Doncaster — a 5in. gauge Gresley A1/A3 'Pacific'

by: DON YOUNG

Part 4 – Tender conclusion

Sheet four is very much a tidying-up exercise on the tender, plus setting the scene on the engine itself, with just a glimpse of what is to come, but before we get into the session for real there are just a couple of points that have come up in conversatson and correspondence. First has been your positive reaction to the appearance of the outline of MALLARD in LLAS No. 19; such has given me a lot of pleasure and encouragement. Several of you have already embarked on building her as she was in the 1950's when I knew her so well, and although the removal of the majority of the skirting does pose a few problems, like some alteration to the cylinders and a different type of steamchest cover/valve crosshead guide, the will certainly exists to overcome these, plus there is promise of photographs as progress is made; all very exciting. Also some of you have been bright enough to make comment about 'engines and tenders facing the wrong way', having been brought up the same as I that Drawing Office tradition says Locomotives face left and Ships face right. Thing is that Doncaster D.O. for some reason drew most of its Locomotives facing right, don't ask me why, but at the outset I decided to follow suit if only to emulate full size. It worked O.K. for DONCASTER as drawn circa 1933 when she was R.H. drive, but in 1963 when she had changed to L.H. drive I turned the engine round to show the driver's side, ditto with MALLARD and the tenders too. When I set out on detailing, the tender frames faced right, but when I came to the body I had to turn it round so that the front view of the tender, with its deep well, came clear of the title block on Sheet 3. Basically though the major assemblies and details do face right and although 'different', should not cause confusion. One thing I must say – you know how to keep me on my toes!

Brake Gear (continued)

We left the brake shaft and some of the beams rather suspended in mid-air at the end of the last session, for lack of concluding details, so let me attend to this first. The two plain brake hanger ends are simple turning; treat the other four similarly then cross drill at No. 52 before parting off. Grip in the machine vice, on the vertical slide, use a No. 52 drill to set level, then mill away the two flanks to accept the brake beam forked end. Mill the top and bottom faces then complete by milling the end radius over a mandrel with an end mill.
Cut the brake shaft trunnions from $\frac{1}{8}$ in. or 3mm steel plate and drill the $\frac{1}{4}$ in. hole for the shaft end; turn up the bearing and bolt in place, then cut the two ribs and fit before brazing together. Erect with the shaft to the frames, drill through the No. 44 holes and secure with 8BA bolts.

Handbrake

The handbrake assembly is straightforward and appears on Sheet 2, but the details require a section all to themselves; let us start at the bottom and work our way up.
For the handbrake link, take a $2\frac{3}{4}$ in. length of $\frac{3}{4}$ in. x $\frac{5}{16}$ in. BMS bar and drill $\frac{5}{16}$ in. diameter in the centre of the $\frac{3}{4}$ in. face at about 11/32 in. from one end. Move on $1\frac{3}{8}$ in. and drill a row of No. 24 holes to rough out the $\frac{3}{4}$ in. long slot, completing with a 5/32 in. end mill. Next mark on the profile, saw out, radius the end over a mandrel with an end mill, then mill the flanks. The $\frac{3}{16}$ in. and 5/32 in. slots extend virtually throughout the whole length of the link, with just a $\frac{1}{8}$ in. bar, which suggest fabrication as an alternative; saw and file to complete.

The nut starts life as a length of $\frac{5}{16}$ in. bronze rod; chuck in the 3 jaw, face and turn down to 5/32 in. diameter over a $\frac{1}{16}$ in. length. Part off at a full $\frac{5}{16}$ in. overall, reverse in the chuck, face and turn on the second spigot. File two flats on the centre portion to arrive at 5/32 in. thickness, so the nut will enter the slot in the link, then centre pop the middle of a face, drill No. 29 and tap 5/32 x 32T.
Although the brake spindle can be fabricated from two or three pieces, I favour turning it from a single $6\frac{13}{16}$ in. length of $\frac{5}{16}$ in. steel rod. Start by reducing the first $1\frac{1}{2}$ in. to 5/32 in. diameter, in about $\frac{1}{2}$ in. increments and screwing 32T, then proceed the same way to reduce the next $4\frac{1}{2}$ in. to $\frac{1}{8}$ in. diameter. Reverse in the chuck, face off to length, and work back to the 9/32 in. diameter collar to complete.
For the bearing housing, chuck a length of $\frac{7}{16}$ in. diameter steel bar in the 3 jaw, face and with a round nose tool, turn down to $\frac{5}{16}$ in. diameter over a 9/32 in. length; centre and drill through at No. 11. Part off at a full $\frac{1}{2}$ in. overall, reverse in the chuck, face, drill $\frac{5}{16}$ in. diameter to $\frac{1}{8}$ in. depth and complete with a 'D' bit to $\frac{3}{16}$ in. depth. The support plate is from $\frac{1}{2}$ in. x $\frac{1}{16}$ in. steel strip, shaped as shown and silver soldered to the housing; erect the pieces made so far, drill the No. 44 holes, spot through onto the tender front, drill No. 50 and tap 8BA for hexagon head screws. The thrust washer is a composite of steel and PTFE, which can be bonded together although such is not essential.
Coming to the brake handle, cross drill a length of $\frac{1}{4}$ in. steel rod at about 5/32 in. from one end, bend up the handle itself from 3/32 in. rod, rounding the ends as shown, locate in the centre boss and braze up. Chuck the $\frac{1}{4}$ in. rod in the 3 jaw, face down until the handle comes flush with the boss, centre and drill No. 28 to $\frac{1}{4}$ in. depth before parting off at $\frac{3}{16}$ in.; erect to the spindle and pin to complete the assembly.

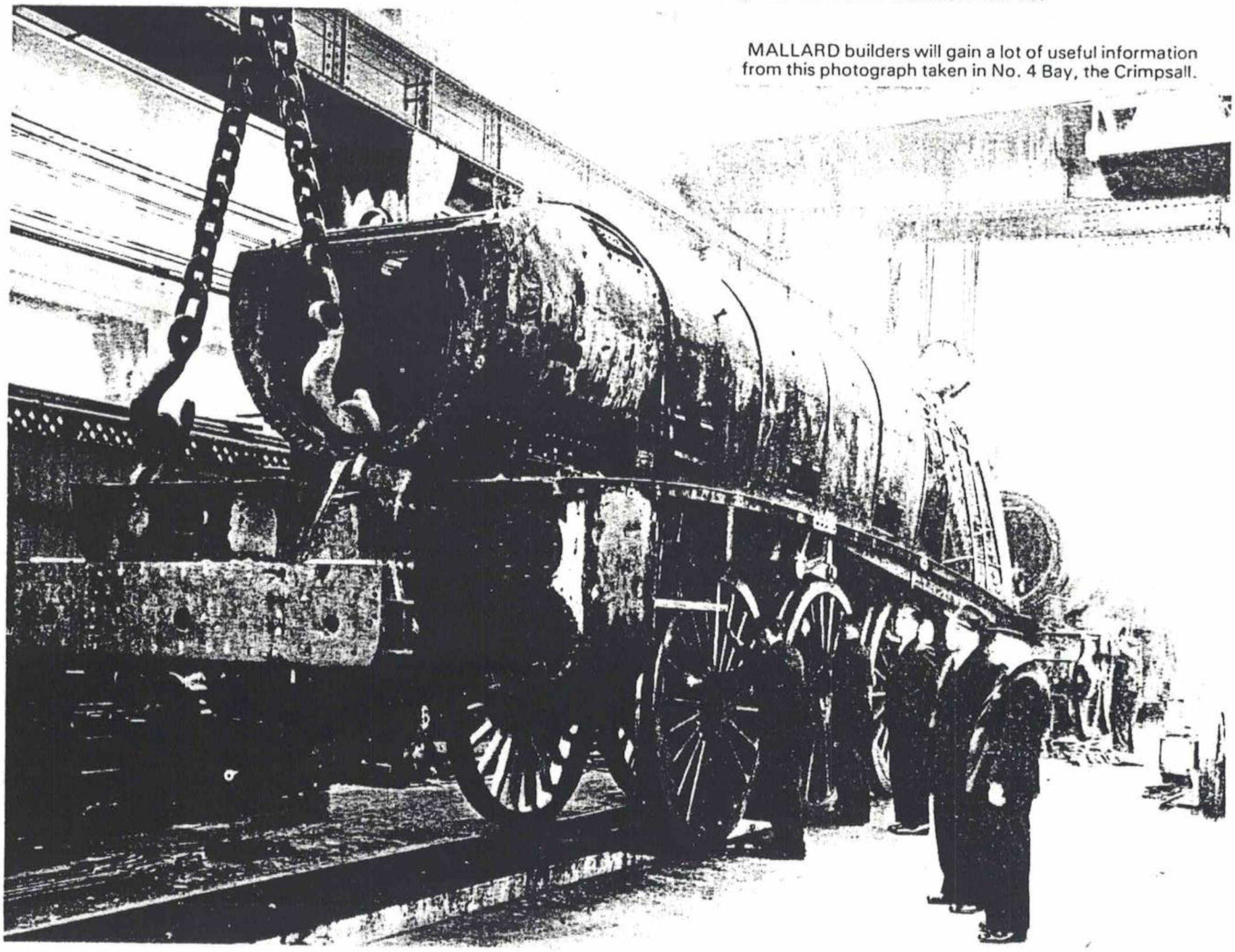
Vacuum Brakes

I think most readers are now well aware that in full size, vacuum brakes and yours truly very rarely hit it off, indeed it was on MALLARD that my youthful confidence took a nose-dive. As an apprentice I went with her to Barkston on trials, what a thrill!, and more so when the trials driver invited me to have his seat and take her round the triangle. A subtle reason for such invitation is that the reverser on a newly refitted 'Pacific' can be stiff and winding from full fore to full back gear requires some effort. but really these were kindly men allowing an apprentice to enjoy a little the fruits of his labour. Anyhow, I set back off the East Coast main line and round the curve onto the Lincoln line at a brisk pace, braking nicely to a halt just past the calling-on signal. Winding MALLARD into fore gear, off came the signal and I eased her forward, for the driver had asked me to stop by the signal box to replenish the signal man's coal supply. In what I judged to be the right spot, I made a brake application – and nothing happened – we rolled straight on past the box with me giving a full application. Luckily the road was set and so no harm was done, except to my ego, but I had overshot the mark by a considerable margin, such that I asked the driver if I should set back again – no way! To this day I do not know why that first application had no effect, but even light engine with a clear road it is disconcerting, and of course ever since I have had the tendency to over-react when using the vacuum brake.

All this happened years before I sampled the Westinghouse air brake, which I took to with such aptitude that many of the 02 drivers on the Isle of Wight gave me complete freedom of use; it was nice to stop where I wanted to! There was an amusing side to this in that on Sunday mornings we would travel from Cowes to Ryde Pier Head and pick up the 11.18 a.m. 'express' to Sandown, riding in the front guards van. On this occasion Driver 'Nelson' was in charge, set off down the pier and despite the guard's green flag waving frantically at the rear, stopped at the Esplanade. I got out and told Nelson he was 'first stop Sandown', but it did not register, for he stopped again at Ryde St. Johns and of course yet another crowd boarded; the train was packed solid. At Brading, Nelson eased right up but then rolled through, then really hammered on towards Sandown. Here he barely eased, took the staff from the startled signalman Syd, and the next thing I heard was the 'clack' of the slide valves as they reseated with Nelson throwing the regulator wide. Thanks to the skill I had acquired on the footplate, I was able to stop the train alongside the platform using the brake cock in the guards van, a secret I managed to keep to myself for some weeks. The comment made by Driver Nelson to his mate as hundreds of passengers decamped was a classic 'I suppose we were supposed to stop here?'

Not many weeks later there was a similar and potentially more serious incident. Again I was riding in the front guards van, this time between Brading and Ryde St. Johns. Coming over the hump in Whitefields Woods, the driver closed the regulator, dropped No. 17 into full gear and coasted down the bank towards Smallbrook Junction with both driver and fireman, both extrememly competent men in my opinion, standing at the rear spectacles and seemingly keeping a good look-out. Through the same spectacles I could see that the outer home signal at Smallbrook was at danger, yet we just ran past with no action at all taken on the footplate. This time I did not touch the brake, thinking there must be some special ruling in force as the crew were so obviously alert. But I was wrong and it took an emergency brake application, plus reversing the engine and opening the regulator, to avert a disaster. This was in broad daylight on a lovely late summer's evening, and it set me thinking about those unexplained accidents in the early 1900's at Shrewsbury, Grantham and Salisbury.

Anyhow, my lack of confidence in the vacuum brake full size led me to make the statement when describing COUNTY CARLOW the engine back in 1969, that said vacuum brake would be a waste of time. It brought forth a tirade from Brian Hughes, designer of a most successful TRAIN vacuum braking system, though after this initial crossing of pens, Brian has become a firm friend, one of the many I have come to rely on to keep me posted with some of the advances in miniature design now that my own experimentation has been halted. There is some hope for the future though, as the earthworks and drainage for the garden railway are vitually complete – soon I can think about laying track! Brian shares my love of Locomotives large and small, for besides being a competent and gifted model engineer he is also a volunteer driver on the Welshpool & Llanfair Railway and has promised one day to tell us of its wonderful collection of motive power; something else for us to look forward to.



MALLARD builders will gain a lot of useful information from this photograph taken in No. 4 Bay, the Crimpsall.

To come back to the Hughes vacuum brake, as marketed by Reeves for their passenger trucks, my engine and tender braking for DONCASTER is pure Hughes with but one small innovation, so the two are compatible. To discover my innovation, look at the system on the top L.H. corner of Sheet four and you will note that there are virutally two vacuum systems, normally 'commoned' through the medium of the brake valve. Apply the brake though and the systems separate, the lower and main pipe vacuum falling as air is admitted through the brake valve. The upper and subsidiary system however now becomes remote from the vacuum limit valve and the vacuum is limited only by the efficience of the small, or pilot, jet. This way the braking force on both engine and tender will gradually increase, which is no bad thing at all, for normally the train halts the engine with a continuous brake, savagely at times. This too is an added safeguard should the engine ever breakaway from its train, but do remember to have the small jet steam valve open on the vacuum ejector at all times, this is vital. Now that I have discussed 'power' brakes at some length, let us make some of the parts for those on the tender, and although the statement about what DYD can supply is currently incorrect, I am sufficiently optimistic of the future to allow the note to be published.

The brake cylinder actually utilises those for the limit valve on the Hughes system, I got caught out so beware!, reason being that it allows us to install two cylinders side-by-side on both engine and tender to be authentic, and although this does reduce the 'piston' area, obviously even the engine weight to be braked is less than for a loaded passenger trolley, plus as I have already described the vacuum is 'intensified'.

Dealing with the upper half of the brake cylinder first, chuck by its periphery in the 3 jaw, true up the chucking spigot, then grip by the latter to face across, turn the periphery to 1 5/8 in. diameter, clean up the back face of the flange, the interior and 'D' bit 1/4 in. diameter x 1/8 in. deep as recess for the 5BA nut; part off. Mark off and drill the four No. 34 holes on 1 7/16 in. p.c.d. then drill one of the raised bosses No. 30 for the 1/8 in. thin wall copper tube; sweat or silver solder this latter in place.

For the bottom half of the cylinder the same casting is employed, so chuck by the periphery in the 3 jaw, turn down to 3/8 in. diameter as shown, reducing the spigot length to 5/16 in. Centre and drill through at No. 30, following up at 7/32 in. diameter to 9/32 in. depth and tapping 1/4 x 40T. You can now grip by the 3/8 in. portion in the 3 jaw; or more accurately chuck a length of 3/8 in. rod, turn down to 1/4 in. diameter over a 7/32 in. length and screw 40T, then screw the cylinder to same. Face across, turn down to 1 5/8 in. diameter and clean up the back face of the flange, then drill the 1/8 in. hole for the copper tube before clamping to the top half and drilling through the No. 34 holes. The bolts are best home-made from 8BA hexagon bar; for the fulcrum, turn a 5/32 in. diameter x 1/8 in. long spigot on a length of 1/4 in. square bar, part off at 5/16 in. overall then drill and tap 6BA. Orientate the cylinder of course for ease of piping. There is one more operation to be dealt with on the bottom half cylinder, drilling through at No. 22, spot-facing to 5/16 in. diameter and then tapping 3/16 x 40T for the cylinder valve.

The piston rod is a fabrication from 1/8 in. stainless steel rod and a 1/4 in. o.d. eye, silver soldered together, the upper end being screwed 5BA for 7/16 in. length. Turn the gland up from 5/16 in. A/F brass bar, the PTFE packing being important for the low friction it gives to movement of the piston rod. Turn up the brass discs either side of the diaphragm to be 1/16 in. thick, the chamfered edge also being important so that it does not cut the rubber.

Punch an 1/8 in. hole in the diaphragm material, assemble to the piston rod with nuts of the specified thickness, over the bottom half of the cylinder of course, fit the top half of the cylinder, push the piston rod hard up to the top, clamp firmly together at the joint, drill through the No. 34 holes, fit the bolts and trim away the excess diaphragm.

The cylinder valve body and cap are plain turning; screw the former hard into the cylinder to orientate the connection for ease of piping. Wind the spring, turn up the striker and assemble with a 5/32 in. ball.

