown in the drawing. After erecting, put a piece of ⅛ in. square rod between the bottom of each axlebox, and the hornstay, and tighten the springs. This holds the axleboxes in running position while the "works" of the engine are being erected, and ensures them being accurately fitted, so that the engine runs easily.

Coupled Wheels and Bogie Wheels

The six coupled wheels can easily be machined in a 4 in. chuck. Hold the castings by the tread, setting to run truly; face off the back, with a roundnose tool set crosswise in the rest, and take a roughing cut off the flange. Centre, drill through with ¼ in. drill, open out with 27/64 in. drill, and ream 7/16 in. Reverse in chuck, and turn the rims and bosses. Make a little rebate with a parting tool, at the point where the spokes join the rim. To turn the treads, chuck an old wheel or disc, or something similar, a little smaller than the finished size of wheel. Face it, and recess the centre for about 1 in. diameter, to 1/32 in. depth. Centre, drill and tap ½ in. × 26, and screw in a stub of ½ in. round mild steel, which should be prepared beforehand, so that it can be screwed in without removing the disc from the chuck. Turn this down until the wheels can be slipped over it without shake; then screw the end and fit a nut. The end can be reduced to ⅜ in. if you like, and screwed to suit a commercial nut.

Put each wheel on this improvised faceplate, tighten up the nut, and rough-turn it to about 1/64 in. of finished size. When the last one is roughed, regrind the tool, turn to finished diameter, and then ditto repeato the finishing cut on the other five wheels, *without shifting the adjustment of the cross slide*. They will all then be exactly the same diameter, an absolute necessity for coupled wheels. The flanges can be rounded off by applying a file to them while the lathe is running—but mind it doesn't catch the chuck jaws!

The bogie wheels are turned by exactly the same process, using a smaller improvised faceplate for finishing; so if you have the castings handy, do the lot whilst you are at it. All dimensions are given in the illustrations.

THE crankpin holes are drilled in the coupled wheel bosses, by aid of a simple jig. Get a piece of ¼ in. × ¾ in. flat steel about 1¾ in. long; scribe a line down the middle, and make two centre-pops on it, ⅞ in. apart. Drill them 7/32 in., then open out one to a bare 7/16 in. diameter, and squeeze a bit of 7/16 in. round steel into it, leaving about ⅜ in. projecting. Scribe a line down the centre of each wheel boss; put the peg of the jig in the hole in the wheel, adjust jig until you can see the scribed line passing across the bottom of the 7/32 in. hole; clamp the jig to the wheel, and put the 7/32 in. drill through the boss, guided by the hole in jig. Open out the holes in the driving bosses to 19/64 in. and ream 5/16 in.; poke a ¼ in. reamer through the others.

The driving crankpins are made from ⅜ in. silver steel, and the others from 5/16 in. ditto; all dimensions are given in the drawings, and as these are the simplest of plain turning jobs, no detailing is needed. The spigots should be a tight fit in the wheel bosses, but don't overdo it and make them so tight that the bosses are split when the pins are squeezed it. The bench vice may be pressed into service (no pun intended!) for this job; put a nut on the screwed part of the trailing pins when pressing, to protect the threads.

Axles

These are just another simple plain turning job. Make the coupled axles from ½ in. round mild steel, and the bogie axles from ⅜ in. material. If your three-jaw chuck isn't accurate, put a bit of packing between the offending jaw and the work, to bring it true; otherwise, set up truly in four-jaw. A collet chuck is just the berries for this sort of work. Turn the wheel seats until they just won't enter the holes in the wheel bosses (says Pat), then carefully ease with a file until they will just push on a little bit by hand. Squeeze one wheel on to each axle, using the vice as press again.

Eccentrics

Before the wheels are erected, we need two eccentrics to mount on the axles; one for pump, and one for lubricator drive. They are both machined in the same way, using stubs of steel shafting, 1⅜ in. diameter for the pump eccentric, and 1⅛ in. diameter for the lubricator eccentric. Chuck in the three-jaw, face the end, and form the groove with a parting tool. Part off at ⅝ in. from the end. The faced ends will show the true centre, by virtue of the tool marks. On the larger one, make a pop mark 5/16 in. from true centre; on the smaller, make it at 3/16 in. Chuck in four-jaw with pop mark running truly; drill ¼ in., open out with 31/64 in. drill, and ream ½ in. Each eccentric can then be mounted on a stub mandrel, made from ⅝ in. round rod, and held in three-jaw; turn the bosses to size, with a knife-tool, and drill and tap the holes for the setscrews. An alternative type of eccentric is shown, which needs no boss, as the setscrew goes into the thickness of the actual eccentric; but this is only suitable for use with Allen or other recessed-head setscrews.

quartering wheels

THIS job has been dealt with very fully, with illustrations, in connection with previous engines described in these notes; but for new readers' benefit, here is a brief synopsis of the process. Press one wheel on each axle, and poke them through the axleboxes on the frames; don't forget to put the eccentrics on, between the axleboxes. The lubricator eccentric goes on the leading axle, and the pump eccentric on the driving axle. Now put the other wheels on, as far as they will go, by hand, setting the crankpins as near right angles as possible, "by eye." The right-hand crank should lead; but this doesn't really matter, as each side has an independent valve gear. Put the chassis on something flat, such as the lathe bed, and put a block against each end, so that it doesn't roll.

Now apply a try square to the driving wheel on one side, setting the wheel so that the edge of the blade passes across the centres of the axle and crankpin. Next, set the needle of a scribing block or surface gauge, to the centre of the axle on the opposite side, and adjust the wheel on the axle until the centre of the crankpin is exactly the same height, when tested by applying the point of the scribing-block needle to it. The centre-line of crankpin and axle on the first wheel will then be exactly vertical, and centre-line of crankpin and axle on the second wheel, exactly horizontal. They will therefore be at right angles, or 90 degrees, and that is correct. Remove the whole issue, by taking out the hornstay screws, and press the second wheel right home, either by using the bench vice as a "squeezer," or by whatever other means may be available.

The other wheels may be set in similar manner; but about the best way to ensure easy running, is to set the other wheels by aid of a pair of dummy coupling rods. For these, two pieces of strip metal about 3/32 in. thick, ½ in. wide, and a little over a foot long, will be needed. Scribe a line down the middle of one of them, and at ⅜ in. from one end, drill a 5/16 in. hole. At 5¼ in. farther along, drill a ⅜ in. hole; and at 6 in. beyond that, drill another 5/16 in. hole. Use this rod as a jig to drill exactly similar holes in the second rod. Put one of the dummy rods on the crankpins in the wheels that are already pressed home on the axles, and adjust the loose wheels until the other rod can be put on the crankpins on the other side, the driving wheel already having been pressed home as described above. This method will make sure that the leading and trailing wheels are in exact unison with the driving wheel. The whole lot should spin freely; if not, it is merely a matter of either the leading or trailing wheel being a little out of correct adjustment, and needing a slight twist either forward or backward. When the wheels will spin freely with both dummy rods on, remove same, take out the complete leading and trailing axles, taking great care not to alter the adjustment of the wheels, and press them right home.

Boiler Feed Pumps

The pump is one of my "standard" types, and can be made up from castings supplied by our advertisers who sell materials for engines described in these notes. As it delivers into a top-feed fitting, the boiler clack is attached direct to the pump valve box. Chuck the casting by one end of the valve box, and set the other end to run truly. Face off, centre, and drill right through with No. 14 drill. Open out and bottom to 7/16 in. depth with 9/32 in. drill and D-bit, and tap 5/16 in. × 32. Reverse the casting, holding it by screwing it on to a piece of rod held in the three-jaw, the end of the rod being first turned down to 5/16 in. diameter, and screwed 5/16 in. × 32. I keep a number of these stub mandrels, of different sizes, in a box, handy to the lathe, and find them very useful. Repeat operations on the other end of the valve box, but instead of using the D-bit, nick the end of the hole with a small chisel made from a scrap of 3/16 in. round silver-steel. The nicks are shown in the illustration, and prevent the outlet being blocked by the valve ball, on the outward stroke of the pump ram. Put a 3/16 in. parallel reamer through.

Next, chuck the casting by the chucking-piece opposite the barrel, and set the barrel to run truly. Face off, centre, and drill 5/16 in., right into the valve box. Open out to 1 1/8 in. depth with 3/8 in. drill. Turn the outside as far as the flange, to 9/16 in. diameter; face the flange, and screw 3/8 in. length of the outside, with a thread of 9/16 in. × 32. Face off the end until exactly 1/2 in. from the flange. The chucking piece can then be cut off.

Seat a 7/32 in. bronze or rustless steel ball on the D-bitted seating in the valve box, and take the distance from top of ball to top of box, with a depth gauge. Chuck a bit of 1/2 in. round rod in three-jaw (bronze or gunmetal if possible, but brass will do if nothing better is available) and turn down the end to the length indicated by the gauge, to 5/16 in. diameter. Screw it 5/16 in. × 32. Part off at 7/8 in. from the shoulder; reverse in chuck, and serve the other end exactly the same as the D-bitted end of the valve box, putting the No. 14 drill clean through the piece, reaming 3/16 in., and cross-nicking the screwed end, as shown in the section.

Two union nipples are needed in this piece. They are made from 5/16 in. rod; just chuck in three-jaw, face the end, centre deeply, and drill No. 30 for about 3/8 in. depth. Part off at 3/8 in. from the end. Drill two 3/16 in. holes in the side of the fitting, one at 1/4 in. from top, the other at 5/8 in. from top, at the angles shown in the plan view. Turn the plain ends of the nipples to fit these holes tightly, press them in, and silver-solder them. For silversoldering these small fittings, I always use either Easyflo, or best grade silversolder. Simply anoint the joint with a paste made from Easyflo flux and water, or powdered borax and water, heat to bright red, and touch with a piece of Easyflo wire or a thin strip of silversolder. Quench in acid pickle (1 part commercial sulphuric acid to 16 of water), wash off under the kitchen tap, and clean up. A blowpipe made from a bit of 3/8 in. boiler tube, with air-hole and gas nipple made in the same way as a Bunsen burner, or the domestic gas stove burners, gives plenty of heat.

Seat a 7/32 in. ball in the D-bitted hole in the same way as that in the top of the valve-box and make a cap to fit, from 7/16 in. hexagon brass rod, allowing the ball 1/32 in. lift. Turn the pump upside down, drop a ball in the other end, and gauge the depth. Chuck a piece of 7/16 in. hexagon rod, and turn the end to the length indicated by the depth gauge to 5/16 in. diameter. Screw 5/16 in. × 32, and part off at 1/2 in. from the shoulder. Reverse in chuck, centre deeply, drill through with No. 14 drill, and follow with 3/16 in. reamer. Turn down 5/16 in. of the outside to 5/16 in. diameter, and screw 5/16 in. × 32. Reverse in chuck, take a very fine skim off the end, to true it up, seat a 7/32 in. ball on it with a gentle tap, and assemble the whole lot.

THE pump ram is made from a piece of 3/8 in. ground rustless steel, or hard-drawn phosphor-bronze, either of which should be a nice sliding fit in the pump barrel, and should not need any turning to fit same. Chuck in three-jaw, and turn down 5/16 in. length to a full 5/32 in. diameter, to form the anti-airlock pin. It is this simple little extension to the ram that ensures my pumps always doing the job, feeding the boiler to full capacity without ever failing because of trapped air in the barrel. Note — the shoulder should be finished off to the same angle as the point of the drill used to drill out the pump barrel; see sectional illustration. The other end of the ram is slotted for the eccentric rod. The easiest way of doing this, if a milling machine isn't available, is to clamp the ram under the slide-rest tool holder, packed up to lathe centre height, and feed it up to a small saw-type milling cutter, 1/8 in. wide, mounted on a stub mandrel (old bolt does fine) held in three-jaw. Run at slow speed, and slop on a good dose of cutting oil, or soapy water if you haven't the cutting oil; but in the latter event give the lathe a jolly good clean-down afterwards!

The ram is cross-drilled No. 32 and reamed 1/8 in. to take a gudgeon pin, or wrist pin, made from 1/8 in. silver-steel, turned down at both ends to 3/32 in. diameter, screwed 3/32 in. or 7 B.A., and furnished with commercial nuts. This should be long enough to allow of the pin being turned with finger pressure, when both nuts are hard up against the shoulders. Anything less will pinch in the jaws of the ram, and cause the eye of the eccentric rod to bind in the slot.

Although I have shown a round gland nut with C-spanner slots cut in it, hexagon material may be used if desired. Chuck the 3/4 in. rod, face, centre, drill 3/8 in. for 3/4 in. depth, open out to a bare 1/2 in. depth with 33/64 in. drill (use 17/32 in. if this isn't available, but you won't get full threads), and tap 9/16 in. × 32, using the tailstock chuck to guide the tap. Chamfer, part off at 5/8 in. from the end, reverse in chuck and chamfer the other end. The gland is preferably packed with a few strands of yarn unravelled from a piece of full-size hydraulic pump packing; but graphited yarn will do. A last resource is darning-cotton soaked in tallow; I used that when I was a kiddy, over sixty years ago: mother's work-basket and the domestic candlestick providing the ingredients!

How to Erect the Pump

Take out the pump stay, and drill four No. 40 holes around the big hole in in the middle, on a circle approximately 1 in. diameter; see drawing of pump flange. Take off the gland nut, and poke the end of the barrel through the hole in the stay, from the side where the flanges are. Set the valve-box vertical; parallel to the ends of the pump stay; temporarily clamp the pump flange to the stay, with a toolmaker's cramp. Put the No. 40 drill through the holes in the stay, and make countersinks on the pump flange; follow up with No. 48 drill, tap 3/32 in. or 7 B.A., and put brass screws in if you have them, in case any water gets on them and causes them to rust and break; otherwise, steel will do. The pump stay can then be replaced.

The eccentric strap is made from a casting. Clean up with a file, centre-pop both lugs, and drill No. 44. Mark one side of the strap, so that it can be put together again same way, after being divided; centrepop on the lugs will do. Then put it in the bench vice with half the hole showing above the jaws, and saw across, keeping the sawblade pressed on the vice jaws for a guide. Rub the cut halves on a file laid on the bench, to take the roughness off the sawcut. Open out the holes in the half-round part with No. 34 drill, and tap those in the other half 6 B.A. Screw the two parts together; chuck in four-jaw with the hole running as truly as possible, face off, and bore to 1¼ in. diameter, to fit the pump eccentric. The size can be measured by the inside jaws of a slide gauge, or by calipers, but I always use a piece of rod turned to the same size as the diameter of the eccentric in the groove. Either reverse in chuck, or mount on a mandrel, and face the other side, so that the strap fits easily in the eccentric groove. Drill the oil hole shown by dotted lines in the drawing, and mill or file a ⅛ in. slot in the back lug, for the eccentric rod.

The rod is sawn and filed from ⅛ in. × ¼ in. mild steel, to the dimensions given, and is soldered into the lug on the strap, two rivets (1/16 in. wire) being put through, countersunk and filed flush both sides, for neatness sake. Put the strap on the eccentric, push the pump ram right home, and put the end of the rod in the slot in the ram, removing the pin for this purpose. Then, with a bent scriber, make a little circle on the end of the rod, through the hole in the ram. Remove eccentric and rod, make a centrepop 1/32 in. nearer the strap, than indicated by the centre of the little circle. Drill No. 32, ream ⅛ in., and file the end of the rod to the shape shown by the dotted lines at the end of the ram. Caseharden the eye by heating to red, dipping in any good casehardening powder ("Kasenit," "Pearlite," etc.), making sure the hole is filled up, reheating until the yellow flame dies away, and quenching in cold water. Clean the eye well, before replacing the strap and rod, and putting the bolt in. Alternatively, the hole may be drilled 3/16 in., and a bronze bush, drilled No. 32 and reamed ⅛ in., squeezed into the hole. This can easily be renewed when wear takes place. When the engine wheels are turned by hand, the pump should work freely, the valve balls making a snorting noise. If it works stiffly, either the gland or eccentric strap is too tight.

Coupling Rods

The coupling-rods are made from mild steel of ⅞ in. × ¼ in. section, two pieces 6¾ in. long, and two pieces 6¼ in. long, being required. Mark off one longer and one shorter piece according to the drawing; but note that the measurements between centres of bushes must tally with the centres of the axles, so check up before marking the rods. Drill the marked rods 3/16 in., and use each as a jig to drill the unmarked ones; then temporarily rivet the two pairs by pieces of 3/16 in. round steel driven into the holes, and mill, or saw and file, to outline. I do mine on a milling machine, clamping the pairs of rods in the machine-vice on the table, and using a small spiral-toothed slabbing cutter on the arbor, usually taking out the whole of the surplus in one cut only, by aid of slow speed, and plenty of cutting oil. This is fed from a can hung on the overhead arm, through a ⅛ in. pipe with regulating tap. To reduce the thickness of the rods between the bosses, I screw them down to a piece of 1 in. square mild steel bar, which is held in the vice on the table, and forms a substantial backing to the frail rod. The flutes are put in, while the rods are still attached to the bar, by a saw-type cutter of suitable width. The ends are rounded off on a vertical milling machine. A 3/16 in. pip is turned on a short bit of square bar, which is held vertically in the machine-vice on the table. The end of the rod is slipped over the pip, and fed up to a 5/16 in. endmill in the miller spindle; this endmill has cutting teeth on its side, as well as the end. When these side teeth begin to cut away the end of the coupling-rod blank, the free end of the rod is slowly swung around by hand, and the cutter forms a perfect boss; but care has to be taken, to avoid swinging the end of the rod too far around, and cutting away the oil box on the boss.

If a milling machine isn't available, it will be a case of saw and file, unless the lathe has a rising and falling boring table or slide-rest, which would be necessary to feed the rods into cut. This, however, isn't the "hard labour" job that it would appear at first sight; I did plenty of them that way, when all my equipment consisted of merely a pedal-driven lathe and a hand-drill. The rod blanks were clamped in the bench vice, with the marked line showing just above the jaws. A gap, just wide enough to take a saw blade on its side, was filed at one end. A good hacksaw blade with coarse teeth, about 18 to the inch, was fixed sideways in the frame, laid in the gap, and operated in the usual way, pressing sideways instead of downwards. Slow strokes, plenty of pressure, and a good dose of cutting oil, enabled it to walk through the double thickness of steel rod at an amazing rate. A vertical cut at the end of the horizontal one, released the surplus material. The vice top guided the blade. A round file soon put in the radii between the cut-away portion and the oil box; and rounding off the ends was a kiddy's practice job, needing merely the amount of gumption required for filing to a marked line. All saw marks were removed from the straight parts with a smooth file, and emery-cloth put on the final finish.

If I needed fluted rods, I made a slotting cutter from silver steel of the required diameter, put it in the three-jaw, clamped the rods under the slide-rest and toolholder at lathe centre-height, by aid of packing strips, and set them at right angles to the lathe bed. The rods were fed into cut by turning the top slide handle, and traversed across the slot cutter by the cross-slide. This left semicircular ends to the flutes, but that was only a minor detail which didn't matter a bean. My old *Ayesha*, over 30 years old, has them to this day, and nobody has complained!

The slotted end of the shorter rod is formed by clamping the rod under the slide-rest tool holder, and feeding it up to a ⅛ in. cutter on an arbor in the chuck, in the same way as the slot in the pump ram was formed. The tongue-piece at the end of the longer rod, which fits this slot, is formed by pin-drilling 1/16 in. away at each side of the rod, and filing away the surplus after the pin-drill has formed a recess. The tongue is placed in the slot, and a 15/64 in. or letter C drill put through, followed by a ¼ in. parallel reamer; the inside jaw of the fork is countersunk with a ⅜ in. drill. The pin is turned from ⅜ in. round steel, a simple exercise in plain turning which needs no detailed description. The end is turned down for a full ⅛ in. length, to 5/32 in. diameter, and screwed 5/32 in. × 40; the parallel part can be turned with a chamfering tool, that is, a square-ended tool with the left-hand edge ground off at an angle. Part off at the sloping shoulder. The pin, as in the case of the pump gudgeon pin, should not pinch in the jaws of the fork when the nut is tightened up. You'll have to make the nut from a bit of hexagon rod, or tap out a 4 B.A. commercial nut, as 5/32 in. × 40 nuts are not made commercially.

