Marie E, A Porter 0-4-0 in 4¾/5 in. gauge

by: DON YOUNG

Part 1 – The Chassis

For once introductions are unnecessary, for unconscious of what would ensue, I compiled the story of the LARGE LOCOMOTIVE of the same name, to the design of Oliver M. Johnston, as it appeared in LLAS No. 3 (May 1980). So any of our newer readers can avail themselves of this back number to avoid repetition.

I mentioned when announcing my humble design that MARIE E was a 'Beginner's Locomotive', which brought forth the question as to my reasons for such a label, particularly as some of you are building DON HUNSLET as your first SMALL LOCOMOTIVE, and by your letters are enjoying the experience. My definition of a Beginner's Locomotive is one of low work content, plus designed with a view to ease of manufacture, as an exercise in basic engineering. I think in this MARIE E meets my specification, though you the reader can be the best judge of this as the series unfolds.

I first looked at MARIE E in 3½ in. gauge, as this is the only worldwide standard and as such is attractive to me as the designer, there being no either/or dimensions to worry about. However, in this instance the end result was puny from a performance point of view and full of 'watchmaking'; no way was it a Beginner's Locomotive. At 4¾/5 in. gauge the whole thing fell into place and I must admit that my thought process stopped right there. As with HUNSLET though, there is a lot to be said for a 7¼/7½ in. gauge variant, though this time there is no Milner Engineering design from which to lift the details. If there is sufficient interest shown in these bigger gauges then I will fill in a few of the details, though at first, and second(!) look I have yet to find a dimension which cannot directly be increased by 50% to arrive at the larger Locomotive, other than rounding up the bar frame section to ⅝ in. square. Providing the builder does not mind a slight alteration in overall appearance, Don Young Designs can supply castings like Wheels, Dome and Sandbox from other existing designs, plus there will be no problem at all with the Fittings – we have you completely covered for these latter!

Back to 4¾/5 in. gauge, where Dennis Hill became interested in MARIE E very early in the project, and started to cut metal almost before the ink was dry on the drawings. That his MARIE E is now complete and running is the best boost to my morale there could be at the beginning of this series, for which my grateful thanks, but I must not steal his thunder and will leave Dennis to tell his own story in 'Builders Corner'. A number of other builders are working ahead of the script, so this should make for a smooth passage, for experience has taught that the existence of a prototype does not remove every possible snag. Five years after my 5 in. gauge RAIL MOTOR No. 1 had been completed for instance, another of my 0-4-0 'quickies' that has proved popular, a South African builder told me it was impossible to set the valves as drawn; I was provided with details of the modifications required. Yet my original drawings checked out O.K. and when this builder called to see me a couple of years back I was able to show him my No. 1. He checked all the dimensions for himself; all was in order. Yet about 1 in 100 builders of RAIL MOTOR No. 1 report the same sort of snag, so this was not a single instance; this sort of thing is very baffling. In the case of MARIE E, Dennis Hill reports that valve setting occupied less than 30 minutes, when all was well, so I am off to a flying start. Talking of start, it is time I did just that with the series, so climb aboard and away we go.

Frames

The whole Chassis adorns the top L.H. corner of Sheet No. 2, not a very daunting prospect, especially when the frames are 18¾ in. finished lengths of $\frac{7}{16}$ in. square steel bar. Cut two 1⅝ in. blocks from the same material for the weighshaft bearings, then mark off one frame, clamp to the other and drill as a pair for both vertical and horizontal holes; fit the weighshaft bearing blocks and deal with these also.

Beams

It is difficult to obtain properly seasoned timber these days, so for the beams purchase a length of 1½ in. x 1 in. hardwood, this will be oak in the U.K. for preference, and leave outdoors under cover for as many months as you are able before planing to the required 1¼ in. x ¾ in. section; saw off to length and radius the front beam ends; my American friends will call this the pilot beam. Although it may sound crude, files are quite suitable for shaping wood, unclogging the teeth with a wire brush at frequent intervals, then finish with fine grade sandpaper.

Gussets

The gussets are from 1 in. x 1 in. x ⅛ in. steel angle, the bright variety with square root and corners if you can get it. Saw out to the shapes shown, clamp the inner pairs to the frames and clamp the beams in turn to the gussets. Lay the assembly on the lathe bed or surface plate to check for flatness, check for squareness across the frames as well, then drill No. 27 holes from the frames through the gussets. Remove the gussets, still clamped to the beams, drill the five fixing holes if not already attended to, these to suit your woodscrews, drill a pilot hole into the beam and screw home.

Equaliser Beam Stay

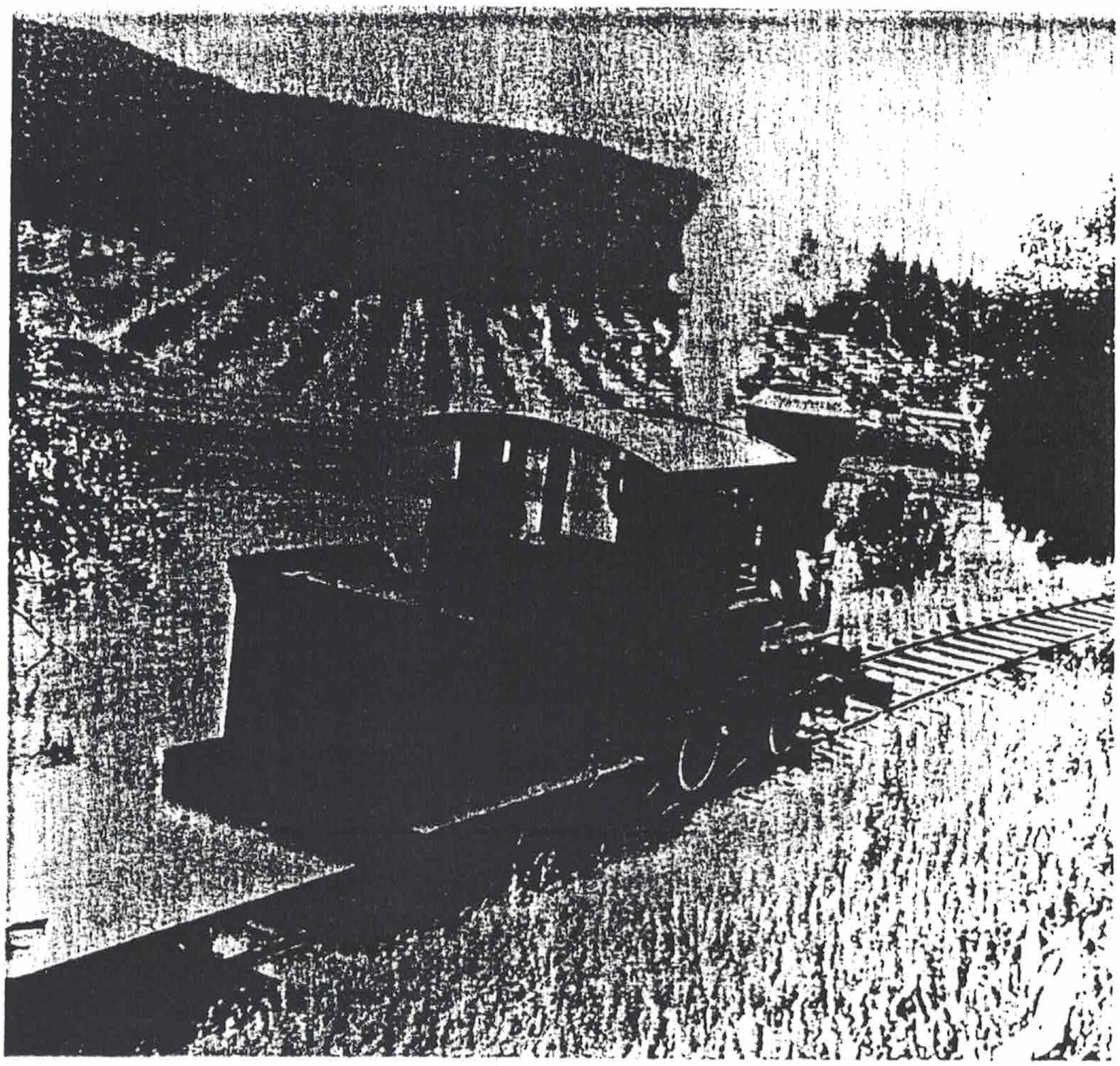
I should have mentioned earlier about frame spacing, and this is best achieved by making the equaliser beam stays. Saw these from ⅝ in. x ⅝ in. x ⅛ in. steel angle, square off to $4\frac{0}{16}$ in. ($4\frac{5}{16}$ in. for 4¾ in. gauge) overall, clamp back to back, mark off and drill the two No. 27 holes, then clamp back to back again on the other face to mark off and drill the No. 11 hole, although this latter is not yet required. Now all you have to do is bolt the stays through any of the vertical holes in the frames to achieve the correct spacing.

The outer gussets have yet to be fitted, so clamp these to the inner pair, still attached to the beams, spot through and drill No. 27 for the frame fixings. Assemble the beams to the frames once more, with the outer gussets in place, then drill for and fit the woodscrews.

Drawbar Stay

We can stiffen the frame assembly with the drawbar stay, so cut a length from 1 in. x ⅛ in. BMS flat to match the overall width of the frames, clamp in place and drill the four No. 27 holes from the frames. Cut two blocks ⅝ in. finished length from ½ in. x ⅜ in. BMS bar, a 1½ in. length from ½ in. x ⅛ in. BMS flat, and clamp to the stay in the position shown. Drill four 3/32 in. holes for snap head iron rivets, but before rivetting over, remove the spacers, use 7BA bolts to fix the lower plate to the stay, and drill through at No. 11 for the drawbar pin.

I don't think much needs to be said about this pitcure by David Gooley; it should set builders of MARIE E dreaming!



Already we can begin to think about wheeling MARIE E, which in itself is very straightforward, thanks to Carl Purinton, founder of the Brotherhood of Live Steamers. For it was Carl who told me that he did not use springing on his Locomotives, as there was nobody on the footplate to feel the effects of a lack of springing. So for MARIE E I was able to think in terms of the classic 3-point suspension, the rear axle being fixed and the front axle pivotting about its mid point. By chance, less than 24 hours after Sheet No. 1 became a reality, I visited the Portsmouth M.E.S., Bill Edwards, who built my RAIL MOTOR No. 2 as his first attempt, was immediately taken by MARIE E and was the first to start construction. He was a little sceptical about the lack of springing, appreciating its importance to the track stability of his RAIL MOTOR, so as soon as the chassiss was wheeled it was taken to the Club track and sent hurtling around the track at high speed. There were no derailments and Bill is now convinced that this is a feasible form of suspension.

Wheels

I love turning wheels, so let us make those the next item to be tackled.

Chuck in the 3 jaw, by the tread, run at the lowest direct drive speed and first check that the wheel is running true. There should be no problem at all, for these castings are good, but if you are at all unhappy, change to the 4 jaw chuck and set to run true. That actually is the second operation, for the first task on picking up any castings is to assess the machining allowances provided; this will always pay handsome dividends! Face right across the back of the casting to remove the established machining allowance, then turn down the flange to 3 11/16 in. diameter, finishing the corner radius with a file. Next centre and drill through to 27/64 in. diameter and ream through at 7/16 in.; complete all wheels to this stage. Take a drill of at least ½ in. diameter, with taper shank to match your headstock, and saw apart at the top of the flutes; this will be much easier than you might imagine. Clean the headstock mandrel thoroughly, tap in the drill shank and turn down to a close fit in the wheel boss. Fit the faceplate, slide a wheel over the mandrel and bolt through the spokes to the faceplate; a large countersunk head screw, maybe with a washer under the head, is ideal here as it does not get in the way of the lathe tool. Face across the front of the tyre to the required 9/16 in. overall thickness, then deal with the crank boss to finish 1/32 in. proud of the tyre. Tackle the tread next using a round nose tool so as to form the root radius at the same time; if there is any tool chatter, stop the motor and pull round by hand to get the required finish. Leave the tread about .010 in. oversize at this stage, but complete the flange to drawing, including the top radius. Repeat for the other three wheels. Leave the last one in place and take a final cut across the tread; leave the cross slide well alone and take this same finishing cut on the other wheels so they have identical tread diameter.

To drill for the crankpin we need a simple jig, so grip a 1¾ in. length of, say, 1 in. x ⅜ in. BMS flat in the machine vice, on the vertical slide, and at ½ in. from one end, centre and drill through in nice easy steps to ⅜ in. diameter. Advance the cross slide by .813 in., centre again and open out in stages to 5/16 in. diameter. Incidentally, this set-up is also best suited for drilling the frames, when if those No. 27 holes are not central in the 7/16 in. bar, at least they are all on the same axis. Back to our jig, where the next job is to chuck a length of 7/16 in. silver steel rod in the 3 jaw, after checking that it is a fairly close fit in the wheel boss, then turn down for ⅜ in. length to ⅜ in. diameter, a press fit in the piece of bar. Part off to leave a

$\frac{3}{16}$ in. length at the original $\frac{7}{16}$ in. diameter, press into the bar and our jig is complete.
Apply marking off fluid to the crank boss on each of the wheels and scribe on the centre line to position the crankpin, this on the outside of the wheel. Fit the drill jig, sight through the $\frac{5}{16}$ in. hole on to the centre line just scribed and position carefully by eye; this will be surprisingly accurate. Clamp the bar to the wheel, set up on the drilling machine table and drill through for the crankpin at $\frac{5}{16}$ in. diameter; repeat for the other wheels.
The leading wheels crankpin boss is relieved to give clearance for the coupling rod, so chuck in the 4 jaw and poke a length of $\frac{5}{16}$ in. rod in the crankpin hole. Grip a dial test indicator (d.t.i.) under the toolpost, bring up to the $\frac{5}{16}$ in. rod and set the wheel for the crankpin to run true, then machine the 1/32 in. recess in the boss as shown, this to complete the wheels.

Crankpins & Caps

The crankpins are plain lengths of $\frac{5}{16}$ in. bright steel rod, so first part off to length; between .005 in. and .010 in. above $\frac{3}{4}$ in. for the leading pair. Chuck a crankpin in the 3 jaw, centre and drill No. 34 to $\frac{3}{8}$ in. depth and tap 4BA. When turning, drilling, or tapping steel, always use plenty of 'cutting oil' and apply with a paint brush or similar. All the cutting and lubricating oil I use in the workshop costs not one penny, being the residue from the tins of oil used in the horseless carriage; you will be surprised how much would otherwise be wasted. Stand the can on a warm surface to reduce the viscosity of the oil, cut off the top with a can opener, and pour the contents into a jam jar; see what I mean!
For the crankpin caps, start with $\frac{1}{2}$ in. steel rod and reduce over a $\frac{1}{4}$ in. length to 31/64 in. diameter. Centre and drill No. 27 to the same $\frac{1}{4}$ in. depth, then change to a 90 deg. Rosebit, a very useful tool, and countersink to accept a 4BA screw; part off a $\frac{1}{16}$ in. slice then repeat the dose.
Degrease the crankpins and their mating holes in the wheels with petrol, better the Primer 'T' that Loctite supply in an aerosol can, apply a drop or two of Loctite 601, or 638 and reassemble; leave to cure. Most Loctite grades these days are 'superfast', which is alright for industry to cut production time, but for us SMALL LOCOMOTIVE builders it can be a curse. The curing time is temperature sensitive, so to give yourself more latitude, choose a cool evening rather than a hot summer day, this way you may get 10 minutes grace instead of 10 seconds!

Axles

For the axles a 12 in. length of $\frac{1}{2}$ in. bright mild steel rod is required. Saw off two lengths and face them to $5\frac{3}{8}$ in. ($5\frac{5}{8}$ in. for $4\frac{3}{4}$ in. gauge) overall. Chances are your 3 jaw chuck is sufficiently accurate to turn the wheel seat concentric with the journal; you can quickly check this with the d.t.i. If any problem, change to the 4 jaw and set to run true with said d.t.i., with about $\frac{3}{4}$ in. protruding from the jaws. Centre the end of the axle quite deeply, this was virtually universal practice full size, then carefully turn down over a 19/32 in. length to $\frac{7}{16}$ in. diameter, a close fit in the wheel boss; repeat at the other end of the axle. Degrease and apply a wheel to each axle with Loctite 601 or 638 and this is as far as we can go for the moment as there are some other pieces to be made and fitted before the other wheels meet their axles.

Eccentric Sheave

The next job, the eccentric sheaves, are pure turning from $1\frac{1}{4}$ in. diameter bright steel bar, length around $3\frac{1}{2}$ in. Chuck in the 3 jaw, centre and bring the tailstock into use. Starting at the tailstock end, cut grooves with a parting off tool down to about $\frac{7}{8}$ in. diameter, first to leave $\frac{3}{16}$ in. at the outer end, then four lengths of a full $\frac{1}{2}$ in. so that they will clean up to the required sheave thickness. We next need a parting off tool with a 7/32 in. wide blade, ground perfectly flat so that the groove can be formed at one pass. Experienced builders will make this from a piece of tool steel, but beginners should look around for a proprietary one suitable for your needs. Tackle the $\frac{3}{16}$ in. wide end piece for a start and reduce to $1\frac{1}{8}$ in. diameter, which dimension can be arrived at with sufficient accuracy with calipers, as this piece will become your gauge for the mating straps later on. Feed on plenty of cutting oil to get that lovely 'frying tonight' sound, though the smell is not so pleasant(!) and make a note of the cross slide reading at the completion of the cut. Now move on to the sheaves themselves and deal with each in turn to arrive at the same groove diameter; part into individual sheaves. Clean up to the required overall $\frac{1}{2}$ in. thickness, to leave a 3/64 in. thick flange, then mark the 7/32 in. eccentric throw onto one sheave and set in the 4 jaw. Turn to produce the $\frac{13}{16}$ in. diameter boss, taking light cuts, then centre, drill and ream through to $\frac{1}{2}$ in. diameter to suit the axle. Undo two jaws only to release and tighten the same two jaws to continue with the rest of the sheaves. Complete by drilling and tapping 5BA for a cup point socket grub screw for securing to the axle later on.

Driving Axlebox

The driving axleboxes are very straightforward and bolt directly to the frames. Start with a length of $1\frac{1}{2}$ in. x $\frac{1}{2}$ in. BMS bar and saw off two pieces $1\frac{3}{8}$ in. long. Chuck in the 4 jaw, face one end on each piece, then chuck together and complete to $1\frac{5}{16}$ in. overall. Mark the axle centre on one piece, chuck the pair again in the 4 jaw, centre, drill through and bore out to an odd end of $\frac{5}{8}$ in. diameter steel as your gauge; this can now be used as a 'button' to align the two boxes for the remaining machining.
On to the machine vice and vertical slide, again as a pair, to mill the $\frac{1}{16}$ in. deep recess to leave a $\frac{1}{16}$ in. flange to 'grip' the frames. Rotate through 180 deg. and mill away the side flanks so that the outer fixing bolts need not be overlong. Get a couple of very small grease nipples, Tecalemit used to do one screwed 4BA, and tap the boxes to suit. If you don't fancy turning up the bronze bushes, Messrs. Whiston stock the oil retaining variety, which are ideal for our purpose, though you may have to cut them to length; this applies to all the bushes detailed. Press these home, drill the grease hole into the bore, and we are ready to erect.
Take one axlebox and clamp firmly to the frame, flange outside, and position as close to drawing as you are able. Drill through the outer holes at No. 27, spot the middle one, drill this latter No. 33 and tap 4BA; secure with hexagon head bolts. Slide in the driving axle, fit the second axlebox and clamp in place, then check for free turning of the axle. When all is well, drill, tap and secure this axlebox in turn.
Nothing attaches to the driving axle by reason of it passing through the ashpan, the reason I should have given for grease lubrication, so we can fit the second driving wheel immediately after we have completed the coupling rods. There are all sorts of quartering jigs, none of which have I ever used; all my Locomotives so far have been set by eye. However, there is a reasonably simple way of achieving the desired result in a more scientific manner, using a surface plate, a scribing block, and an engineer's square. Choose a cool evening, degrease the axle end and wheel boss, apply Loctite of the 601 or 638 variety and assemble. Sit on the surface plate and use pieces of packing to stop the wheels rolling about. Use the scribing block to set one crankpin reasonable horizontal to the axle centre and the square to set the other at 90 deg. to same; it makes no real difference if the right or left crank leads, though if you do want an instruction for this then put the L.H. one in front.

Leading Horns, Axleboxes, and Stays

The leading axleboxes are from 1 in. square BMS bar, so cut a 1½ in. length and face the ends square in the 4 jaw. Find the centre of one end by the 'X' method, scribing lines to opposite corners, and set to run as true as possible in the 4 jaw, then drill through and bore out to ⅝ in. diameter as for the driving boxes. Back to the machine vice and vertical slide to mill a 1/16 in. recess in one face, leaving a ⅛ in. thick flange at each end. Rotate through 180 deg. and repeat the process, when you can saw into individual boxes and face off to ⅝ in, overall thickness. To complete the boxes, press in the bronze bushes and we can move on to the horns.

A 'stick' casting is provided for the horns, being very easy to machine. First chuck in the 4 jaw and machine the top surface, then reverse in the chuck and machine the bottom face to give the correct 1¾ in. dimension; the working face can either be dealt with in like manner, or you can revert to the machine vice and vertical slide to end mill to the required finish. Whatever method you choose for the working face, tidy up the non-working surfaces at the back, plus the ends of the top and bottom lugs, with an end mill. Back to the 4 jaw chuck and face across both ends of the casting, then saw off the first individual horn. Face off the sawn end, cut another horn and repeat until you have the set of four. Pack a horn from the chuck body so that the face left to be machined is clear of the jaws, then face off to 7/16 in. thickness. At the same tool setting and using the same packing piece, face the other three horns to identical thickness.

Clamp a pair of horns to an axlebox, the flange of the latter being inwards, and clamp the whole in turn to the frames. Locate as accurately as possible, position in this instance being more critical than for the driving axle, and spot through from the frames. Drill the outer holes through at No. 27, the inners at No. 33 to ¼ in. depth, and tap 4BA; secure with hexagon head bolts. There is a very easy way to complete the assembly to be free-running, though we have need to start the coupling rods to achieve this.

