E. S. Cox – The Horwich 'Crab' in 5 in. gauge

by: DON YOUNG

Part 7 – Chassis continued

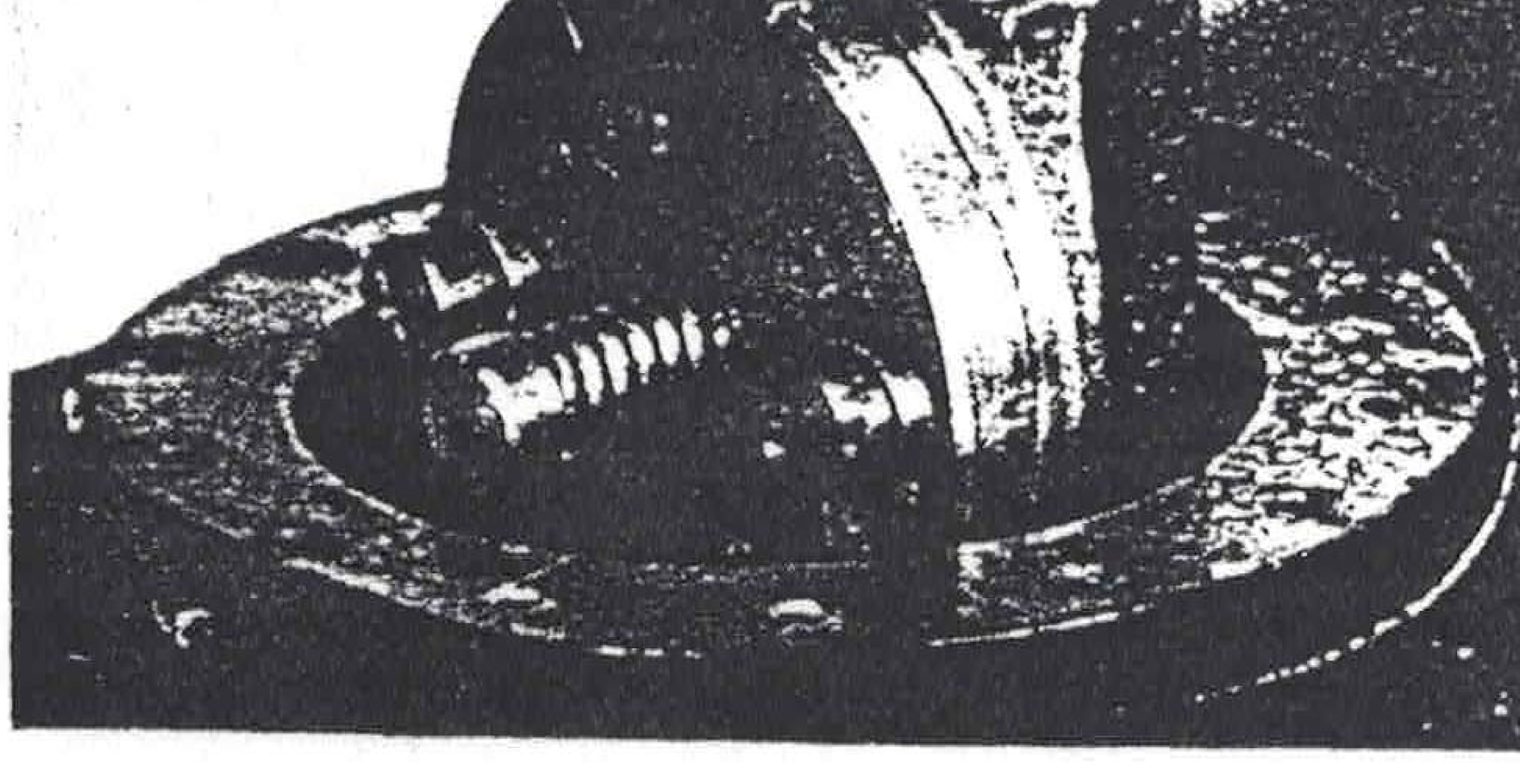
As the saying goes, this is where the story really begins, for Sheet No. 7 certainly taxed my skills on the drawing board and will no doubt give builders a few anxious moments, though it contains nearly all the ingredients to make E. S. COX really authentic; let us jump in at the deep end with the smokebox saddle.

Smokebox Saddle

I have produced such a fabricated saddle for my L.N.E.R. Class K1/1 'Mogul' nearly 20 years back, so know it is entirely feasible, and have tried to justify such statement with notes against the drawing detail, which now require amplification.

Cut the side plates $4\frac{1}{2}$ in. long x $4\frac{1}{4}$ in. deep and snape the bottom edge as shown to match the frames. Whilst these are still individual plates, you can clamp to the frames, if you prefer, drill through the $\frac{1}{2}$ in. hole, mark off and cut the exhaust slots roughly to size. Next stage is to roll the top plate from the same $\frac{1}{8}$ in. or 3mm material, its finished size being of the order of $5\frac{1}{4}$ in. x $4\frac{1}{2}$ in., but the most important feature is that it closely matches the smokebox shell. Drop it in place then cut front and back plates to fit, with an interference of about .010 in. at each side for machining the side plates to fit between the frames. Drill a $\frac{3}{4}$ in. hole in the centre of the top plate for the exhaust pipe, then deal with the slots on each side of same for the steam pipes to the cylinders, when you can assemble all the pieces made thus far with 8BA screws. That $\frac{3}{8}$ in. x $\frac{1}{8}$ in. flange all around at $\frac{11}{16}$ in. from the bottom edge, as well as adding strength at a critical spot, is also for bolting on a, separate, closing plate which latter is essential for a multitude of reasons. The most fundamental, and the one I forgot to mention when Roger Stagg enquired, is that without said access it is impossible to bolt the smokebox to its saddle at front and back. Supplementary to this would be the difficulty in piercing two walls of an enclosed box for the drain cock pull rod, that it is nice to have access to the exhaust 'spider' after assembly, something that my K1/1 lacks, plus it makes filling the saddle with asbestos cement, or magnesium silicate, that much easier if you wish to do so as a precaution against air ingress. I could of course go on and add a few more reasons, but these are sufficient, so make up the flange from strip, or cut from plate, and screw temporarily to place. Now comes the tricky part, or it will be once we make the necessary tube bending tool.

The Stroudley pattern regulator is, just, feasible for E. S. COX



Chuck a length of $1\frac{3}{4}$ in. diameter steel bar in the 3 jaw, centre and bring the tailstock into play. Start parting off two $\frac{3}{4}$ in. slices, but only reduce to around 1 in. diameter in the first instance. Now, in the centre of each slice, cut a 'U' groove $\frac{1}{4}$ in. deep and $\frac{3}{8}$ in. radius to accept the $\frac{3}{4}$ in. o.d. exhaust pipes. Drill through both pieces at $\frac{1}{2}$ in. diameter and part right off. Select a two foot length of $1\frac{1}{4}$ in. x $\frac{3}{8}$ in. BMS bar, or similar section, drill a $\frac{1}{2}$ in. hole at $\frac{1}{2}$ in. from one end, then move on 2 in. and repeat; bolt the 'dies' to the bar so they will just rotate. Take a foot length of $\frac{3}{4}$ in. o.d. x 18 s.w.g. copper tube and find a compression spring that is a good fit in the bore; or fill with sand and plug the ends. Grip the end bolt in the bench vice, fit a peg to hold one end of the tube, then pull round with the extended handle. It does not matter if the inside of the bend buckles a bit, and of course anneal the tube as experience dictates, after which you have either to release the sand, or tap the tube judiciously to release the spring. Fit each exhaust piece individually, flattening in the bench vice, you just squeeze the sides and then tap the top and bottom faces flat; it is surprisingly easy. Fit to the side plates then centralise in the hole in the top plate. When each tube is formed, start marrying them up one at a time to give a $\frac{3}{4}$ in. diameter tube, in four quarters at the outlet, dealing with one joint only at a time. Make up an aluminium ferrule to hold the four pieces together at the outlet, then braze up with high melting point spelter as a separate operation; mind the ferrule though!

Assemble the exhaust spider to the side plates, which may mean slightly elongating the slots in the latter, though keep this to a minimum so that the silver solder will not run straight through, then assemble the rest of the plates; you will have to increase the hole size in the top plate and modify its shape, then turn up the top flange. Coat the joints fairly liberally with Easyflo flux mixed to a stiff paste and silver solder together. Turn or file the exhaust flange flat, then bolt to an angle plate or vertical slide and lightly mill the side plates to $4\frac{1}{4}$ in. overall, going right up to the top plate as the latter comes hard against the top edge of the frames. Locate from the $\frac{1}{2}$ in. steam entry holes, clean up around the exhaust spider entrances to give a smooth transition, then deal with the cylinder fixings, and the side row of shell fixing bolts in the top plate, indeed if you make up a wee drilling template you can deal with all the latter. After that little session, the rest will be, relatively, easy.

Horns and Axleboxes

For what are rather complex objects, the main horns are very easy to deal with, thanks to the patternmaking skills of my 'anonymous' friend. First you will notice the cast-on bosses to which comment was made earlier on in respect of drilling the frames; don't they add that final touch of class? The rest of the intricate patternmaking work means little machining is required, so let us make progress in that direction.

Rub a file over the frame locating lugs to be flat, then bolt to the vertical slide, they are cast in pairs so 'dog' over the top and bottom flanges, then mill right over the inside flange face to be about 19/32 in. proud of the bolting flange. Turn the casting over and pack off from the vertical slide table so that we can mill the axlebox slot without damaging said table, using about six 'dogs' and setting up very carefully. With a $\frac{5}{16}$ in. or $\frac{3}{8}$ in. end mill, first deal with the axlebox slots to $1\frac{1}{4}$ in. width. Next mill down the frame locating lugs to give the correct $\frac{7}{8}$ in. overall thickness, then deal with the $\frac{1}{16}$ in. deep recess to $1\frac{9}{16}$ in. width, the latter nominal, to accept the axlebox outer flange. Still with the same end mill, concentrate on the frame locating lugs to get same a nice tight fit in the frames and of correct depth, cutting a plain path down each in the first instance, then removing one dog at a time so that you can broaden the machined face to include the whole in conclusion. Before separating into individual horns and squaring off the bottom edges, turn the casting over again and skim off each of the bosses with a wee end mill; you can drill through at this stage if you omitted the holes in the frames. Tidy up with files, erect to the frames, fit a bolt and nut to spread the bottom, weakest, section of the horseshoe then drill through and rivet to place.

We will deal with the trailing horns in slightly different fashion, and here BLACK FIVE builders can take note as all their horns are of this type. Carefully clean up the frame fixing face, locate this against the bottom jaw of the machine vice, bolting same to the vertical slide. Now you can mill the sliding surface for the axleboxes and deal with both inside and outside edges, including the $\frac{1}{16}$ in. recess. Rotate the casting through 90 deg. to bring that sliding surface onto the machine vice bottom jaw, adding pieces of packing to keep the top jaw clear of those webs, then simply deal with the edge of the frame locating lug and the bolting face to virtually complete. Face off the bosses, drill if that is your chosen procedure, then fit to the frames, using bolts and nuts top and bottom, opening out to hold hard in place, plus a clamp for each horn, then drill through and rivet in place.

The axleboxes are also cast in pairs, available in either iron or gunmetal, for many of you prefer iron for bearing surfaces, which is no bad idea. The first thing is to arrive at a machined size of $3\frac{3}{4}$ in. x $1\frac{1}{2}$ in. x 1 3/32 in., keeping the cast-in slot roughly central; for some unknown reason the latter does tend to wander about a bit from casting to casting, so beware! Transfer to the machine vice, on the vertical slide and with an end mill of about $\frac{5}{8}$ in. diameter, start from the slot, going down first to $\frac{1}{8}$ in. depth and then gradually widening to $\frac{13}{16}$ in. to keep the two side flanges identical and 9/64 in. thick. Take a note of the vertical slide micrometer collar readings at which the final cuts were taken, then deal with the second slot to identical readings, cutting first to around 7/64 in. depth and then taking further, fine, cuts until the axlebox will just enter its intended horn. At this stage, separate into individual axleboxes and clamp as a pair in the machine vice to mill to identical length. Still as a pair, pack the boxes out slightly and mill the $\frac{3}{8}$ in. slot for the keep, then reverse and mill the oil reservoir in the top face.

To me, the keeps are like miniature and much simpler smokebox saddles, so I would cut them from brass sheet, odd ends, clamp together, silver solder and then file them to a good fit in their axleboxes. So many builders though seem to have trouble here that the alternative is to machine from brass or gunmetal bar. Whichever method be employed, fit to the axleboxes, drill for, make and fit the keep pins.

I always prefer to bore axleboxes in pairs, back to back as they will be when erected, so take two 3 in. lengths of $1\frac{1}{2}$ in. x $\frac{3}{16}$ in. BMS flat and mill a $\frac{3}{8}$ in. slot for $1\frac{5}{8}$ in. down the centre of each so that the inner flanges of each pair of boxes are an easy fit therein. Drill $\frac{1}{4}$ in. holes at $2\frac{1}{4}$ in. centres on the same centre line, when you will be able to bolt the axleboxes together back to back as a pair. Chuck this assembly in the 4 jaw, set to run true and bore out to suit the axle, dealing with the raised face towards you at this setting, then reverse and deal with the other raised face, the keeps being fitted for boring of course. Drill the three No. 60 oil holes and we are ready to erect.

Although squaring off the frames is vitally important, the real acid test is for the axles to turn sweetly, so initially fit the axleboxes to be tight in their horns, slide the axles through and check that all is well, when all the stretchers can be fitted in place and our chassis becomes a proper assembly; now to ease the axleboxes so they will function correctly.

Just as in full size we were taught to bed a horn to an axlebox, just rub a fine file across the horn faces to take off any high spots, then concentrate on the axleboxes to get them a nice sliding fit. Now file a relief on the flanges, as shown, so that at conclusion you can lift each axlebox by a good 5/32 in. relative to its partner, with the axle in place of course, without the latter binding, which means your E. S. COX has a very reasonable chance of staying on the rails – a jammed axlebox will cause derailment.

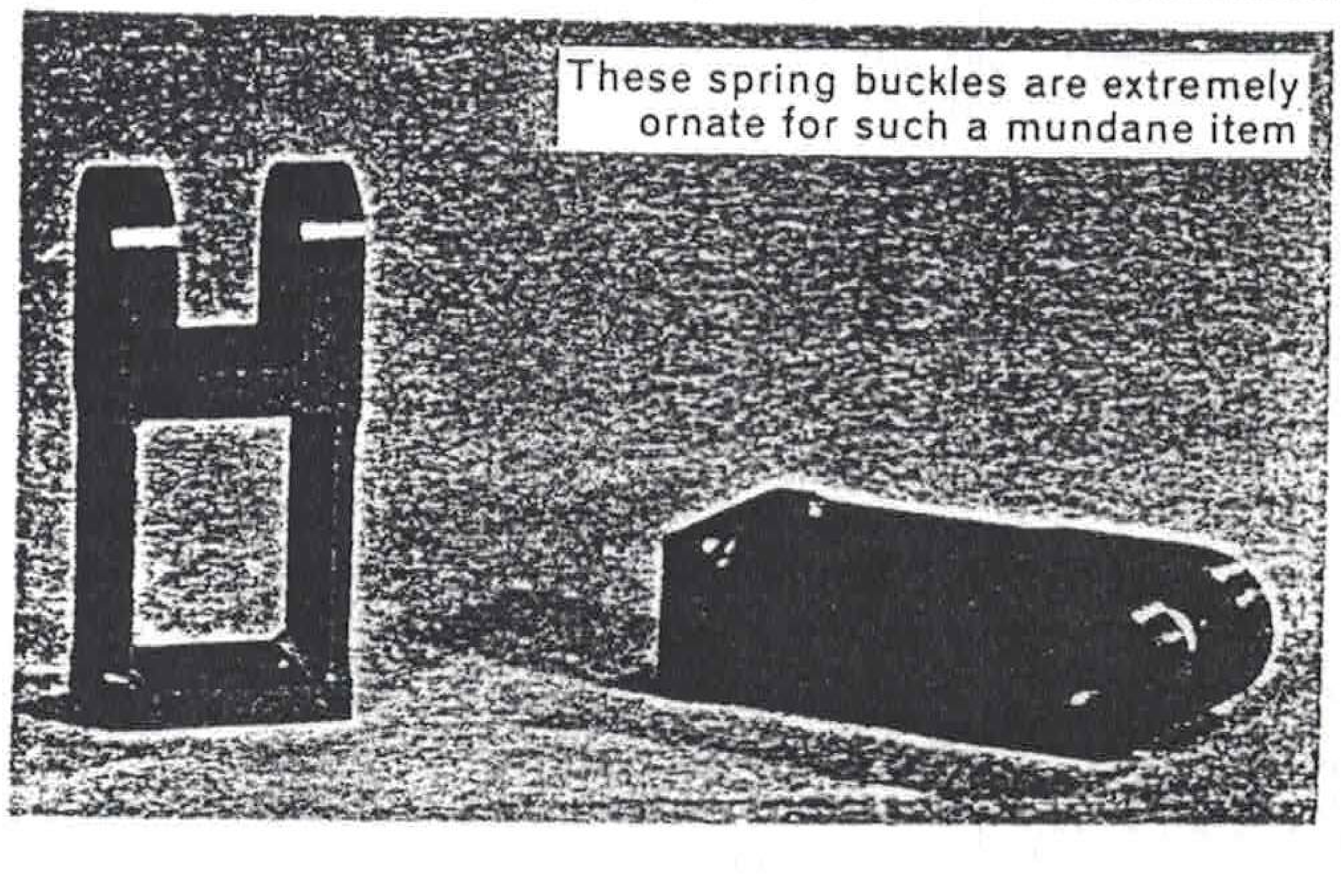
Hornstay

The hornstay is a bit of a misnomer this time, for it has no physical attachment to said horns and simply holds the frames together at the bottom of the horn gaps; even so I made a mess of it the first time round. Take full 3 in. lengths of $\frac{1}{2}$ in. square steel bar, hold up to the frames and scribe back, then rough mill out the slots to $\frac{1}{8}$ in. depth. Gradually widen the slots until both are a close fit over the frames, then mill the ends to suit. To complete, relieve to $\frac{1}{8}$ in. depth over the centre portion at the back of the stay, then by $\frac{1}{16}$ in. at the top face over the same portion, offer up to the frames, drill 3/32 in. diameter in four positions and secure with 7BA bolts.

Springing

A question I am frequently asked at this stage is can I give full leaf spring details so that the piece parts can be made, fitted and forgotten; my answer has to be NO. Springing can only be properly checked with the engine completed; full size they were weighed off in steam. Really it is the attitude the engine takes up when sat on the track, more important if it slips excessively; the latter is the clearest evidence of incorrect weight distribution. To make life easier in correcting same, instead of altering the tufnol/spring steel composition of the spring as I have previously suggested, this time as the spring hangers do not allow for adjustment, I recommend you make additional hangers $\pm$ 1/32 in. on the nominal dimension and use these to correct poor weight distribution; as the spring hangers are simple fabrications I will make no further reference to them.

The hanger brackets do require some description, so start with backplates $\frac{11}{16}$ in. x $\frac{11}{16}$ in. from 2.5mm or 3/32 in. material and drill a No. 22 hole through the centre. Bend up the stirrup from $\frac{11}{16}$ in. wide x 2mm steel strip, so that the distance between the two lugs is about 9/32 in. to easily accept the spring hanger, then file down so that the inner piece is $\frac{5}{16}$ in. deep, this to drawing. Drill the centre of the inner face at No. 4, turn up a stepped bush to fit same, with a $\frac{1}{16}$ in. head at $\frac{1}{4}$ in. diameter and drilled centrally at No. 22, then bolt this to the back plate. To complete, cut corner bosses from


These spring buckles are extremely ornate for such a mundane item

1/32 in. thick steel or brass sheet, radius as shown and deal with the corners of the back plate to suit, clamp in place and braze up. Use the No. 22 hole to locate to the frames, drill the $\frac{1}{16}$ in. holes and secure with snap head soft iron rivets.

Spring buckle next and although it looks a mite fancy, there is nothing too terrible in its manufacture. Take a length of $\frac{5}{8}$ in. x $\frac{1}{2}$ in. BMS bar and at $\frac{1}{4}$ in. from one end on a $\frac{1}{2}$ in. face cross drill at No. 13. Next mill the $\frac{5}{16}$ in. slot for the spring connector, then radius over a mandrel with an end mill, taking down to $\frac{7}{16}$ in. and then milling the two sides to suit over a $1\frac{1}{4}$ in. length. Start forming the hole to accept the spring leaves with a $\frac{7}{16}$ in. drill, then use a $\frac{3}{16}$ in. end mill to get to size, completing the corners with a square file to the spring leaves as gauge. Saw off, chuck truly in the 4 jaw and face to length, then drill and tap 6BA for the spring retaining grub screw, which is of the cup point socket variety. The final touch is to add those $\frac{1}{16}$ in. x 45 deg. chamfers with a file.

As with all things, there are several ways of making the spring connectors, but for a change I prefer machining them from the solid. Take a length of $\frac{5}{8}$ in. x $\frac{5}{16}$ in. BMS bar and drill right cross at No. 22 at $\frac{3}{16}$ in. from one end. Move on another $\frac{3}{16}$ in., then mill away each side by 3/32 in. to give the $\frac{7}{16}$ in. 'drop arm', drilling this again and reaming at $\frac{3}{16}$ in. diameter to drawing. Now use the mandrel and end mill technique to first round the upper part of the connector over its whole length, then carefully deal with the end 3/32 in. to complete the circular boss. Saw off roughly to length, begin to radius the bottom end with a file, and complete with mandrel and end mill. Now for the springs themselves.

For the top spring leaf, cut a 4 in. length from the $\frac{1}{2}$ in. x .036 in. hardened and tempered spring leaf material; I do this with a small chisel, making a mark across both sides of the material and then snapping it off, grinding off any sharp edge remaining. The end connectors can either be cut individually from 5/32 in. (4mm) plate and fitted with a $\frac{3}{16}$ in. spacer for brazing to the leaf ends, or alternatively cut from $\frac{3}{8}$ in. x $\frac{1}{4}$ in. BMS bar, the $\frac{3}{16}$ in. slot being milled after brazing. So that the spring leaf does not lose its temper, poke it through a large potato, with only just enough protruding for the end to be fitted. The bottom leaf is 1 in. long from the same material, the intermediate leaves from 'tufnol', in increasing increments of 5/32 in., all spring materials being available from Reeves. Assemble to the buckle and secure with the 6BA grub screw; now you can erect the spring gear to look like the coupled wheel spring arrangement as depicted.

Pony Truck Fulcrum

The pony truck stay is a simple flanging job from $\frac{1}{16}$ in. (1.6mm) steel sheet; get as close as you can to the $4\frac{1}{8}$ in. dimension at the flanging stage, so that the end pieces which bolt to the frames do not become too thin when arriving at the final dimension. The pivot, or fulcrum, is a rather fancy fabrication; first bend up the top plate from sheet, mark it out and cut to profile. Offer up to the pivot stay to drill the nine $\frac{1}{16}$ in. and single $\frac{1}{4}$ in. hole. Next chuck a length of $\frac{7}{16}$ in. steel rod, face, centre and drill $\frac{1}{4}$ in. diameter to $\frac{11}{16}$ in. depth; part off a $\frac{5}{8}$ in. slice and bolt this under the top plate. For the bottom plate, drill a $\frac{7}{16}$ in. hole in a piece of $\frac{1}{16}$ in. sheet, cut a circle a little over $\frac{3}{4}$ in. diameter, then chuck a $\frac{7}{16}$ in. nut, any thread, and bolt the disc to it to turn down its periphery to match the top plate. Cut away as shown to suit the centre boss, then cut another strip 39/64 in. wide from the same material to form the cup to join the top and bottom plates; braze up. To complete, mill away the centre section of boss to arrive at the 23/64 in. dimensions specified; zinc spray both pivot and stay, then assemble with rivets. The pivot pin completes this part of the assembly, when the pony truck can be fitted, completing the wheeling process; we are winning – gradually!

The two types of running board support brackets fills a little space on the drawing, and other than this call for no comment on my part, so on to the rods and motion.

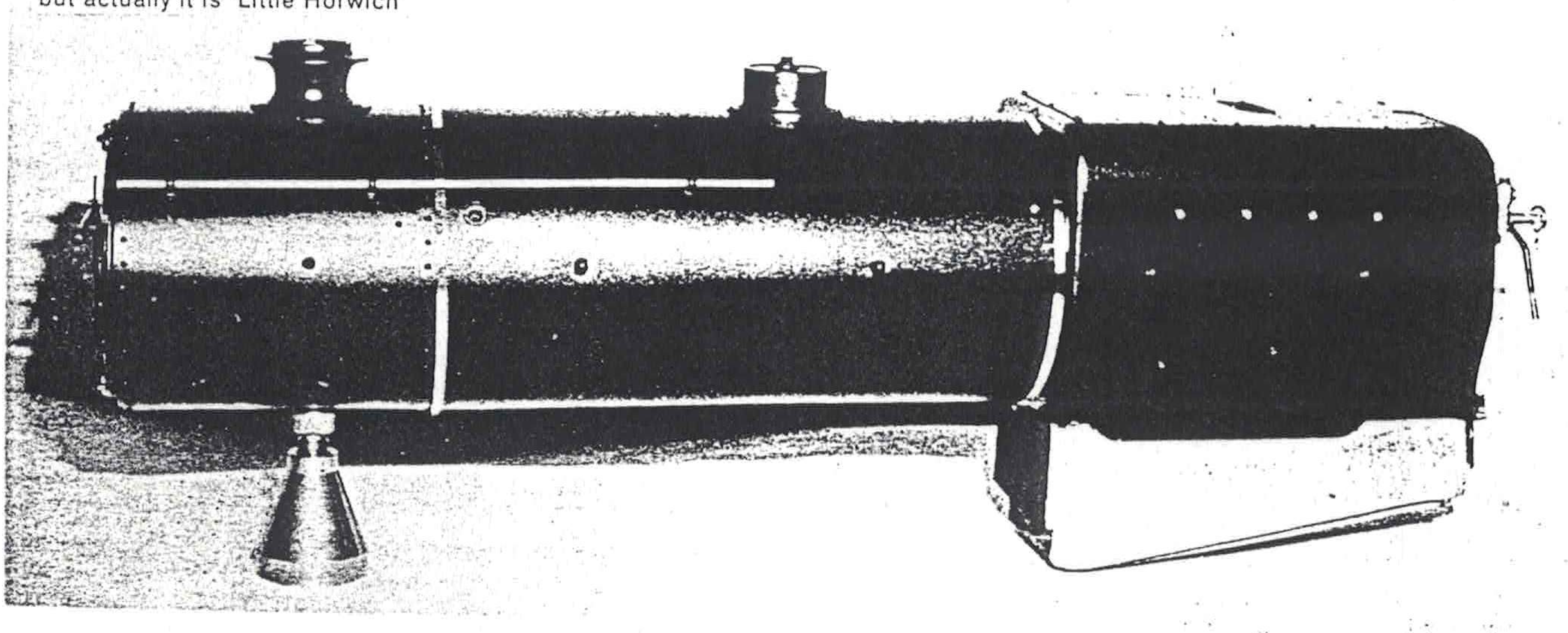
Rods and Motion

At this juncture I must pay particular tribute to the fine photographs of 42700 taken by Norman Gregory at the National Railway Museum; they have been informative throughout, but without them I would surely have failed at the rods and motion stage. As it was I was sorely pressed and needed all my skills to succeed, in fact after completing Sheet No. 7 there was a need to recuperate before picking up the pencil again. Luckily the combination of excellent photographs and patternmaking makes the builder's job rather more straightforward than was my lot, so let me get to grips with at least the first parts of what, apart from the cylinders, are the most outstanding features of E. S. COX, though we shall go in at the shallow end.