Bend up the brake cylinder brackets from 1 in. x 1/16 in. steel strip, drill a 1/4 in. hole and turn up the bearing to suit, then cut the web and braze up before completing the profile to drawing. Cut the 4 3/8 in. x 1 in. doubler from 2.5mm brass sheet and sweat to the tender soleplate, but before we can erect the brake cylinders we need the links. Drill No. 30 holes at 1 3/16 in. centres in a length of 1/4 in. x 1/16 in. steel flat then radius the ends over a mandrel with an end mill. Sweat a link to a backing plate, say a length of 3/8 in. x 1/4 in. BMS bar, so that you can grip the latter in the machine vice to carefully mill out the slot, feeding in plenty of cutting oil to keep the job cool for obvious reasons. Now you can erect the whole to drawing, spot through the No. 44 holes in the cylinder brackets, drill the doubler plate No. 50 and tap 8BA for round head screws or hexagon head bolts as you wish.

A favourite trick when I was at school, that's going back a bit, was to take a gallon can with a screw top, add a little water, bring to the boil, screw on the cap and allow to cool; the can crumpled inwards to illustrate the effect of vacuum. We don't want that to happen to our vacuum reservoir, so after making it up to drawing it should be tested hydraulically to 100 p.s.i.g. The reservoir sits centrally under the drag box on the tender as shown on Sheet 2, the straight front edge of the bands bolting to the front face of said drag box, the bent tabs fitting to the underside, pieces of wooden packing being inserted as per the note. I guess the protector was found necessary to prevent a buckeye coupler from swinging down and striking the reservoir. It is bent up from a 2½ in. length of 1½ in. x 1/16 in. steel strip and attached to the underside of the drag box with five 8BA bolts.

The steps are bent up from 1.2 or 1.6mm steel and bolted to the frames; no need for further elaboration here.

Couplings

By one of those exciting coincidences, the very morning I was penning these notes I had a letter from future DONCASTER builder Dave Brooks in Sleaford, a famous railway name. Dave asked what method I will be recommending to secure from the tender to the driving truck as 'I wouldn't like to run after DONCASTER doing an imitation of PAPYRUS doing 108 m.p.h. down Stoke Bank!'

First and foremost, something I should have mentioned earlier, the provision of vacuum brakes means a 'run-away' will not occur – as soon as a hose parts the brakes will automatically apply. I do not recommend running DONCASTER with a full load of passengers unless the train has continuous vacuum brakes, but for pleasant outings under light load, if you connect the tender hose to a spigot on the front of the driving truck then this will provide the safety feature, though always work the engine with a vacuum created or you will be in trouble!

That takes care of one aspect of Dave's letter, what about the actual coupler? Regretably I no longer have the time to take my RAIL MOTOR No. 1 around the country to savour running on Club tracks; often it was to stand back and enjoy others sampling No. 1. Not possessing a driving truck, though I shall need one at Bardonela says he hopefully!, I gained a lot of experience over compatibility of couplings. The vast majority were variations on the 3-link chain coupling, with links either brazed or welded, though occasionally one came across a 'bar' coupling, just a length of 1/2 in. x 1/8 or 3/16 in. flat bar with two holes drilled in it for the coupling pins. My RAIL MOTOR has a forked end coupling, with 3/16 in. slot, and as this did prove to be a rather close fit at times, for DONCASTER we shall have a 1/4 in. slot. So our working coupler will be a lengthened version of the drawbar end, which is both practical and logical, and for Exhibitions we can replace same with an authentic coupling hook and screw coupling.

For the drawbar end, chuck a length of 1/2 in. square steel bar truly in the 4 jaw and turn down over a 1 in. length to 1/4 in. diameter, screwing the end 3/8 in. at 32T. Reduce the next 1/2 in. to around 3/8 in. diameter then part off at 2 3/16 in. overall. Cross drill 1/8 in. diameter for the pin, then mill the 1/8 in. slot before radiusing the end over a mandrel with an end mill. Finally, grip in the machine vice, on the vertical slide, to mill the 1/4 in. square. The rear coupler is simply 2 in. longer, all in the plain shank, the drawbar pin plain turning with an extra one for coupling to the driving trolley; the spring washer too is simple turning.

The engine should be as close coupled to the tender as is feasible, taking into account our normally tighter than scale curves; you will have to check this at the track. Turn up the end bosses, use a 60 deg. countersink to start belling the hole from each side, then complete with small files. Cut the 1/4 in. steel rod to fit between the end bosses, weld together if at all possible, brazing only as a last resort.

Coupling Hook and Screw Coupling

The rear coupling hook starts life as a 4 1/4 in. length of 1 in. x 3/16 in. steel flat. Mark off, saw away to expose the shank over about a 3/4 in. length, turn the end 7/32 in. down to 9/64 in. diameter, the rest to 3/16 in. diameter, then saw out another 3/4 in. and turn down to 3/16 in. diameter, until the shank is 2 13/16 in. overall. Next deal with the 1/2 in. length down to 1/4 in. wide to suit the drag box when we arrive at the hook. Mark off and drill two No. 30 holes at 3/16 in. and 1/2 in. from the inner end of the hook, slot 5/64 in. into the inner one to accept the screw coupler, then complete the rest of the profile, saw out and file to line. We now have to reduce the thickness of the hook to arrive at the authentic shape and although I will try to provide a photograph as a guide for this, if you are able to look at a full size LNER coupling it will pay dividends, for it is impossible at least for yours truly to describe same.

Turn up the steel washers at the 'spring end', plus the end plate and with any luck there will be sufficient rubber remaining from the vacuum cylinder diaphragms for the spring, bonding two thicknesses together for each. The flat cotter to complete is very optional, but should impress a judge should he look underneath. It is very simple to make, by folding a length of 1/8 in. x 1/32 in. steel strip double, filing to shape, inserting and then just opening out the tails for retention.

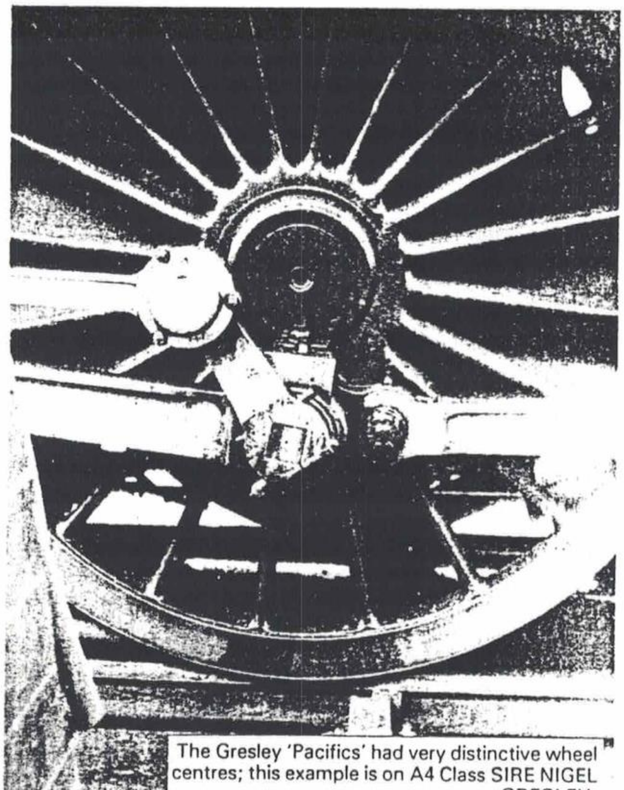
A good point to start the screw coupling is the screw itself, that's logical!, so chuck a length of 1/4 in. steel rod in the 3 jaw and reduce to 9/64 in. diameter over a 1 9/32 in. length, screwing the end 29/32 in. at 4BA. Part off to leave a 5/64 in. thick head and radius this as shown.

For the shackle pins, square off two 9/16 in. lengths of 3/8 in. square steel bar, chuck truly in the 4 jaw and turn an 1/8 in. diameter spigot over an 1/8 in. length at each end. Mill away 3/32 in. at the top and bottom faces, grip carefully by the spigots and turn on the spherical radius, a file will help here, then drill one pin at No. 27, the other No. 34 and tap 4BA. Next we need a collar, 1/4 in. o.d., 3/16 in. thick and drilled centrally at No. 28; fit the plain shackle pin to the screw, drive on the collar and cross drill No. 50. The handle is a 5/8 in. length of 1/16 in. steel rod, the ends being turned to drawing, drilled No. 53 and pressed on, with a touch of silver solder for additional security. That leaves just the shackles and there are several ways to tackle these, like turning from 5/16 in. steel rod, though I prefer fabrication as they are decorative rather than utilitarian. Turn the eyes from 1/4 in. steel rod then bend up the shackles from 7/64 in. wire; if you use 1/8 in. and turn it down then you can slightly flatten the ends to give a proper blending radius. Crimp the top shackle as shown, locally, down to 5/64 in. to slide into the hook, then scallop the ends to suit the eyes and braze up. Assembling shackles over their pins can try one's patience, but opening the eyes out to No. 28 will help and after fitting, lightly peen over the spigots to stop the shackles from springing open.

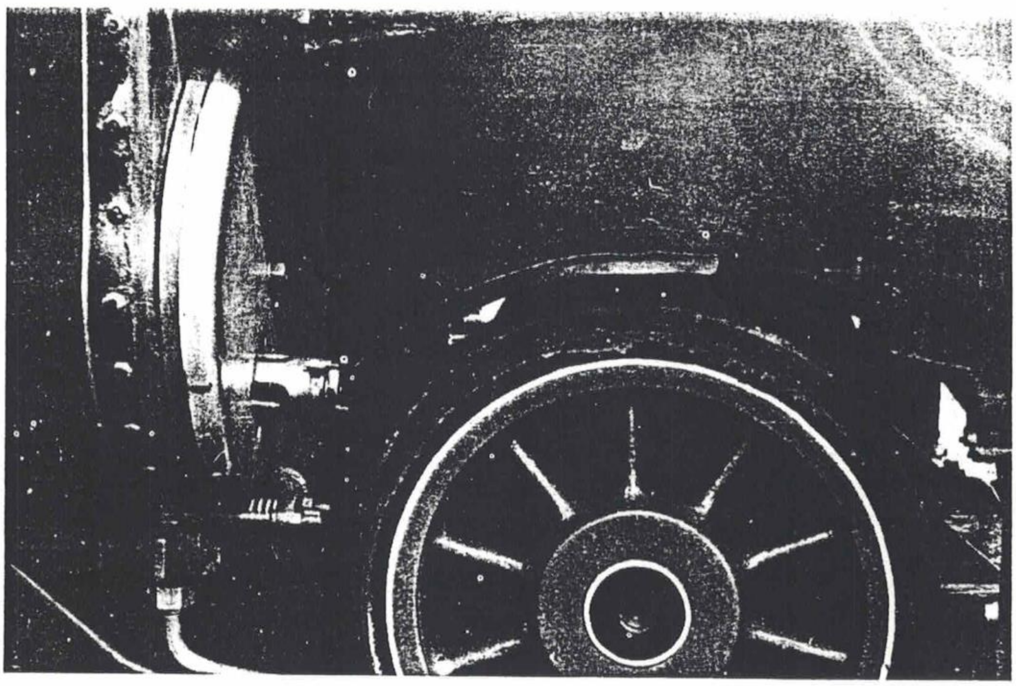
Completing the Tender Body

That takes care of the tender chassis so we can now move 'upstairs' to the body to add the finishing touches. Most of the work is at the front end, but let us first give attention to the filler. For the lid, we can supply a suitable gunmetal casting. Chuck by its periphery, clean up the chucking spigot, rechuck by the latter and turn the periphery down to 2 3/8 in. diameter, then face across. Saw away the fixed portion, clean up the joint and sweat together, then machine to drawing, keeping the job cool so that the solder does not melt at an embarrassing moment; separate and clean the joint. Chuck a length of 1/8 in. brass rod, centre and drill No. 51, then part off four 1/16 in. slices. Silver solder these to lengths of 3/16 in. x 1.2mm brass strip then saw and file away to arrive at the hinge, completing with 1/16 in. pins. Sweat or rivet these to the lid then bend up the lid supports as per Sheet 3, sweating the fixed portion of the lid to two of them.

The 'securing' arrangement is rather unique as the lid is not positively closed, neither can it be forced completely open when the water scoop is in use should the tank be over-filled. This arrangement was also used on the 4,200 gallon tenders, but here the lid did not drop right back on its hinges, but was almost vertical when open, with predictable results, as I found out at Nottingham Victoria one cold night. The lid dropped, trapped the feed bag, which then worked its way out and very nearly drowned me – a notice said SPILL NO WATER – I did!



The Gresley 'Pacifics' had very distinctive wheel centres; this example is on A4 Class SIRE NIGEL GRESLEY.



I did manage a few detail shots of FLYING SCOTSMAN, this one shows the massive bogie wheel centre.

The shackle is a miniature version of that for the screw coupling we have just made, the hinge a miniature of that used for the lid, and a 3/64 in. rivet completes this part. The hook is bent up from 3/64 in. wire, the filler tube being drilled to accept same. A wee baseplate adds the final touch, when all can be soft soldered in place.

Most times we make the shovel plate as an extension of the tank top, but this time it is both separate and removeable. Bend the plate up from 1.0 or 1.2mm steel sheet and trim to size, then rivet on the two stakes. The retaining brackets can either be bent up or milled from 3/16 in. x 1/8 in. section bar. Erect to the locker front, spot through the No. 44 holes, drill No. 50 and tap 8BA for round head screws.

Going into the tender to bring the last coal forward is a bit like going through a shop counter, at least that is what it reminded me of. One lifted up the hinged flap over the bottom door, if the latter was not obstructed then it was pushed open into the coal space, then stood between the lockers and pushed the top coal door open into the coal space; all very civilised. If coal was still pressing against the coal doors then it was a case of 'over the top', still a relatively easy thing to do either over the front coal bulkhead, or using the steps at the back of the tender to gain entry. All this of course was with the flush sided non-corridor tender – the original GN version was a right pig! We shall of course see it in more detail when we arrive at Sheet 15 towards the end of the saga, but perhaps at this stage I can give a few reasons why it was so unpopular with many of the crews, though as fireman Jim Sarney told me just last evening, the Leicester men knew nothing else. First because of the presence of the handbrake, the front bulkhead was scalloped, there was a single coal door of unfortunate shape around this, which of course could only be opened when coal had virtually disappeared from the coal plate. There was no access from the back of the tender so one had to climb over a backward sloping extension to the front coal bulkhead both for filling the tank from a water tower, or to move coal forward; much more dangerous than climbing over a vertical bulkhead. Allan Garraway correctly deduced that I tried my best to steer clear of the GN tender for these reasons – and failed miserably in the process!, but let me progress the superior flush sided version with those coal doors and flap.

The gusset comes first, simply folded up from sheet and trimmed, then secured to the front coal bulkhead and locker top framework with 1/16 in. rivets or 10BA bolts. The flap is bent up from the same material, the lip passing over the locker top framework on the R.H. side, the hinges being smaller editions of those we made for the filler lid; rivet these to both flap and gusset when we have our 'counter'.

For the bottom coal door, cut the frame from 1.6mm sheet, then cut two bars from 3/16 in. x 1/16 in. strip; one 2¼ in. long and the other 2 11/32 in. Chuck a length of 5/32 in. rod in the 3 jaw, face, centre and drill No. 50 then part off a couple of 3/16 in. slices; braze these to the hinge bars. The back of the door is now plated in, with the hinge bars between, 1.0mm plate being sufficient for this, when the whole lot can be rivetted together. For the hinge blocks, chuck a length of 5/32 in. square bar truly in the 4 jaw and turn down for 1/8 in. length to 1/16 in. diameter, screwing 10BA. Cross drill No. 50 for the hinge pin then saw off and radius the end with a file. Erect the hinge blocks behind the locker front, hang the door with 1/16 in. snap head rivets as hinge pins and deal with the top door similarly, hanging this on the back of the front coal bulkhead. After this the locker doors are straightforward, using more miniature hinges as for the filler lid, only this time rivet them to the door and sweat to the locker front. A 1/16 in. split pin on a short length of chain closes the locker door through medium of the hasp, when we can move on to the last item on the tender, the water level gauge.

Water Level Gauge

On the GN tender the only indication one had was when the tender tank was full, a swan necked pipe decanting water into a funnel. That depicted is hardly more sophisticated as when you opened it water spurted out of the little holes, onto one's trouser leg if not careful!, but at least it gave a reasonable indication of how much water was in the tank.

Chuck a length of 3/16 in. silver steel rod in the 3 jaw, set the top slide over about four deg. and turn a taper over a ½ in. length; at the same setting turn a length of 3/16 in. brass rod ditto. File away half of the silver steel rod to form a cutter; harden and temper to deep straw.

For the body, chuck a length of ¼ in. square brass bar truly in the 4 jaw, turn down to ¼ in. diameter over a 7/32 in. length, further reduce the outer $\frac{1}{8}$ in. to $\frac{3}{16}$ in. diameter and screw 40T. Centre and drill No. 48 to about 7/32 in. depth, then with a wee round nosed tool, cut back behind the $\frac{1}{4}$ in. diameter flange to leave it $\frac{1}{16}$ in. thick as shown then part off at $\frac{1}{2}$ in. overall. Grip in the machine vice, on the vertical slide and drill through for the cock at about No. 38, following up with the cutter just made so that it is around 11/64 in. diameter at the top. Radius the end of the body, then drill the No. 48 hole through into the bore, twiddling the cutter by hand to remove any burrs.

