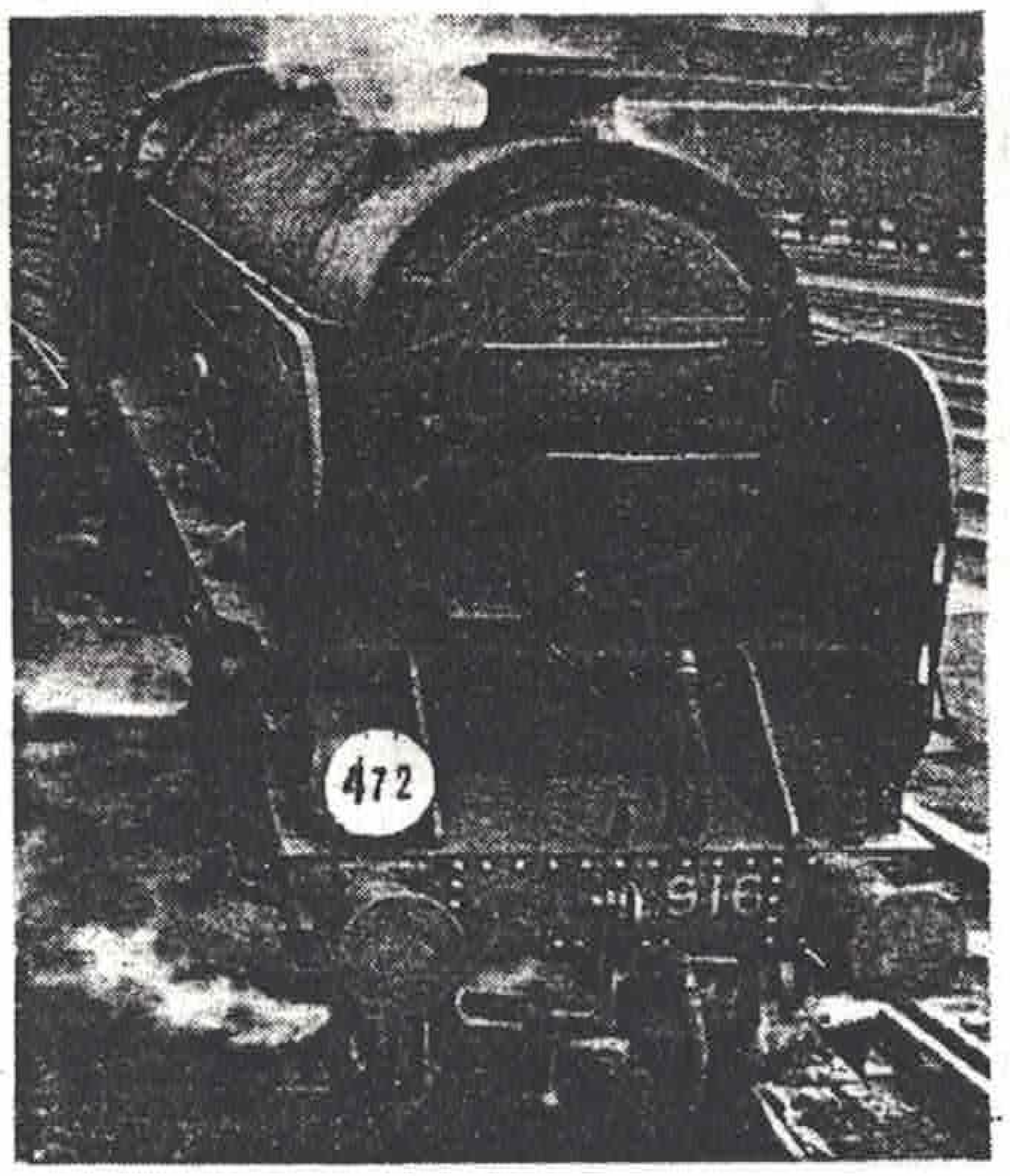
Introducing " Roedean," a Southern " Schools " 4-4-0



Why should the " Schools " Class be limited to boys? L.B.S.C.'s 3½ ins. gauge is " Roedean " — a graceful tribute to a girls' school.

BEFORE starting the description of how to build our readers' own choice, I would like to address a foreword to new readers and beginners in small locomotive construction which may save a lot of time and futile correspondence. Now when I set out to design and build a small edition of a full-sized locomotive, I always approach the job from the same standpoint as a " full-size " C.M.E. Taking into account the rail gauge, height and width limitations, and other usual factors, and considering the work the locomotive is expected to do, *and keep on doing* (very important that) all the various components are arranged for standing up to the job, working with the greatest possible efficiency, and being easy to make and erect.

As there is a vast difference between manufacturing and operating conditions on 4 ft. 8½ ins. gauge, and 3½ ins. gauge, it naturally follows that the small engine will differ in detail from her big sister; to quote one example only, the boiler of a 4 ft. 8½ ins. gauge locomotive may contain 24 superheater flues and over 200 small tubes, the barrel and wrapper being made of steel. In a locomotive of 3½ ins. gauge, which is one-sixteenth the size, it would be impossible to build an exact copy of this boiler which would generate sufficient steam, because you cannot " scale " nature.

Therefore we build our boiler to suit the size of the engine, using a small number of tubes of proportionately larger diameter, and using copper for the shell, to avoid rust and pitting; a rusty place 1/16 in. deep on a 5/8 in. steel boiler plate would not weaken it overmuch, but the same fault on a 1/16 in. steel boiler plate would mean a hole. We also use proportionately thicker plates to avoid the necessity for close staying.

Well, I need not dilate on this subject; I just wanted to call attention to the fact that some of the components of the 3½ ins. gauge " Schools " engine will differ from those of her big sisters, for the above-mentioned reasons, viz., strength, efficiency, and ease of construction. The locomotive is in no sense a " model," but a *real* engine intended for *real* work. I once saw a child's toy clockwork engine in a bazaar with a ticket on it " Scale Model Locomotive, price 2/11½d." !

Brief Specification

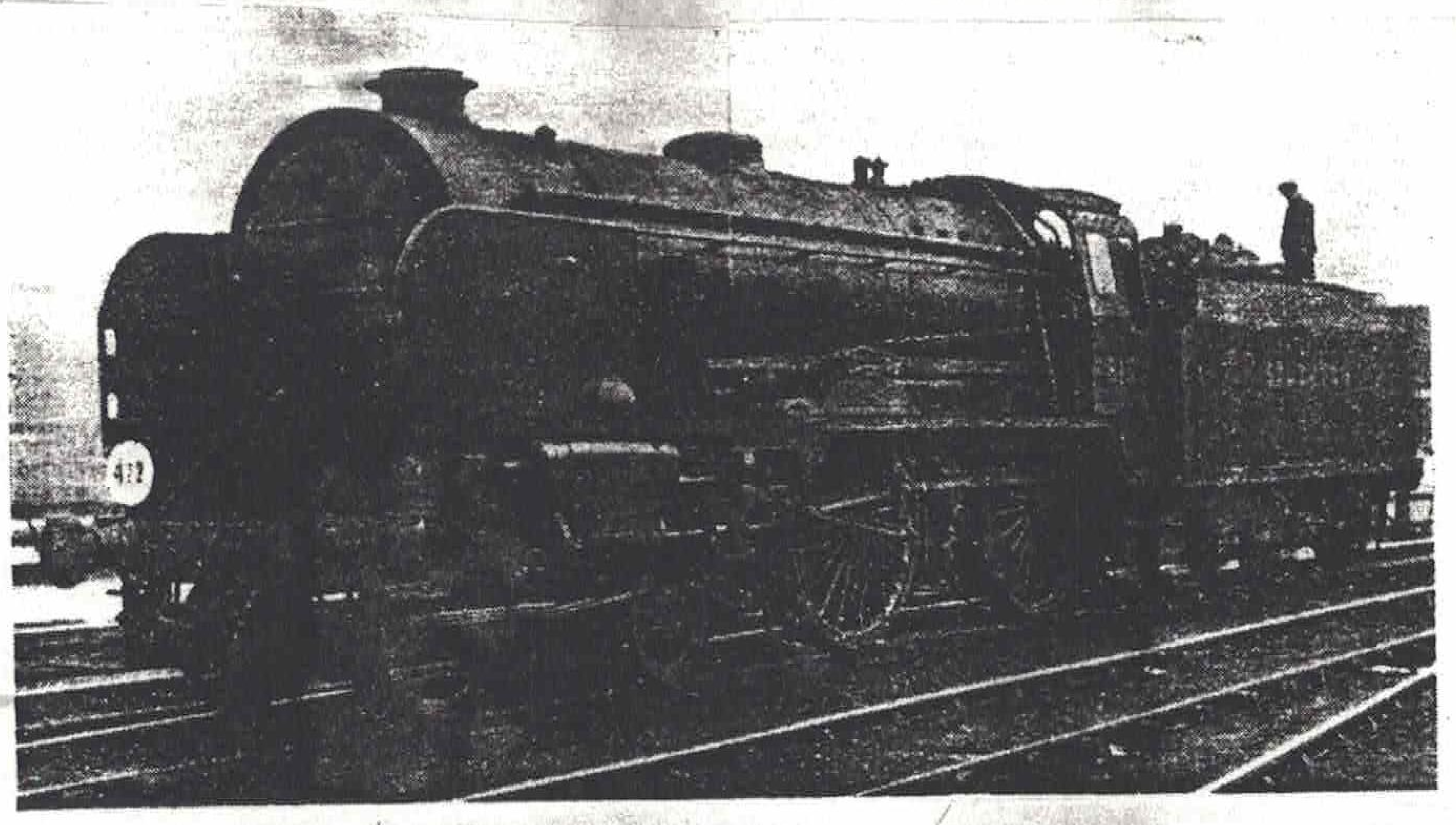
Except for the above-mentioned variations in detail necessitated by the small size, the locomotive will be an accurate copy of the Southern " V " class, popularly known as the " Schools," as they all bear the names of well-known public schools; but as I didn't think it quite fair that boys' schools should hold a complete monopoly, I have carried on where the Southern left off after building No. 939 and calling it " Leatherhead." Our engine will be No. 940 " Roedean."

She is of exact proportionate length, with a correctly-shaped wheelbase, the bogie axleboxes being separately sprung. The coupled wheels are 4 15/16 ins. diameter, the exact equivalent of the big engine's 6 ft. 7 ins. She will have three cylinders, 1 in. bore, 1⅝ ins. stroke, with three separate sets of Walschaerts valve gear arranged as in full size, except that no valve-spindle guides are provided, these being a useless complication not needed in 3½ ins. gauge, though worth while in full size; one big mechanical lubricator will feed all three cylinders, which will have proper piston-valves.

The boiler will be arranged to my usual specifications, arrived at by years of actual experimenting on engines of all kinds, and will be 4⅜ ins. external diameter, with ample firebox capacity, and an efficient superheater. The big engine has an air pump worked off the middle cylinder, to maintain vacuum when running, but as this engine will not have working vacuum brakes (steam brake instead) we might be able to utilise the pump for boiler feed, as on the G.W.R. " 1000." In any case she will have an injector behind the footstep, as in full size.

Some of the big engines have a wide chimney and Lemaitre blastpipe which in the opinion of many good folk, completely spoils the appearance, and is not needed in 3½ ins. gauge, so the original neat type of chimney is shown. The smoke-deflector plates are also non-est, they also are not needed on the little engine, and always remind me of an old-fashioned dame with a shawl around her shoulders to keep the wind off.

The other well-known features of the Southern engines will be shown in the drawing, and the tender will be of the standard



type with solid disc wheels; so now we can proceed to construction. I have given those advertisers who asked for it, all possible information needed for supplying the castings and parts, so these should be readily available by the time these notes appear in print: material already available is "worked in" wherever possible.

Main Frames

For the main frames, two pieces of ⅛ in. steel plate are required, 3⅜ ins. wide and approximately 2 ft. 1 in. long. Mark out one plate as shown (next instalment), drill a couple of the screwholes near the ends, use the plate as a jig to drill two similar holes in plate No. 2, then temporarily rivet them together, and saw and file to outline. I recommend soft blue steel, as it is not only easier to work, but doesn't tend to spring into a bow shape after the hornblock openings have been cut; some of the hard-rolled bright stuff is prone to do this, though I had some very good "soft bright" in days gone by.

If you use a saw with about 22 teeth per inch, and keep the blade wet with the same cutting oil used for turning steel in the lathe, sawing through the ¼ in. thickness of the combined plates isn't such a formidable job as it would appear at first sight. The vice top should be used as a guide, to saw along the straight lines; and if two diagonal straight cuts are made at each of the bogie-wheel clearances, meeting at the top of the arc, there isn't much left to remove with a file.

IN the old days, when I had not much equipment but plenty of energy, I used to bribe my fair lady to stand by with an oil feeder containing cutting oil, and drop it on the sawblade whilst I performed the muscular exercise act. Now, when I have plenty of equipment and not much energy—thanks to Anno Domini—I either cut my frames with a small oxygen cutter, or use the milling machine, circular-saw fashion.

It will be noticed that no holes are shown for cylinder attachment. This is because, with three cylinders in line, you can't very well bolt the outside cylinders to the frame with bolts put through from inside the frame. The cylinders will have end flanges for attachment, and the bolt holes in the flanges will locate those needed in the frame when the cylinders are erected.

There is nothing special to note about the holes shown; the small holes ahead of the hornblock openings are for the brake hanger supports (note the curve underneath, for extra strength as in full size) and the big oval hole is merely a replica of the one on the big engine. The ¼ in. hole at the front end is for the crane hooks when a full-sized engine is lifted. Before parting the frames, mark which is the outside of each, so they can be erected as they were cut out.

Buffer and Drag Beams

Buffer and drag beams are made from 1 in. by ⅛ in. angle, either steel or brass being suitable. Commercial black steel angle will do quite well, if smoothed off with a file, as the beams are, of course, painted. Castings may also be available: if so, much work will be saved, as the lugs for frame attachment will be cast on, and will only need slotting.

When making the beams of angle, note that the back one is ½ in. longer than the front. This is in accordance with big sister, whose clearances had to be cut fine to pass the restricted loading gauge on the section between Tonbridge and Hastings via Robertsbridge. The vertical part of each beam has the corners cut away as shown, and the top slotted to accommodate the frames.

The easiest way to slot these truly is to use a ⅛ in. circular slitting saw mounted on an arbor between lathe centres. Put the beam under the slide-rest tool holder, and feed in, using slow speed and plenty of cutting oil. I use either "Cutmax" or "Vacmul A" with one-third its bulk of paraffin added, and it helps a lot, but ordinary soapsuds will do at a pinch, provided you give the lathe a jolly good clean-down afterwards, to prevent rust. Anybody who has a milling-machine, planer or shaper, won't need any instructions on cutting plain slots!

Failing mechanical means, the slots can be cut by careful hand work with saw and file, using the vice top as guide, up-ending the beam in the bench vice with the marked line just showing. Rough out with two saw-blades placed together in the frame, and finish with a warding file. The frames should be a tight fit in the slots, and it is hardly necessary to add that extreme care should be taken to get the slots dead at right angles to the beam, otherwise the frames will be a rhomboid when assembled.

A piece of ¾ in. x ⅛ in. angle is riveted to the inner edge of each slot as shown; if a bit of ⅛ in. plate is jammed in the slot, and the angle clamped tightly to it with a toolmaker's cramp whilst drilling the rivet holes, the location will be O.K. Countersink the holes on the outside of the beam, and file the rivets flush; also file any projecting bit of angle flush with the beam. Charcoal-iron rivets are best for this, as they seldom come loose.

To make the pin, chuck a piece of 3/8 in. round steel rod in the three-jaw, turn down 1/4 in. of the end to 3/16 in. diameter, and screw it 3/16 in. x 40. Part off at 13/16 in. from the end. Reverse in chuck, turn down 3/8 in. of the other end to 1/4 in. diameter, and screw 1/4 in. x 40, leaving a piece in the middle 3/16 in. long and 3/8 in. diameter. Poke the 1/4 in. end through the hole in the bolster plate, and secure it with a 1/4 in. x 40 nut made from 3/8 in. hexagon rod, either brass or steel. This bogie pin is suitable for a bogie with a centre-piece also made from plate. If you intend to use a cast bogie centre, the plain part of the pin must be left 5/8 in. long, so the overall length of the piece of steel rod needed for it is 1 1/4 ins., machined and screwed at each end as above.

To erect the bolster, turn the frames upside down, and place the angles or flanges between them, so that the edges of the bolster are hard up against the bottom edges of frame. The centre of the bogie pin must be 4 1/2 ins. from the front end of frames, measured behind the buffer beam. Run the No. 30 drill through the holes in the frame, making countersinks on the angles or flanges; follow up with No. 40, tap 1/8 in. or 5 BA, and put screws in, hexagon heads for preference.

Frame Stay

The big engines have a frame stay in front of the firebox, and as the little one will be as powerful in proportion (maybe a bit more so, if anything!) we might as well put one in too, to prevent any frame distortion. The stay can either be plate, with bent or angled ends, or a casting; the drawing shows all variations. For a plate stay with bent ends, you will need a piece of soft ductile mild steel of 1/8 in. thickness, approximately 4 ins. long and 1 1/2 ins. wide. A full 1/2 in. of each end is bent at right angles in the bench vice, and the bends slightly trimmed with a file, so the overall length is 2 7/8 ins.

For angled ends, use a piece of plate 2 7/8 ins. x 1 1/2 ins., and rivet a piece of 3/8 in. x 1/8 in. angle along each short side, filing the angle flush with the ends. If a casting is used, machine the ends in exactly the same way as the bolster, clamping under the slide-rest tool-holder and traversing across an endmill or slot-drill in the three-jaw.

To erect the stay, place it vertically in the frame, angles pointing forward, and set the front face 1 1/2 ins. behind the centre of the driving axle, which will allow the inside crank and big-end just sufficient clearance. Fit the screws exactly as described for the bolster, but countersink the holes, and use countersunk head screws, as projecting heads would run foul of the driving wheels.

Hornstays

The hornstays are 1 1/2 ins. lengths of 3/8 in. x 3/32 in. flat steel. Four pieces are needed; mark one out as shown in the drawing, drill it, and use it as a jig to drill the others, so that all four are exactly alike. Put each one across the lugs of a hornblock, with the offset hole coming in the middle of the lug; run the drill in, making countersinks on the lug, follow with No. 40 drill, and tap 1/8 in. or 5 BA, using hexagon-head screws as shown. Mark each hornstay and each hornblock with a number or other symbol, so that when removed, they can be replaced exactly as originally fitted.

Axleboxes

The axleboxes are of the plain solid pattern that I have found to give excellent service in locomotives of this size. To make the four of them, a piece of good bronze rod is needed, either drawn or cast, 4 1/2 ins. long, of 1 in. x 1/2 in. section. A groove or channel 3/8 in. full wide, and 1/16 in. deep, has to be milled the full length of each narrow side; this can easily be done by clamping the piece of rod under the slide-rest tool-holder, packing it up to centre height, and then traversing it across a 3/8 in. endmill or slot drill held in the three-jaw, feeding into cut with the top slide handle. Set the piece of metal square with the lathe bed by putting the faceplate on the mandrel and running the rest up to it. When the metal touches faceplate full length, tighten the clamp screws on the slide rest and it is set correctly.

When milling the second side, use a gauge, either setting an ordinary slide gauge to the exact width between the hornblock jaws, or cutting a gap in a piece of sheet metal to same width. The axleboxes should slide easily in the horns, without any end-play.

After milling, either part off four 1 in. lengths, or saw up the piece and square off each end of each piece in the four-jaw. Then fit one to each hornblock, and mark them to correspond with the horns and stays. Take out the two axleboxes on one side, and mark the position of axle, making a good deep centrepop; then drill No. 30, either in drilling machine or lathe, as the drill *must* go through dead square with the box. If you use the lathe, with the drill in the chuck, and the axlebox held against a drilling pad on the barrel, with a bit of wood between, to prevent damage to the pad, see that the wood is truly faced both sides.

Next, clamp each axlebox to its opposite mate on the other side of the engine, and drill the holes in the second box, using the hole in the first as a guide. I usually put the pair in a machine-vice, with a toolmaker's cramp top and bottom. Replace boxes in frame, and run a piece of 1/8 in. silver steel through each pair, as a check-up on your drilling. If the steel lies dead square across the frame, all is O.K. If not, correct the holes with a rat-tail file; then open out with a 31/64 in. drill, again using lathe or drilling machine.

Finally drill a 1/16 in. countersunk oil hole in the top of each, replace boxes in frame, and poke a 1/2 in. parallel reamer through each pair, moving the boxes up and down in the horns as you ream. This will give the exact amount of freedom to the axles, without having them slack. The axles must not be as exact a fit as used for a stationary bearing, because the boxes are continually on the move up and down when the engine is running, and an exact fit would cause the axles to bind in the boxes directly they moved out of line, going over rail joints or other unlevel places in the railway.

The spring pins are 1 1/2 ins. lengths of 1/8 in. silver steel or spoke wire, screwed 1/8 in. or 5 BA for 1/4 in. each end. Hold them in the three-jaw, and use a die in the tailstock die holder, to ensure true threads. To fit them, put on the hornstays, then jam each axlebox tight against the hornstay with a wooden wedge, or anything else handy, between the top of axlebox and the horn-block, the frames being upside down on the bench. Run the No. 30 drill through the centre holes in the stay, making counter-sinks on the bottom of the axleboxes. Follow up with No. 40, drilling about 5/16 in. depth; tap 1/8 in. or 5 BA, and screw the spring pins in tightly. The boxes must be quite free to move up and down.

The springs are wound up from 19 gauge tinned steel wire, over a bit of 1/8 in. silver steel held in three-jaw. Bend the end of the spring wire at right angles, and poke it between two of the chuck jaws. Pull the belt by hand, and guide the wire carefully for the first three of four turns, then press your thumb hard on the wire, and pull the belt. Your thumb acts as a nut, and guides on the rest of the wire quite easily. Snip off the pieces of spring, and touch both ends of each on a fast-running emery wheel, to square them off. Springs should be about 1 1/8 ins. long, fully extended.