Crankpins

The trailing crankpins are easiest, the only point to be watched is the length to suit the wheel boss, also the fit and I usually make mine the press variety. The driving pair again are mostly plain turning; reduce the end $\frac{5}{16}$ in. to 13/32 in. diameter in the first instance. As I have no 'luxury' dividing head or the

The scene could be Crewe or Derby, but actually it is 'Little Horwich'

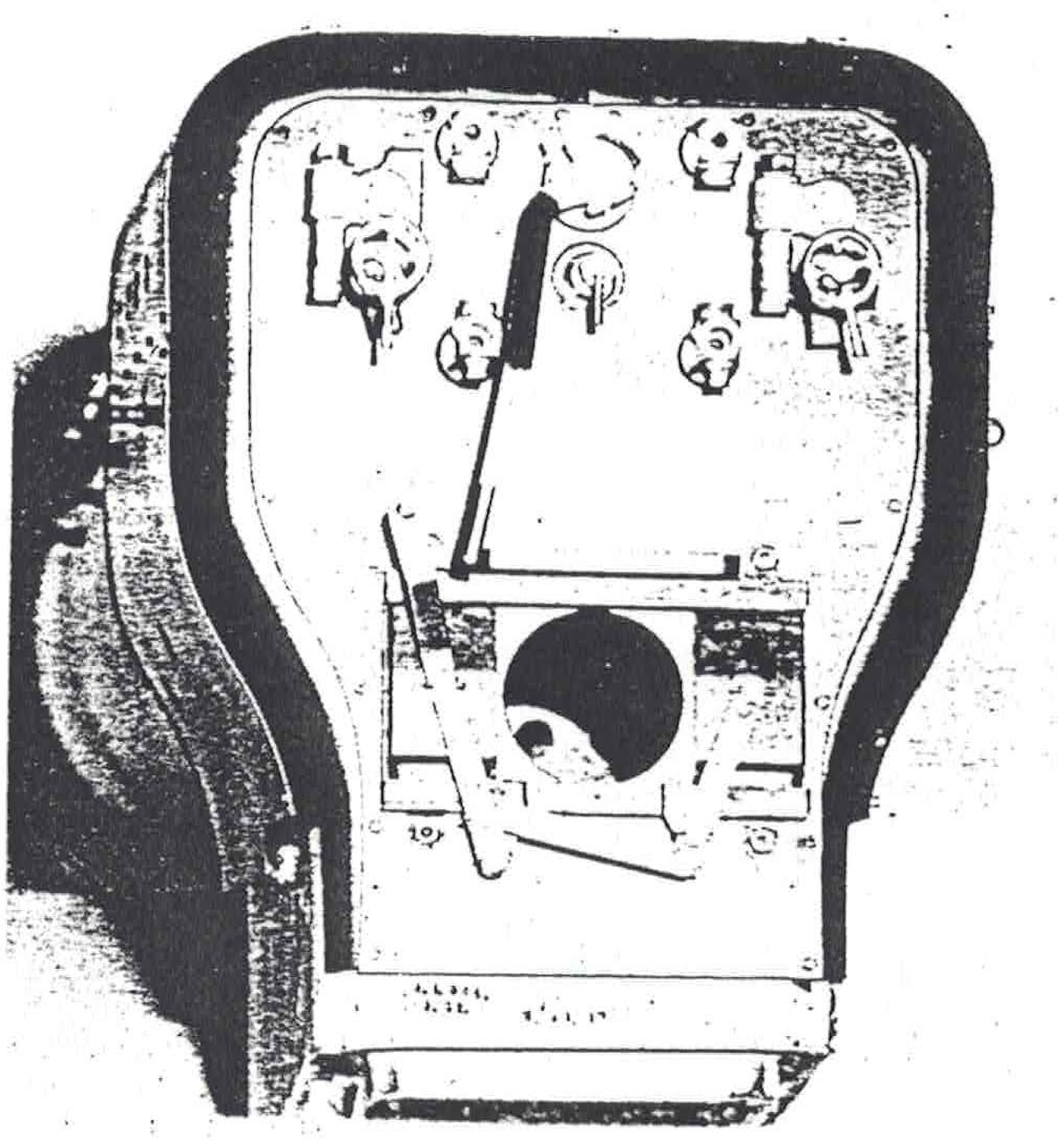


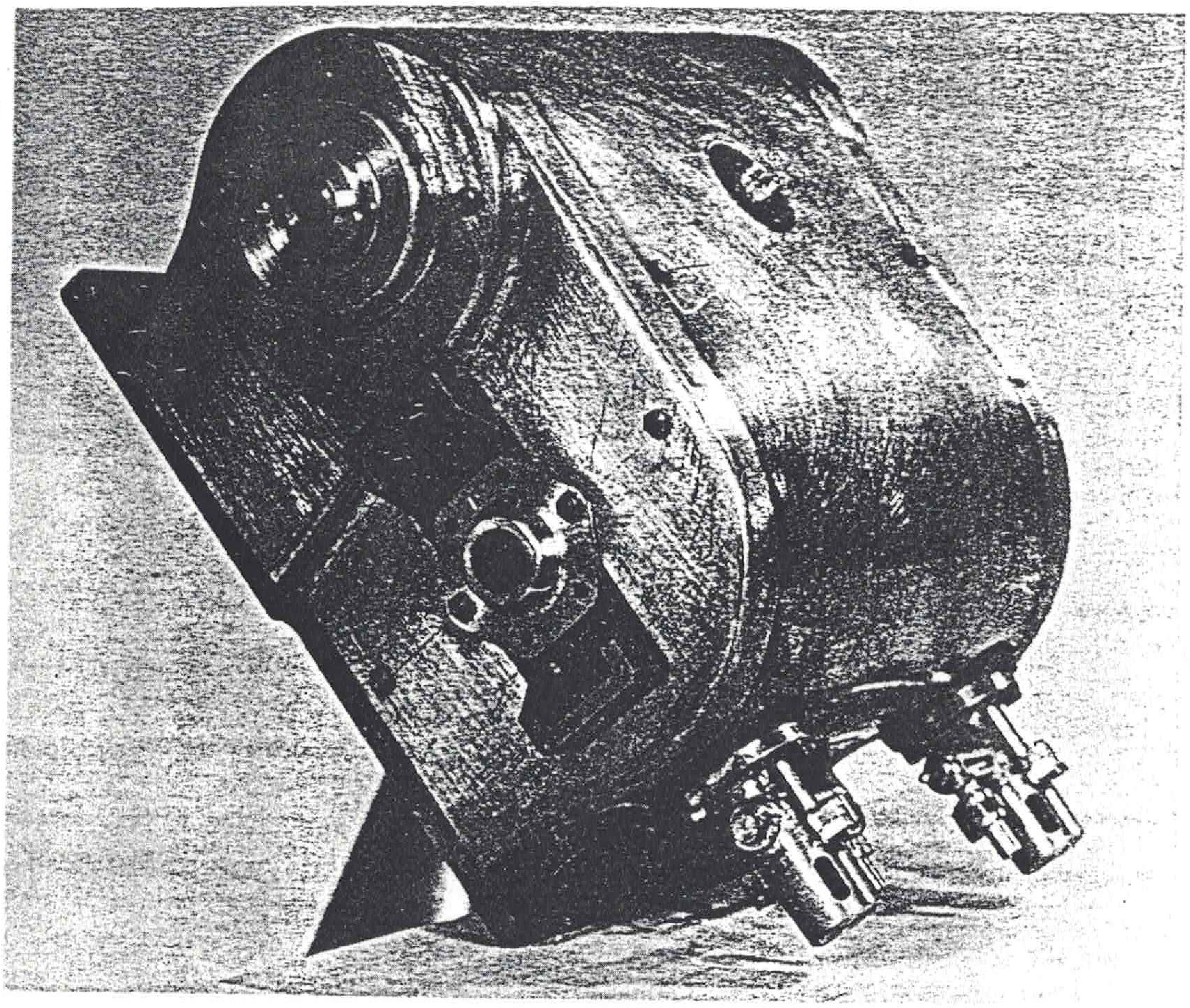
like, milling squares on spindles is a job for the standard set up of machine vice and vertical slide. Removing the top jaw of the Myford machine vice reveals a scalloped recess that I find excellent for holding round work, so do this and check with a d.t.i. that the crankpin is nicely along the lathe axis. Grip a $\frac{3}{8}$ in. end mill in the 3 jaw and carefully deal with one flat so that a micrometer reading over it is .343 in. Now deal with its opposite partner to get a reading of .281 in. over flats; with the vertical slide deal with the other pair of flats in identical fashion. Do not attempt to fit the driving crankpins at this stage as the square just produced needs accurate orientation for the return cranks. The leading crankpins mirror those fitted to my K1/1, a Gresley feature of Horwich origin. I wonder? and I know they work in miniature as well as they did full size, provided the 'keying fit' is a good one. First job is to get the plain portion reduced to suit the crankpin hole in the wheel, then part off 9/32 in. beyond this. Reverse in the chuck, face off to the 17/64 in. length and turn down to 13/32 in. diameter, then either bore or 'D' bit the $\frac{5}{16}$ in. recess to $\frac{1}{16}$ in. depth. Next centre quite deeply to give a start to the end mill for the keyway, then drill No. 50 to a full $\frac{3}{16}$ in. depth, more if you wish, and tap 8BA. Back to the machine vice and vertical slide and with a 5/32 in. end mill, produce the keyway to 3/32 in. depth to complete.
Chuck a length of $\frac{5}{8}$ in. diameter steel bar in the 3 jaw for the crankpin cap, face and then reduce to 35/64 in. diameter over a $\frac{5}{16}$ in. length. Further reduce the end 9/64 in. to $\frac{5}{16}$ in. diameter, a tight fit in the crankpin recess, then centre and drill No. 44 to $\frac{3}{16}$ in. depth. Start parting off at a full $\frac{3}{16}$ in. overall, but stop at around $\frac{1}{4}$ in. diameter. Back to the machine vice and vertical slide to mill two flats 5/64 in. long, to a full 5/32 in. width; now it is a case of very careful filing to arrive at the key being a very good fit in the keyway. If there is any slackness of fit, scrap the cap right now, for WHEN it works loose in service, not if, a lot of damage will result. When satisfied, saw the cap from the remaining bar, rechuck carefully, face off, 'D' bit $\frac{3}{16}$ in. diameter to 5/64 in. depth and radius the mouth as shown. Crosshead pins and rod bushes are plain turning, so let us move on to the rods.

Connecting and Coupling Rods

The rods on E. S. COX are extremely distinctive, but well worth spending time making them as authentic as possible, so let us get stuck into the connecting rods. The material section is a massive $1\frac{1}{2}$ in. x $\frac{3}{8}$ in. and initial length $10\frac{1}{2}$ in. Scribe a centre line along a $1\frac{1}{2}$ in. face then at a full $\frac{1}{2}$ in. from one end, scribe across to represent the big end centre. Move on $9\frac{1}{8}$ in. and repeat for the crosshead or gudgeon pin and carefully drill both holes to drawing size.
We now require a foot length of 2 in. x 2 in. x $\frac{1}{4}$ in. or metric equivilent steel angle, a piece that is perfectly flat and square, as on this will depend the perfection of our rods. In one face, drill a series of 9/32 in. holes at approximately $2\frac{3}{8}$ in. centres, this to suit the vertical slide table; in the other face two $\frac{3}{8}$ in. holes at $9\frac{1}{8}$ in. centres, so that you can bolt the rod in place, only first clamp over the extension of the rod at the crosshead end and using the side teeth of a $\frac{1}{4}$ in. end mill, reduce the thickness in way of the rod 'eye' by 3/64 in.; now fit the second bolt. The next operation is to mill away $\frac{1}{16}$ in. of rod right along its centre section, again with the $\frac{1}{4}$ in. end mill. Turn over, clamp over the end of the rod, deal with the eye of the rod again, then fit $\frac{1}{16}$ in. packing to support the centre of the rod, along its full length if you like, fit the second bolt and complete milling the rod section.
Next job is to mark out the rod profile and saw roughly to line, removing any burrs and sharp edges by filing. Deal first with the rod ends by end milling over a mandrel, noting that there are some very large blending radii that can best be dealt with by filing, also the 'pip' on the bottom at the big end whose original purpose I guess was for a bush retaining screw, though I can see no evidence of same in any of the photographs.
Back to the angle set-up, set the rod over a little and take a trial cut with the end teeth of your end mill, adjusting as necessary until you can mill right along the bottom face to line, though unfortunately as with the earlier operations, you will have to move the angle on the vertical slide table as you proceed, that is unless Myford bring out the ultimate in super-length cross slide/boring tables!; not practical for many reasons of course. We now need a Woodruff key cutter to start fluting the rod, a No. 807 which is $\frac{7}{8}$ in. diameter and $\frac{1}{4}$ in. wide would seem the ideal. If it is possible to grind a wee radius on the corners of the teeth on the shank side, this will provide a root radius to the flute in the rod, both for extra strength and authenticity. Anyhow, at this setting, mill the flute at $\frac{1}{4}$ in. width only and to 3/32 in. maximum depth, a little less if the end result does not offend your eye, to leave a 3/32 in. thick bottom flange. Turn the rod around and exactly repeat for the top face and to complete the rod fluting; oh, and rods do 'banana' when machined, so straighten them out by judicious use of a wooden mallet. Only the oil holes to drill, and tap at the big end, bushes to be pressed in, bores eased as I do like bushes to be a really hard press fit, and then not forgetting to drill the oil holes No. 60 into the bushes after fitting, removing any burr. I guess too that you will have remembered that the rods are handed by the fluting; if not then for once I am not to blame, as a suitable note does appear under the drawing detail!
Whilst the connecting rods can be made of finite length, as any adjustment can be made to the crosshead/piston rod, the coupling rods are very much made to place to match the axle centres, so the first thing we need are some home made drill bushes, each 20mm o.d. and about $1\frac{1}{8}$ in. long; bored $\frac{3}{4}$ in., $\frac{7}{16}$ in. and 15/32 in. respectively.
The front coupling rod, initial, material section is even more massive at $1\frac{1}{2}$ in. x $\frac{1}{2}$ in. than that for the connecting rods, so cut a $10\frac{1}{4}$ in. length, scribe the centre line along a $1\frac{1}{2}$ in. face, then at $\frac{7}{16}$ in. from one end, scribe on the front boss

My backheads are improving!





E. S. COX cylinders besides being huge are very distinctive. This R.H. example is graced with drain cocks/relief valves supplied by DYD

centre. Move back 8½ in. and repeat, then fit drill bushes in the leading and driving axleboxes on the chosen side of the engine, clamping said axleboxes hard down on their hornstays, then bring the embryo coupling rod up to the bushes, sight through and get the 'X' centred by eye, then drill through the rod. Check back from the drilled holes to the centre line, amend if necessary then mark off and drill the 9/32 in. hole for the knuckle pin bush.

Back to the angle set-up, using ⅜ in. bolts to hold the rod in place, then first mill away ⅛ in. from the driving wheel boss right to the front end of the rod, changing from the bolt to a clamp as you reach the leading boss area. Turn the rod over insert ⅛ in. packing pieces to properly support the rod, then reduce the leading boss to 9/32 in. thickness; lower the end mill a further 7/64 in. and mill right through to the back of the rod. Next job is to carefully mark out the profile, milling as much of the bosses as possible over a mandrel, then deal with the central portion as for the connecting rods, setting over to get the correct 'fish-belly'. The fluting could have been carried out at the same settings as the first milling operation, but it needs courage to produce same ahead of profiling the rod, so for the faint-hearted, like me!, deal with this now with the Woodruff key cutter and I am advised that 9/32 in. wide fluting gives a more substantial rod. To deal with the reliefs in way of the knuckle joint, grip the driving boss in the machine vice, on the vertical slide, deal with one face then turn over and complete, after which it is a matter of files and emery cloth to add the finishing touches.

For the rear coupling rod the section is a more modest 1 in. x ⅜ in.; scribe a line along 9/16 in. from an edge along the 1 in. face, the initial length of bar being 9 in. At 5/16 in. from one end, scribe across to represent the knuckle pin centre, grip in the machine vice and drill through at Letter D, changing to a 11/32 in. 'D' bit to produce a counterbore to 1/32 in. depth. At 9/32 in. back from the centre of this hole and in the centre of the ⅜ in. face, drill right through at No. 23 to form the end of the slot. At this stage you can either saw down and file to complete the slot, mill it of course, or form the eye of the rod first to remove a lot of the surplus metal, a decision I can safely leave to builders. In conclusion the forked end should be a good fit over the front coupling rod spigot.

I told earlier of my struggle with Sheet No. 7 and the rest taken before taking up the reins again on Sheet No. 8; it looks as if the knuckle pin and its bush have become victims of this lay-off, for I can find no details of either. As the parts are straightforward, then it will make a pleasant change to describe them from scratch. Chuck a length of 5/16 in. phosphor bronze or gunmetal rod for the bush and turn down to .284 in. diameter over a ¼ in. length. Face the end, centre, drill and ream to ¼ in. diameter then part off a 5/32 in. slice, reversing in the chuck to clean up. Press into the front rod and re-ream the hole. For the pin, chuck a length of ⅜ in. steel rod, the silver variety if you prefer, face and turn down to .142 in. diameter over a 3/16 in. length and screw 4BA. Reduce the next 11/32 in. to ¼ in. diameter, a good fit in the bush, then the next ⅛ in. or so to 11/32 in. diameter, an easy fit in the counterbore, before parting off to leave a full 1/32 in. head; reverse and face off so that the head of the pin is flush with the rod face.

Assemble the front and rear coupling rods with the knuckle pin, use 9/16 in. and ¼ in. dowels from the front rod into the respective drill bushes, then drill the trailing boss. Completing the rod requires no additional description on my part, being a repetition of what has gone before.

Rod Bushes and Quartering

Since mentioning turning the rod bushes in an earlier paragraph, some news/comments have come to hand. The first is that Reeves are again stocking 'Telfos' which is a free machining phosphor bronze and highly recommended for the purpose. I must also seek to justify the massive interference fit specified for the bushes in the rods. The purpose of said bushes is to protect the side rods, a case of an inexpensive item protecting a very expensive, timewise, one. So the bushes are the expendable item and on E. S. COX they will be the bearings that take the most severe pounding. Now, if the normal interference press fit is used, because of the relatively thin bush section, it can come loose in the rod and damage the latter, the very thing it is designed to guard against. There is also the experience with high performance engines in that the combination of thin wall bearings and close fits are conducive to heat transfer; E. S. COX should be capable of some performance on the track! Press said bushes home, drill the oil holes, then ease the bores to a good fit over their respective crankpins.

Again I would quarter the driving wheels on E. S. COX by eye, something that has brought wrath upon my head many times now, and no doubt will do so again! But after earning a living for so long in producing lines at 90 deg. to one another, and there are a whole host of examples on Sheet No. 7, then the slightest error will offend my eye, so I am confident of achieving the right result. For those less fortunate than I, there is still no need in my opinion for any complicated set-up; simply choose a cool evening, degrease with Primer 'T' and apply Loctite No. 601 to the remaining driving wheel and seat, assemble, erect the axle between centres in the lathe and use an engineers square to set the crankpin on the wheel at the headstock end vertical, a scribing block to set its partner horizontal, the right hand crankpin to lead. The cool evening is important as Loctite is temperature sensitive; allow 24 hours to cure, although 30 minutes is usually ample. Assemble the driving wheels in the frames, good job we have split axleboxes!, slide the leading and trailing axles in place, with the single wheel already fitted, then fit the coupling rods on this side. Degrease and apply Loctite 601 to the remaining two wheels, slide them on then bring up the coupling rods and erect, when you should be able to get the wheels turning sweetly as the Loctite cures.

After that feat of quite precise engineering comes the 'butchery' of the coupling rod bushes, for as they are at present they will simply derail E. S. COX at the first opportunity. We have to return to the condition where each axlebox can be lifted independently by around 5/32 in., which means easing the fit of the bushes over their respective crankpins by around .003 in. Take the 17/32 in. drill first and grip upright in the bench vice. Put the driving crankpin bush over same, poke a length of $\frac{1}{16}$ in. rod down one of the flutes, pull the rod round and pare a little metal off the bore of the bush. Deal with each of the bushes in turn, erect and check the axlebox movement, until the wheels turn, albeit a little stiffly, with the axleboxes in various positions in their horns.

Motion Plates

We now reach a most critical stage in construction with components which have to align with several others, starting with the motion plates. Full size the frame bolting flange was cast integral, but to do so in miniature would increase the casting cost by a factor of not less than 4, plus in full size if you look at a 'Crab' motion plate you will see evidence that the moulder had a most unhappy time in places by his trowel marks; in miniature of course such defects would be greatly magnified. The same comment applies to the weighshaft bearings, though for these there is much merit in being able to machine them separately. Let me establish some of the terminology before we commence machining. The appendage to which the frame fixing flange attaches I will call the 'box', whilst the 'jaws' separate the slide bar fixings, hopefully this will now avoid confusion. There is one other point in that I have used centre lines as datum, thus emulating full size practice in that a stretched piano wire extended from cylinder to centre of driving axle and the motion plate was erected to this. We won't do things quite like this, but I think the dimensioning is satisfactory for me to describe machining and erection.

Measure the casting very carefully to establish the machining allowances and the various main features, then grip in the machine vice and mill the inner, frame, face of the box, this to establish a datum surface, tenuous though it is as yet for lack of its flange. We shall be making the latter from $\frac{1}{8}$ in. or 3mm plate later on and brazing in place, so need an allowance of a few thous on the flange face to clean up on final machining; bear this in mind as you proceed. The next job is to deal with the opening for the radius rod/lifting arm, which simply means marking out on the raised boss to give ribs about 3/32 in. thick, drilling out most of the excess and then milling or filing to line. Bolt through said opening onto the vertical slide table, using packing as required, set the datum face on the inside of the box vertical and then mill the outer face of said box to accept a 3/32 in. rib that is cut from plate, though said rib is not mandatory. That outer surface of the box now becomes very important as a second datum; set it on the vertical slide table with the main face of the motion plate protruding at the side and with jaws facing the chuck, then bolt in place with a bar across the inner surface as support; set vertical. Carefully mark out the slots for the slide bars, only make them $\frac{1}{4}$ in. wide instead of $\frac{7}{16}$ in. at this stage, and with a Woodruff key cutter, No. 606 which is $\frac{3}{16}$ in. wide, cut the slot to correct depth and $\frac{1}{4}$ in. wide to suit a piece of 1 in. x $\frac{1}{4}$ in. BMS bar; deal with the second bar slot at the same settings for width. Change to an end mill and using the side teeth, arrive at the 13/32 in. dimension from the centre of the main body of the casting.

Take the length of 1 in. x $\frac{1}{4}$ in. BMS bar, it wants to be at least $4\frac{1}{2}$ in. long, and scribe a line along a 1 in. face at 13/32 in. from one edge; scribe across at $\frac{1}{2}$ in. and $2\frac{3}{8}$ in. from one end. Mill out the $\frac{1}{2}$ in. x 13/32 in. step first, gripping in the machine vice on the vertical slide, then work back from the other end to arrive at the same 13/32 in. deep step, and a distance over the projection of $1\frac{7}{8}$ in. to be a close fit in the slide bar seatings we have just produced. Divide the spigot equally to arrive at the centre line datum, measuring up 2 21/32 in. to arrive at the position of the weighshaft in this plane, then measure 7/32 in. from the machined face to correctly establish its centre; drill and ream through to $\frac{5}{16}$ in. diameter.

Take two lengths of $\frac{5}{8}$ in. x $\frac{5}{16}$ in. BMS bar and square them off to $\frac{7}{8}$ in. overall, clamping together, marking off, drilling and tapping to drawing to start forming the weighshaft bearings; bolt together. Find the bearing centre, chuck to run true in the 4 jaw, then drill through and ream at $\frac{5}{16}$ in. diameter. Radius the corners, mill away $\frac{1}{8}$ in. to form the end flanges, then I reckon you will have to resort to filing to complete. Locate hard against the inner face of the jig, using a length of $\frac{5}{16}$ in. silver steel rod as location, then cut an $\frac{1}{8}$ in. web to be a close fit to both bearing and motion plate. Cut the frame fixing flange from brass or steel, clamp in place and you can braze this, the rib at the front of the box and the weighshaft bearing to place; pickle and clean.

Leaving the jig in position, if you measure back $1\frac{3}{16}$ in. from its inner face you will arrive at the frame fixing datum; machine this flange to line. Remove the jig and carefully complete milling the slide bar fixings, tidying up the rest of the casting as required; there is very little to do. Drilling the flange from the frames is simple, but we will wait until the slide bars are complete and erected to the cylinders before dealing with same, the same goes for the top flange to accept the running board. That probably removes the most difficult piece part on E. S. COX, certainly the most prominent.

Valve Crosshead Guide Bracket

As usual, measure the casting for machining allowances, then chuck in the 4 jaw and face frame fixing face to roughly the spigot dimension. Clean up the two edges of the upper flange to be parallel, grip in the machine vice and mill around three of the five faces of the frame fixing flange. Grip by the two vertical ones in the machine vice, set the datum face along the lathe axis, then mill the feet for the guides, cleaning up the 'U' to drawing dimensions but without destroying those wee webs, then tidy up the ends of the guide supports. Grip over these latter in the machine vice, set the swivelling vertical slide over 6° – 20′ and mill the frame fixing face to leave the 'gripper' at the top. Mill the top edge of this flange, then transfer your attention to the top flange face and mill this to suit the running board. Offer up to the frames in the position shown, 1/32 in. ahead of the 'drop', and drill back through the casting. Mark out the two lightening holes and cut them out – nothing special is required here. You can complete by drilling the four No. 44 holes in the support feet, or leave these to be dealt with from the valve crosshead guides later on; this latter is favourite.

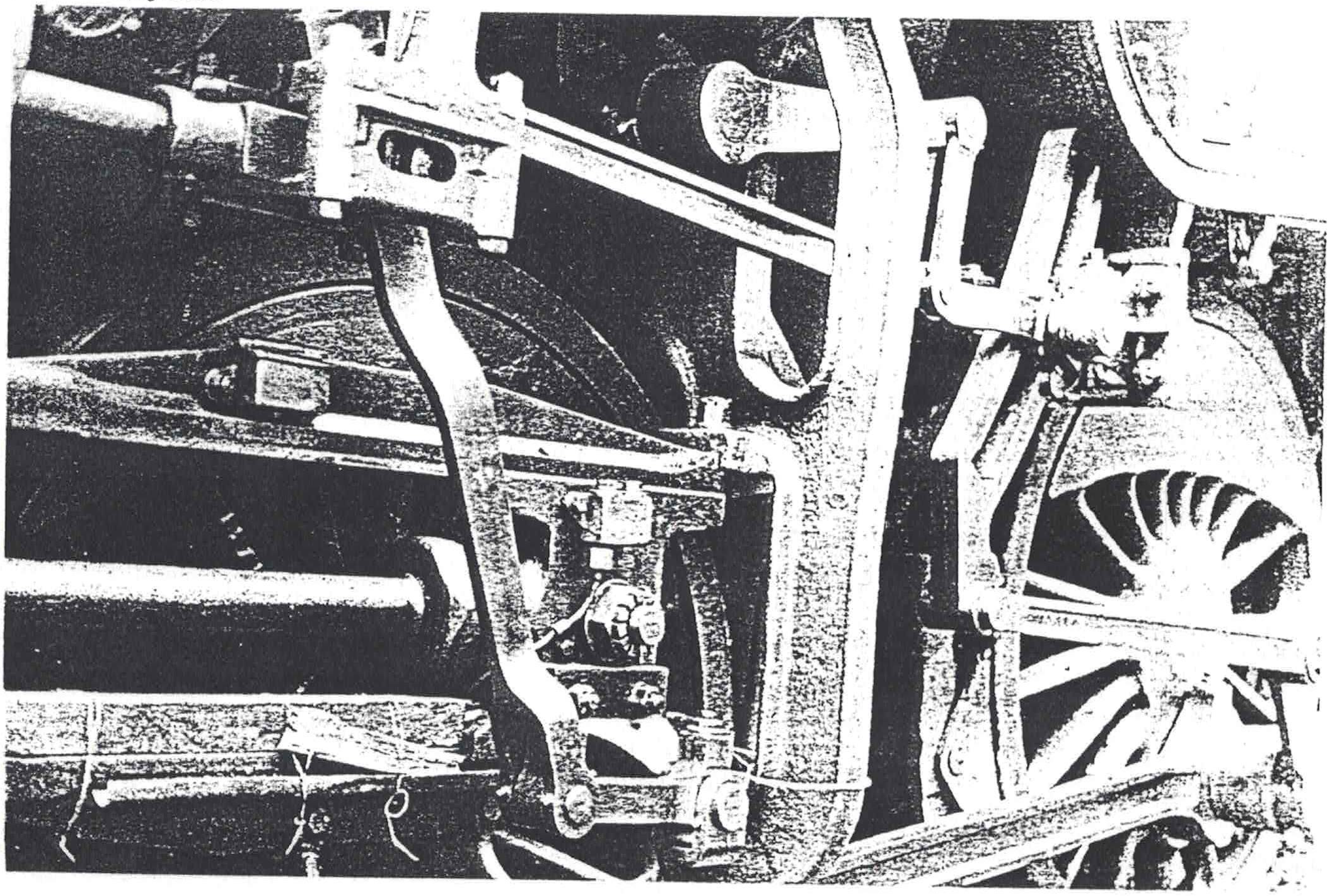
Expansion Link Brackets/Supports

The expansion link support bracket castings are quite neat and require little machining; again establish the allowances provided as a first step. File the two faces for the expansion link bracket attachment feet, sit on the bottom jaw of the machine vice, add packing at the top then tighten up and mill the frame fixing face and top edge, when you can tidy up the edges with a small end mill, completing with files. The fixing holes are quite close to the edges of the flange, so erect to be central over same and drill through, then establish the datum from same. Transfer to the lugs for the expansion link brackets, grip in the machine vice again and mill the slots, then clean up the pair of slots in the rear face with files; that is about all the tidying up that will be necessary.

The brackets themselves are rather fancy, but we shall win! Start with a length of ½ in. x ¼ in. BMS bar and drill through 9/32 in. diameter at ¼ in. from one end. Radius the end over a mandrel with an end mill to be 13/32 in. across, cutting into the bar to arrive at somewhere near to 9/32 in., then saw off and mill square to the 13/32 in. dimension and clean up the two flanks. Drill the oil hole No. 43 and tap the outer ⅛ in. or so at 6BA to complete the boss. For the bracket we need ⅝ in. x 5/16 in. x 3/32 in. angle, about 3 in. in total and milled from ⅝ in. x 5/16 in. BMS bar. At this point the decision has to be made on fixing to the support brackets as once assembled virtually all the holes become inaccessible, so mark off on the angle pieces and drill them all at No. 44, offer up to the support brackets with the feet of the angle flush with the outside of their respective housings, drill through the outer pair at No. 44; for the inner pair, spot through, drill No. 50 and tap 8BA.

Next take a length of 1 in. x ¼ in. BMS bar and mill a 11/16 in. channel in it to 1/16 in. depth to accept the pieces of angle; drill through and bolt them in place. Grip the bar in the machine vice and use a ⅜ in. end mill to scallop out a radius to accept the bosses, completing with files and then tapering the top and bottom edges to drawing. Clamp the bosses in place, with a length of 9/32 in. silver steel rod through the bores, adjust until the rod turns sweetly, then cut out the little webs to fit between boss and angle foot; braze up. Turn up the 7/32 in. bore bronze bushes, press them home, drill a No. 60 oil hole, then erect to the support brackets and run a 7/32 in. reamer right through – we have won!

To the builder's plea for more photographs of full size 'Crabs', I trust this Norman Gregory shot is as useful to you as I found on the drawing board



E. S. Cox – The Horwich 'Crab' in 5 in. gauge

by: DON YOUNG

Part 8 – Motion

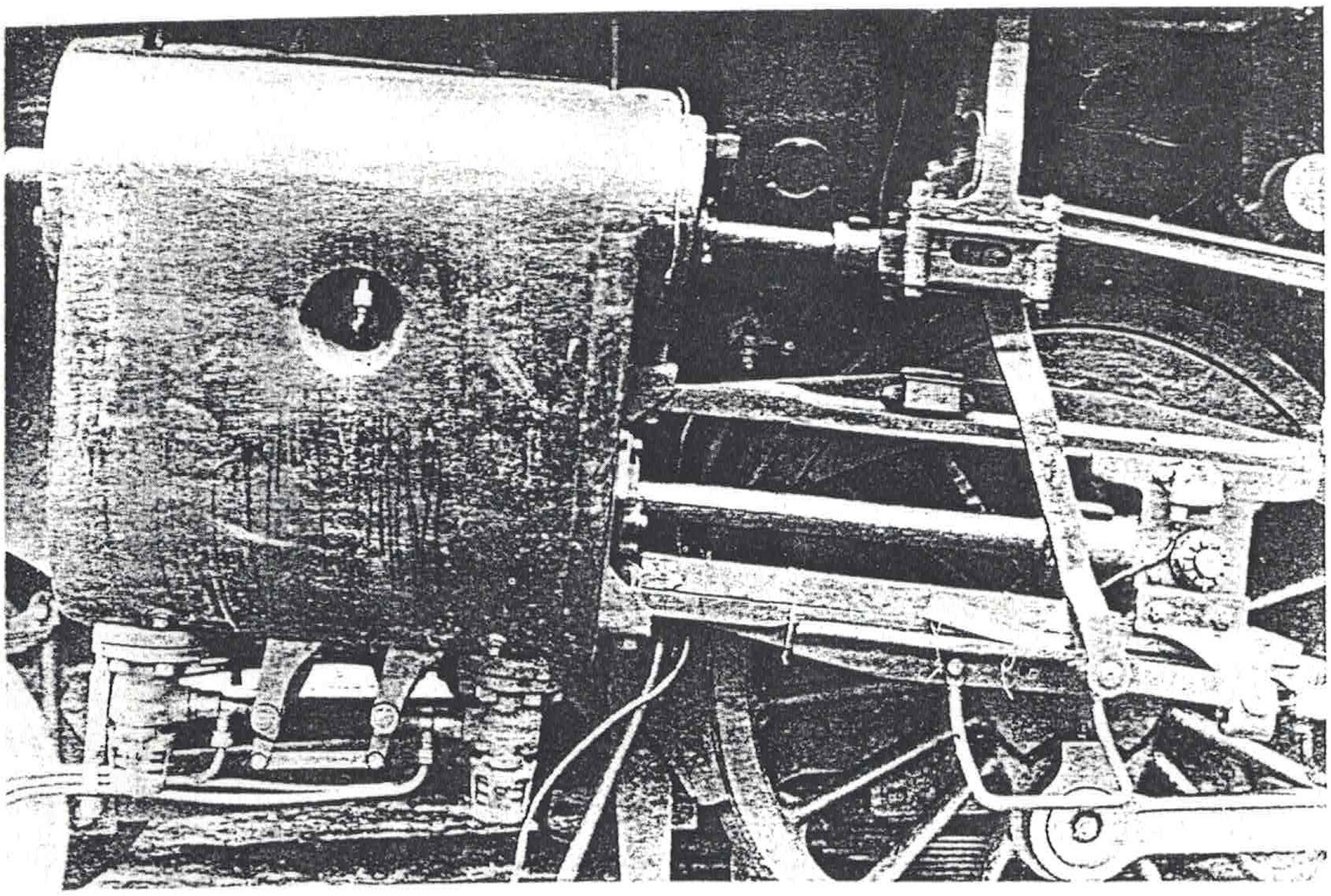
Sorry for the 'break in transmission' in LLAS No. 19 but normal service is now being resumed and I think there will now be 'uninterrupted viewing until we reach the end of the programme'. It is perhaps appropriate that the break came at exactly the same point as on the drawing board some four years earlier, and I feel equally refreshed now as then, so let me hurry on with construction.

