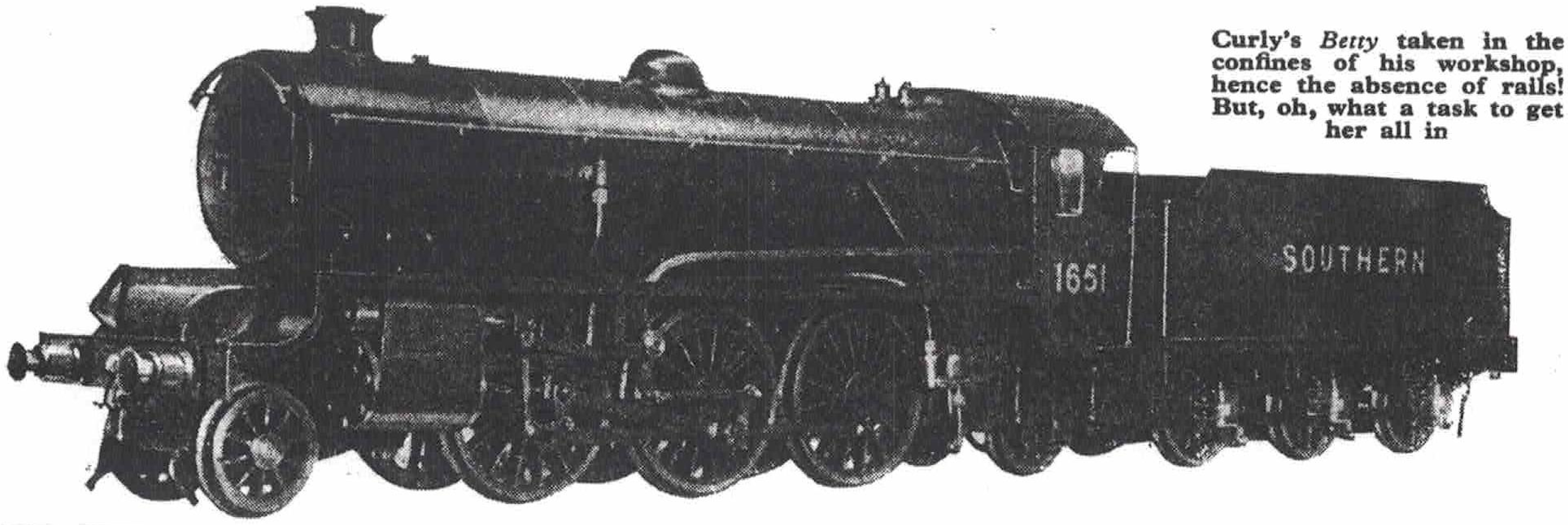
BETTY
THE MONGOLIPER
by L.B.S.C.

A 2-6-2 outside cylinder locomotive in $3\frac{1}{2}$ in gauge to the proposed N2 Southern class of 1934. . . a development of the 'mongoliper' from a series which appeared in Model Maker



Curly's *Betty* taken in the confines of his workshop, hence the absence of rails! But, oh, what a task to get her all in

BETTY THE MONGOLIPER

HAIL once more, good friends all, and please permit me to introduce to you a young lady called *Betty*, who is the small sister of a full-sized engine that never was! That sounds rather paradoxical, so maybe I'd better explain how it comes about.

When the late Mr. Richard Maunsell was appointed Chief Mechanical Engineer of the South Eastern and Chatham Railway in 1913, the whole of the goods traffic was being worked by comparatively small six-wheels-coupled engines with small boilers using saturated steam, or wet steam as the enginemen called it. Most of them had seen years of service, and they were hard put to it to cope with the work. Mr. Maunsell promptly started in to rectify this trouble by designing a much more powerful engine of the 2-6-0 type, with a boiler which could deliver plenty of superheated steam at 200 lb. per sq. in. to cylinders 19 in. dia. by 28 in. stroke, driving six-coupled wheels 5 ft. 6 in. dia. Before any them could be built, a certain party popularly—or rather unpopularly!—known as Kaiser Bill, got an exaggerated idea of his own importance and started pulling the funny stuff, as they say over the big pond. Consequently Ashford Works, instead of building the new engines, had to concentrate on supplying some of the wherewithal needed to put the said K.B. out of business.

After a time things eased up a bit, and so it came to pass that in 1917 the first of the new engines was built, and she was a great success. Unlike anything that had ever appeared on the S.E. and C.R. before, she had outside cylinders and Walschaerts valve gear, long-travel valves, and a Great Western type of taper boiler with a Belpaire firebox. After exhaustive tests—Mr. Maunsell believed in thoroughly trying out a new design before standardising it—which the new engine passed with flying colours, a series of them were built. Officially they were known at the N class, but the enginemen, who were delighted with them, promptly nicknamed them "mongolipers".

All the passenger traffic had up to then been worked by engines of the 4-4-0 type, and when more power was needed, some 2-6-4 tank engines were built with 6 ft. wheels, and the same "works" as the N class. These also did the job very well. Then came the grouping of 1923, when the S.E. and C.R. was absorbed into the Southern Railway. The two-cylinder *King Arthur* class, and the four-cylinder *Lord Nelsons*, appeared in 1925 and 1926 for the express passenger work, but there were some sections of the line where these big engines could not go, and therefore in 1928 some "mongolipers" were built with 6 ft. wheels to fill the need. In 1931 another lot came out with three cylinders, and they were just about the cat's whiskers.

However, as fast as Mr. Maunsell and his able assistant Mr. Harold Holcroft provided the motive power, so the Traffic Dept. piled on the loads, and still greater power was called for; so in 1934 they designed a 4-6-2 "Pacific" and a 2-6-2 "Prairie". Alas, these mighty engines were never built, for the Civil Engineers' Dept. vetoed them on the grounds that the existing bridges were not strong enough to carry the axle loads. By the time the bridges and permanent way had been strengthened, British Railways had taken over, and entirely new standard locomotives had been designed.

It has always been a great delight to me, to build a locomotive which has been designed but never built in full size. I saw the drawings of the two engines just mentioned, and was particularly impressed by the 2-6-2, as she would take the curves on my own little railway if built to $3\frac{1}{2}$ in. gauge. I decided to bring her to life, and did so, but I fitted coupled wheels the equivalent of 5 ft. 6 in. (the original "Mongoliper" size) as I had castings for them in stock. *Betty* is therefore an enlarged "mongoliper", and now you know all about her.

Specification of Betty

There are many refinements in a full-sized engine which aren't needed in a small one, so I have made *Betty* a simple job which can be tackled by anybody with average skill and the usual workshop equipment. The frames are nearly all straight lines, and could be cut out in a single evening, as 3 in. x $\frac{1}{8}$ in. mild steel plate is commercially obtainable. The trailing cradle which carries the wide firebox of the round-topped boiler, can also be cut from $\frac{1}{8}$ in. steel and bent to shape in the bench vice, or it could be a casting. I should not be at all surprised to find that our good friend Mr. Reeves might supply the whole cradle, complete with drag beam, dummy leaf springs, horncheeks, and fixing lugs, cast as a single unit. If so, the amount of work saved would be well worth whatever price he might charge for it, as it would only need to be attached to the main frames, and have the axleboxes and wheels fitted.

The width of the cradle is such that it not only allows for an ample grate and ashpan, but the trailing wheels can be given sufficient side play to allow the engine to run around a 15 ft. radius curve without excessive friction, despite her overall length. For that reason also, I have spaced the coupled wheels as closely as possible, and set the leading pony wheels far enough ahead of the cylinders to allow for them swinging well over without fouling the cylinder covers. The curves on a little railway are usually much sharper than on a full-size line.

The cylinders are 1.3/16 in bore by 1.5/8 in. stroke, and have flat slide-valves. I had castings for these in stock, so used them. I fitted the Laird-type cross-head and guide-bars, as I prefer this pattern to the single bar. The valve gear is Walschaerts, all parts being made robust enough to stand plenty of hard work without undue wear. The radius rods are lifted and lowered by links at the back of the radius rods, and as the lifting arms on the weighbar shaft point to the rear of the engine (this is the usual Ashford practice) the die blocks will be at the top of the expansion links when the engine is running chimney first.

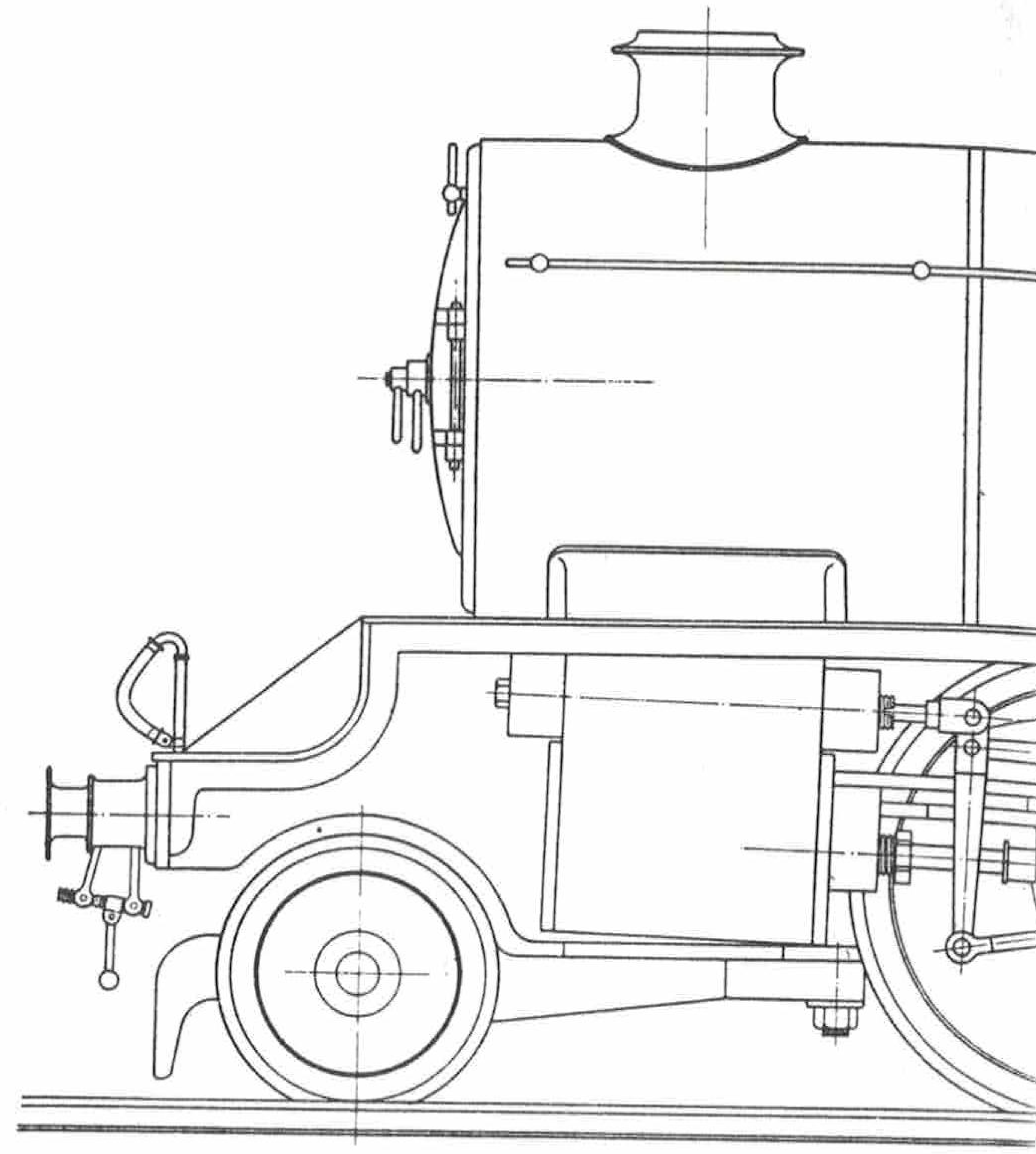
Although the boiler is two or three sizes bigger than *Mona's* it will be found just as easy to build, in fact it will be easier to put the firebox stays in, as you can get your hand right into the firebox to put the stay nuts on. The ashpan is a fixture, as the trailing axle prevents it from being dumped, but the middle part of the grate is arranged to drop into it by moving a lever, and the ashes and clinker can be easily removed with a long-handled rake, just as we used to rake the ashpans out in full size. The firebox has a combustion chamber, stayed by six water-tube struts which add to the heating surface in the best possible place, and keep the water circulating merrily. This also keeps the tube length within the limits of efficiency. The superheater is of the multiple-element pattern as in full size.

The accessories are much the same as on *Mona*. The boiler is fed by an eccentric-driven pump with bypass, and an injector; there is also the usual emergency hand pump in the tender, which is of the ordinary six-wheeler type. The side frames of this may also be made from steel plate, with dummy cast leaf springs having working spiral springs in the hoops; but here again, friend Reeves may be able to supply castings for frames complete with springs and horncheeks cast integral. These save a considerable amount of work. Well, so much for generalities; now to construction.

Main Frames

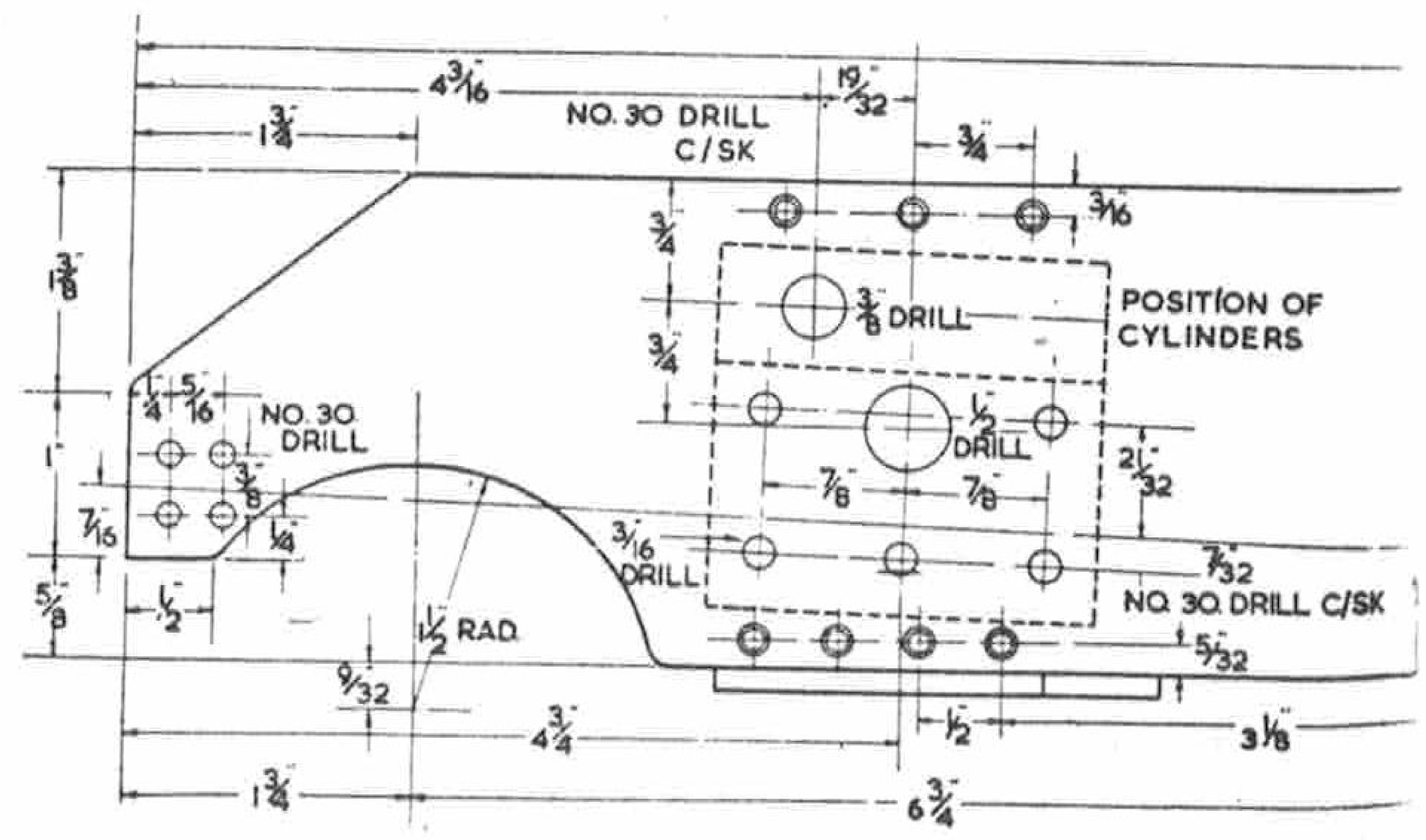
Two pieces of ⅛ in. mild steel plate will be needed for the frames, 21 in. long and 3 in. wide; this will allow for squaring off the ends to exact length. The steel should be soft; if hard, it will not only be difficult to cut the openings for the hornblocks, but when the pieces are removed, the chances are a million dollars to a pinch of snuff that they will distort, and nothing but heat treatment in a rolling-mill will teach them good manners. I used soft blue steel for my own frames, and they panned out O.K.

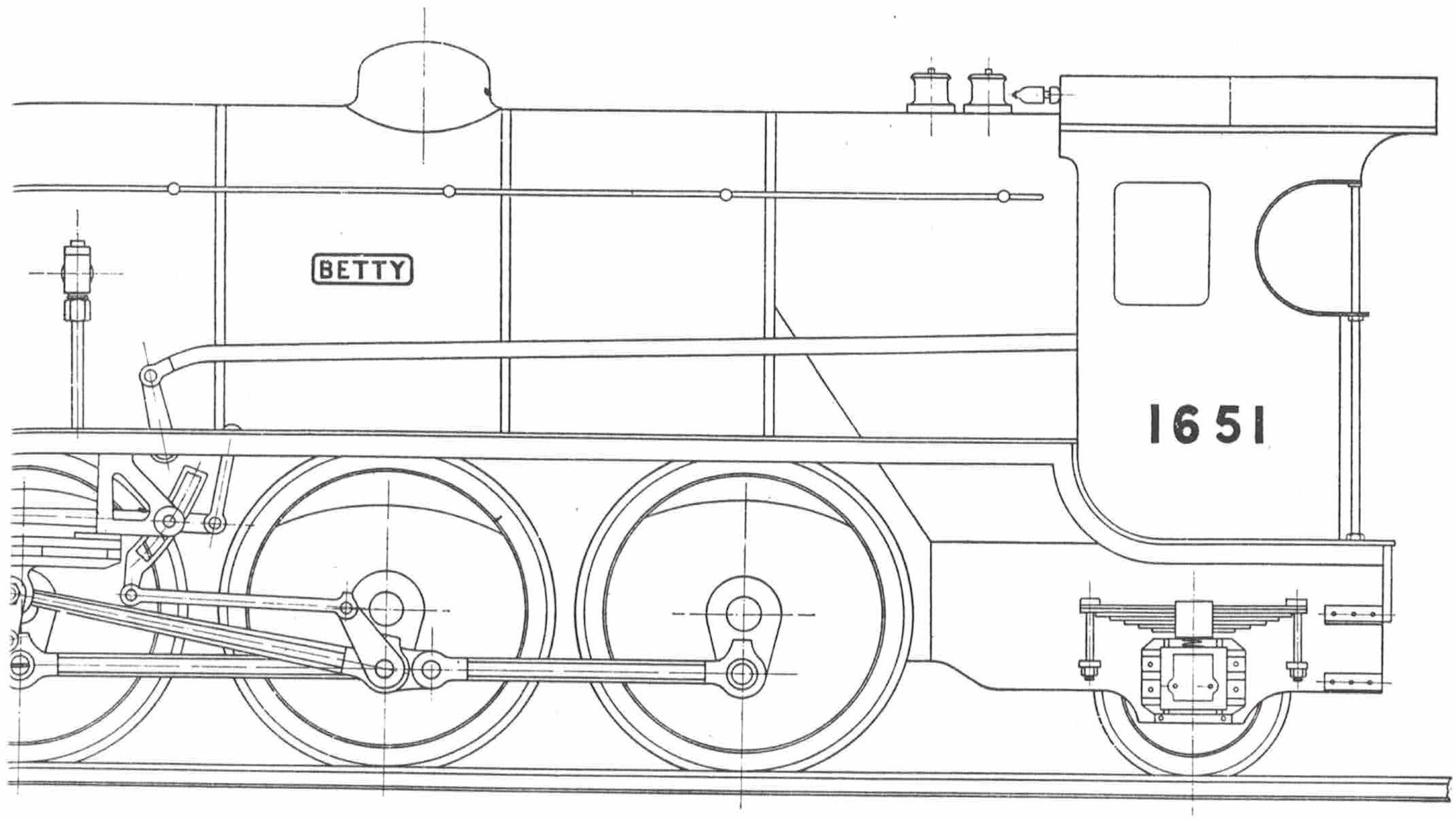
Mark out one frame as shown in the drawing, drill a couple of the screwholes, one at each end, put the plates together, run the drill through the second plate, rivet them together temporarily, then get busy with drill, saw and file until the plates are to the shape and dimensions shown. Now note carefully;



when marking out, set off a point 7/16 in. above the bottom of the extreme front end, at the place where the buffer beam will be attached. In the middle of the marked-out space for the opening for the driving hornblock (the centre one) make a centrepop ⅝ in. from the bottom. Scribe a line between these two points, and make it deep enough to stay put, so that it won't be accidentally rubbed out. This line is shown in the drawing, marked "C/L cylinder bores", and the location of the cylinders, and the holes for the fixing studs, are set off from it.

The centre of the cylinder casting is located on this line at 4¼ in. from front end of frame. The three lower studholes are drilled 7/32 in. below it, and the two upper ones 21/32 in. above it, at 7/8 in. centres. The two larger holes are for the steam and exhaust pipes, and are located from the front end of the frame as shown. The four countersunk holes at the bottom are for the screws securing the pony bolster, and the three at the top are for fixing the smokebox saddle. The three countersunk holes just ahead of the trailing hornblock opening, are for the screws holding the pump stay. At 3 in. ahead of





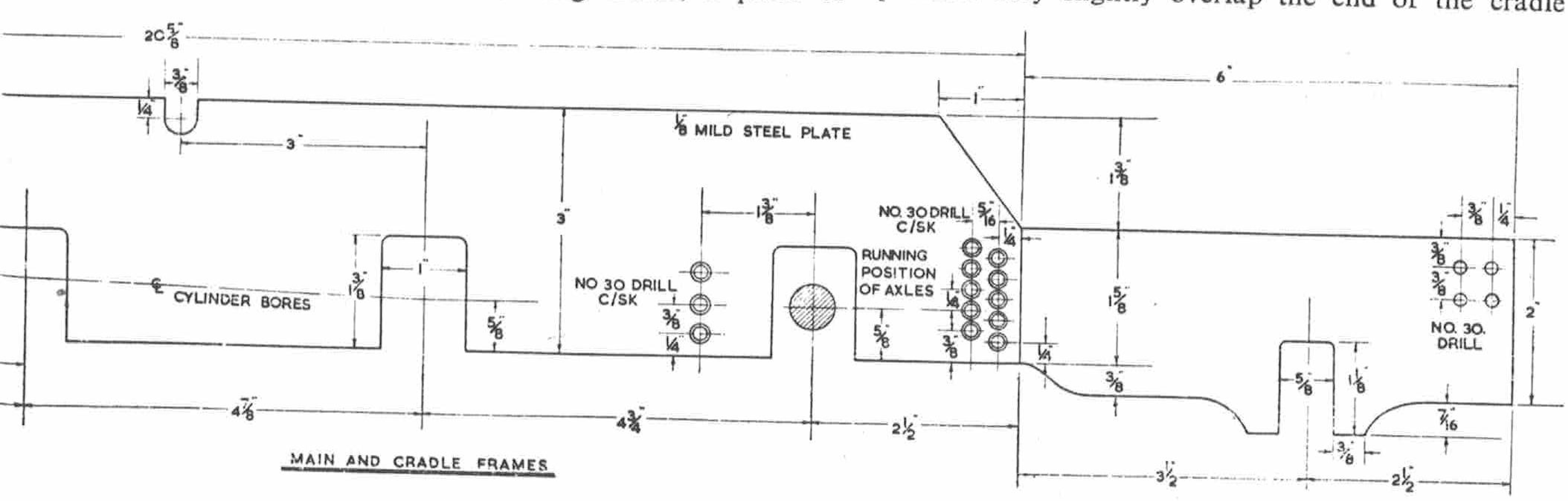
the centreline of the driving hornblock opening, and ¼ in. from the top of the frame plates, drill a ⅜ in. hole, and cut away the top half of it to form the U-shaped opening shown. The bearing for the reversing shaft, or weighbar shaft as it is usually called, is fitted in this when the valve gear is erected.

Take care to get the hornblock openings square with the edge of the frames, and use a piece of 1 in. bar, not less than ¼ in. thick, as a gauge to get them all the same width. The easiest way to cut them, if a milling machine is not available, is to saw down each side just inside the marked line, using a fairly fine-toothed sawblade, then drill No. 40 holes as close together as possible, just below the top line. The pieces can then be broken out with a pair of pliers, and the sides and top filed smooth, until the gauge will just slide in. When all the measurements shown check up O.K. on the plates, part them and file off any burring. There is no need to mark them right and left-hand, as the countersinks show which is right side out.

Trailing Cradle

To make a bent steel trailing cradle, a piece of steel of the same quality as the frames, 17 in. long and 2½ in. wide, will be needed. Square off both ends carefully, checking with a try-square, and mark off the right-hand end exactly as shown. Mark off the other end the other way round, just as you would see it if you held the drawing up to a mirror. Carefully saw and file the plate to outline, then at 6 in. from each end, bend the plate at right angles, leaving the corners rounded, as shown in the plan.

The two openings for the axleboxes should be exactly opposite. Check with a piece of 5/8 in square bar. When this lies at right angles to both sides of the cradle, and the end is parallel with the bar and square with the sides, the cradle is O.K. Measure up and find the centre of the 1.5/8 in. end section, and scribe a line across it, using a try-square to guide the scriber, then at exactly 1.7/16 in. from each side of the centre-line, scribe two more lines in similar fashion. Cut two pieces of ¾ in. x ⅛ in. angle, and in one side of each drill five No. 30 holes at equal spacing, for the rivets. These pieces should be a little over 1⅝ in. long, so that when placed in position they slightly overlap the end of the cradle



at top and bottom. Clamp each one to the cradle, exactly level with the outer scribed lines, and with the drilled side next to the cradle, then put the No. 30 drill through all the holes and drill through the cradle as well. Countersink the holes on the inner side of the cradle, and rivet the angles to the cradle end with $\frac{1}{8}$ in. charcoal-iron rivets. These hold far better than copper rivets for frame work, where they have to stand wrenching stresses, under which copper rivets would work loose. Hammer the shanks well down into the countersinks, file them off flush with the plate, and finally trim off both ends of the angles so that they are level with top and bottom of the cradle end.

If a casting is used for the cradle, all it will need will be the axlebox openings cleaning up with a file until a piece of $\frac{5}{8}$ in. bar fits them easily without shake, the lugs for attachment of main frames cleaning up likewise, so that they are 2.7/8 in. overall width, and the drawbar slot cut in the drag beam.

Buffer and Drag Beams

The buffer and drag beams may either be made from 1 in. x $\frac{1}{8}$ in. angle (brass or steel) or cast. If cast, the lugs for frame attachment will be cast on; the beams will merely need cleaning up with a file, and the holes drilled for buffer shanks and drawbar. If made from angle, two pieces will be needed, each 7 in. long. Mark them off very carefully as shown. If a milling machine is available, the slots in the front beam for the frames, can be formed by clamping the beam in a machine-vice on the table, and traversing it under a $\frac{1}{8}$ in. saw-type cutter on the arbor. Similar slots should be milled in the drag beam at $2\frac{1}{2}$ in. each side of centre. Cut back the ends of the buffer beam for $\frac{1}{2}$ in. as shown, but cut back the ends of the drag beam right to the slots.

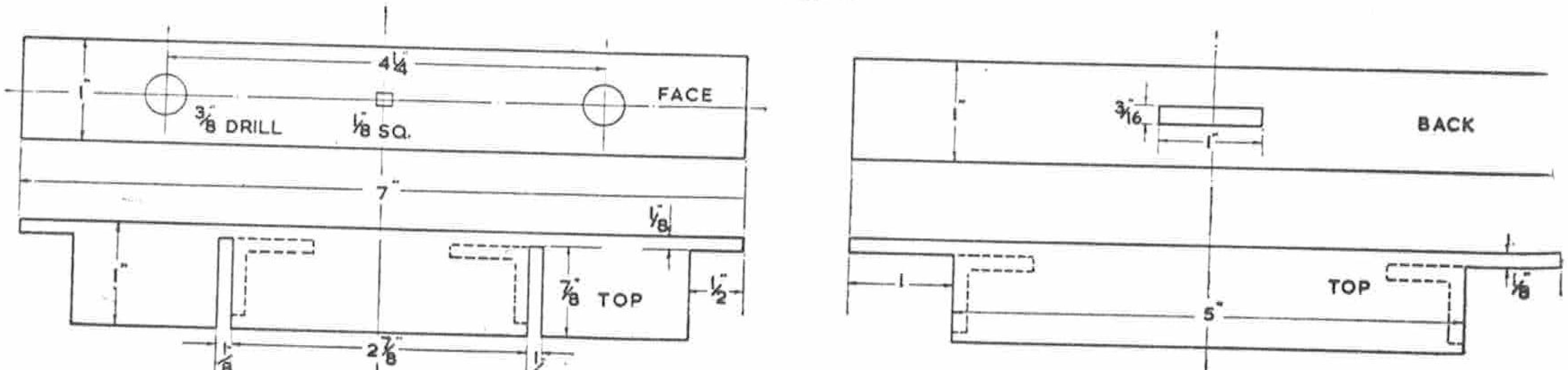
If you havn't a milling machine, the slots can be cut in the lathe, by aid of a $\frac{1}{8}$ in. cutter mounted on a spindle and run between centres. The beams should be mounted on the saddle, in line with the lathe centres, the part to be milled being vertical. Pack up so that the bottom of the slot to be cut will be level with the bottom of the cutter, and secure the beam with a clamp bolt at each end. Run the lathe slowly, with the back gear in, and feed the work against the cutter; that is, if the lathe is running the usual way, start with the beam on the far side of the cutter, and feed the cross-slide towards you. Apply plenty of cutting-oil with a brush. In the days before I had a milling machine I used to do all my milling jobs in the lathe, by aid of a little jerry-wangling.