JAM the ends of the frame plates into the slots in the beams, seeing that they go right home. Try the assembly upside down on the lathe bed, and adjust beams so that the high part of the frames touches the bed full length, whilst both ends of both beams are all at the same height from the bed, measured with a rule or better still, a scribing block. Run the No. 30 drill through the holes in the frames, making countersinks in the angles; follow up with No. 40 drill, and tap 1/8 in. or 5 BA. Screws need not be put in yet, as the frames have to come apart again for fitting hornblocks.

If cast beams are used, they will only need cleaning up with a file, and the lugs slotted to take the frames as described above. The frames can be jammed in the slots, and adjusted as above; you can then either drill No. 30 holes clean through lugs and frame, and use 1/8 in. or 5 BA bolts for securing, or drill right through lugs and frame with No. 40 drill. The holes in the outer sides of the lugs, and the holes in frame, are then opened to No. 30, and the inner sides of the lugs tapped 1/8 in. or 5 BA. On replacing frames, screws go through the clearing holes into the tapped holes, same as on the built-up beams.

Hornblocks

The hornblocks are the same type as used on "Bantam Cock" and other engines described in this series. If those sold are anything like the samples I have received, they will only need cleaning up with a file on the contact face, and riveting to the inside of the frames with seven 3/32 in. rivets, as shown in the erection drawing. Note that the upper corners of the flange fitting into the opening in the frame should be rounded off to suit.

If the contact faces require machining, they can be done with an endmill in the lathe, if a vertical slide is available. Every small lathe should be provided with a vertical slide as part of its standard equipment, as numerous milling jobs can be carried out by its aid.

The hornblock is simply attached to the vertical slide by a flanged block, like half an axlebox, placed between the jaws. The flange must not be as wide as the opening for the hornblock in the engine frames. A bolt through a hole in the block, with its head in one of the tee-slots in the vertical slide, holds the lot secure, and the hornblock can then be manipulated up, down, and across an endmill or slot drill held in the three-jaw, by means of the cross-slide screw and vertical slide screw. The whole rig-up was illustrated in the description of "Bantam Cock."

When riveting, drill the holes in the hornblock first, with No. 40 drill, and file off any burrs on the contact face. Clamp hornblock in place with a toolmaker's cramp, poke the drill through all the holes again, carrying on right through the frame, and countersink them outside the frame. Hammer the rivets well down into the countersinks, and file flush with frame.

To support the rivets, I use a dolly or riveting stake held vertically in the vice; it is merely a piece of 1/4 in. mild steel squared off, and an indentation made in the end with a 3/16 in. cycle ball. The head of the rivet rests in the dint, and retains its pristine beauty, no matter how vigorously the stem is attacked with the riveting hammer.

Place the frames back to back, and see that the edges of the frames are correctly lined up. Then temporarily bolt the frames together, after which an application of a fine file to the faces of the hornblock jaws, with the frames held in the bench vice, will be all that is needed to give a smooth finish. Use a piece of bar, 7/8 in. wide, as a gauge, and file until the bar slides nicely between the jaws, without any shake. Finally, file the lugs or feet of the hornblocks flush with the bottom of the frames, which are then permanently re-erected.

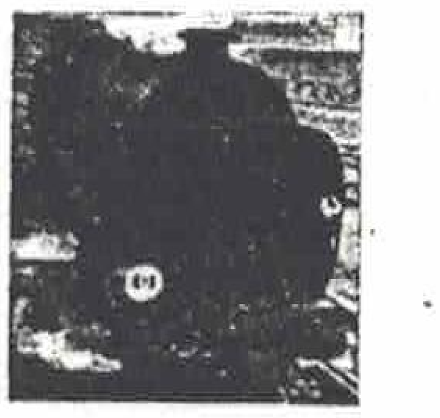
Bogie Bolster

The bolster to which the bogie is attached may either be a casting, or built-up. A cast bolster will have a chucking piece on it opposite the bogie pin and if this is gripped in the three-jaw, the bogie pin can be turned, the end reduced and screwed, and the flat part faced off, all at the same setting. The dimensions are shown in the drawing. Use a roundnose tool for the turning and facing, and change for a knife tool to get the angle between pin and face, to turn the screwed part, and form shoulder.

The chucking-piece can then be cut off, and the stump filed away. The rebates at each side are easily milled in the lathe, by clamping the bolster under the slide-rest tool holder, and setting same at right angles to the lathe bed. When doing this, I usually put the faceplate on, and run the work up to it, same being easily set parallel to the faceplate, which is, of course, at right angles to the bed. The job is then traversed across an endmill or slot drill, not less than 1/2 in. diameter, held in the three-jaw.

I prefer home-made slot drills (how they are made, has been described in these notes several times) as they mow off the surplus metal much faster than any commercial endmill of regular pattern. The bolster must be packed up on the slide-rest to correct height, so that a 1/8 in. flange is left below the milled rebate, see end view of cast bolster.

One advantage of a plate bolster is that no machining is required to the actual bolster; you only have to turn a separate pin. To make it, cut a piece of 1/8 in. steel plate 3 1/8 ins. long x 2 ins. wide, see that the corners are perfectly square, and drill a 1/4 in. hole in the middle. Cut two pieces of 1/8 in. x 1/2 in. angle brass a little over 2 ins. long, and rivet them to the shorter sides of the plate at 1/8 in. from the edges, using 1/8 in. iron rivets, countersunk and filed off flush on the underside. Then file the angles flush with the ends of the plate.



THE spring plates are four ¾ in. full lengths of ¼ in. x 5/32 in. steel strip, each with two No. 30 holes drilled at ½ in. centres. Drill one first and use as a jig to drill the others, same as hornstays. Round off the ends for appearance sake. Place one on each pair of springpins, and secure with ordinary commercial nuts, jamming a little piece of ⅛ in. square rod between each axlebox and hornstay, to keep the boxes in running position whilst the "works" are being fitted to the engine.

Variations for 2½ ins. Gauge

A few readers have expressed a desire to build this engine in 2½ in. gauge, owing to expense, or lack of trackage space for the 3½ ins. gauge engine. This can easily be done by reducing the given dimensions in the proportion of 7 to 5, making the necessary modifications to suit the usual sizes that I specify for 2½ ins. gauge jobs. The frames should be cut from 3/32 in. steel, and set 1 15/16 ins. between. Buffer and drag beams from ¾ in. by ⅛ in. angle, steel or brass. For bogie bolster and various other details appertaining to 2½ ins. gauge, the best advice I could give, would be to purchase the set of blueprints for the Southern S-15 class 4-6-0 issued from *Mechanics* offices.

The bogie bolster, complete bogie, cylinders, axleboxes and horns, and many other details of this engine are practically identical with a 2½ ins. gauge "Schools" class engine, which need only have the two outside cylinders, the cranks being set at 90 deg. as usual. The space between the frames could be used by installing an eccentric-driven pump to feed the boiler, same as specified for the S-15 engine. Regarding the boiler for the 2½ ins. gauge job, I should be glad to give a separate drawing of this, with the Editor's kind approval, if there are sufficient 2½ ins. gauge engines being built, to warrant the time and trouble in getting out the details.

Coupled Wheels

The four coupled wheels are 4 15/16 ins. diameter, which is the equivalent of the 6 ft. 7 ins. wheels of the full-sized engine. If your lathe has a 5 ins. or a 4½ ins. three-jaw chuck, you will have no trouble in gripping them in the usual manner; but if your largest is a 4 ins., it may not be able to do it, though some 4 ins. chucks with a fine-pitch scroll will hold up to 1 in. larger than their own diameter. I have one that will but the trouble is that on an ordinary 3 ins. lathe, the jaws may catch the bed when opened out to this extent. However, for those whose chucks will accommodate the wheels, chuck with the back outwards, gripping by tread, and setting to run as truly as possible.

Take a roughing cut at slow speed with a roundnose tool set crosswise in the slide-rest, right across rim and boss. Then centre the boss with a centre-drill in the tailstock chuck, drill a ⅛ in. pilot hole clean through, follow up with 11 mm. or 27/64 in. and finish with a 7/16 in. parallel reamer. Take a roughing cut off the flange, and a finishing cut over the back and boss, the latter being left flush with the back of the rim.

Reverse the wheel in the chuck, and grip by the flange. Face off rim, balance-weight, and boss, the latter projecting 1/16 in. beyond the rim and with a parting tool in the slide-rest, cut a little rebate at the point where the spokes of the wheel join the rim, to represent what is the joint between wheel centre and tyre in a full-sized engine.

Improvising a Faceplate

To turn treads and flanges, mount the wheels on an improvised faceplate. To make it, chuck an old wheel casting, iron disc, or any similar round piece of metal, a little smaller in diameter than the wheel. Face it truly, and recess the centre about 2 ins. diameter and 1/32 in. deep. Centre it, and drill and tap a hole to take a ½ in. stub of round steel rod; any thread will do, but a fine thread is preferable. Screw in a piece of rod, so that about 1 in. is projecting when the screwed part is tightly home.

Now turn this projection to 7/16 in. diameter, so that the wheels will slide on easily, but without shake; then screw the end, and fit a nut. Any thread will do. Put a wheel on the peg, and tighten the nut; this will hold the wheel tight enough against the rim of the improvised faceplate, to prevent any slipping whilst the tread and flange are being turned. Use an ordinary roundnose tool, run at the slowest lathe speed, with the back gear in, and turn each wheel to a bare 1/64 in. over finished size. When No. 4 has been roughed down, regrind the tool and take your finishing cut; then finish off the other three *without altering the setting of the cross slide.*

The four wheels must then of necessity be exactly the same diameter. The flanges can be rounded off with a file whilst revolving in the lathe which gives just as good a finish as a special form tool, and saves the trouble of making one. The above is ancient history to regular readers of these notes, but there are a lot of new ones building "Roedean" as a maiden effort, and they need the information.

Setting up the Wheels

If your chuck won't take the wheels, they will have to be mounted on the faceplate. They will need packing out a bit from the faceplate, and at the same time must be dead parallel with it, which cannot be guaranteed with wood packing, which compresses when the bolts are tightened; so the best thing to do, is to saw three pieces about 1 in. long, off a piece of, say, ¼ in. by ¾ in. mild steel bar. Each of these pieces will, of course, be the same thickness and if placed between the wheel rim and the faceplate, will keep them parallel. Hold the wheel by bolts through the spaces between the spokes, putting washers under the heads if necessary. If the faceplate is laid on the bench, and the wheels set as nearly as possible truly by eye, the nuts can be tightened just enough to prevent the wheel slipping when the faceplate is screwed on to the mandrel nose. A tap with a lead or hide hammer will soon teach them manners if they wobble when the lathe is started, and the bolts can then be finally tightened.

Machining Rims and Bosses

The backs of the rims are then turned, and the bosses drilled and reamed, as described above. When reversing, to turn the fronts of the rims and the bosses, the wheels can be set truly on the faceplate in half a jiffy, merely by running up the tailstock with the centre point in it, and letting the centre enter the hole in the wheel boss. However, when you mount the wheels to turn the treads and flanges, it would enable beginners to be certain of accuracy if the wheels are located by a peg. Turn up a bit of ½ in. round mild steel to fit the centre hole in the mandrel, and long enough to project about 1 in. from the faceplate. Put it in position, then turn the projection until the wheel slides on it. Put the three bits of packing between rim and faceplate, seeing that they are clear of the flange; the wheel is held in place by bolts between the spokes as before. It wouldn't be any good screwing the peg and fitting a nut to it, as tightening the nut would obviously pull the peg out of the hole in the mandrel, unless you fitted an extension rod from the tail end of the peg, to go through a hollow mandrel and be fixed with a nut and washer at the extreme end, like the drawbolt on a precision lathe. Treads and flanges are then turned and finished as described above.

Some beginners, in an endeavour to turn out a "posh job," may be tempted to polish the treads and flanges with emery-cloth or some other abrasive; well, don't! Leave them "tool finish"; they will soon get all the polishing they can do with, on the rail heads, and if you happen to run anytime in damp weather, you'll be heartily wishing that bit of polish some other place!

THE crankpin holes are drilled by means of a simple jig, so that all four are exactly the same distance from the centre of the axle. Get a bit of steel or brass bar of about 1/4 in. by 3/4 in. section, about 1½ ins. long. Make two centrepops on it 13/16 in. apart, and drill them with 1/8 in. drill, *which must go through the bar dead square,* so use either a drilling machine, or the lathe with the drill in the three-jaw and the work held against a drilling pad on the tailstock barrel. A truly-faced piece of hardwood should be placed between pad and work, and the latter held with a stout pair of pliers.

Open out one of them with a 27/64 in. drill, and the other with a 13/64 in. or No. 6 drill. Chuck a stub of ½ in. round rod in three-jaw, and turn down one end of it to a tight push fit in the 7/16 in. reamed holes in the wheel bosses. Reverse in chuck, and turn the other end to a squeeze fit in the larger hole in the bit of bar; then squeeze it in, using the bench vice as a press. Your jig is then complete.

To use it, scribe a line down the centre of each wheel boss, cutting across the 7/16 in. hole. Put the peg of the jig in this hole, and sight the line through the smaller hole. When the line is seen to be crossing the centre of the small hole, the jig is located correctly. Clamp it in position with a toolmaker's cramp, or any other available means; put the drill down the small hole (same one that was used for drilling it) and carry on through the wheel boss. As the same jig is used for all four holes, the centres must of necessity be exactly the same. Ream all the holes with a 7/32 in. parallel reamer, which you can put through by hand, with a tapwrench on the shank.

The four crankpins are turned from silver steel, and are what I call a kiddy's practice job, needing no detailed description. The sizes are shown in the illustration. Use 3/8 in. steel for the driving crankpins, and 1/4 in. for the trailing; the steel is set to run truly in the three-jaw, the reduced parts formed by a knife tool, and the thread put on with a die in the tailstock holder.

Note: the 7/32 in. spigots must be a tight squeeze fit in the wheel bosses, especially in the case of the driving pin; for if this shifts, it will upset the valve gear, which is driven from the return crank on the outer end. The easiest way for a beginner, is to turn until they just *won't* enter (which may sound like Pat O'Finnegan, begorrah, but you'll see exactly what I mean when you tackle the job) and then ease with a file until they go in very tightly about 1/8 in. or so. But they must not be tight enough to split the wheel bosses; so if you find when squeezing them in, using the bench vice as press, that extra force is needed to force them home, take them out again and ease them a little more. They can easily be removed by putting a piece of 3/16 in. brass rod down the hole in the back of the wheel, resting same on the partly-opened vice jaws, and applying judicious persuasion with a hammer. Put a nut on the screwed ends when pressing, to avoid damaging the threads.

Straight Axle

This is a simple job. If your lathe has a hollow mandrel that will admit ½ in. rod, saw or part off a piece of ½ in. round mild steel 4 3/8 ins. long. Chuck truly in three-jaw, face the end, and turn down ½ in. length to a squeeze fit in the 7/16 in. hole in the wheel boss. Builders who have turning experience won't need telling how to do this, but beginners had better go to work in the same way as mentioned above, for the crankpin spigots. Reverse in chuck; turn down the other end to same diameter, until the distance between shoulders measures exactly 3 9/32 ins., then face the end until the reduced portion is exactly ½ in. long.

If your lathe has a smallholed or solid mandrel, you'll have to turn the job between centres. Cut off a piece of steel say 4½ ins. long, and put it in the chuck as far as it will go. Carefully face the end and centre it with a centre-drill in the tailstock chuck; the excessive overhang won't matter for these jobs. Reverse it and do the other end likewise; then put a carrier on one end, put the steel between the lathe centres, with the catchplate on the mandrel nose, and turn the wheel seats as above, reversing end for end to do the second one. Excess length can then be carefully faced off in the chuck.

Crank Axle

May I assure all beginners that there is nothing at all to be alarmed at in making a truly-running crank axle. It has always been my aim to make things as easy as possible for prospective locomotive builders, not to scare them clean off with tales of how difficult the job is, and how a shopful of elaborate measuring gadgets are necessary for accurate working. All the crank axles that I have made by the method detailed below, have proved O.K. in every respect, the last ones being the single-crank axle for my 3½ ins. gauge L.N.W.R. compound "Jeanie Deans," and the double-crank axle for my L.B. & S.C.R. single-wheeler "Grosvenor," of same gauge.

For the webs you will need two pieces of 5/16 in. by 1 1/4 ins. steel bar, a little over 2 1/8 ins. long. Scribe a line down the middle of one, and make two centrepops on it 13/16 in. apart. Drill them 1/8 in. on drilling machine or lathe, as described for crankpin jig; then use the drilled piece as a jig to drill two similar holes in the second piece. Rivet temporarily together, and mill, or saw and file, to the outline given. Alternatively, you can leave the webs straight-sided, if you so desire; the outline shown is the same as on the full-sized engine. Open out the holes with 27/64 in. drill, and ream 7/16 in. with the pieces temporarily clamped together. Countersink very slightly, merely enough to take the sharp arris off the edges of the holes.

Axle and crankpin are turned from ½ in. round mild steel. For the two halves of the axle, cut off two pieces a little over 2 ins. long and face off each end until they are exactly $\frac{1}{64}$ in. under 2 ins. long. For the pin, cut a piece 1 in. long, and face off to a dead length of $1\frac{5}{16}$ in. Now a spigot has to be turned on each end of the pin and on one end of each portion of axle which, when pressed into the holes in the crank webs, will stay there "for keeps" and stand up to all the stress and strain of a powerful little locomotive shifting a very heavy load. It isn't the least use my assuming that you have reamed the holes to a dead accurate $\frac{7}{16}$ in. for the simple reason that some reamers "cut large," and some small and if I said use a micrometer and turn the spigots to $\frac{7}{16}$ in. plus one thousandth, they might either be too slack or too tight.

Use a Micrometer

If any beginner has a "mike" and knows how to use it, this is the *modus operandi.* Put a short bit of $\frac{1}{2}$ in. round rod in the three-jaw, and turn about 1 in. of it to a tight push fit in the holes in the crank webs. It must be tight enough to just allow of being forced into the hole without having to hit it with a hammer or squeeze it in the vice. Now put your micrometer on it and carefully take the diameter; when you turn the spigots, make them just one thousandth of an inch larger. If you haven't a "mike," note the reading on the graduated collar on the handle of the cross-slide, and turn the spigots half-a-division larger. If you haven't even a graduated collar, you'll have to use your judgment and bring the slide-rest handle back half-a-turn, then set it forward again to within a fraction of where it was before; this takes up error due to backlash.

Chuck the bits of axle, and the pin, in the three-jaw, all in turn, set to run truly, and with a sharp knife-tool in the slide-rest, and plenty of cutting oil applied (I use a mixture of either "Vacmul A" or "Cutmax" with half its bulk of paraffin added) turn down the ends to the lengths given on the drawing, viz., $\frac{5}{16}$ in. for the web seats and $\frac{1}{2}$ in. for the wheel seats, getting the finished diameters as detailed out above.

If your three-jaw chuck is out of truth, put a piece of foil, or even paper, between the offending jaw and the work; I never had any trouble in getting a true setting thus, in the days gone by, when I only had an apology for a lathe, and a "rag-time" chuck. We are then ready for assembly.

How to Assemble the Crank Axle

First press one end of the crankpin into the hole at one end of a web. "But," says the beginner, "it is too big to go in, so how do I go on about that?" Perfectly correct; but if you do exactly the same as they would do in a full-size locomotive works—that is, make the crank web hot—it will go in all right! Not only that, but it won't come out again; not of its own accord, anyway. So just heat up the crank web (not too much, nothing near redhot) hold it with a pair of pliers against one jaw of the vice, put the spigot of the crank pin against the hole, and if you can't manage to move the vice handle with your knee, so as to grip the two parts and hold them together, call in some assistance. Then, making certain the spigot is lined up fair with the hole, give the vice handle a mighty wrench, and hey presto! in will go that oversize spigot. When the web is cold, I doubt if you could shift it with a punch and a sledge hammer.

Now web No. 2 has to be pressed on to the other end of the crankpin, so that the two holes in the other end are dead in line. Difficult? Not a bit of it; just a question of knowing a simple wheeze. You already have a bit of steel turned to a dead fit in the holes in the webs; the bit used for a gauge when turning the spigots. Well, poke that through the two axle holes in the webs, and they can't help being dead in line. Warm up the second web, line up the free end with the spigot on the crankpin, and press it home. If you pull out the gauge piece before the webs get cold, it should come out easily, leaving your two webs exactly in line.

The rest of the job is easy; simply warm up the other ends of the webs and press the shorter spigots on the pieces of axle into them, putting a piece of bar $\frac{5}{16}$ in. thick between the webs, to prevent them being crushed together under the pressing operation. When through, the crank axle will run perfectly true, and it would puzzle anybody to get it apart without using considerable violence. It will be discoloured by the heat treatment, but is easily cleaned up with a bit of fine emery cloth or other abrasive.

Brazed Crank Axle

A crank axle may also be made up by brazing or Sifbronzing. In that case, turn up an axle exactly as described for the coupled axle. Make the webs as described above, but drill them $\frac{1}{2}$ in., a tight fit on the axle. File nicks in each hole, to allow the brazing material to penetrate the full depth of the webs. Mount the two webs on the axle in the position shown in the drawing of the pressed axle, and put a piece of $\frac{1}{2}$ in. round steel, $1\frac{1}{4}$ ins. long, through the crankpin holes. Cover the joints with brazing flux (Boron compo mixed to a paste with water, is the best I know for ordinary brazing) or the special flux used with Sifbronze. Put a ring of $\frac{1}{16}$ in. brass wire, or Sifbronze wire, around each axle close to the webs, and around the bits of crankpin projecting each side of the web. Put the lot in your brazing pan, and heat to bright red; the brass wire, or Sifbronze, will then melt and flow through the joints, filling the nicks. Let cool to black, quench in clean cold water, cut out the piece of axle between the webs, and saw off the bits of crankpin projecting each side of the webs. Finish off with file and emery cloth.