Crossheads and Slide Bars

The crosshead centre is from 1 in. x $\frac{3}{4}$ in. BMS bar, so first square off two pieces to $1\frac{5}{8}$ in. overall. Find the centre of one of the end faces by the 'X' method, centre pop and chuck in the 4 jaw to run true, lightly face, centre and bring the tailstock into play. With a round nose tool, reduce to $\frac{11}{16}$ in. diameter over a full $\frac{5}{8}$ in. length, then reduce further to 17/32 in. diameter to leave a $\frac{1}{16}$ in. collar at the end. Carefully cut into the shoulder of the bar with the round nose tool to arrive at the total stem length of 23/32 in., when you will have to complete the matching lip with the slippers with a file. Centre and drill 7.9mm to no more than $\frac{7}{8}$ in. point depth.
Next reduce the remaining bar section to $\frac{15}{16}$ in. x $\frac{9}{16}$ in., keeping it symetrical with the end boss, then mark on the crosshead pin centre and drill right through at No. 12, opening out to $\frac{5}{16}$ in. diameter to about 11/32 in. depth. We now have to mill the central slot with a side and face cutter, mounted on a mandrel between centres for preference, or use a slitting saw to arrive at the same end result. At the bridge piece we have to mill a $\frac{1}{16}$ in. recess to the same $\frac{5}{16}$ in. width to accept the slippers, this is a job for an end mill. Deal with the back edges of the forks with an end mill also, to arrive at the lips as shown. Those 7BA tapped holes will have to await arrival of the drop arm, so let us move on to the slippers.
As said slippers are made separately from the centre, so they can be from a different metal, and I have listed gunmetal or bronze. Saw off two $1\frac{3}{4}$ in. lengths from the chosen material and reduce the section to $\frac{9}{16}$ in. x 9/32 in. Grip in the machine vice, on the vertical slide and mill, say, a $\frac{5}{16}$ in. slot to $\frac{1}{16}$ in. depth, gradually increasing it in width until you arrive at the required $\frac{7}{16}$ in. dimension with the two flanges of equal thickness; repeat for the second piece. Now turn over and mill away $\frac{1}{8}$ in. at each side to arrive at the $\frac{1}{16}$ in. deep tongue to be a close fit in the crosshead centre. Mill away the ends of this tongue to perfectly match the centre and complete the profile by milling or filing. Lightly clamp the slippers to the centre, mix some Easyflo flux to a stiff paste, then silver solder together using a minimum of spelter and thoroughly clean.
Chuck a length of $\frac{5}{16}$ in. rod in the 3 jaw, tap the crosshead over the end of same, clamp a d.t.i. under the tool post and traverse along the slot in the slipper to check it is true; correct by milling if there does happen to be any error, though this is unlikely. At this stage you can fit the crossheads to their respective piston rods, but don't drive them all the way on as yet.
'T' section slide bars were a menace to machine even in full size, as the heavy milling makes them 'banana' and this was corrected by surface grinding of the working face. I doubt if many builders have this luxury, so we shall have to proceed with some care. I like 'key bar' for this application as it is a fairly stable material with good wearing properties, section $\frac{3}{4}$ in. x $\frac{1}{2}$ in. or the nearest metric equivalent. Although the flanks can be machined away singly, gang milling was employed full size and is preferable in miniature; also note the generous root radius on the photograph hereabouts, as long as I do not forget to include it! Arrive at the 'T' section, leaving about $\frac{1}{16}$ in. on the working face for final machining, but before tackling this, complete the rest of the profiling; now comes the acid test.
Fit the slide bar to its support on the rear cover, drill through at No. 34 and secure with a 6BA screw; deal with upper and lower in like fashion; now check the clearance or lack of same of the crosshead slippers. Minus clearance and you take a skim off the slide bar face until you can insert a .0015 in. feeler gauge between slipper and slide bar; a clearance initially greater than this and you add shims between the slide bar and its support to arrive at the working clearance. Now do exactly the same at the motion plate end until the crosshead slides sweetly along the full length of the slide bars, when you can deal with the 4BA socket screw fixing.
We already have the crosshead pin, so erect the connecting rods and turn towards front dead centre, though I guess the piston will strike the front cover before you get there, so tap the piston rod further into the crosshead until the piston comes within 5/32 in. of the front face of the cylinder block. Undo the back cover, ease it off and apply a wee lump of plasticine, then refit. Turn to back dead centre, ease the back cover off again and check the plasticine indicates a clearance of 3/32 in. Once the piston clearances have been established at 3/32 in. each end, scribe where the piston rod enters the crosshead, part the two and then trim any excess length off said piston rod. Reassemble and secure either with a flat cotter as per photograph, or drill right through and fit a couple of $\frac{1}{8}$ in. taper pins.

Drop Arm

For BLACK FIVE I deliberately avoided the 'bent up from plate' style of drop arm in favour of the later solid pattern, but for E. S. COX I have no such option. I guess the whole thing could be milled out from the solid, but such I would recommend be your last resort; let us see what happens when we try to fold it up.
Take a 2 in. length of 1 in. x 3/32 in. (or 2.5mm) mild steel flat and at $\frac{3}{8}$ in. from one end scribe a line across; bend this at 90 deg. in the bench vice using a wooden mallet. We now have to complete the $\frac{3}{16}$ in. 'trough' to accept the untion link, so grip in the bench vice over a length of $\frac{1}{2}$ in. x $\frac{3}{16}$ in. bar and start tapping over, completing by squeezing in the jaws, still keeping the $\frac{3}{16}$ in. bar in place as a spacer. Now at 13/32 in. from the bottom edge of the embryo arm, produce the third bend to a little less than 45 deg., then produce the final bend about $\frac{5}{16}$ in. further on until you arrive at the $\frac{5}{16}$ in. offset as dimensioned; this is the critical figure. Still with the $\frac{3}{16}$ in. spacer bar firmly in place, mark off, drill and ream the 5/32 in. union link pin hole and use this as datum to arrive at the pair of crosshead fixing holes. Now you can begin to remove excess metal to arrive at the finished profile and I would suggest this be solely by sawing and filing, machining set-ups being far too complex for what is involved. Offer up to the crosshead, check that the union link pin hole is $\frac{7}{8}$ in. below and $\frac{5}{16}$ in. behind that for the crosshead pin, then drill, tap the crosshead 7BA and secure with hexagon head bolts.



In response to many requests, this time I will concentrate on illustrating the full size E S COX as captured on film by Norman Gregory. Builders should find this 'general' view particularly useful

Valve Crosshead and Guides

Unusually, because the frames rather than the steamchest end, is used as the means of support, aligning the valve crosshead to its guide is going to be more difficult than even the main crossheads, but of course we shall win.

The crosshead itself starts life as $\frac{7}{16}$ in. square steel bar, so square off two $1\frac{7}{8}$ in. lengths. Chuck truly in the 4 jaw, turn the $\frac{3}{8}$ in. diameter collar for $\frac{1}{8}$ in. length, then reduce the next $\frac{1}{4}$ in. with a round nose tool to $\frac{5}{16}$ in. diameter; centre and drill No. 13 at least $\frac{3}{4}$ in. depth. Next mark off, drill and ream the pin hole to $\frac{3}{16}$ in. diameter, then drill 7/32 in. diameter at the end of the slot and roughly saw out to form the fork end, completing with end mill or files. Radius the end of the fork over a mandrel with an end mill and mill or file the top and bottom faces to complete the profile; set aside for the moment.

I have shown the crosshead pin as being from silver steel, though case hardened mild steel will suffice; in either case it is a plain turning job, so on to the slippers. Start these latter by producing four identical blocks from gunmetal or phosphor bronze to $\frac{5}{8}$ in. x $\frac{3}{8}$ in. x 5/32 in., then find the centre of the face of one of these, grip together in the machine vice and drill through at 9/32 in. diameter. Now with the smallest end mill you can manage, $\frac{1}{16}$ in. diameter is the ideal, mill the recess to 5/64 in. depth as shown before turning up and pressing in the bush to complete, silver soldering together if you feel this to be necessary; ream through the hole in the bush.

We can now erect all the pieces made so far over the end of the valve spindle and insert packing pieces or shims between the top face of the slippers and the underside of the valve crosshead guide bracket, this as a first attempt at gauging the actual thickness of the $\frac{1}{16}$ in. nominal dimension shown on the valve crosshead guide detail.

I would tackle the guides by fabrication in what might be thought a novel way. Take a $1\frac{1}{2}$ in. length of $\frac{5}{8}$ in. square steel or bronze bar and at $\frac{1}{4}$ in. from one end and $\frac{3}{16}$ in. from one edge, drill through at $\frac{1}{8}$ in. diameter; move on $\frac{7}{8}$ in. along the bar and repeat. Turn up $\frac{1}{8}$ in. pillars to fit these holes, which can be from steel or brass as you like, drilling centrally at No. 44. Now it is a question of shaping the outside of the block of metal to represent the outside of the guide, dropping those pillars in place to check things as you proceed. If you are going to make the guides in halves as full size, then allow $\frac{1}{16}$ in. for slitting in halves and cleaning up the mating surfaces at this stage. When you are happy with the outside profile, braze in the pillars and clean up; slit and clean up the joint if that is your choice, then bolt together so that we can proceed again in unison with those builders having 'one piece' guides.

Grip in the machine vice with the inner face towards the chuck and drill a couple of No. 4 pilot holes right through at about $\frac{1}{4}$ in. centres; mill this out to form the 7/32 in. slot to $\frac{1}{2}$ in. length. Withdraw the end mill by 1/32 in. and concentrate on the upper rubbing surface, to get the '$\frac{1}{16}$ in. nominal' dimension about .005 in. in excess of that which you actually measured with the slippers in place; now deal with the bottom rubbing face to accept the slipper sweetly. Note the micrometer collar readings for each of the final cuts and repeat for the second guide of the pair. Now it is a question of carefully filing the top surface of the guides to match with the bracket until the crosshead slides sweetly, when you can bolt the guides to the bracket. Leave the valve spindle cotter for the moment whilst we make the first two items of the actual valve gear.

Union Link and Combination Lever

Although the valve gear will be heavily loaded for the first hour or so in service as the piston valves bed themselves in, after that the superiority of said piston valves will show and there will be surprisingly little stress on the valve gear components, so it is very feasible to make the parts virtually to scale. You the builder will know how busy your E. S. COX will be in service, so can arrive at the decision as to 5/32 in. or $\frac{3}{16}$ in. valve gear pins, so let us make further progress.

Although it is possible to bend chrome vanadium steel bar, its beauty lies in its ground surfaces as datum, so machining from the solid holds many attractions, apart from first cost! Section for the combination lever is either $\frac{5}{8}$ in. x $\frac{1}{2}$ in. or $\frac{5}{8}$ in. square, depending on availability, and we require two 4 in. lengths. Mark on the centre line of the pin holes and grip in the machine vice, on the vertical slide; set the scribed centre line to coincide with the lathe centre height. At 13/32 in. from one end, centre, drill and ream right through at 5/32 in.

diameter, then move the cross slide on by .531 in. and deal with the second hole to $\frac{3}{16}$ in. diameter. A further cross slide movement of 2.844 in. brings us to the third hole at No. 23. Next job is that $\frac{3}{16}$ in. slot to accept the union link, so drill through at No. 12, roughly saw out and complete with files or end mill, to a tight fit for a piece of packing. We now have to remove the thickness of material to arrive at the elegant shape depicted, so carefully mark this off, using the inner face at the top as your datum. Replace the machine vice on the vertical slide with a piece of angle as for the coupling rods; drill No. 27 and secure the embryo combination lever in place with three 4BA bolts, having the datum face against the angle. Use a $\frac{3}{8}$ in. end mill to rough out the outer surface and indeed to complete the 13/64 in. set, removing each 4BA bolt as you come to it and clamping over the fork end when that particular bolt is removed. Arrive at all the flat faces with the same $\frac{3}{8}$ in. end mill so that use of the vertical slide micrometer collar means your dimensions are exact, then use a $\frac{1}{8}$ in. end mill at the fork end to complete the outer face. Turn over and very carefully pack the lever up to be level, then deal with the inner face. Remove all burrs and sharp edges then mark on the profile before going back to the machine vice to finish the top edge of the lever, marking off, drilling and tapping the 6BA holes and carrying on at between No. 55 and 60 into the bores as the means of lubrication. Radius the fork end over a mandrel, I doubt if the upper pin hole radii will succumb to this method, then saw, file and/or mill to complete the profile.

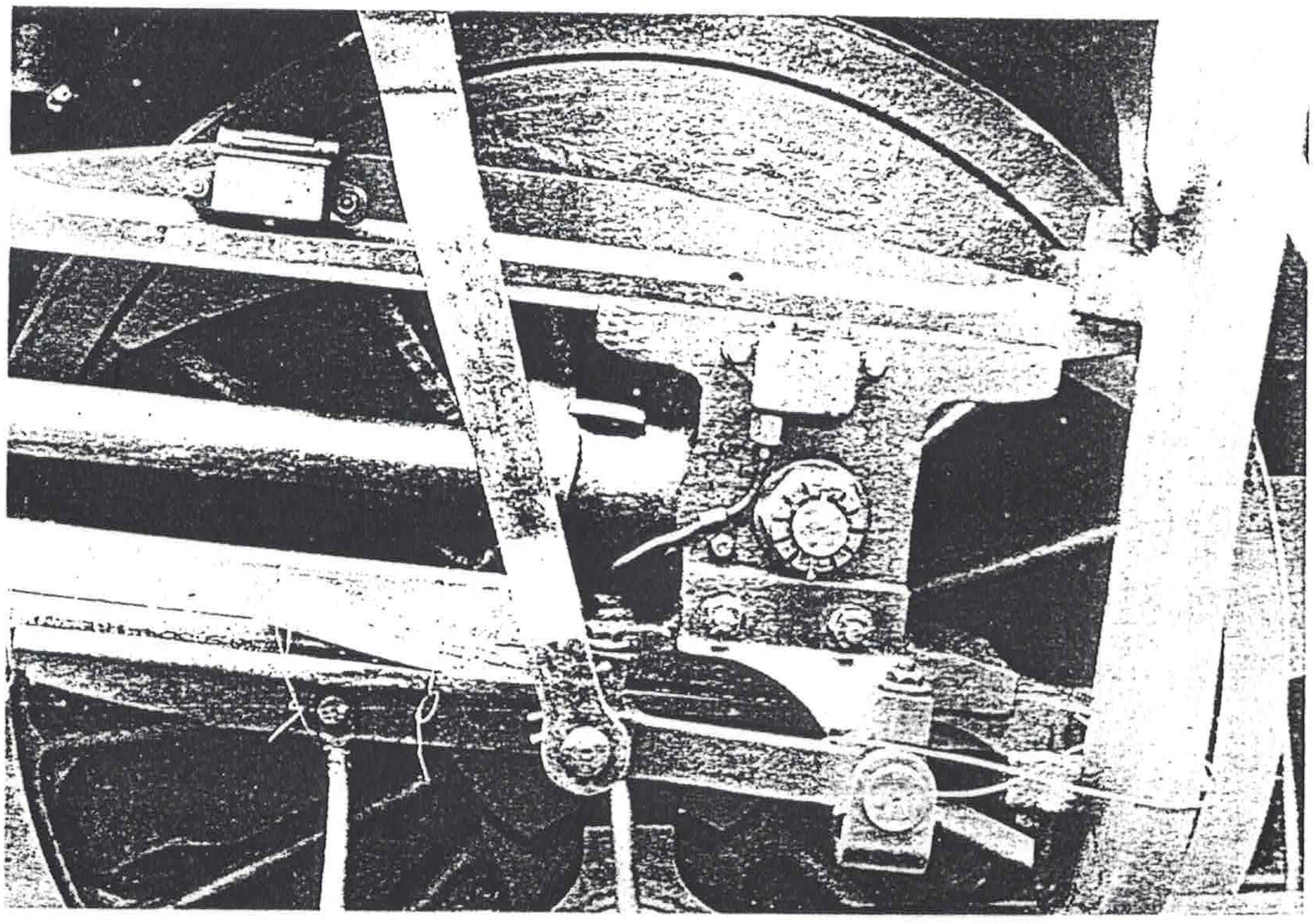
With careful marking out the union links can be made from $\frac{1}{4}$ in. x $\frac{3}{16}$ in. section, or of course the nearest metric equivalent, so drill and ream the 5/32 in. holes at 1.062 in. centres, reduce the centre section to 7/64 in. thickness and then profile, completing with the lubrication arrangement. For the oil plugs I would make what amounts to a 6BA brass bolt, drilled through and countersunk to suit your oil can nozzle, and then silver solder on a wee washer to complete.

Erect union link and combination lever to their respective crossheads, set both at mid position when the combination lever will be at 90 deg. or normal to the centre line of motion, set the valve spindle approximately central and scribe where it enters its crosshead. Remove and drill three No. 54 holes right through, opening out to No. 52 and then with a needle file complete the slot and make up a cotter to be a good fit therein.

Radius Rod and Expansion Link

The radius rod uses techniques we have already employed for the combination lever and connecting rods, so no need for repetition here; on to the expansion links. There is no doubt that the die blocks take the greatest hammering of all valve gear components and it is nice to be able to make the expansion link 7/32 in. thick to increase the surface area, though it is likely to mean an initial milling or grinding operation to arrive at said thickness; well worth the effort though.

Mark out very carefully, drill and ream at 5/32 in. diameter for the eccentric rod pin, then drill a row of $\frac{1}{4}$ in holes along the centre of the slot. I remember as if it were yesterday how back in 1959 I read all I could find about cutting slots in the expansion links for my 'Isle of Wight Locomotive', spent days building up a special jig, got two little pieces of gauge plate specially ground and then 'borrowed' a HSS end mill from the shipyard where I was then employed. A whole week and I was ready to cut the slots; less than 30 minutes later I had two scrap pieces of gauge plate and a week's work lost, for instead of curved slots they resembled bananas; I still keep them as reminders. Having been involved with jigs and tools in my daily employ, though I count myself very fortunate not to have specialised in their design as a full time occupation, I have always tried to avoid them in my hobby, and having broken my own rule I determined thereafter to be even more strict, which is why reference to jigs and tools is very spartan in my writings; some of you do say too spartan! Anyhow, for the second pair of links for FISHBOURNE, I drilled the row of holes as specified for E. S. COX, filed the convex curve in the link to line, followed by the concave side to a piece of silver steel rod as a gauge; I haven't scrapped an expansion link since. So I recommend this be your approach on E. S. COX, using the shank of a 9/32 in. drill if you like as your gauge. It may sound crude, but I did check with a



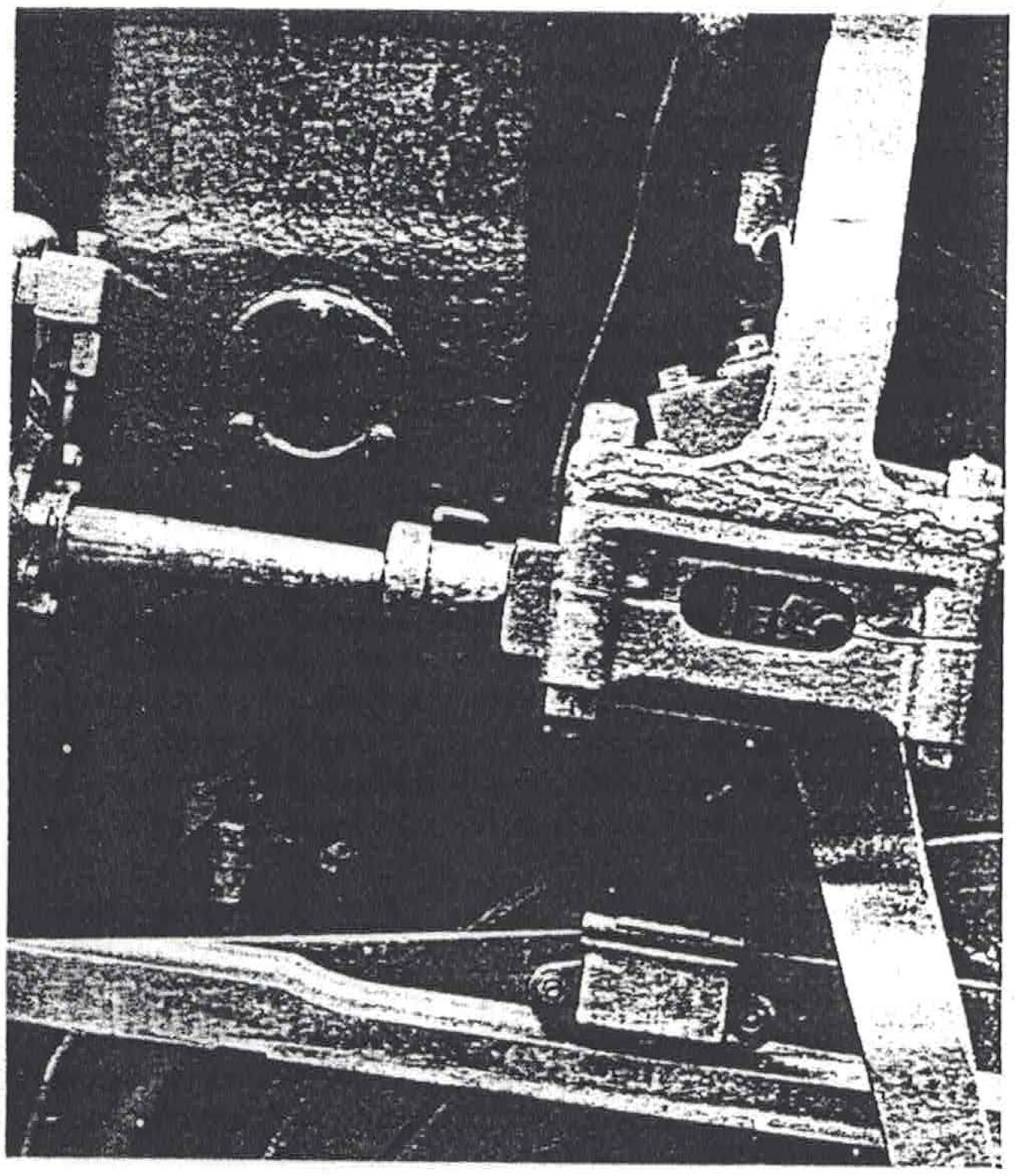
The 'Crab' crosshead is simple, elegant and robust; at least such is my opinion. Note the pair of taper pins at the bottom of the combination lever to hold the valve gear pin firmly in place d.t.i. on my LNER Class K1/1 'Mogul' and found that neither slot wandered more than .003 in. from its true path along the full length; most E. S. COX builders possess far greater skill than yours truly so should arrive at an even better end result.

I envisage making the expansion link trunnions from three pieces. For the first piece chuck a squared 1 5/32 in. length of 7/32 in. silver steel rod in the 3 jaw and turn down over a 5/32 in. length to 5/32 in. diameter. The flange is from 2mm thick steel to the shape shown; clamp together in pairs and drill the No. 52 holes. The lug to complete is from ½ in. x 3/16 in. BMS; drill the 7/32 in. hole first, reduce to 13/32 in. width and radius the end over a mandrel, then saw and square off to 17/32 in. overall. Grip in the machine vice and reduce the arm to 7/64 in. thickness, completing the profile with files. We need one more piece for erection, a 7/32 in. thick sleeve which is 9/32 in. o.d. to suit the expansion link slot and 7/32 in. bore to accept the pin. Set the pin up, drop a lug over it and bring the little flange up to its correct position, clamping firmly in place, then mark off and drill the three No. 52 fixing holes. Use the back edge of the flange to mark the expansion link, complete the profile then saw and file to line. Now bring up the second lug and flange and drill through from the link; secure both flanges with 10BA bolts. Clamp the lugs in place, locate the pin correctly and braze the lug to both pin and flange. Saw away the unwanted centre portion of the pin, file flush, then rivet the trunnions to the link. Complete the link with the oiling arrangement to the eccentric rod pin.

Weighshaft Assembly

I reckon traction engine builders are better qualified than yours truly to describe how to bend up the weighshaft to clear the boiler, as some of their crankshafts make this look positively simple. To check this out I took a foot length of 5/16 in. steel rod, a piece of Mr. Whiston's kindly material of some 20 years vintage, and produced an approximate 3 in. radius bend over 2½ in. at the centre, though I must admit it

The valve crosshead and guides; unusually the latter are remote from the steamchest cover. There is some useful leading sandbox detail in the background



was not very regular. I then gripped the bar in the bench vice, wrapping it with used emery cloth to protect the metal, and smote with a wooden mallet, when I arrived at something like the finished article. I cut off to around 8 in. overall, chucked one end in the 3 jaw and applied a d.t.i. at the other; I should have used my eye first as it went right off the dial! However, by tapping at what I thought were the appropriate spots, the eccentricity gradually came down to within .005 in. of running true at the ends, so the idea is feasible, but I kept thinking there must be a better way, though what it is escapes me.

The reversing arm is easy, by brazing the arm onto a 17/32 in. diameter boss and then completing like a radius rod or combination lever, but the lifting arms posed a bit of a problem for me, until in the end I was forced to make a simple jig. Take a 2 in. length of ⅝ in. x ⅜ in. bar and a bare 5/16 in. from one end and in the centre of a ⅝ in. face, drill and ream to 5/16 in. diameter, then grip with a 'Mole' wrench and mill the end boss over a mandrel. Back to that piece of angle we used for the combination levers, bolt through the 5/16 in. hole and clamp at the other end, then mill away 7/64 in., beginning 19/64 in. away from the 5/16 in. hole and going to the end of the bar; turn over, pack level and repeat, then lay aside.

For the outer end, cut a 13/32 in. square from 7/32 in. steel and chuck truly in the 4 jaw to drill through at No. 23; now for the jig. It consists simply of a 2½ in. length of, say, ¾ in. x ¼ in. BMS bar, drilled at 1¾ in. centres, 5/16 in. diameter and No. 23 respectively. Fit a length of 5/16 in. rod in one hole and another at 5/32 in. diameter in the No. 23 holes, the latter being about 1 in. overall. From ¼ in. rod, make a ½ in. long sleeve drilled at No. 22 to slip over the 5/32 in. pin, followed by the, square, end boss. Now bend that 5/32 in. thick arm that you milled out to fit the end boss, sawing and filing it to a match, after which you can braze up and complete the profile to drawing. The spacers to complete the weighshaft assembly require no description.

The lifting links are simpler editions of the union links, so again no problem, when we can erect another section of the valve gear. It is always a good plan to erect in, small, stages as this way any tight spots can more readily be located and rectified. Slide the reversing and lifting arms onto the weighshaft, plus the spacers, remove the weighshaft bearing caps and erect; at this point I have been well and truly caught out by my own omission!

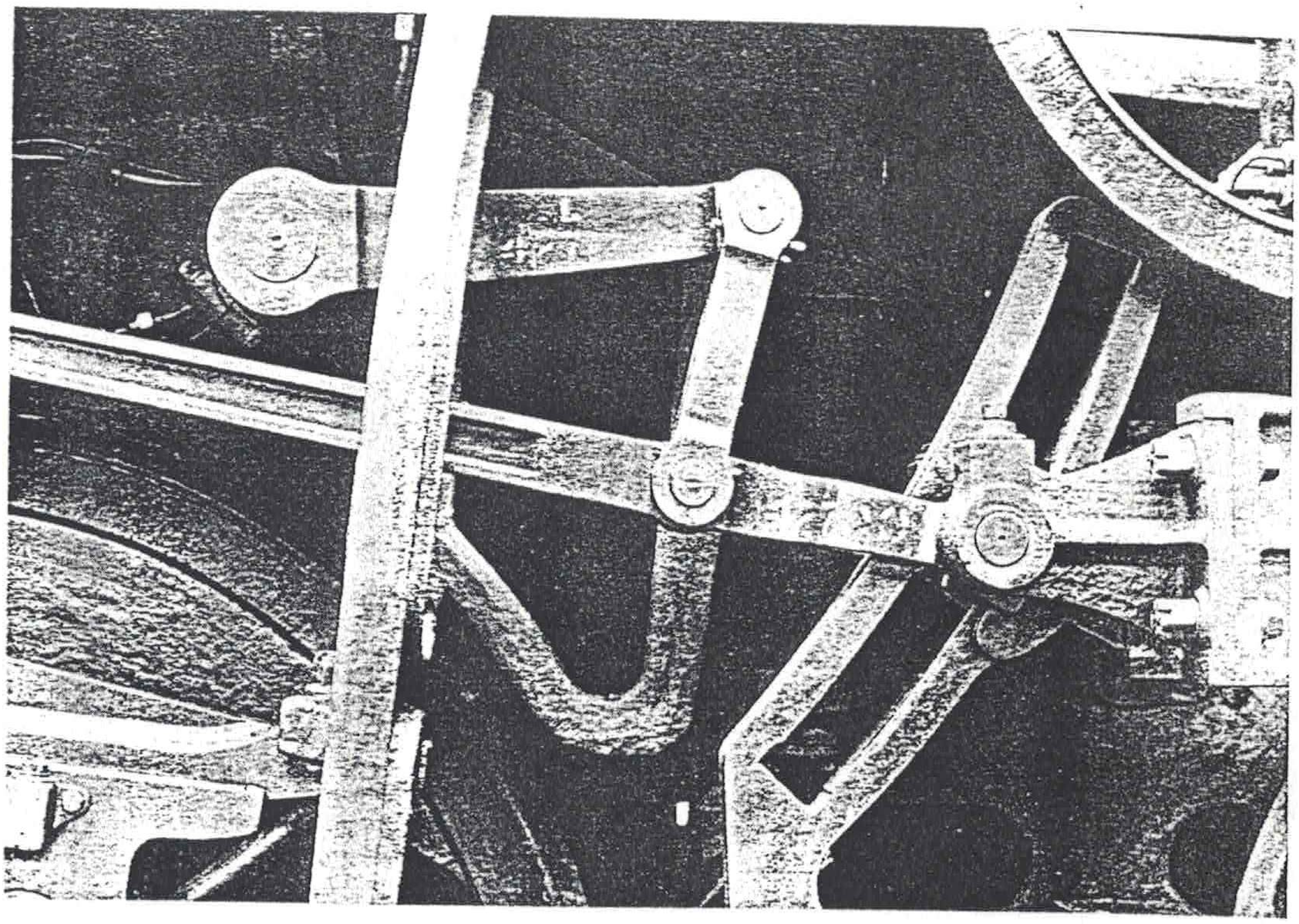
I reckon for fully 50% of my designs that the die block detail is missing, as all the dimensions are there by inference, so let me rapidly turn them into reality. Start with blocks of bronze each 7/16 in. x 11/32 in. x 7/32 in.; drill and ream at 5/32 in. diameter in their centre for the pin. Now file the curved surfaces, keeping the pin central, until the block is a tight fit in the expansion link slot; you can use fine grinding paste to get the nice sliding fit required, but do wash away every grain at conclusion and liberally oil.