The slots can also be cut by careful hand work if the bench vice is used as a guide. Grip a beam vertically in the vice at the end of the jaws, with the marked lines of the slot just showing, and saw along the line, keeping the saw-blade flat on the vice jaw. Ditto repeato with the other side of the slot, break out the thin sliver left between the saw-cuts, then finish with a thin flat file such as key-cutters use for forming wards, so that the frame plates will fit tightly.

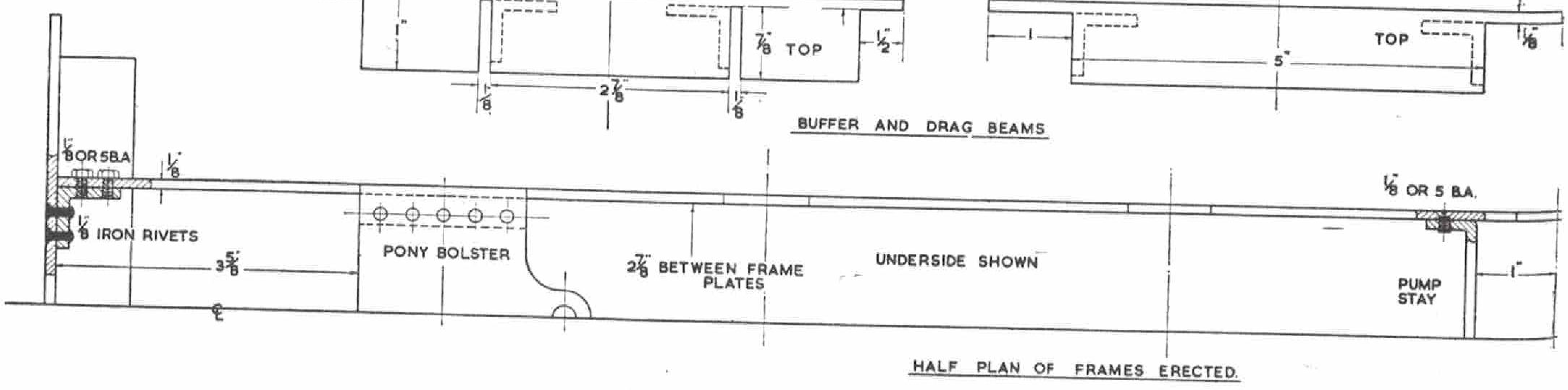
Pieces of $\frac{3}{4}$ in. x $\frac{1}{8}$ in. angle are riveted on the inner sides of the slots, as shown in the half-plan view, for securing the frames to the beams. Cut these to a full 7/8 in. length, and drill four No. 30 holes in one side of each, then clamp them in position and rivet them to the beams, in the same way as those on the cradle. To get them in the right position, I always jam an odd bit of frame steel in the slot, and hold the angle tightly against it while putting on the cramp. After riveting, file the countersunk ends flush with the beam.

To erect the frames, jam the front ends tightly in the slots in the beam, then stand them on the lathe bed, see that each end of the beam is exactly the same height from the bed, and put a clamp over the frame and angle. Run a No. 30 drill through the holes in the frames, making countersinks on the angles, follow up with No. 40, drilling right through the angles, tap $\frac{1}{8}$ in. or 5 BA and put screws in. I have shown hexagon heads, but cheese or round can be used if desired. The cradle is attached at the other end as shown, after the drag beam has been fitted to it. As the drag beam is not slotted, the sides of the cradle are just butted against the pieces of angle riveted flush with the ends as shown in the half-plan. Attach the sides of the cradle to the angles in the same way as the frames are attached to the angles on the buffer beam.

When attaching the cradle to the main frames, spare no pains to have the whole assembly dead true and square, so that the frame and cradle are parallel, the beams square with them, and exactly in line. Test on the lathe bed and make any adjustment necessary, before putting in the screws attaching the cradle to the main frames. Countersunk screws are used for that job, as they come behind the trailing coupled wheel. If the frames are out of truth, the whole engine will be affected, so be sure to start right.



BUFFER AND DRAG BEAMS



HALF PLAN OF FRAMES ERECTED.

Pony Bolster

A LIVE pony wouldn't have much use for a bolster, but *Betty's* pony couldn't do its job without one, and this may be either a casting, or built up from steel plate and brass angle. If cast, the flanges for attaching it to the frames will be cast integral, and will need machining to fit between the frame plates. Anyone who has a milling machine can do this by gripping the casting in the machine-vice on the miller table, with the flange to be machined at the top; be sure to set it level, and then the rebate can be cleaned out with a $\frac{1}{2}$ in. end-and-face cutter on the arbor. One cut did the trick on my own job. To get the other side parallel, I just laid a short piece of $\frac{3}{8}$ in. square bar in the machine-vice between the jaws, rested the machined flange on it, tightened up the vice (a piece of packing is needed between the vice jaw and the bolster) and took the other cut right away. Trust that lazy Curly to find the easiest way! All I then had to do was to smooth off the bottom surface, which was done in two wags of a dog's tail on the emery-belt of my linisher, and drill the hole for the king pin.

The job can be done just as readily in the lathe, if a vertical slide is available. All lathes should have one as part of their standard equipment. Bolt the casting to the slide with the flanges vertical—set one with a try-square—and put an endmill not less than 7/16 in. dia. in the chuck. Move the cross-slide away from you until the flange to be milled is on the far side of the endmill, feed into cut by moving the saddle toward the headstock, and the rebate can be taken out in one cut by moving the vertical slide downwards. Then bring the cross-slide toward you, until the other flange is on the near side of the endmill, and take out the rebate by moving the vertical slide upward. Both flanges will then be parallel.

There is also the method that I described for *Mona's* axleboxes, clamping the work under the slide-rest tool-holder and traversing it across an endmill in the chuck, but as the bolster would have to be turned end-for-end to do the second flange, great care would be needed to reset the casting so that the flanges would be parallel. A planer or shaper could be used, the casting being held horizontally in the machine-vice on the table; a square-ended tool in the clapper-box would then do the needful on both flanges without taking the casting out of the vice, so that they would automatically be parallel. The last resort is the humble file, as long as it is pushed by somebody with patience and perseverance. In my "'ard-up-'n-'appy" days a file was one of my best friends!

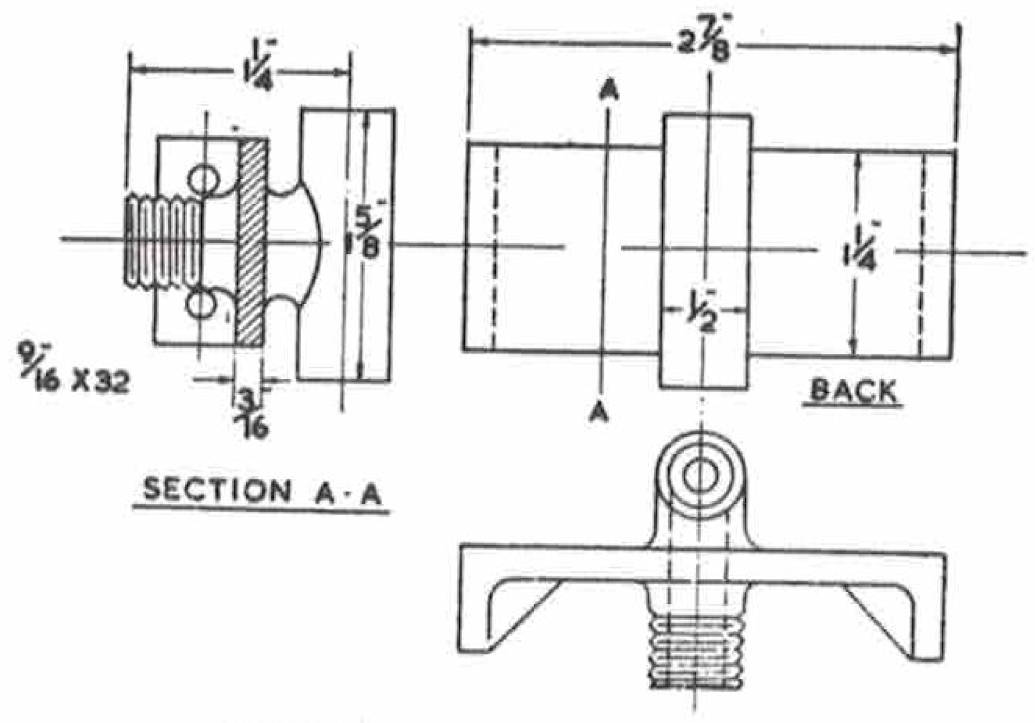
To build up the bolster, saw and file a piece of $\frac{1}{8}$ in. steel plate (a piece of frame steel does fine) to the shape and size shown in the plan view. Drill the $\frac{1}{4}$ in. hole for the king-pin, then rivet a 2 in. length of $\frac{3}{8}$ in. x $\frac{1}{8}$ in. brass angle along each side, at $\frac{1}{8}$ in. from the edge, so that they will fit between the frames. To erect the bolster, set it between the frames at $3\frac{5}{8}$ in. from the buffer-beam, and put a cramp on it to keep the edges tight against the frame. Run a No. 30 drill through the countersunk holes in the frame, making countersinks on the flanges or angles, follow through with No. 40, tap $\frac{1}{8}$ in. or 5 BA, and fix with countersunk-head screws. No need to put the lot in yet; just a couple to hold it until the pony truck is fitted.

Pump Stay

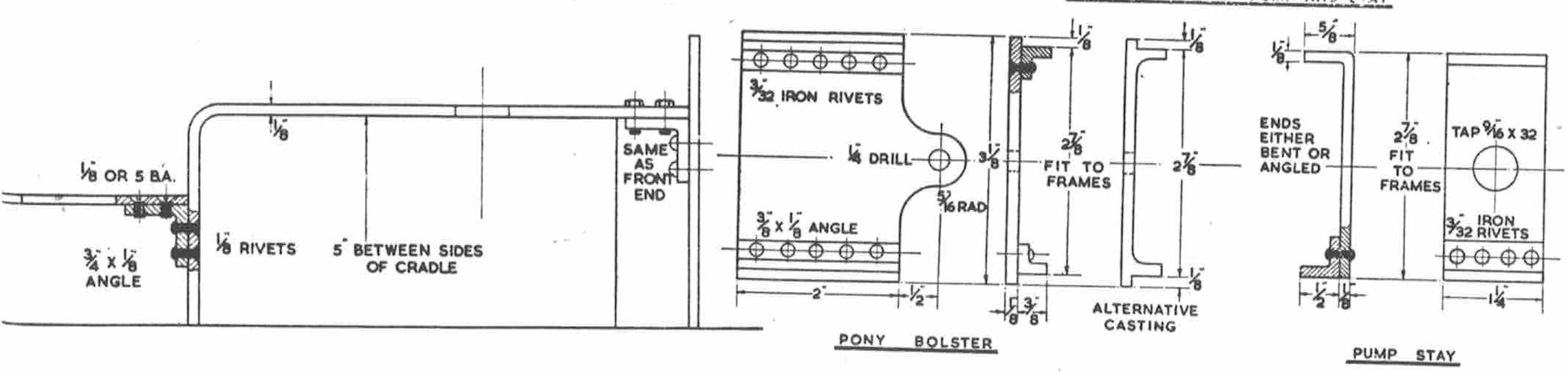
The stay which both supports the frame and carries the boiler feed-pump can be made from steel plate, or cast, in which case the pump body may be cast in one piece with it. The plate stay can be made with a piece of $\frac{1}{8}$ in. steel $4\frac{1}{8}$ in. long and $1\frac{1}{4}$ in. wide, with $\frac{5}{8}$ in. of each end bent to a right angle in the bench vice, so that it fits nicely between the frames; but the steel plate must be soft and ductile, otherwise it will crack at the bends. Alternatively, use a piece of plate $2\frac{7}{8}$ in. long and $1\frac{1}{4}$ in. wide, and rivet a piece of $\frac{1}{2}$ in. x $\frac{1}{8}$ in. brass angle flush with each shorter edge. Drill and tap a 9/16 in. x 32 hole in the middle to accommodate the pump barrel.

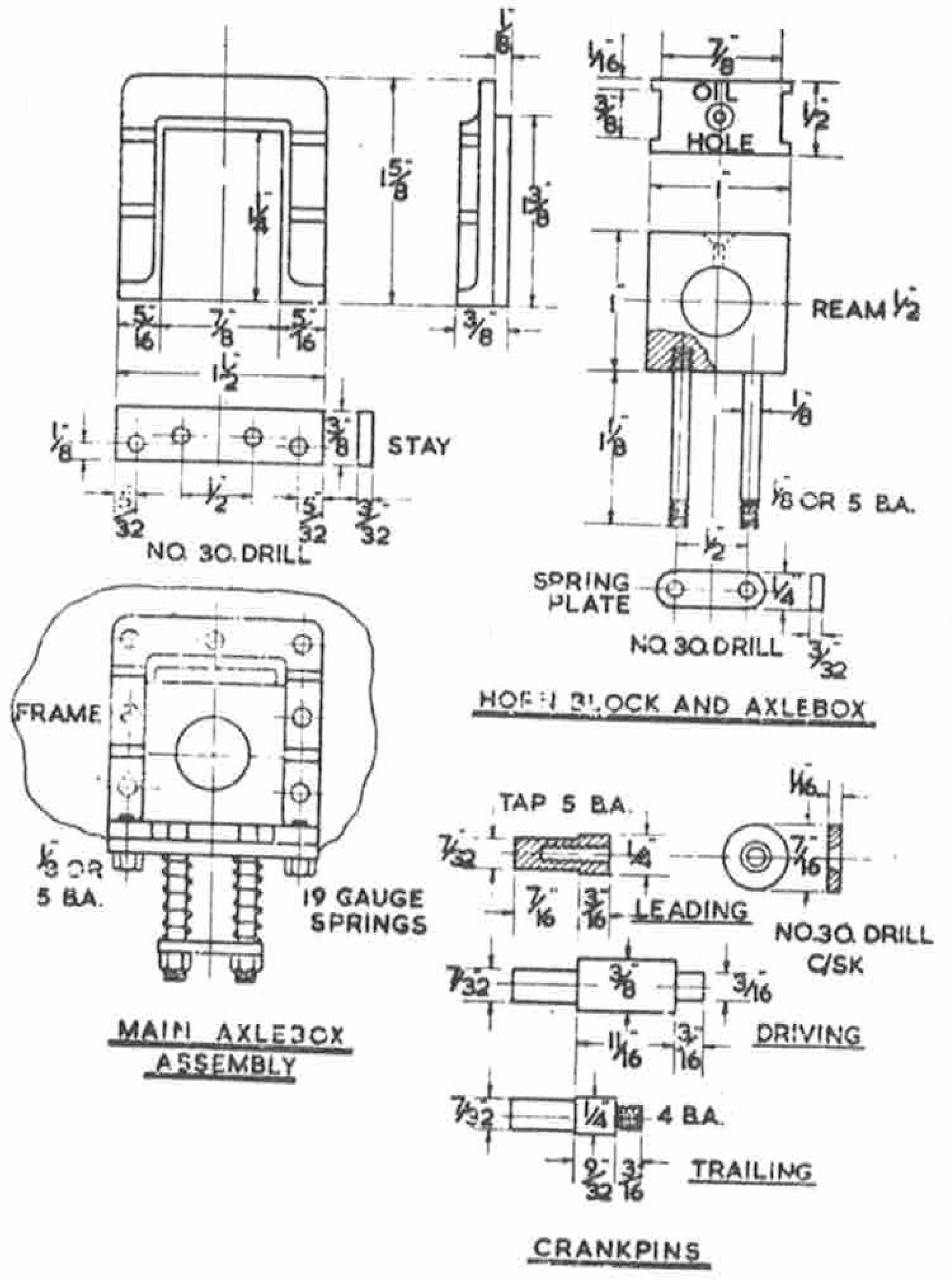
The stay is erected in the frames with the flanges forward, and the back set 1 in. from the middle of the trailing hornblock opening. Take care to set it exactly square with both frames, and keep it vertical. It is fixed by $\frac{1}{8}$ in. or 5 BA countersunk screws as shown in the plan drawing in our last issue. Don't fix it permanently yet, as it must be taken out to fit the pump.

Friend Reeves may be able to supply a casting for a combined pump and stay, as shown in the alternative drawing. My pet design for a combined pump and stay has the frame attachment formed



ALTERNATIVE CAST PUMP AND STAY





by wings at each side of the valve-box, but it can't be used in the present instance, as the valve-box comes within $\frac{1}{8}$ in. of the trailing coupled axle, and the axleboxes prevent it being erected. The one shown has the same dimensions as a separate pump and stay, and can be erected in the same way. The sides are machined off to fit between the frames as previously described, and the pump part can be treated exactly as I shall describe for the separate pump, when we get that far.

Hornblocks and Axleboxes

On my own engine I used Reeves's hot-pressed hornblocks, which need no machining. One side has a flange which fits in the opening in the frames; should this be a shade too large, simply ease it with a file. Don't file out the opening in the frame. Each hornblock is riveted into its opening with seven 3/32 in. iron rivets.

Cast hornblocks can be used, either iron or gunmetal, and the flanges filed to fit the frame openings if the amount of metal to be removed is small. The edges of the flanges can also be end-milled to fit the openings by bolting them to a vertical slide. For this purpose I use a dummy axlebox with a flange on one side only, and a $\frac{3}{8}$ in. hole in the middle. Put this in the hornblock casting with the flange on the side to be machined, and bolt it vertically to the slide. With a $\frac{3}{8}$ in. endmill, or home-made slot drill in the chuck, the whole of the contact side of the hornblock casting can be machined, feeding it into cut by moving the saddle towards the headstock, and traversing it over the cutter by manipulating the handles of the cross and vertical slides. This may seem complicated to read, but as soon as the hornblock casting is mounted on the slide, you'll see, in a couple of ticks, how to wangle the slides and do the job.

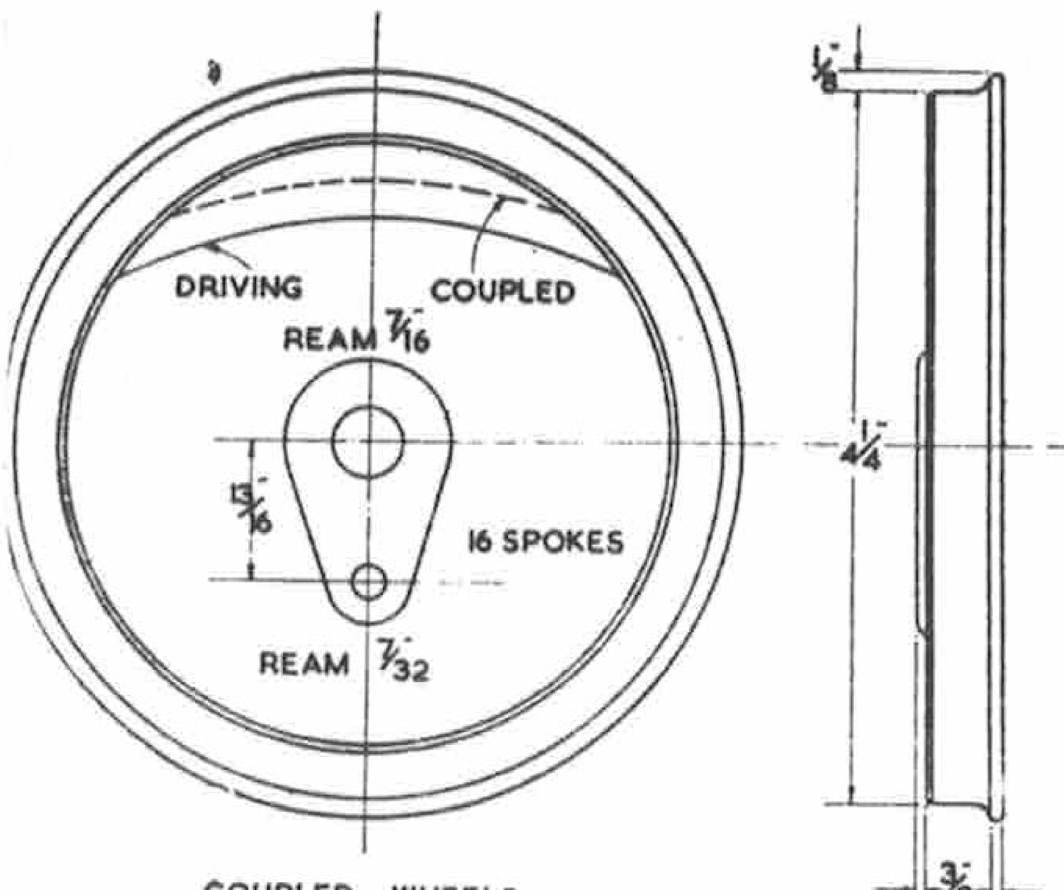
If the frames are attached to the beams by screws, they can be taken apart for the purpose of riveting on the hornblocks, and when this job is done, the openings in the hornblocks can be lined up exactly by bolting the frames temporarily back to back—"inside out," as the kiddies would say. Grip them in the bench vice, and with a fine file, smooth out the inside of each pair of hornblock jaws until a piece of $\frac{7}{8}$-in. square bar slides easily between them without shake. This should be done whether the hornblocks are cast or hot-pressed. If the frames have been brazed to the beams, cut an opening the size of those in the frames, in a piece of iron or steel plate $\frac{1}{4}$ in. thick. Put a hornblock in each side of this, and grip the lot in the bench vice. Smooth out the jaws as above, using the piece of bar as a gauge, then rivet the hornblocks opposite each other in the frames, and they will be found to line up O.K. File the feet flush with bottom of frame.

The axleboxes can be cast, or cut from a piece of good bronze or gunmetal bar of 1 in. x $\frac{1}{2}$ in. section. Don't use the material called brass, but known in the metal trade as "screw-rod", or the boxes will soon wear badly. Cast-iron can be used, or steel bar of the section mentioned, but steel boxes will need bushing with bronze. Real hard brass, which is very different from the "screw-rod" variety, can also be used, but it doesn't resist wear like bronze. It can be bushed with white-metal as in full-size.

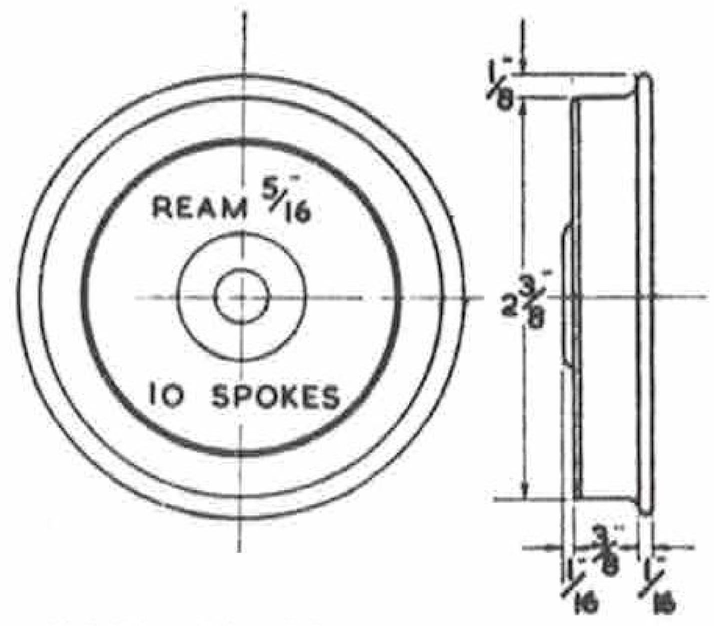
My milling-machine has a long-traverse table, so all I had to do was to saw off a $6\frac{1}{2}$ in. length of bar, grip it in the machine-vice on the table, set it level with a scribing-block, and cut a groove in it 1/16 in. deep with a $\frac{7}{8}$ in side-and-face cutter on the arbor. It was then turned with the grooved side down, and the other side served with a dose of the same medicine. As the handle which operates the vertical screw is furnished with a graduated collar, I didn't have to bother about measuring the depth of groove. I just pulled the belt by hand until the cutter scraped the surface of the piece of bar, traversed the table until the bar was just clear of the cutter, moved the handle of the vertical screw 62 divisions past the zero mark, started the machine, dropped the self-act clutch in, and the machine did the rest. I told you that Curly was a lazy person, didn't I?

The piece of bar was removed from the miller, chucked in the four-jaw, and six 1 in. lengths parted off it. They were a lovely fit in the hornblock jaws, so only needed spring pins and axle holes, and there were my axleboxes, all-present-and-correct-sergeant. Lucky owners of a milling machine can follow-my-leader just as easily! The lathe can also be used, if the piece of bar is gripped in a machine-vice, regular or improvised, bolted to the lathe saddle, and traversed under a $\frac{7}{8}$ in. cutter on an arbor between centres. It must be set so that the cutter takes out the 1/16 in. at one traverse, as there is no screw adjustment for height on the usual lathe saddle. One of the virtues of the once-popular 4 in. Drummond round-bed lathe was the provision of height adjustment on the saddle. If the design were revived by some enterprising tool manufacturer, a back-gear and two or three modern refinements added, it would be a jolly useful versatile machine.

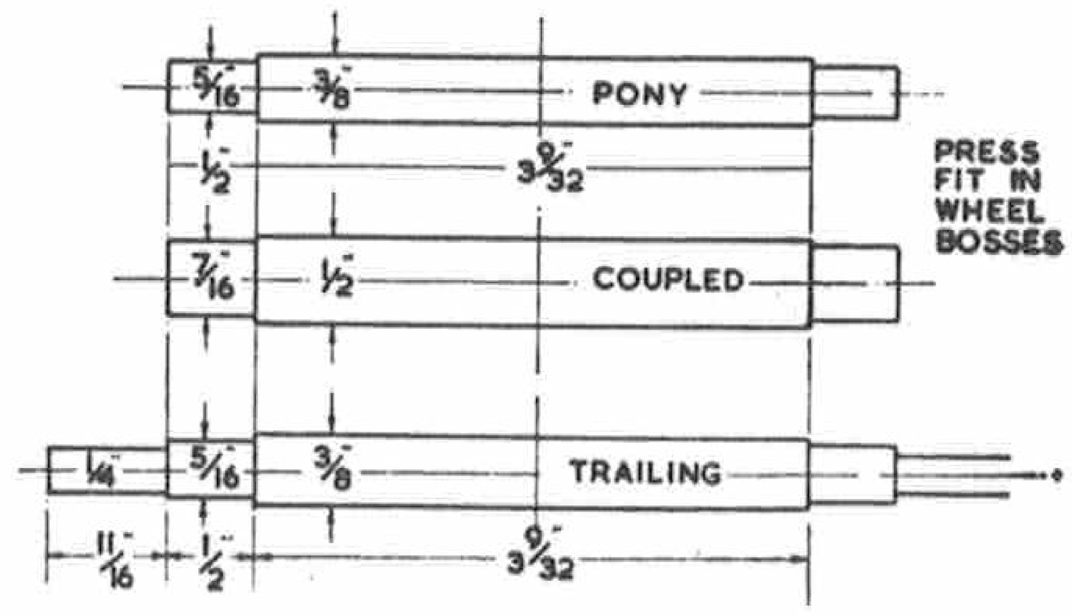
The grooves can also be milled by clamping the piece of bar at right angles to the lathe bed, under the slide-rest tool-holder, and packing it up to centre-height. Put a $\frac{7}{8}$ in. endmill or slot drill in the chuck, and traverse the piece of bar across it with the cross-slide, cutting out the groove to 1/16 in. depth at the one go. If the cross-slide has less than $6\frac{1}{2}$ in. movement, cut the bar in two, and do each half separately. If the lathe is not big enough to allow the boxes to be parted off the bar, saw them off a little over length, then chuck each in the four-jaw, and face to correct length.



COUPLED WHEELS



PONY AND TRAILING WHEELS



AXLES

Fit each axlebox to one of the hornblocks, and mark them 1, 2, 3 on one side, and 4, 5, 6 on the other. Centrepop 1, 2, and 3 exactly in the middle, and drill a ⅛ in. pilot hole through, then follow with 31/64 in. drill. Do this job in the lathe if you haven't a drilling-machine big enough, putting the drill in the chuck and holding the axlebox against a drilling-pad in the tailstock barrel, with a piece of hardwood between. Alternatively, chuck the axlebox truly in the four-jaw, and drill from the tailstock. **The hole *must* go through truly. Next clamp No. 1 to No. 4 (its opposite mate) exactly in line, and drill** No. 4, using the hole in No. 1 to guide the drill, so that the two holes are exactly in line. Repeat operation with Nos. 2 and 5, and 3 and 6: then put the lot back in the hornblocks (don't get them mixed up!) and poke a ½ in. parallel reamer through each pair, moving the boxes up and down slightly while turning the reamer. This will ensure that the axles don't bind when running on an uneven line, or through points and crossing frogs.

The rest of the job is easy. For the hornstays, cut six 1½ in. lengths of ⅜ in. x 3/32 in. mild steel strip, mark off and drill one as shown, and use it as a jig to drill the others. Attach one to each hornblock with two ⅛ in. or 5 BA screws. Temporarily clamp in place, put a No. 30 drill through the end holes and make countersinks on the hornblock feet, follow through with No. 40 and tap to suit screws. Jam each axlebox against the stay with a wooden wedge, put the drill through the middle holes and make countersinks on the axlebox, drill them No. 40 for ¼ in. depth, tap ⅛ in. or 5 BA and screw in pieces of ⅛ in. silver-steel a bare 1⅜ in. long, with a few threads on each end as shown. The springs are wound up from 19-gauge tinned steel wire, and secured by spring plates made from ¼ in. x 3/32 in. steel strip in the same way as the hornstays. They are held in place by ordinary commercial steel nuts, as shown in the assembly.