Eccentrics

Two eccentrics are required, one to operate the expansion link for the valve gear of the inside cylinder, and a slightly smaller one to work the ratchet lever of the mechanical lubricator. Both can be made from a piece of mild steel shafting $1\frac{3}{8}$ ins. diameter; stub ends are often available. Chuck in three-jaw, face the end, and turn down $\frac{3}{4}$ in. length to $1\frac{1}{4}$ ins. diameter. At $\frac{1}{16}$ in. from the end, form a groove with a parting tool $\frac{1}{4}$ in. wide and $\frac{1}{16}$ in. deep. If you run at slow speed, and use plenty of cutting oil, there will be no chatter, as long as the lathe bearings are not slack. Part off at $\frac{5}{8}$ in. from the end. Face off again, so that the piece is full diameter ($1\frac{3}{8}$ ins.) then form another groove as above, again parting off $\frac{5}{8}$ in. from the end.

The marks left by the facing tool will indicate the true centre of each eccentric. On the smaller one, make a centrepop $\frac{3}{16}$ in. away, and on the larger one, $\frac{9}{32}$ in. away from true centre. Chuck each eccentric in the four-jaw with this mark running truly; put a $\frac{1}{8}$ in. pilot hole through first, follow with $\frac{31}{64}$ in. drill, and ream $\frac{1}{2}$ in. using tailstock chuck for both drills and reamer. Then chuck a bit of round rod in three-jaw, nearest size larger than $\frac{1}{2}$ in., and stem down the end to a drive fit in the holes in the eccentrics. Drive each one on in turn, grooved and nearest chuck, and turn the bosses to a diameter of $\frac{7}{8}$ in. as shown, drilling each boss with No. 34 drill and tapping 4 BA for a setscrew. The valve eccentric goes on the right hand side of the crank, and the lubricator eccentric on the left, as shown. Wheel erection and crank setting will be described after we have made the coupling-rods.

Bogie Frames

Next item is the bogie, and the frames for this are shown in the illustration. The axleboxes are separately sprung; I find that they run better on the average small railway, apart from the fact that the springing is a copy of that on the full-sized engine. Two pieces of $\frac{1}{8}$ in. mild steel plate $8\frac{1}{4}$ ins. long and $1\frac{3}{4}$ ins. wide, are needed. Mark one out, drill a couple of the holes through both plates, rivet together temporarily, then drill the rest of the holes, and saw and file to outline given in the illustration. Note that if a built-up centre is to be used, the holes for the fixing screws should not be drilled in two rows as shown, but a single row of four substituted, at $\frac{7}{16}$ in. below the upper edge of the bogie frame directly over the holes. Also note the position of the holes for the shanks of the spring-pin lugs; these are drilled No. 30 at $\frac{7}{8}$ in. from the extreme top of the frame, and $\frac{11}{16}$ in. each side of the centre line of the axlebox openings. Countersink them on the outside of the frames.

Our advertisers will probably supply little castings for the horncheeks, which will only need cleaning up with a file and riveting in position at each side of the axlebox openings, using $\frac{3}{32}$ in. rivets. If no castings are available, use $\frac{7}{8}$ in. lengths of $\frac{3}{8}$ in. x $\frac{1}{4}$ in. x $\frac{1}{16}$ in. angle brass. The odd angle may be difficult to obtain, but if so, get $\frac{3}{8}$ in. and mill or file away one side to $\frac{1}{4}$ in. Even bits of $\frac{1}{16}$ in. sheet brass, bent to an angle in the bench vice, would do at a pinch. Having a powerful milling machine (powerful, that is, for a home workshop !) I often run a bit of ordinary bar material under a side-and-face cutter when I need a piece of angle that isn't stock size, and kind of "cut the corner out," which leaves the angle required. The $\frac{1}{8}$ in. x $\frac{1}{32}$ in. angle on the cab roof of my L.N.W.R. compound "Jeanie Deans" was made that way, from $\frac{1}{8}$ in. square brass wire. Have the horncheeks flush with the sides of the rectangular holes; the easiest way to ensure this, is to put a bit of $\frac{5}{8}$ in. bar in the hole as a guide, and butt the horncheek up against it, holding with a toolmaker's cramp (which can easily be home-made) whilst the rivet holes are drilled.

The lugs for the spring pins are made from $\frac{1}{4}$ in. by $\frac{3}{16}$ in. brass or steel rod. Chuck truly in four jaw, turn down $\frac{3}{16}$ in. length to $\frac{1}{8}$ in. diameter, and part off $\frac{3}{8}$ in. from the shoulder. Drill a No. 30 hole $\frac{3}{16}$ in. from the shoulder, and round off the end with a file. Poke the stern or shank through the hole, close to the horncheek, rivet well down into the countersink, and file flush; see plan of bogie frame. The guard irons are filed up from $\frac{3}{32}$ in. sheet steel, and riveted on as shown, using $\frac{1}{16}$ in. rivets.

Bogie Centre

If a cast centre is used, which I recommend, chuck it in the four-jaw and face off the top, which should make full contact with the bolster on the main frame. The big area of the surfaces in contact will stop the engine from "nosing" or "hunting," which an engine with only four rigid wheels is very fond of trying to do. The sides can be milled by clamping the casting under the slide-rest tool holder, and traversing across an end mill or home-made facing cutter held in the chuck.

THE cutter must not be less than $\frac{5}{8}$ in. diameter. Anybody who owns, or has the use of a milling machine, can put the casting in the machine-vice on the table, and run it under an ordinary cutter on the miller arbor; the width doesn't matter, as you can take as many "bites" as are needed to cover the whole surface. If no methods of machining are available, an ordinary file, used with discretion and care, will smooth off each side of the casting, the overall width of same being $2\frac{7}{8}$ ins.

The bogie pin slot will be cored out, and only need cleaning with a file, unless you happen to have a vertical slide for your lathe. In that case, bolt the casting to it, and clean out the slot with a $\frac{3}{8}$ in. endmill or slot-drill held in the three-jaw. The bogie frames may then be attached to the casting, as shown in the illustrations, by seven $\frac{1}{8}$ in. or 5 BA screws at each side. Hexagon heads may be used if available, but round-heads don't offend the eye, as they look like big rivets after the paint has filled up the screwdriver slots !

Failing a casting, build up the centre. The easiest and most simple centre is merely a piece of $\frac{1}{8}$ in. steel plate, measuring $2\frac{7}{8}$ ins. by 2 ins., with a $\frac{3}{8}$ in. slot $1\frac{1}{2}$ ins. long, in the middle. To make this, drill a $\frac{3}{8}$ in. hole at each end, and two more in between them; file out the bits in between. The plate is either brazed to the bogie frames, or else attached by 2 ins. lengths of $\frac{1}{8}$ in. by $\frac{1}{2}$ in. angle, riveted to the plate centre, and attached to the bogie frames by screws; see cross section showing alternatives. If you adopt the brazing method—I Sifbronze mine, with an oxy-acetylene blowpipe, which is easier and quicker even than soft-soldering !—do it before attaching the horncheeks, as you stand a chance of melting them if you are not a fairly experienced blowlamp artist. Anyway, whatever method you adopt to fix the frames to the centre, make certain that the frames are dead parallel all ways, same as the main frames, or else the engine will cut a funny caper when she gets on the road.

Bogie Axleboxes

The axleboxes should be made from bronze or gunmetal; maybe our advertisers will provide a short stick which will suffice for all four. Failing that, drawn rod can be used, $\frac{3}{4}$ in. by $\frac{9}{16}$ in. section or nearest. The piece should be approximately 3 ins. long, which will allow for parting off and facing the ends. Clamp the piece, wide side down, under the slide-rest tool holder, at right angles to the lathe bed, and traverse across a $\frac{1}{2}$ in. end-mill or facing cutter held in three-jaw, as described for main boxes. It should be packed up to such a height that the cutter will leave the $\frac{1}{16}$ in. flange full width. The piece of metal could also be held in a machine-vice bolted to the lathe saddle, and traversed under an ordinary milling cutter on a spindle between the lathe centres, being adjusted for height in the vice, so that the cutter just machined away the necessary amount. A planer or shaper could, of course, be used to do the machining, with the piece of bar in the machine-vice, and an ordinary square-ended tool in the clapper-box; but if no other way is available, use the humble file once more.

Necessity taught me how to use a file when I was just an enthusiastic but poverty-stricken kiddy !

Either put the piece of bar, after machining the sides, in the four-jaw, and part off the boxes to length, or saw the piece into four, and chuck each separately, to face off the ends. The boxes are then drilled for axles, exactly as described for the main axleboxes; and when fitted to the horncheeks, should slide up and down quite freely without being slack. As they only have one flange, they are perfectly free to tilt, as the wheels follow an uneven road. It is essential that a leading bogie runs freely in every way, so that it holds the road when the engine "does the knots"; and you can safely wager that "Roedean" will be able to do her full share, and one or two extra for luck !

Springing

The springing follows full-size practice, with a beam across the top of each axlebox, carrying a spring pin at each end. These pins pass through the lugs on the bogie frames, and have spiral springs underneath, secured by nuts and washers at the bottom of the pins. The lugs, pressing on the springs, transfer the weight via the spring pins and beams, to the axleboxes. Each box having its own independent springs, the wheels follow the track very well, especially when running through crossing frogs, low joints, or bad places in the rails. Castings will most likely be available for the four beams, and they will only need cleaning up and drilling and tapping for the spring pins. If not, cut them out of 1¾ ins. lengths of ½ in. x ¼ in. brass or steel bar; a simple sawing and filing job which needs no detailing out. The pins are 1⅜ ins. lengths of ⅛ in. round silver steel, screwed at both ends as shown, and furnished with ordinary commercial nuts and washers. The springs are wound up from 20 gauge tinned steel wire, and the assembly is shown in the illustration of the bogie frame, which explains itself. The axleboxes are pushed through the frames so that the flanges come on the outside; a bit of ⅛ in. wire should be placed under each box, to hold them in the running position whilst fitting the wheels, and erecting the engine.

Wheels and Axles

The four bogie wheels are 2¼ ins. diameter on tread, and are turned exactly as described for the coupled wheels, so no repetition will be necessary; the same applies to the axles, the dimensions of which are shown in the drawing. Press one wheel on to each axle, using the bench vice as a press; then poke the axle through the two axleboxes, and press on the other wheel. The wheels should spin freely, and have about 1/32 in. side play. When the bogie is placed on the pin, and the nut, with washer between it and the shoulder, screwed up tightly, the bogie should be quite free both to swivel, and move from side to side, to the full extent allowed by the slot. Bend the guard irons so that they come over the centres of the rail heads when the bogie is placed on the rails.

Coupling Rods

Two pieces of ¼ in. by ⅞ in. mild steel, approximately 8¼ ins. long, will be needed for the coupling rods. Mark one out as shown on the drawing, then drill a ⅛ in. hole at the location of the crankpin holes, the distance between which should correspond exactly to your axle centres. Use a jig to drill the second piece; then temporarily fix them together by short bits of ⅛ in. round steel in the holes, and mill, or saw and file to the given outline.

As I have a milling machine which is fairly powerful for a home workshop, I just clamp the bits of rod in the machine-vice, and take out the surplus metal at top and bottom with a single cut, using a 2 ins. slabbing cutter with spiral teeth, and letting a good dose of "Cutmax" oil diluted with paraffin, run on to the cutter from a small can perched on the overhanging arm of the miller.

However, I couldn't always do it by that means, and in the days when I had only a lathe and a drill, I used the lathe, either bolting the pieces to the faceplate, edgewise, and lying right across it, removing the surplus metal with a facing tool mounted crosswise in the slide-rest; or else I used the late Mr. Tom Averill's way.

THE bits of rod were both marked out, and centred at the ends, on the centre-line of the middle part of the rod. The surplus metal was then easily removed by putting the rod-blank between centres, and turning away the metal between the bosses. This, of course, left the top and bottom of the rod rounded; but a file made short work of that, and wasn't nearly as tedious as it would have been filing the whole lot down from a solid bar.

If anybody has no means of machining the rods, they can be sawn and filed by hand work. If the pieces are caught in the bench vice with the marked-out line level with the tops of the jaws, a notch wide enough to take a sawblade lying flat, can be filed at the end, and a blade put in the hacksaw frame sideways. Put the blade in the notch, and saw steadily along, keeping the blade in contact with the top of the vice jaws. When you reach the end of the jaws, shift the rod-blanks along a bit, and take another bite. If some cutting oil is dropped on the sawblade, or even soapy water, it helps the job no end, and preserves the sharpness of the saw teeth. Judicious application of a file will soon remove the saw-marks.

The ends of the rod can easily be rounded off, and the fluting carried out, in the lathe, if no other machine is available. Drill the crankpin holes ¼ in. and then chuck a bit of ½ in. square steel truly in the four-jaw, turning ¼ in. of the end to a nice running fit in the ¼ in. holes. Put this under the slide-rest tool holder, parallel with the bed of the lathe, and place one end of the rod over the turned pin.

If this is now run up to the side teeth of a ⅜ in. endmill held in the three-jaw, and the free end of the rod carefully manoeuvred by hand (hold it tightly !) the revolving endmill will cut away the surplus metal. Use plenty of cutting oil, and don't swing the free end of the rod around far enough to cut away the oil box on top of the boss. Also note that one boss is larger than the other; the bigger end is the one that goes over the driving crankpin, so make certain you have one rod right-handed, and one left.

Beginners note—the amount of cut is regulated by the cross slide; first set it so that when the rod is swung around the pin, the endmill just takes off the square corners; as it does this, you'll appreciate my admonition to hold the rod tightly ! Then feed in about 1/32 in. and take another cut, repeating operations until the boss is down to the size given in the illustration. The places where the curve of the boss merges into the straight part of the rod can be finished off with a file.

Fluting

For fluting, each rod is clamped under the slide-rest tool holder at right angles to the lathe bed, and at centre height, and traversed across a $\frac{7}{32}$ in. endmill, or home-made slot drill, held in the three-jaw. The ends of the flutes, if done this way, will be rounded; and if square-ended flutes are required, a small chisel can be used to square them off. Anybody using a milling machine can use an ordinary saw-type cutter $\frac{7}{32}$ in. wide on the arbor, and this will naturally leave squared ends with the correct bevel at start and finish of the flute. To prevent springing of the rod when performing this act, and thereby getting an uneven depth of cut plus chatter-marks, I put a piece of 1 in. square bar in the machine-vice, and fix the rod down to it by screws through the pinholes. Such a sound backing teaches it good manners !

Open out the pinhole in the larger boss to $\frac{3}{8}$ in., and try the rods on the wheels. If they don't revolve freely, and the rods bind at any part of the revolution, make quite certain that the adjustment of the crankpins isn't at fault (they should be set as shown in the diagram) and if you find this is O.K., then the rod centres must be slightly out. Ease the tight side of the pinhole with a round file—you'll easily see which side by looking closely at the pin, when same is on dead centre—then when the rods run freely, take another close look at the pins. If there isn't the same amount of clearance both front and back, ease the hole still further with a file until there is; then open out the hole in the big boss to $\frac{1}{2}$ in., and the smaller one to $\frac{3}{8}$ in. The bushes can then be turned from good hard bronze, a kiddy's practice job which needs no detailing out, and squeezed into the holes. Note the larger one projects $\frac{1}{64}$ in. each side of the rod. The smaller one projects the same amount on the plain side of the rod, but on the outside it has a flange $\frac{1}{2}$ in. diameter, and a shade over $\frac{1}{32}$ in. in thickness.

Drill the oil holes $\frac{1}{16}$ in. right into the bores of the bushes, and counterbore with a No. 30 drill as shown by dotted lines. When finished and fitted, the bigger end of the rod should be a nice running fit on the pin without any slackness, but the smaller end should be quite easy, the wheels turning freely. If both ends of the rod are an exact fit, they will bind when the engine runs over any unevenness in the line, causing deflection of the axleboxes. The trailing bushes of the full-sized engine's rods have $\frac{1}{16}$ in. play when new, for the same purpose. The big-end of the connecting rod will keep the forward boss of the coupling-rod from coming off the pin; the trailing boss is retained in place by an ordinary commercial nut and washer, or you can make your own if desired.

Cylinders

The three cylinders are all in line, and drive the leading coupled axle, as on the full-sized engine; the working parts of all three are precisely the same, so the machining and fitting details apply to the lot. In fact, the only fundamental difference between the inside and outside cylinders, is that the inside one is supported on both sides. All external piping between cylinders is eliminated; the exhaust ways are formed in the castings themselves, and maybe our advertisers will be able to supply castings with the exhaust recesses cored out, so that no milling will be required.

THE exhaust steam from the outside cylinders passes through the hole in the frame above the cylinder centre-line (see frame drawing) into the channels in the inside cylinder casting, and goes out at the top via two drilled holes connected by a bridge pipe, on which is mounted the blast pipe. The bridge pipe is necessary, to clear the inside steam chest. Steam from the boiler is fed to each cylinder separately, by pipes connected to the "hot" header of the superheater, those to the outside cylinders passing through holes in the smokebox wall, and the inner pipe going direct to a union on top of the inside steam chest.

The cylinders are secured to the frame by bolts passing through the end flanges of both inside and outside cylinders, the frames being sandwiched between them, as shown in both the cylinder assembly views. The bolt holes in the frame are located from the outside cylinders, and not vice versa, as is the case with an ordinary two-cylinder engine, with bolts or setscrews passing through holes in the frames, into tapped holes in the bolting faces of the cylinders.

Boring and Facing Cylinders

Clean up one end of each casting roughly with a file, and mark out the location of main and steam-chest bores. Maybe the core holes will be exactly right but if not, plug the ends with bits of wood, and on these, mark the correct centres, scribing circles on the metal from these centres, with a pair of dividers. Smooth off the bolting face with a file, if necessary (one side of the inside cylinder only, will be sufficient) then bolt an angle plate to your lathe faceplate, mount the cylinder casting on it, bolting face down, and secure with a bar across its back, with a bolt at each end.

The angleplate is adjusted on the faceplate until the marked circle on the end of the casting, indicating the main bore, is running truly. This is easily checked by standing a scribing block on the lathe bed, and setting the needle to the circle. If the needle touches the circle for the complete revolution of the lathe mandrel, the setting is O.K., and the bolts can be tightened. If not, you can see at a glance which way the casting has to be moved, to make it run truly. Don't forget that the casting must be parallel to the lathe bed, and you can make certain of that by applying the stock of a try-square to the faceplate, and adjusting the cylinder casting to the blade.

Face off the end of the casting with a roundnose tool set crosswise in the slide rest, and go as close as you can to the projecting end flange of the cylinder, without actually cutting it. Then set up an ordinary boring tool in the rest, and take a good cut through the corehole, say about $\frac{1}{16}$ in. deep, to shift all the hard skin off the inside of the hole. It will probably shift the edge off the tool as well, in the process but you can easily regrind after the first cut, and as there is then only virgin metal to remove, and no sandy skin, the tool won't suffer any further casualties.

If your lathe has self-acting feed, use it, with the finest feed available by combination of the change wheels. If you have only a plain lathe, the top slide will have to be set to turn parallel. This should be done previous to setting up the cylinder. Put a piece of rod about ¾ in. diameter in the three-jaw, with 2½ ins. projecting, and take a cut right along it with an ordniary round-nose tool; then take a second traverse *without shifting the cross-slide handle.* Take the diameter at the ends, at start and finish of the cut, with a micrometer or a pair of callipers. If the "mike" readings differ by less than half a thousandth, or if there is no appreciable difference in the feel of the calipers, the slide is O.K. If there is a difference, adjust the top slide and have another go.

Should you be lucky enough to own, or can beg, borrow, or otherwise acquire a 1 in. parallel reamer, bore out the casting until the "lead" end of the reamer will just enter. Beginners should not forget that the reamer is a finishing tool, not a boring tool, and if more than a couple of thousandths or so are left for the reamer to remove, the result will be a polysided hole instead of a perfectly true and smooth one.

If no reamer is available, continue boring until the hole is 1 in. diameter; you can test by aid of a slide-gauge, a pair of inside calipers, or a stub end of 1 in. round steel such as a bit of 1 in. shafting. I prefer the last; it should just slide in easily, but take care there is no burr left around the end. On the average small "home workshop" lathe, there won't be enough room to ream out the bore, as the reamer should go right through; so the reaming will have to be done by hand, if a reamer is available.

Having done the main bore, don't on any account loosen the clamp bar holding the cylinder casting, but slack the bolts holding the angleplate to the faceplate, and readjust the whole issue until the circle indicating the bore of the steam chest is running truly, checking with a scribing block as mentioned above, or with the extreme tip of a pointed tool in the slide rest. When O.K., repeat the boring process described above, only this time bore to ⅞ in. diameter.

It doesn't matter about reaming the steam chest bore; a tool finish is plenty good enough in which to press the liners, but the hole should, of course, be quite parallel, both in itself, and in relation to the main bore. The latter condition is automatically fulfilled, if your lathe is reasonably accurate, by the mere fact of shifting the angle plate bodily on the faceplate for machining the second bore, without interfering with the casting.

The opposite end of the cylinder casting may be faced off by mounting it on a stub mandrel held in three-jaw. Any odd bit of metal will do; just grip in chuck, and turn down until the cylinder will go on tightly; then face off the end as far as you can without cutting into the side flange. The parts that cannot be faced off at each end may be filed flush with the faced part, but don't let the file interfere with the faced part, or the cylinder covers won't fit properly.

IF a milling machine is available, the ends can easily be milled off, likewise the bolting face, simply catching the casting in the machine-vice on the miller table, and traversing it under an ordinary side-and-face cutter not less than ½ in. wide, on the arbor; be careful not to interfere with the vertical adjustment of the table when you take each fresh cut, or the casting will look like a flight of steps by the time you have finished!

The bolting face can be machined easily in the lathe; simply up-end it on the angle plate attached to faceplate and fix with a bolt through the bore, putting a big washer under the nut, and a piece of packing between the end of the cylinder and the angle plate, to raise the flange clear of same. Alternatively, you can let the flange overhang the edge of the angleplate, if the latter isn't very wide.

Once when I was facing a cylinder, the angleplate, which had been in constant use for years, suddenly snapped off clean across the slots. I didn't scrap it, but filed off the ragged edge, and drilled and tapped some holes in the remains of the broken half. I then had an angleplate with a short "step" on which small castings, etc., could be mounted close to the faceplate; the addition of a notched bar, attached to the "step" by a bolt at each end, gave me a very useful faceplate chuck for holding any irregular object, same being gripped between the notched bar and the "step" of the angleplate. This gadget was in use until a friend presented me with a three-jawed universal machine-vice for use as a faceplate chuck.