Take two 9 in. lengths of 1 in. x 5/16 in. BMS flat and at 13/32 in. from one edge scribe a line the full length. At ⅝ in. from each end, scribe vertical lines to roughly represent the centres of the bosses. Clamp one of these embryo rods to the pair of axleboxes fitted to the one frame, packing the leading axlebox down by 5/16 in. to align with its driving partner. The 'cross hairs' you have provided with those scribed lines will allow you to find the centre of the axle holes very easily to the accuracy you require. Drill through from the bushes at ½ in. diameter and repeat for the second coupling rod, when they will be of identical length between centres.

Clamp the second leading axlebox to its horns, clamp in turn to the frames, then poke lengths of ½ in. rod through both leading and driving pairs of axleboxes. Slip on the coupling rods, adjusting as necessary, then fix the second pair of leading horns to the frames. The hornstays are plain 2 in. lengths of 7/16 in. x ⅛ in. BMS flat, the cross ties 4 9/16 in. (4 5/16 in.) long from ⅜ in. x ⅛ in. flat. Clamp firmly to the horns, check the leading axlebox is free to move, then drill right through at No. 27 in four positions and secure with 4BA nuts and bolts.

Coupling Rods

We must now carry on with the coupling rods so that we can completely wheel the engine and for this we need a 12 in. length of bright steel angle, say 1¼ in. x 1¼ in. x 3/16 in. section. Along one face drill a series of holes at about 2 in. centres and of a size to suit the 'T' bolts for fixing to the vertical slide table. On the other face we need two ⅜ in. holes at 7¾ in. centres so that we can bolt the embryo coupling rod in place. Bolt the angle to the vertical slide and set level; I achieve this by using a length of ground stock across the lathe bed and simply winding down the vertical slide until the angle comes in contact with same. Bolt the rod in place, chuck a large diameter end mill in the 3 jaw, and starting from the edge of one boss, remove 1/16 in. of metal as shown. You will have to move the angle along the vertical slide table as no SMALL LOCOMOTIVE builder's lathe to my knowledge has a cross slide travel in excess of 8 in., though this is no problem as you simply reset, gradually bring the end mill to the work again and carry on machining. Reaching the second boss, you have to machine right across it, so put a clamp over the very end of the bar, this is why it is over-long, and mill up to the clamp. Turn the rod over, put 1/16 in. packing between angle and rod where the metal has been removed, and repeat the process to achieve the stepped ends as per drawing.

Next apply marking off fluid and carefully scribe on the profile of the rod. Bolt again to the angle and mill along the straight line closest to the chuck, using a ⅜ in. end mill. Rather than turn the rod and have to set up all over again, the other edge of the rod can best be tackled with a Woodruff key cutter, Reeves can supply this most useful tool, when you will have removed the majority of the metal which was superfluous to our requirements. At this stage there will be a lot of burrs and sharp edges; carefully remove these with files so that the rod is safe to handle.

Those end bosses we can partly machine, so take another piece of the 1 in. square steel bar and drill a ½ in. hole through it. Loctite a stub of the ½ in. axle material into same, to protrude by about ¾ in., then grip this mandrel in the machine vice, on the vertical slide. Fit a ½ in. end mill in the 3 jaw, slide the coupling rod over the mandrel, advance the rod onto the end mill, a very little at a time, and pull the rod around the mandrel towards you, never the other way. Most of us learn the wisdom of that statement the hard way at some stage, so be warned! You now have to complete the rod profile with files, drill the oil holes and press in the bushes flush with the inner face.

Erect the driving axle, then the leading one to include the eccentric sheaves, when you can apply Loctite to the last wheel, correctly orientating it by fitting the coupling rods. When the Loctite has cured and the wheels turn, they are bound to be a trifle stiff; grip a 5/16 in. drill in the bench vice, slip a rod end over it, poke a length of 1/16 in. steel rod down one of the flutes and rotate the coupling rod to ease metal from the bush. Do this to all the bushes, when the wheel should turn sweetly, even when you raise and lower a leading axlebox independent of its partner; this requirement is essential to the wellbeing of MARIE E on the track.

Equalising Gear

Having tried displacing the leading axleboxes by hand we can now provide the equalising gear which will carry out this function for us when running; it is all very simple. The equaliser beam is a 4½ in. (4¼ in.) finished length of ½ in. x ¼ in. BMS bar. Clamp between the two equaliser beam stays which we have already made, mark off for the No. 11 fulcrum hole and drill right through. For the fulcrum pin, chuck a length of 5/16 in. steel rod in the 3 jaw and turn down for ⅝ in. length to 3/16 in. diameter, a nice sliding fit in the No. 11 hole just drilled. Lightly chamfer the end of the pin for ease of entry into said hole then part off to leave a 3/32 in. thick head. Fit the pin and cross drill 1/16 in. diameter for a split pin. Assemble to the frames and the beam is in contact with the frames at both ends; we must mill away the 1/16 in. step at each end so that the beam can operate properly. If the track on which you will run is very uneven, increase the step to 3/32 in., or ⅛ in. as a maximum. To connect from the top of the leading axleboxes to the underside of the equaliser beam we need two push rods 1⅝ in. lengths of 5/32 in. mild or silver steel rod, though lengthen to suit if the steps in the equaliser beam were increased. You can now assemble all the pieces made so far and try the chassis on your track.

Connecting Rod

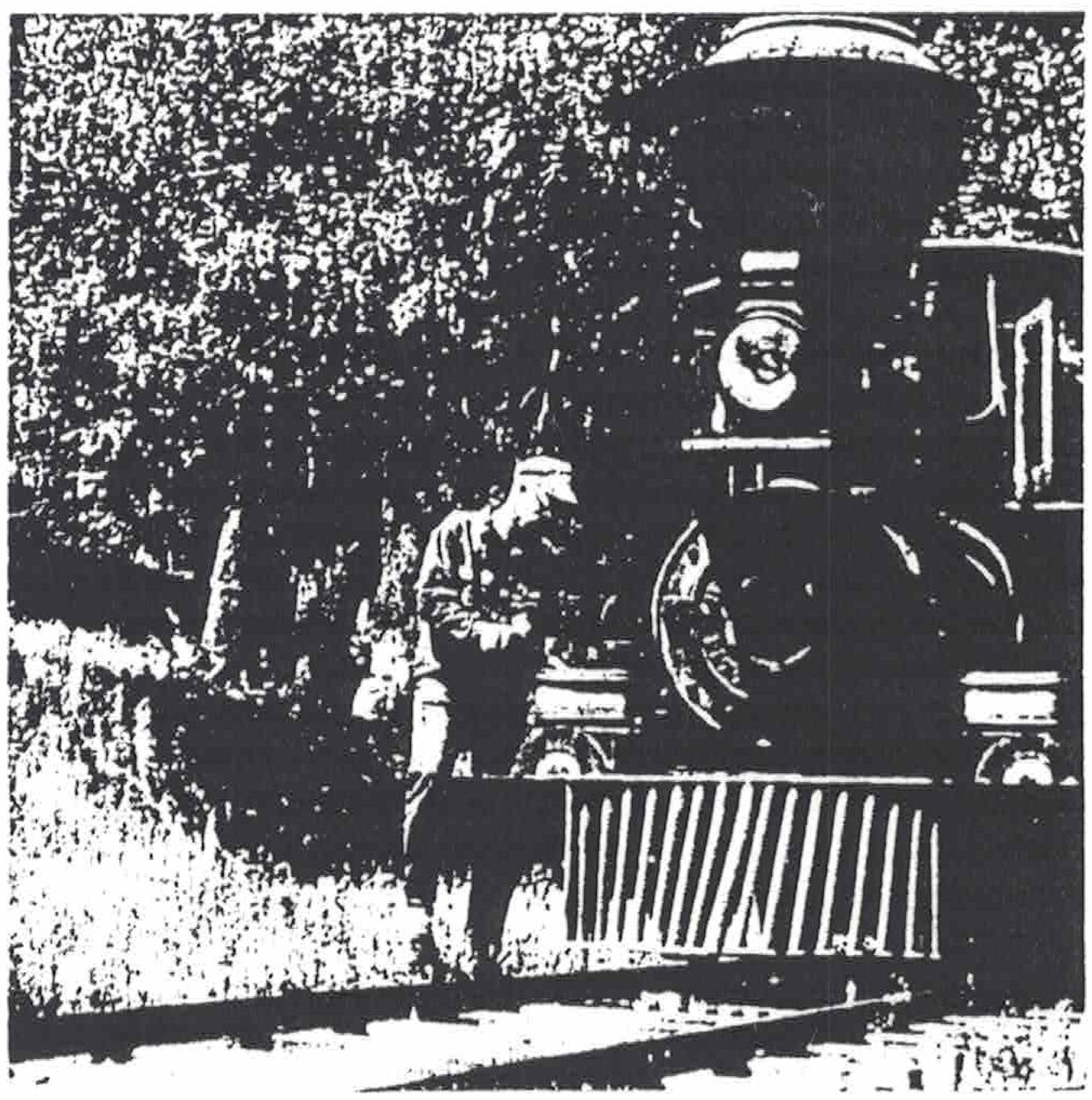
The connecting rod is not next in line in logical sequence, but having just tackled the coupling rods, these are so similar that we may as well get them out of the way; also I can correct the missing dimension! Take two $8\frac{1}{2}$ in. lengths of 1 in. x $\frac{3}{8}$ in. BMS bar and scribe a line 13/32 in. above one edge. At $\frac{3}{4}$ in. from one end, scribe a vertical line, then move on $7\frac{3}{8}$ in. and scribe another; this is the centre distance. Drill one hole $\frac{1}{2}$ in. diameter and the other $\frac{5}{16}$ in. diameter, drill two $\frac{5}{16}$ in. holes at the same centres in your piece of angle, bolt the rod in place, the angle in turn to the vertical slide, and set level.

First use the end mill as for the coupling rods, to reduce the thickness to $\frac{1}{4}$ in. away from the big end boss, then carefully mark out the profile. This time the rod profile is tapered along its length, so release the bolt holding the big end in place and adjust the rod until the end mill follows the bottom line; remove metal to line. Angle the rod the other way and use the Woodruff key cutter to machine the top away to line. Radius the ends over mandrels then complete with files. Press in the bronze bushes, central in the rods, drill the oil holes, then turn up the crosshead pins to drawing, from 7/32 in. mild or silver steel rod.

Cylinders

We now have a fairly long session ahead of us, making the cylinders, in fact once these are out of the way our chassis will be almost complete, so let me hurry on. All the castings come from my 'standard' $3\frac{1}{2}$ in. gauge Great Western Railway designs, and as Churchward was greatly influenced by American practice, their use is thought rather apt. They do need packing away from the frames to achieve sufficient clearance, but the cylinder flange has proved extremely useful in other directions, not being simply a packing piece.
Grip the cylinder block in the 4 jaw chuck and first machine across the bolting face to achieve that 29/32 in. dimension to the centre of the bore. Next turn the casting and face across one end, then reverse in the chuck and set with the bore running true, packing about $\frac{1}{8}$ in. clear of the chuck body to allow the boring tool to pass right through. For ease of setting, drive a hardwood bung into the core hole, file across the end of the casting to give 'bright' metal, then mark on the bore centre. With dividers, scribe a circle at $1\frac{1}{16}$ in. diameter then clamp a scriber under the toolpost and set the cylinder such that the scriber follows the circle; this will be found surprisingly easy, and accurate.
Drill out the bung and then change to a boring tool, one long enough to pass right through the block, and the largest size that will enter the core hole in the casting, this latter in the cause of tool rigidity. Although a 'fancy' boring tool with detachable bits is very useful, the plain tool with $\frac{1}{2}$ in. square shank that is the Myford 'standard' will give the most excellent results. The first cut should be as heavy as the lathe will comfortably cope with, using a fine automatic feed, then reduce to 1/32 in. cuts, or less, increase speed to around 300 r.p.m., and allow the tool to pass both ways through the bore at each tool setting. Approaching finished size of $1\frac{1}{16}$ in., a dimension which you can check with calipers, reduce the cut to around .005 in. and allow four traverses per cut, this to get the bore nice and parallel. Sometimes a much better finish can be obtained by applying paraffin with an old paint brush, depending on the crispness of the gunmetal; check this out before you reach the finished bore size. Face off the end of the casting to achieve the correct $2\frac{3}{8}$ in. overall length, making this the back cover face as it is perfectly square with the bore. Bring the other block up to this stage, handing it so that the back cover face comes in the right place to make a pair.
We now come to the only awkward job on the whole engine, machining the inclined port face. First scribe around the block and if you are adept with a hacksaw, remove some of the metal to reduce machining time, plus make life easier for your lathe. Builders in the U.S.A. using MARIE E castings purchased from our good friends Power Model Supply Co. will be able to ignore that last instruction as these blocks should be cast with the inclined port face. One thing I fervently believe in is a minimum number of involved setting operations, as saving both time and frustration, and this influences the type of machining specified, as we shall see shortly.
Fit an angle plate to the vertical slide and set level, cut a $1\frac{1}{2}$ in. square from $\frac{3}{16}$ in. steel plate and drill a $\frac{3}{8}$ in. hole through its centre. Stand the cylinder block on the angle plate, poke a $\frac{3}{8}$ in. bolt up through the bore, it wants to be around $3\frac{1}{2}$ in. long, slip the plate over the top and complete with a nut. Turn the bolting face towards the 3 jaw chuck, open said jaws and bring the block hard against same to ensure that the bolting face is square across the lathe axis. Next mark off the exhaust outlet tapping; centre and drill this 11/32 in. diameter to 11/32 in. point depth before tapping $\frac{3}{8}$ in. x 32T. Lift the vertical slide table by .625 in. to bring the steam inlet into line for attention, drilling this 9/32 in. diameter to $\frac{5}{16}$ in. point depth and tapping $\frac{5}{16}$ in. x 32T. We are going to use the $\frac{3}{8}$ in. x 32T exhaust tapping to bolt to the angle plate, so screw a length of $\frac{3}{8}$ in. steel rod at 32T and make a nut to suit from an odd end of hexagon bar. Fit to the angle plate with the portface towards the headstock and measure from the vertical slide table to the marked portface line to set roughly square across the lathe axis. That single bolt is hardly sufficient to hold the block for the sort of machining operations that I propose, so cut a couple of $1\frac{1}{4}$ in. lengths of bright steel angle to abut against the ends of the block, with a hole drilled in each to suit slots in the angle plate.
The specification now is to fly-cut the portface, which sounds rather exotic, but in fact involves nothing more than an ordinary round nosed tool and the 4 jaw chuck. Grip the tool in said chuck so that it sweeps a circle to overlap the portface set the tool in motion clear of the job and carefully advance the block onto the cutter; lock the carriage and machine right across. Advance the block by about .005 in. at a time, checking occasionally that the tool is not working loose in the chuck.

Ollie Johnston oils MARIE E ready for another run on the Deer Lake Park and Julian R.R.



As you approach completion, make any minor adjustments necessary so that the portface will finish to line. If the bore is slightly displaced, that 1 1/16 in. dimension will be difficult to achieve; as long as there is clean metal in way of the fixing studs all will be well and any gap can be filled with Isopon P38 or similar on final assembly. Using the fly-cutter technique, the portface should machine to a very good finish; you can try feeding on a little paraffin, but beware the tool swing!
With the block still in place, use an engineers square to mark on the positions of the ports; this is where we shall save a lot of time. For the steam ports, drill a row of No. 37 holes to 1/4 in. point depth, clear of the scribed lines; two rows to the same depth in the exhaust port. Staying with the exhaust port, change to a 1/16 in. end mill and complete nearly to line all around to 1/4 in. depth, then change to a 3/32 in. end mill for the final cut. These small end mills are extremely flexible, so run the lathe at top speed, apply a cut of a few thous only and let the end mill take its time, otherwise you will not get a straight port edge, especially if the end mill digs into a corner. Having got used to the end mill, you can take it with confidence into the more restricted steam ports, again cutting a groove in the centre to full depth and then carefully opening out to a piece of 1/8 in. thick material as gauge. One thing I did learn during my apprenticeship at Doncaster was how to use a hammer and chisel, so I would chip the corners of the ports square to drawing. As the probability exists of damaged ports if this were to be a general instruction, the advice is to leave well alone.
Our blocks are rapidly approaching completion, in fact, apart from a fair number of tapped holes, only the passages require attention. For these latter, start by filing a chamfer in the position shown at each end of the bore and centre pop at a full 1/8 in. centres. The passages are a full 3/4 in. long, which gives a margin for error, so scribe a light line on the bolting face to represent the axis of these holes. Grip in the bench vice, hang a bolt on the end of some lightweight cord, and use as a plumb-bob to set the hole axis vertical. Now drill a pilot hole at 1/16 in. diameter into the port. If there is any error countersink the outer end of the hole, chuck the 3/32 in. end mill in the drill and use this to correct the defect; it will not follow the original hole as another drill would. If you still have a problem, use an 1/8 in. end mill for final correction. To form a slot from the two individual holes, use a dental burr, though if great care is exercised the end mill will achieve the same result. At this point we must lay the blocks aside and make progress in other directions.

Cylinder Covers

The front covers are easy, so let us get them out of the way next. Chuck by the rim in the 3 jaw and clean up the spigot, then rechuck by the latter. Turn down the periphery to 1 5/8 in. diameter and face right across, then concentrate on the step to get this a nice push fit in the bore; it does not matter if you do not achieve this specified fit, but it is the best possible practice for the rear cover to follow, where said fit is vital. Change to a knife edged tool and scribe a circle at 1 3/8 in. diameter for the fixing bolts, then tidy up the outer face before parting off the spigot. Mark off and drill the six No. 27 holes, offer up to the block, spot through, drill No. 33 to 3/16 in. depth and tap 4BA.
Turning to the rear covers, chuck by the rim and face off the slide bar boss, including removal of the spigot. Centre and drill right through at No. 3, follow up at 11/32 in. to 1/4 in. depth and 'D' bit to 5/16 in. depth before tapping 3/8 in. x 32T; poke a 7/32 in. reamer through the remains of the No. 3 hole. Bring the other cover up to this stage then chuck an odd length of 3/8 in. rod, face turn down for 7/32 in. length to 3/8 in. diameter and screw 32T; fit a cover to this holder. Turn down the rim, face and produce the step exactly as for the front cover, then deal with the fixing holes. We shall deal with the slide bar seating later on, but you can drill and tap the cylinder block to fix the cover.

Piston & Valve Rod Glands; Piston & Rod

The piston and valve rod glands are simple turning; I would start to produce the 'C' spanner slots with a hacksaw and complete with a key cutting file to about 3/32 in. width, now for the piston and rod.
Grip the piston blank in the 3 jaw chuck and clean up the spigot, then rechuck by this latter. Face the end then centre and bring the tailstock into play. Turn down to around 1 1/8 in. diameter, then with a parting off tool, rough out the groove for the square packing, again leaving metal to be removed later. Fit the tailstock chuck, that most useful accessory, and drill right through at 3/16 in. diameter. Follow up at No. 3 to 7/32 in. depth, tap the remains of the 3/16 in. hole at 7/32 x 40T, then part off to a full 7/16 in. thickness.
For the piston rods the requirement is two 12 in. lengths of 7/32 in. stainless steel rod; the reason for these long lengths will become clear later. Turn to a point at one end then reverse in the 3 jaw chuck and check with a d.t.i. that the rod is running perfectly true; use the 4 jaw to achieve this if necessary. Face off then use a tailstock die-holder to screw 40T for 1/4 in. length. Screw the piston to the rod and then turn down to 1 1/16 in. diameter, a nice sliding fit in the bore; this operation will also tighten the piston onto the rod. Face off to thickness and then concentrate on finishing the groove, which latter wants to be the same width as your packing but a good 1/64 in. less in depth than the section to provide a bit of 'squeeze'. Don't pack the piston as yet, but here is the way to do it correctly, so that I do not omit description later on in my excitement! Wrap the packing into the groove and cut to length with a sharp knife so that there is no gap. Enter the piston in the bore and with a piece of flat brass, work the packing down into the bore, pushing in the piston as you go. Sometimes it is difficult to get the very last bit of packing into the bore, in which case tap the piston with a wooden mallet, when the excess will be severed. Pack the gland and we can move up to the steamchest.

Steamchest

As always, check the machining allowances, but this time be extra careful to check that the boss will clean up in the position shown, not the same spot as on the casting. Chuck in the 4 jaw and face across, then reverse and face again to the required 11/16 in. thickness. Three of the four external surfaces can also be faced off, or you can mill them in the machine vice on the vertical slide. Now for the important fourth face, the one with the valve spindle boss. Mark this off, scribe a 1/2 in. circle on the boss and set this to run true, using a scriber as for the cylinder bore, chucking of course in the 4 jaw. Face the boss and turn down to 1/2 in. diameter, continuing on and facing the steamchest wall. If you are worried by the stand-out from the chuck, centre drill the boss and bring the tailstock into use. Change to the tailstock chuck and drill through at No. 14, follow up at 9/32 in. diameter to 5/16 in. depth and tap 5/16 in. x 32T. To complete, mark off and drill the seventeen No. 34 holes, then clean up the inside with files.

Steamchest Cover

I much prefer to cut these from brass plate, but for the casting, chuck by its spigot and face right across. Saw off the spigot, grip in the machine vice on the vertical slide and mill the four edges to match the steamchest; you may clamp the pair of items together to achieve this. To machine the upper face, pack off from the back of the vice so said face is clear of the

jaws, then use the largest end mill available to clean up to thickness.
Still in this position, find the centre by the 'X' method, centre, drill through at No. 22 and tap $\frac{3}{16}$ in. x 40T for the oil connection from the hydrostatic lubricator kit called for on Sheet 1. Drill the 17 holes from the steamchest, then offer the latter up to the cylinder block, spot through, drill the block No. 43 to $\frac{5}{16}$ in. depth and tap 6BA for 1 in. long hexagon head bolts.
Whilst drilling holes in the blocks there are a couple more in the portface area to be dealt with. The first is the steam inlet, so mark this off and drill a 3/32 in. diameter pilot hole down to the steam entry tapping. Again rectify any error using an end mill held in the drill chuck, as for the passages, then open out to No. 11. The other hole is to connect from the exhaust port to its tapping, so centre pop in the inner corner of this port and again drill 3/32 in. diameter initially. Open out in stages to $\frac{1}{4}$ in. diameter, keeping clear of the port edges.