To keep the axleboxes in running position while the running-gear, etc., is being erected, put a piece of ⅛ in. square rod between the axlebox and hornstay, and tighten the springs sufficiently to prevent it from falling out.

Wheels and Axles

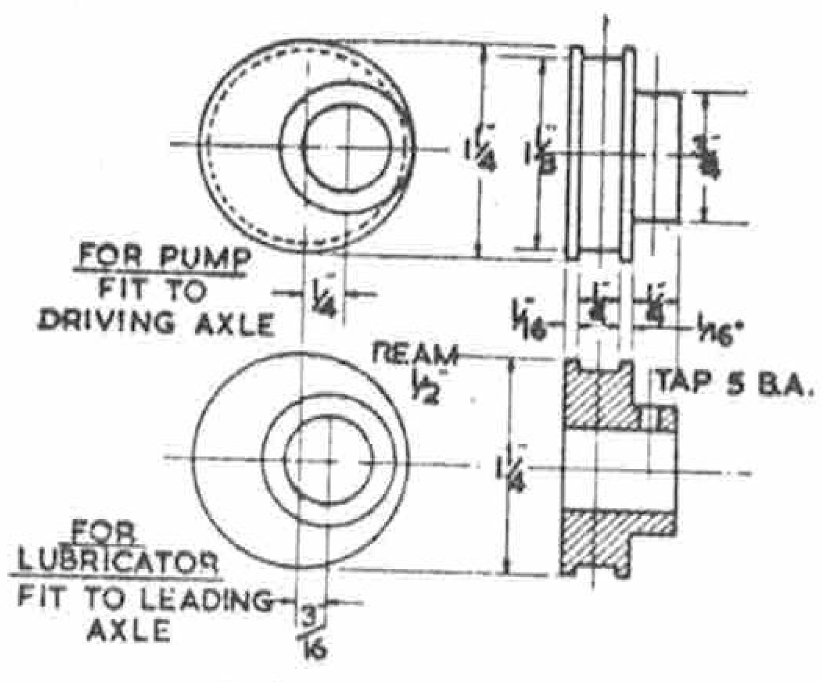
Might as well make one job of all the wheels and axles. The best way I know for turning wheels is as follows. Chuck by tread in three-jaw, back outwards, setting to run as truly as possible, with the flange clear of the chuck jaws. Use a roundnose tool with the business end bent a little to the left, so that the tool will turn and face without having to be reset in the rest. Take a facing cut right across the back of the casting, and turn the flange a little over finished diameter, doing both jobs at slow speed. Change to high speed, centre with a centring-drill, and for the coupled wheels first drill through with 27/64 in. drill, then ream 7/16 in. For the smaller wheels, drill 19/64 in. and ream 5/16 in.

Reverse in chuck and grip by the flange. Face off the rim to dimensions shown, then face off the boss so that it stands out 1/16 in. from the rim. Then put a parting-tool crosswise in the rest, and cut a 1/16 in. rebate at the point where the spokes join the rim, to represent the joint between wheel-centre and tyre in full-size. To turn the treads, an improvised faceplate will be needed, a little less than the diameter of the wheel; I use odd wheel castings, chuck plates or anything else handy. Chuck this in three-jaw, face off, and cut a recess about 1 in. diameter and 1/32 in. deep in the middle. For the coupled wheels, centre, and drill and tap 9/16 in. x 32. Screw in a stub of 9/16 in. steel rod screwed to suit; this must be very tight, and should project about ¾ in. Turn it down carefully until the coupled wheels will just push on without shake. Next turn about ⅜ in. of the end to ⅜ in. diameter. and screw ⅜ in. x 26, making a nut to fit, or using a ⅜ in. BSF commercial nut. Put each wheel on the spigot, boss outwards, and secure with the nut, only tightening same sufficient to prevent the wheel from slipping. Turn the tread to a shade under 1/64 in. larger than finished diameter.

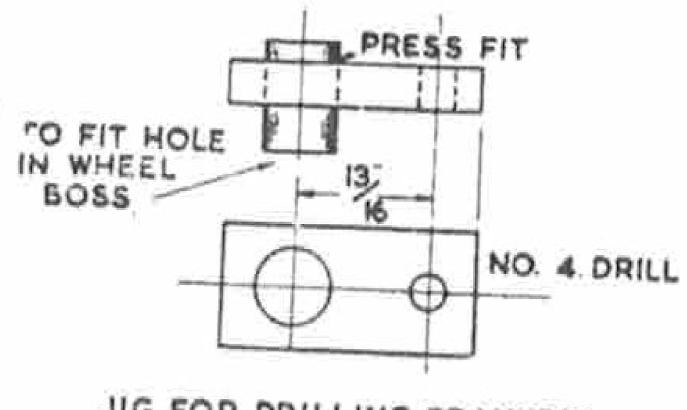
When all the wheels have been turned and the last is on the peg, regrind the tool, and turn the tread to finished size. Without shifting the cross-slide (very important, that!), put the other wheels on the peg in turn, and take the finishing cut with the same setting. They will then all be exactly the same diameter, which is essential with coupled wheels, and no measuring will be needed. The flanges can be rounded off with a file. The smaller wheels are finished in the same way on a faceplate of requisite diameter, the peg or spigot being turned to fit the 5/16 in. hole, then turned down at the end and screwed ¼ in. x 40, for the securing nut.

The coupled axles are turned from ½ in. round mild steel. Use the ground variety if possible, but the ordinary drawn kind will do quite well. If your three-jaw chuck is reasonably true, it can be used for turning the wheel seats. Three pieces about 4⅝ in. long will be needed. Chuck one with about 1 in. projecting. If there is no appreciable wobble when the lathe is started, go ahead; face the end, and turn ½ in. length to a press fit in the wheel boss. If there is a wobble, one or two thicknesses of brass foil, or even paper, between the axle and offending jaw of the chuck, will usually put matters O.K. Reverse in chuck and repeat process, but leave the distance between shoulders exactly 3-9/32 in. and face off any surplus at the end of the wheel seat so that it is ½ in. long.

Now most beginners have a difficulty in turning to a press fit. Some overdo it, and when pressing



ECCENTRICS



JIG FOR DRILLING CRANKPIN HOLES

the axle into the wheel boss—crack!—and a new casting is needed. The easiest way I know of turning the seats to a press fit in the bosses without risk of a split, is to put a taper broach or reamer in the hole at the back of the wheel and take out a tiny scrape, only about ⅛ in. or so, in depth. Turn the wheel seat until it will just—*and only just*—enter the broached end very tightly; it can then be pressed right in without fear of cracking the boss.

If the chuck is very badly out of truth, turn the axles between centres, using steel of a little larger diameter. Centre both ends with a size E centre-drill, put a carrier on one end, and turn right back to the carrier, the full diameter of the axle. Turn the wheel seat about ⅛ in. over length; reverse the piece between centres, and turn the other end, leaving the distance between shoulders as before. The wheel seats can be faced off to ½ in. length in the chuck, as the inaccuracy of the chuck won't affect the facing.

Pony and trailing axles can be turned in the same way, but in the case of the trailing axle a slight inaccuracy in the chuck doesn't matter. As the ¼ in. journals are outside the wheels, they can be turned at the same setting as the wheel seats, so both journals and seats must of necessity be true with each other.

Crankpins and Eccentrics

The crankpin holes in the coupled wheels should be drilled with the aid of a simple jig; if they aren't all the same distance from centre, the coupling-rods will bind. A piece of steel bar about 1½ in. long, of ¼ in. x ¾ in. section, is needed. Scribe a line down the middle of one wide side and make two centrepops on it, 13/16 in. apart. Drill them both with No. 4 drill, then open one out to 27/64 in. Turn one end of a 1 in. length of 7/16 in. steel to a sliding fit in the hole in the wheel boss (it must not be slack) and the other end to a press fit in the hole in the jig, and squeeze it in. Scribe a line down the centre of each wheel boss, cutting across the axle hole. Put the peg on the jig in the axle hole, and adjust the jig until you can see the scribed line crossing the middle of the No. 4 hole. Clamp it in that position and drill through the wheel boss with No. 4 drill, using the hole in the jig to guide it. After all are drilled, ream them with a 7/32 in. parallel reamer.

The crankpins are turned from silver-steel of the sizes shown. The spigots are turned to a press-fit in the holes in the wheel bosses. For the leading pins, reverse in chuck, face off to 3/16 in. length, centre, drill No. 40 for 7/16 in. depth, and tap 5 BA. The driving pins are faced off to ⅞ in. length, and the end turned to 3/16 in. diameter for 3/16 in. length. The trailing pins are faced off to a bare ½ in. length, and the end turned down and screwed 4 BA for 3/16 in. length. When pressing them into the wheels, note that the driving pins should be pressed into the wheels with the bigger balance weights.

Two eccentrics are needed, one for the pump and the other for the mechanical lubricator. They are turned from 1¼ in. mild steel; I use offcuts of shafting for jobs like these. Chuck in three-jaw, face the end, and cut a groove 1/16 in. deep and ¼ in. wide at 1/16 in. from the end. Part off at 5/16 in. from the groove and repeat operation. If the lathe tool chatters when parting off, try running at slow speed and use plenty of cutting oil; this usually does the trick even if the lathe mandrel is slack. The cutting should come off coiled like a watch spring, with a sound like frying bacon.

The toolmarks on the end will indicate the true centre. On one of the embryo eccentrics make a centrepop ¼ in. from this, and on the other 3/16 in. Chuck each in the four-jaw with the pop mark running truly, drill through with No. 30 drill, open out to 31/64 in. and ream ½ in. Chuck a piece of ⅝ in. rod, turn about ½ in. of the end to a press fit in the holes in the eccentrics, press one on, grooved end first, rechuck the rod, and turn down ¼ in. of the eccentric to ¾ in. diameter, which will form the boss. Be mighty careful when starting the cut, as the eccentric will be living up to its name, and if you feed in too quickly it will knock off the end of the tool. Drill a No. 40 hole in the side of the boss and tap it 5 BA for a setscrew.

Coupling-rods

THE coupling-rods are made from ¼ in. x ½ in. mild steel bar; two 5 in. and two 6¼ in. lengths will be required. Mark off one of each to the outlines shown; if the rods are coated with marking-out fluid, the lines stand out very clearly. The fluid can be made by dissolving shellac in methylated spirit, and adding some blue or violet aniline dye to colour it. This is applied with a brush, and dries in a minute or so. Make centrepops at the bush holes, drill ⅛ in. then use the holes for locating to drill the other pieces. Temporarily rivet each pair together and either mill or saw and file them to outline.

The way I mill them is to use a piece of 1 in. square bar as a backing to prevent the thin rods springing under the cut. The rod blanks are attached to the bar by a little clip and bolt at each end, and the bar is held either in the machine-vice on the miller table or, in the case of long rods, bolted to the table itself with the bolt-heads in the table slot, and the stems of the bolts through holes drilled at each end of the bar. As a small-diameter cutter is needed to get the correct radius at each end of the cut, I use a ⅜ in. end-mill in an adapter to fit the taper hole in the mandrel of the milling machine, the side-cutting edges of this doing the job in the same manner as a slabbing cutter. Plenty of cutting oil (a 50/50 mixture of Cutmax and paraffin) is supplied by a small tin can clipped on to the overhanging arm of the machine, with a cock and pipe which lets the oil drip on to the cutter.

If a milling-machine isn't available, the bulk of the metal can be removed in the lathe if a centre-hole is drilled at each end of the rod-blank exactly opposite the middle of the bush hole, and the blank mounted between centres; for this, the blank should be cut about 1 in. longer than mentioned above, to allow room for a carrier on the end. Use a round-nose tool. This process will naturally leave the top and bottom of the turned portion rounded, but a file will soon fix that, and also round off the ends with a little patience and care. The way I rounded off the ends before I had a miller was to turn a spigot the size of a bush hole on the end of a piece of square rod. This was clamped under the slide-rest tool-holder, parallel with the lathe bed, and the bush hole then slipped over the spigot. A 3/8 in. end-mill was put in the chuck and the rod fed up to the side teeth of this. As soon as it started cutting, the free end of the rod-blank was slowly swung around against the cut, and the surplus metal was quickly removed, leaving a nicely-rounded boss—but care has to be taken to avoid swinging the end around too far, or the oil-box will be cut off.

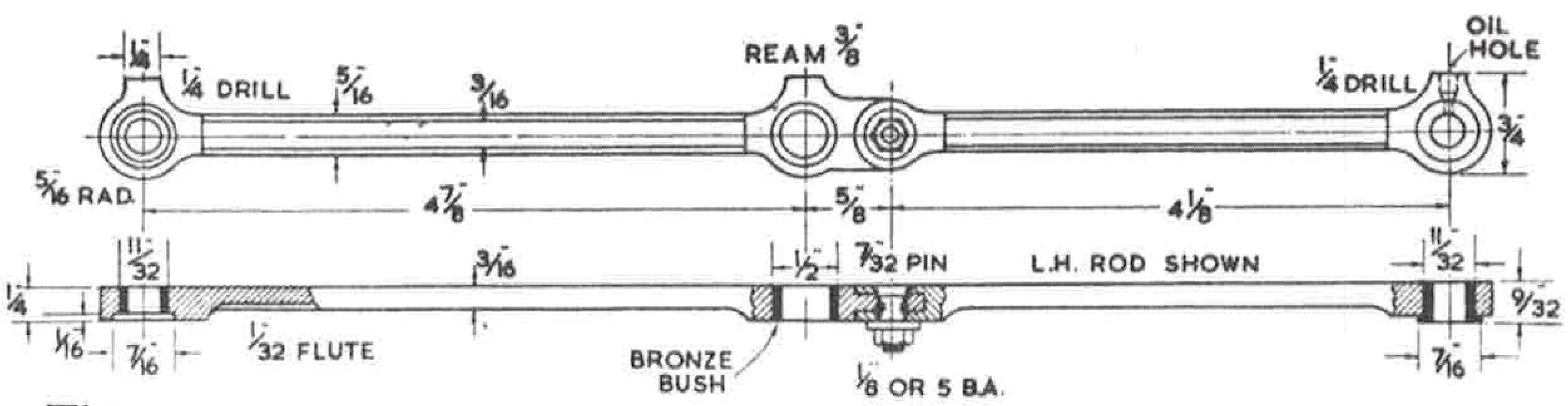
The rods may be fluted on a miller with a 3/16 in. saw-type cutter on the arbor, or they may be left out. Many big engines have plain rods. To slot the end of the short rod for the knuckle-joint, clamp it under the slide-rest tool-holder and run it up to a 1/8 in. saw-type cutter on a spindle held in the chuck or between centres. The screwed end of an old bolt makes a fine cutter arbor, the cutter being clamped between two nuts. The tongue can be formed by pin-drilling the sides of the longer rod to a depth of 1/16 in. and trimming away any "fins" with a file. The pin is turned from 5/16 in. silver-steel and furnished with a commercial nut and washer.

The leading end of each rod is drilled 11/32 in. for the bush, and pindrilled 7/16 in. diameter for 1/16 in. full depth, to take a washer which prevents the rod coming off the pin. The middle boss is drilled out to 1/2 in. diameter and a bronze bush fitted which is flush both sides. Ream this 3/8 in. after pressing in the bush. The trailing boss is drilled 11/32 in. and the bush for this is turned with a 1/32 in. flange 7/16 in. diameter. Beginners note—the driving boss should always be a nice working fit on the crankpin, but the leading and trailing bosses should be quite easy. If they aren't, the axleboxes cannot follow the irregularities in the line, or run through points and crossings, without the rods binding on the pins.

It is quite possible that friend Reeves will supply coupling and connecting-rods cast in malleable iron, with the flutes cast in, and these save a lot of laborious work to those folk who have no milling-machine. They only need cleaning-up, bushing and the knuckle-joint making in the coupling-rods. The rods can also be hand-made, by gripping the blank in the bench vice with the top of the marked line just showing above the jaws. File a gap at the end, down to the marked line, wide enough to take a hacksaw-blade on its side. Put a blade in the frame sideways and saw along to the boss at the other end, with the side of the blade resting on the vice-jaws; then saw down to meet the horizontal cut, and the surplus piece of steel will fall out. Finish with a file. This method needs patience, enthusiasm and "elbow-grease", but it is useful to those with the minimum of equipment.

Boiler feed pump.

It is an easier job to erect the feed pump when there are no wheels on the frame, so we will make and fit the pump right away. A casting will be needed for the pump body and valve-box, and this should have a chucking-piece cast on opposite the pump barrel. First chuck the casting by one end of the valve-box, and set the other end to run truly. Face off, centre, run a No. 24 drill right through, open out and bottom to 7/16 in. depth with 11/32 in. drill and D-bit, slightly countersink the end and tap 3/8 in. x 32 for 1/4 in. depth. Skim off any burr. Chuck a short bit of rod any size over 3/8 in. dia. and turn down 3/16 in. of the end to 3/8 in. dia. with a knife tool. Screw this 3/8 in. x 32, then screw the valve-box on to it by the tapped end. Face off the outer end, open out to 7/16 in. depth with 11/32 in. drill, slightly countersink the end, and tap 3/8 in. x 32 for 1/4 in. depth. Nick the bottom of the hole with a little



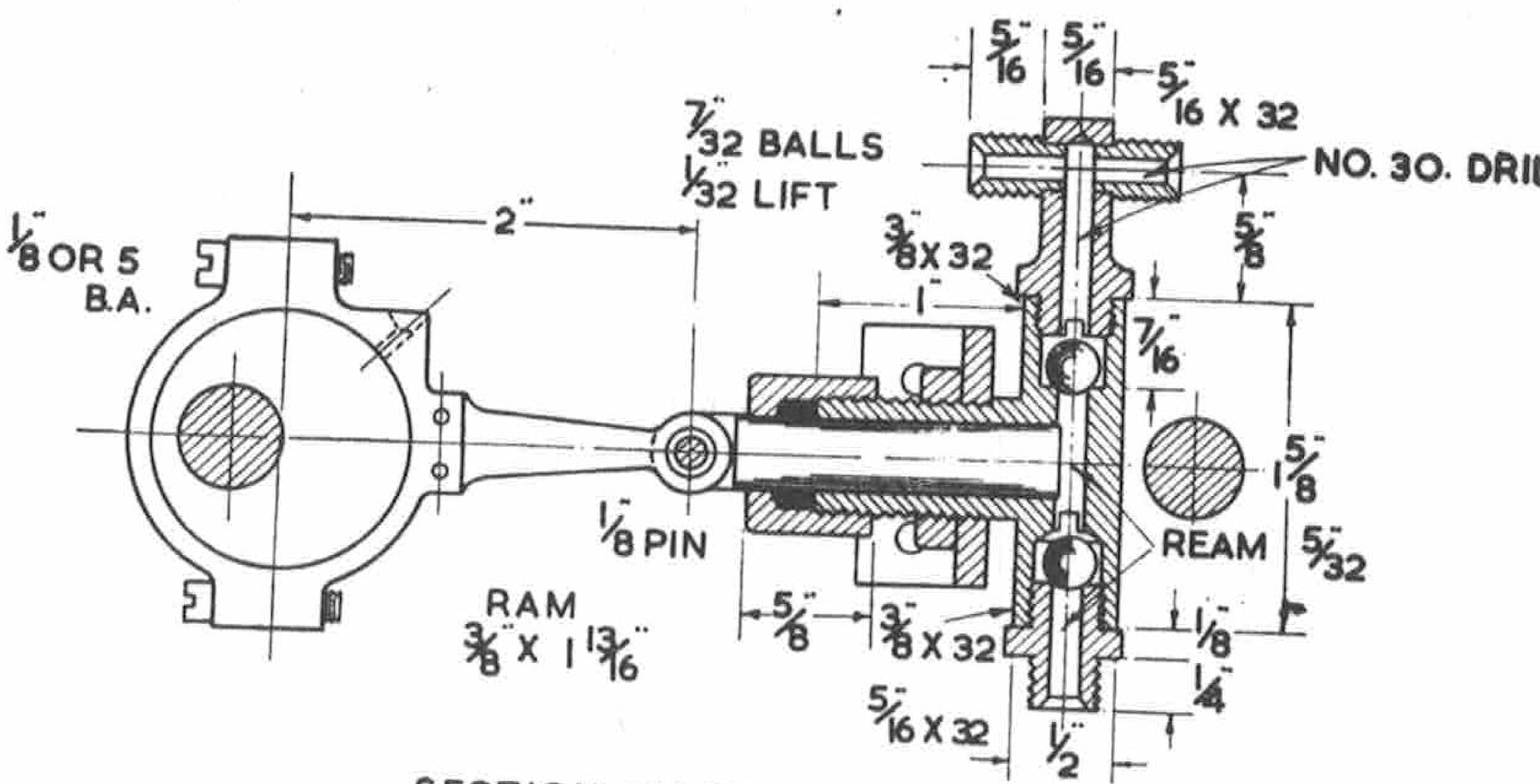
COUPLING ROD

chisel made from a piece of 3/32 in. silver-steel, and put a 5/32 in. parallel reamer through the remnant of the No. 24 hole.

Chuck the casting by the spigot, and set the barrel to run truly. Face the end, centre, drill 23/64 in. until the drill pierces the hole through the valve-box, and ream 3/8 in. Turn the barrel to 9/16 in. dia. and screw it 9/16 in. x 32 to within 1/8 in. of the valve-box. Face the end sufficiently to bring the length of barrel to 1 in. Saw off the chucking-piece and round off the stub with a file.

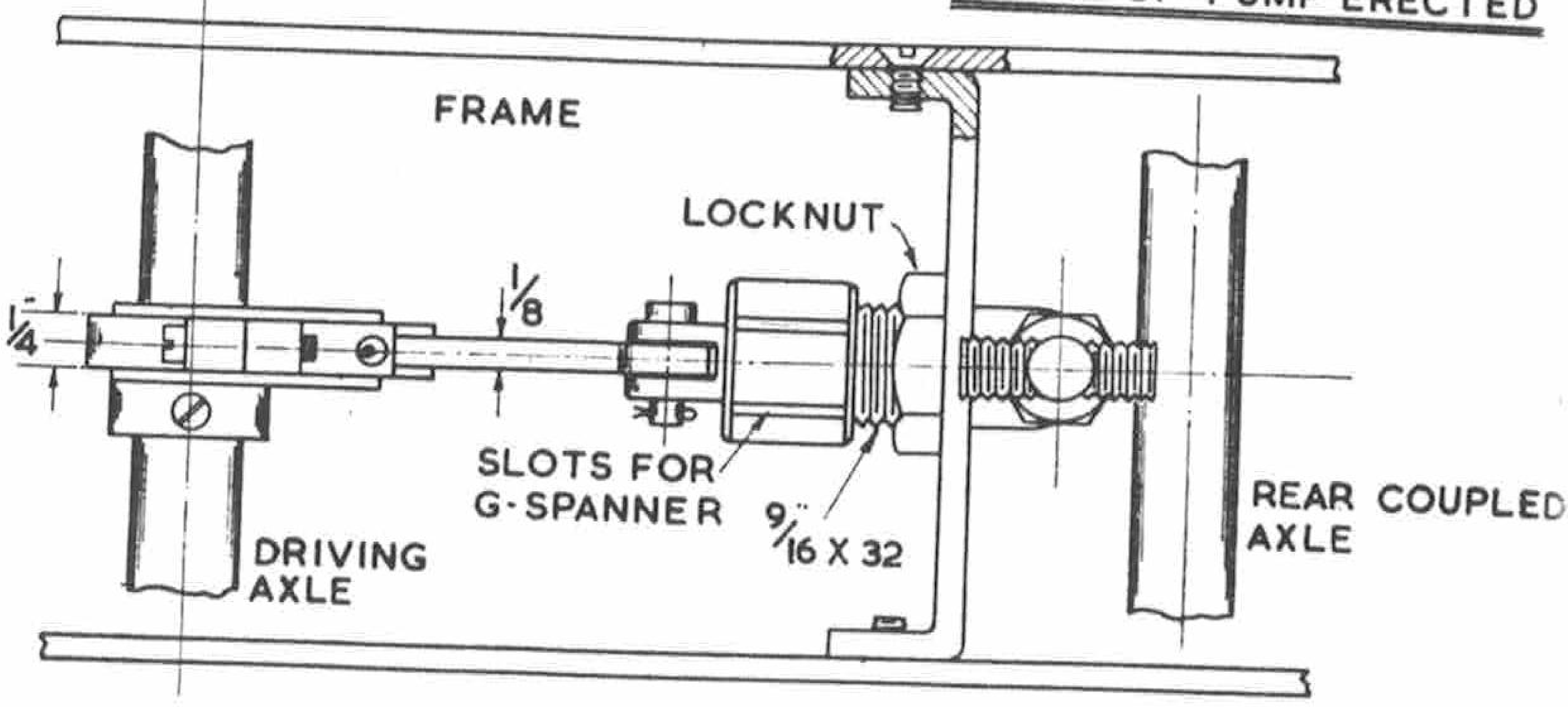
Drop a 7/32 in. rustless ball into the D-bitted end, and seat it on the reamed hole by holding a short bit of brass rod on it and giving it just one sharp crack with a hammer. Take the depth from the top of the ball to the top of the box with a depth gauge. Chuck a piece of 1/2 in. hexagon brass rod, face off, turn the length indicated by the depth gauge to 3/8 in. dia. and screw 3/8 in. x 32. Part off at 7/8 in. from shoulder. Re-chuck in a tapped bush held in three-jaw and turn 5/16 in. dia. to within 1/8 in. of shoulder. At 1/4 in. from the end, drill a 5/32 in. hole right across. Re-chuck by the turned part, centre, and drill No. 30 until the drill pierces the cross-hole. Cross-nick the screwed end with a thin flat file, and skim off any burring.

Fit a 5/16 in. x 32 nipple into each end of the cross-hole. To make them, chuck a piece of 5/16 in. brass rod, face the end, centre deeply and drill No. 30 to 1/2 in. depth. Screw 5/16 in. x 32 for 5/16 in. length, and part off at a full 7/16 in. from the end. Reverse in chuck (it won't hurt the thread as long as the chuck isn't screwed up too tightly), and turn down about 3/32 in. of the end to a tight fit in the cross-hole. Squeeze them in, and silversolder them. Quench



SECTION OF PUMP

PLAN OF PUMP ERECTED



in acid pickle, wash off and clean up. I use a circular fine-wire brush, mounted on a taper spindle, which fits in a taper hole in the end of the spindle of my tool-grinder. As this runs at 2,990 r.p.m. it makes these small fittings bobby-dazzle in a matter of seconds. I use a bit of rod tapped at the end to hold them, so that the wire brush doesn't take the skin off my fingers as well!

Drop another ball into the nicked end, and take depth as before. Chuck the ½ in. hexagon rod again, and turn the length indicated by the depth gauge to ⅜ in. dia. screwing ⅛ in. × 32. Centre and drill to ¾ in depth with No. 24 in. drill, and ream 5/32 in. Face off 1/32 in. to true the end, part off at a full ⅝ in. from the end, reverse and re-chuck in a tapped bush, turn down ¼ in. length to 5/16 in. dia. and screw 5/16 in. x 32 in. Screw the pump barrel through the hole in the pump stay; when right home, the D-bitted end should be at the top, with the valve-box vertical. For the locknut, chuck a piece of ¾ in. hexagon rod, face, centre, drill to about ⅜ in. depth with 33/64 in. drill, and tap 9/16 in. × 32. Chamfer the corners of the hexagon, and part off at ¼ in. from the end. Assemble the lot as shown in the drawing, with the nipples on the top fitting parallel with the pump barrel.

The ram needs a piece of ⅜ in. ground rustless steel or drawn bronze rod, and if this is an easy sliding fit in the pump barrel, no turning is required. Round off one end, and drill a No. 32 cross-hole through it at 3/16 in. from the end. Take care to drill this centrally, and not to one side. I always rest the rod in a vee-block on the table of the drilling machine, and sight the drill across the end of the rod. To cut the ⅛ in. slot for the eccentric-rod, the easiest way is to grip the piece of rod under the slide-rest tool-holder, and run it up to a ⅛ in. saw-type cutter on a stub mandrel held in the chuck. It can be cut by hand if a cutter is not available, first slotting with a hacksaw and finishing with a key-cutter's warding file. Put a ⅛ in. reamer through the cross-hole, then part off at 1-13/16 in. from the cross-hole.

For the gland nut, chuck a piece of ¾ in. bronze rod, face, centre and drill 23/64 in. for ⅜ in. depth. Open out to a full ½ in. depth with 33/64 in. drill, and tap 9/16 in. x 32. Chamfer the end, part off at ⅝ in. from the end, reverse in chuck, chamfer the edge, and put a ⅜ in. parallel reamer through the hole. For packing, use a few strands unravelled from a piece of full-size hydraulic pump packing, or if not available, graphited yarn will do. Don't use the plumbers' pet packing, viz. tallowed hemp, or else when the gland is tightened up sufficiently to prevent leakage, the ram will soon be grooved like a navvy's corduroy trousers. Note—cut four slots in the nut, so that it can be tightened up with a C-spanner; or alternatively, make the nut from hexagon rod and use an ordinary spanner.

The eccentric-strap should be cast. Smooth the outside with a file, and drill a No. 40 hole through each ear or lug. Scribe a line across both, cutting across the middle of the corehole, grip in the bench vice with the line just showing above the jaws, and saw across both lugs with a thin hacksaw blade, keeping it pressed down on the vice jaws. Mark one lug on each half so that they can always be put together correctly, then open out the holes in the ring half with No. 30 drill, and tap those in the other half ⅛ in. or 5 B.A. Smooth off the saw marks, screw the halves together, and chuck in the four-jaw with the corehole running as truly as possible.

Face off the side with a round-nose tool, then bore out the corehole to a nice running fit on the eccentric tumbler. I always use a piece of steel turned to the same diameter as the eccentric, for a gauge. To face the other side, put this piece of steel in the three-jaw and clamp the strap on it by its own screws, putting a piece of paper between the steel and the strap to prevent slipping. Then face off until the strap will fit nicely between the flanges of the eccentric tumbler. Drill a No. 53 hole in the step for oiling, and countersink it, as shown dotted on the drawing.