Before fitting the bushes in the bosses, try the coupling-rods on the wheels. Open out the holes in leading and trailing bosses to 5/16 in. and to ⅜ in. in the driving bosses; put them on the wheels, and see if same will spin freely. If they do, all O.K.; if they bind, turn very carefully, note which pin bears on the side of the hole, and ease the hole with a file until the wheels turn freely. The clearance should be the same at both front and back of the pin. After filing, the holes will, of course, be oval; so measure across the widest part, and put a drill of that size through the holes, to make them round again. The holes can then be opened up to the correct sizes, viz., 7/16 in. leading and trailing and ½ in. driving; the bushes turned from phosphor-bronze or good gunmetal, squeezed in, and reamed in place. The leading boss is pindrilled 1/16 in. full deep, and 9/16 in. full diameter, after the bush is fitted. Finally, drill and counterbore the oil holes. The leading bosses are kept in place by a turned washer (see crankpin drawing), and a countersunk screw; the trailing bosses, by a nut and washer. The connecting-rod big-end looks after the driving boss.

Bogie

The bogie on the full-sized Class 4 engines is the standard type adopted by British Railways, the larger engines having roller-bearing axleboxes, and the smaller engines plain-bearing boxes. Whilst retaining the general characteristics of big sister's bogie for our little edition, I have considerably simplified it, especially in the springing. I am building a small *Britannia*, 3½ in. gauge, and fitted a near-copy of the full-sized standard bogie to her, including the springing; and the job nearly gave the proverbial "pain in the neck"—it certainly tried my patience and skill! I fitted the plate equalisers (four "sets" in each plate, as the equalisers are three different widths when erected), with a 27-leaved spring between each pair of plates; and the time it took to cut the plates, or leaves, assemble the springs, and fit the fiddling little hangers, hanger plates, and cotters, was "just nobody's business"! Hence the simplified arrangement you see in the illustration reproduced here. The channel centre, with the sliding block, is retained, but control springs are omitted, as they would throw the locomotive off the road when traversing the curves of the average club or outdoor line. These are always much sharper, in comparison, than the curves usually encountered on British main lines.

Two pieces of ⅛ in. soft steel, a full 7 in. long and 1¾ in. wide, will be needed for the bogie frames. These are cut in the same way as the engine frames, by marking out one plate, drilling a couple of the end holes, riveting the plates together temporarily, and sawing and filing to outline. The holes for the tie rods at each end are drilled No. 30 and countersunk, and the countersinks will indicate which is the outside of the plate, the horncheeks being riveted to the outside, as shown in the plan.

Bogie Centre

This is another job that my bending brake accomplished very easily, but it can be done quite well, by aid of the bench vice and a bit of ⅞ in. square bar. A piece of 16 gauge soft steel, 1⅞ in. wide and approximately 5 in. long, will be required. At 2 in. from one end, bend the steel at right angles in the bench vice, and at ⅞ in. farther along, make another bend, forming the piece into a channel shape. The bit of ⅞ in. bar should fit nicely between the bent-up ends. Now put the bit of channel between the bench vice jaws, with the bar between; the bottom of the channel should be 13/16 in. below the top of the jaws. Carefully bend each side of the channel outwards, and hammer it down flat on top of the vice jaws. The piece will now look like the side view of the bogie centre, shown in the illustration.

Trim off each end, square with the sides, so that the overall length is 3 in., the channel section being exactly in the middle. In the centre of the bottom of the channel, cut a round-ended slot, 1 in. long and ¼ in. wide, by drilling four or five ¼ in. holes in a row, and running them into a slot, by aid of a round file. The two ends are cut out to ¾ in. radius, as shown; mark off with dividers, and either drill holes all around the marked line, breaking the piece out, or make two diagonal sawcuts or snips, from the edge to the centre part, finishing in either case

Horncheeks

THESE horncheeks are made from ¼ in. by ½ in. angle brass, 1/16 in. thick. If commercial angle of this section is not available, pieces of 1/16 in. sheet brass, ⅞ in. long and ¾ in. wide, can be bent to right angles in the bench vice. Personally I am lucky in this respect, for an American friend who is president of a machine-tool company, sent me some of his products as a free gift, and one was a 12 in. bending brake, with various attachments. This machine converts odd bits of brass into angles, channels, and all sorts of shapes — even miniature corrugated sheet — in two wags of a dog's tail I made the weeny hinges for the tender tool-box of my L.B. & S.C.R. *Grosvenor* by its aid. If you have, or can obtain ½ in. × ½ in. angle, this can be utilised by cutting down one of the angles to ¼ in. Round off the ends as shown, and rivet the pieces to the sides of the axlebox openings, by four 1/16 in. rivets in each, as shown. Don't forget the trick of jamming a piece of bar—in this case 15/16 in. wide—in the opening, and setting the angles close up to it, holding with a toolmaker's cramp whilst drilling the rivet holes. This ensures that the angles, and the edges of the openings, are in line, which is necessary if the axleboxes are to fit properly.

The tie rods are turned from ¼ in. round mild steel. Chuck a length in three-jaw, face the end, and centre it, with a small centre-drill. Turn down about ¼ in. length to a tight fit in the No. 30 countersunk hole in frame. Now pull out about 2½ in. from the chuck, bring up the tailstock, and let the centre-point enter the centre hole in the rod. This will support it whilst you turn down the 5/32 in. part, as shown in the drawing. Part off at 2 1/16 in. from the shoulder. Reverse in chuck, pushing it in far enough to allow the chuck jaws just to grip the little flange; then turn this down to ⅛ in. diameter, so that the distance between the shoulders at each end is 1⅞ in. Face off the pips at each end to a bare 1/16 in. length, then assemble frames as shown, poking the pips through the holes in the frames, riveting tightly into the countersinks, and filing off flush. The two tie rods, if properly fitted, will hold the frames very firmly, and dead in line.

Bogie Centre

This is another job that my bending brake accomplished very easily, but it can be done quite well, by aid of the bench vice and a bit of ⅞ in. square bar. A piece of 16 gauge soft steel, 1⅞ in. wide and approximately 5 in. long, will be required. At 2 in. from one end, bend the steel at right angles in the bench vice, and at ⅞ in. farther along, make another bend, forming the piece into a channel shape. The bit of ⅞ in. bar should fit nicely between the bent-up ends. Now put the bit of channel between the bench vice jaws, with the bar between; the bottom of the channel should be 13/16 in. below the top of the jaws. Carefully bend each side of the channel outwards, and hammer it down flat on top of the vice jaws. The piece will now look like the side view of the bogie centre, shown in the illustration.

Trim off each end, square with the sides, so that the overall length is 3 in., the channel

section being exactly in the middle. In the centre of the bottom of the channel, cut a round-ended slot, 1 in. long and ¼ in. wide, by drilling four or five ¼ in. holes in a row, and running them into a slot, by aid of a round file. The two ends are cut out to ¾ in. radius, as shown; mark off with dividers, and either drill holes all around the marked line, breaking the piece out, or make two diagonal sawcuts or snips, from the edge to the centre part, finishing in either case with a half-round file. Finish off as shown in the plan view. When finished, the centre part should be a fairly tight fit between the bogie side frames.

Side Bearers or Brackets

Instead of a projecting cross stay, this bogie carries separate side bearers or brackets, which are made from ⅞ in. × ⅛ in. angle steel. Two pieces, each 1⅝ in. long, are required, and these are filed to the shape shown in the plan view of the assembled bogie frame. Two holes are drilled, tapped and countersunk in each, for the screws retaining the spiral springs in place. The vertical part of each angle is sawn and filed to fit easily in the channel of the bogie centre, and is reduced to ¾ in. depth by sawing ⅛ in. off the bottom edge. The two brackets are then riveted to the inner sides of the bogie frame. They must be exactly in the middle, and the horizontal part, which is shaped, must bed down tightly on top of each side frame. If the angle is rounded in the V, like a fillet, file the top edge of the bogie frames to match.

Next, place the bogie centre in position, as shown by the dotted lines in the assembly drawing; if this is properly fitted, it will "stay put," whilst being brazed. Put some wet flux all around (Boron compo or similar), heat the lot to bright red, and apply a bit of soft brass to the joints, which will melt and run in, if the heat is sufficient. I did mine, by aid of an oxy-acetylene blowpipe, with 150-litre tip in it, using Sifbronze No. 1 rod, and Sifbronze flux. The job was a jolly sight easier than soft-soldering, and took far less time. The blowpipe flame was gentle "waved" over the bogie centre until the moisture dried out of the flux. The flame was then concentrated on one corner of the bogie centre, where it touched the frame; and as soon as it became red hot (a matter of seconds only), the Sifbronze rod was applied. It immediately melted and flowed in; and all that remained to be done was merely to draw the flame very slowly along the whole run of the joint, applying the Sifbronze rod to it, in the same way that a soldering-iron is run along a joint, and solder applied. The Sifbronze made a lovely clean fillet, and the side brackets also received their share, as the flame passed them.

When the joints are completed, quench out in clean water only, and clean up, knocking off any burnt flux with the end of a file that has seen its best days and retired from its legitimate job. If you knock the end off, the file will do its knocking-off job ever so much better! The guard irons can now be filed up from 3/32 in. steel, bent to the shape shown in the bogie cross section, and attached to the frames by three 8 B.A. screws in each.

Axleboxes and Equalisers

Castings should be available for both the axleboxes and equalisers. Little need be said about the axlebox machining and fitting, for the job is done in the same way as described for the coupled-wheel axleboxes. The bogie axleboxes should be an easy fit in the horns, as they must follow any inequality in the line with perfect freedom otherwise the engine will run off the road. It was a tight bogie axlebox that caused the disastrous train wreck at Stowe Hill Tunnel, near Weedon, some time ago. The morning Liverpool—Euston express was running at high speed when one of the leading bogie axleboxes lifted at a rail joint, and stuck in the horns, keeping the wheel off the rail; the train ran off the road, and went down the bank after it came out of the tunnel. However, don't overdo the freedom business, and make them too sloppy! On the centre line of the top of each box, and 5/16 in. from the outer side, form a recess for the equaliser bearing: this can be done by making a countersink with a 5/16 in. drill, putting a ⅜ in. steel ball in it, and giving it a hearty biff with a hammer. Between the recess and the outside of the box, drill an oil hole, as shown in the section, which the driver can reach by putting the spout of his inseparable companion between the spokes of the wheel. The boxes are retained in place by hornstays made from 1½ in. lengths of ¼ in. × 1/16 in. steel strip, with a No. 40 hole at each end; they are attached by 3/32 in. screws as shown.

The equalisers only need filing up, and the blind holes drilled for the springs. These are 7/16 in. deep, at ¾ in. centres; use 9/32 in. drill. A ⅛ in. or No. 30 hole is drilled at each end of the beam, for the stem of the semi-spherical bearing pad. These are turned from ⅜ in. round steel; or they may be made from ⅜ in. bearing balls ground half away, the remaining half being softened, drilled No. 40, tapped ⅛ in. or 5 B.A., furnished with stems made from ⅛ in. round silver-steel, screwed in and cut to length. The stems should be a tight push fit in the equalisers.

The springs are wound up from 18 gauge tinned steel wire, the outside diameter being an easy fit in the pockets. Touch the ends on a fast-running emery wheel, so that they are square with the coils; the springs should be approximately ⅝ in. long when uncompressed. Put one in each hole, spring the equaliser into place, and put two countersunk screws through the holes in the side bracket, into the springs, as shown in the section. Press one bogie wheel on each axle, poke the axles through the boxes, and press on the other wheels. They should run perfectly free.

A SLIDING block is fitted in the channel in the bogie frame. This may be a casting, or may be made from a block of gunmetal or hard brass, 1¼ in. long, ⅞ in. wide, and ¾ in. deep. In either case it is machined up exactly the same as an axlebox, the block being clamped under the slide-rest tool holder and traversed across an endmill or slot drill held in the three-jaw. Lucky owners of milling machines can hold the block in the machine vice on the miller table, and traverse it under a side-and-face cutter on the arbor; either method should produce perfect rebates. If a casting is clean, and of the correct shape, judicious application of the humble but necessary file will also do the needful. It should fit easily in the channel.

The block could also be built up, no machining being then necessary. The top part would be simply a piece of ⅛ in. brass plate measuring 1¼ in. × ⅞ in. The part fitting the bogie channel would need a piece of ⅝ in. × ⅞ in. brass bar, ⅞ in. long. This can be attached to the top plate by four 3/32 in. countersunk screws, put through clearing holes in the plate, into tapped holes in the block; or the two parts may be silversoldered together. Whether built up, or solid, a 5/16 in. clearing hole is drilled through the lot, for the bogie pin, as shown in the illustrations.

The erection is simple; just put the block in the bogie channel, and see that it is perfectly free to slide from side to side. Then turn the chassis upside down on the bench; put the block over the bogie pin, flange first, place the bogie on top of it, with the block entering the channel, and see that the bogie pin projects through the slot. Move the bogie from side to side, to make sure it is quite free; if O.K. then put a ½ in. brass washer over the projecting end of the pin, and secure the lot with a nut and washer on the screwed end of the pin, as shown in the sectional drawing. The sides of the bolster on the main frames should just bear on the side brackets of the bogie frames when the chassis is right way up. That completes the running gear; next stage will be cylinders.

THE cylinders for the 3½ in. gauge Class 4 engine are of the correct piston-valve pattern, as fitted to the full-sized locomotive, differing only in internal details, for the purpose of simplicity and ease of construction. It would, of course, be possible to follow the detail of the full-sized cylinders exactly; but this would entail more complicated castings, and the machinery and fitting would be much more difficult; also—last, but decidedly not least!—they would not be as efficient as those shown. A famous locomotive engineer, now retired, who has designed some of the most successful engines ever put on British metals, said in my own workshop that a slavish copy of a full-sized engine would never be as satisfactory as a similar one *designed for the gauge of rails it runs on, and the work it has to do.* That is exactly the gospel your humble servant has been preaching and practising for the past 30 years and more. There is also the "wise man of the club," who says that small piston valves are no good, and recommends slide valves. Well, that is all he knows—he probably has never made a pair of piston-valve cylinders in his life, even if he has made any cylinders at all! The fact is, that piston-valve cylinders are easier to make than the slide-valve type. They are merely a plain boring and turning job; there are no flat portfaces to machine, no ports to cut in same, no steam chest and cover joints with an array of studs, and no spindle-glands to leak or blow. Personally I can make a pair of piston-valve cylinders in less time than a similar-sized pair of slide-valve cylinders. As to efficiency, the quick admission and free exhaust, which is a feature of piston-valves (which is one reason why they are used in full-size practice) licks slide-valves into the proverbial cocked hat. As to being liable to wear, and develop leakage, my 18-year-old 2½ in. gauge L.M.S. Pacific *Fernanda* has piston-valves. She is one of the most efficient engines in my whole fleet, and the valves are as steamtight now as the day they were put in, due to correct lubrication. The mechanical lubricator ensures that a film of oil is always maintained between valve and liner. The Class 4's cylinders will be the same, so now to construction.

How to Machine the Cylinder Castings

First check off the core holes and see if they are in approximately the correct position. If so, no marking-out will be required. If not, smooth off one end of the casting with a file, plug the larger corehole with a piece of wood, mark the centre of bore in the correct position on the wood, and scribe a circle from it, 1⅛ in. diameter, with a pair of dividers, on the cleaned-up end of the casting. On the usual home-workshop lathe of 3½ in. centres or over, the easiest way to bore the cylinders is to mount them on an angleplate attached to the faceplate, using an ordinary boring tool in the slide-rest. This is run through by aid of the self-acting feed, in the case of a screw-cutting lathe, or by feeding through with the top slide of a plain lathe. In the latter case, the top slide must first be checked for accurate setting, so that it bores a parallel hole; a taper one, however slight, would naturally be useless.

Put a piece of round rod, say about ¾ in. diameter, in the chuck, and a round-nose tool in the slide-rest. Take a fine cut along the rod, for a length of about 2½ ins. and test diameter at both ends of the cut with a micrometer or a pair of calipers. If there is only half-a-thousandth of an inch difference, registered on the "mike," or if you cannot detect any appreciable difference in the feel of the calipers at either end, the top slide is set O.K.

IF there should be a difference, adjust the slide, take another cut, and test again, until you get the desired result. Once you get it right, don't alter it, for a true setting is needed to turn the outside of the piston-valve liners and the valves themselves.

Bolt a small angleplate to the faceplate. Clean up the bolting face of the cylinder casting with a file, lay it bolting face downwards on the angleplate, and secure with a bar across its back, held down with a bolt at each end. Before tightening the nuts, make sure that the casting is at right angles to the faceplate, checking with a try-square, stock to faceplate and blade to cylinder. Let the casting overhang the edge of the angleplate a little. Then adjust the angleplate on the faceplate, until the corehole, or the marked circle as the case may be, runs truly. Running up the tailstock with a centre in it, will assist in setting a corehole to run truly. A small scribing block, stood on the lathe bed, with its needle applied to the marked circle will indicate at once which way and how much a marked-circle casting needs adjustment for true running.

Measure the overall length of the casting, and subtract 2 7/16 in. from it. Half the difference is the correct amount to face off the overhanging end of the casting, with a roundnose tool set crosswise in the rest. Then put an ordinary boring tool in the siderest, taking care that it is set high enough to prevent it rubbing below the cutting edge, and take a good deep cut through the corehole to clean out scale and any traces of moulding sand. If the lathe is a good stiff one, a coarse feed may be used. If you have a 1⅛ in. parallel reamer, continue boring with successive cuts until the "lead" end of the reamer just enters, leaving only a scraping to come out. If you haven't a reamer, bore to 1⅛ in. diameter, and take a couple of final cuts through, at a fine rate of feed, without shifting the cross slide handle. This should give an excellent finish.

If the coreholes were accurately spaced on the casting, slacken the bolts holding the anglepate to faceplate, shift the angleplate until the smaller corehole runs truly, tighten bolts, and "ditto repeato" the boring job as described above, finishing to ⅞ in. diameter. If the coreholes were "out," mark the correct position of the bore for the liner, on the machined end of the cylinder, *without moving same from the faceplate.* Unscrew the faceplate from the lathe mandrel, lay the whole bag of tricks on the bench, mark the circle as mentioned previously, replace the faceplate on mandrel, then slacken the angleplate, adjust until the circle runs truly, re-tighten angleplate, and bore as above.

The opposite end of the cylinder is machined off with the casting mounted on a stub mandrel held in the chuck; this is just a piece of brass rod, turned down to such a size that the cylinder can be driven tightly on to it. Remember, however, that there is a medium in all things, and don't drive the cylinder on tightly enough to damage the bore!

The hole through the mandrel of a small lathe will not allow of a 1⅛ in. bore cylinder being reamed by operating the reamer from the tailstock centre, so reaming can be done by hand, with the cylinder in the bench vice. Put a big tapwrench on the reamer shank, and feed it gently through the cylinder, turning slowly and pushing forward at the same time. If the cutting edges of the reamer are rubbed with an oilstone, to smooth off any nick, or anything that might scratch the bore, it ensures a good finish; a drop of cutting oil also helps to that end. The bore for the steamchest liner need not be reamed, if the hole is fairly smooth and parallel. File a small bevel, about ⅜ in. long, at the edge of each end of the bore, just underneath the liner hole. From this, drill three 3/32 in. holes at an angle of 45 degrees, into the liner hole, and run them into a slot with a small rat-tail file. The resulting steamways are shown in the longitudinal section of cylinder.

To machine the bolting face, up-end the casting on the angleplate, and secure with a bolt through the larger bore, with a big soft-metal washer at top and bottom, to protect the turned ends. Set the bolting face at right angles to the lathe bed, by applying the blade of a try square to it, the stock resting against the top slide. Adjust angleplate, so that the casting runs as centrally as possible; then face off with a roundnose tool, until the distance between the bolting face and the edge of the larger bore is 7/16 in.

Covers and Pistons

The front cover is a plain turning job. Chuck by spigot provided, face off, turn register to fit nicely in the cylinder bore, face flange, and turn rim to 1⅝ in. diameter. Saw or part off the chucking-spigot, reverse in chuck, holding either by the edge direct, or in an improvised step-chuck, and face off the outside. Repeat operation for back covers; but this time centre and drill right through with 7/32 in. or No. 2 drill. After reversing in chuck, face off boss and outside of cover; turn boss to size—this is circular, as the guide bars are not attached to the cyinders on this engine—open out to 5/16 in. depth with a pindrill 11/32 in. bore diameter, and tap ⅜ in. × 32, guiding the tap by aid of the tailstock chuck. The gland is turned from ½ in. round bronze rod held in three-jaw. Face, centre, and drill down for ½ in. depth with No. 4 drill; turn down ¼ in. of the outside to ⅜ in. diameter, and screw ⅜ in. × 32. Part off at a full ⅛ in. from the shoulder, reverse in chuck, and take a slight skim off the face, then run a 7/32 in. parallel reamer through it.

THE C-spanner slots can either be milled, or filed with a thin flat file as used by clockmakers. The thread should not be slack in the stuffing-box, or the gland may work out when the engine is running, with disastrous results to the crosshead.