Now you can fit the radius rod, with the die block, to the expansion link and erect the latter to its trunnion bearings, then couple the other end of the radius rod to the top of the combination lever. Fit the lifting links, then concentrate on one lifting arm, positioning it so that swinging the expansion link imparts no movement to the valve; clamp in this, mid, position. Check that the set in the weighshaft is facing downwards, clear of the boiler, then drill for and fit either an ⅛ in. taper pin or parallel dowel pin; deal with the other side identically. Set the reversing arm vertically and attach this also.

Return Crank and Driving Crankpin Setting Jig

Full size I have never fitted a new return crank to its crankpin, but I did refit just a few after they had fretted in service, building up the inside of the square with weld and then filing to a decent fit. Full size too there was a special inspection gadget which sat in the axle centre and swept an arc to include

This view gives an indication of the massive proportions of the expansion link



the centre of the return crankpin, which my crankpin setting jig reproduces, so this part of the job always gives me much satisfaction; I hope builders will also be suitably pleased in conclusion.

The jig requires no special instruction for we have tackled many similar, though far more complex, items of late so let us move on to the return crank itself. Looking at Reeves latest Catalogue, the nearest material section seems to be 1 in. x $\frac{5}{16}$ in. as I doubt if any builder can mark out accurately enough to use $\frac{3}{4}$ in. wide steel bar; we require two $2\frac{1}{4}$ in. lengths. Mark the centre line along a 1 in. face then at a full $\frac{1}{2}$ in. from one end, centre and drill through either at 7.0mm or 9/32 in. diameter. Move on 1.355 in. which indicates we use the vertical slide with machine vice and wind on the cross slide, then drill and ream to 7/32 in. diameter. Turn the bar through 90 deg., drill through the No. 34 hole and start that for the 3/32 in. taper pin, drilling right through at No. 51, but only take the taper pin drill/reamer about half way through for the moment. Now with a $\frac{1}{16}$ in. slitting saw, deal with the slot as shown.

The next operations are to remove metal at the back and front of the crank, in that order and exactly as we have done for the other valve gear components, when we can mark on the profile and saw away as much of the unwanted metal as possible. With a little care it is possible to radius the large end of the crank with an end mill over a mandrel, the outer end being much simpler to tackle, when you can either file or mill the side flanks. There is a $\frac{3}{8}$ in., dimension missing from the centre of the 9/32 in. square hole to the end of the crank; square off to said dimension and we can tackle the square; the only way I know how is by filing. It may sound a little primitive but the slot will help us, for full size we drove a wedge into said slot to splay out the ends so we could erect and remove the return crank from its pin; it works equally well in miniature and means the final fitting can be extremely accurate. Run the No. 34 drill through whilst fitted to the crankpin and deal with the 3/32 in. taper pin hole similarly.

Fit the setting jig into the wheel seat, bring up the crankpin with the return crank attached, align the 7/32 in. hole with the setting jig pin and either press home or apply Loctite; now you can quarter the driving wheels. The return crank pin is from 7/32 in. diameter steel, or the silver variety, and I recommend it be brazed to the crank for the security this provides.

Eccentric Rods

Do not make up the finished eccentric rods at this stage but instead make up dummy ones in two pieces, from $\frac{1}{2}$ in. x $\frac{1}{8}$ in. BMS flat and about 3 in. long. Drill a 5/32 in. hole in one piece and a 7/32 in. one in the other, then drill for a 2BA bolt to secure them together at roughly 4 11/32 in. centres, elongating said holes to provide some adjustment about this nominal dimension. Once we have the correct lengths of dummy eccentric rod we can transfer to the $\frac{3}{4}$ in. x $\frac{1}{2}$ in. chrome vanadium steel bar and complete the rods to drawing, though this is a little way ahead yet.

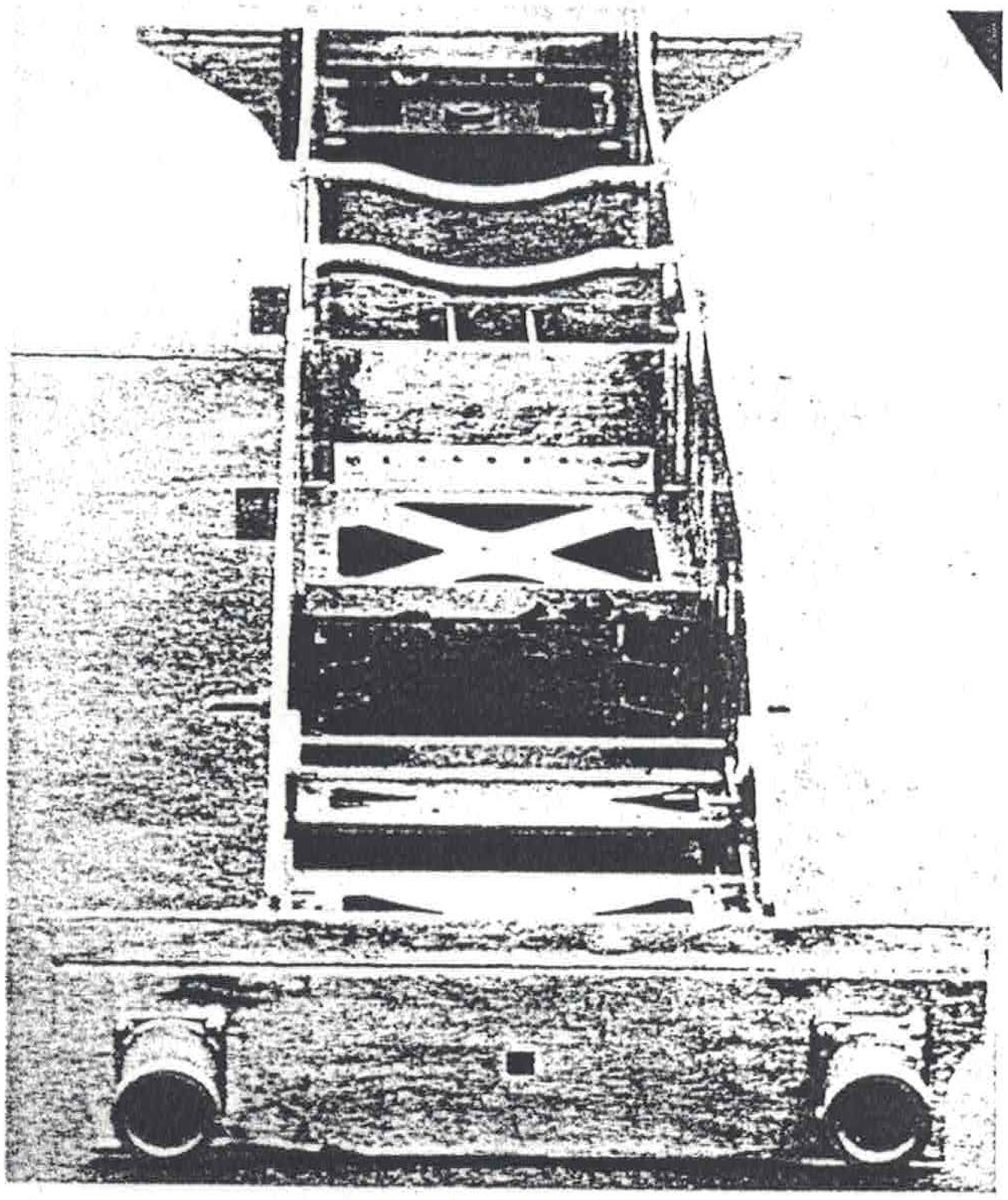
Reverser

Although the temptation is to attempt to set the valves at this stage, it will almost certainly lead to disappointment at the track, so let us do things properly. The reverser is actually quite simple, and rugged, our problem being to reproduce the cast stand as a fabrication, it not being a practical proposition to cast in miniature.

The base is from $\frac{3}{4}$ in. x $\frac{3}{4}$ in. x $\frac{1}{8}$ in. bright steel angle, which can be milled down to 3/32 in. thickness to more closely resemble full size as I have depicted; shape this to drawing. If made about 3 in. long initially, you can add pillars at the ends and drill through at the $\frac{15}{16}$ in. height indicated for a dummy reverser screw. Next items are the end bearings and caps, which are identical save that the caps have clear attachment holes and the mating bearings are tapped to suit. I recommend you turn up the half 'shells' and then add the projections for bolting, brazing together; assemble to the dummy reverser screw. Now cut the upper portion of the stand from 1.6mm steel sheet to suit and make up the tiny ribs from the same material. We now have to add the main bearing block, size $\frac{5}{8}$ in. x 13/32 in. x $\frac{5}{16}$ in., complete with cap and drilling through the pair at 7/32 in. diameter; carefully braze up the complete stand.

The ultimate in reverser screws will have a square thread in lieu of the plain 1BA one specified, but I am not going to describe its manufacture! The nut in any case is a trifle fancy, so let me concentrate on this for a moment.
Start by chucking a length of $\frac{1}{2}$ in. square bronze bar, brass will do at a pinch, truly in the 4 jaw; face, centre and bring the tailstock into play. Reduce the outer $\frac{1}{8}$ in. to $\frac{3}{8}$ in. diameter, then with a parting off tool reduce the next $\frac{1}{8}$ in. to 9/32 in. diameter. Move on $\frac{1}{2}$ in. and reduce the next $\frac{1}{16}$ in. to 9/32 in. diameter, followed by 3/32 in. at $\frac{3}{8}$ in. diameter, before starting to part off. Before completing though, drill No. 20 to about 1 in. depth and tap 1BA. On to the machine vice and vertical slide to next reduce the height of the centre portion to the same 9/32 in. as the rebates, taking a skim off the thicker collar to accept the indicator; you can drill and tap the 10BA hole at this setting. Turn over 90 deg., take 1/64 in. off this face, then mill the $\frac{5}{16}$ in. wide slot to accept the reverser arm. Make a note of the micrometer collar readings at the final cut, then turn over 180 deg. and repeat.
The catch wheel is simple turning and if you do not possess the luxury of a dividing head then the notches will have to be carefully filed in, when 8 or 10 of them will suffice. The locking handle and its fulcrum call for no comment on manufacture, only in use. I made one up for my K1/1 and found it to be a confounded nuisance! It cannot be particularly robust and the locking feature always attempted to work when it should not, with predictable results, so if you do fit the locking arrangement, make sure the arm is a tight fit in the fulcrum, and keep it well away from the catch wheel when running – you have been warned!
I must admit that I was rather at a loss as to how to describe manufacture of the handwheel, until I read how Mike Casey made his handwheels for PEVERIL, a brilliant solution so I will simply refer builders to his article in LLAS No. 19.
For the reach rod arm, take a $1\frac{11}{16}$ in. length of $\frac{5}{8}$ in. x $\frac{3}{8}$ in. BMS bar and drill 7/32 in. and No. 23 holes at $1\frac{1}{8}$ in. centres, then radius the ends over a mandrel, holding the bar with a 'Mole' wrench. Braze in the pin to have the necessary 39/64 in.

Norman Gregory turns his camera towards the chassis of the 5in. gauge E S COX progressing at "Little Horwich"



standout, then I suggest you complete with saw and files, including the 5/32 in. fork. Turn up the collar for the reverser arm, then take a length of $\frac{1}{2}$ in. x $\frac{3}{8}$ in. BMS and fashion the fork before brazing together. It is important to get the $\frac{5}{16}$ in. dimension a good fit in the slots of the reverser nut, otherwise your reverser might start to dance on its stand! Assemble with a 3/32 in. diameter spring dowel pin, or the solid variety to the reach rod arm and erect to the stand; erect the latter in turn to its stool on the L.H. side of the cab.
To complete the reverser we need the indicator and its plate. Chuck a length of 5/32 in. brass rod, face and turn down for 3/32 in. to .135 in. diameter; part off at 11/64 in. overall. Cross drill in the centre of the 5/32 in. portion at No. 57; press in a length of 3/64 in. brass wire, rounding the ends as shown, and braze for additional security, then chuck again and drill through No. 50 for a 10BA round head screw. The indicator plate I have specified from 1.6mm brass and although this is rather overscale in thickness, because of its flimsy nature I would not recommend making it thinner. Cut the 7/64 in. slot first, either with an end mill, or drill a row of No. 36 holes and file into a slot, then complete the rest of the plate around said slot; erect.

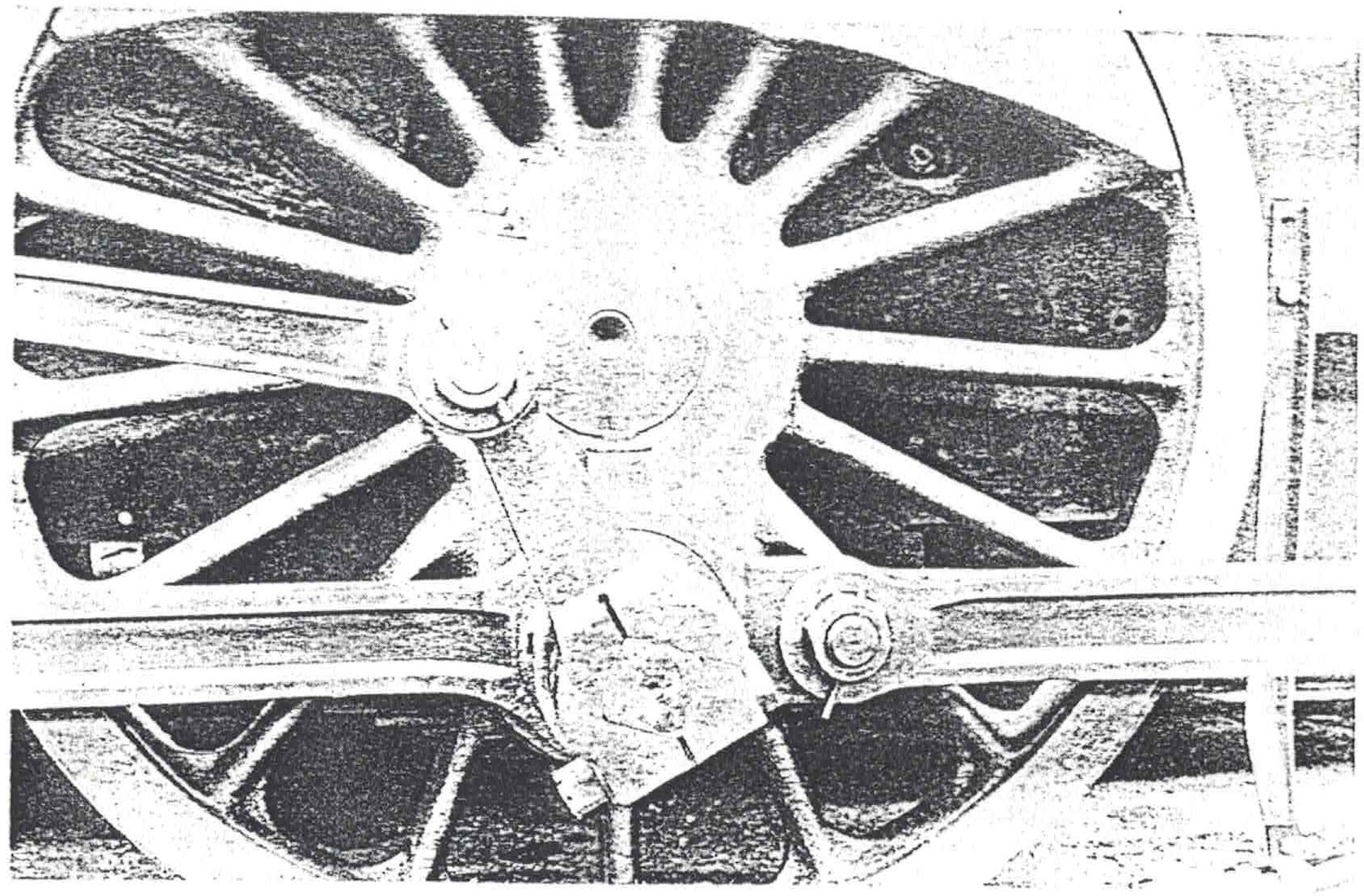
Reach Rod and Support

Set the reverser in mid gear, so the nut has equal travel in each direction, then set the weighshaft to suit and measure the centres of the reach rod. For a pleasant change the latter has no forked ends and is literally plain sailing, though if you do decide to use $\frac{5}{16}$ in. thick material, do make the necessary amendment to reversing arm, reach rod arm and support; the latter can be a fabrication or machined from solid bar.

Drain/Relief Valves

It is pleasant to take an idea I had some 20 years ago now for 'ball type drain cocks', one that has proved highly successful in service, and apply it to E. S. COX to arrive at extremely authentic looking drain/relief valves. The laugh is that the prototype ball type drain cocks nearly got scrapped after their very first outing as they would not close properly on the then new K1/1 'Mogul'. Luckily replacing them was too big a job ahead of her second steaming, when they behaved to perfection, as they have on literally 1,000's of Locomotives ever since, they being adopted commercially, though ironically they do not feature in the current DYD Catalogue. However, I very much doubt if any other fittings supplier will cover the combined valves as detailed, so let us make them.
Chuck a length of $\frac{3}{4}$ in. diameter bronze bar in the 3 jaw, face, and with a round nose tool, turn down to $\frac{7}{16}$ in. diameter over a $\frac{7}{16}$ in. length. Centre and drill No. 42 to $\frac{5}{8}$ in. depth and part off to leave a full 3/32 in. flange; reverse and clean up. Grip in the machine vice, on the vertical slide, centre and cross drill to around $\frac{3}{16}$ in. diameter, checking to see that the cross hole is centrally disposed. If not, adjust the cross slide, centre until a $\frac{1}{4}$ in. end mill will just enter, then feed it through, when all will be well; mill away the flange to arrive at the $\frac{5}{16}$ in. dimension.
The drain cock body itself is from $\frac{1}{4}$ in. rod, a simple exercise, and the outlet union calls for no comment. The two 'ears' to accept the relief valve cap screws can be plain pieces of plate at this stage, or you can shape them and make up a wee jig for their location, when the whole assembly can be brazed up. Drill the No. 42 hole through the cock body, offer up to the cylinder block, drill and tap the 10BA attachment holes. Turn up the spring guides from 7/32 in. (or 6mm) A/F hexagon brass rod, drop an $\frac{1}{8}$ in. rustless ball into the cock body and cut a spring to suit, when adding the wee push rod completes that part of the assembly.
On to the relief valve cap, for which chuck a length of $\frac{1}{2}$ in. bronze rod. Face, centre deeply and drill No. 53 to at least

Return cranks to me are always impressive and that on the 'Crab' particularly so



$\frac{1}{2}$ in. depth, then follow up with a $\frac{1}{4}$ in. 'D' bit to $\frac{3}{8}$ in. depth. Set the top slide over 5 deg. and with a wee boring tool, open out the bore to 11/32 in. diameter at the mouth. At the same top slide setting, turn down the outside to the 3/64 in. wall thickness shown, then part off at $\frac{7}{16}$ in. overall. Clamp in the machine vice, on the vertical slide, to first drill and then mill the four steam escape slots, they want to be of the order of 3/32 in. wide. Fashion the pair of wee 'ears'; if you made a jig for the pair on the valve body then use it again to locate, then braze up. Wipe a file over the joint face to make sure it is flat, offer up to the body, when we have to deal with the actual relief valve. The valve itself is an $\frac{1}{8}$ in. ball, held in place by a $\frac{1}{16}$ in. bore x 24 or 26 s.w.g. compression spring. The $\frac{1}{16}$ in. stainless steel pin pressed into the centre of the relief valve cap acts as a spring guide and should also restrict the lift of the ball so that it goes back every time onto its seat. If you experience any problem with the ball not reseating, then counterbore at 5/32 in. diameter to about $\frac{1}{16}$ in. depth. Unlike the LNER style of relief valve I fitted to my K1/1, those on E. S. COX are not capable of adjustment to operate at boiler pressure, at least not on the surface, but if you fit 10BA brass washers as required over the spring guide pin, this will provide said adjustment.

There is an additional drainage point in the steam circuit at the steam elbow at entry to the steamchest, with 3/32 in. o.d. pipe down to the drain valve sited inboard of those for the cylinder. The drain valve is a variation on my standard ball type theme, secured to a bracket by medium of the wee elbow connector, when the remaining gear to connect back to the cab comes on Sheet 9.

Setting the Valves

It is a very straightforward process to arrive at very accurately set piston valves driven by Walschaerts valve gear; in two stages. Remove the front valve chest cover on one side of the engine and set up two dial test indicators; one on the end of the valve spindle or the piston valve bobbin and the other onto the main crosshead. Now set the engine in mid gear so that rocking the expansion link imparts no movement to the valve, something you can easily check with the d.t.i. Clamp over the cylinder drain valve push rods so that said valves are open and apply a short length of rubber tubing over the outlet connection. Turn the engine towards front dead centre, applying mouth pressure at the front end of the cylinder. Immediately the port uncovers, by as little as .0001 in., you will feel the pressure slightly ease in your mouth and there will be a 'whisper' from inside the steam-chest as air passes. It is a tremendously accurate means of measurement once you get the 'feel' for what you are doing and applies the same principle as pnuematic inspection equipment in industry. Make a note of the d.t.i. reading when the port uncovered, now concentrate on that mating with the crosshead, until it reaches front dead centre On paper this sounds a bit imprecise as one would expect a 'dwell' between the crosshead arriving at the dead centre position before it starts its return journey, but in practice I have found this method very precise. Once at front dead centre, read the d.t.i. against the piston valve and this is the precise amount of 'lead'. However, the valve is very unlikely to be central over the ports as yet, so deal with back dead centre in identical manner, blowing through the rear drain valve, to arrive at the back lead figure; centralise the valve on its spindle until the back and front lead figures are identical; that is Stage 1 of valve setting. Incidentally, with cast iron cylinders using piston rings, there is a small, leakage path around the latter when setting the valves which can upset the procedure, so smear some grease around the piston at the outset, as most of us can only generate around 1 p.s.i.g. by mouth, insufficient to disturb said grease.

Turn the engine to front dead centre and wind the reverser from full fore to full back gear, adjusting the length of your dummy eccentric rod until going from full fore to full back gear imparts no movement to the valve. Turn to back dead centre and check the result; theoretically there should again be zero movement of the valve, but in practice there will be some, though only a matter of a few thous. Finely adjust the length of the eccentric rod again to equalise valve movement when moving from full fore to full back gear, trying to minimise the error in favour of fore gear, though all my engines go better backwards!

That is basically all there is to valve setting with Walschaerts valve gear and you now make the finished eccentric rods to the same centres as the dummies, though you can now play with the valve gear at varying cut-offs and measure port openings through the medium of the d.t.i.; such is always very educational and well worth spending some time over.

E. S. Cox – The Horwich 'Crab' in 5 in. gauge

by: DON YOUNG

Part 9 – Brakes and Sanding Gear

Before we can go into the main part of this session, we left the drain cocks in a less than satisfactory state thanks to the 'spill over' of details onto Sheet 9, so let me first repair this deficiency.

For the inner and intermediate bearings, mark off on 1.6mm steel sheet, or $\frac{3}{4}$ in. x $\frac{1}{16}$ in. strip, and drill through at $\frac{3}{16}$ in. diameter for the bearing; turn up the latter and braze in, remembering this hands the finished article. Now drill the pair of No. 34 holes, these align with the cylinder flange fixing holes, then complete the profile to drawing before erecting as per Sheet 8.

The main cross shaft operates four of the drain valves and to give it sufficient rigidity, three further bearings are required, so let us tackle the centre one next. First though we need to make and fit the smokebox saddle bottom plate, this from $\frac{1}{8}$ in. or 3mm steel plate, to a close fit inside the saddle and secured by about sixteen 6BA bolts to the flange provided. Next deal with the centre bearing itself, from, $\frac{3}{16}$ in. steel rod, feed a $7\frac{1}{2}$ in. length of 3/32 in. steel rod through the intermediate bearings, picking up that for the centre bearing. Now fold up the bearing 'stool' from $\frac{3}{8}$ in. x $\frac{1}{16}$ in. steel strip, fitting to place to sit on the smokebox saddle bottom plate; cut and fit the wee web then remove and braze up, completing the profile to drawing.

The outer bearings are very similar, less the web, so no need for repetition; but for the main cross shaft, either turn its ends down to 5/64 in. diameter to suit the bearings, or drill the bearing itself No. 41 instead of No. 47 as specified.

For the front shaft, check the 1 11/32 in. dimension from the engine and turn the shaft ends to suit, the cam being from 5/32 in. x 3/32 in. section bar, shaped as shown and located against the outer shoulder on the shaft. The arm starts life as 5/32 in. square bar; drill No. 42 and No. 51 at $\frac{3}{8}$ in. centres, cut the 3/64 in. slots, radius the ends with an end mill over a mandrel, then reduce the thickness of arm to 9/64 in., this latter being optional. Erect and braze up with a minimum of spelter.

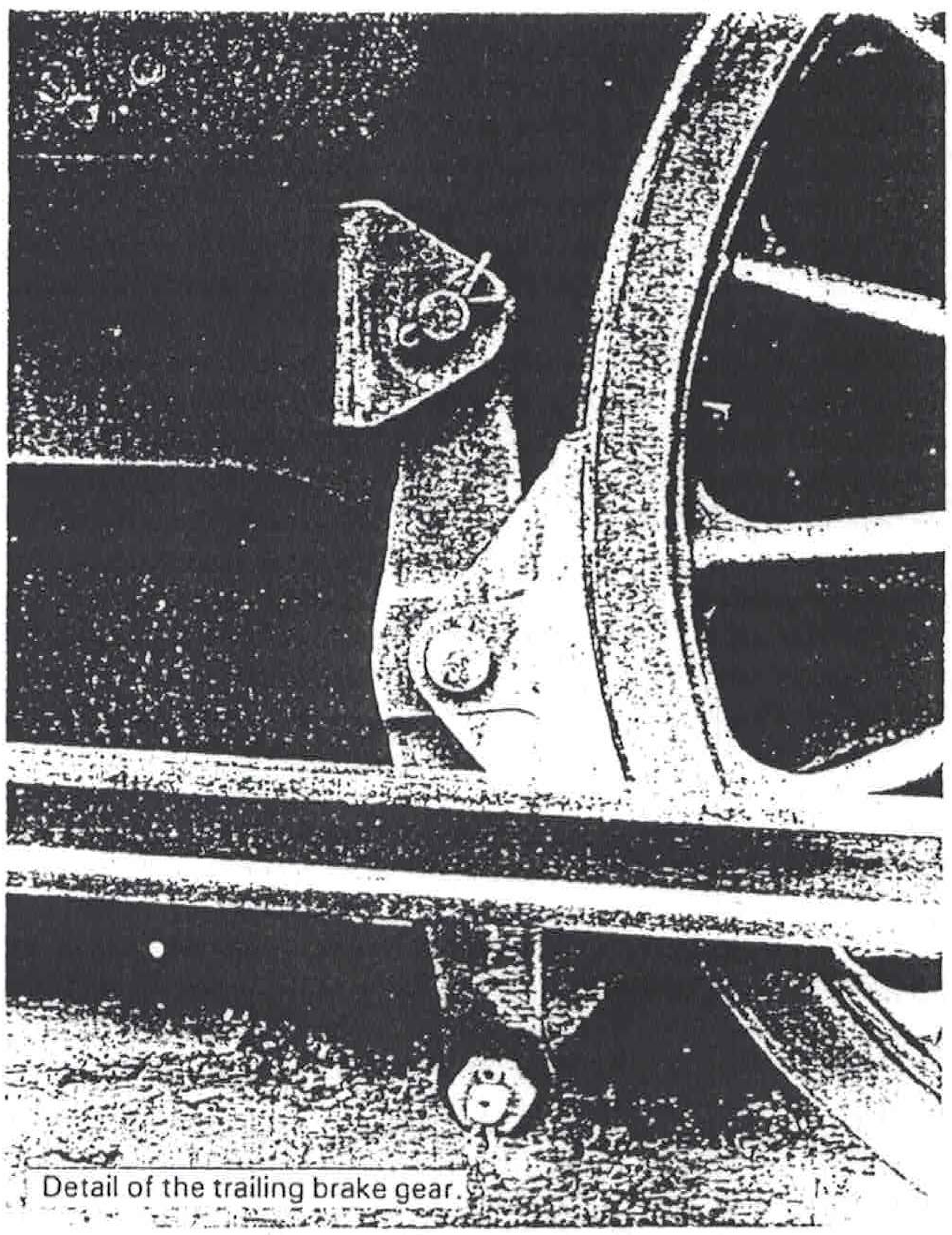
The only additional piece part on the cross shaft is the centre lever, its boss being straightforward. Take a length of $\frac{3}{16}$ in. square steel bar, drill No. 51, cut the 3/32 in. slot then radius the end with an end mill over a mandrel. Saw the end from the bar and scallop to suit the boss and to arrive at the $\frac{5}{16}$ in. dimension, blend in the flanks then file away to give the $\frac{1}{8}$ in. central portion before brazing together. Because we shall have to check operation of the drain cocks when all the parts have been erected, I recommend that the centre lever be pinned to the cross shaft and later, rather than brazing it in place, but of course the cams and arms can be brazed permanently in place, though do not forget to thread on the various bearings first!

For the intermediate shaft, first drill the L.H. mainframe No. 41 in the position specified, feed in a $4\frac{3}{4}$ in. length of 3/32 in. steel rod, then build up the bracket, bearing and inter shaft bearing to suit; the shaft itself uses levers of a type which we have already made.

The drain cock lever fulcrum is a simple fabrication in three pieces, silver soldered together for the strength this provides and then bolted or rivetted to the L.H. cab side in the position shown, this being as full size, though of course said location may be varied for ease of operation. There are several ways of making the drain cock lever, but I would start with a length of $\frac{3}{16}$ in. square bar. Chuck truly in the 4 jaw and turn on the handle, then produce the set approximately as shown before drilling the No. 51 pin hole, turning over and drilling No. 42 holes at the ends of the 9/32 in. slot; use a 3/32 in. end mill to complete said slot. Next clamp to a length of angle bar, bolted in turn to the vertical slide, and with the side teeth of a $\frac{3}{16}$ in. end mill, reduce the section on one side; turn over, pack up and complete the second side. Complete the profile with files, drill the No. 41 fulcrum pin hole, turn up the wee washers and silver solder these in place; erect.

The pull rods call for little comment, being a combination of 3/32 in. steel rod and 5/32 in. diameter end bosses silver soldered on, with lengths taken to place, though I had better say something about the sleeve. Full size I reckon this was a sliding fit over both the front and intermediate pull rods, secured with taper pins; I bet full size it was a problem to knock out said taper pins – in miniature a proper terror! So I have specified the sleeve to be brazed to the intermediate rod and screwed over the front one, though I have hedged my bet somewhat by saying that both rods may be screwed. You will have to cut holes for the pull rods in various places, a real 'fit to place' job this!, when you can complete erection and after making and fitting the little links which I forgot, try the gear and secure the centre lever to the cross shaft.