Valve, Buckle & Valve Spindle

Chuck the valve in the 4 jaw and carefully machine the working face, then reverse and clean up to the required $\frac{1}{4}$ in. thickness. Mark out the valve so that the cavity is central then back to the machine vice and vertical slide to mill the two side flanks to $\frac{7}{8}$ in. width. Next mill to length, then turn the cavity towards the chuck and tidy this up to size with your 3/32 in end mill. Reverse in the vice and pack out from the back of the body until you can mill right around the upper spigot to arrive at the $\frac{11}{16}$ in. square; this again must be centralised to avoid breaking into the cavity. The buckle is like a mini-steamchest and is dealt with in identical fashion, the last operation being to clean up the inside to a nice sliding fit over the $\frac{11}{16}$ in. square just milled on the valve. The valve spindle will cause no problems, when all can be assembled.

Exhaust Fitting & Cylinder Flange

The exhaust fittings are plain turning, so let us deal next with the cylinder flange. Cut from $1\frac{1}{4}$ in.x $\frac{5}{16}$ in. BMS flat and face off in the 4 jaw to $2\frac{3}{8}$ in. overall; they can be machined as a pair. Mark off and drill all the holes, including the four at No. 27 from the frames. Use the exhaust fitting to fix the cylinders to the flange, poke a $\frac{5}{16}$ x 32T tap into the steam entry and erect to the frames, clamping in place with the No. 27 holes aligning. Now you can do the final adjustment by lining up the extended piston rod point with the centre of the driving axle, easing the 21/64 in. steam entry hole if necessary to achieve this. When satisfied, spot through the four No. 27 holes into the block, drill this latter No. 34 to $\frac{1}{4}$ in. depth and tap 4BA. The correct steam entry is by way of two Don Young Designs $\frac{1}{4}$ in. male Unions fitted with bronze nipples, these latter in bronze so there is no fear of their melting when you silver solder in the steampipes.

Smokebox Saddle & Bottom Plate

That virtually completes the cylinders, so let us move on to the smokebox saddle, a very pretty gunmetal casting that requires only a minimum of machining. The saddle itself merely needs some small attention with a half round file to accept the 4 in. o.d. boiler/smokebox tube and to sit snugly thereon. Next grip in the 4 jaw chuck and face across the bottom, taking very light cuts, this to achieve the $1\frac{1}{4}$ in dimension.
The remaining work is best done in the machine vice on the vertical slide, so next cut and fit a piece of hardwood packing inside the saddle, so the vice jaws can be tightened without distorting the casting. Mill the two end faces to a close fit between the cylinder flanges, then concentrate on the two steps to get these a close fit between the frames, to ensure the whole assembly is very rigid. Remove the cylinders, leaving the flanges in place, fit the saddle, spot through, drill and tap the fourteen 6BA holes for countersunk screws.
Cut the bottom plate from $2\frac{1}{4}$ in. x $\frac{1}{8}$ in. strip to be a tight fit between the flanges and deal with these fourteen fixing holes also; use 6BA screws if you are at all worried about breaking through the saddle walls. Those last couple of paragraphs have meant a great leap forward and there are not many pieces left to be made now to complete this first marathon session.

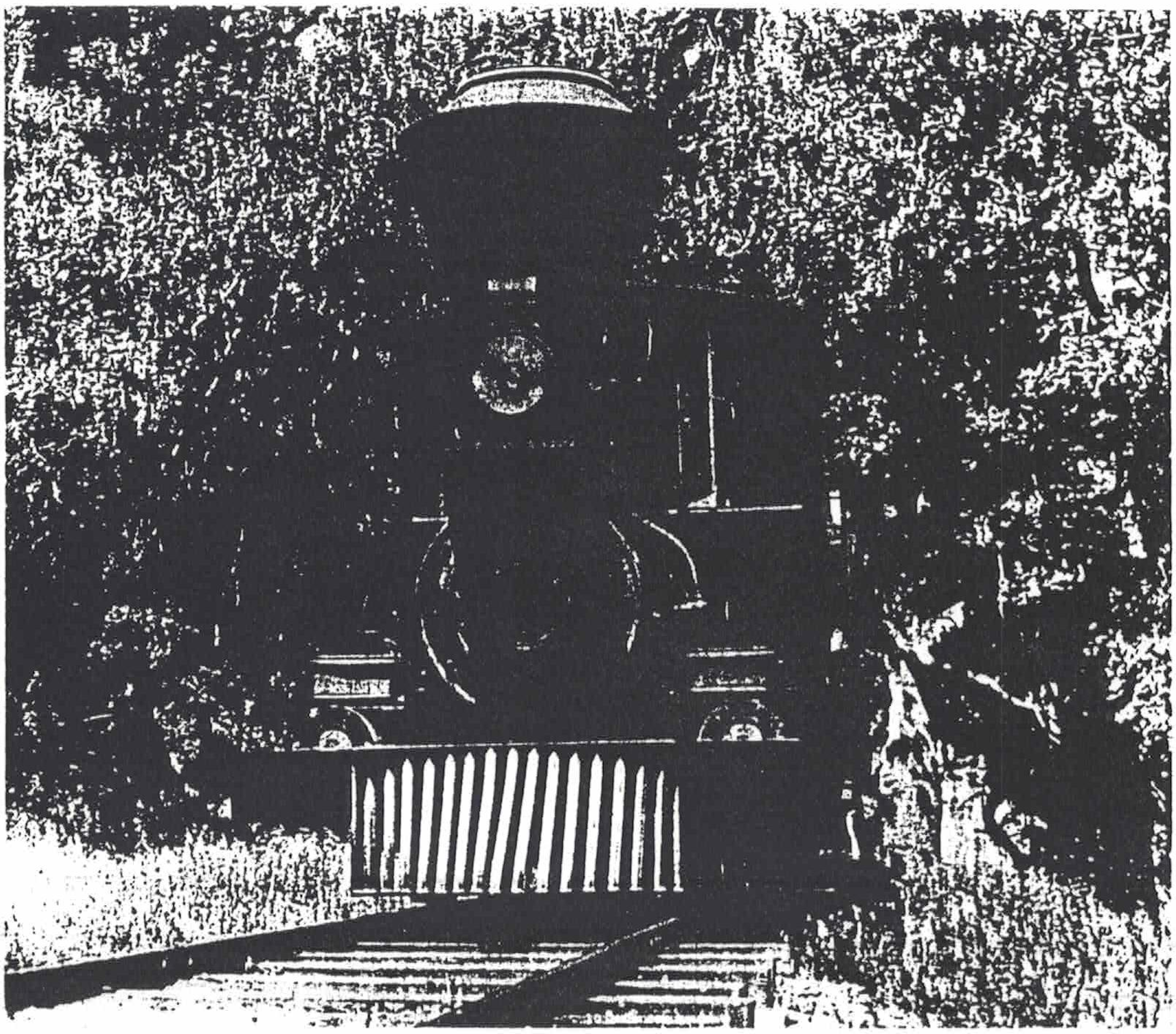
Crosshead

Experienced builders will make their crossheads with $\frac{1}{16}$ in. steel side plates and braze same to the piston rod boss, but my specification here is for machining from $1\frac{1}{4}$ in. x $\frac{1}{2}$ in. BMS bar. First mark off all the holes, drilling those six No. 34 right through as a first step and countersinking the back face. Next drill No. 3 for the piston rod to $\frac{3}{8}$ in. depth, then drill right through at No. 27 at the crosshead pin, following up at 7/32 in. diameter for $\frac{3}{8}$ in. depth. Roughly saw out the bottom profile, then chuck a length of 7/32 in. rod in the 3 jaw, centre, drill No. 33 to about $\frac{3}{16}$ in. depth and tap 4BA. This is our mandrel for milling the bottom radius, this as for the coupling rod ends, the crosshead being held from sliding off the mandrel by a 4BA bolt. Next grip in the machine vice, on the vertical slide, to mill a slot from top to bottom up to the piston rod boss. Use a $\frac{1}{4}$ in. end mill, or $\frac{5}{16}$ in. once the slot is near to size, and open out to $\frac{3}{8}$ in. to a piece of requisite thickness material as your gauge. Saw off to length, or rather height, mill the top edge to line, fit packing in the slot and then mill away above the piston rod boss to complete; the $\frac{1}{8}$ in. taper pin hole will have to wait awhile.

Slide Bar & Slippers

Messrs. Whiston stock $\frac{3}{8}$ in. x $\frac{1}{16}$ in. brass bar and this is ideal for the slippers, so saw off four lengths and square off to $1\frac{1}{4}$ in. overall. Cut the slide bars initially $4\frac{3}{8}$ in. long, square these off also and drill the No. 27 hole, when we can move on to machine the slide bar boss on the cylinder rear cover.
Bolt the complete cylinder to the angle plate on the vertical slide once more, using the exhaust tapping for fixing, and set square across the lathe axis; this time you can use a d.t.i. along the piston rod as an additional check before cutting down to about $3\frac{3}{8}$ in. long. Fit the crosshead and clamp a pair of slippers to the slide bar. Mill across the slide bar facing on the rear cover and clamp the slide bar to it; now you can check how much more metal has to be removed to bring the top slipper down flush with the top edge of the crosshead. Remove this metal at the rear cover, offer up the slide bar, spot through, drill the boss No. 34 to $\frac{1}{4}$ in. point depth and tap 4BA; secure with a hexagon head bolt. Remove the complete unit from the angle plate, clamp over the crosshead to hold the slippers firmly in place and drill through at No. 34 from each side the four ends holes, securing with 6BA countersunk screws, nutted on the outside. Check for freedom of movement, easing the slipper faces slightly if necessary, then deal with the other two holes.
Next job is to fasten the crosshead to its piston rod, once we know the correct position, so erect the cylinders to the frames and fit the connecting rod. Turn the engine to front dead centre, then push the piston rod further forward until the piston strikes the front cover; scribe where the piston rod enters the crosshead. Turn to back dead centre and push the piston further until it strikes the back cover, checking that the overlong piston rod does not foul the connecting rod first; scribe another line at point of entry to the crosshead.

I have more front end shots of MARIE E than any other and no wonder, she is impressive viewed that way! Readers will note the discrepancy between the Diamond Stack on my drawing and the Congdon pattern now on MARIE E; Ollie preferred the Diamond but had to change because of the risk of lineside fires.



Scribe a third line equi-distant between the first pair; this is the correct point of entry of the rod into the crosshead to give equal clearance for the piston at each end of its stroke. Cross drill at No. 41 and follow up with an ⅛ in. taper pin drill or reamer, finishing with a taper pin which for the moment must be finger tight only.

Slide Bar Stay

The outer end of the slide bars is supported by a simple angle stay, which is straightforward after all that has gone before. Shape the end of the slide bar as shown on Sheet 1, checking that free movement remains, then tap the slide bar and secure with a hexagon head bolt.

Eccentric Rod & Straps

We cannot complete the valve gear in this session, although our chassis will be more than 85% complete, but we can make three of the major items, starting with the eccentric rods and their straps. The straps are gunmetal castings which first require chucking in the 4 jaw, not out of the window I hope!, to face off both sides to 7/32 in. thickness, a nice fit in the sheave groove. Carefully mark off the joint, saw in halves, then grip in the machine vice on the vertical slide, this to clean up the joint faces with an end mill. Reverse the front portion and mill the face to accept the eccentric rod flange, this to the ¾ in. dimension. Bring the two halves of the casting together and clamp in the machine vice to deal with the fixing bolt holes, pushing the last face to be machined hard against the back of the vice. Lightly end mill the lugs so the fixing bolt heads will sit properly, then mark off and drill right through at No. 44. Follow up at No. 34 to a bare ¼ in. depth then tap the remainder 6BA, holding both drill and tap in the 3 jaw chuck. Separate the pieces and run the No. 34 drill through the back piece to give a clear hole, then fasten together with 6BA bolts; throughout I am assuming you will use bolts with hexagon heads one size smaller than standard – they look so much neater as well as giving the very necessary clearances.

Fit a wooden bung in the core hole, scribe across the joint and scribe in the centre line in the other axis, to find the centre of the strap; scribe a circle at 1⅛ in. diameter. We now know how to set jobs up to run true on a scribed circle, so carry on and drill out the bung, then bore out to that piece that we produced as a gauge when making the sheaves. Assemble over the chosen sheave, when all should be well; you can now complete the profile with files. Drill the No. 30 oil reservoir to $\frac{3}{16}$ in. depth, then separate the halves, centre pop and drill back at No. 60 from the bore into the oil reservoir, removing any burr with a larger drill, just twiddling it around with your fingers.

For the eccentric rods first cut four 3½ in. lengths from $\frac{3}{16}$ in. square BMS bar. Mark off and drill the No. 31 hole at one end, then turn the bar over and drill No. 12 at the end of the fork. Back to that length of square angle attached to the vertical slide, when you can clamp the eccentric rod in place to mill away the main portion to leave the 3/32 in. thickness; this is the reason for the overlong material. Grip in the bench vice and make two saw cuts down to the No. 12 hole to remove most of the material, then complete the slot with a key cutting file to a piece of $\frac{3}{16}$ in. material as gauge.

Take a piece of, say, ½ in. square bar and drill a No. 31 hole right through; press in an ⅛ in. silver steel pin to leave about ½ in. protruding. To press this type of pin in accurately, I take a short length of $\frac{5}{16}$ in. rod, about 1½ in. long, chuck in the 3 jaw and drill a No. 30 hole to ½ in. depth. Slip this over the pin and life becomes a lot easier. Take a strip of emery cloth, wrap around the projecting pin and remove enough metal so that it slides into the No. 31 hole in the rod, then grip in the machine vice and use as a mandrel to end mill the radius at the fork end. Cut off the rod to a full 2$\frac{3}{16}$ in. from the centre of the No. 31 hole, end mill this square and then profile the rest of the rod with files.

For the end flanges, cut four $\frac{3}{4}$ in. lengths from $\frac{1}{2}$ in. x $\frac{1}{8}$ in. BMS flat, lay on your brazing hearth, which can be a piece of asbestos millboard, and pack to be level. Mix up some Easyflo flux to a stiff paste and apply liberally at the joint, then heat up with your torch and apply Easyflo No. 2 spelter, or equivalent specification of course. Allow to cool, wash off and wirebrush clean; I will cover the subject of silver soldering more fully when we reach the boiler in our next session.

Back to the machine vice and vertical slide, to grip the rod and end mill the flange to the correct $\frac{3}{8}$ in. x 7/32 in. section, this to mate with the strap. We now have to reduce the thickness of the flange, but before doing so we need a simple jig. Take a 5 in. length of, say, 1 in. x $\frac{3}{16}$ in. BMS flat and drill two No. 31 holes at 3 /1/32 in. centres; if you grip the bar in the machine vice on the vertical slide then you will be able to advance the cross slide by 3.031 in. to achieve this very accurately. Press $\frac{1}{2}$ in. lengths of $\frac{1}{8}$ in. steel rod into these holes and emery cloth one of the pins to accept the eccentric rod. For the other end, chuck that gauge you used for the eccentric straps in the 3 jaw, centre and drill through at No. 31. You can either press this over the second pin, or ream at $\frac{1}{8}$ in. diameter to be a sliding fit.

Assemble the rod and strap on the jig, when you will see the amount of metal to be removed from the flange; deal with this by end milling. If you do happen to remove too much metal then a shim can be inserted to restore the status quo, just like full size. To complete, drill the flange No. 41 for the two fixing bolts, carry on into the strap for about 5/32 in. at No. 47 and tap 7BA; assemble with hexagon head bolts.

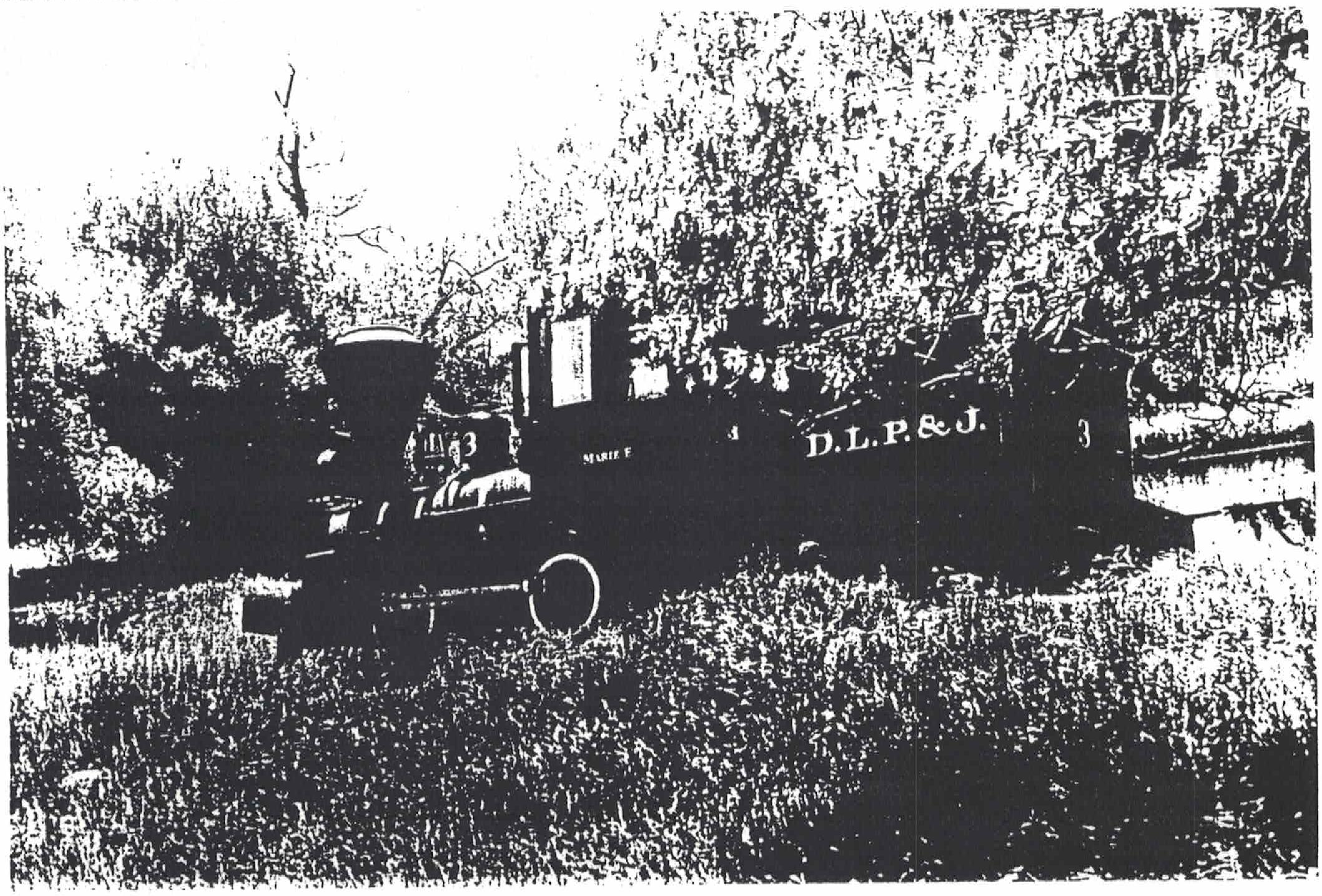
Lifting Link, Valve & Reverser Levers

For the remaining parts to be made we need similar building jigs, again using 1 in. x $\frac{3}{16}$ in. BMS flat, each 3 in. long. In the first piece drill a No. 31 hole, advance the cross slide by 1.438 in. and drill No. 13; for the second piece the same holes are at 1.250 in. centres. Press in lengths of $\frac{1}{8}$ in. and $\frac{3}{16}$ in. steel rod with about $\frac{3}{8}$ in. stand-out.

The lifting link uses the long centres, so chuck a length of $\frac{5}{16}$ in. bronze rod in the 3 jaw, face, centre, drill No. 13 to about $\frac{7}{8}$ in. depth and ream at $\frac{3}{16}$ in. diameter; part off two $\frac{3}{16}$ in. slices for the end bosses. For the link, take a length of $\frac{1}{4}$ in. x $\frac{1}{8}$ in. BMS flat, grip in the machine vice, centre, drill through at No. 31 and ream $\frac{1}{8}$ in. diameter. Radius the end over the mandrel from the eccentric rods, file the side flanks, then cut off to give a good joint with the end boss when fitted to the building jig. We now have to silver solder the two pieces together, but must be careful not to braze the whole to the jig. To prevent this disaster occurring, coat the jig liberally with marking off fluid. Assemble the pieces, apply Easyflo flux at the joint and then apply heat and Easyflo No. 2 in turn. Remove the completed link from the jig before it cools right off, otherwise you will have a problem as the expansion/contraction is uneven between link and jig.

The valve and reverser levers require slightly different treatment; first turn up the end bosses, then drill and ream a $\frac{1}{8}$ in.. hole in a length of $\frac{1}{2}$ in. x $\frac{1}{8}$ in. BMS flat. Assemble and scallop the joint at the end of the lever to suit the boss, then braze up. To complete, file the flanks of the lever to drawing and radius the end over your mandrel; Sheet 2 is complete!

This photograph by David Gooley of Paramount, California was taken with an eye to beauty. LLAS readers would have cut that tree down to reveal the hidden Locomotive detail!