The screwholes should be drilled by aid of a jig. This is merely a steel washer the same size as the cylinder covers, with a hole in it same size as the cylinder bore. Set out and drill the eight No. 34 screwholes in the washer, as shown in the end view of the cylinder; then all you have to do is to place the washer over the register of each cover and poke the No. 34 drill through the lot. Each cover is used as a jig, to drill and tap the holes in the cylinder flanges. Put it in place, hold it there with toolmaker's cramp, or by any other means you fancy; run the No. 34 drill through the holes, making countersinks on the flange. Remove cover, drill the countersinks No. 44, and tap 6 B.A. Put a centre dot against the hole nearest the bolting face, and mark on the register which end of which cylinder the covers belong to, then there will be no trouble when assembling.

The holes for the drain cocks are drilled right at the bottom of the flanges, as shown in the section. Use 5/32 in. drill, and tap 3/16 in. × 40. From the end of each tapped hole, drill a 1/16 in. hole into the cylinder bore, as close to the cover as possible. Scrape off any burr in the bore very carefully with a small scraper, or put the reamer through.

For the piston-rods, cut two 3 9/16 in. lengths of 7/32 in. rustless steel or drawn bronze (nickel or phosphor), chuck in three-jaw, and put ¼ in. of 7/32 in. × 40 threads on one end. Both ends should be squared off in the lathe.

Our advertisers may supply castings for the pistons, or they may be turned from 1¼ in. round rod. Drawn bronze, good gunmetal, rustless steel, or dural are all suitable. If castings are used, they will have a chucking-piece to hold in the three-jaw. Face the end, centre, drill through with 3/16 in. drill, turn the outside to 1/64 in. over finished size, and form a groove with a parting tool, ¼ in. wide, ¼ in. deep, at ⅛ in. from the end. Reverse in chuck, face off to bring the overall thickness to ½ in., open the centre hole to ¼ in. depth with No. 3 drill, and tap the remainder 7/32 in. × 40. Put a piston-rod, threaded end outward, in the tailstock chuck, run it up to the piston, enter it, and pull the lathe belt by hand until the rod is screwed right home. The rods can then be gripped either in a collet chuck, or a truly-bored split bush held in three-jaw, and very carefully turned to an exact sliding fit in the cylinder bore. Some folk don't trouble about a close piston fit, believing that the packing does the needful. It may be so for a few runs, but then very rapidly disintegrates. In the course of my experience, doing overhaul jobs for friends, I have found instances of pistons fitted so loosely that every bit of packing has blown away, leaving no evidence that the pistons ever had any packing on them at all. Conversely, I have just repacked the pistons of one of my own locomotives, after eighteen years' hard work. The old packing was just worn where it rubbed on the cylinder bore; it had not disintegrated. Pistons properly fitted don't need the packing rammed hard in the grooves; they should be steamtight without being mechanically tight.

If rod material is used for the pistons, chuck a piece in three-jaw, and turn down about 1¼ in. length to 1/64 in. over finished size. Face the end, centre, and drill down about 9/16 in. depth with 3/16 in. drill. At ⅛ in. from the end, cut the ¼ in. groove as above, and part off at ½ in. from the end. Repeat operation, then finish the two blanks and fit to rods, exactly as described above.

THE steam chest liners can be made from castings or 1 in. bronze rod. The last pair I made were turned from a broken piece of the bronze propeller-shaft of a small steam-boat (Father Neptune takes to the rails!) and very good metal it proved to be. If castings are used, chuck in three-jaw, face the end, and bore in the same manner as a cylinder casting until the "lead" end of a ⅝ in. parallel reamer will just enter. If the castings are solid, or if rod material is used, centre deeply, drill through about ⅜ in., and open out with 39/64 in. drill. The back centre can be used to support the liner when turning the outside to a press fit in the cylinder, or the liner can be mounted between the lathe centres. Castings should be long enough to allow for gripping the end in the chuck, or mounting the carrier on it.

Beginners and inexperienced workers—*and* some experienced ones, too!—are scared of the idea of turning the liners to a press fit; yet it is so easy that a kiddie could do it. Everything is easy *when you know how*! In the present case, all you have to do is to turn one end of the liner for about ⅛ in. length to such a size that it will just push tightly by hand into the smaller bore in the cylinder casting. Then turn the cross-slide handle back one turn, noting either the reading of the "mike" collar, if the slide rest has one, or the position of the handle if no "mike" collar is provided, before you turn backwards. Now turn it forward again, until the "mike" collar is within half-a-division of the original reading, or the handle almost, but not quite, in the position that it was before. If the finishing cut over the liner is taken with the cross-slide at that setting, it will be an exact press fit in the hole in the cylinder casting. The liner can then be squared off at the ends, to exact length, leaving just enough of the reduced end to allow the liner to be started fair and square, when pressing into the cylinder.

Mark out the position of the steam ports as shown in the illustration. Hold the liner in the three-jaw, with about half of it projecting, and cut a groove ⅛ in. wide and a full 1/32 in. deep, with a parting tool, at the location of each port. The distance between the outside edges of the grooves must be exactly 1½ in., and the inner edges 1¼ in. Now mill or file away the metal at the bottom of the grooves, for a depth of 7/32 in. at opposite sides, as shown in the cross section, leaving 7/16 in. of metal at either side. This operation cuts into the liner bore, and forms the actual ports. Next file away the metal on the outside, at the bottom edge, for 1/16 in. depth and ⅜ in. length, which forms the steam ways between port and cylinder bore. The liners may then be pressed home, making certain that they are inserted so that the filed-away part just mentioned, connects with the passage at each end of the cylinder, as shown in the longitudinal section. If the vice jaws will open wide enough, the vice may be used to squeeze the liners home; a useful tip to remember is that an extra inch or more can usually be obtained by taking out the steel insets in the vice jaws. Failing that, the ancient fitter's method can be used. Start the liner in the bore, by pushing in the little bit at the end already mentioned; then put a long bolt through the lot, with a thick washer of soft metal at each end. Hold the bolt head in the vice, screw down the nut with a long-handled spanner, and the liner will easily be pulled into the cylinder. A bush about 1 in. diameter is placed over the end of the liner, to give the washer something to bear against, as the liner comes through; it projects ½ in. at each end.

Put a 5/32 in. endmill or slot drill through the cylinder casting at both ends of the exhaust recess, and mill right through into the liner bore, or else drill holes and run them into a slot with a rat-tail file. Drill the 7/32 in. steam entrance at the top, and finally put a ⅝ in. parallel reamer through the liner, using the method described for the cylinder.

The covers at each end of the liner can be turned from castings, or ⅞ in. rod. Chuck in three-jaw and turn down ⅜ in. to a tight push fit in the end of the liner. The front cover is finished off flush, drilled 5/32 in. and tapped 3/16 in. × 40 for a plug made from ¼ in. hexagon brass rod as shown, a simple turning job needing no description. The back cover has a 3/16 in. boss, ⅝ in. diameter, turned on it, and is drilled No. 14 and reamed 3/16 in. for the valve spindle. No gland is required, as there is only exhaust pressure to withstand, and there is no loss of efficiency if a slight leakage should occur on the exhaust side. When the cylinders are finally assembled, a couple of 3/32 in. or 7 B.A. screws will keep the covers from coming out of their own accord; see longitudinal section.

Piston-Valves

A piece of ⅝ in. ground rustless steel should be an exact sliding fit in the liner, and no turning of the bobbins on the piston-valves should be necessary; but if not available, the valves can be turned from drawn phosphor-bronze rod held in the chuck. In the first case, chuck the piece of rustless steel, face the end, centre, drill 7/32 in. to a depth of 1⅝ in., and at 1½ in. from the end make a groove about 1/16 in. deep with a parting tool. Turn down the centre part to ⅜ in. diameter, leaving a full 7/32 in. of the rod the full diameter at each end; then part off, rechuck, and take a very fine truing-up skim off the end. The overall length of the valve should be 1/64 in. under 1½ in., giving a shade of exhaust clearance. If phosphor-bronze rod is used, turn down 1⅝ in. length to a shade over ⅝ in. diameter, then turn the valve as above; but before parting off, skim down the outside of the bobbins until they are an exact sliding fit in the liner, then finish as above.

THE valve spindles are simply 3⅝ in. lengths of 3/16 in. rustless steel rod, with 2⅛ in. of 3/16 x 40 thread on one end, and 3/16 in. on the other, put on with the rod in the three-jaw chuck, and the die in the tailstock holder. The valves are located and held on the spindle by locknuts at each end. They can be made from 5/16 in. hexagon bronze rod, as ordinary commercial nuts are not made in this pitch.

Put a valve on each spindle, and secure temporarily with the locknuts; the exact position cannot be ascertained until the valve gear is up. Put the valves in the steam-chest liner, and put the covers on, no jointing being necessary. The pistons are packed with a ring of ¼ in. square braided graphited yarn, the ends being cut off at an angle, and butted together like a metal piston-ring. The packing should fit the grooves just tightly enough to allow the piston to be inserted in the cylinder by aid of a little judicious prodding; they should not fit tightly enough to require considerable effort to move them up and down. The gaskets between cylinder casting and covers may be made with 1/64 in. Hallite, or any similar good make of jointing; or stout brown paper coated with cylinder oil may be used instead. The holes in the bolting face are not drilled and tapped until the cylinders are ready for erection.

Guide Bars and Brackets

The guide bars on this engine are of the three-bar Laird pattern, a type specially suited to locomotives which always run chimney first when hauling a "service" passenger train. For the benefit of the uninitiated, I might here state that when a locomotive is running forward—that is with the chimney leading — the crossheads always bear on the upper guide bars. When running backward, with tender or bunker leading, the lower guide bars take the strain. When the crank is on top centre, going ahead, the tendency is for the piston-rod and connecting rod to pull out into a straight line, and only the top bar holding down the crosshead, prevents it. When on bottom centre, the piston rod is pushing at the connecting rod, and they would double up like a pocket-knife if the top bar didn't hold down the crosshead and prevent it. When going backwards, the push is on the top centre, and the pull on the bottom centre; just the reverse to the above, and it is the bottom bar which prevents the crosshead straying from the straight and narrow path. From that, one can easily understand why, in a locomotive which always does its hard work with the chimney leading, it is advantageous to provide all the bearing surface possible in the top bars. In the type fitted to the "class 4" and other standard British Railways tender engines, the top bar is a solid slab of metal as wide as the crosshead, with half as much again in the way of bearing surface, as the combined area of both bottom bars. Discerning readers will probably have noticed that this type of guide bar is not fitted to the standard tank engines, which have to run in either direction; they are provided with a single bar above and below the "alligator" type of crosshead, both bars giving equal bearing surface.

THE top bar on the little "class 4" is made from a 3½ in. length of mild steel bar ½ in. wide and 5/32 in. thick, reduced to ⅛ in. at the ends, by milling or filing. The bottom bars are made from 3½ in. lengths of 3/16 in. × 5/32 in. section, the extra depth compensating in a small way for the much lesser width. A distance-piece, 3/16 in. wide, ⅛ in. thick, and ½ in. long, is placed at both ends to keep the bars at the correct spacing. After bevelling off the bottom bars, make a centre-pop at each end, on the bevelled side, as shown in the illustration; it should be 3/32 in. from the end. Drill the holes No. 48, and file off any burr. Now assemble the bars as shown, with a distance-piece at each end of the top bar, and the two bottom bars with their sides parallel to the edges of the top bar, leaving a space 9/16 in. wide between them. This is easily done if the whole bag of tricks is turned upside down. Put a toolmaker's cramp in the middle, to hold the lot firmly together, and then run the No. 48 drill through distance-pieces and top bar. Remove cramp, tap the holes in the bottom bars 3/32 in. or 7 B.A., open out the holes in distance-pieces and top bar with No. 41 drill, and pin-drill the ends to form a flat seating for each of the screwheads. The bars can then be temporarily assembled as shown; you can't make a permanent job until the crossheads are made and erected, as the bars have to be taken apart to get the crossheads in place. The bars are the same on both sides of the engine.

The brackets are made either from castings, or 1¼ in. × ⅛ in. angle. Castings will only need cleaning up on the outside of the angle, and drilling for the screwholes, as shown in the illustration. If a milling machine is available they could be held in a machine-vice on the table, and the outsides of the angles machined off with a small slabbing cutter on the arbor. They could also be clamped to an angleplate on the faceplate of a lathe, and faced off with a roundnosed tool set crosswise in the slide-rest; but if the castings are reasonably clean, all that would be needed is just to rub the contact faces on a wide smooth file laid on the bench.

If angle brass or steel is used, each will need a piece a little over 1½ in. long, so as to allow the ends and upper edge to be filed sufficiently to bring the lower edge to the amount of slant shown in the drawing. The ribs could be filed up from ⅛ in. plate or sheet metal, and silversoldered in place, leaving a small fillet in each corner, so that the result looks like a casting. Don't attack the guide bars yet, to either pattern of bracket.

Crossheads

THE crossheads may either be built up from steel, or the nickel-bronze castings sold by approved advertisers for *Britannia* may be used, as they are exactly similar. Three pieces are necessary for a built-up crosshead; the body, slipper or shoe, and drop arm. The shoe is made from 7/16 × ½ in. mild steel bar, or ½ in sq., if the former is not available. Both can be milled at once, if a piece of bar about 2⅛ in. long is used. First mill out a groove 7/32 in. wide and 5/32 in. deep, at ⅛ in. from one of the wider sides; if a regular milling machine isn't available, clamp the piece of bar under the slide-rest toolholder, packed up to correct height and at right angles to the lathe bed, and traverse it across a 7/32 in. endmill, or a home-made slot drill held in the three-jaw. I much prefer home-made slot drills, they remove the metal ever so much quicker, and are easily made from round silver-steel of required diameter. I have given instruction on how to make them when describing other engines in this series. The milling leaves a 3/16 in. web in the centre, leaving the piece looking like an I-section girder. Reduce the thickness of the metal below the web, to 1/16 in., either by milling as above, or filing, and then reduce the width to a full ¼ in. Leave it plenty wide, to allow for fitting tightly to the body when made. Saw the piece in half, and file the ends to length and shape shown.

The shoes can also be built up separately, no milling being required in that case. The top is a 1 in. length of ½ in. × ⅛ in. steel; the web, a 1 in. length of 7/32 in. × 3/16 in. steel, and the bottom part, a 9/16 in. length of 1/16 in. × ¼ in. steel. The three pieces are assembled in the form of an I as shown, held together with a toolmaker's cramp, and a No 51 hole drilled through the lot. A 1/16 in. iron rivet, or a piece of 1/16 in. steel wire, is then put through, and the ends riveted over, to keep the bits together whilst brazing the joints. Smear some wet flux along the joints, heat to bright red with a blowlamp or blowpipe, and touch the joints with a bit of thin soft brass wire. Don't melt too much in, as it only has to be filed away again when cleaning up.

The crosshead body is made from ½ in. × ¾ in. mild steel. Take a piece about 2½ in. long, or longer if you like, and first slot out each end to ¼ in. width and ⅝ in. depth.

THE crosshead ends can easily be slotted on a milling machine by putting the piece of bar in the machine vice on the table and operating with a ¼ in. side-and-face cutter on the arbor; and this process can be imitated in the lathe by gripping the bar under the slide-rest tool holder and running it up to a ¼ in. saw-type cutter on a spindle held in the chuck, or between centres. The bar could also be slotted by traversing it across a ¼ in. endmill or slot drill held in the three-jaw, but it would require a lot of cuts to get out the ⅝ in.

depth. A 7/32 in. hole could be drilled through the thickness of the metal, at ½ in. from the end, and sawcuts made down to it, the resulting gap being finished to size by filing, but I would only recommend this as a last resort when no machining facilities are available.

Saw off each slotted end to 1¼ in. length. Chuck truly in four-jaw, blank end outward, and turn the bosses to the shape shown; centre, drill right through into the slotted part with No. 44 drill, and ream 7/32 in. The slotted part is then filed to the shape shown and cross-drilled with No. 14 drill. The drop arm is filed up from ⅛ in. × ½ in. steel to shape and size shown, the upper hole being drilled No. 14, and the lower 3/16 in. Temporarily clamp it to the body, using the shank of the No. 14 drill to line up the holes. Drill a No. 48 hole through the drop arm and crosshead side, tap 3/32 in. or 7 B.A., and screw in a stub of steel wire or an ordinary screw; the head can be cut off afterwards. This will keep the arm in place whilst being brazed. Fit the shoe into the top of the body as shown in the cross section, the bottom of the groove being flush with the flat top of the crosshead body. Braze the joints, by same process as mentioned above for a built-up shoe; quench in cold water and clean up, taking care to get all traces of superfluous brass out of the grooves. Poke a 3/16 in. parallel reamer through the cross-hole, and fit a bronze bush into the hole at the bottom of the drop arm, reaming it ⅛ in. Don't forget that you will need one right-hand crosshead, and one left-hand when you are attaching the drop arms—mistakes are easily made!

The crosshead pin is a plain turning job; just chuck a bit of 5/16 in. round steel in three-jaw, and turn a base 13/16 in. length to 3/16 in. diameter, a nice sliding fit without shake, in the hole in the crosshead. Turn down enough of the end, to ⅛ in. diameter, to leave a bare ⅝ in. in length of the 3/16 in. part, and screw the reduced end ⅛ in. or 5 B.A. Part off to leave a head 3/32 in. thick. The pin could also be made from 3/16 in. silver steel, turning the screwed end as shown, reducing the other end to ⅛ in. also, and putting a " button " on it 5/16 in. diameter and 3/32 in. thick, with a ⅛ in. countersunk hole in the button. Rivet over the projecting end and, after putting the button on, file flush.

How to assemble and erect guide bars and brackets

This is a game of trial-and-error, but it ensures sweet working of the parts. First press the crosshead on to the piston-rod, so that about 5/16 in. of the rod enters the boss. Take the guide bars apart, put the big slab on top of the crosshead, the small bars in the grooves at each side, insert the end distance-pieces, and put the screws in. If, when the screws are tightened, the crosshead won't slip freely up and down between the bars, ease the crosshead grooves a little, or thin the top slightly, as the case may be. Put the crosshead in the middle of its travel, and then set the guide bars on it, so that they are exactly ⅝ in. from the back end of the cylinder, as shown in the elevation drawing of the assembled gear.

Next, put the guide bar bracket in place, resting it on the bars so that the front end of it is 1⅛ in. from the front ends of the bars; see plan view. The vertical flange should be in close contact with the frame; put a toolmakers' cramp over the flange and frame, and tighten it up, so that the bracket cannot shift. Put the No. 41 drill through two of the holes, one at each end, and make countersinks on the frame. Follow up with No. 48, drilling through frame; tap 3/32 in. or 7 B.A., and put a couple of screws in tightly. The cramp can then be removed. Now, taking great care to avoid moving the guide bars endwise, and making quite certain they are parallel to the frame (test with inside calipers at each end), run the No. 34 drill through the end holes, and make countersinks on the top guide bar. Drill these out with No. 44 drill, tap 6 B.A., and file off any burring under the bar. It will be best to remove the bar whilst doing the drilling and tapping.

REPLACE the bar and secure with a couple of screws, which must not project under it. The four screws will hold the bar and bracket in position, tightly enough to check if the erection is perfectly accurate. If it is, it should be possible to move the crosshead up and down, still on the end of the piston rod, without any sign of the crosshead binding or running hard at any part of the movement. If there should be a tight place, locate and ease it before going further with the job. If the bars are slightly out of alignment—the best of fitters occasionally make a slip, there is no disgrace in it!—the screwholes in the bracket can be slightly eased, and the necessary adjustment made to bracket or bars, as the case may be. When all is O.K. and the crosshead slides easily from end to end, locate, drill, and tap the rest of the holes in frame and bars, using those in the bracket for a guide, and put the screws in.

Connecting Rods

The connecting rods are made in a manner similar to the coupling rods, but are an easier job, as there is no joint. Each needs a piece of mild steel bar approximately 8¾ in. long, ⅞ in. wide, and ¼ in. thick. Mark off the outline of the rod on one of the bars, drill 3/16 in. holes at the bush centres, and use the rod as a jig to drill similar holes in the unmarked piece. Drive bits of 3/16 in. round steel into the holes, to act as rivets to hold them together, and then mill, or saw and file to the given outline, exactly as described for the coupling rods. There will be a little difference in setting up, as the connecting rods are tapered, but the adjustment is easy. All I do, is to put the pieces of rod in the vice on the table of my milling machine, and instead of setting them exactly horizontal, like the coupling rods, one end is set a wee bit higher than the other, by aid of a scribing block or surface gauge. The needle of this is set to the upper marked-out line of the rod, at one end; and the other end of the marked line, near the boss at the end of the rod, is then set to the same height, and the machine vice well tightened up. This leaves the pieces of rod slightly sloping from one end to the other. The job is done with a small slabbing cutter on the spindle; this is 1 in. dia. and 1½ in. long, and cost a shilling at Buck & Ryan's as "government surplus" at the end of the Kaiser's war. It has milled scores of coupling and connecting rods, and is as good as ever. I wonder what a new replacement would cost nowadays! The table is adjusted until the cutter takes a "bite", and then eased up still further until the cutter has "bitten" down to the marked line. The self-acting feed is then engaged, and I can get on with another job whilst the machine slowly chaws away the surplus metal. Cutting oil is supplied from a can hung on the overhead arm, via a cock and ⅛ in. pipe arranged to let the oil drip on to the cutter.