The eccentric-rod can be filed to shape and size shown, from a piece of ½ in. x ⅛ in. mild steel strip, or a bit of frame steel. It is fitted into a ⅛ in. slot cut in the lug on the strap below the step. Solder it in first, then drill two No. 53 holes through and countersink them, squeeze in two bits of 1/16 in. steel wire, and hammer the ends into the countersinks, filing flush both sides. Fit a bronze bush in the eye like those in the middle of the coupling-rods. Drill the boss 7/32 in. and turn the bush to a press fit, reaming it ⅛ in. after it is pressed in. The gudgeon-pin can be turned from ¼ in. round steel and fitted with a little split-pin as shown, or it may be a piece of ⅛ in. silver-steel ⅝ in. long, turned down to 3/32 in. for ⅛ in. length at each end, screwed 3/32 in. and furnished with nuts; just as you like!

To erect the assembly in the frames, set it with the pump stay vertical, the bottom of it flush with bottom line of frame and the valve-box ⅛ in. away from the rear coupled axle (put this temporarily in place) then put a toolmaker's cramp at each side to hold it. Run a No. 30 drill through the countersunk holes in the frame, making countersinks on the ends of the stay, follow through with No. 40, tap

$\frac{1}{8}$ in. of 5 B.A. and put screws in to suit. If preferred, longer screws may be used with locknuts inside the stay flanges.

How to erect coupled wheels.

Press one wheel on each axle, using the bench vice as press. Poke the driving axle through the middle pair of axle boxes, threading on the pump eccentric, then put the other driving wheel on the outer end as far as it will go. Set the crankpins as nearly at right angles as you can sight them, right-hand leading. Now take out the lot by removing the hornstay screws; stand it on something flat, with a block front and back of one of the wheels to prevent it rolling. Put a try-square against one wheel, setting the wheel so that the edge of the blade passes across the centre of the wheel and the centre of the crankpin when the latter is exactly above the middle of the axle.

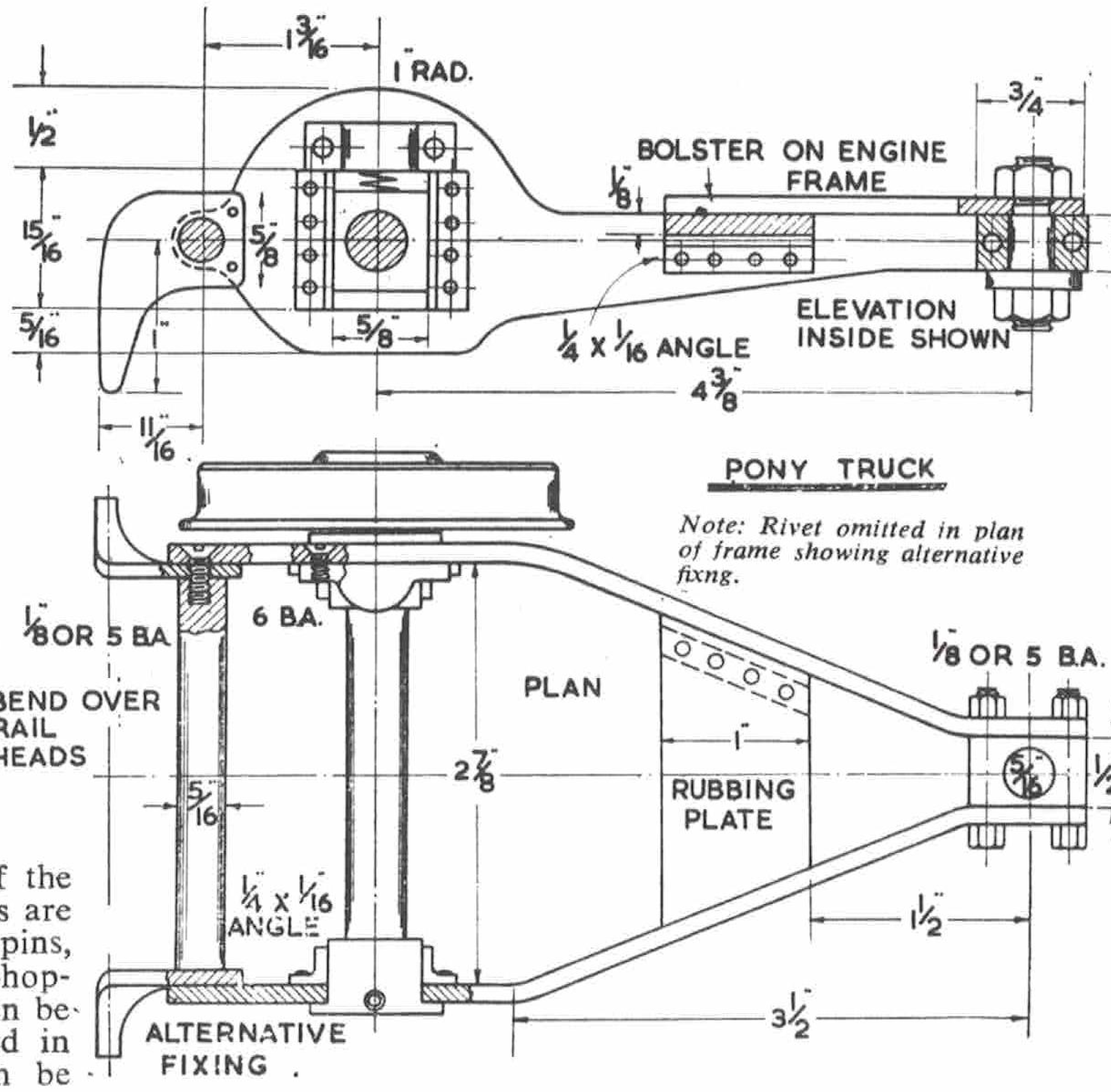
Set the needle of a scribing-block to the middle of the axle on the other side, and adjust the wheel on the axle until the middle of the crankpin is at the same height. When both sides are as stated, **at the same time,** the setting of the crankpins, or the quartering of the wheels, as the railway shopmen call it, is correct. The second wheel can then be pressed right home, and the assembly replaced in the frames. The pump eccentric-strap can then be fitted to the tumbler, the rod coupled up to the ram, and the eccentric lined up with the pump before tightening the setscrew for keeps. The pump should work quite easily when the wheels are turned by hand.

Now put the leading and trailing axles through the boxes, and put on the other wheels as far as they will go by hand. Put the coupling-rod on the pressed-on side, and adjust the wheels on the other side until that coupling-rod will go on, too, and the whole lot turns by hand without binding or jamming. The leading and trailing wheels and axles can then be removed with their axle-boxes, and the wheels presed right home. Don't forget to put the other eccentric on the leading axle! Replace the wheel-and-axle assemblies in the frame, and put on the coupling-rods, securing the leading bosses with 5 B.A. countersunk screws and the turned washers shown in the crankpin drawings, and the rear bosses with 4 B.A. nuts and ordinary washers. The wheels should turn quite freely by hand, while the bits of $\frac{1}{8}$ in. packing are between the hornstays and axle-boxes to keep them in the correct running position.

Pony truck.

On my own engine I used a cast pony truck. It was intended for another engine, and was $\frac{3}{8}$ in. too short but by aid of a little jerrywangling at the kingpin end, I worked it in. The casting comprised the side frames, hornchecks, spring pockets, tie-bar, and rubbing-plate all in one piece, so the only work involved was to fit axleboxes, wheels and axles, and a couple of guard-irons made from 3/32 in. steel. If friend Reeves comes up to scratch with similar castings, my honest advice is to use them, and save time and labour.

However, for those who prefer the built-up arrangement, the side frames are cut from $\frac{1}{8}$ in. sheet steel, of the same kind as used for the main and cradle frames. The process is exactly the same, too, so I needn't waste space with needless repetition.

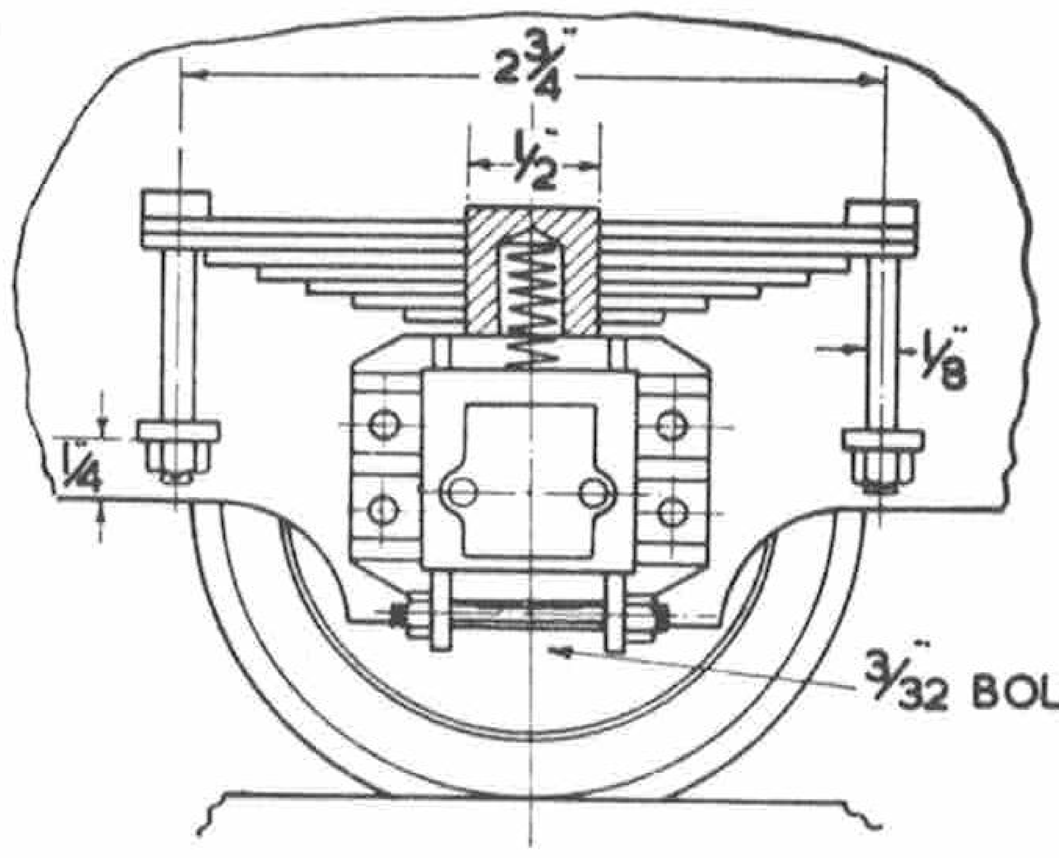


Bear in mind that the distance from the centre of the kingpin to the centre of the axle should be $4\frac{3}{8}$ in. **after bending** to the shape shown in plan. Allow approximately $\frac{3}{8}$ in. extra length when marking out, then after bending, the kingpin block can be set in the right place, and any surplus projecting from the back can be cut off.

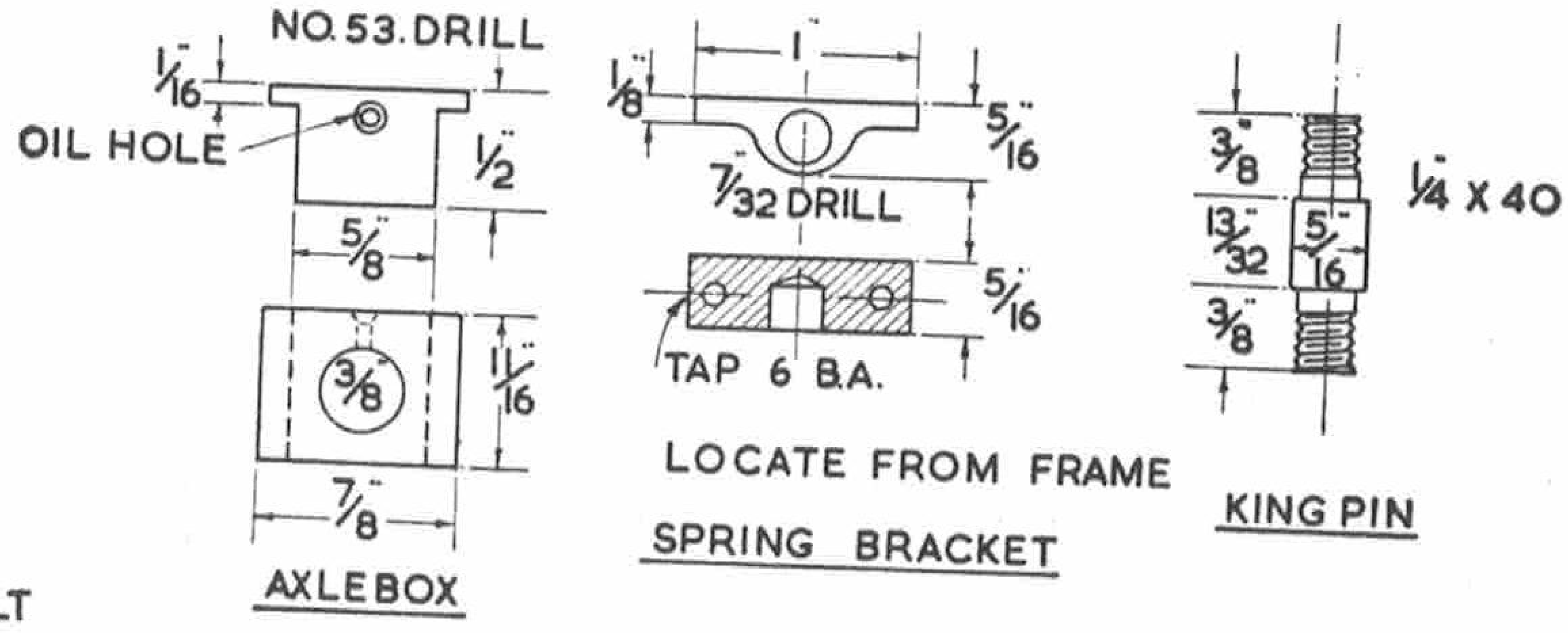
The holes for the axle-boxes should be 15/16 in. deep and $\frac{5}{8}$ in. wide. Rivet a piece of $\frac{1}{4}$ in. x 1/16 in. angle at each side, as shown in plan, using 1/16 in. iron rivets, countersunk on the outside of the frames. The spring pockets or brackets can be filed up from 1 in. lengths of 5/16 in. square brass bar, and have a 7/32 in. blind hole drilled in each, as shown in the detail sketch. They can be attached to the inside of the frame, over the middle of the opening for the axlebox, either by 6 B.A. screws running through No. 34 countersunk holes in the frame into tapped holes in the bracket (see plan view) or they may be attached by 3/32 in. iron rivets, the holes in frames being drilled No. 41 and countersunk on the outside. Once fitted, the brackets never have to come off again.

The tie-bar is made from 5/16 in. round steel, either a piece 2-11/16 in. length with a $\frac{1}{8}$ in. or 5 B.A. tapped hole in each end, or $3\frac{1}{4}$ in. overall length, with 9/32 in. of each end turned down to $\frac{1}{8}$ in. dia. leaving 2-11/16 in. between shoulders. Cut the guard-irons from 3/32 in. sheet steel to size and shape shown, and drill a No. 30 hole for the tie-bar screw or spigot. Assemble as shown in plan, with the guard-iron next to the frame, and secure either with $\frac{1}{8}$ in. or 5 B.A. countersunk screws, or by rivetting over the pip on the end of the tie-bar, as the case may be. Two 1/16 in. rivets are put through the end of each guard-iron and frame, to keep them from turning, should the engine happen to hit something on the line.

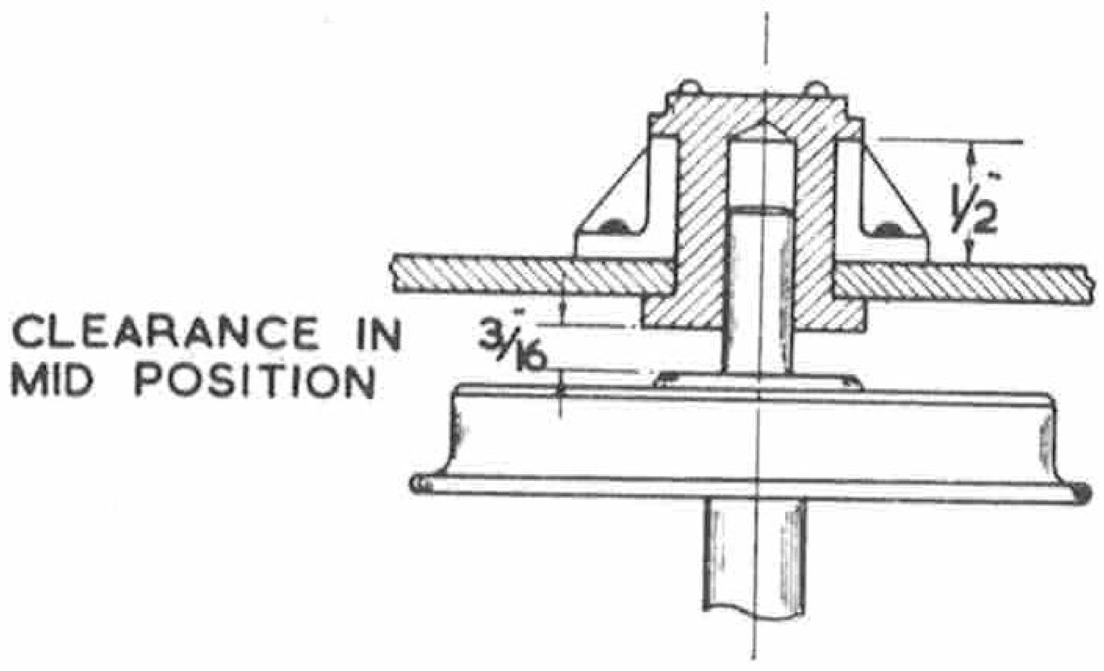
The kingpin block is made from $\frac{1}{2}$ in. x $\frac{3}{8}$ in. steel or bronze bar, and is $\frac{3}{4}$ in. long. It is fixed between

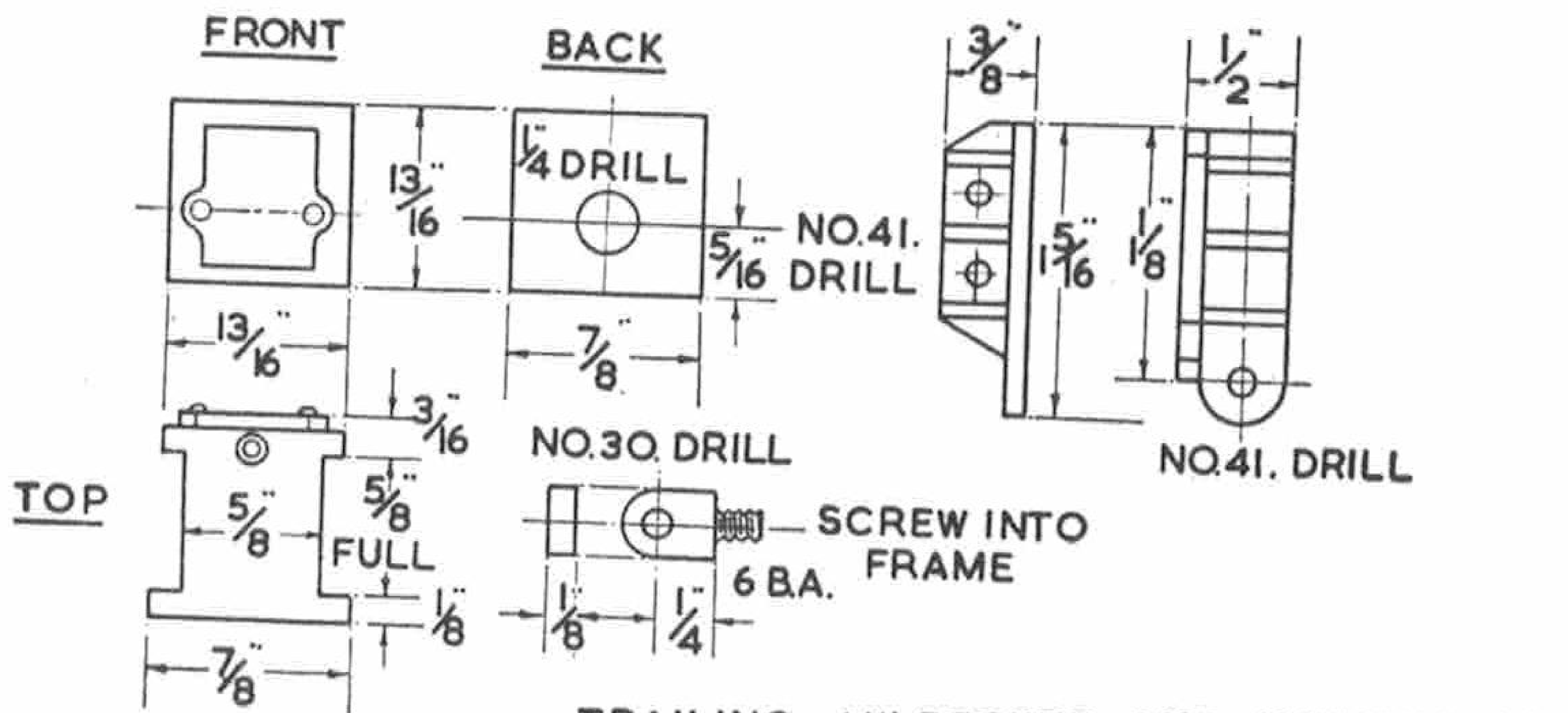


TRAILING AXLEBOX ASSEMBLY



PONY DETAILS



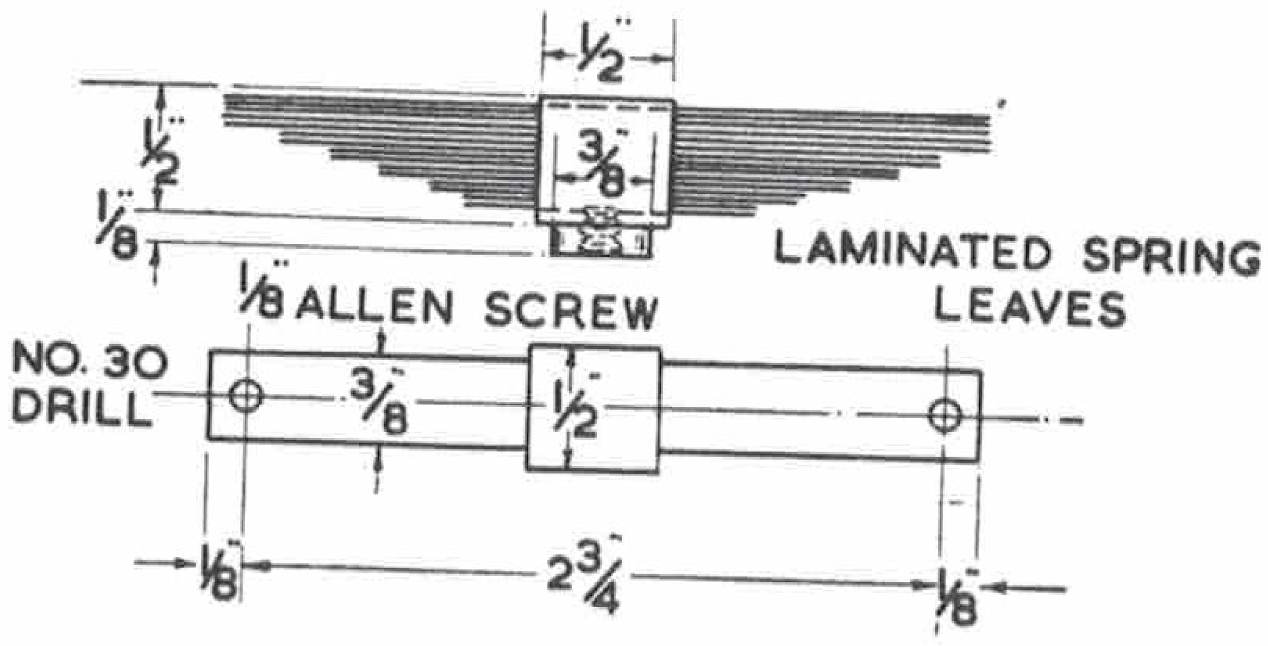


TRAILING AXLEBOXES AND HORNCHEEKS

the frames by two $\frac{1}{8}$ in. or 5 B.A. bolts, and has a 5/16 in. hole drilled through the middle. If steel, it can be brazed to the frames instead of bolted. The rubbing-plate is a piece of $\frac{1}{8}$ in. steel 1 in. wide, cut to fit between the frames, the rear edge being located $1\frac{1}{2}$ in. ahead of the centre of the kingpin hole. It is attached to the frames by a piece of $\frac{1}{4}$ in. x 1/16 in. angle at each side, using 1/16 in. iron rivets, hammered down into countersunk holes on top of the plate, and filed smooth.

The axle-boxes are made from $\frac{1}{2}$ in. x $\frac{7}{8}$ in. bronze or gunmetal bar, cast or drawn, the process being the same as described for the main axle-boxes. Use a piece $1\frac{1}{2}$ in. long, saw in half after milling the sides, and face to length in the four-jaw. The boxes should be an easy fit in the horncheeks. Drill a $\frac{3}{8}$ in. hole in each for the axle, lining them up as for the main boxes, and don't forget the oil hole. The springs are wound up from 19-gauge tinned steel wire, and should just start to compress when the boxes are at the bottom of the openings. To erect, put a spring in each pocket, put the axle-boxes in from outside the frames (see plan), press one wheel on the axle, put it through both boxes, and press on the other wheel. The wheels should spin freely, with the boxes in lowest position. They will adjust themselves to running position when the engine is on the line.

To make the kingpin, chuck a piece of 5/16 in. mild steel rod, face, centre, turn down $\frac{3}{8}$ in. length to $\frac{1}{4}$ in. dia. and screw $\frac{1}{4}$ in. x 40. Part off at a bare 13/16 in. from shoulder, reverse in chuck and repeat turning and screwing. Put one end through the hole in the bolster on the engine, and secure with a nut made from $\frac{3}{8}$ in. hexagon steel rod. Put the block at the end of the pony truck over the pin, and secure it with a similar nut with a washer between nut and shoulder, see elevation. The pony truck should swing quite freely. No side control is needed; the pony just follows the road when the engine is at work. The natural friction between the engine bolster and the rubbing-plate will provide all the control necessary.



WORKING LEAF SPRING

Trailing axle.

HERE again, on my own engine I utilised a pair of cast side frames that I had in stock for years, and they had the dummy leaf springs and horncheeks cast on, so all I had to do was to fit the axle-boxes, wheels and axle, and dummy hanger pins to the springs for appearance sake, so that the trailing end of the engine didn't look as though it depended on air hooks. If castings for the trailing frame are available, that will also be all that is needed.

If the cradle is made from $\frac{1}{8}$ in. steel, or cast without adornments, fit a couple of cast dummy tender springs (these are available). They should need no machining; just drill the blind hole for the spiral spring in the hoop, using $\frac{1}{4}$ in. drill, and if they have hangers and pins cast on, as some have, drill the bosses at the ends of the springs with No. 30 drill, and attach the springs to the cradle side over the axle-box opening. If the springs have no pins, but are like those shown in the assembly drawing, drill a No. 30 hole at each end for separate pins. Exactly below these, at $\frac{1}{4}$ in. from the bottom of the cradle frame, fit a couple of lugs made from $\frac{1}{8}$ in. x 5/16 in. steel, as shown in the detail sketch. These should have a No. 30 hole in each, to correspond with the hole in the end of the spring. The pins are just $1\frac{1}{8}$ in. lengths of $\frac{1}{8}$ in. silver-steel with $\frac{1}{8}$ in. of thread on each end. The upper end has a boss screwed on, like a round nut (says Pat) and an ordinary nut goes at the bottom. The assembly is clearly shown in the drawing.

The same suspension could be used if anybody likes to go to the trouble of fitting working leaf springs. Each plate could be built up of three laminations of $\frac{3}{8}$ in. spring steel of about 30-gauge, the hoop being a $\frac{5}{8}$ in. length of $\frac{1}{2}$ in. square steel bar with a $\frac{3}{8}$ in. square hole through it, and a $\frac{1}{8}$ in. boss at the bottom, tapped to take a $\frac{1}{8}$ in. Allen screw to hold the plates in position. The spring should be erected exactly in the same way as the cast dummy shown in the assembly, the boss resting on the axle-box instead of the end of the spiral spring.

The horncheeks can either be cast, or made from $\frac{1}{2}$ in. x 3/32 in. brass angle. If cast, they will have the webs on as shown, and will only need smoothing with a file, and drilling for the rivets and hornstay bolt. If made from angle, four pieces will be needed, each 1-5/16 in. long. There will be no need to fit webs, thev work iust as well without, and the absence isn't noticeable. File to shape shown, drill the bolt and rivet holes, and rivet one at each side of the opening for the axle-box, using 3/32 in. iron rivets.

The axle-boxes can be cast, or built up. If cast, they will have the cover cast on, and the pair will probably be cast together, end-on. The groove at each side can be milled out exactly as described for the main axleboxes, then saw the piece across the middle, face off each box, and drill the axle-hole and oil hole. As the axle-holes don't go right through the box, the two cannot be drilled together, so be very careful when marking out and drilling. If the holes are not exactly opposite, the axle will lie what the kiddies call "skew-whiff" across the frame, and there will be excessive friction between the wheel flanges and the rail heads.

The axle-boxes can also be cut from a $1\frac{3}{4}$ in. length of $\frac{7}{8}$ in. square bronze bar. Don't use anything softer. Billy Stroudley, the famous locomotive engineer of the London, Brighton and South Coast Railway, always insisted that the trailing wheels of a locomotive took the lion's share of guiding it around the curves; and according to my experience with little engines, he was certainly right. The trailing axle-boxes on my own engines are always first to wear. The curves on the line are, of course, sharper than those on the running lines of any full-size railway, and the engines travel around them proportionately much faster, but the journals wear slack in the boxes, and the boxes wear slack in the horns, twice as quickly as coupled and bogie boxes.