Marie E, A Porter 0-4-0 in $4\frac{3}{4}$/5 in. gauge

by: DON YOUNG

PART II

Expansion Link

Between sorting out the valve gear and detailing it I saw there was a possibility of reducing work on the expansion link, which is why the detail is of simpler profile. Experienced builders will make these links from $\frac{3}{4}$ in. x $\frac{3}{16}$ in. section gauge plate with 'original' profile, but for beginners I recommend a piece of gauge plate, 9 in. x 2 in. x $\frac{3}{16}$ in., obtainable from A. J. Reeves & Co. (Birmingham) Ltd. Scribe a line down the centre of the piece, then with dividers mark out the slot, then the two $\frac{1}{8}$ in. holes for the eccentric rod ends, finally building the profile around, when you will find that from the centre of the slot to the front of the link, a dimension of 11/32 in. should have appeared on the drawing detail. Drill and ream the two $\frac{1}{8}$ in. holes, followed by two at 3/32 in. diameter for the rivets, then drill a row at $\frac{3}{16}$ in. diameter down the centre line of the slot, as close to each other as possible, say 13/64 in. centres. Use a square Swiss file to break the holes into a slot then take a small, smooth flat file and concentrate on the convex side of the slot, filing down to the scribed line. Select a piece of 7/32 in. silver steel rod and start filing the concave side of the slot, with a half-round file a little at a time and using the silver steel rod as your gauge as you proceed; this method will provide a surprisingly accurate slot. I did once try building up a quite substantial and intricate jig so that I could mill the curved slots on the lathe, it took me 3 or 4 evenings to make it; the end mill then proceeded to show me how flexible it was and milled an almost straight slot, a waste of both time and good material! Saw out the links and profile to line with files.

For the trunnions, cut two $\frac{13}{16}$ in. lengths from $\frac{5}{16}$ in. x $\frac{1}{8}$ in. BMS flat and square off to $\frac{3}{4}$ in. overall, this to match the links; do this singly and clamp in place to drill the rivet holes from the link, countersinking both sides of each hole. On to the trunnion pin, which starts life as a length of $\frac{3}{16}$ in. steel rod. Chuck in the 3 jaw, face and turn down to .110 in. diameter over a 5/32 in. length and screw 6BA. Leaving a $\frac{3}{16}$ in. length of the original bar, start parting off, only stop when the spigot gets to around $\frac{1}{8}$ in. diameter. Move on $\frac{1}{8}$ in. and part right off before measuring the actual diameter of the spigot with your micrometer. Mark off the trunnion and drill so that this spigot is a light press fit; put a 6BA nut over the fragile thread and press in. Silver solder for additional security -- from the inside so that the spelter does not get onto the bearing surface. To complete, erect to the link, scribe back at each side of the slot and mill the 5/64 in. recess to clear the head of the die-block pin; secure to the link with a pair of soft iron rivets.

Fulcrum Bush and Pin

For a bit of light relief after that, let us deal with the fulcrum bush and pin, the latter being $1\frac{3}{8}$ in. finished lengths of $\frac{3}{16}$ in. bright steel rod. For the bushes, chuck a length of $\frac{1}{2}$ in. diameter bronze bar and turn down to $\frac{7}{16}$ in. diameter over a $\frac{7}{8}$ in. length. Centre and bring the tailstock into play, then with a parting off tool, turn down the centre portion to .377 in. diameter over a $\frac{7}{16}$ in. length, to be a tight fit in the frames, being held firmly in place on assembly by the bearing block. Drill to about 1 in. depth at No. 14, follow up with a $\frac{3}{16}$ in. reamer and part off at $\frac{3}{4}$ in. overall.

Weighshaft

For the weighshaft assembly, we already have the reverser arm and neither the shaft itself, a $4\frac{7}{8}$ in. finished length of $\frac{1}{4}$ in. steel rod, or the collar, should cause any builder problems, so on to the lifting arms. Cut two $1\frac{1}{4}$ in. lengths from $\frac{7}{16}$ in. square bar, a bit left over from the frames, finish to identical length and grip in the machine vice on the vertical slide. At $\frac{1}{4}$ in. from one end, on the centre line, centre, drill through and ream at $\frac{1}{4}$ in. diameter. Advance the cross slide by .813 in., centre, drill through at No. 32 and ream $\frac{1}{8}$ in. diameter. The $\frac{1}{8}$ in. slots are to suit the lifting arms, so fit two hacksaw blades into your frame and saw out the beginnings of the slot, completing with a key cutting file to the lifting link as gauge. All that remains is the profiling and with such short pieces I recommend you rely solely on files, taking your time to produce a neat job. The taper pins will have to await assembly.

Spacer, Die-Block and Pin, also Valve Gear Pins

Die-block and valve gear pins are very easy to produce, in two pieces. Start with a length of $\frac{1}{8}$ in. bright steel rod, chuck in the 3 jaw, face, turn down for $\frac{1}{8}$ in. length to .110 in. diameter and screw 6BA. Now part off to cover the plain length of pin plus thickness of head; in the case of the die-block pins 43/64 in. Chuck a length of 7/32 in. steel rod, face, centre and drill No. 31 then part off a $\frac{1}{16}$ in. slice. Press this onto the pin, silver solder for extra security, then clean up with a light machining cut and emery cloth. The spacer is plain turning, as is the die-block initially, for it starts life as $\frac{3}{8}$ in. bronze rod chucked in the 3 jaw, faced, centred, drilled and reamed at $\frac{1}{8}$ in. diameter; part off a $\frac{3}{16}$ in. slice. Grip in the machine vice, on the vertical slide and mill away about 3/64 in. to form the first flat. Turn through 180 deg., pack off the back of the vice onto the first flat and repeat the dose, this will give the 9/32 in. length of block. Grip a length of 5/32 in. rod in the 3 jaw, hold one of the flats just milled against the rod, bring up the machine vice and grip then mill away $\frac{1}{16}$ in. to form the third flat. Again turn through 180 deg., pack off this latest produced flat and repeat to give $\frac{1}{4}$ in. width. Now you can carefully reduce by filing, keeping the pin hole central, until the die-block fits neatly into its expansion link; complete with the oil hole.

Valve Rod

For the valve rods we need a very simple jig, two $\frac{1}{8}$ in. pins about $\frac{3}{4}$ in. long pressed into No. 31 holes at $4\frac{1}{16}$ in. centres in a length of $\frac{3}{4}$ in. x $\frac{3}{16}$ in. BMS bar, just like we did for the lifting links earlier on. Turn up collars $\frac{1}{8}$ in. and $\frac{3}{16}$ in. thick from $\frac{1}{4}$ in. bronze rod, reamed through at $\frac{1}{8}$ in. diameter for the end bosses, plus a 13/32 in. long spacer, this from steel, to drop over one pin and achieve the required offset. Cut the rod from $\frac{1}{8}$ in. steel to fit between the bosses, pack in place then silver solder together.

Valve Crosshead and Pin

We know how to deal with the pin from previous description, so for the crosshead, take a length of $\frac{5}{16}$ in. square steel bar and at 5/32 in. from one end, cross drill and ream at $\frac{1}{8}$ in. diameter. Form the slot as for the lifting arms then radius the end over a mandrel; the dimension given at $\frac{1}{4}$ in. for thickness may be left at $\frac{5}{16}$ in. if you prefer as it means less work. Saw off slightly over-long, put a piece of packing into the slot and chuck truly in the 4 jaw. Face off to length, centre, drill No. 29 and tap 5/32 x 40T to complete.

Assembly

We now have a lot of valve gear components ready for erection, so will have to refer back to Sheet 2. First take a valve lever, slip it over the end of a fulcrum pin, cross drill No. 40 and follow up with a taper pin drill or reamer. Use for preference taper pins at least $\frac{3}{4}$ in. long, check as you open out the hole until the pin protrudes about $\frac{1}{16}$ in. then drive it home and cut off the excess to leave about $\frac{1}{16}$ in. proud at each end. If you think you might have difficulty lining up the second valve gear lever exactly 180 deg. apart, then drill and tap its boss 6BA for a socket head grub screw and secure to the pin by this means until the valve gear has been set.

Next cut four $\frac{5}{16}$ in. lengths from $\frac{1}{8}$ in. silver steel rod (drill rod) as the eccentric rod pins, ease one end slightly so it will enter a rod eye, line up the expansion link hole and press home. Do the same with the second eccentric rod, checking from the chassis assembly drawing for correct orientation. Erect to the eccentrics, fit the die-block to its pin, followed by the spacer, push through the expansion link slot into the end of the valve lever and secure with a 6BA nut. Screw on the valve crosshead, slip on the valve rod and assemble with headed pins.

For the weighshaft, fit the reverse lever to the shaft with an $\frac{1}{8}$ in. taper pin, push through the R.H. bearing block, slide on the collar, push home, then drill said collar for a taper pin, but don't fit it at this stage. Fit one of the lifting arms, couple to the expansion link through the medium of the lifting link, set the reverse arm vertical and the die-block in the centre of the slot; the engine is in mid gear. Clamp in place then drill for and lightly fit another $\frac{1}{8}$ in. taper pin. For the second lifting arm, erect all the pieces, then mark the axial position of the arm onto the weighshaft. Remove the whole assembly and re-erect with an $\frac{1}{8}$ in. rod through both lifting arms to ensure correct alignment; drill for and fit the last $\frac{1}{8}$ in. taper pin. Reassemble to the frames to complete the valve gear, when the temptation arises to set it up; I prefer to delay this until the reverser and reach rod are in being, then valve gear setting can be both positive and 'once only', so on we go.

Reverser

For the stand, cut a $3\frac{1}{4}$ in. length from $2\frac{1}{2}$ in. x $\frac{1}{8}$ in. BMS flat and square off one end. Mark off and drill one hole only at $\frac{1}{8}$ in. diameter, or No. 30, for the rack, which latter we shall have to attend to next. For those possessing bending rolls, and as this is one tool I would give house-room it will have to be the subject of an article in LLAS for the future, then racks are simply rolled up from $\frac{1}{4}$ in. x $\frac{1}{8}$ in. BMS bar. The alternative is to mark out on another piece of that $2\frac{1}{2}$ in. x $\frac{1}{8}$ in. BMS flat then saw and file to line. Drill as a pair $\frac{1}{8}$ in. diameter at each end and radius, then offer one rack up to the stand, drill the second hole, secure with 5BA bolts and shape the top of the stand to match the rack. For the bottom end of the stand, cut a $2\frac{3}{8}$ in. length from $\frac{3}{8}$ in. x $\frac{3}{8}$ in. x $\frac{1}{8}$ in. brass or steel angle and rivet to the stand. Position the stand on top of the R.H. frame and trim to clear the drawbar stay; drill the five No. 34 holes, offer up to the frame again, spot through, drill No. 43 and tap 6BA.

The pole comes next in line for treatment, so turn up the boss from $\frac{5}{16}$ in. steel or bronze rod, scallop the end of a 7 in. length of $\frac{5}{16}$ in. x $\frac{1}{8}$ in. BMS flat and silver solder together. Mark off the plain $\frac{1}{8}$ in. hole and the ends of the slots and drill these; you can now either complete the slots by filing or grip the pole in the machine vice, on the vertical slide, and complete with an end mill. At $\frac{3}{4}$ in. from the end of the top slot, drill through at $\frac{1}{16}$ in. diameter, following up at $\frac{1}{8}$ in. and 'D' bit to $\frac{1}{16}$ in. depth for the spring pocket; now you can bend over the top of the pole to form the handle and then trim off the excess length.

Start with a $2\frac{1}{2}$ in. length of $\frac{5}{16}$ in. x $\frac{1}{8}$ in. material for the latch and first produce the 90 deg. bend, laying against the pole and trimming the handles to match. Clamp in place, spot through the $\frac{1}{16}$ in. hole, drill and 'D' bit to $\frac{1}{16}$ in. depth to form the second spring pocket. Next mark off, drill and tap the two 7BA holes, turning up the latch bolts to suit, plus the rack spacers. Assemble the latch to the pole, fitting a latch spring and checking that all works sweetly, then assemble the pole to the stand, fit the inner rack, plus spacers and bring up the outer rack; use lengths of $\frac{1}{8}$ in. rod to erect the racks at this stage. Now you can check the position of the tooth at the end of the latch against the $1\frac{7}{8}$ in. dimension given and cut it to drawing. Set the pole vertical, bring up the outer rack again and mark off for the mid-gear slot, filing this to place and checking against the latch as you go. Additional slots can now be cut, full gear first with the pole hard against the spacer, and then intermediate ones roughly as shown. Completely erect the reverser, set in mid-gear and set the reverser arm on the weighshaft vertical. Measure the reach rod length and I guess 7 11/32 in. centres is being a bit optimistic on my part!

Reach Rod

We now know how to make simple brazing jigs and one will come in very handy for building up the reach rod, so drill holes $\frac{1}{8}$ in. diameter at the reach rod centres in a 10 in. length of $\frac{3}{4}$ in. x $\frac{3}{16}$ in. BMS flat and press in $\frac{5}{8}$ in. long pins. Take two $\frac{11}{16}$ in. lengths of $\frac{5}{16}$ in. square steel bar and at 5/32 in. from one end, cross drill at No. 31. Emery cloth the pins so that these blocks fit easily over them and then cut a piece from $\frac{1}{4}$ in. x $\frac{1}{8}$ in. BMS bar to fit between the end blocks. Pack this centre piece up from the jig, to be central with the end blocks then braze up. Drill $\frac{1}{8}$ in. holes at the end of the slots, saw down by the 'double hacksaw blade method' and file to fit reverser arm and pole. Now all you have to do is shape these fork ends to drawing to complete. When finally erected plain $\frac{1}{8}$ in. pins will be pressed in at both ends, but for now use pins which have been very slightly reduced in diameter to be a light push fit as we shall have to strip down several times after setting the valves, though these latter can be finally dealt with at this stage.

Setting the Valves

Take off the steamchest covers and refasten the steamchests firmly in place by the corner bolts, fitting spacers under the heads if necessary. Those eccentric sheaves with bosses for the fixing screws means valve setting is much more civilised than when the screw is within the confines of the sheave slot; even so I do not expect every builder will be so fortunate as Dennis Hill with his 30 minutes. Turn the L.H. side to front dead centre and if you hold a d.t.i. against the crosshead, dead centre is when the needle stops moving. Drop the engine into full fore gear, loosen the fore gear eccentric sheave and turn until the valve just 'cracks' the port, so you can just see the port edge. Tighten the sheave onto the axle, turn to back dead centre and check the port opening; move the valve on its spindle to centralise the openings. Put the engine into full back gear and repeat the process with the back gear eccentric, then it is a case of first fore gear and then back gear, gradually reducing the errors until you arrive at the correct setting. If this cannot be perfectly achieved and your outside valve lever is only temporarily secured, move this slightly and check the effect, securing with a taper pin when all is well. Your engine will spend most of her working life 'notched-up', so check valve setting with the pole in the first slot from mid-gear, getting equal 'lead' openings at this position to the expense of those in full gear if necessary. My method of valve setting is to get equal lead at the dead centre positions, at the expense of equal valve openings; this is the way we set up the 'Pacifics' at Doncaster Plant, and like full size, any discrepancy in equal port openings will be negligible. Use cup point socket grub screws to fix the eccentric sheaves and when valve setting is complete, really tighten them into the axle so that they will never move in service.

Pilot

Just the pilot to complete the chassis and it really does add the finishing touch, as both LARGE MARIE E and SMALL LADY ROSE bear witness. As this is an 'adornment' rather than a functional part of our Locomotive, then in this instance I will allow the constructional notes on the drawing to speak for themselves, content that the performance will not suffer.

The Boiler

At this point in the proceedings I am sorely tempted to 'Call for Coulson', knowing that Jack's article has been an inspiration to many SMALL LOCOMOTIVE builders; yours truly must hope that he can kindle the same spark of enthusiasm. If this does not prove to be the case then at least there is the consolation that advertiser Reg Chambers will be only too pleased to produce a complete and certificated boiler for you.

For those still with me, the first requirement is one of those superb boiler kits from A. J. Reeves & Co. (Birmingham) Ltd., complete with ready flanged plates – the latter take the hard work out of boilermaking.

The boiler barrel will be a roughly 9¾ in. length of 4 in. o.d. x 13 s.w.g. seamless copper tube which first requires squaring off to length. Chuck, very carefully, by the bore in the 3 jaw and check the outer end is running fairly true; the skilled turners of earlier days used to do this by holding a piece of chalk up to the job and marking the limit of eccentricity, but we can do this with a lathe tool, pulling the job round by hand. When running true, bring a knife edged tool up to the chuck end of the tube and using plenty of paraffin (kerosene) as cutting oil, take a cut down as close as you can to the chuck jaws without touching them. Remove the tube from the chuck and finish square by filing, then treat the other end likewise to finish to 9⅝ in. overall. Next grip by the outside in the 4 jaw and set to run true; fit a scriber under the tool post. Turn by hand until the scriber strikes one of the chuck jaws then wind the carriage along to scribe on a centre line; repeat at the other 3 jaws which will then allow us to position all the holes, and bushes accurately.

Start with the opening to mate with that in the smokebox saddle, marking out and checking by sitting over said saddle. To support large tube for working without it rolling all over the place, the front of my work bench has a raised edge from heavy section steel angle, which I hold the tube against and then nail a block of wood behind. For producing large openings in tube I find the easiest way is to drill holes about ⅛ in. diameter at close pitches inside the scribed line and open out gradually until these holes break into one another, assisted by a Swiss file as necessary until the redundant material falls away. In this instance, however, we can use a hacksaw for two sides of the opening and only need to resort to drilling on the other two sides; complete by filing to line. The 1 in. hole on the top centre line for the petticoat pipe is a case of drilling, breaking out the middle and then filing to line; a slack fit is necessary here to allow for a little adjustment. Next mark off and drill for the two blind bushes to support bell and sandbox, also the pair on the horizontal centre lines for the check valve bushes. Turning up these bushes should pose no problems, but I will describe the check valve bushes to set the ball rolling. Chuck a length of ½ in. bronze rod in the 3 jaw, face and turn down for about ½ in. length to $\frac{7}{16}$ in. diameter. Further reduce to ⅜ in. diameter over a 7/32 in. length, a tight fit in the hole in the boiler barrel, then centre and drill 7/32 in. diameter to $\frac{7}{16}$ in. depth before parting off to leave a full ⅛ in. flange. Reverse in the chuck, face the flange and lightly countersink the hole entrance before gripping a ¼ x 40T taper tap in the tailstock chuck and pulling the lathe around by hand to cut about 4 threads – no more. This means that after all the abuse of heat and pickle you will be able to complete tapping out the bushes and get good clean threads.

We are now nearly ready for our first braze and I know this will incur Jack Coulson's displeasure. Cut a piece 2½ in. x 1 in. from 1.6. mm copper and bend to fit inside the boiler barrel. The strip laps the boiler barrel by ¼ in. and a single rivet will hold it in place for brazing; let us deal with this rivet. Clamp the strip firmly in place, centre pop ⅛ in. from the end of the barrel on the bottom centre line and drill right through at No. 51, countersinking the outside of the barrel with a 60 deg. Rosebit. To support the rivet head we need a 'dolly', a large lump of steel bar which can be gripped in the bench vice. The second item required is a rivet 'set', a 4 in. length of ¼ in. steel rod with a No. 49 hole drilled about ¾ in. deep at one end. Take a $\frac{1}{16}$ in. diameter snap head copper rivet ¼ in. long, insert from the inside and sit the head on the dolly. Hold the set over the projecting shank and apply a couple of sharp blows to bring the pieces into close contact, then hammer the shank into the countersink; this will 'mushroom' the rivet head which is of no consequence.

For brazing equipment I can do no better than refer builders to LLAS No. 7 and Jack Coulson, with only one cautionary note; when mixing pickle ALWAYS ADD ACID TO WATER, NEVER THE REVERSE. There are but three rules in boilermaking – clean copper at all times, plenty of heat, and always use the correct grade of flux with the chosen spelter. To start getting the copper into the right condition, put the barrel and bushes in the pickle whilst you prepare for the first braze. Build up a hearth with refractory bricks, or put a piece of asbestos millboard across the top of a dustbin, lay out the B6 or C4 spelter and mix some of the relevant flux to a paste. Fit the No. 2943 burner to your Sievert propane torch and you can remove the barrel from the pickle, wash off under the cold water tap and flux the four bushes and the piece of strip. Light up the torch, get it going with a quiet diffuse flame at medium pressure setting on the regulator, stand the smokebox end in the hearth and heat the area around the doubler strip. Choose a cool evening when the light is poor for preference, then you will see the copper begin to glow red, when you can apply the spelter, which should immediately flash right round the joint. Deal with the four bushes at this heat, allow to cool to 'black heat' and dump into the pickle. Give it about 20 minutes, remove and wash off, then inspect for any 'misses', reheating immediately if you are not 100% satisfied with what you see.

Take the outer wrapper sheet from the boiler kit and scribe on the top centre line. Fit this to the barrel with top centre lines coinciding, clamp firmly in place and pull round by hand to start forming the wrapper. Take the flanged throatplate, scribe on its centre line, hold against the barrel end after filing the scallop to fit hard against the strip, mark the positions for the reverse bends on the wrapper, transfer to the bench vice and pull these round. Saw the doubler strip into five tabs and hammer these over the throatplate, clamping the wrapper to the side flanges with top centre line coinciding with that on the barrel and with ⅜ in. overlap. In the centre of this overlap on the top centre line, drill right through at No. 41 and fit a 7BA bolt. Move about 1 in. each side of this first hole, drill again at No. 41 and fit another two 7BA bolts. Remove the first bolt, countersink the wrapper, fit a 3/32 in. snap head copper rivet from the inside, sit on the dolly, use the rivet set to bring wrapper and barrel into intimate contact and hammer the shank down into the countersink. Now it is a question of another two holes, 7BA bolts, removing the previous pair, rivetting, and so on down to within $\frac{3}{4}$ in. of the bottom of the throatplate. Trim away the excess wrapper ahead of the throatplate, but don't worry about the bottom profile as yet. Just try the backhead from your boiler kit in the outer end of the wrapper to check there are no huge gaps, then pickle, wash off, flux the joints and stand in the hearth on the backhead end. Light up the torch and first concentrate on those tabs, feeding in more spelter to get a really good joint with a fillet on the outside. Staying now on the outside and starting at a bottom corner, work right round the wrapper joint; cool, pickle, wash and inspect.