As the machine-vice on my milling machine has only 4 in. jaws and the long rods overhang, each end is supported either by packing or by weeny screw bottle-jacks, which are merely hexagon-headed screws in conical brass sockets, and were made in a few minutes from odd bits of scrap metal.

Support is also needed at the ends of the rod, when reducing the thickness to the dimension shown in the plan view. For this I use a piece of 1 in. square steel bar about 9 in. long. The rod to be milled is screwed down to this by ordinary setscrews through the holes in the bosses, and the bar clamped in the machine vice. The 1 in. bar supports the coupling or connecting-rod quite easily, holding it perfectly rigid against the cut without any extra support at the ends where it overhangs the vice jaws.

The ends of the connecting-rods are formed in the same way as those on the coupling-rods, and the bushes are turned from bronze rod and squeezed in, using the bench vice for a press. Ream after pressing to counteract distortion. To erect the rods, slip the big end over the driving-wheel crankpin, put the little end in the crosshead jaws, and put the crosshead pin through. Put the crank on front-dead centre. As the crosshead isn't adjusted on the piston rod the piston will hit the cover and force the piston-rod a little more into the crosshead boss. Take off the front cylinder cover, carefully drive another 1/32 in. of piston-rod into the crosshead, then drill a No. 43 hole through crosshead boss and piston-rod, and squeeze in a pin made from 3/32 in. silver-steel. Next stage, valve gear.

ON previous engines described in this series, we haven't done any plumbing work until the whole of the cylinders and motion have been erected; but in the present case, if the exhaust pipe assembly is fitted before the cylinders are erected " for keeps," it will be an advantage, as the heads of the screws holding the exhaust flanges, are covered by the cylinder bolting face. The exhaust pipe assembly is made up as a complete unit, which fits between the frames, and is attached to them by two oval flanges, opposite the large holes in the frames, which in turn line up with the exhaust cavities in the cylinders. Thus the exhaust pipes are not attached to the cylinders in any way whatever; and if the cylinders should have to be taken down at any time, they are freed of pipe connections, by removing the screws in the steam pipe flanges, which will be described later.

The usual cross pipe between the cylinders is replaced, in the present instance, by a " streamlined " connection of the breeches pattern, and this is easy enough to make. First form the bends from 5/16 in. copper pipe of about 22 gauge, or a little thicker would not matter. If you soften the ends of a piece of tube, anything over, say, 6 in. long, put a piece of rod into one end for about ½ in., and grip the other end of the rod in the bench vice, the tube can be bent to the requisite curve, by merely pulling over the end, using a little care and discretion. Although I have a " Diacro " rod, tube and channel bender, I usually bend small pipes with my fingers only, and there is no fear of kinking! An alternative way would be to put a grooved pulley in the vice, about 1½ in. diameter, and bend the pipe into the groove, holding pipe in one hand and the rod in the other. When you have the bends O.K. cut them to length, and file away the upper ends until, when placed together as shown, the top of the joint is a circle 5/16 in. diameter, same as a single pipe.

Put a piece of 3/8 in x 20 gauge tube in the three-jaw chuck, square off the end, and put about 3/16 in. of 3/8 in. x 40 thread on it. Part off at 7/8 in. from the end, scrape out any burr left by the parting tool, and put the plain end over the joint formed by the two bends. The flanges may then be fitted; these are simple jobs needing no detailed description. They are sawn and filed from 1/8 in. brass plate, to shape and dimensions shown in the detail illustration. The large hole in each is slightly countersunk, and this end goes on the pipe first. Warning—*don't drill the screwholes before attaching the flanges to the pipe;* these are located from the holes in the frame when erecting. Adjust the flanges on the ends of the pipe bends, so that the distance between the outer faces is 2 7/8 in. full. If any pipe projects beyond the flanges, leave it until the flanges have been silversoldered on, and the projections may then be filed flush. To silversolder, simply cover the joints with a paste made from Boron compo, or powdered borax, mixed with a little water; heat to medium red, by aid of a small blowlamp or blowpipe, and touch each joint with a strip of best grade silversolder, which will immediately melt and flow into the joint. Let cool to black, quench in acid pickle (one part of commercial sulphuric acid added to about sixteen of water) wash off in clean water, and clean up. The silversolder should fill the countersinks in the flanges, and form a neat fillet around the pipes. Any pipe which projects beyond the flanges can then be smoothed off.

At 7/16 in. on each side of the centre of the exhaust hole in the frames, drill a No. 30 hole, and countersink it. File off any burring; then place the exhaust pipe assembly in the position shown between the frames. Run the No. 30 drill through the holes in frames, and carry on right through the exhaust flanges; then secure with 1/8 in. or 5 B.A. countersunk screws and nuts. If frame and flanges are quite smooth, no joint is needed between them, as there is only exhaust pressure to withstand; but if slightly roughened, either smear the flanges with plumber's jointing (Boss White or any similar preparation), or put a 1/64 in. Hallite gasket between. The copper pipes will be found flexible enough to allow for any small adjustment needed to ensure good contact.

Cylinder Erection

The accompanying illustration shows the exact location in which to erect the cylinders. Put one in the position shown, the front edge of the casting—not the cover—being 3 9/16 in. from the front edge of the frame, at that point on the casting which is level with the centre of cylinder bore. Tilt the cylinder as shown, and put a big cramp over it and the frame, to hold it temporarily in position. These cramps can easily be home-made in any size, merely consisting of a couple of pieces of bar, and two long screws. I have given instructions how to make them in previous instalments of various other locomotives, and it is only a matter of a few minutes' work to make one, for the job in hand. If the guide bars, crosshead and connecting-rod have already been erected according to the drawing previously shown, pull out the piston-rod and see that it enters the crosshead boss truly. If it doesn't, slight adjustment of the angle of the cylinder will be needed. The correct location is when the wheels can be turned, and the crosshead moves up and down the guide bar, taking the piston-rod with it, the whole movement being quite free, and having no tight place anywhere in the full length of the stroke.

The holes in the bolting-face of the cylinder can then be located, as shown in the

Bantam Cock serial. A No. 30 drill at least 3¾ in. long, will be needed. These are made commercially (I have one) but there is no need to go to the expense of purchasing one. File a step on the shank of an ordinary No. 30 drill, file a similar step on a bit of ⅛ in. silver-steel of suitable length, and braze the bits together, filing off any superfluous brazing material, to enable the brazed joint to go through the holes in the frame.

FOR these "spotting" jobs on cylinder erection a broken tip off a No. 3 drill if only ¼ in. long can be used, by butting it against the end of a piece of ⅛ in. silver-steel, and brazing the joint, or a 3¾ in. length of ⅛ in. silver-steel could have an arrowhead filed on one end, and backed off like the old-fashioned "diamond" drills. Harden and temper the arrowhead, to a dark yellow. Anyway, whatever kind of long drill you have, put it in a handbrace, poke it through *both* holes in frame and make countersinks on the bolting face of the cylinder. Remove, drill the countersinks with No. 40 drill, to about 5/16 in. full depth, and tap ⅛ in. or 5 B.A. Repeat operations on the other cylinder, then attach cylinders to frame with ½ in. studs and nuts, or ⅜ in. hexagon-headed setscrews, whichever you prefer.

If the guide-bars and crossheads haven't already been erected, do this job now; the location was given in the illustration showing the whole lot assembled. Push the piston-rod right home, put crank on front dead centre, so that the crosshead boss goes over the piston-rod. Advance piston-rod into crosshead another 1/32 in., and drill a No. 43 hole through boss and rod, squeezing in a bit of 3/32 in. silver-steel, to act as a crosshead cotter. When the wheels are turned by hand, the whole movement should be easy; if there is a tight place, correct it before proceeding further.

Left-hand Motion Bracket

Now we come to a tricky job. The motion brackets on the B.R. standard engines of classes 7 to 4, are built up by welding, and are complicated boxes of tricks. It is a puzzle to your humble servant, why this design was adopted, in view of the fact that the B.R. locomotive engineers say that the designs are as simple as possible, consistent with efficiency. I could—indeed have already—designed a much simpler arrangement. However, we are copying full-size practice as far as it can be adapted to 3½ in. gauge; and the accompanying illustrations show the standard B.R. bracket in a form suitable for the small engine.

There is a further complication; on most locomotives, the brackets are of the same pattern on both sides of the engine, being merely made right and left-handed; but that wouldn't do for B.R.! The left-hand bracket carries the reversing screw, in addition to the expansion link and lifting-arm; and that means that the bracket on the right side of the engine has to be of different design altogether. You can see the difference by comparing the drawings.

The brackets may be cast, or built-up. One approved supplier of castings for locomotives of my design is an absolute wizard at pattern-making and moulding, and does all his own foundry-work from A to Z. When I sent him a drawing of the proposed brackets for his consideration, asking if it were possible to cast them, and if not, what alteration would he suggest (it is no game of mine to put some lines on a piece of paper and say in effect "There you are—get on with it!" as has been too often done in the past), his reply was short and to the point. He just sent me two castings made to the drawing, saying that it was an easier job than casting a girl on horseback jumping a five-barred gate! He actually did the latter job; I have two samples, beautifully clean, and they make lovely fireplace ornaments, though he suggested using them for book-ends. However, if castings are used they will only need cleaning up and drilling for the reversing-screw bearings, bushes and fixing screws, as detailed below for the built-up version.

I had better state right here that it is a physical impossibility to build up the brackets for a 3½ in. gauge engine in the same way as those on the full-sized job. To give one example only, the lugs holding the link-trunnion bushes are, in full size, built up from sheet metal, in several pieces, and are hollow. How that could be done in one-sixteenth the size, even without taking strength into consideration, is something that is beyond my ken. There is another trouble, too; in full size the welded joints are far enough apart to allow them to be done separately. In the small one, they are so close together that unless the parts are screwed or pinned, it would be impossible to make one joint without breaking another, so the only way is to pin them together, and do the lot at one heat.

The back plate, by which the bracket is attached to the main frame, is cut from ⅛ in. mild steel, a piece of 1⅜ in. long and 1⅛ in. wide being required. The left-hand plate, which is nearest the front of the engine, and carries the lugs for the expansion link, is also cut from ⅛ in. mild steel, 1⅞ in. x 2 in. After cutting to the shape shown in the front-end view, and cutting out the slot necessary for clearing the swing of the expansion link, the plate is bent to an angle as shown in the illustration. The right-hand plate, or back support, is cut from ⅛ in. mild steel, to the shape and size shown in the cross section through the reverse-shaft bearing. This also shows the piece of ⅛ in. angle, which fits between the two side plates, as shown in both the front end view (by dotted lines) and the cross section. It can be made from a piece of 1 in. x ⅛ in. angle, 1 in. long, as the vertical member only carries the reverse-shaft bush, and its exact thickness is of no moment, as long as the distance between its outer face, and the bolting-face of the bracket, is 1 9/32 in. This allows for a 1/16 in. flange on the bush, and brings the measurements right for correct clearance of the reverse arm.

THE two lugs, carrying the expansion-link trunnion bushes are cut from steel plate and are shown 5/32 in. thick, which is 1/16 of the thickness of those on the big engine, the latter being hollow, as stated previously. However, if the lugs were made from ⅛ in. plate, they would do just as well, as long as the distance between them is kept at ⅝ in. If that is done, the flanges of the bushes would be 3/32 in. thick, instead of 1/16 in., and the distance from the shoulder to the end of the ⅜ in. part, reduced by 1/32 in., so that the inner ends are 7/16 in. full apart. Otherwise, the expansion link won't go between them.

Bosses for the reversing screw bearings are needed on the two supports. The position of these can be seen on the front end view (front bearing) and the section (rear bearing). The former is just a 1/16 in. slice of 5/16 in. round rod, held in position for brazing, by a screw or rivet. The rear one is a ⅛ in. slice of ⅜ in. round rod held in similar manner. The screw or rivet heads are afterwards filed off.

To assemble, first attach the lugs for expansion link, to the inclined part of the front support, by two 1/16 in. steel screws in each, put through clearing holes in the support (No. 51 drill) into tapped holes in the thickness of the lugs. It is a good wheeze to drill a No. 30 hole in the middle of the circular part of each lug, and line up the second with the first, by putting either a piece of ⅛ in. silver-steel through, or even the drill itself. The next stage is to attach the two supports to the back flange in similar manner, so that they are 1 in. apart at the top, as shown. The final stage is to file the lower part of the piece of angle, so that it fits between the two supports, with the horizontal part just ¼ in. below the top of the back flange. This can be held in position by two 1/16 in. screws at each side, in the same way as before mentioned. Note, the hole shown in this part in the plan view is merely for lightening the bracket (the full-size job has similar holes) and is ½ in. diameter.

See that all the screws are tight, and that there is no chance of anything shifting. Cover all the joints with Boron compo paste, as previously mentioned. Heat the whole issue to a good bright red, with a blowlamp or a gas blowpipe, and touch all the joints with a piece of 1/16 in. soft brass wire. This will melt, and flow in, if the heat is sufficient, making nice fillets in every corner. If the job is properly done, the result will be like a nice clean die-casting. Anybody who is lucky enough to own, or have the use of an oxy-acetylene or oxy-coal-gas blowpipe, can use Sifbronze, and the special flux sold for use with it. This makes a really posh job, and the Sifbronze flux doesn't burn on, into a hard glossy state, hard to remove. Don't forget to braze on the washers for the reverse shaft bearings. When the job is cooled to black, quench out in clean cold water, knock off any bits of burnt flux that may be sticking to the assembly, and clean up. Novices please note that steel or iron brazing jobs must never be put in acid pickle.

Now we have to drill the holes and fit the bushes. Seven No. 41 holes are needed in the bolting flange, for attaching the bracket to the main frame; the approximate position of these is shown in the elevation, "mike" measurements being unnecessary. Open up the two holes in the lugs for the expansion link, with a 23/64 in. drill, and then poke a ⅜ in. parallel reamer through both of them at once, as it is essential that they should be dead in line. Clean off any burrs, and very slightly countersink the outside; merely take the sharp edge off the holes, so that the flanges of the bushes will seat properly against the lugs.

The centre of the hole for the reverse shaft bush is 27/32 in. above, and the same amount to the rear of the centre of the holes in the lugs, so be careful with your marking out. Drill a ⅛ in. hole first, then enlarge it 23/64 in., finally reaming ⅜ in., and be sure to put the reamer through, parallel with the holes in the lugs. The bushes should be turned from good quality drawn bronze or gunmetal, a piece of 11/16 in. diameter or slightly larger, being used. For the reverse shaft bush, chuck in three-jaw, face, centre, and drill to ⅜ in. depth with 15/64 in. or letter C drill. Turn down ¼ in. of the outside, to ¼ in. diameter, a tight push fit for the hole in the bracket. Part off at a full 1/16 in. from the shoulder. Reverse in chuck, take a truing-up shim off the face of the flange, and poke a ¼ in. parallel reamer through. Drill four No. 48 holes in the flange, countersink them, put the bush in place, and secure with four 9 B.A. countersunk screws, using the holes in the flange to locate the holes for the screws, same as I have often described for cylinder covers.

The bushes for the link trunnion bearings are made and fitted to the lugs, by the same process; but the diameter of the flanges are reduced to ⅝ in. diameter, and the hole for the trunnion pin is drilled No. 19, and reamed 3/16 in. Put the 3/16 in. parallel reamer through both the bushes at once, after they have been fitted to the lugs, and attached by 9 B.A. roundhead screws.

Centre the two bosses for the reverse shaft, at the top of the bracket, and put a No. 40 drill through each; then test if they are in line, by aid of a piece of 3/32 in. round silver-steel, or by using the drill itself. If so, open them out with a No. 30 drill, putting it first through one, and then pushing straight through into the other, which will ensure proper alignment. Then carefully open the back one with a 9/32 in. drill, and tap it 5/16 in. x 40; the reversing screw has to pass through this when being erected.

Cast brackets are drilled and bushed in exactly the same way as above. It may probably be asked why bushing is necessary in a gunmetal casting; but if the holes for the link trunnion pins were drilled and reamed direct in the lugs, it would be impossible to erect the expansion links, as you will see when we get that far.

THE right-hand bracket is a much simpler job than the left-hand one, as there is no extension at the top for a reversing screw; also this allows the front support to be a simple piece of plate, set far enough back, to allow the expansion links to clear, without any necessity of cutting a slot. If a cast bracket is used, it will only need cleaning up with a file, and drilling for the screws and bushes. It can be built up in a similar manner to the left-hand bracket. The bolting flange will need a piece of ⅛ in. steel, 1¼ in. square, filed to the shape shown, and drilled for the screws. Both the lugs for carrying the expansion link are cut from 5/32 in. or ⅛ in. steel plate; and unlike those on the left-hand bracket, they extend right back to the rear of the bracket, rectangular holes being made in them, to allow access to two of the screws holding the bracket to the frame. The rear part of the outer plate is rectangular, as shown, but the inner one has the round-topped extension for carrying the bush for the reversing shaft, as shown in the cross section. Distance-pieces, as shown, are placed between the two plates, to keep them ⅝ in. apart; see plan view. A piece of 1 in. x ⅛ in. angle is placed between the inner plate, and the bolting flange; this is ¾ in. wide. The horizontal part is 1 in. long, and has a ½ in. lightening hole drilled in it. The vertical part is reduced to ¾ in. and is level with the back end of the side plates. The whole doings is temporarily fixed together by aid of 1/16 in. screws, same as the left-hand bracket, and the joints either brazed, or Sifbronzed, by the same process. After cleaning up, drill the bush holes, and fit the bushes, in exactly the same way as described for the left-hand bracket.

Erection of Motion Brackets

The exact position of the motion brackets on the main frames is shown in the accompanying diagram. The vital point is the centre of the bush which will carry the trunnion pin of the expansion link. Make sure that the axleboxes of the driving axle are in the running position, as given when fitting them: then temporarily clamp the motion bracket to the frame so that the centre of the link trunnion bush is exactly 3 29/32 in. ahead of the centre of the axle, and 1 3/8 in. above it. Run the No. 41 drill through the screwholes in the bracket, carrying on through the main frame; file off any burrs, and attach the brackets to frames by 3/32 in. or 7 B.A. bolts, or screws and nuts as shown.

Valve Gear

Once the rather complicated motion brackets are disposed of, the rest of the valve gear becomes a fairly plain and straightforward job. As this locomotive is intended to perform hard work in an efficient manner, it would be useless to make a " scale " copy of the full-size gear, which might please the good folk whom I call, in all good humour, " scale fanatics," but would be only suitable for a museum piece to spend its time in a glass case. It would be too flimsy for serious work, therefore, while retaining the " family likeness," in a manner of speaking, the gear has been strengthened up to perform its allotted task, and all unnecessary complications eliminated. There is, for example, no need for valve spindle guides, as the weight of the lap-and-lead movement is not sufficient to call for extra support. In addition to the plain outline of the general arrangement of the gear, I have included a plan, which shows the layout to be practically straight-line movement.

If I give here, a brief note on the way all the parts are made, it will hasten the job and save needless repetition. All the rods can be milled, or sawn and filed, from solid bar, by anybody who cares to go to all that trouble. They can also be built up, by using flat strip—mild steel is plenty good enough; there is no need to use rustless steel, as the " works " are always oily—for the main part of the rod, and brazing on thickening pieces, or small blocks, where forked ends are required. All forked ends can be slotted by clamping the piece under the slide-rest tool holder, and running it up to a cutter (saw-type) mounted on a spindle between lathe centres, or on an arbor held in the three-jaw chuck. I have often, in days gone by when I had no milling machine, used old bolts for cutter arbors, holding the cutter between two nuts on the threaded part of the bolt.