Mill the sides, and face the ends after parting, just the same as the main boxes. Note that the flanges at the front are narrower than those at the back. The boxes made from bar can be drilled together, to ensure the axle-holes being in line, and the covers cut from 1/16 in. sheet brass and attached to the fronts of the boxes, over the axle-holes, by two 1/16 in. or 10 B.A. screws.

Press both wheels on the axle, and put an axle-box on each journal. Turn the frame upside down, drop a 19-gauge spiral spring into each spring-hoop, insert the axleboxes between the horncheeks, and secure them with hornstay bolts made from bits of 3/32 in. silver-steel screwed at each end and furnished with commercial nuts. When the nuts are tight, the bolt should be free enough to turn with finger pressure. If too tight, the horns will pinch the axle-box and the engine won't stay on the road. Small railway tracks are usually well blessed with what country folk call 'umps and 'ollers, and the axle-boxes should be free enough to allow the wheels to ride over them without coming off. Note that when the axle and wheels are erected, there should be $\frac{3}{8}$ in. end movement. This does away with the need for fitting radial axle-boxes, and allows the locomotive to take a 15-ft. radius curve at a fair speed.

Cylinders

As the cylinders for Betty are very similar to those specified for one of my earlier engnes, a $3\frac{1}{2}$ in. gauge L.N.E.R. Bantam Cock, the same castings can be used, which will save friend Reeves from having to make fresh patterns, thus cutting cost. They are $1\frac{1}{8}$ in. bore and $1\frac{5}{8}$ in. stroke, with large ports and slide valves, which have a long travel giving quick admission and free exhaust. They are easy to machine up and assemble, and no beginner need have the slightest apprehension about tackling the job.

If the coreholes are reasonably true in the castings, as my own were, no marking-out will be required for the boring job. If they are out, smooth one end of the casting with a file, plug the corehole with a bit of wood, mark the true centre on the wood, and scribe a circle the diameter of the bore with a pair of dividers, on the end of the casting. This should be coated with marking-out fluid so that the circle stands out clearly.

Should the portface be slightly rough or uneven, smooth it with a file. Bolt an angleplate to the lathe faceplate and mount the casting on this, portface down, securing it with a bar across its back, with a bolt at each end. The casting must be in line with the lathe centres; check this by applying a try-square with the stock to the lathe faceplate, and the blade to the bolting-face of the casting. Tighten the clamp bolts well, but not enough to spring the angleplate or strain the casting. Now adjust the angleplate on the faceplate until the corehole, or marked circle as the case may be, runs truly. This can be checked by standing a scribing-block or surface-gauge on the lathe bed, and setting the needle to the edge of the corehole or marked circle. When this touches the needle for a complete revolution, the setting is O.K. and the bolts holding the angleplate can be tightened. Note that the casting should overhang the edge of the angleplate by about $\frac{1}{4}$ in.

Bolt a balance-weight to the faceplate opposite to the angleplate before starting to machine the casting, otherwise there will be a good imitation of an earthquake when the lathe is started. I filled several tin lids with melted lead, and when they cooled, drilled a $\frac{1}{4}$ in. hole in the middle so that they could be attached to the faceplate by a $\frac{1}{4}$ in. bolt. The casting and angleplate are correctly balanced when the faceplate stays put at any point in its revolution when the lathe belt is off the pulley.

First face off the end of the casting with a roundnose tool set crosswise in the slide-rest. The amount to be taken off should be half the difference between the length of the casting and the length of the finished cylinder, which is $2\frac{3}{8}$ in. Next mount a boring-tool in the rest, and set it a little above centre, so that the part below the cutting edge doesn't rub on the metal below it. The first cut through the corehole should be about 1/16 in. deep, so that all the hard skin inside the hole is removed. If the lathe is self-acting or screwcutting, use the self-act with a fine feed. I keep my Milnes lathe set up for a feed of 110 turns per inch, and use this for all cylinder-boring on that machine. My Myford Super-7 has a gearbox, and when cylinder-boring on that, I use the 0.010 in. feed for rough-boring, and 0.004 in. for finishing. No reaming is then required.

If the lathe has no self-act, the top slide must be set to bore truly before mounting the casting. Put a piece of round rod about $\frac{5}{8}$ in. dia. in the three-jaw chuck, and leave about $1\frac{1}{2}$ in. projecting. With a roundnose tool in the rest, take a fine cut about 1/64 in. deep for about $1\frac{1}{4}$ in. length. Then measure the diameter of the rod at beginning and end of cut, with a "mike" or calipers. If the "mike" shows a difference of not more than 0.0005 in. (half a thousandth) or you can detect no difference in the feel of the calipers, the slide is all right for boring. If the "mike" shows a greater variation, or if the calipers are tighter at one end than at the other, alter the top-slide accordingly and have another go, ditto-repeating until you get it O.K. The third shot usually does the trick!

Bore to within about 1/64 in. of finished size, then regrind the boring-tool, as the rough cuts will probably have taken the fine edge off it. Replace and continue boring to finished diameter, and if using the top slide, turn the handle very slowly and evenly. Finally run the tool through two or three times without altering the cross-slide setting. This will make up for any spring in the tool, and the bore should be truly circular, smooth inside, and parallel from one end of the casting to the other.

The other end of the casting can be faced off by mounting the job on a stub mandrel held in the three-jaw. This is just a short piece of round rod turned to a tight fit in the cylinder bore. Don't take it out of the chuck, just push the cylinder on it with the rough end outwards, and face this off to bring the casting to correct length. If the cylinder slips on the mandrel, a piece of paper around the mandrel will not only teach it better manners, but won't damage the finished bore.

How to machine the flat faces.

To true up the portface and bolting-face, mount the casting end-up on the angleplate, fixing it with a bolt through the bore. To protect the faced ends, put a piece of soft sheet metal (brass, copper or aluminium) between the end and the angleplate, first drilling a hole in the middle for the fixing bolt. Put a similar piece on the upper end, and a big washer on top of that, under the nut. Set the casting as centrally as possible, then apply a try-square with its stock against the faceplate, and adjust the casting until the bolting-face touches the blade of the square for its full width. This will bring the portface right sides, and one $\frac{1}{8}$ in. wide for the ends. They can be home-made from silver-steel in a matter of minutes.

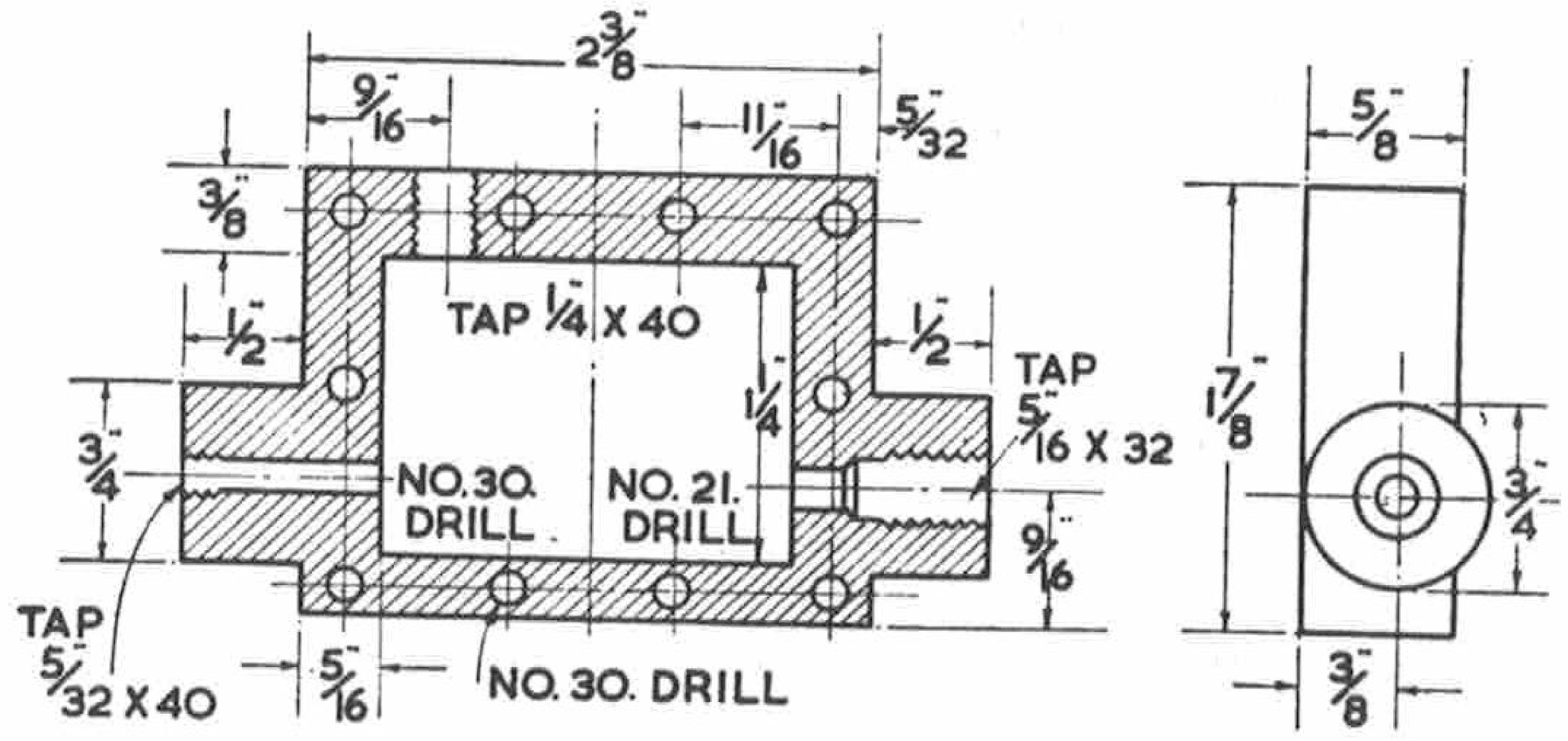
To drill the passages, file a bevel at the lip of each bore, about $\frac{1}{2}$ in. long, as shown in the end view of the cylinder. It should be level with the seam port. Make three centrepops on it, one in the middle, and the others at a bare 3/16 in. either side. From these, drill $\frac{1}{8}$ in. or No. 30 into the steam port. Set the casting in a machine-vice on the drilling machine table at such an angle that the drill will go straight down into the port; you can sight this by bringing the drill down outside the casting. When drilling, keep withdrawing the drill every $\frac{1}{8}$ in. or so, to clear the chips, and be mighty careful as the drill breaks through into the port, or away will go the tip. If the drill is ground a little off-centre, it will make a hole a shade larger than its own diameter, and if it breaks, the fragments are easily shaken out.

Passages can be drilled with a hand-brace if the casting is held in the bench vice on an angle, so that the hand-brace can be held in a horizontal position, and the drill will go straight for the port. Take the same strict caution as before, to avoid chip-clogging, and watch your step as the drill pierces the port wall, or you've had it!

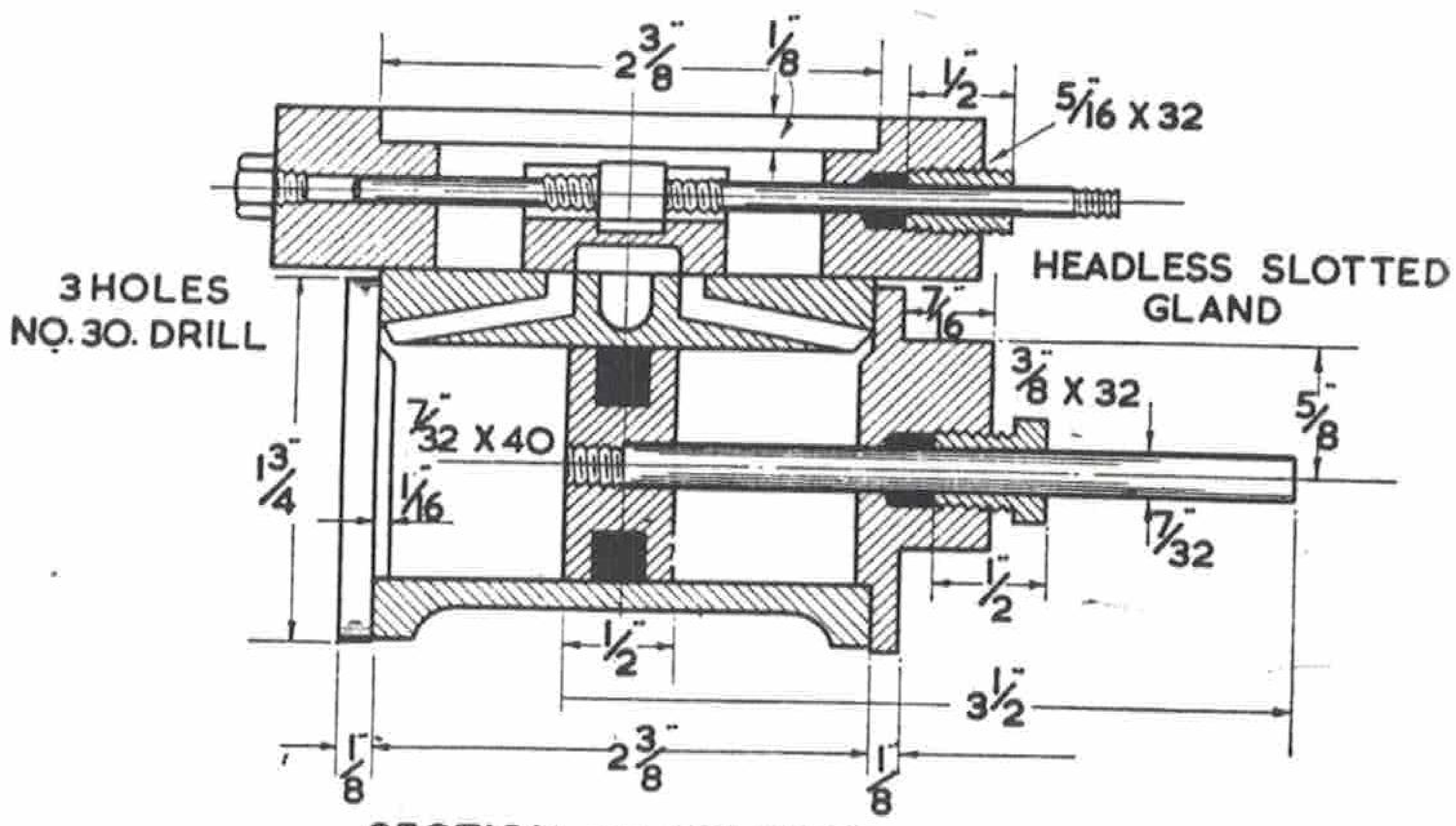
On the centre-line of the bolting-face at $\frac{3}{8}$ in. from the top, drill a 9-32 in. hole $\frac{3}{8}$ in. deep, and tap it 5/16 in. x 32. Drill a 7/32 in. hole down the corner of the port to meet it, as shown in the section. That forms the entrance to the way out (says Pat) for exhaust steam.

Cylinder covers

The covers should have chucking-pieces on the outside. Chuck the front cover in the three-jaw, setting



STEAM CHEST



SECTION OF CYLINDER

it to run as truly as possible. Face off, turn the register to a nice fit in the cylinder bore, face the flange with a knife tool, and turn to diameter. Saw off the chucking piece, reverse in chuck, either holding by the edge, or preferably in a stepped bush, and face the other side. Ditto-repeato on the back cover, but after turning the register, which must be an exact fit in the bore of the cylinder, centre with a centre-drill and put a 7/32 in. drill through. Turn to diameter, then cut off the chucking-piece, re-chuck the other side out (a stepped bush is advisable here) face off the boss which supports the guide-bar, open out the hole with an 11/32 in. pin-drill to a bare $\frac{1}{2}$ in. depth, and tap $\frac{3}{8}$ in. x 32. Always use a pin-drill for opening out holes for piston and spindle glands. An ordinary drill doesn't always follow the smaller hole when opening out, and the tap will follow the enlarged hole; consequently the hole in the gland won't line up exactly with the one in the cover, and the piston-rod will bind.

The flat top of the boss can be endmilled in exactly the same way as an axlebox, by clamping the cover under the slide-rest tool-holder, packing it up to centre-height, and running it across a $\frac{1}{2}$ in. endmill held in the chuck. For the gland, chuck a piece of $\frac{1}{2}$ in. round bronze rod, face, centre, and drill to about $\frac{5}{8}$ in. depth with 7/32 in. drill. Turn $\frac{3}{8}$ in. length to $\frac{3}{8}$ in. dia. and screw $\frac{3}{8}$ in. x 32. The screw should fit the tapped hole fairly tightly so that it won't work loose when the engine is running. Part off at $\frac{1}{8}$ in. from the shoulder, reverse in chuck, skim off any burring, and cut four saw-slots as shown. If preferred, the gland can be made from hexagon rod, so that an ordinary spanner can be used for adjustment.

Use a simple jig to drill the screwholes in the covers. Get a metal washer $1\frac{3}{4}$ in. dia. chuck it truly in the three-jaw and bore it out to a nice fit on the for machining, which is then done with a roundnose tool set crosswise in the rest.

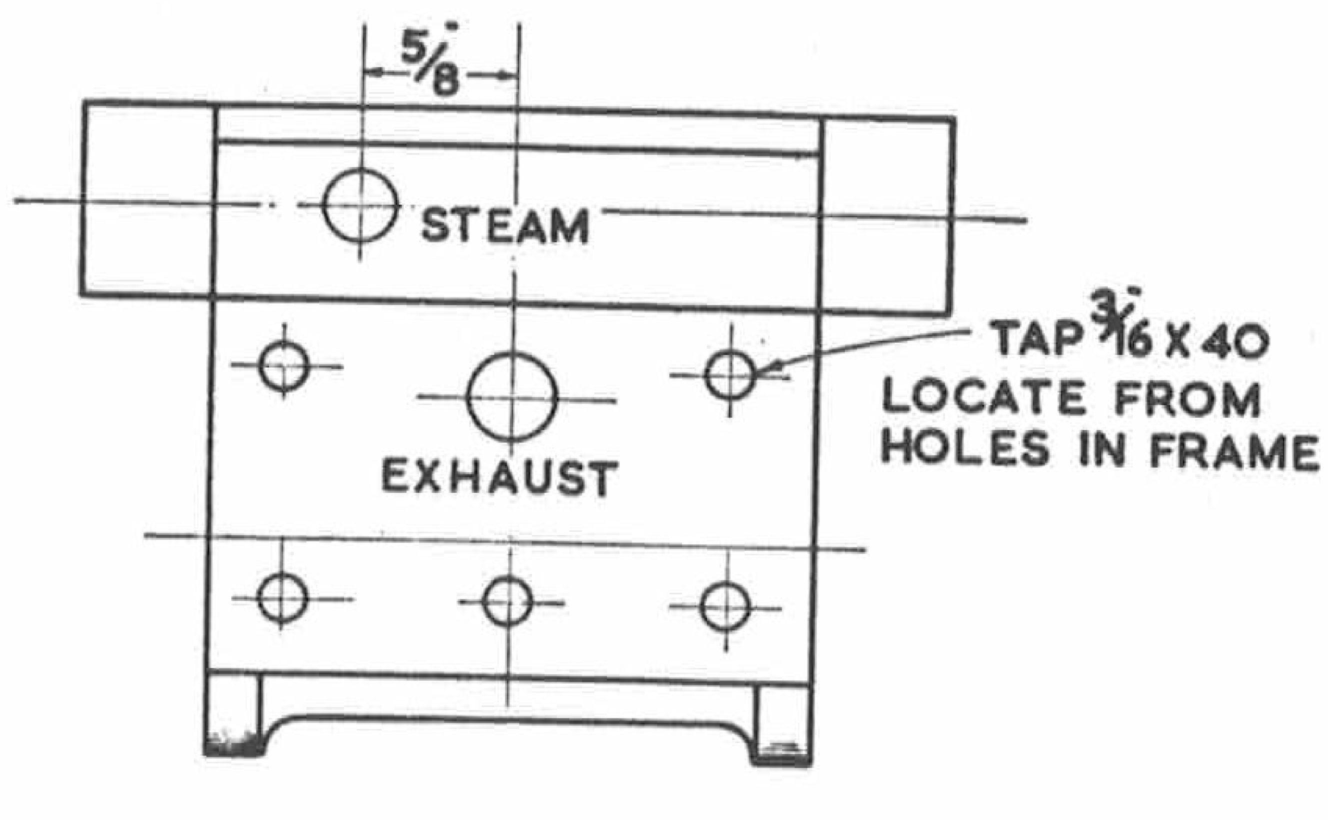
No marking-out is needed; just face off until the portface is exactly $\frac{3}{8}$ in. from the edge of the bore. Then slew the casting around a quarter-turn, and apply the try-square again, stock to faceplate, and blade to the machined portface. When the blade lies close against this for its full width, the bolting-face is right for facing off, so give it a dose of the same medicine as the portface, and carry on until it is 7/16 in. from the edge of the bore. That settles the boring and facing; nothing to be alarmed about, is it?

Ports and passages

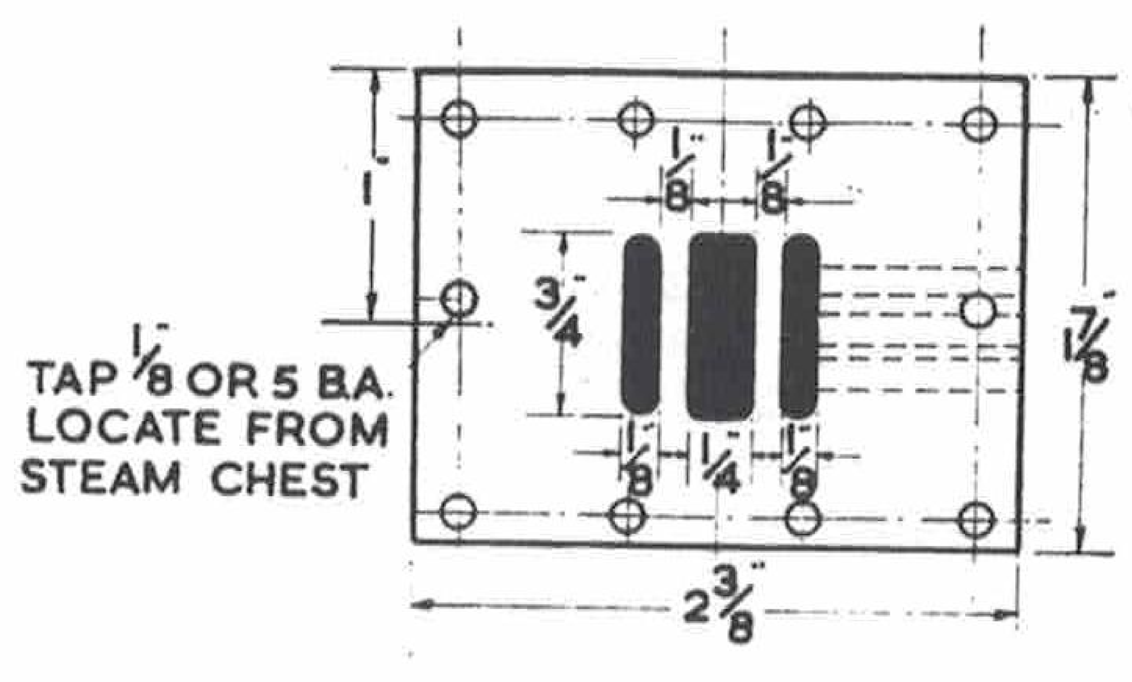
Coat the portface with marking-out fluid, then mark off the ports as shown in the drawing. Note that they are not exactly central, the middle being 1 in. from the bolting-face. The easiest way to cut the ports is with an endmill or slot-drill held in the chuck, with the cylinder up-ended and secured to an angleplate exactly in the same way as for the facing job. The angleplate should be bolted to a vertical slide on the lathe saddle, and by adjusting the height of the slide, all three ports can be presented to the cutter in turn. The cylinder should be fed on to the cutter until it penetrates about 1/16 in. and then traversed across the cutter by turning the handle of the cross-slide. Warning—take great care to avoid turning the handle too far and running past the marked end of the port. Repeat operation until the port is $\frac{1}{4}$ in. deep.

The same cutter can be used to cut the exhaust port, although it is twice the width; simply take three traverses, each overlapping, but be careful to cut to the same depth each time. The same method of port-cutting can be used if a vertical slide isn't available, by mounting the casting on the saddle with suitable thicknesses of packing under it, to bring the port level with the cutter. The portface should be exactly at right angles to the lathe centres.

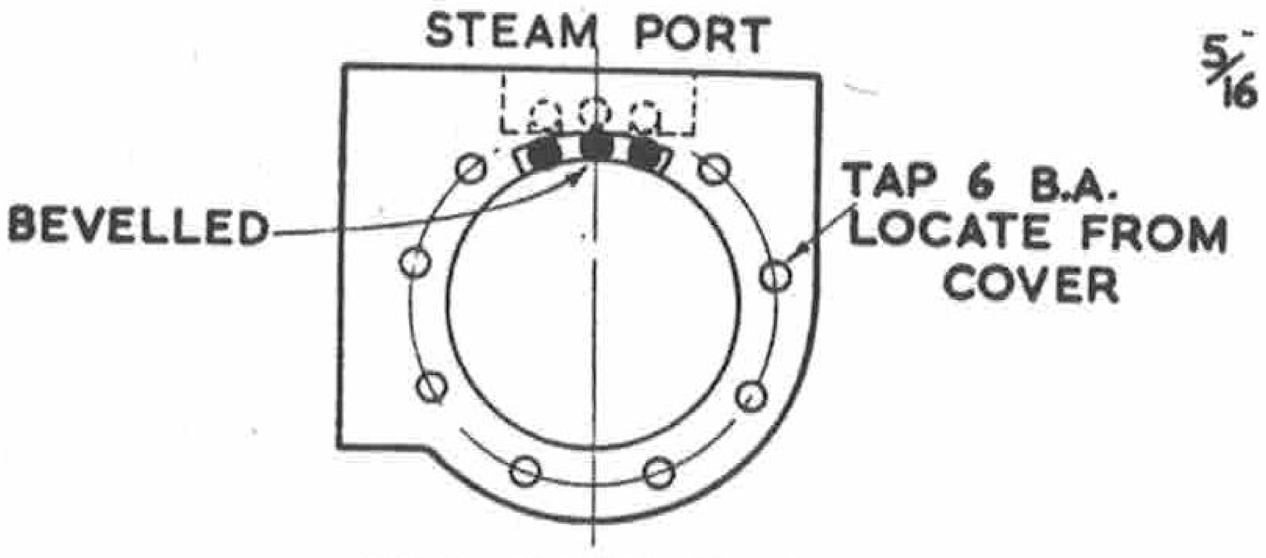
Ports can be cut by hand, if facilities for doing the



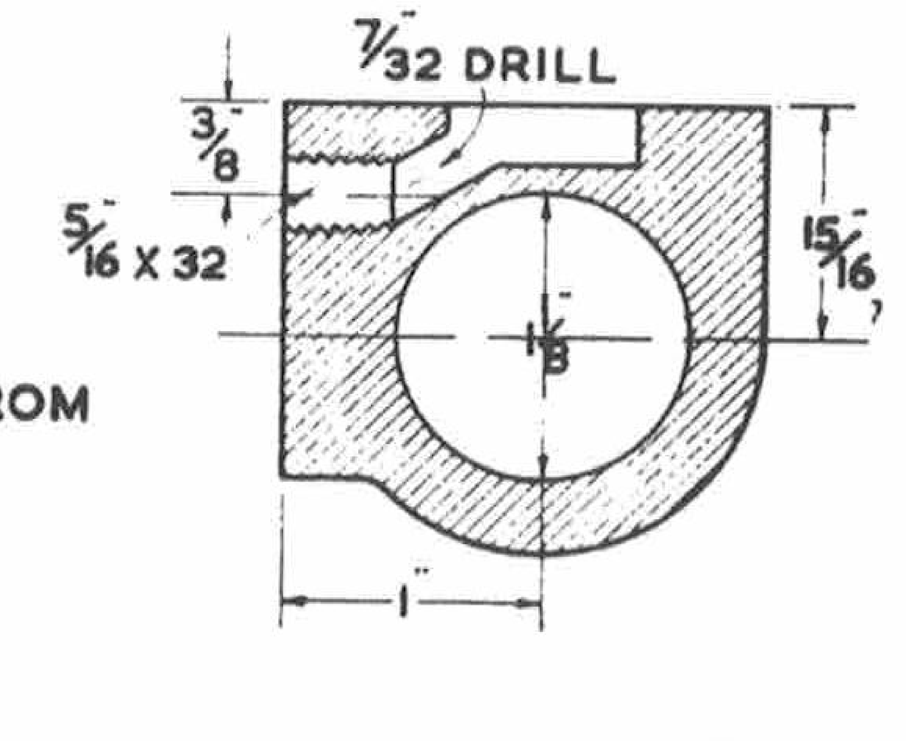
BOLTING FACE OF R.H. CYLINDER



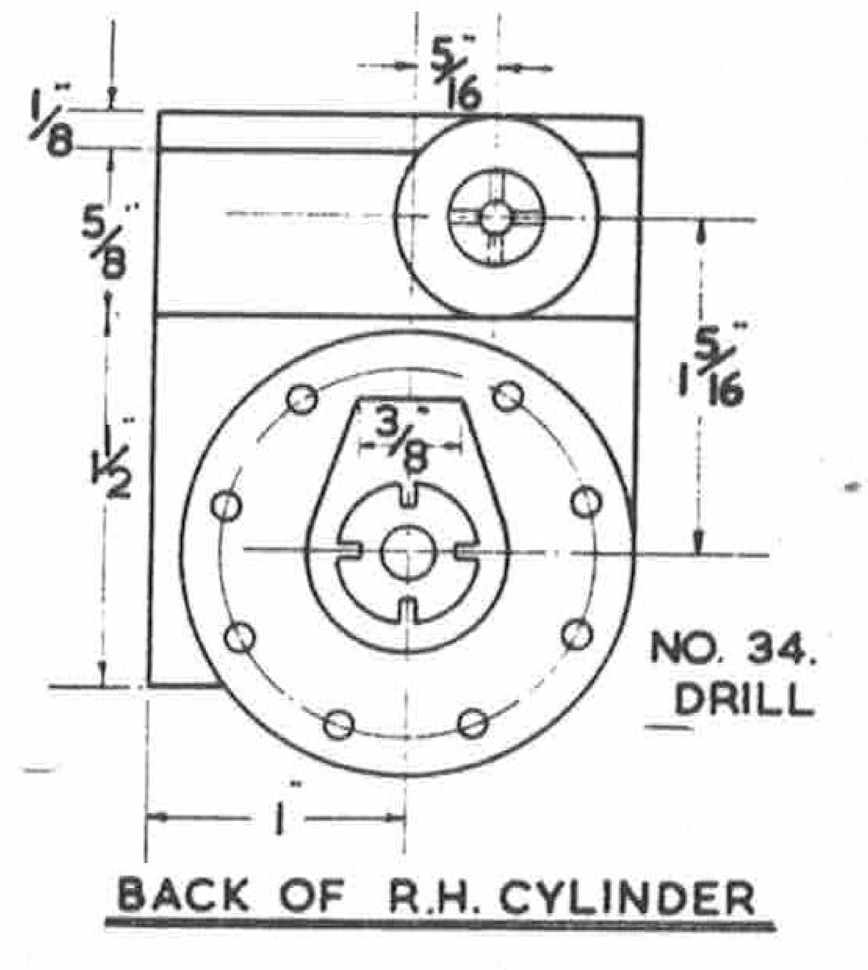
PORTFACE



END OF CYLINDER SHOWING STEAM PASSAGES



SECTION THROUGH EXHAUST PORT



BACK OF R.H. CYLINDER

job as above aren't available. Drill holes $\frac{1}{4}$ in. deep and as close together as possible, in the marked-out space, using No. 34 for steam ports and 7/32 in. for exhaust port. Chip the edges to the correct dimensions with two small chisels, one $\frac{1}{4}$ in. wide for the registers on the covers. Set out the screw-holes on it as shown on the back cover; the wider spacing of the topmost pair is to miss the steam passages. Drill the holes with a No. 34 drill, then clamp the washer to each cover in turn, and poke the drill through the lot. Set the washer so that the wide space will match the passage entrances when the covers are fitted. Watch this point when setting the covers on the cylinders for locating the screwholes in the flanges.