On to the firebox and those flanged plates have already given us a good start. Mark out the tubeplate for the 18 firetubes and if you are going to use the 'Coulson method' of spigotting the tube ends for positive location, use 20 s.w.g. thick tubes and drill the tubeplate 23/64 in. or 9mm diameter. Take the tube provided for the firehole, chuck by the bore in the 3 jaw, face off and turn down for $\frac{3}{16}$ in. length to about 1 13/32 in. diameter. Reverse in the chuck, face off to 23/32 in. overall and turn down to the same 1 13/32 in. diameter for 7/32 in. length to leave $\frac{5}{16}$ in. at the original tube diameter. Mark off the position of the firehole on the firebox backplate, working from the top as it will be over-long at this stage, then chuck in the 4 jaw, set to run true, drill and bore out to size. Fit the firehole ring, right way round please, stand on a block of lead and peen over as shown on the drawing. Do not anneal unless absolutely essential as the other spigot will likely distort and cause you all sorts of problems.

You will have scribed on centre lines on both tube and back plates when marking out, so now do the same for the firebox wrapper. Scribe further lines $1\frac{1}{4}$ in. each side of the centre line to indicate the start of the top corner radii, clamp over a $\frac{5}{8}$ in. diameter bar in the bench vice and pull round, checking to place as you proceed. With the plate so held, you will be able to form the rest of the wrapper shape by hand, checking against the end plates; assemble the three pieces by the same method as used for the outer wrapper, using longer rivets on the centre line to attach that $4\frac{5}{8}$ in. length of $\frac{5}{16}$ in. square copper as the crown stay; this is all the fixing the crown stay will require.

We now come to the most awkward job in the whole construction of the boiler, the crown girder stays, but I do consider them to be essential from a safety aspect. Readers will note that apart from the girder stays mating with the outer wrapper where possible, they also fit into slots in the dome bush to provide support at the front end. Reg Chambers has commented that to avoid this latter the stays could be snaped back to behind the dome bush, which is perfectly acceptable for a professionally built boiler, so carry on Reg; for us amateurs I prefer the 'belt and braces' approach.

Take the dome bush and flange casting, chuck by the outside in the 3 or 4 jaw, face across and bore right through to $1\frac{7}{8}$ in. diameter. Open out for $\frac{3}{16}$ in. depth to 2 in. diameter to suit the dome tube then rechuck by the bore, turn down the outside to $2\frac{1}{2}$ in. diameter and part off a 9/64 in. or 5/32 in. slice for the dome flange. Face off again, reverse in the chuck, face to length and turn on the $2\frac{7}{16}$ in. diameter spigot over a 19/32 in. length. Anyone possessing a slitting saw can clamp the bush in the machine vice and cut the slots to accept the girder stays, end milling the scallop to clear the regulator tube at the same time, otherwise use hacksaw and files to achieve the same result. Mark off and cut the opening in the outer wrapper as for the chimney; but make sure the bush is a tight fit so it will not tilt and spoil the whole effect; a dome that looks like a leaning tower of Pisa is a real eyesore. Mark off and drill a $\frac{1}{2}$ in. hole for the manifold bush at this stage, plus a $\frac{3}{8}$ in. one $\frac{5}{8}$ in. aft for the top water gauge connection, both on the top centre line of the outer wrapper; turn up the bushes to suit.

Next trim off the bottom of the throatplate, plus the adjacent outer wrapper, to length and cut a piece from the $\frac{5}{16}$ in. square foundation ring material to fit between the throatplate flanges, getting it a good fit. Locate the bar between 1/32 in. and $\frac{1}{16}$ in. above the bottom edge of the throatplate; immediately above this on the centre line drill a $\frac{3}{8}$ in. hole for the blowdown valve bush. Although a standard $\frac{5}{16}$ x 32T Blow-Down Valve is specified, we can alternatively supply the same pattern valve screwed $\frac{1}{4}$ x 40T, or the much superior genuine American 'Everlasting' Blow-Down Valve, this latter also screwed $\frac{1}{4}$ x 40T – we aim to please!

With the front section of the foundation ring in place, offer up the firebox to the boiler shell, clamp over the throatplate and firebox tubeplate, and centralise the firebox inside the outer shell. With internal calipers, measure the depth of the girder stays from outer wrapper to firebox top and bend these up from 3mm copper in the boiler kit; the strips want to be $4\frac{5}{8}$ in. long and $2\frac{1}{8}$ in. wide. Scribe one line along $\frac{3}{8}$ in. above the base edge, set this line level with the top of the bench vice jaws and hammer over. Position the second, reverse, bend from the caliper dimension, hammer it over and check to place as you go, cutting this top flange away for $2\frac{1}{4}$ in. in way of the dome bush. When all is well, scribe lines along the firebox top to position the girder stays, extract the firebox and sit the stays in place, drill a 3/32 in. hole through in two positions in each flange, about $\frac{1}{2}$ in. from each end and fit snap head copper rivets, heads inside, just 'mushrooming' the shanks over to hold in place for brazing, our next job.

Into the pickle, wash, flux and start warming at the tubeplate end, being careful not to overheat the copper in way of the tube holes; feed in C4 or B6 spelter and of these two C4 is slightly easier to use, at least that is my experience. Move on to the top of the firebox and braze on the crown and girder stays, then tip the box over again, always work 'downhand' for preference, and tackle the back plate joint and firehole ring; pickle, wash off and inspect.

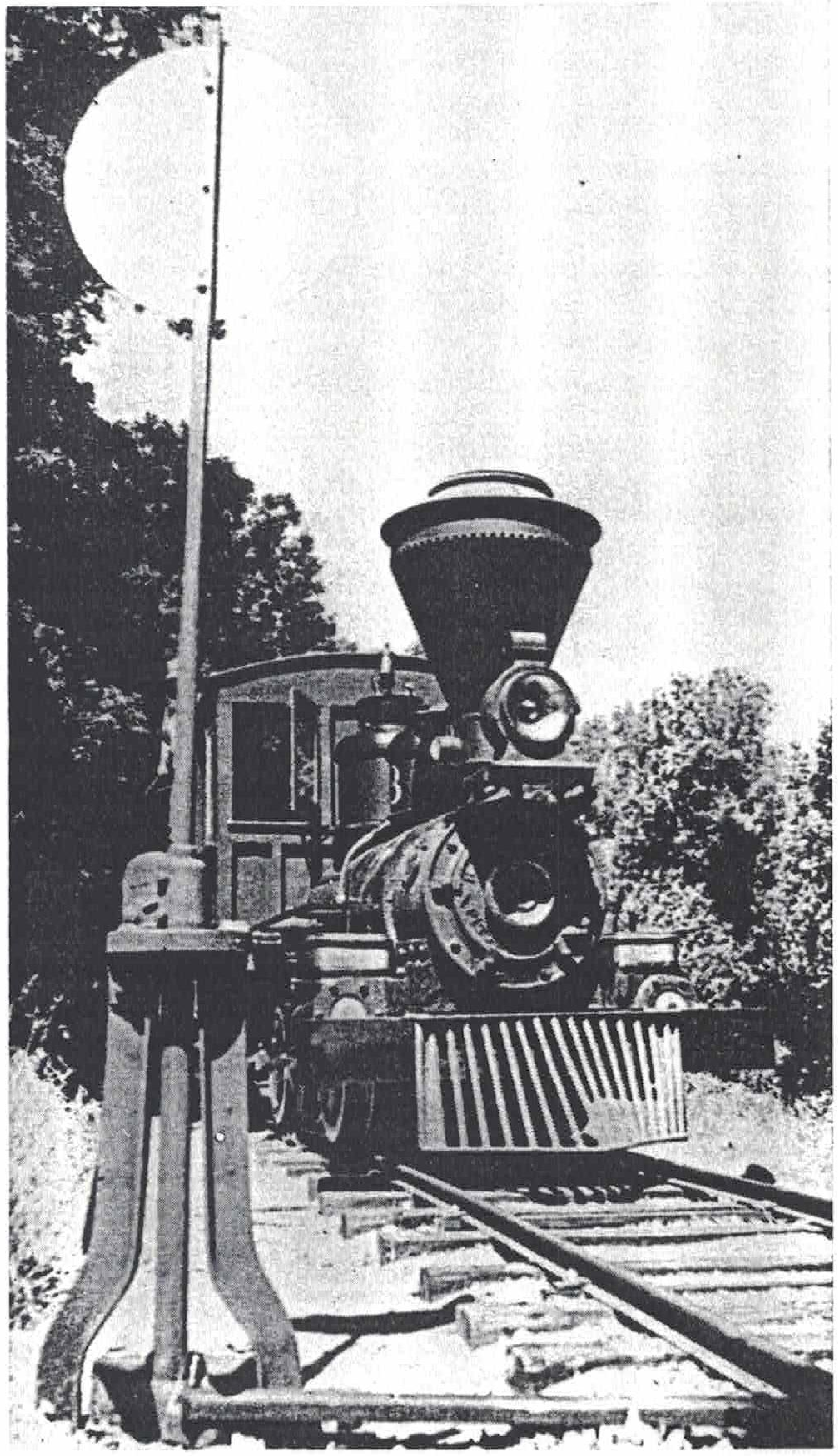
Before we can fit the tubes we must attend to the smokebox tubeplate. Rub a file around the bore of the barrel at the smokebox end to remove any burrs, then chuck the tubeplate by the inside of its flange in the 3 jaw and turn down the outside to a sliding fit in the barrel, tidying up the end of the flange at the same set-up. Mark off and drill all the firetube holes at $\frac{3}{8}$ in. diameter, another two at 9/32 in. diameter for the longitudinal stay ends and start tapping them $\frac{5}{16}$ in. x 40T from the front end, then a final hole at $\frac{5}{8}$ in. diameter for the steam pipe. Drilling large holes through relatively thin material, clamp either to a block of aluminium or hardwood, then instead of breaking through and making a mess of the hole, and possibly you as well, the drill will continue and produce a nice round hole.

Pickle the firebox again, and all 18 firetubes, then wash off, flux the tubeplate, for Easyflo No. 2 this time, and insert all the tubes. Wind silver solder in a spiral over a $\frac{3}{8}$ in. rod, cut into 18 individual rings and slip one over each tube, allowing to fall to the firebox end. Now fit the smokebox tubeplate over the outer end of the tubestack and although I have used Jack Coulson's practice of making rows of tubes of slightly differing lengths, I have also made them all the same length and not found assembly the problem imagined; the result looked much neater too. So as with all things, you pays your money and takes your choice. Set the tubestack square with the firebox tubeplate and parallel with the firebox sides, a job for engineer's square and straightedge, then set up in the brazing hearth and apply heat right around the area until the Easyflo does just as its name suggests, checking on the inside that a little fillet of silver solder has built up around each tube end and applying more Easyflo No. 2 if indicated. Remove the smokebox tubeplate, bring each outer tube end up to a dull red, allow the whole to cool slightly then pickle, wash off and inspect. Erect the firebox in the outer shell, check that the girder stays come into good contact with the outer wrapper, adjusting if necessary, then mark off and trim away the bottom of the firebox to drawing profile, dealing then with the outer wrapper in similar fashion, checking with the backhead held in place.

Time to assemble the firebox to the boiler shell, so fit that front section of foundation ring in position again, followed by the firebox, clamp firmly in place and again check that the girder stays are in close contact with the outer wrapper, adjusting if necessary to ensure there is no need for fitting rivets in awkward places. When all is well, drill right through throatplate/foundation ring/firebox tubeplate in three positions, between $\frac{5}{8}$ in. and $\frac{3}{4}$ in. pitches, countersink the throatplate and fit 3/32 in. or $\frac{1}{8}$ in. snap head copper rivets. These latter want to be $\frac{3}{4}$ in. long initially, crop after insertion, use the rivet set and then hammer down into the countersinks. Go ahead now and fit the side sections of the foundation ring, again $\frac{5}{16}$ in. square, securing with 3 or 4 rivets each side and filling the gap at the radius of the firebox tubeplate with an odd sliver of copper hammered into place.

Next in line for treatment is the steam pipe, a 12 in. length of $\frac{5}{8}$ in. o.d. x 16 s.w.g. copper tube, with ends squared by facing in the lathe and removing a minimum of metal to finish around $11\frac{15}{16}$ in. overall. For the ferrule, chuck a length of $\frac{3}{4}$ in. diameter bronze bar in the 3 jaw, face, centre and drill to about $\frac{9}{16}$ in. diameter to at least $1\frac{1}{4}$ in. depth, then bore out to $\frac{5}{8}$ in. diameter, a tight sliding fit over the steam pipe. Position the ferrule $3\frac{9}{16}$ in. from the rear end of the tube and braze with B6 or C4 spelter as a separate operation, then drill 11/32 in. and start a $\frac{3}{8}$ x 32T taper tap so you can complete in situ in the boiler. Turn up the steam pipe flange $\frac{1}{4}$ in. thick from 1 in. diameter bronze bar and bore out to $\frac{5}{8}$ in. diameter to fit over said steam pipe. If you make the fit a fairly tight one and are lucky with your steam pipe wall thickness, as I was on checking the feasibility of the following, then tapping a $\frac{1}{2}$ in. steel ball into the bore of the tube will expand it sufficiently to really grip the flange, making erection and brazing that much easier, though don't forget to thread on the smoke box tubeplate first. Slide the smokebox tubeplate into the barrel and engage the firetubes using pencils in their bores. If there is a tendency for the tubeplate to slide further into the barrel, use a well greased $\frac{5}{16}$ in. taper pin to expand one or two of the tubes to hold the tubeplate firmly in position. See that the standpipe hole is pointing vertically upwards through the dome bush, then pack the steam pipe away from the crown stay to be parallel through the boiler and hold in place with copper wire wrapped around its end and the firehole; we are ready for the next braze.

Pickle, wash off, flux all around the smokebox tubeplate, the tubes and steam pipe flange, move back to the dome bush, manifold and top water gauge bushes, then along the top of the girder stays, down to the front and side sections of the foundation ring and complete with the blow-down valve bush. Lay the boiler upside-down in the brazing hearth with the firebox protruding over the end, light the torch and play the flame on the outside of the outer wrapper. If as they should be the girder stay flanges are in close contact with the outer wrapper, then you will see the heat transfer and both outer wrapper and girder stay flanges come up to dull red together, and I should have said at the fluxing stage that we shall be using Easyflo No. 2 from now on, so feed said spelter in and watch it flow around with consummate ease. Deal with the



dome bush at this stage, but if manifold or water gauge bush falls out, leave until we reach the backhead. Still in this attitude, tackle the front and sides of the foundation ring, plus the blow-down valve bush, watching as far as you are able that full penetration of the silver solder occurs. Next stand the boiler on the backhead end, packing clear of the exposed steam pipe, then play the flame around the outside of the barrel in way of the smokebox tubeplate. As soon as it begins to glow dull red, transfer the flame inside, through the saddle opening if you like at the outset, and feed in Easyflo No. 2, when it should do the trick in no time at all. If progress slows due to the copper oxidising, the rule is stop, pickle, wash off, reflux and try again – never try to press on regardless. Carefully inspect again, reheat and deal with any problem spots before going any further; in any case we are fast approaching completion.

Make up the three bushes for the backhead, dealing with the regulator rod gland and housing at the same time, then mark off and drill the $\frac{5}{8}$ in. hole in the backhead for the steam pipe. Position the blind bush from this hole, drill for the other bushes and also for the longitudinal stay ends. Offer the backhead up to the boiler, scalloping its flange in way of the water gauge top bush, then scribe back through the firehole ring, drill and file this out to line. Now it is a case of carefully opening out this hole still further with files until it slips over the spigot; support the inner end of the firehole on your rivetting dolly and peen over the spigot end. The wrapper should be in close contact with the backhead flange and the copper now being soft, any slight gaps can be closed by gentle tapping, though if there is appreciable gap, fit home made 6BA gunmetal or bronze screws, clearance holes in the wrapper and tapping the backhead flange. To close the boiler, fit that last section of foundation ring and I usually find this is a tight enough fit such that rivets are not required. Refit those manifold and top water gauge bushes if they fell out and we are ready for our last brazing session.

Pickle the boiler, pour out the acid that will be trapped, wash out, flux all the joints to be dealt with and stand on the smokebox end, packing firmly upright. Light up the torch and starting at the bottom corner of the backhead, work all around the joint, dealing with the various bushes, regulator rod housing, and the firehole tube as you come to them. Turn the boiler on its back and tackle the rear section of the foundation ring to complete. Lower very carefully into the pickle, for the boiler is now virtually a closed vessel, plus acid loves fizzing up the tubes; leave for about 30 minutes then thoroughly wash and inspect. If all appears well, have a cup of your favourite brew.

Boiler Air Test

We now have to blank off all the openings to carry out a preliminary air test and whilst it is easy to tap out the bushes and longitudinal stay end holes and fit temporary hexagon head plugs, the dome opening in this instance can best be covered by the inner dome itself; sounds a bit logical that. Square off the dome tube from the kit to 2¼ in. overall then cut a circle from 3mm copper to be a tight fit in the bore. Drill two ½ in. holes at ⅞ in. centres and turn up the safety valve bushes, then fit the bottom flange and braze up with Easyflo No. 2. Pickle, wash off and inspect, then chuck in the 3 jaw and carefully face off the bottom flange to be flat. Change to a knife edged tool and scribe a circle at 2¼ in. diameter then divide up for the fourteen 6BA home made bronze cheese head screws, turned from $\frac{3}{16}$ in. rod. Offer up to the dome bush, making sure that the safety valve bushes are on the centre line of the boiler, then spot through four holes, drill No. 43 and tap 6BA. Now you can spot through the other ten holes, drill No. 43 to at least ¼ in. depth and tap 6BA in turn. As a gasket, I use heavyweight brown paper soaked in raw linseed oil; its a bit messy, but highly successful. Stick the paper to the flange and lightly tap around the periphery and bore, cutting out with scissors. Put the gasket in place again and use a scriber to locate and make the holes; done carefully this is all that is required and you can go right ahead and fit the screws. Two openings to go, one a plain plug and to the other safety valve bush we have to couple our air supply. Cut a valve stem from a redundant cycle inner tube and soft solder the stem into the second plug; with valve screwed in and connected to a cycle pump you are just about ready for the air test, the last requirement being domestic approval to completely immerse the boiler in sink or bath. Apply no more than 10 pumpfuls of air and look for tell-tale strings of bubbles, though I very much hope you don't see any. The rule here is that a tiny stream of bubbles should be inspected as it is most likely a pin-hole caused by a naughty bit of flux; if this is the case then forget it as boilers at this stage should only be reheated if absolutely essential – faults tend to get worse instead of better.

Staying the Boiler

We must now press on quickly to the hydraulic test stage, starting with the firebox stays. Mark their positions and only lightly centre pop, otherwise you will dent the soft copper. Starting with the top row of stays on a firebox side, drill a hole at No. 34 right through into the firebox, checking that it is square with the surface. Poke another No. 34 drill into this first hole and use it as a 'sight' to drill the remainder of that row. The selection of 4BA stays was to make use of the ready screwed copper stay rod that was a Reeves 'standard'; unfortunately they were experiencing problems with supply a few months back, so I am keeping my fingers crossed that this has been resolved. To successfully tap soft copper 130 times, brand new carbon steel taps are the answer, a small investment for a sound boiler, and as I do not supply said 4BA taps there is no vested interest in this statement, just experience. Put the 4BA taper tap through an outer hole, annointing with tapping compound; withdraw the tap, clean it, put 2nd and plug tap throuh this hole, then proceed with the taper tap through the firebox shell, again repeating the ritual. Tapping soft copper is akin to cutting butter with a sharp knife, so if you feel resistance then chances are that a bit of swarf has got where it shouldn't; ease the tap backwards and forwards to work the swarf out and then remove and clean before proceeding any further. Once you have dealt with one stay hole it is now a question of repeating another 64 times, though for many reasons, among them being that variety is the spice of life, deal with the stays one row at a time, screwing in the copper stay rod, fitting a 4BA commercial brass nut on the firebox end, screwing it up hard against the firebox shell with about one full thread projecting, then cropping off on the outside with at least $\frac{1}{16}$ in. projecting. You can file off a little on the outside of each stay on completion and before hydraulic test, but do leave a minimum of 1/32 in. projecting at conclusion. Do one side of the firebox, then the other, followed by the throatplate and finally the four stays in the backhead; now to seal them.

The screwed stays provide all the structural strength at the firebox, so the spelter we are about to apply is only a sealant for the threads; a beginner can thus use Tinmans soft solder with confidence, whilst more experienced builders will use 'Comsol'. To soft solder the stays, very little equipment is required – some Bakers fluid as flux, a very small burner for your propane torch as the heat required is minimal, plus a simple tool. This latter comprises a short length of ¼ in. o.d. copper tube, a tuft pulled from your wire brush and held by flattening the tube, plus a file handle on the other end of the tube, this for your personal comfort. Warm the boiler, dip the brush in Bakers fluid and pick up some soft solder from your stick of same. Dip in Bakers fluid again, hold against a stay head or nut, there will be a wee 'sixzle' and solder will flash around the threads. You can virtually paint on soft solder with this brush by continually dipping in the Bakers fluid.