Cleaning Up

Watch your step as you start to clean up the bolting face, as same has gaps in it which will knock off the point of the tool if too greedy a cut is attempted. A round-nose tool set crosswise in the rest, is the best weapon for the job. Face off until the bolting face is 15/16 in. from the centre-line of the outside cylinder bore, or 7/16 in. from the edge of it, which is easier to measure. In the case of the inside cylinder, you'll have to put a bit of packing between the casting and the angleplate, as there is a flange both sides. The overall width should be 2⅞ ins. so that the casting fits exactly between the frames; see cross section. Before machining the second side, make certain that the first is exactly parallel with the faceplate.

Steam and Exhaust Ways

Communication between cylinder bore and steam chest bore is made by a slot at each end, a far easier and simpler job than drilling the long passageways of a slide-valve cylinder. Simply drill a few 3/32 in. holes close to the edge of the main bore at each end, into the steam chest bore, and file them into a slot with a rat-tail file. A long-stemmed endmill or slot drill held in three-jaw, would also do the job, the casting being bolted to the lathe saddle, or held in a machine-vice at a slight angle, and traversed across the cutter, but it isn't worth while buying or making a cutter, and spending time setting up, when a little careful hand-work does the needful. If the holes are very close together, it doesn't matter about filing the metal away between them. The slot, or row of holes, should be approximately 7/16 in. long.

At the time of writing I don't know if our advertisers will be able to supply castings with the exhaust recesses cast in; if not, they will have to be endmilled, with a ⅜ in. endmill or home-made slot drill in the three-jaw, and the casting bolted to the saddle or slide-rest with the centre-line of the recess packed up to lathe centre height. Whether cast or cut, however, the communication between the recess and the ends of the steam chest is the same. Either endmill a slot as long as the width of the recess, and ⅛ in. wide, at the extreme end of each recess (you should be an endmilling expert after doing the axleboxes and other previous jobs!) or else drill ⅛ in. holes as close together as possible.

The view showing bolting face of outside cylinder, indicates where the "entrances to the way out " are located, and the perspective sketch shows both the " bore " ends of the steam and exhaust ways, and the tapped holes for the drain cocks. The latter are necessary with piston-valve cylinders, as the valves cannot lift off their faces and let the water out, as slide valves do; unless some means of releasing trapped condensate water is provided, the pistons will just lock, and it will be an awful job to start the engine from all cold. The drain holes are shown in the longitudinal section illustration of the cylinder.

Drill a blind hole with 5/32 in. drill to a depth of 3/16 bore, and tap 3/16 in. by 40; then put a 1/16 in. drill from this into the cylinder bore, close to the cover, as shown in the illustration mentioned. Any burr inside the bore should be carefully *scraped* off; don't use a file. Note that the drain holes on the inside cylinder are drilled a little off centre, to allow more room for the cocks.

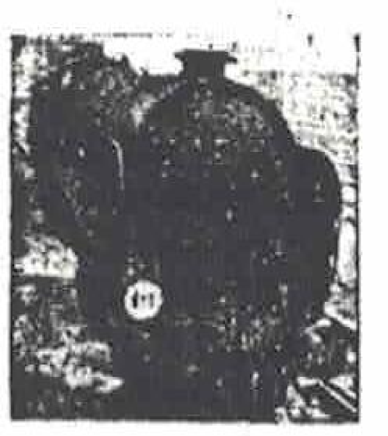
Beginners note carefully: on the inside cylinder, the exhaust outlets are drilled or milled in the shallow recess, from the side nearest the steam chest. The recess on the other side receives the exhaust from the left-hand cylinder. Drill two 5/16 in. holes, in the position shown in plan of assembled cylinders, and section of inside cylinder, from the top of the latter, into the exhaust recesses. On the finished job, these will be bridged by the blastpipe base.

On the outside cylinders, a flat seating will be found on top of the steam chest, to accommodate the steam pipe flange. Smooth this off with a file, making certain it is perfectly flat, then drill a 7/32 in. hole in the middle, right into the steam chest. There will be a circular boss on the inside cylinder; drill this 7/32 in. into the steam chest, then open out the top with letter R or 11/32 in. drill, and tap it 3/8 in. by 32, for the steam pipe union connecting the middle cylinder to the superheater. Finally drill the five No. 27 bolt holes through each flange, at a little over 3/8 in. centres, on the outside cylinders only.

How to Locate Position of Cylinders

It will be easier if at this stage we locate the cylinders in the frame, because if this is left until after the steam-chest liners are pressed in, the projecting ends of them will obstruct the bolt holes, and it will be impossible to enter the drill in the upper holes in the outside cylinder flanges to locate the corresponding holes in the frame and the inside cylinder flanges.

The inside cylinder is easy enough to locate correctly as the flanges are ¼ in. from the bottom of the frame and the flanges of the bogie bolster are ¼ in. deep, and project that much upwards. All you have to do is to push the inside cylinder down between the frames until the flanges rest on those of the bogie bolster. If the latter are correct to measurement, the cylinder will then be at its correct level.



THE front end of the casting itself (not the flanges) should be exactly 3 7/32 ins. from the front end of the frames measured from the back of the buffer beam. If a built-up bolster is used, and the nut on top of the centre pin fouls the bottom of the cylinder, file a little off it, so that it clears. Check off the centre of the bore, which should be horizontal, and 1 5/16 in. above bottom of frame at this point; a line drawn through the bore should cut through the centre-line of the driving axle, when same is in running position, at 11/16 in. from the bottom of the frames, as shown in the frame drawing.

As all three cylinders are exactly level, see plan and elevation of cylinders as erected, all you have to do, is to line up both outside cylinders with their inside fellow-conspirator, temporarily clamp them in position, and run the No. 27 drill into each hole in the outside cylinder flanges, carrying on clean through the frame and the flanges of the inside cylinder. A carpenters' cramp does very well for holding the lot together whilst drilling.

Commercial 4 BA bolts can be used for holding the whole issue together when finally erected; alternatively, instead of drilling through frame and inside cylinder flanges with No. 27 drill, let the drill go through frames only, and make countersinks on the inside flanges. These could then be drilled No. 34 and tapped 4 BA, and screws used instead of bolts, same passing through the clearing holes in the outer flanges and frames, into the tapped holes in the inner flanges, thus dispensing with nuts altogether. Remove cylinders from frame again, and they can now be finished off.

Steam Chest Liners

The liners for the steam chests may be turned either from castings or drawn rod, good quality phosphor bronze of 1 in. diameter being about the best material in the latter case. If castings are used, our advertisers will supply the right quality metal, but hard cored stick, as used for automobile and other bearing bushes, does quite well. Chuck the rod in the three-jaw, with about 3¼ ins. projecting; if solid rod is used, face, centre, drill a pilot hole about 3/16 in. diamter to about 3 ins. depth, and open out with 31/64 in. drill. If cored stick is used, open out the corehole with 7/16 in. drill, and true up with a little boring tool, using the same method as for cylinder bores, until the end of a ½ in. parallel reamer will just enter.

When turning the outside, it would be advisable to run up the tailstock and enter the centre point into the bored hole, to steady the piece. Then turn down a full 3 ins. to a squeeze fit in the hole in the upper part of the cylinder. The easiest way for a beginner or novice to get the proper fit, is to turn down the full length to 1/64 in. over size, then carefully reduce a little at the end, say about 3/32 in. long, until it will just enter the cylinder tightly; then turn the rest one thousandth larger. You can either use a " mike," or turn the cross-slide handle back half-a-turn, bringing it forward again to within half-a-degree of its previous position as shown on the graduated collar on the spindle. If no graduated collar is provided, you'll have to use your judgment.

Now put a 1/8 in. parting tool in the slide-rest, and at 25/32 in. from the end, cut a groove 3/32 in. deep. Repeat operation 1 1/8 ins. farther along; then part off at 3 ins. from the end. Chuck again in three-jaw, and skim a shade off each end, so that the overall length is 2 15/16 ins. If you have a milling machine, put a 1/8 in. cutter on the arbor, and with the job in the machine-vice, take a cut across the grooves at top and bottom of the liner. This cuts into the bore and forms the ports; see cross section of liner. If you cannot mill this job, it may be carefully hand-filed.

Next, file or mill away 7/16 in. length on the outer side of each groove, at the bottom of the liner. This allows steam to pass from the port to the steam slot at each end of the cylinder bore, as shown in the longitudinal section. Each liner can then be squeezed into the cylinder, taking care that the clearances under the liner register with the steam slots at the ends of the bores; the bench vice will do this job all right, but put a piece of soft metal between the vice jaws, liner, and the cylinder, to prevent marking the softer metal. The liner should project 3/8 in. each end of the cylinder.

Poke the 7/32 in. drill down the hole on top of the steam chest, and carry on right through into the liner bore; then drill or mill through at the ends of the exhaust recesses until you also pierce the liner bore. Making these holes after the liner is pressed home, eliminates any likelihood of their not lining up properly, and thus restricting the flow of steam. Finally, ream out both liner and cylinder bores, if you have the necessary reamer for the latter.

Catch the cylinder in the bench vice; run your thumbnail along the cutting edges of the reamer, and if you feel the slightest roughness, oilstone it off. Then, with a good big tapwrench on the shank of the reamer and a spot or two of cutting oil on the blades, you can drive the reamer clean through. Turn steadily, and push forward at the same time. The result should be perfectly true bores with a surface like glass. It is far better to do the reaming last of all, as the pressing operation may easily distort a previously-reamed bore.

Steam Chest and Cylinder Covers

The steam chest covers are turned either from cast or drawn rod, 1 in. diameter. For the front covers, chuck the rod in three-jaw, face the end, and turn down about ¼ in. to 7/8 in. diameter. Further reduce 3/16 in. to a push fit in the end of the liner, and part off 1/8 in. from the shoulder. For back covers, repeat first operation, but also centre, and drill down with No. 22 drill to about 5/8 in. depth. Part off at ¼ in. from the end; reverse in chuck, and turn down 3/16 in. of the other end to 3/8 in. diamter. Drill four No. 43 screwholes in each flange, place the covers in position, run the 43 drill into the holes and make countersinks on the ends of liners. Drill the countersinks No. 51 and tap 8 BA. Alternatively the covers can be drilled No. 41, the liners No. 48, and tapped 3/32 in. or 7 BA.

The front cylinder covers are turned from castings; chuck in three-jaw by chucking-piece provided, turn the outside to 1¼ ins. diameter, face the spigot or register and contact flange, and turn the register to a tight fit in the cylinder bore. As the cylinders are rather short for the stroke (they are "scale" length, but we have to use a much wider piston in proportion to size) the register should only project 1/32 in. from the cover into the bore. Cut off the chucking piece, rechuck, holding either by the edge, or in a stepped bush held in the three-jaw, and face off the outside.

For the back covers, repeat operations, but centre, and drill with 7/32 in. or No. 3 drill to a depth of about ½ in. Cut off chucking piece, reverse in chuck, holding either by the edge, or in a stepped bush; face the outside of the cover, and turn the boss. Open out the hole with an 11/32 in. pin drill to ensure concentricity of the gland, and tap 3/8 in. by 32, guiding the tap by aid of the tailstock chuck.

The gland is turned from a bit of ½ in. round bronze rod held in three-jaw. Face, centre, drill down about ½ in. with 7/32 in. or No. 3 drill, turn down 5/16 in. of the outside to 3/8 in. diameter, and screw 3/8 in. by 32, using the die in tailstock holder; part off at 7/16 in. from the end, and file four C-spanner nicks in the flange. Note, the threads should be a good fit, so that the glands won't come out when the engine is running. Drill the screwholes in the covers as shown in the elevation, and fit the covers to the cylinders with eight 6 BA screws in each, as described for the steam chest covers, but don't put all the screws in until the pistons have been made and fitted.

Pistons and Rods

The piston rods are merely three 3⅜ ins. lengths of 7/32 in. round steel, rustless for preference, with 3/16 in. of 7/32 in. by 40 thread on one end. Castings will be supplied for the pistons. Chuck by the extension provided; face the end, centre, and drill 3/16 in. Turn the outside to 1/64 in. over size, and form the groove with a parting tool; reverse in chuck, saw or part off the extension, and face to a length of 3/8 in. Open out the centre hole to a depth of 3/16 in. with No. 3 drill, and tap the rest 7/32 in. by 40. Put a piston rod in the tailstock chuck, threaded end outwards; run it up to piston, enter it in the hole, and pull the belt by hand until the threaded part is right home, and 3/16 in. of the plain part has been drawn into the counterbore in the piston. This way of fitting, is like a chuck on a precision lathe; the piston will be true on the rod, and will remain so.

The pistons are finish-turned on the rods. Chuck an odd end of 3/8 in. brass rod about 3/4 in. long, face the end, centre, and drill it 7/32 in., making sure the drill enters truly. Make a dot opposite No. 1 jaw, then remove the bush from the chuck, and split it down one side with a hacksaw. Rechuck, with the dot opposite No. 1 jaw; put the drill through again, to clean off any burr, then put a piston-rod in it, with the piston just far enough out of the chuck, to let the tool clear it. Then tighten the chuck, and carefully reduce the piston with a roundnose tool, until it will just slide in the cylinder bore without any sign of shake.

THE valve spindles are pieces of 5/32 in. rustless steel or bronze 3⅜ ins. long, with 2 ins. of 5/32 in. by 40 thread on one end, and 3/16 in. of same pitch on the other. If you can get a piece of ½ in. ground rustless steel for the piston-valves, they should not need fitting to the liner, as this size should be a perfect sliding fit in the reamed hole. If the ground material is not available, turn from the next size larger drawn rod held in three-jaw. Face, centre, and drill down 1½ ins. depth with 3/16 in. drill. At 7/32 in. from the end, reduce to 3/8 in. diameter as shown, for a length of 15/16 in., then carefully turn the outside for about 1½ ins. length, to a sliding fit in the liner, as described for the pistons. Part off at a full 1⅜ ins., then reverse in chuck, and face the end to 1⅜ in. bare, so as to allow a shade of exhaust clearance. The full-size parts of the bobbins should be 7/32 in. long, as shown in the detail illustration.

The valves are secured to the stems or spindles by a pair of locknuts at each end, but the exact position cannot be found until the valve gears are made and erected. Pack the pistons, and the piston glands with graphited yarn, and put gaskets of oiled paper between the cylinder covers and the flanges, when assembling the cylinders: no gaskets are needed for the steam-chest cover joints, nor are there any glands. Beginners should recollect that pistons should be steamtight, but not mechanically tight: the packing should merely form an oil seal, and should not be expected to stand pressure.

Guide Bars

The job of scheming out the arrangement of guide bars and brackets for "Roedean" made me earnestly wish that this engine had not headed the poll! I have the drawings of the full-sized job, also some excellent *Mechanics* photographs, taken close-up especially for these notes; and on top of that I naturally am conversant with the big engines. Contrary to usual practice, the guide bars are not attached to the cylinder covers, but are entirely separate, being of the Laird pattern and supported by an overhanging bracket outside the frames, with an extra cross-stay between. On the big engines, these brackets are complicated hollow castings and it would puzzle the patternmakers employed by our advertisers, and give the foundrymen the proverbial "pain in the neck," to turn out absolutely correct replicas for $3\frac{1}{2}$ ins. gauge. I have therefore done a bit of "simplification," in a manner of speaking, retaining the outward appearance, but making the job a little easier both from the casting merchant's and the builders' points of view. I'm calling attention to the above, to save a lot of unnecessary correspondence.

The actual guide bars are one-sixteenth replicas of those on the full-sized engines. The top bars—three will be needed—are $3\frac{3}{16}$ in. lengths of $\frac{7}{16}$ in x $\frac{5}{32}$ in. mild steel. Silver-steel, or rustless steel can, of course, be used if desired but owing to the great width of the bearing surface, wear will be negligible, and mild steel will do all that is necessary in the wear-resisting line. As the bars are always oily, they don't have a chance to go rusty. The bars are reduced by filing or milling, to $\frac{1}{8}$ in. depth at each end, for a distance of $\frac{5}{16}$ in., then sloped off upward slightly, leaving a length of $1\frac{1}{2}$ ins. the full $\frac{5}{32}$ in. depth: but note very carefully that this full-depth piece is not in the centre of the bar. The middle of it is $\frac{1}{8}$ in. behind the true centre (see illustration of bars). The reason for this is that the brackets are set back, so that their centre-lines are $\frac{1}{4}$ in. behind bar centre. The object of this, on the big engines, was to support the bars in the best position to take the pressure on the crosshead when the engine is starting a heavy load, or pulling hard.

The bottom bars look like those in the firebox, and are made from $\frac{1}{8}$ in. x $\frac{7}{32}$ in. (or the nearest larger size) mild steel. They are also reduced and sloped off as above, but in this case the parallel part is only $\frac{3}{4}$ in. long, and is actually in the true centre of the bar. The distance pieces are $\frac{1}{4}$ in. lengths of $\frac{1}{8}$ in. square steel rod.

On the full-sized engine, the bars are held together by four 1 in. bolts at each end. Very nice too—but the trouble is that in $3\frac{1}{2}$ ins. gauge, 1 in. is only $\frac{1}{16}$ in., and if we start assembling with small bolts like that, trouble is coming in bagsful when the engine sets her back into live passenger-hauling with all the power she will be able to put out! So we have to compromise once more, and build our engine to suit the work it has to do. Drill the bars and spacers No. 48, as shown in the drawing, and assemble with little bolts made from pieces of 15 gauge spoke wire (real tough stuff, that) $\frac{5}{8}$ in. long, screwed 9 B.A. at both ends and furnished with ordinary commercial 9 B.A. steel nuts. Don't put more thread on than is necessary to allow the bars and spacers to be clamped tightly together.

Outside Guide Bar Bracket

The outside brackets are castings which are the same for both sides of the engine. The centre part is approximately $\frac{3}{16}$ in. thick (exact thickness doesn't matter; it depends on the foundrymen) with a double flange at the squared end for attachment to frames, a web or beading $\frac{5}{16}$ in. wide all around, and a ribbed slab at the bottom $\frac{1}{2}$ in. wide and $1\frac{1}{2}$ ins long, to which the top guide bar is attached. A nobby box of tricks compared to the usual simple yoke—but please don't blame your humble servant: I didn't design the full-sized engines, am just endeavouring to make a reasonably correct copy of them as they exist! However, not much is required in the way of machining. The seating for the guide bar should be attended to first. If a regular milling machine is available, it is easy enough to clamp the casting upside down in the machine vice on the table, setting the slab level, and taking out a "bite" $\frac{1}{32}$ in. deep with a $\frac{7}{16}$ in. end-and-face-cutter on the arbor. A narrower one can be used, taking two or more cuts without altering the height of the table.

The job can also be done in the lathe, using a $\frac{7}{16}$ in. end mill, or preferably a home-made slot drill as it cuts more freely (mine do, anyway) held in the three-jaw. The bracket is clamped under the slide-rest tool holder, with the slab to be machined, set at right angles to the lathe bed and at centre-height. I have described many times, how to set up work for endmilling in the lathe.

The contact side of the end flange which bolts to the frames can be machined in exactly the same way, the distance between the centre of the slab, and the contact face of the flange, being the same distance as cylinder centre line from frames, viz., $1\frac{5}{16}$ in.

THE top of the casting is next smoothed off, either by filing, or milling as above; this part supports the running-board or side platform. Finally, a rebate is milled or filed in the outer edge of the casting, to accommodate the small piece of the valance that forms the outer link girdles. This is $\frac{9}{16}$ in. deep and $\frac{1}{16}$ in. wide, and should be $1\frac{11}{16}$ in. from the contact face of the flange, as shown in the side view of the erected brackets. Four screwholes are drilled at each side of the contact flange, with No. 41 drill, starting at $\frac{3}{16}$ in. from the top and continuing at $\frac{1}{4}$ in. in centres (see illustration showing guide bars erected). A No. 48 hole is drilled at each corner of the slab, on either side of the centre rib, for the screws supporting the guide bar assembly. File off all burrs.

In passing, the machining of this bracket in the lathe, using an endmill or slot drill in the chuck, once more illustrates the extreme usefulness of a vertical slide, which should form part of the regular equipment of any small lathe, just as much as a slide-rest. With a small machine-vice bolted to the slide, it is the work of a few seconds only to grip the casting in the vice, and present any of the various surfaces to be milled off to the cutter in the chuck. In addition to the movement of the cross-slide for traversing the work across the cutter, you have also the vertical movement of the slide, both for adjustment, and making vertical cuts. In the days before I owned milling machines, both horizontal and vertical, I found that a vertical slide was indispensible if speed plus accuracy were aimed at. In fact, I still have one which fits the lathe I use for "intermediate" jobs (a 3½ ins. Drummond) and occasionally use it.

Inside Guide Bar Stay

The inside guide bar assembly is supported by a stay extending right across the frames; this is a ribbed casting with a slab at the bottom, same as that on the outside brackets, and a contact flange at each end. The two end flanges can be machined off, same as the flange on the outside bracket, but they must, of course, be dead parallel with each other, to fit nicely between frames. The top can be smoothed off with a file or if the casting is clean, it need not be touched, as nothing is attached to it on top. The underside of the slab for supporting the guide bars can also be machined as described for the outside bracket; but it may be a bit more difficult to set up, on account of the width.

If your lathe is of the type which has the slide-rest mounted on a boring table, such as the Drummond pattern, take off the slide-rest altogether, and stand the casting on it end up, packing it so that the slab is level with lathe centres and at right angles to the bed. It can be secured by a bar across the top, with a bolt at each end, the heads of the bolts taking a bearing in the tee-slots in the saddle or boring table. Better still, if you have a small machine-vice to bolt to the boring table, the job is "in the bag," as vertical and horizontal adjustment of the casting in the machine-vice is the work of a minute or so only.

At the time of writing, I don't know if the suppliers of the castings will sell them with the holes cored in: but if not, they will have to be drilled and filed on both outer brackets and inner stay. The oval holes are merely for lightening the casting: the egg-shaped holes allow the radius rods of the valve gear to pass through. Their exact size and shape is of no moment: the illustrations show the holes as they are made in the castings on the full-sized engines.