Because the rods are being pushed to open the drain cocks, they may well flex; if this proves to be the case then bend up stirrups from 3mm x 1.2mm strip and fit in the appropriate spots, when another portion of E. S. COX is complete.



Detail of the trailing brake gear.

Brake Gear

The rest of this session has an 'either/and/or' flavour about it, something I try to avoid, but this time I have no real option; let me explain the history of the brake gear. The Horwich 'Crabs' were of course one of the very few truly 'mixed traffic' designs, regularly used on excursions and on expresses when the need arose, completely at home on fish trains as Ken Wood has told us and on other fitted freights, plus those 21 in. cylinders were capable of handling really massive unfitted frieght trains where every ounce of brake power was required – any fool can start a train, but it takes an expert to stop it! Anyhow, at the outset all 'Crabs' had power brakes on all engine and tender wheels, those on the engine being unusual enough to warrant a little space. A, steam, brake cylinder was located under the cab, nothing unusual in this, and was conventionally coupled to brake shoes acting on the trailing and driving wheels. Ahead of the driving axle a second steam brake cylinder was located as shown on Sheet 1; this did not connect direct to the leading coupled wheels brake beam, but to a large bracket attached to same. From higher up the bracket, a sort of 3:1 lever, a pull rod went forward to just behind the pony truck axle, then through a series of rods and levers to operate brake shoes by a clasping action on both sides of each pony truck wheel; it was quite a clever arrangement.

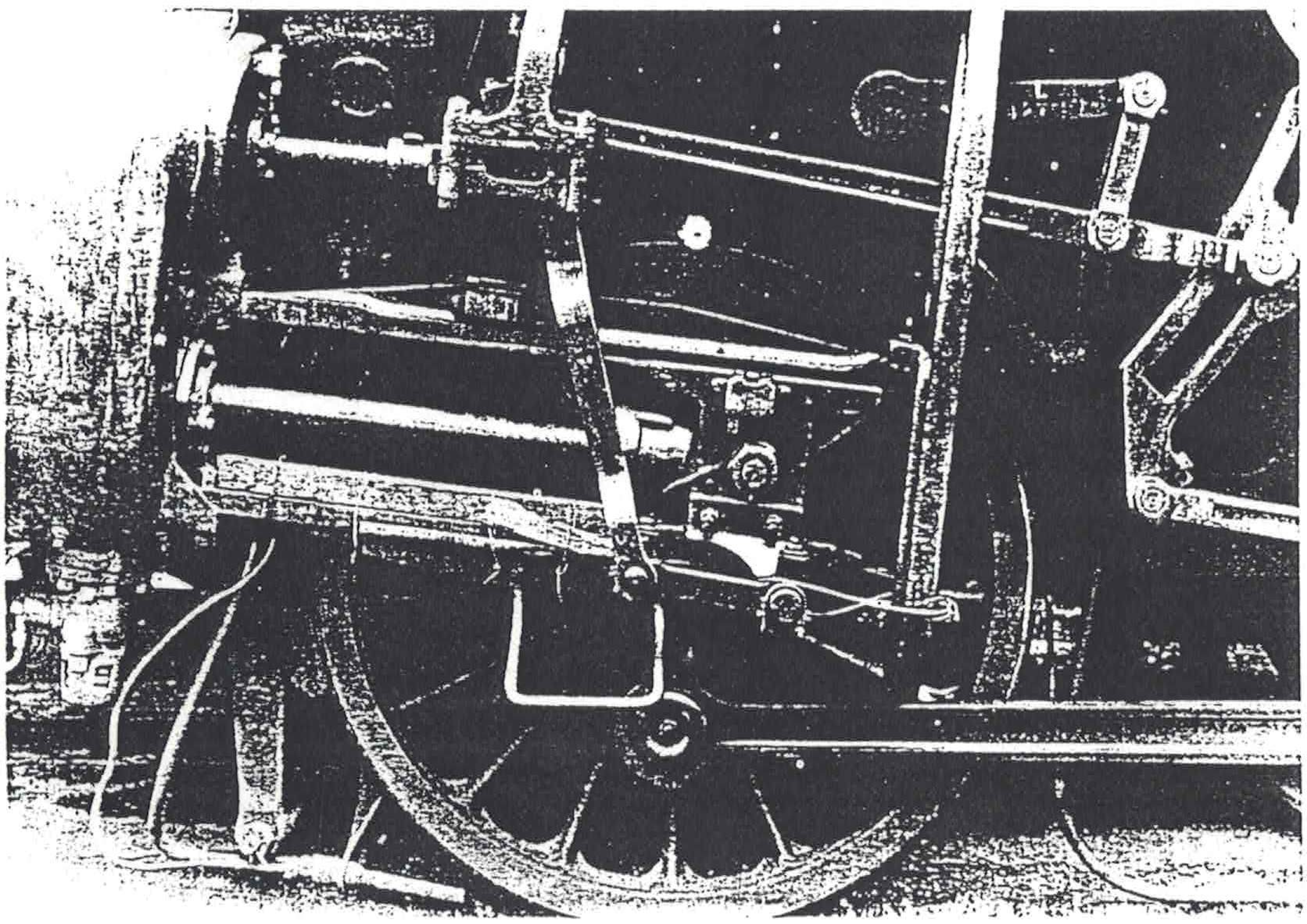
There seems to have been a period in the early 1930's when brake gear was removed from guiding wheels on Locomotives in the U.K., both pony trucks and bogies, one I have often sought a reason for, believing it might be on the recommendation of an Accident Inspector from the Board of Trade, yet not being able to prove it. The same logic would apply to guard irons fitted to mainframes ahead of bogies and the like, as I mentioned for DONCASTER. That the pony truck braking was removed is not in any doubt, but evidence is very conflicting thus far as to how long the second brake cylinder was retained, if at all, for many of the 'Crabs'. My detailing therefore covers the majority of a 40 year working life, but I hope one or two examples will be built as Sheet 1 just to ring the changes. Don't be tempted to fit pony truck brakes though, or you could take a nose-drive!

The front hanger brackets I would make in three pieces, an $\frac{1}{8}$ in. base, a $\frac{5}{16}$ in. o.d. collar and a $\frac{13}{16}$ in. length of 5/32 in. steel rod pressed home to hold the bits together, with a touch of silver solder to tidy it up. The other four brackets, or rather two pairs, are not so clear-cut and although they were bent up from mild steel in full size, such does pose a problem for some builders in miniature, when the alternative is to mill from solid bar. The rear advantage in starting from flat bar is that the four $\frac{1}{16}$ in. rivet holes can be drilled and countersunk before bending, though snap head rivets are permissible for the front pair of holes; rivet all brackets to the frames.

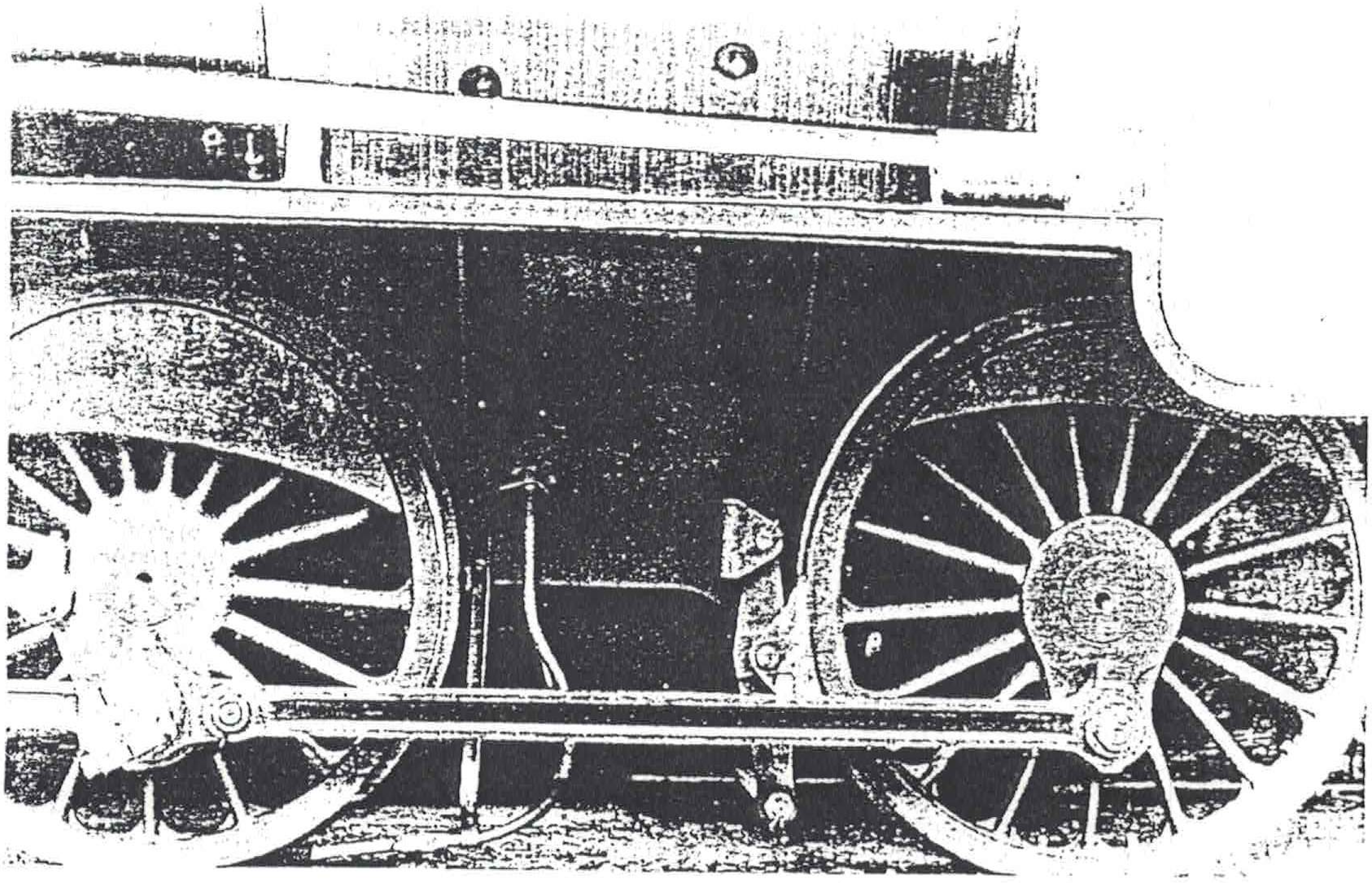
The main body of all the brake hangers is from $\frac{3}{8}$ in. x $\frac{3}{16}$ in. BMS flat, which can be bolted to a piece of angle by way of the No. 22 and No. 30 holes to be milled down with the side teeth of a $\frac{3}{16}$ in. end mill to achieve the required section as per the valve gear parts. Mark on and saw out the profile, completing by filing or milling, then turn up the top end bosses and braze together; I doubt if a jig will ne becessary to align the parts.

The brake beams are $5\frac{1}{8}$ in. finished lengths of $\frac{3}{4}$ in. x $\frac{1}{4}$ in. BMS flat; chuck each end truly in the 4 jaw, centre and drill No. 43 to about 5/32 in. depth. Now turn the ends from 5/32 in. steel rod to include a spigot to be a press fit in the beams and braze up; shape the beams and drill the No. 22 hole to complete.

A flame cut ring from $\frac{1}{2}$ in. mild steel plate would come in very handy for the brake shoes, when it can be bored out to size and a radius turned on to match that between tread and flange on the wheels. Mark and saw out individual shoes, complete the profile then drill the No. 30 hole and slot to fit the brake hanger. After finding why brake shoes are NOT fitted on the centre line of wheels, it came as s shock when I saw the leading pair on E. S. COX did just that, all my Works Drawings and photographic evidence supports this and whereas a problem arose with HUNSLET, here the much greater wheel diameter works in our favour. Turn up the hanger and brake shoe pins; I would braze the heads onto plain lengths of rod and then finish turn, when we can erect the pieces made thus far.



Illustrating the leading brake gear allows me to provide more motion and sanding gear detail, thanks to the camera of Norman Gregory.



More useful detail in the firebox area; note the angle support from the mainframe to the sand nozzle.

Because the brake gear is not compensated, we shall have to proceed with caution on the pull rods, though first we need the connectors, these starting life as 5/16 in. square steel bar. Drill the No. 22 pin hole in the centre, then plug it, turn through 90 deg. and drill No. 22 again, this latter to pass over the brake beam end; drill further No. 22 holes at ⅜ in. centres on each side. Mill down the sides to 5/32 in. thickness, leaving the raised boss at the centre, then drill a row of No. 33 holes to start forming the ⅛ in. slot, completing with an end mill to an easy fit over the beam; radius the ends to complete and erect.
Pull rod, fork, ends are from 5/16 in. square bar; drill the No. 22 hole, then ⅛ in. diameter at the end of the slot and deal with the latter with saw and files. Radius the fork ends over a mandrel with an end mill then complete with files; turn up the pins and erect. Clamp the brake shoes hard onto the wheels, then cut lengths of 5/32 in. steel rod to be a tight fit between the pull rod ends; braze together. The rear pull rods are similar, but instead of 5/32 in. rod take the larger 3/16 in. size, screw the end ¾ in. at 2BA, then reduce the rest to 5/32 in. diameter.
I must admit I made a mess of the brake shaft the first time around and I still don't know how, as fitting shafts between trunnions has been a common practice with me on the drawing board for getting on for 30 years now – yet Norman Lowe proved in 3D I could still get it wrong! Thanks to Norman though I have been able to correct the details ahead of publication, so hopefully his problem or rather the one I gave him, will remain unique. Bend up the trunnion from 3/32 in. or 2.5mm steel, the 1 1/16 in. length of channel from the same material, and braze up. Now you have a very stiff structure to shape, cut the lightening holes, drill those specified and preferably bore through at 13/32 in. diameter for the bearings; erect to the drag box.
I would make the main arm of the brake shaft from ⅝ in. x ½ in. BMS bar, first drilling 9/32 in. diameter and No. 22 at 1 9/32 in. centres. Mill down to 9/16 in. x 13/32 in. section, radius the shaft end then bolt to the length of angle, on the vertical slide, to mill to the correct shape. Deal with the slot, radius this end and complete the profile to drawing, then drill the No. 41 hole for the return spring gear. The pair of bottom lugs are from 3/32 in. thick steel, scalloped to suit the boss and clamped to it with a 5/32 in. spacer between, the shaft itself a 1⅛ in. length of 9/32 in. rod, probably silver steel, when the whole can be brazed up. The bearings are plain turning and the push rod to connect to the brake piston calls for no comment, so on to the spring rod. For this I recommend you make the fork end in the same way as for the pull rods, and from the same 5/16 in. square bar, though I have had a lot of success in bending these up from 1.6mm strip. Braze to a length of ⅛ in. steel rod, cut to length and screw the end 5BA. Erect as per drawing, then once the gear is complete and erected you can experiment to find a spring that will pull the brake off successfully without absorbing too much of the brake force available at the piston; I reckon 22 s.w.g. will prove the ideal spring wire.
Brake cylinder, its covers and the piston are all plain turning and much easier than those 1⅜ in. bore ones we have already dealt with! The main problem with brake cylinders is water and several steps have been taken to control it. First time I grooved a piston as shown the idea was to soft pack it; somehow I omitted to do this before the first steam-up, yet the brakes worked and well – I guess the groove provided a hydraulic seal – so I have never packed a steam brake piston. However, it is important that water does not build up under the piston, hence the No. 41 'vent' in the bottom cover. The 1/16 in. pin is fitted at the top of the piston so that there is always clearance under the top cover; lose this and water will provide the perfect seal. Finally, to get rid of the water which does collect on the piston, an ⅛ in. ball is seated down its centre, with ball retainer so it cannot inadvertantly come out; this ball will 'float' as water builds up and allow it to pass, seating as steam pressure is applied – simple but it works. Erect the cylinder, make up and fit the adjuster and our brake gear is complete.

Lubricators

Although quite a few E. S. COX builders have purchased their lubricators from DYD, the statement on the drawing no longer applies, at least for the moment, though of course suitable lubricators are widely available, like from Reeves, so this will pose no problem. Lubricator drive rods are a mixture of fork ends and plain ⅛ in. rod, something we are now adept at, so with the drive arms and cab support brackets bent up from 1.6mm steel sheet we arrive at the last part of this session.

Sanding Gear

The more I look at Horwich 'Crab' photographs, the more I smile at the simplicity of my notes concerning the number of sandboxes one is likely to see, for although my note is strictly correct as far as function is concerned, several examples retained the rear sandboxes, though it appears they were non-working. So here builders have a choice and as Norman Lowe experienced problems in fabricating the boxes, I do have his patterns for the leading three sandboxes, each side, so can provide castings for these on request. Personal preference is to build them up over wooden formers, silver solder the seams, round the edges and corners to represent castings, then sweat on the filler tube, lugs, etc.; each to his own though. Either way it takes care of a large chunk of the drawing details remaining and leaves just a tidying-up operation.

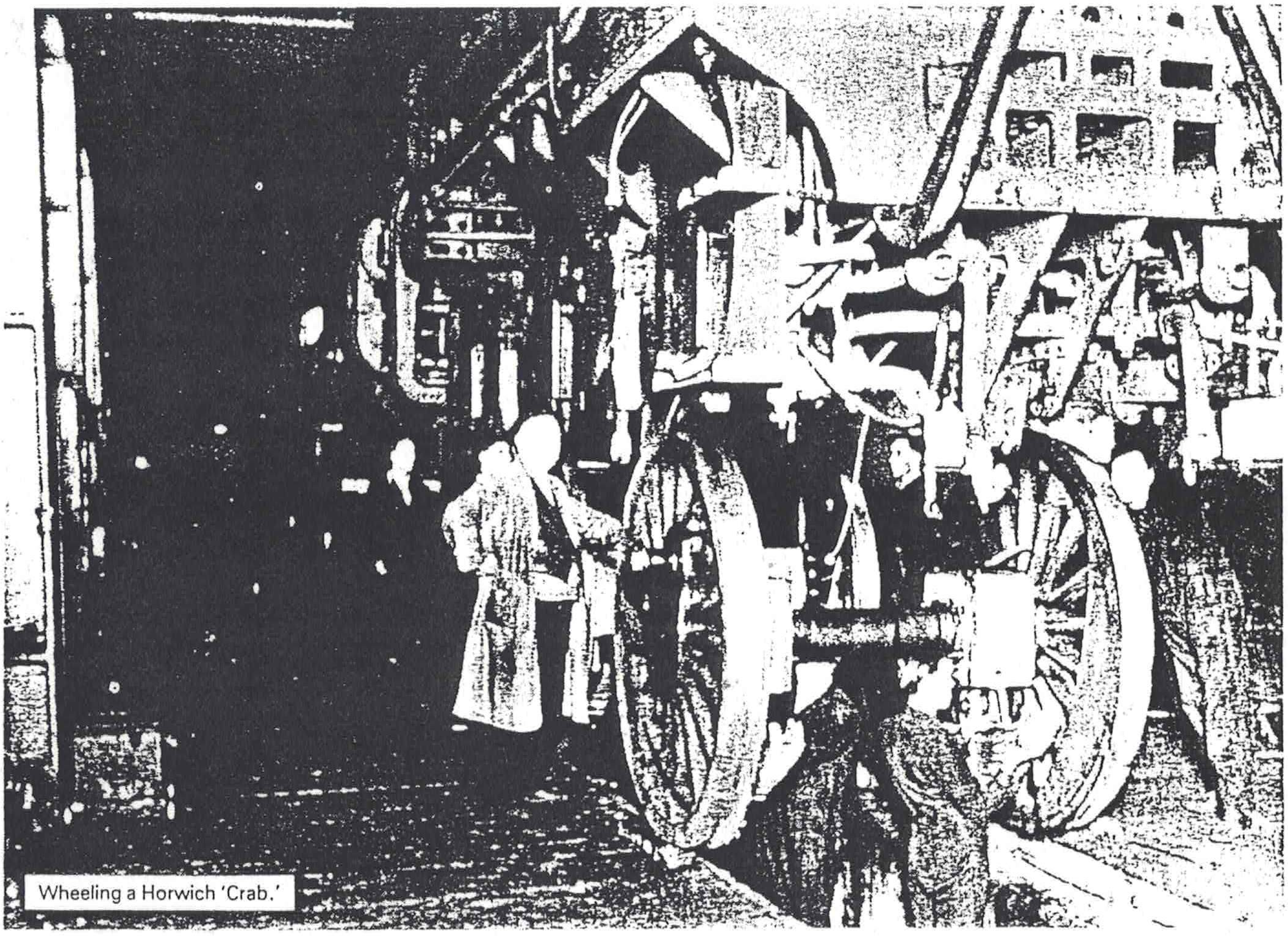
The fall tube I would turn from $\frac{1}{2}$ in. diameter bar, the centre can be a plain $\frac{3}{16}$ in. drilled hole if you wish, and then braze on the $\frac{11}{16}$ in. square flange to bolt to the sandbox. The filler caps are turned from $\frac{3}{8}$ in. diameter brass bar with an $\frac{1}{8}$ in. x $\frac{1}{16}$ in. bar brazed in as a hand-hold. Although full size they were a very slack fit over the filler tube and had a retaining chain so they didn't get lost, ours need to be a push fit for the same reason. The rear sandbox lid is a brass fabrication; make the hinge $\frac{1}{2}$ in. long from $\frac{1}{8}$ in. rod drilled No. 53 at the outset, braze to a piece of 1.2mm sheet, then finish said hinge to fit the sandbox.

Although we do not want to spread sand all over our lovely motion, fitting working steam sanding gear adds a touch of class and gives a lot of pleasure in the making. The main part of the sand trap body is plain turning from $\frac{1}{2}$ in. diameter brass bar. For the trap portion, and the sandpipe flange, I suggest you take a length of $\frac{1}{4}$ in. x $\frac{1}{2}$ in. brass bar, shape to the dimensions shown, drill No. 55 at $\frac{3}{8}$ in. centres, No. 30 in the centre and then cut off slices as required. File a wee flat on the body and trap to arrive at the $\frac{3}{16}$ in. dimension, braze up, then drill the No. 41 connecting hole.

Many of the 'Crabs' seem to have cast sand trap shields, as the photographs of 42700 bear witness, but I have chosen the fabricated variant as being a bit easier to make, though they still pose a few problems. Take a piece of .015 in. brass shimstock and punch a bulge roughly as shown. Shape to drawing, offer up to the trap body and drill the No. 50 holes. Take a second piece of shimstock, about $1\frac{1}{4}$ in. x $\frac{5}{16}$ in. and wrap it around the top plate, sweating it place, then trim away as shown to complete – just for once this is an 'easier said than done' operation!, but you will win; of course.

For the steam sanding ejector, start with a $\frac{7}{16}$ in. length of $\frac{3}{8}$ in. x $\frac{3}{16}$ in. brass bar, drill through at No. 30 for the sandpipe, move over 5/32 in. and drill No. 40 to about $\frac{1}{8}$ in. depth before tapping 5BA. Feed in a length of sandpipe, braze in place, drill No. 54 into its bore, then complete profiling the ejector body.

Although I have detailed all the sandpipe supports, these are very much 'make to place' items from 5/32 in. brass angle which is available from Reeves; I simply love knocking up little brass clips to secure the sandpipes. Complete the sandpipe runs back to the sand traps, braze or sweat on the flanges, then turn up nuts from $\frac{1}{8}$ in. A/F brass bar for the steam supply pipe ends at the ejector. The steam pipes I recommend just for once have swaged ends, when those nuts will trap them, and change to 3/32 in. o.d. copper tube for the, common, pipe run back to the steam sanding valve below the brake ejector in the cab.



Wheeling a Horwich 'Crab.'

E. S. Cox – The Horwich 'Crab' in 5 in. gauge

by: DON YOUNG

Part 10 – Smokebox and Boiler completion

There is a saying that nature cannot be scaled, one which I do not totally agree with though I appreciate its sentiment, for to me **principles** apply whatever the scale and much of what I purport is based on what I learnt in full size. Chief among these were the teachings of Andre Chapelon, ones which have been proven many times over in practice and I should have mentioned one of them at the cylinder stage, the important one of steamchest volume; a query from builder Larry Loughborough reminded me of my omission. Stated simply, Chapelon said that it was pointless generating steam of quality if it could not be delivered to the cylinders to the same quality, and in the quantity required. Now enhanced steamchest volume is a vital factor in achieving this, which I was able to do with the cast cavity between steamchest and cylinder flange, at the same time making the casting of a more regular section. The question then arose – won't the steam in the cavity lose some of its quality whilst waiting to go forward to the cylinders? The answer to this is a very definite **no.** The transfer, or loss, of heat to the atmosphere by conduction, convection and radiation is a constant factor determined by the surface area exposed. With a greater amount of thermal energy within the 'cylinder envelope' by reason of the greater volume of steam, then its intrinsic value reduces by a smaller degree, plus the steam is on hand so to speak to do its useful work, rather than having to come forward from within the steampipes.

Of course, all this business about getting the steam into the cylinders would come to nought if we could not get it out again just as rapidly and here we come to my favourite topic above all else for the Stephensonian steam locomotive – the smokebox. The first requirement is that a vacuum be maintained inside the smokebox, sufficient to draw the gases of combustion through from the firebox and generate draught through the fire to produce heat sufficient and above the cylinder demand, so that the complete cycle is a stable one. Now one way of achieving this is by use of a tiny blast nozzle exhausting into a tubular chimney, this will give you stable steaming, but at the expense of high back pressure in the cylinders. On the other hand, one can design an efficient exhaust ejector to create the same vacuum within the smokebox, but by using a much larger blast nozzle, reducing back pressure in the cylinders to a very minimum. This solution I call Ell Draughting after the leader of the test team at Swindon who evaluated the correct proportions for a plain nozzle and chimney; I simply apply their results. I can now do this with sufficient confidence that apart from a few minor alterations to suit particular installations, I have what are standard ejectors for each power classification. The cylinders are largely ignored in assessing the power of a Locomotive, for power stems from the boiler, the grate ultimately, so E. S. COX comes within my Class 5 power classification, right alongside the BLACK FIVE with its almost identical boiler, and John Edwards among others has demonstrated how good this draughting is, so we can proceed with confidence. Just before we do so, however, there is one other important feature in any smokebox, the facility to easily and thoroughly clean all the tubes; it is no good fitting ultra-efficient superheaters if they block up at the first steaming, so this is another design point to be watched. I reckon my smokeboxes have improved as they have got simpler over the years, which reflects more credit on builders than yours truly.

The Smokebox

I doubt if many builders will be able to avail themselves of brass tube for the smokebox shell, so roll it out of sheet and silver solder the joint. If you want to avoid loose nuts inside the smokebox, fit an 1/8 in. thick doubler plate inside as shown. Chuck by the bore and true up the ends to arrive at 5 27/32 in. overall; on to the boiler joint ring. Chuck this by its periphery in the 4 jaw chuck and bore out to a press fit over the boiler barrel, only don't press it on. Rechuck by the bore in the 3 jaw, face the ends to 1/2 in. overall, turn down to 5 31/32 in. diameter, then reduce further over a 3/8 in. length to a light drive fit in the smokebox shell.

Chuck the front ring by its periphery in the 4 jaw, face across the front to include the step, then bore out to 4 1/2 in. diameter. Rechuck by this bore in the 3 jaw, clean up the inside, face off then turn down the rim to a light drive fit in the shell. I have so arranged things that the superheater can be removed with the front ring left in place, so this and the joint ring can now be permanently silver soldered to the shell to ensure air-tightness; pickle and clean. If personal experience is repeated, the boiler joint ring should now be an easy push fit over the barrel, when a few 6BA countersunk screws will do the needful in a moment or two.

Getting a smokebox shell to perfectly match the smokebox saddle is neither easy, nor necessary. Cut an opening in the bottom of the shell roughly 3 1/2 in. x 2 15/16 in., as this will allow the shell to flex such that it can be pulled down onto the saddle flange. Sit the shell on the smokebox saddle and either drill through from the side flanges for a through bolt, or drill and tap 6BA. Use the template you made for the saddle to deal with the front and back rows of holes. Next find the top centre of the smokebox shell, mark off and cut a 1 7/16 in. diameter hole for the petticoat pipe. Take the casting provided for the latter, grip by the bore at the upper end and turn down the outside to drawing, facing across the flare. Chuck very carefully by the flare to reduce to 2 3/16 in. overall length, then chuck again by the 1 3/8 in. diameter plain portion. Bore out to 1 3/16 in. diameter, then with around files and emery cloth, deal with the flare to arrive at the choke 29/32 in. up from the bottom. Set the top slide over 2 deg. and bore out the upper portion until the taper extends right down to the choke. The flange to secure the petticoat pipe to the smokebox shell is a 1 3/4 in. square of 1.6mm brass; bore out to 1 3/8 in. diameter, bend it to suit the smokebox shell and ease the bore to a tight push fit over the petticoat pipe. The flange is located 3/16 in. down from the top lip of the petticoat pipe and should be silver soldered to place.

I love cast iron chimneys, they are authentic and look nice when turned, even though it was a shock to find they were fitted 'as cast' full size. Norman Lowe has provided a generous chucking spigot on the casting, so grip initially by the bore, set the casting to run true and clean up said chucking spigot. Chuck by the latter in the 3 jaw and turn down as much of the profile as you can to drawing, then bore out to 1 1/4 in. diameter. Next concentrate on the 1 3/8 in. diameter recess to 1/8 in. depth, this to be a push fit over the petticoat pipe. Set the top slide over 2 deg. and bore out the chimney until it is a perfect match with the petticoat pipe bore; your finger will tell you when this is so. Transfer to the bench vice, deal first with the flange to sit on the smokebox shell, then complete the rest of the profile with files and emery cloth. Only when satisfied, part off the chucking spigot to reveal the final E. S. COX trademark. Normally I specify the chimney be a push fit only over the petticoat pipe with no other means of securing, but the chimney photograph taken by Norman Gregory shows so clearly the six bolt fixing that we must emulate it at 10BA, only not until we have achieved the vital alignment with the blast nozzle.