The flat on the guide-bar boss on the back cover much be exactly at right angles to the bolting-face, so after putting it on as near as you can by eye, lay the cylinder on the lathe bed with the bolting-face down. Apply a try-square with the stock on the bed, and set the flat on the boss to the blade of the square; that will make certain of it. Clamp the cover to the cylinder in that position, run the No. 34 drill through all the holes, making countersinks on the flange, remove cover, drill the countersinks No. 44 and tap 6 BA. The screwholes in the front covers are located in similar fashion.

Pistons and rods

The piston-rods are $3\frac{1}{2}$ in. lengths of 7/32 in. rustless steel rod with $\frac{1}{4}$ in. of 7/32 in. x 40 thread at one end. For the pistons, chuck a piece of $1\frac{1}{4}$ in. drawn or cast bronze rod with about $1\frac{3}{8}$ in. projecting from the jaws. Face, centre, drill to about $1\frac{1}{8}$ in. depth with 3/16 in. drill, turn $1\frac{1}{4}$ in. length to a little over $1\frac{1}{8}$ in. dia. then at $\frac{1}{8}$ in. from the end, cut a groove a full $\frac{1}{4}$ in. wide and deep with a parting-tool. Part off at a full $\frac{1}{8}$ in. beyond that, then turn a similar groove, skimming the end true first if the parting-tool has left any raggedness, as some of them are fond of doing. Part off the second blank, re-chuck with the parted side out, face to $\frac{1}{2}$ in. length, open out the hole to $\frac{1}{4}$ in. depth with No. 3 or 7/32 in. drill, and tap the remnant 7/32 in. x 40. Put one of the piston-rods in the tailstock chuck, screwed end outwards, run it up to the piston, enter it, and pull the lathe belt by hand until the rod seats home in the plain part of the hole. The piston will then be perfectly true on the rod.

Chuck the rod in a 7/32 in. collet if your lathe has them, otherwise use a split bush. To make it, chuck a $\frac{1}{2}$ in. length of $\frac{3}{8}$ in. rod in the three-jaw, face, centre, and drill 7/32 in. right through. Make a mark on the bush opposite No. 1 jaw, remove bush, slit it longways with a fine hacksaw, replace in chuck with the mark opposite No. 1 jaw, run a 7/32 in. drill or reamer through it to remove any burring, put the piston-rod in it with the piston close to the bush, and tighten the chuck jaws. The rod will then run truly. Very carefully turn the piston with a roundnose tool, a few thousandths at a time, until it fits the cylinder bore exactly, without shake.

Steam chests

Grip one boss in three-jaw and set the other to run as truly as possible. Centre it with a centre-drill, bring up the tailstock to support it, and turn the outside to $\frac{3}{4}$ in. dia. facing off the end of the casting at the same setting. Reverse and repeat operation on the other boss, facing both bosses as close as the tool will go to the centre-point. Make sure that the chuck is holding tightly, then run the tailstock back and finish facing off the little bit close to the boss very carefully indeed. Put the tailstock chuck in, with No. 21 drill in it, drill right through boss and end of steamchest, open out with a 9/32 in. pin-drill to 9/16 in. depth, and tap 5/16 in. x 32.

Reverse in chuck, gripping by the tapped boss, and set the other boss to run truly by running the centre point in the tailstock up to it. Finish the little bit of facing as above, then put a No. 30 drill right through boss and end of chest. Tap the end of the hole 5/32 in. x 40 for about $\frac{1}{4}$ in. down.

The flat side of the steam chest can be faced off by setting the casting in the four-jaw chuck and using a roundnose tool set crosswise in the rest. If a milling-machine is available, the part between the bosses can be machined off with the casting in a machine-vice on the table, running it under a small slabbing cutter on the arbor. It can be done in the lathe in similar manner, in a machine-vice on the saddle, and a cutter on an arbor between centres, but will have to be set at correct height to true up the face at one cut, as there will naturally be no height adjustment. As a last resort, the face can be trued up by judicious use of a file—my good old universal stand-by in the days when I was " 'ard-up-'n'-'appy".

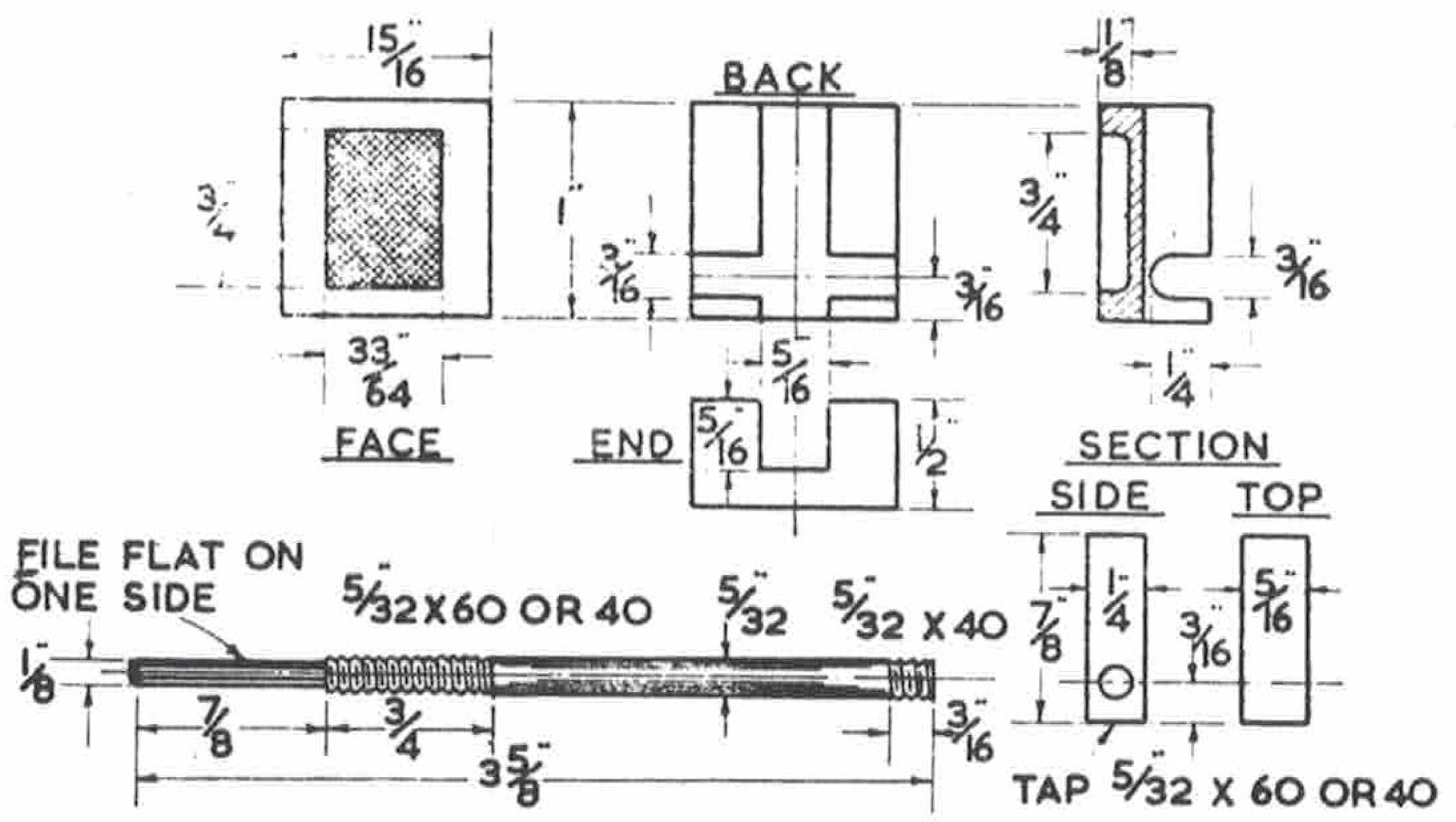
The two side walls can also be smoothed off with a file; then in the wall farthest away from the bosses, at 9/16 in. from the end, drill a 7/32 in. hole and tap it $\frac{1}{4}$ in. x 40 for the steam pipe. Finally set out and drill the studholes as shown in the section.

Temporarily clamp the steam chest to the portface on the cylinder, run the No. 30 drill through the studholes and make countersinks in the portface, remove chest, drill the countersinks No. 40 and tap $\frac{1}{8}$ in. or 5 BA. The steam chest cover can be either cast or made from a piece of $\frac{1}{8}$ in. brass plate measuring $2\frac{3}{8}$ in. x $1\frac{7}{8}$ in. If cast it will have a chucking-piece in the middle, which can be held in the three-jaw and the contact side trued up. The plate version will need no machining. To locate the studholes, clamp the cover to the steam chest between the bosses, and put a No. 30 drill through, using the holes in the chest walls to guide the drill. The gland is headless, and is made from a piece of 5/16 in. rod; grip in three-jaw, face, centre, drill No. 21 for $\frac{5}{8}$ in. depth, screw the outside 5/16 in. x 32 and part off at $\frac{1}{2}$ in. from the end. Cross-slot the end with a thin flat file.

Slide-valve, spindle and nut

THE slide-valves can be cast, or made from 1 in. x 1/2 in. bronze or gunmetal bar. If cast, they will have the grooves and exhaust cavity cast in, and will only need cleaning up to size. To make them from bar, saw off two pieces a full 1 in. long, chuck each in four-jaw, and face off each end to an overall length of 15/16 in. If a vertical slide is available, bolt a small machine-vice to it, grip the blank in it, and traverse it across a 1/8 in. endmill or slot-drill in the chuck, to cut the exhaust cavity. This should be carefully marked out, and must not differ from the dimensions shown, although rounded corners won't make any difference to the working of the engine.

The cavity can be hand cut if a series of 1/8 in. holes are drilled all over the marked space, 1/8 in. deep and as close together as possible. The surplus metal between the drillings can then be removed with a little chisel. If a regular milling machine is available, the grooves in the back can be cut with the valve in a machine-vice on the table, using a 1/4 in. side-and-face cutter for the nut slot, and a 3/16 in. cutter with rounded teeth for the spindle slot. It can be done in the lathe with the cutters on an arbor between centres, and the valve held in a machine-vice (regular or improvised) bolted to the saddle. The grooves can also be end-milled like those in an axlebox, with a suitable end-mill in the chuck; it doesn't matter if the spindle groove is flat-bottomed instead of rounded.



SLIDE-VALVE, SPINDLE AND NUT

The spindle is a 3 5/8 in. length of 5/32 in. round rustless steel or drawn phosphor-bronze. Chuck in three-jaw with 1 in. projecting, and turn 7/8 in. length to 1/8 in. dia. then pull it out an inch or so, and screw the next 3/4 in. length 5/32 in. x 60 if you have that size tap and die. If not, 40 will do. Put 3/16 in. of 5/32 in. x 40 on the other end. The nut is a 7/8 in. length of 1/4 in. x 5/16 in. bronze or brass rod with a hole through the wider part, 3/16 in. from one end, tapped to suit the thread on the spindle.

The complete assembly is shown in the section. The pistons are packed with a ring of 1/4 in. braided square graphited yarn, the ends being cut on the slant like a metal piston-ring. The glands are packed with ordinary stranded graphited yarn. The joints between covers, steam chest, and top cover are made from 1/64 in. Hallite or similar jointing, but thick paper doped with cylinder oil can be used at a pinch. Commercial screws can be used for holding the parts together; on my own engine I used hexagon-headed screws for the circular covers, and countersunk screws for the steam chest and cover, which saved the trouble of making long studs. Don't forget to give portfaces and valves a few rubs on a piece of fine emrycloth laid on the lathe bed, or something equally flat and true, before putting the screws in. This insures the valves being steamtight on the portfaces.

Guide bars

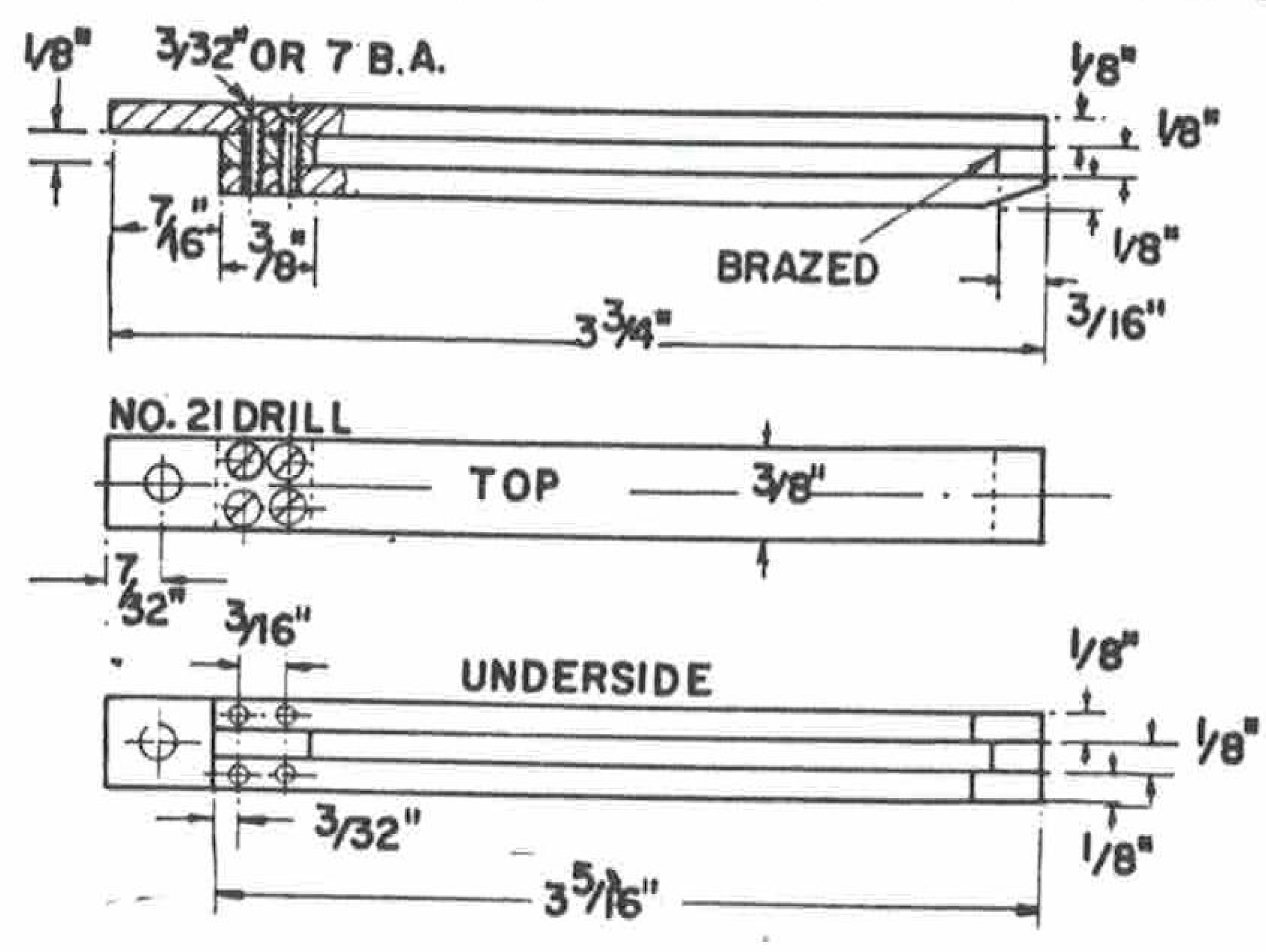
Several types of guide-bar and crosshead are used on Southern locomotives, but the one I prefer is the Laird kind, and so I am specifying that type for *Betty*. Beginners may be interested to know that when an engine is running chimney first, all the bearing pressure comes on the top bar. When the crank is on bottom centre, the thrust of the piston tends to make the piston-rod and connecting rod double up like closing a pocket knife, but the top bar prevents that antic. When the crank is on the top centre, the piston tries to pull the rods into a straight line, but again the top bar says no. When the engine goes tender first, the process is reversed, and it is the bottom bar that performs the restraining act.

As a tender engine usually does all its work with the smoke-box end leading, naturally the top bar takes the lion's share of stress. With the Laird type, the top bar can be made the full width of the crosshead, as will be seen in the accompanying drawings, and wear of the bar and crosshead is practically negligible in a small locomotive.

In the case of *Betty*, each top bar is made from a piece of 3/8 in. x 1/8 in. silver-steel. Saw off two pieces about 3 7/8 in. long, chuck them together in the four-jaw, and face off the end. Reverse in chuck, taking care to keep the faced ends level, and face the other end until the overall length is 3 3/4 in. This will make certain that the ends are square with the sides. At 7/32 in. from one end, and on the centre line of the bar, drill a No. 21 hole.

The bottom bars are twins, so four pieces of 1/8 in. square silver-steel will be needed, each finished off to 3-5/16 in. length. The spacer at the cylinder end is a 7/8 in. length of the same kind of steel used for the top bar, and that at the outer end a piece of the same stuff but only 3/16 in. long. This spacer is brazed to the bars, but the one at the cylinder end must be fitted with screws, otherwise you won't be able to get the crosshead in place.

At one end of each bottom bar, drill two No. 48 holes as shown in the underside view, then assemble the bars as shown, putting a toolmakers' cramp near each end to keep them in position. Be sure all three are exactly parallel. Now drill through



GUIDE BARS

the spacer and the top bar with the No. 48 drill, using the holes in the bottom bars as a guide. Take off the cramps, tap the holes in the bottom bars 3/32 in. or 7 B.A., open out the holes in the spacer and top bar with No. 41 drill, and countersink those in the top bar. Replace the bars and fix them together with countersunk head screws as shown.

Next, put the spacer at the outer end in place, and wind a few turns of thin iron wire, such as used for making up bunches of flowers, around the bars just clear of the spacer, which can then be brazed in place. Apply some wet flux (Boron compo mixed to a paste with water) to the joints, heat to bright red, and touch the joints with a bit of thin soft brass wire, which will melt and flow in. Be sparing with it, don't get any on the working surface of the bars. Let cool to black, then quench out in clean cold water and clean up with fine emery cloth. Finally file a bevel on the bottom bars as shown in the drawing.

Each assembly is attached to the flat place on top of the gland bosses on the back cylinder covers by a 5/32 in. x 40 screw, either hexagon or cheese head. This will have to be made, as it isn't a commercial size. Just chuck a bit of ¼ in. rod, face the end, turn ⅜ in. length to 5/32 in. dia. screw it 5/32 in. x 40 and part off at ⅛ in. from shoulder. If round steel is used, slot the head with a thin hacksaw. When locating the hole in the gland boss, keep the bar pressed well up against the cylinder cover, and make sure the bar is at right angles to the cover. Locate, drill and tap the screwholes same as described for the steam chest.

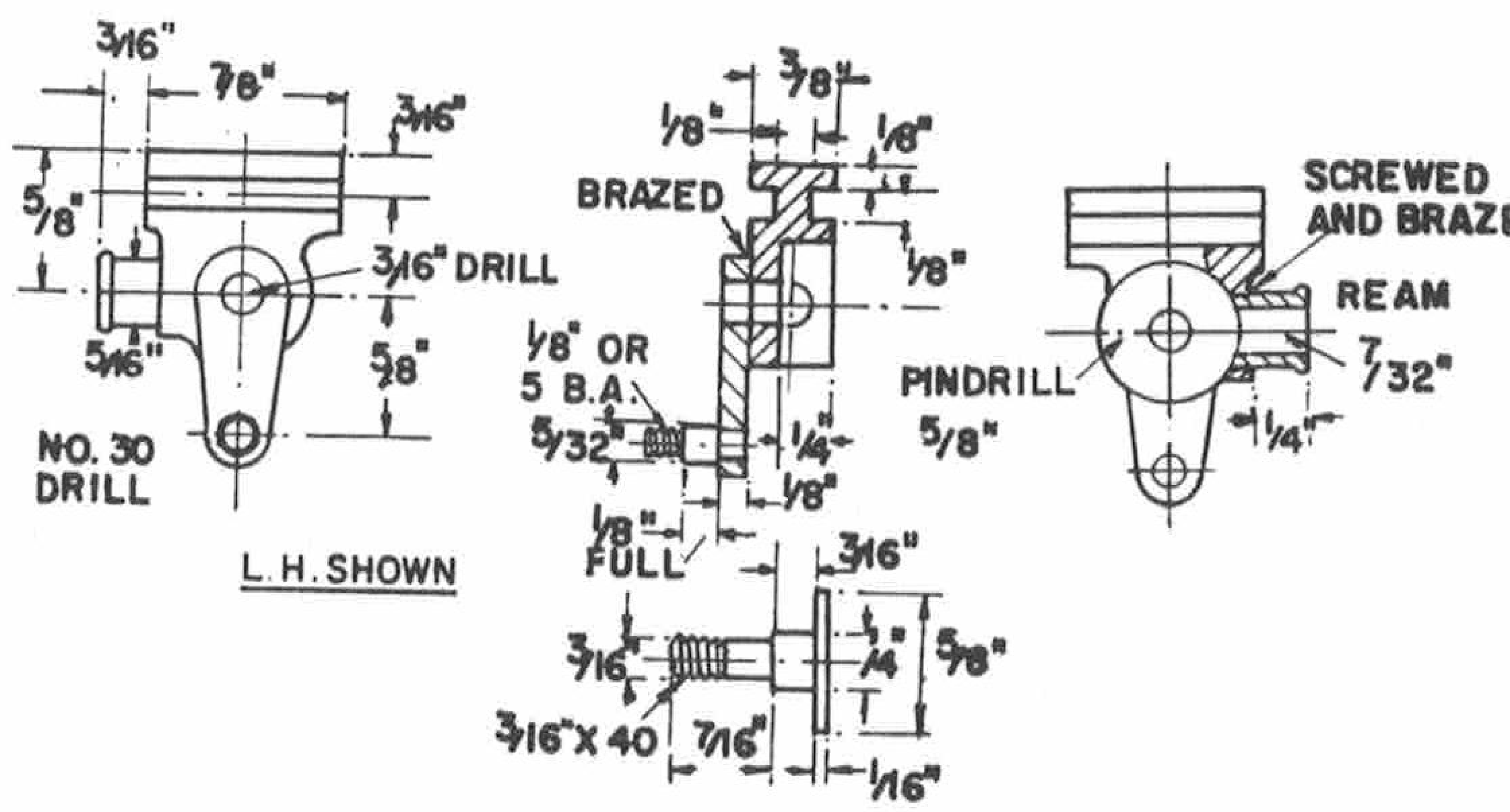
Crossheads

Friend Reeves may be able to supply crossheads ready cast complete with drop arm, in nickel bronze (German silver) in which case they will only need cleaning up with a file, holes drilled for crosshead-pin and piston-road, and a pin for the union-link fitted. If built up, a piece of ⅜ in. x 1 in. mild steel bar will be needed, about 2 in. long.

The first item is to mill a ⅛ in. groove ⅛ in. deep, along each wide side, at ⅛ in. from the edge, as shown in the section. If a milling-machine isn't available, this can be done with a ⅛ in. saw-type cutter mounted on an arbor between lathe centres, the piece of bar being held in a machine-vice (regular or improvised) bolted to the saddle. Set the bar so that the cutter can take out the full ⅛ in. depth at one cut. It will do this easily if the lathe is run slowly, and pleny of cutting-oil applied to the cutter. When one cut is finished, don't on any account shift the saddle sideways, but just turn the bit of bar over, and ditto-repeato the operation. The two grooves will then be exactly in alignment.

Square off each end of the bit of bar in the four-jaw chuck. At ⅝ in. from the top (above the grooves) and 7/16 in. from each end, make a heavy centrepop, and drill through the bar with 3/16 in. drill. These holes must go through dead square. Next, with a ⅝ in. pin-drill having a 3/16 in. pilot pin, drill a recess ¼ in. deep. Saw the piece of bar in half, and file each half to the shape shown, so as to form right-hand and left-hand crossheads. The lower half is filed to the edge of the pin-drilled hole, as shown in the back view.

On the centre-line of the flat end, at ⅝ in. from the top—in line with the hole for the crosshead pin—make a centrepop, drill a 9/32 in. hole and tap it 5/16 in. x 40 or 32. Use the finer thread if you



CROSSHEAD AND PIN

have the tap and die. Note that this hole must be dead parallel with the grooves, and the best way to ensure this is to do the drilling with the crosshead in the four-jaw chuck. If you bring up the tailstock with a centre-point in it to act as guide, it is easy enough to adjust the chuck jaws until the centre-point enters the pop mark, but be sure that the top of the crosshead is touching one of the chuck jaws for its full length. Then tighten the jaws, first drill a No. 30 hole with the drill in the tailstock chuck, open out to 9/32 in. and tap as above. Clamp the tapwrench on the tap close to the flutes, and hold the shank loosely in the tailstock chuck. Then pull the lathe belt with your left hand, and enter the tap in the hole, into which it will be guided by the tailstock chuck. Put a taste of cutting oil on the tap, work the lathe belt back and forth while preventing the tap from turning by holding on to the tapwrench, and you'll have a lovely true thread in a few wags of a dog's tail. I hope that our experienced readers won't mind my using space to help beginners!

To make the boss, chuck a piece of ⅜ in. round rod, face, centre, and drill to ½ in. depth with No. 4 drill. Turn ⅜ in. length to 5/16 in. dia. and screw to match the tapped hole in the crosshead. Part off at 1/16 in. from the shoulder, reverse in chuck and round off the flange with a fine file. The distance from the end of the screwed part to the flange should be ¼ in. Screw the boss tightly into the crosshead.

The drop arm is filed up from a piece of ⅛ in. steel; the odd bits left over from the frames do fine for these oddments. Drill the larger end 3/16 in. and the smaller No. 30. To hold this merchant in place while you braze it and the boss, chuck a piece of 3/16 in. round steel in three-jaw, centre it, drill about ¾ in. deep with ⅛ in. drill, and part off two ¼ in. full lengths. Put the drop arm in place, and poke one of the drilled bits of rod through the holes in it and the crosshead. Then if you put the end of a centre-punch in the hole in the rod and give it a wallop with a hammer, the end of the rod will be spread and will hold the drop-arm in place. Both ends of the pin will need spreading, naturally. See that the drop-arm hangs straight down when the crosshead is horizontal.

Both drop-arm and boss can then be brazed at the same heating, by the process already mentioned, and avoid putting too much brass on, or the pristine beauty of the job will be cattled up. After cleaning, put a 3/16 in. drill through the hole in the pin. This will clean out the pin altogether, and leave a true hole through crosshead and drop arm for the crosshead pin on which the little end of the connecting-rod works. Ream the piston-rod boss 7/32 in.