Don't drill any bolt holes in the contact flanges of the inside stay, and don't erect the brackets in the frames yet, the exact position is best determined by the position of the crossheads, after these and the connecting rods have been made and fitted, as I will explain later. You can, however, bolt the guide bar assemblies to the undersides of the slabs. Temporarily clamp each one in place, setting them ⅛ in. out of centre, the flat place on top of each bar coming flush under the slab, see drawing of bars erected. Run the No. 48 drill through the holes in the ends of the slab, making countersinks in the bar. Follow up with No. 53 drill, drilling right through the top bar: tap 9 B.A. and put 9 B.A. hexagon-head screws in. The bar must be quite smooth underneath, otherwise the crosshead cannot slide on it, so if any parts of the screws project through the bar, carefully file them off flush.

On the full-sized engine, the bolt-holes are drilled clearing size through both bar and casting, and those in the bar are recessed or counterbored on the underside, to take a headed pin fitting the counterbore and leaving the slide surface quite clear. The pins are nutted on top of the casting. There is no objection to following suit on the small engine, but it involves much more work, and you would have to turn up the bolts, 12 all told, from ⅛ in. steel: something of a watchmaking job, as such bolts are not made commercially.

Crossheads

The design of suitable crossheads was another "headache" job. The full-size arrangement could not be used as it stood, because the connection between the crosshead jaws and the part that slides in the guides, is made on the big engines by a kind of "fin" at each side, and the inner sides of the lower guide bars are cut away to clear. Our bars are small enough, in all conscience, as it is, taking into account what the power of the engine will be, and it would be unwise to weaken them further: so I had to make other arrangements, without altering the appearance. This involved making the crossheads in two parts, one piece comprising the jaws and boss, and the other the slipper. The arm for actuating the union link of the Walschaerts gear is attached to the crosshead, so we might as well kill two birds with one shot, and do that job at the same time.

To make the crossheads proper, that is the part which is attached to the piston rod and embraces the little end of the connecting-rod, a piece of ⅝ in. x 5/16 in. mild steel will be needed, a length of about 3½ ins. being enough for all three. Beginners will find it easiest to cross-drill and slot each crosshead blank before shaping it: so first of all drill a No. 14 or 11/64 in. hole through it at 5/16 in. full from the end: then slot it 3/16 in wide, to a depth of ⅝ in. bare. Failing a milling machine, the easiest way to do this is to clamp the bit of bar in a machine-vice on the lathe saddle, and traverse it under a regular 3/16 in. milling cutter or a spindle between lathe centres. Two or more cuts may be necessary to attain full depth, but the height of the piece is easily adjusted in the machine-vice. The slot could also be endmilled out, with a 3/16 in. endmill or slot drill in the three-jaw, and the bar clamped on its side under the slide-rest tool holder, packed up level with lathe centres. Saw or part off the piece to 1 in. length, then chuck truly in the four-jaw with the blank end outward. Turn down the boss to the shape shown, leaving the little beading at the end for appearance sake. Centre, drill No. 5 or 13/64 in. through the boss into the slot; ream 7/32 in., but don't put the reamer in fully, only put the "lead" end in, as the piston-rod should be a tight fit. Then round off the jaws with a file, and file the tops of them flat, to a distance of 3/16 in. above the centre of the pin hole. This will allow them to clear the wide part of the guide bars.

The slippers or crosshead shoes are made from 7/16 in. square mild steel, and a fair bit of milling is needed to form the T-heads. Maybe one of our advertisers who supply finished parts, would "come to the aid of the party" with a length of ready-milled T-section steel, enough for the three crossheads. Anyway, if there is nothing doing in that line, set up the piece of bar, say about 3 ins. long, exactly as described for the axleboxes, and cut a rebate in it at each side, using an endmill or slot drill in the three-jaw.

The cutter should take out ⅛ in. each side, to a depth of 5/16 in., which will leave a T-head full width of the bar, 7/16 in. the head of the T being ⅛ in. deep, and the stem a good fit between the crosshead jaws; see cross section. Saw the piece into three, square off the ends in the four-jaw to ⅞ in. overall length, then file away the rib to the shape shown in the illustrations. A half-round gap must also be filed in the centre, to clear the little end when the whole lot is assembled (see sectional view). The rib or stem of the T is then inserted into the crosshead jaws above the flat part, and adjusted so that the top of the T is 9/16 in. above the centre line of the cross hole, and the hole in the boss.

BEFORE brazing this in position, make and fit the drop arm for the valve gear drive; then this can be brazed at the same heating, and you'll never be troubled with the arm shifting and upsetting the timing or valve setting. The arm is made from a piece of 3/32 in. steel 3/8 in. wide and approximately 3/4 in long. Drill two 7/64 in. or No. 35 holes at 25/64 in. centres; file up the arm to the shape shown, and open out the upper hole with No. 14 or 11/64 in. drill. Attach this arm to the side of the crosshead by a single 1/16 in. or 10 B.A. screw put through a No. 51 hole in the arm, midway between the two larger ones, into a tapped hole in the side of the crosshead. Poke the shank of the No. 14 or 11/64 in. drill through the holes in crosshead and arm to ensure them being in line whilst you put the screw in.

Put a little wet flux such as Boron compo mixed to a paste with water, along the joints between slipper, crosshead and arm; heat to bright red, and touch the joints with a bit of soft brass wire, which will immediately melt and run in. *Caution to beginners*: don't overdo it, a very little makes a sound job. Sifbronze wire, or Johnson Matthey's B6 brazing alloy, used with the special fluxes sold, are excellent for jobs like these. Let cool to black, quench in clean cold water, and clean up. The rib of the T must be eased slightly at each side with a file, so that it will slide between the two lower guide bars whilst the top is taking a bearing against the upper one. Note when attaching crosshead arms; two are attached to the right-hand side of the crosshead, as the middle cylinder is right-handed, and one to the left as shown in the illustration.

The hole through crosshead and arm is reamed 3/16 in., and a pin made to suit from a bit of 5/16 in. hexagon rod held in the three-jaw. Face the end, turn down 19/32 in. length to 3/16 in. diameter, an exact push fit in the reamed hole; then turn down 3/16 in. of the end to 1/8 in. diameter, and screw 1/8 in. or 5 B.A. The little pin at the end of the drop arm is made from a bit of 1/8 in. silver steel turned down for a full 1/8 in. at one end, to a diameter of 3/32 in., and screwed 3/32 in. or 7 B.A. A 3/32 in. pip is turned on the other end, to a tight squeeze fit in the hole in the end of the drop arm, leaving a full 1/8 in. between shoulders. Squeeze it in, and if it is the slightest bit slack, burr the pip over slightly where it shows behind the arm.

How to Erect the Guide Bars and Crossheads

Fit a crosshead to each of guide bars; have the drop arms outside, and the middle one on the right of the crosshead. Now put the whole lot temporarily in place on the engine, and enter the three piston rods into the crosshead bosses as far as they will go. Next, with the piston rods fully extended, adjust the brackets and stay so that the centre-lines of all three are 2¼ ins. from the back of the cylinder castings; the blocks themselves, not the covers. The tops of the brackets and stay should then be approximately 1/16 in. below top line of frames. Hold the whole lot temporarily in place; a big carpenter's cramp is very handy for jobs like these, or you can use small toolmarker's champs, putting one over each pair of flanges and the frame.

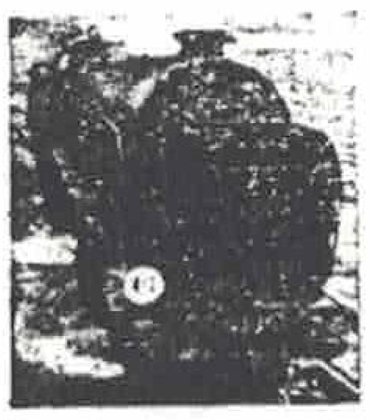
Now work the piston rods in and out by hand, and if they move freely without binding the guide bar assemblies are correctly adjusted. If they *do* bind, then adjust position of brackets and stay until they don't. When all O.K., run the No. 41 drill through the holes in the contact flanges of the outside brackets and carry on clean through frames and inside brackets, and secure with 3/32 in. bolts; either regular turned bolts, or made up from pieces of 3/32 in. round steel, screwed at both ends and furnished with ordinary commercial nuts. You won't be able to get the drill in the bottom holes, as they are masked by the ribs, so their location on the frames must be marked by a bent scriber, and the outer brackets removed to drill frame and inner stay. If preferred, the holes in the contacts flanges of the inner stay may be drilled No. 48 and tapped 3/32 in. or 7 B.A., and set-screws used instead of bolts.

Connecting Rods

The outside connecting rods are made exactly the same as the coupling rods already described, so we need not go over the whole ritual again. Simply use previous instructions, but work to the sizes given on the drawing of the rods. Note that there is no projecting boss at the little end, the rod being reduced to 3/16 in., right from the big end to the little end, which must of necessity be only 3/16 in wide, to fit between the crosshead jaws. Each rod needs a piece of 1 in. by ¼ in. mild steel approximately 6¼ ins. long.

The inside rod is a bit of a different proposition, inasmuch as it must have a pair of split brasses to fit over the crankpin. The main part of the rod can either be milled, or sawn and filed, from a piece of 1⅛ in. by ¼ in. mild steel bar approximately 5¼ ins. long, or can be built up from a piece of 3/16 in. by 3/8 in. mild steel, brazed to a crosspiece cut from 1/8 in. by ¼ in. mild steel, to a depth of 1⅛ in. This rod is milled, or sawn and filed to the dimensions shown in the drawing, by the methods already described for coupling rods, the length from the centre of the little-end bush to the contact side of the T being 5 1/16 ins.

I always make split brasses from two pieces of bronze bar as it is the easiest way I know to get a perfect butt joint between the two halves. In the present instance, you need two pieces of ½ in. by 5/16 in. bar about 1⅜ in. long. Clean one of the long narrow sides of each, by rubbing them on a file laid on the bench, which ensures truth; then put a little soldering fluid on each, clamp together, and solder the joint. This leaves you with a block 1 in. wide. Right in the centre, on the joint, make a centre-pop; don't take the clamp off, or you'll split the two pieces apart. Drill a 1/8 in. pilot hole right through, and follow up with 31/64 in., using either drilling machine or lathe, as the hole must go through dead square. On one narrow side, make two centre-pops at 11/32 in. each side of the centre of the hole. Drill these to 13/16 in. depth with No. 44 drill, again using either machine or lathe. The pieces can now be parted by melting the solder, and wiping off surplus whilst the metal is hot.



OPEN out the "thoroughfare" holes in one half with No. 34 drill, and tap the "blind" holes in the other half 6 B.A.; then temporarily clamp the two halves together with a couple of 6 B.A. screws. File the outside to the shape and dimensions shown: whilst this is not absolutely necessary, as the big-end would work just as well if left rectangular, it gives it the same shape as the big-end on the full-sized engine, which will delight the heart of Inspector Meticulous. Chuck a bit of ½ in. rod in three-jaw, and turn down ¼ in. of the end, to a tight fit in the hole in the brasses. Mount them on this improvised mandrel, then face off part of each side, so as to leave a circular ridge around the hole ¾ in. diameter, the rest of the brasses being cut back 1/32 in., leaving them ¼ in. wide. Take them apart again, and temporarily clamp the larger half to the T end of the connecting-rod, carefully lining it up with the head of the T; then run the No. 34 drill through the holes in the brass, carrying on through the T. File off any burrs, assemble the lot as shown in the illustration, using 6 B.A. long screws to hold the parts together, and finally poke a ½ in. reamer through the hole in the brasses.

How to Erect Rods and Pin Crossheads

The big-ends of the outside connecting-rods are simply slipped over the crankpins; the return cranks, when fitted later, will keep them in position. The inside big-end is taken apart to get it over the big crank-pin, and when the bolts are tightened, it should move freely but without shake. The little-ends are just inserted into the jaws of the crossheads, and secured with the turned pins already made, put in from the side opposite the drop arm, and secured by ordinary commercial nuts.

Push the piston-rods right home, then put one of the cranks on front dead centre. The boss of the crosshead will go over the piston-rod, and should fit tightly. Now carefully advance the piston-rod into the crosshead 1/32 in. more, thus giving that amount of clearance between piston and cylinder cover. Drill a No. 43 hole clean through crosshead boss and piston-rod, and squeeze in a ⅜ in. length of 3/32 in. silver-steel, to act as a cotter. When all three have been pinned, the wheels should turn easily by hand, without feeling any extra resistance at any point. They will not "spin" cold, owing to the friction of the packing, and the initial slight stiffness of new bearings; but there shouldn't be any tight places anywhere. If there are, seek them out, and correct, before proceeding with the valve gear.

Valve Gear

The full-sized "Schools" class engines have three complete sets of Walschaerts valve gear, one for each cylinder, and although the gear itself is of the ordinary type, the layout constitutes one of the most complicated boxes of tricks that I have ever had the doubtful pleasure of sorting out and simplifying for the benefit of those readers of this journal who are building "Roedean." As most folk are aware, there exists a certain section of the community who cling very tenaciously to the fetish of "scale," and argue that the correct thing to do is to reproduce every part in exact proportion to the corresponding parts of the full-sized engine. That may be all right for a "drone" intended to spend its existence in a glass case; but for an engine intended for work, and jolly hard work at that, the fact that Nature cannot be "scaled" completely upsets the applecart.

To quote just one instance alone, a 1 in. bolt may be perfectly O.K. for holding two parts of a full-sized engine's "works" together: but on one the size of "Roedean," that bolt "scales" down to 1/16 in., and would not last the proverbial five minutes, either continually working loose or breaking altogether. What I aim at is to reproduce as far as possible the characteristics of the engine we are copying in the small size, but redesigning the parts to make them strong enough to stand the racket, and be at the same time easy to make and erect.

I showed the working drawings of the valve gear of a full-sized "Schools" engine to the Editor, and he promptly agreed that if they were reproduced in these notes without any alteration, builders would all be scared clean off the job: whilst the comment of one of our principal advertisers was "I'm thankful it isn't me who has to sort them out!" But the job is done; here is an arrangement which looks exactly like the valve gear of a full-sized engine, is strong enough to stand up to plenty of hard work before renewals are needed, and will give the correct steam distribution which is necessary for efficient working, and is a feature of "big sister."

Brief Specification

The two outside sets are of the type in which the expansion link is carried by a block at each side, into which the trunnions are screwed. The bearings are carried in two separate frames or girders, the outer one of which forms part of the valance under the edge of the running-board. The radius rod does not extend beyond the link, but is raised and lowered by a lifting link ahead of the expansion link, operated from an overhead weighbar shaft. The expansion link on the inside set is of similar pattern, but the trunnions are carried in two brackets projecting from a separate cross-stay.

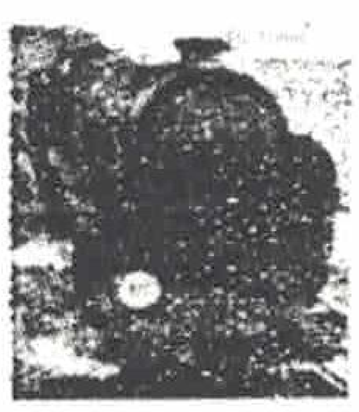
The radius rod is lifted and lowered by a long link operated from an underneath weighbar shaft, coupled to the one above it by two arms and a connecting link, so that both shafts operate in unison. The outside expansion links are waggled back and forth by the usual return crank and eccentric rod; but to keep the ordinary eccentric working the inside expansion link as small as possible, this link has no tail, the eccentric rod being connected to a separate arm alongside the link, the point of connection being practically level with the end of the slot. It is therefore only necessary for the eccentric to have the same throw as one in a Stephenson link motion. In all three sets of gear, the lap-and-lead movement is obtained by the usual arrangement of combination lever and union link, and as these components are exactly alike, we might as well start on the three sets in "mass production" style!

Combination Levers

Each lever needs a piece of ¼ in. square mild steel approximately 2⅜in. long. For beginners' benefit I will repeat that the best way to ensure the holes in each side of a fork being exactly opposite, is to drill them through the solid, before cutting the slot and so forming the jaws. Scribe a line down the middle of one side of each blank and make a deep centrepop on it a little over ⅛ in. from the end; then mark off to spacings shown in the illustration, making another deep pop at each location. Drill all three with No. 32 drill, using either a drilling machine, or the lathe, the drill being held in three-jaw, and the work held against a drilling pad on the tail-stock barrel, with a bit of hardwood, which must be true on both sides, in between. I do mine on a drilling machine, with the piece of rod held in a machine-vice, level with tops of jaws.

Next, cut the slot; clamp the piece under the slide-rest toolholder at right angles to lathe bed and run it up to an ordinary saw-type slotting cutter 1/8 in. wide, mounted on a stub spindle held in three-jaw. When at my old first-floor-back workshop at Norbury, with only a pedal lathe and hand drill, I used this method, an old bolt serving for the stub spindle. If I hadn't a cutter of the required thickness, I used to make one, cutting it roughly out of a bit of "gauge" steel (cast steel plate used for gauge-making, and a commercial article, known in the trade as "ground flat stock").

It was sawn out roughly, the hole drilled, mounted on spindle, turned to size, the teeth filed by hand and the result hardened and tempered, the tempering being done by emeryclothing one side without touching the teeth, and heating it in a bit of sheet iron over the domestic gas stove until it turned yellow, then quenching out in water. It doesn't matter about the teeth being even, as a cutter with irregular teeth seldom or never chatters. When using the cutter, whether home-made or regular commercial, give it plenty of cutting-oil to ensure a smooth finish in the slot.



THE sides of the lever are then milled or filed away for 1/16 in. at each side, as shown in the drawing, and the ends rounded off with a file, aided by a couple of Wilmot filing jigs or buttons. These are made by turning a 1/8 in. pip on the end of a bit of 1/4 in. round silver-steel about 1/4 in. long and hardening them right out. Put one in each eye of the fork, put a bit of 1/8 in. plate between the jaws so that they won't be crushed in, then grip in the bench vice and file away the surplus metal between the two jigs until the file touches them. This wheeze leaves beautifully rounded ends.

The levers can then be tapered as shown and a 1/8 in. parallel reamer put through the middle and bottom holes. These should be case-hardened to resist wear. Just make the ends of the levers red hot and roll them in some good case-hardening powder (Kasenit, Pearlite, Ecosite, or any other known brand) and reheat until the yellow flame dies off, then quench in clean cold water. For an extra depth of hard skin, repeat process before quenching: see that the eyes are well filled up with the powder. After quenching, clean up and polish with a bit of fine emery cloth or other abrasive.

Union Links

Three union links are required: these are just small editions of the combination lever, but with only two pinholes to drill, instead of three. They are made exactly as described immediately above, so we needn't recite all the ritual again, the dimensions being shown in the drawing. Tip: as a long bit of rod is easier to clamp under the slide-rest toolholder than a short bit, take a bit of rod about 4 in. long; mark out one link on the end, drill it, slot it, then saw it off, and repeat twice more.

Valve Crossheads

Three valve forks or crossheads will also be needed. Take a bit of 1/4 in. x 3/8 in. mild steel rod long enough to grip under your slide-rest tool holder: scribe a line down one narrow side, make a centre-pop on it about 5/32 in. from the end, drill No. 32, and slot the end 1/8 in. wide and 3/8 in. deep, same process as for combination lever being used. If you haven't a 1/8 in. cutter, but only a smaller one, use that, and take two or more "bites." Saw off at 5/8 in. from the end, and repeat operation twice more. Round off the end of each, using filing jig described, then chuck each truly in four-jaw, solid end outwards. Face off until the end is 7/16 in. from centre of hole: turn down about 1/16 in. of the end to 7/32 in. diameter, for appearance sake. Centre, drill No. 30, and tap 5/32 in. by 40 to match the thread on valve spindle. Ream the cross-hole 1/8 in. and case-harden as described for combination lever.

Radius Rod

This is another "three-off" job, and no detailed description will be required, as they are slightly bigger relations of the combination levers and are made in exactly the same way from mild steel of the same section used for the valve crossheads, viz., 3/8 in. x 1/4 in. The reamed eye only need be case-hardened.

Expansion Links

Only two of this type are needed, as the inside one is of a different type and emulates a Manx cat; it will be described after we have finished and erected the outside gears. The best material to use for the expansion links is the "ground flat stock" previously referred to, readily obtainable at most tool dealers' stores in all thicknesses; but ordinary mild steel can be used, and will give lasting wear if case-hardened. The same material may be used for the die blocks, but ordinary mild steel will serve for the trunnion blocks, using pins of silver steel with its "natural" finish.

When making slotted links of any kind, a good tip for beginners—or anybody else, as a matter of fact—is to cut the slot first, and form the outline of the link around it. If you spoil a slot in a piece of unshaped metal, there isn't much harm done, and very little time wasted: but a spoilt slot in a carefully filed-up link is quite enough to exasperate the mildest of locomotive-builders! The slots can be machined easily on a lathe, if the owner has a drilling spindle for attaching to the slide rest. A piece of 3/16 in. steel plate of either quality mentioned above, and big enough for two links, is soldered to a piece of 1/8 in. brass plate slightly larger, the whole issue then being bolted to the lathe faceplate, so that the centre line of the slot is 3 in. from lathe centre line.

The drilling spindle, with a 3/16 in. slot drill in it (these are easily home-made: I have described how to make them in previous notes) is fixed in the slide-rest and adjusted so that its centre-line is also 3 in. from lathe centre. It can be driven either from an overhead countershaft or from a separate motor. Put the back gear in, start the spindle, feed into cut with the top slide, and pull the lathe belt very slowly by hand. Use plenty of cutting oil, and a few "ditto repeatos" will produce a perfect sausage-shaped slot of correct radius.

The ends can be squared with a small square file, the extreme ends of the slot being slightly relieved each side for about 1/16 in., so that the die block will not form a ridge each side after considerable running. Once the slot is formed, it is little more than a kiddy's practice job to mark the outline of the link around it, and saw and file to the lines. The hole in the tail is drilled No. 32 and reamed 1/8 in., and the hole must go through dead square, so use either drilling machine or lathe. One side of the tail is thinned down to 1/8 in. as shown in the end view.