The pair of longitudinal stay ends are plain turning, so let me deal with the other longitudinal stay, the hollow one that serves the dual purpose of conveying steam forward to the blower in the smokebox. Chuck the $\frac{7}{16}$ in. A/F hexagon bronze bar in the 3 jaw, face and turn down for $\frac{5}{16}$ in. length to $\frac{5}{16}$ in. diameter before screwing 40T. Centre and drill No. 41 to ⅝ in. depth, following up at No. 22 to ⅜ in.. depth and tapping $\frac{3}{16}$ x 40T. I prefer square ends to my blower elbows, mainly because it removes the temptation to tighten up by using a spanner over the union, but beginners can turn down to $\frac{5}{16}$ in. diameter in lieu of the square specified; it is that much easier. Tighten the embryo elbows hard into the backhead and smokebox tubeplate, mark off the position for the union as per drawing and file a flat on at this point. For the union, chuck a length of 7/32 in. brass or bronze rod in the 3 jaw and screw 40T for $\frac{3}{16}$ in. length. Centre deeply to form the seat for the pipe nipple, almost out to the base of the threads, then drill No. 41 to ⅜ in. depth. Start parting off at 7/32 in. length, but only reduce to around 5/32 in. diameter, then move on about $\frac{1}{16}$ in. and part right off to leave a spigot. Drill No. 41 from the flat on the elbow into the centre passage then 'mike' the spigot on the union and open out the end of the hole to a press fit, silver soldering to complete. Measure the distance from smokebox tubeplate to backhead with a length of rod, or use the actual stay material, then cut the stays $\frac{1}{8}$ in. less than this dimension and screw 40T for $\frac{3}{8}$ in. at each end. Enter the stay in the front end fitting, enter this in turn in the smokebox tubeplate and screw in until the stay pokes out about $\frac{1}{16}$ in. from the backhead. Engage the rear end fitting over the stay, screw in until it engages the thread in the backhead, twiddling the front end fitting until the threads engage cleanly, then tighten up at both ends. I should of course have mentioned that the threads must be annointed with liquid jointing compound, like 'Hermetite' or 'Osotite' before assembly.

The Regulator

Next job is to fit out the boiler for the hydraulic test and we may as well start with the bit that matters, the regulator. For the body, chuck a length of 1 in. diameter drawn bronze bar in the 3 jaw, face then turn down for $\frac{1}{4}$ in. length to $\frac{1}{2}$ in. diameter, a nice sliding fit in the end of the steam pipe. Centre and drill 15/64 in. diameter to $\frac{5}{8}$ in. point depth, lightly countersink the end of the hole until a $\frac{1}{4}$ in. 'D' bit will enter and take this down to the full $\frac{5}{8}$in. depth; part off at $\frac{3}{4}$ in. overall. A glance at the smokebox arrangement shows that the steam pipes on to the cylinders are connected to the regulator body by way of male unions, so grip the body in the machine vice, on the vertical slide with and a large diameter end mill, produce a wee flat. In the centre of this flat, centre drill, open out to 9/32 in. diameter into the centre hole and tap $\frac{5}{16}$ in. x 32T. Rotate the body through 90 deg., if you chuck an odd length of rod in the 3 jaw and hold this against the milled flat this will give the required result, then repeat the dose. Chuck the body again in the 3 jaw, face the outer end and then scribe a circle at $\frac{3}{4}$ in. diameter for the fixing screws. Mark these off clear of the steam unions, drill No. 34 and countersink, offer up to the steam pipe, spot through, drill the flange No. 43 to $\frac{3}{16}$ in. depth and tap 6BA.
The regulator valve is turned from $\frac{1}{2}$ in. diameter bronze bar, first reducing over about a 1 in. length to a very easy fit in the steam pipe. Face, centre, drill No. 29 to $\frac{1}{4}$ in. depth and tap 5/32 x 40T; now rough out the valve and part off. Chuck the $10\frac{3}{4}$ in. length of 5/32 in. stainless steel rod, face and screw 40T using a tailstock die-holder, then screw the valve to this and complete to drawing; remove from the chuck and grip in the bench vice to file in the steam, scalloped, passages. Erect to the boiler and check that the regulator rod is of correct length, then screw the bǎckhead end 40T and make up two more fork ends as the valve crossheads. The fulcrum post is turned from $\frac{1}{4}$ in. stainless steel rod, erected and the regulator handle made up, fitted to place with pins as for the valve gear, the hole for the fork end on the regulator rod slotted so as not to bend said rod in service. To complete the regulator, cut the stand pipe from $\frac{3}{8}$ in. o.d. x 16 s.w.g. copper tube, face off to length, screw one end 32T and slot the other for a screwdriver to assemble.

Manifold

For the manifold, saw a $2\frac{3}{16}$ in. length from $\frac{1}{2}$ in. square bronze bar, face off one end then chuck truly in the 4 jaw, face off to length, centre and drill right through at $\frac{1}{4}$ in. diameter. The top and rear faces have to be flat in way of the tapped holes and the best way to deal with this is to lightly mill right across, holding in the machine vice, then mark off, centre, drill and tap the holes to drawing. Turn again to bring the bottom face towards the chuck, centre, drill $\frac{3}{8}$ in. diameter and 'D' bit to about $\frac{3}{16}$ in. depth. Chuck a $1\frac{1}{8}$ in. length of $\frac{3}{8}$ in. bronze rod in the 3 jaw, face, centre and drill right through at 7/32 in. diameter; reverse in the chuck, face and then screw 32T for $\frac{3}{8}$ in. length. Fit to the horizontal top portion and scallop so there is no restriction into the bore, turn up and fit the end plug and pressure gauge union then silver solder together, pickle and wash off. Fit to the boiler top with a backnut to secure in the correct position. The two top fittings are for Injector Steam Valves of the angle pattern, the R.H. one on the back face for a Blower Steam Cock and the L.H. one for the Hydrostatic Lubricator Steam Cock; fit these to place.

Water Gauge Elbow

The Water Gauge is another Don Young Designs 'standard' fitting, so any builder wishing to make his own can refer to the GLEN series, but the elbow to connect from the boiler to the top fitting is a 'special'. For the stem, chuck a length of $\frac{3}{8}$ in. A/F hexagon bronze bar in the 3 jaw, face and turn down for $\frac{1}{4}$ in. to $\frac{1}{4}$ in. diameter and screw 40T. Centre and drill No. 30 to about 1 in. depth, release a little more material from the chuck and reduce this to $\frac{5}{16}$ in. diameter over a full $\frac{1}{2}$ in. length and part off. Screw hard into the boiler, mark off, saw and file the 45 deg. chamfer so the connector will face aft. Turn this latter up from $\frac{7}{16}$ in. bronze rod, chamfer to give a 90 deg. elbow and silver solder together; fit the water gauge. Screw in the Feed Check and Safety Valves, the former one of our 'standards' and the latter ex MOUNTAINEER and we are ready for the hydraulic test.

Hydraulic Pressure Test

Couple from the $\frac{1}{2}$ in. ram Tender Hand Pump, another of our 'standards' or as described for both HUNSLET and GLEN, and immerse said pump in a saucepan of water. Fill the boiler with water, right to the top of the dome, and couple from one of the safety valve bushes to the Master Pressure Gauge, the one employed by your Club Boiler Inspector. Pump up the boiler in increments of 40 p.s.i.g., inspecting at each stage until you arrive at twice the chosen working pressure, for which latter my recommendation is 80 p.s.i.g. Whether your Boiler receives its Certificate or not is completely in the hands of your Club Boiler Inspector and the only stipulation I would make is that the full pressure be held for at least 20 minutes; well done!

The Smokebox

I managed to squeeze an awful lot onto Sheet 3 and there is still some way to go, so let me hurry on to the smokebox. The rear section of the foundation ring sits on a bar located across the underside of the frames, this is actually detailed on Sheet 4 though all we have to do for now is clamp a temporary bar in place and erect the boiler. Correct position is indicated by the cut-out in way of the smokebox saddle, so spot back from the No. 27 holes, drill through the shell and secure with a few 4BA bolts for now.
The blast pipe is a 1 in. length of $\frac{5}{16}$ in. o.d. x 16 s.w.g. copper tube, or may be turned from solid bronze bar; next job is to bend up the exhaust pipes. Find a tension spring that is a close fit in the exhaust pipe bore then produce the bend by hand, using a longer piece of tube than necessary. Saw the blast pipe end of the tubes to match and insert into the blast pipe itself and braze up with either B6 or C4 spelter; pickle and wash. Measure the distance between the exhaust unions, saw the pipes off to a close fit keeping the blast pipe central, slide on the union nuts, turn up two collars 25/64 in. o.d. x $\frac{5}{16}$ in. bore x 3/32 in. thick, fit them to the pipe ends and secure with Easyflo No. 2; erect.

Petticoat Pipe

On to the petticoat pipe; chuck by the outside and bore out to $\frac{11}{16}$ in. diameter, opening out the bottom flare, first by turning, then with files and finally polishing with emery cloth. Deal with the outside of the flare at this setting and face across the bottom. Now carefully chuck by the flare and turn down the outside to a push fit in the chimney tube sawing off to length and lightly facing across. For the flange, cut a 1½ in. square from 1.6mm brass, find its centre by the 'X' method. chuck in the 4 jaw and bore out to 1 in. diameter. Bend the flange to mate with the smokebox shell, ease the hole with a round file to a tight fit over the petticoat pipe, position and silver solder together. Drill four No. 41 holes on a 1⅜ in. p.c.d. in the shell, bring up the petticoat pipe and fit the chimney tube to it. Take a 10 in. length of $\frac{5}{16}$ in. rod, any material as long as it is perfectly straight, and turn down for 1 in. at one end to a push fit in the blast pipe; fit a nut like that on the manifold over the blast pipe threads. Now adjust until the chimney tube is vertical and the $\frac{5}{16}$ in. rod central in same from top to bottom; the nut on top of the blast pipe will prevent distortion of those fragile threads. Drill through those No. 41 holes into the petticoat pipe flange and secure with 7BA countersunk screws.

Diamond Stack and Base

All you have to do with the stack base is carefully chuck and bore out to an easy fit over the chimney tube, then clean up with files, a few minutes work only.

I have specified the diamond stack from aluminium as it is a 'solid dummy' and would add far too much top-weight in bronze. The casting has a chucking spigot on the bottom, so fit a hardwood bung in the top of the core hole, chuck in the 4 jaw to run true, then centre the bung and bring the tailstock into use. Little if any turning is required, in fact I would simply polish with emery cloth and call that it for the outside; really this is one decision I can safely leave to builders. You have bored out cylinders, so dealing with that in the stack will be a piece of cake, though we do need to finish with an interference fit to prevent the embarrassment of the stack sliding down the tube to half-mast when in steam! To achieve this, turn the top ½ in. or so to a nice sliding fit over the tube, then take the tool back .003 in. and bore right through. Part off the spigot, remove any burr, then warm up with your propane torch until the smaller bore slips over the tube. Heat a bit more then pop on the stack before the heat transfers to the copper and all is lost. If this does happen to you, simply shorten the chimney tube to retain the correct overall length. I suppose a more scientific method is to cool the tube with liquid nitrogen, but I am not going to meet the bill for frost-bitten fingers! Neither the steam pipes from the regulator body to the cylinder connections or the blower pipe will present any problems, so we can move on to the 'adornments'.

Outer Dome

The outer dome is a real beauty, consisting of a cast top and bottom portion, integral cast, plus a piece of copper tube as the centre portion; deal with this latter first, chucking by the bore, facing off to length and removing any burrs. Now take the casting, grip by the bore at the top and clean out the inside to an easy fit over the inner dome flange. Saw into two pieces, rechucking the top. clean up the outside then turn the spigot to a light drive fit in the tube. Chuck the bottom portion by the cleaned out bore, tidy up the outside and turn the spigot; the final operation to clean up the bottom scallop to suit the cleading will have to wait awhile.

Sandbox

The sandbox is of identical construction and is retained to the boiler top by a crossbar, which sits on top of the lower casting and secures to the blind bush in the boiler with a 4BA bolt. The lid I would flange up from 1.6mm copper over a wooden former, though it can just as easily be turned from 1 in. diameter bar; it just works out more expensive that way. From bar, turn the concave bit then centre and drill No. 40 to about $\frac{3}{16}$ in. depth. Now turn the outside as you part off, erect to the 3 jaw with a 7BA bolt and polish, then turn up the little knob from brass rod and rivet or sweat to the lid.

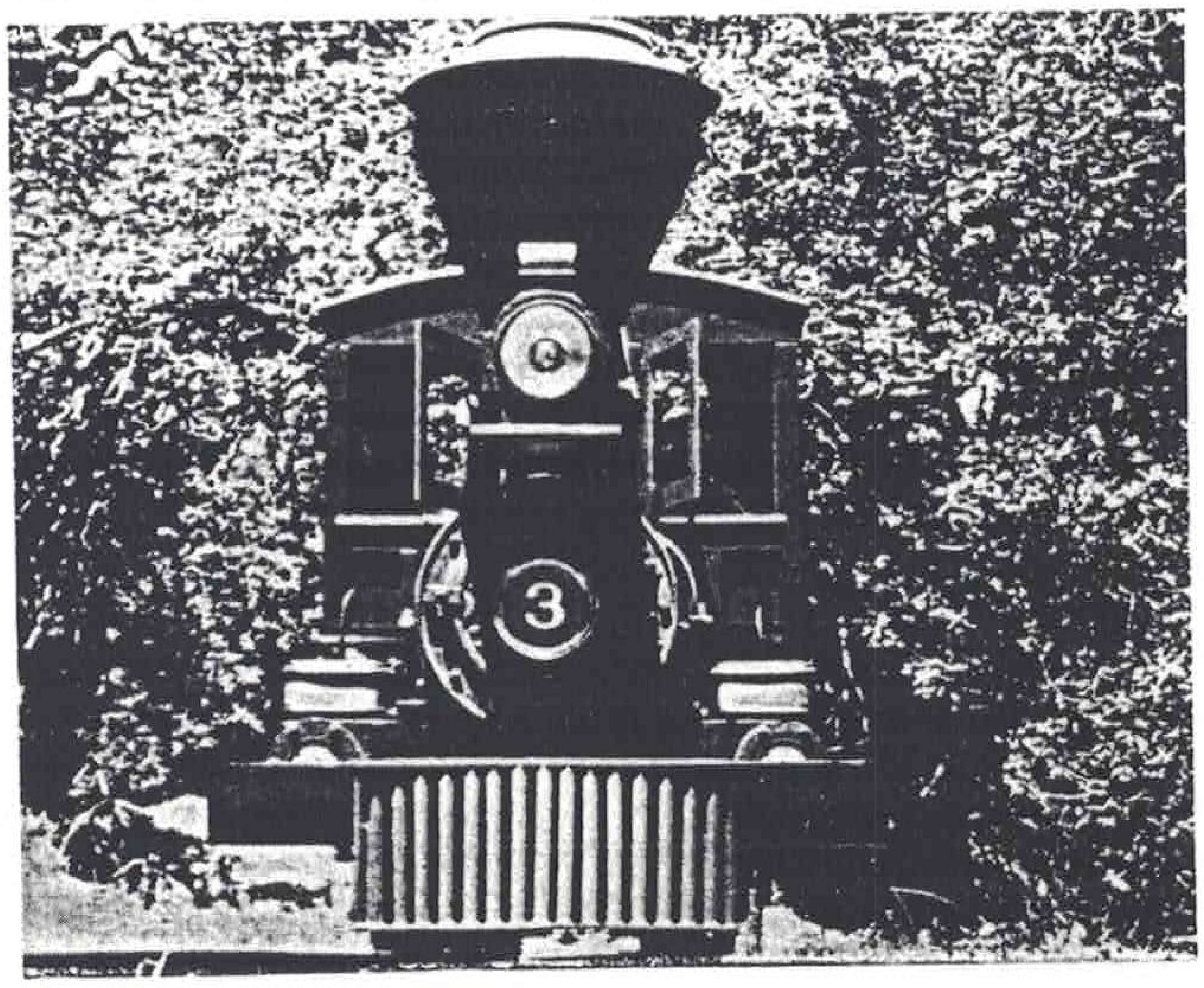
Bell

Two more jobs to complete Sheet 3, the first being the bell; it is a wee bit tricky in parts. For the stand, take a length of ⅝ in. x ⅛ in. BMS or brass strip about 6 in. long, find its centre, scribe a circle at ⅝ in. diameter and drill a No. 27 hole. Reduce the rest of the strip to ⅜ in. width, leaving a radius at the centre, then bend up roughly to drawing; getting both sides to look alike is the thing that matters. Saw off the two legs and scallop them to accept a 2 in. length of ¼ in. brass or steel rod. Chuck this rod in the 3 jaw, centre and drill No. 30 for about $\frac{5}{16}$ in. at each end, then silver solder in place. The assembly is now fairly rigid and can be held in the bench vice to blend the side legs into the top bosses, after which the centre portion of the rod can be cut away. The bell yoke is dealt with in identical fashion, except the ends of the rod are tapped 5BA before assembly. To complete, make up the bearings from ⅛ in. rod, screwing to suit the yoke, which can now be assembled to the stand.

The bell itself wants to be from a nice yellow brass, the cheap and nasty screw-rod variety is very satisfactory here, so chuck in the 3 jaw, first turn the $\frac{3}{16}$ in. spigot and then carry on and produce the outer profile. Before parting off, centre and drill No. 42 to about ¼ in. depth and tap 6BA. You can now chuck by the ⅞ in. portion and bore out the inside as desired, but I refuse to describe how to make and fit a clapper as the resulting sound is 'orrible. Fit by the spigot to the bell yoke and secure with a 6BA bolt and large washer; on to the last piece this session, and probably the most vital component of the whole engine.

Blast Nozzle

Chuck a 1 in. length of ⅞ in. diameter brass bar in the 3 jaw, face, centre and drill right through at No. 1. Bore out to 25/64 in. diameter to ⅜ in. depth and tap $\frac{7}{16}$ x 26T, then produce the tapered portion, which need not extend the full height of the nozzle. Chuck a length of $\frac{7}{16}$ in. rod, screw 26T, fit the embryo blast nozzle to same and turn to drawing. The sleeve is either a piece of tube, or bored from solid, and after the union has been attached it slips over the nozzle and is silver soldered in place, providing a chamber for the blower steam. To complete, we have to drill three No. 70 blower holes equi-spaced in the top flange, so centre pop lightly and I always use a hand drill for such small holes, it is much the more sensitive. Any builder who has managed to keep up with me is only a couple of days off steaming now!



Marie E, A Porter 0-4-0 in 4¾/5 in. gauge

by: DON YOUNG

PART III – Conclusion

All the hard work is done and builders, like yours truly, can now begin to relax all ready for the home run. From the confines of the smokebox we now emerge into the daylight again, to close up the large front opening.

Smokebox Door and Ring

Both door and ring are gunmetal castings, so let me start the ball rolling with the latter. Grip by the outside in the 3 jaw, bore the central hole to 2⅝ in. diameter and face across the front. Hold this front face hard against the chuck body and grip by the 2⅝ in. hole, then turn down to 3$\frac{13}{16}$ in. diameter, to be a tight fit in the smokebox shell, leaving a 3/32 in. flange, the latter being only lightly skimmed to finish as close to 4$\frac{1}{16}$ in. diameter as possible and with sharp corners taken off with a file to complete the profile as per drawing; there is no necessity to machine internally. Mark off, drill and tap the six holes at the specified sizes and lay aside for the moment. The door casting comes complete with chucking piece and should be machined all over, though the only important surface is that which abuts to the ring to deny air ingress. Before parting off the chucking piece, centre, drill No. 47 for about ⅜ in. depth from the inside and tap 7BA; part off and put the tap through again to remove any burrs.

Clips and Hinges

The clips are bent up from $\frac{3}{16}$ in. x $\frac{1}{16}$ in. mild steel strip, just hammer them over in the vice and then drill the No. 44 hole. Erect to the ring with 8BA bolts, fit the door and centralise it by eye, then fasten up the clips.
For the hinge blocks, chuck a length of $\frac{3}{16}$ in. square BMS bar truly in the 4 jaw, turn down for ⅛ in. length to .11 in. diameter and screw 6BA; part off at $\frac{7}{16}$ in. overall and repeat for the second hinge block. Screw the blocks into the ring, rechucking in the 4 jaw if necessary and taking a light skim to correctly orientate the blocks. I know how difficult this can be and would much prefer a plain hole in the ring; although this may be possible at the top hinge, it certainly isn't at the bottom one. Cross drill at No. 43 and press in a ⅜ in. length of 3/32 in. rod, silver steel will be ideal here, then fashion the end radius with a file.
For the hinges on the door itself, take two 1¼ in. lengths of $\frac{3}{16}$ in. square material, brass or the same steel as for the hinge blocks, and cross drill a full 3/32 in. from one end at No. 41. Now file the hinge until it fits the door snugly, when you can drill through and fix with a couple of $\frac{1}{16}$ in. countersunk copper rivets before silver soldering firmly in place. Assemble the whole smokebox front, set true by eye and tap into place with a mallet.

Number Plate

The number plate is really a suggestion to add a finishing touch at the head end, the surround being turned up from a lump of brass, the figure '3' being cut from 1mm brass sheet and sweated in place, though maybe Comsul would be better to save the number falling off! Fit a ¼ in. spacer as for the firehole and fasten with a 7BA screw, or 3/32 in. copper rivet.

Boiler Erection

We have dealt with this operation at the front end and now need to provide the boiler support stay at the back; it is so simple that no description on my part is required. My note mentions the alternative copper expansion bracket, secured to the firebox itself as on DON HUNSLET and GLEN, but I reckon the piece of BMS flat without drilling and tapping any additional holes in the boiler will appeal.