Fit the embryo plug cock into the body, mark its lower end, file on a square for the washer then turn down the remainder to .086 in. diameter and screw 8BA. Part off to arrive at the 5/32 in. dimension at the top end, rechuck, centre and drill No. 30 to about $\frac{1}{8}$ in. depth, carrying on at No. 48 to $\frac{5}{16}$ in. depth. You may well have difficulty in bending $\frac{1}{8}$ in. o.d. thin wall copper tube to the tight radius indicated for the handle, in which case turn a ball end on a length of $\frac{1}{8}$ in. rod, bend this and braze to the tube. Cut to length and drill a series of No. 55 holes at $\frac{1}{4}$ in. pitch as indicated. The cock is open with the handle facing forward, closed in the position shown on Sheet 2, so now drill from the body into the cock accordingly. Erect to the tender and bend up the guide to place; it is rivetted or bolted to the tender side.

Bogie, Driving and Coupled Wheels

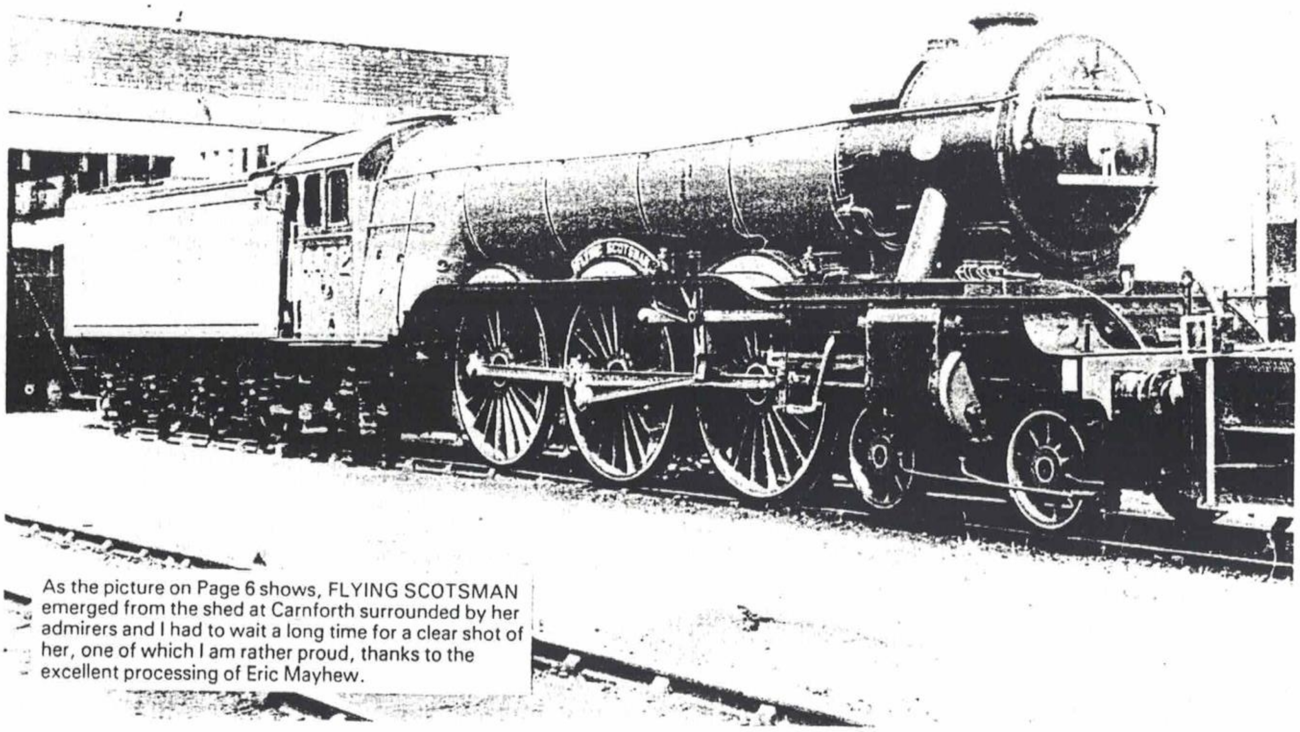
At the time of penning these notes I was still awaiting the first set of driving and coupled wheel castings, though latest word is that some have been cast; I have at least machined up some of the bogie wheels and know the close grained iron machined to a mirror like surface – its lovely! Full size the wheel seat is invariably of a larger diameter than the journal and I am now able to emulate this at least for the bogie axles, which are turned between centres from $\frac{3}{4}$ in. diameter steel bar. I wanted a maximum journal diameter for the driving and coupled wheels, so these are turned to the same $\frac{7}{8}$ in. diameter as the wheel seat, the raised portion being 'faked' on the wheel itself as I feel to bore it any bigger would weaken the boss, apart from the ease of machining mentioned in the note! It also makes things practical for turning the main body of the crank axle as a single item, so that we can braze it up.

The nearest, rather only, section I can find in Reeves Catalogue for the crank webs is $2\frac{1}{2}$ in. x $\frac{1}{2}$ in., though it will suit our purpose well. Cut two 4 in. lengths and either mill, or surface grind if you can, down to $\frac{7}{16}$ in. thickness, then mark out one piece. Grip as a pair in the machine vice, on the vertical slide, then drill out the axle hole in stages to 55/64 in. diameter, completing with a $\frac{7}{8}$ in. reamer. Move the cross slide on by 1.156 in. and deal with the crankpin hole similarly to $\frac{3}{4}$ in. diameter. Saw out and file roughly to line as a pair, when if your nerve will allow, mill the radius over a mandrel with an end mill, otherwise complete with files; assemble and braze up. If you are going to press the wheels on, leave the portion of axle between the crank webs for the moment, otherwise cut it out and file flush.

Setting the Wheels

For once I cannot specify setting wheels by eye, for even mine cannot detect 113 or 127 deg. accurately, they only being 'graduated' to 90 deg.!

Erect the crank axle between centres in the lathe, when if you add a piece of $\frac{1}{16}$ in. packing at the crankpin, the middle crank can be set vertically downwards with an engineers square. It pays to take a lot of time at this point orientating yourself to the crank setting diagram I have provided, so your cranks will be properly orientated – of course! The necessary dimensions are that the centre of the L.H. crankpin will be .696 in. above the lathe centre line, the R.H. one .452 in. above. Practically it will be better to measure from the underside of the crankpin itself and taking the 17/32 in. diameter of that for the coupling rods then the dimensions reduce to .430 and .186 in. respectively. Add your, known, centre height of lathe and you will be able to very accurately position the cranks by use of a vernier height gauge.



As the picture on Page 6 shows, FLYING SCOTSMAN emerged from the shed at Carnforth surrounded by her admirers and I had to wait a long time for a clear shot of her, one of which I am rather proud, thanks to the excellent processing of Eric Mayhew.

Doncaster — a 5in. gauge Gresley A1/A3 'Pacific'

by: DON YOUNG

Part 5 – The Boiler

Before we get down to the real business of this session, there is a little bit more to be said about the tender. For in my bid to describe all the detail of the tender body, I missed the most important point of all, access to the cab for driving DONCASTER; me of all people with my short, fat, hairy arms! I still cannot comprehend how I forgot this, it could only have been in the general excitement, but it is now almost 14 years since I first got behind Alan Fay's BLENHEIM and found I virtually had to climb onto the tender to reach the controls, a feat I have emulated many times since on other fine examples. Anyhow, builder Bill Holland has saved me a few blushes for not allowing my omission to run on, having reached this stage with his tender body, and after discussion we agree that for yours truly it will be best if the front coal bulkhead be made portable above the locker tops, except of course in way of the wing tanks. The way to do this is to rivet two lengths of ¼ in. brass angle to each tender side, this to form a slot for the front coal bulkhead to slide in, and cut a slot in the curved top section of the tender sides so that the bulkhead will lift out. Builders with longer arms than I may well get away with a much less drastic alteration, those with G.N. tenders no alteration at all.

This is the boiler that with relatively minor differences, graced nearly 350 of the largest Locomotives on the LNER; in BR days the A1, A2, A3 and A4 'Pacifics', plus the 'Green Arrow' 2-6-2's. Provided it was decently draughted, as it almost invariably was in later days, this boiler would produce steam and plenty using less than the best quality coal. Reducing the boiler to 5 in. gauge, to achieve the same end result, posed some interesting problems.

I have said before and many times that I will avoid combustion chambers if I can, so there was determination that DONCASTER would not be saddled with one, yet at the same time I needed a lot of firebox volume to deal properly with the combustion of coal on the grate; valuable firebox heating surface too. The firebox therefore had to extend into the barrel, for with such a long boiler one must be very careful in fixing the height of the firebox crown so that it does not become uncovered when going over a summit at the track. It was imperative that said firebox extension be stayed to the barrel and this I was able to do and arrive at an authentic looking end result, perhaps more akin to an A4 than the A3, which is no bad thing.

The tubes are necessarily long and this posed both structural and thermodynamic problems. Taking the structural problem first, tubes are of course subject to external pressure, and length is a contributory factor in assessing their strength, so the stated thicknesses must be adhered to; under no circumstances use a thinner gauge. Now it is a fairly well known phenomenon that a hot flue will pass greater volume of gas than a cool one and with a long boiler the gases can become choked towards the front end. It is therefore also important that injector delivery reach the front end of the boiler via the internal pipe; this will also greatly aid internal circulation. Getting those pipes forward posed a major problem in that my usual pattern plate girder stays were in the way, and this was resolved by use of rod stays, for no way would I leave a firebox crown unsupported. This means at long last I am able to do something that has been recommended to me for many years now by LLAS reader 1021, Stuart Davidson – it got through my thick skull in the end Stuart!

Other than positioning the water gauge top and bottom fittings to ensure safe operation, the rest of the backhead was straightforward and uses fittings that have now become my standards, as they were indeed in full size. I was determined to 'do a Chapelon' on the steam circuit and am pleased with the result, each coaxial superheater element handling the steam for one cylinder. The double seating regulator valve was one of the less successful LNER features in my humble opinion, so I crossed to Crewe and fashioned a valve around that fitted to the 'Duchesses', one which will do the needful.

The other feature of note, and one of paramount importance, is the 'pop' safety valve. For these to be reliable, there is a minimum length of spring which can be used, and apart from increasing the height of said safety valves above scale, the alternative was to lower the ball into the boiler, and in this instance it is feasible, though I am sure that with a new boiler and its tendency to prime, there are going to be a few early baths! Enough of the pre-amble, almost, but just before we get down to construction a few words on materials.

Although I am totally confident, competent too, in arriving at my boiler designs, just as I submitted my work to Lloyds as an instance when in industry, so there is the greatest merit in having an independent assessment of my miniature boilers, and in this I consider myself extremely fortunate in that Alec Farmer has looked at most of mine and made several helpful recommendations. Maybe I am gradually designing boilers the way you would like Alec, for on DONCASTER the main point you raised was the need for formers to be cast for both throatplate and firebox front plate. Arising from this, though it would be said the same anyhow, builders are recommended to make use of the Reeves boiler kit service, for apart from its size, DONCASTER's boiler is a relatively easy one to build. Time to cut the chat and start the action.

Having been a factor in Reeves introducing 6 in. bore x 10 s.w.g. seamless copper tube for such designs as DON HUNSLET and LUCKY 7, I now feel a bit of a traitor for reverting to 6 in. o.d. for DONCASTER, though by the number of HUNSLET's built I would hope this venture with the bore size has paid off. For the front portion of the barrel for DONCASTER our required finished length is 12¾ in. Scribe on the top centre line, for the original 180 p.s.i.g. boiler come forward 2½ in. for the dome bush centre, scribe on a 2¼ in. diameter circle and another at a full 2 5/16 in., then drill round to the inner circle and break out the centre, filing roughly to line. Take the dome bush casting, chuck in the 4 jaw, face off and bore out to 1⅞ in. diameter. Grip by the bore in the 3 jaw with the machined face hard to the jaws, face the other end, turn down to 2⅜ in. diameter over the whole length, then reduce further to 2 5/16 in. diameter to leave a 7/32 in. shoulder as shown. Open out the hole in the barrel to a close fit for the 2 5/16 in. diameter spigot, then scallop the bottom of said spigot to match the barrel, with about an ⅛ in. projection, again as shown.

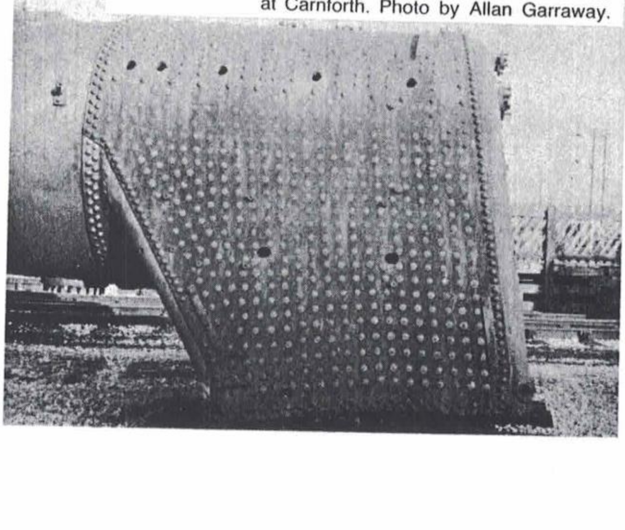
The tapered portion of the barrel on LNER 'Pacifics' is a frustum of a cone, unlike GWR/LMS practice where the bottom is parallel and all the taper on the top, not that this makes life a great deal easier. Whilst it is possible to take an 11 in. length of 7 in. o.d. (or bore) x 10 s.w.g. copper tube, cut a triangular piece from same, tap together to close the joint, rivet in a butt strap and braze up, such is both wasteful and expensive, the alternative being a piece of 3mm copper sheet,

size $21\frac{1}{4}$ in. x 11 in. First though cut a stout piece of cardboard to the same size, some of the boxes in the supermarket are ideal for this, and roll up to represent the barrel, stapling or clamping the overlap together. Now reduce the overlap to a uniform $\frac{3}{4}$ in. and castellate to give $\frac{3}{4}$ in. wide interlocking fingers, the professional joint that Alec Farmer recommends. Open out the carboard, lay on the copper and clamp it in place, mark off and saw out. Now clamp the cut sheet to the front portion of the barrel and begin pulling round, leaving the sheet in the 'as purchased' condition which is very likely half-hard as long as possible, this to avoid damage. For the final closure of the castellations you will require an 18 in. length of around 4 in. o.d. steel tube gripped horizontally in the bench vice, when you can tap the joint together, but don't worry too much about the barrel being round at this stage.
Pickle, wash off, flux the joint and braze up; now put the barrel over the tubular mandrel and with a soft face or wooden mallet, tap it judiciously until the front end slides over the parallel barrel and your calipers show the rear end to be circular. Again mark on the top centre line, mark back to $9\frac{5}{16}$ in. and saw away the half at the back end, but don't worry about the lower, sloping, portion for the moment. Join the two portions of barrel with three or four copper rivets, just to hold them firmly together, pickle, flux and braze up, dealing with the dome bush at the same time, the steampipe/injector delivery pipe support too at the same heat if you wish, then no further heat need be directly applied in this area. For the later boiler with dome right on the joint, I recommend you braze the barrel joint first, then mark off and cut the hole for the bush, fitting a $\frac{1}{2}$ in. wide half ring from 3mm copper under the front part of the bush and securing this with about three snap head rivets. Bring the steampipe/injector delivery pipe support back the same $2\frac{1}{2}$ in., then braze this and the dome bush as a second operation.
Warren Shepherd, the sheet metal wizard at Boston Lodge, once showed me wooden blocks he had made for a 5 in. gauge 'Britannia' boiler, these for forming the firebox and outer wrapper around. He even had included recesses to accept the end, flanged, plates to ensure a neat joint; we can do no better than follow suit for the outer wrapper, though the block for the firebox will need some modification when we come to same. First take the flanged throatplate and match it to the end of the barrel, when you can trim the end of said barrel, then clamp the throatplate to the wrapper former block. The backhead only wants its flange trimmed and filed when it too can be fitted to the wooden former block. Cut a piece 23 in. x $9\frac{5}{8}$ in. from 3mm sheet and wrap it around the former, scribing around backhead and throatplate back onto the wrapper and adding further lines to arrive at the $\frac{3}{8}$ in. dimension shown for stand-out of the backhead; the throatplate is exactly similar. Saw and file to line, then offer the throatplate up to the barrel and secure with a few copper snap head rivets, heads inside and hammering down the shanks into countersinks in the throatplate flange. This joint is very weak, so quickly bring up the outer wrapper and clamp it in place, then carefully check that all is well before rivetting the outer wrapper to both barrel and throatplate flanges at about 1 in. pitch; pickle, flux and braze up.