It is an easy matter to file the slot by hand: in fact, a skilful file artist could very nearly do the job whilst the machinist was setting up his outfit! Drill a series of 5/32 in. holes all down the middle line, as close as possible; then run them into a slot with a rat-tail file. A small flat file can then be used to open out the slot until a piece of 3/16 in. silver steel rod can be run from top to bottom, easily but without any appreciable shake. Quite simple!

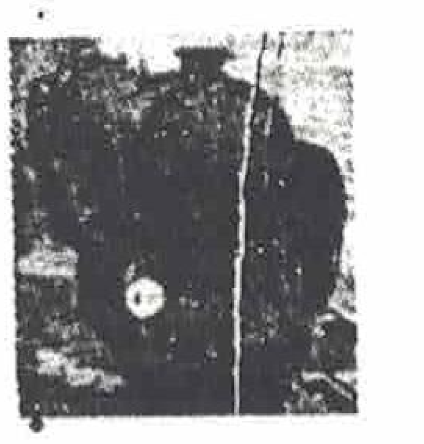
Trunnion Blocks

The trunnion blocks are made up in a manner somewhat similar to the valve cross-head. Get a piece of 1/2 in. x 5/8 steel rod, long enough to held under your slide-rest toolholder. Scribe a line down the middle of one narrow side, and make a centrepop about 3/16 in. from the end. Drill clean through with No. 41 drill, making absolutely certain that the hole goes through dead square. Next clamp the rod under your slide-rest toolholder, and form the wide jaw by running up to a cutter on a spindle in the chuck, same as combination lever and other components, taking two or more cuts if the cutter is narrower than 7/16 in. This jaw must be 3/8 in. deep. Then form a little nick 1/8 in. deep and 3/16 in. wide, in the middle of it, as shown in the detail sketch: this must be of such a width that the link will jam tightly into it, and "stay put" whilst being brazed. Saw off the piece, file to shape, and repeat for second block.

Pin Holes

It is important that the trunnion pin holes shall be exactly on the middle line of the slot, and it is easy enough to locate them exactly and ensure that they don't shift whilst the block is being brazed to the link. All you have to do is to make a dummy die-block, a fairly good fit in the slot, and drill a No. 41 hole plumb through the middle of it. Put this in the slot, in such a position that the hole is 13/16 in. from the top of the slot, and 5/8 in. from the bottom. Put the block on the back of the link, then poke a piece of 3/32 in. silver steel or 13 gauge spoke wire through the lot: a little adjustment of the block will be necessary, but when the wire goes through, you know it it must be o.k. as it couldn't very well be otherwise! Leave the wire in place, anoint all around joint between link and block with some wet flux (Boron compo, Tenacity No. 3, Sifbronze flux, or other good make), heat to bright red, and touch the joint with a bit of 16 gauge soft brass wire, or 1/16 in. Sifbronze rod. This will immediately melt and flow in. *Warning—don't use too much;* if you do, it will probably braze the dummy die-block into the slot as well.

Let cool to black, quench in water, pull out the wire, and remove the dummy die-block: tap the holes 1/8 in. x 60 if you have the necessary tap and die. If not, use 5BA. Then screw in two stubs of 1/8 in. silver steel; only have a short thread on the end of each, but screw in as tightly as you can. If any threads project into the jaw of the trunnion block, file them away with a thin flat file, and square off the pins to a length of 1/4 in. as shown in the detail sketch.



IF the link is cast steel, it can be hardened and tempered at one fell swoop by heating the lot to dull red and dropping into some sperm oil. Water will do if this isn't available, but the link will be more brittle. If the link is mild steel, heat up, and roll in casehardening powder two or three times, finally heating to dull red and plunging into water; be careful not to get it hot enough to melt the brazed joint. Clean up, and polish with a bit of fine emerycloth or other abrasive.

Observant builders will have noticed that the upper half of each link is longer than the lower half. This is in accordance with the full-sized engine, the small links being made in exact proportion. The upper half of the full-sized engine's die block is not only longer, but carries a brass oil-box cap, and the slot has to be long enough to allow this to clear in full back gear. Also, according to the table of valve movements on the full-size drawings, the travel of the valve in full back gear is longer than in full forward gear, the actual travels being 6 9/16 ins. and 6 3/16 ins. respectively, whilst the slip of the die is over twice as much in back gear, as in forward gear. This variation in die slip is common to all gears in which the radius rod is suspended from a swinging lifting link, and is caused by the lifting link and lower (forward gear) end of the expansion link swinging in the same arc; whilst in back gear, the upper (back gear) end of the expansion link naturally swings in the opposite arc to the end of the lifting link, so that the dieblock slips the total "offset" of both arcs.

The dieblocks are filed up from cast or mild steel so that they will slide easily from top to bottom of the expansion links without either bind or shake. The hole must go through exactly square and the blocks, if cast steel, may be hardened right out. If mild steel, well caseharden them, and clean and polish.

Return Cranks

Two return cranks are required and they are sawn and filed, or milled, from 1/2 in. x 1/8 in. flat steel, a simple job requiring no detailing out. One side of each is slightly relieved as far as the large boss. The crank-pin is a 7/16 in. length of 1/8 in. round silver steel, turned down to 7/64 in. diameter for a bare 5/32 in. at one end, and screwed 6 BA. If you put a brass nut on the thread whilst squeezing the pin into the hole in the return crank, the threads won't be damaged. As the actual length of the eccentric rods is automatically obtained when setting the return cranks in correct relation to the main cranks after the gear is erected, leave the making of these for the time being, and proceed to tackle the gear frames.

Gear Frames

The gear frames or link supports provide another instance where the "scaling down" of the big engine's components would be useless for serious work; the frames thus made would be far too thin and flimsy. Four plates are needed, two inner and two outer, and all four can be made at one shot, as the outlines of them all are the same, the inner ones being merely shortened. Four pieces of steel plate, 16 gauge, 4 1/4 ins. long and 1 in. wide, will be required; mark one off to the outline of the longer frame, and drill the two end holes. Use as a jig to drill the others; temporarily rivet all four together, and saw and file the whole bunch to outline.

Put a pilot drill, say No. 30, through at the location of the hole for the link bearings, and follow up with 7/32 in. drill. Part the frames, then finish drilling one outer frame, and use it as a jig to drill the other. Warning—as one frame is left hand and the other right hand, don't forget to do the countersinking on opposite sides. Cut the two inner frames to length, mark off one for screwholes as shown, drill it, and use as a jig to drill the other. Same warning about countersinking applies. The link bearing holes in the outer frames are tapped ¼ in. by 40, and a square-headed bush (to simulate the split bearing on the big engine) is screwed in (see assembly sketch).

The bearing holes in the inner frames are reamed ¼ in. and ordinary round bushes pressed in as shown. All the bushes should be turned from a good quality bronze rod, if you wish your valve gears to keep accurate. The holes through them are drilled No. 32 before parting off the rod in the chuck; put the ⅛ in. reamer through later on, when the frames are erected, and when it goes through both at once, you will have no fears about them being out of line. A tab of 1/16 in. steel, ¼ in. wide and ½ in. long, is riveted to the front end of each outer frame, to join the valance under the running board.

Brackets for Gear Frames

The inner gear frame is supported by two brackets, one of which also supports the back end of the outer gear frame; the front end of the latter is carried by the bracket which supports the guide bars, a 1/16 in. recess being provided for its accommodation; see illustration of the bracket recently published. The front bracket of the inner frame is made by bending a ½ in. strip of 16 gauge steel into an inverted channel ¾ in. across (see detail illustrations both elevation and plan).

In the plan, you will see that one end has to be filed away a little, to clear the flange of the guide bar bracket or support. The outer end of this bracket carries the plummer-block type bearing for the reverse shaft. This is made from two pieces of ¼ in. x 3/16 in. bronze or hard brass rod, each ⅝ in. long, screwed together by a couple of 8 BA screws, hexagon head for appearance sake, as they show above the running board. Drill a 15/64 in. hole through, on the joint line, ream it ¼ in., then file the top to the shape shown, and there is your plummer-block looking just like its full-sized relation. It cannot very well be screwed or bolted to the bracket, being right on the extreme edge, so the best way to make it a permanent fixture, is to silver-solder it, which is O.K. as it will not have to come off the bracket during the lifetime of the locomotive. The bracket can then be permanently riveted to the front end of the inner frame, as shown in the cross section.

A look at the plan of the gear frames erected will show that the rear ends of both frames are attached to a channel-shaped bracket screwed to the main frames, the screws going right through the main frame into the flange of the cross stay that carries the bearings of the expansion link of the inside valve gear. This channel is bent up from ¼ in. x ½ in. steel, 16 gauge, the end next to the main frames being ⅝ in. long, and the outer end ⅞ in. long, the part projecting beyond the end of the outer gear frame being for the purpose of attaching the end of the valance under the running board. Both ends of the channel are filed away to the contour of the outer gear frame, to clear the flange of the driving wheel at the main frame end, and for appearance sake at the outer end. At ¾ in. from the frame end, rivet a ½ in. length of 3/32 in. x ⅜ in. angle brass, as shown in the plan view, and drill two screwholes in the main frame end, corresponding to those shown in the back end of the outer gear frame.

How to Erect Gear Frames

Now comes the part where you have to be mighty careful. Attach the inner gear frame to the angle on the rear bracket by a couple of 3/32 in. or 7 BA countersunk screws put through the clearing holes in the gear frame into tapped holes in the angle. These may be locknutted, if you so desire, for safety, as shown in the plan view. Now temporarily clamp the bracket to the main frames, with the bracket carrying the reverse shaft bearing against the guide-bar bracket, as shown in the plan view, and the top of the gear frame level with the top of the main frame.

ADJUST so that the centre of the expansion link trunnion bush is 3⅜ ins. ahead of the vertical centre line of the driving axle; see elevation of complete gear. Now with a bent scriber, mark off on the main frame, the position of the screwholes in both the bracket carrying the reverse shaft bearing and the holes in the rear bracket. Take great care over this job.

Remove frame with brackets; carefully centre-pop the marked places on the main frame, and drill No. 41 holes, filing off any burrs. Then temporarily attach the assembly again, to the main frames, by a couple of bolts, 3/32 in. or 7 BA, through each bracket and the main frame. Check off the location of the link trunnion bearing again, and make certain you haven't slipped up in the drilling. If all O.K., put on the outer frame, holding temporarily in place with a toolmaker's cramp over frame and rear bracket.

To locate the frame in exact position, poke the No. 32 drill through the two link trunnion bushes. When it passes easily through both at once, and you can twist it with your fingers, the frame is in its correct position. Tighten the clamp; put the No. 41 drill through the three holes at the front end, making countersinks on the guide bar bracket; follow up with No. 48, and tap 3/32 in. or 7 BA. Put one screw in to hold it temporarily, then put the No. 41 drill through the two holes in the back end, carrying on right through the bracket. File off any burrs, and put in a 3/32 in. or 7 BA countersunk screw and nut.

Finally put a ⅛ in. parallel reamer through both link trunnion bushes at once, which will ensure both lining up exactly, and allowing the link to swing freely without being slack. Repeat the whole complete ceremony on the other side of the engine.

BY the good rights, the next items in the construction of the valve gear should be the reverse shaft, or weighbar shaft as enginemen call it, and the lifting links; but as there are two of the former on this engine, a main one "upstairs" which operates the outside motion direct, and another auxiliary one down below, for operating the inside motion, both being connected to work in unison, it would be advisable to leave these for the time being, and make and erect the inside valve gear. Then both shafts can be made, erected, and all necessary adjustments effected, at one fell swoop.

In the brief specification of the valve gear, I referred to the principal differences, and a study of the reproduced general arrangement drawing of the gear will make them quite clear. It will be seen that by adapting the "Manx cat" link and driving it from a separate arm at the side, the throw of the eccentric, and consequently that component itself, can be kept within reasonable dimensions. This considerably reduces the "band-brake" effect set up by eccentrics and straps of very large diameter, and there is no chance of bumping the underside of the boiler barrel when the engine hits a junction or a high joint whilst she is making the "Thanet Belle" look like a stage coach.

In place of the complicated hollow casting which carries the link brackets on the full-sized engine, I have substituted a simple cross stay with two bronze-bushed angle or sheet-metal brackets screwed to it; or they can be castings, if our advertisers can supply.

The stay itself will be cast, and when scheming it out, I happened across another useful idea. The earlier full-sized engines had an air pump, similar to the one on the G.W.R. engines, for maintaining the vacuum in the train pipe whilst the engine was running. As some builders still prefer a pump feed to an injector, and we cannot use an ordinary eccentric-driven pump under "Roedean" because there are too many other "works" in the way, we can utilise this pump for water, same as we did on the "1000," and bolt it to a flat seating which can be cast integral with the cross stay, saving no end of a lot of time and trouble. I have shown this seating in the drawing. Builders who are relying on the injector only, can saw the seating off if they so desire, or just leave it "holding up nothing," as the kiddies would say.

The lap and lead movement, as I stated in the specification mentioned above, is the same for all three sets of gear so if you haven't already done it, go ahead and make the combination lever, union link, and radius rod, just the same as you did for the right-hand side of the engine, and erect them in precisely the same way. Then carry on as follows.

Link Bracket or Stay

The sides of the link bracket can be machined off in the lathe by clamping it on its side under the slide-rest tool holder, and traversing it across an endmill or slot drill in the three-jaw, preferably one over 1/2 in. diameter, so that only one cut is necessary. Beginners need not have any trouble in setting the job square; all I used to do, in the days when I hadn't any milling machine, was to put the lathe faceplate on, run the slide-rest up to it, and set the job with a try-square. In the present instance you would simply apply the stock of the square to the faceplate and line up the top edge of the casting to the blade; then tighten your clamp, put the chuck back, with the endmill in it, and go ahead. Unless both the square and the lathe were emulators of Ananias, the machined surface must come out at exactly right angles to the top edge, which is what we are after. Naturally, lucky owners of a milling machine, or a planing or shaping machine, won't need detailed instructions for a simple job like that; all that is necessary is to catch the casting in the machine-vice on the table, and operate with a side-and-face milling cutter, or an ordinary round-nose tool in the clapper box, as the case may be.

If you have a vertical slide, use that, with the casting held in a machine-vice bolted to it; and in that case a smaller cutter than 1/2 in. could be used, if the big one were not available, adjusting the slide up and down as needed, so that the whole surface is presented to the cutter by instalments, in a manner of speaking. The flat face of the pump seating could be done same way. However, if no means of machining are available, the humble but necessary file, in the hands of a careful and painstaking individual, will do the trick.

The stay could also be built up, using a piece of 1/8 in. brass or steel plate, 1 1/16 ins. wide and 2 7/8 ins. long, with a 1 1/16 ins. length of 3/8 in. x 1/8 in. angle riveted to each side of it, for attaching to frames. The pump seating could be made from two pieces of 3/4 in. x 1/2 in. x 1/8 in. brass angle, bolted or riveted back to back with the stay in between, the distance from the top of stay to the underside of the angles being 1 7/16 ins. This would cut out all machining. The angle on the same side as the two brackets carrying the trunnions, would have to be cut away at one corner, to allow the bracket to be fitted.

The trunnion brackets may either be bent up from a piece of 5/8 in. x 3/32 in. brass or steel, or cut from 3/8 in. x 7/8 in. x 3/32 in. angle. If this size isn't available, use nearest larger, and cut down to suit; the shape and size of the brackets are shown on the drawing. At 5/8 in. from the foot of each bracket, drill a 7/32 in. hole—this can best be done by clamping them together, back to back, with the feet in line—and squeeze into each of them a little bronze bush turned from 5/16 in. round rod held in three-jaw. Simply face, centre, drill down about 1/2 in. with No. 32 drill, turn down 1/8 in. of the outside to a press fit in the hole in the bracket, part off at 1/4 in. from the end, reverse in chuck and skim 1/32 in. off the head, to true up and bring it to the correct thickness. Drill two No. 34 holes in each foot.

Set the brackets on the stay in the position shown, with the face of one bush at 11/16 in. from edge of stay, and 3/4 in. full between; a couple of small toolmaker's cramps are useful for these jobs, and are easily home-made. When I was a kiddy, I made a whole lot of them with odd bits of bar, and screws, all salvaged from a broken and discarded kitchen fender. Put the 32 drill through both bushes, and if you can't turn it with your fingers, adjust brackets until you can; run the 34 drill into the hole in the feet, making countersinks on the stay.

DRILL through with No. 44 drill, tap 6 B.A. and put in 6 B.A. screws, hexagon head for preference. Finally poke a 1/8 in. parallel reamer through both bushes at once; then you are absolutely sure they are dead in line, and there will be no binding of the link trunnions.

To erect the stay, proceed thus. At 2 7/16 ins. ahead of the centre of driving axle, and 1/4 in. below top of frames, drill a No. 30 hole, with three more below it at 1/4 in. centres and countersink them; see general arrangement drawing of the complete gear.

File off any burrs (very important when erecting), set the stay in position shown, level with frame top, and the front face 2 3/4 ins. ahead of driving axle; clamp temporarily in position, then make countersinks with No. 30 drill on the flanges, through holes in frame, follow up with No. 40, tap 1/8 in. or 5 BA, and put countersunk screws in.

Expansion Link

The only difference between the expansion link itself, and its fellow-conspirators on the outside valve gears, is that it has no caudal appendage, the top and bottom ends being finished off to the same outline; so builders can go ahead and make the link and trunnion block to the instructions already given. Then cut out a piece of 1/8 in. steel plate to the outline shown in the illustration; the upper part is the same shape as the top of the trunnion block, and the "leg" similar to the curve of the link. The hole is drilled No. 32 and reamed 1/8 in. Attach this temporarily to the side of the trunnion block by a 1/16 in. screw, or a pin, before brazing the link to the trunnion block; then braze all the lot at one heating, to instructions already given.

The only difference in the trunnion pins is that the one going through the side with the driving arm attached, is made 1/8 in. longer in the screwed part, as shown. Use the same strict caution as before to see that the trunnion pins line up exactly with the centre-line of the curved slot.

Eccentric Strap and Rod

For beginners' benefit, the easiest way to machine eccentric straps is first to clean up the outside with a file, then centre-pop the ears or lugs, and drill right through with tapping size drill, in this case No. 40. Scribe a line across the middle of the lugs, catch in bench vice with this line just showing above tops of jaws, and saw across, keeping the sawblade pressed sideways against the tops of vice jaws. By this means you get a true parting.

Rub each half on a flat file laid on the bench, to take off the roughness left by the saw; then open out the holes in the ring part to No. 30, and tap those in the lug part 1/8 in. or 5 BA. The two halves can then be screwed together. Make a mark on both the lugs at one side, so that they can be replaced in correct relation whenever taken apart.

Chuck in four-jaw with the hole running as truly as possible; face off with a round-nose tool set crosswise in the rest, and then bore the hole to size with the same tool used to bore the cylinders. To get the correct diameter I always use a plug gauge; simply a bit of round rod the same diameter as the eccentric itself. It is only a few minutes' work to chuck the bit of rod and turn it to correct size, measuring with a "mike" or callipers. Bore until the gauge just slips in easily without shake. To face the other side of the strap, wrap a strip of paper around the gauge (one turn is enough) slack the screws in the strap, place on the end of the gauge, and tighten screws. It will now be held tightly enough to allow for facing off, with the gauge held in the three-jaw. If the strap wobbles sideways, slack the screws and tap it until it runs truly. Face off until the strap will fit easily, without shake, between the flanges of the eccentric.

The lug can be slotted with the same cutter used for the forked ends of the valve gear components, by holding the strap in a machine-vice on the lathe saddle, setting it at the correct height for the cutter to form the slot at one cut, and traversing it under the cutter by turning the cross-slide handle. *Note to beginners*: always feed *against* the teeth of the revolving cutter, never with them, otherwise if there is the least bit of slack in the slide screws, the teeth will catch in the work and drag the slide forward to the extent of its slackness, dig in, and damage the work, cutter, or both.

The eccentric rod can either be milled, or sawn and filed, from a piece of 1/2 in. x 1/4 in. steel, or built up, using 1/2-in. x 1/8 in. strip for the rod itself, and brazing on a little block to form the forked end, which is machined up as described for the outside eccentric-rod forks, or the top of the combination lever. The tongue that fits into the lug in the eccentric strap should be a drive fit.

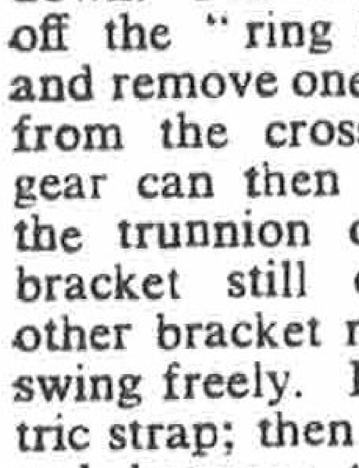
Assemble the lot to the dimensions given, but don't fix the rod into the strap permanently yet, as the length between centres may need slight adjustment owing to some slight inaccuracy in some other part of the gear. For instance, 1/64 in. error either way, in setting the link stay, would necessitate adjustment to suit, so that there would be no deleterious effect on the running of the engine. The old saw says "Two wrongs don't make a right," but the merchant who thought up that one, did not build locomotives, or he would have realised the truth of another old saw, which says "There are exceptions to every rule!"

Lifting Links

Three lifting links are needed, two for the outside valve gears, and a longer one for the inside gear. They are all made from 1/4 in. square steel. No detailed instructions will be needed, as the operations have already been described for similar valve gear components. Just saw and file, or mill to shape and sizes given, same as for the combination levers and other parts. Thin-headed pins, turned from 1/4 in. hexagon or 5/16 in. round steel, will be needed for the long link connecting the two weigh-bar shafts, another component which is made from 1/4 in. square steel, same as the lifting links. The pins are just a plain turning job with the rod held in three-jaw, the sizes being given in the illustration.

Inside Valve Gear Assembly

Put the solid end of the long lifting link between the jaws of the radius rod, opposite the inner holes, and drive a piece of 1/8 in. round silver-steel through the lot, filing off flush both sides. Put the eccentric-rod fork over the eye at the bottom of the driving arm of the expansion link, and pin that in similar fashion. To avoid any damage whilst squeezing in the pin, which can be done in the bench vice, put a piece of steel between the outside of the eccentric-rod fork and the link; then you can grip the lot, and squeeze the pin right home without fear of damage.