PERFECT rounded ends can be easily formed by aid of toolmakers' button jigs. A piece of silver-steel, of the diameter of the rod end required, and about 5/16 in. long, has a pip about 1/16 in. long, turned on one end, to fit the hole in the rod. This piece is made redhot, and dropped into cold water; or preferably sperm oil, if any is available, as the risk of cracking is avoided. When I was in charge of a small munition shop making aero engine parts, during the Kaiser's war, we kept a small pailful of cold water, with a couple of inches of sperm oil floating on the top, close by the forge in which tools were heated for hardening. The redhot tool was plunged through the sperm oil, into the water below; the tools never cracked, and required no tempering. These button jigs should be made in pairs, and of several sizes, so that time is saved. To use, place one at each side of the end to be rounded off, with the pips in the pinhole; grip the lot in the bench vice, and file down the projecting metal until flush with the hardened buttons.

To braze on thickening pieces, bosses, and so on, see that the parts are quite clean, and that they fit properly. Clamp wherever necessary, or secure with thin iron binding wire. Smear with wet flux, such as Boron compo mixed to a creamy paste with water. Heat to bright red, and touch the joint with a piece of soft brass wire, 1/16 in. thick, or less. If the heat is right, this will instantly melt the flow into the joint, leaving a nice neat fillet. Quench out in clean cold water (never use acid pickle for quenching steel brazing jobs), clean off, and polish up. That is how the jobs are done: below is a brief description of the various parts of the valve gear.

Lap and Lead Movement

This comprises the valve crosshead, combination lever, and union link. The valve crosshead is only a wide-jawed fork, which accommodates the upper end of the combination lever. It can be made from mild steel bar of 5/16 in. x 3/8 in. section, or 3/8 in. square, if the former is not available. A piece long enough to clamp under the slide-rest tool holder is needed. First run a No. 34 drill through, at about 3/16 in. from each end, to form the pinholes; this ensures that the holes in each side of the jaws line up. If drilled after milling the jaw, the drill may wander after the first side is drilled, and the holes may then be out of line. Next, clamp the piece under the slide-rest tool-holder, and mill out the jaws as described above, turning it end for end, and serving the second end likewise. If a 1/4 in. saw-type cutter isn't available, a thinner one can be used, by taking two " bites," to bring the jaw to correct width. Part or saw off about 9/16 in. from the centre of the pinhole.

Chuck truly in four-jaw with the sawn or parted end outwards; face the end, turn down 1/8 in. length to 1/4 in. diameter, then centre the boss thus formed, drill 5/32 in. or No. 22, and tap 3/16 in. x 40 to suit the thread on the valve spindle. The fork can then be filed or milled to the dimensions given; the ends rounded off, by aid of the filing jigs mentioned above, and a 1/8 in. parallel reamer put through both pinholes.

Screw the finished crossheads or forks, tightly on to the valve spindles.

The combination levers are made from 1/4 in. square steel, the slot being milled as above; the rounded bottom of the slot can be formed by judicious application of a rat-tail file. Don't forget to drill the pinholes first! The surplus metal is then milled or filed away, the eye at the bottom rounded off, and the rod polished up. An excellent finish can be obtained by rubbing the piece on a sheet of fine emery-cloth on which beeswax has first been rubbed.

The union links will require either ¼ in. x 5/16 in. steel, or 5/16 in. square. Drill the pinholes first with No. 34 drill; then form the slots, taking care to get the 1/16 in. offset; file or mill away the surplus metal, open out the pinholes at one end with No. 32 drill, and ream the other ⅛ in. as shown. Don't start any assembling yet, as the combination lever has to be pinned to the radius rod, and erected with it.

Radius Rod

The radius rod is a glorified edition of the combination lever, and is made in exactly the same way, from ¼ in. square mild-steel. As all dimensions are given in the drawing, there is no need to dilate on the construction; but here is a tip for those builders who are lucky owners of milling machines. I keep a couple of pieces of 1 in. square bright steel bar handy; one about 6 in. long, and the other longer. These have various tapped holes in them. When making a component like the long radius rod, I start with a piece of steel a little longer than the finished rod. This is clamped to one of the bars, by a setscrew or small dog clamp at each end, and the whole issue held in the machine vice on the table of the machine. The surplus metal is then chawed away with a good hefty cut, as the piece of 1 in. bar under the comparatively weak valve-gear part, prevents it from buckling or distorting.

Expansion Link

As only two of these are required, it would only be a waste of time to make up a jig for milling out the curved slot; it amuses me very much, to read about good but misguided folk who spend a week making a jig, to do a job taking five minutes or so! They don't seem to realise that whilst careful hand-craftsmanship may take longer than doing a job by jig, the total time spent is considerably less, as there is no jig to make.

The best way to set about making the expansion links, is to emulate Pat who built a barrel around a bunghole, and cut the slots in a couple of pieces of ⅛ in. flat steel about 2½ in. long and 1 in. wide. Mark the outline of the link first. If you can get a piece of "ground flat stock" (the trade term for the fine-grades cast steel used for gauge-making) that is the best stuff to use. If not, flat mild steel will do. On the centre-line of the marked slot, either drill a series of 5/32 in. holes, and run them into a slot with a rat-tail file, or drill a single hole at each end, and cut out the piece with an Abrafile or a spiral-tooth file. Then, with a small flat file, such as used by clockmakers, and key cutters, carefully file to the marked lines, using a piece of 3/16 in. round silver-steel as a gauge. It only needs patience, perseverance, and a little common sense, to produce a slot in which the bit of silver-steel will slide from top to bottom without any appreciable shake.

Having got the slot right, check the outline of the link around it; and if O.K., simply file to the outline. What could be easier? Tales of difficulty in making up a Walschaerts gear, are just moonshine. If you should "make an apple-pie" of one of the slots, it is only a matter of having another go, on a fresh piece of metal; it isn't a question of scrapping a nearly-completed link, as it would be if the outline were filed first.

THE side members which support the expansion link, and carry the trunnions, are made from pieces of ⅛ in. steel approximately ¾ in. square. File to outline; drill the rivet holes with 1/16 in. or No. 53 drill, and the trunnion-pin holes No. 14. Each piece has to be rebated on the side next to the link, to allow the radius rod fork to pass, as shown in the section. If you have a milling machine, clamp the two pieces together, in the machine vice on the miller table, and run them under a ⅛ in. saw-type cutter on the arbor, so that the cutter is dead on the centre-line between the two, and take 1/16 in. out of each piece. A similar process can be used in the lathe, by clamping the pieces together in a machine vice (regular type, or improvised with two bits of angle-iron, and a couple of bolts) at the proper height, and bolting the vice to the lathe saddle or cross-slide. The cutter is mounted on a spindle between centres, and the cross-slide traversed under it very slowly, as the whole depth has to be taken out at one cut, the slide having no height adjustment. However, it can be done quite well, aided by a drop of cutting oil, same as used for turning steel. The job can also be done by hand, by clamping the pieces together in the bench vice, and using a warding file, just as a key cutter uses it, cutting a ⅛ in. "ward" 1/16 in. deep, right down the centre line. When parted, this naturally leaves the 1/16 in. rebate in each piece.

Put one piece at each side of the expansion link, and line up the trunnion holes by putting the shank of the No. 14 drill through them and the curved slot. Hold them in place temporarily with a toolmaker's cramp over the lot, and drill a couple of the rivet holes through the link, using those in the side pieces as guide: then rivet up with 1/16 in. rivets, or pieces of soft steel wire. Countersink both sides, as shown in the section; then remove cramp and put the third rivet in. Countersink the trunnion holes slightly, and with the "lead" end of a 3/16 in. parallel reamer, ease the holes sufficiently to allow the 3/16 in. silver-steel trunnions to be squeezed in. If a piece of 1/16 in. sheet steel is placed in the space between the side member and the link, at each side, the 3/16 in. pins can be squeezed in without risk of damage to the link. They can then be brazed, or silver-soldered if you like, letting the molten metal fill up the countersinks. Any roughness on the inside of the side pieces should be smoothed off with a fine flat file. The space between them, and the link, at each side, should just allow the fork of the radius rod to pass easily. Finally clean and polish the lot, then fit the die blocks. These are merely little bits of ⅛ in. steel, with a ⅛ in. reamed hole in the middle. They should slide from top to bottom of the curved slot quite easily, but without appreciable shake. If made from "gauge" steel, as previously mentioned, they can be hardened right out, and wear will be practically nil.

First Stage of Assembly

As soon as the lifting links are made and fitted, the parts already made can be assembled and erected. The lifting links are very simple indeed, being merely two short lengths of ¼ in. square steel, drilled No. 32 and reamed as shown, and filed or milled to the shape and size given in the illustration. Each lifting link fits in the long fork of the radius rod; place it opposite the second hole, and squeeze a bit of ⅛ in.

round silver-steel through the lot, filing off flush each side. All the squeezed-in pins are made from round silver-steel, the "natural" finish of which ensures freedom from wear, and practically frictionless working. The pieces should be cut a little over the required length, and one end bevelled off sufficiently to allow it to enter the drilled hole; then squeeze home, using the bench vice as a press, and filing off any superfluous metal projecting at each side. Note when fitting the lifting links to the radius rods, that one will be right-hand and the other left-hand, as the forks are offset with the main part of the rod.

The eye of the radius rod is then placed in the fork of the combination lever, opposite the top hole, and pinned to it by a silver-steel pin, as above. Here again, watch your step, and be careful to avoid putting on the combination lever the wrong way around, for the reason shown in the end view of the lap-and-lead movement. This shows that the combination lever, when correctly erected, just clears the guide bars and bracket nicely, but with not too much room to spare. The offset of the fork should incline *toward* the frame on each side of the engine, whilst the offset of the radius rod should incline *away* from the frame; see plan view of the motion erected.

Next, attach the union link to the bottom of the combination lever, putting the fork with the No. 32 drilled hole in it, over the eye of the combination lever, and securing with a pressed-in pin. The offset of the union link is erected on the same side as the offset of the fork in the combination lever.

Be mighty careful about the next operation, to avoid damage to the expansion link. Put a die block in the slot of the expansion link and slide it to the top of the slot. Place the end of the radius rod over the link and die block, and squeeze a $\frac{1}{8}$ in. silver-steel pin through the holes in the fork and the die block, filing off flush. Warning: this pin must be absolutely tight in the fork, so that there is not an earthly chance of it shifting or coming adrift, when the engine is travelling at a high speed. Therefore, if the pin goes in easily, as it may do if the 32 drill is not ground exactly true, and "cuts large," slightly countersink the holes in the fork, and rivet the ends of the pin into the countersinks before filing flush.

If the two bearings are taken out of the expansion link bracket, it will be found that the expansion link can be easily placed in position between the sides; then, holding the link so that the trunnions are central with the holes, replace the bearings, the holes in same going over the trunnions, and put the screws in. The expansion link should oscillate freely, without any appreciable slackness in the bearings.

Now countersink the hole in the valve-spindle crosshead, on the side nearest the frames; put the combination lever between the jaws, with the lower holes opposite the holes in the valve crosshead, and secure with a countersunk bolt. This can be turned up from a piece of $\frac{1}{4}$ in. round silver-steel; or a head may be formed on the end of a piece of $\frac{1}{8}$ in. silver-steel by holding it vertically in the bench vice between two copper clams, burring it with a hammer, and then turning the "blob" to shape. Yet another way would be to reduce the end of the $\frac{1}{8}$ in. steel to $\frac{5}{32}$ in. and screw it; put a $\frac{5}{32}$ in. nut on very tightly, slightly burring over the end of the thread, and turning the nut to the shape of the countersink. The outer end of the little bolt is turned down to $\frac{5}{32}$ in. bare, screwed 8 B.A., and secured with an ordinary commercial nut, for neatness' sake.

The loose end of the union link is placed over the end of the drop arm already on the main crosshead, and secured by a bolt made from a piece of $\frac{1}{8}$ in. round silver-steel turned down at both ends to a shade under $\frac{3}{32}$ in. diameter, screwed 8 B.A. and finished with commercial nuts. Note: this bolt must not be tight enough to pinch in the jaws of the fork on the union link, or undue friction will be caused; a fault to be avoided at all costs. When the nuts are tight against the shoulders on the bolt, it should still be possible to turn the bolt by finger pressure, thus ensuring that the jaws are not in any way pinched in. A tiny amount of endplay in the bolt is quite permissible.

Return Cranks

The return cranks are sawn and filed, or milled, from mild steel of $\frac{7}{16}$ in. x $\frac{3}{16}$ in. section, or nearest larger, all dimensions being given in the drawing. The pin at the top is made from $\frac{3}{16}$ in. round silver-steel, the working part being left in its natural state; the turned-down end should be a tight fit in the $\frac{5}{32}$ in. drilled and countersunk hole in the small end of the crank. Rivet the pin into the countersink, and file off flush. As the hole in the larger end must be a tight fit on the turned-down end of the main crankpin, drill the hole with $\frac{15}{64}$ in. or letter C drill, and open it out with the "lead" end of a $\frac{1}{4}$ in. parallel reamer, until it is just a press fit on the pin. Temporarily plug the holes with pieces of steel or brass, whilst drilling the No. 43 bolt holes through the thickness of the square boss, otherwise the drill will wander when it hits the big hole. Press the return cranks on the main crankpins, setting them "by eye" in the approximate position shown on the elevation of the valve gear; the return crankpins follow the main crankpins, as shown, for inside-admission piston-valves. The exact position of the cranks will be determined as below.

How to Find the Exact Length of Eccentric Rods

The next job will be the eccentric rods; but before making these, the *exact* length must be obtained from the actual engine. The length between centres of pinholes, shown on the drawing of the rods, is approximate only. One simple operation determines the position of the return cranks on the main cranks and gives the exact lengths of eccentric rods; and this is how you do it. First set the main crank on front dead centre; that is, with the crosshead as near the cylinder as possible. Then set the expansion link in such a position, that the die-block can be run from end to end of the slot, without causing any movement of the valve spindle. Temporarily fix the link in that position, by any means you like; I use a little clip. Now, with a pair of dividers, take the distance from the centre of the hole in the link tail, to the centre of the return crankpin. Now turn the wheels, so that the main crank is on back dead centre, with the crosshead at its farthest point from the cylinder, making sure that the expansion link doesn't move. Check the distance between the centres of hole in link tail and return crankpin, with the already-set dividers. If they tally, it will be a miracle! If they don't, which is most likely, shift the return crankpin to half the difference, by aid of a pair of pliers (don't damage the crank!) and have another go. When the distance between the centres of hole in link tail, and return crankpin, is exactly the same, on both front and back dead centres of the main crankpin, the return crank is correctly set; and *the distance between the divider points is the exact length of the eccentric rod between the centres of the bush and the pinholes in the fork.* Don't shift the divider points on any account, but put them aside for a few minutes, whilst drilling the main crankpin for the bolts which retain the return crank in correct position. Just run the drill very carefully through the holes in the thickness of the square boss; it will cut the necessary grooves in the pin. If a piece of 3/32 in. silver-steel won't enter tightly, put a No. 42 drill through, which should do the trick. Then make two little bolts for each crank, by cutting the 3/32 in. steel to length, and threading the ends; squeeze them in, and put nuts on tightly, and the cranks will neither come off, nor turn on the pins.

THE eccentric rods may be cut from ½ in. x ⅜ in. mild steel bar, if a milling machine is available; for hand work ⅛ in. x ¼ in. can be used, with bits brazed on for the fork and the large boss. The latter simulates the housing of the ball-bearing used on the full-sized engines; there is not the slightest objection to using a ball-bearing on the little engine, if one can be obtained small enough. Otherwise, fit a pressed-in bronze bush, as shown in the drawing. Note the offsets very carefully. The forked end is machined in the same way as that on the combination lever and other parts; it is attached to the link tail by a ⅛ in. silver-steel bolt, turned down and screwed 8 B.A. at both ends, and nutted. The bush is placed over the return crankpin, and the boss kept from coming off by a commercial nut and washer, as shown in the plan drawing.

Reversing Gear

As the reversing screw is mounted on the left-hand motion bracket, the reversing and lifting arms are combined in a single unit. On the full-sized engines, this is machined up from a forging; and on the small edition, it could be cut from the solid, by anybody who wished to take the trouble, and had the necessary milling machine. However, the reproduced drawing (see May 22 issue) shows an easy way of building up the whole component, from pieces of ½ in. x 1/16 in. steel, mounted on a stepped steel bush. The drawing gives the shape and dimensions of the two lifting arms and two reversing arms, which are filed, or milled, to the shape shown. The ends of the lifting arms are reamed ⅛ in., and the upper ends of the reversing arms are slotted ⅛ in. to accommodate the pips on the reversing nut. When drilling the larger ends of all four arms, make a pilot hole first with a No. 30 drill, then open out with 23/64 in. drill and ream ⅜ in.

Next, chuck a piece of ½ in. round mild steel in the three-jaw. Face, centre, and drill down to a full ½ in. depth with 15/64 in. or letter C drill. Turn down ⅛ in. of the outside, to a tight fit in the ⅜ in. reamed holes in the arms. Part off at a bare ½ in. from the end; reverse in chuck, and turn down a full ⅛ in. of the other end to a similar tight fit in the arms; leaving a collar 7/32 in. wide, and the full ½ in. diameter in the middle. Put a ¼ in. reamer through the hole. Now squeeze on the two lifting arms, next to the shoulders on the stepped bush, lining them up with a piece of ⅛ in. round rod, or the reamer shank, through the eyes at the small end. Outside these, squeeze on the reversing arms, using a piece of ⅛ in. flat steel, to line up the slots. Carefully adjust the two pairs of arms to the angle shown in the drawing; then braze the arms to the stepped bush by the method mentioned earlier. Be sparing with the brazing material; coarse grade silver-solder may be used if desired. File off any superfluous metal, and clean and polish up.

The lifting arms on the right-hand side are made exactly similar to those on the left; but instead of drilling and reaming the larger ends to ⅜ in. drill 15/64 in. or letter C, and ream ¼ in. Only put the reamer in far enough to make the holes a very tight fit on the reversing shaft, which is a piece of ¼ in. round steel rod 6½ ins. long. Square off both ends in the lathe, then press on the arms, setting the outer one 1/32 in. from the end of the shaft, and the inner one 7/32 in. away from it. Line up the two arms by aid of a piece of ⅛ in. silver-steel, or a drill shank, and braze them to the shaft.

How to Erect the Reversing Shaft

The drawing of the main frames showed a little depression—not the kind that comes from Iceland!—filed in the top of each, to provide clearance for the reversing shaft. A similar clearance will be needed in both motion brackets, at the top of the plate which is bolted to the frames; so if this has not already been done, do it now. The end of the reversing shaft can then be entered into the bush on the right-hand bracket, pushed right across into the bush on the left-hand bracket, and pressed into the boss of the combined lifting-and-reversing gadget. This should be held in position to receive it, with the arms projecting through the ⅜ in. slot in the bracket, and the arms embracing the expansion link, which swings between them. The shaft should come through the boss about 1/32 in., and the right-hand pair of arms should then embrace the link on that side.

Line up the two pairs of lifting arms "by eye," and drop them over the upper ends of the lifting links, which should fit nicely between the ends of the arms. Secure them by bolts made from ⅛ in. silver-steel, turned down, screwed, and nutted at both ends, as described for union link and other parts. To get the right- and left-hand lifting arms exactly parallel, is a simple matter of trial and error. Temporarily disconnect the eccentric rods from the expansion links, so that the latter can be waggled back and forth by hand. Put the left-hand die block in mid-position, so that when the link is waggled, the radius rod doesn't move, then try the other side without moving the reverse shaft. If the rod moves when the link is waggled, the arms are out of line, and need adjusting. When the expansion links on both sides of the engine can be waggled (or "oscillated" as the Third Programme would say) at the same time, without moving the radius rods, the die-blocks being in mid-position, opposite the trunnion pins, the arms are correctly set. Drill a No. 43 hole through the boss of the left-hand combined lifting and reversing gadget, and the shaft; squeeze in a pin made from 3/32 in. silver steel, and "Bob's your uncle." The gear on both sides should reverse easily, at any point in a revolution of the wheels, by operating the slotted reversing arm by hand.

Reversing Screw and Nut

The reversing screw should now have a left-hand thread; so if builders happen to have a 3/16 in. Whitworth left-hand tap and die, they can use it. If not, an ordinary right-hand screw can be used; it only means turning the wheel anti-clockwise to go ahead. To make the screw, chuck a length of 3/16 in. round steel in the three-jaw, with about ¾ in. projecting, and turn down ⅝ in. of it to ⅛ in. diameter. Now pull another inch out of the chuck, and screw it with a die in the tailstock holder. If using the left-hand die, be sure the lathe chuck is screwed on tightly, and pull the side of the lathe belt that is farthest from you, when working the die down the rod. Use plenty of cutting oil. Part off at a bare 1¼ ins. from the shoulder. Reverse in chuck, and hold the screwed part in the jaws; you won't hurt the threads if you don't wrench the chuck key too hard. Turn down enough of the end, to ⅛ in. diameter, to bring the length of the screw to 1 in. bare; then face the end, bringing the length of the spigot to 7/32 in.