Lagging, Cleading and Running Boards

Although this is best left until the cab is made and fitted, I will describe these items now as they appear on the boiler erection drawing detail.
For the running boards support, either bend this up from ¼ in. x ⅛ in. mild steel strip to drawing, or refer to the excellent alternative employed by Dennis Hill and illustrated in his LADY ROSE article in LLAS No. 8. Lagging the boiler is really a matter of best available material and in this I still have a supply of asbestos tape as used for insulating pipe clips on steam lines in marine applications. Felt hats have been known to extend their useful life as boiler lagging and of course there are the proprietary materials such as the woven cloth stocked by Reeves; there is plenty of choice here. Wrap the chosen material around to build up the required $\frac{3}{16}$ in. thickness over the barrel, 3/32 in. over the firebox, and hold in place around the barrel with 15A fuse wire. At the front end, pull the lagging back about 3/32 in. from the position shown for the boiler band; the reason for this will become clear in a moment.
Cut a first piece of cleading 2¼ in. wide and of length to wrap right round the barrel with about ½ in. overlap – be generous with this rather than mean. Mark off and cut the holes to clear the bell stand and feed check valves, fit to place, tie a loop of string over the outside, insert a short length of bar and wind up the loose string, this is called a Spanish windlass, to bring the cleading into close contact with the lagging. Take an electric soldering iron, warm up, dip in Bakers fluid to cleanse, then pick up some soft solder. Apply the iron to the seam, this latter should be near or on the bottom centre of the boiler, and join the overlap. For the front boiler band, take a length of ¼ in. wide brass strip, wrap around the cleading, measure off, cut and then bend up tabs at the ends to give a gap of around ⅜ in. Drill the tabs No. 43 and assemble with a long 8BA bolt. To tidy up the front end, mix some Isopon P38, fill the gap between barrel and cleading with same, allow to harden and file flush. If you do not wish the Isopon to adhere to the cleading, rub a little soap or grease on the cleading surface before applying the Isopon.
Cut the next piece of cleading about 2⅜ in. wide and start with a hole on the top centre line at about No. 25, this to clear the sandbox fixing bolt. Wrap around the barrel, mark off and cut slots to accept the side running board support lugs, slide into place and secure with string before dealing with the seam. You can complete this portion with a second boiler band.
The last piece of cleading is 4⅜ in. wide, though this dimension must be checked to place with the cab in position, as about $\frac{1}{16}$ in. clearance must be allowed at the latter for boiler expansion. The cleading wraps right around the barrel up to the throatplate, is secured at its front end by a third boiler

band, and of course has a large hole on the top centre line to clear the inner dome flange. At the back end it will be held in place by a length of angle wrapped around to suit and secured to the cab front with woodscrews.

The running boards are folded up from 18 s.w.g. (1.2mm) steel sheet, fitted hard against the cleading, which means small recesses in way of the boiler bands, drilled through and secured with 6BA screws at the front end, the wood variety to the cab.

Grate and Ashpan

The ashpan is folded up from 16 s.w.g. (1.6mm) steel sheet; mark it out in the flat, saw out and bend up in the bench vice, then silver solder the front corners after checking the fit over the bottom extension of the inner firebox. Mark off and roughly saw out the slots to clear the driving axle then file to complete, remembering that the boiler will expand backwards from the fixed support at the saddle, so allow $\frac{1}{16}$ in. for this. Complete the fabrication by flanging up and fitting the stiffener at the rear end of the ashpan.

For the grate, start by cutting six $4\frac{1}{8}$ in. lengths from $\frac{1}{4}$ in. x $\frac{1}{8}$ in. BMS, or stainless, bar. Mark off one piece for the $\frac{1}{8}$ in. rods, drill this and use as a jig for the other five pieces. Chuck a length of $\frac{1}{4}$ in. steel rod in the 3 jaw, face, centre, drill $\frac{1}{8}$ in. diameter and part off $\frac{3}{16}$ in. slices for the spacers. Assemble the grate sections with $\frac{1}{8}$ in. steel rod and hammer over the ends to complete.

The grate supports start life as $3\frac{1}{4}$ in. lengths of $1\frac{1}{4}$ in. x $\frac{1}{8}$ in. mild steel flat. First flange over the ends to fit snugly inside the ashpan; you can make the flanges separate and braze them on if you prefer. Mark off and cut the slots to accept the grate bars by the two hacksaw blades and key-cutting file method, making sure each grate section is an easy fit for dumping the fire. Complete the profile to drawing, when the 'archway' underneath will allow you to rake out the ash without dumping the fire.

Mark off the ashpan for the front grate support, clamp the latter in place and drill through, securing with 6BA bolts. Clamp the rear support in place, erect the ashpan to the boiler and feed in the grate sections through the firehole. Check that the rear support, through the medium of the spacers, holds the grate bars nicely clear of the firebox end plates; adjust if necessary, then drill through and fix this support also. Erect once more and check the position shown for the dumping pin hole, this for ease of pulling out the dumping pin between the driving wheel spokes, then mark off and drill from each side. Bend up the dumping pin from $\frac{1}{8}$ in. rod and to stop it coming out and getting fouled in the spokes, use a Junior hacksaw to split the end as shown and splay it out slightly to give a positive fit. The alternative is to adopt the dumping device suggested by Dennis Hill.

Firehole Door

We can now move inside the cab, only it's a bit draughty as yet!, to deal with the backhead, starting with the firehole door; one of my pet 'standard' features.

For the door itself, scribe a $1\frac{1}{2}$ in. circle on 1.6mm brass sheet, cut it out roughly to line and drill a No. 41 hole in its centre. Chuck a 7BA nut in the 3 jaw, bolt the embryo door in place and lightly skim the periphery to line; the baffle is dealt with likewise and the spacer is straightforward. Further spacer-like pieces are required for the hinges; cut the straps from $\frac{3}{16}$ in. x $\frac{1}{16}$ in. brass strip and silver solder together. Turn up the hinge pin from rod, or press a head onto a length of 3/32 in. stainless steel rod, erect to the door and secure with $\frac{1}{16}$ in. rivets. The catch at the other side of the door is bent up from $\frac{1}{4}$ in. x $\frac{1}{16}$ in. brass strip and again rivetted in place, when the baffle and spacer can be secured by a 3/32 in. rivet. Three No. 41 air holes complete the door, when we can turn attention to its fixings.

For the hinge block, cut a $\frac{1}{2}$ in. x $\frac{3}{8}$ in. piece from $\frac{1}{8}$ in. or 3mm thick brass, set the hinge on same and silver solder together. Drill the two No. 41 holes and make up 7BA bronze cheese head screws to fix to the backhead. Erect the door and check that it opens cleanly without the baffle fouling, also that the door sits closely on the projection of the firehole ring, then spot through, drill the backhead No. 48, tapping 7BA and annointing the threads with jointing compound.

The catch spring is the last component for the door assembly, and the most important functionally. Without doubt, if you are able to get a piece of hard rolled phosphor bronze of requisite thickness, this is the ideal, but as I am unable to give you a suitable source for such a minute piece, spring steel is specified on the drawing. First bend it up as shown, trim off, centre pop for the holes on a lead block and drill through, opening up to size in increments. Hold against the backhead and set so that the catch just picks up the outer end of the spring, this to hold the door ajar for additional 'top air' to enter the firebox as required, but not preventing the door being snapped shut using the shovel. Spot through, drill and tap the backhead 7BA and secure with home-made bronze screws.

Pipework

Before tackling the cab structure, a little more on the pipework to tidy up what I said when putting the fittings on the backhead ready for the hydraulic test. Incidentally, it is a very good idea at this point in the construction to raise steam in the boiler, filling same with cold water to about $\frac{3}{4}$ glass. You can use either a propane torch through the firehole, very civilised this, or light a fire on the grate. Fit the pressure gauge if you like, as this will be the only unplugged opening in the boiler and gradually raise steam to about 30 p.s.i.g. Open the injector steam valve and blower cock, to blow out any 'foreign bodies'; go on and blow down the water gauge. Although you can press on further and lift the safety valves, this is not the object of the exercise, which is to get some of the salts in the boiler into solution, and blow them down together with copper filings and the like which have become trapped. The salts in solution lead to severe priming, water carrying over with the steam into the cylinders, where it can do a lot of harm, or out of the safety valves to give you an early bath! So let the boiler pressure fall to around 15 p.s.i.g., open the blow-down valve, and let the whole boiler contents drain.

I mention the above procedure here as the first pipework to be dealt with is for the injectors, and most problems with injectors arise at the 'commissioning' stage. For instance, we have found copper slivers, or a mass of filings, jamming the steam cone, and obviously this sort of problem does not re-occur once the boiler is clean internally. Much more debris however is likely to arrive from the tender tank, so this too should be carefully washed out; we will deal with this in a page or so. The last, and most persistent, problem with injectors is air ingress into the water suction line, chiefly at the flexible pipe joints to the tender. An injector when working creates a vacuum of around 20 in. Hg, this is why it is able to suck such a large volume of water from the tender for its size, but the least ingress of air breaks the vacuum and the injector then feeds steam and/or water onto the track, or rather the cab in the case of MARIE E if we don't cut a hole in the floor under the overflow!

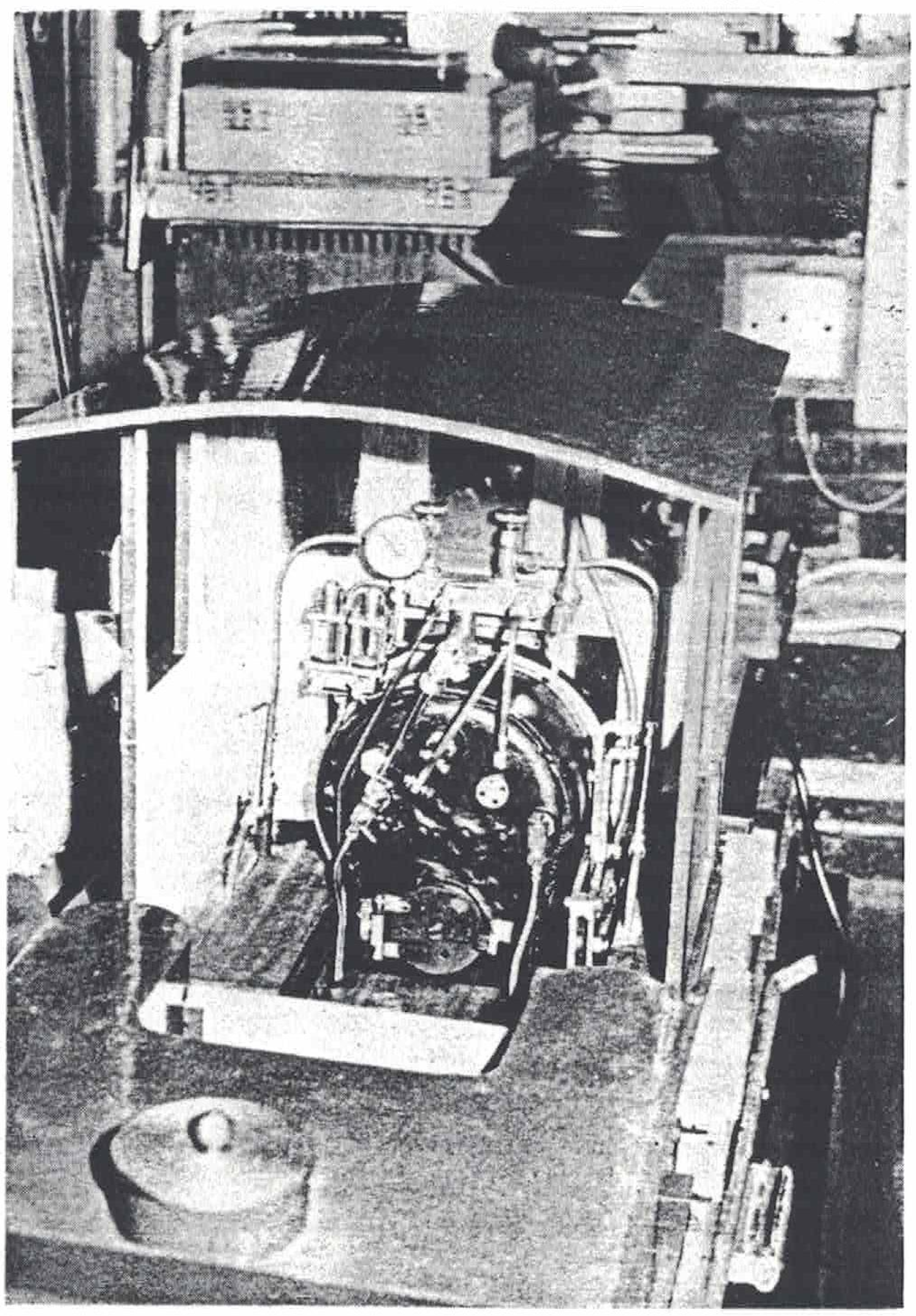
Locate the injectors in positions so that the direct fitting injector water cock handles are readily accessible to you, not necessarily where I have shown the L.H. one. I have located same so that the 5/32 in. o.d. thin wall delivery pipe is perfectly horizontal and without bends right up to the vicinity of the feed check valve on the boiler barrel, then sweeping gracefully into the bottom of same as shown. The steam pipe,

$\frac{1}{8}$ in. o.d. thin wall, is straightforward and with bronze nipples provided with all the relevant fittings, all you have to do is bend up the pipes to suit and silver solder to said nipples. If your copper tube is supplied coiled, to straighten same drill a good clearance hole in a block of wood, grip it in the bench vice, thread the end of the pipe through and simply pull it straight. Bends are best produced by finger pressure, then you will not flatten the tube and cause restriction. There are other ways, like filling the tube with sand and plugging the ends, but I am not going to specify this one as likely we shall get an injector back filled with said sand! That leaves the water suction pipes and from the water cock I suggest you run a 5/32 in. o.d. thin wall tube down through the cab floor and back through the rear cab support, terminating with a serrated connector very similar to that detailed on Sheet 4 for the tender itself. Couple between the two connectors with rubber or plastic hose, making sure it does not flatten under vacuum and cut off the water flow, then complete the seal with pipe clips, which are mini boiler bands as far as construction goes.

There is very little other piping to do, the water gauge blow-down which is 3/32 in. o.d. and open ended somewhere near the bottom of the ashpan uses the same pipe as for the pressure gauge, whilst that from the blower cock to the elbow on the backhead is $\frac{1}{8}$ in. o.d. The pipe from the hand pump delivery check valve on the R.H. side of the backhead is 5/32 in. o.d. and employs the same type of connection to the tender as for the injectors, only this time it has to withstand around 90 p.s.i.g. pressure instead of 20 in. Hg vacuum.

Just one piece of equipment to install, and it is of vital importance, being the Hydrostatic Lubricator. The steam cock is already fitted to the manifold and the next job is to locate the oil tank under the cab floor, the photograph of LADY ROSE on Page 33 of LLAS No. 8 shows the perfect position. Use a small piece of angle to bolt to the bracket provided on the tank and to the underside of the drawbar stay, then fit the drain valve from the kit. The first pipe run is from the steam cock to the bottom of the oil tank, using 3/32 in. o.d. tube. For a neat backhead, take the pipe down alongside that for the water gauge blow-down, then turn it back to the tank. Steam must be allowed to condense in this pipe, so you may bend it one turn around the tank for extra length/surface area if you wish.

Driver's eye view of LADY ROSE and just as I imagined it!



The position of the sight glass unit should be such that the pipe runs from the top fittings, which run along to the front of the engine inside the cleading (good job I said fit the latter after the cab!), should either be horizontal or have a slight fall from back to front. This suggests a position between the blower pipe and reverser pole, with the L.H. pips across the backhead before going ahead into the lagging; the top fittings will turn 90 deg. O.K. as they are jig drilled to allow for this style of installation. The cylinder connections are part of the kit and screw into the steamchest covers, so connect to these; the last length of pipe is from the top of the oil tank to the bottom of the sight glass unit. Geoffrey Charles has given us many useful tips in his letter on operation of the lubricator, so no problems here, but I will describe commissioning to complete the picture.

Fill the sight glasses with water by removing the top plugs, then fill the oil tank. Raise steam with the steam cock open, this is a first time only instruction, and open the valves below the sight glasses which will allow oil to pass forward and fill up the pipes. Once oil arrives at the cylinder connections, these are metering devices, and any attempt to feed more oil than they will pass simply means that oil builds back into the top of the sight glasses. This is a common fault at the outset, but once you accept that one drop of oil every 2/3 minutes is more than sufficient to lubricate each cylinder, and adjust the control valves to achieve this flow, the whole system simply settles down and gives an impeccable performance. To refill the oil tank, and one filling lasts for 8 hours upwards, turn off the steam cock, open the drain valve, then the filler plug. Allow the water to drain, close the drain valve and fill the tank.

I was brought up with mechanical lubricators at Doncaster, I don't think I was involved with more than 3 hydrostatic lubricators the whole time I was there, and us apprentices were told of the superiority of mechanical lubrication. LBSC used to make the point very strongly as well, in favour of his oscillating pump, neither of which I thought to question. When it came to my 5 in. gauge LANKY design, I just could not find room to fit a mechanical lubricator within the chassis, and thanks to the help of the late Henry May, I arrived at a hydrostatic solution. This has proved so successful that over 95% of our orders for lubricators are for the hydrostatic kits – there is always a backlog of orders!

Cab

On that cheerful note let me take the last steps to complete the engine; only the cab is required. For the base, I can do no better than refer builders to Fig. 5 on Page 33 of LLAS No. 8; this shows the pieces as made up by Dennis Hill and is a perfect example of the 3D engine providing the solution that would have been difficult to arrive at on my 2D drawing board. The 'wood-butchery' I am going to say very little about other than it makes a pleasant change of work in other than metal, and with modern glues the chances of scrappage is far less, one can retrieve 'disasters'. As for the actual wood sections, if these are not obtainable I would recommend using the nearest available and not bothering to plane down. So go ahead and have a 'holiday in wood', though there is more to come, and I know many builders are, sensibly, starting with the Tender.

THE TENDER

Tender Frame and Draw Plates

Those builders who have just finished the cab can leave the 'wood-butchering' tools on the bench, for the tender frame is of basically wooden construction, though we require some metal items first, like the simple tie rods. These latter are four $13\frac{3}{4}$ in. lengths of $\frac{3}{16}$ in. steel rod, screwed for about 2 in. at 2BA at each end and as can be seen, these transmit all the power developed at the engine drawbar back to the driver's truck, when the tender frame itself becomes merely the medium for attaching the wheels and sitting the tank upon, a lesser duty than that performed by more conventional tenders. The draw plates consist of a backing plate, the doublers being an exact copy of same, to which lugs are brazed. Take a length of $\frac{1}{2}$ in. x $\frac{1}{4}$ in. BMS bar and drill a No. 11 hole at a full $\frac{1}{4}$ in. from one end. Radius the end over a mandrel, using an end mill, a procedure we are now familiar with, then saw off overlong and repeat another three times. Poke a length of $\frac{3}{16}$ in. rod through all four pieces, clamp in the machine vice and mill to a common length, the exact dimension not being critical. I recommend fixing the lugs to the back plates for brazing with a single 6BA bolt, the head of which can then be filed off once the spelter is holding the lugs in place. In the corners of the tender frames I have shown pieces of 1 in. x 1 in. x $\frac{1}{8}$ in. steel angle, each $\frac{3}{4}$ in. long and drilled for No. 6 or 8 woodscrews.

Cut the two end beams from hardwood and drill off for the tie rods from the draw plates, then assemble, not forgetting the doubler plates. At this point I am reminded that Brian Patton told me of my mistake in that the rear draw and doubler plates would indicate 2BA bolts in the two lower holes whereas I have specified woodscrews on the assembly; I left this one in to give you a mention Brian! Next cut the two side frame members to a close fit between the end beams and attach the pieces of angle to them. Annoint all the joints with glue, erect and screw the angles to the two end beams, laying on a flat surface to prevent any 'winding'. Complete the framework with the $\frac{3}{4}$ in. square crossbeam on the underside, simply glueing in place; the woodscrews holding the side frames can penetrate into the main side members for extra strength, though the glue is likely to be the stronger of the two methods of attachment. To complete the wooden assembly, cut and plank the floor. Isn't it fun, in fact I would not be surprised if the next request was for a wooden engine! Back to metal now and it will not be long before MARIE E is complete, so let me hurry on.

Wheels, Axles and Axleboxes

Wheels we already know how to turn and as there are no crankpins to worry about this time, these will soon be ready for the axles, though I am going to vary the theme for the latter and describe the good old fashioned drive fit in lieu of Loctite, just to show what us 'oldies' had no option but to produce. Saw the axles from $\frac{1}{2}$ in. diameter steel bar and face off to the requisite length, then chuck in the 3 jaw with $1\frac{3}{8}$ in. projecting and check with a dial test indicator (d.t.i.) that it is running true; if not, revert to the 4 jaw and set true. Next centre the end and bring the tailstock into play as support, greasing the centre liberally to prevent it heating and the work binding. Turn down carefully to .440 in. diameter by micrometer measurement over a $1\frac{1}{4}$ in. length, checking with said mike to see if there is any taper over this length; this has to be allowed for in the final calculation. Now concentrate on the end $\frac{1}{4}$ in. and turn down until the wheel can be pushed on without the fit being at all slack. Make a note of the cross slide micrometer collar reading, withdraw the tool about .020 in. and then advance to within .0005 in. of the previous reading; take a cut the full length of the seat. If say the taper over the length was .001 in., increasing towards the chuck, the tool must then be taken back and advanced another .00025 in. to compensate for this. If the taper is the other way, the diameter reducing towards the chuck, then the instruction is to try taking a cut moving away from the headstock and open the lid of the scrap box in readiness! Turn down the outer $\frac{5}{8}$ in. to $\frac{3}{8}$ in. diameter, again you can use your micrometer although the end result is not critical, then use a smooth file to relieve the very end of the wheel seating, so the wheel will enter. Support the wheel on a block of wood, then drive the axle through it with a wooden mallet, hoping that your fit is the correct one and that the axle will not simply drop through, or jam half way home. Of course, before you fit any wheels, both ends of the axle have to be dealt with, so there is a 200% chance of scrappage! We used to manage to build Locomotives in the pre-Loctite era, and our engineering was the pure form of limits and fits, yet how many of those who are scathing of the 'Loctite' approach shy away from piston valve cylinders? Engineering to my mind is making use of the advances in technology in the pursuit of excellence. With that little side-track, our wheel and axle assemblies will be complete, by one means or another, and we can move on to the axleboxes.

These are best machined from $\frac{7}{8}$ in. square bar, brass being first choice, though steel is satisfactory, especially if bushed with an oil retaining bearing. A roughly 5 in. length is our requirement, so first chuck in the 4 jaw and face across both ends, this being the inner datum face for one of each pair of boxes. From said end faces, mark off each pair of boxes, the second one of each pair being inverted by reason of the 20 deg. slope for which latter allow for a saw cut plus a few thous. for cleaning up the faces with files. Our purpose here though is to mark off the slots to accept the horns, or pedestals as our American friends will know them.