The Firebox

Make the firebox block to the regular section, slope the back of same and cut a groove to accept the flanged back plate, but there is nothing we can do at the front end, so cut a piece 19 in. x $9\frac{1}{4}$ in. from the 3mm sheet and fold up, trimming the back end to suit the flanged end plate. Remove from the former, insert the front plate which in this instance is not the tubeplate, position correctly, mark off and slit the wrapper; do not saw completely away. Now bend in the two front portions, trimming away as you go, until if at all possible you can arrive at a castellated joint and a fit inside the firebox tubeplate flanges; if not successful then fit a butt strap in lieu. The firehole tube is from 49mm o.d. x 5mm wall copper tube, a Reeves standard, and may be bored out initially to a bare $1\frac{5}{8}$ in. diameter before squaring off to 29/32 in. overall. Rechuck by the bore and turn down over a 9/32 in. length to $1\frac{13}{16}$ in. diameter, then reverse and turn the other spigot to leave $\frac{3}{8}$ in. at the original size. Flatten in the bench vice, offer up to the firebox backplate, roughly $3\frac{3}{16}$ in. down from the crown of the plate, scribe round, drill out the middle and file to a close fit. Stand the firehole ring on a lump of lead, offer up the backplate and carefully peen over the lip; now you can assemble the firebox with a minimum number of snap head copper rivets.
The crown stay is basically two 8 in. lengths of $\frac{3}{4}$ in. x $\frac{1}{2}$ in. x 2.5mm copper angle, flanged up from strip of course. Grip them back to back, secure with about six $\frac{1}{16}$ in. snap head rivets, then trim the top edge as shown. Offer up to the firebox crown, tapping down the flange to be a close fit, then secure with a minimum number of snap head copper rivets. There are of course many ways of dealing with the rod crown stays, they can be fitted to the firebox crown at this stage, when the complete firebox can be brazed up using B6 or L7 spelter, though I favour leaving them until a little later on.
I have got a bit ahead of myself, for before we can braze up the firebox the tubeplate has to be dealt with to accept the tubes. Drill a couple of $\frac{1}{8}$ in. pilot holes in both firebox and smokebox tubeplates, bolt them back to back, then drill and ream the twenty two $\frac{1}{2}$ in. diameter holes. Now open out for the three flues as far as you are able, completing with a round file to a tight fit for the flues; separate the plates and ease the smokebox tubeplate to be an easy fit over the flues. Now chuck the latter by the inside of the flange and turn down to a close fit in the barrel. Next take the tubes, square off to length and polish the ends with emery cloth; the flues you will have to attend to with files and emery cloth. Use a $\frac{1}{2}$ in. taper pin in the bore of each firetube to slightly expand one end, carefully tapping it sideways to ease it out, then tap the tubes into the firebox tubeplate, one at a time. Complete by inserting the flues, which should already be a push fit, fit the smokebox tubeplate over the outer end of the tubestack, after cutting rings from Easyflo No. 2 wire and slipping them over each tube. Pickle, apply Easyflo flux as a fairly runny paste so it covers the tubeplate area, set up the assembly on the brazing hearth and check the tubestack is parallel to the firebox. Now heat up using a fairly diffuse flame, keeping on the move so you do not get a green tinged flame which indicates the copper is burning, until the silver solder melts and flashes through the joints; add more spelter as found necessary. Anneal the tubes at their outer ends, carefully knock off the smokebox tubeplate, then allow to cool, pickle, clean and inspect.

The firebox of the spare boiler for FLYING SCOTSMAN at Carnforth. Photo by Allan Garraway.



Cut a length from $\frac{1}{2}$ in. x $\frac{3}{8}$ in. copper bar and fit it to the throatplate, then bring up the firebox assembly, insert the smokebox tubeplate at the front, and clamp over the front section of the foundation ring. Now carry out as many checks as you can to see that the firebox is nice and central within the outer wrapper, before marking off and drilling for the 40 rod stays in said outer wrapper at about No. 9 and countersinking with a 60 deg. Rosebit. Spot through onto the firebox crown, then because the distance involved is around 2 in., remove the firebox from the outer wrapper, check everything carefully and correct any errors with a centre punch. Now drill through No. 12 if you are using plain rod stays, No. 17 if a spigotted end is your choice, and turn up the rod stays from $\frac{3}{16}$ in. copper or phosphor bronze rod and allowing for at least $\frac{1}{2}$ in. projection through the outer wrapper; braze the stays to the firebox crown. Use the 60 deg. Rosebit on the inside of the wrapper to give the rod stays a nice lead into same, then erect once more and clamp to the front section of the foundation ring.

At this stage we have to trim away all excess metal along the firebox and outer wrapper sides, then fit these sections of foundation ring, drilling right through and securing with about six snap head copper rivets in each section, heads inside and hammering down into countersinks in the outside plates. Turn up the steampipe bush for the smokebox tubeplate and braze it in as a separate operation, then fit the tubeplate into the barrel and engage the tubes. On the bottom centre line of the tapered portion of the barrel there is a $1\frac{1}{2}$ in. length of $\frac{1}{2}$ in. x $\frac{3}{8}$ in. copper bar, which sits on top of the star stay and helps support the boiler; for the moment just file the bar to fit the barrel and secure with a couple of 6BA bronze screws. On the top centre line of the outer wrapper, we can turn up and fit the pair of safety valve bushes, when we are ready for the 'big braze'.

Thoroughly pickle, then flux the rod stay ends, safety valve bushes, then turn over for the foundation ring and support bar, going forward to the smokebox tubeplate to complete the preamble. Sit the boiler upright, start heating up around the rod stays, dealing with each in turn with Easyflo No. 2, then going on to the safety valve bushes. Roll the boiler over, pack it securely with firebricks, then deal with the foundation ring and support bar. Finally, pack the boiler to be vertical, then deal with the tubeplate/barrel joint and finally the tubes. Allow to cool, pickle, clean and inspect. Now I doubt very much if all this will be accomplished at a single heating, so as and when the silver solder stops running freely, you do the same, pickle and start again; don't try to press on regardless, it is the road to disaster.

Although the backhead can be tried in place as you proceed, only now can you tell how good a fit it will be, though this component gives less trouble than one often imagines. Offer it up to the outer wrapper, scribe back from the firehole ring, add on the thickness of spigot, carefully mark out drill round and break out the centre, then file metal away to achieve a good fit over said spigot, checking to place as you proceed. We now have to fit out the backhead with all its bushes before assembly.

The water gauge and blower bushes are simple turning; drill $\frac{3}{8}$ in. diameter at the given centres then file the spigots so the bushes are horizontal. The blow-down valve bush can be identical to that for the bottom, water gauge pair, although there is no need to file a taper on the spigot. The regulator box facing is a $\frac{3}{4}$ in. diameter disc from 2.5mm copper; drill and file the slot then offer up to the backhead, mark off and deal with this also. Fixing for brazing can be by a couple of 3/64 or $\frac{1}{16}$ in. snap head rivets located on the horizontal centre line with heads inside. The injector facings have now become one of my pet standards, indeed by the time these notes appear it will be more than 20 years since I made the pair for my K1/1, sloping backhead and all. A description of the facings appeared in LLAS No. 14 for E. S. COX, so there is no need for repetition, save for a final operation to file the spigot to suit the sloping backhead. Braze the bushes in place with B6 or L7 spelter and we are ready to erect.

Cut a length of $\frac{1}{2}$ in. x $\frac{3}{8}$ in. copper bar for the rear section of the foundation ring and shape to suit the backhead. Fit in place, bring the backhead up, then check the blowdown valve bush is not fouling, filing the foundation ring locally to obtain clearance if necessary. Peening over the lip on the firehole ring should now trap the rear section of the foundation ring without any other fixing, though use three or four rivets if there is any slackness. Next mark off and drill for the longitudinal stays at each end, forming the countersink, with a taper pin drill and waggling it around to arrive at about a 20 deg. angle. The stays themselves at 31 in. overall will project a good 1 in. from either end of the boiler; crimp at about 1 in. from one end so the stays will not drop right through when inserted. The final operation, apart from making up and fitting the manifold bush on the top centre line, is to check around the backhead joint for any excess clearance, closing same by carefully tapping the outer wrapper; we are ready for the final braze.

Pickle the boiler thoroughly, make sure you drain off all the acid then flux around the backhead, rear section of foundation ring, stay ends, and don't forget the firehole ring. Stand the smokebox end of the boiler in the brazing hearth, support it well!, then deal with the backhead joint, firehole ring and stay ends, plus manifold bush. Now lay the boiler upside-down to deal with the foundation ring, finally supporting on the backhead to deal with the three stay ends at the smokebox tubeplate, and using Easyflo No. 2 throughout. Allow to cool, pickle and clean. If you have any doubt as to your workmanship, plug up all the openings and fit a cycle inner tube valve to one of them, apply about 20 pumpfuls of air and completely submerge in water, a domestic bath job I reckon! Over that hurdle and we can add the firebox stays and start fitting out.

Sadly a look at Reeves latest Catalogue still shows an absence of 4BA screwed copper rod, so we must resort to skimming down 5/32 in. phosphor bronze rod and screwing it 4BA. Another **must** is the investment in a new set of 4BA screwing tackle, die and all three taps in carbon steel, for we have 178 stays to fit, rather 356 holes to tap out, and the last thing we want is to strip any threads in the soft copper. To reduce the tedium of this job, I suggest you deal with a single row of stays at a time, though mark off for them all initially and very lightly centre pop to avoid distortion. Drill a single hole through at No. 34, poke another drill in this hole and use as a sight for the remainder of the row. Again use the sighting drill to get the 4BA tap entered squarely, use a tapping compound, ease the tap backwards and forwards to break the swarf into small pieces, and don't press on regardless, but use the 2nd and plug taps to complete threading the outer wrapper. Clean the swarf off the taps, apply tapping compound again, then deal with the firebox shell. Screw the stay in with a tap wrench, apply a commercial brass full nut and tighten it, then crop off the excess stay on the outside to leave about $\frac{1}{16}$ in. standing proud after filing flat. That reminds me that the longitudinal stay ends require the same treatment. Only the nine stays around the barrel to support the firebox extension require special mention in that their inner end should be positioned such that the 4BA stay nuts are properly landed; for once it takes me less time to describe a job than to carry it out!

It does no harm at all to again pickle the boiler before we proceed to seal the stays, as this will remove any remaining tapping compound which just might prevent full spelter penetration. Our sealing medium is Comsol or SX2, so apply the appropriate flux to the outside on one side of the wrapper, the nuts on the opposite side, lay the boiler on its side, warm up and deal with one stay at a time, first on the outside and then the stay nuts on the inside; pickle and repeat for the other side of wrapper and firebox. Carry out exactly the same procedure for the throatplate and backhead, dealing with the row around the firebox extension at the same time as the backhead; our boiler is now structurally complete.

The dome this time consists only of a dished copper cover, from 3mm material. A skilled coppersmith will 'dome' the copper with a ball pein hammer on a piece of lead and at the very worst we can press it out between two formers. Drill and tap a 4BA hole in the centre, chuck a 4BA nut in the 3 jaw and bolt the plate to same, then carefully turn down the periphery and clean up the joint face. Scribe a 2⅛ in. diameter circle for the bolts, drilling No. 34. Offer up to the dome bush, spot through then drill and tap 6BA to 5/32 in. depth. Assemble using a 1/64 in. thick CAF gasket.

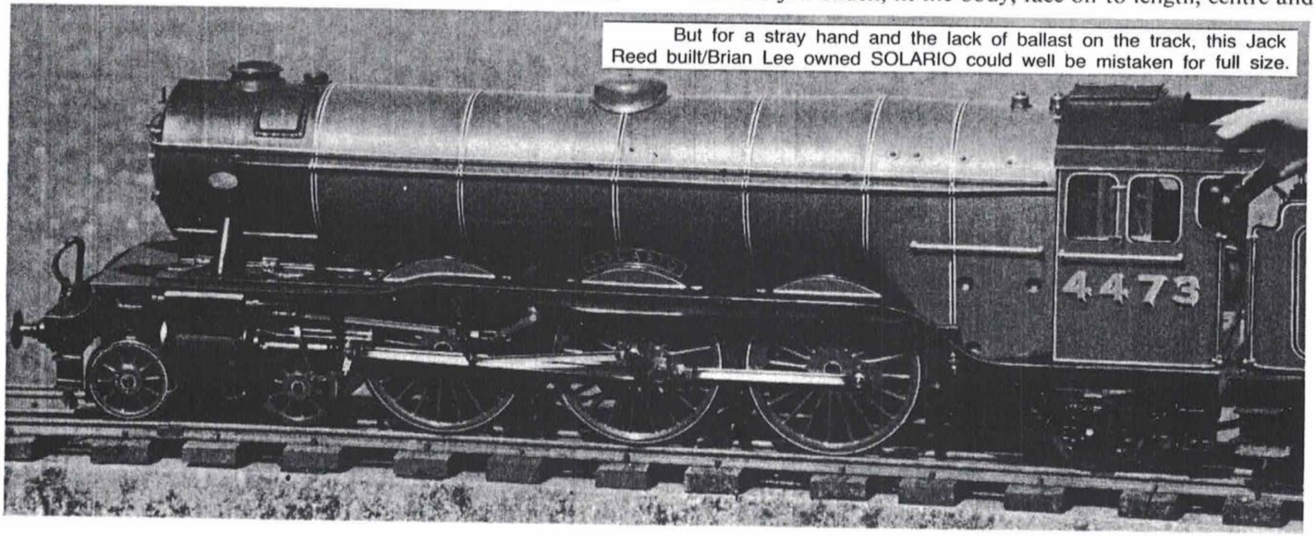
Moving along the bottom of Sheet 5 in logical sequence we come to the safety valves, though only the earliest engines were graced with this particular pattern; the more familiar body comes on a later sheet, though the internals are common to both. For those building the historic GREAT NORTHERN, the body starts as 1 in. diameter bronze or gunmetal bar, probably the continuous cast variety, so chuck in the 4 jaw and turn down to 15/16 in. diameter over a 2½ in. length, parting off two pieces at around 1 in. overall. Chuck these in the 3 jaw, face off, turn down to ⅝ in. diameter over a ⅜ in. length and screw 26T. Chuck an odd end of 1 in. diameter bar in the 3 jaw, face, drill through at 19/32 in. diameter and tap ⅝ x 26T; screw in an embryo body. Turn down the outside to drawing, remembering the 9/16 in. dimension, then centre and drill through at Letter D. Follow up at 13/32 in. diameter to about 11/16 in. depth and 'D' bit to ¾ in. depth. The 'pop' recess wants to be 19/64 in. diameter and about 1/32 in. deep, so make up a 'D' bit and tackle this, then ream through the remains of the Letter D hole at tap the outer ⅛ in. at 7/16 x 26T to complete the body.

We are now on common ground, so for the top chuck a length of bronze or brass rod and reduce to 7/16 in. diameter over a ⅜ in. length. Further reduce the end 1/16 in. to 7/32 in. diameter, facing across of course, then centre and drill No. 41 to ⅜ in. depth. Start parting off at ¼ in. overall, but screw the main portion at 7/16 x 26T before parting right off. Mill or file the steam escape slots, removing any burrs from the threads and we can move on to the spindle.

I suggest this be made as a single piece from 7/32 in. stainless steel rod, so chuck in the 3 jaw and turn down to 3/32 in. diameter, an easy fit in the No. 41 hole in the cap, over an 11/16 in. length and screwing the end to accept a 7BA thin brass nut. Part off to leave an ⅛ in. collar at 7/32 in. diameter, reverse in the chuck and use a round nose tool to produce the recess for the 5/16 in. stainless steel ball. All we need is the spring to complete and I suggest it be ordinary spring steel wire rather than the more exotic phosphor bronze or stainless steel. Reason is that the latter materials tend to 'relax' in service with the rough treatment that a 'pop' valve gives; try 19 s.w.g. wire using one of the standard range from Reeves in the first instance and about ⅜ in. free length, though it is really a case of trial and error.

On to the blower and to keep the valve as neat as possible, I have gone back 20 years to my LNER Class K1/1 'Mogul' and not attached the internal blower pipe to the valve. Chuck the ¼ in. o.d. x 18 s.w.g. blower pipe in the 3 jaw, the initial length wants to be around 30 in., face off and screw 40T for ¼ in. length. Feed through from the smokebox end, pick up the bore of said tube with a scriber point and engage the threads, then screw home using a tap wrench. Mark where the tube enters the smokebox tubeplate, remove and saw off the excess, then face off and screw this end 40T over a ⅜ in. length. Turn up the blower union, one of the easiest jobs for this session!, fit the blower tube again after annointing the threads with jointing compound, engage at the backhead end, followed by the blower union at the front end, engage the latter in turn in the smokebox tubeplate and screw right home.

I should have mentioned much, much earlier that the blower be fitted on the driver's side, either right or left hand as you prefer. Almost certainly because of the problems of fitting a R.H. boiler to a L.H. engine and vice-versa, Gresley's final solution was to locate the blower on the centre line of the boiler and just below the regulator box, which I could have followed with an E. S. COX type arrangement, only the crown stay gets right in the way. I pondered long and hard over this, but safety must be paramount and removing or modifying the crown stay weakened this area such that I could not countenance it. The LNER pattern of blower valve is distinctive by its square body and well worth the effort in emulating. Chuck a length of 7/16 in. phosphor bronze rod in the 3 jaw, face and turn down to ¼ in. diameter over a ¼ in. length before screwing 40T; part off at a full 11/16 in. overall. Screw hard into the backhead, you can file on two wee flats to give it a final 'tweek' with a spanner, then mark on the top centre. Fit a screwed adaptor in the machine vice, mount it on the vertical slide, screw the embryo body hard into same, then mill the main portion of the body to 9/32 in. square. Turn up the union, it can be lightly clamped to the body for silver soldering instead of producing a spigot; pickle and clean. Make a ¼ x 40T screwed adaptor, or fit an existing one in the 3 jaw chuck, fit the body, face off to length, centre and

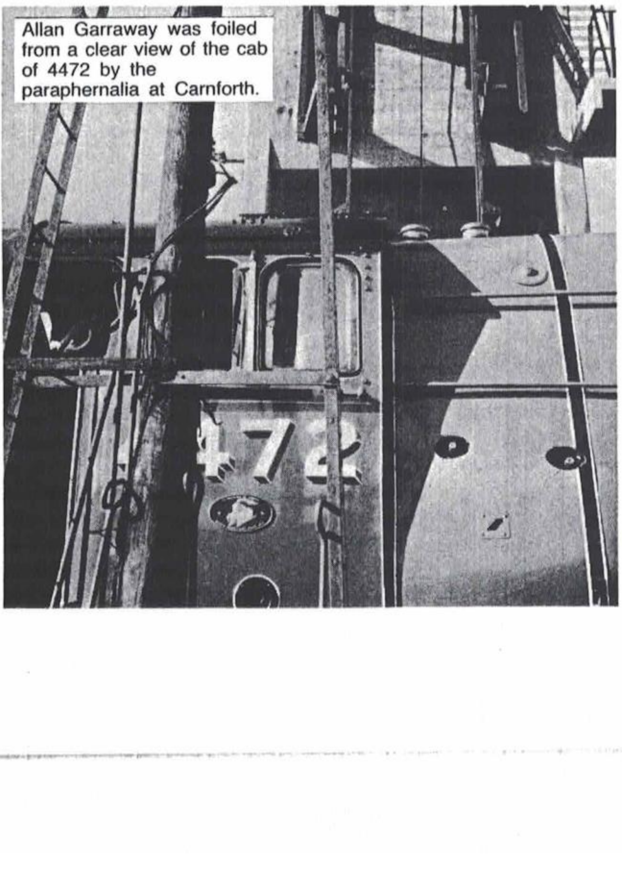


But for a stray hand and the lack of ballast on the track, this Jack Reed built/Brian Lee owned SOLARIO could well be mistaken for full size.

drill right through at No. 41. Follow up at $\frac{3}{16}$ in. diameter to about 9/32 in. depth, 'D' bit to 11/32 in. depth and tap the outer $\frac{3}{16}$ in. at 7/32 x 40T. To complete, drill No. 41 from the union into the main bore and remove any burrs.