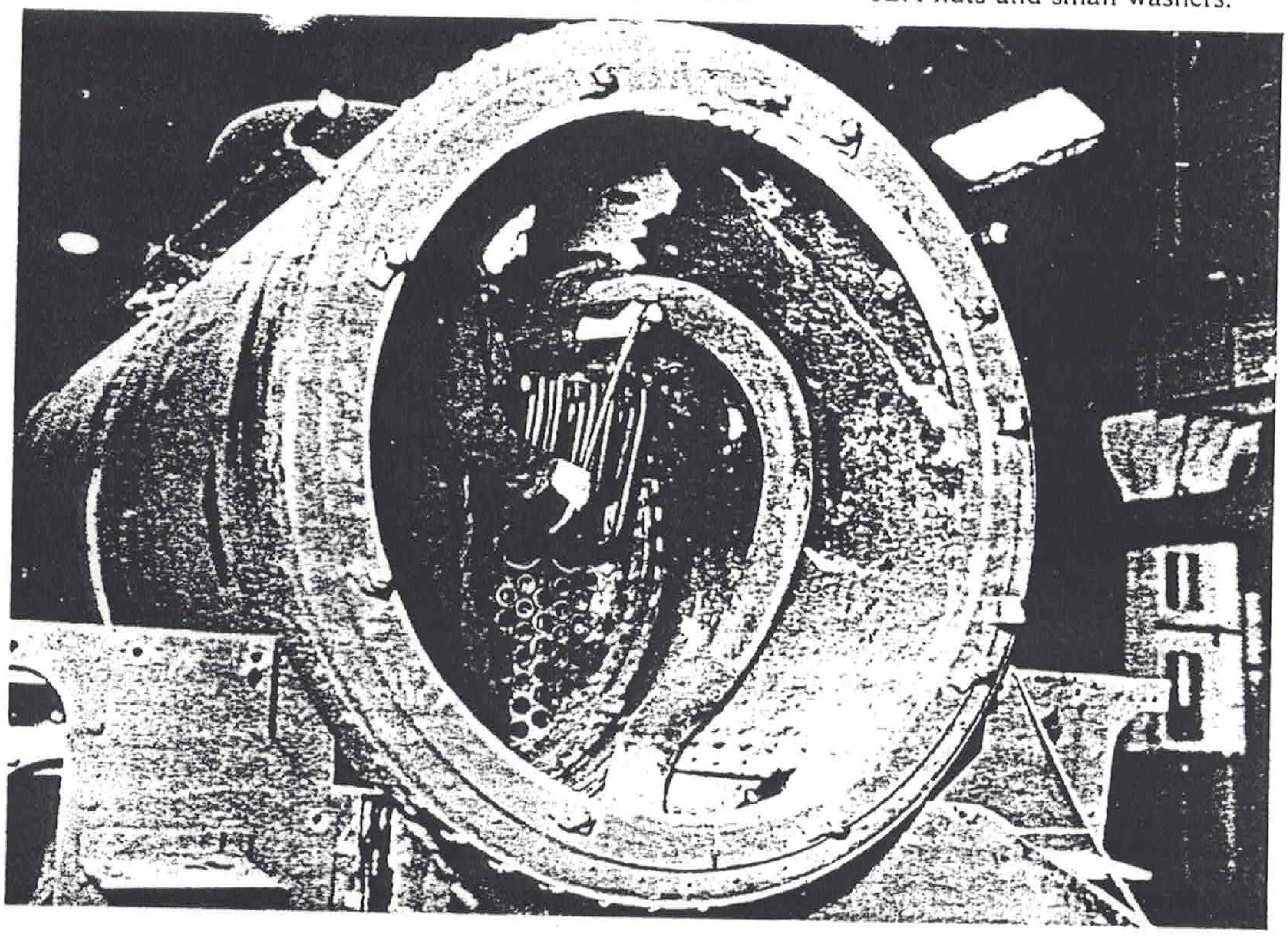
Chuck a length of 1¼ in. diameter brass bar, or use a casting, to start forming the blast nozzle, first facing off and turning down to 1⅛ in. diameter over a 1⅜ in. length. Deal with the outer profile, but leave both of the $\frac{1}{16}$ in. flanges at 1 in. diameter as we shall have to use these for chucking in a moment. Centre and drill ⅜ in. diameter to 1⅜ in. depth before parting off to leave a full 5/32 in. flange; rechuck, face off to thickness, scribe on the bolting circle, mark off and drill the four No. 34 holes. Offer up to the blastpipe flange, spot through, drill and tap 6BA; secure with brass screws. Erect petticoat pipe and chimney then drop an 8 in. length of ⅜ in. rod down the blast nozzle; use calipers to get choke and chimney lip concentric around this setting rod, just as we did full size. Now it is a case of drilling and countersinking the smokebox shell for four 8BA screws on a 2⅛ in. p.c.d., tapping the flange to suit, then fixing the chimney in its turn. Back to the blast nozzle, which now has to be bored out at roughly a 6 deg. taper to arrive at the dimensions shown, then chuck by the base flange and reduce the upper one to ⅞ in. diameter to suit the blower belt tube. Square off the latter to $\frac{5}{16}$ in. overall, fit the steam union, drop the belt in place and braze up. Pickle and clean, then to complete, drill the four No. 70 blower holes.

E. S. COX will be a very civilised engine to drive, for with a condensate drain from the steam elbow which will also take care of most of the steamchest, as well as the normal cylinder drains, very little wetness should come out of the chimney; let us deal with the elbow. Chuck a length of ⅝ in. A/F hexagon bronze bar, face and turn down to ½ in. diameter over a $\frac{5}{16}$ in. length, screwing 26T. Leave 5/32 in. of hexagon and then turn the next ¾ in. down to ⅝ in. diameter, just to remove the flats, then centre and drill 11/32 in. diameter to 1⅛ in. depth, parting off at 1$\frac{3}{16}$ in. overall. Next chuck a length of ⅝ in. diameter bronze bar in the 3 or 4 jaw, depending on the surface finish, turn down for 1 in. length to match the lower portion, face, centre and drill 11/32 in. diameter to 1 in. depth. Follow up at 15/32 in. diameter to about ⅜ in. depth and tap ½ x 26T, part off at ⅞ in. overall, then mitre the two pieces as shown. Turn up the wee drain boss, then braze up, pickle and clean. Erect from inside the smokebox saddle, then turn up and fit the standpipes. Fit the smokebox to the boiler, sit on the saddle and pack up level at the back for the moment, then bend the steampipes to suit the standpipes and complete with nuts and nipples. Our steam circuit is now complete, so let us put the finishing touches to the smokebox.

Originally the door was an iron casting, so successful was that on BLACK FIVE, but although customers invariably have received sound castings, my scrappage rate was high and the solution has been to cast in gunmetal. Chuck by the periphery, clean up the chucking spigot, then rechuck by the latter. Turn down to size, face across the sealing surface, then tidy up the outer profile; very little is required here. The hinge is what I call the Robinson pattern as that great engineer used it almost universally. Make the main body of the hinge from $\frac{1}{16}$ in. strip or sheet, hammering down to fit the door, then take a 1½ in. length of 5/32 in. rod that has been drilled through at No. 47, braze the two together, then cut away to finish as shown; rivet to the door.

For the hinge blocks, chuck a length of 5/32 in. square steel bar truly in the 4 jaw, face and turn down to 3/32 in. diameter over a $\frac{5}{16}$ in. length, screwing the end ⅛ in. at 7BA. Cross drill at No. 47, part off at 19/32 in. overall and radius this end with a file, or mill over a mandrel if you have the courage required. Mark off and drill the front ring No. 41 in two positions as shown, turn up the hinge pin, I would use 5/32 in. rod and braze the head on, then erect the door to the smokebox.

The lamp iron can either be machined from the solid or fabricated, being flush rivetted to the door; handrail stanchions are standard, the handrail itself from tube, with fancy ends pressed in to complete. A lightly scribed circle when machining the front ring would be helpful when marking out for the dogs; drill and tap these 8BA and fit studs with $\frac{5}{16}$ in. stand out. Bend up the dogs, drill No. 43 and secure with 8BA nuts and small washers.



This shot from the 'Horwich Bible' shows a steam pipe being installed on a 'Crab' — plenty of room inside that huge smokebox!

Boiler Erection

What I usually call the boiler erection view, in this instance contains a lot of detail, but let us start with the expansion and boiler retaining brackets. On reflection, the length at 4 9/32 in. seems a bit fussy for such a mundane object, one which in any case is very much made to place. Reason for this is those stay heads which really regulate everything, so check again that the boiler is sitting level, bend up the expansion brackets from 2.5mm copper, mark for the stay ends and drill around 7/32 in. diameter to clear same. Between said clearance holes, drill five further holes at No. 30, offer up to the wrapper, drill this No. 40 and tap 5BA for homemade bronze cheesehead screws, annointing the threads with jointing compound before screwing home. The brackets of course sit on top of the frames with the edge of the flange almost flush with the outside edge of the frame; just leave a few thous for expansion. Now bend up the pair of boiler retaining brackets to suit and secure to the frames with six 8BA hexagon steel bolts.

Ashpan and Grate

The ashpan is one of those objects easier to draw and dimension than to build; it is of course a permanent fixture, though this will cause not the slightest problem in service. I suggest you first make the sides out of stiff cardboard, scoring heavily at the bend lines and clamping in place, then lay out in the flat onto 1.6mm sheet, saw out the latter, bend up and clamp in place. Now it is a question of cutting and fitting the bottom plate, front portion above the damper door, and the rear plate, using odd ends of $\frac{1}{4}$ in. brass angle and rivetting together before brazing up. Air entry is normally at the back and up the chute provided, which also ensures that ash does not build up under the back of the grate.

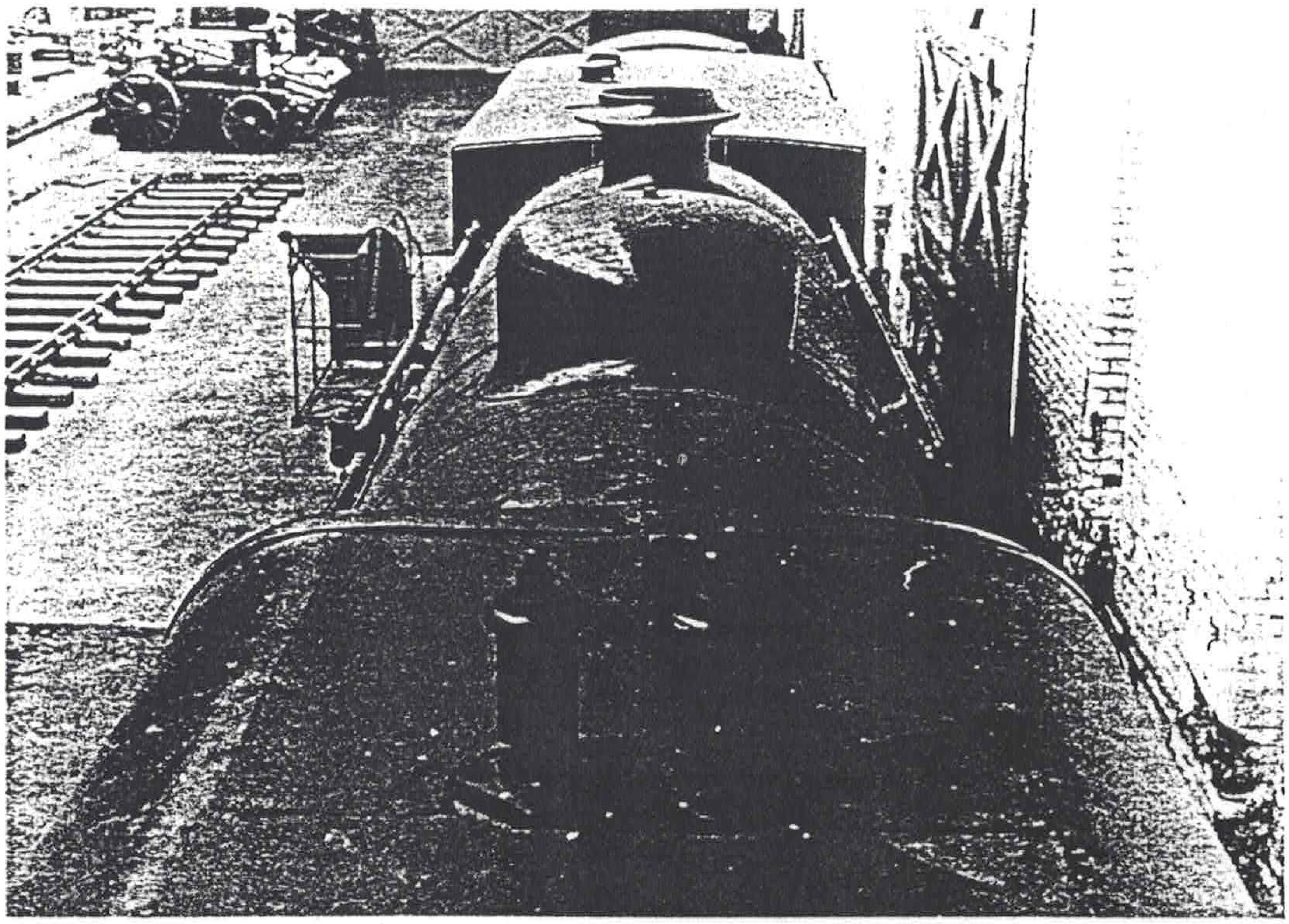
Damper Gear

The damper door is $2\frac{5}{8}$ in. x $1\frac{1}{4}$ in. from $\frac{1}{8}$ in. or 3mm steel; I have specified it that robust so that it does not warp in service and of course it wants to fit the ashpan closely. The hinge is from $\frac{3}{16}$ in. rod, brass or steel, drilled No. 41 for a 3/32 in. pin. Make up two $2\frac{5}{8}$ in. lengths and silver solder to ashpan and door, then cut away to arrive at the completed hinge. A bracket is rivetted to the door in the position shown; pull rod, bearing and damper shaft resemble items we have already made to operate drain cocks and the like, so no need for repetition here. Bend up the damper handle, fit under the cleading and as the damper wants normally to be closed, I suggest you just wedge the handle in the open position for cleaning out the ashpan.

A gently sloping grate is the ideal for firing, as long as you remember to keep a sloping fire and not build up level at the front. The way I have designed the air flow, you build the fire right up to the door at the back and keep it very thin at the front, that way E. S. COX will really steam! The grate is in three very simple sections, the outer ones being left in place, the centre one being pulled out through the door when the fire is dropped, when you open the damper door and push the dead fire out that way. The grate bearers are also one of my pet standards; the outer sections can be a fairly tight fit in same, but the centre section must be slack to be readily removable. Frank Pearce asked the question as to why it cannot be stated that grates be set level with the top of the foundation ring; well, it has said just that on the E. S. COX detail for five years since it was set down on paper, though I take his point. Sit the bearers in the ashpan, clamping them in place and clear of the grate spacers, check the grate position relative to the boiler, then drill through at No. 34 and secure with 6BA bolts.

Firehole Door

The base of the firehole surround is a piece $3\frac{1}{8}$ in. x $2\frac{1}{2}$ in. from 1.6mm steel sheet; saw and file to profile then drill the four lugs at No. 34. The slides are $3\frac{1}{8}$ in. lengths of 7/32 in. square bar and the $\frac{1}{16}$ in. wide x 3/32 in. deep slots cut with a slitting saw. Cut pieces $1\frac{9}{16}$ in. x $\frac{13}{16}$ in. as the start of the doors, fitting into the slots and then attaching the bars to the surround with a few copper rivets. The oil tray is folded up from 1.2mm sheet and attached to the top bar with a couple of 8BA screws. The door handle and lever fulcrum plates are from $\frac{7}{16}$ in. x $\frac{1}{16}$ in. steel strip, drilled No. 31 for the pin. Part off 21/64 in. lengths from $\frac{1}{8}$ in. rod, press into the fulcrum plates and turn up the 3/64 in. thick collars to complete. Rivet to the bottom bar then silver solder the whole surround together for the strength this provides.



Intrepid photographer Norman Gregory climbed on to the cab to show us the chimney, dome and safety valves on 42700 at the National Railway Museum.

We have the backs of the doors, so ease them in the slots, then drill four air holes at No. 45 and a central one at No. 31; press a 13/32 in. length of $\frac{1}{8}$ in. rod into the latter. Bend up the front plates as shown, then fill the sides in with odd ends of 1.2mm material and braze up. The firehole door handle gets a bit close to the regulator handle; especially when the latter is closed, so to avoid the possibility of knocking the regulator open when firing, on safety grounds I think a shortening of $\frac{1}{8}$ in. is permissible? Turn up the collar, pin and handle, mill $\frac{1}{4}$ in. x $\frac{1}{16}$ in. steel strip down to 7/32 in. width, deal with holes, slot and scallop and braze together. The lever is similar but simpler, the link straightforward and the four collars self-explanatory. Erect and cross drill from the collars through the $\frac{1}{8}$ in. pin and secure with 1mm spring pins. Two further collars are required to hold the link in place, exactly as the others save for a 3/32 in. bore.

The backhead cleading is a very much 'make to place' affair to clear all the bosses and needs $\frac{1}{16}$ in. thick asbestos lagging bonded to same. Offer up the complete firehole door assembly, mark off, drill the No. 34 holes and then cut out the centre as shown. Offer up the cleading in turn to the backhead, spot through the four No. 34 holes, drill the backhead No. 44 and tap 6BA for hexagon head bronze bolts; secure in place.

The backhead surround can either be formed from the same .015 in. brass sheet as used for the boiler cleading, or the thinnest copper you can obtain, the latter probably .7mm; flange over a wooden former and cut out the centre, or of course deal with it in sections. Either rivet to the backhead cleading, or use self-tapping screws as the drawing specifies.

Dome and Safety Valve Casings

The dome casing for E. S. COX is a real beauty and Norman Gregory has captured it on film to perfection. The gunmetal castings thus far have fallen into the same category, so first deal with the base to suit the cleading, then chuck by the spigot provided and tidy up as much as you can with files and emery cloth, reverting to the bench vice to deal with the lower portion after boring out to suit the dome flange. Saw or part off the chucking spigot, drill a No. 44 hole in the centre, to secure with an 8BA bolt, one with a thin head, to the dome plug.

The more I look at 'Crab' photographs, the fewer seem to have been fitted with a safety valve casing in their later days, so I veered away from a special casting and reckon a standard front cylinder cover casting would make an excellent substitute, though forming from .7mm thick copper appeals even more. Drilling large holes in thin metal is relatively simple provided the job is clamped firmly down and the drill allowed to cut into hardwood so that it does not 'pick up'.

Dummy Whistle

Although such a fitting is absolutely useless, nevertheless it adds a touch of class to the completed E. S. COX such that it is worthy of spending time in producing. Also it provides me with an opportunity to describe some of the fittings which I have designed, ones which I had rather taken for granted whilst they were on the shelf as finished items.

Chuck a length of 5/32 in. A/F hexagon brass rod, face and turn down to .086 in. diameter over a 35/64 in. length, this in about $\frac{1}{16}$ in. increments, screwing the end $\frac{5}{16}$ in. at 8BA; part off at 1 13/32 in. overall. Reverse in the chuck, gripping by the hexagon portion and first reduce to .050 in. diameter over a $\frac{3}{16}$ in. length, screwing 12BA. Reduce the next $\frac{7}{16}$ in. to .065 in. diameter, then another 9/64 in. at .086 in. diameter, screwing this 8BA, to finish up with a 5/64 in. length of the original hexagon bar. For the bottom of the bell, chuck a length of $\frac{5}{16}$ in. brass rod, face and turn or file on the spherical radius over a 9/64 in. length, so that the minor diameter matches the hexagon on the centre spindle. Centre, drill No. 50 and tap 8BA, then part off at 9/64 in. and screw to the spindle. The upper portion of the bell is from the same $\frac{5}{16}$ in. rod; face, centre, drill at $\frac{1}{16}$ in. diameter to $\frac{1}{4}$ in. depth and 'D' bit to $\frac{5}{16}$ in. depth. Reduce the outer 3/64 in. to 9/32 in diameter, then part off at a full $\frac{7}{16}$ in. overall. Reverse in the chuck, turn the outer profile by eye to look like the detail, there is no point in my giving precise dimensions here, then centre and drill No. 55; assemble over the top of the spindle with a 12BA nut and washer.

Next we need the dummy valve body, so take a length of $\frac{3}{16}$ in. rod and at 9/32 in. from one end, cross drill at No. 44. Chuck in the 3 jaw with the 9/32 in. end proud, leave the first 3/32 in. and turn a spherical radius on the next 3/32 in., then part off at 15/32 in. overall. Reverse in the chuck, turn a spherical radius on the end 3/32 in. to leave $\frac{1}{16}$ in. around the No. 44 hole at $\frac{3}{16}$ in. diameter. Centre, drill and tap this end 12BA for a hexagon head screw and washer.

Chuck the $\frac{3}{16}$ in. rod again, face, centre and drill No. 44 to $\frac{5}{16}$ in. depth, parting off a 7/32 in. slice; file a scallop to suit the valve body. Repeat on a second piece, the only difference being it is tapped 8BA, when you can assemble the lower portion of the whistle. All we need is the lever and its lugs, made from 3/32 in. x 3/64 in. strip, a rivet being fitted at the pivot to hold things together. You can now either just silver solder the pair of lugs to the valve body, or deal with all the joints in like manner. Securing directly to the cleading is perfectly O.K., with a large washer and 8BA nut underneath. Now I suggest you use Duraglit to polish the whistle to a mirror finish.

Whistle

Before retiring to the backhead, the whistle which I would mount under the drag box requires attention. Although I can still supply super whistles, water gauges too, I will run through manufacture of both.

Take a $4\frac{3}{8}$ in. length of $\frac{5}{8}$ in. o.d. drawn brass tube and starting $\frac{1}{2}$ in. from one end, cut the mouth with saw and files. Next chuck a length of $\frac{5}{8}$ in. diameter brass bar and turn down over a $\frac{3}{16}$ in. length to a tight fit in the tube; part off an $\frac{1}{8}$ in. slice. File away 1/32 in. to match the mouth in the tube, pushing home in the position shown. Turn up a plug for the outer end of the tube to a close fit, hold in place and then blow into the open, disc, end of the tube. This will give you a very close approximation of the true whistle note; if your ear is sufficiently tuned it will also tell you if the note is a clear one, and of course you can shorten the tube to get a higher pitch. When satisfied, turn up the steam end and silver solder the whole assembly, taking care not to block the steam slot with either flux or spelter. One of our readers painted the whistle that we had supplied a lovely orangy colour and then complained it was mute; it took me hours of trying to get enough paint out of the steam slot to get even a 'peep' out of it! To be able to pass on that tip was worth all the trouble and more Bob.

Water Gauges

As a designer, obviously what I draw can be open to criticism, for there are many ways of tackling most components, and when builders are kind enough to take time to write to me, their comments are invariably helpful and can lead often to design improvements, indeed my work does reflect this feed-back of information. When it comes to safety though, I have done my homework, and one comment that my specifying 4mm glass for water gauges was unsafe sent me through the roof. Now I think that anyone who has worked on boilers, and I had my share of locomotive, marine and stationary ones, appreciates the water gauge above all else, and being a fitter who had to refurbish them and fit new glasses, this engendered a healthy respect for them. After all my experience full size, when it came to design for them in miniature, I was sufficiently curious to carry out a number of tests, one of them the degree of false reading one would obtain through surface tension with glasses of varying bores.

The results were surprising, not so much by the bore sizes as by the difference of reading between plain and Schellbach glass, a difference in initial reading of up to 100%, even with well-wetted walls. Now as far as I am aware, I am the only designer to take this into account when positioning the bottom nut of the water gauge relative to the firebox crown, and although I have allowed for fitting the Schellbach glass that Reeves stock, a plain glass will give a greater factor of safety. There is a reverse side of the coin though in that it is easier to see the water level in Schellbach glass, so maybe this cancels out my remark in the previous sentence. Enough of the preamble, let us make the water gauges.

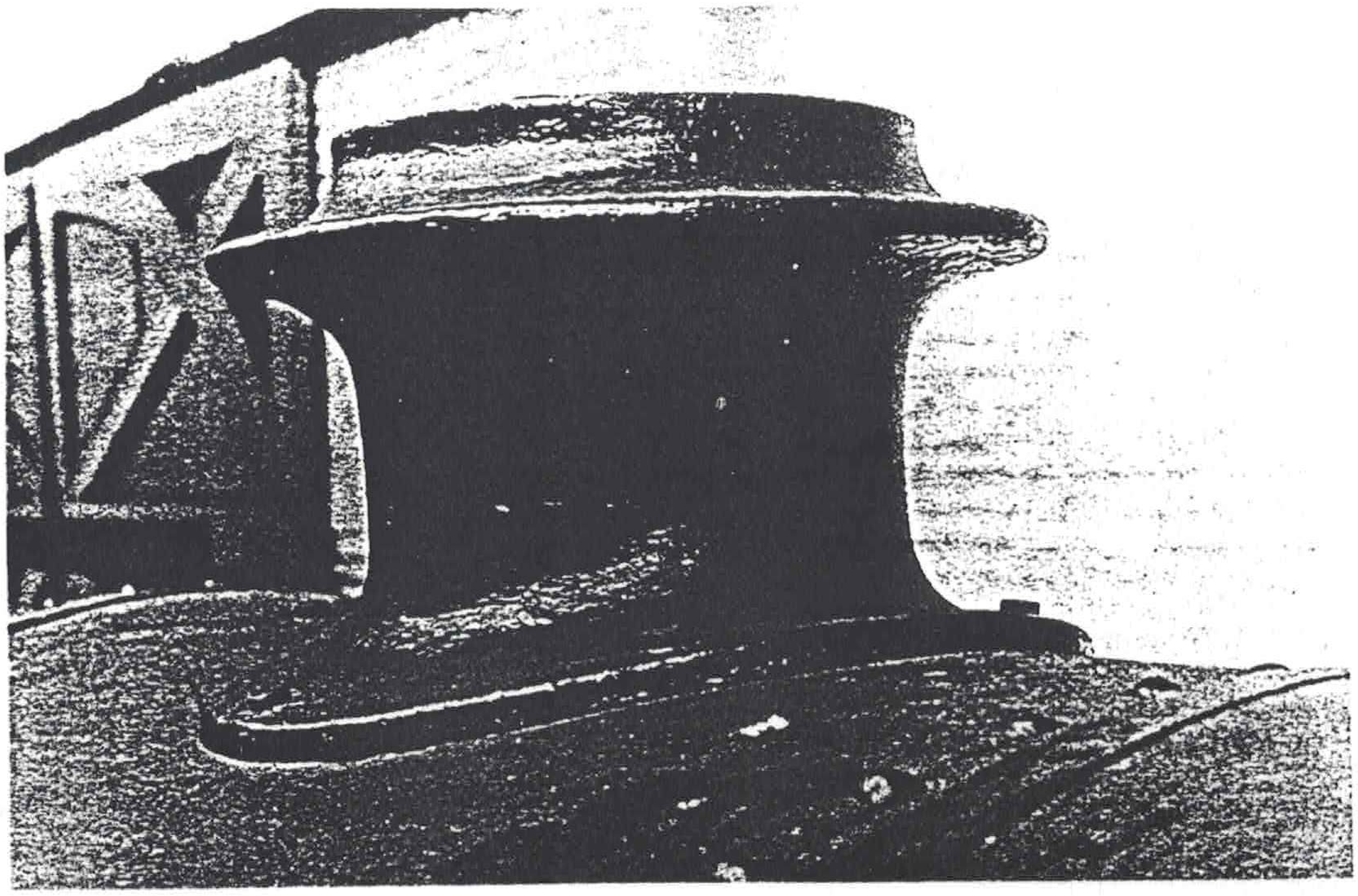
Top fitting first, for which $\frac{7}{16}$ in. bronze rod is my specification. Grip first in the machine vice, removing the top jaw on the Myford vice gives a positive clamping action, and attach to the vertical slide. Mill across the end to square it off, then concentrate on one flank of the square body, milling down over a 17/32 in. length until the micrometer reading is .360 in.; deal with the opposite flank to arrive at 9/32 in., then repeat for the other two sides. Chuck in the 4 jaw and set the $\frac{7}{16}$ in. diameter to run true, part off to leave a $\frac{5}{16}$ in. length at said diameter, then turn down for $\frac{1}{4}$ in. length to $\frac{1}{4}$ in. diameter and screw 40T; centre and drill right through at No. 30. Cross drill at No. 22, checking that your 4mm glass is a free fit and opening out as far as No. 20 to achieve this, then turn up the screwed end to accept the gauge glass nut from $\frac{1}{4}$ in. rod, completing with a 5/64 in. spigot to about 13/64 in. diameter. Mike the exact size, drill the main body to be a press fit and silver solder together. Tap out the $\frac{3}{16}$ x 40T and 3BA holes and we can deal with the plugs for same.

Chuck a length of $\frac{1}{4}$ in. rod in the 3 jaw, face and turn down to $\frac{3}{16}$ in. diameter over a full 5/64 in. length and screw 40T; centre and drill No. 51 to $\frac{3}{16}$ in. depth, then part off at a full $\frac{1}{8}$ in. overall. Chuck a length of 5/32 in. A/F hexagon rod, this can be brass, reduce to $\frac{1}{16}$ in. diameter over an $\frac{1}{8}$ in. length, part off to give a 5/64 in. thick head, fit to the main body of the plug and silver solder together. For the second, rodding plug, chuck the $\frac{1}{4}$ in. rod again and reduce to 7/32 in. diameter over a $\frac{1}{4}$ in. length, then further reduce to 5/32 in. diameter over an $\frac{1}{8}$ in. length and screw 3BA. Centre and drill No. 56 to $\frac{1}{4}$ in. depth, then part off at 11/64 in. overall. This time the hexagon is $\frac{1}{8}$ in. A/F, the spigot 3/64 in. diameter; silver solder together to complete.

The outer profile of the bottom fitting is dealt with exactly the same as the top one, then fit a $\frac{1}{4}$ x 40T adaptor in the 3 jaw, screw the embryo body to same, centre, drill and ream through at $\frac{1}{8}$ in. diameter. Follow up at $\frac{3}{16}$ in. diameter to 7/32 in. depth and 'D' bit to 9/32 in. depth, then cut about four threads with the 7/32 x 40T taper tap so that it can be tapped out squarely by hand later on. The drain valve depicted is extremely neat, hence its adoption, though it does suffer one drawback in that it is not captive, though $\frac{1}{2}$ turn will be sufficient to blow down the gauge, giving a safety factor of at least 10. If this worries you, simply 'D' bit the seat in the body a further $\frac{1}{16}$ in., then turn up a valve stem akin to that for the injector steam valve only it needs no gland, then turn up a captive valve spindle from 5/32 in. stainless steel rod. Before doing either though we have to turn up and fit the bottom gauge glass union and the smaller drain one; press into the body and silver solder.

For the valve as detailed, chuck a length of 7/32 in. stainless steel rod, face and turn down to $\frac{1}{16}$ in. diameter over a 5/32 in. length, screwing the end 3/32 in. at 10BA. Turn the next 3/32 in. down to 3/32 in. diameter, then screw a $\frac{3}{16}$ in. length of the original rod at 40T. Reduce the threaded length to 5/32 in. when you start to form the valve at 5/32 in. diameter. run the die over the threads again, then part off at a full 5/32 in. for the valve. Either grip by the 3/32 in. portion in a collet chuck, or screw into a 7/32 x 40T adaptor, to form the valve itself to a 90 deg. angle, 45 deg. taper. The wee handle is from $\frac{3}{16}$ in. nickel silver or stainless steel rod, turn on the handle itself over a 11/32 in. length, with rounded end and slightly tapered as shown, then start forming a spherical boss, gradually parting off. File two flats on the spherical end to arrive at 3/32 in. thickness, then drill No. 53, press onto the spindle and add a 10BA nut to complete.

Many of you now prefer 'O' rings in lieu of rubber sleeving for gauge glass sealing and an Australian reader showed me some 'O' rings which he had machined to a 'D' section, so that not only did he gain the benefits of using an 'O' ring seal, but they fitted inside the union nuts which I have specified and gave a very neat finish. Screw the fittings into the boiler, using a pin drill to cut back the facings if necessary so that the fittings assume their correct orientation, then slide in a length of gauge glass and check it is absolutely free, or it will break first time you light up. Cut the glass to length by



The L & Y pattern chimney that E. S. Cox was able to perpetuate on the BR Standard Classes, a shape I would sum up as "charming austerity".

nicking with a Swiss file and breaking with the fingers, then touch the ends on a grindstone, wearing goggles of course! Assemble and nip the nuts up finger-tight only; another golden rule to avoid breakage.