Grip the bar in the machine vice, on the vertical slide, and bolt a block to the table to act as a register for one end of the bar. Chuck a $\frac{3}{8}$ in. end mill in the 3 jaw and in the centre of the first marked slot, mill to $\frac{1}{16}$ in. depth. Now widen the slot to line, using a piece of $\frac{1}{2}$ in. wide material as gauge and obtaining a free fit; make note of the cross slide micrometer collar readings when the final cut is taken. Deal with the remaining three slots on this side of the bar, again recording final readings, then rotate the bar 180 deg., hold against the register, and repeat four slots on this face to match those opposite. Saw off into individual boxes, tidy up the sloping faces, and for two boxes you have to face off to length. For the last one to be dealt with, set to run true after facing off, then centre and drill 25/64 in. diameter to $\frac{3}{4}$ in. depth; for bushes, bore out to $\frac{5}{8}$ in. diameter, press in the bush and poke the 25/64 in. drill through the bore. Release two jaws only, take the next box and tighten the same two jaws and repeat. We only need the spring pocket and No. 60 oil hole to complete, and the pocket can best be located from the side frames.

Horns, Side Frames and Step

For the horns, cut eight 1 13/32 in. lengths from $\frac{1}{2}$ in. x $\frac{3}{8}$ in. BMS bar and face off one end of each. Reverse the last piece in the 4 jaw chuck, with the headstock centre in place to locate it axially, then face off to length. Clamp the carriage and face the other seven pieces to identical length. Back to the machine vice and vertical slide to mill away the centre portion to allow us to fit the retaining bolts. Clamp the horns over the axleboxes, fit the wheel and axle assemblies and erect to the tender frame, setting so that the axles are square across the frame and checking on a length of track.

You can now bend up the upper side frames to place rather than produce them from the drawing detail and its dimensions, which latter involves the use of Pythagoras to arrive at the length of the sloping portions, with a more than even chance of scrapping some $\frac{1}{2}$ in. x $\frac{1}{8}$ in. steel strip! Use the upper side frames as template for bending the lower pair, remembering there is only a $\frac{5}{8}$ in. set at the centre of the latter and leaving the rearward extension for the moment. Clamp together and drill the eight No. 34 holes, then separate and drill the $\frac{1}{4}$ in. spring holes in the upper pair. Assemble the side frames to the horns, axleboxes and wheels by clamping together, check for squareness, then drill through all the No. 34 holes and fit 6BA bolts. Mark the tops of the axleboxes from the side frames for the spring pockets, remove in turn, chuck in the 4 jaw, drill and 'D' bit to 5/32 in. depth and carry on at No. 60 into the bore as oil supply.

Hold the upper side frames against the tender frame, and at this stage the decision has to be taken whether it is to be secured with woodscrews or 6BA bolts right through the wooden side members; if the latter, it is a good plan not to fix the tender floor until the bolt heads have been recessed into said side members, being a tight fit so they do not rotate. The springs are shown going into plain drilled holes in the side members, but you can make up brass thimbles from $\frac{3}{8}$ in. rod as a better means of support, glueing them in place. Erect the whole side gear to the tender frame and complete bending of the lower side frames to attach to the rear beam. After all that, bending up the side steps and fastening them to the tender frame with woodscrews is a piece of cake, the dimensions being relatively unimportant; just try to get them the same size for appearance sake.

Tender Tank

Only one large assembly to complete, this being the tender tank and although it is relatively small, it will consume a fair amount of 1.6mm brass sheet. All tanks start with the soleplate as a sort of building base, so cut this 10 in. long and either 8 in. or $8\frac{1}{4}$ in. wide to suit the floor.

The horseshoe style of tank is by far the easiest to construct, there being a distinct separation between the coal and water spaces as against the coal sitting on the tank top; American practice has a lot to commend itself in miniature, as it did in full size for that matter. The secret, if there is one, of a sound tank is to make it with the minimum number of joints, which means in this instance making the side and front walls in one piece and then slipping in the rear section to complete; for this we need a piece of brass 3 feet long and $3\frac{11}{16}$ in. wide, the hope being that a supplier will provide this piece cut to size.

Mark on the vertical centre line and at $1\frac{5}{8}$ in. centres either side of same, scribe further lines to denote the start of the $\frac{1}{2}$ in. bends. Grip a length of 1 in. diameter bar horizontally in the bench vice, cramp the sheet to same and produce the first bend by hand pressure. Due to the natural springiness of the material you will have to slightly tighten the radius away from the bar, again by hand pressure only, using said bar as gauge to check the correct finished bend. Set this up on the soleplate and measure back $1\frac{1}{16}$ in. from the front edge of the latter, this to indicate the start of the 1 in. radius bend, dealing with this in exactly the same manner over a 2 in. bar or length of tube. If you mark out the correct profile on the soleplate, you can use this as a guide as you proceed. The idea now is to produce the second wing tank to be as closely identical to the first as you can manage, never mind the actual drawing dimensions, and you will have learnt from experience on the first wing tank what happens when you take a piece of brass and bend it much better than any words of explanation, especially as I do not know to what degree of hardness the plate will have been rolled. Lay on the soleplate and scribe on the backward limit of the side walls, cutting to length, then attach the back sheet with lengths of $\frac{1}{4}$ in. brass angle as per drawing. This $\frac{1}{4}$ in. x $\frac{1}{4}$ in. x $\frac{1}{16}$ in. brass angle we shall now use in gay profusion, first as a means of attaching the tank walls to the soleplate; it looks as if around 8 feet is the total requirement.

Attach the brass angle first at the bottom of the side walls, using 10BA bolts at about $\frac{3}{4}$ in. pitches and nutting on the outside, then fix to the soleplate, again by 10BA bolts, pitching them clear of the fixings to the side walls. Right across the top, at the back of the horseshoe, fit another piece of angle with 10BA bolts and rivet other short pieces of angle to same to pick up the back end of the wing tank tops; complete this phase by adding side pieces of angle for said wing tanks.

We now have to replace all those 10BA bolts, either with $\frac{1}{16}$ in. rivets or 8BA brass countersunk screws, using the former where possible. Remove a 10BA bolt, insert a snap head copper rivet, brass ones are generally far too hard, and sit on a rivetting dolly. Draw the two surfaces together with that tool we made for the same job on the boiler and knock down into a countersink in the outer wall. You will see that rivets can be used only where the dolly will allow the head to sit on same; where this is not possible, open up the outer shell to No. 44 and countersink to suit the 8BA screw, tapping the brass angle to suit. To complete this part of the assembly, cut the wing tank tops to place and screw to the angles provided; we must now seal the tank, which by now is firmly attached to the soleplate.

Sit the tank on a firebrick, begin warming with your propane torch using the smallest nozzle, and pour in some Bakers fluid. Swill this around, holding the tank with pliers, and warming the whole tank as evenly as possible to avoid distortion. Feed in some soft solder and use the brush we made for the firebox stays to paint the solder on all the seams. When complete, scrub out the tank with soapy water, rinse it clean then dry; fill with water again and inspect for leaks. We shall be painting the tank gloss white internally later on, as this shows up any 'foreign bodies' in the water, so if there is a minor leak the paint will form a seal; if there is a major leak, warm up and apply more solder. At the front of the wing tanks are the injector suctions, bushes being made up as for the boiler and soft soldered into $\frac{7}{16}$ in. holes; wash thoroughly again.

Tender Water Connections

These are plain turning exercises and if anyone is doubtful as to the note on serrations to accept the tube, have a look at a garden hose connector or end fitting – this is what is required. On to the $\frac{3}{16}$ in. plain spigot, on the inner end, we have to fit the finger gauze, from 100 mesh bronze. Wind this around a length of $\frac{3}{16}$ in. rod. pinch one end flat and trim the corners away so it passes through the $\frac{5}{16}$ in. x 32T tapped hole and tighten the other end to a push fit over the spigot; lightly soft solder the seam so as not to lose too much valuable surface area. I have shown these finger gauzes approximately 1 in. long, but if you are at all heavy-handed with the soft solder, increase the length to as much as 2 in., as the last thing we want is to restrict water flow to the injectors.

Coal Gate and Top Flare

Coal is retained within the horseshoe section by means of $\frac{1}{2}$ in. x $\frac{1}{4}$ in. wooden planks, which are removeable, so guides are required to accept same; these are made from $\frac{1}{4}$ in. x $\frac{1}{8}$ in. brass strip soft soldered to the tank as shown.

Experienced builders will have formed the top flare integral with the side and back sheets of the tank, but the rest of us will form them separately from $1\frac{1}{2}$ in. wide strip. Fold up three identical 9 in. lengths, clamp the two side pieces in place then cut the rear piece to fit between same before finishing the two side pieces to drawing. Cut pieces of $\frac{1}{4}$ in. brass angle to complete the support for the tank top and secure both these and the flare to the tank walls with 8BA screws. To make the whole assembly nice and rigid, carefully warm and sweat together, including the corner seams; wash thoroughly and we are almost home and dry!

Removeable Tank Top

This rear portion of the tank top should be made easily portable so that you can gain access to the hand pump should the suction ball ever stick; it does happen and pouring hot water over the pump quickly retrieves the situation. So if you make the tank top a good fit, no other fixing is required; if at all slack then use four 8BA screws to teach it manners. The easiest way to attach the filler tube is not as I have shown, but to sit it on the tank top, sweat in place and then cut out the hole to suit. A heavy chunk of a filler lid seems to prevent such portable things getting lost, so you can turn this from solid bar quite happily, though if your fit is a good one, drill an air hole through or you will finish up with a vacuum in the tank, which is not good for feeding the boiler!

Position the hand pump, you have had this since the boiler test, under the filler tube and check with an extension handle, which latter is a length of copper tube flattened at one end to suit the pump, for ease of operation before bolting down to the soleplate; 6BA is the ideal size. The bulkhead fitting can be located as desired, with a $\frac{3}{8}$ in. hole cut in the tender floor planking to suit, when a pipe between same and the pump delivery adds the final touch. Mark off and screw the soleplate down onto the tender floor and construction is completed.

Painting

Until now I have maintained that all small engines look best painted black, with maybe a minimum of lining, this to avoid giving the impression of an ornate toy; this stems from my love of black engines full size. But for MARIE E this is just not right, she is so flamboyant as to demand individual treatment – to your taste, not mine! Only one stipulation will I make, that the finish be gloss and not matt, though of course the wood can be varnished for extra effect; get those paint brushes going! All this, however, should be delayed until after the third steaming; the first to find any faults, the second to prove that most if not all have been corrected, and the third to really sample her delights.

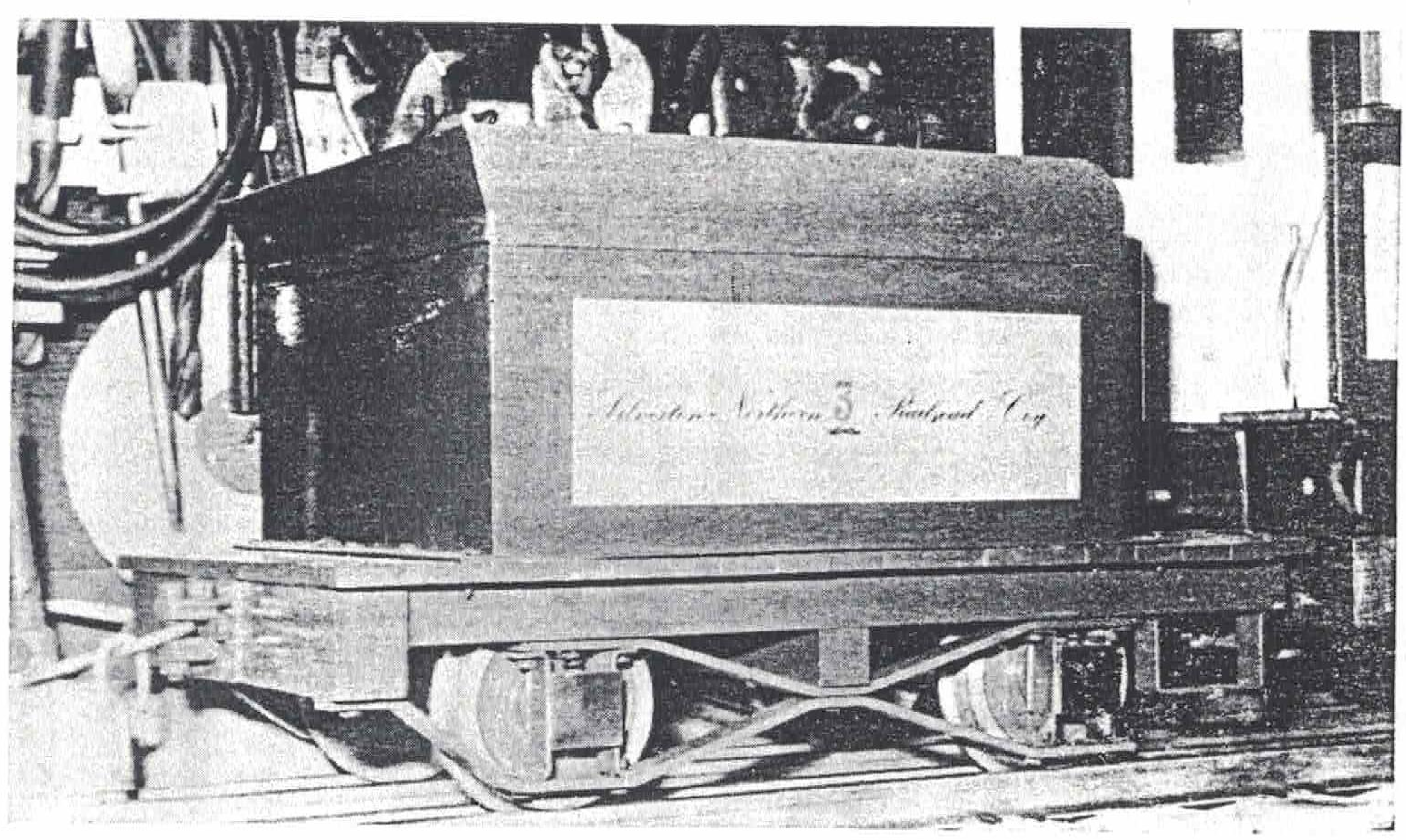
Raising Steam

As this is my first 'beginners' Locomotive in LLAS, though many who are building her are far removed from this category, let me round off proceedings with a few tips on running her. The evening before lighting up for the first time for track testing, fill the smokebox saddle with soft setting asbestos cement, or calcium silicate, from the level of the smokebox tubeplate at the back end and tapering up to the lip of the smokebox door at the front, this for the dual purpose of sealing the smokebox bottom against air ingress plus ease of sweeping out after a run. Other preliminaries include filling the hydrostatic lubricator oil tank and sight glasses as already discussed, greasing the driving boxes and generally oiling round.

For fuel, a Welsh steam coal is the ideal, and of a size that will pass through the firehole, not too small, and for lighting up purposes some pieces of wood or charcoal soaked overnight in paraffin (kerosene). Firing tools consist of a shovel, (for many years I used a teaspoon for this!) plus a length of $\frac{1}{8}$ in. rod flattened at one end and with a handle bent on at the other, this being the 'pricker' with which to rake through the bars on occasion, though please don't get into the bad habit of continually poking the fire.

Arriving at the steaming bay, connect the engine to the tender, and I did not describe the drawbar made from $\frac{3}{8}$ in. x $\frac{1}{8}$ in. BMS strip, so I hope you won't have been caught out and come to a premature conclusion! Couple up the pipes, fill the tender with clean water and use the hand pump to fill the boiler to no more than $\frac{1}{2}$ glass showing in the water gauge; top up the tender. Check that all the valves are shut, including the blow-down, but not the steam cock for the lubricator, then feed the lighting up fuel into the firebox right up to the door. Fit an extractor fan to the chimney, and again it is a good idea to check this out before the event of first steaming, in case an adaptor is called for, then light a piece of soaked wood or charcoal on the shovel and feed it into the firebox, at the same time getting a friend to switch on the extractor fan, though I guess by this time you will have plenty of support!

Both wood and charcoal burn amazingly fast, hence the instruction to fill the box initially, but at the first steaming, keep feeding it in until the pressure gauge shows about 20 lb. on the clock, at which stage open the engine blower cock and remove the extractor fan. Keep the blower turned up for a moment and feed in coal; once this is alight, ease back on the blower or you will be blowing off in 30 seconds flat! At full pressure, check the safety valves against the pressure gauge and ease the pressure down if called for; never increase it at this stage but wait until you can check your miniature gauge against the Club master if there is any discrepancy, for it is sure to be of a small order. Next check the means of boiler feed available to you whilst the engine is stationary, namely the hand pump and the two injectors, for the latter carrying out the 'ultimate test' of your installation by opening the steam valves at least 10 seconds ahead of turning on the



Ollie Johnston's original drawing showed a tool box on the back of the Tender and although this was not subsequently fitted, it would make for an interesting variation water – after that you can use water or steam first as you like forgetting all about the 10 second lapse. Incidentally, at the first light up it is common for the water gauge glass to leak profusely at the seals, and at a very low pressure. The temptation is to take a spanner to the nuts immediately this is seen, with the fatal result of a gauge glass breakage. So resist the temptation and most likely the seals will establish themselves, though if leakage does persist, give the offending nut(s) the merest nip with a spanner; too much and you will be going home early!

As soon as you have checked the means of boiler feed, and before your courage deserts you, open the regulator slightly, with the engine in full gear, and push gently forward to expel all the water that has condensed in the cylinders up the chimney – wipe off the engine. Build up a good fire, right up to the door at the back end, fill the boiler to a good ½ glass and with safety valves lifting out onto the track and couple up to the driving truck. Climb aboard, open the regulator and chances are you will be away first time without as much as a push. Once on the move, pull the reverser lever back as far as it will come without your progress becoming jerky, ease back on the regulator and then keep an eye on the boiler water level, this is the most important duty you have to perform apart from keeping an eye on the road ahead. The first run is always the worst, for apart from the normal driving process you may be beset by little problems which still have to be corrected. So I suggest you make this a short run, making a note of any defects on a piece of paper as you go, and not worrying overmuch about the fire other than to keep it alight. It is no crime to have to stop and 'blow up' the fire, but try not to have to halt for lack of water, the latter being an infinitely more serious defect on your part. From all this I confidently predict that you will have more trouble with water level than anything else on the first outing, so the advice is to persevere in the sure knowledge that the boiler will settle down after the first 2/3 steamings, as long as you blow it down after every run.

I guess you will have reached the conclusion by now that it is preferable to have the track all to yourself for the first steaming, so that you can take your time without spoiling others' pleasure. Of one thing I am positive; your MARIE E will perform such as to interest your friends and you will receive wise counsel as a result, so at this point I can hand over responsibility and retire happily from the scene; good steaming.

7¼/7½ in. gauge MARIE E

The drawings for this larger version should be well advanced by the time these notes appear, the design stage having been completed in October 1981, from which I can at least refer to some of the differences in construction.

The most major one is the first item to be tackled, the bar frames, where I finally decided to use 1 in. x ½ in. section in lieu of ¾ in. square, for the extra ¼ in. it provided for firebox width I found very attractive. Whilst retaining the excellent 3-point suspension, a slightly more sophisticated alternative approach has been made; this provides for stiff, leaf springing on the driving axle and horseless carriage type suspension at the front. The only other feature of note is an ash shield over the driving axle, though I am not absolutely convinced of its necessity as the beauty of a grease lubricated plain bearing is the ability of the grease gun to pump contaminated lubricant clear of the bearing; the shield largely prevents this from happening.

To sum up, apart from these differences, all the text for the 4¾/5 in. gauge MARIE E applies, apart from actual dimensions of course, and details of the availability of drawings and castings will be given in this and future issues of LLAS, a sort of continuing saga!

Oops!

Verily, he who takes a short cut comes unstuck. It concerns the valve gear, which was lifted directly from my 3½ in. COUNTY CARLOW design and which will appear in these pages for SAINT CHRISTOPHER. Knowing I had a correct and proven valve gear at my disposal, plus it was a perfect fit in the space available, I reasoned it out in my head, (which was asking for trouble!) instead of setting it down on paper. Thus for the 'primary motion' I reasoned that the reversal of direction by use of the leading axle was balanced by an equal and opposite reversal through the medium of the rocking arms; so far so good. What escaped my notice was a reversal of the 'secondary motion', that covering the lead function, and by not taking remedial action the result is a gear in which lead reduces towards mid-gear, a case of what makes a Steam Locomotive stop ticking! I have to thank builder Dave Churchman for opening my eyes to this discrepancy; not the best Christmas present I received, but certainly the most timely.

Now, because the basic valve gear is O.K., it is a matter of manipulation rather than whosesale scrappage, and there are three possible solutions. The first leaves the valve gear exactly as per drawing and shortening the valves by 1/32 in., reducing the 31/32 in. dimension to 15/16 in. and increasing lead in full gear from the specified .005 in. to .020 in.; this will result in a better working engine. A second way out is to leave the valve itself well alone and at the position shown on Sheet 2 of the drawings, merely swop over the two eccentric rod ends on the expansion link, this to give 'crossed rods' which results in an increasing lead function and is therefore the correct solution of the valve gear. Leaving everything else strictly alone, there is one small side effect in that the reverser pole comes towards the back of the cab for forward running and to the front for back gear. The 'ultimate' solution is to cross the rods and then move the pole fulcrum above the reach rod pin, this to reverse its motion and give conventional pole movement.

Over the holiday period I have had time both to reflect on the folly of my ways and the best possible solution, my conclusion being to recommend the second approach of simply crossing the eccentric rods and leaving all else well alone, for my attempts to redesign the reverser only ruined its graceful proportions.

LADY ROSE complete and resplendent in the Dennis/Ellis Hill workshop. Actually it was Ellis Hill, father of Dennis, who featured on Page 34 of LLAS No. 8 – if there is a choice, then I am bound to get it wrong!