The valve stem is from $\frac{1}{4}$ A/F hexagon bronze rod and is a simple machining job, as is the gland nut from the same material. Take a length of $\frac{1}{8}$ in. stainless steel rod for the valve spindle, chuck in the 3 jaw and reduce over a $\frac{5}{8}$ in. length to 3/32 in. diameter, a nice sliding fit in the valve stem. Screw the next $\frac{1}{4}$ in. at 5BA then part off at 1 in. overall before rechucking to turn on the actual valve to about a 90 deg. cone. Assemble to the valve stem and pack the gland with PTFE yarn; gone are the days of messy graphite asbestos yarn. The collar for the handle is an $\frac{1}{8}$ in. length of $\frac{3}{16}$ in. stainless steel rod, drilled centrally at No. 43 and pressed onto the spindle end. Cross drill through collar and spindle at No. 53 and press in a $\frac{7}{16}$ in. length of $\frac{1}{16}$ in. stainless steel rod, rounding the end to complete; assemble and erect to the backhead.

We now move inside the boiler to deal with the regulator and steampipe, in that order. In recent weeks I have received two sketches of a regulator body which does not need attachment to the boiler shell; this made me smile as I had done just that for DONCASTER. Keeping the steamways as large as possible dictated a fabricated body in lieu of a casting and again our thoughts were common, which I find encouraging, so in buoyant mood let me proceed. The main part of the body is a 1$\frac{9}{16}$ in. finished length of $\frac{3}{4}$ in. square bar; gunmetal is the prefered material though brass will do at a pinch. First cross drill at No. 22 for the valve arm spindle, then drill a couple of $\frac{1}{4}$ in. holes to start forming the main steam passage. Grip in the machine vice, on the vertical slide, and mill out the passage to $\frac{9}{16}$ in. x $\frac{5}{16}$ in. section and 1$\frac{1}{16}$ in. depth. Tilt the body over 45 deg. and mill to give a $\frac{9}{16}$ in. square opening at the top, using a file to get the corners nice and square, so there is a full opening through both valve seating slots. Turn up the outlet boss from $\frac{3}{4}$ in. diameter bar, mark the spigot which enters the main part of the body, then chuck said body in the 4 jaw, centre, drill and bore out for the spigot to be a press fit. The valve seat I recommend starts life from $\frac{3}{16}$ in. thick material; cut and mill to $\frac{7}{8}$ in. x $\frac{3}{4}$ in. section, then drill and mill the pair of 5/32 in. slots, finishing the corners square with a file. Silver solder the assembly, then chuck in the 4 jaw to face across the valve seating to specified thickness, before finish tapping the boss.


Allan Garraway was foiled from a clear view of the cab of 4472 by the paraphernalia at Carnforth.

The regulator valve can be fabricated or machined from solid, it really depends on the material to hand. First deal with the 5/32 in. slot to $\frac{9}{16}$ in. width, then drill the lugs at No. 30 and file into slots as shown, shaping the tongues of the lugs to drawing. The working face can best be dealt with by rubbing on emery cloth, the latter on a sheet of glass to ensure flatness. Chamfer two edges to arrive at a $\frac{3}{4}$ in. wide working face, checking with engineers blue that the valve has a good 'bed' on its facing, then apply molybdenum disulphide grease to both faces to avoid the possibility of scoring; now for the operating gear.

The valve arm is from $\frac{5}{16}$ in. x $\frac{1}{16}$ in. stainless steel strip and is brazed to the 5/32 in. spindle, with a thin 4BA washer to give clearance from the regulator body. Erect, fit another 4BA washer, then the follower arm and complete with a 6BA nut. Cut a 1$\frac{3}{16}$ in. length from $\frac{1}{8}$ in. stainless steel rod, screw the end 7/64 in. at 5 or 6BA, then erect through the No. 30 holes in the two arms and engage the slot in the valve; check for operation.

The regulator box to attach to the backhead caused me considerable thought to get things worked out so that the end result was both practical and authentic. Although it is specified as a bronze fabrication, copper may be substituted where the latter is more readily available. Start with the flange to mate with the backhead, cut the $\frac{3}{8}$ in. x $\frac{1}{4}$ in. slot in same to mate with the backhead. Take a length of $\frac{3}{8}$ in. x $\frac{1}{16}$ in. (1.6mm) strip and bend up to start forming the housing, matching it to the flange and arriving at the dimensions shown; radius the edges. Next cut and fit end plates to the housing; braze up the pieces made thus far with a high melting point spelter, pickle and clean. Next chuck in the 4 jaw, centre, drill and ream through the end plates at $\frac{3}{8}$ in. diameter for the gland housings. For these latter, chuck a length of $\frac{1}{2}$ in. bronze rod in the 3 jaw, face and turn down to $\frac{3}{8}$ in. diameter, a close fit in the main housing, over a 9/64 in. length, then centre and drill $\frac{1}{4}$ in. diameter to $\frac{5}{16}$ in. depth before parting off a $\frac{1}{4}$ in. length. Reverse in the chuck and face to leave a 3/32 in. flange, then shape this to match the gland we have to make next.

Although the gland is specified from brass, it can be made from the $\frac{1}{2}$ in. bronze rod we have just been using; chuck in the 3 jaw, face and turn down over a 13/64 in. length to 9/32 in. diameter. Centre, drill No. 23 and ream at 5/32 in. diameter to $\frac{3}{8}$ in. depth then part off to leave a full $\frac{1}{16}$ in. flange. Reverse in the chuck, clean up said flange, then shape to drawing and drill the pair of No. 50 holes. The second gland is identical save spigot length reduces to 9/64 in.

Fit the gland housings into the regulator box, check the 3/32 in. dimensions to accept the drive arm, then use Easyflo No. 2 to secure them in place. Poke a $\frac{1}{4}$ in. drill through the bore, chuck the regulator box in the 4 jaw and check with a d.t.i. on the drill shank until running true, then carefully bore out and ream to 9/32 in. diameter, gaining a nice surface finish for the pair of 5/32 in. bore x $\frac{1}{16}$ in. section 'O' rings. I actually give the instructions on the drawing for dealing with the regulator shaft, though on reflection I now reckon a 6 in. initial length will give more scope for adjustment later on; the drive arm is of course made to suit the square on the shaft, or vice-versa.

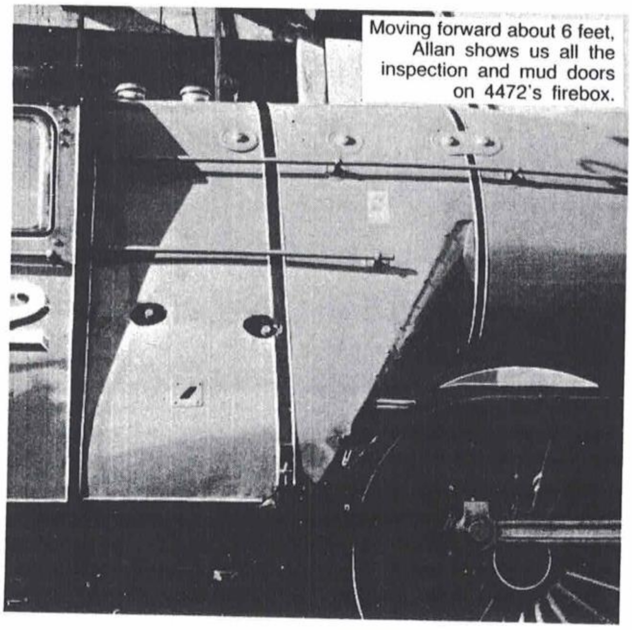
Take a 20 in. or so length of $\frac{1}{4}$ in. square stainless steel bar, cross drill No. 30 and slot to accept the drive arm. Assemble to same with a $\frac{1}{4}$ in. length of $\frac{1}{8}$ in. stainless steel rod, erect through the slot in the flange to the regulator box, engage the shaft, fit 'O' rings and glands, then spot through from the glands, drill and tap the housings 10BA for bronze or stainless steel bolts. Erect to the backhead, mark off for the five fixing holes, checking bolts can be fitted O.K. in the positions shown, then drill and tap 8BA; No. 44 clearance holes in the regulator box flange of course. Turn the regulator shaft until the drive arm strikes the back of the box, close the valve on top of the regulator, then mark the regulator rod in way of the valve arm pin. The regulator rod needs about a $\frac{9}{16}$ in. set in it; I recommend this be almost over its full length rather than a local one, then drill No. 30 and slot $\frac{1}{16}$ in. to suit the valve arm. Turn up the pin to connect the valve arm to the regulator rod from $\frac{1}{4}$ in. stainless steel rod, turning down over a $\frac{1}{4}$ in. length to $\frac{1}{8}$ in. diameter and parting off to leave a 1/32 in. thick head. Completely erect the regulator box again, feed the regulator rod into the boiler, then push the regulator valve right forward on its facing to bring the bottom of the valve arm clear of the regulator body. Align the regulator rod, push in the pin and when you bring the regulator box right up to its backhead facing, this will bring the valve to its correct closed position and the pin will be 'captive', so no fear of its dropping out in service. I should of course mention that the regulator rod length reduces by $2\frac{1}{2}$ in. for the banjo-dome version, which brings us neatly to that final area of Sheet 5, only I have forgotten the steampipe!

Turn up the steampipe flange from gunmetal bar to the dimensions shown, screw it hard into the boiler and mark on the top centre. Next take an $8\frac{1}{2}$ in. length of $\frac{5}{8}$ in. o.d. x 16 s.w.g. copper tube, an 11 in. length for the banjo-dome version, face and screw 26T over about a $\frac{1}{2}$ in. length. Screw hard into the regulator body and again mark on the top centre line. Assemble 'dry' with a length of $\frac{1}{2}$ in. rod through flange and steampipe, assess the position of the regulator relative to the dome opening, adjust the steampipe length to correct as necessary, then braze together. Annoint the threads with jointing compound and erect.

Hydraulic Test

Although I much prefer to hydraulically test the boiler with all the fittings in place, really it is the soundness of construction of the boiler itself that we are now seeking to prove, plus in any case it is for your Club Boiler Inspector to specify at which stage he wishes to witness said test. Readers will note on all my boiler drawings that two pressures are specified; recommended working and design. The latter signifies that the scantlings are such that the boiler can safely be worked at this higher pressure, in this case 110 p.s.i.g., for the slightly improved thermal efficiency this provides. However, I feel there is little point in working at the design pressure when it cannot be usefully employed; even at 90 p.s.i.g. DONCASTER will easily pick her feet up on anything but a perfectly dry rail. I know there are those who believe in adding weight to reduce the possibility of slipping, but it is something that was a fact of life full size, most 'Pacifics' being particularly prone in the U.K. through lack of equalised springing, and I reckon one of the most exciting aspects in miniature is to be able to emulate full size, be it good or bad. Anyhow, the point of the hydraulic test is to ensure that the boiler structure will withstand twice working pressure for around 30 minutes, after which it can be pronounced as being fit for service.

I do not believe in steam testing a boiler above its intended working pressure, but it is a very good plan to raise steam to about 10 p.s.i.g. and blow the boiler down, this to remove the salts that accumulate during brazing, ones which guarantee priming at the first few steamings. I get a letter most weeks, there was one this morning that prompted this paragraph, saying all went well at the first steaming except that water level could not be maintained with the hand pump, and could I suggest a modification to the design to cure this. Such makes me shudder, for mention of the hand pump usually means that the other means of feed, injectors/axle driven feed pump, are probably choked with debris from the boiler, and what of the muck that chose the easier way out through the cylinders?



Moving forward about 6 feet, Allan shows us all the inspection and mud doors on 4472's firebox.

Boiler Clothing and Superheater

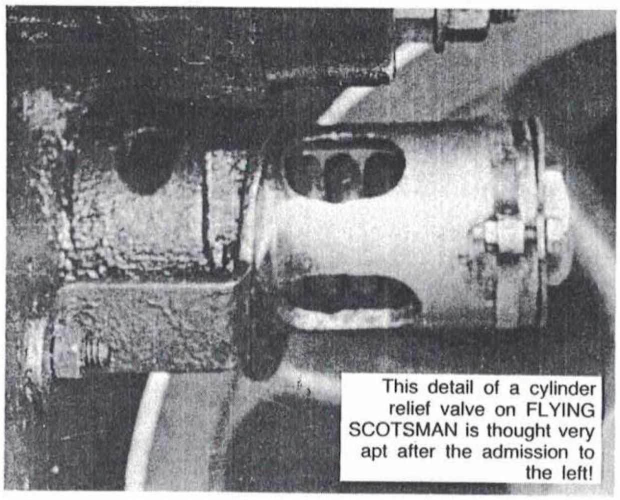
Although we cannot lag or clead the boiler at this stage, as the specification for same appears with the steam circuit, this is as good a point as any to discuss it. My note concerning the lagging is slightly ambiguous in that around the firebox it does not extend below the running boards, nor was the throatplate area between the frames lagged or cleaded full size, though there are definite advantages in doing the latter in miniature. Perhaps I am wrong in still specifying asbestos as a suitable material for lagging, but old habits die hard, and I still reckon a majority of Locomotives are so lagged. Felt is a very acceptable alternative, but some fibreglass cloth can be crushed and you might be alergic to same. I secure lagging as far as possible with 15A fuse wire. It isn't possible to use a single piece of cleading for DONCASTER, so cut it so that the joints come where the boiler bands are fitted, just as full size. Some 25 years ago and more when I was looking for suitable cleading for my O2 Locomotive FISHBOURNE, in the shipyard where I was then employed, I espied sheets of .015 in. thick brass shimstock, used when assembling steam turbines and the like. It was extremely hard and springy, but cut well with tinsnips and was very difficult to 'bruise'. The only drawback appeared to be in getting paint to adhere to it, but I solved this by a light spraying of zincplate from an aerosol can and reckon this to be the perfect answer; Reeves can supply all your requirements in this direction. Fit the sections to the barrel, use stout string to hold the sheets hard to the lagging, then sweat the seam before adding the boiler bands; the firebox will have to await erection of the boiler to the frames.

There is a break in the steam circuit for lack of the superheater header detail, but we can deal with the elements. I have made them such that each element is separately removeable for repair or replacement. Having no personal preference in respect of flue tube or radiant superheaters, this choice I am happy to leave to you the builder, simply giving the dimension for either. The sheath must be of stainless steel with the firebox end plug welded in place, but the return pipe can be from copper. It is important for the return tube to be concentric with the outer sheath and there is a simple way of ensuring this, one that will also increase superheater efficiency two-fold. The way to achieve this is to wind a very coarse spiral of 2mm copper wire, about 2 in. pitch, around the return tube and just tack it in place with a few blobs of silver solder. This not only ensures concentricity so that the steam flow is regular, but the spiral means the steam will better 'wipe' the bore of the sheath, giving a better heat transfer.