Thoughts on Fittings

Although Roy Amsbury has designed delightful injectors with moving steam cones to cope with a wide range of working pressures, 14 years back he had much success with cones of my design, though fitted into much neater bodies than I then specified; his magnificent GWR Prairie Tank was so equipped when performing so splendidly in the early 1970's. This neatness of injector body design alerted me to some of the finer points of fittings design and although I had made some progress in this direction, an evening spent with Roy in his workshop back in 1972 really sowed the seeds for my own success, for which my grateful thanks Roy. LANKY builders gained a lot of praise at Exhibitions for their 'neat backheads', so I had to do at least as well for E. S. COX, both being of Horwich origin. Even with this fidelity, it has been possible to create standards, for many of the boiler and other fittings full size were 'bought in', so the injector steam valves and delivery clacks depicted on Sheet 10 will be equally at home on DONCASTER's backhead.

Injector Steam Valve

For the steam valve body, chuck a length of 7/16 in. bronze rod in the 3 jaw, face, turn down to 5/16 in. diameter over a 7/32 in. length and screw 40T; part off at 11/16 in. overall. Grip a 5/16 x 40T screwed adaptor in the chuck, screw the embryo body into same, face and turn the profile to drawing. Centre and drill through at No. 29, then follow up at 7/32 in. diameter to 5/16 in. depth, 'D' bitting to 3/8 in. depth and tapping the end 5/32 in. so at 1/4 x 40T; run a No. 28 drill through the remains of the No. 29 hole. Screw into the facing, sight the outlet union to be not quite vertically downwards, turn it up from 1/4 in. rod, completing with a 1/16 in. spigot to roughly 3/16 in. diameter. Mike said spigot, drill the body to be a press fit and silver solder together.

Chuck a length of 5/16 in. A/F hexagon bar for the valve stem, face and turn down to 1/4 in. diameter over an 1/8 in. length and screw 40T. Centre and drill No. 40 to 3/8 in. depth, tap 5BA to 1/4 in. depth and part off at 1/2 in. overall. Chuck a screwed adaptor, fit the stem to same, reduce to 3/16 in. diameter over an 1/8 in. length, screwing 40T, then complete the profile. In the cause of neatness, it is worthwhile reducing the hexagon remaining to 9/32 in. A/F, though this is by no means essential.

Chuck a length of 1/8 in. stainless steel rod for the spindle and reduce to 3/32 in. diameter, an easy fit in the valve stem, over an 11/16 in. length. Reduce the next 1/4 in. to 1/8 in. diameter and screw 5BA, then the next 1/4 in. to 11/64 in. diameter and part off. Chuck a 5BA screwed adaptor, fit the spindle and cut the valve working face to a 45 deg. taper as shown. Mike Casey told us how to make neat handwheels in his PEVERIL articles, pleased this fine design is now catching on, so no need for me to describe manufacture, only to fit the wee 'tail' and silver solder together. Punch a square hole in the centre, file the spindle to suit, push home and peen over the end of the spindle.

Assemble the complete valve, remembering the spindle and gland must be fitted to the valve stem ahead of fitting the handwheel, then erect to the backhead facing. The adjustment so that the outlet union comes vertically downwards is the wee collar on the end of the internal pipe, though I have found that by careful tightening, this will crush to a degree. All you have to do now is mark off and drill the connecting hole to the steam brake and whistle valve supply.

Ring nuts add a touch of class; they were fitted to the injectors on DONCASTER in the early days ahead of the 4-stud flange and double tapered olive which became the later standard. Chuck a length of 3/8 in. bronze rod, brass is O.K. here, in the 3 jaw and centre, then bring the tailstock into play. Now you can plane the eight 1/16 in. wide slots to a bare 1/32 in. depth by winding the tool along with the carriage. Drill No. 11 to 1/4 in. depth, enter a 7/32 in. drill and 'D' bit to 9/64 in. depth, then tap 1/4 x 40T. Turn down to 5/16 in. diameter over a 3/64 in. length at the end, move on 3/32 in. and repeat, then part off to complete. The olive wants to be from 7/32 in. phosphor bronze rod, then it won't melt when you braze it to the pipe. Chuck in the 3 jaw, skim a few thous off the outside to be a rattling fit in the nut, centre and drill No. 12 to about 1/4 in. depth. Form the 30 deg. cone to be almost a knife edge with the No. 12 hole, then part off to leave about 1/32 in. at .210 diameter; remove any burrs.

Injector Delivery Clack

This fitting is fairly easy to make, though unfortunately its banjo bolts is detailed on Sheet 11, so we cannot complete it. Start again with 7/16 in. bronze rod, face, centre and drill 5/16 in. diameter to 1/4 in. depth then part off a 13/32 in. slice; rechuck and face to 25/64 in. thickness. The valve body is from 3/8 in. bronze rod; first reduce to 11/32 in. diameter over 1/2 in. length after facing, then centre and drill No. 23 to 5/8 in. depth, following up at 1/4 in. diameter to 1/4 in. depth and 'D' bitting to 5/16 in. depth. Tap the outer 5/32 in. or so at 9/32 x 40T then run a 5/32 in. reamer through the remains of the No. 23 hole. Part off at a bare 1 in. overall, reverse in the chuck and turn down to 1/4 in. diameter over a 3/8 in. length, shaping the transition as shown; face off to length and screw the end 5/32 in. at 40T. Centre deeply to form the seating for the olive, then drill No. 28 to break into the upper bore. Offer up to the sleeve, mark off and scallop the latter until you arrive at the 11/32 in. dimension, then drill a No. 30 hole in both pieces and open out into a 5/32 in. slot to reduce any restriction to flow. Bind together with wire and silver solder the joint; all fittings need pickling, suede brushing and polishing to a high finish. Seat the 3/16 in. ball then make up the cap as we did for the water gauge, but to the dimensions shown of course.

Regulator Handle and Stop

Before we arrive at the last fitting for this session, let us take a breather and complete the regulator with its handle and stop.

Cut a 1 in. length from 1/2 in. square steel bar and grip in the 4 jaw to first turn on the 1/4 in. diameter boss as shown; centre and drill through at No. 28. Punch or file the 9/64 in. square to suit the end of the regulator rod, then cross drill No. 51 for the 10BA bolt, saw the excess off this end, then radius and slit. To complete this portion of the handle, reduce the 'stop' end to 3/16 in. width by filing. Although 1/16 in. thick is slightly overscale for the main portion of the handle, even this is rather flimsy and for hard work 3/32 in. is to be preferred. Form from 5/16 in. wide material, bending and shaping to drawing, but checking also on the backhead to see things are comfortable and that you don't get entangled with the boiler fittings. Turn the actual handle from 5/32 in. rod, stainless if you so wish, slit it over about 1/8 in. length to accept the flat portion and braze up.

Although the stop is fully detailed, again it is a make to place item, plus I have gone bronze crazy and a good quality brass would be acceptable here. Chuck a length of 1 in. diameter bar in the 3 jaw and reduce to 27/32 in. diameter over a 7/16 in. length. Centre, drill and bore out to 11/16 in. diameter and 3/4 in. depth, this to match the boss on the backhead, then part off at a full 11/16 in. length. Face, then cut in halves and start forming the slot to accept the end of the regulator handle. It is best that the dome be removed at this stage so that you can see the position of the regulator valve, to make sure it goes from closed to fully open. Once, satisfied, trim the excess from the stop, drill the No. 44 holes, offer up to the backhead, spot through, drill and tap 8BA to 5/32 in. depth; secure with hexagon head bolts.

Vacuum/Steam Brake Valve

I must say I am rather proud of the vacuum/steam brake fittings as they came off the drawing board for E. S. COX and all have been made to check them out, so all is well, plus the vacuum fittings are perfectly compatible with the Hughes system of braking on passenger trucks, so she can haul huge loads in safety. Having said that, actually making the components is not quite so easy, though we shall win – of course.

Vacuum brake body first, so reduce a length of bar to $\frac{11}{16}$ in. diameter and part off a 13/32 in. slice. Chuck this piece, face across, centre, drill and ream through at $\frac{1}{8}$ in. diameter. The groove for the 'O' ring requires a special tool made from $\frac{1}{4}$ in. silver steel rod, like a 'D' bit with a .02 in. radius in the corner, though on reflection a slightly simpler way would be to 'D' bit at 7/32 in. diameter to 3/32 in. depth and turn up a PTFE sleeve to suit. Reverse, face off to thickness and deal with the second recess. Turn up the union connections, cross drill the body at No. 30, taking care when you reach the bore, then mike the spigots on the union connections and deal with the body to be a press fit. Make the two lugs from $\frac{1}{8}$ in. x $\frac{1}{16}$ in. strip, bend up the guide from the same material or turn from bar, bolt together, sit on the body and silver solder together.

For the steam brake body, arrive at an $\frac{11}{16}$ in. diameter x $\frac{1}{4}$ in. thick chunk with an $\frac{1}{8}$ in. hole reamed centrally. Scribe on the bolting circle at $\frac{9}{16}$ in. diameter, mark off and drill the six No. 51 holes, offer up to the vacuum brake body, drill and tap the latter 10BA to a full $\frac{1}{16}$ in. depth. Back to the steam brake body; turn up the 7/32 x 40T union connections, mike the spigots, drill the body to suit and press in. That leaves just the facing to accept the elbow, so file to shape and allow 1/32 in. for final machining of the face later on; silver solder together. Mark off the two ports and drill them No. 51, then drill from the steam connections to complete the passages. To get steam from the elbow into the chamber, I have specified a $\frac{1}{16}$ in. slot which I envisaged as a drilled hole which was then opened out; you can use a $\frac{1}{16}$ in. end mill in lieu.

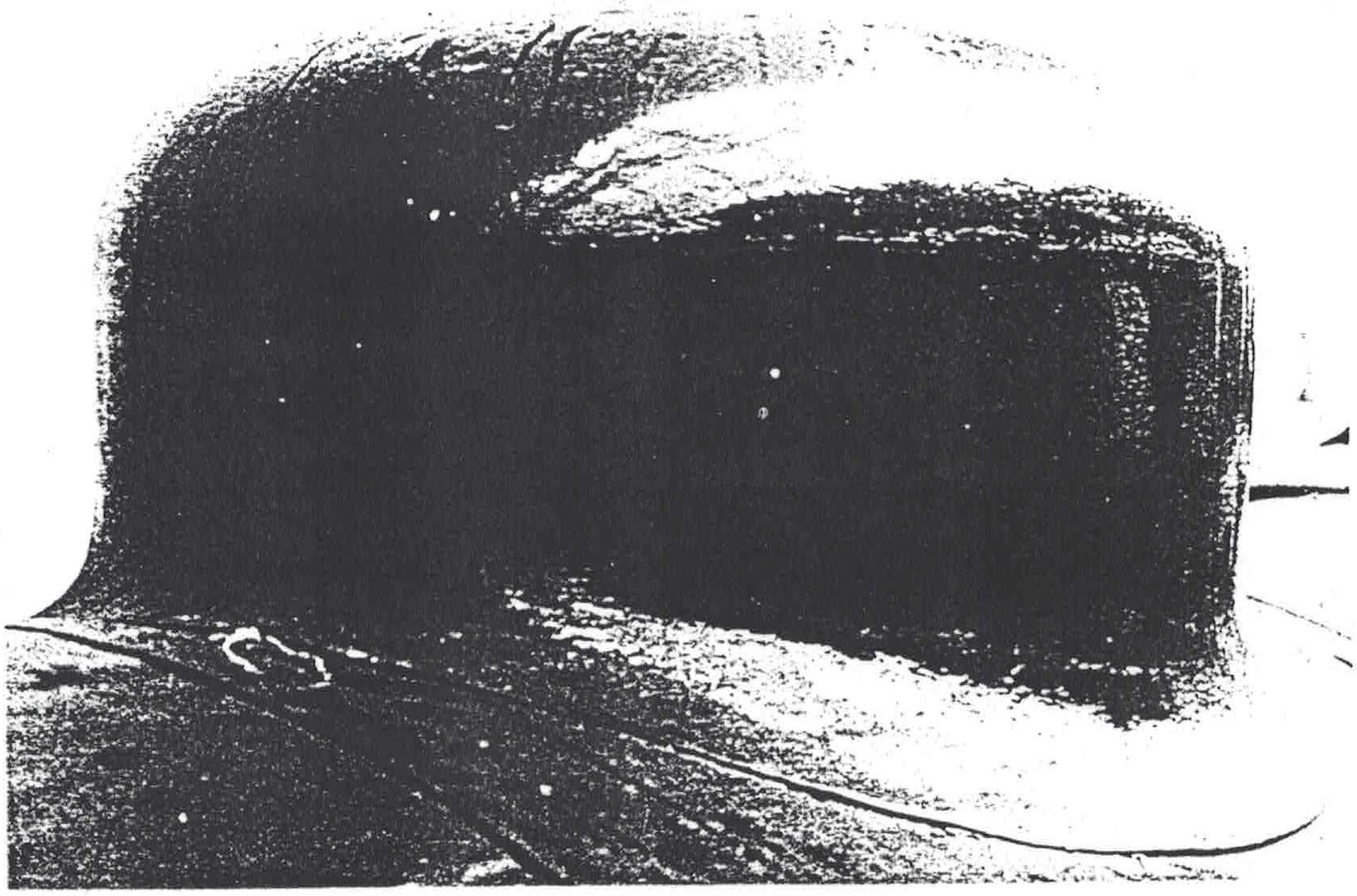
The cap is straightforward after what has gone before; just ease the wall locally to ensure free steam access to the chamber. Silver solder the boss in place, drill the holes No. 51 from the steam brake body, bolt together and face across the elbow seating. The elbow itself has a base of 2.5mm brass, $\frac{3}{16}$ in. rod shaped to drawing, clamped together, the No. 41 passageway drilled, a length of 3/32 in. o.d. thin wall copper tube fitted and then the whole silver soldered together. Offer up to body and cap, drill and tap 10BA for hexagon head bolts, fitting a 1/64 in. CAF gasket on final assembly. We now have to deal with the 'works', starting with the steam brake valve.

Grip a 1 in. length of $\frac{7}{16}$ in. brass rod in the 3 jaw, face and turn down to 13/32 in. diameter over a $\frac{1}{4}$ in. length and scribe on a circle at 9/32 in. diameter with a knife edgetool. Mark off on this circle the steam entry and blind ports, grip in the machine vice on the vertical slide, drill the $\frac{1}{16}$ in. hole to 5/32 in. depth and an arc of them to start forming the blind port to a full $\frac{1}{16}$ in. depth; use an end mill to form a complete slot of the latter to around 5/64 in. depth. Back to the 3 jaw chuck to face across until the blind port is around 3/64 in. depth, then centre, drill and tap the 5BA hole to $\frac{3}{16}$ in. depth before parting off a 3/32 in. slice to complete.

For the spindle, chuck a length of $\frac{1}{8}$ in. stainless steel rod and turn down to .086 in. diameter over a 7/32 in. length, screwing the outer 5/32 in. at 8BA. Move on 7/32 in. and reduce the next $\frac{1}{8}$ in. to 3/32 in. diameter before parting off at 1 1/32 in. overall. Reverse in the chuck, face off to length and screw the end 3/32 in. at 5BA using the tailstock dieholder; screw on the steam brake valve.

The vacuum brake valve is a 3/32 in. disc of $\frac{11}{16}$ in. diameter bar with a 3/32 in. square hole filed or punched in its centre; add a piece of strip and a turned handle then silver solder together to complete. Drill the No. 34 air entry hole, then grind the valve lightly onto its seat. Assemble the whole valve, minus the cap, set the steam valve to be 'cracked', then mark the spindle end for a square to suit the vacuum valve; file or mill this on. Reassemble, check operation, and when satisfied, drill a No. 34 hole in the vacuum brake body from the valve, nicking the side to provide a 'pilot' effect. A kind reader tells me that 8BA double coil spring washers are available from Whistons, when we can finally assemble the valve, turning up little spacers to properly locate the guide, with 10BA bolts added to complete.

Just one more session to go and E. S. COX will be ready for the track.



The dome on a 'Crab' is so distinctive that I simply had to publish this detail to as large a scale as possible from the Norman Gregory photograph.

E. S. Cox – The Horwich 'Crab' in 5 in. gauge

by: DON YOUNG

Part 11 – Conclusion

All good things must come to an end and so we reach the last stage on E. S. COX. It was hoped that at least one example would be in steam on the track before I typed up the last article, though the possibility still exists for this to happen before it is published as several engines are well advanced; what a thrill it would be to sample one at Birmingham on the occasion of the 3rd DYD Rally! To bring that day nearer for all builders, let me take description to its conclusion, continuing with the vacuum brake equipment.

At the front of the barrel on the L.H. side is a bush tapped $\frac{1}{4}$ x 40T to accept the vacuum ejector steam supply valve. Start with a $\frac{5}{16}$ in. finished length of $\frac{5}{8}$ in. square bronze or gunmetal bar, marking on the centres of the main bore and outlet connection. Chuck in the 4 jaw and turn down the outlet connection to $\frac{3}{16}$ in. diameter, blending into the main body as shown and screwing 40T, then countersink deeply for a 3/32 in. pipe nipple. Rechuck by the main part of the body, face off as necessary and then turn down to $\frac{5}{16}$ in. diameter over a $\frac{3}{16}$ in. length; radius the end, then centre and drill right through at No. 31. Follow up at 7/32 in. diameter and 'D' bit to 9/32 in. depth, tapping the outer $\frac{1}{8}$ in. or so at $\frac{1}{4}$ x 40T. Reverse in the chuck, face off to $\frac{1}{2}$ in. overall length, enter the 7/32 in. drill, 'D' bit to $\frac{1}{8}$ in. depth and tap $\frac{1}{4}$ x 40T before running an $\frac{1}{8}$ in. reamer through the remains of the No. 31 hole. Turn the boiler connection from $\frac{1}{4}$ in. A/F hexagon bronze rod to drawing, I would make the $\frac{5}{16}$ in. diameter collar separately, clamp to the main body and silver solder together. To complete the body the two No. 50 passages have to be drilled and I suggest this is one job best done by hand, taking care when the drill breaks through.

The cap we can either make as for the water gauges in the last issue, or as above for the boiler connection – either way you will arrive at a neat end result. I expect the, ball, valve to reseat on its own when the ejector supply is cut off, but if there is a problem in service then a wee spring fitted inside the cap will provide a positive cure. Gland and spindle are straightforward, though the latter will require careful piercing to accept the lever, the latter another simple component. Ring nuts we have already made, the only difference with this one is that it is to suit an $\frac{1}{8}$ in. spindle, which brings us to the fulcrum. First requirement for this is a steel sleeve, 11/32 in. o.d. x $\frac{1}{4}$ in. bore x $\frac{1}{8}$ in. thick. Next take a length of 5/32 in. square bar and cross drill No. 52 at 3/32 in. from one end. Radius this end and then cut a $\frac{1}{16}$ in. slot as shown. Bend also as shown, mainly to clear the ring gland nut, and reduce the main portion to 3/32 in. thickness; saw off to length and braze up. Assemble to drawing, pack the gland and erect to the boiler, when we can move on to the vacuum ejector, my piece de resistance!

Vacuum Ejector

It took days of thought to get the vacuum ejector working internally whilst retaining the correct external appearance and I will first try to describe the internal passageways and features to aid understanding, which should then ease the problems of manufacture. In this you will find the photograph shown hereabouts and taken by Norman Gregory to be invaluable, as I did at the design stage. From the steam supply valve, a pipe runs down to the front end of the ejector and although full size it was possible to fit a nut and nipple at each end of the pipe, it must have been a very awkward one to fit, impossible in 5 in. gauge, so our pipe has to be brazed into the ejector body. The first problem is that steam entry is actually in the vacuum side of the body, the little block on the extreme right of the assembly, so first we have to get the supply to the steam side; this we do via a diagonal drilled passage into the forward, dummy, chamber. From here steam passes to the rear chamber by means of another drilled passage, one that has to be plugged at the front end, when the chamber allows us to drill downwards out of the steam body and into the bore of the cone tube. Now the cones themselves form a miniature edition of the blast nozzle/petticoat pipe in the smokebox, but because our brake vacuum is measured in inches of mercury instead of inches of water in the smokebox, a proper venturi is required in the draft cone, with parallel. portion to provide for the necessary increased efficiency. Between the two cones, a passageway leads into the limit valve chamber on the vacuum side, said limit valve not being sufficiently sensitive to deal with the system on its own, so fit a Hughes/Reeves pattern in the main train pipe. Connecting the two chambers, the second contains the ball valve going down to the train pipe, a branch off the outlet taking another pipe back to the brake valve in the cab to complete the system; it works, and well, so let us hurry on to make the vacuum ejector.

For the steam side, first requirement is a $\frac{3}{4}$ in. finished length of $\frac{1}{2}$ in. x $\frac{5}{16}$ in. brass bar. Grip in the machine vice, on the vertical slide, drill and 'D' bit the $\frac{3}{16}$ in. holes to 7/32 in. depth and tap the outer $\frac{1}{8}$ in. or so at 7/32 x 40T. Leave the diagonal hole into the forward chamber until the vacuum body is complete, but drill the No. 51 hole to join the chambers, plugging the front portion as shown on the assembly. Next drill diagonally downwards from the rear chamber to complete the steam passages within the body. Turn the body through 90 deg. and with a $\frac{5}{16}$ in. end mill, produce the scallop to accept the cone tube, finishing with a flat over the first 5/32 in., as shown. The No. 30 hole can be drilled at this stage as it is virtually going to find its own direction from the scallop, though I suggest you drill around No. 51 in the first instance and open out to size in a couple of stages.

The cone tube is plain turning, its main outside diameter being varied from $\frac{5}{16}$ in. if necessary to match the steam body. The length and recess depths must be accurate for the ejector cones to perform correctly, so use a micrometer and vernier depth gauge. Clamp to the steam body and drill both the No. 51 and 30 holes, removing any burrs. For the ejector cone, chuck a length of $\frac{3}{16}$ in. brass rod and ease to .185 in. diameter, an easy fit in the recess over a full $\frac{1}{2}$ in. length, before reducing to .157 in. diameter over a $\frac{3}{8}$ in. length to be a press fit in the cone tube. Next centre and drill No. 56 to $\frac{9}{16}$ in. depth, following up at No. 54 and I will assume that you have the cone reamers by you, so enter the stubby end and open out to 3/32 in. diameter at the mouth. I prefer to do it this way round and then chamfer the end of the cone to produce a knife-edge, though builders can do so in reverse order if they wish. Part off at $\frac{7}{16}$ in. overall, reverse in the chuck and face to length, then use the long reamer to get the exit around 3/32 in. diameter. Don't press the cone in until the body assembly is complete, but I will assume for the moment that it is, when you repeat the procedure for the steam cone to be approximately 11/32 in. overall, the critical dimension being the 1/32 in. gap between the cones. Once satisfied, centre and drill No. 76 to $\frac{3}{16}$ in. depth, use the stubby reamer to arrive at the exit diameter of 3/64 in., taper to a knife-edge then part off, rechuck, face and drill No. 48 to $\frac{3}{16}$ in. depth to complete.

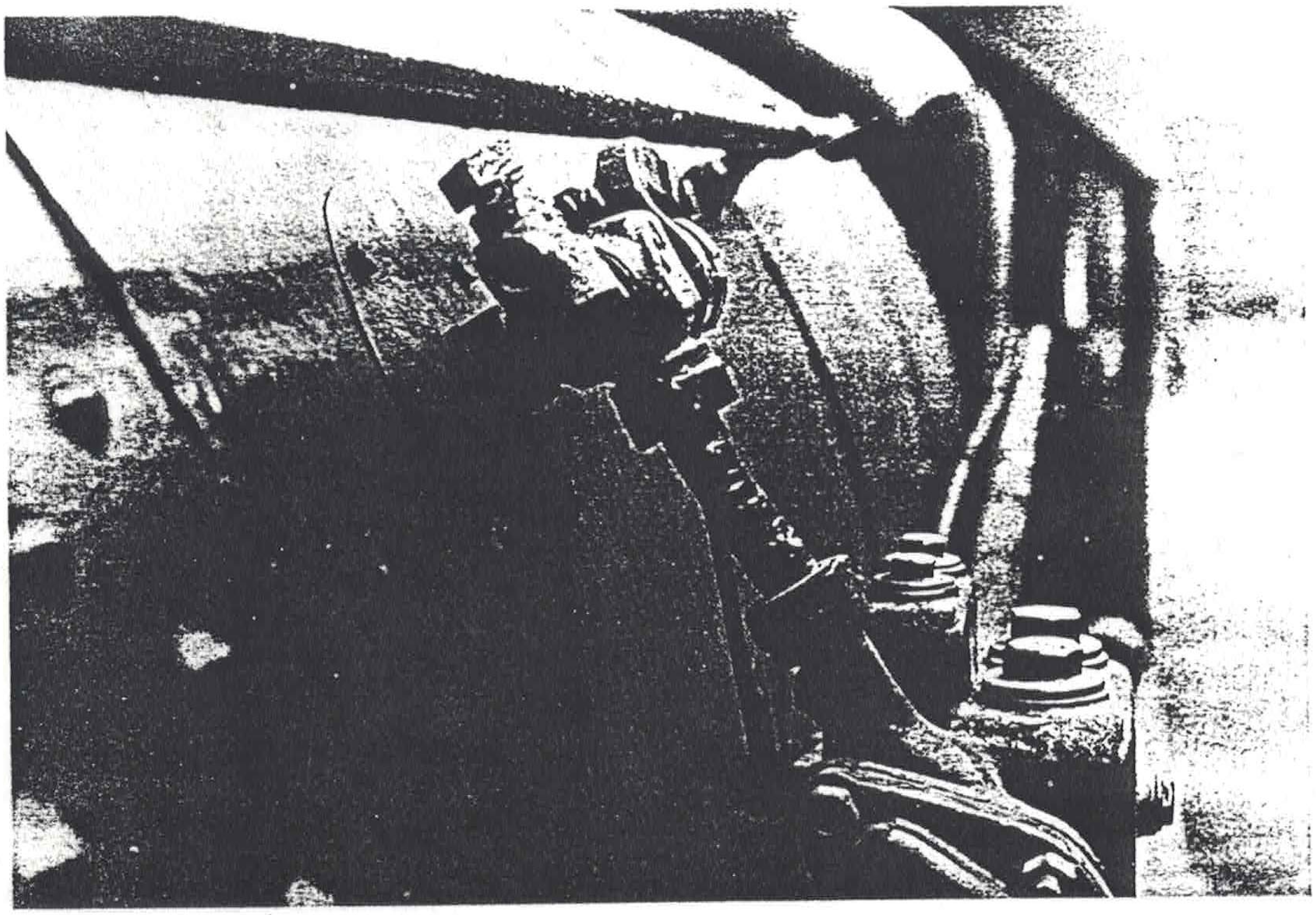
Now for the vacuum body, for which we need a machined block, size $\frac{7}{8}$ in. square x $\frac{5}{16}$ in. thick. Working this time from the back end, for the first chamber that will be used for the non-return valve, centre and drill through at No. 31. Follow up with a 7/32 in. drill and 'D' bit to $\frac{5}{16}$ in. depth, tap the outer $\frac{1}{8}$ in. or so at $\frac{1}{4}$ x 40T and run an $\frac{1}{8}$ in. reamer through the remains of the No. 31 hole. Move on $\frac{5}{16}$ in., centre and drill right through at No. 53. Follow up with a 7/32 in. drill and 'D' bit to 23/32 in. depth, again tapping the mouth at $\frac{1}{4}$ x 40T. Drill an $\frac{1}{8}$ in. hole to join the chambers, plugging the rear end, then reduce the overall length to 27/32 in. and height to $\frac{13}{16}$ in. Next offer up to the steam body and drill the No. 30 hole into the limit valve chamber, then scallop the rear end as shown to $\frac{5}{16}$ in. depth to accept the brake outlet. This latter is from $\frac{5}{16}$ in. brass rod and has a $\frac{1}{4}$ x 40T union connection pressed into the 7/32 in. recess. Right at the front we have to mill away 7/32 in. of bar to reveal the steam entry block. Drill the 3/32 in. hole to accept a length of thin wall tube, then that at No. 51 to connect to that in the steam body. Looking two views to the right you will see a flange of identical shape to that which is our next item for manufacture, so these can be made as a pair from 1.6mm and 2.5mm brass respectively. Mark off on one piece, drill and tap the 10BA holes, bolt together and then produce the shape, drilling right through at $\frac{3}{16}$ in. diameter, then separate and open out the hole in the thicker piece to $\frac{1}{4}$ in. diameter to slip over the cone tube. Assemble all the pieces, I would use a mixture of clamps and wire to hold them together, then silver solder all the joints, pickle and clean; not forgetting the steam supply pipe.
The caps we have dealt with before, so no need for repetition, save I recommend that for the limit valve be made in identical fashion, then chucked in a $\frac{1}{4}$ x 40T adaptor to drill through and ream at $\frac{1}{8}$ in. diameter. Cut and press in the spring guide, followed by the spring, 5/32 in. rustless ball and then the cap; deal with the non-return valve similarly and turn a wee pip on the cap to limit the ball lift if you wish. Fit the cones and complete this section with the closing cap and we have a vacuum ejector.

Handrail Stanchions

For the next bits I have to assume that the cab front is in place, as it will be shortly, but first we need some special handrail stanchions; commercially these were a disaster and should have been priced at around £10.00 each, so this will give you a good idea of the time you will spend over them. Incidentally, Norman Lowe discovered that another three of them are required for the R.H. side of the boiler as the main handrail is of bigger diameter than the others, so for 4 off read 7 off, though the other three will not require the No. 50 hole; some consolation! Chuck a length of $\frac{5}{16}$ in. stainless steel or nickel silver rod in the 3 jaw, form the 9/32 in. spherical end, then turn down the rest to drawing, including the $\frac{3}{16}$ in. stub to .110 in. diameter, this latter to be screwed 6BA after parting off. Screw the stanchion into a piece of bar, which latter can be gripped in the bench vice to file two flats on the 9/32 in. spherical end to bring it down to $\frac{3}{16}$ in. thickness. Next drill through at around 3/32 in. diameter, check that the hole is true and correct with a swiss file if not so, gradually opening out to No. 11 to accept a length of $\frac{3}{16}$ in. o.d. thick wall copper tube. Use this latter as a sight to drill the No. 50 hole to complete, then erect with large 6BA nuts under the lagging, although those with superior skills could braze tapped bosses to the boiler to emulate full size practice.

Coupling up the Vacuum Equipment

A nice and straight $17\frac{1}{2}$ in. length of $\frac{3}{16}$ in. o.d. x 18 s.w.g. copper tube is required for the brake valve pipe to slide into the handrail stanchions, but first we have to screw one end at 40T over a full $\frac{1}{2}$ in. length and reduce to 5/32 in. diameter over an $\frac{1}{8}$ in. length at the other, the latter so that we can fit a 5/32 in. plain union, using a ring nut as for the injectors. Another piece of the same pipe, with ends turned down again, takes us to the bulkhead union in the cab front, all this as per Sheet 1, then the last length of pipe takes us up to the top connection on the vacuum brake valve. Incidentally, although the top bend looks ridiculously tight on Sheet 1, this is simply because this view foreshortens said bend, it being of quite normal radius as it bends forwards as well as sideways.
Next job is to connect from the ejector steam supply lever back to its partner in the cab, so make up the pull rod ends, fulcrum and lever, none of which require description after what has gone before, in fact on E. S. COX there is quite a remarkable consistency of detail design, so somebody exer-



The ejector steam supply valve is screwed directly to the boiler barrel and connects with a short length of copper tube to the vacuum ejector.

setting the end piece over to align with the cab handrail, then slit a length of $\frac{1}{8}$ in. o.d. thin wall copper tube and fit over the top edges of the inset portion.