If using the vice, put a piece of soft sheet copper between each jaw and the work otherwise there will be teethmarks on both link and outer fork, and that won't do at any price.

Next, put the dieblock in the expansion link, right up at the top, and put the radius rod over it, with the lifting link hanging down. Pin that, same as above. Now take off the "ring half" of the eccentric strap, and remove one of the link trunnion brackets from the cross stay. The complete valve gear can then be put in from underneath, the trunnion on the link slipped into the bracket still on the cross stay, and the other bracket replaced, when the link should swing freely. Replace the half of the eccentric strap; then put the free end of the radius rod between the jaws of the combination lever and squeeze a pin through that too. Alternatively, you can disconnect the union link at the crosshead arm, where it is only fixed by a nut, take out the bolt holding the combination lever to the valve crosshead or fork, and attach the combination lever to the radius rod before putting the whole bag of tricks in position. It signifies little, which route anybody takes, as long as they get there !

There is a "scientific" way of setting the eccentric, and getting the exact length of the eccentric rod between centres; but as that clever old locomotive superintendent, David Joy, said when giving instructions about his valve gear, it is easier to do it by trial and error. Put the crankpin right down, as shown in the general arrangement illustration, and turn the eccentric so that the expansion link is at the extreme end of its movement, as shown. You can gauge this easily, by rocking the eccentric back and forth gently, and watching the movement of the expansion link, noting when it ceases to move one way, and starts in the opposite direction. The dead point is the one you need, and when you get that, tighten the setscrew on the eccentric boss.

To get the length of the eccentric rod, put the crank on front dead centre, and run the dieblock up and down the link. If the valve spindle doesn't move, the length is correct. If it does, adjust length by moving the eccentric rod in the slot in the strap, which was why we left it unfixed. When you have got it, try it on back dead centre; still the valve rod should not move. If it does, the eccentric is slightly out of setting; move this *half* the distance needed to bring the link to the required position, then repeat operations. That should do the trick. When you can run the dieblock up and down the expansion link, with the crank on each dead centre, without moving the valve spindle, both eccentric-rod length, and eccentric setting, are correct.

To avoid any chance of moving the eccentric-rod in the slot in the strap, whilst removing the lot to pin the joint, temporarily solder it in place, using a small soldering bit that will go between the frames. Don't use an acid flux, or the "works" will all go rusty; use a pinch of resin, or a taste of the non-corrosive flux sold for electrical work. Then take the lot out temporarily again, pin the rod to the strap by a couple of $\frac{1}{16}$ in. rivets (bits of steel wire do fine) and replace.

Outside Adjustments

The outside valve gear is erected and set in similar fashion, but the short lifting links are pinned to the radius rods so that they point upwards, and the lap-and-lead movement, radius rods and expansion links erected without connecting up the eccentric rods beforehand. Take off the outer plate of the gear frame to get the expansion links in position. To get the exact length of eccentric rods, and position of return cranks, at one operation, I will repeat for benefit of beginners, set the return crank as near as you can "by eye," to the position shown in the recent illustration of the gear assembly. Set the expansion link in such a position that you can run the radius rod up and down without moving the valve spindle, and temporarily fix it thus. Then, set the main crank on front dead centre, and with a pair of dividers, take the distance from the centre of hole in link tail, to centre of return crankpin. Shift crank around to back dead centre, and check, *without altering the dividers,* distances as above. If they tally, all is O.K., if not shift the return crank so that its pin moves half the difference, and try again. When the measurements are the same on both dead centres, the return crank is correctly set, and the distance between the divider points is the exact length of the eccentric rod between centres.

Fix the return crank by drilling four No. 53 holes half in crankboss and half in pin, and driving in four stubs of $\frac{1}{16}$ in. steel wire; or you can drill No. 55, tap $\frac{1}{16}$ in. or 10 BA as preferred, and put four countersink screws in. Projecting heads, as on the full-sized engine, can only be used if the eccentric rod is set out to clear them, and on the little engine this is not necessary. The eccentric rods have already been illustrated in the recent drawings of the outside valve gear, and are made in the same way as described for the other rods, the ends running on the return crankpins being bronze bushed.

Weighbar or Reversing Shafts

The upper weighbar shaft in this engine is unlike any hitherto described, as it is set downwards in the middle to clear the underside of the boiler barrel. Owing to the limited load gauge on the piece of line between Tonbridge and Hastings, over which the "Schools" class do excellent work, it was not possible to set the boiler any higher. We need a piece of $\frac{1}{4}$ in. round mild steel set over in similar way: and the easiest way to set it, is to place it between three blocks in the jaws of the bench vice, and use that as a "Jim Crow," as the platelayers call their rail bender. It may require a little judicious wangling to get the ends to run truly, but recollect the old saying "Patience is a virtue"—and be virtuous ! Square off the ends to a length of $5\frac{5}{8}$ ins., with the bend exactly in the middle.

THE inner lifting arm, which connects with the lower shaft, should be made and fitted first. Cut it to shape, as shown in the detail sketch, from $\frac{1}{8}$ in. x $\frac{3}{8}$ in. flat steel, without any fork, and drill the holes No 32 at $\frac{13}{16}$ in. centres. Chuck a bit of $\frac{3}{8}$ in. round rod in three-jaw, and turn a $\frac{1}{16}$ in. pip on it to fit the No. 32 hole in the large end very tightly. Part off $\frac{1}{8}$ in. from the shoulder; squeeze in the pip, and braze or silver-solder the joint. Wash off and clean up; then chuck the boss in three-jaw, and drill right through with letter C or $\frac{15}{64}$ in. drill, cutting out the pip. Put the "lead" end of a $\frac{1}{4}$ in. parallel reamer in the hole, just far enough to enlarge it to a drive fit on the shaft; then drive it on until it is $1\frac{1}{4}$ ins. from the end, and just at the beginning of the "set." It should be just a wee bit over right angles to this; see general arrangement drawing. Ream the small end $\frac{1}{8}$ in.

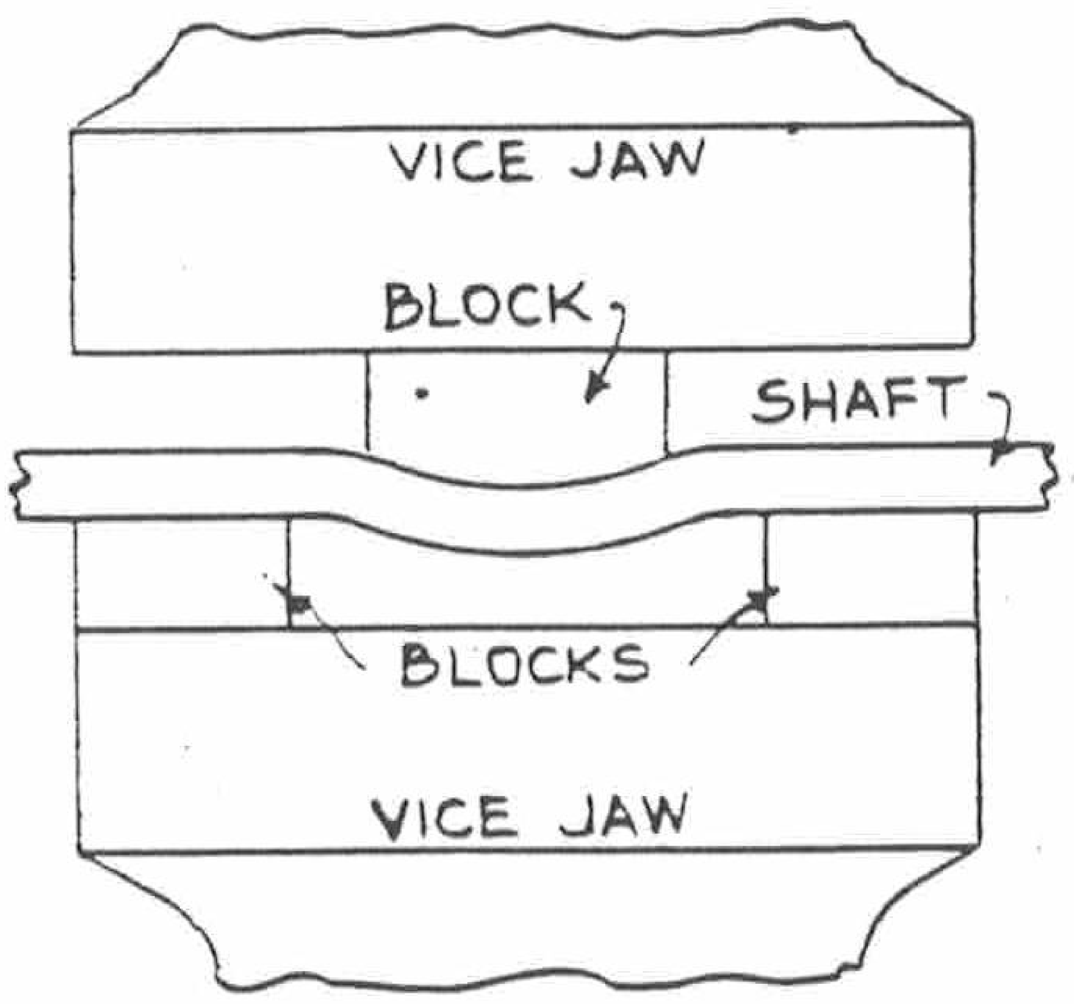
Next comes the reverse arm. This is also cut from $\frac{3}{8}$ in. x $\frac{1}{8}$ in. steel, but it has no boss, and is $\frac{11}{16}$ in. centres, but drilled and reamed as above. Drive it on to the shaft, so that it is $\frac{3}{4}$ in. from the end, and diametrically opposite to the "set." A collar, drilled a drive fit for the shaft and parted off a bit of $\frac{3}{8}$ in. round rod, is driven on to the other end of the shaft in a corresponding position. The distance between the outer sides of collar and reverse arm, should correspond to the distance between the inner sides of the shaft bearings on the outside gear frames, with a very slight amount of clearance, to ensure the shaft working easily.

Outer Lifting Arms

The outer lifting arms are made from $\frac{3}{8}$ in x $\frac{1}{4}$ in. steel and the easiest way to slot them, is to take a piece of bar long enough to be gripped under your slide-rest tool holder plus about 1 in. overhang. Cut the slot by running the bar up to a $\frac{1}{8}$ in. saw-type slotting cutter on an arbor or stub mandrel, as before, then reversing it to cut the slot in the other end. Saw off the slotted ends, each piece being about $1\frac{1}{4}$ ins. long, then file or mill the arms to the given outline. Drill, ream, and press them on to each end of the shaft, in line with the lifting arm first fitted. Check by poking a piece of $\frac{1}{8}$ in. silver-steel rod, through all three at once. Don't braze them yet; wait until we can assemble the whole lot temporarily, and then set inside and outside gears exactly in unison.

The lower weighbar shaft is a very simple affair compared with the upper one, being simply a 3 ins. length of $\frac{1}{4}$ in. round steel, with two arms and a collar on it. The arms are made exactly as described above for the reverse arm, but they are $\frac{25}{32}$ in. between centres; they are driven on the shaft at the spacing shown in the illustration. Check for parallelism with a piece of $\frac{1}{8}$ in. silver-steel through the holes; this material is usually straight enough for lining-up purposes. The collar is the same as fitted to the upper shaft. Braze the arms in position, but the collar need not be brazed if a tight fit. After quenching out in water, clean up with fine emerycloth or other abrasive.

The shaft is carried by two brackets screwed to the frame. Cut them out of $\frac{1}{8}$ in. brass plate, to the shape and sizes shown. The hole for the shaft is drilled with letter C or $\frac{15}{64}$ in. drill, and reamed $\frac{1}{4}$ in.: the holes for the screws are drilled No. 44, their exact position does not matter, as the screws only hold the bracket to the frame. To locate the brackets in their proper position, set them *outside* the frame in the position shown in the general arrangement of the gear, viz., with the hole for



HOW TO PUT SET IN UPPER WEIGHBAR SHAFT (DIAGRAM ONLY)

shaft $\frac{3}{4}$ in. below centre line of motion, and $3\frac{5}{8}$ ins. ahead of the centre of driving axle. Hold temporarily with a toolmaker's cramp on each, then run a bit of $\frac{1}{4}$ in. round steel through both holes at once, noting if it lies square across the frames, and is dead level. Adjust if necessary; when O.K. drill clean through the frames with No. 44 drill, using the holes in the brackets as guides. Then remove brackets, marking them R and L, so that you know which is which, and tap the holes 6 BA. Open out the holes in frame with 34 drill, and file off any burrs. Then put the brackets on the ends of the weighshaft, collar at the right-hand end, and put the brackets in position, *inside* the frame this time, with the weightshaft between them. Secure with three 6 BA screws, hexagon heads for preference, put through the clearing holes in frame, into the tapped holes in the brackets. The shaft should then be quite free.

Put the centre lifting arm in the fork of the hanging lifting link (that sounds like Pat!) and secure it with a bolt made from $\frac{1}{8}$ in. silver-steel, reduced to $\frac{3}{32}$ in., screwed and nutted each end, same as the one in the valve fork or crosshead. If the arm at the end of the shaft is now operated by hand, the gear should reverse easily in any position of the expansion link or cranks.

Take the caps off the bearings for the upper shaft, put same in place, and replace caps. The two outside arms are connected to the short lifting links of the outside motion, by little bolts made from $\frac{1}{8}$ in. silver-steel, as mentioned directly above. The connecting link between the two shafts is attached to the upper and lower lifting arms by the two thin-headed pins, made as illustrated in the drawing of the lifting links. The thin heads are necessary to clear the frame: we can't shift the arms nearer centre, because of the "set" in the top weighbar shaft. Now check off carefully: all three die-blocks must be dead in line with the link trunnions at one and the same time; if they are not, move the arms on the upper weighbar shaft, until you get the desired result. Then carefully disconnect the upper shaft, braze the arms, clean up, replace and reconnect: if the upper (vertical) reverse arm is operated by hand, all three sets of gear should reverse together, with a perfectly easy and free movement.

BUILDERS of "Roedean" will have noticed that owing to the lifting arms on the weighbar shaft pointing to the rear of the engine the reversing arm has to be pushed forward to lift the die blocks to the top of the links and put the engine in back gear. This introduces a complication in the reversing gear in the cab. With an ordinary "pole" lever, or a wheel-and-screw connected up in the usual manner, with the reach-rod going direct from the nut to the reversing arm, the engine would go the opposite way to the lever, which is confusing to a driver.

Some of the engines of the Victorian era actually had this arrangement, and a bad accident was caused in a dense fog on the old Midland Railway, directly attributable to this way of connecting up. The driver had stopped for a signal and when restarting, being strange to the engine, put her into what he inadvertently thought was full forward gear and opened the regulator. Owing to the very dense fog, he did not realise he was going backwards until the train collided violently with a following train which was proceeding the right way.

One of our own fitters on the L.B. & S.C.R., when re-erecting a valve gear, inadvertently connected the back gear eccentric-rods to the top of the links; when the shed driver put the lever forward to go out of the shed, the engine backed and knocked a hole through the end wall, fortunately without hurting anybody.

To save any trouble and misunderstanding, Mr. Maunsell arranged matters so that when the reversing nut was at the forward end of the "Schools" engines, they went forward, and vice versa, by the simple expedient of connecting the nut to a centrally-pivoted lever which pulled the reach-rod back when the nut went forward. On his 2-6-0's, which have the nut directly connected to the reach-rod, he got the same result by setting the return cranks to lead the main cranks instead of following them as on the "Schools," and using the top half of the expansion link for forward motion. On our little "Schools" engine, the gear is arranged as on the big sisters, as you can see by examining the drawing.

I have, however, made one variation, for convenience in driving the 3½ ins. gauge "Roedean." On the big engine, the wheel-and-screw is set right in the corner of the cab, and is located partly between the boiler and the cab side, projecting forward into a recess in the cab front. This arrangement was also used on the Webb engines on the L.N.W.R., so that the drivers could keep well under the short cab roofs. To make the wheel a bit more accessible on the little engine, as the driver doesn't ride under the cab roof, I have brought the whole box of tricks back, so that you can reach the wheel easily from the driving car behind the tender. Now to construction.

Stand and Bearings

It is quite possible that the advertisers who are supplying the needful for this engine, will be able to supply a cast stand complete with bearings for the screw, also a cast handwheel. If they don't, the stand is easily made from a piece of 1/8 in. mild steel (piece left over from frames will do fine) a little over 4 ins. long, and 15/16 ins. wide. This is filed up to the shape shown in the illustration, and then set over 11/32 in., as shown in view, to ensure the reach-rod clearing the trailing splasher when erected. Drill and tap the holes as shown.

To make the bearings, chuck a bit of 3/8 in. round rod (brass or steel), face the end, centre, and drill No. 30 for about ¼ in. depth. Part off two 3/16 in. slices. Re-chuck one of them, open it out with 7/32 in. drill, and tap ¼ in. by 40. Now mill or file a groove in each, 1/16 in. deep, and a tight fit on the upper edge of the stand. Anybody who owns a milling machine, could, of course, mill the groove in the bit of rod before parting off; I do it that way.

Mount the two bearings on the edge of the stand, the tapped one at the curved end. If brass, or gunmetal, silver-solder them; if steel, bronze them. Don't use too much brazing material and make a clumsy job. The screw plug for the tapped bearing is made just the same as a small piston or spindle gland, so I needn't detail that out again; just make it from 5/16 in. hexagon bronze, gunmetal, or brass rod.

Screw, Nut and Hand Wheel

The screw is made from 3/16 in. round mild steel. Chuck a length in three-jaw, face the end, and turn down 3/32 in. length to 5/64 in. diameter; screw 9 B.A. Turn down a further 13/32 in. to 1/8 in. diameter, and file 3/16 in. of that to a 3/32 in. square. For beginners' benefit I will repeat briefly that an excellent square can be filed by putting the rod back in the chuck so that only the part to be squared shows beyond the jaws.

Set one of the jaws vertically (12 o'clock position) and file a flat on the steel with a "safe-edge" (one edge plain) file, letting the safe edge rub against the chuck jaws. Repeat operation with the jaw at 3, 6 and 9 o'clock positions, and there is your square.

The next 15/16 in. of the rod requires screwing with a die in the tailstock dieholder. By rights this should be a left-hand thread (3/16 in. Whitworth in this case) so that you turn the wheel clockwise to go ahead, same way as you turn your lathe cross-slide handle to move the slide forward; but if only a right-hand die and tap are available, just use them.

Screw the rod for about 1⅛ ins. so as to have full threads right up to the end, then part off at 13/16 in. from the beginning of the thread. Reverse in chuck, and turn down ¼ in. of the other end to 1/8 in. diameter, a nice running fit in the little gland. The length of the threaded part is such that it just fits nicely between the bearings on the stand.

THE nut can either be made with a separate pin to engage the fork in the lever, or pin and nut can be made in one piece. For the former, chuck a piece of 5/16 in. x 3/8 in. rod in four-jaw; either steel or bronze will do. Set to run truly; face the end, centre, and drill a No. 30 hole for about 3/8 in. depth; part off 5/16 in. from the end.

Mill or file a groove in one of the short sides, 1/8 in. wide and a full 1/16 in. deep, making it easy enough to slide along the top edge of the stand. Drill a No. 40 hole in one side, going right into the centre hole: tap it 5 B.A., or 1/8 in. x 60 if you have that pitch available, and screw in a stub of 1/8 in. round steel, leaving 5/32 in. projecting. Then tap the central hole to fit the screw.

To make the nut and pin in one piece, chuck a piece of 5/16 in. x 3/8 in. bronze or steel rod truly in four-jaw; face the end, and turn down 5/32 in. length to 1/8 in. diameter. Part off at 5/16 in. from the shoulder. Centre-pop the end, drill No. 30 and tap to suit the screw, either doing the job on a drilling machine, holding the nut in a machine-vice on the table, or else setting the nut in the four-jaw with the centre-pop running truly, and drilling and tapping as described above for the separate-pin fitting. Finally, file or mill the groove, as previously mentioned.

To assemble, set the nut on the stand between the bearings, making sure the pin is on the correct side. Insert the squared end of the screw through the tapped bearing, and screw it through the nut until the plain part behind the square is right home in the back bearing.

Screw in the little gland over the front journal of the screw; when this is right home, the screw should be perfectly free to turn, without having any end play, and the nut should move freely up and down between the bearings when the screw is turned by finger and thumb. It should have 5/8 in. of travel.

The wheel, if no casting is available, can be made from a 3/16 in. disc of metal 1⅛ in. diameter, or from a piece of rod that size or nearest larger available. Chuck the rod in three-jaw; face off, leaving a boss ¼ in. diameter standing out 1/32 in. from the face. With a rather pointed roundnose tool set crosswise in the rest, make a slight recess between boss and rim. Part off to 3/16 in. from the face off the boss: reverse in chuck, gripping by the edge and setting to run truly, then face off to leave a boss about 3/8 in. diameter, projecting 1/32 in. Centre, and drill through with 3/32 in. or No. 42 drill.

The hole is squared by driving a square punch through it, resting it on a block of brass, over a 1/8 in. hole, to allow the punch to go right through. The punch is merely a couple of inches of 3/32 in. square silver-steel, squared off at one end, and hardened and tempered. Instead of punching, the hole could be filed square with a watchmaker's square file.

Drill a hole in the rim, about No. 48 will do, and turn up a little handle from 3/16 in. round rod, with a spigot on the end to drive into the hole in rim; a job that needs no detailing out. The wheel is then fitted to the square on the screw, and secured by a commercial nut: any part of the screw projecting beyond the nut should be filed off, otherwise you may get scratched fingers when notching up or reversing.

A cast wheel merely needs turning up, either holding in chuck and doing each side alternately, or mounting on a temporary spindle, like a running wheel; the square hole is formed as above described. If the spokes are rough, file them smooth for appearance sake.

There is really no need to cut spokes in a wheel turned from solid: if you need them, merely drill four equidistant holes about 3/16 in. diameter, in the recess between boss and rim, and file the metal between the holes to the shape of spokes with a watchmaker's file. Any metal will do for the wheel, but nickel-bronze (German silver) or dural makes a very nice-looking wheel, and is easier to machine than steel.