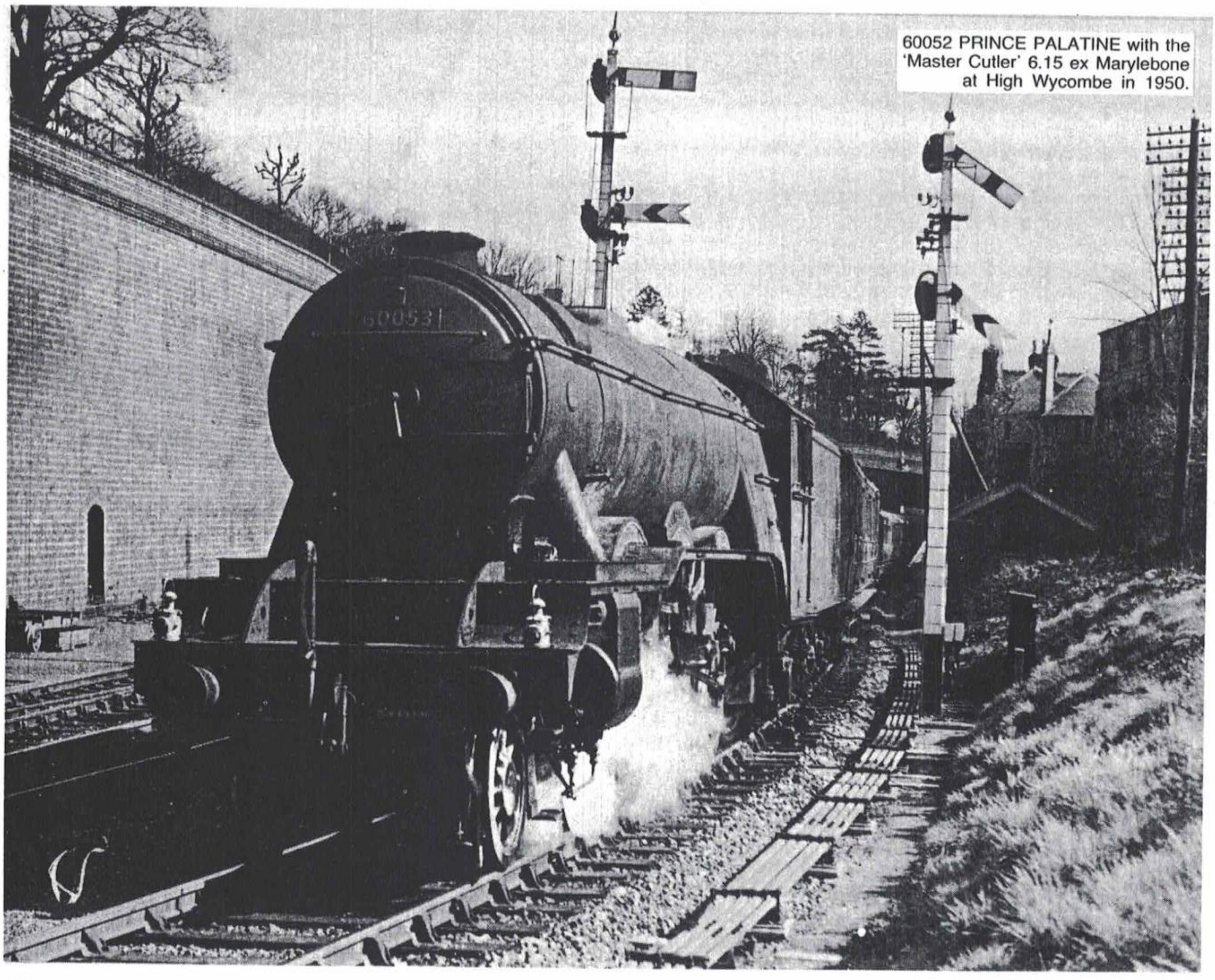
We have now dealt with the 'steam generator' for DONCASTER which I hope you will agree is impressive; next time we will move on to the 'power house', the cylinders, which are even more impressive!

Don's Mistakes

Two drawing errors have come to light in the preliminary copies of the Drawings sent to builders, for which apologises. The first concerns the overall length of mainframes and I guess I was trying to impress by adding a whole 2 in. to the correct dimension of 3 ft. 8$\frac{3}{4}$ in.; several builders have been kind enough to point out this error. The second error occurs on Sheet 10 being the length of return crank which should read 1.441 in.; how I ever arrived at 1.109 in. is beyond me, though at least I discovered it before any parts were made.



This detail of a cylinder relief valve on FLYING SCOTSMAN is thought very apt after the admission to the left!



60052 PRINCE PALATINE with the 'Master Cutler' 6.15 ex Marylebone at High Wycombe in 1950.

NOTE OF APPRECIATION:

This is the second in a whole series of superlative photographs to grace these pages, a tribute both to the skill of H. K. Harman and his generosity in allowing us a sight of them. Processing from the negatives has been by Jim Sarney and some have never previously been printed, never mind published. It is a thrill for me to set down Mr. Harman's great record of the A3's, in which the 'Master Cutler' train features prominently, as do Leicester engines.

Doncaster — a 5 in. gauge Gresley A1/A3 'Pacific'

by: DON YOUNG

Part 6 – Cylinders and part Bogie

Arriving at the cylinders, a number of important decisions had to be taken, as in this instance I knew from the outset that there would be a high price to pay for, visible, authenticity. To keep the outside cylinders to scale length meant that the rear cover had to be cast integral as full size; this immediately provided sufficient side movement to the bogie, plus I knew from the fabricated cylinders I made for my LNER Class K1/1 'Mogul' almost exactly 20 years back that there was not the slightest problem in machining. I envisaged having to machine the rear passageway from cylinder bore to steam-chest, but the patternmaker was able to have this cast in for us, so all machining is now straightforward. Do please ignore the instruction about the $1\frac{1}{8}$ in. diameter cutter as I am sure that blowing into the main bore of the casting will convince you it is totally unnecessary. It is relatively easy to get steam into the cylinders, especially with such short passages, but getting it out again required generous coring of the casting, though I feel the end result is really magnificent and will be very evident at the drawbar. Last night there was nothing of interest on TV, it is all too often the case, so I played a recording of LNER 'Pacifics', and knowing what effect generous exhaust passages have on the sound issuing from the chimney, reckon in a few years time we shall be able to produce a rival recording!

It was no good having generous passages in the outside cylinder blocks if these did not continue to the blast nozzle(s), said continuation being cast into the smokebox saddle. I knew the horrors of the inside cylinder/smokebox saddle joint in full size and that as we cannot climb inside our smokeboxes it is not feasible to reproduce, but by casting a 'floor' into the saddle it gave me a simple and practical solution. All this really put the pressure on the inside cylinder, to complete the specification in a proper manner; it posed a lot of problems on the drawing board, more for the pattern-maker. The integral back cover followed from the outside pair, there was nothing too terrible about the steamchest being horizontal and the cylinder bore being inclined, and piping from superheater to steamchest was no problem. The area which caused all the problems was getting exhaust steam from each end of the steamchest up to the smokebox, terminating in a plain flange, the only feasible way without ending up as a mess was to have cast-in passageways. It is of course an expensive solution, but the first time DONCASTER starts to shout I am sure you will think it worth every penny. There are those who have questioned my wisdom in such expensive castings and I am the first to admit this could be a drawback to DONCASTER's popularity, but once seen, these castings have captivated and I have no regrets about my decision to date, just as long as they remain exclusive to DYD.

Whilst I was writing this preamble, the idea was to retire to the workshop to proof machine the cylinder blocks, but in this I failed miserably. I am sure readers will agree that when setting up castings in the lathe, hours of work can be lost if there be interruption and the telephone invariably had to be answered at the most critical moments, so in the end I capitulated, for it is not the slightest good getting angry when good friends and customers want to speak to me. One who called when I had the inside cylinder casting half set up was Dick Stockings who organises my castings at Jay's of Norwich; he was particularly interested in how I was getting on with this casting and no way could I have told him that if he had delayed his call by an hour or so I might have been able to answer positively! Anyhow, the decision was arrived at to hand the castings over to Merlin Biddlecombe, who does work professionally for me, with the remit to tell me how to machine them on the Myford ML7, though this brief has been extended to produce jigs and tools for machining the cylinders commercially where other builders encounter the same problems that I did. Anyhow, I will never commit machining operations to paper without first checking its feasibility, so whilst Merlin is sorting out the cylinder blocks, let me set the cylinders aside for the moment and progress the rest of the details on Sheet 6.

An item which attaches to the cylinders but does not require them to be in existence to produce are the six cylinder relief valves, simple components that add a touch of realism as they not only look the part, but can be made to operate correctly. Chuck a length of $\frac{5}{16}$ in. A/F hexagon bronze bar in the 3 jaw, face and turn down to 7/32 in. diameter over a 5/32 in. length and screw 40T; part off at a full 17/32 in. overall. Chuck a 7/32 x 40T screwed adaptor, fit the embryo relief valve body, face off to length and turn down to 19/64 in. diameter to leave 3/32 in. of hexagon. Centre and drill through at No. 43, following up at $\frac{3}{16}$ in. diameter and 'D' bitting to 21/64 in. depth, then either poke a 3/32 in. reamer, 'D' bit or drill in that order of preference, through the remains of the No. 43 hole. Grip the whole assembly in the machine vice on the vertical slide, drill a 3/32 in. hole and elongate with an end mill into a $\frac{3}{16}$ in. long slot, repeating until you have four of them equi-spaced. The cap is turned from $\frac{7}{16}$ in. rod, brass is O.K. here, and the hexagon head we can fit as just described for E. S. COX; silver solder together. Seat an $\frac{1}{8}$ in. rustless ball, the compression spring being 3/32 in. o.d. x 24 s.w.g. and about $\frac{5}{16}$ in. free length, though adjust this and test hydraulically to achieve a setting roughly 10 p.s.i.g. above boiler pressure, then the valves will operate automatically if there is condensate trapped in the bore. If the ball refuses to reseat properly on every occasion, this usually means that the ends of the spring are not perfectly square, the remedy being to drill the cap centrally at No. 57 and press in a $\frac{5}{16}$ in. length of 3/64 in. stainless steel rod, this to act as a guide.

Smokebox Saddle

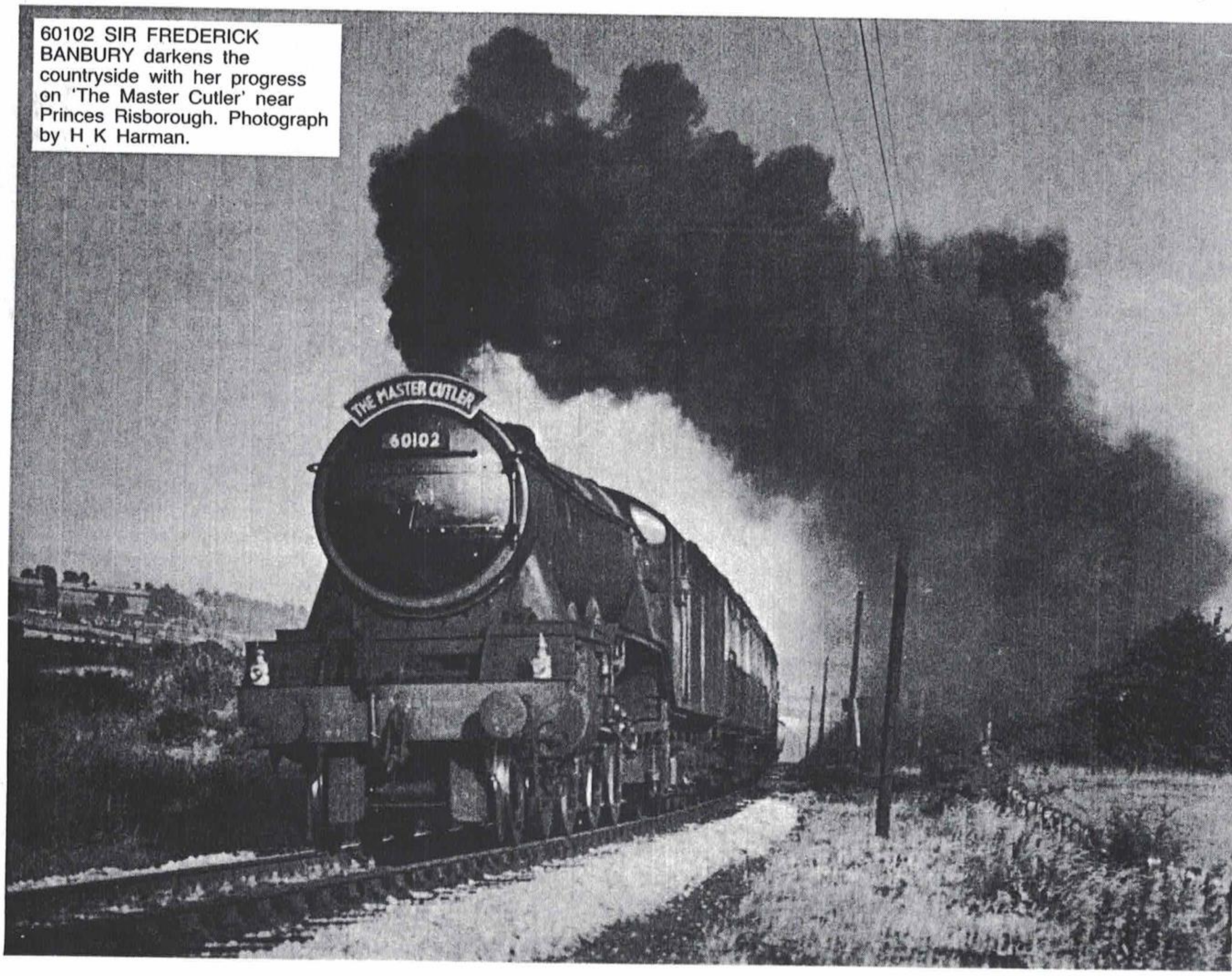
This is one feature where working on the full size DONCASTER has proved invaluable, for I have seen at first hand the problems involved in arriving at proper joints, so knew in which direction salvation lay. The result is very simple as far as machining is concerned, and very robust. The smokebox flange is cast such that only a file is required to clean up to be a good 'bed' to the smokebox shell, in fact the latter is made flexible by reason of a huge cut-out to take up any slight irregularities, again as full size. You can mark off and drill the 56 holes in this flange next, then one big job is out of the way, countersinking the outside face for 7BA screws. Next cut triangular pieces $\frac{5}{16}$ in. x $\frac{1}{4}$ in. from 1.6mm brass and position clear of the holes, as shown, silver soldering in place; now to move downstairs.

Mark off the side flanges to drawing, then sit on a large angle plate, bolted in turn to the vertical slide. Drill a $\frac{3}{8}$ in. hole somewhere in the area to be cut away for the inside cylinder and use this to bolt to the angle plate. The cross slide travel on the Myford ML7 is a full 5 in., so if you set up carefully you will be able to mill away the side flanges with a $\frac{3}{4}$ or 1 in. end mill and leave only a couple of corners to be filed to complete. Use very light cuts because of the overhang and then tidy up the bottom profile of the flange; reverse and repeat. Although the $\frac{13}{16}$ in. hole for the middle cylinder steam pipe connection can be drilled, I suggest you make up a cutter as described by Jack Couson in his boilermaking article in LLAS No. 7; the actual cut-away portion will have to wait erection of the middle cylinder, being very much a fit-to-place job, and of course all the fixing holes, both plain and tapped, will be dealt with from the mainframes.

That leaves just the facing and screwing of the outside cylinder exhaust standpipe. Chuck a length of $\frac{3}{4}$ in. diameter bar in the 3 jaw and turn down over a $\frac{1}{2}$ in. length to a nice sliding fit in the standpipe. Pack the saddle casting to the vertical slide table and bolt in place, then align the standpipe to the spigot just machined. Take a square shank round nose tool and grip in the 4 jaw to just clear the outside of the standpipe when the chuck is rotated, then advance the tool a few thous by slackening one jaw and tightening its opposite partner, set the lathe in motion and wind the carriage forward, measuring the machined diameter with a micrometer, and gradually reducing to $\frac{7}{8}$ in. Next chuck the $\frac{3}{4}$ or 1 in. end mill, it does not matter if it is offset in the 4 jaw, in fact it must be if the smaller size is used, to clean up the top face to arrive at the $\frac{3}{8}$ in. dimension. Change to the 3 jaw chuck, fit a $\frac{7}{8}$ x 26T die directly in the jaws, with a wee piece of strip trapped in the gap to stop the die turning in the chuck and also cutting too slack a thread, then screw the standpipe to complete.

Starting the Bogie

Although there are insufficient details on Sheet 6 to complete the bogie, we can at least discuss it and make some of the parts, plus we already have the wheels and axles from Sheet 4. Gresley was greatly in favour of the swing link method of both bogie and pony truck side control, and having made the latter on my 5 in. gauge K1/1 and watched it in operation, I share the great man's enthusiasm. Although having side control springing has perhaps the greater merit, and it will be offered as alternative in line with what happened later on to DONCASTER and her sisters, the swing link action is perfect in that its geometry means that more weight is transferred to the wheel(s) being pushed into the curve. We have an 'S' bend in our Club track at Cowes on the Isle of Wight, simply because some Members slapped a 'preservation order' on an ash tree, one which my K1/1 will negotiate at full speed with the inside wheel of the pony truck on each curve lifting from the rail; from this I am hooked on swing links. The other feature of the swing link bogie, and like more things on DONCASTER it stems from Patrick Stirling's 'Singles', is that the bogie fulcrum is behind the true centre of the bogie, though in the later and sprung side control version the two coincide. It is said that the swing link bogie went out of favour on the A1/A3's when evidence of the rear bogie wheels striking the outside cylinders was found, though as they were phased out over several years it could not have been too serious a problem. Anyhow, of the items detailed on Sheet 6, the pivot pin, swing link pin and collar are peculiar to the swing link bogie and as all are straightforward, I can dispense



60102 SIR FREDERICK BANBURY darkens the countryside with her progress on 'The Master Cutler' near Princes Risborough. Photograph by H K Harman.

with their description. The flat cotters to retain the collars to the swing link pins are made in identical fashion to those described for the screw couplings on E. S. COX. For the rest we must assume that the bogie frames are in existence, as they will be in the next session.

The bogie horns, despite their intricate shape, require surprisingly little machining. Grip in the machine vice, on the vertical slide, to first mill the working face, then turn through 90 deg. and skim off the inside face. Turn through 180 deg. and reduce the working face to ⅝ in. width, then advance the tool by ⅛ in. and deal with the frame 'gripper'. Tidy up with files, drill the No. 29 hole and bell mouth very slightly so that the spring pins will not bind as the bogie passes over uneven track, or heels into a curve. Offer up to the frames, clamp in place and use a couple of 4BA bolts and nuts between the working faces to force the 'grippers' hard against the frame opening. Drill the 5/64 in. holes for rivets, and here I must applaud Reeves for stocking this odd size, for I found out from bitter experience that $\frac{1}{16}$ in. rivets are not quite robust enough here, and substitution of 3/32 in. causes all sorts of problems with heads fouling ribs, etc. The hornstays are from $\frac{3}{16}$ in. square steel bar and must be machined to fit the frames properly, otherwise they are a waste of time, after which it is a simple matter to drill and countersink for the pair of 8BA fixing screws. Yoke pivot and bogie spring pins are plain turning, which brings me to the axleboxes and their keeps.