The nut is made from 5/16 in. x ⅜ in. bronze rod; don't use soft brass. Maybe our approved advertisers will supply a little casting; or ⅜ in. square rod could be used. Chuck truly in four-jaw, and turn a pip ⅛ in. diameter and ⅛ in. long, on the end. Part off at a bare ½ in. from the shoulder; reverse in chuck, and turn a similar pip on the other end, leaving the middle part a full 5/16 in. wide. To get the tapped hole O.K. it would be advisable to chuck the embryo nut in the four-jaw, with the end running truly, two jaws holding the body tightly, and the other two lightly bearing against the pips. Then centre, drill through with 9/64 in., or No. 27 drill, and tap to suit the screw.

Chamfer the corners

Make a gland from ⅜ in. hexagon bronze or gunmetal rod, screwing the outside 5/16 in. x 40, and drilling it No. 30, by same process as making piston-rod glands; see the sectional illustration. Hold the nut in position between the two sides of the reversing arm, with the side pips in the slots; put the reversing screw through the large hole in the back boss of the motion bracket, screw it home through the nut until the spigot enters the front bearing, then put the gland over the back part of the spindle, and screw it home. The movement can be tested by clamping a small tapwrench or watchmaker's lathe carrier on the spindle; the screw should turn freely, but without end play. We shall be fitting a small universal joint on the spindle, later on, when the cab reverser is made and erected.

THE lubricator is my standard oscillating cylinder type, which has a definite advantage over any employing a fixed cylinder, as it completely closes the "entrance to the way out," on the suction stroke; and even if the oil check valve leaks, the lubricator still functions. With other types, if the check valve leaks, steam blows back into the tank, condenses, and not only does no oil get to the cylinders, but the condensate water soon fills the tank and "pushes the oil overboard." I know this, both from my own experimenting, and other folks' experiences.

Oil Tank

The easiest way to make the tank, is to cut a strip of 20-gauge sheet brass or steel 1¼ in. wide and 5 in. long, and bend it into a rectangle 1¼ in. square. Stand it on a piece of 16-gauge brass, a little larger than 1¼ in. square, and silver-solder the joint all around and up the corner. File the bottom flush. Drill a 3/16 in. hole in centre of bottom, and a similar hole 3/16 in. from the top, on the centre-line of one of the sides. A lid can be made by cutting a piece of 20-gauge metal 1¾ in. square, and cutting a ¼ in. nick out of each corner. Bend ¼ in. of each edge, to form a kind of tray, and silver-solder the corners. The lid can also be flanged up from a piece of metal the same size, over a 1¼ in. square former, in the same way as you would flange a boiler plate.

Oil Pump

For the pump stand, part off a 1¼ in. length of 5/16 in. square brass rod. On one side, file or mill away a rebate ½ in. long and 1/16 deep; at 3/16 in. below it, file or mill away a recess 5/16 in. long and 1/16 in. deep. At 3/16 in. from top of rebate, drill a 5/32 in. hole and tap it 3/16 in. x 40. This must go through dead square. At 13/32 in. from bottom in the middle of the recess, drill a No. 41 hole right through; pin-drill this on the back, with ¼ in. pin-drill, to 5/32 in. depth. Chuck truly in four-jaw, face, centre, drill 3/16 in. deep with No. 22 drill, and tap 3/16 in. x 40. On the part below the recess, at 5/32 in. from bottom, make two centrepops ⅛ in. apart. Drill right through the right-hand one into the blind hole, with No. 54 drill. Be careful as it breaks through, or the point will snap off. Drill the left one only 1/16 in. deep, and chip a little groove from it, right to bottom of stand. A wee chisel made from 3/32 in. silver-steel, will do this job fine; just grind the end of it off to an angle, and harden and temper to dark yellow.

True up the contact faces by rubbing the stand first on a smooth file laid on the bench, and finishing on a piece of fine emery cloth or similar abrasive, laid on the lathe bed or any other flat and true surface.

For the pump cylinder, part off a piece of 5/16 in. square brass rod ⅝ in. long. On one end, make a centrepop 1/16 in. off true centre. Chuck in four-jaw with this pop mark running truly, open it with a centre-drill, drill right through with No. 34 drill, and ream ⅛ in. Open out 3/16 in. of the end with a 3/16 in. drill, and tap 7/32 in. x 40. Make a gland to suit, from ¼ in. hexagon rod, by same process as described for cylinder glands. On the face farthest from bore, at 3/32 in. from the bottom, drill a No. 54 hole into the bore. At ¼ in. above it, on the centre line, drill a No. 48 hole, but this time, don't pierce the bore; tap it 3/32 in. or 7 B.A. Run the ⅛ in. parallel reamer through again, to clean off any burring, then true the contact faces by rubbing on file and emery cloth, as described for the stand. Cut a 13/16 in. length of 3/32 in. silver-steel, screw both ends of it 3/32 in. of 7 B.A. for about ⅛ in. length, and screw it into the trunnion pin-hole on cylinder. This must be exactly at right angles to the sliding face, or the faces will not make proper contact, and oil will leak out between them, and the pump will not deliver oil against pressure. Turn up a little plug, to a drive fit in the bottom of the bore, squeeze it in, and solder over the head as a precaution.

The pump ram is a ¾ in. length of ⅛ in. bronze or rustless steel, turned down at the end for 1/16 in. length, to 5/64 in. diameter, and screwed 9 B.A. The big-end is filed up from a scrap of brass, to size and shape shown, and tapped to suit the ram. As there is so little screw thread, it might be advisable to silver-solder it as well.

The gland is packed with a few strands of graphited yarn. Put the trunnion through the hole in the stand, and secure with a spring and nut, as shown in the section. The nut should be fairly tight on the screw, to avoid any chance of it coming off in service.

Bearing and Crankshaft

To make the bearing, chuck a piece of 5/16 in. hexagon rod in the three-jaw. Face the end, turn down 3/4 in. length to 3/16 in. diameter, and screw 3/16 in. x 40. Centre, and drill No. 41 for 7/8 in. depth; part off to leave a 3/32 in. head, reverse in chuck, and chamfer the corners of the hexagon. Make a locknut to suit, from the same size of rod.

The crankshaft is a piece of 3/32 in. round silver-steel 1 5/16 in. long, 1/8 in. of one end being screwed 3/32 in. or 7 B.A. To make the crank, chuck a piece of 3/8 in. brass rod in three-jaw. Face, centre, and drill No. 48 for about 3/16 in. depth, tap 3/32 in. or 7 B.A., and part off a 1/8 in. slice. At a bare 1/8 in. from centre, drill a No. 53 hole, tap it 9 B.A. and fit a crankpin, 1/4 in. long, made from 15-gauge spoke wire, screwed 9 B.A. The ratchet wheel may be pressed on the shaft before erecting; it is 7/16 in. diameter with from 35 to 40 teeth, and can be obtained from our advertisers. It is hardly worth while setting up the necessary rig, just to cut one wheel. The hole should be drilled No. 43, and the wheel very carefully pressed on to the shaft from the plain end, using the bench vice as press. The process is just the same as for pressing the engine wheels on the axles, only a little more delicate! Press on until approximately 1/4 in. from the plain end. Mind that you have the teeth the right way around, as shown; the pawls must hit the buttress side, to turn the wheel clockwise.

Oil Check Valve

Chuck a piece of 5/16 in. round rod in three-jaw, face the end, and turn down 3/16 in. length to 3/16 in. diameter; screw 3/16 in. x 40. Part off at 7/16 in. from shoulder. Reverse in chuck, drill through No. 43, open out and bottom with 3/16 in. drill and D-bit to 3/8 in. depth, tap 7/32 in. x 40 for halfway down, and put a 3/32 in. reamer through the remains of the No. 43 hole. Drill a 5/32 in. hole in side, 7/32 in. from shoulder, and in it, fit a 7/32 in. x 40 union nipple. To make this, chuck a piece of 1/4 in. brass rod, turn down 3/8 in. length to 7/32 in. diameter, and screw 7/32 in. x 40. Centre deeply, and drill down 3/8 in. depth with 3/32 in. drill. Part off at a full 5/16 in. from shoulder. Reverse in chuck, and don't screw the jaws down tight enough to damage the threads. Turn a pip on the end, to a tight fit in the valve body; press it in, and silver-solder the joint. Pickle, wash, and clean up; then fit a 1/8 in. ball to the seating, same as for pump valves. Make a screwed cap from 5/16 in. hexagon rod as shown; drill a blind hole in it with No. 30 drill. The drawing shows how the valve is assembled, with a light spring in the recess, to hold up the ball against the seating.

How to Assemble Lubricator

Put the stand and cylinder in the tank, over the bottom hole, and screw the check valve through it into the tapped hole in the bottom of the stand. Put the bearing through the side hole in the tank, screw the locknut on for a few threads, then adjust the stand so that the tapped hole at the top, lines up with the bearing. Screw in the bearing until the head just touches the tank side. Then tighten up the check valve, and run the locknut back against the tank side; note:—the union nipple on the check valve should point to the left, when you are looking at the side where the bearing comes through. It doesn't matter if the nipple points slightly to right or left of centre line, as long as it faces backwards—says Pat!

Put the crank in place with the pin through the big-end, hold crank in line with bearing, push the shaft through, and screw it into the crank. When right home, the shaft should have just the weeniest bit of end play; if too tight or too loose, adjust position of ratchet wheel on spindle.

THE ratchet lever is filed up from a bit of 1/4 in. x 1/16 in. steel strip, and drilled as shown; use No. 41 drill for the larger end, and drill No. 48 and tap 3/32 in. or 7 B.A. for the screw carrying the moving pawl. Both pawls are filed up from 3/32 in. steel, and drilled No. 41. The best stuff to use is the cast steel used for gauge making, known as ground flat stock, as pawls made from this can be hardened right out, and tempered just sufficiently to prevent them breaking. If mild steel is used, they must be case-hardened. Heat to bright red, roll in any good case-hardening powder, such as "Kasenit," "Pearlite," or similar preparation; reheat until the yellow flame dies away, then quench in cold water. The moving pawl is attached to the lever by a screw with 3/32 in. of "plain" under the head; this is easily home-made from 3/16 in. steel rod. The stationary pawl is mounted on a stud turned from 3/16 in. rod as shown; the short end of this goes through a No. 41 hole drilled in the tank, and is nutted inside. This pawl is kept in engagement with the ratchet wheel by a wire spring, like those used on alarm clocks, fitting into a slot in the top of the pawl. The other end is looped, and attached to the tank by a screw as shown, nutted inside. The tail of the moving pawl is connected to the ratchet lever by a light spring as shown.

The end of the crankshaft outside the ratchet wheel, is screwed just sufficiently to allow the nut, with a washer under it, to be tightened fully without locking the lever, which should swing quite freely without side shake. I usually put the lever on the shaft, plus a washer, hold the spindle in the chuck, and run a 3/32 in. die on to it, by aid of the tailstock die-holder, until the die barely touches the washer. That does the trick!

How to Erect Lubricator Frames

The lubricator is erected with the ratchet gear on the right-hand side of the engine. A piece of 3/32 in. x 3/8 in. angle, 1 in. long, is attached to the front of the tank, at 7/16 in. below the top edge, by two 3/32 in. screws nutted inside the tank. At 3/16 in. from centre of top of buffer-beam, and 1/4 in. from the edge, drill two No. 41 holes and countersink them. Hold the lubricator in position shown, run the 41 drill down the holes, making countersinks on the angle; drill through No. 48, tap 3/32 in. or 7 B.A. and put countersunk screws in.

The ratchet lever is driven from the eccentric on the first coupled axle. Machine the strap in the same way as that described for the pump; drill the boss 1/8 in. or 5 B.A., and screw in a piece of 1/8 in. rod long enough to reach to the ratchet lever. Make up a fork by same process as described for the valve gear forks, and screw it on to the rod, adjusting the length so that when the eccentric is on top or bottom centre, the ratchet lever is vertical. Pin the fork to the ratchet lever with a bit of 15-gauge spoke wire, screwed 9 B.A. at both ends, and nutted. Incidentally, correspondents often ask where spoke wire can be obtained. You can get cycle spokes of all standard gauges, at any cycle dealers, and the wire they are made of is just about the cat's whiskers for valve gear pins, and other purposes as mentioned in these notes. I always use them, and they never seem to wear out. The ratchet should click one tooth at each revolution of the coupled wheels. The connecting oil pipe cannot be fitted until the boiler is on, as the oil is delivered into the steam pipes.

Brake Gear

On the little 75000 we are up against a brake-rigging difficulty not found on big sister, as our grate and ashpan has to be detachable, and therefore no brake rigging can be fitted underneath it; whereas on the big engine, the brake pull-rod can pass centrally underneath. Therefore we must use two rods, spaced wide enough apart, to allow the grate and ashpan to be dumped. How this is done, is shown in the plan and elevation drawings.

The brake cylinder and main shaft are carried by two small frame plates, extending from a special stay behind the trailing axle, to the drag beam. Each end of the shaft carries a drop arm, which is connected by a long pull rod at each side of the ashpan, to the trailing hangers. Two similar rods connect the trailing hangers to the driving hangers, which are cross-connected by the usual beam. This is coupled to a similar beam between the leading hangers in the usual way. The arrangement is clearly shown in the plan view.

Brake Blocks and Hangers

The first job is to make the brake block and hanger assemblies. Six hanger pins will be needed, and these are turned from ¼ in. round mild steel, to the dimensions given in the drawing; a kiddy's practice job needing no detailing out. At ⅝in. from bottom of frame, and 2 9/16 in. ahead of each axle centre, drill a No. 30 hole in the frame, poke the shank of the hanger pin through, and secure with a commercial nut.

The hangers are filed or milled from ⅛ in. x ⅜ in. steel, and drilled No. 30. Note that the trailing hangers carry special pins at the bottom, as shown in the detail illustration. Advertisers supplying castings for my locomotives, can supply cast-iron brake blocks; some of these have grooves for hangers cast in, so only need drilling for the pins. Brake blocks on full-size engines are not machined. They can also be sawn and filed from ¼ in. x ½ in. steel bar, the radii being formed by soldering the blocks to a piece of brass plate, bolting same to faceplate with edges of blocks at correct distance from lathe centre, which is slightly less than 2⅛ in. and boring to that radius with an ordinary boring tool. This process has been fully described and illustrated in previous notes, when dealing with component parts. The back slots can be formed by sawing and filing, or milling. The blocks are pinned to the hangers by pieces of ⅛ in. silver-steel, squeezed through and cut off flush. If at all loose in the blocks, rivet the ends over slightly. They should not be loose enough to rub on the wheels all the time, but just free enough to bed to the wheel treads when brakes are applied. Mount the block-and-hanger assemblies on the hanger pins, and secure with 6 B.A. nuts.

Brake Beams

The brake beams are made from 4⅛ in. lengths of ½ in. x ⅛ in. mild steel. Chuck truly in the four-jaw and turn the ends to the sizes as shown, screwing the extreme ends 6 B.A. Note that the beam connecting the driving-wheel hangers has a long spigot at each side, to carry the distance-pieces needed for lining up the pull-rods (see plan). File the beams to shape shown, and drill a No. 30 hole in the middle of each. The two distance-pieces are made by chucking a piece of ¼ in. steel rod, centring, drilling No. 30, and parting off two 5/16 in. lengths.

Brake Cylinder Frame

This is made up from two side members and a cross stay. The side members are cut from 16 gauge steel, by same process as described for main frames, and drilled whilst still bolted together. I have shown the ends bent over, for attachment to cross-stay and drag beam; but if preferred, the frames may be flat, and attached to stay and beam by pieces of angle riveted on. It is also quite probable that advertisers may supply cast frames and stay. The stay is made from 9/16 in. x ⅛ in. steel, either bent over at the ends as shown, or furnished with pieces of angle. Since I was presented with a 12 in. Diacro bending brake, by an American friend some years ago, I'm afraid that I have become rather partial to bending, as the machine bends jobs like these, to precision limits if required, quicker that I can write instructions! Rivet one side frame to the stay, but leave the other off until the brake shaft is made, otherwise you won't be able to erect it.

At 2 1/16 in. from back edge of frame, and 5/32 in. above the level of the bottom of the drag beam, drill a No. 30 hole in each side frame, and another at ¼ in. above it, countersinking all four. These are for the screws supporting the front end of the completed brake frame.

THE brake cylinder is machined up from a casting, the boring process, cover fitting, etc. being done in the same way as described for the engine cylinders; but the casting can be held in the three-jaw chuck for facing the first flange, and boring, as there is no steam-chest. The second flange is machined with the casting on a stub mandrel, held in the chuck, same as for the engine cylinders. After machining the top cover, drill two No. 23 holes in it, for steampipe union and drain cock. Both the nipple and the drain cock are silver-soldered in, as there isn't sufficient thickness of metal for satisfactory screwing. The nipple is made similarly to those described for the pump, except that a small collar is left between the screw thread, and the pip which enters the hole in the cover. Any small commercial plug cock can be used for the drain cock, but my experience of such, is that they invariably leak or stick; so it would be better to wait until the coming note appears, describing how to make the cylinder drains, and make one extra for the brake cylinder.

The bottom cover has no gland, but a vent hole should be drilled (No. 60 drill is big enough) to allow air to enter, or the cylinder may not operate. Each cover is attached by four 9 B.A. screws.

The piston is also fitted like those on the engine cylinders, the rod being a piece of

⅛ in. bronze or rustless steel approximately 1⅛ in. long. One end is screwed for ⅛ in. length, with either ⅛ in. or 5 B.A. thread, the other being turned down to 5/64 in. and screwed 9 B.A. as shown. The piston is turned from bronze or gunmetal rod, any size over ⅜ in. leaving it a shade oversize: Centre, drill No. 40, open out for ⅛ in. depth with No. 31 drill, and tap the rest of the hole to suit thread on piston rod. Screw the rod into it, and finish-turn, as described for the main pistons, with the rod held in a collet or split bush. It should be a close sliding fit in the bore; pack the groove with a few turns of graphited yarn.

Before assembling the cylinder, drill a No. 44 hole in each side boss, and tap 6 B.A. for the trunnion pins, which are turned from 3/16 in. hexagon steel, to dimensions shown in illustration, and need no detailing. A gasket of thin oiled paper can be put between top cover and flange, but nothing is needed for the bottom one. The big-end is merely a ¼ in. bush, 3/16 in. wide, drilled No. 30. A hole is drilled and tapped in the thickness, for attachment to the piston-rod; but as there is so little hold for the threads, it would be advisable to silver-solder it also.

Brake Shaft

The brake shaft is a 2⅞ in. length of ¼ in. round steel, turned down at each end to 3/16 in. diameter for 3/16 in. length. The long arms are sawn and filed from 16-gauge steel, to sizes shown, the holes in the larger ends being reamed to a drive fit on the brake shaft, on which they are mounted at 3/32 in. each side of centre. To ensure them being in line, put the No. 30 drill through the holes in the smaller end and adjust arms until drill and shaft are parallel; then braze the arms to the shaft. The two outer arms are sawn and filed from 3/16 in. x ⅜ in. steel, cross-drilled No. 32 for the pins, and slotted 3/32 in. to accommodate the pull-rods. The slotting can be done as described for the valve gear parts, in the ends of a piece of rod, before sawing off and filing to shape. The holes in the larger ends should be reamed to a tight fit on the ends of the shaft.

To make the bushes, chuck a piece of ½ in. round bronze or gunmetal rod in the three-jaw, face the end, centre, and drill down a full ½ in. with 15/64 in. or letter C drill. Turn down ⅛ in. length to a tight squeeze, fit in holes in frame, and part off at 1/16 in. from the shoulder. Fit to frame with flanges outside, and put a ¼ in. reamer through. The collars are 3/16 in. slices of ⅜ in. brass rod, with ¼ in. hole through each.

How to Erect Brake Cylinder Frame

First put the brake shaft through the bush in the frame already fixed to the stay, then put on the other frame and rivet to stay, setting the frames 1 3/16 in. apart. Put the brake cylinder between frames, and put in the trunnion pins. Pin the big-end between the ends of the long brake arms with a ⅛ in. bolt, made from ⅛ in. silver-steel reduced to 7/64 in. at each end, screwed 6 B.A. and nutted. This should be able to be turned quite freely, when the nuts are tight up against the shoulders. Run the collars up to the brackets, and pin them in and hanger assemblies. Six hanger pins will be needed, and these are turned from ¼ in. round mild steel, to the dimensions given in the drawing; a kiddy's practice job needing no detailing out. At ⅝in. from bottom of frame, and 2 9/16 in. ahead of each axle centre, drill a No. 30 hole in the frame, poke the shank of the hanger pin through, and secure with a commercial nut.