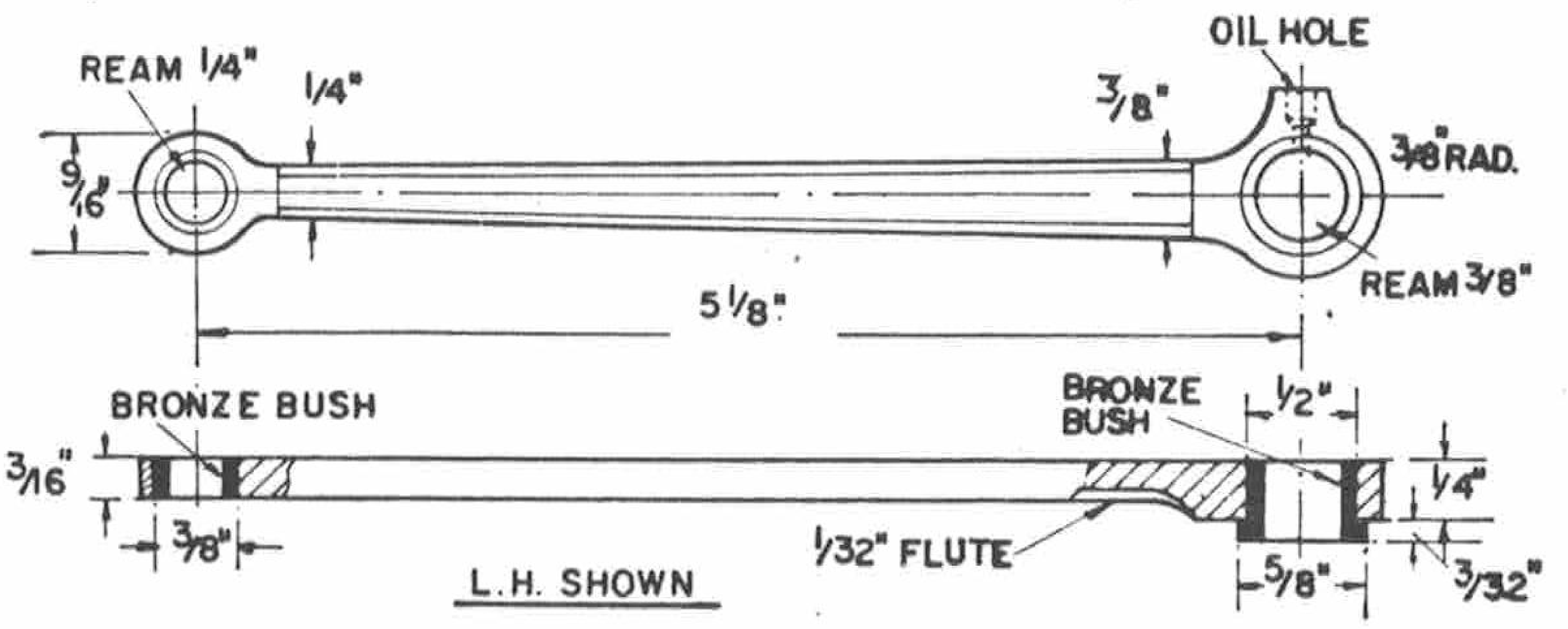
The final stage is to fit the pin for the union link at the bottom of the drop arm. Chuck a bit of 5/32 in. silver-steel and turn 3/16 in. length to 1/8 in. dia. screwing 1/8 in. or 5 B.A. Part off at 5/16 in. from shoulder, reverse in chuck and turn a full 5/32 in. to a tight fit in the No. 30 drilled hole at the bottom of the drop-arm. Squeeze it in and rivet over the projecting end behind the arm ; put a nut on the threaded part while squeezing and riveting, or the threads may get damaged.

To make the crosshead pin, or wrist pin as it is sometimes called, chuck a piece of 3/8 in. round steel, face the end and turn 5/8 in. length to 1/4 in. dia. Further reduce 7/16 in. bare length to 3/16 in. dia. and screw half of this 3/16 in. x 40. Part off at a full 1/16 in. from shoulder. The pin should fit tightly in the hole through crosshead and drop arm.

Connecting-rods

The connecting-rods can be machined up from two 6 in. lengths of 1/4 in. x 7/8 in. mild steel, or nearest size larger. As the actual machining is done in the same way as described for the coupling-rods, there is no need to go through the whole rigmarole again. Coat one of the rods with marking-out fluid, mark out the shape of the rod very carefully, drill 1/8 in. holes at the centres of big and little ends, temporarily rivet the blanks together with bits of 1/8 in. steel, and mill or saw and file them to outline.

If milling, take care to set the blanks in the machine-vice so that the taper is parallel to the table of the machine. Set the needle of your scribing-block or surface-gauge to the marked line at one end of the rod, and adjust the other end of the line to the same height. If doing the job by hand, set the blanks in the bench vice with the taper line just showing at the jaws, and go right ahead as for coupling-rods.



CONNECTING ROD

After getting the blanks to shape, part them for milling the faces, which is done by clamping them to a piece of bar held in the machine-vice as previously described, and operating with a small slabbing cutter on the arbor of the machine, or on a mandrel between centres if the job is done in the lathe. I have shown tapered flutes on the drawing, but taper flutes aren't essential (neither are the flutes, for that matter !) and a straight flute about 5/32 in. wide looks quite all right. Most of my own engines have parallel flutes, and Inspector Meticulous hasn't raised a single moan about them.

The little ends of the rods are flush-bushed, in the same way as the middle boss of the coupling-rods. The big-ends are furnished with pressed-in flanged bushes, like those in the rear coupling-rod bosses, made to the given dimensions. Note that the flange is 3/32 in. thick, which gives plenty of surface for resisting wear on the hardest-worked bearing on the whole engine. Incidentally, if anybody building *Betty* can obtain small ball-bearings that would fit both big and little ends of the connecting-rods, I advise their use by all means. If I'm spared to complete the super-pacific in 3½ in. gauge that I started some years ago and was not able to carry on with for many reasons, I shall fit ball bearings to the connecting-rods. She already has ball-bearing axle-boxes ; might as well go the whole hog ! Drill a 1/16 in. or No. 53 hole for oiling purposes in the top of each big-end boss, and counterbore it to 1/8 in. depth with No. 30 drill.

How to erect cylinders

First fit the crossheads to the guide bars, which is done by removing the screwed-in spacer, inserting the crosshead between the bars, and replacing spacer. The crosshead should slide freely from one end of the bars to the other, but without slackness at any part of the movement. If there should be any tightness, ease it before fitting the guide-bars to the cylinders. When the screw holding the bars to the gland boss is tight, and the piston-rod has entered the hole in the crosshead boss, the lot should work quite freely.

The location of the cylinders was shown in the drawing of the frame, and should be clearly marked on both frames. Very carefully set one of the cylinders in this position, and hold it there with a big cramp put over the cylinder and frame. Pull out the piston-rod as far as it will go, and see if it is on the centre-line of motion. The way I do this would give Inspector Meticulous an awful shock.

I just take a piece of ordinary sewing cotton about a foot long, stretch it tight, and hold it against the cylinder so that it lies along the middle of the piston-rod. If the other end of the taut thread passes exactly across the middle of the driving axle where it is showing on the wheel boss, the cylinder is set O.K. If it doesn't, then the cylinder is adjusted until it does. Note that the distance from the vertical centre-line of the cylinder to the front edge of the frame-plate (not the front of the beam) should be 4¼in.

To locate the holes for the screws on the bolting-face of the cylinder, use a 3/16 in. drill in a hand-brace, and put it through the holes in both frames at once. A new 3/16 in. drill is long enough to reach, if only about 1/4 in. of it is held in the chuck on the hand-brace. If your drill is worn and won't reach, lengthen it by brazing a short piece of 3/16 in. silver-steel to the shank. File away half the shank for 1/4 in. length, do the same with the bit of silver-steel, put the two flats together with a dab of wet flux in the joint, heat to bright red and touch the joint with a piece of brass wire. Let it cool to black, then quench in water and clean up. Take care to avoid heating the drill above the bottom of the flutes, or it won't be of much use for drilling !

With the drill through the holes in both frames, make deep countersinks on the bolting-face of the cylinder; then remove it, drill the countersinks to 5/16 in. depth with 5/32 in. drill, and tap 3/16 in. x 40. Serve the other cylinder with a dose of the same medicine, then make the screws from 5/16 in. hexagon steel. Chuck a length in three-jaw, face the end, turn $\frac{3}{8}$ in. length to 3/16 in. dia. and screw 3/16 in. x 40. Part off at 3/16 in. from shoulder. Make a dozen while on the job, then chuck each lightly by the threaded part, and chamfer the corners of the hexagon heads.

Don't erect the cylinders permanently yet, just attach them temporarily to the frames by a couple of the screws in each. They have to be taken off again several times when fitting and erecting the valve gear. Then put the connecting-rods on the driving crank-pins, and attach the little ends to the crossheads by the large-headed crosshead-pins. Run the crosshead along until the little-end enters the recess, then put the pin in from the side nearest frame. The nuts can be made from 5/16 in. hexagon rod. Chuck a piece in three-jaw, face, centre, drill No. 22 for about $\frac{3}{4}$ in. depth, tap 3/16 in. x 40, chamfer the corners of the hexagon, and part off $\frac{1}{8}$ in. slices.

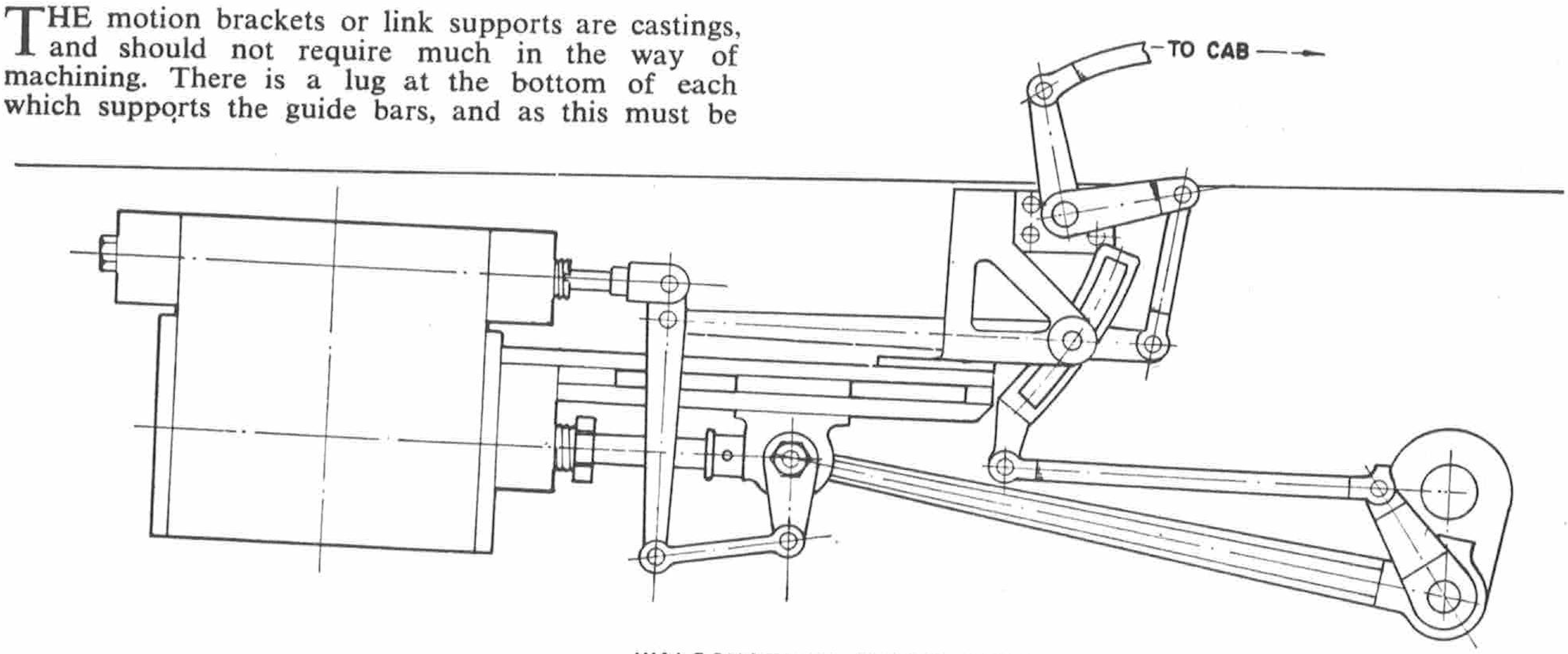
Turn the wheels until the crank is on front dead centre. The piston will hit the front cylinder cover, so take off the cover, and carefully drive the piston in 1/16 in. so that it clears the cover by that much, and the piston rod goes a similar amount farther into the crosshead boss. Replace the cover, then drill a No. 43 hole through crosshead boss and piston-road, and squeeze in a short bit of 3/32 in. silver-steel to act as a cotter.

When the wheels are turned by hand, the connecting-rods and crossheads should operate quite easily, without any tight spots. We are then all ready for fitting up the valve-gear, the complete layout of which is shown in the accompanying drawings. I have shown a simple type of bracket which serves a threefold purpose, viz., it carries the expansion link, supports the outer ends of the guide-bars, and provides a bearing for the reversing shaft.

The expansion link is single-sided; that is, it has a trunnion pin on one side only, but being $\frac{1}{4}$ in. wide and $\frac{1}{4}$ in. dia. it provides better support and more resistance to wear, than a smaller bearing at each side. It is also easier to make and fit up. The die-block is attached to one side of the radius rod; the die-block cannot come out of the slot in the link, as it is kept in place by the side of the gap in the link bracket through which the rod works. The lifting arrangement is the same as used on the full-size Southern 2-6-0 engines, and as the reversing-shaft is ahead of the link bearing, and the lifting-arms point to the rear, the die-blocks will use the upper half of the expansion links for forward running.

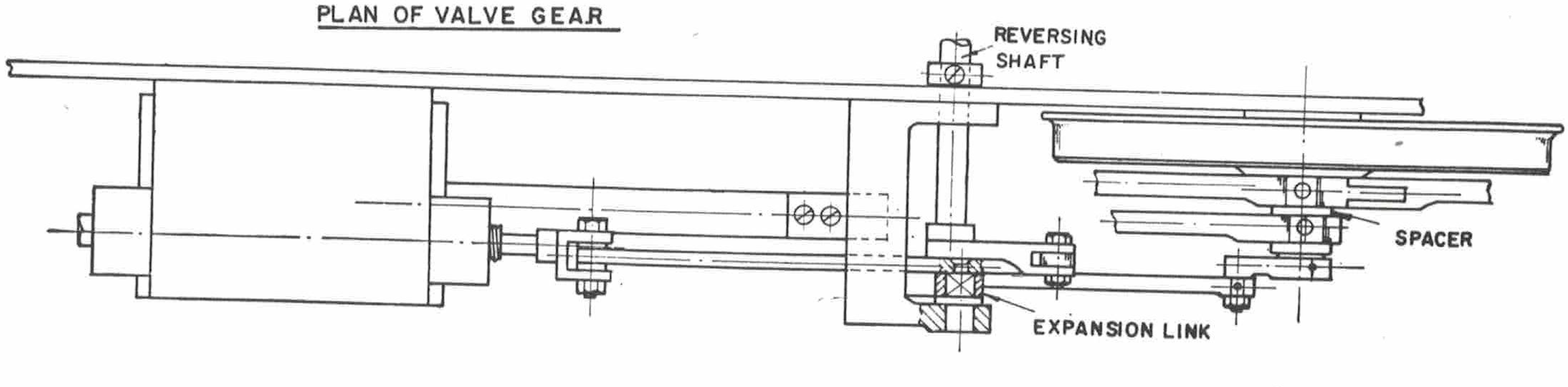
Motion Brackets

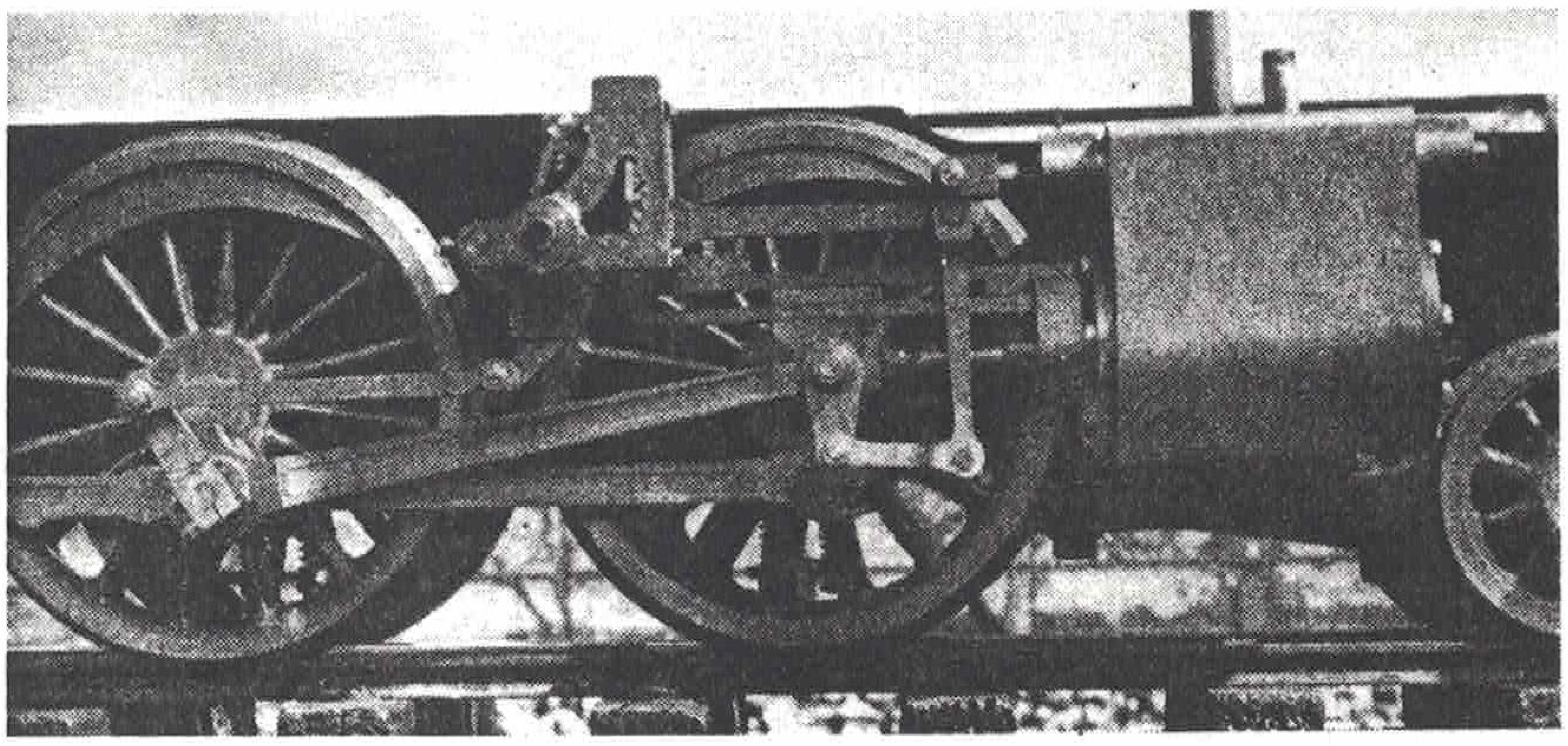
THE motion brackets or link supports are castings, and should not require much in the way of machining. There is a lug at the bottom of each which supports the guide bars, and as this must be



WALSCHAERTS VALVE GEAR

PLAN OF VALVE GEAR



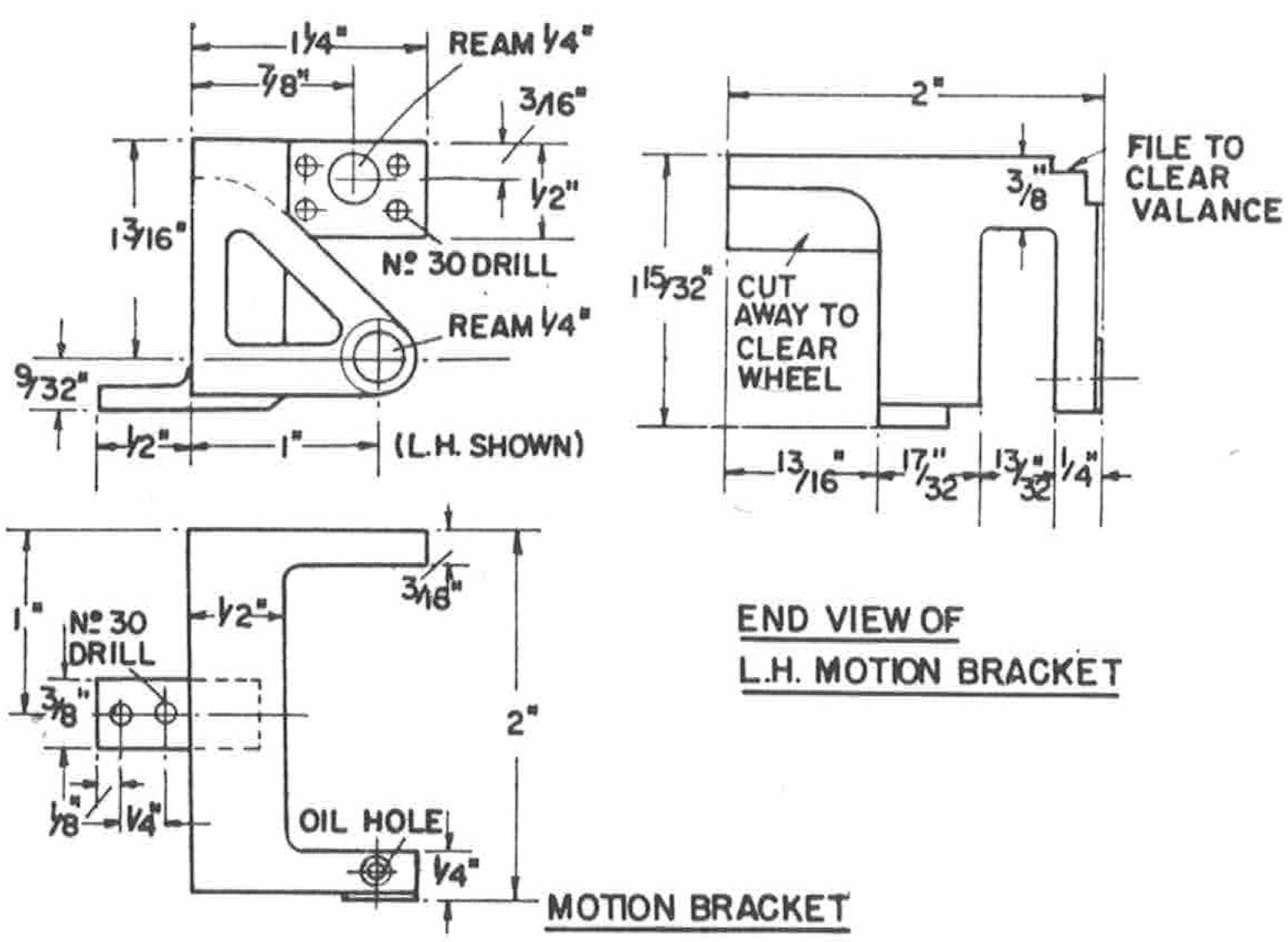


Picture on left shows detail of Curly's own Mongoliper, taken during construction

fitted centrally with the bars, it would be advisable to use it as a base for measuring. Smooth off the underside with a file, and drill the two screwholes as shown.

The side of the casting which goes up against the frame should be exactly 1 in. from the centre of the lug, and at right angles to it. If a milling machine is available, the casting can be held in a machine-vice on the table, set true with a try-square, and the surface cleaned up with a small slabbing cutter on the arbor. It can also be done in the lathe by aid of vertical slide, the casting being either held in a machine-vice bolted to the slide, or clamped to a small angleplate on the slide. The side to be machined can be set truly in a minute or so, by putting the faceplace on the lathe mandrel and running the casting up to it. Adjust casting so that it makes full contact with the faceplate, tighten vice or clamp bolts as the case may be, put an endmill about ½ in. diameter in the chuck, and traverse the casting across it by operating the slide-rest handles.

The hole for the link trunnion must be dead square with the machined side, and it is easy enough to make sure of that. Make a deep centrepop in the middle of the boss, and clamp the casting to the drilling-machine table with the machined side down, and the pop mark right under a 15/64 in. drill in the chuck. Drill through the boss, then put a ¼ in. parallel reamer in the chuck, and run that through as well. If the drilling spindle is true with the table, the hole will be O.K. Drill a 1/16 in. oil hole as shown in the plan, and countersink it.



The end view of the bracket shows a gap at the right-hand side, 13/32 in. wide. The left-hand side of this gap should be smoothed off with a file, at it acts as a check to prevent the radius-rod from moving sideways and letting the die block come out of the slot in the expansion link. If the casting is reasonably clean, as my own was, the only remaining bit of filing is the clearance at the top for the valance, or edging under the running-board. The clearance for the leading coupled wheel will be formed in the casting.

The hole which forms the bearing of the reversing shaft is drilled and reamed in the side of the casting next the frame, 7/8 in. from the front and 3/16 in. from the top. The screwholes for attaching the bracket to the frame are drilled No. 30 and should be well clear of the bearing hole, so that the screws won't break into the U-shaped opening in the frame through which the reversing shaft passes.

To erect the bracket, place it against the frame with the hole for the reversing shaft in the middle of the U-shaped opening, and the bottom lug resting on the guide bar, Clamp it temporarily in place with a toolmaker's cramp, make countersinks on the guide bar with a No. 30 drill put through the holes in the lug, and on the frame through the holes in the side flange. Remove bracket, drill the countersinks No. 40 and tap ⅛ in. or 5 BA. Don't attach the brackets permanently until the rest of the valve gear is ready for erection. If preferred, the holes in the frame may be drilled No. 30, and the brackets attached by ⅛ in. bolts, as on my own engine. Tip to beginners—don't forget that the brackets are right-hand and left-hand. If you want to see a drawing of the bracket on the opposite side, do the same as I did when I was a small kiddy—just hold the drawing of the one shown in front of a mirror, and look at the reflection!

Lap and Lead Components

These consist of the valve fork or crosshead, combination lever, union link, and crosshead arm, or drop-arm as the enginemen call it. The last-named is already attached to the crosshead, so we don't have to bother any further about that merchant. I have included an end view of the whole bag of tricks erected, which shows the clearances between the crosshead and the moving parts, and beginners should take a good look at it before starting to make the various blobs and gadgets, as they will find it will help on the job.

Both valve crossheads can be made from a piece of 7/16 in. x 5/16 in. mild steel about 2 in. long. File both ends square, then clamp the piece under the slide-rest tool-holder, packing it up to lathe centre-height, and setting it at right angles to the lathe bed. Feed it up to a ¼ in. saw-type cutter on a stub mandrel held in the three-jaw chuck. Just after the end of the Kaiser's war, when there were lashings of "Government surplus" tools on the market at ridiculously low prices, I bought a ¼ in. side-and-face milling cutter 2 in. diameter for a shilling. I mounted it between two nuts on the end of a ½ in. bolt, cut off the bolt head, so that the bolt could be held in the chuck, and believe it or not, that useful bob's-worth is still cutting slots in valve-gear components for a friend who hasn't a milling-machine.

A cutter less than ¼ in wide can be used by taking two or more bites. Note, all the forks in *Betty's* valve gear can be slotted in similar fashion, so there is no need to repeat the ritual. Run the lathe at slow speed, and use plenty of cutting oil. Soapy water is a good lubricant for milling steel, but it makes the lathe in a shocking mess, and I don't recommend it.

Cut the slot 13/32 in. deep, then repeat operations on the other end of the bit of steel bar. Saw off the slotted ends about 3/8 in. from the slot. Chuck each in the four-jaw with the sawn end outward, and set at 3-32 in. off centre. Turn to ¼ in. diameter as shown in the drawing, centre, drill No. 30 and tap 5/32 in. x 40 to suit the valve spindle. Drill and ream the cross hole, and round off the end. It is a good wheeze for beginners to drill the cross holes before cutting the slots, as there is then no risk of the drill running to one side. Alternatively, put a piece of metal in the slot, and drill through the lot.

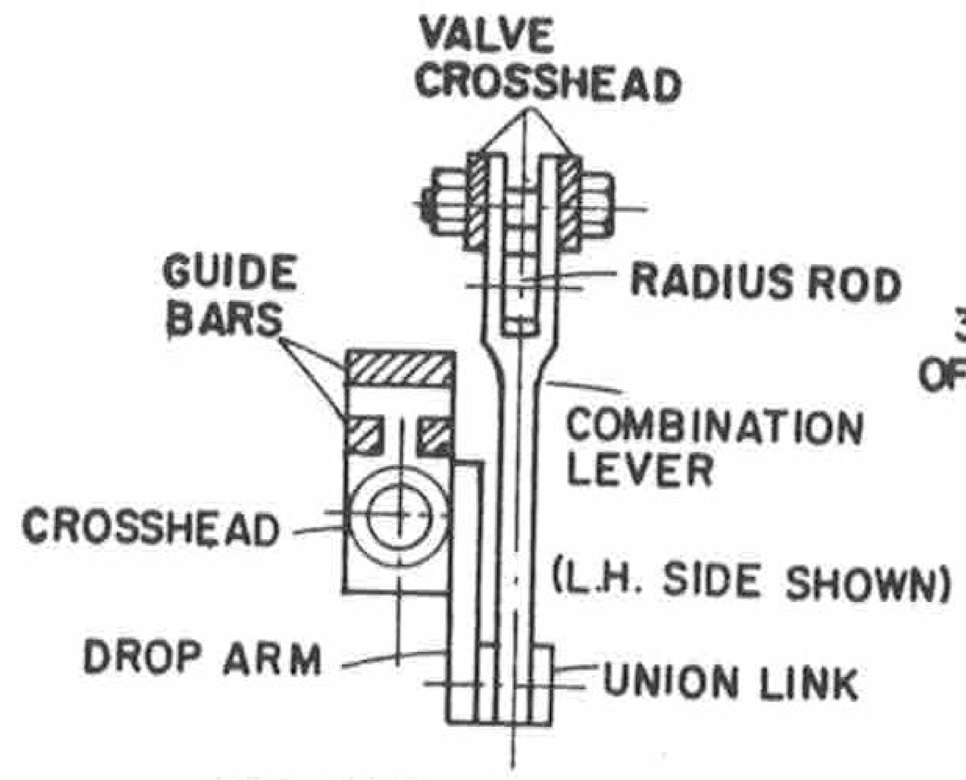
The combination lever is made from ¼ in. x 5/16 in. mild steel. Mark off and drill the holes first, using No. 23 drill. Next slot the head as described above, round off the end, mill or file to the shape shown, and finally poke a 5/32 in. parallel reamer through the holes at the ends. The union link is made in similar fashion, but mill or file away one side only, so as to leave the forked end offset.