The bogie axleboxes are cast as a plain stick, so first turn in the 4 jaw, or mill in the machine vice, to a regular $1\frac{1}{16}$ in. x 27/32 in. section. The next operation is definitely for the machine vice and vertical slide, this to cut a ⅝ in. wide slot along one face to ⅛ in. depth. Turn end for end to tackle the second slot using the same vertical slide micrometer collar readings for the final cuts, but for depth, check against the pairs of horns erected to the bogie frames and stop when the axlebox stick just enters between them. Cut into individual axleboxes and face each off to $1\frac{1}{16}$ in. overall. The next job is to produce the recess for the keeps and I suggest the latter be made from ⅝ in. square commercial brass bar, which usually is remarkably square and regular, when you mill the recess to accept the bar, a tight push fit. Drill the two No. 52 holes right through for the keep pins, then mill off the surplus keep material at the bottom. Having said that, the foundry has decided that cast gunmetal keeps are the order of the day, have supplied me with excellent cast stocks for same, and these will be added to the castings list.

We will deal with the holes for the axles in matched pairs, so first take two 2 in. lengths of, say, 1¼ in. x $\frac{3}{16}$ in. BMS flat, drill two ¼ in. diameter holes at 1⅝ in. centres and bolt together, then mill a full $\frac{3}{16}$ in. wide slot down the centre line for about 1¼ in. length, so a pair of inner flanges will enter back to back. Square up a pair of boxes in this simple jig and tighten the two, 1½ in. long, bolts. Find the centre of one box of the pair by the 'X' method, centre pop and scribe a circle around ⅞ in. diameter, then chuck the whole assembly in the 4 jaw, a scriber under the tool post, and set so the scriber point traces the circle accurately. Centre, drill and ream to $\frac{9}{16}$ in. diameter, though on reflection I would bore out to a gauge, the latter just a length of rod turned down to exactly the same diameter as the journel, when you can achieve an easy running fit. Cut back 1/64 in. in the corners to arrive at the raised face as shown, then reverse in the chuck, fit the stub of axle and set to run true with a d.t.i., then complete the second raised outer face. Mill the reservoir in each keep, using the smallest end mill possible for the final profiling and fit a wee felt pad, starting off the right way by soaking same in oil.

Next job is to fit each axlebox to its chosen pair of horns. Ease the axlebox slot faces with a smooth file until you can push it part way into the horns, when you will probably find the working faces of the latter are not quite square to the frames, 'toeing-in' very slightly, so ease these too with a file until the boxes slide sweetly from top to bottom. We now have to arrange that each axlebox can lift independently of its partner and by at least 5/32 in. without jambing, so relieve the flanges as shown, trying to place as you proceed and using the actual wheelsets. The final operation is to produce the spherical indent on the top of each box to accept the yoke pin, for which a 'D' bit ground up with spherical end is the ideal; those cylinders can be delayed no longer.

The Cylinders

It so happened at this stage that the Festive Season came upon me and with it the opportunity to retire to the workshop after slaving over a hot stove, for it has become a ritual that I cook the Christmas dinner; enjoy it too! Now I was at least able to have a look at machining the outside cylinders, which took me back exactly 20 years to when I dealt with nearly identical ones, though fabricated, on the K1/1. This time I had the choice of 22 cast blocks in either iron or gunmetal, and the first one I picked up could not be bettered so it was that I made a start on a R.H. gunmetal one; it was exciting to be cutting metal again rather than drawing it!

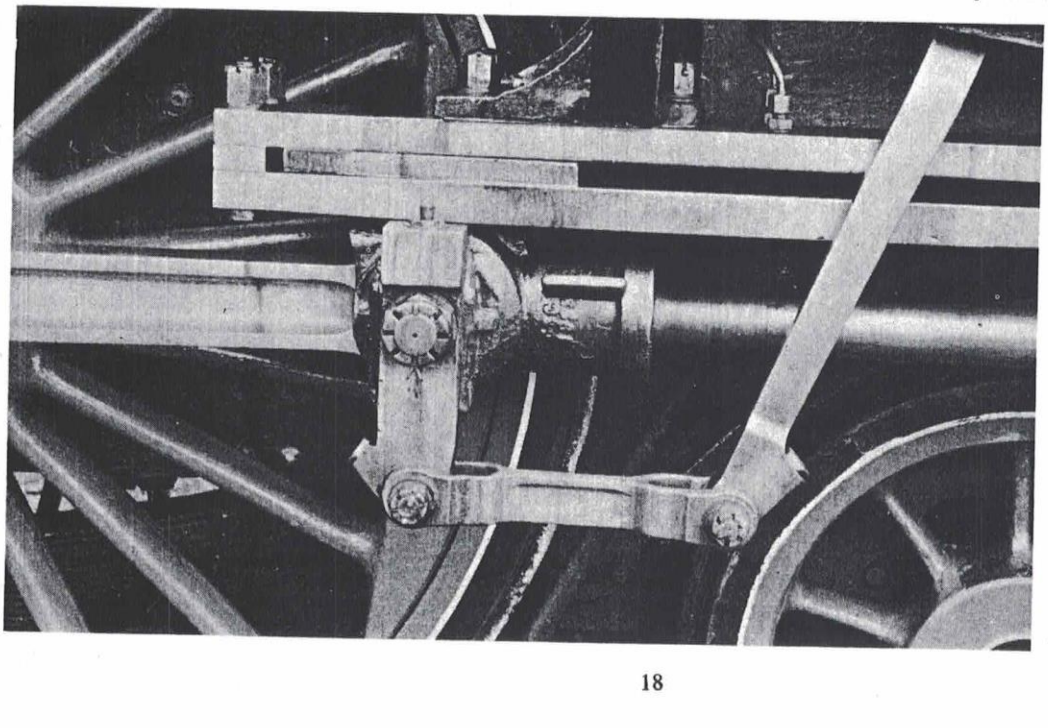
Sitting the casting on the lathe bed, it was a revelation to find how accurate and square it was, so bungs were fitted to both main bore and steamchest, marking blue added and soon everything was marked out. The 'T' face on top of the block, in lieu of a plain circular boss for the steampipe flange, was originally envisaged as a main datum and so it proved, for I found it was just possible to set up in the 4 jaw and face off to line, when I had a lovely flat face to work from.

The next set-up was a bit Heath Robinson, but it worked brilliantly, so I have no hesitation in explaining it. The angle plate I use with my vertical slide is the Myford one that is 4 in. long and 2¼ in. x 2 in. section; this I bolted to the top tee slot on the vertical slide with machined face horizontal so that I could suspend the cylinder block underneath, with the datum face hard against the angle plate. Initially I was stumped for a means of fixing, until I poked a 5½ in. length of ⅝ in. diameter steel bar through the steamchest bore. I cross drilled this for ¼ in. bolts at around 4 ⅞ in. centres, brought up a 5½ in. length of ¾ in. x ⅜ in. bar and drilled through this at the same centres, assembled with 3½ in. long bolts, slid the rectangular bar over the unmachined top surface of the angle plate and tightened up, using the opened jaws of the 4 jaw chuck to get the bolting face square across the lather axis. I found initially that my 1 in. end mill would not quite cover the whole of the bolting surface as set up, but by setting it off centre in the 4 jaw chuck it coped, and well, and in less than five minutes I had a machined face to line; only wish the brain had worked that fast when setting up! I also used this set-up, turning the angle plate through 90 deg., to face off the drain cock bosses; now I could begin to make rapid progress.

I must admit that I am one of those who once 'rediscovers' a particular item of equipment, and until now the machine vice had for years been a permanent fixture to the vertical slide, will try to make every use of the angle plate now that it was back in favour. So I set it up on the back slot on the boring table, for that is what the cross slide was about to become, setting the working face parallel with the lathe axis. The slots in the 2 in. face on the angle plate are on the same axis as the tee slot in the boring table, so I slid in four tee nuts, using the outer pair to bolt the angle plate firmly in place. The next requirement was to pack the cylinder block casting up so that its main bore was at lathe centre height, a matter of some $\frac{13}{16}$ in., and as later I would want to lower the block by ¼ in. to bore out the steamchest, one of my 3 in. square pieces of packing was ¼ in. thick. The only material I could find to make up the remaining $\frac{9}{16}$ in. thickness was a length of 3 in. x $\frac{3}{16}$ in. flat for some future main frames, only by cutting off three 3 in. lengths they will now be somewhat short of requirement! I sat the block on the packing and realised the

strong-backs would be 7 in. long with holes at $6\frac{1}{2}$ in. centres, so made the pair from $\frac{3}{4}$ in. x $\frac{1}{4}$ in. BMS bar, securing with $2\frac{1}{2}$ in. long bolts, the 'T' facing on top of the block being hard against the angle plate. I had scribed the centre lines onto the piston rod boss, this being towards the chuck, now with the help of my magnifying glass I was able to get the point of the centre drill to align with the 'cross-wires', a bit like target practice!, then centred deeply. The deep centre meant I could use the 1 in. end mill to face off the boss to the $\frac{3}{8}$ in. dimension from the back cover face, drill through to 31/64 in. diameter and ream out to $\frac{1}{2}$ in.
Because I had not done my homework, at this stage I had to remove the cylinder block to fit the top slide as part of the process of making my boring bar; other builders will be brighter than I and make their tools first! Part reason for this was my progress had been unexpectedly swift, but I was at least fortunate in having discussed my method of boring out with Merlin a couple of days previously, so knew how I was going to set about it. The just over 8 in. length of $\frac{1}{2}$ in. silver steel rod I had by me was a smashing fit in the reamed piston rod housing, so I set up each end in turn in the 4 jaw chuck and set with a d.t.i. to run perfectly true, then faced off and centred to get a between centres boring bar. It was of course a wee bit slender, especially to bore out to $1\frac{3}{4}$ in. diameter, and a cross drilled hole to accept the tool bit would have weakened it even further. The stub axle from a hay turner scrapped more than 25 years ago produced me a collar $1\frac{1}{4}$ in. o.d. x $\frac{1}{2}$ in. reamed bore x $\frac{1}{2}$ in. thick, after a struggle, as whoever made that piece of steel did not intend it to turn freely! From the periphery I crossed drilled No. 21 and tapped from both sides at 2BA for cup point grub screws, this to rigidly hold the collar to the boring bar. From close to the periphery, on a flat face, I then drilled No. 12 at roughly a 45 deg. angle for the $\frac{3}{16}$ in. tool bit, again drilling down from the periphery, this time at No. 39 to meet the tool bit hole and tapping 5BA for a cup point grub screw. I was ready to bore, or almost so, for it took me ages to get back to the stage of the cylinder block on the boring table with the boring bar sliding sweetly through the piston rod housing; I sure learnt my lesson the hard way. Because the length of bearing surface in the housing was a factor in getting the boring bar to run sweetly. I added the countersink as shown to reduce the length of bearing and then ran the $\frac{1}{2}$ in. reamer through again by hand.

I found the block I had chosen measured exactly 2 31/32 in. as cast, which meant I had to bore to $2\frac{13}{16}$ in. depth to leave the 5/32 in. 'cover' thickness at the back, so I set the boring tool to cut an approximate initial .010 in., set the carriage in motion and found it took me a little time to get used to the job moving away from the headstock as the feed progressed. I worked at the lowest direct speed and fed grease onto the boring bar as it passed through the piston rod housing. Arriving at the back 'cover', I found it prudent to stop the motor and use the special handle that I received about a year ago courtesy of Myford, which grips the headstock mandrel bore, and with this I was able to complete to depth by hand without any undue stress. I must admit that this handle did not seem a very useful asset at the outset, but I have learnt differently since, to a point where I am tempted to leave it in the spindle during normal turning, only I must practice what I preach on safety. For some reason, I had got the tool sharpness and setting just about perfect and with cuts of around .010 in. the swarf really began to pile up and soon I was close to finished size. By now the daylight was fast departing and I found that my workshop lighting had suffered by my becoming used to fluorescent lamps in the office, so I draped some kitchen foil around and it did wonders; I could see what I was doing again. When the cylinder block detail was drawn, I of course envisaged a machined back passage, so specified an end relief to the bore; now I could not find a way to produce it and as it had completely lost its importance, decided very quickly to omit same and bored out parallel. I then let the tool traverse backwards and forwards at the final cut whilst I thought about the next stage; other pleasant things too!
With gunmetal cylinders, an 'O' ring is specified for the piston, which needs a nice 'lead' into the bore so the ring is not pinched and damaged when inserted. With cast iron cylinders you can also use an 'O' ring, though the preference must be to fit proper piston rings, which Reeves supply at $1\frac{3}{4}$ in. diameter x $\frac{1}{8}$ in. thick. This means the piston head must be carefully machined as there will only be 3/64 in. metal between the grooves, just a fraction more at each end. The point though I am trying to make here is that the taper into the bore is equally helpful when fitting piston rings. I simply ground a piece of $\frac{3}{16}$ in. tool steel rod like a parting tool but at roughly a 40 deg. angle, when I was able to feed it in by hand to achieve the mouth with very little tool chatter.



The lightweight Greslay crosshead was always considered the fitter's friend at The Plant, though those who had to keep the slide bar retaining bolts tight in service thought otherwise!

On to the steamchest, for which the ¼ in. packing was first removed and then the boring table wound back 1.656 in. I had a ⅝ in. boring bar made 20 years back when I did the K1/1 cylinders, so tried chucking this in the 4 jaw, but couldn't make any sense of it at all. I therefore decided on a between centres boring bar from ⅝ in. diameter steel, a piece about 8 in. long that had been destined for a tender axle, so cross drilled it at No. 12 for a 3/16 in. tool bit, secured with a 5BA grub screw. To gain a datum, I chucked the 1 in. end mill eccentrically in the 4 jaw, brought it up to the piston rod housing and took note of the handwheel micrometer collar reading on the end of the leadscrew, that most useful of Myford accessories. It was then a matter of moving back by .094 in. to arrive at the dimension to face off the rear steamchest face for the cover, when I was ready to start boring.

With a round nose tool, I first bored right through to ⅞ in. diameter, checking with vernier calipers; one has to be a bit careful when measuring a bore with same, but it is a marvellous tool and a treasured momento from my days with Plessey Radar. I had a tool bit ground square like a parting off tool from the K1/1 exercise, so fitted this to the boring bar and opened out the end of the steamchest to 15/16 in. diameter and .469 in. depth, both dimensions being arrived at accurately with the vernier calipers. At first I was in a quandary as to how to tackle the same operation at the other end of the steamchest, then I miked up the boring tool at .187 in., added this to the required 2.969 in. between shoulders for the valve liners, and then knew the micrometer collar reading on the leadscrew handwheel to arrive at the correct end point; later I was able to check it out as being within a couple of thous, much to my relief.

Having had so much trouble by not thinking ahead, for the second and L.H. block, once the top 'T' and bolting faces had been dealt with, at the set up used for the R.H. block, I set up with the 13/16 in. of packing, chucked a cranked turning tool eccentrically in the 4 jaw to fly-cut to around 2¼ in. diameter, and faced off for the front cover, taking care not to cut too deeply into the steamchest, in fact if I were doing it again then I would definitely use the angle plate and vertical slide set-up. Anyhow, it was then a matter of pulling the block back .53 in. from the chuck and facing across the front steamchest end, which solved most of my earlier problems. After boring out the L.H. block, only time was fast running out so I rather skimped it, this time with the angle plate in the closest slot at the front end of the boring table, I was then able to set up the R.H. block at this setting and complete the front cover face and steamchest end to bring things very close to completion.

With the 13/16 in. of packing in place, I turned the bottom of the block towards the 3 jaw chuck and centred, following up with a 5/32 in. 'D' bit to 5(32 in. depth before tapping 3/16 x 40T for the drain cocks, though I have yet to drill No. 55 into the bore. I then swivelled the block around through about 150 deg. to centre for the steam entry hole at the top. I did this so that the diameter of the countersink, at the top face was a little over 5/16 in., it was like a giant crater!, drilled No. 12 into the chest and followed up with a 5/16 in. end mill. I guess my blocks are going to remain incomplete for a long time ahead as everything from now on is on familiar ground, like I omitted to face, drill and tap the 7/32 x 40T boss for the relief valve, which can best be done after boring the cylinder and before moving on to the steamchest. Another job will be to file a flat at the end of the bore, drill three No. 22 holes into the steam belt cavity at the front end, and then mill into the specified steam passage slot. The other job and one I am still thinking about, is facing off the inside of the back 'cover' which is still as cast from about 1½ in. diameter down to ⅞ in. at the top of the countersink. It should of course be done at the same setting as when the front cover and steamchest end face is tackled, but for once my 1 in. end mill failed me through being too short in the shank, so I can only guess that a 'long series', chucked eccentrically in the 4 jaw, is the answer; the finish is not critical here, only to remove metal to provide the very necessary piston end clearance.