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At 2 1/16 in. from back edge of frame, and 5/32 in. above the level of the bottom of the drag beam, drill a No. 30 hole in each side frame, and another at ¼ in. above it, countersinking all four. These are for the screws supporting the front end of the completed brake frame.

position, so that the shaft is free to move around, but cannot slide sideways; then put on the outer arms at each end, setting them at right angles to the long arms, and pin those as well. Drill a No. 53 hole through boss and shaft, and use bits of 1/16 in. steel wire for pins. To ensure brakes releasing, fit a pull-off spring as shown; this is just a fairly strong tension spring, wound 20-gauge steel wire. One end is hooked through a hole drilled in the long brake arm, and the other looped around the head of a screw in the brake frame, as shown. Use 3/32 in. or 7 B.A. screw.

The whole assembly is then placed between the main frames at the back, as shown in plan and elevation. The stay is secured to the engine frames, by ⅛ in. or 5 B.A. countersunk screws put through the previously-drilled holes, into corresponding tapped holes in the stay angles. Locate, drill, and tap these as previously described. The back ends of the brake cylinder frame are attached to the drag beam by 3/32 in. or 7 B.A. countersunk screws, nutted inside, as shown in plan. Two are fitted in each angle.

How to Connect Rods

The long pull-rods can be made either from ¼ in. x 3/32 in. steel filed or milled to shape, or—much easier?—from ⅛ in. x 3/32 in. steel strip, with separate eyes pinned and brazed on, as shown in the self-explanatory detail sketch. Check the lengths from the actual job. They are attached to the brake shaft arms by bits of ⅛ in. steel rod, slightly reduced at one end, and squeezed through the holes in the arms and eyes. The intermediate rods are made in the same way, and erected as shown in the plan. Note, the distance-pieces are fitted between the pull-rod eyes and the driving-wheel hangers, so as to keep the pull-rods parallel. The two cross brake-beams are connected by a centrally-located single pull-rod, made from ⅛ in. silver-steel, furnished at both ends with forks, made to the given size by the same method as described for forks in valve gear. The bolts are made from ⅛ in. round silver-steel, screwed and nutted at both ends.

If a tyre pump is now connected to the union on the brake cylinder, and the drain cock closed, quite a moderate amount of air pressure should "plonk 'em on quick," as the enginemen would remark. If the release isn't equally quick, tighten the release spring a little, but don't overdo it, as more pressure will be required for a brake application. Although the brakes work, they are of no use for stopping a heavy load, because the wheels would simply lock and slide. Any engine-driver who works passenger trains, will tell you that it is the engine that pulls the train, but the train that stops the engine. On small passenger-carrying railways, a good hand-brake on the car carrying driver and passengers, is all that is needed for normal operation. I have described how to make and fit continuous brakes for the larger sizes, in previous issues of this journal.

The Boiler

WE shall now have to make a slight variation in the usual procedure in building this engine. By the good rights I should now describe how to make and fit the cylinder drain cocks, and the cab reverser; but as the cock operating gear lever is attached to the cab side, and the wheel-and-screw reverser is mounted on a bracket which is also attached to the cab side, we cannot fit these gadgets until the cab is made and fitted. In turn, the cab cannot be fitted until the boiler is made and erected; so the only thing to do, is to carry on with the boiler. This is of the latest type which I have evolved in my own experimental work, and embodies certain improvements, especially in the superheater.

3 Larger Flues

In place of the usual one element per flue, I am specifying three larger flues, each containing two elements, which is not only more like full-size practice, but provides nearly 50 per cent. more superheating surface, a higher steam temperature, and in consequence, a greatly-improved efficiency. Unlike those on the standard class 7 Pacifics, the regulator is in the usual position in the dome; but it is operated by a similar type of outside regulator rod, having a pull-and-push handle at the side of the backhead, which the driver can operate without having to move from his seat. This is certainly more convenient than the usual quadrant handle in the middle of the backhead. The rest of the fittings and mountings are arranged, as far as possible, in the same manner as on the full-sized engines. Now to construction.

Boiler Barrel

The boiler barrel can be made either from tube or sheet material. The former will need a piece of 4⅛ in. x 13-gauge copper tube (or the nearest larger size would do) long enough to finish to 10 in. length after tapering. Slit the tube lengthwise in the form of a V, a full 1⅛ in. wide at one end. Close in the cut edges, and rivet a butt strip of 16-gauge copper ½ in. wide, on the inside, leaving it 5/8 in. short at the smaller end. Use 3/32 in. copper rivets at about ¾ in. centres. As the boiler is not a true cone, set this joint at the bottom of the barrel, and square off the ends at right-angles to it, same as on the Great Western boilers. The overall length should be 10 ins. exactly.

To make the barrel from sheet, a piece of 13-gauge (3/32 in.) is required, approximately 10¼ ins. wide, one edge being 13¼ ins. long, and the other 12¼ ins. The copper should be soft; if hard-rolled, anneal it before rolling, by heating to red and plunging into water. The given measurements will allow for a full ¼ in. overlap when the piece is rolled up into a cone. A lap joint will be perfectly satisfactory, if riveted with a single row of 3/32 in. rivets, spaced as above. The lap joint should be at the bottom, and the ends square with it. The overall length should be 10 ins. as before.

Braze Immediately

It would be advisable, especially for inexperienced coppersmiths, to braze this joint right away, whilst both ends are easily accessible. It is important that all contact surfaces to be brazed, must be very clean. Cover the joint with wet flux (Boron compo mixed to a paste with water) and lay the barrel in the brazing-pan with the joint downwards, on the coke. Heat the barrel to bright red with a blowlamp or gas blowpipe, and apply some easy-running brazing strip to the seam. If the heat is sufficient, this will melt and run well in. The blowlamp flame can be directed on the joint from both ends of the barrel. If the melted metal runs well in the joint, and covers the rivet heads, there will be no chance of leakage developing. If the heat has been sufficient, the brazing material will sweat clean through the joint, and be visible on the outside. If oxy-acetylene apparatus is available, the joint can be made from outside the barrel, using Sifbronze and the special flux supplied for use with it. In that case, the edges of a barrel made from tube, should be V-shape when brought together before riveting the butt strip inside; the groove is filled with Sifbronze by heating to bright red at one end, melting a little blob off the end of the Sifbronze rod into it, and repeating operation, drop by drop, along the full length of the joint. Each drop should overlap the previous one, and the finished joint should have a rippled appearance. Don't forget to cover all the rivet heads!

Battery Jar

When the job is through, let it cool to black, then quench out in acid pickle made by adding 1 part of commercial sulphuric acid to about 16 parts of water. A leaden or earthenware container should be used, big enough to accommodate the finished boiler. At one time I used a two-gallon battery jar; now I use a wooden box lined with sheet lead. Let the job stay in the pickle for about 20 minutes, then remove it with a pair of tongs, and well wash it in running water under the domestic tap. If any burnt flux clings to it, knock it off, and clean up the job with a handful of steel wool, or with domestic scouring powder. Also file off any superfluous blobs of brazing material.

Throatplate and Firebox Wrapper

The throatplate is made from ⅛ in. or 10-gauge sheet copper, flanged over an iron former. The latter is made from a piece of ¼ in. plate. Mark it out to the shape of throatplate as shown in drawing, but 3/32 in. less in measurement all around except at bottom. If it were made ⅛ in. less, as might be supposed at first glance, the finished throatplate would be too small, as the "bashing" process, plus cleaning up with a file, would make the flange thin. Saw and file the plate to outline; the sawing will be quite easy if a drop of cutting oil, as used for turning steel in the lathe, is applied to the saw blade. Round off one edge of the finished former plate, so as to give a radiused flange to the throatplate.

LAY the former on to a piece of ⅛ in. copper, and mark the outline of the former on it, at 5/16 in. away. Cut out the piece with a saw, anneal it by heating it to bright red and plunging into cold water, then clamp it alongside the former plate in the bench vice, and beat down the projecting edges on to the edge of the former. Re-anneal the copper at once if it shows signs of going hard. Smooth off the ragged edges, and clean flange with a file; then cut a hole 3¾ ins. diameter as shown, either with a piercing saw, Abrafile, Tyler spiral blade, or by the time-honoured method of drilling a ring of holes all around the circle, breaking out the piece, and filing the ragged edges smooth. This hole will come flush with the flange at top and sides; and to help in locating the barrel, and preventing the same from shifting out of position when being brazed on, cut three little pieces of 16-gauge copper sheet, about ½ in. wide and ¾ in. long, and rivet them to the flange at top and sides of the hole, where it meets the flange. They should project through the hole, like tongues sticking out. I usually specify a "piston-ring" joint between barrel and throatplate, but as the barrel and wrapper are flush on this boiler, a ring would have to be stepped and would be thick enough to foul the tubes.

The wrapper sheet, or firebox casing, is made from 3/32 in. or 13-gauge sheet copper, a piece 6¾ ins. wide and 17 ins. long being required. To save cutting the bottom edges to outline after brazing, they can be cut whilst the plate is still in the flat, to the angle shown at the bottom of the firebox in the longitudinal section of the boiler. The plate is then bent to the shape of the throatplate.

Before I had a bending roller, I used to do a job like this, by aid of a round bar held in the bench vice. The hardened insets were taken out (this only needed the removal of the two screws in each) and the bar rested on the ledge exposed, which prevented it slipping down while the bending job was in progress. The locating of bends were marked on the copper sheet, and the piece of copper placed on the bar, with the marked places resting on it, in turn. A good hefty press down, by hand pressure at each side of the bar, bent the copper sheet to the required angle, leaving a nicely-rounded corner, with no marks on the copper. Anybody with average strength of wrist, can do the same—it is easier than most folk would imagine! The curves at the side can be formed in the same way, using the throatplate itself as a guide.

Clean all round the inside of the longer edge of the wrapper, then insert the throatplate, and rivet it in place with 3/32 in. copper rivets at about ¾ in. centres. Only enough rivets are needed to keep the wrapper in close contact with the flange, while brazing or Sifbronzing. Stand the assembly throatplate up, in the brazing pan, and put the barrel on it. The three little tongues should be bent outwards, so that they touch the barrel when same is in place, and prevent any side movement. The barrel should come flush with sides and top of wrapper, and the underside should be at right angles to the narrow part of throatplate. Both sides should be at the same angle of taper, in relation to the firebox shell so that the centre-lines of barrel and firebox are in proper alignment.

Cover the joints with wet flux, and pile up the coke until almost level with the throatplate flange. Get the blowlamp going good and strong, and have a general warm-up of the whole job; then concentrate the heat on one bottom corner. When this becomes bright red, apply a piece of easy-running brazing strip, which will at once melt and run in, if the temperature is right. Then move the frame gradually along the joint, feeding in more brazing material. When the barrel is reached, direct the flame on the joint between barrel and throatplate, running in a good fillet of brazing material, working the flame slowly around, and making certain that the joint is completely filled up. When the opposite side of the throatplate is reached, shift flame to bottom corner and work up again, on the joint between wrapper and throatplate flange. When once more arriving at the barrel, carry on completely around it, and when the corners at the top of the Belpaire throatplate are reached, direct the flame right on them, until bright red. Give them a jolly good rose of brazing material; the corners can be filled right up for both strength and appearance sake. Apply plenty of brazing material as you go "over the top," or rather, what would be the top if the boiler were right way up. When arriving at the point on the opposite side of the barrel, where the first spasm finished, again be careful to have the copper well heated, so that the join amalgamates perfectly. If the melted brazing material tends to bubble, scratch at it with a pointed wire dipped in the flux, until the bubbling ceases; this will reduce the risk of "pin-holes" forming. Examine carefully for missed places, as the job cools to black; then pickle, wash off, and clean up as before.

Firebox

The firebox is made in very similar fashion to the above. First cut out an iron former-plate, measuring 1/16 in. less in size, all around except at bottom, than the outline of the firebox tubeplate shown in the cross-section. The *inside* dimensions of this, are the same as the *outside* dimensions of the door plate, shown separately, except for length. This plate is also used as a drilling-jig for the tube holes in both firebox and smokebox tubeplates, so set out the centres of the tube holes on it, and drill No. 40. Cut out a piece of 3/32 in. or 13-gauge sheet copper to the same shape as the former, but 1/4 in. bigger all around except at bottom. Flange it over the former, as previously described, and before removing the copper from the former, poke the No. 40 drill through all the holes, right through the copper. Smooth off all raggedness, and clean the flanges with a coarse-cut file (the more the flanges are scratched, the better the brazing material will hold) then open out the tube holes with 23/64 in. drill, and the flue holes with 55/64 in. drill, reaming 3/8 in. and 7/8 in. respectively. Note: as the tubes should fit very tightly in the firebox tubeplate, don't put the reamer in too far; just enough to true up the irregularity left by the drill. Countersink slightly on the opposite side to the flange.

Before flanging the door plate, which is made in similar manner to the tubeplate, but is 1 in. shorter, bevel off the top of the former as shown, as the top flange of the door-plate is at an angle, as shown in the longitudinal section of the boiler. After flanging, and cleaning up with a file, the firehole ring can be fitted. To make it, chuck a short piece of 1 3/8 in. x 1/8 in. copper tube (which should be annealed) in the three-jaw, face the end, and turn a step on it 3/16 in. long and 1/16 in. deep. Part off at 19/32 in. from the end. Reverse in chuck, and turn a similar step 5/32 in. long on the other end. Put the ring in the bench vice and carefully squeeze it oval; lay it on the doorplate at the position shown in the drawing, and scratch a line all around it with a sharp scriber. Cut out the piece, insert the 5/32 in. end of the ring on the side opposite to the flange, and beat the projecting lip of the flange outwards and downwards on to the copper, as, shown, thus clamping the doorplate tightly to the shoulder.

THE firebox sides and crown are all in one piece, bent in similar manner to the outside wrapper over a bar in the bench vice. The width of the piece of 3/32 in. copper is 6 ins. and the length of the two sides can be ascertained exactly, by running a bit of lead fuse wire, or soft copper wire around the flanges of the tubeplate and doorplate, and straightening it out. After bending, cut to length shown, also cut away the sides to required slope; then rivet the tube and door-plates into the ends, using just enough 3/32 in. copper rivets to keep the plate in close contact with the flanges.

The crown stays are of my usual girder pattern, which are far stronger, and easier to fit, than any rod stays, which waste away in the middle. The two outer ones are of H form, made by riveting two pieces of copper, bent channel-shape, back to back. The middle one is an inverted T, and made by riveting two angles back to back. Use 16-gauge copper. The drawing shows the dimensions. Note that the top of the middle girder is arched, 3/4 in. high in the middle, and 7/16 in. at the ends. All three girders have five 5/16 holes drilled directly above the flanges, at 1 in. centres, to allow the wrapper stays to pass through. The girders are riveted to the firebox crown, spaced as shown, with 3/32 in. rivets at about 5/8 in. centres.

The firebox assembly can then be brazed up in the same way as the outer shell of the boiler. Cover all the joints with wet flux; up-end the firebox in the brazing-pan with the firehole ring on top. First heat all over, then concentrate on one corner until it becomes bright red, apply the strip of brazing material, and work slowly right around. Run a good fillet around the firehole ring. Turn the firebox the other way up, and do the joint at that end, but be extra careful to avoid blowing the full force of the blowlamp flame on the metal between the tube holes, or you'll suddenly find one big ragged hole in place of a lot of nice little round hole.

Stand the firebox right way up, to do the crownstay flanges. It will help a lot here, if a strip of coarse-grade silver-solder is laid alongside each flange, and the flame played directly on the joint; the silver-solder will melt, and sweat right through, after which a little of the brazing strip can be added. Be sure to cover all the rivet heads. Let cool to black; pickle, wash off, and clean up as before.

Smokebox Tubeplate, and Tubes

Three 7/8 in. x 20-gauge superheater flues will be needed, plus twelve 3/8 in. x 22-gauge ordinary fire-tubes. Square the ends in the lathe, and clean both ends with coarse emerycloth. A circular former will be required for the smokebox tubeplate; anything round, of correct diameter can be used—an old chuck back, iron wheel, or whatever may be handy, as long as it is 3 3/8 in. diameter. Cut a circle of 1/8 in. sheet copper to a diameter of 4 1/2 in. and flange it over the former; the flange being fairly deep, it will probably need annealing three or four times, to avoid cracking. Chuck in three-jaw, flange outwards, and turn off the ragged edge; then reverse, and hold it on the outer edges of the outside jaws, to turn the flange to a tight fit in the end of the boiler barrel. This should be slightly bevelled, as shown, to form a groove for the brazing material. Scribe a line down the centre, then clamp the firebox former to it, so that the line shows through the guide holes in the middle of the bottom, third, and top rows. Run a No. 40 drill through the lot, then open out and ream, as given for the firebox tubeplate; but this time, put the reamer right through and countersink *both* sides. Drill and tap the stay and pipe holes as shown.

Whilst old hands at the game can silver-solder the whole bunch of tubes at once, inexperienced coppersmiths had better do the job in two instalments. Put in the three flues and the top row of tubes, putting the smokebox tubeplate on the end, to act as spacer and support. Line them up carefully with the firebox, and stand the assembly in the brazing pan with the tubes pointing skyward. Put some wet flux all around each tube; Boron compo will be all right for best grade silver-solder, but if Easyflo is used (I use it myself) use the special flux supplied for same. Pile coke or breeze all around, and put some inside the firebox; heat the tubeplate first, and then, when the flux boils up and fuses, direct the flame on the tube ends as well. When the lot is dull red, apply a strip of silver-solder, which will melt and "flash" around each tube. Let cool to black, then put the job in pickle, which will clean the rest of the tube holes. The rest of the tubes can then be put in, and the silver-soldering process repeated. After this, pull off the smokebox tubeplate, and make the ends of the tubes red-hot for about an inch down; this is to soften them for expanding into the holes at final assembly. Pickle, wash off, and clean up as before; then, if the job is O.K. a silver ring should show all around each tube end inside the firebox.

PUT a good layer of red flux all around the foundation ring and backhead joints. Lay the boiler on its back in the brazing pan, and pile up the coke or breeze almost to the level of the foundation ring. Put some asbestos cubes, or pieces of millboard, in the firebox, to protect the ends of the tubes. If using an oxy-acetylene blowpipe, no coke packing will be necessary. Once again, if you can get a " mate " to hold another blowlamp and direct a flame on the opposite side of the joints, the job will be rendered much easier. Heat the job evenly all around, until the flux starts to fuse, then concentrate on one corner. When bright red, apply the brazing strip, and when it melts and starts to flow—which it will do immediately if the heat is sufficient—gradually move the flame along, feeding in the brazing material all the time, until you have completed the course, right around the ring. If a " mate " is assisting, the flame of the second lamp should be moved in unison, so that the heat is concentrated on the spot where the brazing material is being applied. Then, as quickly as possible, to avoid letting the job cool off, up-end the boiler in the pan by aid of the tongs, and give the backhead joint a dose of the same medicine. Some coarse-grade silver-solder can be run around the flange of the firehole ring. Finally stand the boiler the right way up, and direct the flame on each of the bushes in turn, applying some best-grade silver-solder, which will run around them and seal them in very neatly.

Inexperienced workers may, if they so desire, use silver-solder for the foundation ring and backhead joints, in place of brazing strip. It costs much more, but melts at a lower temperature, and has the necessary strength and ductility; but DON'T, on any account, use one of the cheaper alloys containing silver and phosphorous. These are far too brittle for boiler work. A nod is as good as a wink to a blind horse!

Don't be too quick about putting the completed boiler in the pickle bath, and take all precautions to keep clear of splashes. If the boiler isn't too heavy, enlist the aid of the garden rake or domestic clothes prop, to help with the final baptismal ceremony. When the acid pickle first runs inside, it promptly blows out again as soon as it comes in contact with the hot firebox and tubes; and acid splashes on your clothes, or overalls, will soon make them more " holey " then righteous. If you are unlucky, remember that liquid ammonia, as used in washing, will neutralise the destroying effect of the acid if applied quickly. Splashed skin should be washed instantly with soap and hot water. Prevention is better than cure—the number of boilers that I have personally built, ran into three figures years ago, but I'm still unscathed—touch wood!

Leave the boiler in the pickle for about half-an-hour, then fish it out with the garden rake or anything else handy, drain out any acid pickle still inside, and well wash under the domestic tap, scrubbing the outside with some scouring powder and a nail brush, and finishing with steel wool, if you have any. A quick test for "pinholes" in the brazing, can be made by plugging all the bush holes except one, fitting an adapter in that, to suit a tyre pump, placing the boiler in the domestic bath, under water, and pum ing about 20 lb. of air pressure in it. there should be a small leak, it will shown by bubbles coming out of the defe tive place. Weeny leaks can easily be pe manently cured by drilling a No. 55 ho tapping 10 BA, and screwing in a stub copper wire, threaded to suit, with a sme of plumbers' jointing on the threads.