Radius Rods and Expansion Links

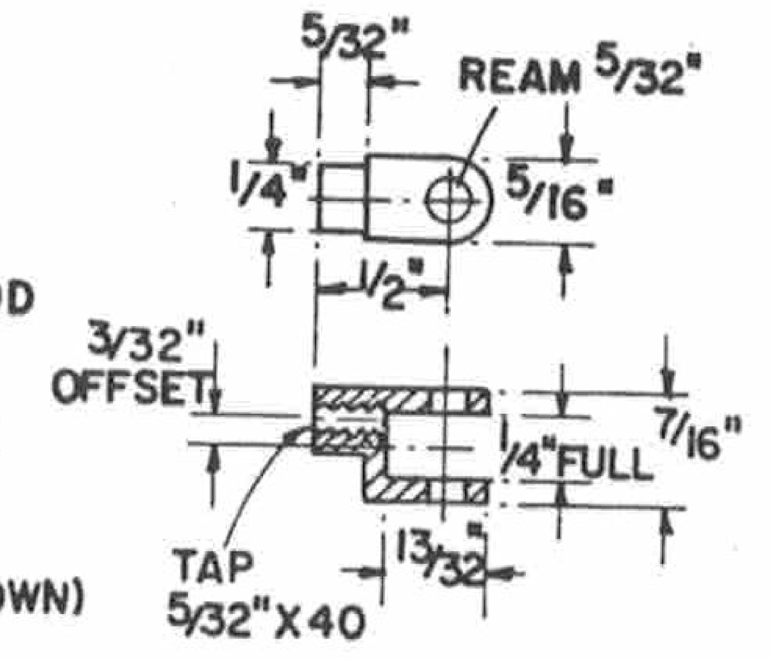
The radius rods are milled or filed to the dimensions shown, from ⅛ in. x 5/16 in. mild steel strip; a simple job needing no detailing. Drill the end holes with No. 24 drill, and be sure they go through dead square with the sides before putting the 5/32 in. reamer through. Same applies to the hole for the die block pin, which is drilled No. 40 and tapped ⅛ in. or 5 BA.

The expansion links should be made from the fine grade of cast steel used for gauge-making, and known in the trade as "ground flat stock". It can be purchased in various thicknesses. If not available, 3/16 in. mild steel can be used. It isn't worthwhile setting up a machine for the purpose of cutting two curved slots only; the job can be done quicker by hand. Take a piece of 3/16 in. steel large enough to make two links, clean one side, coat with marking-out fluid, and very carefully mark the outline of the links.

Cut the slots first. If you spoil a slot, which isn't exactly unknown among beginners, you only lose the labour involved in cutting it, plus the

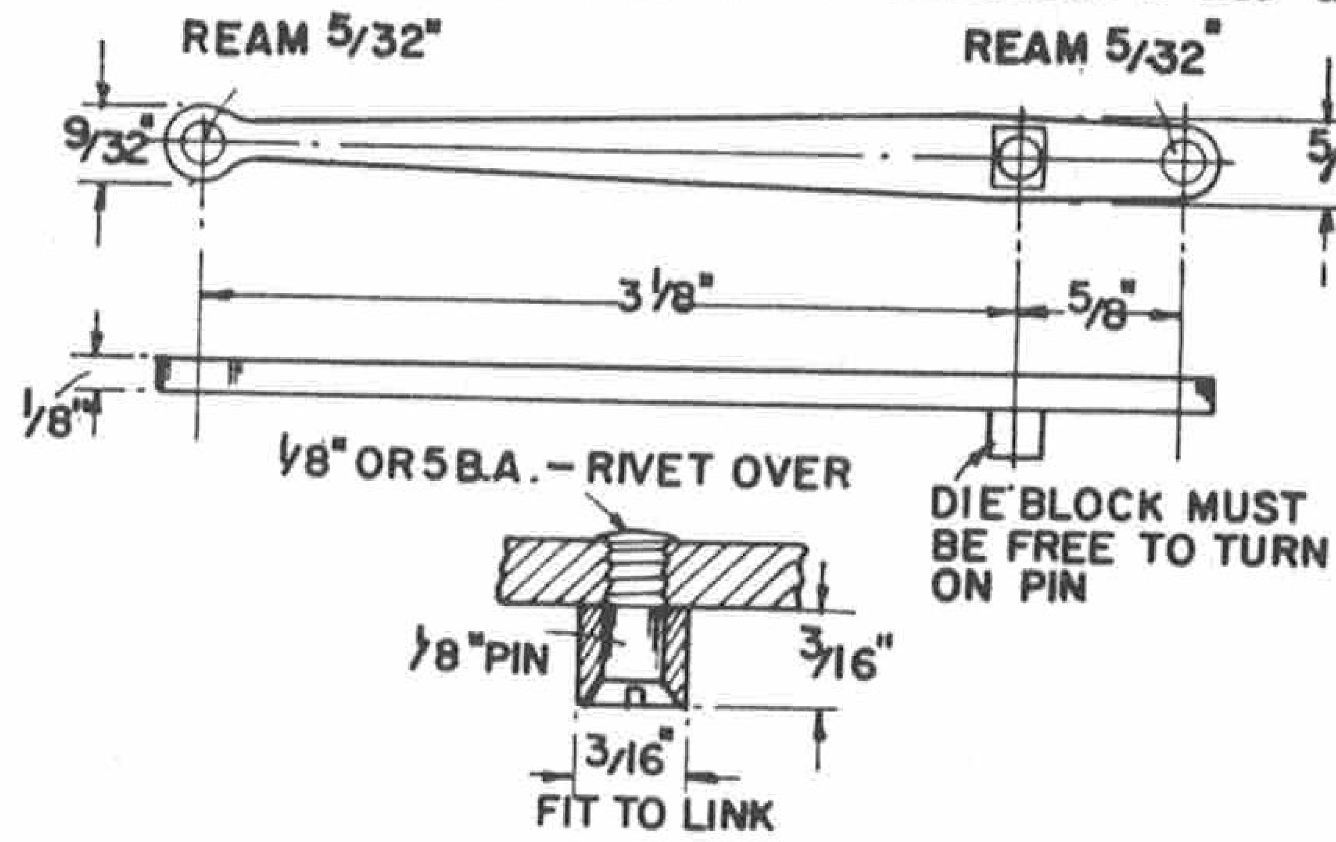


END VIEW OF LAP-AND-LEAD MOVEMENT



VALVE CROSSHEAD

little bit of metal (unless you happen to one of those impetuous folk who lose their temper as well, when things go wrong!) but if you cut what the children call a "wonky" slot in a link carefully filed to outline—nuff sed! On the centre-line of the slot, drill a series of 5/32 in. holes as close together as possible. Run them into a slot with a rat-tail file or an Abrafile, then very carefully open out the slot with a fine-cut Swiss or watchmaker's file until

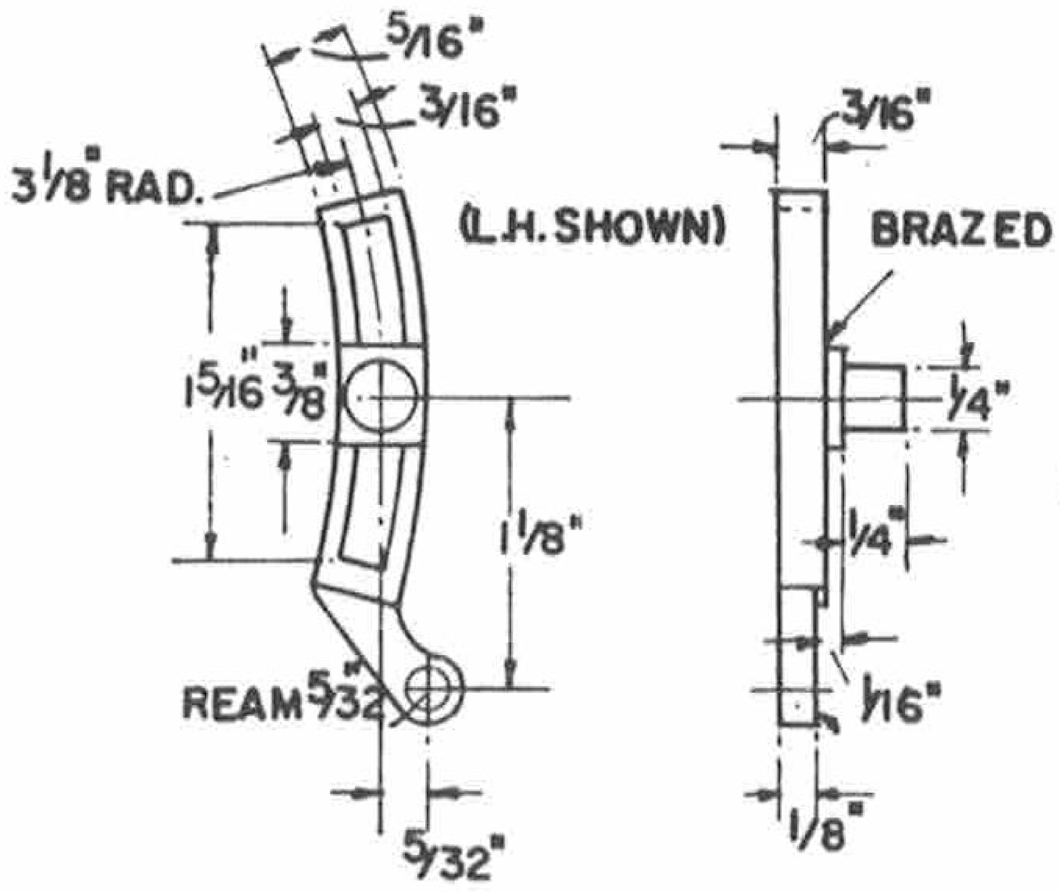


RADIUS ROD

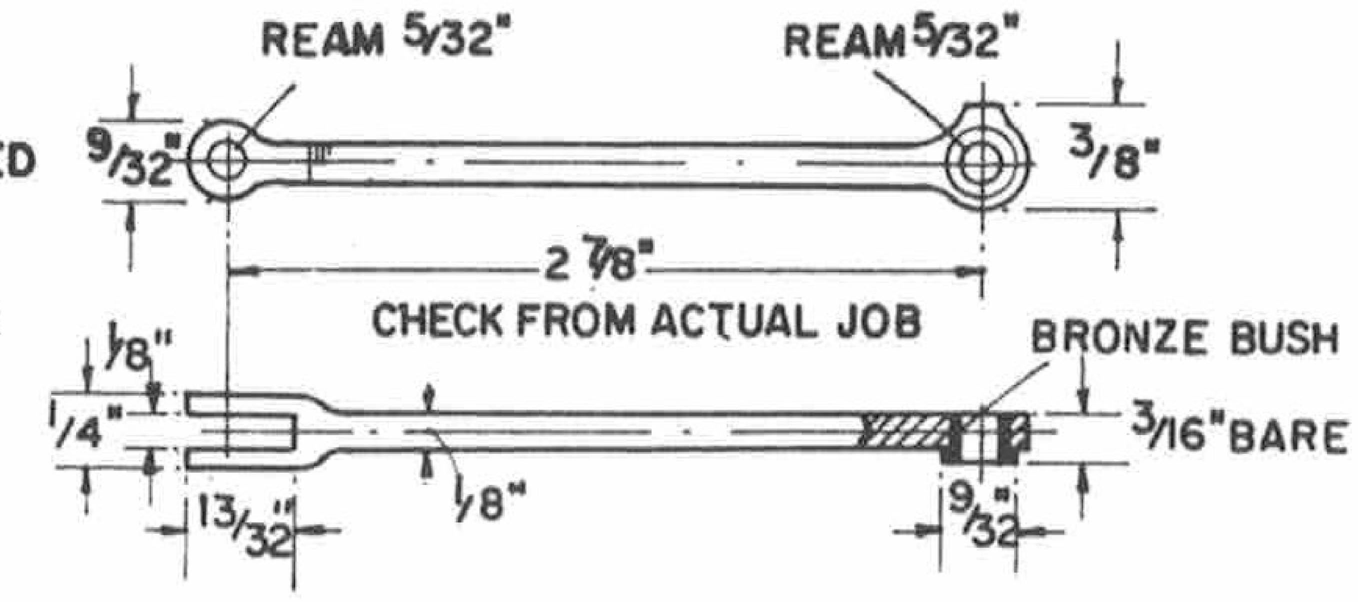
a piece of 3/16 in. silver-steel will run easily from one end to the other without any shake. I use what is known as a fishback file, both sides of which are shaped like one side of an ordinary half-round file; and honestly, the job is quite easy, it only needs ordinary care and patience. My few friends often chaff me about saying that things are quite easy, but the fact is that *everything* is easy *when you know how*. I do my best provide the "know how."

It is a simple job to file the outline of the link around the slot—Pat says it's as easy as building a barrel around a bunghole—so I needn't dilate on that. The tail is milled or filed away on one side for 1/16 in. to fit the slot in the eccentric-rod. The die block is made from ¼ in. square silver-steel. Chuck a piece truly in the four-jaw chuck, face, centre and drill No. 30 for about ½ in. depth. Part off two 3/16 in. slices, and file two opposite sides, one convex and one concave, to fit the slot in the expansion link. The die blocks should slip easily from one end of the slot to the other, without any shake. Countersink the holes on one side, to accommodate the heads of the pins, which can be turned from 3/16 in. round silver-steel to the size shown in the detail sketch. The die-blocks can be hardened right out by heating to red and plunging into cold water, cleaning off all the scale; this will make them practically everlasting.

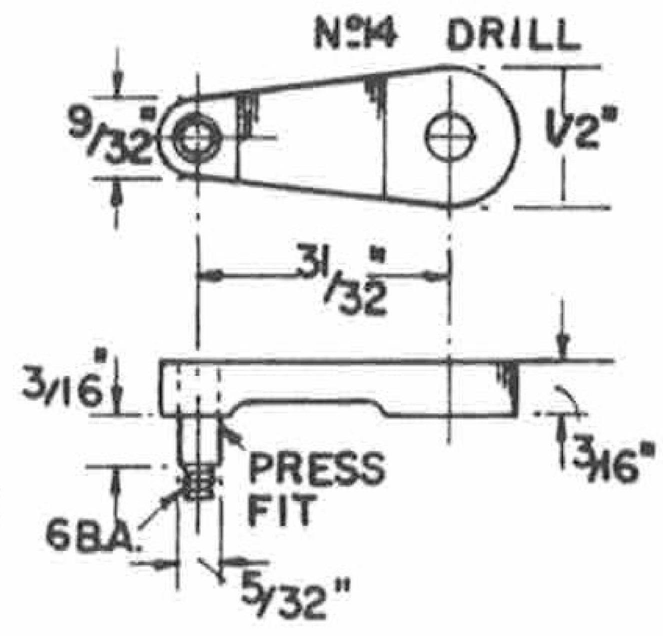
Each link requires a ¼ in. trunnion pin at the side



EXPANSION LINK



ECCENTRIC ROD



RETURN CRANK

The way I made those on my own engine was as follows. Having a piece of 7/16 in. square silver-steel, I chucked it in the four-jaw and set it to run truly. The end was faced, ¼ in. length was turned to ¼ in. diameter with the smoothest possible finish, and the piece parted off at 1/16 in. from the shoulder. The square head was filed away for 1/32 in. on opposite sides, bringing the width to ⅜ in. and the pin then clamped to the middle of the link as shown in the drawing, leaving 1/16 in. projecting at each side. Great care was taken to line up the pin with the centre of the slot.

For clamping jobs that have to be brazed. I made a few rough cramps, like toolmakers' cramps, from odd bits of square steel, using ordinary commercial stove screws. It doesn't matter a bean about these becoming redhot when doing the brazing job, whereas ordinary toolmakers' cramps would be ruined. For the job in hand, a little wet flux was applied to the little bit of head that projected at each side of the link, the job put in the brazing pan, heated to bright red, and touched with a piece of thin soft brass wire where the head projected. The great aim was to prevent any of the melted brass wire from getting into the slot, and in this I was lucky, as the brass penetrated between the head and the link, and formed a little fillet on the outside. The job was quenched out in cold water before the redness died away, which left the link and pin quite hard. The projecting bits of head at each side of the link were then very carefully ground off, as they were too hard to file, and the whole issue cleaned up with fine emery cloth. The links will last longer than I shall!

Return Cranks and Eccentric Rods

The return cranks are milled or filed from ½ in. x 3/16 in. mild steel to the dimensions given in the drawing. Use No. 23 drill for the hole in the smaller end. The pin is a 9/16 in. length of 5/32 in. round silver-steel, one end being turned down to 7/64 in. diameter for a bare 3/16 in. length and screwed 6 BA; the other end is eased with a file until it will just start in the hole, and then pressed in. Put a nut on the thread while pressing, or it will be cattled up.

As the exact length of the eccentric-rods has to be obtained from the actual job, at the time that the return cranks are pressed on and set in correct position, we must now erect the parts so far made. Attach the die blocks to the radius rods as shown; note, they must be quite free to turn without shake, when the pins are screwed right home. The ends of the pins may be riveted over slightly to prevent any risk of their working slack when the engine is in service. Put the eye end of the radius rod in the fork of the combination lever opposite the lower hole, and pin it by squeezing in a piece of 5/32 in. silver-steel, filing the pin flush at each side. The reamed hole in the radius rod should work nicely on the pin without shake.

Put the bottom of the combination lever in the fork of the union link, and pin it likewise. Take good care that the offset is the right way around; it can easily be checked by holding the lever in position, as if O.K. the plain end of the union link will fit over the pin in the drop arm. Screw the valve crosshead on to the valve spindle with the offset outwards (see plan of valve gear in last instalment); put the top of the combination lever between the jaws, and secure it with a little bolt made from a piece of 5/32 in. silver steel, a bare ¾ in. long, turned down at each end to 7/64 in., screwed 6 BA and furnished with commercial nuts. When both nuts are tight, the bolt should be free to turn by finger pressure. If tight, it will pinch the jaws of the fork and cause undue friction in the valve gear. The eye end of the union link goes over the pin at the bottom of the drop arm, as shown in the elevation of the gear, and is secured by a nut.

Next, put the trunnion pin on the link in the reamed boss of the motion bracket, in which it should fit without shake. The bracket is then placed in position, the radius rod passing through the gap, and the die-block entering the slot in the link. This calls for a little jerrywangling, but you'll see how to manage it when doing the job, far easier than I can explain in print, if you swing one end of the link right back, put the bracket over the radius rod, line up the die-block with the link slot, and guide it into the slot as the bracket is adjusted to its correct position. The bracket can then be attached permanently to frame and guide bars. Take care that the screws holding the lug to the guide bars don't project and foul the crosshead; file them flush underneath the bar.

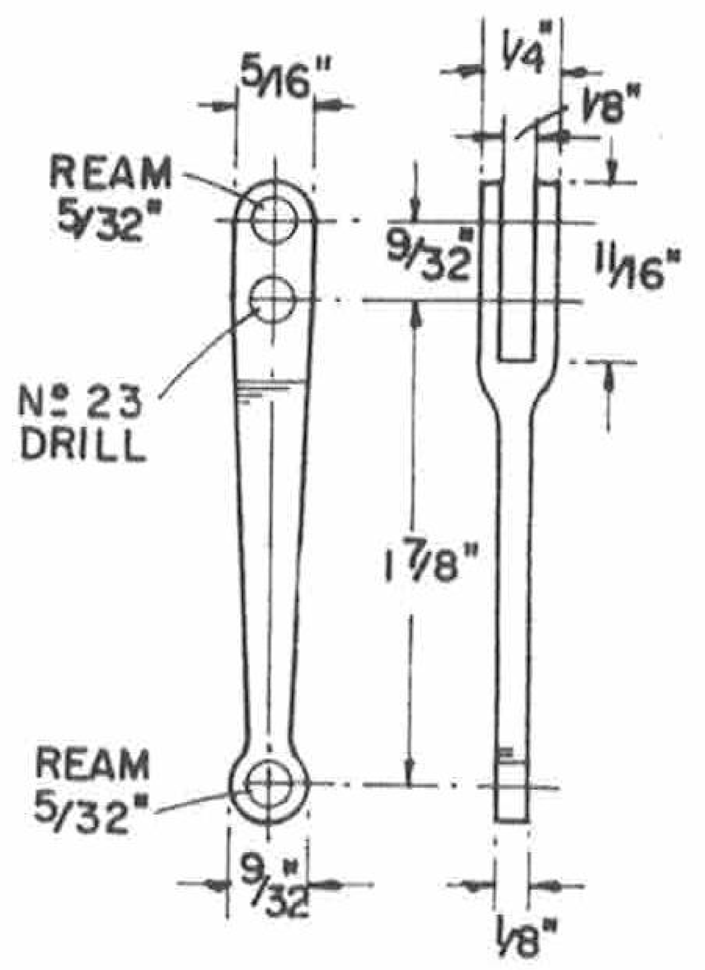
Put the return cranks on the spigots on the end of the main crankpins in the position shown in the elevation of the valve gear in the last instalment, as near as you can by eye. To find the exact position, turn the wheels until the main crank is on front dead centre, and set the link in such a position that the die-block can be run from top to bottom of the slot without moving the valve spindle. Temporarily clamp it there so that it can't shift of its own accord. Now with a pair of dividers, take the distance from the centre of the return crankpin, to the centre of the hole in the link tail. Next turn the wheels until the crank is on back dead centre, and without altering the dividers, apply the points again to return crankpin and link tail. If they don't tally—and the odds are a million dollars to a pinch of snuff that they won't—shift the return crank so that the pin moves half the difference, and check again.

When the centres tally exactly with the main crank on either front or back dead centre, the return cranks are correctly set, and—note this carefully—*the distance between the divider points is the exact length of the eccentric-rods between the holes in eye and fork*. That is why the drawing says "check from actual job." Go right ahead and make your eccentric-rods by the same process as the combination lever and other forked rods. Open out the eye with 7/32 in. drill and fit a weeny bronze bush in it, like those in the coupling-rods, to fit over the pin in the return crank. The fork is connected to the hole in the link tail by a 5/32 in. bolt like that in the valve crossheads. The return cranks are pinned to the main crankpins by drilling a No. 43 hole through boss and spigot, and squeezing in a little bit of 3/32 in. silver-steel for a pin.

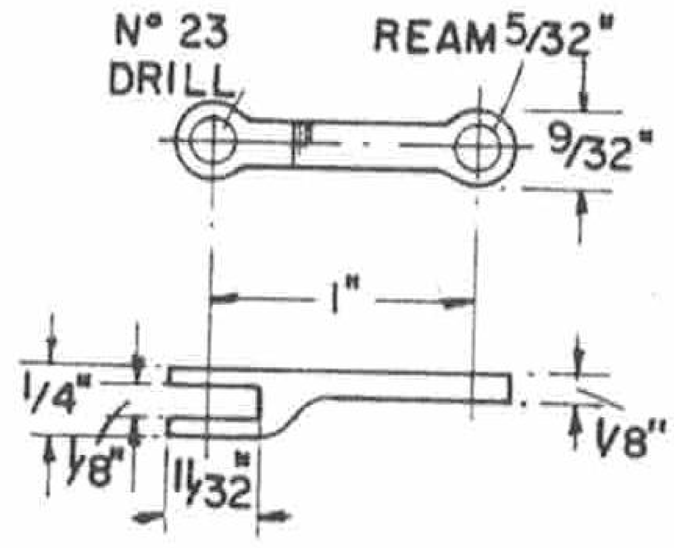
Reversing Shaft

The reversing shaft is a piece of 1/4 in. round silver-steel faced off at each end to an overall length of 5-13/16 in. Turn 1/4 in. of one end to 3/16 in. diameter and 5/16 in. of the other end likewise. The reversing arm is flat, filed up from 3/8 in. x 1/8 in. mild steel to the shape shown in the end view of the shaft. This goes on the 1/4 in. end. The two lifting arms are made in exactly the same way as the union links, but to the dimensions shown. One of them is fitted outside the reversing arm, and set at right angles to it, both being brazed in position. The other has to be adjustable. After drilling the 3/16 in. hole in the end, chuck a piece of 3/8 in. rod in the three-jaw, and turn down a full 1/8 in. to a tight fit in the hole. Part off at 3/16 in. from shoulder, press the pip into the hole in the lifting arm, and braze it. After cleaning up, chuck the boss in the three-jaw—keep your fingers well clear of the spinning arm when you start the lathe—face off anything projecting through the arm, centre, and drill through arm and boss with No. 14 drill. The arm should then fit tightly on the 5/16 in. seating on the end of the shaft.

Two collars are required to keep the shaft central. Chuck a piece of 1/2 in. rod, face, centre, and drill 1/4 in. for about 1/2 in. depth. Part off two slices a full 3/16 in. thick, and fit a 3/32 in. or 7 BA set-screw in each. To erect the shaft, take off the adjustable arm, and push the shaft through the hole in the motion bracket flange on the left side of the engine. Thread on the collars as the shaft passes between the frames, push it on through the other motion bracket, and put on the other lifting arm parallel to the fixed one. Adjust the collars so that the same



COMBINATION LEVER



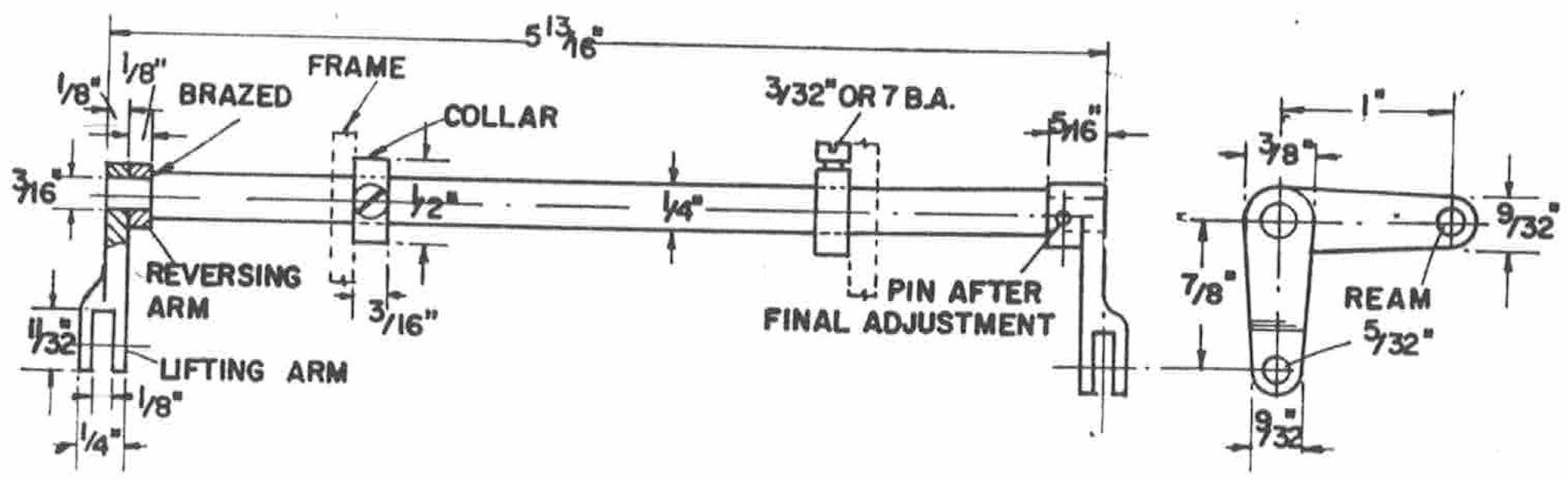
UNION LINK

length of shaft projects at each side of the frames, run them up against the frames, and tighten the setscrews.

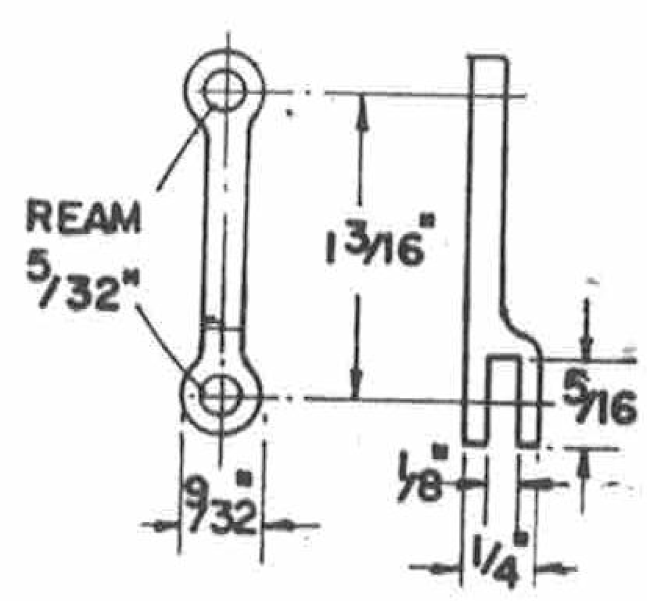
The lifting links are made in the same way as the union links, but to the size shown on the drawing. The eye end fits in the slot at the end of the lifting arm, and the forked end fits over the end of the radius rod, both ends being secured by 5/32 in. bolts made in the same way as those in the valve crossheads.

To get the two lifting arms exactly in line, put the left-hand die-block in the middle of the link, so that the wheels can be turned by hand without any movement of the radius rod taking place. Clamp the reversing shaft temporarily in position, so that the die-block can't shift away from the centre. Then carefully adjust the lifting arm on the other side until the die-block on that side is also in the middle of the link. When the wheels can be turned without any movement of either radius rod, the lifting arms are set O.K. and the adjustable one can be pinned to the reversing shaft by drilling a No. 43 hole through boss and shaft, and squeezing in a 3/32 in. silver-steel pin, as was done with the return cranks.

The valve gear should now reverse quite easily with the wheels in any position, and the expansion links at any angle, the die-blocks sliding freely in the link slots when the reversing arm is moved back and forth. If the gear catches up anywhere, the tight place can usually be found by carefully watching each part as the reversing arm is slowly moved. It can also usually be checked by turning the wheels slowly, when the tight place can be distinctly felt. Put it right before proceeding with the next job, which will be the wheel-and-screw reverser at the footplate end.



REVERSING SHAFT



LIFTING LINK