Piston and Rod

Talking of pistons, and from now on I reckon you will be moving light years ahead of my favourite A3 HUMORIST even though it must have a GN tender!, chuck the blank in the 4 jaw, face and turn down to around 1 25/32 in. diameter. Centre and bring the tailstock into play to first turn on the tapered spigot over a 3/32 in. length at the end, the reason for the countersink, at the inner end of the piston rod housing. The 'O' ring groove, or that for the piston rings if used, requires a special form tool, when the groove(s) can be cut to a little over 1½ in. diameter. Drill 7/32 in. diameter to ⅝ in. depth, follow up at 6.3mm to ¼ in. depth and enter a ¼ x 40T taper tap, then part off at a full ½ in. overall.

Chuck the piston rod material in the 3 jaw, check with a d.t.i. that it is running true and change to the 4 jaw if there is any discrepancy. Face, turn down to ¼ in. diameter over a full ½ in. length and screw the end ¼ in. or so at 40T; screw on the embryo piston. Now complete turning the piston to drawing, facing off to thickness first as this will help screw the piston hard onto the rod, and tackling the groove(s) as the final operation: the piston wants to be a nice sliding fit in its bore.

Piston Rod Bush and Gland Plate

Brass would by my preference for the piston rod bush, so chuck a length of ⅝ in. diameter in the 3 jaw, face and turn down over a ½ in. length to .502 in. diameter, a tight press fit in the block. Centre, drill and ream 5/16 in. diameter to ⅝ in. depth and use a 'D' bit with .030 in. radius in the corners to deal with the 'O' ring recess. Ease the outside over the length of the recess to be a sliding fit in the piston rod housing, then it won't get squashed, before parting off, facing off to length and pressing home; run the 5/16 in. reamer through the bore again to complete.

The gland plate I would turn from 1 in. diameter bar, ignoring the ⅞ in. o.d. dimension and matching instead to the cast boss. With a knife edged tool, scribe on the bolting circle at 21/32 in. diameter, then centre, drill and ream to 5/16 in. diameter before parting off an ⅛ in. slice; rub on a sheet of fine emery cloth to remove any tool marks. Erect piston and rod, drill the gland plate and bring it up to its boss, then spot through, drill and tap the housing 8BA to around 3/16 in. depth, securing after the 'O' ring has been fitted with hexagon head bolts.

Front Cover and Cylinder Flange

To keep the cylinder block at scale length, no spigot is included on the front cover; it is simply a 2¼ in. disc of 5/32 in. thick material. File the flat to match the steamchest then mark off and drill as specified, remembering that these covers are handed by the relief valve tapping; erect to the cylinders with 6BA hexagon head bolts. The cylinder flange is straightforward from 4mm thick, flat, brass sheet. Check that the rows of holes for fixing to the cylinder block come nice and central in the cast bars provided for the purpose and adjust if found necessary, the datum hole being the bottom countersunk one in the L.H. vertical row as it coincides with the centre of the main bore. Don't fix the flange to the block as yet, for it will first serve as our drill jig for the mainframes.

Valve and Liners

We arrive at the 'clever bits', the valves and their liners on which depends the performance of DONCASTER. Nobody should be frightened of piston valves doing it my way, when with proper lubrication they will last the lifetime of the engine, that I guarantee. I ran through the procedure for E. S. COX, but as many new readers are joining for the DONCASTER series, I trust a little repetiiton will be in order? One thing I never do is refer to previous descriptions, so this may well be a variation on a theme!

Liners first, so chuck the cast bar in the 4 jaw, face, centre and bring the tailstock into play before turning down over a $1\frac{1}{8}$ in. length to $\frac{15}{16}$ in. diameter, a rattling fit in the steamchest end. Next turn down over a 27/32 in. length to a .003 in. interference fit over the actual bore size you arrived at with your vernier calipers or inside micrometer; this is vital for success in my book. Ease the leading end with a smooth file, running the lathe at top speed, so it will enter the bore by about $\frac{1}{16}$ in., then drill and bore out to within a few thous. of $\frac{11}{16}$ in. diameter and complete with a reamer. Slightly bell mouth the outer end then part off, reverse in the chuck, face off to length and bell mouth this end also.

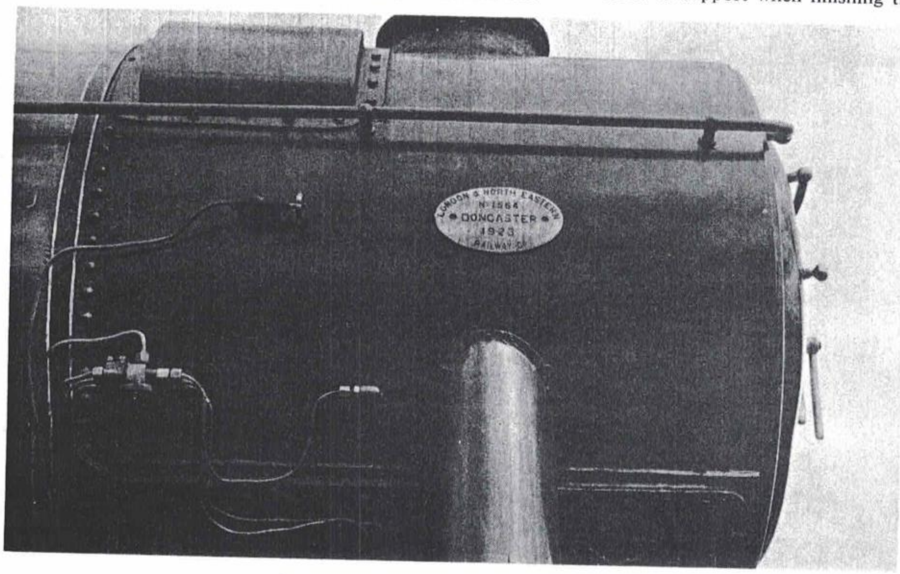
We now need two thimbles, some would call them cups, to allow us to complete the liners. Chuck a length of $1\frac{1}{4}$ in. diameter steel bar in the 3 jaw, face, drill $\frac{5}{8}$ in. diameter to about 1 in. depth, then carefully bore out to $\frac{7}{8}$ in. diameter, an easy fit over the liner, and 25/64 in. depth, the latter being critical. Part off at $\frac{1}{2}$ in. overall, then repeat on a second piece, only bore this to $\frac{15}{16}$ in. diameter and 23/64 in. depth; case harden both pieces. If you slip these thimbles over the ends of the liner, it will leave an exact $\frac{3}{16}$ in. band in way of the ports, so you can mark off at equi-distance for the six holes, drill them at around No. 14 and with a square file, open them out using the thimbles to get the steam and exhaust edges accurately located.

I was tempted to specify seven ports, but one passes the square file through opposite pairs of holes to get a decent stroke and the odd number does not work out, but you can elongate the length of the ports slightly above $\frac{3}{16}$ in. if you wish for the extra cross sectional area this provides, indeed these two edges can be filed to a taper from $\frac{3}{16}$ in. at the valve up to $\frac{1}{4}$ in. at the cavity. The important thing is that at least 50% of the circumference be available to support the valve; much below this figure and you will begin to get wear. Poke the reamer through to remove all the burrs and we can begin to think about fitting them to the blocks.

We will do this exactly as I was taught full size, so first chuck a length of $1\frac{1}{4}$ in. diameter bar in the 3 jaw, an odd end of any material you have by you, face, centre and drill $\frac{3}{8}$ in. diameter to $\frac{3}{8}$ in. depth. Next turn a spigot over an $\frac{1}{8}$ in. length to $\frac{15}{16}$ in. diameter, an easy fit in the steamchest end, then part off at $\frac{1}{4}$ in. overall. Either use more of the same material, or an odd end of 1 in. bar, to first turn down over a $\frac{3}{8}$ in. length to 59/64 in. diameter, then face, centre and drill $\frac{3}{8}$ in. diameter to $\frac{3}{8}$ in. depth. Turn on a spigot over a 5/32 i[n.] length to $\frac{11}{16}$ in. diameter to suit the valve liner, then part o[ff] at $\frac{1}{4}$ in. overall. Start a liner into its bore in the steamches[t,] fit the smaller end plate and a 5 in. long bolt, or length o[f] screwed rod, then the dummy cover at the other end with nut to complete. Tighten the nut to pull the liner into positio[n] checking its spigot comes hard against the recess in th[e] steamchest, then repeat for the other liner. We now have t[o] put the reamer right through the pair of liners, because the[y] have been squeezed very slightly and you will find this can b[e] done by hand as there it so little metal to be removed an[d] then mainly at the port bars.

I have been told many times that the beauty of piston valve[s] is that the passages can be both short and direct, arising fro[m] which there was criticism of some of my earlier designs in tha[t] I had not taken advantage of said feature and that th[e] passages I specified were unnecessarily long; builders ar[e] now going to discover the reason for this supposed fault. It is that EVERY lathe will turn to a slight taper over a length, the more so with the uses we put ours to as witness what has gone before in this session, and we must get our valve heads to almost exactly the same diameter for success, so the shorter the overall length the greater chance of success. I suppose the ultimate answer is to produce separate heads as full size and locate them against collars on the valve spindle, but the valves I specify are meant to 'float' just a little on the spindle to take up any slight concentricity errors between steamchest covers and valve liners, and I will not specify anything that I have not tried and proved in practice, alternatively that no builder has been kind enough to prove for me.

To proceed with the valves, chuck a $2\frac{1}{2}$ in. length of iron or bronze cast rod in the 4 jaw, it will be around $\frac{3}{4}$ in. diameter, face, centre and bring the tailstock into play. Turn down to a bare 45/64 in. diameter up to the chuck jaws, then with a round nose tool, reduce further to $\frac{7}{16}$ in. diameter to leave a 21/64 in. thick head, this latter by micrometer. Ideally the stand-out from the chuck should be around $1\frac{3}{4}$ in., when you can now reverse in the chuck, gripping by the $\frac{7}{16}$ in. diameter portion with sufficient projecting to check with a d.t.i. that it is running perfectly true. We are talking about supreme accuracy here, so the d.t.i. graduations want to be .0001 in., after which we can face off to length, centre and use the tailstock as support when finishing this end to the same stage.



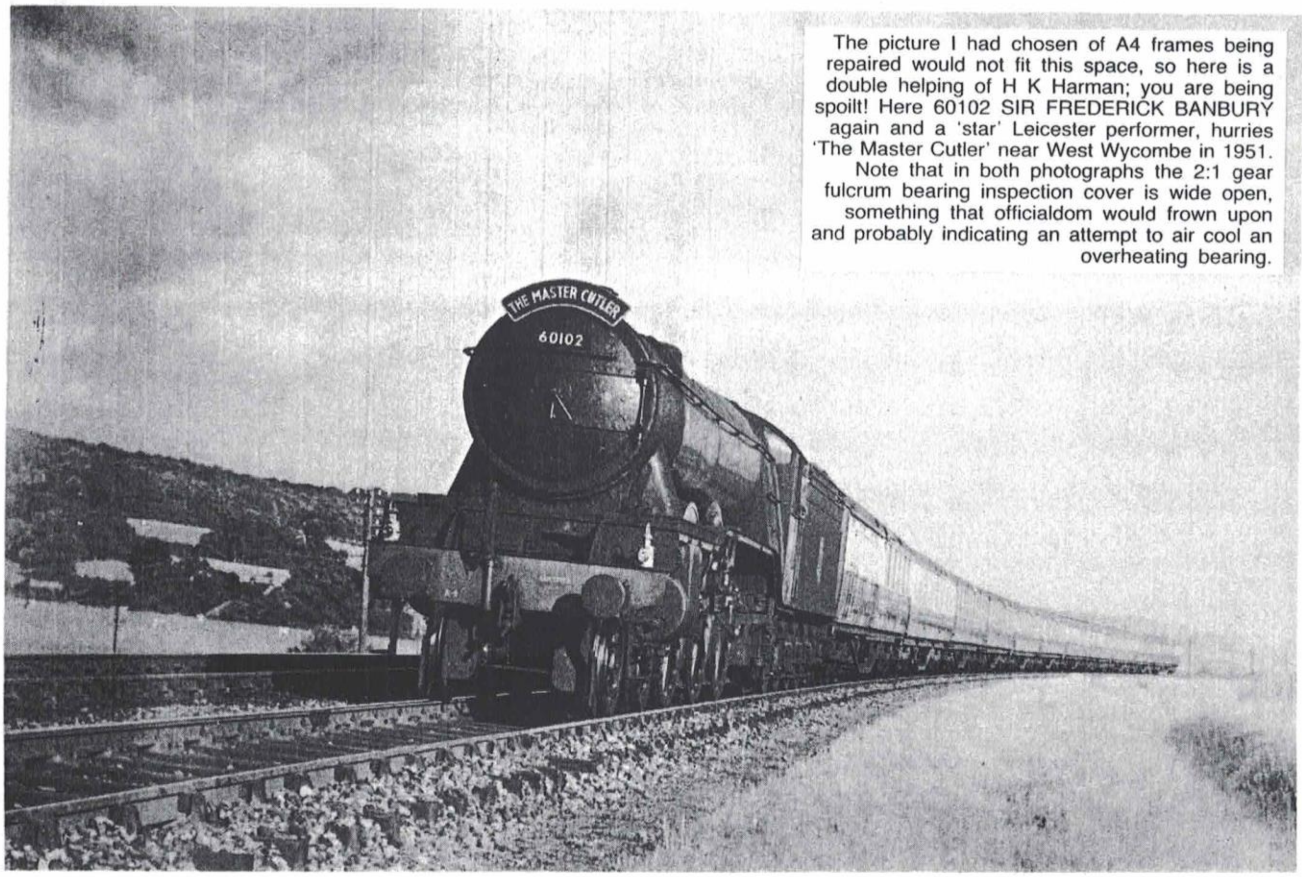
FLYING SCOTSMAN's smokebox and works plate as captured for us on film by John Michael Foster.

Anyhow, this crude set-up did allow me to mill at least some of the top face, though I did have to rotate the block through 180 deg. and set it all up again to complete. I also came across a first snag, for I did not know the thickness of metal on the top face of the cast-in exhaust passages and I doubt if Dick Stocking would have appreciated a call late on Boxing Day afternoon, so I used my own discretion and left these top faces, together with those on the main ribs, $\frac{1}{16}$ in. proud of the steam entry boss; it was a hard fought struggle! I drilled and tapped the steam entry at $\frac{1}{2}$ x 32T, but found I could not carry out my good intention to taper bore into the steamchest itself for the little extra volume this would provide, so finished up with a plain 15/32 in. hole, which when viewed looked more than adequate. At this setting I also dealt with the exhaust pipe stub, finding it was at the wrong angle and $\frac{1}{16}$ in. short of the drawing dimension. The former does not matter one iota as machining takes care of this, and whilst the pattern is being corrected, early builders can simply make their exhaust flange $\frac{1}{16}$ in. thicker to compensate. The idea anyhow is that the two exhaust flanges match when the middle cylinder and smokebox saddle are erected to the frames, so a little machining allowance to achieve this will not be amiss.

I won't bore readers/builders by repetition of boring out the middle cylinder, for to do so would be fictitious as my time was fast running out, but I did drill and ream the piston rod housing, remembering because it happened to be cast in exactly the right place that the bore was $\frac{1}{16}$ in. off centre, which was essential to leave sufficient metal between steamchest and main bores; perhaps that is why I refer to it as the inside cylinder rather than the middle one on the drawing! To tackle the steamchest bore, I turned the casting over onto its top face and supported with flat bars on the three main ribs and top of the exhaust passages which I had skimmed. It was easy to set the casting perfectly square on the boring table from the side flanges, but having dispensed with the angle plate as a register, there was no absolutely accurate way of arriving at the 1 17/32 in. dimension between the main and steamchest bores. Functionally it is not too critical, for the link from the 2:1 gear is a long one, so I just stuck a length of $\frac{1}{2}$ in. silver steel rod in the piston rod housing and measured from this as accurately as I could; it had been a long, hard day licking that casting into shape and of course by Murphy's Law, the bung with the centre accurately marked on it was at the other end! After taking a proof cut which at least removed metal from all around the cast bore, I brought proceedings to a halt and began to type up these notes whilst everything was reasonably fresh in my mind.

I always leave the slide bar facings on my cylinders until said slide bars and their crossheads have been made, but for the middle cylinder it is easy, relatively speaking!, to sit the bottom of the casting on the vertical slide table, clamp in place and use an $\frac{1}{8}$ in. end mill to deal with the slide bar seating. Fit the $\frac{1}{2}$ in. silver steel rod in the piston rod housing, bring the end mill up to same, then withdraw by exactly $\frac{1}{2}$ in. to arrive at the facing, at least that will be the reading for the final cut. The outside cylinder facings I will tackle with a length of $\frac{3}{16}$ in. square tool steel, easing one face over a $\frac{1}{2}$ in. length to give a bit of top rake just like for a punch, then harden and temper. The block will be clamped to the angle plate on the vertical slide, the tool chucked in the 4 jaw and set vertical, though I reckon this will try my patience. Then at least it is simply a matter of winding the carriage along to plane the face, using the cross and vertical slide screws to give depth and width to the cut. Incidentally, on LNER engines the top slide bar does not abut to the back cover, so simply shorten the front end as necessary to sit on your flat surface.

I am not going to say much about the next session, except to warn builders to sharpen their No. 34 drill in anticipation, for you are going to find out in no uncertain manner how I love my 6BA fixings!



The picture I had chosen of A4 frames being repaired would not fit this space, so here is a double helping of H K Harman; you are being spoilt! Here 60102 SIR FREDERICK BANBURY again and a 'star' Leicester performer, hurries 'The Master Cutler' near West Wycombe in 1951. Note that in both photographs the 2:1 gear fulcrum bearing inspection cover is wide open, something that officialdom would frown upon and probably indicating an attempt to air cool an overheating bearing.