Staying

The cross stays between the sides of wrapper are made from 4 in. lengths 3/16 in. copper or bronze rod, screw 3/16 in. x 40 at each end. One of the lon tudinal stays is of similar material, but other is made from a piece of 16-gau copper tube, 3/16 in. diameter, through wh steam passes to the blower jets. The so stays are fixed in the plates by blind nipp made from 3/8 in. hexagon rod. Chuck three-jaw, face the end, centre, drill 5/32 or No. 22 for 3/8 in. depth, and tap 3/16 x 40. Turn down 3/8 in. of the outside 5/16 in. diameter, and screw 5/16 in. x Part off at 1/8 in. from shoulder, reverse chuck, and chamfer; make a dozen wh you are at it. Drill 9/32 in. holes in the s of the wrapper at the position shown the general arrangement drawings of boiler, tap 5/16 in. x 40, screw a nipple about two turns on the stay rod, insert wrapper hole, and screw in until the end the stay rod appears through the hole the opposite side, far enough to al another nipple to be started on it. T screw both nipples right home. The se longitudinal stay is put in, in similar m ner, through the hole in the backhead, as it will be difficult to guide it to the h in the smokebox tubeplate without any s port, a piece of thin 1/4 in. tube should put through, and the end of the stay serted in the end of the tube. It can t easily be guided through, to the other h and the nipple put on. The hollow stay a thoroughfare nipple at the smokebox e which is simply a blind nipple exten beyond the hexagon, screwed 1/4 in. x and drilled right through. The backh end is furnished with an elbow nipple; is like a blind nipple with an extended h into which is silver-soldered a 1/4 in. x union screw. Both fittings are shown detail, and need no further explanation.

There are 48 stays in each side of firebox, and 9 each in backhead and thr plate. They are made from 1/8 in. cop rod, screwed through both plates, riv over outside, and locknutted inside. In years of boiler experimenting, I have fo that a goodly number of small stays fairly close spacing, are far more effec that a smaller number of stays of la diameter, more widely spaced. Wide s ing allows the metal to bulge between stays, and the sides of the firebox s resemble an old-fashioned buttoned c cushion. The smaller stays carry far stress, as there are many more of them share the given load; and in any case, stays shown for this boiler, *are over t the " scale " thickness*, a fact which ginners wouldn't realise unless it is poi out to them. Set out and drill the h as shown, with No. 40 drill, clean thro both plates, and tap them with a pilot (commercial article sold by our adverti which will ensure continuity of the thr in both plates. If plenty of cutting o used when drilling and tapping holes in soft copper, and screwing staybolts, torn threads will be avoided.

To make the stays, I usually start with a few pieces of copper rod about 6 ins.

long, screwing about ⅝ in. of each end. These are screwed home through both plates, to the end of the thread, by aid of a tapwrench clamped on close to the part being screwed in. The rod is then snipped off about 3/32 in. from the plate. A commercial brass locknut is screwed on to the projecting part inside the firebox, and any surplus cut off. The end outside the wrapper is riveted over to form a cup head, the inner end of the staybolt being rested on a piece of bar held in the bench vice. When all the screwed ends are used up, the pieces of rod are re-screwed, and the process repeated, until the rods are too short for further use.

The threads should fit tightly in the holes in the firebox and wrapper sheets, and by the good rights, should be quite free from any steam and water leakage, without further treatment; but as soft copper is usually torn, more or less, not only by inexperienced workers, but by old hands who don't exercise due care, it is advisable to sweat over all the stayheads and nuts, as a precautionary measure. This is an easy job. Lay the boiler on its side in the brazing pan, and brush some good *liquid* flux all over the stayheads and nuts. Don't on any account, use a paste flux; if any gets inside the boiler, it cannot be removed without great trouble, and the boiler will prime or foam when working. Put a few blobs of plumber's solder (which has a higher melting-point than tinman's solder) among the heads and nuts, and then slowly heat the boiler to the melting point of the solder, with a blowlamp. When the solder melts and runs, brush it all over the heads and nuts with a wire brush. This can be homemade in a matter of minutes, by putting a bunch of " black " iron wires in the end of a piece of copper tube about ⅜ in. diameter, and flattening the end, to grip the wires; fit the tube into an old file handle, or something similar, as it gets mighty hot while in use! Turn the boiler over, naturally, to do the opposite side; and if there is any place to which the solder doesn't seem inclined to " stick," dip the wire brush in the flux and apply it to the bad place. This will teach it good manners. When every head and nut has been covered, wash the whole boiler in running water, scrubbing the outside with a nailbrush, and squirting plenty inside as well, to remove all traces of the flux. If any flux is left inside, it will corrode the copper and form a poisonous green deposit, which will rot the fittings and mountings. The boiler is then ready for a water-pressure test.

Regulator Bush and Dome Cap.

As the position of the regulator bush is important, I have shown a separate drawing of it, to ensure its correction location. If not fitted properly, the spindle won't connect up with the inside lever operating the valve. The bush is a ½ in. length of ½ in. round bronze or gunmetal rod, squared off at both ends and tapped ⅜ in. x 26. At 1 in. below the top of the boiler at the dome bush, and 5/16 in. back from the centreline of same, drill a ⅛ in. pilot hole in the boiler shell, enlarging it to 7/16 in. Then enter the end of a ½ in. taper reamer in it, and gradually open the hole until the bush will barely enter, at the same time pressing the reamer down to a horizontal position. Finally finish the hole to size with a ½ in. parallel reamer held horizontally, but don't put it in too far, as the bush must fit tightly. It can then be silver-soldered in place, by directing the blowlamp flame direct on it, which will heat both it and the surrounding metal sufficiently to melt either best-grade silver-solder, or Easyflo.

To save time, the dome cap might be fitted right away. This is a casting, which may be gripped in the three-jaw, flange outwards, the flange being turned to 1¾ in. diameter, and about ⅛ in. thick. If the inside of the casting is rough, clean it out while the casting is still chucked. For jobs like this, I use a round-nosed tool made from a wornout file, complete with handle. A bit of square bar is put in the slide-rest tool-holder, and set across the hole; the hand tool is then rested on it, eased into cut, and the handle moved in an arc. This cleans out any roughness in two wags of a dog's tail. The casting can then be reversed in the chuck, and gripped by the flange; the outside is turned to the dimensions shown. Centre, drill No. 40 and tap ⅛ in. or 5 B.A. for the screw holding the outer cover.

Twelve No. 41 holes are then drilled equidistant around the flange at 3/32 in. from the edge. The cap can then be placed in position on the dome bush, and the screwholes in the flange located, drilled, and tapped exactly as described for cylinder covers. Put a 1/64 in. Hallite or similar jointing gasket between the flanges before putting the screws in, and put a countersunk brass screw in the hole in the top, as a temporary seal while testing the boiler.

How to Test the Boiler

Fit temporary screwed plugs in the hole in the smokebox tubeplate, and the regulator bush. Fill the boiler with water, right up to the safety-valve bushes. Connect one of these to a hand pump (a tender pump will do very well) and the other to a full-sized steam gauge. Suitable adaptors can easily be made from any odd scraps of brass rod which may be available. Stand the hand pump in a pan of water, and give the handle a few strokes, to bring the pressure up to about 40 lb. Then examine for leaks or bulges; if O.K. increase pressure by easy stages to 160 lb. keeping a sharp lookout for any untoward happenings. If any faults show up, correct same before proceeding with the test. Don't take any notice of a slight movement in the firebox crown sheet, this will probably move 1/32 in. or so, as the soft copper adjusts itself to the best position for resisting pressure. If the boiler does not show any signs of leakage, and doesn't bulge anywhere at 160 lb. you can reckon it O.K. for service. It should stand much more than that, as I always allow a good margin; but it is very unwise to strain a boiler by excessive test pressure, and is contrary to full-size practice.

The best material for the smokebox barrel is a piece of 16-gauge brass tube 3¾ ins. diameter, and about 5½ ins. long. This can be rough-sawn to full length; and if a disc of wood or metal is put in the end, it can be gripped tightly enough in the three-jaw, to enable the ends to be squared off to dead length. I usually plug mine with an old wheel casting, or a chuck back. Take light cuts, naturally, or the tool will dig in, with unpleasant results. If tube is not available, the barrel can be rolled up from 16-gauge brass or steel sheet, putting a narrow butt strip inside, with a few 1/16 in. rivets to hold it while brazing, if steel, or silver-soldering, if brass. At 2½ ins. from one end, drill a 1 in. hole, starting with a small pilot hole, enlarging by easy stages, and finishing with a reamer. If you try to drill the full size in thin metal, the hole always comes out polysided. Exactly opposite, drill a ⅜ in. hole for the exhaust pipe, as shown on the drawing; and about 1 in. ahead of this, drill a ¼ in. hole for the snifting valve. At ⅞ in. below the centre-line, and dead in line with the chimney hole, drill a ⅜ in. hole at each side, for the steampipes.

The smokebox front (usually called the "ring") may be made from castings. Chuck the ring on the outer steps of the three-jaw, same as described for the smokebox tubeplate, and turn and face it in exactly the same way, cleaning out the hole with a boring-tool. Chuck the door by the cast-on spigot, and turn the edge to diameter, facing it truly, to ensure airtight contact with the ring. If the hinge straps are not cast on, the door can be reversed in chuck, gripped by the edge in the outside jaws, and the front turned all over. If they are cast on, the door will have to be finished with a file.

The ring can also be knocked up from a ⅛ in. brass blank 4½ ins. diameter. Flange it exactly the same as the smokebox tubeplate. Chuck in three-jaw, flange outwards, and face off the ragged edges; reverse, rechuck as above, turn the flange to a tight push-fit in the smokebox barrel, cut the hole with a parting-tool set crosswise in the rest, and face all over. The door can be made from a ⅛ in. brass blank 3¼ ins. diameter. Anneal by heating to dull red and plunging into cold water: then dish it by hammering it with the ball end of the hammer, resting it on a block of lead. Chuck in three-jaw by the edge, concave side out, centre and drill it with No. 30 drill, and face off a patch about 1 in. diameter. Chuck a bit of brass rod about ½ in. diameter turn an ⅛ in. pip on the end, push it into the hole in the embryo door, and solder it. Grip the rod in the chuck, and the door can then be turned all over, the edge turned to diameter, and the contact part trued up with a parting-tool, or a right-hand knife tool. Melt out the chucking-piece.

Smokebox Fastenings

The easiest way of making the hinge straps, is to cut them from 18-gauge steel, looping the ends around a bit of 1/16 in. wire, and silver-soldering them. The lugs can be turned from a piece of ⅛ in. square brass rod held truly in the four-jaw; turn ⅛ in. length to 7/64 in. diameter, and screw 6 B.A. Part off at 5/32 in. from the end, and round off as shown. The hinge straps can be riveted to the door with 1/32 in. rivets, or bits of domestic blanket pins; or they may be silver-soldered on with best-grade silver-solder, or Easyflo. Temporarily clamp door in position with a ⅛ in. screw through the hole in the middle, entering a tapped hole in a bit of bar placed across the back of the ring. See that it is exactly in the middle, then mark off the position of the lugs, between the jaws of the hinge straps. Centre-pop, drill No. 44, and tap 6 B.A. Remove door, screw lugs in, replace door, and drill the holes in the lugs for the hinge pin, through the holes in the straps. The door should not be permanently attached until the crossbar brackets have been made and fitted.

The crossbar is made from two 3 in. lengths of ¼ in. x ⅛ in. flat mild steel, riveted together with spacers made from slices of ¼ in. rod between. These are a bare 3/16 in. thick, and drilled No. 40. The brackets are bent up from ¼ in. x 1/16 in. strip as shown, and riveted or screwed to the inside of the ring, so that when the crossbar is in position, it lies exactly across the middle of the opening. Countersink the rivets on the outside, and file flush, so the door closes airtight.

The dart can be turned up from ⅜ in. round mild steel held in the three-jaw, and the button on the end filed flat. All sizes are shown in the illustration. It can also be built up, turning the stem from ⅛ in. mild steel rod, and filing up the head from ⅛ in. x ⅜ in. steel strip. Drill a little hole in the edge of the head, and turn a pip on the end of the stem to fit it; if the pip is pushed into the hole in the head, it will hold the parts in alignment whilst being brazed. The bosses of the handles are just slices parted off drilled rod of suitable diameter, or rod turned to size. The smaller one is tapped 3/32 in. or 7 B.A., to suit thread on dart, and the larger one has the hole filed square, to suit the square on the dart. The grips can be made from 3/32 in. round steel, and either screwed or brazed into the bosses, just as you fancy. Assemble the lot as shown in the section, and fit a 1/16 in. headed pin through the hinge joints. The completed front is not fitted permanently to the smokebox shell, until the boiler is erected.

Chimney and Liner

THE chimney liner is a 2½ in. length of 1 in. x 18 or 20 gauge copper or brass tube, belled out at the bottom as shown; this is easily done by annealing the tube, and either driving a taper drift into it, or hammering the end from the inside, on the edge of a block of lead. The flange is a piece of 18 or 20 gauge copper sheet, 2 ins. square. Drill a 3/16 in. pilot hole in the middle, and enlarge it until the tube fits tightly; then bend it to the radius of the inside of the smokebox, place it on the chimney liner at 1 3/16 in. from the top, and silver-solder it, using as little silver-solder as possible, filing off any that seeps through to the convex side. Push the liner up into position from the inside of the smokebox, putting a smear of plumbers' jointing around it, then drill four No. 41 holes in a 1⅝ in. square, through the smokebox shell and flange, countersink outside, putting brass screws in, with nuts on the inside of the smokebox. File the heads smooth on the outside.

The casting for the chimney can be chucked in the three-jaw, and bored out to a sliding fit on the liner. Then mount it on a mandrel, either in the chuck or between centres, and turn the outside to the shape and dimensions given in the drawings. The flange at the bottom must be finished with a fine file, and smoothed off with emerycloth or any similar abrasive. The chimney is not fixed to the smokebox in any way, being just pushed on over the liner. It won't jump off!

Smokebox Saddle

If a casting is used for the smokebox saddle, it will only need cleaning up with a file, to fit nicely between the frames, and to allow the smokebox barrel to bed into the radius. If castings are not available, the saddle can be built up, by cutting out the four sides to dimensions given, from 1/16 in. sheet steel or brass, and joining the corners by pieces of angle riveted in. Alternatively, the ends could be left about ¼ in. longer at each side, bent over at right angles to fit between the side plates, and riveted or brazed in position. When cutting the side plates, leave a tag at each end, as shown, for attaching them to the frames. The flange is a piece of 16-gauge material 3⅛ ins. x 3⅝ ins. bent to the radius of the smokebox barrel, and silver-soldered or brazed to the sides of the saddle. Cut away the centre part after the latter operation. If a casting is used, and the attaching lugs are not cast integral, fit pieces of angle as shown in the drawing. Don't forget to file the clearances in the sides, for the exhaust flanges.

Safety Valves

Plain non-pop safety-valves are specified for this engine, as I have found that small pop safety-valves tend to lift the water when the level is high, and cause priming. The sudden release of pressure under the valve when it lifts, causes a miniature waterspout to form on the surface of the water; and if the apex touches the outlet of the valve, the water sprays out, the action continuing until the valve shuts down again. I have actually seen this happen, in a glass laboratory boiler which I fitted with a pop-valve for experimental purposes.

To make the valve, chuck a piece of ⅝ in. round bronze or gunmetal rod in the three-jaw; face the end, turn ¼ in. length to ⅜ in. diameter, and screw ⅜ in. x 26. Part off at ½ in. from the shoulder. Re-chuck in a tapped bush held in three-jaw; centre, drill through with 9/64 in. or No. 24 drill, open out and bottom to 19/32 in. depth with 9/32 in. drill and D-bit, and tap the end 5/16 in. x 32 or 40. Put a 5/32 in. parallel reamer through the remnants of the small hole. Turn the outside to the shape and dimensions shown, leaving a 3/32 in. collar in the middle which is filed to hexagon shape. Seat a 3/16 in. rustless steel ball on the hole, by putting a piece of brass rod on it, and hitting it just one good crack with a hammer. Alternatively, the seating can be formed with a cycle ball, and a bronze one used for the actual valve. The ball is held down by a cup and spindle turned from ¼ in. round bronze rod as shown in the section. The spring is wound up from 22-gauge tinned steel wire, around a piece of 3/32 in. rod held in the three-jaw. Bend about 1 in. of the wire at right angles, poke it between the chuck jaws, and pull the belt by hand, guiding the wire on to the rod as the lathe mandrel slowly turns. Perfect springs can be made after a very little practice.

To make the nipple, chuck a piece of 5/16 in. round rod, face, centre, drill No. 40 for about ¼ in. down, screw 5/16 in. x 32, and part off a ⅛ in. slice. File two nicks in this section as shown, to let the steam out. The spring should just start to compress when the threads engage; blowing-off point is set when the boiler is in steam, by adjustment of the nipple. Two valves are needed.

Regulator

The full-sized engines have dome regulators with slotted ports and two sliding valves, which would be tricky to copy in 3½ in. gauge size; so I have substituted the circular disc type, similar to those fitted to the engines of the old L.B. & S.C.R. which I can personally testify worked easily, and never leaked or gave any other trouble. This type is easy to make, and can be operated by the side spindle and standard handle of the B.R. engines. The stand can be made from a casting, or built up, the machining and fitting being the same in either case; if built up, use a piece of 5/16 in. square brass rod, 1⅝ in. long, for the column. At one end of this. silver-solder a boss ½ in. diameter and ⅛ in. thick; at the other end, directly opposite, silver-solder another ½ in. boss 3/16 in. thick. Centre-pop and drill the column with 7/32 in. drill, to within 3/32 in. of the bottom; on a built-up stand, this can best be done before silver-soldering on the bosses, by chucking the stand in the four-jaw, setting to run truly, and drilling from the tailstock. Tap the upper end of the column ¼ in. x 40, and fit a screwed plug as shown.

Scribe a line down the middle of the portface, and set out and drill the port and pivot holes, as given in the drawing: the pivot hole is drilled No. 48 and tapped 3/32 in. or 7 B.A., and slightly countersunk. Drill the upper port right into the plug, as shown, to ensure a free passage for the steam. The bottom boss is drilled 7/32 in. to meet the vertical hole in the column, then opened out and tapped 5/16 in. x 32 for 3/16 in. depth, to take the steam pipe. The bracket for the regulator spindle, which is made from ⅜ in. x ⅛ in. angle, may either be screwed on as shown, or silver-soldered at the same heating with the bosses. If a casting is used for the stand, the bracket will be cast on it and will only need drilling for the end of the spindle, as shown.

The Valve

THE valve can be cut from ⅛ in. brass plate or can be made from a ⅛ in. slice of ½ in. bronze rod, with a 3/32 in. lug silver-soldered on. The ports are drilled at such an angle, that they are uncovering the ports in the stand half-way, when the lug is horizontal. This is shown in the erection drawing. Note that the upper hole is elongated slightly, to enable the engine to be started without slipping, by admitting a very small quantity of steam to the cylinders; this serves the purpose of the pilot port in the full-sized regulator. The pivot pin is a ¾ in. length of 3/32 in. bronze rod, screwed at each end, and fitted to the portface as shown; face the latter truly, before fitting the pin, by rubbing it on a piece of emerycloth, or similar abrasive, laid on the lathe bed. or something equally flat and true. Give the valve a dose of the same medicine, and attach it to the portface by a light bronze spring and nut as shown. Only a light pressure is required, as the steam keeps the valve on the face; the spring merely retains it when there is no steam in the boiler, and prevents scale and grit getting between the working faces, and causing leakage.

The regulator rod is similar to a forked valve-gear rod, with the eye set at right angles to the fork. It can be filed up from 3/16 in. square brass rod, and slotted by the method described for valve gear forks. The forked end is pinned to the lug of the regulator valve by a bit of 3/32 in. bronze rod, squeezed through the holes in fork and lug. Should the pin appear to be loose, rivet over the ends very slightly. The joint must be perfectly free; very important, that! The lever is filed up from ⅛ in. x ¼ in. brass, a simple job needing no detailing. The pin should be turned from drawn bronze rod; on no account use any steel for any rods, pins, or levers inside the boiler. I don't recommend even so-called rustless steel, as certain kinds lose their rustless properties when they become hot. All threads should be a very good fit, so that they have no chance of working slack.