Lever

A piece of 1/2 in. x 1/8 in. mild steel will be needed for the lever. This is filed to the shape shown, and slotted at the top to take a 1/8 in. pin, by the same method described for slotting valve gear forks. At 1 1/8 in. from the top, and 3/4 in. below that, drill No. 44 holes. Tap the bottom one 6 B.A., chuck a bit of 1/2 in. round steel in three-jaw, and turn a pip about 5/32 in. long on the end of it, to a tight fit in the middle hole in lever. Press it in and braze it; then chuck the rod again, with the lever brazed on it.

Centre with a centre-drill, then drill down about 1/4 in. depth with No. 14 drill; part off to leave a boss projecting 3/32 in. from the lever, and then ream the hole 3/16 in., which can be done by hand, using a tap-wrench to hold the reamer. File off any burrs, and take the sharp edge off the holes by applying a centre-drill to them with your fingers. Turn up the two little pins shown, one from 5/16 in. hexagon steel, and one from 1/4 in. ditto, a simple job that I have described many times, so need not repeat here.

Attach the lever to the stand by means of the larger pin, as shown in the end view, and put a 1/8 in. or 5 B.A. locknut on the bit of thread projecting through the stand. The lever should be free to swing when the pin is screwed right home, but should have no movement at all endwise. The slot should fit over the pin on the nut, and any movement of the screw should be transmitted to the lever without backlash.

Erecting and Connecting Up

Put the complete stand in position shown in the drawing of the whole bag of tricks erected, viz., 1/2 in from back edge of frame, and 1/4 in. from bottom. Run the No. 30 drill through the holes, making countersinks on the frame; follow up with No. 40, tap 1/8 in. or 5 B.A., and put screws in as shown. Hexagon heads look pretty, but any kind will do, as long as the stand is rigidly held to frame.

The exact length of the reach-rod, or reversing-rod (some enginemen call it one thing, and some another!) should be obtained from the actual job. The lever on the reverser should be exactly in mid-travel; then set the valve gears so that the die-blocks are exactly opposite the trunnion pins in the links. Measure from the centre of the bottom hole in lever, to the centre of the hole in the reversing arm on the weigh-bar-shaft, and that is the required length of your reach-rod between centres.

The rod can be filed from 1/4 in. x 1/8 in. mild steel; it tapers a little toward the ends. Note very carefully the bends, or "sets" as the blacksmiths term them, that have to be made in the rod, to clear the driving-wheel splashers, and make the ends of the rod line up with the lever and reversing arm respectively. The fork that embraces the reversing arm, is formed from a little block of steel brazed on the end of the rod, and machined up exactly as described for forked ends in the valve gears.

The fork is attached to the reversing arm by a pin made from a bit of 1/8 in. silver steel shouldered down to 3/32 in. at each end, screwed, and furnished with commercial nuts, same as the valve crosshead pins; the back end is attached to the bottom of the lever by the special pin shown. When the wheel is turned, all three sets of valve gear should move quite easily, and in perfect unison.

Mechanical Lubricator

When first going into details of "Roedean's" arrangement of steam pipes and lubricator, I thought it would entail separate branches to each cylinder, with a twin-pump lubricator and separate feeds; but it is always my endeavour to make the job as simple and easy as possible, consistent with efficiency. I therefore sought and found an easy way of piping up, which entails only one pipe connection to the superheater—a flange joint at that—and a single-pump lubricator will do all that is needed, as the oil is introduced into the steam flow at the point where the steam diverges to the three cylinders. They can thus get fair shares from the one solitary pump, which is big enough to supply the lot.

The lubricator is the same in principle as I have described for most locomotives in these notes, so there is hardly any need to go into very elaborate details of construction. For beginners' benefit I will run through the principal items. The oil reservoir, or tank, can be made from a 1 1/4 in. length of 1 1/4 in. square brass tube (commercial article) if available; if not, just bend a strip of 20 gauge brass or copper, 5 ins. long and 1 1/4 ins. wide, into a square. Stand it on a piece of 16 gauge metal a little bigger, say, 1 3/8 ins. square, silver-solder all around the bottom, and up the open corner, if the tank has been bent up from sheet.

AFTER pickling and washing off, file the bottom flush with the sides. This job can be done in a few minutes over a small burner on the domestic gas stove. Put some wet flux around the bottom, and up the corner; stand the whole issue over the burner, light the gas, and as soon as the tank gets to dull red, apply the strip of silver-solder. As soon as it melts and runs in the joint, turn the gas out. Clean up the tank, then drill a 3/16 in. hole in the middle of the bottom, and another on the vertical centre line of one of the sides, 3/16 in. from the top.

Stand and Pump

The stand is a piece of 5/16 in. square brass rod, squared off each end in the four-jaw chuck to a length of 1¼ ins. Set it to run truly, centre one end, and drill a 5/32 in. hole 3/16 in. deep; tap 3/16 in. x 40. File or mill a rebate ½ in. long and 1/16 in. deep at the top, and a recess 5/16 in. long and 1/16 in. deep, starting ¼ in. from bottom. Drill a 5/32 in. hole 3/16 in. from the top—be absolutely certain it goes through square—and tap it 3/16 in. x 40.

Drill a No. 41 hole in the middle of the recess, 13/32 in. from the bottom; open this out with ¼ in. pin-drill, at the back of the stand, to a depth of 5/32 in. (see section of complete lubricator). This hole must also be dead true, so if you haven't a drilling machine, use the lathe, with the drill in the three-jaw, and the work held against a drilling-pad on the tailstock barrel.

The right-hand port is drilled No. 54, right into the blind hole at the bottom of the stand, and mind that the point of the drill doesn't snap off as it breaks through "on the angle." The left-hand hole should only be drilled 1/16 in., and a small groove chipped or filed from it to the bottom of the stand as shown. Face the sliding surfaces of the stand by rubbing it on a piece of fine emerycloth, laid working-side up, on the lathe bed or something equally flat and true.

To make the pump cylinder, part off a ⅝ in. length of 5/16 in. square brass rod, and make a centre-pop on the end, 3/16 in. from one side. Chuck in four-jaw with this pop-mark running truly; open it with a centre-drill, then put a No. 32 drill clean through. Open out to 3/16 in. depth with 3/16 in. or No. 12 drill, tap 7/32 in. by 40, put a ⅛ in. reamer through the remains of the No. 32 hole, and plug the bottom with a turned plug driven in and soldered over (see section). Make a little gland from ¼ in. hexagon brass rod, as shown.

Drill the port with No. 54 drill, 3/32 in. from bottom, running right into the bore. At ¼ in. above the port, drill a No. 48 hole, but don't pierce the bore this time. Tap it 3/32 in. or 7 B.A., and fit a bit of 3/32 in. round silver-steel or 13 gauge spoke wire 13/16 in. long, screwed both ends. Round off the opposite side of the cylinder as shown in plan, then take out the trunnion pin and true up the rubbing face on a piece of emerycloth, same as the stand, replacing trunnion tightly. If you fit the trunnion after facing, you'll have a burr form around the hole, and will have to take it out again and reface, anyway!

The ram is a piece of ⅛ in. round steel (silver or rustless) or phosphor- bronze, 13/16 in. long, with a No. 48 cross-hole drilled near the end. If it doesn't slide freely, put the reamer down the cylinder again. Pack the gland with a few turns of graphited yarn. Poke the trunnion through the hole in the stand, see that both faces (cylinder and stand) are in perfect contact all over, then put a spring, wound up from 22 gauge steel wire (piano wire does fine, or a bit of a mandolin string) on the trunnion, and secure with a nut and washer.

Bearing, Spindle and Crank

For the bearing, chuck a bit of 5/16 in. hexagon brass rod in three-jaw, face, centre, and drill No. 41 for a full 1 in. depth. Turn down ¾ in. length to 3/16 in. diameter, screw 3/16 in. by 40 and part off to leave a 3/32 in. head. Reverse, and chamfer the corners. The locknut is a ⅛ in. slice of the same size rod, drilled No. 21 and tapped 3/16 in., x 40.

The spindle is a piece of 3/32 in. silver steel or 13 gauge spoke wire 1 9/32 in. long, screwed each end as shown. The crank is a slice, a bare ⅛ in. wide, parted off a piece of ⅜ in. rod held in three-jaw. Drill and tap to suit spindle before parting off, then drill a No. 50 hole ⅛ in. from centre, and squeeze in a bit of 15 gauge spoke wire for a crankpin, leaving 3/16 in. projecting.

Check Valve

Chuck a bit of 5/16 in. round brass rod in three-jaw, face, centre, and drill down about ⅝ in. depth with No. 44 drill. Open out and bottom to 5/16 in. depth with 3/16 in. drill and D-bit; tap the end 7/32 in. x 40. Take the sharp edge off the hole. Part off 9/16 in. from the end. Reverse in chuck, turn down 3/16 in. of the other end to 3/16 in. diameter, and screw 3/16 in. x 40. Poke a 3/32 in. parallel reamer through the remnants of the little hole.

Drill a 5/32 in. hole in the side of the ball chamber, and in it fit a 7/32 in. x 40 union nipple as shown. If you haven't a bit of 7/32 in. brass rod, chuck a bit of ¼ in., turn about ⅜ in. of it to 7/32 in. diameter, and put a few threads on, with the die in tailstock holder. Centre deeply with size E centre-drill, drill No. 41 for about ⅜ in. depth, and part off 5/16 in. from the end. Reverse in chuck, turn the end for about 1/16 in. to a tight fit in the hole in side of valve body, squeeze it in and silver-solder it.

Make a little cap from 5/16 in. hexagon brass rod, drilling it up with No. 30 drill as shown in the section, to accommodate the spring, which is wound up from 30 gauge brass or bronze wire. Drop a ⅛ in. rustless steel ball in the recess, and seat it on the hole by holding a short bit of ⅛ in. brass rod on the end and applying brute force with a hammer, finally assembling as shown. The spring should just start to compress when the threads engage.

How to Assemble Lubricator

Stand the pump over the hole in the bottom of the tank, with the trunnion pointing to the side of the tank which has the hole in it. Screw the check valve into the pump stand through the bottom hole, and have it just finger-tight. Poke the bearing through the side hole, put on the locknut, then enter bearing into top of pump stand and screw it in until the head just touches the side of tank; then run locknut back, and tighten against inner side of tank. Tighten check valve, and set it so that the nipple points to your right, when you are looking at the side of tank where the spindle will come through; see view showing ratchet drive.

ANYBODY who has a wheel-cutting attachment for his lathe can cut the 7/16 in. x 35 tooth ratchet wheel if they so desire, making it 3/32 in. thick, and drilling No. 43; those who have not, can get a suitable wheel from Dick Simmonds or other advertisers supplying "Roedean" requisites.

Carefully squeeze it on the spindle so that the buttress sides of the teeth are to your left (see end view showing ratchet gear). Put the pin in the crank disc through the hole in the pump ram, and hold the disc against the end of the bearing. Insert spindle in bearing, and screw the end home in the crank. When quite tight home, the spindle should have about 1/64 in. end play. If too loose or too tight, adjust position of ratchet wheel on spindle.

The pump may now be tested. Put a drop of oil (ordinary motor oil will do for testing) in the tank, and turn ratchet wheel clockwise until a spot of oil shows at the nipple on the check valve. Put your thumb over it, squeeze as hard as you can, and turn the ratchet wheel again. No matter how hard you squeeze, even if you were as strong as Samson, if the pump is O.K. you won't be able to prevent the oil coming out of the nipple.

One of these little pumps, tested in a full-size locomotive works to settle an argument, pumped against 400 lbs. pressure, so it will have an easy job feeding "Roedean's" cylinders. If it fails on the test, the chances are that you haven't got the contact faces true and oil is escaping between them.

Ratchet Gear

The side view of the complete lubricator practically explains the ratchet drive without any words. The lever is filed up from a bit of 1/4 in. x 3/32 in. mild steel, the hole working on the spindle being drilled No. 41. At 5/16 in. below this, drill a No. 48 hole, and tap it 3/32 in. or 7 B.A. Drill three No. 48 holes at bottom. Both the ratchet pawls may be filed up from odd bits of 3/32 in. steel, to the shape given; drill the moving pawl No. 41 for the pivot screw, and 1/16 in. for the tail spring. Drill the stationary pawl No. 41, and file a groove in the head, to receive the click-spring. If cast steel is used for the pawls, they can be hardened right out and will last the lifetime of the engine. If mild steel, case-harden them; heat to bright red, roll in Kasenit, Pearlite or any other good hardening powder, reheat until the yellow flame dies out, and quench in clean cold water. No need to polish them up; just wash off all the residue of the powder. They work just as well black, as bright!

The moving pawl is attached to the ratchet lever by a 3/32 in. or 7 B.A. screw with a bit of "plain" under the head, only the part entering the lever being threaded. You can turn this screw from a bit of 3/16 in. round steel rod held in three-jaw. Screw it home, so that the pawl is quite free to see-saw, but without side movement, then give the projecting bit of screw a tap with a hammer, so that it won't come adrift when the engine is running.

Slip the large end of the lever over the spindle, and fix with a commercial nut and washer. When the nut is tight, the lever should be free to swing. Fit a little spring, wound up from 30 gauge wire over a 1/16 in. rod, to the tail of the pawl and a 1/16 in. hole in lever, as shown.

The stationary pawl is mounted on a stud, which is a bit of 5/32 in. or 3/16 in. round steel, turned down to 3/32 in. each end and screwed as shown. Leave enough "plain" at one end to allow the pawl to move easily when the nut is right home. Put the pawl, nut and washer on, then poke the other end of the stud through a No. 40 hole drilled in the side of the tank, 3/16 in. from the top, and 7/32 in. from the side (see side view). Secure the stud by a nut inside the tank.

The spring is a bit of 20 gauge steel wire bent as shown, the lower end being formed into a complete loop, which is attached to the tank by a 3/32 in. or 7 B.A. screw just below the pivot stud. Make a distance-piece to go between the eye of the spring and the tank; simply a bit of 5/32 in. or 3/16 in. rod 1/8 in. long, with a No. 40 hole in it. Erect the lot as shown in the little detail sketch, putting just sufficient tension on the wire spring, to make certain the ratchet clicks home in the teeth of the wheel, and prevents it from turning backwards when the ratchet lever operates.

How to Erect and Drive Lubricator

The lubricator is attached to the underside of the front buffer beam by an inch of 3/8 in. x 3/16 in. brass angle. This is attached to the lubricator 3/8 in. from the top, by three 3/32 in. or 7 B.A. screws, nutted inside the tank, as shown in the illustration; you can solder it as well, if you like. Drill a No. 40 hole in the middle of the top of the buffer beam, 7/32 in. from the back edge, and another 3/8 in. each side of it; countersink them all, hold the lubricator up in place, run the 40 drill in the holes and make countersinks on the angle, drill them through with No. 48 drill, tap 3/32 in. or 7 B.A., and put countersunk screws in.

A lid can be made for the lubricator by bending down the edges of a piece of 20 gauge brass sheet, 1 5/8 in. square, or flanging it over a little former 1 1/4 in. square, in the same manner as a boiler plate is flanged. The lid should fit tight enough to prevent falling off if the engine is turned upside down, or jumping off when the engine is running fast.

The lubricator is driven from the eccentric on the left side of the crank. Machine up and fit a strap to it, exactly as described for the eccentric strap on the valve gear side. One end of a long piece of 3/32 in. silver-steel or 13 gauge spoke wire is screwed into the boss or lug of the strap, and the other end carries a little fork or clevis, made the same as the valve gear forks, but from 3/16 in. square steel. The exact length of this rod is obtained from the actual engine, with the ratchet lever hanging straight down, and the eccentric either on top or bottom centre.

The rod will need bending a little "to clear obstructions" in a manner of speaking; to prevent any whip when at speed, put a little bridle on it, as shown in the erection sketch. This is merely a bit of 3/32 in. steel wire, bent like a picture ring, the shank being screwed 3/32 in. or 7 B.A. It can be screwed into the back flange of the inside cylinder casting, and the rod pushed through it before screwing on the fork. The latter is attached to the ratchet lever by a 9 B.A. screw, and should swing sufficiently to click one tooth at every revolution of the wheels.

Exhaust Pipes

A free exhaust is an essential for a free-running economical engine, and in "Roedean" I have tried to arrange for the minimum of back pressure. As you will know from machining and fitting the cylinders, the exhaust goes out at each end of the liner into a recess in the casting, steam from the outside cylinders passing through holes in the frame, into recesses in the inside cylinder casting, in each of which there is a vertical 5/16 in. hole. These are bridged by a fitting like an inverted Y, the stem of same forming the blast pipe; see illustration.

The whole bag of tricks could be one casting, if our advertisers like to supply. It could be cast solid, the blastpipe being drilled out first, with 11/32 in. drill, and the side branches drilled into it, using 9/32 in. drill. The flange could be drilled for screws, and faced off with a file, and a blastpipe cap made as described below for the built-up version.

To build up, cut the flanges from 1/8 in. sheet brass, and drill the screwholes, plus a 5/16 in. hole in the middle of each. The blast pipe is a piece of 7/16 in. copper about 20 gauge, and 13/16 in. long. One end of this is screwed with any fine thread for which taps and dies are available; the other end has a plug driven in, merely a disc parted off a bit of brass rod turned to size.

TWO 5/16 in. holes are drilled on opposite sides of the pipe. Two short pieces of 5/16 in. pipe are filed off "on the skew" as shown, to fit the holes in the blastpipe, and rest on the flanges. Note particularly that the blastpipe is not centrally placed between the flanges, as the holes in the cylinders are at varying distances from the centre line. If the branch pipes are made a tight fit in the holes in the blastpipe, the inverted Y thus formed, will stand of its own accord on the two flanges, which should be placed on a bit of asbestos millboard in the brazing pan. The whole of the joints can then be silver-soldered at one heat; apply a little wet flux to the joints, heat the lot to dull red, and touch each joint with a strip of silver-solder, best grade. Pickle, wash off, and clean up.

For the blast nozzle, chuck a piece of 9/16 in. or 5/8 in. brass rod (hexagon or round), face the end, centre, and drill about 3/4 in. depth with No. 20 drill. Open out with 13/32 in. drill to 3/8 in. depth, and tap to suit thread on blastpipe. Part off at 5/8 in. from the end; reverse in chuck, and turn the top to a cone shape, as shown. The complete assembly is then attached to the inside cylinder casting, the flanges being located over the exhaust holes, and the blastpipe being central, 7/16 in. ahead of the transverse centre line of the cylinders; 1/8 in. or 5 B.A. screws can be used, any shaped heads you may have handy. Drill and tap the screwholes, but don't fix the blastpipe "for keeps" yet, as it has to be temporarily removed to screw in the central fitting of the steam pipe.

Steam Pipes

To save a lot of complicated "plumbing" inside the smokebox, I am specifying one single cross pipe with connections for all three cylinders, a feed from the superheater, and an oil union. The illustration shows the whole issue fairly clearly. If our advertisers can supply a little casting for the centre fitting, it will save work; all it needs is a block of metal 1/2 in. square, with a 1/4 in. projection each side for the connections to outside cylinders, one 3/8 in. diameter underneath for the connection to inside cylinder, and one 1/4 in. in front for the oil union nipple, plus a chucking spigot on the back, and a boss on top for the steam pipe.

To machine it, chuck by the boss, turn and screw the 3/8 in. x 32 spigot; centre, and drill right through with 1/4 in. drill. Chuck by one of the side projections, setting the other to run truly. Turn and screw it 1/4 in. x 40, drilling with a 3/16 in. drill into the centre hole. Reverse in chuck, and repeat operation in the other side projection. Next, chuck by the back chucking piece, turn and screw the oil pipe union 1/4 in. x 40, then face the end, centre deeply, and drill 3/32 in. into the central hole. Open out the boss to take a 5/16 in. pipe, cut off the chucking piece, and the fitting is completed.

To build up, chuck a piece of 1/2 in. square brass rod in four-jaw; set to run truly. Face the end, centre, and drill 7/8 in. depth with 1/4 in. drill. Turn down a bare 1/4 in. of the outside to 3/8 in. diameter, and screw 3/8 in. x 32. Part off at 1/2 in. from the shoulder. Drill a 1/4 in. hole right across, and open out the hole in the end opposite the screwed part, to take a 5/16 in. pipe to 1/8 in. depth. Drill a 3/16 in. hole in one of the other sides. Chuck a bit of 1/4 in. by about 20 gauge copper tube in three-jaw; screw it 1/4 in. x 40 for 1/4 in. length, and part off 3/8 in. from the end.

Repeat operation, then push the plain ends into the two side holes in the brass cube.

Make a union nipple from 1/4 in. brass rod, as described for the lubricator check valve, but screwed 1/4 in. x 40; reverse in chuck after parting off, and turn down 1/16 in. of the end to a tight squeeze fit in the hole in the front of the brass cube. Squeeze it in. Bend a 1 3/4 ins. length of 5/16 in. copper tube, to the shape shown in the section, with a 3/8 in. offset, and push this into the enlarged hole in the top of the brass cube.

Chuck a piece of 7/8 in. brass rod in three-jaw; face the end, centre, and drill a 1/4 in. hole 3/8 in. deep. Part off at 7/16 in. from the end. Drill a 5/16 in. hole in the edge to meet the blind hole in the middle; also drill the four No. 40 screwholes shown. Mount this on top of the offset steam pipe, as shown in both assembly and sectional views. All the joints can then be silver-soldered at one heat. Pickle, wash off, and clean up. Temporarily remove the blastpipe assembly, and screw the steam fitting into the boss on top of the middle cylinder steamchest, with a little smear of plumber's jointing ("Boss White" or similar good brand) on the threads.

When right home, the steam pipe should incline towards the rear of the engine, the contact side of the flange with the 1/4 in. hole in pointing backwards (see section). The little union for the oil pipe connection should point ahead, and the small stubs of screwed pipe at each side should be at right angles to the centre line. The blastpipe assembly can then be replaced, with a 1/64 in. Hallite or similar joint between flanges and cylinder casting.

Connection is made between the central fitting and the outside cylinders, by two pieces of 1/4 in. copper pipe with an oval block on the outer end, and a socket and locknut on the inner end, same as plumbers and gasfitters use, and known by them as "connectors." The blocks may be castings, or filed from 9/16 in. square brass bar; the