The cab handrail is another awkward piece, but I can see the reason why it does not extend right down to the running board as this would deny a foot-hold. Chuck a length of $\frac{1}{4}$ in. free-cutting steel rod in the 3 jaw with about $\frac{3}{4}$ in. projecting, face first though, then centre and bring the tailstock into play. Turn the 5/32 in. top, collar then undercut to 7/64 in. diameter. Although it is possible to turn on the taper, it is extremely difficult and I much prefer to rough file in about $\frac{3}{4}$ in. steps, until the taper extends over $3\frac{1}{8}$ in., then tidy it up to be regular, first with smooth files and then emery cloth. Part off to leave 7/32 in. at the original $\frac{1}{4}$ in. diameter, reverse in the chuck holding by the tapered portion and using paper between work and jaws, then turn down to 3/32 in. diameter to leave a $\frac{1}{16}$ in. thick collar and screw 7BA. Tap a piece of plate 7BA and grip in the bench vice, screw in the handrail and heat with a concentrated flame, bedding to 90 deg. as shown. Although finite dimensions are given for both the handrail and its fixings, it is best to drill the bottom hole in the cab side to place and then erect with a 7BA nut. Now at the top end, drill into the handrail at No. 55 and tap 10BA; there is plenty of metal here for a change so you can drill well past the centre we used when turning.

Because of the proximity of the spectacles in the cab front, it is not easy to attach to the cab sides with pieces of angle in the usual way, in fact a silver soldered joint is worthy of consideration; if this be your choice then of course delay fitting the spectacles.

Erect the cab side to its base using $\frac{1}{4}$ in. brass angle, rivetting the angle to the cab side if possible for the neatness this gives in lieu of a row of countersunk screw heads, then screw down to the base. The next part is crucial, this to inspect that the lagging and in particular the cleading ahead of the cab, leaves at least a $\frac{1}{16}$ in. gap to allow for expansion; trim away if necessary to achieve this gap. To hide such an unsightly blemish, do exactly as full size and rivet 5/32 in. brass angle directly to the cab front as shown on Sheet 1.

The cab window slides can either be fabricated or milled from $\frac{1}{8}$ in. x $\frac{1}{4}$ in. brass bar, the notes on the drawing detail explain its use. Make up the windows as for the spectacles, offer up to the apertures and clamp the slides in place. I say on the drawing to fix the slides to the cab sides with 10BA bolts, if so then the hexagon heads will be inside, though rivets can be substituted if you wish; the front window is definitely rivetted to the dab side. We are messing about with all the odds and ends when the most important job of all remains outstanding, that of mounting the reverser, in fact I have already boxed it in with the casing in front of the cab!

Cut the top of the reverser stool to drawing from 1.6mm steel and pack it up $1\frac{5}{16}$ in. from the running board, poking it through the cab front; this will give you the best idea of what is involved. All the vertical members of the stool are $\frac{1}{8}$ in. (or 3mm) thick, both to make the stool itself substantial and for tapping into, so make up the pieces, add the $1\frac{1}{4}$ in. length of brass angle to the inside face and braze up; clean and zinc spray. Now erect and use as many screws and rivets as you feel necessary to make the whole structure a solid one, but before fixing permanently, offer up the reverser stand, spot through, drill and tap 7BA; at last we have an engine that will work!

Cab splashers are dealt with as for the reverser casing and fixed with 10BA screws, or self-tappers if you wish, then lay the wooden floor to be $\frac{3}{8}$ in. above the base plate. A vertical cross piece is required across the back end as attachment for the fall plate, the latter with a slight radius as shown and back end filed to fit snugly to the tender. Check the $1\frac{1}{8}$ in. dimension just to make sure that the fall plate cannot be trapped between engine and tender when E. S. COX is pulling hard, then make up three more miniature hinges, rivet them to the fall plate and screw to the wooden floor. For the cab seats, take a $2\frac{5}{16}$ in. length of $\frac{3}{16}$ in. steel rod, turn up the fancy bit from $\frac{3}{4}$ in. diameter bar, then the seat itself from hardwood, glueing together and fitting into No. 11 holes drilled in the wooden floor. Distance out from the centre line is a round $3\frac{1}{2}$ in. and the back of the seat is about $\frac{1}{4}$ in. ahead of the cab side recess, though no crew is going to worry about the odd thou here!

All we have to do now is close the cab to the elements and again I would use stiff card to establish the size and shape of the roof, transferring then to 1.6mm steel sheet, cutting out and bending to place. The edge of the roof is mitred to match the cab sides, no overhang at all here, and the $\frac{3}{16}$ in. x $\frac{1}{16}$ in. strip continues up from the rear edge of the cab side, right to the back corner of the roof. The back edge of the roof is supported by 5/32 in. brass angle on its upper face, reinforced by another length on the inside but sited $\frac{3}{8}$ in. forward as shown. The centre stiffener is a massive 1.6mm one from $1\frac{3}{4}$ in. wide strip; cut to fit to the cab roof and to the dimensions shown. It can either be sweated directly to the cab roof, or more lengths of 5/32 in. brass angle used for fixing with 3/64 in. brass rivets. Check as you go along that the profile continues to match both cab sides and front, or you will be in real trouble. The gutter angles are self-explanatory and again can be rivetted or sweated to the cab roof, when you can cut a $1\frac{1}{2}$ in. square hole in said roof for the ventilator and build around it with $\frac{1}{4}$ in. brass angle, mitring the corners and sweating the whole in place. The ventilator is bound to get in the way of a sleeve at sometime, so will be best as a silver soldered fabrication. Cut a piece $2\frac{1}{8}$ in. x $1\frac{15}{16}$ in. from 1.2mm brass and fold the ends to $\frac{1}{4}$ in. radius before trimming off. Cut end pieces and lugs, the latter with slotted shole as shown, pack carefully, silver solder, pickle and clean then erect to the cab roof with 10BA bolts.

Now you must judge if E. S. COX can be driven with the roof in place; if not then there is a simple solution. Full size that cab stiffener was a joint between the main and rear sections of the roof; once the rear section had been removed, lifting gear could be affixed to the drag beam, as per Page 26 in LLAS No. 21. We too can cut our roof into two pieces, with a centre stiffener at the joint and bolting together, only of course they become end stiffeners. That way the main portion of the roof can be permanently attached to the sides by medium of doubler strips, say $\frac{3}{8}$ in. wide and 1.2mm thick.

Although initially some of the 'Crabs' were painted in early LMS passenger livery, for most of their long lives they were 'black engines', more attractive to my eye in BR days with their secondary passenger style of lined black livery. I am not going to tell you how to paint your E. S. COX, but hope that Geoff Swift of Ashdown Models will tell us something of the art one day.

This has been an exciting series for me in paying tribute to a man who has been both a help and inspiration over more than 20 years. All good things though as I said earlier, must come to an end and in one respect this is a blessing, for running two series simultaneously on large 5 in. gauge engines is not everyone's cup of tea, yours truly included.

I am hoping to be able to relinquish this particular spot for a wee while to promote another of our advertiser's design, in fact several most interesting designs have been produced commercially of late, any one of which would enhance our Magazine, so maybe a public invitation to make use of this space will work? If not then I reckon there are sufficient DYD's already in existence to last another 25 years and more, without introducing any new ones! New ones there will be though of course, but just like 10 years ago pressure of work stopped me building, so now it is increasingly difficult to find sufficient hours in the day to uncover the drawing board. never mind put pencil to paper. When I retire . . .

then it is a case of completing the profile with files, noting that for a change the radius is a plain one instead of being spherical. Fit the shackle pins to the coupling screw, trap the lower one with a 6BA washer, peening over the end of the screw, then for the upper end, turn up a collar 7/32 in. o.d. x $\frac{1}{8}$ in. thick and tapped centrally at 5BA. Fit to the coupling screw and I would then cross drill at No. 60 for a 1mm diameter spring pin to secure. For the screw bar, take a $1\frac{3}{8}$ in. length of $\frac{1}{16}$ in. steel rod and turn down to 3/64 in. diameter for $\frac{1}{8}$ in. at each end. Blind drill a 5/32 in. ball at No. 56 to accept one end, a 3/32 in. thick collar at the other; silver solder on the ball then erect and peen over as shown at the other end, when we reach the piece that always causes most of the problems, the lower shackle.

This time we are very fortunate though, for the eyes are not radiused, so face off a $\frac{1}{2}$ in. length of $\frac{1}{4}$ in. steel rod, centre and drill through at No. 30. Take a $2\frac{5}{8}$ in. length of 5/32 in. steel rod and turn down the centre portion to 7/64 in. diameter. letting the very ends blossom out to the original 5/32 in. diameter to form a blending radius with the eye. Bend up, file the ends to match the eyes, then braze up and saw out the unwanted centre portion. The shackle is quite long, so will splay out fairly easily and should fit over the spigots on the shackle pin, though if there is a problem, simply open out the eyes to No. 29. Erect and peen over the shackle pin ends, dealing with the upper links in like manner.

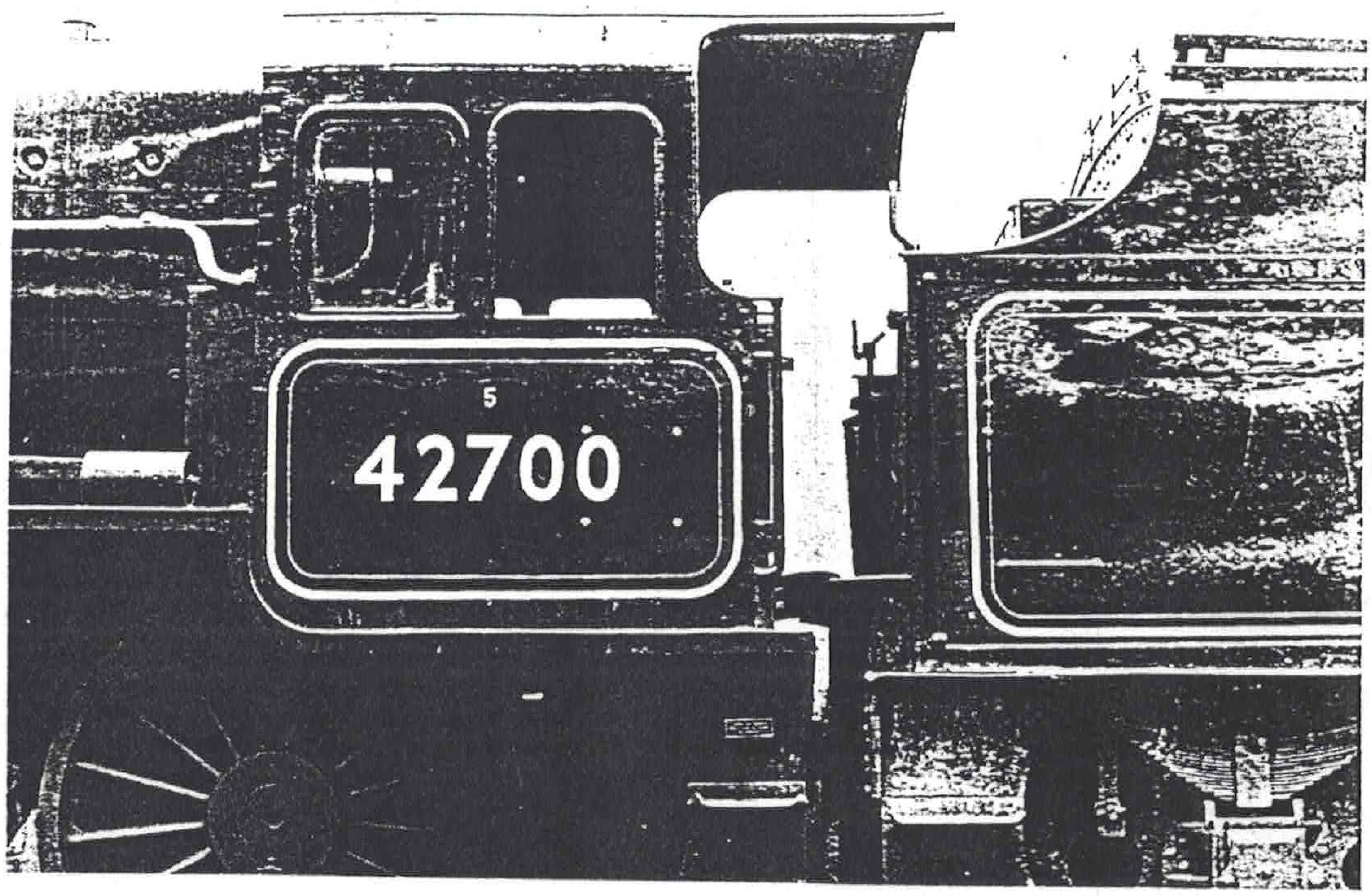
So that we can fit a screw coupling to the tender when E. S. COX is being exhibited, a socket is required to marry up the hook with the beam. Start by chucking a length of $\frac{3}{8}$ in. square bar truly in the 4 jaw, centre and drill No. 3 to $\frac{1}{4}$ in. depth before parting off a $\frac{3}{16}$ in. slice. File out this hole to a 7/32 in. square to suit the hook, then grip in the machine vice on the vertical slide, to reduce to $\frac{5}{16}$ in. square over an $\frac{1}{8}$ in. length with an end mill.

The Cab

Unless I am mistaken, everything remaining is in the cab area, so let us adjourn there for the last push to completion, beginning with the cab front. Although there is a little lattitude in the fit to the boiler by reason of the backhead cleading and surround. it is a nice feeling to achieve a neat fit here, so use a cardboard template, transfer to the 1.6mm steel sheet and cut out. The centre joint will be a butt one, so rivet a $\frac{3}{8}$ in. wide doubler to one piece and use 8 or 10BA countersunk screws to complete the joint, only we have a lot to do ahead of final assembly. For the R.H. side, the easy one first!, cut out the window aperture, followed by the frames. clamp the latter over a sheet of mica or similar material and trim to match said frames. Now erect the whole to the inside of the cab front, drill and secure with 1/32 in. brass rivets.

On the L.H. side we have holes to drill for the brake valve vacuum pipe, the ejector steam valve lever fulcrum and pull rod, all a bit tense as space is limited, then a large cut-out to clear the reverser, after which we can go outside and tackle the reverser casing. I broke off at this point to deal with the day's post and in the 10 hours or so I have been able to give a lot of thought as to how I would make up the casing. This morning I would have made up a wooden former block and built the casing around it; now I favour fitting the flanges, 7/32 in. x 1.2mm strips of brass, directly to the cleading, cab front and running board with self tapping screws, then building the box onto the flanges, clamping to place and soft soldering the seams. The cut-out for the reach rod completes another item.

Cab sides next and they are rather involved, but then E. S. COX will tax builders skills to the very end. At the rear end of the cab side there is an $\frac{11}{16}$ in. set which nominally matches up with the much narrower tender, then the side sheet turns back again for another $\frac{1}{4}$ in. I can see no better way than to make this from a single piece of 1.6mm steel sheet, in which case size is $6\frac{9}{16}$ in. x $6\frac{5}{16}$ in. Mark off and saw out, bending up to drawing before cutting the window apertures, these latter being trimmed with 3/32 in. half round beading which is sweated to place. I am sure readers can see that the main side running board could be extended by $1\frac{1}{4}$ in. to avoid the separate piece attached to the cab side, but I have done it this way for the extra strength it provides at an otherwise weak point as it is not so easy to attach to the curved section of running board. Either make the extension in two pieces, or fold up from a single piece, cut out to clear the rear coupled wheel and then silver solder to the cab side, rather than using soft solder, for the additional strength this provides. Use $\frac{3}{16}$ in. x $\frac{1}{16}$ in. brass strip as edging at the back of the side sheet proper,



This cab side view is as good as any with which to say goodbye to E S COX, though I hope she will feature in "Builders Corner" in the future. It also allows me to say a big thank you to Norman Gregory for all his fine work in illustrating the series.

operation is to drill the four No. 41 delivery holes and these must be spaced accurately to leave sufficient metal between them to avoid the possibility of a disaster. For this reason, instead of cross drilling right through in the usual manner and maybe getting a hole out of position as a result, deal with each hole individually into the centre bore, then remove all burrs before brazing in the 19 in. long delivery pipe; erect to the boiler.

Drawbar

Neither drawbar or its pins pose any problems, save that the drawbar ends should be welded if at all possible to the 7/32 in. steel rod, which means that all three pieces should be from welding quality material, not the free cutting variety. I suggest you make the tender drawbar pin so that it is trapped and cannot come out inadvertantly, the engine one with a 6BA bolt fitted so that the head comes flush with the wooden cab floor, when you will be able both to extract it easily, and see if it is working out in service, though thank goodness the latter is extremely rare.

Platework

Although the valances are fully detailed, many of the dimensions will of course have to be checked to place. At least the radii to which the $\frac{1}{4}$ in. x $\frac{1}{4}$ in. x $\frac{1}{16}$ in. brass angle has to be bent are generous, though if any cause problems, simply cut the offending piece away and cut from plate to fill in. Ahead of the cylinders the running boards are of course somewhat narrower and as there is a special feature on the latter which I will come to in a moment, the horizontal piece of angle which matches the smokebox is important. I suggest you build up the valances on the engine, clamping the joints or using doubling strips and rivetting toegther, then when you are satisfied, silver solder everything together; erect to both front and drag beams as specified.

Full size the running boards were a massive $\frac{3}{8}$ in. thick, almost twice the norm, but even so this only works out at a scale 1/32 in. thickness, though our 1.6mm material will not look so much out of place for a change, in fact it will look just right. The upper section of running board not only sits on the cross pieces of valance, but also on those brackets we fitted to the cylinders, plus the top of the motion plate, so will be really firm. The inner edge is of course a close fit to the boiler and smokebox, and a piece of $\frac{1}{4}$ in. brass angle across the rear end will allow us to attach the continuation of the running board back to the cab, this latter portion sitting on top of the frames for much of its length so is also well supported, plus there are a pair of substantial brackets. The cab area you can best work out to place, but basically it fits to the frames, with cut-out to clear the rear coupled wheels, the extent of which will become clear when we make up the splashers and their boxes. All this brings me neatly back to the front end, where the fancy bits occur.

For the side running boards at the front, cut two pieces $3\frac{9}{16}$ in. x $1\frac{7}{8}$ in. from 1.6mm steel or brass sheet, then drill all the holes to drawing. Attachment to the valance is by $\frac{1}{16}$ in. rivets at $\frac{5}{16}$ in. pitch, although raised countersunk head screws make a fine alternative, with slots filled in with Isopon P38 or similar, as this means nil distortion when fitting together, plus the ability to take apart should you be unfortunate enough to damage the platework. Grab rails we have already made on the tender, small hinges too, and the lamp irons are bent up from strip and shaped as per the tender; fix to the running boards. Now comes the clever bit; the curved portion ahead of the cylinders is hinged to allow access to the piston valves, and we may as well emulate said feature.

Cut a piece $4\frac{1}{4}$ in. x $2\frac{7}{16}$ in. from 1.6mm material, then cut away at the outside to drawing to leave the main portion at $1\frac{7}{8}$ in. width; bend up to suit the valance and trim away the excess to give a neat joint at the hinges. If this portion of the running board is made to full profile, then when it hinges forward it will foul the smokebox shell, so has to be cut away as shown and this is best done to place to arrive at the necessary clearance. That leaves a small, fixed, portion to support and as it is also best if the hinged portion also rests in a 'cradle', then make up a duplicate of the front portion of the valance and bolt to the frames, rivetting the fixed portion of running board to same. Bend up the step from 1.2mm material and rivet to the running board, when we can rivet the latter in turn to the hinges to complete. The centre section of running board between the frames is a flat plate extending back to the smokebox saddle.

Normally when a full size design reaches this stage it is heavier than the original estimate, so the superstructure can be rather skimpy. Those $\frac{3}{8}$ in. thick running boards show that all was well with the Horwich 'Crab' and this continues to be in evidence in the massive backplates for the steps; note particularly their symmetry. We have already dealt with those on the tender, so simply make pairs to the new dimensions and attach to the running boards.

Most builders leave the cab to last, though really we wanted part of it ages ago to locate the reverser, but let me deal with the screw couplings next, for they add the final touch of class.

Screw Couplings

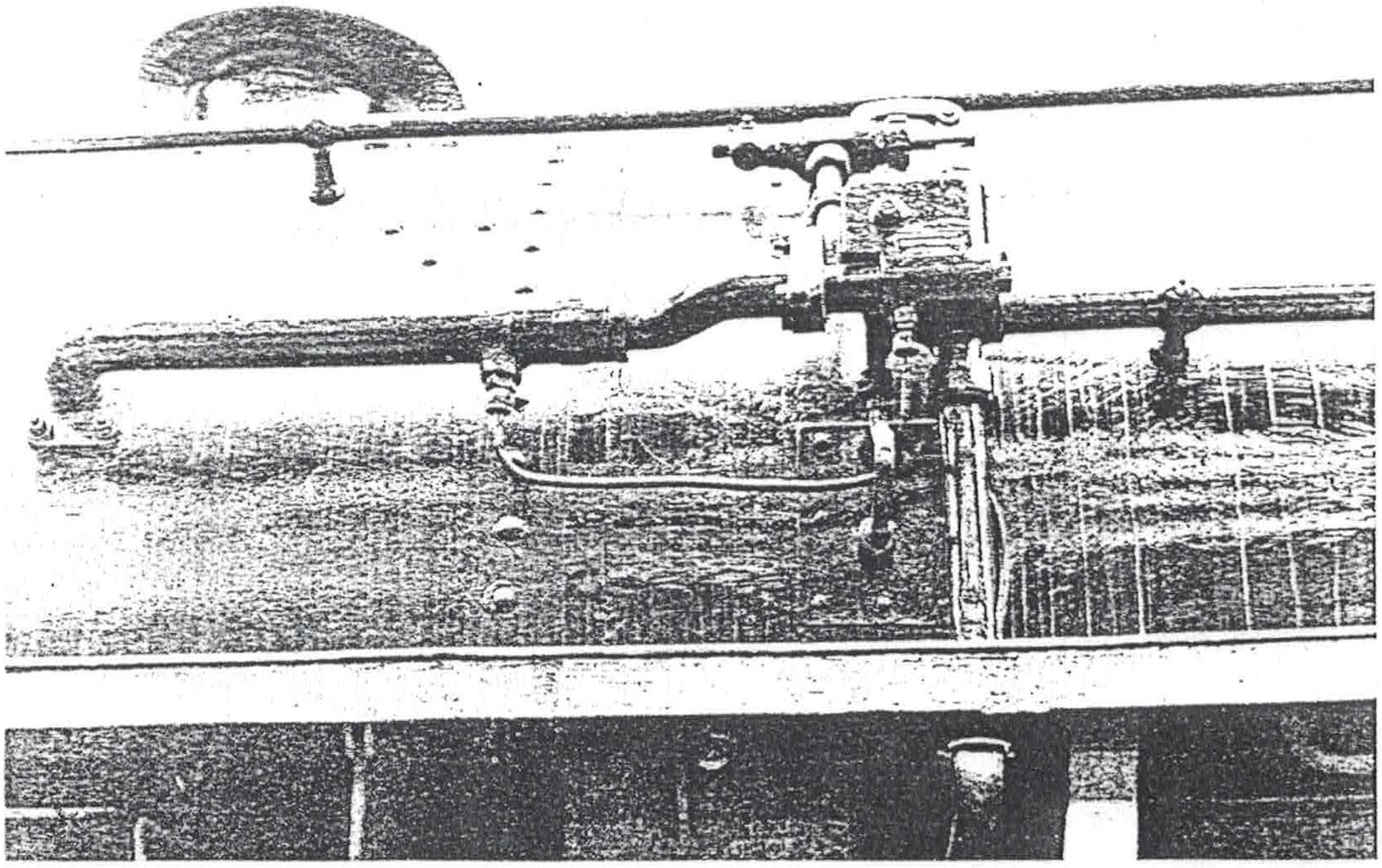
Just one word of warning – do not employ the screw couplings for hauling the passengers that E. S. COX will be able to manage in quantity, otherwise you will be sitting on the driving truck and waving goodbye to her! Mention of the driving truck reminds me that after all the pressure put upon me to design and describe something suitable, as I did in LLAS No. 9, to date sales of this drawing have been a disappointing 50 or so, though as it can be built directly from the Magazine and I have only handled a few sets of castings for overseas customers, taking my supply from Reeves, possibly I do not have a true picture of its popularity or lack of same.

Back to the coupling and let me start with the hooks, for which we need two pieces of good quality steel, size $2\frac{1}{4}$ in. x 1 in. x 7/32 in. (or 6mm.). Scribe on the centre line, mark off and drill a 7/32 in. hole to start forming the hook, then move on 9/32 in. and drill another at No. 27 for the upper link pin. Chuck truly in the 4 jaw with about $\frac{1}{2}$ in. projecting and turn this down to $\frac{3}{16}$ in. diameter, screwing the end $\frac{3}{8}$ in. at 2BA. Move on in two stages to arrive at a finished length of shank at 1 7/32 in. The next part is the $\frac{3}{8}$ in. length at 7/32 in. square to suit the buffer beam, then mark off, saw and file the hook profile. Regrettably 42700 was hard against a coach at York and it proved impossible to photograph the hook from an angle which showed its cross section, but basically a hook is right when it looks right to your eye, and showing its section at various points is of little help.

Several of you were kind enough to tell me that the perfect material for shock absorbers on DONCASTER was the humble $\frac{1}{2}$ in. tap washer, even the central hole is the right size! So now I am looking at you for further inspiration as to a source for the rubber spring depicted hereabouts. Turning up the end plates from 2.5mm material is easy; the upper links and their pin too. The slot drawn in the latter is 7/64 in. x $\frac{1}{16}$ in. section; for the mating cotter take a $\frac{1}{2}$ in. length of 5/32 in. x 1/32 in. steel strip and fold it double, hammering flat. Now all you do is file down 9/32 in. of the length to 7/64 in. width to suit the slot, then insert and open out the tabs to secure; the cotter is then exactly as full size.

The coupling screw is plain turning, which brings us nicely on to the shackle pins. Chuck a length of $\frac{3}{8}$ in. x $\frac{3}{16}$ in. steel bar truly in the 4 jaw, face and turn down to $\frac{1}{8}$ in. diameter over an $\frac{1}{8}$ in. length. Part off at $\frac{9}{16}$ in. overall, reverse in the chuck, face off to 17/32 in. length and turn on the second spigot. Cross drill to drawing, tapping the lower shackle at 3BA.

This foreshortened view from ground level shows all the vacuum equipment, save for the brake valve in the cab.



cised good control over such things in the Drawing Office at Horwich. The fulcrum rivets to the bottom of the pair of holes in the L.H. cab front, the lever being secured with handle upwards by a 3/16 in. plain length of 3/32 in. steel rod. Feed in a 19 in. length of 1/16 in. stainless steel rod from the front end through the holes provided in the handrail stanchions, opening out the latter as far as No. 48 to obtain freedom of movement. Assess the final length required, cut to suit and screw both ends 10BA over a 3/16 in. length and erect. Use thin 10BA nuts if you wish to positively trap the rod ends, then fit 1/16 in. snap head brass rivets as pins, cross drilling for 1/32 in. split pins to complete; you now have something good to look at for your efforts thus far.

On to the ejector elbow, the majority of which is 5/16 in. brass rod drilled centrally at No. 22. To obtain the tight radius at the smokebox end, I have shown what in coppersmiths language is called 'lobster backing'. I expect builders can see that if the single mitred section I have shown is increased to three smaller pieces, then this will make life a lot easier afterwards in blending them together with a file. 'D' bit the inlet end at 7/32 in. diameter to 7/32 in. depth and tap the outer 1/8 in. at 1/4 x 40T, then turn up the drain connection and press home to face vertically downwards. At the smokebox end, turn a 1/4 in. spigot over a 9/32 in. length of the 5/16 in. rod, make up the 1/2 in. square flange from 2.5mm thick sheet, fit a 3½ in. length of 5/32 in. o.d. thin wall copper tube at the outlet end and silver solder the whole together. Erect to the smokebox shell with 8BA bolts, bend the outlet pipe up into the petticoat pipe, shortening it if necessary to avoid interfering with the main exhaust flow, then fit a male union to the drain connection and run a 1/16 in. or 3/32 in. pipe down between the frames to get rid of condensate clear of the motion. We have already made the flange and neither ferrule or nut need tax us. Braze a 1 in. length of 3/16 in. o.d. thin wall copper tube to the flange, then double set the tube so that it enters the ejector elbow, shortening as found necessary to come just clear of the bottom of the 7/32 in. recess. Remove, slide on the nut and ferrule, then erect again and tighten the nut to trap the pipe with the ferrule; apply a drop of liquid jointing if there is a chance of leakage here.

The positioning of the main train pipe, 3/16 in. o.d. thin wall copper tube, is best left to the builder so that it can be placed clear of all obstructions. Basically all it has to do is tie up with the standpipes on engine and tender, plus the pipe coming downwards from the ejector as shown on Sheet 1. For the elbow(s), and you can use these as a standard feature, reduce a length of 1/4 in. brass rod to 15/64 in. diameter, then centre and drill No. 22 before tapping 3/16 x 40T. Saw off two 11/32 in. lengths and mitre to form the elbow, silver soldering together and then running the tap through to remove any stray spelter. The standpipe itself is 3/16 in. o.d. copper tube; you can directly screw the 18 s.w.g. wall at 40T. Turn up the brass collar, this can be sweated in place, then bend the top end as shown, opening out the bore with a No. 27 drill to aid said bending. No need to describe the hose and dolly as magnificent examples of these are obtainable from Doug Hewson; I have a pair of them in front of me as I write this. Complete with a triangular flange to fix to the running board with 10BA bolts, then make up a clip from 7/32 in. x 1/32 in. brass strip to hold the dolly in place. The end of the dolly is a rubber bung to seal the pipe when not connected to the train, as it rarely will be at the front end.

Coupling up the Injectors

Most builders thus far have already taken delivery of their injectors, so can couple up as shown. I have now standardised on a medium horizontal, which means the piping will have to be slightly altered and although this is a definite disadvantage, it is more than outweighed by the reliability of the injector itself, which is far less susceptible to failure through air ingress in the suction system, as the total lack of telephone calls from users this past year bears witness.

This brings me on to the injector delivery clack banjo bolt that I could not squeeze onto Sheet 10. Chuck a length of 1/2 in. phosphor bronze rod in the 3 jaw, face and turn down to 5/16 in. diameter over a 5/8 in. length. Change to a round nose tool and further reduce to 1/4 in. diameter over a 3/16 in. length to leave a 5/64 in. shoulder at the flange end. Next centre and drill No. 30 to 11/16 in. depth, following up at No. 11 to 1/2 in. depth for the 3/16 in. delivery pipe to go forward to the front of the barrel. Screw the outer end 40T over a 1/4 in. length then part off at 23/32 in. overall and rechuck in a screwed adaptor. Face off and turn the flange to drawing, tap 5/32 in x 40T to 5/32 in. depth and turn up the, rodding, plug to suit. The last